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Submitted On
7/5/2018 9:02:45 PM
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I first started purse seining in Prince Willaim Sound in 1975, which was the time before the hatcherys came. Heavy fall rains would sometimes come and scour the salmon streams, washing all the salmon eggs away. The controled stream flow of the hatcheries solved this problem. Now days the hatcherys in PWS are the main stay of our salmon fisheries.

I find it ridiculous that certain people believe that biological harm comes from straying pink salmon. Pink salmon are found in the North Pacific Ocean from Vladivostok in the east to Puget Sound in the west. How did they poplulate sucn a large area, the answer - by straying from their home stream to other streams. Straying salmon is part of the dynamics of our North Paciefic Ocean pink salmon, and is a wonderful thing to ensure the continuation of the pink salmon specie.

I also object to the timing of this issue whcih is being considered by the Board of Fish. Commercial fishermen are in the middle of their salmon season and don't have any spare time to adequetely address this issue in front of the Board of Fish. This business needs to be addressed in the winter when all parties can come together in a puclic forum.

Alaska Fisheries Development Foundation, Inc.
Julie Decker, Executive Director
Alaska Fisheries Development Foundation
www.afdf.org

PACIFIC SEAFOOD PROCESSORS ASSOCIATION
Est. 1914
Glenn Reed, President
Pacific Seafood Processors Association
www.pspafish.net

Alaska Board of Fisheries
Mr. John Jensen, Chair
Via email: dfg.bof.comments@alaska.gov

RE: Oppose Emergency Petition on Valdez Salmon Hatchery Permit July 9, 2018

Dear Chairman Jensen and Board members,

AFDF and PSPA are writing this joint letter in opposition to the emergency petition on the Valdez Salmon Hatchery Permit in order to offer our unique perspectives as the Clients for the two seafood sustainability certifications held by the Alaska salmon fishery. AFDF is the Client for the Responsible Fisheries Management (RFM) certification and PSPA is the Client for the Marine Stewardship Council (MSC) certification, which will be transferred to AFDF in the Fall of 2018.

In short, below is the justification for our opposition to the emergency petition:

1) ***This topic is not an emergency.*** The Valdez permit now in question was approved in 2014.
2) ***The BOF has scheduled a meeting on the topic in October***, where the issue can be thoroughly discussed and affected parties can attend. AFDF and PSPA can provide more extensive information to the BOF at that time, if there is interest.
3) ***Our analysis suggests that the BOF does not have the authority to manage egg takes, in this case, and that this authority lies with the Regional Planning Teams (RPT).*** The RPT process is public, transparent, and requires input and overview from ADF&G. The RPT process was followed in this case. If there is disagreement, this issue should be definitely determined at the scheduled October BOF meeting.
4) ***The Alaska salmon fishery (including all regions, species, and gear types) is certified as sustainable by two separate third-party programs,*** MSC and RFM which also include a public process (more information below).
5) ***If there is specific interest in the issue of ocean carrying capacity, it is an international issue to be further researched and addressed by international science based organizations,*** such as the North Pacific Anadromous Fish Commission.

Sustainability certification has become a necessity for accessing markets and selling seafood internationally. The Alaska salmon fishery has been certified as sustainably managed by MSC and RFM since 2000 and 2011, respectively. These programs use third-party scientific experts to serve on

Assessment Teams and review Alaska's management practices against the programs' standards. The certification period is five years with annual audits by the Assessment Team to assure no drastic changes have occurred which would negatively affect certification.

In 2013, the 2nd re-certification under the MSC program identified questions about Alaska's pink and chum salmon enhancement programs, consequently placing conditions on continued certification relevant to large-scale chum enhancement in Southeast (SE), and Kodiak pink and chum salmon. PWS salmon was not certified by MSC due to an identified need for additional data, although the RFM certification remained in place. Since then, RFM became the first certification program in the world to be recognized by the Global Sustainable Seafood Initiative (GSSI) as meeting the rigorous FAO guidelines for the Ecolabelling of Fish and Fishery Products from Marine Capture Fisheries.

Since 2013, PSPA and AFDF have worked with the hatchery associations in SE, PWS and Kodiak to satisfy the MSC conditions for certification. Several SE conditions specific to chum have been resolved. An Action Plan has been developed which satisfies Kodiak pink and chum salmon conditions.

In 2017, PWS was brought back into the Alaska salmon certification by MSC for two reasons. First, the research plan from the Alaska Hatchery-Wild Interaction Study showed intent to provide extensive scientific data on the questions and preliminary results of the research looked positive. Second, PSPA conducted extensive education and outreach efforts. PSPA facilitated two separate 3-day workshops in Cordova with Assessment Team members, concerned NGO participants, ADF&G staff, and hatchery staff in order to more thoroughly discuss salmon management in Alaska. As a result, channels of communication were opened which allowed for a deeper understanding of the complex issues and Alaska's precautionary approach. ***Consequently, since 2017, the Alaska salmon fishery (every region, gear group and species) is certified as sustainable by two separate third-party programs. This is critically important to selling Alaska seafood into global and domestic markets.***

Thank you for your consideration of our perspective while making your determination.

Sincerely,

Julie Decker

Julie Decker, Executive Director, AFDF

Glenn Reed, President, PSPA

Alaska Board of Fisheries

July 17, 2018
Emergency Petition Meeting Anchorage, Alaska

Scientific Analysis & Review of Journal Articles Submitted by Petitioners KRSA et al.

Respectfully Submitted by Alaska PNP Aquaculture Associations:

Valdez Fisheries Development Association (VFDA), Mike Wells
Prince William Sound Aquaculture Corporation (PWSAC), Casey Campbell
Cook Inlet Aquaculture Association (CIAA), Gary Fandrei
Kodiak Regional Aquaculture Association (KRAA), Tina Fairbanks
Douglas Island Pink and Chum (DIPAC), Eric Prestegard
Northern Southeast Regional Aquaculture Association (NSRAA), Steve Reifenstuhl
Southern Southeast Regional Aquaculture Association (SSRAA), David Landis
Armstrong Keta Inc. (AKI), Bart Watson

Representing over 5,000 Alaska Fishermen

Dear Chairman Jensen and Board of Fish Members:

We recognize this is a dense response, and that your time is limited. The fact is this document only scrapes the surface of the complex issues of ocean carrying capacity and straying. These topics cannot and should not be reduced to sound bites, considering that the foundational research, like most science, has been ongoing for decades, and is anything but simple. For example, the Alaska Hatchery Research Project (AHRP) took a year to plan and will require eleven years to execute the fieldwork.

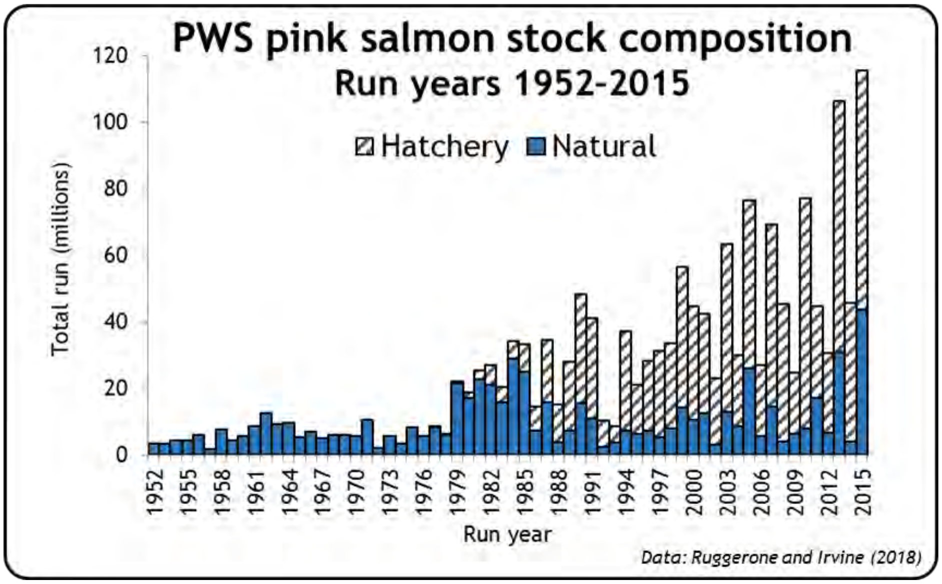
I. Ruggerone and Irvine (2018). Numbers and Biomass of Natural- and Hatchery-Origin Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean, 1925–2015.

This is an excellent compendium of the best available data on numbers and biomass of pink, chum, and sockeye salmon in the North Pacific Ocean. The authors have done a commendable job of compiling diverse data sources of harvest, harvest rates, and escapement. They have used reasonable approaches to estimating total salmon escapements by species by region, and to estimate hatchery and wild origins. They find that the abundance and biomass of pink, sockeye, and chum salmon has been higher in the past 2.5 decades (1990–2015) than at any time in the 90-year time series. The lead author is well known for his "concern" about the impacts of pink salmon (wild and hatchery) and hatchery salmon on the growth and survival of wild stocks of salmon. There is some obvious bias in the discussion of the implications of the results. An example of the anti-hatchery bias is seen in the Discussion on page 162, where Hilborn and Eggers (2001) and Amorosa et al (2017) are cited to minimize the contributions of enhancement to Prince William Sound fisheries, while ignoring the results of Wertheimer et al. (2004a, 2004b). The major recommendations of the paper, however, are quite reasonable: 1) mass-marking of hatchery salmon; and 2) estimate and document abundance of natural and hatchery salmon in the catch and escapement. Alaska has been a leader in both of these areas in order to properly manage the salmon enhancement programs in the state.

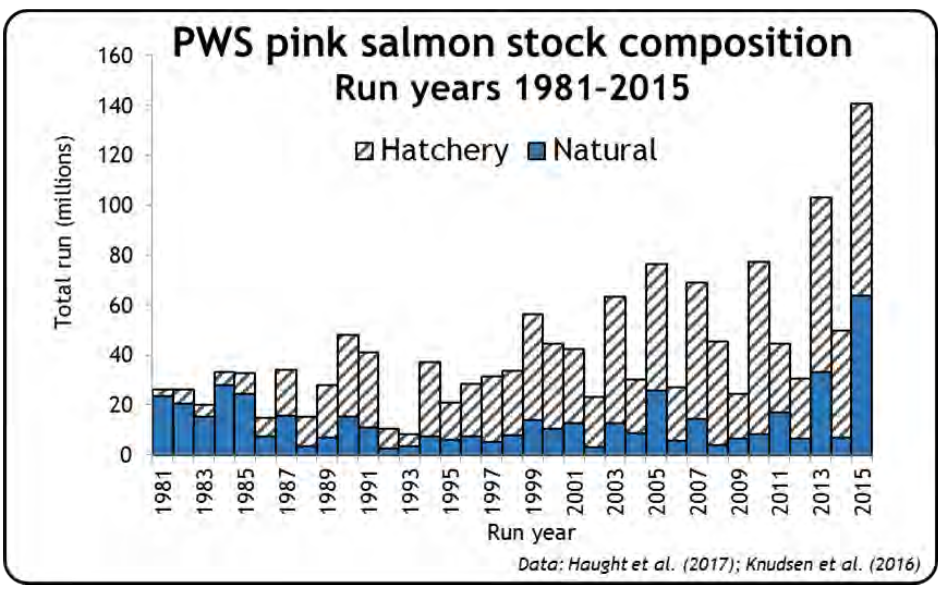
Most Alaska PNP programs have been marking their production for two decades, and ADF&G has been assessing wild/hatchery escapements for the past decade.

Here are major take-aways from the paper.

1. The high-sustained abundance of these species is good news. These abundances are consistent with the renaissance of Alaska salmon, recovering from catches of 22 million fish Statewide in 1974 to an average of 177 million from 1990–2015 (Stopha 2018). The recovery of Alaska salmon can be attributed to the change in ecosystem dynamics associated with the 1977/1978 "regime shift," which resulted in greatly increased zooplankton productivity in the North Pacific and significant changes in species composition of fish and crustaceans (Brodeur and Ware 1992). Also contributing to the high biomass of salmon have been the large-scale enhancement of chum salmon in Asia, especially Japan, and of pink and chum salmon in North America, especially Alaska. Ruggerone and Irvine's (2018) summaries of wild and hatchery pink salmon abundance in Prince William Sound (PWS) from 1952–2015 do well to show a trend in increasing pink salmon production in the region, as depicted in the following graph:

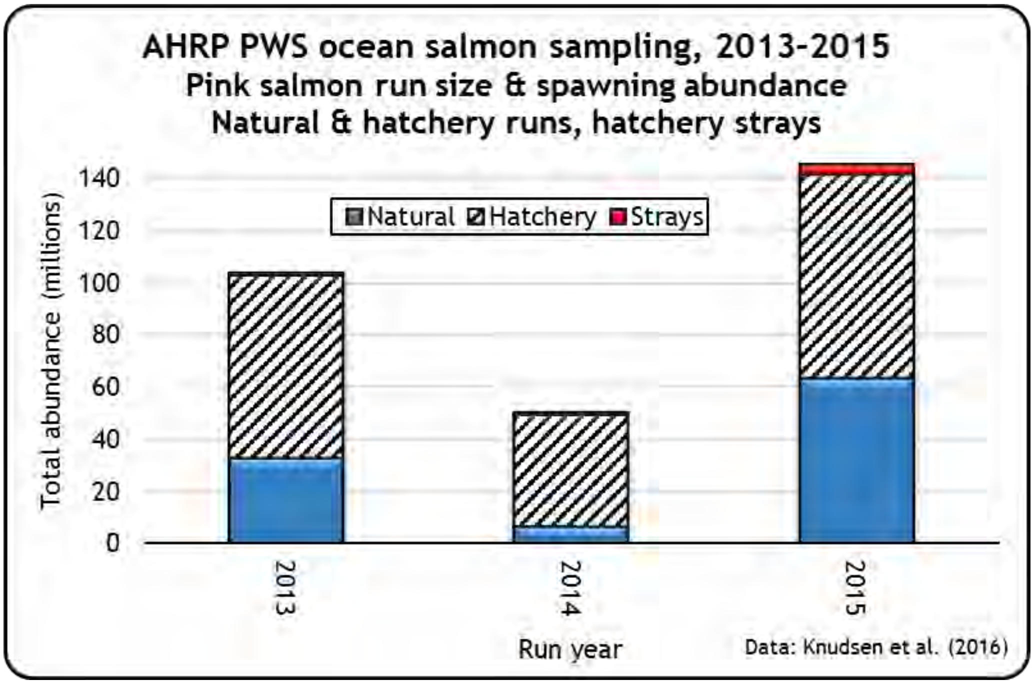


However, there are notable differences between Ruggerone and Irvine's (2018) and Knudsen et al.'s (2016) estimates for PWS pink salmon run size and stock composition for the years 2013–2015. Ruggerone and Irvine (2018) estimate a total run estimate of approximately 115 million pink salmon returning to PWS in 2015, whereas data collected through ADF&G's collaboration with the groundbreaking Alaska Hatchery Research Project (AHRP) indicate a total run estimate of over 140 million pink salmon (Knudsen et al. 2016):



The AHRP may be found further described at
http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.current_research

For the years 2013–2015, the AHRP combined ocean and stream sampling to estimate run size and spawning abundance for both wild and hatchery fish in PWS, including estimates of the hatchery fraction of spawning populations (Knudsen et al. 2016). Knudsen et al. (2016) report a total 2015 run size of PWS pink salmon to be over 140 million fish, which was record setting and approximately 37% larger than the previous record in 2013. Germane to current reviews of PWS pink salmon hatchery production is the estimation of hatchery fractions as measured by the number of hatchery fish assumed to have spawned in PWS natural streams, which Knudsen et al. (2016) report as being 4.4% in 2013, 14.8% in 2014, and 9.5% in 2015. Or, put another way, for these same years between 1% and 5% of the total pink salmon hatchery returns were estimated to have spawned naturally. Numerically, these estimates equate to a potential for approximately 702,000 fish in 2013, 742,000 in 2014, and just over 4 million fish in 2015, as shown graphically below in relation to total run estimates (data from Knudsen et al. 2016):



As summarized in the AHRP 2018 Project Synopsis (http://www.adfg.alaska.gov/static-f/fishing/PDFs/hatcheries/research/alaska_hatchery_research_project_synopsis_june_2018.pdf), preparations are underway to publish run reconstruction and straying results.

2. In Alaska, the management system developed by ADF&G has certainly played a major role (Clark et al. 2006) in sustaining wild and hatchery production. This management includes the capacity to mass mark hatchery fish and sample for these marks in commercial fisheries to avoid the over-exploitation of wild stocks. Finally, the cessation and ultimate ban of high-seas drift netting can also be considered a contributing factor.

3. The high salmon abundance has been relatively consistent over the 1990–2015 period, with higher variability in pink salmon numbers than the other species (Figure 3 of Ruggerone and Irvine). Thus, recent changes in abundance, survival, and size of coho and Chinook salmon have NOT been in response to any recent changes in aggregate salmon numbers or

biomass.

4. This paper makes clear that in the context of salmon carrying capacity, hatchery pink salmon are a relatively minor player. Only 15% of the abundance of pink salmon is attributed to hatchery production.

5. The 20 million scheduled increase in egg takes at VFDA would have virtually no effect on numbers or biomass in relation to current numbers of pink salmon or biomass of salmon in the North Pacific. Assuming 90% egg-to-fry survival and 3% marine survival, this increment would produce approximately 500,000 adults. This is 0.1% of the pink salmon in the North Pacific. In terms of biomass of salmon in the North Pacific, this is < 0.02%!

6. In the Discussion, it is clear that the Russian view of the impacts of density-dependent competition among salmon is very different from the North American academic view cited extensively by the authors, and presented in the several of the papers submitted to the BOF by the petitioners asking to rescind the 2014 VFDA PAR. The perspective championed by Ruggerone and Irvine (2018) is that density-dependent competition is having profound impacts on growth and survival of North American salmon stocks. Three papers cited by Ruggerone and Irvine (2018) and the petitioners (Batten et al. (in press), Springer et al. 2018, Shaul and Geiger 2016) propose that pink salmon are keystone predators, controlling the population dynamics and abundance of epipelagic zooplankton and nekton. In contrast, Shuntov (2017) is cited in Ruggerone and Irvine (2018) as stating that **Pacific salmon consume only 1-5% of prey consumed** by all epipelagic nekton in the Western Bering Sea, and up to 15% near eastern Kamchatka (where returning mature salmon are concentrated), and thus have only a low to moderate impact on the food epipelagic food web. Similarly, Radchenko et al. (2018) reviews studies showing that "as a rule, no significant correlations occur among pink salmon growth rate, stock abundance, or zooplankton standing crop." (Note that the Russians have the most extensive and intensive monitoring of salmon in offshore and coastal waters of any nation in the salmonsphere.) This view of low to moderate impact on epipelagic food webs is consistent with mass-balance modeling of North Pacific ecosystems by Pauley et al. (1996). **Pacific salmon** were estimated to make up **less than 7% of the biomass of the epipelagic fish biomass** in the Alaska gyre. If squid are including as competitive nekton for zooplankton production, Pacific salmon made up less than 3% of the biomass.

II. Springer et al. (2018). Transhemispheric ecosystem disservices of pink salmon in a Pacific Ocean macrosystem.

This is a very poor scientific paper. Frankly, it is surprising it was published. The authors have greatly overreached their data. They accept results that have low statistical significance when the data analyzed agrees with their hypothesis, and dismiss them at the same level of significance if they disagree with their hypothesis. They ignore or dismiss data and results that contradict their conclusions.

The authors attempt to demonstrate that indices of shearwater abundance are being driven by changes in abundance of pink salmon in the North Pacific Ocean. They present data from four indices of abundance of shearwaters on nesting colonies, and analyze data from three of the colonies (the fourth has only five years of data). One of the data series, Montagu Island, extends back to 1967; the others are more recent, and coincident with the high abundance of pink salmon that has persisted in the North Pacific Ocean since 1990 (Ruggerone and Irvine 2018). Because of higher abundance of pink salmon in the North Pacific from the odd-year line, they attempt to use differences in the mean and median of the indices for odd- and even-years to show that pink salmon abundance is affecting shearwater abundance. They also look at trends in abundance, regressing the indices on pink salmon abundance across all years. They construct a multiple regression model with rainfall and measures of regional pink salmon abundance as prediction variables for the dependent variable, the shearwater abundance indexes.

Here is a litany of problems with Springer et al.'s (2018) data presentation, analysis, and interpretation.

1. In their trend analysis, there is a negative trend for two colonies and no trend for the third, Wedge Island. The Wedge Island colony is the only one of the three evaluated that actually measured abundance; the others actually measure nesting success. The lowest abundance in the Wedge Island data series occurred in an even year. The major change in the longer-term data set for Montagu Island is coincident with the 1977/1978 regime shift. This regime shift resulted in big increases in zooplankton productivity in North Pacific (Brodeur and Ware). Large changes in relative species composition occurred. Salmon abundance increased dramatically; shrimp, king crab declined precipitously in the Gulf of Alaska; gadids and flatfish increased. Could pink salmon be the mechanistic explanation for the downturn in shearwater dynamics, when there is higher productivity in general? Perhaps, if pinks (and other salmon) caused local depletion of the amount of shearwater prey near the surface. (Another possible scenario is that salmon drive prey to the surface where they would be more susceptible to shearwater predation). Given the large changes in productivity and species composition, there are probably multiple factors causing the shearwaters to decline at a time of increased productivity of their general prey groups.

2. The authors take the approach that odd/even year differences in abundance of pink salmon are reflected in odd/even year medians and mean averages at the nesting colony. They point out a tendency for shearwater averages to be higher in even years. However, at all three nesting colonies, none of the differences are statistically significant, regardless of how they truncate the data series (Tables 1,2,3). For the long-term data series at Montagu Island, the p-value for the comparison is 0.3 (p greater than 0.05 = not significant).

3. The authors discuss shearwater-pink correlations ostensibly to show the connection between pink salmon abundance and shearwater abundance indexes. They actually do not give the correlations, but rather the direction and significance of pink salmon abundances as covariates in a multiple regression model including rainfall. The amount of variation explained by rainfall alone is not presented. Rainfall must be a big driver in this relationship; note the nest failures on Montagu attributed to rainfall in 1971 and 1999. Shearwaters migrate through North Pacific waters through the ocean range of Asian and North American pink salmon (Figure 1). The salmon covariates are broken into four regional components, three Asian and one North American ("Alaska").

4. For the rainfall/salmon model, there was no relationship with salmon abundance at two of the three colonies evaluated: Wedge (with the actual measures of abundance) and Forneaux. At Montagu, the pink salmon covariates were negatively related to pink salmon abundance for Japan/Okhotsk and Alaska, positively related for East Kamchatka, and either negative or positive for Western Kamchatka, depending on how the data series was truncated (Table 4). Significance level for each region also varied depending on how the data series were truncated. In summary, two colonies had no relationship to salmon abundance; and one colony had no consistent relationship with salmon abundance.

5. The authors then use an arbitrary model selection process to drop Japan/Okhotsk and West Kamchatka from the model for Montagu. Certainly, among the long list of authors someone has heard of using criteria such as the AIC (Akaike Information Criterion) to select the best model. At any rate, this action results in Table 5, showing significant negative effects of Alaska salmon. The relationships for Eastern Kamchatka salmon remain positive. The authors make a big deal that the regions "importance" declined markedly, but note that this positive relationship remains significant for the 1990–2016 interval, and "marginally" significant (p = .1) for the most recent interval.

6. For the rainfall/salmon model, there is no relationship with salmon abundance for two of the three colonies. The Montagu colony model showed a positive relationship with Eastern Kamchatka pink salmon, which contribute the most to the overall abundance of pink salmon, and a negative relationship with Alaskan pink salmon. When looking at the map of Shearwater distributions, their migration overlaps to a greater degree with Asian pink

salmon. By the time the birds are swinging down to the eastern part of their range, pink salmon from Southeast Alaska and Prince William Sound are probably eastward in more coastal waters. Thus, the pink salmon with which the shearwaters are most likely to co-occur are Asian pink salmon, which have no discernable effect or even a positive effect in the authors' models.

7. The authors acknowledge these contradictions, but that does not stop them from affirming their hypotheses. They note that the positive relationship of the Montagu shearwaters with East Kamchatka salmon "was not expected." They then go through the statistical gymnastics to dismiss the significance of these positive relationships, **even though non-significant** but consistent differences in odd/even year averages were evidence of a pink salmon effect. As for the results of NO relationships for the other two colonies, "…we believe that this does not materially controvert our hypothesis, based on the totality of the evidence that competition by pink salmon leads to negative effects on overwintering and nesting shearwaters." There you have it: no point in letting contradictory results spoil the hypothesis of a true believer.

III. Batten et al. (In press). Pink salmon induce a trophic cascade in plankton population in the southern Bering Sea and around the Aleutian Islands.

This paper attempts to show top-down control of plankton populations around the Aleutian Islands and in the southern Bering Sea. This paper is in the genre of "tail wags dog." The authors purportedly show that zooplankton standing crop is affected by the number of pink salmon present. They do this by comparing odd/even year data from a surface layer tow of a continuous plankton recorder, attributing the difference to higher odd-year abundance of pink salmon. They correlate the findings to specific regional abundances of Asian pink salmon, and explain anomalies in their data series with particular changes in relative abundance by region. They characterize these results as a "trophic cascade", with pink salmon controlling zooplankton trophic dynamics.

This paper has some serious flaws, both conceptually and in its analysis of the data:

1. Conceptually, it is highly unlikely that pink salmon control the zooplankton population dynamics in these oceanic regions. Localized depletion of zooplankton can certainly occur due to foraging by zooplanktivorous nekton. However, broad-scale description of trophic structure in the North Pacific Ocean **show that salmon in general have a low to moderate position** in the grand scheme of things. Mass-balance modeling of North Pacific ecosystems by Pauley et al. (1996) estimated that Pacific salmon make up less than 7% of the biomass of the epipelagic fish biomass in the Alaska gyre. If squid are included as competitive nekton for zooplankton production, Pacific salmon make up less than 3% of the nekton biomass. This is all salmon, not just pink salmon, and the majority of the biomass of salmon in the Gulf of Alaska and Bering Sea is chum salmon. In the mass-balance model, zooplankton biomass was over 40 times that of ALL planktivorous nekton consumption.

   Another conceptual problem to the odd/even evidence of plankton depletion is **prey-switching by salmon species**. Pink, chum, and sockeye salmon have substantial overlap in their diets, and the latter two species have been shown to switch to other, "lower-quality" prey when pink salmon are abundant (e.g., Davis 2003). These changes in feeding habit are often used to support the concept of density-dependent interactions with pink salmon and their congeners, e.g., Ruggerone and Connors (2015). Why would we not expect these species to switch back to the preferred prey when pinks are not abundant? Given higher biomass of chum salmon and sockeye salmon in the North Pacific, why would they not consume the "pink prey" when pink abundance is lower in even years?

2. The conclusions of the authors go well beyond the scope of the sampling, in space and time. The plankton recorder is at 7.5 M (~23') depth. **Zooplankton biomass occupies much more of the water column, and is typically more abundant below 20 M (60' depth)**, with diel migrations from depth to near-surface waters (e.g., Orsi et al. 2004). Even

if local surface depletion of zooplankton was occurring by foraging salmon, that in no way shows general depletion of zooplankton standing crop.

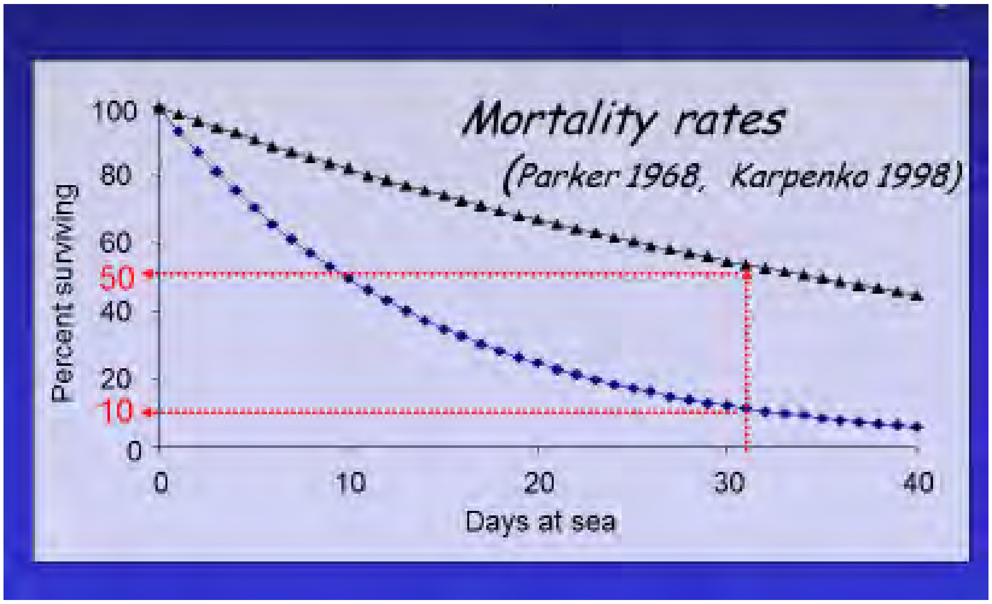
3. In some odd years, sampling extended into August. By this time, most pink salmon would have left the sampling area to migrate into coastal waters; many are entering their natal streams! Thus, depletion of surface zooplankton must have been due to other zooplanktivorous nekton.

4. The glaring problem of the analysis of the plankton indexes to pink salmon abundance is the selection of specific indexes of abundance of pink salmon based on putative distributions by region. The authors have a map showing their sampling areas delineated into Eastern, Central, and Western regions (Figure 1). They cite Tagaki et al. (1981) and Myers et al. (1996) to assign the eastern and central region for correlation with Eastern Kamchatka pink salmon as the primary population in these areas, and the western region to other regions of Alaska. However, except for the central region, these assignments are not consistent with maps from Tagaki et al (1981). of the distribution of pink salmon by region (reproduced in Heard 1991). Their eastern sampling area is at the edge of the range for East Kamchatka pink salmon, but is well within the range of North American pink salmon originating from the Gulf of Alaska and western Alaska. In a more recent overview of pink salmon ocean distribution, Radchenko et al. (2018) also show ocean distributions that place Batten et al.'s (In press) eastern sampling stations at the edge of the Eastern Kamchatka pink salmon range, and well within North American pink salmon distribution.

   This mis-assignment of "principle" regional stocks has large implications for the authors' conclusions. For example, in the Western sampling region, even though large numbers of East Kamchatka pink salmon are present, surface zooplankton has no trend in relation to the abundance of these fish. In the Eastern sampling region, it negates their explanation of high zooplankton counts in 2013. This year had the highest large copepods counts observed in their data series. The authors emphasize that Eastern Kamchatka pink salmon abundance was lower than average in that year. However, North American pink salmon abundance was at a record high in 2013. Thus, the high zooplankton counts in the region are actually associated with high pink salmon abundance. Indeed, the high productivity of zooplankton in 2013 may have been a driver in the record abundance of North American pink salmon.

5. In contrast to the authors' observations of the relationship between surface zooplankton and pink salmon abundance, Radchenko et al. (2018) reviews extensive Russian studies showing that "as a rule, no significant correlations occur among pink salmon growth rate, stock abundance, or zooplankton standing crop." These studies included comprehensive sampling of zooplankton, concurrent salmon abundance, and analysis of growth and diet of the salmon. Supporting evidence for lack of significant correlation is that the first 30 to

45 days of a salmon fry/smolt sustain 50% to 90% mortality (Parker 1968 & Karpenko 1998), with predators likely being the main driver rather than zooplankton abundance.



IV. Shaul and Geiger (2016). Effects of climate and competition for offshore prey on growth, survival, and reproductive potential of coho salmon in Southeast Alaska.

This paper finds that size of Southeast Alaska coho salmon, and survival of Berners Bay coho salmon, are driven by climatic conditions and density dependent-interactions with pink salmon. The paper is both data and analytically intensive, and is a very thoughtful approach to understanding the processes affecting size and other population characteristics of Southeast Alaska coho salmon. The authors develop models to support their hypothesis that pink salmon are a top-down controlling factor in the abundance of North Pacific squid (*Berryteuthis anonychus*) populations that are the primary prey for coho salmon in offshore waters. Pink and coho salmon have similar duration of time at sea. In offshore regions, squid are the primary prey of coho salmon at all sizes, whereas pink salmon do not consume substantial quantities of squid until they reach a size greater than 1000 g. The authors' model indicate that size of coho salmon is not affected by direct (within year) competition of pink salmon for squid, but rather by impairing the reproductive potential of squid in subsequent years.

1. The authors present strong evidence for size declines in Southeast Alaska coho salmon, with differing trends for odd- and even-year returns indicating a density-dependent relationship with pink salmon abundance. Declines in size with increased pink salmon abundance have also been observed for Prince William Sound pink salmon (Wertheimer et al. 2004b) and for pink salmon in BC (Jeffrey et al. 2017). Jeffrey et al. (2017) also found that body size of chum salmon in BC species has declined with ocean biomass of North American salmon, but also found that body size Chinook, coho, and sockeye salmon in BC fisheries have increased with higher ocean biomass of North American salmon.

2. While the size decline data are compelling, we are not convinced of the proposed mechanism for how pink salmon affect coho size. It seems another "tail wags dog" concept. The biomass of pink salmon is only a small fraction of the nekton in the Alaska gyre, with squid estimated to have a 30-fold higher biomass (Pauley et al. 1996). In contrast to the conclusions of Shaul and Geiger (2016), **Aydin (2000) concluded** that the trophic position and high productivity of **squid give it a controlling position in the ecosystem** in relation to salmon predation and growth. Aydin (2000) found that squid abundance, while highly variable, had increased greatly (as did salmon) after the 1977/1978 regime shift. That squid abundance increased commensurate with salmon abundance indicates the species were responding similarly to the increased productivity in the North Pacific (Brodeur and Ware 1992). If squid were controlled by pink salmon predation, there should have been a decline in squid production as pink salmon increased.

   In addition, the consumption of squid on the high seas by pink salmon is limited by their size and temporal distribution. Substantial quantities of squid are not consumed by pink salmon until they reach 1000 g in weight (Aydin 2000, Davis 2003). Pink salmon typically attain this size by mid- or late-June (Radchenko et al. 2018). At this time, the fish are starting to migrate from offshore (squid) areas towards coastal water as they move towards their natal streams to spawn. This limited feeding opportunity is more consistent with the Aydin (2000) hypothesis of squid population size and biomass affecting salmon growth than with the Shaul and Geiger concept of pink salmon controlling the reproductive potential of the squid. Aydin (2000) also estimated that coho salmon consume more squid overall than pink or sockeye salmon. Coho salmon have a much broader temporal window for foraging on squid, as ocean age 1 coho salmon are larger than ocean age 1 pink salmon, and eat large quantities of squid even at sizes less than 500 g (Davis 2003). Coho salmon have much greater growth rates than pink salmon as they attain a size of 7 pounds in the same two years that pink salmon mature at 3.5 pounds.

The Shaul/Geiger lag response model requires that the squid have an obligate two-year life-history cycle as proposed by Jorgensen (2011). This is contradicted by other literature, which characterizes *B. anonychus* as an annual species with high productivity (Katugin et al. 2005, Drobney et al. 2008). Aydin (2000) cites studies showing that *B. anonychus* is highly productive, and spawns twice a year.

3. If direct or indirect competition for squid is not driving the size decline, **what are the alternative hypotheses?** Aydin (2000) thought that the winter ocean period was when salmon growth was most susceptible to density-dependent interactions; however, it is not clear how density-dependent interactions between pink salmon and coho salmon would affect coho salmon growth at this time. However, Aydin (2000) also found distinct differences in the distribution of squid in odd- and even-years in the 1990s, which he attributed to variations in in oceanographic conditions. If such biennial differences are persistent, the interaction of squid distribution with SEAK coho distribution could produce the odd/even differences in size.

4. Given the differential association of SEAK coho size and BC coho size to North Pacific salmon abundances observed by Shaul and Geiger (2016) and Jeffrey et al. (2017), the effect of competitive interactions between coho and other salmon must vary with the ocean domains used by the different stocks. It is interesting that Shaul and Geiger found an increase in size for Southeast Alaska pink and sockeye salmon in recent years, while coho sizes were declining. They attribute that to the “flexibility” in their diets, which may indeed make them less susceptible to variations in squid abundance than coho salmon. Ruggerone and Irvine (2018) report recent general declines in average size of pink and sockeye salmon, again indicating **heterogeneous responses across regions** to ocean conditions.

5. The authors also attribute declines in marine survival of Berner’s River coho salmon to the lagged-impact of pink salmon on squid. Yet, year-class strength of coho salmon and pink

salmon in Southeast Alaska are strongly and positively correlated. We looked at the time series of coho and pink salmon harvest from 1960 to 2017; the association is 0.82, significant at $p < 0.001$. Since the 1977/1978 regime shift, the relationship has not been quite as strong, but is still 0.70, also significant at $p < 0.001$. This suggests that pink salmon and coho salmon are responding similarly to ocean conditions. Briscoe (2004) and LaCroix et al. (2009) suggested predator buffering as a mechanism that could explain this association: strong year-classes of juvenile pink salmon could improve survival of coho salmon smolts by deflecting predation pressure from less abundant coho salmon juveniles. However, Mallick et al. (2009), in examining survival trends for 14 stocks of hatchery and wild coho salmon in Southeast, did not find consistent effects of hatchery or wild juvenile salmon on the survival data. Shaul and Geiger also looked for such an effect on Berner's River coho survival, but did not find any indication that survival was influenced by estimated numbers of juvenile salmon in northern Southeast Alaska waters. Nevertheless, in terms of numbers of fish harvested, pink and coho salmon in Southeast Alaska generally are positively associated, indicating no or little density-dependent effect of pink salmon on coho salmon survival.

6. The authors have tied reduction in coho salmon size to the general increase in pink salmon biomass in the North Pacific. The correlation in year-class numbers of Southeast Alaska coho and pink salmon, and the differing response of pink salmon size in Southeast Alaska than in Prince William Sound suggest that density-dependent interactions, both negative and positive are regionally driven. This may be due to shared ocean distributions. Because production of hatchery pink salmon in Southeast Alaska is quite small (< 5%), these interactions are driven primarily by wild stocks of pink salmon.

V. Aydin (2000). Trophic feedback and carrying capacity of Pacific salmon on the high seas of the Gulf of Alaska.

This dissertation is an impressive body of work. The author used field samples of salmon food habits in conjunction with bioenergetics models, foraging models, climate data, and salmon size data to examine the relative effects of environmental variation and potential density-dependence on “carrying capacity” in the northeastern Pacific Ocean. The author’s main conclusions are that (1) the winter prior to maturation is a critical time for salmon competitive interactions; (2) small differences in salmon body size after the winter period can limit foraging capability and thus growth and size at maturity; and (3) micronektonic squid are an important driver in adult salmon growth, and may function as a keystone species. The author expresses concern that “pumping up production with hatcheries” may have deleterious impacts on the salmon ecosystem, possibly resulting in “trophic cascades” that could limit growth and potentially impact survival.

1. Squid is a very important salmon prey item across wide areas of the Pacific, especially for coho salmon. Its abundance and distribution is highly variable, depending on oceanographic conditions. Squid abundance generally increased in the 1980s and 1990s, when salmon abundance also generally increased.

2. In the 1990s, the distribution of squid was different between odd and even years. These differences were attributed to differing oceanographic conditions.

3. Salmon diet varies across large ocean domains; there are large areas with low populations of squid where zooplankton or fish larvae are primary prey.

4. Density-dependence is most likely during winter. The strongest controller of growth during this time is zooplankton. Density-dependence is likely strongest for pink salmon and age .2 sockeye salmon.

5. The differential feeding habits of chum salmon on gelatinous organisms make them less susceptible to density-dependent effects.

6. Local depletion of prey resources can occur as salmon school density increases, even if prey is not depleted over large ocean areas. This is an important point in understanding regional differences in changes in size at return.

7. Despite the concern expressed by the author some 15 years ago about density-dependent interactions resulting in negative feedback loops**, abundance and biomass of salmon in the North Pacific Ocean remains at historically high levels**, albeit with high variability and differing responses depending on species and region.

VI. Davis (2003). Feeding ecology of Pacific salmon in the central north Pacific and central Bering Sea.

This paper provides extensive food habit information for Pacific salmon in the central North Pacific and Bering Sea during June and July. The author also determines caloric densities of prey, and uses these data and a bioenergetics model to estimate salmon growth and prey consumption during June and July. The author considers the effect of pink salmon abundance on diet composition. This is an important contribution to the understanding of summer food habits of Pacific salmon on the high seas. Major results from the analyses include:

1. Diet items varied greatly among the three regions (two in the North Pacific and one in the Bering Sea) sampled.

2. Shifts in prey composition were observed in chum, sockeye, and pink salmon when pink salmon were abundant. All three species consumed more low-caloric content prey at higher pink salmon abundances, and had lower stomach fullness. Chinook salmon in the central Bering Sea had lower stomach fullness in years pink salmon were more abundant. Coho salmon did not show either diet shifts or changes in stomach fullness in relation to pink salmon abundance.

3. The author concludes that the shifts in prey composition in the presence of abundant pink salmon are indicative of feeding competition among pink, sockeye, and chum salmon, and that this composition could result in density-dependent reduction of the growth of these species in the Central Bering Sea.

4. Bioenergetic models indicate that salmon are feeding close to their physiological maximum. When prey is abundant, there is an upper thermal limit to growth due to large metabolic requirements. At lower temperatures, growth is limited by a decreased capacity for prey consumption.

5. **The major take-away:** feeding competition causes diet shifts in pink, chum, and sockeye salmon. Reliance on lower quality food, along with localized prey depletion at high salmon abundances, may result in lower growth, with some decrease in size at maturity for pink, sockeye, and chum salmon, and shifts to older ages at maturity for sockeye and chum salmon. However, these **impacts have not prevented the sustained high biomass** of these species in the North Pacific Ocean over the last 30 years. In addition, **Russian studies of growth and feeding habits of pink salmon have not found an association of lower growth rates with pink salmon abundance (Radchenko 2018).**

VII. Lewis et al. (2015). Changes in size and age of Chinook salmon returning to Alaska.

This is a very good analysis of temporal trends in size at age and age at maturity for 10 stocks of Alaska Chinook salmon that occur from southern Southeast Alaska to Yukon River. The authors use regression analyses to quantify decadal trends, and suggest possible causes for the changes observed.

1. On average, these stocks of Chinook salmon have become smaller over the past 30 years because of a decline in the predominant age at maturity and because of a decrease in age-specific length.

2. Average size has declined for all 10 stocks of Chinook salmon evaluated. The observed smaller size is a result of trends in size-at-age and age at maturity.

3. Size-at-age has declined in all stocks for older (1.3 and 1.4) ages. However, **no overall trend in size at age 1.2 was found**. Six stocks had no significant trend, two stocks (Kenai and Copper) had significantly negative trends, and two stocks (Nushagak and Unuk) had significantly positive trends in size at age 1.2 (Table 2).

4. The age-at-maturity has declined for all 10 stocks. The proportion of age 1.4 fish has decreased, and the proportion of age 1.2 fish has increased.

5. The authors conclude that the concordant trends among these ten Chinook stocks across a broad geographic range indicate a common suite of large-scale mechanisms may be responsible for the changes.

6. Three possible mechanisms are identified: 1) **size-selective fishing removing larger**, older fish; 2) marine environmental conditions affecting growth and maturation rates; and 3) competition with the high abundance of salmon in the North Pacific affecting growth and thus size at age and age at maturity.

7. While size-selective fishing can affect the size and age structure of Chinook salmon (Bromaghin et al. 2011), the concordant trends are occurring in stocks with widely different fishery exploitation rates and exposure to size selective fishing (such as trolling with a minimum size limit), which makes it unlikely that fishing is the primary driver of these changes.

8. Differing environmental conditions could certainly play a major role in growth of Chinook salmon. **However, size at age 1.2 has not declined**; indicating that growth during at least the first two years at sea has not been impacted. Given broad prey overlap of 1.2 and older

Chinook salmon, it is unclear why older fish would experience reduced growth in response to the same environmental conditions.

9. The high abundance of other species of salmon has been persistent over the past 25–30 years, and thus is not an obvious cause for the trend in sizes. There is no apparent odd/even cycle in the size data (Figure 3), as was found by Shaul and Geiger (2016) for Southeast Alaska coho salmon, so pink salmon is not singled out! In addition, the size-class with the greatest diet overlap with congener species is age 1.2, which does not show a downward trend in size.

10. We can **identify another possible mechanism causing the changes in size and age:** increasing predation by a rapidly expanding marine mammal population that has a strong preference for Chinook salmon in its feeding habits. Resident killer whales preferentially feed on large Chinook salmon (Olesiuk et al. 1990; Hansen et al. 2010). Resident killer whales in northern BC and Gulf of Alaska waters have increased at annual rates of 2.9% and 3.5%, respectively (Hilborn et al. 2012; Matkin et al. 2014). At these rates, numbers of killer whales in these areas have increased 2–3 times over the 30-year time series evaluated by Lewis et al. (2015). Differential removal of large fish could cause the reduction in both the proportion of older fish and the size at age of older fish.

VIII. Jeffrey et al. (2017). Changes in body size of Canadian Pacific salmon over six decades.

This paper is an excellent update of Ricker's (1981) analyses of trends in body size of Pacific salmon. The data are extended to cover 1951–2012. Average body size for each species was calculated from commercial catch statistics over this timeframe. General additive models (GAM) were used to test the importance of potential factors affecting change in body size. Four climatic indices were used to examine for broad-scale environmental impacts, and estimates of biomass of potentially competing species (pink, chum, and sockeye salmon) were used to examine for density-dependent interactions.

1. The mean weight of all species changed over time.

2. Chinook salmon size declined markedly from 1951 to the early 1970s but then increased to close to its maximum annual weight in the 1990s. Since 2000, Chinook weight has again declined slightly.

3. Coho salmon size also declined from the 1950s, and did not reach its minimum until around 1985. Since then it has increased and is now at the highest level in the data series.

4. Chum and pink salmon declined initially in size, and then have remained relatively stable since the 1990s at a size that is 20–30% less than in the 1950s and 1960s. There was little change over the time series in the average size of sockeye salmon.

5. Annual size data for Chinook, chum, and sockeye salmon can be confounded by differing proportion of ages at return; the assumption is made that these effects are smoothed out over the long time series.

6. The GAM models identified at least two of the climate variables as important in explaining annual variations. There was no indication of abrupt climate effect, but rather more of a response to continuous changes in the climate indices.

7. The biomass of North American pink salmon entering the Gulf of Alaska was the most important biomass variable in explaining size variation in BC pink salmon. The direction of the effect was negative, suggesting some degree of intra-specific competition.

8. The combined biomass of North American pink, sockeye, and chum salmon was the most important biomass variable explaining size variation in chum salmon. The direction of the effect was negative, suggesting some degree of competition among these congeners.

9. The biomass of North American chum salmon was the most important biomass variable explaining size variation in sockeye salmon. Adding Asian chum salmon to this (or combined measures of biomass) did not improve the fit. **The direction of the effect was positive, indicating that when chums are abundant, growth conditions for sockeye are positive.**

10. The combined biomass of North American pink, sockeye, and chum salmon was the most important biomass variable explaining size variation in Chinook and coho salmon. The effect was again positive for these species. **The authors note there is less diet overlap of these species with pinks, chums, and sockeye.** They speculate that the positive relationship may be driven by environmental conditions, which when favorable allow for greater total biomass of salmon species and higher growth (thus larger size) in Chinook and coho salmon.

11. Relaxation of fishing pressure may have contributed to some increase in body size. For Chinook and coho salmon, **fishing pressure has shifted from commercial to recreational fishing.** The authors conclude that the effect of fishing is unclear, but place it as less important than the ecological (salmon biomass) and climatic effects. Their results are consistent with the "unclear" conclusion. They have no analytical approach to determine if and to what degree fishing influenced annual variation in size.

12. The most striking take-aways from this paper are the positive relationships of body size to ocean salmon biomass for sockeye, Chinook, and coho salmon. These relationships are consistent with the Russian view that environmental conditions are driving variability in biomass, and that **growth and survival is driven more by density-independent changes in productivity than density-dependent interactions among salmon species**. The authors do present evidence of density-dependent effects on growth for pink and chum salmon, with pinks most affected by intraspecific density and chums by total salmon biomass. Perhaps this latter is the effect of chum salmon switching to gelatinous prey to avoid more intense competitive interactions with pinks and sockeye.

13. The results for coho salmon are a striking contrast to Shaul and Geiger's (2016) finding of size decline in commercial weights of coho salmon in Southeast Alaska. Restating what was said in the critique of Shaul & Geiger: these opposite results indicate that stock-specific differences in ocean distribution may be very important in determining growth potential and the degree and direction of species interactions.

IX. Jones et al. (2018). Population viability improves following termination of coho hatchery releases.

This is an interesting case history study of the response of a natural-spawning coho salmon population to the termination of an in-stream hatchery. It has **little relevance to the concern the petitioners expressed vis-à-vis ocean carrying capacity**. It does have some relevance to the on-going debate on impacts of domestication selection of hatchery fish on the fitness of wild stocks.

The hatchery on the Salmon River in Oregon was operated from 1978–2005, representing 27 brood years (generations) of directed hatchery influence. The brood stock was derived from the local Salmon River coho population. Once hatchery returns began, the hatchery, located some 8 km up-river, would collect approximately 270 adults for brood stock, and allow the other hatchery fish to spawn naturally. During the hatchery period for which data are presented (1992–2005 broods, 1995–2008 returns), the hatchery would release approximately 200,000 smolts annually. The majority of naturally spawning fish during this period were first-generation hatchery fish; productivity of naturally-spawning fish was low. After termination of the hatchery, productivity has increased and the natural spawning fish have produced runs of approximately the same size as when the hatchery was operating (from 1995–2008; 1978–1994 numbers are not shown). The authors suggest that density-dependent interactions between hatchery smolts and naturally-produced fish reduced survival of the naturally-produced juveniles. There also could have been density-dependent loss of productivity through competition for limited spawning habitat, and potentially lower fitness of the hatchery fish spawning naturally. Marine survival was higher for smolts after the hatchery period, which would also contribute to increased productivity.

Coho salmon are typically reared in hatcheries until yearling smolts. This long period of hatchery rearing makes them more susceptible to domestication selection that could affect their reproductive success when spawning naturally (Theriault et al. 2011). In addition, the authors note that there had been a substantial shift to earlier-spawn timing from the original brood stock. Spawn timing is quite heritable and hatchery programs can easily select for earlier timing by filling up on eggs from the early returns.

In spite of the concerns for domestication selection and reduced reproductive success of hatchery fish, this population recovered quickly from the density-dependent impacts of in-river hatchery releases after 27 generations of direct hatchery/wild interactions. Productivity is similar to neighboring wild-stock systems, and the population appears to be self-sustaining. These results support the policy of deriving hatchery populations from local stocks; it also demonstrates the need to evaluate the efficacy of hatchery programs to ensure they are meeting their management goals. Supplementation of coho salmon populations with in-river fry and smolt releases can result in replacement of wild production due to density-dependent interactions in their freshwater spawning and rearing habitats (Nickelson 2003). When this occurs to the degree observed in the Salmon River, termination of hatchery releases is the reasonable and cost-effective course of action. This is a very different from lake stocking of sockeye fry in lake systems, which have been identified as spawner-limited, e.g. Babine Lake, Tahltan Lake, and the Gulkana program.

This case history study demonstrates that appropriate brood-stock selection, and maintenance of spawning and rearing habitat, can ensure that wild stocks retain their viability and productive capacity even when exposed to long-term and direct interactions with hatchery fish. It is important to note that Alaska's hatchery program is dissimilar to the one described here. Most pink, chum, Chinook, and coho salmon are released to the ocean and not in freshwater rivers, and programs are located away from major wild stock systems.

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Submitted By
ALEC PFUNDT
Submitted On
7/7/2018 7:58:08 AM
Affiliation
Commercial salmon fisherman

My name is Alec Pfundt owner and operator of the fishing vessel Haley Marie out of Petersburg. I am a Southeast salmon seiner living in and operating out of Petersburg. I am concerned about the July 17th bof meeting dealing with an interest groups concerns about salmon hatcherys at a time when commercial fishermen are in the middle of a busy season. The timing of this seems like someone is trying to get away with something, and I am sure that the bof does not want this appearance or that of being reactionary. The board of fish needs to be transparent and fair to all user groups. Please set this topic aside until the scheduled October BOF meeting. At that time, good science and history can be examined and discussed and all concerned parties heard well. Thank you for your time. Alec Pfundt, 4th generation SE seiner and raising the 5th generation.

Submitted By
Andrew Broders
Submitted On
7/3/2018 6:44:57 PM
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This proposal has been designed with one purpose in mind; to hit the fisherman in their wallets. Making commercial fishing non profitable is the same tactic that has been used in Washington, and other states to rid the sport fisherman of the commercial menace. I'm sure that others have explained this in more depth and with more charm than I am capable of, but please consider this one thing. The commercial fisherman are the ones who are out here in order to feed people. Sure, we try to make a living, but we are not out here for trophy's, or to fill our own freezers. We are here to supply people with food. Hatchery production is vital to our ability to do that. I would also like to address the timing of the meeting. Hearing this proposal while the fishing fleet is out fishing is nothing short of malicious, I would go as far as to say it's slimey and rotten. With all due respect, Andrew Broders

Date: 6-28-18
Fisherman: Andrew Scudder
Fishing Vessel: F/V Gorbuscha
Homeport: Cordova, AK

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Andrew Scudder

I am writing as a fisherman in response to the Alaska Board of Fisheries decision to hold a hearing on the Emergency Petition filed May 16, 2018.

Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria.

I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families.

The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions.

I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session.

Thank you,

Submitted By
Andrew Tresness
Submitted On
7/4/2018 9:41:27 PM
Affiliation

Phone
503-593-1380
Email
tresness@hotmail.com
Address
P.O. box 2046
Cordova, Alaska 99574

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries. Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually. Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation. PLEASE DENY THIS EMERGENCY PETITION REQUEST Signed, Andrew Tresness

Submitted By
Andrew Wilder
Submitted On
7/9/2018 6:23:53 PM
Affiliation
commercial fishermen

Phone
907 362 1438
Email
fvvigilant@gmail.com
Address
503 A st.
pob 2905
Seward, Alaska 99664

My name is Andrew Wilder. I own the fishing vessel Claire Oceana. We are currently a salmon tender in Kodiak. We are also active in the longline and cod fisheries. We utilize the board process regularly.

I am writing because I do not approve of the latest special meeting called on July 17. This meeting is circumventing the public process and denies the stakeholders involved ample opportunity to respond to the petitions in the middle of a fishing season. It is very important in my business to have an open and transparent BOF process. We are all independent businesses that need ample time to react to BOF petitions, especially special interest groups.

Thanks for your consideration.

Andrew Wilder

RE: Comments on KRSA et al. Hatchery Emergency petition.

Dear Alaska Board of fish, Chairman Jensen and members of the board:

My name is Anneliese Langer and I have been working in the great state of Alaska for seven years. If it wasn't for my years of hard work in the fisheries, in Alaska, I wouldn't have been able to afford my continued education or pay off my undergraduate degree. I watch my peers suffering under crippling debt and unable to get ahead in life. Because of the hatcheries, other fisherman and I have been able to afford to chase our dreams in Alaska and outside of Alaska. Please don't limit this oppurtunity to us young folks.

I support the findings of the ADF & G that no emergency exists & ask you to act in accordance with that.

Please deny this emergency petition request.

Signed,

Anneliese Langer

3238 Undell Rd NE
Olympia, WA 98506

June 27th 2018

ARMSTRONG-KETA INC.
P.O. Box 21990, Juneau, Alaska 99802
Phone: (907) 586-3443; Cell: (907) 723-2222
E-mail: aki@ak.net

Comments Re. Board of Fish Emergency Meeting Petition on VFDA Permit Increase

July 9, 2018

Alaska Board of Fish
John Jensen, Chair
PO Box 5115526
Juneau AK 99811

Dear Members of the Board of Fish,

Armstrong-Keta, Inc. is a private, non-profit aquaculture corporation headquartered in Juneau, that owns and has operated the Port Armstrong Hatchery, located on southern Baranof Island, since 1981. I would like to take this opportunity to comment on the emergency petition to override ADF&G on their approval of a permit increase for the Valdez Fisheries Development Association. I encourage the Board to reject that petition and follow the established procedures for evaluating proposals to the board.

I and the board members of AKI feel that it is important to weigh in on this issue for a variety of reasons, even though we have no direct stake in the permit alteration request that is in question.

Alaska has gained a sterling international reputation for its successful fisheries management program. The decimation of its fisheries as a territory was the driving force behind the push for statehood, and the Alaska constitution institutionalized the principles of sustained yield and the optimization of natural resources for the good of all citizens. The establishment of a Board of Fish independent from the oversight of the legislative and executive branches of the government, along with the scientific management of the resources by a professional staff in the Department of Fish and Game, have ensured that Alaskan fisheries have rebounded and thrived remarkably over the years since statehood.

In contrast, fisheries throughout most of the rest of the world have been characterized by politically-driven decision making. The outcomes in many instances have been appalling, with far too many examples of decline or collapse of the fish populations and the economic activities dependent upon them.

The establishment of hatcheries in Alaska has been a major part of the professional fisheries management in this state. The Alaskan hatchery program was initiated by ADF&G's FRED Division, carefully vetted at every step by analysis and tracking of any impacts on the health of the wild fish resources, and subsequently transferred for the most part over to the private non-profit sector, which has demonstrated its ability to manage hatcheries efficiently and completely within the parameters and safeguards ADF&G established. Central to all Alaskan hatcheries is the concept of enhancement of wild runs, as opposed to mitigation for damaged wild runs as has been the case in the Pacific Northwest. PNP hatchery operators are almost all scientists whose professional priority is maintaining the strength of wild salmon runs and enhancing those robust runs with additional production only where appropriate. The constituents of the hatcheries are commercial and sports fishermen, who comprise the boards of directors and whose interests are paramount to the aquaculture corporations and hatchery operators. Hatcheries have consistently partnered with ADF&G to strive for the healthiest possible fisheries statewide, based on the best available scientific evidence including in-season data collection and long-range evaluation.

The current proposal for an emergency meeting of the Board of Fish to jump into the issue of a permit increase for the Valdez Fisheries Development Association threatens the very foundation of Alaska's long-standing and successful scientific process. The application requested by the Kenai River Sportfishing Association has cited flawed studies and an alarmingly one-sided perspective on a complex issue. KRSA has resorted repeatedly to drumming up political pressure on the legislature and the Board of Fish to promote its agenda. There is a well-established process for evaluating Board of Fish proposals, and KRSA's petition has gone through that process and been rejected by the scientists at ADF&G. To override ADF&G and grant a stay to KRSA on the VFDA permit increase, already vetted in a public process and subsequently approved by the Commissioner of ADF&G, would set a very disturbing precedent by the Board of Fish.

The Board of Fish was never intended to get into the weeds of scientific analysis and evaluate competing technical points of view. The question of ocean carrying capacity and ecosystem analysis is particularly complex and requires specialized education and expertise in negotiating impartial biological and ecological data in order to make informed decisions. Such a background is not a basis for membership on the Board of Fish, which is charged with making broad policy decisions. That is a fundamental reason that ADF&G must be relied upon in their evaluation and decision-making processes.

It would be imminently irresponsible on the part of the Board of Fish to support this emergency petition after the standard process was followed fully, and after ADF&G in fact declared that an emergency meeting on this particular issue was not justified, in order to mollify a handful of persistent voices who apparently don't understand the science behind ADF&G's conclusions. It is easy to cherry-pick data from assorted studies to support any given point of view; it is much more difficult to assimilate all the data into a comprehensive understanding of the state of the science on an issue.

It is particularly egregious to ask for an emergency in the middle of the fishing season, when many of the people most impacted by the meeting are out on the waters plying their trade during the short and intense summer season. There is a good reason that the Board of Fish doesn't hold its regular public meetings during the summer months. There is plenty of time to address the broader long-term issues during the normal Board of Fish process, without bowing to those who would like to politicize Alaska's fisheries management. There is no emergency now, and I encourage the Board of Fish to reject this emergency petition and allow time for gathering the broad spectrum of scientific data before acting precipitously on an issue of such huge consequence.

Sincerely,

Bart Watson
President

From: HATCH
To: DFG, BOF Comments (DFG sponsored)
Subject: Hatchery emergency petition
Date: Monday, July 9, 2018 8:09:11 PM

My name is Arne A. Hatch and I am a Prince William Sound commercial fisherman.
I am writing to comment on the request for an emergency petition concerning salmon hatchery production, currently before the Board of Fisheries. I am currently out fishing and cannot attend.

Salmon Hatchery production is a significant contributor to my catch and has been a stabilizing force for the fleet especially in lean years. While there have been unusual marine conditions in the Gulf of Alaska, there is scarce scientific evidence to support the petitioners claims of emergency.

Please take no action on this emergency request and take up this subject as planned in October.

Thanks for your time,

Arn A. Hatch

Sent from my iPhone

ASHBURN & MASON P.C.

LAWYERS

LAURA C. DULIC • MATTHEW T. FINDLEY • EVA R. GARDNER • REBECCA E. LIPSON
DONALD W. MCCLINTOCK III • JEFFREY W. ROBINSON • THOMAS V. WANG
OF COUNSEL JULIAN L. MASON III • A. WILLIAM SAUPE

July 9, 2018

VIA EMAIL: dfg.bof.comments@alaska.gov

Chairman John Jensen
Alaska Board of Fisheries
P.O. Box 115526
Juneau, AK 99811-5526

Re: **Public Comments of Ashburn & Mason, P.C., Counsel for Prince William Sound Aquaculture Corporation In Opposition To May 16, 2018 KRSA et al. Emergency Petition Regarding VDFA Hathcery Production (Comment Due Date July 9, 2018).**

Dear Chairman Jensen and Members of the Board of Fisheries,

Ashburn & Mason, P.C., counsel to Prince William Sound Aquaculture Corporation ("PWSAC"), submits the following opposition and public comments to the above-referenced petition:

INTRODUCTION

Petitioners ask the Board to declare an emergency and reduce the current permitted salmon production at Valdez Fisheries Development Association's ("VFDA") Salmon Gulch Hatchery. The Department of Fish and Game (the "Department") granted VFDA's production permit in 2014, which provided for gradual production increases on a yearly basis. In year three of the permit, Petitioners now ask the Board to declare an

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"emergency" and essentially veto this permit without engaging in the notice and comment rulemaking required by statute. The Petition establishes no "emergency," nor does the Board of Fisheries ("Board") have the statutory authority to veto the Department's prior permit decision regarding salmon production.

A permit granted four years ago does not qualify as an "emergency" under any definition of the word, let alone the strict definition governing emergency petitions under Alaska law. By statute, true regulatory emergencies are held to a minimum and rarely found.[1] The reason for this strict standard is that enacting regulations outside of the notice and comment rulemaking procedures mandated by the Administrative Procedure Act is strongly disfavored. Here, establishing an emergency requires "unforeseen" and "unexpected" threats against fish and game resources.[2] VFDA's long-standing permit is neither unforeseen nor unexpected. The fact that Petitioners chose not to engage in the public process leading to the permit grant does not make the permit "unforeseen."

Even if there were an emergency, the Board lacks statutory authority to grant the relief requested by Petitioners. As set forth in detail below, the legislature invested the Department with the legal duty to oversee all aspects of hatchery creation, operation, and

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[1] AS 44.62.270.

[2] 5 AAC 96.625(f).

production,[3] including but not limited to how many fish hatchery operators are allowed to incubate and release each year. By statute, the Department, not the Board, regulates hatchery activities that directly impact production levels, such as the harvest of eggs from hatchery broodstock.[4] The Board, on the other hand, is tasked with regulating and allocating the harvest of both hatchery and wild salmon among all user groups that the hatcheries were established to serve, including commercial, personal use, sport, subsistence, and hatchery cost recovery.[5] The Department and the Board have respected and abided by this division of labor and authority for over 30 years. To our knowledge, the Board has never before attempted to second guess a decision by the Department to authorize a specific level of egg take in a hatchery permit.

The Petition seeks to disrupt this well-established division of authority by interjecting the Board into the realm of production management. Specifically, the Petition asks the Board to micro-manage egg take levels from hatchery broodstock, which is squarely within the Department's sphere of authority and expertise, and outside the Board's jurisdiction over allocation of harvest levels. The Petition's only ground for this change in the *status quo* is a narrow statutory subsection, AS 16.10.440(b), addressing

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[3] AS 16.10.400-.470; 5 ACC 40.005-.990.

[4] AS 16.10.445; 5 AAC 40.300; 5 AAC 40.340; 5ACC 40.840.

[5] *E.g.*, AS 16.05.251.

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the Board's authority to amend hatchery permits regarding the "source and number of salmon eggs." This provision cannot bear the weight Petitioners place on it.

When this statute was enacted in 1979, the legislative's reference to "the source and number of salmon eggs" almost certainly referred to the collection of *wild* salmon eggs, before the hatcheries' cost recovery operations had been fully established. Back in 1979, collection of salmon eggs from wild stocks involved the harvest of wild salmon still swimming out in the ocean. In those early days, egg take had a potential to affect the Board's allocative decisions. By contrast, hatchery egg take today is conducted entirely from returning hatchery broodstock, captured in terminal harvest areas, not out in the Sound, with little or no allocative implications.

Even if the statute could be construed to apply to eggs recovered from returning hatchery broodstock, it is an insufficient legal basis for disrupting the Department's comprehensive regulatory regime, which includes hatchery production planning and detailed permitting requirements. Again, the Board has jurisdiction over harvest levels, and the Department has jurisdiction over all aspects of hatchery production, including egg take levels.[6]

[6] *E.g.*, AS 16.10.445, granting the Department exclusive authority over "the source and number of salmon eggs taken" by hatchery operators.

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The Petition is also premature. The potential effects of hatchery fish straying into wild salmon streams, which is the stated impetus for the Petition, have been closely watched by the Department's biologists over the years. These effects are now the subject of an ongoing, in-depth scientific study. Until the study results are known, it is premature to consider curtailment of hatchery production that has already been permitted by the Department. Further, the Board has already stated its intent to address hatchery issues during its regular fall meeting cycle. These important issues can be addressed at that time where there is full opportunity for public participation and comment.

ABOUT ASHBURN & MASON AND PWSAC

Ashburn and Mason is submitting these comments, which focus on the relevant statutes, regulations, and established administrative practice, as a supplement to the comments submitted directly by the Prince William Sound Aquaculture Corporation ("PWSAC"). Ashburn & Mason has represented PWSAC since its creation in 1974. Our firm worked closely with PWSAC's visionary founders in the legislative process that resulted in the creation of the private nonprofit hatcheries ("PNPs") regional aquaculture associations, now codified at AS 16.10.375, *et. seq.*

PWSAC's founders were commercial fishers and community leaders who were responding to repeated wild salmon run failures, and the resulting economic distress throughout the Prince William Sound region in the early 1970s. Working together, the fishermen, local community representatives, the Department, and key legislators developed an innovative legal framework for the creation and operation of the state's PNPs and regional aquaculture associations.

Over the past 40-plus years, the statewide hatchery system has been a resounding success, and is an integral part of Alaska's world class sustainable fisheries. Alaska's hatcheries have generated tens of millions of dollars of economic benefit every year spread across all user groups, supplementing, but not displacing, the sustained yield of Alaska's wild salmon stocks. In fact, all of PWSACs hatcheries were started with salmon eggs collected originally from local wild stocks. The genetics of all Prince William Sound hatchery fish are therefore traceable back to local streams.

DISCUSSION

I. NO EMERGENCY EXISTS TO JUSTIFY THE PETITION TO RESTRICT VFDA'S PERMITTED EGG TAKE

By statute, true regulatory emergencies, which allow the Board to issue regulation without public notice and comment, are held to a minimum and rarely found.[7] This is because public notice and comment are essential to the fairness and transparency of

[7] AS 44.62.270.

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regulatory rulemaking in Alaska. The explicit state policy against the adoption of emergency regulations is so fundamental to the function of regulatory rule-making that it is codified in the Administrative Procedure Act.[8] The Commissioner's decision to deny the emergency Petition reflects this well-established policy and decades of Alaska law and regulation, and must be respected.

The Petition does not present an emergency. Rather, it challenges a permit granted several years ago. The narrow exception for adoption of emergency regulations is limited to "unforeseen" and "unexpected" threats against fish and game resources.[9] These threats must be so imminent that regulatory intervention cannot wait for the usual notice and comment process under the Administrative Procedure Act.[10] For example, the Board adopted an emergency regulation to reorganize the Chignik fishery in 2005 when the Supreme Court issued a decision invalidating the previous fishery rules just six weeks before the season was slated to open.[11] The Superior Court agreed that the timing of the Supreme Court's decision created a legitimate emergency because no one could

[8] *Id.*

[9] 5 AAC 96.625(f).

[10] 5 AAC 96.625(f).

[11] As referenced *infra.* at 3-4, the Commissioner currently has standing authority to review petitions for emergency regulation. See, 2015-277-FB. Prior to the adoption of this policy in 2015, the Board retained the authority to review petitions for emergency regulation.

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reasonably rely on when the Supreme Court would issue its decision, or what that decision would be. In addition to the "unexpected" and "unforeseen" nature of the Supreme Court's decision, the timing also created a sense of imminence. With less than six weeks before the fishing season opened, the Board "had to act quickly…because it had to have something in place for the June opening."[12]

Here, the Petition fails to demonstrate how VFDA's long-standing permit, or the current conditions in the Sound, present an unexpected or unforeseen situation threatening the salmon fisheries. No acute biological or environmental event has impacted the Sound or Cook Inlet in recent months, creating an unpredictable threat. Rather, the purported justification for an emergency petition is an alleged trend, observed over the last several *years*. There is no reason why the proposed Board action could not have been presented a year ago or, more to the point, why it could not wait until the next regularly scheduled Board meeting, which will provide a fuller and fairer opportunity for interested parties and members of the public to comment and participate in the process.

In short, the Commissioner properly exercised his authority under AS 16.05.270 and 2015-277-FB to determine that the Petition failed to present an emergency under the

[12] See, *State of Alaska, Alaska Bd. of Fisheries v. Grunert,* 139 P.3d 1226, 1241 (Alaska 2006).

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Administrative Procedure Act. For the reasons explained in the Commissioner's June 14, 2018 letter to Petitioners, emergency action is unwarranted under these circumstances.

II. THE BOARD DOES NOT HAVE VETO AUTHORITY OVER HATCHERY PRODUCTION PERMITS

A. The Commissioner Has Primary Authority Over Hatchery Permitting and All Hatchery Operations

1. History and Purpose of the Hatchery Program

The desire of Alaskans to manage their abundant salmon fisheries was a driving force behind Alaska Statehood.[13] The importance of protecting and developing natural resources such as salmon is embedded in the Alaska Constitution, which directs the legislature to "provide for the utilization, development, and conservation of all natural

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[13] *See, e.g.*, *Pullen v. Ulmer*, 923 P.2d 54, 57 n. 5 (Alaska 1996); Alaska Legislative Affairs Agency, *Alaska's Constitution: A Citizen's Guide* (4th ed. 2002) at http://w3.legis.state.ak.us/docs/pdf/citizens_guide.pdf (Many Alaskans concluded "that the notion of the federal government's superior vigilance as a trustee of the public interest was really a cloak for the institutional interests of bureaucrats and the economic interests of nonresident corporations exploiting those resources (principally Seattle and San Francisco salmon canning companies)."); HOUSE COMM. ON INTERIOR AND INSULAR AFFAIRS, *Act Providing for the Admission of the State of Alaska into the Union of 1957*, H.R. REP. No 85-624 (1958) (The Statehood Act "will enable Alaska to achieve full equality with existing States, not only in a technical juridical sense, but in practical economic terms as well. It does this by making the new State master in fact of most of the natural resources within its boundaries . . . ."); Univ. of Alaska Anchorage, Institute for Social and Economic Research, *Salmon Fish Traps in Alaska* (1999), at 14, at http://www.iser.uaa.alaska.edu/publications/fishrep/fishtrap.pdf ("Alaska political entrepreneurs used the [fish] trap issue to rally the citizens of the territory around the quest for statehood.").

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resources belonging to the State, including land and waters." It also requires the legislature to make decisions that "provide for the maximum benefit of its people."[14] The Alaska Constitution proclaims that "fish, wildlife, and waters are reserved to the people for common use,"[15] and dictates that "Fish, forests, wildlife, grasslands, and all other replenishable resources belonging to the State shall be utilized, developed, and maintained on the sustained yield principle, subject to preferences among beneficial uses."[16] Further, the Constitution expressly references the goal of "promot[ing] the efficient development of aquaculture in the State," and protecting Alaska's economy from outside interests:[17]

> No exclusive right or special privilege of fishery shall be created or authorized in the natural waters of the State. This section does not restrict the power of the State to limit entry into any fishery for purposes of resource conservation, to prevent economic distress among fishermen and those dependent upon them for a livelihood ***and to promote the efficient development of aquaculture in the State.***

By the early 1970s, salmon runs were in steep decline throughout Alaska. In Prince William Sound, seining did not open at all in 1972 and 1974 due to dangerously

[14] ALASKA CONST. art. VIII, § 2.

[15] ALASKA CONST. art. VIII, § 3.

[16] ALASKA CONST. art. VIII, § 4.

[17] ALASKA CONST. art. VIII, § 15. The Constitution has since been amended to provide for the limited entry permit system now in place, *See infra* n. 7, but the reference to promoting the "efficient development of aquaculture" remains unchanged.

low wild stock returns. In response, the State of Alaska resolved to restore the salmon fisheries. A constitutional amendment provided the basis for limited entry legislation for commercial fisheries,[18] and the state hatchery program was initiated through the creation of the Fisheries Rehabilitation & Enhancement Division (FRED).[19]

Under AS 16.05.020, the Commissioner must "manage, protect, maintain, *improve, and extend* the fish, game ... of the state in the interest of the economy and general well-being of the State." The Department is further required to: "develop and continually maintain a comprehensive, coordinated state plan for the orderly present and long-range rehabilitation, *enhancement*, and development of all aspects of the state's fisheries for the perpetual use, benefit, and enjoyment of all citizens" and "through rehabilitation, *enhancement*, and development programs do all things necessary to ensure perpetual *and*

[18] AS 16.43.400 *et seq.* Alaska's limited entry fishery essentially provides that only permit holders may engage in commercial fishing. The granting of these permits, and the management of the commercial fisheries, are tightly regulated by numerous state agencies including the State Commercial Fisheries Entry Commission (CFEC), the Alaska Department of Fish & Game (ADF&G), and the Board of Fisheries (BOF). *See generally Johns v. CFEC*, 758 P.2d 1256, 1263 (Alaska 1988) ("The Limited Entry Act has two purposes: enabling fishermen to receive adequate remuneration and conserving the fishery.").

[19] AS 16.05.092. As explained more fully below, FRED no longer exists as a distinct division within the Department. However, the operation of most or all of the original hatcheries owned and operated by FRED has been transferred to the regional aquaculture associations, under long-term professional services agreements. PWSAC, for example, currently operates the Cannery Creek, Main Bay, and Gulkana Hatcheries, all of which were constructed and initially operated as FRED hatcheries in the early 1970s.

increasing production and use of the food resources of state waters and continental shelf areas."[20] Similarly, the Department is required generally to "manage, protect, maintain, *improve, and extend* the fish, game and aquatic plant resources of the state in the interest of the economy and the general well-being of the state."[21] The Department is also generally charged to do everything possible to assist with hatchery operations.[22]

In addition, the legislature created the Fisheries Enhancement Revolving Loan Fund to promote the enhancement of Alaska's fisheries by, among other things, providing long-term, low-interest loans for hatchery planning, construction, and operation.[23] PWSAC has received significant support from this program over the years, particularly for capital investments.

In 1974, the FRED state-owned and managed hatchery program was expanded to include private ownership of salmon hatcheries with the passage of the Private Non-Profit (PNP) Hatchery Act.[24] The Act stated that its purpose was to "authorize the private ownership of salmon hatcheries by qualified non-profit corporations for the purposes of

[20] AS 16.05.092(3) (emphasis added).

[21] AS 16.05.020(2) (emphasis added).

[22] AS 16.10.443.

[23] AS 16.10.500-.560; *see generally* Alaska Division of Investments, "Fisheries Enhancement Revolving Loan Fund Program Overview," April 2007 at http://www.commerce.state.ak.us/investments/pdf/FEover07.pdf.

[24] These provisions are now codified at AS 16.10.375 *et seq.*

contributing, by artificial means, to the rehabilitation of the State's depleted and depressed salmon fishery." Further, as noted above, a separate fisheries enhancement loan program was created in 1976 to provide state financing for nonprofit hatcheries.[25]

Over time, the State has transferred operation of some of the FRED hatcheries to other entities, including the nonprofit hatcheries operated by the regional aquaculture associations, concluding that it would be more cost-effective for these hatcheries to be operated by the regional associations. The legislature specifically authorized the sub-contracting of state hatcheries in 1988,[26] acknowledging that after 17 years of the State planning, building and operating hatcheries, Alaska sought an even more efficient way of ensuring a healthy, robust, and sustainable salmon fishery.[27]

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[25] AS 16.10.500 *et seq.; see also State Commercial Fisheries Entry Comm'n v. Carlson*, 65 P.3d 851 (Alaska 2003) ("The state operates a revolving loan fund to support investments in developing and operating fish hatcheries and other fish enhancement projects.").

[26] AS 16.10.480.

[27] Alaska's partnership with the nonprofit hatcheries is unique. Almost all states operate hatcheries of some kind (salmon, trout, walleye, catfish, etc.), but no state operates a hatchery program like Alaska's, and no state works with private nonprofit entities to assist the state government in its hatchery programs. By way of example, California has 21 state hatcheries (http://www.dfg.ca.gov/fish/Hatcheries/HatList.asp), Oregon has 33 state hatcheries (http://www.dfw.state.or.us/fish/hatchery/), and Washington has 91 state hatcheries (http://wdfw.wa.gov/hat/facility.htm), and all of these hatcheries are operated by the government.

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Alaska law provides that the hatcheries may only be non-profit.[28] By design, the hatcheries are allowed to recover operating and capital expenses, as well as costs for research and development and expansion of the production system, including wild stock rehabilitation work.[29] The system is designed to provide benefits to the common property resource users. The nonprofit regional aquaculture associations have no stock-holders, owners, or members. Today, five regional aquaculture associations, from Southeast Alaska to Kodiak, including PWSAC, produce hatchery salmon for common property fisheries.

Thus, the Alaska Constitution, combined with numerous statutes, including those creating the Department of Fish and Game,[30] the Limited Entry Act,[31] the Private Non-Profit Hatcheries Act,[32] and the Fisheries Enhancement Revolving Loan Fund,[33] together

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[28] AS 16.10.380.

[29] AS 16.10.455.

[30] AS 16.05.010, *et.seq.*; *see also* 5 AAC 40.100-.990.

[31] AS 16.43.400 *et seq.* Alaska's limited entry fishery essentially provides that only permit holders may engage in commercial fishing. The granting of these permits, and the management of the commercial fisheries, are tightly regulated by numerous state agencies including the State Commercial Fisheries Entry Commission, the Alaska Department of Fish & Game (ADF&G), and the Board of Fisheries (BOF). *See generally Johns v. CFEC*, 758 P.2d 1256, 1263 (Alaska 1988) ("The Limited Entry Act has two purposes: enabling fishermen to receive adequate remuneration and conserving the fishery.").

[32] AS 16.10.375-480.

[33] AS 16.10.500-.560.

demonstrate a strong and long-standing state policy in Alaska of promoting hatchery development for the purpose of enhancing and ensuring the long-term vitality of Alaska's fisheries.

2. The Department Strictly Regulates All Aspects of Hatchery Creation, Operation, and Production

The Alaska Department of Fish and Game has been charged by the Alaska legislature with final authority over how many fish hatchery operations are allowed to incubate and release each year,[34] and to regulate all other details of hatchery operation.[35]

Pursuant to AS 16.10.375, the Commissioner must designate regions of the state for salmon production and develop a comprehensive salmon plan for each region through teams consisting of Department personnel and nonprofit regional associations of user groups. The Commissioner also has the task of classifying an anadromous fish stream as suitable for enhancement purposes before issuing a permit for a hatchery on that stream. As 16.10.400(f).

Of particular relevance to the issue presently before the Board, AS 16.10.400(g) requires a determination by the Commissioner that a hatchery would result in substantial public benefits and would not jeopardize natural stocks. The statutes also require the

[34] AS 16.10.445; 5 AAC 40.300; 5 AAC 40.340; 5 AAC 40.840.

[35] AS 16.10.400-.470; 5 AAC 40.005-.990.

Department to conduct public hearings near the proposed hatcheries, and to consider comments offered by the public at the hearings before issuance of a permit.[36]

All state hatcheries are operated pursuant to a permit issued by the Department.[37] Standard permit conditions include: (1) provisions that eggs used for broodstock come from a source approved by the Department;[38] (2) no placement of salmon eggs or resulting fry into waters of the state except as designated in the permit; (3) restrictions on the sale of eggs or resulting fry; (4) no release of salmon before department inspection and approval; (5) destruction of diseased salmon; (6) departmental control over where salmon are harvested by hatchery operators; and (7) hatchery location to prevent commingling with wild stocks. [39]

Further, there is an intricate system of basic and annual hatchery plans that are reviewed annually by the Department and provide for performance reviews, and in

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[36] AS 16.10.410.

[37] AS 16.10.400; 16.40.100-.199; 5 AAC 40.110-.240.

[38] AS 16.10.445. This requirement is related to regulations regarding fish transport permitting. *See* 5 AAC 41.001-.100. These regulations provide that no person may transport, possess, export from the state, or release not the waters of the state any live fish unless that person holds a fish transport permit issued by the Commissioner.

[39] *See generally* McGee, *Salmon Hatcheries in Alaska – Plans, Permits, and Policies Designed to Provide Protection for Wild Stocks,* Published for 2004 American Fisheries Society Symposium, at 327.

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appropriate cases, permit alterations.[40] The basic management plans include a complete description of the facility, including the special harvest area, broodstock development schedules, and description of broodstock and hatchery stock management.[41]

Year-to-year hatchery production is regulated through the annual management plans (AMPs) approved and adopted by the Department. For example, each year, PWSAC and the other PNPs across the state work with the Department, which ultimately formulates an AMP for each hatchery. That plan, among other things, determines the number of eggs the hatchery will collect, how the eggs will be collected, the number of fish it will incubate, and how many fish will be released from the hatchery. [42] The AMP also addresses how PNPs will conduct their cost recovery harvest at each hatchery and addresses other specifics of hatchery operation.[43]

3. The Board's Proper Role is to Allocate Harvest, Not to Override the Department's Permitting and Production Decisions

[40] 5 AAC 40.800-990. As noted above, there is also an extensive Regional Comprehensive Planning Program established under AS 16.10.375 and 5 AAC 40.300-.370, with full public participation. This process creates Regional Planning Teams who are charged to "prepare a regional comprehensive salmon plan . . . to rehabilitate natural stocks and supplement natural production . . . ." 5 AAC 40.340.

[41] *See generally* McGee, at 329.

[42] 5 AAC 40.840.

[43] McGee, at 329.

The Board of Fisheries is established by AS 16.05.221, "for purposes of the conservation and development of the fishery resources of the state."[44] In general terms, the Board's duties complement those performed by the Department. While it has broad statutory authority, the Board has historically focused on allocation of fisheries resources between and among the various user groups and gear types. For example, under AS 16.05.251(a) the Board has the power to set time, area, and methods and means limitations on the taking of fish. Under AS 16.05.251(a)(3), the Board also establishes quotas, bag limits, and harvest levels. To the best of our knowledge, however, the Board has always deferred to the Department's expertise and experience with respect to the detailed management of hatchery permitting and production levels.

B. The Board Cannot Override Annual Hatchery Production Permits Issued by the Department

Petitioners contend that AS 16.10.440(b) grants the Board the authority to upend the Department's carefully constructed regulatory framework governing hatchery

[44] AS 16.05.221.

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production.[45] This interpretation of the statute reads it out of context and is inconsistent with its historical origins. Under Alaska law, this statutory provision must be construed in light of the overall statutory scheme governing Alaska's salmon hatcheries,[46] its legislative history and intent,[47] and over 40 years of consistent administrative interpretation and practice, during which the Board (to our knowledge) has never

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[45] AS 16.10.440 provides: (a) Fish released into the natural waters of the state by a hatchery operated under AS 16.10.400 - 16.10.470 are available to the people for common use and are subject to regulation under applicable law in the same way as fish occurring in their natural state until they return to the specific location designated by the department for harvest by the hatchery operator. (b) The Board of Fisheries may, after the issuance of a permit by the commissioner, amend by regulation adopted in accordance with AS 44.62 (Administrative Procedure Act), the terms of the permit relating to the source and number of salmon eggs, the harvest of fish by hatchery operators, and the specific locations designated by the department for harvest. The Board of Fisheries may not adopt any regulations or take any action regarding the issuance or denial of any permits required in AS 16.10.400 - 16.10.470.

[46] *See, e.g. Monzulla v. Voorhees* Concrete Cutting, 254 P.3d 341, 345 (Alaska 2011), *citing In re Hutchinson's Estate*, 577 P.2d 1074, 1075 (Alaska 1978), where the Supreme Court articulated the doctrine of *in pari materia*: the "established principle of statutory construction that all sections of an act are to be construed together so that all have meaning and no section conflicts with another."

[47] *See, e.g. Native Village of Elim v. State* 990 P.2d 1, 5 (Alaska 1999), *Kochutin v. State,* 739 P.2d 170, 171 (Alaska 1987) *citing Hammond v. Hoffbeck*, 627 P.2d 1052, 1056 & n. 7 (Alaska 1981).

attempted to use this statute as the basis for usurping the Department's traditional control over hatchery production.[48]

At the time Section 440(b) was enacted in 1979, the hatchery system was in its infancy. Most hatchery egg take was from wild stocks, not returning hatchery fish, which is how egg take is conducted today. The thinking at the time was that salmon eggs harvested from wild stocks were still a "public resource" while the fish were swimming out in the ocean, and the harvest of wild fish for egg take had allocation implications that could potentially fall within the Board's purview. In contrast, today's egg take procedures are conducted almost exclusively from returning hatchery broodstock that are captured in the special harvest areas directly in front of the hatcheries. At that point, the hatchery salmon cease to be a public resource and their capture and the collection of their eggs have very limited allocative implications. Further, as the Commissioner noted in his January 14, 2018 Memorandum to the Board on the subject of the current Petition, "the

[48] *See e.g. Marathon Oil Co. v. State, Dep't of Nat. Res.*, 254 P.3d 1078, 1082 (Alaska 2011), *Premera Blue Cross v. State, Dep't of Commerce, Cmty. & Econ. Dev., Div. of Ins.*, 171 P.3d 1110, 1119 (Alaska 2007), and *Bullock v. State, Dep't of Cmty. & Reg'l Affairs*, 19 P.3d 1209, 1219 (Alaska 2001), where the Alaska Supreme Court held that agency decisions based on "longstanding, consistent and widely known" interpretations of agency expertise should be given "great weight."

Board's authority over the possession, transport and release of live fish had not been delegated to the department when AS 16.10.440(b) was amended."[49]

Moreover, the legislative history of Section 440(b) indicates that it was never intended to be used by the Board as back door means of overriding the Department's permitting authority or limiting hatchery production. The Resources Committee's letter of intent on HB 359, which included the language in question, states as follows:

> There are three other major changes made by the bill:
>
> (1) Section 2 of the bill amends AS 16.10.440(a)(b). The amendment clarifies the role of the Board of Fisheries. The role of the Board of Fisheries as envisioned by the original legislation was to regulate the *harvest* of salmon returning to the waters of the state. That role extends to regulating those fish which are returning as a result of releases from natural systems and also from hatchery releases. There are provisions in other specific locations for the harvest of salmon by the hatchery operator for sale, and use of the money from that sale, for the specific purposes as stated in AS 16.10.450. The added language clarifies that the Board of Fisheries may adopt regulations relating to the *harvest* of the fish by hatchery operators at the specifically designated locations. The Board of Fisheries in the past year or two has enacted regulations relating to those harvests for several of the private nonprofit hatcheries in the state.[50]

[49] Memorandum from Sam Cotton, Commissioner, to John Jensen, Chair, dated January 14, 2018, Re: Emergency Petition to the Alaska Board of Fisheries requesting the Board to reverse a department decision to allow a 20 million increase in the number of pink salmon eggs to be harvested by VFDA in 2018.

[50] House Journal, March 15, 1979, pp. 601-602 (emphasis added).

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The exclusive reference to regulation of harvest, and the absence of any mention of production controls, corroborates the conclusion that the legislature never intended to authorize the Board to limit hatchery production.

The Board's traditional function has always been to allocate harvests among competing user groups, not to regulate production of fish. This legislative history, with its emphasis on "harvest," is also consistent with PWSAC's long-held belief (apparently shared by the Department) that Section 440(b) was intended to cover egg take from wild salmon streams, not to apply to egg take from returning hatchery fish.

Further corroboration of this conclusion is found in AS 16.10.445(a), which unambiguously requires the Department, not the Board, to "approve the source and number of salmon eggs taken under AS 16.10.400-16.10.470." Additional evidence that the Department, not the Board, is responsible for regulating hatchery egg take can be found in 5 AAC 41.001, *et. seq.* For example, 5ACC 41.005 prohibits the release of hatchery fish without a permit issued by the Commissioner. Regulation of egg take and release of the resulting salmon fry are obviously two sides of the same coin. The regulatory scheme clearly and consistently assigns exclusive responsibility for regulating those two closely related hatchery activities to the Commissioner.

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Given the legislative history, the 30-plus year pattern of administrative interpretation, the anomalous language in Section 440(b) regarding regulations to "amend...the terms of a permit," and the mandate of Section 445(b), it is quite clear that the Board has little or no role in regulating hatchery production, including but not limited to egg take permit restrictions.

Moreover, regulation of hatchery production by the Board would overlap and almost certainly conflict with the comprehensive and detailed hatchery regulations that are currently in place and operating effectively. As noted above, the Department has a rigorous permitting process for new hatcheries, 5 AAC 40.100-.240. There is an extensive Regional Comprehensive Planning program established under AS 16.10.375 and 5 AAC 40.300-.370, with full public participation. By regulation, the responsibility of the Regional Planning Teams is to "prepare a regional comprehensive salmon plan ... to rehabilitate natural stocks and *supplement* natural production . . ." 5 AAC 40.340 (emphasis added). As mentioned earlier, there is also an intricate system of basic and annual hatchery plans that are reviewed annually by the Department, performance reviews, and, in appropriate cases, permit alterations. 5 AAC 40.800-.900. Production levels are carefully monitored by the Department under these regulations and adjusted if necessary for economic or biological reasons. The Department's statutory authority for

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this intense level of hatchery regulation is quite clear, and there seems to be little room for the Board to insert itself into a very public process that has been working well for many years.

CONCLUSION

Back in the early 1970s, Prince William Sound experienced recurring wild salmon run failures, which caused serious financial distress throughout the region. In response, the framers of the Constitution and the Alaska Legislature took active and far-sighted steps to first establish a state run hatchery system and, shortly thereafter, the private non-profit and regional hatchery regime that has consistently stabilized the runs and enhanced salmon harvests throughout the state since 1976. Overall, Alaska's hatcheries have been a remarkable success and have helped the state's salmon resources to thrive and expand over the past 40 years, creating millions of dollars of positive economic impact, without any demonstrable harm to wild salmon stocks.

From the very beginning, every aspect of Alaska's hatcheries' creation, operation, and production have been closely supervised and regulated by the Department, with harvest area and allocation decisions made by the Board. This division of responsibility has served Alaska well for many years and there is no good reason to abandon it now.

For these reasons, the Board should deny the Petition.

ASHBURN & MASON P.C.

ASHBURN & MASON, P.C.

Matthew T. Findley

for:

A. William Saupe

Laura C. Dulic

July 2, 2018

Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board Members:

This emergency petition should never have been brought forward for consideration.

Hatchery production is critical to the economic health of many communities across Alaska. Without them, this state would be much less prosperous. As an example, there would not be the extensive marine trades in Homer. Also, hundreds of of young kids have gone to college on crew shares earned on both seine and gillnet vessels participation in hatchery-based fisheries.

We and our family depend on hatchery production for our livelihood.

Please DENY this Emergency Petition.

Emil "Beaver" Nelson
Beaver Nelson

Box 130
Homer, AK 99603

F/V Nuka Point

Jessie L. Nelson
Jessie Nelson

Box 130
Homer, AK 99603

Permit Holder

Submitted By
Ben Van Alen
Submitted On
7/8/2018 11:54:08 PM
Affiliation

Phone
907-723-2995
Email
bvanalen@gmail.com
Address
3860 Caroline Street
Juneau, Alaska 99801

It is impossible to maintain healthy salmon stocks and fisheries in the face of industrial-scale hatchery releases. There is only one ocean and the production of salmon from the ocean is ultimately limited by its carrying capacity. Wild and hatchery fish can fill this carrying capacity but only wild fish help to sustain it. It is the natural spawning and dying of millions of salmon in thousands of natal streams that helps maintain the productive capacity of our watersheds, estuaries, bays, straits, and ocean. Hatchery fish are elbowing their way into the ecosystem potluck without bringing a dish. The “nutrient mining” inherent with ocean ranching is lowering the productivity for all biota. The 1.6+ billion "nutrient miners" now released from Alaskan hatcheries each year are in direct competition for space and food with wild fish. We observe declining and depressed runs of eulachon, herring, Chinook, Sockeye, Coho, Pink, and Chum Salmon wherever we have industrial scale hatchery programs. Why do we continue to think that the ocean is limitless and that we will have more salmon if we just release more salmon? Why allow hatcheries to employ whatever rearing and release strategies they can “afford” to provide their releases with a survival advantage over wild fish? Why allow hatchery strays? Why spend millions of dollars to supplant wild fish with hatchery fish? Instead of joining Japan and Russia as world leaders in ocean ranching nutrient mining we must stand tall and go wild for healthy runs and healthy fisheries. We all know the key to abundant salmon is to maintain the habitat and maintain the spawners. Minimizing hatchery releases is critical to maintaining the habitat and maintaining the spawners – and completely under our control. How can a hatchery fish help a wild one?

Submitted By
Benjamin Trocki
Submitted On
6/27/2018 10:23:39 AM
Affiliation
PWS Drift permit holder

Phone
9073179204
Email
papaweishnook@yahoo.com
Address
1769 Dimond Drive
Anchorage, Alaska 99507

I am in strong opposition to the emergency petition request by KRSA. I am a PWS drift gillnet permit holder in the heart of my season and like all fisherman cannot be present , in body or mind, in these matters that could so dearly affect us. Please deny the emergeny request.

RECEIVED
JUL 03 2018
BOARDS

6-27-2018

Bernard Culbertson

F/V NINKASI

Valdez, Alaska

To Alaska Board of Fish

RE: Comments on KRSA et al. Hatchery Emergency Petition

Chairman Jensen and Board of Fish Members:

I am a commercial fisherman in PWS and have been since the mid 70's. I fished both Drift and Seine for years and saw the days when there were years when it didn't open to the seine fishery.

We started the hatchery program in PWS to augment the poor returns to Pink, Chum, and Coho salmon. It has been a continuing sucess and commercial and sport interests have benifited through a 10 fold increase in participation. The commercial interests of charter and net fisheries have rarely had conflicts in PWS and the sport people from the Interior to Anchorage have enjoyed the increased benifits of hatchery production.

Finally convening an emergency meeting in the middle of the summer when the fleet is unable to attend seems biased toward a KRSA agenda. This petition has already been denied as not meetin the Emergency Criteria so why not wait until the already scheduled October work session.

PLEASE DENY THIS EMERGENCY PETITION REQUEST

Bern W. Cutt

Box 2906
VALDEZ,, AK 99686

July 8, 2018

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

My wife Patty and I have lived in Seward year around for almost 40 years. Our three kids were born, raised, and attended local Seward schools through graduation. We love this place and it is by making a living commercial fishing that we have managed to stay and raise our family here. My first year as a seine deckhand in PWS was in 1985 on Arne Hatch's boat, the Phoenix. In the years since, we as a family have gillnetted from our own boat in PWS and on the Copper River for 14 years and setnetted in Main Bay, PWS for 15 years. Both our sons, Gus and Bobby, have owned and operated PWS seine operations for the last ten years. Ann, our daughter, works as fleet manager for Camtu's Alaska Wild Seafoods, a 100% local Cordova processor. Many others in our town of Seward, and almost all of Cordova, make a living from the PWS fisheries between tendering, gillnetting, seining, and processing. In Seward, guided charter fishing is also a major economic driver for our town supporting many families. A major component of the salmon charter catch which supports our local charter fleet stems from hatchery releases which have a decades-long history in Resurrection Bay. As major local stakeholders, we take the request made to the Board of Fish by this petition very seriously.

My concern with this "emergency" petition, and more importantly, that it is being brought forth during a hastily called meeting right in the middle of the most active part of the year for all of the local fishermen described above, is this. There can be no proper public process if it is to be done in this manner. It is my belief that the most important role that the Board of Fish provides is to bring stakeholders from all sides to the table. Nearly all those who would be taking an economic hit should the actions requested by this petition be approved cannot attend this July 17th meeting due to the ongoing salmon seasons in PWS and may not even be able to comment with the short notice provided, as the petitioners well know. The original Notice of Permit Alteration for the increased egg take at Solomon Gulch was signed by ADF&G in May 2014 after public RPT process earlier that year. Subsequent Annual Management Plan reviews occurred during the 2015, 2016, and 2017 PWS RPT meetings. Throughout this four year public process, the KSRA was welcome to step in with their concerns. In reading the minutes of all of these meetings, it does not appear to me that they made that effort even once. And now, once all permits have been received, necessary infrastructure funded and completed, staff to complete the egg take already on the payroll, and commercial fishermen known to be unable to attend during the height of the 2018 salmon season, comes KSRA et al with their request to overturn it all. This request should be denied outright on the basis of the need to protect the BOF process and the necessary public trust and participation that must underlie that process if it is to be successful in the long term.

Approval of the KSRA et al. Hatchery Emergency Petition at this time will cause harm to me, my family, my community, all other communities surrounding Prince William Sound, and many other people and businesses all over Alaska. Prior to doing anything of this sort, the underlying scientific reasoning presented by KSRA or any other entity needs to be analyzed by ADF&G, vetted through public process, and action taken only after thorough participation by all sides throughout. As of this date, almost none of this has taken place.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Sincerely,

Robert Linville
Seward, Alaska

Submitted By
Brad Marden
Submitted On
7/9/2018 9:20:18 AM
Affiliation

Phone
9077996005
Email
brad.m.marden@gmail.com
Address
c/o Icicle Seafoods Inc. PO Box 30
Larsen Bay, Alaska 99624

My name is Brad Marden. I own and operate a Kodiak seiner, FV Renaissance, and I live in Homer with my wife and two kids. Income gained from salmon fishing is my family's primary way to put food on the table and pay bills. During the summer I live away from home on the boat- this is my work season- and rarely have access to phone or email. I would like to ask the board to delay making critical allocation decisions to salmon fisheries during the salmon fishing season. It is extremely difficult to get representative comments, feedback, and attendance from commercial fishermen if emergency meetings are held in the summer months. Please consider posponing these proposals until your October meeting. Thanks, Brad Marden

Submitted By
Brad Reynolds
Submitted On
7/8/2018 2:55:13 PM
Affiliation

Phone
19074245141
Email
bradfreynolds@gmail.com
Address
PO Box 1936
Cordova, Alaska 99574

Dear Board of Fish members, I am an area E permit holder and resident of Cordova. My family is one of many young families earning their livelihoods fishing both wild and hatchery stocks along Prince William Sound and the Copper River delta. I am urging the board to deny the latest KRSA petition. The board has previously found no emergency and this third KRSA emergency petition is resulting in a July hearing that greatly precludes participation by commercial fisherman who are fully engaged in their summer fishery. The board has scheduled a work session in October to carefully consider relevant data regarding hatchery production. Denying the current KRSA petition and delaying any further consideration on this topic until the October work session ensures an open and fair public process. Thank you for considering my request. Sincerely, Brad Reynolds

Submitted By
Brett Egeland
Submitted On
6/27/2018 12:27:59 PM
Affiliation
Commercial Fisherman

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

I remeber also going to hatcheries many times in my growing up in public eduction system on feild trips and learning many things. This would be taken away and the young would not be able to learn what I did and have that expirience.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Brett Eric Egeland

Submitted By
Brian lee
Submitted On
7/7/2018 9:12:39 PM
Affiliation
Self

Phone
9073551854
Email
blee@mtaonline.net
Address
31250 W Lee drive
Sutton, Alaska 99674

I have depended on the hatcheries in pws for the majority of my commercial fishing income since 1985. I do not believe that pws pinks are fully responsible for the weak king runs in Cook Inlet. I have invested heavily in the pws pink salmon fishery this year. To decrease hatchery production would greatly affect my income as a commercial fishermen. Thank you. Brian lee

Submitted By
Buck Laukitis
Submitted On
7/8/2018 10:20:40 AM
Affiliation

Dear Chairman Jensen,

I am writing to ask that you deny the emergency request to curtail the already permitted hatchery egg take by the Valdez Fisheries Development Association.

On process, it seems an embarrasment to your fine organization which is built around public participation to have a meeting July 17 that denies meaningful input by stakeholders most effected. I am writing from the grounds in Prince William Sound. We have both a seiner and a tender that benefit from hatchery production here. I don't think I can provide you with the detailed comments I would like to because I am trying to catch fish land maintain my boat to support my family. This is a distraction at this time of year. I believe this same petition has already failed at a recent board meeting. Where is the new information or a change in the fishery that constitutes an emergency that cannot be deliberated at an already scheduled meeting or by your new hatchery committee?

Prince William Sound was never much of a salmon producting area. The topography, a major earthquake, and an unprecedented man made ecological disaster caused by the Exxon Valdez oil spill all set the table for fishermen and the state to make long term investments in a successful productive hatchery program. The oil spill alone makes the PWS hatchery program a unique mitigating factor — enabling communities like Cordova, Homer and Seward to maintain fishing businesses. You have to ask what these communities would be like without the hatchery program? Wouldn't you want more of a good thing? ADFG has successfully managed enhanced salmon and wild salmon in PWS. Just a few years ago in 2015 PWS enjoyed both record wild and enhanced production with over 100 million fish. In my community, Homer, and also in Cordova there are young fishermen who graduate from gill netting to seining who are doing exactly what every policy maker in the state is striving to achieve. They are successfully making it, and their success is entirely dependent on hatchery salmon.

I think you should take the net benefit approach to this petition. Who are you possibly helping by subscribing to the hypothesis by a special interest group that increased VFDF production is harming xyz/ fill in the blank? Then compare that unknown to the known harm, economic disruption, potential lawsuit, loss of production, etc. you willl cause. For what good reason? There is no new information. There is no causal link. You would be harming one group of users that includes sport fishermen, charter fishermen, personal use fishermen and commercial fishermen and hoping and speculating that your actions would help another group. Bad policy.

Thank you for your efforts in considering these important matters. The work you do is very much appreciated by all of us who live in coastal communities and who rely on fishery resources in the state of Alaska.

Sincerely,

Buck Laukitis

From: Buck Meloy
To: DFG, BOF Comments (DFG sponsored)
Cc: director@ufa-fish.org
Subject: Board of Fish Meeting Scheduled for July 17, 2018
Date: Wednesday, June 27, 2018 2:48:49 PM

Dear BOF:
I gillnetted salmon in Area E (Copper River & Prince William Sound) for about 30 years before retiring in 2012. I agree completely with UFA's letter to the Board of Fish.
Whether hatchery production of salmon in Prince William Sound should be expanded, in quantity and/or locations, is something that should not even be considered in a vacuum. The locations and potential risks of additional sites, the possibility of production increases overwhelming existing habitat, and many other factors need to be carefully taken into account.
It is inconceivable to me that you would pick the middle of July, when the many hundreds of knowledgable fishermen, hatchery professionals, processors, and on the ground ADFG scientists and employees are all immersed in Prince William Sounds fisheries.
I don't claim to have special knowledge. I don't know whether, where, or when existing hatcheries should be expanded, or whether new should be built, and where. But I do know that it took many years for us to come to agreement on promising plans that, over time, demonstrated the wisdom of all of that careful consideration and effort.
Please reconsider the date of this meeting so that many of the most knowledgable Alaskans will be available to share what they know.
Thank you,
Buck Meloy

****

Date: June 27, 2018
Name: Buck Meloy
Fishing Vessel: F/V Spindrift
Home Port: Cordova

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

buck@buckmeloy.com

Submitted By
Caleb Maness
Submitted On
7/8/2018 5:04:45 PM
Affiliation

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

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Please deny this emergency petition request.

Signed,

Caleb Maness

Submitted By
Carlos Gonzalez
Submitted On
7/8/2018 5:13:40 PM
Affiliation

Phone
4238475653
Email
calebrmaness@gmail.com
Address
112 Forestry Way
Cordova, Alaska 99574

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

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Please deny this emergency petition request.

Signed,

Carlos Gonzalez

Submitted By
Cathy Renfeldt
Submitted On
7/9/2018 8:02:05 AM
Affiliation
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July 8, 2018

Chairman John Jensen

Alaska Board of Fisheries

Boards Support Section

PO Box 115526

Juneau, AK 99811

Submitted via email: dfg.bof.comments@alaska.gov

RE: Comments on KRSA et al. Emergency Petition on VFDA

Dear Chairman Jensen and Alaska Board of Fisheries Members:

The Cordova Chamber of Commerce has recently been made aware of Kenai River Sportfishing Association (KRSA) et al.'s Emergency

Petition on Valdez Fisheries Development Association (VFDA). As the voice of the Cordova business community comprising a variety of industries including lodging, transportation, outfitting, retail, transportation, shipping, seafoc processing and many others areas; **we do not support this emergency petition.**

We echo the City of Cordova, Alaska Resolution 06-18-17 **supporting the Alaska Department of Fish & Game's approval of VFDA's permitted increase of 20 million pink salmon eggs at the Solomon Gulch Hatchery. We recommend that the Alaska Board of Fisheries confirms Alaska Department of Fish and Game's (ADF&G) findings for a lack of emergency with regards to this petition, and request that the board take no action to reduce the permitted capacity of the Solomon Gulch Hatchery by 20 million pink salmon eggs in 2018.**

We feel that the City of Cordova benefits greatly from Prince William Sound salmon fisheries enhancement programs through hatchery propagation; both sport and commercial fisheries enhancement efforts of the Valdez Fisheries Development Association. We also feel these programs provide sustainable direct economic and social benefit to the community of Cordova. This benefit is realized through the creation of local seafood processing jobs, fisheries business tax, increased commerce and seafood industry investment in our community. In addition, the enhancement of the sport fishery by VFDA provides significant fishing opportunity for coho salmon throughout eastern Prince William Sound, and this sport fishing activity significantly increases summer tourism by attracting visitors to Cordova to sport fish in eastern Prince William Sound; further benefiting local commerce through the sale of sporting goods, custom processing, lodging, fuel, harbor moorage, float plane charters, fishing charters and other purchases. The sport fish enhancement program provided by VFDA is substantially funded through the sale of cost recovery pink salmon; and salmon hatchery programs like the ones at VFDA are permitted using a public process. They employ strong scientific methodology and are built upon sound and sustainable fisheries policies intended to protect wild salmon populations.

Sincerely,

Cathy Renfeldt

Executive Director

Cordova Chamber of Commerce

Submitted By
Christopher L Maxcy
Submitted On
7/8/2018 4:41:35 PM
Affiliation

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07/07/2018

Christopher L. Maxcy

F/V Carol Rose

Home Port: Cordova

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound. A large portion of my family's income depends upon the commercial salmon harvest. Due to the untimely submission of this petition I have limited time to comment. There are many commercial fishermen who will not have an opportunity to comment at all. This denies their right and mine to due process and is completely unreasonable, especially since the same petition has already been denied due to not meeting emergency criteria.

As the Board is well aware hatchery programs are economic drivers for Alaskan communities. Hatcheries benefit entire communities, including the sport fishermen, subsistence and personal use. The Board has access to the independent research statistics for VFDA as well as other hatcheries state wide.

Address the issue during the October 2018 work session as planned and make a decision based on biological facts and scientific data. Please do not make a decision based on pressure from petition filers that are denying the appropriate use of the system.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Thank you,

Christopher L. Maxcy

Dear Chairmen Jensen and Board of Fisheries Members,

I am a commercial fisherman in Prince William Sound. My great grandfather came to Alaska in 1936. He started commercial fishing in Alaska his very first summer here. Once his sons were old enough, they went out as his crew. Fishing has been my family's life blood ever since.

My Dad's father moved his family to Alaska in 1963. They settled in Cordova, where he started fishing the copper river flats, and then seining Prince William Sound. When my dad turned eight, he started fishing every summer with his dad. At age 19. my dad bought his first copper river gillnetter. I first began fishing with my dad at age 5 and have been on the water ever since. At age 18, I bought my own copper river gillnet operation. Four years later I sold it and bought a Prince William Sound seining operation. This is my 8th season captaining a seine boat in PWS and marks 82 years that my family has been commercial fishing and living in Alaska. This is my heritage and one I hope to pass onto my children as well.

I have participated in the salmon fisheries in Bristol Bay, Kodiak, Prince William Sound, and Southeast Alaska. With the exception of Bristol Bay, all of these fisheries have experienced a positive boost from hatcheries. They helped produce viable and most importantly, sustainable fisheries throughout this state. In Prince William Sound alone, there are 1,500 active salmon permit holders and crew members. As well as benefiting many sport and subsistence users within the state. My family, and many others, have been harvesting hatchery fish alongside wild fish for over thirty years. Not only have they been a crucial part of our fisheries earning potential, they are also a massive boost to the ecosystem. From shrimp to birds to marine mammals, they all feed on salmon at various points throughout their life.

It is of great concern that an emergency meeting is being convened in the middle of our fishing season, while we are busy trying to provide for our families. This is poor process and leaves fishermen vastly under represented.

Please deny this emergency petition request.

Sincerely,

Colten Tutt

Colten Tutt

6/28/18

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

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PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Colten Fett

Cook Inlet AQUACULTURE ASSOCIATION

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Alaska Department of Fish and Game
Alaska Board of Fisheries
P.O. Box 115526
1255 W. 8th Street
Juneau AK 99811-5526

July 9, 2018

Re: Comments Regarding a Petition for a Finding of Emergency for a Permitted Increase of 20 Million Pink Salmon Eggs for a Prince William Sound Hatchery

Dear Chairman Jensen and Board of Fisheries Members:

We respectfully request the Board reject the petition to amend the recommendation of the Prince Willian Sound (PWS) Regional Planning Team (RPT) and reject the petitioners request to deny a permitted increase of 20 million pink salmon eggs at a PWS hatchery. The petition does not clearly demonstrate the increased production of 20 million pink salmon eggs at the Valdez Fisheries Development Association's (VFDA) Solomon Gulch Hatchery will have harmful effects on wild stocks. We agree with the comments submitted by other hatcheries that the literature cited in the emergency petition provides weak, corollary assumptions, and in some cases contradictory evidence to support the claim for a finding of an emergency. Thus, we support the decision by Commissioner Sam Cotten that the increased production does not constitute an emergency pursuant to 5 AAC 96.625(£).

The Cook Inlet Aquaculture Association (CIAA) is a regional association formed in 1976 and is dedicated to providing and protecting salmon resources for all users groups. We currently operate three hatcheries that provide sockeye, coho, and pink salmon for harvest by commercial, sport, personal use and subsistence fishermen. Like other Alaska hatcheries we operate under the regulations, policies and practices approved by the Alaska Department of Fish and Game (ADF&G). Key requirements of these regulations, policies, and practices provide safeguards that protect wild salmon stocks; safeguards like the use of local brood sources, the marking and recovery of fish released, and limnological sampling of rearing lakes. We encourage our staff to remain current on the best hatchery management practices and support studies on hatchery/wild salmon interactions. Successful hatchery programs, like natural fish populations, require good management practices based on sound scientific principles to be successful.

Alaska's current hatchery program was developed in response to the low harvest of salmon and mirrors the development of other hatchery programs throughout the North Pacific. Production from Alaska's current hatchery program began in the 1970s and grew through the 1980s through carefully regulated management plans to its current level of production. Since the mid-1990s Alaska's hatchery production has been relatively stable with only limited variations from year to year.[1] Although hatchery production has remained relatively constant over time, other variables such as marine survival have fluctuated up and down suggesting other environmental factors may be driving the fluctuations seen in salmon populations.

Alaska's salmon hatchery programs have been developed over several decades and are based on shared, well-thought-out, science-based information. The permit alteration request to increase the Solomon Gulch Hatchery pink salmon egg take by 20 million eggs has been well planned and has been available for public review since 2014. CIAA requests the Board reject the emergency petition to deny the increased egg take at the Solomon Gulch Hatchery.

Respectfully

Gary Fandrei

Gary Fandrei
Executive Director

[1] *See ADF&G Alaska Salmon Fisheries Enhancement Annual Report, 2017, RIR No. 5J18-02.*

Effects of Hatchery-Origin Pink Salmon On Ecosystems and Other Pacific Salmon:

An Annotated Bibliography

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For

Cook Inletkeeper

Homer, AK
www.inletkeeper.org

July 2018

Agler, B.A., G.T. Ruggerone, L.I. Wilson, and F.J. Mueter. 2013. Historical growth of Bristol Bay and Yukon River, Alaska chum salmon (*Oncorhynchus keta*) in relation to climate and inter-and intraspecific competition. Deep-Sea Res II 94, 165-177.

This study of Bristol Bay and Yukon River adult chum salmon scales from 1965 through 2006 showed that increased growth was associated with higher regional ocean temperatures but slower growth associated with wind mixing and ice cover. Lower third-year growth was associated with high abundance of Asian chum and warmer sea surface temperatures (SST) in the Gulf of Alaska. High abundances of Russian pink salmon was also associated with lower third-year growth but the effects were smaller than those shown for high abundance of Asian chum and warmer GOA SST.

Amoroso, R. O., M. D. Tillotson, and R. Hilborn. 2017. Measuring the net biological impact of fisheries enhancement: Pink Salmon hatcheries can increase yield, but with apparent costs to wild populations. Canadian Journal of Fisheries and Aquatic Sciences 74:1233–1242.

This research estimated the net effect of the largest hatchery program in North America, the Prince William Sound pink salmon. Using other Alaska regions as reference sites (Kodiak, SE Alaska, and southern Alaska Peninsula), the authors used catch data from before establishment of hatchery programs (1960-1976) and after (1988-2011). The reference sites all had smaller programs than PWS (with no southern Alaska Peninsula pink hatchery program). Post late-1970s climate regime shift, all regions had higher catches, with PWS having the greatest increase. Changes in wild salmon abundance were estimated for each region. Hatchery releases did not appear to decrease year-to-year variability in catches. No net positive effects (that is, taking into account the cost of the hatchery programs <u>and</u> reduced wild abundance) from the hatchery programs were detected for in Kodiak or SEAK. In PWS, the net effect was an increase in catch by 28%, lower than that estimated by other studies. This does not take into account other negative effects (e.g., other ecosystem effects, smaller size of returning fish), so any increases in hatchery programs should be done with a full accounting of risks and benefits.

Armstrong, J.L., Myers, K.W., Beauchamp, D.A., Davis, N.D., Walker, R.V., Boldt, J.L., Piccolo, J.J., Haldorson, L.J. and J.H. Moss. 2008. Interannual and spatial feeding patterns of hatchery and wild juvenile pink salmon in the Gulf of Alaska in years of low and high survival. Transactions of the American Fisheries Society, 137(5), pp.1299-1316.

This research compared hatchery and wild pinks in PWS and the northern coastal Gulf of Alaska (CGOA) with regard to their summer diets and feeding patterns (e.g., prey composition) in 1999-2004 (encompassing both high- and low-survival years). Hatchery and wild pink salmon had similar diets both during their residence in PWS and after they initially migrate to the CGOA. This lack in difference means that PWS hatchery pink can compete with wild fish for the available prey. Also, it appears that faster-growing fish can migrate from PWS earlier in summer and take advantage of better feeding opportunities in the CGOA.

Atcheson, M. E., K. W. Myers, N. D. Davis, and N. J. Mantua. 2012. (abs) Potential trophodynamic and environmental drivers of steelhead (*Oncorhynchus mykiss*) productivity in the North Pacific Ocean. Fisheries Oceanography 21:321–335.

"Information on prey availability, diets, and trophic levels of fish predators and their prey provides a link between physical and biological changes in the ecosystem and subsequent productivity (growth and survival) of fish populations. In this study two long- term data sets on summer diets of steelhead (*Oncorhynchus mykiss*) in international waters of the central North Pacific Ocean (CNP; 1991–2009) and Gulf of Alaska (GOA; 1993–2002) were evaluated to identify potential drivers of steelhead productivity in the North Pacific. Stable isotopes of steelhead muscle tissue were assessed to corroborate the results of stomach content analysis. We found the composition of steelhead diets varied by ocean age group, region, and year. In both the GOA and CNP, gonatid squid (*Berryteuthis anonychus*) were the most influential component of steelhead diets, leading to higher prey energy densities and stomach fullness. Stomach contents during an exceptionally warm year in the GOA and CNP (1997) were characterized by high diversity of prey with low energy density, few squid, and a large amount of potentially toxic debris (e.g., plastic). Indicators of good diets (high proportions of squid and high prey energy density) were negatively correlated with abundance of wild populations of eastern Kamchatka pink salmon (*O. gorbuscha*) in the CNP. In conclusion, interannual variations in climate, abundance of squid, and density- dependent interactions with highly- abundant stocks of pink salmon were identified as potential key drivers of steelhead productivity in these ecosystems. Additional research in genetic stock identification is needed to link these potential drivers of productivity to individual populations."

Azumaya, T., and Y. Ishida. 2000. Density interactions between Pink Salmon (*Oncorhynchus gorbuscha*) and Chum Salmon (*O. keta*) and their possible effects on distribution and growth in the North Pacific Ocean and Bering Sea. North Pacific Anadromous Fish Commission Bulletin 2:165–174.

Data from Japanese salmon research vessels from 1972-1998 were analyzed to evaluate the long-term spatial and temporal distribution of chum and pink salmon. Chum salmon distribution varied out-of-phase with the odd-even differences in pink salmon abundance (pinks having higher abundance in odd years). Chum salmon growth was not directly affected by pink salmon abundance but was affected by chum salmon abundance (higher abundance = slower growth), indicating that intra-species competition was more important than inter-species competition. Dietary (stomach content) research would shed more light onto the importance of inter-specific competition.

Batten, S. D., G. T. Ruggerone, and I. Ortiz. In press. Pink Salmon induce a trophic cascade in plankton populations in the southern Bering Sea and around the Aleutian Islands. Fisheries Oceanography. DOI: 10.1111/fog.12276.

This study examined time series (2000-2014) of phytoplankton and copepod abundances around the Aleutian Islands and the southern Bering Sea and compared those numbers with pink salmon abundances, which were eight times higher in odd years than in even (2000-2012). In 2013 (odd year), the abundance was 73% lower than previous odd years and the next year, pink abundance was relatively high (although lower than the average odd year abundance). There are opposing biennial patterns in abundances of large phytoplankters and copepods relative to pink salmon abundances: in odd years, pink salmon abundance and large diatom abundance is high, while copepod (prey of pink salmon and grazer of diatoms) abundance is low. These associations were stronger than comparisons to "stanzas", the 4-6 year cycle of warm or cold temperatures found in the Bering Sea.

Beamish, R. J., R.M. Sweeting, T.D. Beacham, K.L. Lange, and C.M. Neville. 2010. A late ocean entry life history strategy improves the marine survival of Chinook salmon in the Strait of Georgia. NPAFC Doc. 1282. 14 pp. (Available at www.npafc.org).

One aggregated population of Georgia Strait Chinook salmon (South Thompson drainage of the Fraser River) has increased in recent years while most other Georgia Strait Chinook populations have declined. The South Thompson Chinook juveniles are not abundant in Georgia Strait in July but are by September, and by November are moving to sea, probably through the Strait of Juan de Fuca. Harrison River sockeye salmon are also a "late-entry" juvenile and doing better than others. It is theorized that high populations of pink and chum salmon present in Georgia Strait at the same time as earlier-entry populations of Chinook and sockeye are the reason why these populations of Chinook and sockeye are not doing as well as late-entry populations. Focused research is needed.

Brenner, R. E., S. D. Moffitt, and W. S. Grant. 2012. Straying of hatchery salmon in Prince William Sound, Alaska. Environmental Biology of Fishes 94:179–195.

The authors (all ADFG employees) sampled streams in PWS to determine stray rates using data gathered in two time periods, 1997-1999 and 2008-2010. Percentages of hatchery pink salmon in spawning areas varied from 0 to 98%. Most (77%) of spawning locations had pink salmon from three or more hatcheries, and the escapement at 51% of locations consisted of more than 10% hatchery pink salmon during at least one year surveyed. Application of an exponential decay model indicates that many streams would have over 10% hatchery pinks, even if distant from a hatchery. Besides the implication of genetic effects on wild populations, the authors express concern that estimates of wild escapement may be inflated by the assumption that all fish seen in weirs or in aerial surveys are assumed to be wild.

Debertin, D. J., J. R. Irvine, C. A. Holt, G. Oka, and M. Trudel. 2017. Marine growth patterns of southern British Columbia Chum Salmon explained by interactions between density-dependent competition and changing climate. Canadian Journal of Fisheries and Aquatic Sciences 74:1077–1087.

The authors report the results of a study of 39 years of scale growth measurements of chum salmon from Big Qualicum River (BC) in regard to climate variation and competition with other North American salmon (chum, sockeye, and pink). When the North Pacific Gyre Oscillation was positive, growth increased (attributed to higher primary production). Growth at all ages was negative when the combined biomass of NA salmon was high. Competition effects increased when the NPGO was more positive and the Pacific Decadal Oscillation was more negative. The authors recommend the use of biomass estimates over abundance estimates to take into account inter-species variations and the observed trend of smaller returning salmon. The authors believe this study is the first to use a longitudinal model to examine growth versus the interactions of climate and density dependent competition. If their results are typical of wild salmon populations, reductions in hatchery releases should be considered.

Grant, W.S., 2012. Understanding the adaptive consequences of hatchery-wild interactions in Alaska salmon. Environmental Biology of Fishes, 94(1), pp.325-342.

This is a review of hatchery-wild interactions with an emphasis on genetic effects to wild populations. While the author acknowledges that some may argue that studies conducted elsewhere may not be applicable to Alaskan salmon populations for a variety of reasons, the near-universal result that introgression between hatchery fish and wild fish leads to reduced fitness in wild populations is a fact that must be considered when evaluating hatchery programs. The adaptive potential of wild populations must be preserved as a buffer against climate change and diseases.

Gritsenko A.V. and E.N. Kharenko. 2015 (abs). Relation between biological parameters of Pacific salmons of the genus Oncorhynchus and their population dynamics off the northeastern Kamchatka Peninsula. J Ichthyol 55:430–441.

"Results are provided of a 7-year study of biological parameters in females of three Pacific salmons of the genus *Oncorhynchus* (pink salmon *O. gorbuscha*, chum salmon *O. keta*, and sockeye salmon *O. nerka*) in the Olyutorsky and Karaginsky gulfs, Bering Sea. Abundance of the pink salmon is identified as the main determining factor of the interannual dynamics of maturity index in female Pacific salmon in coastal waters. Maturity index rises at high levels of abundance as a result of differently directed changes in two parameters: decreasing body weight and increasing ovary weight. In female chum salmon, maturity index depends on the age structure of the population and body weight dynamics of different age groups, factors influenced by high abundance of some pink salmon generations, and does not depend on the abundance of spawning chum salmon. The revealed association between pink salmon and sockeye salmon in dynamics of their biological parameters may result from the similarity of their diets; during the last year of fattening in the sea, the sockeye salmon is affected by the pink salmon, the most abundant of the three species. The interannual variation of biological parameters in pink salmon and chum salmon is more pronounced in Olyutorsky Gulf than in Karaginsky Gulf."

Heard, W.R., 2012. Overview of salmon stock enhancement in southeast Alaska and compatibility with maintenance of hatchery and wild stocks. Environmental Biology of Fishes, 94(1), 273-283.

This review of the hatchery programs of SEAK, as well as some relevant studies of wild-hatchery interactions, acknowledges that some interactions between hatchery salmon and of wild salmon are unavoidable, but concludes that “obvious adverse impacts from the current levels of hatchery releases and population trends in Alaska’s wild salmon populations are not readily evident.” The author believes that SEAK hatchery chum programs have been successful in increasing numbers for fisheries, but says that additional increases (which have been requested) should be limited to “gradual incremental steps” given concern over straying in some streams, until better information is generated on the possible impacts of hatchery programs on wild populations.

Hilborn, R. and D. Eggers. 2000. A review of the hatchery programs for pink salmon in Prince William Sound and Kodiak Island, Alaska. Transactions of the American Fisheries Society 129:333-350.

Wertheimer, A. C., W. W. Smoker, T. L. Joyce, and W. R. Heard. 2001. Comment: A review of the hatchery programs for pink salmon in Prince William Sound and Kodiak Island, Alaska. Transactions of the American Fisheries Society 130:712–720.

Hilborn, R. and D. Eggers, 2001. A review of the hatchery programs for pink salmon in Prince William Sound and Kodiak Island, Alaska: Response to Comment. Transactions of the American Fisheries Society 130:720–724.

Hilborn and Eggers used ADF&G catch data from four Alaska regions. The initial paper concluded that while the PWS hatchery program was successful in producing fish to be harvested, the overall increase in harvest wasn’t necessarily due to the PWS pink salmon hatchery programs, because other AK regions (with no, or geographically separated hatchery programs) experienced an increase in wild pink production. In fact, increases in pink salmon harvest in PWS occurred before large-scale hatchery programs there. Therefore, the hatchery-produced pink salmon replaced rather than augmented the wild fish. A decline in wild production in PWS was attributed to lower wild escapements and hatchery releases (the authors claim no evidence has been produced to show that the Exxon Valdez oil spill was detrimental to long-term pink salmon production).

Wertheimer et al. (2001) commented that Hilborn and Eggers vastly over-estimated wild pink production and therefore underestimated the proportion of the PWS pink harvest that could be attributed to hatchery production. They also used a longer time-series of catch data, along with other approaches to the data. Hilborn and Eggers (2001), in a response, stand by their conclusions and point out that in this case a longer time-series is not appropriate (positive changes in pink salmon habitat after the 1964 earthquake). They maintain that an increase in PWS pink production was evident before large-scale hatchery releases took place, and that hatchery releases replaced rather than augmented wild production.

Holt, C.A., Rutherford, M.B, and R.M. Peterman. 2008 (abs). International cooperation among nation-states of the North Pacific Ocean on the problem of competition among salmon for a common pool of prey resources. Marine Policy 32, 607–617.

“A common-pool problem in the North Pacific Ocean that remains largely ignored in international policy is competition for prey resources among salmon populations (*Oncorhynchus* spp.) from different countries. Hatcheries release large abundances of juvenile salmon into the North Pacific and the resulting decrease in mean body size of adult wild and hatchery salmon may lead to reductions in benefits. We examine incentives and disincentives for cooperation among nation-states on this issue. We recommend that either a new international organization be created or that amendments be made to the mandate and powers of an existing organization. The resulting organization could encourage collective action to reduce competition among salmon from different nations by using side-payments to change the incentive structure, by establishing a multi-national scientific assessment team to create a common frame of reference for the problem, and by implementing policy prescriptions.”

Irvine, J. R., and M. Fukuwaka. 2011. Pacific salmon abundance trends and climate change. ICES Journal of Marine Science 68:1122–1130.

This study compared abundance of five species of salmon (represented by commercial catch data) in both Asia and North America with five climate regimes (1925-1946, 1946-1976, 1977-1988, 1989-1998, and 1999-2009). Higher catches in the western north Pacific are attributed to hatchery programs (both releases and better hatchery technology resulting in healthier fry). The results confirm earlier studies indicating regime “shifts” in 1947, 1977, and 1989. Higher catches of pink and chum since 1990 in all regions have occurred and can be attributed to hatchery releases in only the northwestern Pacific region because only Russia has significantly increased hatchery releases.

Jeffrey, K. M., I. M. Coté, J. R. Irvine, and J. D. Reynolds. 2016. Changes in body size of Canadian Pacific salmon over six decades. Canadian Journal of Fisheries and Aquatic Sciences 74:191–201.

Commercial catch data for five salmonid species from 1951-2012 were analyzed along with climatic variables (four Pacific Ocean indices), latitude of catch, and total salmonid biomass to determine if size of caught fish has changed, and if so, what variables are associated with the changes. Catch data from the least-selective method were used to minimize any size-selective gear bias. Analyses from the earlier part of the catch dataset agree with the results of previous research. The results from this study indicate changes in body size over time from oceanic changes as well as density-dependent effects. Pink salmon size declined initially but has changed relatively little over the last 20 years. Body size of Chinook, chum, and coho was most influenced by the total biomass of sockeye, chum, and pink salmon in the Gulf of Alaska. Inclusion of Asian chum salmon did not improve model performance. Pink salmon size was reduced as total biomass increased, with odd-years (higher abundances of pinks) showing a more pronounced effect. Chinook and coho body size increased with total salmon biomass, possibly reflecting better overall environmental conditions, given the lack of overlap in diet preferences between Chinook and coho vs. the other three species.

Jenkins, E.S., Trudel, M., Dower, J.F., El-Sabaawi, R.W. and A. Mazumder. 2013. Density-dependent trophic interactions between juvenile pink (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*) in coastal marine ecosystems of British Columbia and Southeast Alaska. North Pacific Anadromous Fish Commission Technical Report 9:136-138.

This study employed stable isotopes to determine the degree of dietary overlap between juvenile chum and juvenile pink salmon (the southern end of SEAK to the northern end of Vancouver Island), and how that is affected by temperature, abundance (juvenile salmon), and prey availability. Juveniles were collected 2000-1 and 2004-5. The niches of pink and chum overlapped more when abundance was high and prey availability was low. The size difference between the species was not significantly correlated with overlap. It appears that when competition was greater (fewer prey items) both species became less selective and therefore they overlapped more. Hatchery releases resulting in greater numbers of juveniles may thus increase competition.

Kaev, A. M. 2012 (abs). Wild and hatchery reproduction of Pink and Chum salmon and their catches in the Sakhalin-Kuril region, Russia. Environmental Biology of Fishes 94:207–218.

“In the Sakhalin-Kuril region hatchery culture of pink and chum salmon is of great importance compared to other regions of the Russian Far East. During the last 30 years the number of hatcheries increased two-fold, and significant advances were made in hatchery technologies. As a result, chum salmon capture in regions where hatcheries operate (southwestern and eastern Sakhalin coasts, and Iturup Island) was 9 times as high during 2006–2010 than during 1986–1990, whereas wild chum salmon harvest markedly declined. Recent dynamics in pink salmon catch appear to track trends in natural spawning in monitored index rivers, suggesting natural-origin pink salmon play a dominant role in supporting the commercial fishery. It remains uncertain as to whether hatcheries have substantially supplemented commercial catch of pink salmon in this region, and I recommend continued research (including implementing mass marking and recovery programs) before decisions are made regarding increasing pink salmon hatchery production. Location of hatcheries in spawning river basins poses problems for structuring a management system that treats hatchery and wild populations separately. Debate continues regarding the existence and importance of density-dependent processes operating in the ocean environment and the role hatcheries play in these processes. Loss of critical spawning habitat for chum salmon in the Sakhalin-Kuril region has lead to significant declines in their abundance. I conclude by recommending increases in releases of hatchery chum salmon numbers in the region to help recover depressed wild populations and provide greater commercial fishing benefits in the region.”

Kaev, A. M., and J. R. Irvine. 2016. Population dynamics of Pink Salmon in the Sakhalin-Kuril region, Russia. North Pacific Anadromous Fish Commission Bulletin 6:297–305.

Run size (catch plus escapement) data and numbers of hatchery and wild fry were estimated for eight areas around Sakhalin Island and the southern Kuril islands over the 1975-2015 period. Marine survival was also indexed by dividing run size by the number of fry for each area. Odd-year runs are greater than even-year runs, with the difference increasing over time. The recent increase in pink salmon catch does not appear to be the result of hatchery releases (greater numbers of fry) but instead is the result of environmental conditions in early life stages. Increasing size of adults is attributed to conditions in the common area where pinks (from a number of investigated areas) mingle later in life.

Kaga T., Sato S., Azumaya T., Davis N.D., and M-a. Fukuwaka. 2013. (abs) Lipid content of chum salmon Oncorhynchus keta affected by pink salmon *O. gorbuscha* abundance in the central Bering Sea. Mar Ecol Prog Ser 478:211–221.

"To assess effects of intra- and inter-specific interactions on chum salmon in the central Bering Sea, chum salmon lipid content was analyzed as a proxy for body condition. We measured the lipid contents of 466 immature individuals collected during summer from 2002 to 2007. Individual variation in log-transformed lipid content was tested using multiple regression analysis with biological and environmental variables. A regression model that included chum salmon fork length and pink salmon CPUE (number of fish caught per 1500 m of gillnet) was the most effective in describing variation in lipid content. Path analysis showed that the negative effect of pink salmon CPUE was stronger than the effect of chum salmon CPUE on chum salmon lipid content. Stomach content analysis of 283 chum salmon indicated non-crustacean zooplankton (appendicularian, chaetognath, cnidarian, ctenophore, polychaete, and pteropod) was higher under conditions of high pink salmon CPUE. Increased consumption of non-crustacean zooplankton containing a low lipid level could lower the lipid content of chum salmon. Thus, chum salmon lipid content could be affected directly by their shift in prey items and indirectly by interspecific competition with pink salmon."

Malick, M.J. and S.P. Cox. 2016. Regional-scale declines in productivity of pink and chum salmon stocks in western North America. PloS one, 11(1), p.e0146009.

Historical population data from 99 wild chum and pink stocks in WA, BC, and AK were assessed, and trends in productivity noted. While productivity of some pink stocks in Alaska declined over time, others increased. The authors believe that the productivity of pink and chum stocks in western North America is driven by common processes "operating at the regional or multi-regional spatial scales." The effects are not constant but can change over time. While some environmental factors operating at the regional scale (and thus, are potential drivers of productivity) were identified, they were not investigated. "Mechanisms that operate over these spatial scales may include freshwater or marine processes such as disease or pathogens, changes in stream flow and stream temperature, competition with abundant hatchery salmon, or shifts in oceanographic condition such as the timing of the spring phytoplankton bloom or sea surface temperature." They found that most chum and some pink salmon stocks declined, in contrast to Stachura et al. (2014) and other reports.

Malick, M.J. 2017. Multi-scale environmental forcing of Pacific salmon population dynamics. PhD thesis, Simon Fraser University, School of Resource and Environmental Management, Burnaby, BC. http://summit.sfu.ca/system/files/iritems1/17425/etd10171_MMalick.pdf

This researcher considered variable environmental factors (e.g., phytoplankton phenology, horizontal and vertical transport patterns) and their influence on salmon productivity (*see* Malick and Cox 2016). The thesis also contains a section on policy analysis where the author outlines the problems that arise from management of migratory anadromous fish species, e.g., multiple national and sub-national polities, the fact that management decisions of one entity can impact the resources of another, and incomplete use of real-time data to make management decisions. The author believes that an "international ecosystem synthesis group" could integrate information from various managers and provide "strategic management advice" based on their synthesis of the various information they receive. Because of the complexity of managing Pacific salmon, a multi-faceted approach is warranted.

Manhard, C.V., Joyce, J.E., Smoker, W.W. and A.J. Gharrett. 2017. Ecological factors influencing lifetime productivity of pink salmon (*Oncorhynchus gorbuscha*) in an Alaskan stream. Can. J. Fish. Aquatic Sci. 74(9), 1325-1336.

A study of the pink salmon populations (both even- and odd-years) of a short (323 m) lake-outlet stream indicated that early marine survival was the primary determinant of overall productivity. An overall downward trend in productivity was associated with an observed decline in freshwater spawning habitat quality. A nearby hatchery released large numbers of pink fry 1988-2002 but no difference in marine survival was noted between that time period and afterwards (with no hatchery releases). "[W]hile commercial harvest and hatchery straying do occur, the effects of these processes on adult recruitment are more likely to be stochastic than deterministic."

Morita, K. 2014. Japanese wild salmon research: toward a reconciliation between hatchery and wild salmon management. North Pacific Anadromous Fish Commission Newsletter 35:4–14.

This English-language article summarizes some Japanese-language literature on wild and hatchery salmon management in Japan. The author believes that wild salmon productivity is higher and more important than many people believe. Most large rivers in Japan have hatchery programs, and protecting wild populations is a way to guarantee continued success of the hatchery programs (e.g., genetic reserve, source of broodstock in integrated programs). Integrated hatchery programs are probably the best management option in highly-developed, hatchery-dominated Japanese watersheds.

Morita, K., S. H. Morita, and M. Fukuwaka. 2006. (abs) Population dynamics of Japanese Pink Salmon (*Oncorhynchus gorbuscha*): are recent increases explained by hatchery programs or climatic variations? Canadian Journal of Fisheries and Aquatic Sciences 63:55–62.

“Hatchery programs involving the mass release of artificially propagated fishes have been implemented worldwide. However, few studies have assessed whether hatchery programs actually increase the net population growth of the target species after accounting for the effects of density dependence and climatic variation. We examined the combined effects of density dependence, climatic variation, and hatchery release on the population dynamics of Japanese pink salmon (*Oncorhynchus gorbuscha*) from 1969 to 2003. The population trends were more closely linked to climatic factors than to the intensity of the hatchery programs. The estimated contributions of hatchery-released fry to catches during the past decade are small. We concluded that the recent catch increases of Japanese pink salmon could be largely explained by climate change, with increased hatchery releases having little effect.”

Moss, J.H., Beauchamp, D.A., Cross, A.D., Myers, K.W., Farley Jr, E.V., Murphy, J.M. and Helle, J.H., 2005. Evidence for size-selective mortality after the first summer of ocean growth by pink salmon. Transactions of the American Fisheries Society 134(5)1313-1322.

Juvenile pink salmon originating from PWS hatcheries were sampled in PWS and the Gulf of Alaska in 2001 to identify the hatchery of origin and determine if larger, faster-growing pink salmon had higher survival rates. Adult pink salmon were also sampled in PWS (at cost-recovery fishing sites) in 2002 for scale analysis to determine if size-selective mortality was occurring after the juvenile sampling (through scale analyses). Both juveniles and adults showed high growth rates in June but lower in July. In July 2001, far fewer juveniles were caught in the Gulf of Alaska than in PWS, although catch rates were similar in August and September, a time when elevated growth rates were also seen. This indicates a bottleneck in growth for PWS pink salmon in July and possible density-dependent effects. The results also indicate that juveniles must attain a critical size in order to survive over the winter and bottlenecks in growth could prevent juveniles from attaining that size.

Myers, K.W., R.V. Walker, N.D. Davis, and J.L. Armstrong. 2004. Diet overlap and potential feeding competition between Yukon River chum salmon and hatchery salmon in the Gulf of Alaska in summer. Final Report to the Yukon River Drainage Fisheries Association. SAFS-UW-0407. School of Aquatic and Fisheries Sciences, University of Washington, Seattle. 63 p.

The overlap in diets and the potential for feeding competition distribution between Yukon River chum salmon and hatchery chum, pink, and sockeye from Asia and Alaska were investigated in summers in the Gulf of Alaska from 1993 through 2003 by examining almost 5000 salmon stomach contents. Inter-specific overlap in salmon diets was low to moderate, however the quality of chum salmon diets was lower than the diets of all sizes of pink salmon and large-sized sockeye salmon. There was a higher potential for competition between Yukon River chum and Alaska hatchery pink salmon in the northeast region of the GOA than in the southeast region.

Stomach contents analyses were consistent with previous studies that showed that chum salmon switch their diets to lower-calorie prey when pink salmon abundance is high. The results lead to hypotheses that competition with hatchery salmon in the GOA may reduce the growth of immature Yukon River chum, especially when adverse ocean and climate conditions limit prey abundance, and that the reduction in growth may reduce survival by various mechanisms such as increased predation, decreased lipid storage, and increases in disease and parasites.

Ohnuki, T., K. Morita, H. Tokuda, Y. Oksutaka, and K. Ohkuma. 2015. (abs) Numerical and economic contributions of wild and hatchery Pink Salmon to commercial catches in Japan estimated from mass otolith markings. North American Journal of Fisheries Management 35:598–604.

“Evaluating the contribution of wild and hatchery fish to a fishery is essential to understand economic feasibility as well as the impact of hatchery fish on the ecosystem. However, a precise estimate of this contribution is often difficult to obtain, particularly when hatchery and wild fish are mixed in the catch. In this study, we quantified the contribution of hatchery and wild Pink Salmon *Oncorhynchus gorbuscha* to the mixed- stock commercial fishery in Japan by identifying the ratio of otolith- marked hatchery fish to unmarked and presumably wild fish. The contribution of hatchery fish to the total coastal catch of Pink Salmon in Japan was estimated to be 16.6% and 26.4% in 2011 and 2012, respectively. Thus, the majority of the commercial salmon catch originated from naturally spawned wild fish. Economic yield per release by Japanese hatcheries was 2.2 yen (¥2.2) (≈US$0.022) and ¥1.5 in 2011 and 2012.”

Pearson, W.H., Deriso, R.B., Elston, R.A., Hook, S.E., Parker, K.R. and J.W. Anderson. 2012. Hypotheses concerning the decline and poor recovery of Pacific herring in Prince William Sound, Alaska. Reviews in Fish Biology and Fisheries *22*(1), pp.95-135.

In 1993, the Pacific herring stock of Prince William Sound dramatically declined: the stock was about 20% of the predicted record-breaking biomass. The authors examine a number of studies advancing a number of different hypotheses on the reason(s) for the observed decline, and could find no evidence that any of the following have led to either the decline or the poor recovery of PWS herring: oil exposure from the *Exxon Valdez* oil spill; harvest effects; spawning habitat loss; the spawn-on-kelp fishery; disease. Instead, the authors attribute the decline to poor nutrition that began in the mid-1980s and reached a low in 1993. Disease was a secondary response. The fact that the recovery of PWS Pacific herring has been poor despite fishery restrictions is attributed to oceanic conditions outside of PWS and juvenile pink salmon releases (pink salmon predation on age-0 herring and food competition between pink salmon and age-1 herring). Multi-species or ecosystem-based management, rather than single-species management is recommended.

Peterman, R. M., C. A. Holt, and M. R. Rutherford. 2012. The need for international cooperation to reduce competition among salmon for a common pool of prey resources in the North Pacific Ocean. North Pacific Anadromous Fish Commission Technical Report 8:99–101.

These researchers accept that density-dependent competition is occurring in the north Pacific and is caused by hatchery programs. Increasing hatchery releases may result in a diminishing return on the costs of hatchery programs, but if competition increases sufficiently wild populations will also be affected as well. The situation is that the “common-pool” resource that is the north Pacific is subject to the classic “Tragedy of the Commons”. The North Pacific Anadromous Fish Commission, after amendments to its mandate, is the body best equipped to deal with the situation. The NPAFC should “identify and implement collective actions to prevent further increases in competition among salmon from different nations or even reduce it” as “[a]ction on this problem of multinational grazing of salmon food is long overdue.” Action needs to be taken before a crisis occurs, such as climatic changes that may limit overall salmon productivity, and will likely lead to a knee-jerk call for more (ultimately counter-productive) hatchery releases.

Prince William Sound Science Center studies on hatchery-wild interaction:

Gorman, K., McMahon, J., Rand, P., Knudsen, E., and D.R. Bernard. 2018. Interactions of wild and hatchery pink salmon and chum salmon in Prince William Sound and Southeast Alaska. Final report for 2017. Prince William Sound Science Center, Cordova, AK.

Gorman, K., McMahon, J., Rand, P., Knudsen, E., and D.R. Bernard. 2016. Interactions of wild and hatchery pink salmon and chum salmon in Prince William Sound and Southeast Alaska. Progress Report for 2016. Prince William Sound Science Center, Cordova, AK.

Knudsen, E., Buckhorn, M., Gorman, K., Rand, P., Roberts, M., Adams, B., O’Connell, V. and D.R. Bernard. 2015. Interactions of wild and hatchery pink salmon and chum salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2014. Prince William Sound Science Center, Cordova, AK; Sitka Sound Science Center, Sitka, AK.

Knudsen, E., Buckhorn, M., Gorman, K., Crowther, D., Froning, K., Roberts, M., Marcello, L., Adams, B., O’Connell, V. and D.R. Bernard. 2015. Interactions of wild and hatchery pink salmon and chum salmon in Prince William Sound and Southeast Alaska. Final Progress Report for 2013. Prince William Sound Science Center, Cordova, AK; Sitka Sound Science Center, Sitka, AK.

Knudsen, E., Rand, P., Gorman, K., McMahon, J., Adams, B., O’Connell, V. and D.R. Bernard. 2016. Interactions of wild and hatchery pink salmon and chum salmon in Prince William Sound and Southeast Alaska. Progress Report for 2015. Volume 1. Prince William Sound Science Center, Cordova, AK; Sitka Sound Science Center, Sitka, AK.

Prince William Sound Science Center. 2013. Interactions of Wild and Hatchery Pink and Chum Salmon in Prince William Sound and Southeast Alaska. Annual Report 2012. For Alaska Department of Fish and Game Contract IHP-13-013

These reports were generated as part of a research effort sponsored by ADF&G. The purposes are to: “1) further document the degree to which hatchery pink and chum salmon straying is occurring; 2) assess the range of interannual variability in the straying rates; and, 3) determine the effects of hatchery fish spawning with wild populations on the fitness of wild populations.” Ocean sampling was conducted in 2013-2015 in nine locations near the entrances to PWS to determine wild or hatchery origins of pink and chum in PWS (via examination of otoliths). Stream studies were also conducted to determine the proportion of hatchery-origin fish on the spawning grounds and an investigation into the relative survival of the offspring of naturally spawned fish (wild and hatchery-origin). These reports have reported basic data with no advanced statistical or biological analyses. Proportions of hatchery-origin pink salmon on spawning grounds range from zero to over 80% in some PWS streams.

Riddell, B., M. Bradford, R. Carmichael, D. Hankin, R. Peterman, and A. Wertheimer. 2013. Assessment of Status and Factors for Decline of Southern BC Chinook Salmon: Independent Panel’s Report. Prepared with the assistance of D.R. Marmorek and A.W. Hall, ESSA Technologies Ltd., Vancouver, B.C. for Fisheries and Oceans Canada (Vancouver. BC) and Fraser River Aboriginal Fisheries Secretariat (Merritt, BC). xxix + 165 pp. + Appendices. Available at www.psc.org/publications/ workshop-reports/southern-bc-chinook-expert-panel-workshop. Accessed June 5, 2018

Evidence presented at a workshop discussing the decline of southern BC chinook did not support the hypothesis that pink salmon abundance had a role in the decline of southern BC Chinook. There was no apparent odd- and even-year pattern in Chinook survival (which would thought to be present if pinks were having an effect), although some recent literature (referenced in this report) indicated that there may be an effect.

Ruggerone, G.T., and J.R. Irvine. 2018. Number and biomass of natural- and hatchery-origin pink, chum, and sockeye salmon in the North Pacific Ocean, 1925-2015. Mar Coast Fish 10:152-168.

Abundance and biomass data are presented for pink, chum, and sockeye for the time period 1925-2015; this is the most comprehensive tally to date. These species are at an all-time high, as the late 1970s regime shift benefited these species. If immature salmon are included, the north Pacific contains 5 x 10^6 metric tons of these species. Pink salmon were the most abundant adult fish of the three (67%) and were 48% of the total biomass (chum 20% and 35%; sockeye 13% and 17%, respectively). Alaska produced 39% of the pink salmon with Japan and Russia producing most of the remainder. Hatcheries accounted for 15% of the pink salmon production (Alaska produced 68% of hatchery pink salmon) although hatchery fish dominated in some regions, such as PWS and SEAK. In the period 1990-2015, hatchery fish composed 40% of the total biomass in the north Pacific, which may be at its carrying capacity. Density-dependent effects are occurring although hatchery-wild interaction effects are difficult to quantify. Management agencies should mark hatchery fish and estimate hatchery- and natural-origin fish in their catch and escapement data to aid focused research efforts.

Ruggerone, G.T., Agler, B.A., Connors, B.M., Farley Jr., E.V., Irvine, J.R., Wilson, L.I. and E.M. Yasumiishi. 2016. Pink and sockeye salmon interactions at sea and their influence on forecast error of Bristol Bay sockeye salmon. North Pacific Anadromous Fish Commission Bulletin 6:349–361. doi:10.23849/npafcb6/349.361 (Available at http://www.npafc.org).

Ruggerone et al. (2010) showed that abundance of sockeye salmon in western and central Alaska tended to be positively correlated with pink salmon abundance, in contrast to more southern regions where sockeye abundance was negatively correlated with pink salmon abundance. Ocean conditions may be an overriding factor, so this research was focused on evaluation of the evidence of competition between Bristol Bay sockeye and pink salmon from Russia and central Alaska. Sockeye scales from 1965 through 2009 were evaluated for growth patterns; abundance of adult pink salmon was available in previously published literature. Growth patterns from all five BB sockeye stocks indicated a strong alternating-year growth pattern, consistent with the hypothesis that sockeye and pinks compete for food on the high seas. Sockeye growth at sea during odd-years was low; other referenced research indicated that pink and sockeye have a high diet overlap. Also, in odd-years sockeye stomach fullness was reduced. Examination of the ADF&G's sockeye salmon abundance forecasts from 1968-2010 indicated errors in an alternating-year pattern; a tendency for a too-high forecast in even-years, and too low in odd-years, consistent with a hypothesis that competition at sea between sockeye and pink (in the year previous to the sockeye return year) was indeed a factor but was not considered in the forecasts.

Ruggerone, G.T. and B.M. Connors. 2015. Productivity and life history of sockeye salmon in relation to competition with pink and sockeye salmon in the North Pacific Ocean. Can. J. Fish. Aquat. Sci. 72, 818–833.

The Fraser River (BC) sockeye salmon return in 2009 was the lowest in over 60 years, capping a decline that had started in the 1980s. Scientists indicated that declining productivity at sea was responsible rather than factors like spawner abundance or freshwater factors. Pink salmon abundance was identified as a possible factor due to overlapping spatial distribution in the north Pacific and diets. This research uses stock-recruitment dynamics and data from 36 sockeye salmon populations ranging from Washington State north to SEAK (18 were Fraser River drainage populations). Sea-surface temperature (SST) and farmed salmon were also considered as possible confounding factors. Results indicated that 1) during odd-years (high pink abundance), sockeye survival rates and length-at-age of returning sockeye were lower, as well as a higher proportion showing delayed maturation; 2) for all but one population (with a unique "ocean-type" life history) sockeye growth in the second year was negatively correlated with pink salmon abundance and led to lower sockeye productivity; 3) inclusion of environmental factors did not improve performance; and 4) there did not seem to be evidence that returning pink salmon preyed on out-migrating sockeye salmon. The 1970s regime shift saw an actual increase in pink salmon abundance from 200 million to 400 million; a model of pink salmon abundance and Fraser River sockeye returns predicted a reduction in Fraser River sockeye returns of approximately 5.5 million.

Ruggerone, G. T., B. A. Agler, and J. L. Nielsen. 2012. Evidence for competition at sea between Norton Sound chum salmon and Asian hatchery chum salmon. Environmental Biology of Fishes 94:149–163.

An important chum salmon population in Norton Sound, Alaska (Kwiniuk chum) has experienced reduced adult length-at-age, age-at-maturation, productivity, and abundance, corresponding with increased hatchery Asian chum salmon abundance. Analyses of the relevant data indeed show that hatchery Asian chum salmon abundance is negatively correlated with the size and age parameters, productivity, and abundance of the Kwiniuk chum. Inclusion of Asian and western Alaska wild chum salmon abundance did not improve the model. Lower productivity of Kwiniuk chum was correlated with high abundance of wild eastern Kamchatka Island pink salmon during odd-years; the effect was less than that of hatchery chum. This evidence for density-dependent effects points out the need for international cooperation on hatchery releases.

Ruggerone, G.T., Peterman, R.M., Dorner, B. and K.W. Myers. 2010. Magnitude and trends in abundance of hatchery and wild pink, chum, and sockeye salmon in the North Pacific Ocean. Mar Coast Fish 2, 306–328.

Total abundance numbers for both Asia and North America populations of chum, pink, and sockeye salmon were reconstructed from catch and spawner abundance data from 1952–2005. Pink salmon were the most abundant (70%), followed by sockeye (17%) and chum (13%). After the mid-1970s regime shift, pink and sockeye became more abundant while chum numbers decreased. Asian salmon numbers did not increase until the 1990s. Hatchery releases increased during the 1990s and early 2000s, reaching 4.5 x 10^9 juveniles/yr. Hatcheries were responsible large numbers of adult fish returning: 62% of the chum, 13% of the pink, and 4% of the sockeye in 1990-2005. Combined, wild and hatchery salmon in the same time period averaged 634 million fish, twice as many as during 1952-1975. Better data gathering and management are needed, as well as international cooperation to better manage the common waters, especially in light of possible increases in hatchery releases in the face of evidence of changing climate and density-dependent effects.

Ruggerone, G.T. and J.L. Nielsen. 2004. Evidence for competitive dominance of pink salmon (*Oncorhynchus gorbuscha*) over other salmonids in the North Pacific Ocean. Rev Fish Bio Fish 14, 371–390.

The alternating yearly cycle of pink salmon abundance lends itself to studies of competition with other Pacific salmon. This review article examined studies to date indicating that competition between pink salmon and other salmon is an important process negatively influencing other salmon species because pink salmon are efficient predators of the (common) prey. The authors are not aware of any studies of pink salmon being negatively affected by other Pacific salmon. Their abundance (pink salmon are the most common Pacific salmon), rapid growth, high feeding rates, and early entry combine to make pink salmon a dominant competitor. It also appears that pink salmon have been the dominant competitor in the north Pacific across multiple climate regimes.

Ruggerone, G.T., Zimmermann, M., Myers, K.W., Nielsen, J.L. and D.E. Rogers. 2003. Competition between Asian pink salmon (*Oncorhynchus gorbuscha*) and Alaskan sockeye salmon (*O. nerka*) in the North Pacific Ocean. Fish Oceanogr 12, 209–219.

The researchers hypothesized that competition between Bristol Bay sockeye and Asian pink salmon would be greater in odd-years when pink salmon abundance was generally greater. BB sockeye scale samples from 1955 to the 1990s (from variously aged fish) and fish length (from adult returns in each river system) from 1958-2000 were used to determine growth estimates. Scale growth estimates showed a distinctive alternating-year pattern as growth was typically below average in odd-years and above average in even-years for both ocean age-2 and age-3 sockeye. Lengths of adult BB sockeye were inversely related to Asian pink salmon abundance (of the previous year) for years other than the year of homeward migration. Sockeye survival also was negatively influenced by pink salmon abundance. In the years after the mid-1970's, when pink salmon abundance greatly increased, BB sockeye returns averaged a 22% reduction in the alternating years the when higher pink salmon abundance would exert greater influence. The alternating-years phenomenon is due to Asian, primarily the eastern Kamchatka pink salmon population. In the (smolt) years 1977 to 1997, the researchers estimate 59 million fewer sockeye salmon returned to BB due to the high Asian pink salmon abundance in alternating years.

Saito, T., Hirabayashi, Y., Suzuki, K., Watanabe, K. and H. Saito. 2016. Recent decline of pink salmon (O*ncorhynchus gorbuscha*) abundance in Japan. North Pacific Anadromous Fish Commission Bulletin, 6:279-296.

In-river catch data from twenty-two pink stocks from the coast of the Sea of Okhotsk were analyzed (separated into five regional groups) along with sea surface temperatures (SST). The long-term decline in pink salmon abundance is related to higher coastal SSTs which can cause decreased juvenile survival, preliminary adult mortality, and increased straying. The higher coastal SSTs can also cause a shift in migration timing, although pink salmon hatchery programs have been consciously selecting for earlier migration. No data were available to determine the proportion of wild fish in the escapement.

Schindler, D., C. Krueger, P. Bisson, M. Bradford, B. Clark, J. Conitz, K. Howard, M. Jones, J. Murphy, K. Myers, M. Scheuerell, E. Volk, and J. Winton. 2013. Arctic-Yukon-Kuskokwim Chinook salmon research action plan: Evidence of decline of Chinook salmon populations and recommendations for future research. Prepared for the AYK Sustainable Salmon Initiative (Anchorage, AK). v + 70 pp. Available at www.aykssi.org/wp-content/uploads/AYK-SSI-Chinook-Salmon-Action-Plan-83013.pdf. Accessed June 5, 2018

The decline in AYK Chinook populations since the 1990s is discussed. All evidence (for and against) various hypotheses is summarized and research recommendations are made. The authors are careful not to be conclusive in their summary, instead stating that the hypotheses are not “statement of facts” but instead represent how the “salmon system” “may work”. One hypothesis, on anthropogenic changes to ocean conditions, includes a discussion of the evidence that hatchery releases of chum, pink, and sockeye are affecting (or not) the survival of AYK Chinook.

Shiomoto, A., Tadokoro, K., Nagasawa, K., and Y. Ishida. 1997. Trophic relations in the subarctic North Pacific ecosystem: possible feeding effect from pink salmon. Marine Ecology Progress Series, 150, 75-85.

Biomass of phytoplankton and macrozooplankton were sampled from 1985 to 1994 in the north Pacific Ocean and year-to-year variations noted. After comparing these data to pink salmon abundance data, the researchers noted that years in which the biomass of macrozooplankton was low corresponded with years when pink salmon were more abundant and phytoplankton biomass was higher. In years when pink salmon were less abundant, macrozooplankton biomass was higher and phytoplankton biomass was lower. Temperatures and surface nutrient concentrations did not show any year-to-year variation, ruling out phytoplankton blooms; also, phytoplankton productivity was higher in even-years than in odd-years. This indicates that the variation in phytoplankton biomass was not regulated by the chemical or physical environment, nor by the productivity of the phytoplankton. Similarly, the macrozooplankton biomass variation did not seem to be influenced by their own productivity. Instead (post-1989), the variations were regulated by predation by pink salmon.

Shaul, L.D. and H.J. Geiger. 2016. Effects of climate and competition for offshore prey on growth, survival, and reproductive potential of coho salmon in Southeast Alaska. North Pacific Anadromous Fish Commission Bulletin 6:329–347. doi:10.23849/npafcb6/329.347. (Available at http://www.npafc.org).

The relationship between Gulf of Alaska and their prey can be described as a “trophic triangle” where both pink and sockeye salmon prey upon minimal armhook squid and also compete with the squid for zooplankton prey. The squid is also the primary prey of coho; this research explored relationships between adult coho weight, environmental conditions, and top-down control on squid by pink and sockeye salmon, using data from 1970-2014 (for some variables, 1990-2014). Most of the variation in the size of coho salmon was equally explained by pink salmon biomass, and a PDO index corresponding with squid emergence and development. The late-marine period may be crucial for coho survival. Pink salmon is a keystone predator that controls the trophic structure of salmon food and directs energy flow in the offshore GOA. Sea ranching of chum salmon may offer an alternative to pinks as a way to lessen effects on higher trophic level species.

Springer, A., van Vliet, G.B., Bool, N., Crowley, M., Fullagar, P., Lea, M.A., Monash, R., Price, C., Vertigan, C., and E.J. Woehler. 2018. Transhemispheric ecosystem disservices of pink salmon in a Pacific Ocean macrosystem, PNAS 2018 115 (22) 5038-5045.

Short-tailed shearwaters make annual 30,000 km, non-stop round-trip migrations from their breeding grounds in southeastern Australia, the Bass Strait, and Tasmania to the north Pacific Ocean and Bering Sea (NP/BS). Other research has noted dietary overlap between pink salmon and shearwaters in the NP/BS and greater numbers of shearwaters (more than an order-of-magnitude greater) dying in the Pribilof Islands in odd years (high pink salmon abundance) than even years. This research used proxies to estimate shearwater abundance at their breeding grounds and compared those data to pink salmon abundance data (catch plus escapement). There are strong correlations between low bird abundance and high pink abundance in all five examined time intervals. In recent odd-years, there have been increasing numbers of "wrecks": massive bird mortality upon reaching their breeding grounds due to malnutrition during their time in NP/BS (the non-stop migration means that the birds rely on their reserves established in the NP/BS). Greater numbers of birds nest in even years than in odd years. Reduced numbers of shearwaters on the breeding grounds are thought to be responsible for changes in local (breeding ground) ecology, and forced reductions in commercial harvest of shearwaters by Aboriginal residents. These results suggest that pink salmon--and the hatchery releases of pink salmon--are "altering the distribution of wealth stored in this macrosystem."

Springer, A.M. and G.B. van Vliet. 2014. Climate change, pink salmon, and the nexus between bottom-up and top-down control in the subarctic Pacific Ocean and Bering Sea. PNAS 2014 111 (18) E1880-E1888.

Monitoring data from four major seabird colonies (four islands) in the southern Bering Sea and Aleutian Islands were examined and indexed, such as "mean hatch date" and any anomalies noted (e.g., days before ["early"] or after ["late"] the mean). Thirteen of twenty omnivorous species/island samples had later hatch dates in even years, and this result was seen on all four islands. Clutch size was smaller in odd-years than in even-years for one bird species on all three islands where that species is found. Other significant effects were found for some species for parameters such as laying success, hatching success, fledgling success, and productivity, consistent with a hypothesis that in odd-years (high pink abundance) bird reproductive success was reduced. Some species build nests and in all cases where sufficient nests were counted to make comparisons, more nests were built in even-years than in odd-years. Many of these same nesting parameters were negatively correlated with a more specific parameter, the run size of eastern Kamchatka pink salmon. There were no consistent geographic patterns in the strength of the relationships (i.e, no island showed significantly more or fewer significant differences). As might be expected given these results, planktivorous seabirds showed an opposite response (or there was no relationship). The abundance of pink salmon in the northern Pacific and the results here that indicate top-down forcing call for a re-examination of fishing and hatchery practices and an ecosystem-based management.

Stachura, M. M., Mantua N. J., and M.D. Scheuerell. 2014. Oceanographic influences on patterns in North Pacific salmon abundance. Can. J. Fish. Aquatic Sci. 71(2), 226-235.

Authors took the 34 time series of regional salmon (wild North American and Asian, pink, chum, and sockeye) abundance used by Ruggerone et al. (2010) and applied three separate ordination techniques to identify patterns of abundance (as represented by the salmon abundance time-series) vs atmospheric and oceanographic variability (data from 10 environmental indices/datasets previously identified in the literature). Three dominant patterns were identified, accounting for 47% of the variability seen. Asian and North American populations had opposite trends for on pattern, indicating that large-scale climatic events may have different regional effects (e.g., NW Pacific vs. NE Pacific), or that density-dependent relationships become more important during these particular climatic events. Other factors "[f]or example, changes in harvest, hatchery practices, or freshwater habitat may contribute to abundance trends unrelated to climate and ocean variability" but were not investigated.

Sturdevant, M.V., R. Brenner, E.A. Fergusson, J.A. Orsi, and W.R. Heard. 2013. Does predation by returning adult pink salmon regulate pink salmon or herring abundance? North Pacific Anadromous. Fish Commission Technical Report 9: 153–164. (Available at www.npafc.org).

This study investigated predation by returning adult pink salmon on 1) juvenile pink salmon (cannibalism) and 2) Pacific herring in SEAK and PWS through 1) diet comparisons, 2) contrasting adult pinks with more piscivorous but less abundant coho and immature Chinook, and 3) examining climate mechanisms' influence on predator-prey relationships. In the SEAK straits, herring and salmon were uncommon in adult pink salmon diets, unlike coho salmon diets; Chinook consumed herring but not salmon. In alongshore areas, pinks consumed greater numbers of fish. In PWS alongshore areas, pink diets varied monthly and between years. Pink salmon cannibalism was uncommon in either PWS or SEAK. No evidence was found to support that pink salmon cannibalism was a factor in the alternating-year nature of pink returns, although some results indicate that retuning pinks may locally affect herring in PWS. Environmental factors such as annual temperature variations can affect adult return timing as well as out-migration by juveniles and migration routes, and therefore shift temporal and spatial overlaps of prey and predators.

Sydeman, W.J., Thompson, S.A., Piatt, J.F., Garcia-Reyes, M., Zador, S., Williams, J.C., Romano, M. and H.M. Renner. 2017. Regionalizing indicators for marine ecosystems: Bering Sea - Aleutian Island seabirds, climate, and competitors. Ecological Indicators 78, 458-469.

Marine predators occupying upper-trophic levels, like birds, mammals, and piscivorous fish, are more affected by ocean climate variability than ones in mid-trophic levels. Seabirds are secondary and tertiary consumers and multivariate seabird indicators can be used as indicators of marine ecosystem health. This study used data from 1989 to 2012 on birds' breeding and diet (collected in the Alaska Maritime National Wildlife Refuge), pink salmon abundance, and environmental factors to investigate food webs and developed multivariate indices (principal components or PCs). Besides significant correlations between some PCs representing breeding success with some environmental PCs, there was a strong negative correlation for one breeding PC with pink salmon abundance. This is interpreted as regional kittiwake breeding success is negatively related to pink salmon abundance. Regional murre breeding success is unrelated to pink salmon abundance. The authors recommend keeping bird data separated by genera when developing PCs. Negative and positive relationships between environmental factors and breeding success show the importance of “early season” conditions and how those conditions affect food webs. For kittiwakes, the abundance of pink salmon is another such factor.

Toge, K., R. Yamashita, K. Kazama, M. Fukuwaka, O. Yamamura, and Y. Watanuki. 2011. The relationship between Pink Salmon biomass and the body condition of short-tailed shearwaters in the Bering Sea: can fish compete with seabirds? Proceedings of the Royal Society B: Biological Sciences 278:2584–2590.

From October to March, short-tailed shearwaters (*Puffinus tenuirostris*) breed mainly in Tasmania but spend May to September in the North Pacific Ocean. About 16 million can be found in the Bering Sea in summer, feeding on upper water-column krill, fishes, and small squid; thus they possibly compete with pink salmon for prey. Birds were sampled 2002-2008 for stomach contents and various condition factors, along with pink salmon to estimate pink salmon biomass. Body mass and liver mass were similar among the birds sampled in the central Bering Sea and the birds sampled in the northern Pacific Ocean, suggesting that the birds had in fact recovered their body condition after migration. Bird body mass and bird liver mass were found to be negatively influenced by pink salmon biomass (as represented by pink salmon catch per unit-effort or CPUE). Pink salmon CPUE was higher in odd-years. No significant relationship between stomach contents and pink salmon biomass was found, possibly because of the daytime feeding habits of the birds did not lend itself well to the nighttime sampling of birds.

Ward, E. J., M. Adkison, J. Couture, S. C. Dressel, M. A. Litzow, S. Moffitt, T. Hoem-Neher, J. T. Trochta, and R. Brenner. 2017. Evaluating signals of oil spill impacts, climate, and species interactions in Pacific Herring and Pacific salmon populations in Prince William Sound and Copper River, Alaska. PLoS ONE [online serial] 12(3): e0172898.

Pre- and post-oil spill (the 1989 *Exxon Valdez* oil spill, or EVOS) were used to determine what has driven changes in productivity of Pacific salmon (wild PWS pink, two PWS-lake sockeye populations, as well as Copper River Chinook and Copper River sockeye) and PWS Pacific herring. Five possible drivers were evaluated: 1) intraspecific density dependence; 2) EVOS, 3) changing environmental conditions, 4) interspecific competition, and 5) competition with and predation by adult fish (for salmon)/predation by humpback whales (for herring). Support was found for the first hypothesis for all evaluated fish stocks except wild PWS pink salmon. No support was found that the EVOS event negatively affected long-term productivity. The strongest environmental factor was that freshwater discharge negatively affected herring productivity. Little support was found for effects of juvenile-juvenile competition. A negative relationship was found between adult pink salmon hatchery returns and sockeye salmon

(Copper River and both PWS stocks) productivity but was not shared with herring, Chinook, or PWS wild pink salmon. The lack of support seen in this study for so many of the drivers suggests that other factors may be important and operating on these fish stocks (e.g., disease).

Wertheimer, A. and E.V. Farley Jr. 2012. Do Asian Pink Salmon Affect the Survival of Bristol Bay Sockeye Salmon? North Pacific Anadromous Fish Commission Technical Report No. 8: 102-107.

Ruggerone, G.T., Myers, K.W., Agler, B.A. and J.L. Nielsen. 2012. Evidence for bottom-up effects on pink and chum salmon abundance and the consequences for other salmon species. North Pacific Anadromous Fish Commission Technical Report No. 8: 94-98.

Using the data analyzed by Ruggerone et al. (2003), Wertheimer and Farley conclude there is no evident effect on Asian pink salmon numbers on Bristol Bay sockeye. Using correlation analyses, they found no consistent response in the three BB sockeye stocks with pink numbers (separated into odd-even years). They reject the contentions of Ruggerone et al. (2012) that correlation analyses are not sufficiently robust to detect effects and stand by their conclusion that Asian pinks did not have a detrimental effect on BB sockeye.

Ruggerone et al. stand by the conclusions in Ruggerone et al. (2003) and later manuscripts (linking declines in Bristol Bay sockeye growth and survival to increased Asian pink salmon abundance), thus offering a rebuttal to Wertheimer and Farley (2012). They list a number of reasons why the use of correlation analyses by Wertheimer and Farley (2012) is incorrect, while acknowledging that use of correlation would lead to a conclusion that there is not a significant relationship between Asian pink abundance and BB sockeye survival. Ruggerone et al. also review a number of other papers offered as evidence of density-dependent relationships (while respecting changes in oceanographic conditions).

Wertheimer, A.C., Heard, W.R., Maselko, J.M. and W.W. Smoker. 2004. Relationship of size at return with environmental variation, hatchery production, and productivity of wild pink salmon in Prince William Sound, Alaska: does size matter? Reviews in Fish Biology and Fisheries, 14(3), pp.321-334.

Historically high returns of PWS pink salmon has been accompanied by decreasing body size. This research considered body size at return of PWS pink salmon against ten biophysical factors including hatchery inputs. Body size was also evaluated against wild pink salmon productivity. Two measures of temperature conditions were positively correlated to body size while three measures of pink salmon abundance (hatchery releases, hatchery returns, and overall GOA catch) were negatively correlated with body size. This is evidence that the growth of salmon in the ocean is density dependent and is also affected by environmental factors operating on the basin- and regional-scale. Body size significantly affected wild stock productivity, although marine environmental conditions explained most of the variability. Productivity of PWS pink salmon was affected more by regional environmental indices (e.g., GOA SST) than by basin-scale conditions (e.g., PDO) during their first year in ocean. Overall, density-independent factors affect wild pink salmon productivity more than do than density-dependent ones. While wild stocks may be affected by hatchery programs, the overall net benefit of hatcheries is much greater than the reduction in wild production. Continued evaluation of the efficacy of the hatchery programs is essential to give managers and policy -makers the data they need for informed decision-making.

Wertheimer, A.C., Heard, W.R. and W.W. Smoker. 2004. Effects of hatchery releases and environmental variation on wild-stock productivity: consequences for sea ranching of pink salmon in Prince William Sound, Alaska. Pages 307-326 *in*: K.M. Leber, S. Kitada, H. L. Blankenship, and T. Svasand, eds. *Stock Enhancement and Sea Ranching: Developments, Pitfalls and Opportunities*, Blackwell Publishing, Oxford, UK.

This study is a follow-up to the Wertheimer et al. (2001) comment on the Hilborn and Eggers (2000) study. Wertheimer et al. (2001) believed that the Hilborn and Eggers population model over-estimated wild production and did not consider other factors. Here, the researchers evaluate wild stocks (returns per spawner) against a number of parameters, including hatchery releases. Wild stock data (derived from ADFG harvest data and spawner surveys) from 1960-1998 were used. Environmental variables included winter air temperature; spring air temperature; spring zooplankton abundance; herring biomass; Gulf of Alaska (GOA) summer sea surface temperature (SST); GOA summer wind stress; Pacific decadal oscillation (PDO); PDO-1 (variable using the annual winter PDO index in pink brood year y -1; evaluates conditions during the adult ocean life-history phase of pinks); GOA pink salmon abundance; marine survival index (MSI); and hatchery releases. Three separate time series were used (1980-1998; 1975-1998; and 1960-1998) because data on all the variables were available only in 1960-1998. For all three time series, indices/variables of environmental conditions better explained variability in wild stock productivity than did hatchery releases. In the 1975-1998 time period, while hatchery releases were significant, MSI explained more variability. The authors believe that the assertions made in Wertheimer et al. (2001) are validated and that wild stocks in PWS have only been marginally negatively affected by hatchery releases, and that the net benefits of pink salmon hatchery programs are substantially greater (an increase in total runs 3x to 6x).

Yasumiishi, E.M., Criddle, K.R., Helle, J.H., Hillgruber, N. and F.J. Mueter. 2016. Effect of population abundance and climate on the growth of 2 populations of chum salmon (*Oncorhynchus keta*) in the eastern North Pacific Ocean. Fishery Bulletin, 114(2).

The seasonal and annual marine growth of chum salmon from an Alaskan creek and a Washington river were compared to abundances of pink and chum salmon and climate indices. Data from the early 1970s through 2004 were used. Pink salmon abundance negatively affected immature growth of chum salmon, except in the case of the first immature year of WA river chum. The exception may be due to the marine distribution of WA river chum; they were not as far west or as far north as the AK creek chum and thus did not overlap with pinks to be affected. Growth of both populations (except mature growth) was positively related to surface sea temperatures after accounting for density-dependent effects.

Zador, S., Hunt Jr., G.L., TenBrink, T., and K. Aydin. 2013. Combined seabird indices show lagged relationships between environmental conditions and breeding activity. Mar Ecol Prog Ser (485), 245-258.

Seventeen data sets related to the reproductive effort of five predacious seabirds were integrated into two indices using principal components analysis and then compared to environmental variables in the eastern Bering Sea. The two principal components (PC1 and PC2) accounted for 65% of the variability. Pink salmon abundance was not one of the environmental variables evaluated, but a “sawtooth” pattern in PC2 values was noted that corresponds to the odd/even year pattern in pink salmon abundance, reflecting lower kittiwake reproductive success in the odd-years (high pink abundance). The authors hypothesize that increased competition for prey between kittiwakes and pink salmon lead to lower kittiwake reproductive success in odd-years.

Zavolokin, A. V., V. V. Kulik, and L. O. Zavarina. 2014. The food supply of the Pacific salmon of the genus *Oncorhynchus* in the Northwestern Pacific Ocean 2: comparative characterization and general state. Russian Journal of Marine Biology 40:199–207.

The intent of the study was to determine how diet, growth, and survival interacted at various levels of salmon abundance and food abundance for salmon species in the northwestern Pacific, based on a hypothesis that salmon consume only a small portion of the prey available to them, even in periods of high salmon abundance. Periods of low food supply were identified for the western Bering Sea, the southern Sea of Okhotsk, and the northwestern Pacific Ocean, and most of these periods coincided with strong shoreward salmon migration. This evidence for a density-dependent effect included a shift in the diet composition and the feeding patterns of salmon. Because there was no reduction in growth or survival of salmon, the effect is thought to be small. The increase in salmon abundance in the 2000s was sufficiently supported by the available food.

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June 29, 2018

Alaska Division of Fish & Game
Boards Support Section
PO Box 115526
Juneau, AK 99811

Dear Members of the Alaska Board of Fisheries:

We are writing as a major user group of the resource produced by Prince William Sound Aquaculture in regard to the most recent emergency petition filed by KRSA. We know a lot of time, money and consideration was put into the decision to allow the increase production of pink salmon by Valdez Fisheries Development Association and those efforts should not be overturned.

The Alaska hatchery program is important to the state and with declining salmon runs as seen in the first half of this season the hatcheries will likely become even more important in the future. Regional and local economies depend on them to support their communities through sport fishing, tourism, personal use fishing, commercial fishing and seafood processing.

In addition, the practice of holding such a meeting in the middle of the fishing season when most stakeholders are unable to participate as they are out fishing is poor form. It is our understanding that a committee was formed to address this concern in October when all stakeholders would have the opportunity to participate and this plan should have been adhered to rather than addressing it as an emergency.

The hatcheries of Alaska are backed with many years of experience, science and by people who have a true interest in bettering the communities. Please deny this emergency petition request.

Regards,

Martin Weiser
Chief Development Officer

July 8, 2018

Cordova Chamber of Commerce
PO Box 99
Cordova, AK 99574
907-424-7260
cordovachamber.com

Cordova
CHAMBER OF COMMERCE

Chairman John Jensen
Alaska Board of Fisheries
Boards Support Section
PO Box 115526
Juneau, AK 99811
Submitted via email: dfg.bof.comments@alaska.gov

RE: Comments on KRSA et al. Emergency Petition on VFDA

Dear Chairman Jensen and Alaska Board of Fisheries Members:

The Cordova Chamber of Commerce has recently been made aware of Kenai River Sportfishing Association (KRSA) et al.'s Emergency Petition on Valdez Fisheries Development Association (VFDA). As the voice of the Cordova business community with members comprising a variety of industries including lodging, transportation, outfitting, retail, transportation, shipping, seafood harvesting, processing and many others areas; **we do not support this emergency petition.**

We echo the City of Cordova, Alaska Resolution 06-18-17 **supporting the Alaska Department of Fish & Game's approval of VFDA's permitted increase of 20 million pink salmon eggs at the Solomon Gulch Hatchery. We recommend that the Alaska Board of Fisheries confirms Alaska Department of Fish and Game's (ADF&G) findings for a lack of emergency with regards to this petition, and request that the board take no action to reduce the permitted capacity of the Solomon Gulch Hatchery by 20 million pink salmon eggs in 2018.**

We feel that the City of Cordova benefits greatly from Prince William Sound salmon fisheries enhancement programs through hatchery propagation; both sport and commercial fisheries enhancement efforts of the Valdez Fisheries Development Association. We also feel these programs provide sustainable direct economic and social benefit to the community of Cordova. This benefit is realized through the creation of local seafood processing jobs, fisheries business tax, increased commerce and seafood industry investment in our community. In addition, the enhancement of the sport fishery by VFDA provides significant fishing opportunity for coho salmon throughout eastern Prince William Sound, and this sport fishing activity significantly increases summer tourism by attracting visitors to Cordova to sport fish in eastern Prince William Sound; further benefiting local commerce through the sale of sporting goods, custom processing, lodging, fuel, harbor moorage, float plane charters, fishing

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Cordova
CHAMBER OF COMMERCE

charters and other purchases. The sport fish enhanc[ement] provided by VFDA is substantially funded through the sale of cost recovery pink salmon; and salmon hatchery programs like the ones at VFDA are permitted using a public process. They employ strong scientific methodology and are built upon sound and sustainable fisheries policies intended to protect wild salmon populations.

Sincerely,

Cathy Renfeldt
Executive Director
Cordova Chamber of Commerce

CITY OF CORDOVA, ALASKA
RESOLUTION 06-18-17

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF CORDOVA, ALASKA, SUPPORTING THE VALDEZ FISHERIES DEVELOPMENT ASSOCIATION INC., SOLOMON GULCH HATCHERY PERMITTED INCREASE OF 20 MILLION PINK SALMON EGGS

WHEREAS, the City of Cordova benefits greatly from Prince William Sound salmon fisheries enhancement programs through hatchery propagation; and

WHEREAS, both sport and commercial fisheries enhancement efforts of the Valdez Fisheries Development Association, provide sustainable direct economic and social benefit to the community of Cordova; and

WHEREAS, this benefit is realized through the creation of local seafood processing jobs, fisheries business tax, increased commerce and seafood industry investment in our community; and

WHEREAS, the enhancement of the sport fishery by VFDA provides significant fishing opportunity for coho salmon throughout eastern Prince William Sound; and

WHEREAS, this sport fishing activity significantly increases summer tourism by attracting visitors to Cordova to sport fish in eastern Prince William Sound; further benefiting local commerce through the sale of sporting goods, custom processing, lodging, fuel, harbor moorage, floatplane charters, fishing charters and other purchases, and

WHEREAS, the sport fish enhancement program provided by VFDA is substantially funded through the sale of cost recovery pink salmon; and

WHEREAS, salmon hatchery programs like the ones at VFDA are permitted using a public process, they employ strong scientific methodology and are built upon sound and sustainable fisheries policies intended to protect wild salmon populations.

NOW, THEREFORE, BE IT RESOLVED THAT, the City of Cordova affirms its support for the Valdez Fisheries Development Association salmon fishery enhancement programs, and

BE IT FURTHER RESOLVED, that the City of Cordova supports the Alaska Department of Fish & Game's approval of VFDA's permitted increase of 20 million pink salmon eggs at the Solomon Gulch Hatchery.

PASSED AND APPROVED THIS 27th DAY OF JUNE 2018.

CITY OF CORDOVA
CORPORATE
SEAL
JULY 8, 1909
ALASKA

Clay R Koplin

Clay R. Koplin, Mayor

ATTEST:

Susan Bourgeois, CMC, City Clerk

CITY OF CORDOVA

July 9, 2018

Chairman John Jensen
Alaska Board of Fisheries
Boards Support Section
PO Box 115526
Juneau, AK 99811
Submitted via email: dfg.bof.comments@alaska.gov

RE: Comments on KRSA et al. Emergency Petition on VFDA

Dear Chairman Jensen and Alaska Board of Fisheries ("Board") Members:

The City of Cordova strongly opposes both a finding of emergency to consider countermanding Alaska Department of Fish and Game ("Department") approved VFDA 2018 hatchery release levels, and the July 17, 2018 meeting schedule for public participation for the emergency petition.

Hatchery release levels represent decades of public process and Department Management. Emergency modification of those levels without the orderly and comprehensive evaluation scheduled for October which KRSA implies in their petition is an irresponsible approach, represents a cart-before-the horse solution to an unqualified problem.

They City of Cordova particularly resents considering an emergency order of this ecological and economic magnitude on July 17th at the peak of the harvest and processing season when most of the key stakeholders, including the City of Cordova, are limited in their ability to participate. Whether coincidental or not, the timing presents the appearance of bias and motive on the part of the Alaska Board of Fisheries and undermines confidence in the public process. I joined dozens of stakeholders in committing personal time and resources to participating in the PWS finfish meetings in Valdez last fall where I developed an appreciation for the Board's thoughtful and deliberate consideration of the large volume and complexity of issues you consider. I noted that compensated representatives of the KRSA were in attendance at that meeting and strongly question why concerns with hatchery releases were not raised at that more appropriate time. Please deny consideration of this emergency request at this time and proceed with appropriate care and consideration, our community livelihoods and highly complex ecosystems depend upon it.

Respectfully,

Clay R Koplin

Clay Koplin
Mayor of Cordova

602 Railroad Avenue P.O. Box 1210 Cordova, Alaska 99574 Telephone (907) 424-6200 Fax (907) 424-6000

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CORDOVA DISTRICT CDFU FISHERMEN UNITED

Cordova District Fishermen United
PO Box 939 | 509 First Street | Cordova, AK 99574
phone. (907) 424 3447 | fax. (907) 424 3430
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July 9th 2018

Chairmen Jensen and Board members,

Cordova District Fishermen United is a non-profit membership organization representing over 900 commercial fishing families who participate in commercial fisheries in Alaska's Area E, which includes Prince William Sound, the Copper River region, and the northern-central Gulf.

We would like to address the abuse of public process that is currently being practiced regarding the second Emergency Petition submitted by the Kenai River Sportfishing Association, and the third Emergency Petition on Prince William Sound Hatchery production and pink salmon straying. It is of great concern that the Board would support enacting emergency regulation at this time.

ADF&G has found, for the second time, no emergency regarding the petitions submitted by KRSA. The Board of Fish found no emergency when they discussed the first petition at the statewide meeting this spring. Further, the Board determined that discussion on hatchery production would be taken up at the October work session, when the public had the opportunity to participate.

Our commercial seine and gillnet fleets are in the middle of the fishing season. 1,500 commercial salmon permit holders and their crews depend on hatchery production, as 64% of their gross earnings come from PWSAC salmon. Most have been in remote areas for weeks, in effort to provide for their families, our communities, and support the State of Alaska's most valuable renewable resource. A hearing in the middle of the fishing season infringes on the rights of a permit holders ability to participate in the public process of these meetings. This meeting is scheduled during one of the worst times, to the detriment of the user group most affected.

Further, it has come to our attention that the two individuals who have nominated this meeting, will supposedly not be in attendance at the July 17th hearing. It is farcical that board members would call for a meeting, potentially resulting in detrimental emergency regulations, when they do not have the time themselves to attend in person. The hearing is clearly untimely for those board members to properly attend, just as it is for the commercial fleet.

There is no question about the vital role hatcheries play in the State of Alaska. Hatcheries in Prince William Sound support the economic foundation of Alaska's economy and benefit all user groups. Sport users depend on the VFDA hatchery production, as VFDA fish make up 75% of all Coho and 90% of all pink salmon caught in the Valdez area. The fleet has seen the heavy presence of subsistence users in Main Bay this year, as many come to harvest PWSAC sockeye salmon. Data provided by the McDowell Group states that almost 700,000 PWSAC sockeyes were harvested between 1999 and 2011 by subsistence and personal use fishermen, 73% of which went to Anchorage, Fairbanks, and the Matsu Borough.

These petitions have been exhausted, as they have appeared at almost every Board of Fish meeting over the last 6 months. Despite the continued findings of no emergency, the petitioners continue to press the Board with making a decision in their favor. **As the Board of Fisheries supports open and equally available public process, we request this petition be denied and initial plans to hold conversations with the public during the October work session be pursued.**

Sincerely,
The Cordova District Fishermen United Board of Directors

Submitted By
Craig Evens
Submitted On
7/7/2018 10:54:23 AM
Affiliation

Dear Chairman Jensen and Board of Fisheries Members,

I, Craig Evens, captain of F/V Orion do not like interest groups circumventing public process by using the emergency petition process during the busy commercial fishing summer months. As a commercial fisherman from Petersburg for over 40 years, 25 of which I operate F/V Orion as a salmon purse seiner in the summer, I rely heavily on the resource.

I urge you to postpone the emergency petition of egg take permitting of Valdez Fisheries Development Association until the October work session or the March meeting.

Sincerely,

Craig Evens

F/V Orion

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

My name is Dam Mclean and I was born on the park strip in Providence Hospital, Anchorage, AK in 1958. As a child I grew up in Anchorage on Campbell Lake and fished for king and silver salmon, that fishery is gone to my knowledge along with steamer and butter clams in K Bay and razor clams on the Kenai Peninsula, the next to go will probably be the large king salmon on the Kenai River. I do not feel that hatcheries are the problem, I feel the problem is people. There are far too many users on the Kenai River and Cook Inlet.

Years ago I watched the Surgeon General state on National TV that cigarettes are not harmful to your health- so I am very wary of pedigree experts spewing propaganda to support a hidden agenda, or even worse, donations to their foundations.

I commercial fish in PWS on a purse seiner. I am a fractional owner of Silver Bay Seafoods (SBS) in Valdez and I employ 3 seasonal workers. I have health insurance through SBS and have funded my own retirement and support state and federal government through direct and indirect taxes. I catch far more king salmon trolling with sport fish gear than I do while fishing for pink salmon with a purse seine.

I believe pink salmon do not compete with king salmon since they live in different parts of the ocean. Mid-water trawlers in Alaska harvest a lot more king salmon, similar to the sport fishing fleet, and few pink salmon. The king salmon I catch appear to be eating herring, sand lance, hooligan, smelt, small cod, small pollock, and what I believe to be black worms whiel pink salmon eat zooplankton, and small insects.

It is my understanding that the U.S. Supreme Court has ruled that there is no difference between hatchery and wild fish on the Columbia River and it may be the only way to save the large Kenai gene pool is with a hatchery program before they become extinct, and catch and release is not an option in any system.

I am alarmed that the BOF can stop an enhancement program that has been permitted during the summer months when commercial fishermen are at sea and unable to have a voice on something that their lives depend on. While at the same time Bradley Hydroelectric is proceeding with diverting Battle Creek into turbines and that late coho run will stray to suitable habitat as salmon are known to do, or they will become extinct.

In closing ocean acidification is probably our bigger challenge and we have ignored Canadian warnings and now it is starting to affect Alaskan waters. Additionally, plastic in the Pacific Gyre is not helping. We are the invasive species, God help us all.

Sincerely,
Dan Mclean- F/V Miss Danica

Date: 7-5-2018
Fisherman: Daniel M Patterson
Fishing Vessel: FV Lucas
Homeport: Cordova Alaska

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed, Dan Patterson

Submitted By
Dave Beam
Submitted On
7/8/2018 3:14:57 PM
Affiliation

Phone
907-244-4701
Email
girdwood52ak@yahoo.com
Address
PO Box 297
Girdwood, Alaska 99587

July 7, 2018
Dear Board of Fish Members:

I have lived and commercially fished in Alaska since 1979, and I am extremely concerned about the emergency order put in by the KSRA aimed at limiting hatchery production in PWS. Since 1985, I have been relying on hatchery production to make my living and support my family. As a seine operator since 2009, easily 70% of our season's catch is produced by the hatcheries. It would be devastating to the 500 plus gillnetters and more than 230 seiners who rely on hatchery production in PWS, not to mention the crews, fish processors, hatchery workers, tenders and towns of Prince William Sound and the entire state of Alaska. Although the KSRA are considered a sport fishing association, they are not necessarily representing the thousands of recreational fishermen who rely on and enjoy the hatchery production in PWS.

In my opinion, the cause that the KSRA is supporting is personally charged rather than scientifically founded. The theory that hatchery-produced pink salmon are competing with chinook salmon in the open ocean is unfounded. No such study has ever been done.

The timing of this emergency meeting is very unfortunate for the commercial fleet. During the summer, we are all working to make our living and will be unable to attend. There will be a group of fishermen's wives from Girdwood, Alaska, including my wife, attending the July 17 meeting.

Thank you for considering my comments.

Sincerely,
Dave Beam

From: Eye of the Storm
To: DFG, BOF Comments (DFG sponsored)
Subject: Proposed additional 20 million pink salmon egg take in Prince William Sound
Date: Thursday, June 28, 2018 11:40:38 AM

Dear Sir/Madam,

I must weigh in on the proposed addition of a 20 million egg take for pink salmon by the Private Non-Profit hatcheries in Prince William Sound. As a recreational and charter fisherman for over 25 years in Prince William Sound, my thoughts actually focus on ***less*** raising/release of pinks in Prince William Sound! All hatchery release fish compete for limited food supplies with natural runs...adding more is just simply the wrong approach. Scientific data shows that natural pink runs in Prince William Sound have been significantly compromised with hatchery fish. When I read about some streams in Lower Cook Inlet having up to a 70% return of Prince William Sound hatchery pinks, I really didn't need to read further. This says it all!!

Please don't let the proposal for an additional 20 million pink salmon egg take by the hatcheries. Instead, please turn your thoughts to reducing and more closely regulating what the hatcheries turn out.

Thanks for the opportunity to comment,

Capt. Dave Goldstein
Prince William Sound Eco-Charters, LLC
www.pwseco.com
(907) 244-0234

Submitted By
David Blake
Submitted On
7/5/2018 1:10:54 PM
Affiliation

I have been a commercial fisherman in Prince William Sound and Copper River District for the last 35 years. I have been following the attack on Prince William Sound hatcheries since the begining of the year. While out on the Fishing Grounds I have become aware of a 3rd Emergency Petition on the subject filed by KRSA. This petition resulted in a hearing being scheduled in the middle of my fshing season when I cannot fully participate in the public process lain our for ouir fishery. This same issue has now come before the Board of Fisheries and ADFG on 4 occasions in a six month time span. ADFG has stated that there is no finding of any emergency each time. The Board of Fish has set a date for an October Work Session in Anchorage to address the subject, when they have more data and more time to review said data. The fileres of the petition are berating the Board of Fiheries into making a decision in thier favor, when they are unsatisfied with the previous answers from the previous 3 petitions.

It is an abuse of public police that a 3rd Emergency Petition is being brouight to the Boatd of Fisheries once again after id was already determined thate was no finding of Emergency and afger it was decided that this issue would be taken up at the October Work Session in Anchorage.

Once again I am strongly opposed to this petition and ask the Board to once again to take no action and continue forward with the plan to meet in October as previously determined for this subject.

I believe that the Board of Fisheries need to have the time in October to closely explore the claims by KRSA and review the actual facts behind the data that is in my opinion being distorted to reflect a possible emergency. The distorted presentation need to be sorted out and acctual facts need to be in place at the October meeting that has previously schedled.

Thank You for the opportunity for comment and for your service on the board

David Blake

Submitted By
David Blount
Submitted On
7/8/2018 9:16:23 PM
Affiliation
drift gillnet permit holder

Phone
575 317 1723
Email
dkblount@hotmail.com
Address
box 1912
Cordova, Alaska 99574

Greetings Board of Fish Members: Thank you for an opportunity to comment on this proposal. There seem to be no end to the good comments regarding the hatchery system that was rescued from the state by commercial fishing. This resource benefits all citizens including numerous visiting tourist and sport fishermen. The specifis merits are to be discussed in October at a workshop. This emergency petition has been denied a few times and this attempt is no emergency. It is a very unfair attempt to catch the people with the most to lose and biggest interest at a very vulnerable time in order to push the agenda of a small special interest group. The vast majority of the supporters of the hatchery system are in the midst of a very difficult fishing season, mostly away from home ports and many out of touch with fisheries politics. Please deny this motion and allow for it to be heard properly at a time when all user groups can be fairly represented. Thank you. David Blount F/V Salmon Shark

From: David Branshaw
To: DFG, BOF Comments (DFG sponsored)
Subject: Emergency Petition about PWS hatchery production
Date: Wednesday, June 27, 2018 12:09:17 PM

:

Name: David Branshaw
Fishing Vessel: F/V Hero
Home Port: Cordova Alaska

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

Regards

David Branshaw
Alaska resident/Commercial fisherman

Submitted By
David Branshaw
Submitted On
6/28/2018 1:01:12 PM
Affiliation

Phone
9074247694
Email
davidbranshaw@ctcak.net
Address
1.25 mile whitshed rd
po box 2241
cordova, Alaska 99574

To: BOF

I oppose the emergency petition limiting hatchery production in PWS. CPF hatchery production is vitial to my livelyhood. Without hatchery production I would be out of business. With the clousure of the 2018 Coper River gilnett fishery hatchery production is my only means of making a living. This hatcherery production is also vital to my community of Cordova, without it, our town would be struggling to survive. Thank you for taking my coments.

DW Branshaw

Submitted By
David Edens
Submitted On
7/8/2018 9:15:54 AM
Affiliation

Phone
907-399-4458
Email
dnaedens@gmail.com
Address
P.O. box 3456
Homer, Alaska 99603

Chairmen Jensen and Board members,

I am a commercial fishermen of the Prince William Sound and Copper River District. I have been following the attack on Prince William Sound Hatcheries since the beginning of the year. While out fishing on the grounds, I became aware of a 3rd Emergency Petition on the subject, the second filed by KRSA. This petition resulted in a hearing in the middle of the fishing season, when I cannot fully participate in the public process laid out for our fisheries.

This same issue has now come before Board of Fish and ADFG on 4 occasions, in a 6 month time span. ADFG has stated that there is no finding of an emergency each time. The Board of Fish has set a date for an October work session in Anchorage to address the subject, when they have more data and more time to review said data. The filers of the petitions are berating the Board into making a decision in their favor, when they are unsatisfied with the answer.

It is an abuse of public policy that a 3rd Emergency Petition is being brought to you once again, after it was already determined there was no finding of Emergency, and after it was decided that this issue would be taken up at the October work session in Anchorage.

I am strongly opposed to this petition, and ask the Board to once again to take no action, and continue forward with the plan to meet in October on the subject.
Thank you,

Submitted By
David Goldstein
Submitted On
6/28/2018 12:22:07 PM
Affiliation
ACA, PWSCBA, GWCC, PWSRCAC

I must weigh in on the proposed addition of a 20 million egg take for pink salmon by the Private Non-Profit hatcheries in Prince William Sound. As a recreational angler and charter fisherman for over 25 years in Prince William Sound, my thoughts actually focus on less raising/release of pinks in Prince William Sound! All hatchery release fish compete for limited food supplies with natural runs, Adding more fish is just simply the wrong approach. Scientific data shows that natural pink runs in Prince William Sound have been significantly compromised with hatchery fish. When I read about some streams in Lower Cok Inlet having up to a 70% return of Prince William Sound hatchery pinks in 2017, I really didn't need to read further. This says it all!

Please don't let the proposal for an additional 20 million pink salmon egg take by the hatcheries. Instead, please turn your thoughts to reducing and more closely regulating what the hatcheries turn out.

Thanks for the opportunity to comment,

Captain Dave Goldstein

Prince William Sound Eco-Charters, LLC

www.pwseco,.com

(907) 244-0234

David Roemhildt
PO Box 2294 Cordova, Alaska 99574
Managing member
Roemhildt Holdings LLC
Cordova Hardware LLC
Viking Marine LLC
Plumbline Supply LLC
Facility Contractors LLC

July 9, 2018

Chairman John Jensen
Alaska Board of Fisheries
Boards Support Section
PO Box 115526
Juneau, AK 99811
Submitted via email: dfg.bof.comments@alaska.gov

RE: Comments on KRSA et al. Emergency Petition on VFDA

Dear Chairman Jensen and Alaska Board of Fisheries Members:

As a lifelong Alaskan and operator of several business interests in Prince William Sound and coastal Alaska, I am opposed to the Kenai River Sportfishing Association (KRSA) et al.'s petition for a finding of emergency and their request to deny the previously approved 20 million increase in the number of pink salmon eggs taken at Valdez Fisheries Development Association's (VFDA) Solomon Gulch Hatchery in 2018**. I recommend that the Alaska Board of Fisheries confirms Alaska Department of Fish and Game's (ADF&G) findings for a lack of emergency with regards to this petition, and requests that the board take no action to reduce the permitted capacity of the Solomon Gulch Hatchery by 20 million pink salmon eggs in 2018.**

Sincerely,

David Roemhildt
Cordova, Alaska
david@facilitycontractors.com

Submitted By
Deborah Eckley
Submitted On
6/29/2018 5:56:36 PM
Affiliation

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST

Submitted By
Dennis Gease
Submitted On
7/9/2018 3:57:29 PM
Affiliation
Southcentral Alaska Dipnetters Association

Phone
907-252-9291
Email
dennisgease@gmail.com
Address
36710 Virginia Drive
Kenai , Alaska 99611

Dear BOF members,

I support the emergency petition regarding halting the additional 20 milllion egg take of Prince William Sound hatchery pink salmon. I support a finding of emergency, and then an action by you to halt the further egg take.

Since its inception I have been the vice-president of the Southcentral Alaska Dipnetters Association (SCADA). I also served five years on the Kenai- Soldotna Advisory Committee, six years on the Kenai Watershed Forum board of directors, and was a committee member of the BOF Cook Inlet task force for king salmon.

SCADA members fish for kings and sockeyes in the Kenai, Kasilof and Copper Rivers, when numbers are adequate for harvest. We have ongoing concerns of the poor returns of kings to these rivers, which have too often resulted in restrictions and closures. Many folks also fish with a rod and reel in the sport fisheries for these same fish and are negatively impacted in that fishery too. While reds make up the majority harvest, a king salmon is a great fish to harvest for food. My wife and I depend upon these harvests to feed ourselves throughout the year, as do many other Alaskan families.

The statewide decline of king salmon has had impacts beyond the dip net and sport fisheries on these rivers. Subsistence fisheries for king salmon have been too often restricted or closed on the Yukon, the Kuskokwim and the Copper River, causing much hardship in these rural communities of the state. These are arguablhy some of the oldest continous salmon fisheries in Alaska. Sport fisheries for kings have also been shut down or severely restricted elsewhere in Cook Inlet, Kodiak and SE Alaska.

Ironically (or not) during the very same time we are having poor returns for king salmon across Alaska, there have been record numbers of salmon in the ocean, stretching back for the past two decades. More mouths to feed than ever before in the ocean, two out of three being pinks.

I grew up on a farm in Wisconsin - we kept a careful eye for overgrazing of our pastures and my dad kept to a rigid plan of crop rotations. The farmers who didn't pay attention to these details were not very successful and exhausted their lands quickly. It doesn't take a genius to figure out there are limits of what we ask the earth to produce, whether on the farm or in the ocean.

More salmon, especially pinks, is having an impact. Smaller size fish, returning earlier to spawn, with fewer females surviving, all indicate over-grazing and greater competition for a limited amount of food in the ocean. While we keep expanding the production of hatchery fish, we have not kept pace by also increasing the plankton and other food that salmon feed on. More mouths, same food supply, smaller salmon - for what end? Kings are being impacted - everyone knows it, everyone can see it, everyone has a story to tell about it.

The question for you as board of fish members - how long are we going to keep our collective heads buried in the sand and ignore what is evident in front of our very eyes?

I believe you are on the start of journey to repair and restore the ocean fields to their former productivity for king salmon. If you don't take this first step, who will?

Respectfully,

Dennis Gease

Submitted By
Dennis M. Zadra
Submitted On
7/1/2018 8:36:26 AM
Affiliation
Commercial Fisherman

Dear Chairman Jensen and Board Members,

My name is Dennis Zadra and I have been a commercial Fisherman in Prince William Sound for 30 years. The hatchery programs in PWS are extremely valuable to me and my family and usually account for the majority of my fishing income.

It is troublesome to me that you are now faced with the 3rd emergency petition to alter hatchery production when there is no evidence that an emergency exists. It also occurs at a time when all fishermen are fishing and can not participate in this public process.

I urge you to deny this petition and defer action until October when the data can be more thoroughly considered. These hatcheries have been in production since before I started fishing, and there is no new information that warrants an emergency.

Thank you for your consideration.

Submitted By
Dina Gregg
Submitted On
7/8/2018 10:12:31 PM
Affiliation
Commercial Fisherman

Date: July 8, 2018

Fisherman: Dina Gregg

Fishing Vessel: F/V Patriot

Homeport: Juneau, AK

To: Alaska Board of Fisheries
RE: Comments on KRSA et al. Hatchery Emergency PetitionDear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Dina Gregg

Douglas Island Pink and Chum, Inc.
2697 Channel Drive ◦ Juneau, Alaska 99801
(907) 463-5114 ◦ www.dipac.net

July 9, 2018

To: Mr. John Jensen, Chair and Board of Fish Members
Alaska Board of Fisheries

Subject: Response to an emergency petition to reverse a department decision allowing a 20 million increase in the number of pink salmon eggs taken by Valdez Fisheries Development Association (VFDA) at Solomon Gulch Hatchery and comments on the operational priorities of the Douglas Island Pink Chum, Inc (DIPAC) hatchery.

We respectfully submit this letter in support of the final decision by Commissioner Sam Cotten that an increase of 20 million pink salmon eggs at VFDA does not constitute an emergency pursuant to 5 AAC 96.625(f). The Commissioner's final decision was made clear in two documents released June 14, 2018 to John Jensen, Chair of Alaska Board of Fisheries and to Mr. Ricky Gease, Executive Director of Kenai River Sportfishing Association; such that the original petition did not demonstrate in a clear and convincing manner that the increased capacity at VFDA would elicit harmful effects on wild stocks and that under AS 16.10.440(b) would not reverse the original decision to allow said increase. As you will see in the comments submitted by other hatcheries, the literature cited in the emergency petition provides weak, corollary assumptions, equivocal, and in some cases contradictory evidence to support their claims for the finding of an emergency petition. We also find that the meeting scheduled in July by the Board of Fish is inconsiderate to all those working in the industry; providing little time for the preparation of adequate commentary and participation from those affected by this important petition.

The development of hatcheries in Alaska began in 1971 as a means to supplement and relieve fishing pressure on failing wild stocks throughout the state. A further iteration of these policies was in 1974 with legislation passed for the Private Nonprofit Hatchery Act; with the main operating objective being "…rehabilitation of the state's depleted and depressed salmon fisheries. The program shall be operated without adversely affecting natural stocks of fish in the state and under a policy of management which allows reasonable segregation of returning hatchery-reared salmon from naturally occurring stocks" (McGee 2004). Several key requirements for hatcheries were established to safeguard wild stocks, which include: hatcheries located away from significant wild stocks, use of local brood sources, management priority focused on wild stock protection, tagging/marking of hatchery fish, and special studies on hatchery/wild interactions (McGee 2004).

Douglas Island Pink and Chum, Inc. operates as a Private Nonprofit hatchery and strives to operate above and beyond statute to the benefit all salmon user groups while also ensuring, to the best of our ability, no harm to wild stocks. DIPAC was founded in Juneau in 1976 and started with 10 million chum salmon eggs. The facility has now grown to 135 million chum eggs, 1.5 million coho eggs, and 1.1 million chinook eggs, annually. All chum have been thermal marked since 1989, as well as coded wire tagging 10% of chinook since 1984 and 7% of coho salmon since 1985. The sockeye program at the state owned Snettisham hatchery was taken over with an operational contract by DIPAC in 1996, with 100% of all sockeye thermal marked since 1988. The Snettisham facility currently releases up to 9 million sockeye smolt, 500,000 fry are released into Sweetheart Lake for personal use and sportfishing, and 11 million fry are taken for Transboundary River supplementation in cooperation with U.S.A. and Canadian management and accordance with the Pacific Salmon Treaty.

The founder of DIPAC, Ladd Macaulay, and its board of directors have always and continue to be dedicated to the responsible stewardship and protection of wild salmon through the focused management of hatchery-origin salmon for the benefit of all common property user groups, as well as being ardent supporters of education by providing funding opportunities. During the first ten years of the Macaulay hatchery a wet-lab and office space were provided for University of Alaska Southeast faculty and students to conduct their own research. DIPAC now provides funding opportunity to many fisheries focused programs, such as: up to $60,000 annually in scholarships to baccalaureate and vocational students in fisheries and science related fields, $1 million endowment fund for UAF graduate fisheries research, and over $3 million to the State of Alaska Hatchery/Wild Research Project and other professional research projects in Southeast Alaska.

This State of Alaska Hatchery/Wild Research Project was initiated on the urging of the Southeast PNP's and is the most extensive and in depth research on hatchery/wild interactions of pink and chum salmon in Prince William Sound and Southeast Alaska. DIPAC is a proud supporter of this project and always interested in ways we can better our production or to help protect wild stocks. The project outline and updates are publicly accessible on the ADF&G website at, http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.current_research Preliminary results of this study estimate low proportions, 3% - 15%, of hatchery-origin spawners in streams and harvest rates of hatchery-produced fish >90% and naturally-produced fish <60%; this is further evidenced by some of the most productive returns of both hatchery and natural-origin salmon (Irvine & Ruggerone 2016). The strong returns of both wild and hatchery salmon align consistently with the statutes: Policy for the Management of Mixed Stock Fisheries, sustained yield of wild fish stocks, and sustainable salmon fisheries (5 AAC 39.220, AAC 39.222, and AS 16.05.730).

All of the efforts by DIPAC do not stand alone, but are part of the region-wide efforts made by hatchery associations throughout the state of Alaska; each hatchery is striving to keep wild stocks healthy, provide financial opportunity for all common property gear groups, subsistence and sport fishing, and to give back to our community by funding a variety of educational programs.

Respectfully,

Adam Zaleski – Data & Evaluation Supervisor

Eric P Prestegard – Executive Director

Literature Cited:

Irvine, J.R. and Ruggerone, G.T. (2016). Provisional estimates of numbers and biomass for natural-origin and hatchery-origin pink, chum, and sockeye salmon in the North Pacific, 1925-2015. NPAFC Doc. 1660. 45 pp. Fisheries and Oceans Canada, Pacific Biological Station and Natural Resources Consultants, Inc.

McGee, S.G. (2004). Salmon Hatcheries in Alaska - Plans, Permits, and Policies Designed to Provide Protection for Wild Stocks. American Fisheries Society Symposium 44:317 - 331.

From: Don
To: DFG, BOF Comments (DFG sponsored)
Subject: Too Many Salmon?
Date: Thursday, July 5, 2018 11:39:11 AM

Dear Alaska Board of Fisheries,

I would like to comment on the board addressing the emergency petition from the Kenai River Sportfishing Association.
I am requesting that the board grant this petition because I believe the U.S. along with many other Pacific Rim nations
has been allowing their hatchery production capacity to cloud their good judgement. I am convinced that our salmon hatcheries are seriously impacting Alaska's wild fish resources and they need to be immedently reduced. I claim that
each hatchery salmon you drop into the North Pacific reduces or damages wild salmon resources to some degree. It is just a matter of time before you finally realize that damage has occurred. If you wish to understand why I claim a real salmon hatchery emergency is taking place continue reading.

It is currently Department of Fish & Game policy to allow hatchery production to expand Alaska fish stocks. It is also ADF&G policy to protect our wild fish stocks. These policies eventually resulted in ADF&G policy to NOT introduce hatchery salmon into freshwater rivers and streams that already have wild salmon runs. The reason being that more abundant hatchery populations realize an advantage over less-abundant wild populations within similar environments. The ADF&G therefore claims that the displacement of wild salmon in the freshwater is not good for the environment. So the question becomes why is our ADF&G granting hatchery permits that end up displacing our wild salmon within the saltwater? I claim that ADF&G policy to displace wild salmon in the saltwater but not in the freshwater is hypocritical fisheries manage and should be ended immedently.

The North Pacific Ocean had 500 million hatchery salmon released into it annually by1970. By 2008 it had 5
billion hatchery salmon released into it annually and most were pink and chum salmon.
https://e360.yale.edu/features/hatch-22_the_problem_with_the_pacific_salmon_resurgence

James A. Estes published a study on "Salmon, Seabirds, and Ecosystems Dynamics" back in 2014. That study
showed how a 10-fold increase in the pink salmon with a two year life cycle and odd-even year variation has
been severely impacting seabirds off the coast of Alaska since 1980. The consistent recurrent nature of the rise
and fall of the pink salmon biomass was used to prove his findings are impervious to alternative interpretation.
So our seabirds are being displace by hatchery pink salmon, I wonder what else is being displaced by pink
salmon? PNAS May 6, 2014. 111 (18) 6534-6535; published ahead of print April 16, 2014.
https://doi.org/10.1073/pnas.1404905111
https://news.nationalgeographic.com/news/2014/03/140331-salmon-seabirds-pacific-fish-animals-science/

Pink salmon get pretty interesting when you start seeing how they affect the ocean around them. It gets even better when you discover that pink and juvinal king salmon prey on the same food. Both salmon prey on zooplankton, zooplankton prey on phytoplankton, phytoplankton prey on chlorophyll. Chlorophyll abundance equals zooplankton abundance and in a perfect world both king and pink salmon locate enough zooplankton for everyone to be happy forever.

Unfortunately a feeding contest can develop if one salmon type gets expanded beyond the other, thus a sort of zooplankton feeding contest can develop. Recently we have been seeing some of the largest pink salmon ever recorded along with some of the smallest king salmon ever recorded. Does this give you a clue as to who is winning the ocean zooplankton feeding contest? Any kind of numbers advantage granted to either salmon would result in a starvation death sentence for the other. This means that a substantial hatchery increase in either salmon type could cause many of the other salmon type to starve to death in the ocean.

Alaska's wild salmons runs are currently declining into oblivion without explanation while our ocean struggles
to support a record number of billions of additional hatchery salmon. Recently the ADF&G has been denying
some permits to release even more millions of hatchery pink salmon while approving increases in some hatchery
sockeye permits. Russia is now planning to super-size its hatchery pink salmon production along with Canada,
Japan, China and Korea. This is an ocean food web being pushed towards collapse while we have zero
international regulatory authority capable of preventing or even slowing down that collapse.

It is very obvious to me that hatchery salmon are the core reason behind the reduction in size and decreased
numbers of wild salmon. If that is not a emergency to the Alaska Board of Fisheries I don't know what is.

Thank you for reading my concerns regarding hatchery salmon.

Donald Johnson
36160 Schultz Street
Soldotna, Alaska 99669
907 262 7893
donaldjohnson@alaska.net

Submitted By
Dorne Hawxhurst
Submitted On
7/7/2018 5:27:39 PM
Affiliation

My husband and I live in Alaska year around. Jeff is a commercial seiner in Prince William Sound. I am a licensed attorney.

We depend on Jeff's income from commercial fishing, and more specifically on his fishing income directly attributable to the hatcheries in our area.

I understand you decided to hold a hearing in Anchorage on July 17--at the height of the commercial fishing season--about the so-called Emergency Petition filed on May 16 by a special interest sport fishing group based in Kenai. You already know that hatchery production is scheduled for a BoF discussion at the October 2018 work session after the 2018 commercial fishing season. You also already know that ADF&G has repeatedly informed the BoF that the petition is not emergent in nature. And of course you must also know that the timing of your July 17 hearing has the effect of denying due process to Alaskans like us who stand to be most harmed by the petition, by making us least able to particpate in your "public process." In short, you presume to intentionally act against our financial business interests without allowing us any meaningful opportunity to be heard.

For these and all the other obvious reasons, please deny the emergency petition request. Thank you for your consideration.

Dorne Hawxhurst

Submitted By
Eleanor Hand
Submitted On
6/27/2018 11:48:10 AM
Affiliation

Phone
9073172958
Email
nellyhnd@gmail.com
Address
Po box 2181
Cordova , Alaska 99574

Chairmen Jensen and Board members,

I am a commercial fishermen of the Prince William Sound and Copper River District. I have been following the attack on Prince William Sound Hatcheries since the beginning of the year. While out fishing on the grounds, I became aware of a 3rd Emergency Petition on the subject, the second filed by KRSA. This petition resulted in a hearing in the middle of the fishing season, when I cannot fully participate in the public process laid out for our fisheries.

This same issue has now come before Board of Fish and ADFG on 4 occasions, in a 6 month time span. ADFG has stated that there is no finding of an emergency each time. The Board of Fish has set a date for an October work session in Anchorage to address the subject, when they have more data and more time to review said data. The filers of the petitions are berating the Board into making a decision in their favor, when they are unsatisfied with the answer.

It is an abuse of public policy that a 3rd Emergency Petition is being brought to you once again, after it was already determined there was no finding of Emergency, and after it was decided that this issue would be taken up at the October work session in Anchorage.

I am strongly opposed to this petition, and ask the Board to once again to take no action, and continue forward with the plan to meet in October on the subject.
Thank you,

Eleanor Hand

Submitted By
Elias Schoener Eckley
Submitted On
6/29/2018 5:59:30 PM
Affiliation

I am writing as a fisherman in response to the Alaska Board of Fisheries decision to hold a hearing on the Emergency Petition filed May 16, 2018.

Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria.

I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families.

The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions.

I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session.

Submitted By
Eric Fleming
Submitted On
7/9/2018 10:59:18 AM
Affiliation

I have commercial fished out of Prince William Sound my entire life. My father, Joseph Fleming, has as well, along with my brothers, Joe and David. My father has seen the great contribution PWS hatcheries have made to the livelihood and entertainment of all the fishers visiting Prince William Sound. Fishermen and their crew would not be able to make a living without the great enhancement of the PWS hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST. THANK YOU!

Submitted By
Eric Harvey
Submitted On
7/7/2018 1:12:11 PM
Affiliation

I am a commercial fisherman in Prince William Sound.

I oppose the May 16, 2018 Emergency Petition filed with the Alaska Board of Fisheries.
The Prince William Sound Alaska hatchery program is critical to state, regional, and local economy and commercial and sports fishermen. The hatchery program is implemented based on solid science and is carefully monitored by expert teams of state biologists.

I am very disappointed that the Board would hold a meeting on this issue and require comment by July 9th at the peak of our commercial fishing season, and hold a meeting on July 17 when we are all out commercial fishing trying to earn a living for our families. This is poor public process.

I strongly recommend you deny this emergency petition. The Board should use sound science in making its decision. The May 16, 2018 Emergency Petition is not based on sound science.

Eric Harvey

Submitted By
eric tutt
Submitted On
6/27/2018 11:34:44 AM
Affiliation

Phone
9072991156
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erixtut@gmail.com
Address
P.O. box 2452
Homer, Alaska 99603

iFirst off I would like to clearly state that I do not support this emergency order, or anything that reduces or attempts to reduce our hatchery programs. I am a 3rd generation commercial fisherman. I was born and raised in Alaska, my grandparents moved to Alaska in the 1930s. We have depended on commercial fishing as our livelihood my entire life, both my brothers lives, my dads entire life, and most of my grandparents lives, and I hope that when my son gets old enough he too will beable to support his family through commercial fishing in pws on enhanced salmon runs. I and 1500 other pws fisherman depend on the the hatchery runs for over 90% of our annual income, if the hatchery systems were reduced or eliminated you would be essentially destroying our way of life. Rendering our permits, boats, skiffs, nets, and our entire investments in fishing obsolete and worthless. The other side is that our hatchery fish are benefiting the sports fishing community as well and bringing in money to the towns, Valdez alone is boosted by approximately $6.6 million annually just from the sports fishing traffic that are catching Vfda released cohos and pink salmon.

Next I would also like to bring up my concern about our rights as commercial fisherman being stomped on by allowing this petition to be convened in the the middle of our commercial fishing season, thus unjustly keeping 99% of commercial fisherman from even attending the meeting to voice their concerns in person. Especially when this same petition was allready denied once for not meeting emergency meeting criteria. It is my understanding that the board allready had scheduled for October 2018 a discussion on hatchery production and should have been the time for this petition to be brought before the board and discussed.

Next getting back to the hatchery systems in general, as well as the correlation that people are trying to claim with no scientific backing. It is well known and documented that the pink salmon not only feed in different areas but also on a completely different food source than red salmon do, thus putting a major damper on the claims that the hatchery released pinks are the reason for the declining red returns. I would like to point out that when the copper has been properly managed to alow the necessary returns, instead of overescapment, the copper river has had much better returns, on average. The other factor that no one outside the commercial fishing fleet seems to want to bring up, is the subsistence and sport caught salmon reds and kings that are taken above any fish counting station on the river systems. Between fish wheels and sportsfisherman who are hardly monitored, and also have no annual limit on the amount of fish they can take. There is a huge issue here that I believe needs to be looked at more closely. I'm not saying to ban sportsfishing as I'm an avid sportsfisherman myself, I also am not suggesting shutting down all subsistence as that is a way of life and food source that they need. But there does need to be some limitations, and checks to determine how many fish can be sustainably harvested up river. Or how many have been harvested so they can shut down after a quota is filled. On the other side of things there have been quite a few years now where the river got overescaped by a lot because they did not alow the commercial fisherman the time to fish.

Lastly I would like to caution against any petitions for change in Alaska that are backed by money from people not from Alaska. It is my understanding that some of the major backers of this petition are largely out of state activists with money. They do not represent Alaska's best interest, they ultimately don't want to just stop this increase in roe take, they will continue to try to eliminate commercial fishing all together. And that is not in anyone's best interest for Alaska.

Thank you

Eric tutt

Native Village of Eyak
110 Nicholoff Way
P.O. Box 1388
Cordova, Alaska 99574-1388
P (907) 424-7738 * F (907) 424-7739
www.eyak-nsn.gov

10,000 years in our Traditional Homeland, Prince William Sound, the Copper River Delta, and the Gulf of Alaska

Resolution 2018-07-01

A RESOLUTION BY THE NATIVE VILLAGE OF EYAK AGAINST THE EMERGENCY PETITION TO REDUCE HATCERY PRODUCTION AND IN SUPPORT OF THE ALASKA HATCHERY RESEARCH PROJECT

WHEREAS: The Native Village of Eyak (hereinafter "Tribe") is a federally recognized self-governing Tribe; and

WHEREAS: The Native Village of Eyak Traditional Tribal Council is the duly elected governing body of the Tribe; and

WHEREAS: The Tribe recognizes that subsistence and commercial fishing is the cultural and economic cornerstone for its Tribal members since time immemorial; and

WHEREAS: The tribe supports sustainable wild fisheries, enhanced by fish hatcheries where it is responsible and necessary to do so; and

WHEREAS: The Tribe recognizes the regions wild and enhanced fisheries as necessary to meeting the needs of a growing world to have access to sustainable, high quality protein; and

WHEREAS: The State of Alaska invested hundreds of millions of dollars in hatchery infrastructure to meet these needs while benefiting the region with a sustainable economy; and

WHEREAS: Interactions between wild salmon and hatchery raised salmon have been observed in the past, and because of these observations the Alaska Hatchery Research Project has been established, at a cost of tens of millions of dollars, to ensure our hatcheries are used responsibly without negatively impacting wild stocks; and

WHEREAS: The emergency petition submitted by the Kenai River Sportfish Association to the Alaska Board of Fish demanding a halt to the approved production increase by the Valdez Fisheries Development Association is irresponsible and occurs outside of the open and participatory process by which this increase was approved, and reviewed by the ADFG Regional Planning Team; and

WHEREAS: The potential meeting date to address this emergency petition is during the only six weeks of the year during which the very industry to be disrupted cannot fully participate due to its highly seasonal nature representing an improper barrier to their participation.

NOW THEREFORE BE IT RESOLVED:

That the Native Village of Eyak Traditional Tribal Council calls upon the Alaska Board of Fish to dismiss this emergency petition and allow this matter to be addressed by the normal processes by which hatchery production is reviewed and approved, and the normal Board of Fish meeting cycle; and

BE IT FURTHER RESOLVED:

Any suggestion that immediate remedies to the observations of hatchery fish interacting with wild fish should be dismissed, and the Alaska Hatchery Research Project be allowed to provide high quality, peer reviewed scientific data so that our hatcheries can continue to provide high quality, sustainable protein to the world.

CERTIFICATION:

I, hereby certify that I, Darrel Olsen, am Chairman of the Native Village of Eyak Traditional Tribal Council, consisting of 5 duly elected members, and that this **Resolution 2018-07-01** was considered and APPROVED by the council on July 9, 2018 and that the vote was 3 For, ⌀ Against, ⌀ Abstaining, and 1 Absent and that the foregoing resolution has not been rescinded or amended in any way.

Darrel Olsen

Darrel Olsen, Chairman

July 9, 2018

Date

Pamela J. Smith

Pam Smith, Secretary-Treasurer

7/9/18

Date

Submitted By
Ezekiel Brown
Submitted On
7/9/2018 9:41:32 AM
Affiliation

Chairmen Jensen and members of the Board, I am a commercial fishermen of the Prince William Sound and Copper River District. This 3rd Emergency Petition on Hatchery production, the second filed by KRSA is a shameful waste of all of our time and resources. The very idea of bringing up this issue while an entire user group is busy fishing and cant attend is an insult to commercial fishermen and proper public process. This same issue has now come before Board of Fish and ADFG on 4 occasions, in a 6 month time span. ADFG has stated that there is no finding of an emergency each time. The Board of Fish has set a date for an October work session in Anchorage to address the subject, when they have more data and more time to review said data. The filers of this petition are abusing the emergency petition system and by taking this issue up when there is already a set meeting on this subject the Board is only encouraging this behavior. I am strongly opposed to this petition, and ask the Board to once again to take no action, and continue forward with the plan to meet in October on the subject. Thank you, Ezekiel Brown

Submitted By
gail nowicki
Submitted On
7/2/2018 12:05:07 PM
Affiliation
fishwife

i disagree with any proposal to limit hatcheries in prince william sound. i also think it is unfair to hold any hearings on fishing issues during the fishing season. seems to be intentional to not get comments against the proposals from frishermen and fish families. our livelyhood of the past 38 years is at stake and we should be heard. please be fair

Submitted By
Heather Durtschi
Submitted On
7/9/2018 9:43:21 AM
Affiliation
fisherwoman

Date: June 9, 2018

Fisherwoman: Heather Durtschi

Fishing Vessels: Halberd and Chicane

Homeports: Whittier and Valdez

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherwoman, the wife of a commercial fisherman, and the mother of two commercial fishermen in Prince William Sound. Needless to say, my family's livelihoods depend on the area's commercial salmon fishery and have done so for the past 29 years. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production.

The mission of a hatchery as stated by the VFDA is "to raise, propagate, and market fish and fish products, and to develop renewable fisheries resources for the benefit of sports fishermen, commercial fishermen, fish processors, tourists, and all businesses dependent upon the fishing industry in Alaska." Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. Based on the following statistics, the hatcheries are doing their job well and are integral to making a living as a fisherman in PWS.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, holding an emergency meeting on this critical issue which will impact so many Alaskans during the middle of our commercial salmon fishing season is outrageously unjust and undemocratic! The people most impacted will not be able to participate in the process because they will be working. Let's recall that this same petition has already been denied because it does not meet "emergency criteria." The board has previously scheduled a discussion on hatchery production at the October 2018 work session. Stick to the plan! By holding this meeting in Anchorage on July 17, you have denied my fellow PWS fishermen an opportunity for meaningful participation. I have changed my plans, spent $500 on a ticket change, and will be there to voice my concerns.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Sincerely,

Heather Durtschi

Submitted By
Heather Maxcy
Submitted On
7/7/2018 8:19:25 AM
Affiliation
Maxcy Fishing Inc

Phone
4065991397
Email
maxcyfishing2@gmail.com
Address
PO Box 2016
Cordova, Alaska 99574

July 7, 2018

Heather Maxcy

Wild By Nature LLC

Cordova, AK

To: Alaska Board of Fisheries

RE: comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members,

I am a commercial fishermen and the owner of a direct marketing business in Prince William Sound and Copper River District. While out fishing on the grounds with my husband I became aware of another Emergency Petition filed by KRSA. This same petition has been denied as it it did NOT meet emergency criteria. The board has scheduled discussion on hatchery production during its October 2018 work session.

Choosing to hold this meeting in Anchorage on July 17, 2018 DENIES me and my fellow fishermen and processors our constitutional right to DUE PROCESS. It is disappointing and alarming that BOF would even consider limiting all interested parties right to actively participate. As a lifetime sport fisherman and individual trained in fisheries and wildlife management it is also alarming that the BOF is not sticking to their decision to address the issue in October, but is bending to the unreasonable and nasty pressure of the petition filers. This decision must be based on science and data, NOT on an abuse of public policy, political pressure, and emotion.

The Board is well aware that hatchery programs have a strong impact on the economics of Alaskan communities. I do not feel it necessary to repeat the economic facts and figures but ask that the Board remember that PWS seiners and gillnetters make over 60% of their gross earnings from harvesting PWSAC salmon. These earnings directly impact the people and communities throughout the state. Perhaps the most important thing to remember in this discussion is that VFDA hatchery production does not only benefit commercial fishermen but accounts for 75% of all coho and 90% of all pink salmon caught by sport fish Anglers in the Valdez area. Total sport fish economic output for VFDA is estimated at $6.6 million annually. Furthermore both subsistence and personal use fisheries also benefit from the hatchery production with approximately 700,000 PWSAC sockeye salmon harvested between 1999 and 2011.

I am strongly opposed to this petition and ask the Board to take no action but remain on track to discuss this issue during its October work session.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Thank you,

Heather L. Maxcy

Submitted By
Hendrik Kruithof
Submitted On
7/9/2018 8:35:06 AM
Affiliation
Prince William Sound Purse Seiner Captain

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64%of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Sincerly,

Hein Kruithof

7/6/2018
From Hughie R. Blake
F/V Kelly Ann
Cordova, AK

To: Alaska Board of Fisheries
RE: Comments on KRSA et al. Hatchery Emergency Petition

I am a life-long third generation commercial fisherman from Cordova, Alaska. I seine salmon in Prince William Sound. My family depends on VFDA salmon for our livelihood. Many years it is a large portion of our revenue. Other seiners from Cordova similarly rely on VFDA salmon to make a living.

I know personally that hatcheries in Prince William Sound are vitally important to the town of Cordova. The majority of the residents of Cordova rely on the hatcheries to survive and the town's economy is very dependent on the hatchery revenue from commercial fishing. To limit or take that away would be at best devastating and possibly catastrophic. The community of Cordova also relies on PSWAC sockeye salmon for subsistence and personal use.

Reducing the salmon fry release numbers is unlikely to provide any environmental benefit. Alaskan hatchery salmon fry releases represent a small percentage of the hatchery fry release in the Pacific. Without international cooperation, all a reduction in fry release from VFDA will accomplish is reducing Alaska's stake in the resource. This would make Alaska less competitive globally, with no environmental benefit.

Finally, I wish to voice a concern about process. The timing of the meeting isn't critical to the group filing the petition. However, it is critical to the fishermen. It is unreasonable to think that fisherman who rely on salmon seining for their yearly income can be involved in the process during the middle of their fishing season. The petition has already been denied due to not meeting emergency criteria and there is already a board meeting on hatchery production in October. Therefore, there is no need to have this earlier meeting in July or to make a rushed, uninformed, and potentially biased decision without due process on an issue that is so critical to so many people's livelihoods.

With these things in mind, I ask you to deny the emergency petition request.

Sincerely,

Hughie R. Blake

Submitted By
Ivan Stonorov
Submitted On
7/4/2018 1:15:57 PM
Affiliation
Fisherman

Dear Chairman Jensen and Board of Fisheries Members,

We are Prince Willam Sound fisheman, who make the majority of our income harvesting salmon in PWS. As Alaskan residents we are writing today to voice our concern about the upcoming emergency meeting that will be held during our fishing season. This is a very poor way to conduct a fair and balanced process. Especially as the issue of hatchery production is scheduled to be discussed at the October session. As you all well know, that time would give everyone a chance to participate in the process.

That said we do not feel that a slight increase in hatchery production constitutes an emergency. We need to have an approach based in science, not on politics. This approach takes time and should never be decided in an emergency session.

There are not only the Permit holders, there are, Crewman, Tenderman, and Processors depending on this decision, Tourism, Sport fishing, and, Local economies also benefit from the management of the PWS hatchery production.

Please deny this emergency petition request.

Respectfully

Ivan and Amy Stonorov

F/V Hadassah

Submitted By
Jacob Gerrish
Submitted On
6/28/2018 11:56:46 AM
Affiliation
Self

Dear Board Members,

Please consider the emergency petition relating to additional hatchery production in the Prince William Sound. There is no denying the impact of hatchery pinks on wild stock. Hatchery fish compete for food with wild Sockeye and other species. Fot too long, you have ignored diminishing wild stocks by supplementing them with hatchery fish, thereby pleasing the strongest interst groups. This is no way to manage our fishery resources.

One hatchery fish is not equal to one wild fish. You have all the data and reseach you need to come to the conclusion that something needs to be done. Don't ignore the facts any longer, lest you risk sacrifcing the genetic diversity of millions of years of biological evolution. There is no reason that natural stocks, if managed correctly, can survive for generations to come. Thank you for your consideration of my comments.

-Jake

RECEIVED
JUN 2 9 2018
BOARDS

DATE 6-27-18
FISHERMAN Jacob Mclean
FISHING VESSEL Labrador
HOMEPORT Homer, AK

To Alaska Board of Fisheries

RE Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members

My name is Jacob Mclean. I began seining PWS in 2003 with my Father. Commercial fishing is the only occupation I have ever had in my 25 years of life. This is the life style I love and want to pass down to the generations to come. I am just now getting married and starting a family as well as buying my own seiner this year. I fear that if hatcheries were to close the amount of wild stock will not sustain the fleet. By taking away our hatcheries you are taking away my ability to support my family and make my boat payments. These hatcheries support and benefit not only the lives of commercial fisherman but also the lives of Alaskan residents.

Also, I'd like to note that it is unfair to plan a meeting during our salmon season. By scheduling this meeting for July 17th you are taking away my ability and fellow fisherman to be present and take part in this meeting. I am asking that you honor the original meeting date of October 2018 when I able to attend.

PLEASE DENY THIS EMERGENCY PETION REQUEST

Jacob Mclean

Jacob Mclean

Submitted By
JacobPrivat
Submitted On
6/27/2018 12:32:38 PM
Affiliation

Phone
337-412-8785
Email
Jnprivat@gmail.com
Address
PO Box 1951
Cordova, Alaska 99574

I am writing as a first year drift permit holder for Area E. This emergency meeting to reduce hatchery production would directly effect my ability to make a living as a commercial fisherman. I decided to invest in this particular fishery because of its diverse array of salmon runs. Already, this year has proven that the hatchery programs of PWS are an economical and sustainable resource; I would not have been able to generate any income from my investment without the hatchery programs. If one of the wild runs had a weak year I would be able to rely on the consistency of one of the hatchery runs to make ends meet. It is my understanding that this issue has already been brought up and denied on multiple occasions and was to be re-evaluated in the October session. I find it unfair that this meeting is being held during the middle of the summer when those affected are out on the water or managing their business that these hatcheries allow for. As it is, I am sending this comment while on anchor on the fishing grounds for hatchery fish as are many other fisherman who may or may not be able to have access to the Internet at this time.

I strongly oppose this emergency petition and seek to have it voted down.

Thank you for your time and work.

Submitted By
jake nowicki
Submitted On
6/30/2018 4:41:52 PM
Affiliation

Chairmen Jensen and Board members,

I am a commercial fishermen of the Prince William Sound and Copper River District. I have been following the attack on Prince William Sound Hatcheries since the beginning of the year. While out fishing on the grounds, I became aware of a 3rd Emergency Petition on the subject, the second filed by KRSA. This petition resulted in a hearing in the middle of the fishing season, when I cannot fully participate in the public process laid out for our fisheries.

This same issue has now come before Board of Fish and ADFG on 4 occasions, in a 6 month time span. ADFG has stated that there is no finding of an emergency each time. The Board of Fish has set a date for an October work session in Anchorage to address the subject, when they have more data and more time to review said data. The filers of the petitions are berating the Board into making a decision in their favor, when they are unsatisfied with the answer.

It is an abuse of public policy that a 3rd Emergency Petition is being brought to you once again, after it was already determined there was no finding of Emergency, and after it was decided that this issue would be taken up at the October work session in Anchorage.

I am strongly opposed to this petition, and ask the Board to once again to take no action, and continue forward with the plan to meet in October on the subject.
Thank you, jake nowicki crew man

From: Jakob Nelson
Sent: Saturday, June 30, 2018 8:34 PM
To: tsnelson6@hotmail.com
Subject: Fwd: Opposition to Emergency petition

RECEIVED
JUL 06 2018
BOARDS

---------- Forwarded message ----------
From: **Jakob Nelson** <jakobnelson399@gmail.com>
Date: Wednesday, June 27, 2018
Subject: Opposition to Emergency petition
To: Tsnelson@hotmail.com

---------- Forwarded message ----------
From: **Jakob Nelson** <jakobnelson399@gmail.com>
Date: Sunday, June 24, 2018
Subject: Opposition to Emergency petition
To: "dfg.bof.comments@alaska.gov" <dfg.bof.comments@alaska.gov>

Members of the bored of fish, I would like to voice my opposition to the emergency petition to limit production of hatcheries. Hatcheries cause no proven harm to the Other salmon or any other species. They only benefit fishermen, processors, and the state.

Jakob Nelson Homer Alaska

P.O. Box 1392
PWS salmon seiner

Jake Nelson

Submitted By
James Honkola
Submitted On
7/6/2018 10:14:25 PM
Affiliation
Bluff Point Salmon

I am writing as a fisherman in response to the Alaska Board of Fisheries decision to hold a hearing on the Emergency Petition filed May 16, 2018. Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria. I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families. The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions. I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session. Thank you,

Submitted By
james monroe
Submitted On
7/9/2018 1:16:39 PM
Affiliation
fisherman 30 years

Phone
9074863656
Email
whitneycreek@gci.net
Address
720 Thorsheim Street
P.O. Box 1202
Kodiak, Alaska 99615

Disapprove of all emergency petitions being sent to the BOF at this time, Area M and Kodiak sockeye fishing, as I fish the Kodiak Island fisheries, for the past 30years. These petitions should be handled at the meeting in October, not in the middle of a busy fishing season, isn't fair to anyone, is it open and transparent????. as it should be. Siene boat fisherman F/V Lady Ashley.

James D. Monroe

Submitted By
James Mykland
Submitted On
6/30/2018 6:27:43 PM
Affiliation

I oppose this emergency petition, submitted by KRSA and other organizations. There is no emergency, that needs to be acted on now . The BOF, has already decided to have a committee look at this situation and see if there is any real scientific facts, that support this petition summary. This is actually become a political football, since basically, the content of this petition has been discussed and voted down. Mr, Chairman and members of the BOF, I am asking you to deny the petition, until a full study with scientific facts is developed. Thank you for your time and energy on this state board, and in reading my comments. Sincerely, James Mykland

Submitted By
Jane Petrich
Submitted On
7/8/2018 8:24:22 AM
Affiliation
Commercial Fishing family Kodiak Island

Phone
907 942-2724
Email
jpetrich@gci.net
Address
PO Box 51
Larsen Bay, Alaska 99615

My name is Jne Petrich and I have been commercial salmon fishing on the westside of Kodiak Island since 1979. I fish the set net fishery with my 3 sons who have all been apart of the fishery since their births (Erik 1980, David 1983, Stephen 1986). All three of my sons have worked in the fishery and now own permits and sites and rely on the salmon fishery for the financial security of thier families. As a senior resident of Alaska I too rely on my income from my participation in the fishery for my financial security.

Members of the Board of Fisheries need the input and participation of all fishers in order to ensure an open and transparent process. Allowing special interst groups to use the emergency petition process in the middle of the busy summer salmon season as a way to avoid the public process iis not the way to an open and transparent process. You are excluding me and my family from the process by Accepting emergency petitions to restrict or stop Area M and Kodiak sockeye fishing You have a worksession coming up in October and should put these agenda items on the schedule for that time instead.

Submitted By
Jason Gonzalez
Submitted On
7/8/2018 5:10:39 PM
Affiliation

Phone
4238477836
Email
jason_elenano@hotmail.com
Address
112 Forestry Way
Cordova, Alaska 99574

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

Please deny this emergency petition request.

Signed,

Jason Gonzalez

Submitted By
Jeff Bailey
Submitted On
6/27/2018 10:12:55 AM
Affiliation
Bailey Fisheries

Phone
9074416775
Email
jjeffish@gmail.com
Address
1413 Sunrise Drive
Anchorage, Alaska 99508

Alaska Board of Fish,

As a 35 year commercial fisherman in Prince William Sound I was witness to the begining and development of our Prince William Sound Aquaculture projects. These haturies contribute a substancial amount of income for my family and the surounding communities. Without the hatchery contributions of common property salmon our boats and permits would be worthless and many of the costal communities would fail. This legal manuver by the Keni River Sports Fishing Association to continue to petition for a 3rd emergency hearing in the middle of our fishing season disinfracshizes all of us who would have a say in our public process. I strongly disagree with having an emergency hearing in July when stake holders are not available to participate and ADF&G has already taken the position that no emergency is warrented. This manuver is an attack on the princples of living in a democracy where all people should have a right to voice their concerns in a reasonable and prudent manor.

Jeff Bailey

Area E Commercial Drift and Purse Seine Fisherman

I am writing as a board member of the Prince William Sound Aquaculture (PWSAC) board member regarding the most recent emergency petition that was filed. I am one of 45 board members that represents a large section of the region with diverse interests. As a board member and resident of the State of Alaska I am deeply concerned with the current effort to reverse a decision that was years in the making through a collaborative effort between the Alaska Department of Fish and Game, Regional Planning Team and Valdez Fishermens Development Association. The Alaska hatchery program is important to state, regional and local economies, they help provide for a stable community by supporting sport fishing, tourism, personal use fishing, commercial fishing, seafood processing, along with other economic benefits that spread throughout the state.

It is important to remember that our board discusses production changes with great detail. These discussions are first vetted by our Production Planning Committee, then past to the full board for a vote even before being submitted to the Alaska Department of Fish and Game. Through the years PWSAC has submitted Permit Alteration Requests that have been denied for various reason, which is proof the process in place works.

I ask that the board fully consider the whole process regarding the Permit Alteration Request, as I attest that the effort put into these is significant. We are in the middle of the salmon season and should be focusing our time on the fishing season before us.

Holding a meeting during the salmon fishing season is poor public process when the topic has been addressed several times this winter and spring. At this point you are now limiting the opportunity for impacted users to support the hatchery program. The board of fish established a committee to address these concerns in October, and should stick to that plan. This will be an opportunity for fishermen, processors, public, and hatchery operators to devote the attention to the topic and help explain the program and what it means to them.

Our Hatcheries are backed by years of experience, science, and by people who have a true interest in bettering the communities.

Please deny this emergency petition request

Thank you,

Jeff F. Berger

From: Jeff Berger
To: DFG, BOF Comments (DFG sponsored)
Subject: Hatchery programs
Date: Wednesday, June 27, 2018 4:08:24 PM

Dear BOF,

Please do not alter our Hatchery programs. There have been hatcherys and enhancement programs all over the world for over 100 years and just now a few special interests AND A SMALL SEGMENT OF THE PUBLIC HAVE MADE IT THEIR AGENDA TO ATTACK THESE PROGRAMS.

Without these programs the fishing industry would be gutted and the benefit that is realized by all users would be gone. Too many family's depend on these programs for their futures.

Why is it only now that aquaculture is under attack.

If there is good sound science that indicates we need to modify or change our programs then we can do it at that time.

Jeff Berger

Sent from Mail for Windows 10

Submitted By
Jeff Cabana
Submitted On
6/27/2018 4:25:47 PM
Affiliation
Fisherman

Phone
9072057933
Email
bamacabana@gmail.com
Address
Box 26
Homer, Alaska 99603

We are out fishing for the year, please take this up in the fall. King Salmon eat pink fry...this is a good thing for them. Not bad. How can they possibly harm them. Show some science.

Submitted By
Jeff Kovac
Submitted On
7/7/2018 9:51:59 PM
Affiliation
Crew member

Phone
907/982-5579
Email
4K.jkovac@gmail.com
Address
65531 South Victory Rd.
Sutton, Alaska 99674

To the board,

As a commercial fishing crewman I have seen first hand the contribution that Alaska's fishery have made to countless families. Each season we fish as a way to provide for our families and in that endeavor we peruse a lifestyle and a way of life that promotes and encourages self reliance and, at the same time, interdependence. There are very few locations that provide this environment for their residents and I trust we look long and hard at any changes that would impact this fisheries participants, this state and its economy.

With Kind Regards,

Jeff Kovac

FV Chelsea D / FV Lady Lori

Submitted By
Jeffrey H. Guard
Submitted On
7/7/2018 4:49:21 PM
Affiliation
PWS Seine Permit Holder

Phone
907-423-8111
Email
dornehawxhurst@hotmail.com
Address
PO Box 856
Cordova, Alaska 99574

I am a commercial fisherman in Prince William Sound (PWS) and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. But for the hatcheries, there would not be many fish at all in PWS during many years.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. CONVENING AN EMERGENCY MEETING ON THIS ISSUE DURING THE MIDDLE OF OUR COMMERCIAL SALMON FISHING IS UNREASONABLE, POOR PROCESS, ESPECIALLY WHEN THE SAME PETITION HAS AREADY BEEN DENIED BECAUSE IT DID NOT MEET EMERGENCY CRITERIA. The board has scheduled a discussion on hatchery production at its October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST

Signed,

Jeff Guard

Chairman John Jensen and Alaska State Board of Fisheries Members,

I am writing to ask that you cancel this additional 20,000,000 pink salmon eggs from the Solomon Gulch Hatchery request as well as any other PWS hatchery that asks for increased expansion in the future

I have been a remote builder in Alaska since 1990 and have a small guiding business that takes hikers and skiers into the back country within the Kenai Range especially in Kachemak Bay State Park.

The last number of years spent working on trails within the Park at the head of Tutka Bay.

This trail runs along what is known as the Tutka Head End Creeks and is catalogued in the Anadromous Waters Catalogue to contain wild Chum salmon and wild Coho salmon wild pink salmon.

Since 2015 we have seen a huge volumes of dead and dying pink salmon piled deep in the river which now we realize are not only the excess strays from the Tutka Hatchery infecting the creeks but also from the hatcheries of Prince William Sound.

The wanton waste is profound. The more I learn about why this is happening , the more alarmed at how hatchery special interest people have infiltrated ADFG and using the government positions to create a special harvest single species ranching regardless of all other obstacles or damaging effects. This is not a joke. This shows excess, It shows gluttony, It shows greed. When is enough, enough?

To inundate our wild streams in not acceptable and we realize the only way this problem will cease is for the Board of Fisheries to exert it authority to get us out of this problem. ADFG does not seem to have any power to act because the Commissioner has two sons with seine permits in LCI and he stepped down from the Cook Inlet Aquaculture Board to become Commissioner.

Sam Cotten is completely tainted with special interest and pointedly acts accordingly. I have watched CIAA biologists when after claiming that there is no scientific data supporting that there is anything wrong with what they are doing be presented with a stack of scientific papers showing otherwise. His reaction was to with shaking hands in fury throw the papers on the ground walking away saying " I am not going to read any of your stinkin' biased science"

I have watched Gary Fondrai of CIAA exclaim in his best preacher prose about this huge first straying event after Cotten took office where all of the fish they produced overwhelmed natural streams simply said "yes, that was unfortunate and we soon hope to put that behind us." and that is how it has gone. No accountability!

Sam Raybung , in Juneau head of Hatchery program, is on every Regional Planning Team in the state and then signs on for all permits for the hatcheries, whose previous job was in in hatchery production. How is that for special interest inside jobs?

At a public meeting aquaculture board meeting when asked about the concerns for the impacts of the exceptionally not natural release of the pink salmon fry in tutka on what they are eating and who the pinks are taking the food from? Rabung says" its ok, the pinks don't eat anything because we have already fed them." good god! how far polluted by greed and private motives does it take a for a person to be able to create such arguments of illegitimate authority and expect to get away with it. He went on to say how great they are in Prince William sound and how the hatcheries are spending 14 million on a new report that will show how well they are doing. This study is known by most scientists to be flawed with no peer review and a protocol designed exactly to show how great they are! It explains the reaction of the CIAA biologist in refusing to look at any other info other than the propaganda they write and believe for themselves.

We have had many meetings that seem to come to no conclusion as though we have no control over these out of control private non-profit corporations. It is a laugh the thought of the words private or nonprofit. These are corporate empires that serve and pay themselves not the Alaskan public while funneling public funds into private pockets. It is called graft.

I watched a CIAA board meeting where public came in to express their concerns about the lack of action towards the pike invasive problem. He was ridiculed. After he left then when I asked if they had an idea about how large the pike problem was, I was ridiculed also and told that's bigger than I can imagine and no point of trying to do anything as some people want the pike and will just transplant them again.

I then watched as they put 170,000.00 at pike removal and write a great article about how great they are in smolts report, then approve over 250,000.00 to fix a small septic problem for a short term seasonal facility at tutka lagoon hatchery. About 200,000.00 more then necessary. this is for the $900,000.00 seasonal employee bunkhouse recently built. As a builder for 30 years I could see how such a structure could cost up to $350,000 only. Where went the extra 550,000.00. Of course, CIAA need the pinks to pay for themselves at the expense of everything else. The pinks that choke out every stream and creek they can force themselves into. Its the PWS business model and it needs to stop in a way that can never be to this extent of a problem again!

Please help get this stopped it is way out of control and we are sick and tired of dealing with the arrogance of these bullies on the park process and wasting our time. Hatcheries are less than 5% of the x vessel value but cause more problems and waste more state resources than most of the rest.

There is no respect or consideration except for their competitive empire building to see who has the biggest hatchery, and pocket the construction expenses while doing it. This is ridiculous. This log jam needs cleared

Alaska has enough pinks. Hatchery pinks outnumber wild sockeye and far outnumber king salmon. Sockeye kings coho are the preferred species for Alaskans not pinks for china.

Thank-you for listening we are really fed up with this corporate take over of our fish and our parks

Sincerely,

Jeffrey Troy Lee
Box 44
Seldovia, Alaska 99663
7/8/18

Submitted By
Jeremy Cabana
Submitted On
7/8/2018 10:45:48 PM
Affiliation
I'm a Commercial fisherman

Phone
9073990678
Email
jeremycabana@yahoo.com
Address
P.O. box 719
Homer, Alaska 99603

Dear board of fish,

I am writing this to you from just outside Valdez. It's the middle of fishing season and you have called a emergency meeting that impacts thousands of people who cannot be there. I understand that it's easy to call one of these meetings but this time it is completely wrong to take seriously the emotional pleas of people not even associated with this industry. I understand that one of the largest scientific studies of it's kind is close to being completed, on this topic. I hope that I'm not sounding like a person that is scared but that's exactly what I am. I am a permit holder and a boat captain on a seiner in PWS. I plan on fishing here for another 30 years and I've been here 30 already. This is my livelihood, my lifeblood. I've got a 4 children's futures that I am now worried about. There are literally thousands of people out here right now that will miss your meeting and our future is possibly in danger. I ask that this meeting be rescheduled to a later date so that we can be better able to defend ourselves. It's ludicrous to think that a group of sports fishing guys, in Cook Inlet, have the ability to stop the harvest of eggs that has already been approved by everyone. Anyways I'm sorry for my rambling message but I'm a fisherman not a English major. I have a wife, 4 kids and three guys that depend upon the Sound to survive. Let's not forget how many people's lives are depending on the wonderful aquaculture programs around our amazing state. We are lucky to have this amazing resource for the benefit of so many people. So many people. Anyways to wrap it up, please reschedule the meeting and let's wait for the largest scientific study ever underway on the effects of hatchery fish. Please. Let's go with the science on this point and not a bunch of misplaced emotions from people that don't know what they are talking about. Thanks for reading this if you did. I would like to see this state continue to be the best place on earth.

Jeremy Cabana

Submitted By
Joel Carroll
Submitted On
7/7/2018 2:34:25 PM
Affiliation
PWS commercial fishermen

Phone
9074060527
Email
jpenguin22@gmail.com
Address
PO Box 3013
2043 Jakes Little Fireweed Ln
Homer, Alaska 99603

I am part of a commercial fishing family in Prince William Sound. I have grown up fishing with my dad and salmon provides the income for our family and my future. I was disappointed to hear that a hearing on this petition would be held in July right during the middle of our season. It seems that we are being ambushed by a special interest group at a time when we should be focused on making a living. The prudent thing would be to wait until the scheduled meeting in October when the facts can be presented and discussed in a more productive and meaningful way. PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Submitted By
Joel
Submitted On
6/27/2018 11:21:21 AM
Affiliation

Phone
9073992211
Email
Msfish1001@gmail.com
Address
Po box 387
Homer, Alaska 99603

Dear board of fish chairman and board of fish members:

I am a fourth generation commercial fisherman in Alaska.

My great grandparents homesteader in homer Alaska, I have had my own commercial fishing operation since I was seventeen years old. I have both gillnetted and now siene in pws where my family and I work hard to make a living for ourselves. The value of hatcheries in pws is huge, with 74% of all Valdez commercial salmon harvest going to AK residents. In addition to commercial these hatchery fish are also utilized by many sports fisherman 73% of these being Alaska residents. The estimated annual economic output from the sports fishery in Valdez alone is 6.6 million annually. I would really like to continue being able to support my family by catching pws enhanced runs. Finally I would like to voice concern for our democratic process in allowing yourselves to be pushed into an emergency meeting on the issue of our fish production at a time when we as fisherman cannot attend, which is clearly the intent of the petitioners to try and get something passed when the present voices of those whose livelihoods they intend to destroy are unable to be there. This petition was already previously denied due to not meeting emergency criteria, to change it now with no new criteria being met is disheartening. Please for the sake of 1500 permit holders their family's and the families of everyone employed by these permit holders deny this emergency petition request. Thank you signed Joel Tutt

Submitted By
John Love
Submitted On
6/27/2018 10:48:17 AM
Affiliation
Area E Permit holder

Phone
(907)306-8791
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johnolove@gmail.com
Address
PO Box 141
Girdwood, Alaska 99587

DATE: 6/27/18

FISHERMAN: JOHN LOVE

FISHING VESSEL: STEADFAST

HOMEPORT: WHITTIER ALASKA

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Submitted By
jon henson
Submitted On
7/3/2018 3:39:38 PM
Affiliation

Phone
6193412464
Email
Fvluckydog@yahoo.com
Address
box 176
kodiak, Alaska 99615

Kodiak is already not fishing igvak section of area k. We are not catching much of any reds. So i dont think interseption is the problem. At least from area k

Submitted By
Joshua brandenburg
Submitted On
7/8/2018 9:00:54 AM
Affiliation

Phone
8086392965
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Joshuaberger3@yahoo.com
Address
1604 Davidoff st #4
Sitka, Hawaii 99835

I have been a commercial fisherman in Alaska for 25 years now. I own and operate the f/v Leilani-Marie out of sitka Alaska. My dependence on salmon fishing is critical to me, my family and many of my associates. It is important to my business that the board of Fisheries should have an open and transparent process. Quite frankly it upsets me that interest groups are using the emergency petition process, bringing up concerns for the livelihood of so many commercial fishermen during our busiest time of year. Of course this is done to be passed right under our noses which is not against the law but very cowardly, all to avoid the public process.

June 27th 2018

To Whomever it may concern:

I am a commercial fisherman writing in response to the recent emergency petition by the Alaska Board of Fisheries. As an ardent believer in the ecological foundations of Alaska fisheries, I support the research into and regulation of salmon fishing, one of the State's most beloved and iconic resources. As a college student working on a science degree, however, I do not see that there is any substantial evidence to treat this matter as an emergency. Likewise, measures that affect the livelihood of thousands of Alaskans - and by extension, my tuition payments at Princeton University - should not be discussed behind doors in the middle of a fishing season. I encourage Chairman Jensen and the Board of Fisheries members to move the discussion to the October Work Session, and allow everyone to participate without jeopardizing their proffession.

Sincerely,
Juan Sarmiento

Submitted By
Keegan fancher
Submitted On
6/27/2018 12:15:37 PM
Affiliation
Commercial fisherman

I vote to deny this emergency petition.

July 5, 2018

Alaska Board of Fisheries
Boards Support Section
P.O. Box 115526
Juneau, AK 99811-5526

Re: Petition for finding of emergency and denial of additional capacity of 20 million egg take and rearing of hatchery pink salmon resulting from recent amendments to Prince William Sound Private Non-Profit Hatchery Management Plan

Dear Alaska Board of Fisheries,

We, the undersigned organizations and individuals, submitted the petition requesting that the Alaska Board of Fisheries (BOF) make a finding of emergency and subsequently exercise their statutory authority to limit the number of pink salmon eggs allowed to be taken and incubated by the Private Non-Profit (PNP) hatcheries in the Prince William Sound (PWS). Specifically, our petition requests that the BOF amend actions taken in Permit Alteration Request (PAR) made by the PWS Regional Planning Team (RPT) and deny the increase in the number of pink salmon eggs taken in 2018 by 20 million. We provide these additional public comments in support of our petition.

First, we believe that the problem outlined in the petition justifies a finding of emergency. The next schedule meeting of the BOF is in October 2018, well after the planned additional egg take of 20 million for increased PWS hatchery pink salmon production occurs this summer. It was unforeseen and unexpected that the Alaska Department of Fish and Game, through the RPT process, would authorize additional egg take by PWS hatcheries that pose a threat to wild salmon in the Gulf of Alaska, contrary to the Alaska Sustainable Salmon Policy. As evidence, we cite the very high rates of inter-regional straying of hatchery pink salmon into Lower Cook Inlet, and scientific research studies and agency reports that document the adverse impacts on wild salmon and other wildlife from increased food competition in the North Pacific Ocean, where there are record high salmon abundance levels and an increasingly variable ocean environment.

Thus, we believe delay of the finding of emergency will be significantly burdensome to the petitioners because not taking immediate action to halt an increase in the capacity of hatchery pink salmon production in PWS will only further stress wild salmon in the broader Gulf of Alaska ecosystem.

Factors in support of finding of emergency:

1. Hatchery permits are required for the construction and/or operation of a private non-profit salmon hatchery in Alaska. Hatchery permits specify the species and number of salmon that can be incubated at the hatchery, as well as the number released, release sites, broodstock sources, and other conditions of operation.
2. BOF authority as it relates to hatcheries. AS Sec. 16.10.440 (b) The Board of Fisheries may, after the issuance of a permit by the commissioner, amend by regulation adopted in accordance with AS 44.62 (Administrative Procedure Act), the terms of the permit relating to the source and number of salmon eggs.
3. The Joint Protocol on Salmon Enhancement (#2002-FB-215) entered into by the Alaska Board of Fisheries and the Alaska Department of Fish and Game (ADFG) on June 28, 2002 establishes a framework design to inform the public and coordinate department and board interaction on certain aspects of salmon hatchery policy and regulation.
4. The State of Alaska law mandates that hatcheries shall operate without adversely affecting natural stocks of fish - 5 AAC 39.222. Policy for management of sustainable salmon fisheries. (c) (1) (D) effects and interactions of introduced or enhanced salmon stocks on wild salmon stocks should be assessed; wild salmon stocks and fisheries on those stocks should be protected from adverse impacts from artificial propagation and enhancement efforts.
5. The total number of pink salmon eggs that were taken for rearing in PWS hatcheries in 2016 was 740 million. That same year, 643 million pink salmon fry of hatchery-origin were released into PWS.
6. PWS fishermen have the highest hatchery fish catches. In 2017, 45 million salmon returned to the five hatcheries in PWS, accounting for 87 percent of the total salmon harvest. Ninety-three percent of pink salmon were hatchery-origin, and 68 percent of chum salmon were hatchery-origin. In all, PWS hatchery harvest added up to 62 percent of the total with a dockside value of $64 million.
7. Pink salmon that showed up in streams across Lower Cook Inlet in 2017 weren't all local stocks — in some streams, up to 70 percent were releases from PWS hatcheries. PWS hatchery-marked fish were present in every Lower Cook Inlet stream sampled. In Fritz Creek, 70 percent of the 96-fish sampled were from PWS hatcheries. In Beluga Slough, 56 percent of the 288-fish sampled were from PWS. In Dogfish Lagoon Creeks, Barabara Creek and Sadie Cove, hatchery pink salmon from the Solomon Gulch Hatchery in PWS composed 34.4, 14.2 and 12.5 percent respectively, of fish sampled. Overall, PWS hatchery pink salmon comprised 15 percent of the pink salmon escapement in LCI in 2017.
8. In addition to the straying issues of PWS hatchery-origin pink salmon observed in Lower Cook Inlet, recent scientific publications (building on past published reports and internal ADFG reviews) have provided cause for great concern over the biological impacts associated with continued release of very large numbers of hatchery salmon into the North Pacific Ocean,

including the Bering Sea and the Gulf of Alaska. See bibliography of scientific publications and agency reports, with summary points.

Second, we request that the BOF use its statutory authority to deny additional capacity of 20 million egg take and rearing of PWS hatchery pink salmon.

In response to *arguments against the BOF taking this action*, we provide further comment:

1. *Regulatory action requested is not clear.*
    a. To be unequivocal, the regulatory action requested is that the BOF exercise its authority provided in AS 16.10.440(b) and through use of the Administrative Procedure Act amend the 2018 PAR to deny allowing for the taking of an additional 20 million pink salmon eggs by PWS PNP's.

2. *The Department comments are summarized as follows, "The petition does not satisfy criteria described in 5 AAC 96.625(f) because it is not unforeseen that some level of straying occurs in pink salmon stocks and concerns over straying effects and potential fishery management complications arising from increased pink salmon production levels were discussed by the RPT and department when the 2014 SGH PAR was considered and approved."*
    a. Let's take a close look at the Department comment in more detail. It was not unforeseen because SOME LEVEL of straying in pink salmon stocks was anticipated? How much is SOME LEVEL and where is the straying anticipated? The level and locations of straying are not detailed, thus there is no criteria against which to evaluate either the level or location of straying by hatchery pink salmon.
    b. "Concerns (please be specific, what concerns exactly are being referenced here?) over straying effects and potential fishery management complications (what fishery management complications specifically?) arising from increased pink salmon production levels were discussed by the RPT and Department. Again, what if any specific threshold levels were discussed?
    c. More on the open nature of the RPT process later but the Commissioner's response to this Petition is essentially, "trust me, we got this" and it is woefully lacking in specifics on threshold criteria and evaluation metrics.

3. *Continuing with the Department comments, "while there were relatively high numbers of PWS hatchery produced salmon found in several recent sampling events in LCI streams, not enough information is currently available to determine whether their presence threatens a fish or game resource."*

a. What is the bar here? Doesn't the presence of up to 70 percent non-local stocks in the spawning streams of Lower Cook Inlet seem like the very definition of "threatens"? Has the Department established a set of decision criteria to help them determine when they have enough information to make a conclusion? We believe not and fully support the application of the precautionary principle in situations like this.

4. *The Alaska Board of Fisheries has scheduled a discussion on hatchery issues during their October 2018 Work Session.*
   a. We agree that a general discussion on how the BOF should proceed with regard to Private Non-Profit hatchery production is good, but the egg take in question will take place in August 2018. A discussion scheduled for October is no reason for the BOF to refrain from denying the increase now.

5. *BOF should look at this issue more broadly and not act on this specific request now.*
   a. The respective obligations of the BOF and ADFG to wild stock preservation and authorities under the law are unambiguous. In the face of documented straying of hatchery-origin PWS pink salmon into Lower Cook Inlet and compelling science-based evidence of ocean food competition issues of wild and hatchery-origin salmon, the fact that the BOF and ADFG have until now neglected to follow through on the Joint Protocol signed in 2002 is not a justifiable pretext for the BOF to refuse to act to deny an incremental increase in PWS hatchery pink salmon production. The promise of a more comprehensive approach in the future does not excuse the respective responsibilities of the BOF and ADFG for due diligence today.

6. *The Regional Planning Team (RPT) process is a public process and it is unfortunate that the authors of this petition did not participate and make their concerns known.*
   a. The RPT is about as closed, opaque and esoteric as any process deemed "public" can be. Whereas the BOF process and its historical records are open, transparent and accessible to the public, both in person and online, the RPT is the opposite. In fact, the Joint Protocol on Enhancement was entered in part precisely because both the BOF and ADFG recognized the shortcomings of the RPT process, including but not limited to compliance with the Administrative Procedures Act and record-keeping. A member of the petition did in fact attend both RPT meetings in Cook Inlet and Prince William Sound to discuss the issue of inter-regional straying of PWS hatchery pink salmon in streams across Lower Cook Inlet. The request to have the issue on the agenda and discussed in detail were not accommodated in either RPT process.

7. *It is unfair at this point to deny the PNP as it has made an investment in the infrastructure necessary to accommodate the additional 20 million pink salmon eggs and rearing needs.*
    a. Here, where one must weigh the risk to sustainability of the State's wild stocks of salmon against the private investment, the law is clear, wild stock integrity comes first.

Left undiscussed in the ADFG response and in serious discussion to date is the building body of scientific evidence that pouring hundreds of millions of pink salmon fry into the marine waters of the North Pacific is having dramatic and negative effects on the growth and actual survival of all wild salmon that compete for food sources in those same marine waters. See bibliography of scientific research and agency reports, with summary points.

Conclusion:

1. It is certainly unforeseen, unexpected and poses a threat to fishery resources that ADFG, the state agency charged with stewardship of the state's salmon resource, would agree to an amendment to the Annual Management Plans for Private Non-Profit Hatcheries in Prince William Sound, providing for a substantial increase in the taking of pink salmon eggs when up to 70 percent of all pink salmon sampled on spawning streams of Lower Cook Inlet in 2017 were of Prince William Sound hatchery origin.

2. A building body of scientific evidence concludes that stocks of Chinook and sockeye salmon are being impacted negatively in the marine waters of the North Pacific by being forced to compete for food with hundreds of millions of hatchery-origin pink salmon fry.

3. It is certainly unforeseen, unexpected and poses a threat to fishery resources that the BOF and ADFG would continue to ignore the Joint Protocol on Salmon Enhancement (#2002-FB-125) entered into on June 28, 2002 and fail to hold public meetings designed to provide an opportunity for the board and the public to receive reports from ADFG on hatchery issues, including most recent scientific research and production trends.

We request that the Alaska Board of Fisheries make a finding of emergency on this issue and subsequently use its statutory authority to halt the RPT authorization for an additional 20 million egg take for PWS hatchery pink salmon production. Thank you for your time and attention to this important issue. Please note the bibliography of scientific and agency reports, with summary points, from a wide range of state and federal agencies as well as university and independent scientists.

Respectfully,

Alaska Outdoor Council

Alaska Sportfishing Association

Chitina Dipnetters Association

Fairbanks Fish and Game A/C

Kenai River Professional Guide Association

Kenai River Sportfishing Association

Southcentral Alaska Dipnetters Association

Tsiu River Coalition

<u>Concerned Citizens for Lower Cook Inlet</u>

John Allardice - LCI set netter

Sera Baxter – LCI set netter

Emily Chalup – LCI set netter

Eddie Grasser – LCI angler

Mako Hagerty – LCI water taxi

Nancy Hillstrand – LCI fish processor

Wesley Humbyrd – UCI drift gillnetter

Brad Langvardt – LCI set netter

Dave Lyon – LCI water taxi

Kristi McLean – LCI set netter

Rory Millar – LCI set netter

Bibliography, with summary points.

a. **"Numbers and Biomass of Natural- and Hatchery-Origin Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean, 1925-2015" Gregory T. Ruggerone and James R. Irvine 2018.**
   i. Numeric abundance from 1925-2015 of North Pacific Ocean salmon show that pink, chum, and sockeye salmon are more numerous now than ever, in contrast to king and silver salmon. From 1990-2015, pinks dominate adult abundance (67 percent) and biomass (48 percent), followed by chums (20 percent, 35 percent) and sockeyes (13 percent and 17 percent).
   ii. Alaska produces approximately 39 percent of all pinks, 22 percent of chums, and 69 percent of sockeyes, while Japan and Russia produce the rest.
   iii. Although production of natural-origin salmon is currently high due to generally favorable ocean conditions in northern regions, approximately 60 percent of chums, 15 percent of pinks, and 4 percent of sockeye are hatchery-origin. Alaska generated 68 percent and 95 percent of hatchery pink and sockeye salmon, while Japan produced 75 percent of hatchery chum salmon.
   iv. Salmon abundance in large areas of Alaska (Prince William Sound and Southeast Alaska), Russia (Sakhalin and Kuril Islands), Japan and South Korea are dominated by hatchery salmon. In Prince William Sound, approximately 76 percent of pinks, 73 percent of chums, and 36 percent of sockeyes originated in hatcheries.
   v. During 1990 – 2015, hatchery salmon represented 40 percent of the total biomass of adult and immature salmon in the ocean.
   vi. Density-dependent effects are apparent, and carrying capacity may have been reached in recent decades.

b. **"Population Viability Improves Following Termination of Coho Salmon Hatchery Releases" Kim K. Jones, Trevan J. Cornwell, Daniel L. Bottom, Staci Stein, and Kara J. Anlauf-Dunn 2018.**
   i. Concerns exist that some hatchery programs replace rather than supplement wild production. Density-dependent interactions between hatchery and wild silvers, such as disease transmission, competition and predation, were issues in wild productivity.
   ii. On the Salmon River in Oregon, the ODFW decision to allow an independent population of silver salmon to recover without supplementation led to the reestablishment of a naturally reproducing population at the same level of abundance, supporting ESA recovery goals without adversely affecting fisheries management.
   iii. Adverse effects of hatchery fish on wild population abundance and productivity may be reversible.

c. **"Transhemispheric Ecosystem Disservices of Pink Salmon in a Pacific Ocean Macrosystem" Alan M. Singer, Gus B van Vliet, Natalie Bool, Mike Crowley, Peter Fullagar, Mary-Anne Lea, Ross Monash, Cassandra Price, Caitlin Vertifan, and Eric J. Woehler 2018.**
   i. Pink salmon in the North Pacific Ocean have flourished since the 1970s, with growth in wild populations augmented by rising hatchery production.
   ii. As their abundance has grown, so too has evidence that they are having important effects on other species and on ocean ecosystems.
   iii. In alternating years of high abundance, they can initiate pelagic trophic cascades in the northern North Pacific Ocean and Bering Sea and depress the availability of common prey resources of other species of salmon, resident seabirds, and other pelagic species.
   iv. For short-tailed shearwaters, seabirds that migrate annually between their nesting grounds in the South Pacific Ocean and wintering grounds in the North Pacific Ocean, in this century (2000-2016) the frequency and magnitude of mass mortalities of shearwaters as they arrive in Australia, and their abundance and productivity, have been related to the abundance of pink salmon.
   v. This highlights another example in a growing list of disservices of the abundant pink salmon in the North Pacific Ocean, and the need to include ecosystem processes in conservation and management considerations for this northern open ocean.

d. **"Pink Salmon Induce a Trophic Cascade in Plankton Populations in Southern Bering Sea and Around the Aleutian Islands" Sonia Batten, Greg Ruggerone and Ivonne Ortiz 2018.**
   i. Top-down (predator) control of plankton populations around the Aleutian Islands and in the southern Bering Sea were examined using a 15-year series (2000-2014). The analysis reveals opposing biennial patterns in abundances of large phytoplankton and copepods, likely caused by the predation on copepods from biennially abundant eastern Kamchatka pink salmon that results in a trophic cascade.
   ii. In odd years, pink salmon are exceptionally abundant, large copepod abundance is low, and abundance of large diatoms grazed on by copepods is high. Furthermore, large copepod abundance was inversely correlated, and diatom abundance was positively correlated, with pink salmon abundance.
   iii. These findings emphasize the importance of variability in predator abundance and its effect across the ecosystem, which in this case was greater than physical oceanographic variability.
   iv. Findings support other studies indicating consequences for predators that directly or indirectly rely on plankton in the Bering Sea in summers when pink salmon are numerous.

v. Growing evidence indicates that foraging pink salmon affect feeding and reproduction of seabirds, growth and survival of sockeye, king, chum and silver salmon, and may influence the declining size-at-age and abundance of king salmon throughout Alaska.

e. **"Lower Cook Inlet Pink Salmon Otolith Sampling Summary, 2017" Ted Otis and Glenn Hollowell, ADFG 2017.**
   i. In Lower Cook Inlet, at Tutka Bay, straying rates of Tutka hatchery fish ranged from 12.5 percent to 87.4 percent; outside of Tutka Bay, those levels in LCI dropped to 4.2 percent at Sadie Cove, 2.9 percent at English Bay River, and 2.1 percent or less at five locations and none at 6 other locations.
   ii. Straying rates of Port Graham hatchery fish was 1.1 percent for Port Graham and English Bay River, 1 percent at Lower Tutka Bay, and no straying at 13 other locations.
   iii. Prince William Sound hatchery-produced pink salmon were found at straying levels similar to previous years (2 – 70 percent), in all sixteen locations. Half of the locations had straying rates of PWS hatchery-produced pink salmon of more than 15 percent, with five of those locations at rates more than 45 percent. Overall, PWS hatchery fish comprised approximately 15 percent of all pink salmon sampled in LCI streams.

f. **"Effects of Climate and Competition for Offshore Prey on Growth, Survival, and Reproduction Potential of Coho Salmon in Southeast Alaska" Leon D. Shaul and Harold J. Geiger 2016.**
   i. In the Gulf of Alaska, coho salmon exhibit strong dependence upon a single prey species, the minimal armhook squid.
   ii. Study coho salmon adult size in SE Alaska reflects predator-prey interactions among coho salmon, pink salmon, and squid, where squid are the main prey coho salmon while pink salmon mediate squid abundance as both competitors and predators of squid.
   iii. Female-to-male ratio, weight, and marine survival exhibit an even-year, odd-year biennial pattern.
   iv. 65 percent of variation in size of coho salmon over a 45-year period was explained equally by the catch biomass of pink salmon in the Gulf of Alaska and by the PDO index during squid emergence and development.

g. **"Changes in Body Size of Canadian Pacific Salmon over Six Decades" Kyla M Jeffrey, Isabelle M. Cote, James R. Irvine, and John D. Reynolds 2016.**
   i. Body size of Chinook, coho, and chum salmon was most influenced by the total biomass of the three most abundant salmon species in the Gulf of Alaska – pink, chum and sockeye salmon, many of which are of hatchery-origin. The body size of sockeye salmon was most influenced by the biomass of chum salmon, many of which are also of hatchery-origin.

ii. Intraspecific density-dependent interactions appeared to be more important among pink salmon as pink-only biomass emerged in the top models for body size of both lines (even and odd year) of pink salmon.

h. **"Pink and Sockeye Salmon Interactions at Sea and Their Influence of Forecast Error of Bristol Bay Sockeye Salmon" Greg Ruggerone, Beverly Agler, Brendan Connors, Edward Farley, James Irvine, Lorna Wilson, and Ellen Yasumiishi, 2016.**

   i. Sockeye growth during the second and third years at sea exhibited a strong alternating-year pattern and was negatively correlated with pink salmon abundance from eastern Kamchatka and central Alaska.
   ii. Forecast error of sockeye stocks from SE Bristol Bay exhibited an alternating-year pattern suggesting competition with pink salmon also affected survival; forecasts in even-years were too high and forecasts in odd-years were too low, likely reflecting competition from pink salmon during the year prior to the return year.
   iii. Findings highlight sockeye growth and survival dynamics that cannot be explained by physical oceanographic patterns and support the hypothesis that competition with pink salmon adversely affects the growth and survival of Bristol Bay sockeye salmon.

i. **"Changes in Size and Age of Chinook Salmon *Oncorhynchus tshawytscha* Returning to Alaska" Bert Lewis, W. Steward Grant, Richard E. Brenner, and Toshihide Hamazaki 2015.**

   i. Findings indicate that Chinook salmon throughout Alaska have become smaller over the past 30 years (six generations), because of a decline in the predominant age at maturity and because of a decrease in age-specific length.
   ii. The proportion of older and larger 4-ocean fish in the population declined significantly in all stocks examined by return year or brood year.
   iii. Age-specific lengths of 4-ocean fish and 3-ocean fish declined significantly.
   iv. These wide-spread phenotypic shifts influence fecundity and population abundance, and ultimately may put populations and associated fisheries at risk of decline.

j. **"Productivity and Life History of Sockeye Salmon in relation to Competition with Pink and Sockeye Salmon in the North Pacific Ocean" Greg Ruggerone and Brendan Connors, 2015.**

   i. Sockeye salmon populations from Southeast Alaska through British Columbia to Washington State have experienced similar declines in productivity over the past two decades, leading to economic and ecosystem concerns. Because the declines have spanned a wide geographic area, the primary mechanisms driving them likely operate at a large, multiregional scale at sea.

ii. Report analyzed hypothesis that competition between pink and sockeye salmon for prey has led to reduced growth and productivity and delayed maturation of up to 36 sockeye populations spanning the region during the past 55 years.
iii. Findings indicate the abundance of North Pacific pink salmon in the second year of sockeye life at sea is a key factor contributing to the decline of sockeye salmon productivity, including sockeye in the Fraser River where an increase from 200 to 400 million pink salmon is predicted to reduce sockeye recruitment by 39%.
iv. Length-at-age of Fraser River sockeye salmon declined with greater sockeye and pink salmon abundance, and age at maturity increased with greater pink salmon abundance.
v. The analyses provide evidence that interspecific competition for prey can affect growth, age, and survival of sockeye salmon at sea.

k. **"Evidence for Competition at sea between Norton Sound Chum Salmon and Asian Hatchery Chum Salmon" Greg Ruggerone and Jennifer Nielsen, 2012.**
   i. Salmon from distant regions overlap in the ocean, and wild salmon populations having low productivity may compete for food with abundant hatchery populations.
   ii. Smaller adult length-at-age, delayed age-at-maturity, and reduced productivity and abundance of the Norton Sound chum salmon population were associated with greater production of Asian hatchery chum salmon since 1965.
   iii. The increase in adult hatchery chum salmon abundance from 10 million to 80 million adult fish led to a 72 percent reduction in the abundance of the wild chum salmon population.
   iv. Findings indicate that competition with hatchery chum salmon contributed to the low productivity and abundance of Norton Sound chum salmon, which includes several stocks that are classified as Stocks of Concern by the State of Alaska, and is evidence indicating that large-scale hatchery production may influence body size, age-at-maturation, productivity and abundance of a distant wild salmon population.

l. **"Alaska Department of Fish and Game Internal Review of Prince William Sound Aquaculture Corporation" Bert Lewis, Jeremy Botz, Steve Moffitt, Glenn Hollowell, Dan Gray, Jeff Regnart, Sean Palmer, Craig Farrington, and Bruce White 2009.**
   i. PAR review criteria by Department staff include genetics, pathology, fishery management, straying, regulatory, enhancement planning and allocation.
   ii. Genetic concerns document high levels of straying of hatchery-produced fish into wild salmon populations for chums and pinks. Staff recommended that a rationale be developed and implemented for how the hatchery could be operated or the fishery prosecuted so that high levels of straying **(GREATER THAN 2 PERCENT)** do not occur, because consistent

increases in the proportions of hatchery strays into streams is not consistent with the Department's mission to manage on the sustained yield principle.

iii. Straying of enhanced salmon has negative implications for wild salmon escapement goal management. PWS hatchery salmon straying rates in 2009 averaged 18 percent for pinks and 14 percent for chums. This impairs the Department's ability to meet statutory and regulatory requirements to manage for the sustained yield of wild salmon as the highest priority.

iv. Proportions of hatchery pink salmon more than 50 percent are documented in wild stocks more than 22 miles from the release site. Intermingling of hatchery and wild salmon potentially causes harmful genetic and ecological impacts to wild salmon stocks. Large numbers of stray hatchery fish have ecological effects on wild fish, where extensive research findings show negative density dependent and competitive interactions between wild and enhanced salmon.

v. Increases of hatchery production in PWS cannot be viewed in isolation. Rather, a large suite of ecological and economic tradeoffs must be considered, with a growing body of evidence suggesting hatchery salmon production could come at a substantial cost to other fisheries and wild salmon stocks.

vi. Many studies have concluded there is inter and intra-specific competition for pink and chum salmon food resources in the North Pacific Ocean nearshore and offshore waters. This competition has been linked to a substantial decrease in productivity and body size of PWS pink salmon wild stocks, and can significantly reduce yields of high value salmon species, such as sockeye, Chinook and coho salmon.

vii. Department research and management biologists, consistent with statutory and regulatory requirements to maintain a precautionary approach to salmon management, advised against additional increases to PWS hatchery pink and chum salmon production.

m. **"Climate Change and a Dynamic Ocean Carrying Capacity: Growth and Survival of Pacific Salmon at Sea" Jennifer Nielsen and Greg Ruggerone 2009.**

i. Salmon growth and survival responses to oceanic changes can vary with season and life stage and that density-dependent growth at sea is an important, yet often elusive, mechanism affecting salmon survival.

ii. The abundance of salmon in the ocean has doubled with a large component of that productivity based on artificial propagation from hatcheries with approximately 5 billion salmon fry released annually into the Pacific Ocean.

iii. Marine growth has been associated with age-at-maturity; older, maturing salmon are usually larger adults; fish size has been directly correlated with egg number, size and reproductive success. Therefore, salmon that are impacted by climatic variation and / or density-dependent factors, leading to reductions in growth and development, may lose reproductive potential despite overall increases in total abundance.

n. **"Seasonal Marine Growth of Bristol Bay Sockeye Salmon in relation to Competition with Asian Pink Salmon and the 1977 Ocean Regime Shift" Greg Ruggerone, Ed Farley, Jennifer Nielsen and Peter Hagen, 2005.**
   i. Research demonstrates significantly lower growth and survival of Bristol Bay sockeye salmon during odd-numbered years of their second or third years at sea, a trend that was opposite that of Asian pink salmon.
   ii. Reduced scale growth in odd-numbering years began after peak growth in spring and continued through summer and fall even though most pink salmon had left the high seas by late July (10 to 18 percent growth reduction in odd vs. even years).
   iii. The alternating odd and even year growth pattern was consistent before and after the 1977 ocean regime shift.
   iv. Conclude high consumption rates of prey by pink salmon during spring through mid-July of odd-numbered years, coupled with declining zooplankton biomass during summer and potentially cyclic abundance of squid and other prey, contributed to reduced prey availability and therefore reduced growth of Bristol Bay sockeye salmon during late spring through fall of odd-numbering years.

o. **"Diet Overlap and Potential Feeding Competition Between Yukon River Chum Salmon and Hatchery Salmon in the Gulf of Alaska in Summer" Katherine W. Myers, Robert V. Walker, Nancy D. Davis, and Janet L Armstrong 2004.**
   i. Overlap in diets among different body size groups of chum salmon in the Gulf of Alaska was high, indicating a high potential for intra-specific feeding competition between Yukon River chum salmon and Japanese and Alaska hatchery chum salmon.
   ii. Although inter-specific overlap in salmon diets was low to moderate, the quality of chum salmon diets (mean calorie per fish) was low compared to diets of all size groups of pink salmon and large-sized sockeye salmon in all geographical regions where these species co-occur.
   iii. When the amount or quality of prey available to chum salmon is reduced by locally abundant stocks of hatchery salmon, adverse climatic and oceanographic changes are more likely to result in a decrease of ocean growth and survival of Yukon River chum salmon.

p. **“Evidence for Competitive Dominance of Pink Salmon over other Salmonids in the North Pacific Ocean” Greg Ruggerone and Jennifer Nielsen 2004.**
    i. Pink salmon are numerous and have an alternating-year pattern of abundance that provides a natural experimental control to test for interspecific competition in the North Pacific Ocean and Bering Sea.
    ii. Pink salmon significantly altered prey abundance of other salmon species (zooplankton, squid) leading to altered diet, reduced total prey consumption and growth, delayed maturation, and reduced survival, depending on species and locale.
    iii. Growth of pink salmon was not measurably affected by other salmon species, but their growth was sometimes inversely related to their own abundance.
    iv. In all marine studies, pink salmon affected other species through exploitation of prey resources, with competition observed in nearshore and offshore waters of the North Pacific Ocean and Bering Sea.
    v. Key traits of pink salmon that influenced competition with other salmonids included great abundance, high consumption rates and rapid growth, degree of diet overlap or consumption of lower trophic level prey, and early migration timing into the ocean.
    vi. The consistent pattern of findings from multiple regions of the ocean provides evidence that interspecific competition can significantly influence salmon population dynamics and that pink salmon may be the dominant competitor (keystone predator) among salmon in marine waters.

q. **“Survival of Puget Sound Chinook Salmon in response to Climate-Induced Competition with Pink Salmon” Greg Ruggerone and Frederick Goetz, 2004.**
    i. Competition between pink and Chinook salmon was reviewed for the Puget Sound area, where many juvenile pink salmon enter the marine waters in even-numbered years, whereas few migrate during odd-numbered year.
    ii. During 1984-1997, juvenile Chinook salmon released during even-numbered years experienced 59 percent lower survival than those released during odd-numbered years, a consistent trend among 13 Chinook salmon stocks.
    iii. Lower even-numbered year survival of Chinook salmon was associated with reduced first-year growth and survival and delayed maturation. In contrast, Chinook salmon released into coastal streams, where few pink salmon occur, did not have an alternating-year pattern.
    iv. Alternating-year mortality accounted for most of the 50 percent decline in marine survival of Chinook salmon between 1972-1983 and 1984-1997.

r. **"Feeding Ecology of Pacific Salmon (*Oncorhynchus* spp.) in the Central North Pacific Ocean and Central Bering Sea, 1991-2000" Nancy Davis 2003.**
   i. Small decreases in the daily ration for salmon can cause significant decreases in growth over a relatively short time period.
   ii. Prey consumption was more important than temperature for determining salmon growth at summertime temperatures.

s. **"Competition between Asian Pink Salmon and Alaskan Sockeye Salmon in the North Pacific Ocean" Greg Ruggerone et al 2003.**
   i. Using the unique biennial abundance cycle of Asian pink salmon from 1955-2000, interspecific offshore competition between Bristol Bay sockeye salmon and Asian pink salmon was evaluated.
   ii. Sockeye salmon growth during the second and third year growing seasons at sea (scale measurements) declined significantly in odd-numbered years, corresponding to years when Asian pink salmon are most abundant. Bristol Bay sockeye salmon do not interact with Asian pink salmon during their first summer and fall seasons and no difference in the first-year scale growth was detected.
   iii. The interaction with odd-year pink salmon led to significantly smaller size at age of adult sockeye salmon, especially among younger female salmon. BB smolt to adult survival rates during even-numbered years (interacting with abundant off-year pink salmon during the following year) experienced a 26 – 45 percent lower survival compared with smolts migrating during off-numbered years.
   iv. Adult sockeye salmon returning to Bristol Bay from even-year smolt migrations were 22 percent less abundant (reduced by 5.9 million fish per year) compared with returns from odd-year migrations, with the greatest reductions in adult returns occurring among adults spending two compared to three years at sea.

t. **"Evaluating Alaska's Ocean-Ranching Salmon Hatcheries: *Biologic and Management Issues"* Environment and Natural Resources Institute, UAA 2001.**
   i. Alaska's ocean-ranching salmon hatcheries operate amidst considerable uncertainty, including the many gaps in the scientific data from which to draw conclusions on the effects hatcheries may or may not have on wild salmon, and if salmon biodiversity has been adequately protected.
   ii. The need to conserve genetic information is fundamental to salmon biodiversity. It is important not to overharvest or impact through hatchery straying the small salmon populations that may contain unique adaptive traits.

iii. It is difficult to ascertain if Regional Planning Teams perform any substantive review of hatchery operations as is specified in the description of planning team duties.
iv. Industrial-scale hatchery salmon production, which releases billions of smolts into the North Pacific Ocean, could be jeopardizing Alaska's wild salmon, and questions remain as to whether hatchery operations in Alaska are in line with current ADFG policies, including the Sustainable Salmon Fisheries Policy.

u. **"Trophic Feedback and Carrying Capacity of Pacific Salmon (*Oncorhynchus* spp.) on the High Seas of the Gulf of Alaska" Kerim Y. Aydin 2000.**
   i. Detailed examination of ocean feeding patterns of pink, chum, sockeye and coho salmon in the offshore waters of the Gulf of Alaska, to provide a context for comparing the relative effects of environmental variation and density-dependence on post-juvenile salmon "carrying capacity" in the NE Pacific Ocean.
   ii. Interannual changes occur not only in the quantity of food available to salmon, but in the structure of the food web itself.

v. **"Memorandum from SOA Department of Law to Alaska Board of Fisheries, on the Authority of the Board of Fisheries Over Private Nonprofit Hatchery Production" Robert Nauheim and Lance Nelson 1997.**
   i. The Legislature placed primary administrative authority over the permitting and day-to-day operations of hatcheries with the Department. It also vested considerable general and specific authority in the Alaska Board of Fisheries. The Board has broad authority to adopt regulations it considers advisable…as needed for the conservation, development, and utilization of fisheries. The Board's authority extends to the regulation of the harvest of hatchery fish and egg collection.
   ii. The Board of Fisheries (AS 16.10.440 (b) may, after the issuance of a permit by the commissioner, amend by regulation adopted in accordance with the Administrative Procedures Act, **the terms of the permit relating to the source and number of salmon eggs,** the harvest of fish by hatchery operators, and the specific locations designated by the department for harvest.

STATE OF ALASKA

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DEPARTMENT OF FISH AND GAME

DIVISION OF COMMERCIAL FISHERIES

MEMORANDUM

TO: Bill Templin, Chief Fisheries Scientist, Division of Commercial Fisheries
Jack Erickson, Regional Research Coordinator, Central Region
Chris Habicht, Genetics Section, Division of Commercial Fisheries

FROM: Ted Otis, Lower Cook Inlet Area Finfish Research Biologist
Glenn Hollowell, Lower Cook Inlet Area Finfish Management Biologist

DATE: 1 December 2017

SUBJECT: *Lower Cook Inlet Pink Salmon Otolith Sampling Summary, 2017*

Lower Cook Inlet staff received data requests from the public, media, and the Marine Stewardship Council for results of pink salmon otolith sampling in 2017. The text, table, and map below provide a response to those data requests.

In 2017 Lower Cook Inlet staff continued a fourth year of sampling pink salmon otoliths as part of baseline data collection associated with two recently restarted hatchery production programs. Otolith sampling of harvest and escapement allows for a complete assessment of hatchery programs and wild stock performance. Beginning in brood year 2012, otoliths of all pink salmon cultivated at the Tutka Bay Lagoon Hatchery and Port Graham Hatchery were thermally marked. Otolith sampling associated with these programs is comprised of two components: 1) sampling otoliths from pink salmon commercial harvests (purse seine and set gillnet) in the Southern District, and 2) sampling otoliths from spawned out pink salmon carcasses in streams throughout the Southern and Outer districts (Figure 1). This is an ongoing work that is intended to continue as the two programs come up to full production levels.

Similar to the previous three years, pink salmon from Tutka and Port Graham Bay hatcheries were found to have spawned in 11 of the 16 Lower Cook Inlet streams surveyed (Table 1). Port Graham Hatchery marks were found in samples at low levels (1%) in three streams. Tutka Bay Lagoon Hatchery marks were found in 10 of the 16 streams at widely varying proportions (1%–87%) with highest proportions generally found closest to release sites. In addition, Prince William Sound hatchery-produced pink salmon were found at levels similar to previous years (2%–70%). Hatchery-marked pink salmon (Prince William Sound and Lower Cook Inlet combined) outnumbered unmarked pink salmon on 5 of the 16 streams sampled, including three small streams sampled in response to public reports of unusually high escapements (i.e., Beluga Slough, Fritz Creek, Lou's Creek). Preliminary escapement indices (either peak count or area-under-the-curve) derived from periodic ground surveys were estimated to provide context to the proportions of hatchery marks in the samples (Table 1).

cc: Prince William Sound Aquaculture Corporation, Cook Inlet Aquaculture Association, Valdez Fishery Development Association

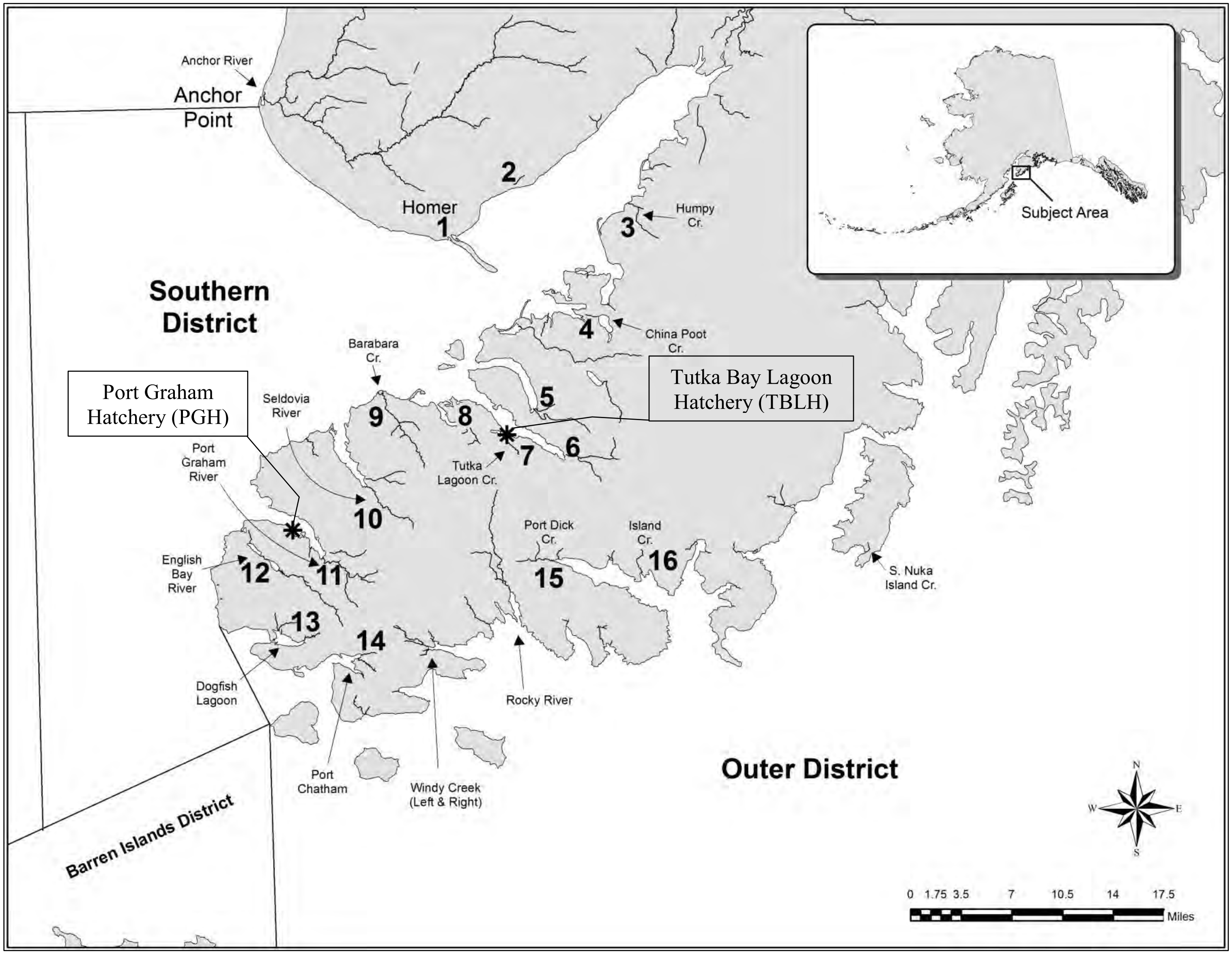
Table 1.- Preliminary percentages of thermally marked pink salmon otoliths in samples from Lower Cook Inlet streams and commercial fisheries, 2017.

	Port Graham Hatchery, (LCI)	Tutka Lagoon Hatchery, (LCI)	LCI hatchery total	Armin F. Koernig Hatchery, (PWS)	Cannery Creek Hatchery, (PWS)	Wally Noerenberg Hatchery, (PWS)	Solomon Gulch Hatchery, (PWS)	PWS hatchery total	unmarked otoliths[1]	Total otoliths sampled	Preliminary 2017 escapement index
LCI streams											
1. Beluga Slough[2]		1.4%	1.4%	30.2%	14.6%	10.4%	1.0%	56.3%	42.4%	288	2,500
2. Fritz Creek[2]			0.0%	40.6%	20.8%	5.2%	3.1%	69.8%	30.2%	96	2,000
3. Humpy Creek			0.0%				1.6%	1.6%	98.4%	191	71,073
4. China Poot		1.1%	1.1%	4.3%	2.1%	2.1%	2.1%	10.6%	88.3%	94	2,379
5. Sadie Cove		4.2%	4.2%	2.1%			12.5%	14.6%	81.3%	96	5,790
6. Tutka Head End Creek[2]		33.9%	33.9%				5.8%	5.8%	60.3%	189	19,786
7. Tutka Lagoon Creek[2]		87.4%	87.4%	0.5%	1.6%	0.5%		2.6%	9.9%	191	61,369
8. L. Tutka Bay (Lou's Ck.)[2]	1.0%	12.5%	13.5%	25.0%	14.6%	9.4%		49.0%	37.5%	96	3,000
9. Barabara Creek		2.1%	2.1%	4.2%			14.2%	18.4%	79.5%	190	25,002
10. Seldovia River			0.0%	3.7%	1.0%	0.5%	7.3%	12.6%	87.4%	191	27,025
11. Port Graham River	1.1%		1.1%	2.1%			3.2%	5.3%	93.7%	95	20,642
12. English Bay River	1.1%	2.9%	4.0%	9.2%	12.1%	1.7%	6.9%	29.9%	66.1%	174	30,000
13. Dogfish Lagoon Creeks			0.0%	13.3%	2.2%	1.1%	34.4%	51.1%	48.9%	90	13,331
14. Port Chatham			0.0%	29.2%	13.5%	4.2%	1.0%	47.9%	52.1%	96	44,291
15. Port Dick Creek		2.1%	2.1%	3.2%	1.1%			4.2%	93.7%	95	62,098
16. Port Dick-Island Creek		1.0%	1.0%	9.0%	3.5%	2.0%	3.5%	18.1%	80.9%	199	22,579
Commercial harvest, (Southern District)											Total harvest
Purse Seine	1.0%	26.7%	27.7%	0.6%	0.5%	0.2%	0.8%	2.1%	70.2%	1,154	352,000
Set Gillnet	0.5%	15.6%	16.1%	4.2%	0.5%	1.0%	6.3%	12.0%	71.9%	192	44,000

[1]Unmarked otoliths- otoliths without discernable hatchery thermal marks.

[2]Denotes streams where 100% of the otoliths were read a second time to evaluate reader agreement.

Figure 1. Map of Southern and Outer districts of Lower Cook Inlet, illustrating the locations of pink salmon hatcheries (denoted by asterisks*), pink salmon index streams, and the 16 streams that were targeted for otolith sampling in 2017 (numbers correspond with those in Table 1).



MEMORANDUM

State of Alaska
Department of Law

TO: Dr. John White
Chair
Alaska Board of fisheries

The Honorable Frank Rue
Commissioner
Department of Fish & Game

DATE: November 6, 1997

FILE NO.: 661-98-0127

TELEPHONE NO.: 269-5240

SUBJECT: Authority of the Board of Fisheries Over Private Nonprofit Hatchery Production

FROM: Robert C. Nauheim
Lance B. Nelson
Assistant Attorneys General
Natural Resources-Anchorage

I. Introduction

In your memorandum of June 24, 1997, and in discussions at the recent Board of Fisheries (Board) work session, you requested guidance regarding the authority of the Board over private, nonprofit salmon hatcheries and their operations. Specifically, you asked for a review of (1) statutes and regulations relating to the authority of the Board and the Commissioner of the Department of Fish and Game (commissioner) over hatchery salmon production and cost recovery, (2) the historical development of Board authority in this area, (3) the scope of the Board's authority over hatchery salmon production, and (4) the relationship between the Department of Commerce and Economic Development's hatchery loan program, the Board, and the Department of Fish and Game (department). We understand that you require an analysis of these issues to assist the Board in its discussions during its upcoming meetings.

II. Summary Answers

1. The legislative scheme for the regulation of private, nonprofit hatcheries vests the more detailed, comprehensive authority in the commissioner and department.

2. Although the board initially had broad rule-making authority over all aspects of the private, nonprofit hatchery program, the legislature significantly restricted that authority by an amendment to AS 16.10.440(b) in 1979.

3. The Board may exercise indirect authority over hatchery production by regulating the harvest of hatchery-released fish in the common use fishery, hatchery brood stock and cost-recovery harvests, and by amending those portions of hatchery permits relating to the source and number of salmon eggs, hatchery harvests, and the designation of special harvest areas by the adoption of appropriate regulations. However, Board action that effectively revokes, or prevents the issuance of, a hatchery permit is probably not authorized.

4. The Commissioner of the Department of Commerce and Economic Development is independently responsible for the implementation of the hatchery loan program under AS 16.10.500 - 16.10.560.

III. Discussion

This discussion focuses primarily upon an evaluation of existing Board authority over the operation of private, nonprofit salmon hatcheries. It opens with a review of the extensive statutory authority of the commissioner and the department over hatcheries.

Beginning in 1974, the legislature adopted various statutory provisions regulating the construction and operation of private, nonprofit salmon hatcheries in Alaska. The goal of the program was "the rehabilitation of the state's depleted and depressed salmon fishery." Sec. 1, ch. 111, SLA 1974. Although the legislature initially granted both the department and the Board responsibility for the program, it limited what was initially a broad grant of rule-making authority to the Board over the implementation of the program by statutory amendment in 1979.

A. Commissioner/Department Authority over Hatcheries

The hatchery statutes place direct and nearly comprehensive responsibility for the private, nonprofit hatchery program in the hands of the commissioner and the department. The legislature has granted exclusive authority to the commissioner to issue permits for the construction and operation of salmon hatcheries. *Id.* at § 2; AS 16.10.400-16.10.430 (as amended). We believe this broad and detailed permitting authority was intended to assign responsibility for the fundamental policy determination of whether to authorize the operation of a private, nonprofit hatchery to the commissioner and department.

1. Pre-permit Responsibilities

Pursuant to AS 16.10.375 the commissioner must designate regions of the state for salmon production and develop a comprehensive salmon plan for each region through teams consisting of department personnel and nonprofit regional associations of user groups. The commissioner also has the task of classifying an anadromous fish stream as suitable for enhancement purposes before a permit for a hatchery on that stream may be issued. AS 16.10.400(f). AS 16.10.400(g) requires a determination by the commissioner that a hatchery would result in substantial public benefits and would not jeopardize natural stocks. The statutes also require the department to conduct public hearings near the proposed hatcheries, and to consider comments offered by the public at the hearings before issuance of a permit. AS 16.10.410.

2. Permit Issuance and Hatchery Operation Responsibilities

For issuing a private, nonprofit hatchery permit, the legislature delegated to the department the power to control the following:

(1) the specific location where eggs or fry may be placed in the waters of the state (AS 16.10.420(2));

(2) the source of salmon eggs procured by the hatchery (AS 16.10.420(1));

(3) the resale of salmon eggs procured by the hatchery (AS 16.10.420(3));

(4) the release of salmon by the hatchery (AS 16.10.420(4));

(5) the designation of the manner and place for the destruction of any diseased salmon (AS 16.10.420(5));

(6) the specific locations for the harvest of adult salmon (AS 16.10.420(6));

(7) the first option to purchase surplus eggs from a hatchery and inspection of eggs and the approval of sale of those eggs to other hatcheries (AS 16.10.420(7));

(8) the determination of reasonable segregation by location) of hatchery from natural stocks (AS 16.10.420(10));

(9) the source and number of salmon eggs to be used by the hatchery (AS 16.10.445(a)); and

(10) the inspection of hatchery facilities (AS 16.10.460).

3. Alteration, Suspension, or Revocation Authority

The commissioner may suspend or revoke a permit after determination of a failure to comply with conditions and terms of the permit. AS 16.10.430(a). Upon a finding "that the operation of the hatchery is not in the best interests of the public, the commissioner may alter the conditions of the permit to mitigate the adverse effects" and, in extreme cases, may "initiate termination of the operation under the permit over a reasonable period of time under the circumstances, not to exceed four years." AS 16.20.430(b).

The foregoing authorities demonstrate that the legislature granted detailed and broad authority to the commissioner and the department for the implementation and day-to-day regulation of salmon hatcheries. On the other hand, the specific authority given to the Board is more circumscribed.

B. Board of Fisheries' Authority over Hatcheries

Although the legislature placed primary administrative authority over the permitting and day-to-day operation of hatcheries within the department, it also vested considerable general and specific authority in the Board of Fisheries. The Board's regulatory authority over private, nonprofit hatcheries is governed primarily by AS 16.05.251, 16.10.440 and 16.10.730.

1. Board Authority under AS 16.05.251

The Board's general rule-making powers over fish and the taking of fish are set out in AS 16.05.251. These powers include setting time, area, and methods and means limitations on the taking of fish. AS 16.05.251(a)(2), (4). The Board also establishes quotas, bag limits and harvest levels. AS 16.05.251(a)(3).

The Board has broad authority to "adopt regulations it considers advisable . . . for regulating commercial, sport, guided sport, subsistence, and personal use fishing as needed for the conservation, development, and utilization of fisheries." AS 16.05.251(a)(12).

This authority includes the power to allocate fishing opportunities between competing user groups. *Meier v. State*, 739 P.2d 172, 174 (Alaska App. 1987); AS 16.05.251(e). The Board's authority extends to the regulation of the harvest of hatchery fish and egg collection. *See* 1990 Inf. Op. Att'y Gen. 41 (August 1; 663-90-0327) (Board's regulatory authority extends to management of hatchery brood stock and allocation of cost-recovery fishing). Existing regulations reflect this principle. *See* 5 AAC 40.005 (harvest of hatchery-produced fish governed by Board regulation). The Board also has general authority to adopt regulations for "prohibiting and regulating the live capture, possession, transport, or release of native or exotic fish or their eggs." AS 16.05.251(a)(9). This provision would include, but is not limited to, regulation of the capture, possession, transportation, and release of salmon and their eggs by hatcheries. *Id.*

2. Board Authority under AS 16.10.440

In former AS 16.10.440, the legislature initially vested broad rule-making authority in the Board of Fisheries and Game[1] over hatchery-produced fish and the implementation of the hatchery program in general. Sec. 2, ch. 111, SLA 1974. Former AS 16.10.440 provided:

> REGULATION: (a) Fish released into the natural waters of the state by a hatchery operated under secs. 400 - 470 of this chapter are available to the people for common use and are subject to regulation under applicable law in the same way as fish occurring in their natural state until they return to the specific location designated by the department for harvest by the hatchery operator.
>
> (b) The board may promulgate regulations necessary to implement secs. 400 - 470 of this chapter.

[1] Prior to 1975, regulatory authority over the harvest of fish and game resources was vested in the Board of Fisheries and Game. In 1975 the legislature abolished the Board of Fisheries and Game and simultaneously created a separate Board of Game and Board of Fisheries, each having broad regulatory powers. Ch. 206, SLA 1975; *see also* AS 16.05.221, 16.05.241, 16.05.251, 16.05.255. The legislature also amended AS 16.10.440(b) to clarify that the authority over hatcheries formerly resting in the Board of Fisheries and Game was to be held by the newly created Board of Fisheries.

Alaska Statute 16.10.440 (a), which has remained unchanged since 1975, confirms that fish released by hatcheries into the natural waters of the state are, as are all wild fish and game within the state, available for common use and subject to lawful regulation. *See generally McDowell v. State*, 785 P.2d 1, 5-9 (Alaska 1989)(equal access clauses of art. VIII of Alaska Constitution are intended to provide the broadest possible public access to state's fish and game.)

Alaska Statutue 16.10.440(a) does purport to exempt the effect of at least some applicable law to hatchery-produced fish once the fish arrive at areas designated by the department for harvest by the hatchery operator. *See* AS 16.10.440(a) (fish subject to regulation "until they return to the specific location designated by the department for harvest by the hatchery operator"). For reasons discussed in greater detail below, AS 16.10.440(a) does not significantly limit the authority of the Board or the department to regulate hatchery-produced fish at these locations, since AS 16.10.440(b) goes on to grant specific authority for regulation at the point of return.

Former AS 16.10.440(b) vested in the Board of Fisheries and Game broad authority to "promulgate regulations necessary to implement sec. 400 - 470 of this chapter." This broad language purported to give the Board of Fisheries and Game expansive rule-making authority over all aspects of carrying out the hatchery program.

In 1979, the legislature amended AS 16.10.440(b), eliminating the broad authority "to promulgate regulations necessary to implement" the hatchery program, and replacing it with more specific, but limited responsibilities:

> (b) The Board of Fisheries may, after the issuance of a permit by the commissioner, amend by regulation adopted in accordance with the Administrative Procedures Act (AS 44.62), the terms of the permit relating to the source and number of salmon eggs, the harvest of fish by hatchery operators, and the specific locations designated by the department for harvest. The Board of Fisheries may not adopt any regulations nor take any action regarding the issuance or denial of any permits required in AS 16.10.400-16.10.470.

Sec. 3, ch. 59, SLA 1979.[2]

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[2] In 1979, the legislature also authorized the Commercial Fisheries Entry Commission to issue special harvest area limited entry permits to operators of private, nonprofit hatcheries. Sec. 1, ch. 64,

The legislative history of the 1979 amendment reveals the legislative intent behind the new, more restricted language:

> Section 2 of the bill [HB 359] amends AS 16.10.440(a)(b). The amendment clarifies the role of the Board of Fisheries. The role of the Board of Fisheries as envisioned by the original legislation was to *regulate the harvest of salmon returning to the waters of the state. That role extends to regulating those fish which are returning as a result of releases from natural systems and also from hatchery releases.* There are provisions in other portions of the non-profit hatchery Act which allow the designation of specific locations for the harvest of salmon by the hatchery operator for sale, and use of the money from that sale, for the specific purposes as stated in AS 16.10.450. *The added language clarifies that the Board of Fisheries may adopt regulations relating to the harvest of the fish by hatchery operators at the specifically designated locations.* The Board of Fisheries in the past year or two has enacted regulations relating to those harvests for several of the private non-profit hatcheries in the state.
>
> The intention of the original bill relating to the non-profit hatchery Act as amended in recent years was that the permits for the construction and operation of the private non-profit hatcheries were to be issued by the Commissioner of the Department of Fish and Game. Specific language in AS 16.10.400 lays out the grounds for the issuance of the permits and AS 16.10.420 lays out the statutory guidelines that must be included in such a permit. Those statutory provisions remain the same under this amendment.
>
> In this bill AS 16.10.440(b) is deleted and the necessary powers are substituted in the language which is added to (a).[[3]] That deletion helps

SLA 1979; AS 16.43.400-16.43.440. Special harvest areas may be designated by the department in a hatchery permit, by emergency orders under AS 16.10.420, or by regulation adopted by the Board under AS 16.05.251 or AS 16.10.440(a). *See* 1993 Inf. Op. Att'y Gen. 273 (July 16; 663-93-522).

[3] In the final version of the bill passed by the legislature, the language referenced here was again divided into two subsections, leaving AS 16.10.440(a) intact and moving the new language into subsection (b).

> clarify a technical problem which has arisen because the original section (b) stated that the Board of Fisheries may promulgate regulations necessary to implement subsections 400 - 470 of this chapter. That in effect gave the Board of fisheries the power to enact regulations regarding a requirement by the Department of Commerce and Economic Development. In section .470(b) the Department of Commerce and Economic Development is instructed to provide a form to the permit holder for submission of an annual report regarding the financial aspects of the hatchery operation, if such a hatchery operator has obtained a loan from the State of Alaska.

House Journal, March 15, 1979 (remarks of Rep. Fred Zharoff, Chm. House Resources Committee regarding HB 359) (emphasis added).

3. Board Authority under AS 16.05.730

In 1992, the legislature enacted AS 16.05.730[4], which requires the department and Board to manage all fish stocks consistent with the sustained yield of wild fish stocks and authorizes, but does not require, management consistent with the sustained yield of enhanced stocks. AS 16.05.730(a). In addition, the statute mandates Board consideration of the need of enhancement projects to obtain brood stock when allocating enhanced fish stocks, and authorizes the Board to direct the department's management to achieve an adequate return for brood stock. AS 16.05.730(b). The Board may also consider the need for enhancement projects to harvest and sell fish to obtain funds for project operation, may direct the department to provide a reasonable harvest of fish to the hatchery for those purposes, and may adopt management plans to provide fish to a hatchery to obtain funds for the purposes allowed under AS 16.10.450 or AS 16.10.480(d). AS 16.05.730(c). Significantly, while the statute requires Board consideration of hatchery brood stock needs, it does not mandate any particular level of hatchery harvest of enhanced fish stocks. Consideration of harvest and sale of fish for project funding is authorized, but not required.

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4 AS 16.05.730 provides:

> **Management of wild and enhanced stocks of fish.** (a) Fish stocks in the state shall be managed consistent with sustained yield of wild fish stocks and may be managed consistent with sustained yield of enhanced fish stocks.
>
> (b) In allocating enhanced fish stocks, the board shall consider the need of

C. The Balance between Department Commissioner and Board Authority over Private Nonprofit Hatchery Production

As the foregoing discussion suggests, the department and the Board share regulatory authority over private, nonprofit hatcheries. Although primary responsibility over permitting and the administration of the hatchery program rests with the department, the Board has substantial, indirect control over hatchery production by virtue of its regulatory authority to amend hatchery permits with respect to special harvest areas, the harvest of brood stock[5] and cost-recovery fish.[6]

> fish enhancement projects to obtain brood stock. The board may direct the department to manage fisheries in the state to achieve an adequate return of fish from enhanced stocks to enhancement projects for brood stock; however, management to achieve an adequate return of fish to enhancement projects for brood stock shall be consistent with sustained yield of wild fish stocks.
>
> (c) The board may consider the need of enhancement projects authorized under AS 16.10.400 and contractors who operate state-owned enhancement projects under AS 16.10.480 to harvest and sell fish produced by the enhancement project that are not needed for brood stock to obtain funds for the purposes allowed under AS 16.10.450 or 16.10.480(d). The board may exercise its authority under this title as it considers necessary to direct the department to provide a reasonable harvest of fish, in addition to the fish needed for brood stock, to an enhancement project to obtain funds for the enhancement project if the harvest is consistent with sustained yield of wild fish stocks. The board may adopt a fishery management plan to provide fish to an enhancement project to obtain funds for the purposes allowed under AS 16.10.450 or 16.10.480(d).
>
> (d) In this section, "enhancement project" means a project, facility, or hatchery for the enhancement of fishery resources of the state for which the department has issued a permit.

5 In this memorandum, we use the term "brood stock" to designate fish returning to the hatchery as a result of hatchery operations that are harvested for the purpose of the biological reproduction of fish.

6 In this memorandum, we use the term "cost-recovery" fish to designate those fish or eggs authorized to be harvested for purposes of sale under AS 16.10.450.

Though no statute expressly grants the Board regulatory authority over hatchery production *per se*, it may exercise considerable influence over hatchery production by virtue of its authority to directly amend hatchery permit terms relating to fish and egg harvesting.[7] We have previously advised that while the Board is authorized to do so, it is not required to allocate cost recovery fish to a hatchery. 1990 Inf. Op. Att'y Gen. 41 (Aug. 1; 663-90-0327); AS 16.05.730(c). Similarly, we have advised that the Board has authority to regulate brood stock harvest. *Id.*

The Board must *consider* hatchery brood stock needs in determining appropriate harvest levels. AS 16.05.730(b). The Board may also consider hatchery cost recovery needs. AS 16.05.730(c). However, it is not *required* to provide harvest opportunities that are inconsistent with what the Board reasonably determines to be appropriate. 1990 Inf. Op. Att'y Gen. 41 (August 1; 663-90-0327). For example, to the extent the Board believes that a hatchery permit issued by the department provides too liberal or restrictive an opportunity to harvest salmon or collect eggs,[8] it may amend the permit by adopting appropriate regulations.

As previously noted, AS 16.05.730 requires the Board to manage all stocks of fish consistent with the sustained yield of wild fish stocks and to consider the need of fish enhancement projects for brood stock. Accordingly, in evaluating whether to amend a hatchery permit or adopt regulations governing hatchery harvests, the Board must carefully consider the needs of fish enhancement projects to obtain brood stock and manage harvests so as to be consistent with the sustained yield of wild fish stocks. AS 16.05.730(a), (b).

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7 It might be argued that the authority set out in AS 16.10.440(b) to amend hatchery permits, particularly as to the "source and number of salmon eggs," is express and direct authority to regulate hatchery production. Since the statute does not expressly address "hatchery production" or any similar concept, we have, in previous oral comments to the Board, characterized the authority over this area to be "indirect" and "implied." We continue to believe that this advice is correct.

8 It has been suggested that the Board's authority to regulate the harvest of eggs from returning hatchery fish may be distinguishable from its authority to regulate the harvest of eggs from wild fish stocks. We see no reason to distinguish between these two. The Board has authority to amend hatchery permits as they relate to "the source and number of salmon eggs." AS 16.10.440(b). We believe this language covers the harvest of eggs from both wild and hatchery stocks.

The Board's authority over hatchery production is circumscribed by the 1979 amendment to AS 16.10.440(b) and, to a lesser extent, by AS 16.05.730. The Board's authority to amend permits is limited to terms in the permit "relating to the source and number of salmon eggs, the harvest of fish by hatchery operators, and the specific locations designated by the department for harvest."[9] Under AS 16.10.440(b) the Board "may not adopt any regulations or take any action regarding the issuance or denial of any permits required in AS 16.10.400-16.10.470." Although the meaning of this limitation is not completely clear, we conclude for the reasons set forth below that the limiting language contained in AS 16.10.440(b) was intended to clarify that the Board's specific regulatory authority over the amendment[10] of hatchery permits is to be limited to the authority set out in AS 16.10.440(b).[11]

The following principles would guide a court in interpreting AS 16.10.440(b). In interpreting a statute, a court's goal is to give effect to the intent of the legislature with due regard to the plain meaning of the statute. *Cook v. Botelho*, 921 P.2d 1126, 1129 (Alaska 1996). In addition, a court may consider the overall purpose of a statute and its legislative history. *Muller v. BP Exploration (Alaska), Inc.*, 923 P.2d 783, 789-91 (Alaska 1996). Whenever possible, each part or section of a statute must be interpreted to create a harmonious whole. *Rydwell v. Anchorage School District*, 864 P.2d 526, 528 (Alaska 1993).

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9 AS 16.10.440(a) provides that hatchery-released fish are subject to Board regulation "until they return to the specific location designated by the department for harvest by the hatchery operator." However, given the Board's general authority over the allocation of fishery resources under AS 16.05.251 and its specific authority to amend hatchery permits by regulation under AS 16.05.440(b), it may, therefore, regulate the harvest of salmon or collection of eggs *after* salmon have returned to the location designated for harvest or egg collection in that manner.

10 The legislature's use of the concept of "amending" permits by the adoption of Board regulation presents an unusual mixture of administrative law principles. We believe the legislature's use of the concept of amending a hatchery permit by regulation was not intended to vest the Board with administrative adjudicatory authority over permits. *See* AS 16.05.241 (the Board has rule-making authority, but does not have other administrative powers). Instead, we interpret the legislature's use of the term "amend" to allow the Board to adopt regulations that may *effectively* change or modify an existing permit by virtue of the change in regulatory setting created by appropriate Board regulation. *See also* AS 16.10.400(a) (commissioner-approved permits are "subject to the restrictions imposed by statute or regulation under AS 16.10.400-16.20.470").

11 This view is supported by AS 16.10.400(a), which specifically provides that permits are subject to "restrictions imposed by . . . regulation under AS 16.20.400-16.10.470."

Finally, where a potential conflict or ambiguity exists, a statute that deals more specifically with a particular issue must govern over a more general statute. *Welch v. City of Valdez*, 821 P.2d 1354, 1363 (Alaska 1991).

Given (1) the detailed statutory scheme granting specific authority to the department over nearly every aspect of the permitting and operation of nonprofit hatcheries, (2) the more general statutory authority of the Board over the harvest of fishery resources, and (3) by contrast, the limitations imposed upon the specific statutory authority of the Board over hatchery permits by the amendment to AS 16.10.440(b) in 1979, we conclude the following. Though the Board may effectively amend hatchery permits by regulation in a manner that affects hatchery fish production, we do not believe the Board may either (1) adopt regulations that effectively veto or override a fundamental department policy decision regarding whether to authorize the operation of a particular hatchery or (2) adopt regulations preventing the department from exercising its authority to permit a hatchery operation. We believe that Board actions falling into either of these two categories would risk being viewed by a court as constructing an impermissible impediment to the department's role as the primary government agency responsible for the regulation of hatcheries. In particular, such actions would risk being deemed incompatible with the limitations imposed by the 1979 amendment to AS 16.05.440(b).

A recent decision by the Alaska Supreme Court supports this view. In *Peninsula Marketing Ass'n v. Rosier*, 890 P.2d 567, 573 (Alaska 1995), the court held that in absence of specific statutory authority for the commissioner to issue emergency orders concerning a question previously considered by the Board, the commissioner could not effectively veto a decision by the Board for which there was specific statutory authority. The court ruled that "[i]nferring a broad veto power would make superfluous the detailed provisions dividing power and authority within the Department" and effectively eviscerate the powers explicitly granted to the Board. *Id.* Similarly, to read the limited grant of authority to the Board over hatcheries set out in AS 16.10.440(b) to permit the Board to effectively veto fundamental policy decisions by the department for which there is specific statutory authority would upset the balance of the statutory scheme chosen by the legislature.

Additional reasons support that conclusion. As previously noted, the Board "may not adopt any regulations or take any action regarding the *issuance* or *denial* of any permits required under AS 16.10.400-16.10.470." AS 16.10.440(b) (emphasis added). We believe that a Board regulation that so drastically amends a hatchery permit to render the hatchery's operation impracticable might be viewed by a court to be an impermissible action by the Board "regarding the issuance or denial . . . of a permit." *See* AS 16.10.440(b). In other words, a Board amendment that puts a hatchery out of operation might be construed as an effective revocation or denial of a hatchery permit, an action that is expressly prohibited by AS 16.10.440(b). Similarly, Board regulations prohibiting the establishment of a hatchery in a particular area deemed by a court as an action by the Board regarding the issuance of a permit and, therefore, unlawful under AS 16.10.440(b).[12]

One additional aspect of Board and department authority merits some discussion. AS 16.05.251(a)(9) specifically authorizes the Board to adopt regulations "prohibiting and regulating the live capture, possession, transport, or *release* of native or exotic fish or their eggs" (emphasis added). This statute must be read, if possible, to be harmonized with AS 16.10.420, the statute governing the department's authority to issue hatchery permits, and the limitation on Board authority with respect to Board "amendment" of hatchery permits set out in AS 16.10.440(b). *See Borg-Warner v. Avco Corp.*, 850 P.2d 628 (Alaska 1993). Although AS 16.10.420 requires the department to issue hatchery permits specifying that a hatchery may not place or release salmon eggs or fry in the waters of the state other than those provided in the permit, the statute does not directly conflict with the Board's authority over the release of fish set out in AS 16.05.251(a)(9). However, AS 16.10.440(b) does not specifically authorize the Board to adopt regulations that amend the terms of the permit governing the release of hatchery fish.

Currently, the Board has delegated its authority over the release of fish to the department commissioner by the adoption of 5 AAC 41. These regulations establish a process for the issuance of permits by the commissioner according to regulatory criteria for the release of fish. Accordingly, absent a repeal by the Board of this delegation of authority, there may not be significant potential for conflict between the Board and the department.

D. Fisheries Enhancement Loan Program

In 1977, the legislature created the fisheries enhancement revolving loan fund within the Department of Commerce and Economic Development for making loans to private, nonprofit hatchery permit holders and to regional associations for long-term, low-interest loans for the planning, construction, and operation of salmon hatcheries, and the

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12 We realize that without additional clarification from the legislature the parameters of permissible Board regulations remain somewhat murky. However, we believe that the more significantly a particular Board regulation restricts the effective functioning of a hatchery in a way that is incompatible with a departmental decision to permit the hatchery's operation, the greater is the risk that the Board regulation may be invalidated by a reviewing court.

rehabilitation and enhancement of salmon fisheries. Sec. 9, ch. 154, SLA 1977; AS 16.10.500-16.10.500. The Commissioner of the Department of Commerce and Economic Development independently administers this loan program.[13] *See* AS 16.10.500-16.10.560.

The Commissioner of the Department of Commerce is authorized to make loans from the fisheries enhancement revolving loan fund to holders of private, nonprofit salmon hatchery permits issued by the Department of Fish and Game under AS 16.10.400-16.10.470. AS 16.10.505, 16.10.510. The commissioner may also make grants to qualified regional associations for "organizational and planning purposes." AS 16.10.510(9).

While this loan and grant program is administered independently from the Department of Fish and Game and the Board, only qualified regional associations and private, nonprofit hatchery permit holders are eligible to receive them. *See* AS 16.10.510-16.10.520.

IV. Conclusion

We hope this discussion provides answers to your questions. Please do not hesitate to contact us if we can provide additional assistance.

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13 As the legislative history set out previously in this memorandum suggests, the broad rule-making authority under former AS 16.10.440 created uncertainty regarding whether the Board could, by adopting appropriate regulations, affect the requirement of hatcheries to report to the Department of Commerce and Economic Development under AS 16.10.470. The 1979 amendment to AS 16.10.440 clarifies that the Board may not regulate in this area.

Diet Overlap and Potential Feeding Competition Between Yukon River Chum Salmon and Hatchery Salmon in the Gulf of Alaska in Summer

by

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Final Report to the Yukon River Drainage Fisheries Association, Contract Number: 04-001; Financial Coding: #4 NRDA, Obj. 1; Project Name: Stock Origins, Migration Patterns, and Marine Productivity of Yukon River Salmon

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Diet Overlap and Potential Feeding Competition Between Yukon River Chum Salmon and Hatchery Salmon in the Gulf of Alaska in Summer

Study History

The Yukon River Drainage Fisheries Association (YRDFA) funded this study in late November 2003 to begin to address concerns about the effects that competition with hatchery salmon may have on the ocean growth and survival of Yukon River chum salmon. Data compilation and analyses were completed in September 2004. A final report of research results was submitted to YRDFA in November 2004.

Abstract

Diet overlap and potential feeding competition between Yukon River chum salmon and Asian and Alaskan hatchery chum, pink, and sockeye salmon in the Gulf of Alaska in summer (1993-2003) were investigated. Our results indicate that overlap in the diets and geographic distribution of Yukon River chum salmon and hatchery salmon in the Gulfof Alaska in summer varies by species, body size group, and geographic region. We identified regions of our Gulf of Alaska study area with the highest potential for feeding competition betweenYukon River chum salmon and Japanese and Alaska hatchery salmon in summer. Overlap in diets among different body size groups of chum salmon in these regions was high, indicating a high potential for intra-specific feeding competition between Yukon River chum salmon and Japaneseand Alaska hatchery chum salmon. Although inter-specific overlap in salmon diets was low to moderate, the quality of chum salmon diets (mean calories per fish) was low compared to diets of all size groups of pink salmon and large-size sockeye salmon in all geographical regions where these species co-occurred. When the amount or quality of prey available to chum salmon is reduced by locally abundant stocks of hatchery salmon, adverse climatic and oceanographic changes are more likely to result in a decrease the ocean growth and survival of Yukon River chum salmon.

Key Words

Gulf of Alaska, chum, diet overlap, food habits, competition, hatchery, wild.

Project Data

Project data result from the analysis of salmon stomach content samples collected during the Gulf of Alaska survey of the R/V *Kaiyo maru* (August 2003) and historical data collected during research vessel surveys of the T/S *Oshoro maru* (July 1993-2002). These data include environmental (sample location and date, sea surface temperature), salmon biological (species, size, sex, age), and salmon food habits data. Data are formatted as Microsoft Excel spreadsheets.

Project data are archived by the High Seas Salmon Research Program, School of Aquatic and Fishery Sciences, University of Washington, Box 355020, Seattle, WA, USA 98195-5020 (contact: K.W. Myers, kwmyers@u.washington.edu, tel. 206-543-1101). There are no access limitations to the project data, but costs associated with filling sample and data requests (staff salaries, data storage media, shipping costs) must be paid by the person(s) or agency requesting the data.

This report should be cited as follows:

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Executive Summary

With funding from the Yukon River Drainage Fisheries Association (YRDFA; contract no. 2004-001), we investigated diet overlap and potential feeding competition between Yukon River chum salmon and hatchery chum, pink, and sockeye salmon in offshore waters (primarily, international waters beyond the U.S. 200-milezone) of the Gulf of Alaska in summer. The specific objectives of this study were: (1) to estimate salmon diet overlap by species, body size group, and region, (2) to provide information on the times and areas where intermingling of hatchery salmon and Yukon River chum salmon in the Gulf of Alaska are likely to occur, and (3) to evaluate these results with respect to the potential effects of large-scale releases of hatchery salmon on the marine growth and survival of Yukon River chum salmon in the Gulf of Alaska.

We collected salmon stomach contents data aboard Japanese research vessels during NOAA-funded international cooperative high seas salmon research cruises in the Gulf of Alaska in summer 1993-2003. The pooled (summer 1993-2003) stomach contents data were stratified into six geographic regions, including two (North and South) latitudinal regions and three (West, Mid, East) longitudinal regions in the Gulf of Alaska. The boundary of the two latitudinal regions was defined by the position of the annual summer (July) sea surface temperature minimum, which is associated with two distinct summer feeding zones for salmon in our Gulf of Alaska study area. The three longitude regions (West, 157°-165°W; Mid, 149°W-156°W; and East, 139°W-148°W) included transect lines with the most similar oceanographic conditions.

We assumed that similarity in diets is likely to be highest among salmon of similar body sizes. The results of a previous study indicated that in the Gulf of Alaska, pink and sockeye salmon between the body weights of 600 and 1200g switch from feeding on zooplankton to squid. We stratified our stomach contents data into three body size groups (small=<600 g, medium = 600-1200 g, and large = >1200 g) of chum, sockeye, and pink salmon in each of the six geographic regions.

Diet overlaps of the three species (chum, pink, and sockeye salmon) and body-size groups in the six regions of our Gulf of Alaska study area were estimated using a modified Schoener's index, called the Percent Similarity Index (PSI). For each species and body-size group, we also calculated an index of diet quality (Q) or the mean number of calories consumed per fish in each of the six regional strata.

The North Pacific Anadromous Fish Commission (NPAFC) high seas salmon tag recovery database (1956-2003), the high seas coded-wire tag recovery database (1980-2004), and the otolith mark recovery database (1997-2002) were used to plot maps of the ocean distribution of Yukon River chum salmon and salmon from geographic regions that produce the majority of hatchery chum (Japan, Prince William Sound, and Southeast Alaska), pink (Prince William Sound and Kodiak Island), and sockeye salmon (Cook Inlet and Prince William Sound) by month with respect to the Gulf of Alaska food habits study area. We also reviewed information from the literature on the genetic stock composition of immature and maturing chum salmon in the Gulf of Alaska. These data were used to infer spatial and temporal overlap in distribution and potential feeding competition between Yukon River chum salmon and hatchery chum, pink, and sockeye salmon in the Gulf of Alaska in summer.

Food habits data from 4,996 salmon stomachs collected in 1993-2003 were analyzed, including 1,719 chum, 1,499 pink, and 1,778 sockeye salmon. The samples included a mixture of immature and maturing chum and sockeye salmon and maturing pink salmon. For all body weight groups of chum salmon the percentages of fish with empty stomachs, which may indicate poor feeding conditions, were highest in the eastern regions of our Gulf of Alaska study area. The quality of chum salmon diets was low compared to the diets of all size groups of pink salmon and large-size sockeye salmon in all geographical regions where the species co-occurred. The diets of medium- and small-size chum and sockeye salmon were often similar in quality, except in the eastern regions of the study area, where chum salmon had lower quality diets than sockeye salmon. Overlap in the diets of chum, pink, and sockeye salmon in the Gulf of Alaska varied by species, body size group, and geographic region.

The PSI values for pairwise comparisons between different size groups of chum salmon in regions north of the SST minimum were usually high, and tended to be higher in northern regions than in southern regions. In northern regions, the prey category with the highest PSI values for all size groups of chum salmon was usually pteropods, which are a low-calorie food. In the three southern regions, PSI values were highest for small- and medium-size chum salmon that fed on amphipods, which are also a relatively low-calorie food (although they have a higher caloric content than pteropods). The PSI values were moderate to low in the Southwest region, and were high in the Southeast region.

The PSI values for pairwise comparisons between different size groups of chum and pink salmon were usually low to moderate. The PSI values for pairwise comparisons between different size groups of chum and sockeye salmon were often higher in northern regions than in southern regions. Interspecific overlap in diets tended to be highest when all species were feeding on amphipods or pteropods or both.

Limited data from high seas tagging experiments indicate that immature Yukon River chum salmon are distributed in the Gulf of Alaska throughout the summer, although their distribution shifts to the north and west as the season progresses. Older age groups of immature Yukon River chum salmon tend to be distributed farther to the north and west than younger age groups. Maturing Yukon River chum salmon are distributed primarily in the northern regions of our study area. Maturing Yukon River chum migrate from the Gulf of Alaska to the Bering Sea in June and July. By July maturing Yukon River summer chum salmon have left the Gulf of Alaska, and maturing Yukon River fall chum salmon may occur only in the Northwest region of our study area.

High seas salmon tag, otolith-mark, and genetic data indicate that in our study area in summer overlaps in the distributions and diets of Yukon River chum salmon and Japanese hatchery chum salmon are most likely to occur in the West regions, and overlaps with Alaskan hatchery chum, pink, and sockeye salmon are most likely to occur in the Mid and East regions.

In our Gulf of Alaska study area in summer, the highest potential for feeding competition between maturing Yukon River chum salmon and hatchery chum salmon is probably in the Northwest region. Tag recovery data indicate that by late June and early July, many maturing Yukon River and Japanese hatchery chum salmon have already migrated to the Bering Sea. Previously published genetic stock composition estimates indicate that approximately 30% of maturing chum salmon in the western regions of our study area in summer are Japanese hatchery fish, and only 10% are western Alaska fish. Even though similarity in the diets of different size groups of chum salmon in the Northwest region was high, the quality of large- and medium-size chum salmon diets was also high relative to other regions of our study area, and percentages of fish with empty stomachs were low. These results suggest that the potential for intra-specific feeding competition between maturing Yukon River chum salmon and Japanese hatchery salmon in our Gulf of Alaska study area in summer may be relatively low.

Our results indicate that the highest potential for feeding competition between immature Yukon River chum salmon and Alaska hatchery salmon is in the eastern regions of our study area. Chum salmon in the Northeast and Southeast regions had relatively high percentages of empty stomachs and low calorie prey (e.g., gelatinous zooplankton) in their diets compared to fish in other regions. Although chum salmon have a diverse diet, it is likely that competition for food within and between stocks of chum salmon could occur, particularly when chum salmon are locally abundant. The potential for intra-specific feeding competition between immature Yukon River chum salmon and Alaska hatchery chum salmon may be particularly high in the Northeast region, where all size groups of chum salmon had lower diet quality and higher diet similarity than in the Southeast region. The potential for inter-specific competition with Alaska hatchery pink and sockeye salmon also seems to be higher in the Northeast region than in the Southeast region. In the Northeast region, the diets of large- and medium-size pink salmon and large-size sockeye salmon contained higher percentages of high-calorie zooplankton and squid and the diets of large-size chum salmon contained a higher percentage of low-calorie gelatinous zooplankton than in the Southeast region. Previous studies have indicated that when pink salmon abundance is high, chum salmon may switch their diets to alternative low-calorie prey, e.g., gelatinous zooplankton, which decreases feeding competition with other zooplanktivorous salmon.

We hypothesize that inter- and intra-specific competition with hatchery salmon in the Gulf of Alaska may reduce the growth of immature Yukon River chum salmon, particularly when adverse oceanographic and climatic conditions limit prey availability. We also hypothesize that reductions in growth due to competition with hatchery fish may reduce the survival of immature Yukon River chum salmon by several possible mechanisms, e.g., an increase in predation, a decrease in storage of lipids, and an increase in parasites and diseases.

In conclusion, our results indicate that overlap in the diets and geographic distribution of Yukon River chum salmon and hatchery salmon in the Gulf of Alaska in summer varies by species, body size group, and geographic region. Regions of the Gulf of Alaska with the highest potential for feeding competition between Yukon River chum salmon and hatchery chum, pink, and sockeye salmon in summer were identified. Overlap in diets among different size groups of chum salmon in these regions was high, indicating a strong potential for intra-specific feeding competition between Yukon River and hatchery chum salmon. Although inter-specific overlap in salmon diets was low to moderate, the quality of chum salmon diets in the Gulf of Alaska was low compared to the diets of pink and sockeye salmon. Consumption of low quality prey (e.g., gelatinous zooplankton) by chum salmon may decrease intra-specific competition between different size or maturity groups of chum salmon and inter-specific competition with pink and sockeye salmon. When the amount or quality of prey available to chum salmon is reduced by abundant stocks of hatchery salmon, adverse climatic and oceanographic changes are more likely to result in a decrease the ocean growth and survival of chum salmon.

A better understanding of the spatial and temporal patterns of ocean distribution, abundance, food habits and feeding behavior, growth, and bioenergetics of hatchery and wild salmon and their prey is needed. Future investigations of potential feeding competition between Yukon River chum salmon and hatchery salmon should be expanded to include other oceanic regions where they are distributed, particularly the central North Pacific Ocean, Aleutian Islands, and eastern Bering Sea. Little is known about interactions between immature and maturing Yukon River chum salmon and hatchery salmon in coastal and offshore waters within the U.S. 200-mile zone. In the international waters of the Gulf of Alaska, new field research should focus on interactions between maturing Yukon River chum salmon and Japanese hatchery chum salmon in the western regions of our study area, and immature Yukon River chum salmon and Alaska hatchery chum, pink, and sockeye salmon in the Mid and East regions of our study area. Historical salmon food habits data collected in the Gulf of Alaska and other oceanic regions during the winter, spring, and fall seasons should be incorporated into the existing summer database. Further analyses of these data would expand our knowledge of other critical locations and seasons when inter- and intra-specific competition between Yukon River chum salmon and hatchery salmon are most likely to occur. Finally, new research should emphasize the development and application of methods to identify the stock origins of individual fish in mixed-stock ocean fishery and research vessel samples, including the tagging or marking of all hatchery salmon released into the North Pacific Ocean and Bering Sea.

Introduction

Approximately 5 billion juvenile Pacific salmon (*Oncorhynchus* spp.) are released annually into the North Pacific Ocean by hatcheries in Asia and North America (Table 1). Limited information from high seas tagging studies indicates that in summer Yukon River chum salmon (*O. keta*) are distributed in both the Bering Sea and Gulf of Alaska (Myers et al. 1996), where they intermingle with Asian and North American hatchery salmon. There is increasing evidence that western Alaska stocks of salmon are food limited during their offshore migrations in the North Pacific Ocean and Bering Sea (e.g., Rogers 1980; Rogers and Ruggerone 1993; Aydin 2000; Aydin et al. 2000; Kaeriyama et al. 2000, 2004; Ruggerone et al. 2003). Since the mid 1970s, there has been a large increase in the commercial catches of Asian and North American salmon (Fig. 1). This increase in commercial catches is correlated with climate change (e.g., Beamish and Bouillion 1993), as well as an increase in the production of hatchery salmon and a decrease in the body size of adult salmon returning to both continents, indicating a limit to the carrying capacity of salmon in the ocean (e.g., Kaeriyama 1989, Ishida et al. 1993, Helle and Hoffman 1995, Bigler et al. 1996). U.S. marine research on salmon carrying capacity in the ocean has focused largely on the early (juvenile) life-history phase, when salmon are migrating in waters over the continental shelf during their first summer at sea (Brodeur et al. 2003). Results of international cooperative high seas salmon research, however, suggest that inter- and intra-specific competition for food and density-dependent growth effects occur primarily among older age groups of salmon, when stocks originating from all geographic regions around the Pacific Rim mix and feed in offshore waters (e.g., Ishida et al. 1993, Ishida et al. 1995, Myers et al. 2000; Tadokoro et al. 1996, Walker et al. 1998, Azumaya and Ishida 2000, Bugaev et al. 2001, Davis 2003). In addition, time-series analysis of scale pattern and abundance data indicates a substantial decrease in marine survival of western Alaska salmon during years of peak abundance of Asian salmon (Ruggerone et al. 2003). The period of overlap when marine survival was affected seems to be from winter of the first year at sea, when western Alaska salmon move off the continental shelf, through at least summer of the second year at sea, when they are distributed across broad regions of the North Pacific Ocean and Bering Sea (Ruggerone et al. 2003).

In a previous study funded by the Yukon River Drainage Fisheries Association (YRDFA), food habits data from salmon collected in fall 2002 from the Bering Sea and in summer 1991-2002 were analyzed for seasonal (summer-fall 2002) and long-term comparisons of salmon diets (Davis et al. 2003). Samples were grouped into three major habitats, representative of the distribution of Yukon River salmon: (1) eastern Bering Sea shelf (<200-m depth contour), (2) central Bering Sea basin (>200-m depth contour), and (3) Aleutian Islands. In fall diet overlap values (modified Schoener's index) were low to moderate for sockeye (*O. nerka*) and chum salmon (49%, basin) and chum and chinook (*O. tshawytscha*) salmon (28% basin, 30% shelf). Diet overlap between sockeye and chum salmon was very high (80%) in the Aleutian Islands, where both species consumed macro-zooplankton (crustaceans and pteropods), and was reduced when chum salmon consumed gelatinous zooplankton (medusae and ctenophores). Shifts in prey composition of sockeye, chum, and chinook salmon between seasons, habitats, and salmon age groups were likely due to changes in prey availability. Davis et al. (2003) concluded that if prey availability is reduced by poor ocean conditions, then increased food competition could decrease growth and survival of Yukon River salmon in the Bering Sea and Aleutian Islands.

In the current study we extend our work on trophic interactions to salmon in the offshore waters of the Gulf of Alaska, primarily in international waters beyond the U.S. 200-mile zone. Limited information from high seas tagging studies indicates that in summer immature Yukon River chum salmon are distributed in both the Bering Sea and Gulf of Alaska (Myers et al. 1996), where they intermingle with salmon released from hatcheries in Asia and North America. Poor offshore rearing conditions (low zooplankton abundance, warm water temperatures) in the Gulf of Alaska in summer may increase food competition between hatchery salmon and Yukon River chum salmon (Kaeriyama et al. 2004). We examine this problem by analyzing time-series data on salmon food habits (1993-2003) and stock distribution (1956-2003) in the Gulf of Alaska in summer. We assume that these stomach contents data are representative of the food habits of all hatchery and wild salmon stocks (including Yukon River chum salmon) migrating in the study area.

Objectives

The specific objectives of this study were: (1) to estimate salmon diet overlap by species, body size group, and region, (2) to provide information on the times and areas where intermingling of hatchery salmon and Yukon River chum salmon in the Gulf of Alaska are most likely to occur, and (3) to evaluate these results with respect to the potential effects of large-scale releases of hatchery salmon on the marine growth and survival of Yukon River chum salmon in the Gulf of Alaska.

Methods

The methods used to collect high seas salmon food habits data in the Gulf of Alaska are described by Kaeriyama et al. (2000; 2004). In August 2003, the Japanese research vessel *Kaiyo maru* conducted an extensive (approximately 1-month) survey of salmon in the Gulf of Alaska. Scientists from the School of Aquatic and Fishery Sciences (SAFS), University of Washington participated in this survey (Myers et al. 2004a). The YRDFA funding was used to analyze salmon food habits data from the 2003 survey. The results were combined with our existing time-series of summer (late June-July 1993-2002) Gulf of Alaska salmon food habits data. Diet overlap by species, size group, and geographic region were estimated. Stock identification information from tags, thermal otolith marks, and genetics was used to infer spatial and temporal overlap in distribution and to evaluate the potential for feeding competition between Yukon River chum salmon and hatchery chum, pink (*O. gorbuscha*), and sockeye salmon in the Gulf of Alaska in summer.

Study Area and Fishing Methods

Our Gulf of Alaska study area was located primarily in international waters beyond the U.S. 200-mile zone (Fig. 2). In 1993-2002, SAFS scientists collected salmon stomach contents data during cooperative Japan-U.S. salmon gillnet surveys aboard the Japanese research vessel *Oshoro maru* in the Gulf of Alaska, primarily along two north-south transects (145°W and 165°W) in June and July. Salmon were caught using a research gillnet. The net, designed to eliminate fishing (salmon body size) selectivity, was constructed of web panels with 10 different mesh sizes (48, 55, 63, 72, 82, 93, 106, 121, 138, and 157 mm stretched mesh). The net hung from the surface to a depth of approximately 6 m below the surface, and was soaked overnight.

In 2003, SAFS scientists collected salmon stomach contents data during a cooperative Japan-U.S. salmon trawl survey aboard the R/V *Kaiyo maru* in the Gulf of Alaska in August (research funded by NOAA Contract 50ABNF1-0002; Myers et al. 2004a). Salmon were caught using a NICHIMO model NST-60-K1 surface rope trawl (manufactured by NICHIMO CO. LTD., Japan; 202.2 m total length, 63 m headrope length, hexagonal mouth opening, 13-mm liner in the codend, and a typical vertical and horizontal spread of 60 m). Floats were attached to the headrope to keep it at the surface, and weights were attached to the front of the trawl to sink the footrope. The trawl was towed for 1 hour at the surface at 5 knots with 250 m of warp. Four north-south transects were fished (160°W, 155°W, 150°W, and 145°W).

Analysis of Salmon Stomach Contents

Scientists on board the research vessels sorted the salmon catch by species, and biological data, including fork length (mm), body weight (g), sex, gonad weight (g), and a scale sample for age determination, were collected. The stomachs of salmon representing a range of body sizes and maturity groups from each specieswere collected for food habits analysis. Aboard the research vessels, the stomach of each fish was weighed to the nearest gram (full weight, FW), and then opened. The stomach fullness was examined, and the number of fish with empty stomachs was recorded. If the stomach contained food, the fresh contents were removed, and the empty stomach was weighed (empty weight, EW). The total weight of stomach contents or prey weight (PW) of each fish *i* was calculated as:

$$PW_i = FW_i - EW_i \tag{1}$$

The fresh stomach contents were sorted into taxonomic groups, using a binocular dissecting microscope in most years. The major taxonomic groups of prey included euphausiids (EU), copepods (CO), amphipods (AM), larval crabs (CR), squid (SQ), pteropods (PT), fish (FI), polychaetes (PO), chaetognaths (CH), and gelatinous zooplankton (medusae and ctenophores, GE). The percent volume of each prey category was estimated visually.

Data Analysis

For each fish *i* in the summer 1993-2003 Gulf of Alaska stomach contents samples, the weight (W, in grams wet weight) of each prey category j was calculated as:

$$W_{ij} = V_j \times PW_i \tag{2}$$

where V is the percent volume of each prey category j (estimated visually).

The pooled summer 1993-2003 stomach contents data were stratified into six geographic regions, including two (North and South) latitudinal regions and three (West, Mid, East) longitudinal regions (Fig. 2). Aydin et al. (2000) found two distinct summer feeding zones for salmon associated with the July latitudinal sea surface temperature minimum. The diets of salmon in the southern zone are often high in micronektonic squid (primarily 60-120 mm mantle length, *Berryteuthis anonychus*), while the diets of salmon in the northern zone are often higher in mesozooplankton (e.g., euphausiids, copepods, amphipods, pteropods). The boundary between the North and South latitudinal regions in summer varied from year to year and between longitude regions, depending on the location of the sea surface temperature (SST) minimum. The annual summer position of the North-South boundary was determined from satellite data or from CTD data collected at the fishing stations in the study area, according to methods described by Aydin (2000) and Aydin et al. (2000). In general, the three longitude regions (West, 157°-165°W; Mid, 149°W-156°W; and East, 139°W-148°W) include transect lines having the most similar oceanographic conditions (Fig. 2; Aydin 2000).

We assumed that similarity in diets is likely to be highest among salmon of similar body sizes. In the Gulf of Alaska, pink and sockeye salmon between the body weights of 600 and 1200g switch from feeding on zooplankton to squid (Aydin 2000). We calculated the percentage prey composition by total prey weight in the stomach contents of three body size groups (small=<600 g, medium = 600-1200 g, and large = >1200 g) of chum, sockeye, and pink salmon in each of the six geographic regions (Fig. 2).

A modified Schoener's index, called the Percent Similarity Index (PSI), was used to calculate diet overlap between pairwise combinations of the three size groups of chum, pink, and sockeye salmon in the six geographic regions. The PSI is the sum of the proportional weights of individual prey categories in common betweentwo predators, and is calculated according to the formula (Buckley et al. 1999):

$$PSI = \sum [\min (p_{xj}, p_{yj})] \qquad (3)$$

where p is the proportion of prey category *j* in predators *x* and *y*.

The PSI ranges from 0 to 100%, where 0% indicates no overlap and 100% indicates complete overlap in diet of the two predators (low similarity = 0-24%, moderate = 25-40%; high = 50-74%, very high = 75-100%; Buckley et al. 1999). Because stomach contents were identified to general taxa, the PSI may overestimate diet similarity. Prey identified to the lowest possible taxa, however, included the same major species in the stomach contents of all species of salmon in our Gulf of Alaska data time series (Kaeriyama et al. 2004; Appendix Table 1).

An index of diet quality (Q) or the mean number of calories consumed per fish *i* by each predator *x* in each region and body weight stratum, was calculated as:

$$Q= \sum [(p_{xj} \times \sum W_{ij} \times C_j)/n] \qquad (4)$$

where C_j is the mean caloric content (cal/g wet weight) of prey category *j*, and n is the number of fish in each strata, including fish with empty stomachs. Caloric values used to calculate the mean for each prey category were derived from previously published studies.

The North Pacific Anadromous Fish Commission (NPAFC) high seas salmon tag recovery database (1956-2003), the high seas coded-wire tag recovery database (1980-2004), and the high seas otolith mark recovery database (1997-2002), archived at SAFS, were used to plot maps of the ocean distribution of Yukon River chum salmon and salmon from geographic regions that produce the majority of hatchery chum (Japan, Prince William Sound, and Southeast Alaska), pink (Prince William Sound and Kodiak), and sockeye salmon (Cook Inlet and Prince William Sound) by month with respect to the Gulf of Alaska food habits study area. We also reviewed information from the literature on the genetic stock composition of immature and maturing chum salmon in the Gulf of Alaska. We are not aware of any published genetic stock composition estimates for pink and sockeye salmon migrating in the international waters of the Gulf of Alaska in summer. Data from ongoing studies by the Fisheries Agency of Japan on the genetic stock composition of chum salmon and the recovery of otolith-marked hatchery salmon in the August 2003 *Kaiyo maru* catches were not available at the time of completion of this report.

Results

Food habits data from 4,996 salmon stomachs collected in 1993-2003 were analyzed, including 1,719 chum, 1,499 pink, and 1,778 sockeye salmon (Table 2). For all body weight groups of chum salmon, the percentages of fish with empty stomachs were highest in the eastern regions of the study area (Table 2). The estimated mean caloric density of salmon prey categories used in the analysis ranged from 92 cal/g wet weight (gelatinous zooplankton) to 1,561 cal/g wet weight (squid; Fig. 3, Table 3). The maturity composition of chum and sockeye salmon in the stomach contents samples by body weight group and study area region is shown in Table 4. All pink salmon in the 1993-2003 food habits samples were maturing fish. For all body weight groups, the quality of chum salmon diets (mean calories consumed per fish) was always lower than that of pink salmon in all regions where the two species co-occurred (Table 2, Fig. 4). The quality of large sockeye salmon diets was higher than that of large chum salmon in all regions (Table 2, Fig. 4). The diets of medium and small size chum and sockeye salmon were often similar in quality. In the Northeast region, however, the diets of medium-size sockeye salmon were higher in quality than those of medium-size chum salmon (Table 2, Fig. 4). In the Southeast region, the diets of small sockeye salmon were higher in caloric content than those of small size chum salmon (Table 2, Fig. 4).

The PSI values for pairwise comparisons between different size groups of chum salmon in regions north of the SST minimum were usually high, and tended to be higher in northern regions than in southern regions (Figs. 5-10). In northern regions, the prey category with the highest PSI values for all size groups of chum salmon was usually pteropods (Figs. 5, 7, and 9), although in the Northeast region similarities between small- and medium-size chum salmon were highest for euphausiids (Fig. 9). In the three regions south of the SST minimum, diet overlaps were highest for small- and medium-size chum salmon feeding on amphipods (Figs. 6, 8, and 10). The PSI values were moderate to low in the Southwest region (Fig. 6), and were high in the Southeast region (Fig. 10). Samples of chum salmon were insufficient to adequately characterize diet overlaps in the South Mid region (Fig. 8).

The PSI values for pairwise comparisons between different size groups of chum and pink salmon were usually low to moderate (Figs. 11-15). The PSI values were high between medium-size chum salmon and large-size pink salmon in the North Mid region (61.6%, Fig. 12), between small-size chum salmon and medium-size pink salmon in the Southwest region (56.0%, Fig. 12), and between small- and medium-size chum salmon and medium-size pink salmon in the Southeast region (53.8% and 62.0%, respectively; Fig. 15).

The PSI values for pairwise comparisons between different size groups of chum and sockeye salmon were often higher in northern regions than in southern regions (Figs. 16-21). Overlap in diets was highest when both species were feeding on amphipods or pteropods or both.

The results of high seas tagging experiments indicate that immature Yukon River chum salmon likely occur in the Gulf of Alaska throughout the summer, although their distribution shifts to the north and west as the season progresses (Fig. 22). Older age groups of immature Yukon River chum salmon tend to be distributed farther to the north and west than younger age groups (Fig. 22). Maturing Yukon River chum salmon are distributed primarily in the northern (Mid and West) regions of our study area in summer (Fig. 23). Maturing Yukon River chum migrate from the Gulf of Alaska to the Bering Sea in June and July. By July maturing Yukon River summer-run chum salmon have left the Gulf of Alaska, and maturing Yukon River fall-run chum salmon may occur only in the Northwest region of our study area.

There have been few recoveries from tagged and otolith-marked Japanese chum salmon in the Gulf of Alaska in summer (June-July; Figs. 24 and 25). The majority of tag recoveries in Japan were from fish released farther to the west (west of 165°W) in the North Pacific Ocean, Aleutian Islands, and Bering Sea (Figs. 24 and 25). With respect to our study area, overlaps in the summer distribution of Yukon River chum salmon and Japanese hatchery salmon are most likely to occur in the western regions (Figs. 22-25).

The high seas tag and otolith mark recovery data indicate that maturing Prince William Sound (PWS) and Southeast Alaska (SE) chum salmon are distributed primarily in the North Mid and Northeast regions of our study area in June and July (Figs. 26 and 27). The distributions of immature PWS/SE chum salmon in international waters in June and August are not well known, but in July they seem to be distributed primarily in the eastern region of the study area. Overlaps in the summer distribution of PWS/SE hatchery chum salmon and Yukon River chum salmon are most likely to occur between maturing fish in the North Mid region, between maturing PWS/SE fish and immature Yukon fish in the North Mid, Northeast, and Southeast regions, and between immature fish in the Northeast and Southeast regions of the study area (Figs. 22, 23, 26, and 27).

In June and July, maturing Kodiak Island (KI) and PWS pink salmon are distributed throughout the mid- and east-regions of the study area (Figs. 28 and 29). In addition, limited otolith-mark recovery data show that PWS hatchery pink salmon also occur in the western regions of the study area in summer. By August, KI/PWS pink salmon stocks may remain only in the North Mid region of the study area. Overlaps in the summer distribution of maturing KI/PWS pink salmon and maturing Yukon River chum salmon are most likely to occur in the Northwest and North Mid regions, and overlaps with immature Yukon fish may occur throughout the entire Gulf of Alaska study area (Figs. 22, 23, 28, and 29).

In June and July, maturing Cook Inlet (CI) and PWS sockeye salmon are distributed across the northern regions of our study area, with major concentrations in the North Mid and Northeast regions (Figs. 30 and 31). Immature CI/PWS sockeye salmon are distributed to the south and west of maturing CI/PWS fish. Overlaps in summer distribution of maturing CI/PWS sockeye salmon and immature and maturing Yukon River chum salmon in our study area are most likely to occur in the North Mid and Northeast regions (Figs. 23, 30, and 31). Overlaps in summer distribution of immature CI/PWS sockeye salmon and immature Yukon River chum salmon are most likely to occur across the southern regions of our study area (Figs. 22, 30, and 31).

Discussion

The results of high seas tag and otolith-mark recovery experiments and genetic stock identification studies show that chum, pink, and sockeye salmon originating from most major salmon producing regions in Asia and North America are distributed for at least part of their ocean life in the Gulf of Alaska (e.g., Myers et al. 1996, Kawana et al. 1999, Urawa et al. 2000, Seeb et al. 2004). We assumed that the 1993-2003 Gulf of Alaska salmon food habits data used in our study are representative of hatchery and wild salmon originating from all Asian and North American regions, including Yukon River chum salmon. Maturing chum salmon were present in our summer samples from the Gulf of Alaska (Table 4). Because of the sample period (late June-August) and the long distance of our Gulf of Alaska study area from the Yukon River, however, it is unlikely that many of these were maturing summer-run Yukon River chum salmon, which by convention are defined as those fish returning to the mouth of the Yukon River by July 15. We consider stomach content data from immature chum salmon in our study to be representative of both summer- and fall-run Yukon River fish.

Our results do not account for any species, size-related, or seasonal differences in diel behavior of salmon or their prey. Davis et al. (2000) found inter-specific differences in diel gillnet catches and feeding behavior of chum, pink, and sockeye salmon in the central Bering Sea, as well as shifts in their prey between daytime and nighttime feeding periods. Pearcy et al. (1984) found that the consumption of diel migrating prey (e.g., euphausiids, fish, squid) by salmon in the Gulf of Alaska varies throughout the day. We may have under- or over-estimated diet overlaps for salmon consuming diel migrating prey because our 1993-2002 samples were collected by driftnets soaked overnight and hauled in the early morning, and our 2003 samples were collected only during daylight hours by a surface research trawl. In addition, diel vertical distribution of salmon varies among species, as well as by season and maturity stage. For example, chum salmon migrate vertically throughout the day, and their maximum swimming depths can exceed 300 m below the surface, whereas sockeye salmon usually remain within 30 m of the surface (Walker et al., in press).

To our knowledge, the only published estimates of the genetic stock composition of immature and maturing chum salmon our Gulf of Alaska study area in summer (June and July 1998) are by Urawa et al. (2000). These estimates indicate that most chum salmon in the eastern region of our study area are of North American origin (15% western Alaska, 25% Alaska Peninsula/KI, 28% SE/PWS, and 18% British Columbia), and most chum salmon in the western region are of Asian origin (25% Japan, 53% Russia, and 13% western Alaska). Percentages of immature SE/PWS stocks are higher in the Southeast region than in the Northeast region, and are highest among age 0.1 fish. Percentages of western Alaska stocks are low (<1%) in age 0.1 fish, and are higher in older age 0.2 (21%) and age 0.3 (17%) fish. A high percentage (58%) of maturing fish in the Northeastern region of our study area in July is from southern North American stocks (British Columbia and Washington). Genetic analyses of chum salmon tissue samples collected by Japanese researchers in our Gulf of Alaska study area after 1998 are ongoing or postponed until funding is available.

Direct information on the distribution of Alaska hatchery salmon in our Gulf of Alaska study area in summer was limited to a few published studies of high seas recoveries of otolith-marked fish. At present, approximately 1.4 billion otolith-marked hatchery salmon are released by hatcheries in Asia and North America (Table 5). Alaska hatchery releases of otolith-marked sockeye salmon, however, are relatively low (31.2 million fish in 2004) compared to pink (695 million fish) and chum (448 million fish) salmon (Table 5). To date, there have been no attempts to recover otolith-marked sockeye salmon in our Gulf of Alaska study area.

One of the largest salmon hatchery programs in the world is located in PWS, where over 600 million pink salmon fry are released each year (e.g., McNair 2002). All otolith-marked hatchery pink salmon recovered in our Gulf of Alaska study area in summer 1998 (27 June-10 July) were from four hatcheries in PWS (Kawana et al. 1999), where about 295 million otolith-marked pink fry were released in 1997 (Geiger and Munk 1998). The catch per unit effort (CPUE) of the marked PWS hatchery pink salmon was higher in the eastern regions of our study area than in the western regions, and in the eastern region the CPUE was higher in the Northeast region (55-56°N) than in the Southeast region (49-52°N) (Kawana et al. 1999). There were no otolith-marked hatchery pink salmon among samples collected from our Gulf of Alaska study area in late July 2002 (Myers et al. 2004b).

Recoveries of otolith-marked hatchery chum salmon in our study area in July 1998 (9.7% of fish examined) were mostly immature fish from four hatcheries in SE/PWS, where about 200 million marked chum fry were released annually (Urawa et al. 2000). Percentages of otolith-marked hatchery chum salmon were higher in the eastern region of our study area (14.5% of the total number of fish examined) than in the western region (1.1%; Urawa et al. 2000). The percentages of otolith-marked chum salmon were higher in the Southeast region (21.5%) than in the Northeast region (8.9%). Urawa et al. (2000) concluded that most of the SE/PWS chum salmon in the eastern regions of the study area in summer may be hatchery fish, if the survival rate is similar among otolith-marked and unmarked hatchery fish. Mass otolith marking of Japanese hatchery chum salmon began with 1998 brood year stocks. Analyses of chum salmon otolith samples collected by Japanese researchers in our Gulf of Alaska study area after 1998 are ongoing or postponed until funding is available. The first reported recovery of an otolith-marked Japanese hatchery chum salmon in the Gulf of Alaska in summer was in the Northeast region of our study area in July 2002 (Fig. 24; Myers et al. 2004b).

For maturing Yukon River chum salmon in our Gulf of Alaska study area in summer, the highest potential for feeding competition with hatchery salmon is probably in the Northwest region (Fig. 2). Tag recovery data and published genetic stock composition estimates indicate that by late June and early July, most maturing Yukon River and Japanese hatchery chum salmon have migrated to the Bering Sea (Figs. 23 and 25; Seeb et al. 2004). Genetic stock composition estimates indicate that approximately 30% of maturing chum salmon in the western regions of our study area in summer are Japanese hatchery fish, and only 10% are western Alaska fish (Urawa et al. 2000). Even though similarity in the diets of different size groups of chum salmon in the Northwest region was high (Fig. 5), the quality of large- and medium-size chum salmon diets was also high relative to other regions of our study area (Fig. 4), and percentages of fish with empty stomachs were low (Table 2). These results suggest that the potential for intra-specific feeding competition between maturing Yukon River chum salmon and Japanese hatchery chum salmon in our Gulf of Alaska study area in summer may be relatively low. Overlap in distribution and feeding competition between maturing Yukon River chum salmon and Japanese hatchery chum salmon in the Gulf of Alaska are more likely to occur in winter and spring.

Although chum salmon have a diverse diet (Table 2), our results indicate that intra-specific competition for food between different size groups of immature chum salmon is likely (Figs. 5-10). In locations where large numbers of Asian and North American chum salmon intermingle, growth reductions of immature Yukon River chum salmon may result. Significant negative relationships have been observed between the abundance of chum salmon and mean fish size (e.g., Ishida et al. 1993, Kaeriyama 1996), and density-dependent factors explained 35% of the decrease in average size of chum salmon in the central North Pacific Ocean (Ishida et al. 1993). Analyses of scale patterns indicate that density-dependent interactions may reduce body size of immature chum salmon in the third year of ocean life (Kaeriyama 1989; Ishida et al. 1993; Walker et al. 1998; Azumaya and Ishida 2000). Migration routes estimated from fish abundance and genetics data show that after their second summer at sea immature Japanese hatchery chum salmon migrate between summer feeding grounds in the Bering Sea and winter habitat in the Gulf of Alaska (Urawa 2004).

For immature Yukon River chum salmon in the Gulf of Alaska in summer, the highest potential for feeding competition with hatchery salmon is in the eastern regions of our study area. Chum salmon in the Northeast and Southeast regions had relatively high percentages of empty stomachs and low calorie prey (e.g., gelatinous zooplankton) in their diets (Table 2). The potential for intra-specific feeding competition between immature Yukon River chum salmon and immature and maturing hatchery chum salmon may be particularly high in the Northeast region, where all size groups of chum salmon had lower diet quality and higher diet similarity than in the Southeast region (Table 2, Figs. 8 and 9).

Our results substantiate earlier food habits studies in the Gulf of Alaska in summer, which have shown that chum salmon feed primarily on zooplankton, whereas pink and sockeye salmon may feed alternatively on zooplankton or gonatid squid (*B. anonychus*; LeBrasseur 1966, 1972; Pearcy et al. 1988; Aydin 2000; Aydin et al. 2000; Kaeriyama et al. 2000, 2004; Table 2). Carbon and nitrogen stable isotope ($\delta^{13}C$ and $\delta^{15}N$) analyses indicate that all species of Pacific salmon in the Gulf of Alaska occupy the same branch of the food web, and that sockeye salmon occupy a slightly higher trophic level than chum and pink salmon (Satterfield and Finney 2002; Kaeriyama et al. 2004). The potential for inter-specific competition between immature Yukon River chum salmon, maturing Alaska hatchery pink salmon, and immature and maturing Alaska hatchery sockeye salmon seems to be higher in the Northeast region than in the Southeast region. In the Northeast region, the diets of large- and medium-size pink salmon and large-size sockeye salmon contained higher percentages of high-calorie zooplankton and squid, and the diets of large-size chum salmon contained a higher percentage of low-calorie gelatinous zooplankton than in the Southeast region (Table 2). When pink salmon abundance is high, chum salmon may switch their diets to alternative prey, e.g., gelatinous zooplankton, to decrease feeding competition with other zooplanktivorous salmon (Andrievskaya 1966, Tadokoro et al. 1996, Davis 2003). Although gelatinous zooplankton are a low-calorie food, they may provide some dietary advantages because chum salmon guts are anatomically specialized to quickly digest prey (Welch 1997), and gelatinous zooplankton are more easily and quickly digested than prey with higher lipid content (Arai et al. 2003; Dulepova and Dulepov 2003). In future studies, inter-specific differences in digestion and consumption rates should be considered when assessing diet quality.

Inter-specific competition for food among Asian and North American chum, pink, and sockeye salmon is a likely mechanism for density-dependent reduction in their ocean growth (e.g., Takagi et al. 1981, Heard 1991, Bugaev et al. 2001). Length and weight of Ozernaya River (western Kamchatka) sockeye salmon were substantially reduced in years when marine abundance of Kamchatka pink salmon was high (Bugaevet al. 2001). Edge-of-scale growth in high-seas chum salmon was negatively correlated with Asian pink salmon abundance (Walker et al. 1998). Davis (2003) observed increases (13% in sockeye, 19% in chum, 72% in pink salmon) in the weight of low calorie prey (pteropods, amphipods, or gelatinous zooplankton) in salmon stomach contents collected in the central Bering Sea in odd-numbered years, when maturing pink salmon were abundant. Bioenergetic models indicate that salmon in summer are feeding at rates close to their physiological maximum, and that small, short-term decreases in daily ration caused by competition could significantly decrease growth (Davis et al. 1998). Under these conditions, small- and medium-size pink and sockeye salmon in the Gulf of Alaska may not attain a size large enough to feed on squid, and would continue to compete with chum salmon for zooplankton prey (Aydin 2000).

Our results showed that there were differences in diet overlap among species and size groups in different regions in the Gulf of Alaska. Regional differences in diet overlap could result from the effects of physical oceanographic conditions (water temperatures, salinity, currents, mixed-layer depth, etc.) on the distribution, abundance, or progression of life-history stages of salmon and their prey (Davis et al. 2003). Wehypothesize that intra- and inter-specific competition with hatchery salmon in the Gulf of Alaska may reduce the growth of immature Yukon River chum salmon, particularly when adverse oceanographic and climatic conditions limit prey availability. Kruse (1998) discussed the potential link between salmon run failures in western Alaska in 1997-1998 and anomalous ocean conditions. Kaeriyama et al. (2004) reported an increase in food-niche overlap among chum, sockeye, and pink salmon in our Gulf of Alaska study area in summer 1997-2000, i.e., a shift in diets from micronekton (in pink and sockeye salmon diets) or gelatinous zooplankton (in chum salmon diets) to a more diverse array of zooplankton prey in all species, which corresponded to changes in ocean conditions caused by climate events (El Niño, La Niña).

Competition for food may also be a direct cause of shifts in ocean distribution of salmon. For example, Azumaya and Ishida (2000) observed a southeastward shift in the summer distribution of Japanese hatchery chum salmon in years when Asian pink salmon are abundant, which could increase competition between Japanese hatchery chum and less abundant North American stocks distributed in the southeastern Bering Sea and Gulf of Alaska. Shifts in salmon diets or geographic distribution and reductions in growth due to competition with hatchery fish may also reduce the survival of Yukon River chum salmon by several possible mechanisms, including increased predation (Ruggerone et al. 2003), decreased storage of lipids needed to sustain salmon through winter (Nomura et al. 2002), and increased susceptibility to parasites and disease.

Conclusions

Our results indicate considerable overlap in the diets and distributionof Yukon River chum salmon and hatchery salmon in the Gulf of Alaska in summer. Our study does not address the potential for feeding competition between Yukon River chum salmon and major wild populations of salmon that are distributed in the Gulf of Alaska,e.g., Bristol Bay and Fraser River sockeye salmon. Regions of the Gulf of Alaska with the highest potential for feeding competition between Yukon River chum salmon and hatchery chum, pink, and sockeye salmon in summer were identified. Overlap in diets among different size groups of chum salmon in these regions was high, indicatinga strong potential for intra-specific feeding competition between Yukon River and hatchery chum salmon. The quality of chum salmon diets in the Gulf of Alaska was low, compared to the diets of pink and sockeye salmon. Consumption of low quality prey (e.g., gelatinous zooplankton) by chum salmon may decrease intra-specific competition between different size or maturity groups of chum salmon and inter-specific competition with pink and sockeye salmon. When the quantity or quality of prey available to chum salmon is reduced by abundant stocks of hatchery pink, chum, and sockeye salmon, adverse climatic and oceanographic changes are more likely to result in a decrease of the ocean growth and survival of chum salmon.

A better understanding of the mechanisms that cause variation in the spatial and temporal patterns of ocean distribution, abundance, food habits and feeding behavior, growth, and bioenergetics of hatchery and wild salmon and their prey is needed. Future investigations of potential feeding competition between Yukon River chum salmon and hatchery salmon should be expanded to include other oceanic regions where they are distributed, particularly the central North Pacific Ocean, Aleutian Islands, and eastern Bering Sea. Little is known about interactions between immature and maturing Yukon River chum salmon and hatchery salmon in coastal and offshore waters within the U.S. 200-mile zone. In the international waters of the Gulf of Alaska, new field research should focus on interactions between maturing Yukon River chum salmon and Japanese hatchery chum salmon in the western regions of our study area, and immature Yukon River chum salmon and Alaska hatchery chum, pink, and sockeye salmonin the Mid and East regions of our study area. Our salmon food habits data were limited to summer, but feeding competition may be more intense in winter, spring, or fall. Historical salmon food habits data collected in the Gulf of Alaska and other oceanic regions during the winter, spring, and fall seasons should be incorporated into the existing summer database. Further analyses of these data would expand our knowledge of other critical locations and seasons when inter- and intra-specific competition between Yukon River chum salmon and hatchery salmon are most likely to occur. Finally, new research should emphasize the development and application of methods to identify the stock origins of individual fish in mixed-stock ocean fishery and research vessel samples, including the tagging or marking of all hatchery salmon released into the North Pacific Ocean and Bering Sea.

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Table 1. Preliminary 2003 hatchery releases of juvenile salmon in Canada, Japan, Korea, Russia, and the United States in millions of fish. Data source: North Pacific Anadromous Fish Commission (2004).

	Sockeye	Pink	Chum	Coho	Chinook	Cherry	Total
Canada*	234.69	15.75	137.69	18.34	50.20	-	456.66
Japan	0.16	144.03	1,840.60	-	-	15.05	1,999.83
Korea	-	-	14.74	-	-	-	14.74
Russia	10.29	236.52	363.18	3.45	0.74	1.93	616.10
USA	85.61	962.46	496.25	67.13	210.57	0.00	1,822.01
Alaska	66.11	962.46	435.57	23.10	9.29	-	1,496.53
WOCI	19.50	-	60.68	44.03	201.28	-	325.48
Total	330.74	1,358.76	2,852.45	88.92	261.50	16.97	4,909.34

*Not including releases from facilities that operate outside the direction of Oceans, Habitat, and Enhancement Branch.

Table 2. Percentage prey composition by prey wet weight (W, grams) in the stomach contents of three size groups of chum, sockeye, and pink salmon caught in six regions of the Gulf of Alaska in summer 1993-2003. Mean calories consumed per fish is an index of diet quality (Q, see methods section). Study area regions are shown in Fig. 2. Salmon body weight categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. n = total sample size, including fish with empty stomachs. % empty = percentage of fish with empty stomachs. Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

Species	Study area regions	Salmon body weight	n	% Empty	Total Prey W (g)	Mean calories per fish	% Prey composition by total prey wet weight									
							EU	CO	AM	CR	SQ	PT	FI	PO	CH	GE
Chum	Northwest	Small	19	10.5	50.9	2,386	0.0	2.5	12.4	7.7	10.5	37.4	20.8	0.0	6.9	1.7
Chum	Northwest	Medium	100	14.0	404.1	2,825	9.6	7.2	22.3	4.2	3.1	45.3	0.5	0.2	0.9	6.6
Chum	Northwest	Large	71	2.8	377.0	4,118	10.5	1.3	10.5	22.5	5.7	38.0	5.1	3.9	0.0	2.4
Chum	Southwest	Small	47	17.0	89.8	1,408	0.0	5.2	38.7	0.0	7.6	20.6	0.0	0.0	24.0	3.8
Chum	Southwest	Medium	70	8.6	265.4	1,599	0.0	12.0	25.3	0.0	1.0	8.3	0.3	0.0	0.4	52.6
Chum	Southwest	Large	30	6.7	149.4	3,488	66.4	12.6	9.6	0.0	0.0	0.1	0.0	0.0	0.0	11.4
Chum	North Mid	Small	7	14.3	13.5	1,503	0.4	2.8	36.3	1.8	3.2	50.5	3.2	1.8	0.0	0.0
Chum	North Mid	Medium	64	12.5	253.5	2,706	4.6	0.7	6.3	31.3	11.3	23.2	0.7	1.5	0.2	20.2
Chum	North Mid	Large	55	12.7	277.0	3,328	5.4	0.0	7.4	11.5	4.5	40.8	5.5	6.2	0.0	18.6
Chum	South Mid	Small	5	0.0	17.0	3,001	0.4	0.9	98.3	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Chum	South Mid	Medium	24	0.0	96.5	3,557	0.1	1.2	98.5	0.0	0.1	0.1	0.0	0.0	0.0	0.0
Chum	South Mid	Large	2	0.0	8.0	6,109	0.0	0.0	5.0	0.0	95.0	0.0	0.0	0.0	0.0	0.0
Chum	Northeast	Small	44	22.7	67.6	1,058	50.7	4.0	6.4	0.0	0.2	21.7	0.3	6.1	0.0	10.7
Chum	Northeast	Medium	343	21.3	1,135.2	2,209	27.6	4.0	26.0	0.1	0.5	19.5	0.5	4.5	0.4	17.0
Chum	Northeast	Large	450	23.8	2,228.0	2,335	10.7	3.4	15.8	0.3	0.7	18.9	1.6	3.6	0.0	45.0
Chum	Southeast	Small	50	24.0	80.0	1,231	2.1	0.2	48.4	0.0	2.2	37.6	0.0	5.7	0.0	3.8

Table 2. Continued.

Species	Study area regions	Salmon body weight	n	% Empty	Total Prey W (g)	Mean calories per fish	% Prey composition by total prey wet weight									
							EU	CO	AM	CR	SQ	PT	FI	PO	CH	GE
Chum	Southeast	Medium	190	28.9	529.6	1,933	2.4	12.1	41.1	0.0	0.3	11.9	6.0	6.4	0.0	19.7
Chum	Southeast	Large	148	26.4	673.2	3,025	5.9	3.5	11.6	0.0	4.3	31.2	14.3	1.7	0.0	27.5
Sockeye	Northwest	Small	50	18.0	92.9	1,804	0.5	9.1	41.9	2.1	11.2	17.4	18.0	0.0	0.0	0.0
Sockeye	Northwest	Medium	88	17.0	462.4	6,223	1.8	3.9	20.1	4.7	46.6	13.7	8.7	0.4	0.0	0.0
Sockeye	Northwest	Large	92	17.4	1,592.9	22,930	14.3	8.9	3.4	0.6	69.7	1.2	2.0	0.0	0.0	0.0
Sockeye	Southwest	Small	13	7.7	20.0	1,458	2.7	3.7	76.8	0.0	12.5	4.2	0.0	0.0	0.0	0.0
Sockeye	Southwest	Medium	9	0.0	92.7	14,191	0.3	3.0	21.9	0.0	74.4	0.1	0.0	0.0	0.0	0.3
Sockeye	Southwest	Large	31	19.4	577.4	27,423	0.1	0.8	11.3	0.0	87.3	0.1	0.0	0.2	0.0	0.1
Sockeye	North Mid	Small	17	5.9	32.9	1,549	8.3	7.5	14.2	3.6	6.8	51.4	8.1	0.0	0.0	0.0
Sockeye	North Mid	Medium	44	2.3	127.8	2,869	5.6	3.2	14.4	9.8	23.5	31.1	12.1	0.4	0.0	0.0
Sockeye	North Mid	Large	53	11.3	422.4	8,571	14.4	12.8	5.7	9.5	41.1	13.2	2.9	0.0	0.0	0.4
Sockeye	South Mid	Small	0													
Sockeye	South Mid	Medium	8	0.0	187.9	33,816	0.0	0.0	17.8	0.1	82.0	0.0	0.0	0.0	0.0	0.0
Sockeye	South Mid	Large	4	0.0	251.4	96,117	0.0	0.0	4.7	0.0	95.3	0.0	0.0	0.0	0.0	0.0
Sockeye	Northeast	Small	122	18.0	218.9	1,542	4.8	15.6	31.2	0.5	8.7	29.6	9.0	0.0	0.2	0.3
Sockeye	Northeast	Medium	70	17.1	330.9	4,854	16.8	8.6	33.9	0.1	29.6	9.7	1.1	0.2	0.0	0.1
Sockeye	Northeast	Large	732	21.0	9,904.5	17,390	10.1	13.1	2.5	0.0	66.0	3.5	2.9	0.9	0.0	0.9
Sockeye	Southeast	Small	17	29.4	92.5	5,779	29.5	0.2	35.9	0.0	31.1	2.8	0.3	0.0	0.0	0.0
Sockeye	Southeast	Medium	15	46.7	50.5	3,416	44.0	0.9	27.0	0.0	26.2	1.9	0.0	0.0	0.0	0.0
Sockeye	Southeast	Large	413	15.3	11,222.8	39,846	1.1	1.8	6.0	0.0	87.3	2.5	1.1	0.0	0.0	0.2
Pink	Northwest	Small	2	0.0	16.5	8,426	0.0	0.0	0.0	1.1	0.9	43.9	54.1	0.0	0.0	0.0
Pink	Northwest	Medium	74	4.1	898.0	8,665	23.3	56.1	7.8	0.0	2.6	8.5	0.8	0.0	0.8	0.0
Pink	Northwest	Large	75	5.3	1,204.9	17,563	6.5	28.1	4.8	6.8	43.9	5.4	4.0	0.0	0.5	0.0
Pink	Southwest	Small	0													

Table 2. Continued.

Species	Study area regions	Salmon body weight	n	% Empty	Total Prey W (g)	Mean calories per fish	% Prey composition by total prey wet weight									
							EU	CO	AM	CR	SQ	PT	FI	PO	CH	GE
Pink	Southwest	Medium	44	20.5	234.0	4,923	0.0	32.0	33.1	0.0	21.9	1.9	3.0	0.0	8.0	0.0
Pink	Southwest	Large	30	16.7	188.0	8,359	0.0	0.9	16.0	0.0	69.0	11.2	3.0	0.0	0.0	0.0
Pink	North Mid	Small	2	0.0	10.0	3,975	0.0	0.0	0.9	86.4	5.6	1.5	5.6	0.0	0.0	0.0
Pink	North Mid	Medium	23	17.4	139.2	4,323	9.0	50.6	12.1	9.9	1.3	14.1	2.9	0.0	0.0	0.0
Pink	North Mid	Large	59	10.2	755.1	12,757	1.2	15.3	3.7	30.3	34.9	13.6	0.9	0.0	0.0	0.0
Pink	South Mid	Small	0													
Pink	South Mid	Medium	0													
Pink	South Mid	Large	0													
Pink	Northeast	Small	1	100.0	0.0											
Pink	Northeast	Medium	313	13.1	1,835.3	4,886	15.0	40.9	16.5	0.3	14.1	12.2	1.0	0.0	0.0	0.0
Pink	Northeast	Large	496	22.2	3,862.1	7,800	19.0	23.5	9.2	0.7	32.5	12.7	2.2	0.0	0.1	0.0
Pink	Southeast	Small	0													
Pink	Southeast	Medium	91	20.9	534.3	6,412	0.8	9.1	38.5	0.1	38.2	11.8	1.1	0.0	0.0	0.3
Pink	Southeast	Large	289	16.6	5,213.6	26,379	0.4	0.7	3.9	0.1	86.1	6.0	2.9	0.0	0.0	0.0
Total Sample Size			4996													

Table 3. Mean caloric values (cal/g wet weight) of prey categories used to calculate an index of salmon diet quality (Q, mean calories per fish, Table 2).

Group	Species	Sample Month	Body Part & Size	Sample Area	Reference	cal/g wet wt
EU: Euphausiids						
	Thysanoessa spinifera	Jul	whole, 23 mm TL	Gulf of Alaska	Davis 2003	840
	Thysanoessa spp.	Jun-Jul	whole, 11-26 mm TL	N Pacific & Bering Sea	Davis et al. 1998	743
mean						792
std dev						69
CO: Copepods						
	Neocalanus cristatus	Jun-Jul	whole; 7-8 mm TL	N Pacific & Bering Sea	Davis et al. 1998	627
mean						627
std dev						
AM: Amphipods						
	Themisto pacifica	Jul	whole; 4 mm TL	Gulf of Alaska	Davis 2003	887
mean						887
std dev						

Table 3. Continued.

Group	Species	Sample Month	Body Part & Size	Sample Area	Reference	cal/g wet wt
CR: Crabs						
	crab zoea	Jun-Jul	whole	Bering Sea	Nishiyama 1977	712
mean						712
std dev						
SQ: Squids						
	Berryteuthis anonychus	Jul	whole; 40 mm ML	Gulf of Alaska	Davis 2003	1307
	Berryteuthis anonychus	Jul	whole; 82 mm ML	Gulf of Alaska	Davis 2003	1737
	Berryteuthis anonychus	Jul	whole; 86 mm ML	Gulf of Alaska	Davis 2003	1562
	Berryteuthis anonychus	Jul	whole; 90 mm ML	Gulf of Alaska	Davis 2003	1636
mean						1561
std dev						184
PT: Pteropods						
	Limacina spp.	Jun-Jul	whole; 3 mm TL	N Pacific, Gulf of Alaska, Bering Sea	Davis et al. 1998	624
mean						624

Table 3. Continued.

Group	Species	Sample Month	Body Part & Size	Sample Area	Reference	cal/g wet wt
FI: Fish						
	Gasterosteus aculeatus (threespine stickleback)	Oct	whole; 32-44 mm SL	Gulf of Alaska	Davis et al. 1998	1166
	Gasterosteus aculeatus	Oct	whole; 56-62 mm SL	Gulf of Alaska	Davis et al. 1998	1533
	Clupea pallasi (Pacific herring)	Jul-Aug	whole	Gulf of Alaska & Bering Sea	Perez 1994 (mean value)	2050
	Clupea pallasi	Oct	whole; 97-104 mm SL	Gulf of Alaska	Davis et al. 1998	1914
	Mallotus villosus (capelin)	Jul-Aug	whole	Gulf of Alaska & Bering Sea	Perez 1994 (mean value)	1680
	Mallotus villosus	Oct	whole; 63-71 mm SL	Gulf of Alaska	Davis et al. 1998	1277
	Thaleichthys pacificus (eulachon)	Mar & Aug	whole	Gulf of Alaska	Perez 1994 (mean value)	2630
	Theragra chalcogramma (walleye pollock)	Oct	whole; 75-95 mm SL	Gulf of Alaska	Davis et al. 1998	1011
	Theragra chalcogramma	Summer	whole; 52 mm SL	Gulf of Alaska	Boldt 1997 (mean value)	908

Table 3. Continued.

Group	Species	Sample Month	Body Part & Size	Sample Area	Reference	cal/g wet wt
FI:Fish (cont'd)	*Theragra chalcogramma*	Summer	whole; 55 mm SL	Gulf of Alaska	Boldt 1997 (mean value)	927
	Theragra chalcogramma	Summer	whole; 53 mm SL	Gulf of Alaska	Boldt 1997 (mean value)	934
	Tarletonbeania crenularis (blue lanternfish)	Jun	whole; 43 mm SL	N Pacific	Davis 2003	1199
	Tarletonbeania crenularis	Jun	whole; 24-50 mm SL	N Pacific	Davis et al. 1998	896
	Tarletonbeania crenularis	Jun	whole; 65-75 mm SL	N Pacific	Davis et al. 1998	1283
	Pleurogrammus monopterygius (Atka mackerel)	Jun-Jul	whole; 42-70 mm SL	N Pacific, Gulf of Alaska, & Bering Sea	Davis et al. 1998	1186
	Anoplopoma fimbria (sablefish)	Feb & Aug	whole; 184-258 g BW	Gulf of Alaska	Perez 1994 (mean value)	1300
	Malacocottus kincaidi (blackfin sculpin)	Feb	whole; 50-59 g BW	Gulf of Alaska	Perez 1994 (mean value)	840
	Hemilepidotus hemilepidotus (red Irish lord)	Jul	whole; 21 mm mean SL	Gulf of Alaska	Davis 2003	1561

Table 3. Continued.

Group	Species	Sample Month	Body Part & Size	Sample Area	Reference	cal/g wet wt
FI: Fish (cont'd)	*Hemilepidotus* sp. (Irish lord)	Jul	whole; 18-31 mm SL	N Pacific & Bering Sea	Davis et al. 1998	1184
mean						1341
std dev						465
PO: Polychaetes	Polychaetes	no data	whole; mean for 11 species	NW Atlantic	Steimle & Terranova 1985	1094
	Polychaetes	no data	no data	NW Atlantic	Tyler 1973	673
	Polychaetes	no data	whole; mean for 3 species	NW Atlantic	Thayer et al. 1973	849
mean						872
std dev						211
CH: Chaetognaths	Chaetognaths	Jun-Jul	whole	Bering Sea	Nishiyama 1977	455
mean						455
GEL: Gelatinous zooplankton	Small medusae	Jun-Jul	whole; 10-13 mm TL	N Pacific & Bering Sea	Davis et al. 1998	136
	Beroe sp.(ctenophore)	Jun	whole; 100 mm TL	N Pacific	Davis 2003	47
mean						92
std dev						63

Table 4. Maturity composition of three size groups of chum and sockeye salmon in six regions of the Gulf of Alaska in summer 1993-2003, collected for stomach content analysis. Salmon body weight categories: small=<600 g, medium=600-1200 g, and large=>1200 g. UN = unknown maturity, IM=immature, MT=maturing. Study area regions are shown in Fig. 2.

Species	Study Area Region		Small body weight				Medium body weight				Large body weight			
			UN	IM	MT	n	UN	IM	MT	n	UN	IM	MT	n
Chum	Northwest	No.	0	19	0	19	6	81	13	100	1	48	22	71
		%	0.0	100.0	0.0		6.0	81.0	13.0		1.4	67.6	31.0	
	Southwest	No.	0	47	0	47	0	64	6	70	0	14	16	30
		%	0.0	100.0	0.0		0.0	91.4	8.6		0.0	46.7	53.3	
	North Mid	No.	0	7	0	7	1	61	2	64		39	16	55
		%	0.0	100.0	0.0		1.6	95.3	3.1		0.0	70.9	29.1	
	South Mid	No.	0	5	0	5	0	24		24	0	2		2
		%	0.0	100.0	0.0		0.0	100.0	0.0		0.0	100.0	0.0	
	Northeast	No.	1	43	0	44	22	312	9	343	29	344	77	450
		%	2.3	97.7	0.0		6.4	91.0	2.6		6.4	76.4	17.1	
	Southeast	No.	4	46	0	50	23	165	2	190	11	120	17	148
		%	8.0	92.0	0.0		12.1	86.8	1.1		7.4	81.1	11.5	
Sockeye	Northwest	No.	0.0	47	3	50	2	75	11	88	2	28	62	92
		%	0.0	94.0	6.0		2.3	85.2	12.5		2.2	30.4	67.4	
	Southwest	No.	0.0	10	3	13	0	7	2	9	0	7	24	31
		%	0.0	76.9	23.1		0.0	77.8	22.2		0.0	22.6	77.4	
	North Mid	No.	0.0	17	0	17		42	2	44	0	26	27	53
		%	0.0	100.0	0.0		0.0	95.5	4.5		0.0	49.1	50.9	
	South Mid	No.	0.0	0	0	0	0	8		8	0	4		4
		%	0.0				0.0	100.0	0.0		0.0	100.0	0.0	
	Northeast	No.	0.0	106	16	122	1	54	15	70	4	83	646	733
		%	0.0	86.9	13.1		1.4	77.1	21.4		0.5	11.3	88.1	
	Southeast	No.	0.0	16	1	17	0	15		15	1	33	379	413
		%	0.0	94.1	5.9		0.0	100.0	0.0		0.2	8.0	91.8	

Table 5. Number of otolith-marked salmon released from Pacific Rimhatcheries in 2003 (A), and preliminary number of otolith-marked salmon released from Pacific Rim hatcheries in 2004 (B). WOCI = Washington, Oregon, California, and Idaho. Data source: North Pacific Anadromous Fish Commission (2004).

A. 2003 releases of otolith-marked salmon

	Sockeye	Pink	Chum	Chinook	Coho	Masu	Total
Canada*							
Japan	0	3,078,000	64,783,000	0	0	32,000	67,893,000
Korea	0	0	0	0	0	0	0
Russia	8,745,060	271,050	46,869,070	524,207	3,702,000	0	60,111,387
USA	54,338,000	736,752,763	450,840,665	9,490,000	7,124,000	0	1,258,545,428
Alaska	31,481,000	736,752,763	449,379,665	6,535,000	6,680,000	0	1,230,828,428
WOCI	22,857,000	0	1,461,000	2,955,000	444,000	0	27,717,000
Total	63,083,060	740,101,813	562,492,735	10,014,207	10,826,000	32,000	1,386,549,815

*Data not available

B. Preliminary 2004 releases of otolith-marked salmon

	Sockeye	Pink	Chum	Chinook	Coho	Masu	Total
Canada*							
Japan	0	1,400,000	78,800,000	0	0	2,310,000	82,510,000
Korea	0	0	0	0	0	0	0
Russia	11,424,000	17,918,000	49,785,000	1,800,000	4,457,000	0	85,384,000
USA	31,181,000	695,000,000	448,000,000	6,640,000	6,680,000	0	1,187,501,000
Alaska	31,181,000	695,000,000	448,000,000	6,640,000	6,680,000	0	1,187,501,000
WOCI*							0
Total	42,605,000	714,318,000	576,585,000	8,440,000	11,137,000	2,310,000	1,355,395,000

*Data not available

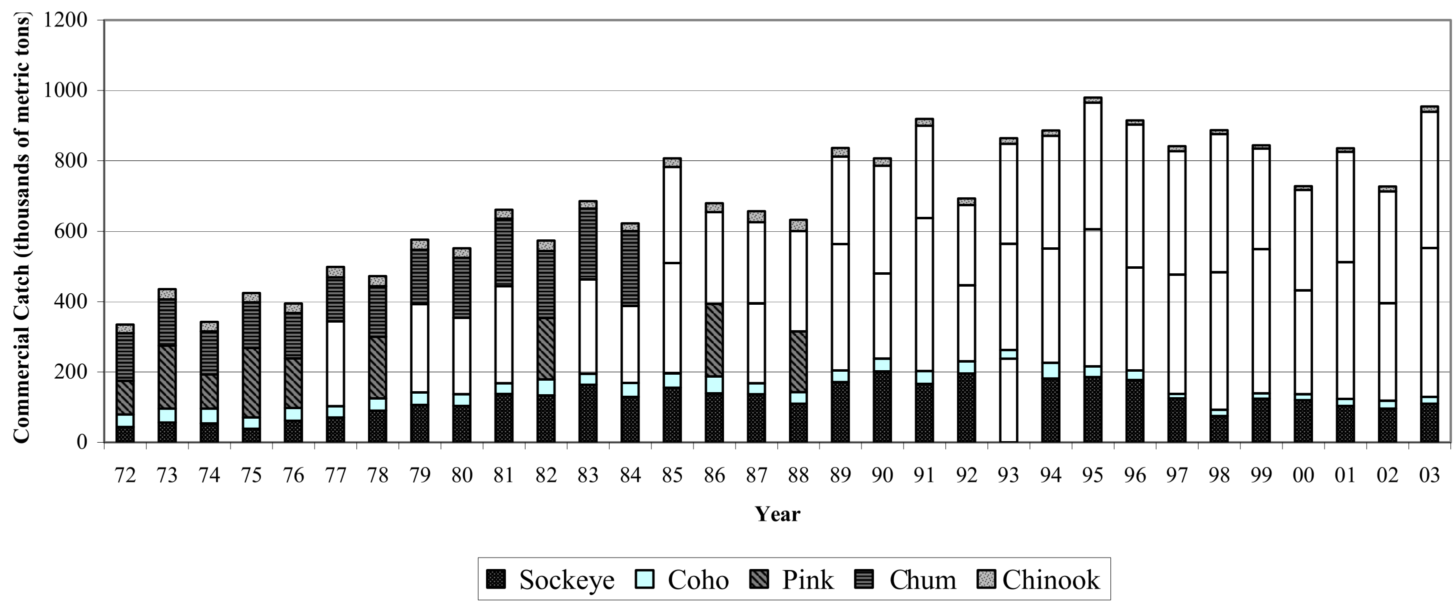


Fig. 1. Commercial salmon harvests, by species, in Canada, Korea, Japan, Russia, and the United States from 1972 to 2003 (round weight in metric tons). Source: North Pacific Anadromous Fish Commission (2004).

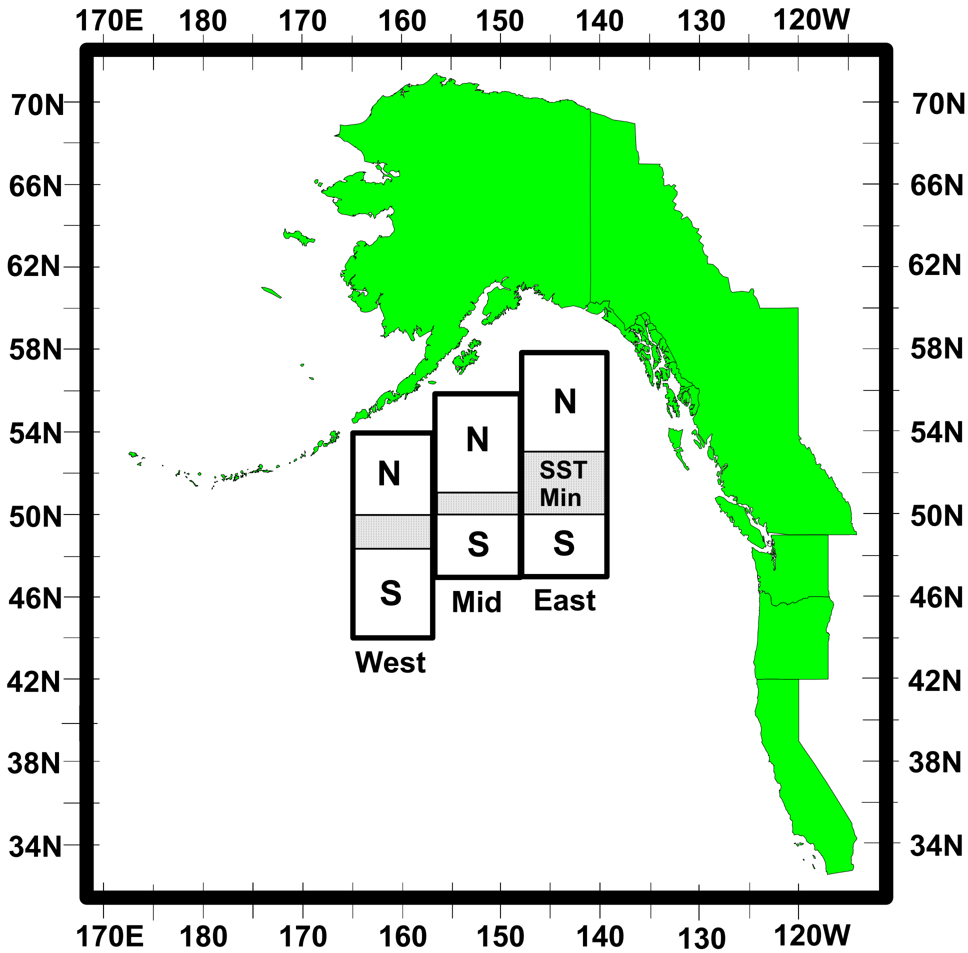


Fig. 2. Map of the study area in the Gulf of Alaska and adjacent North Pacific waters. The shaded areas indicate the approximate range of latitudes of the sea surface temperature minimum (SST Min) in 1993-2003. The data were stratified into six regions: three longitudinal regions (West, Mid, and East) and two latitudinal regions (S = south of the SST Min and N = north, including stations at the SST Min). N = north, S = south.

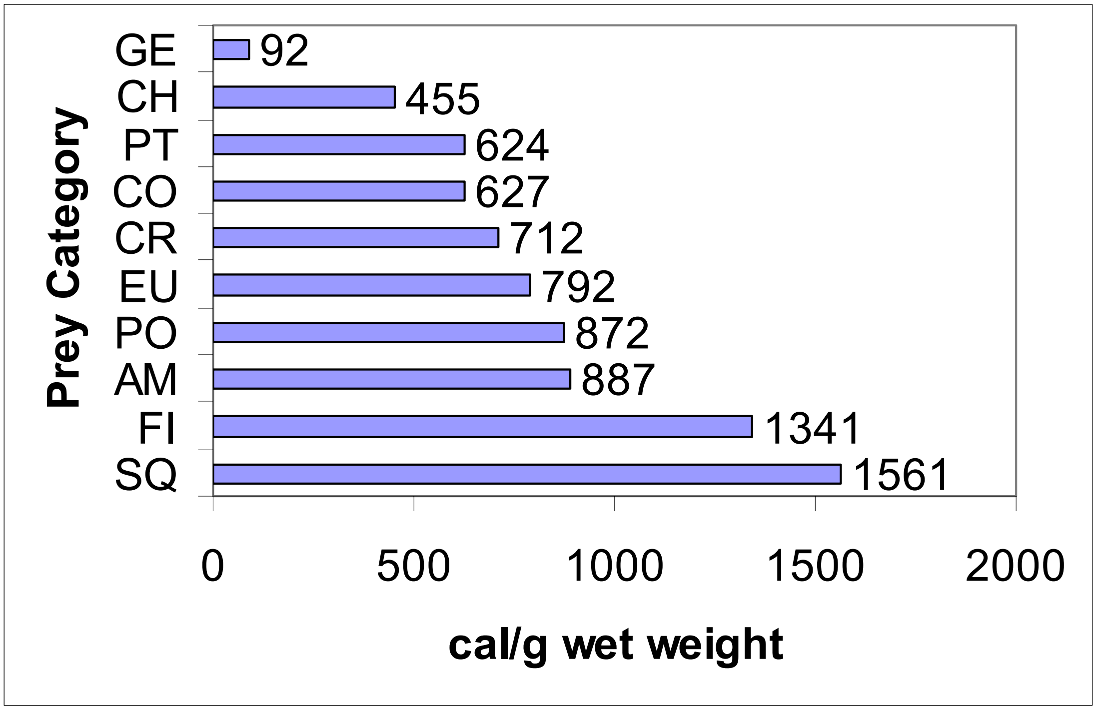


Fig. 3. Mean caloric content (cal/g wet weight) of prey categories used in analysis of salmon diet similarity (see Table 2 for data sources). Prey categories include: GE = gelatinous zooplankton (medusae and ctenophores), CH = chaetognaths, PT = pteropods, CO = copepods, CR = larval crab, EU = euphausiids, PO = polychaetes, AM = amphipods, FI = fish, and SQ = squid.

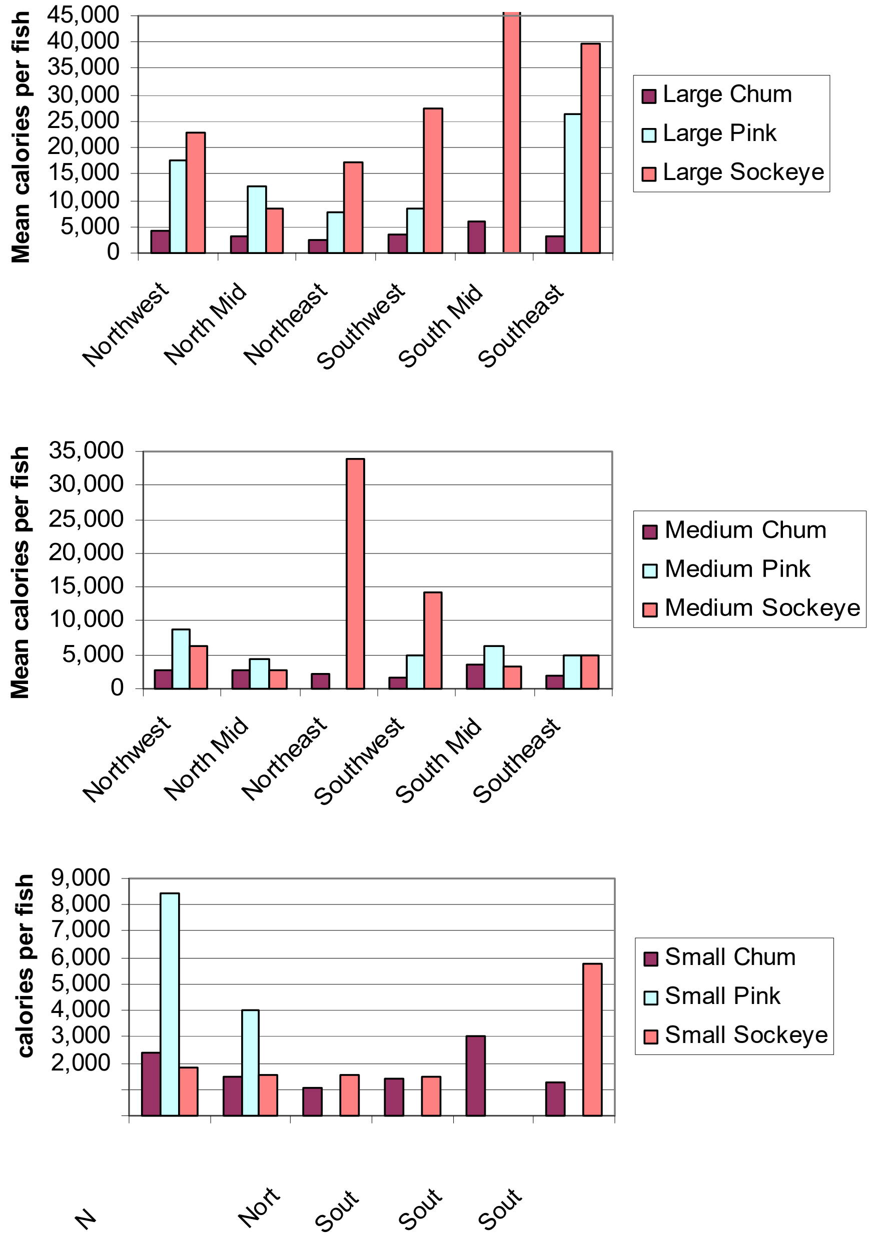


Fig. 4. Mean number of calories per fish in the diets of large (top panel), medium (middle panel), and small (bottom panel) body weight categories of chum, pink, and sockeye salmon in the Gulf of Alaska food habits study area by region (Fig. 2). Salmon size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g.

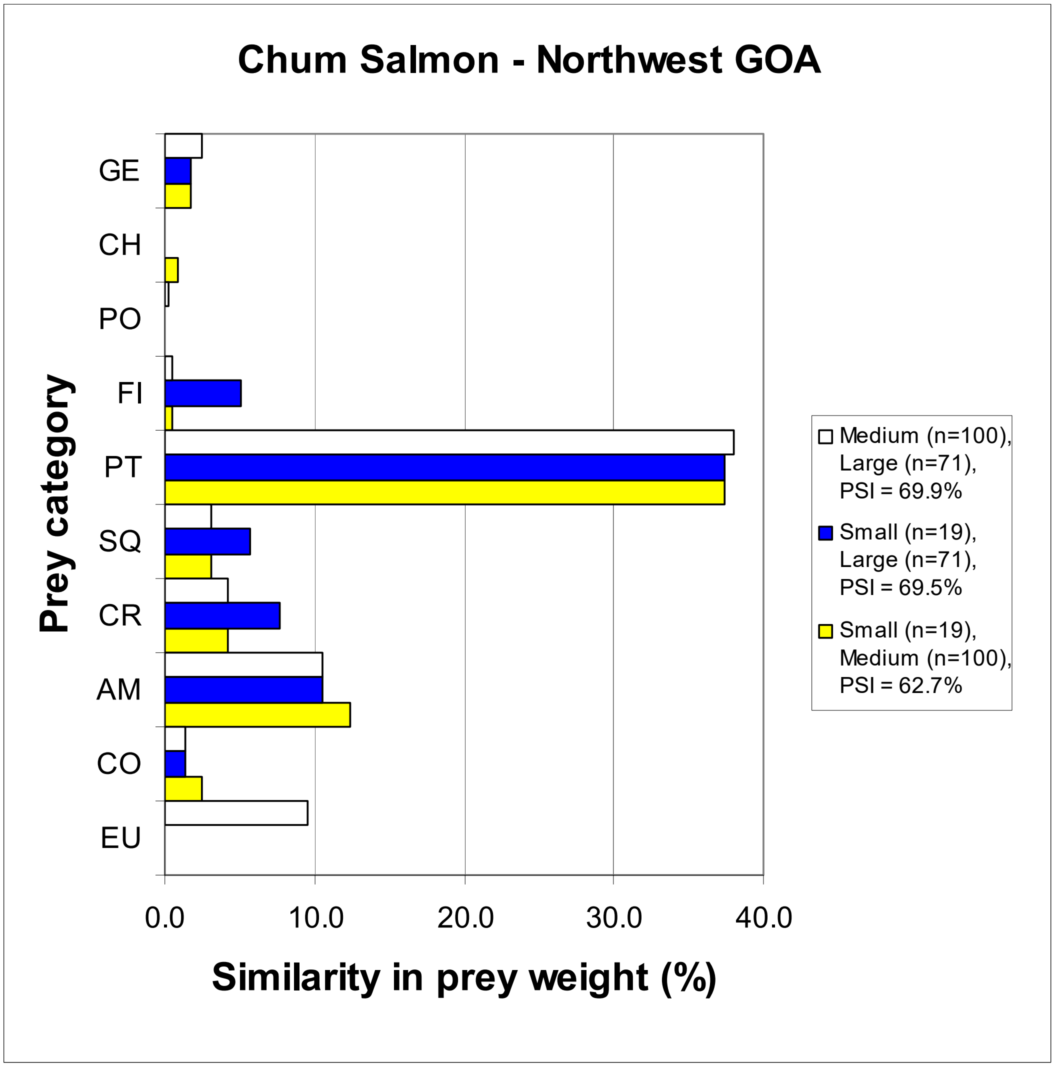


Fig. 5. Percent Similarity Index (PSI; values shown in figure legend) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon in the Northwest region of the Gulf of Alaska (GOA; north of and including the sea surface temperature minimum and between 157°-165°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

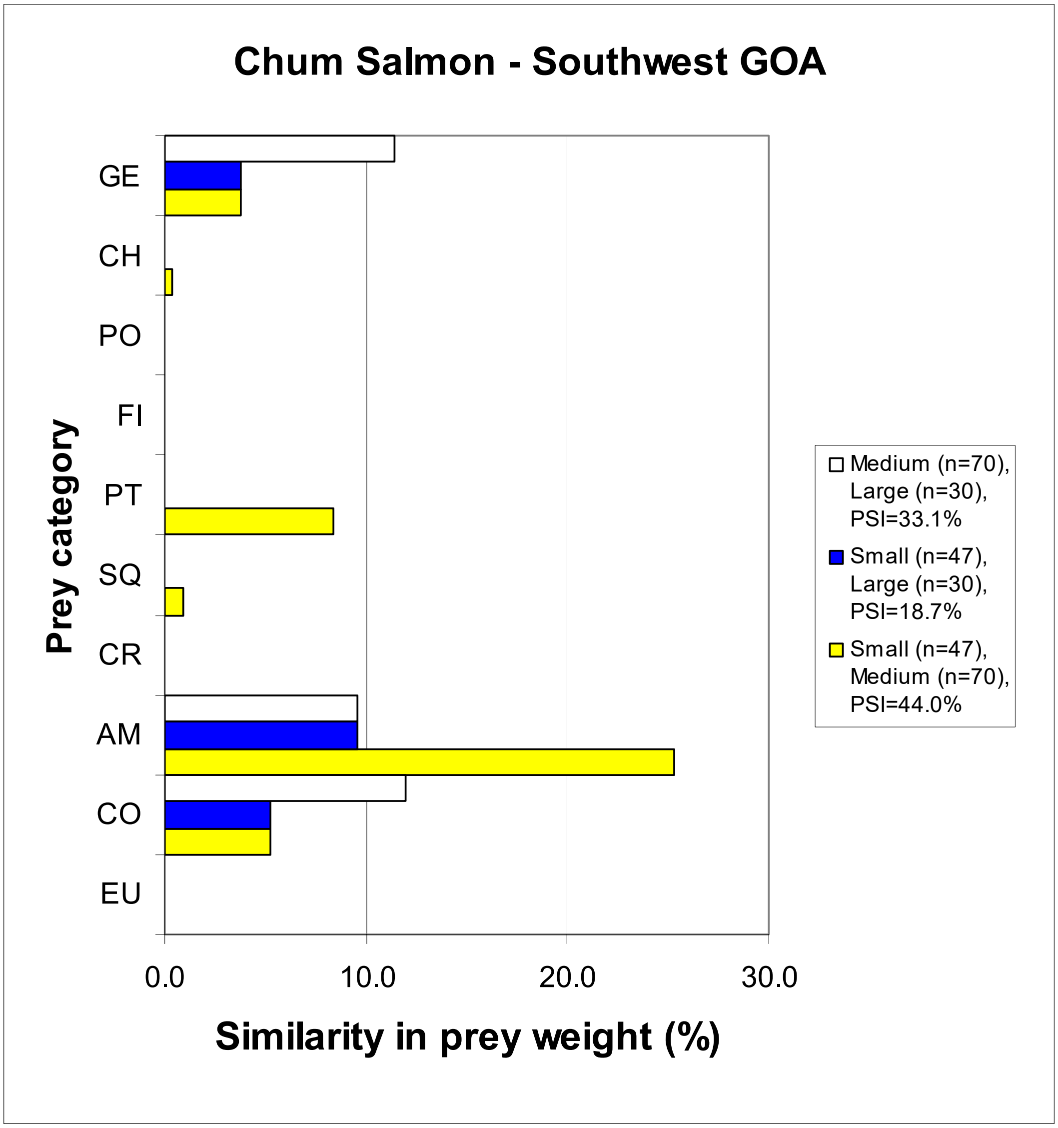


Fig. 6. Percent Similarity Index (PSI; values shown in figure legend) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon in the Southwest region of the Gulf of Alaska (GOA; south of the sea surface temperature minimum and between 157°-165°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

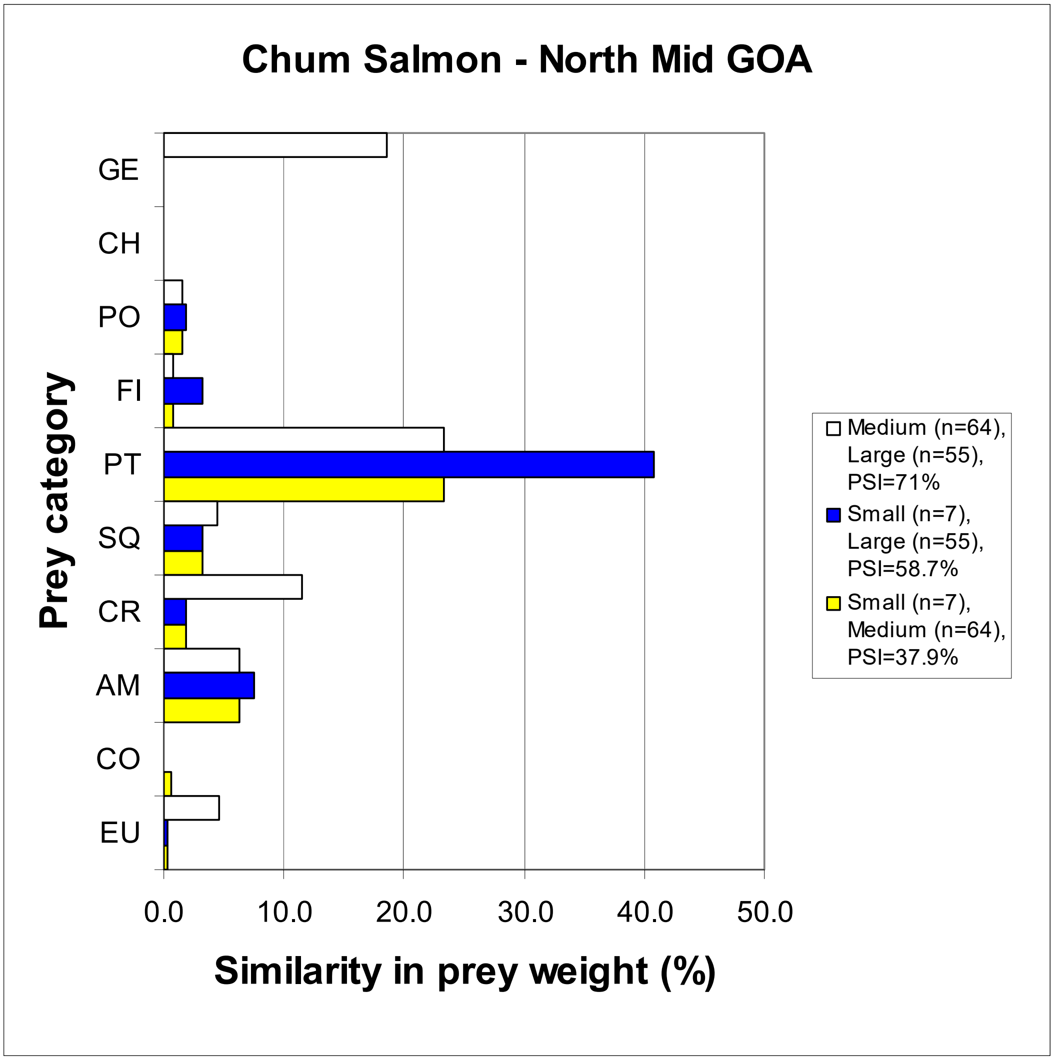


Fig. 7. Percent Similarity Index (PSI; values shown in figure legend) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon in the North Mid region of the Gulf of Alaska (GOA; north of and including the sea surface temperature minimum and between 149°-156°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

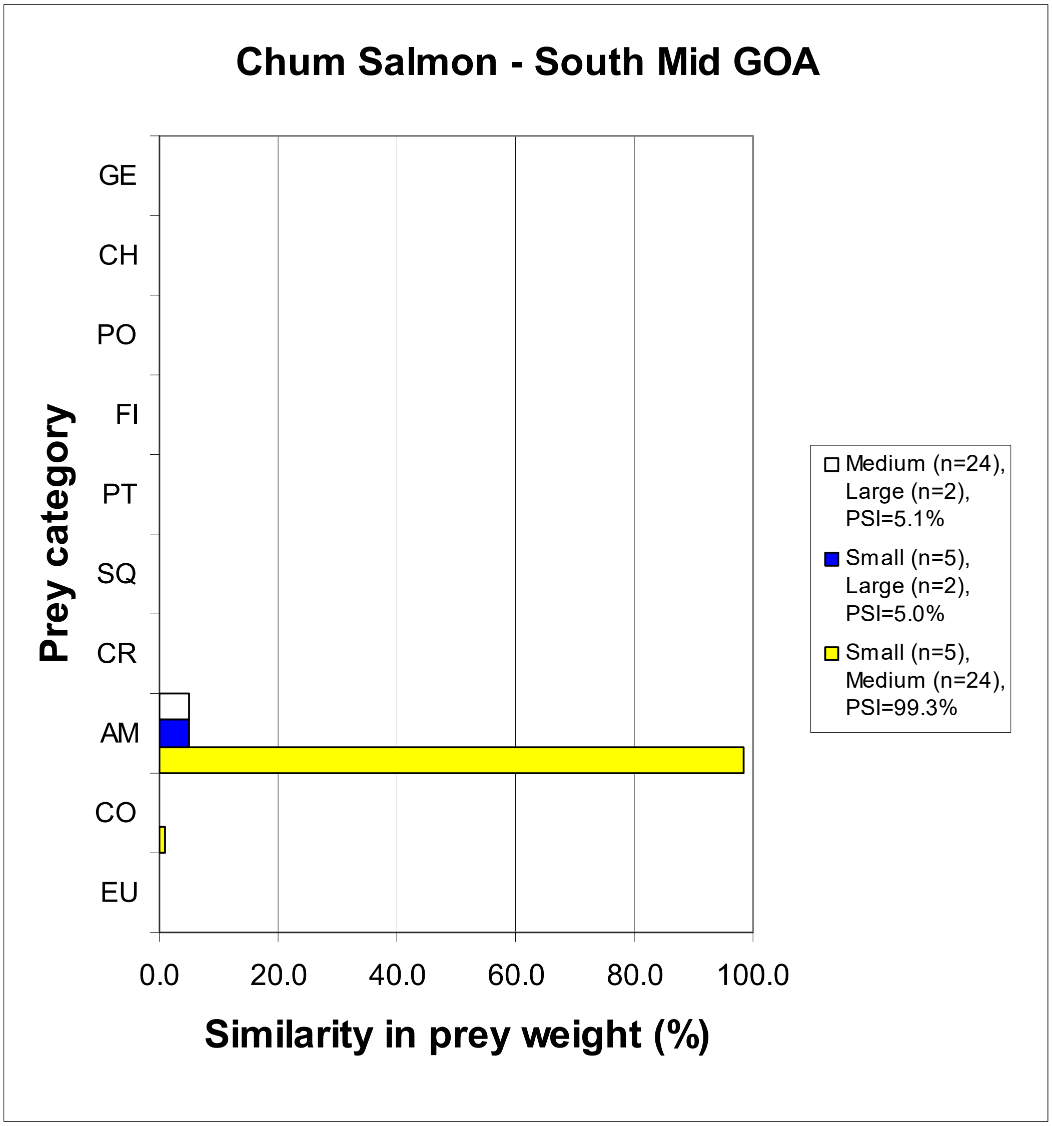


Fig. 8. Percent Similarity Index (PSI; values shown in figure legend) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon in the South Mid region of the Gulf of Alaska (GOA; south of the sea surface temperature minimum and between 149°-156°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

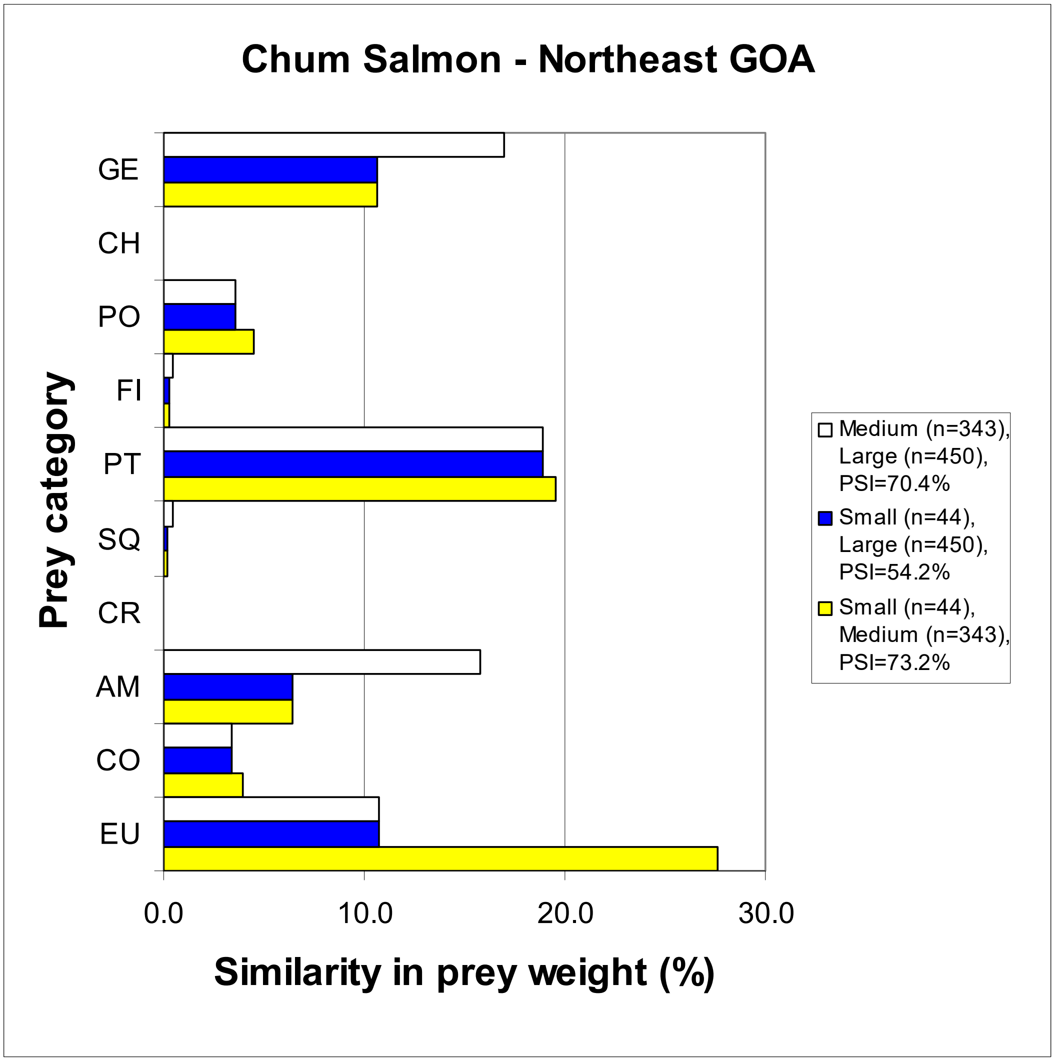


Fig. 9. Percent Similarity Index (PSI; values shown in figure legend) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon in the Northeast region of the Gulf of Alaska (GOA; north of and including the sea surface temperature minimum and between 139°-148°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

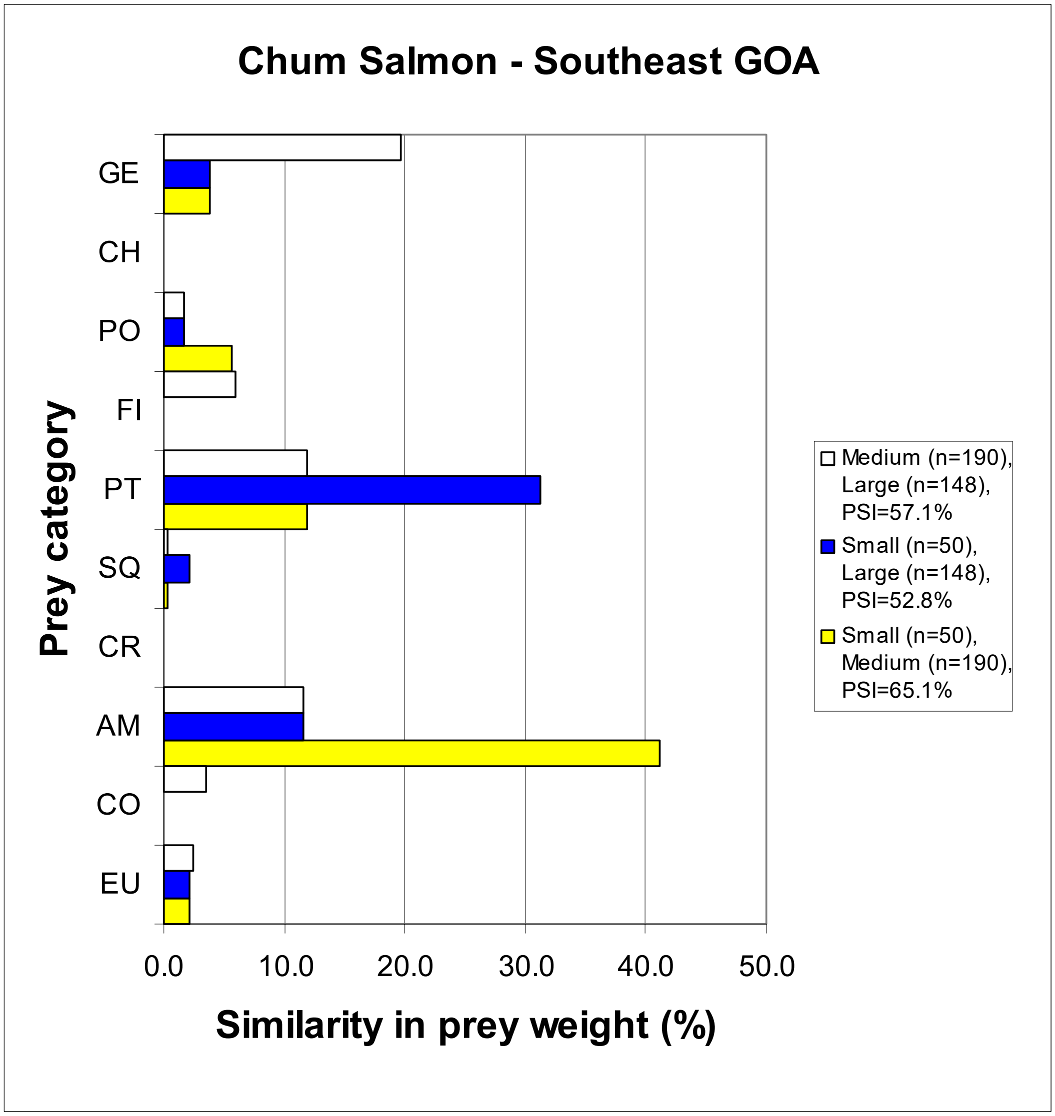


Fig. 10. Percent Similarity Index (PSI; values shown in figure legend) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon in the Southeast region of the Gulf of Alaska (GOA; south of the sea surface temperature minimum and between 139°-148°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

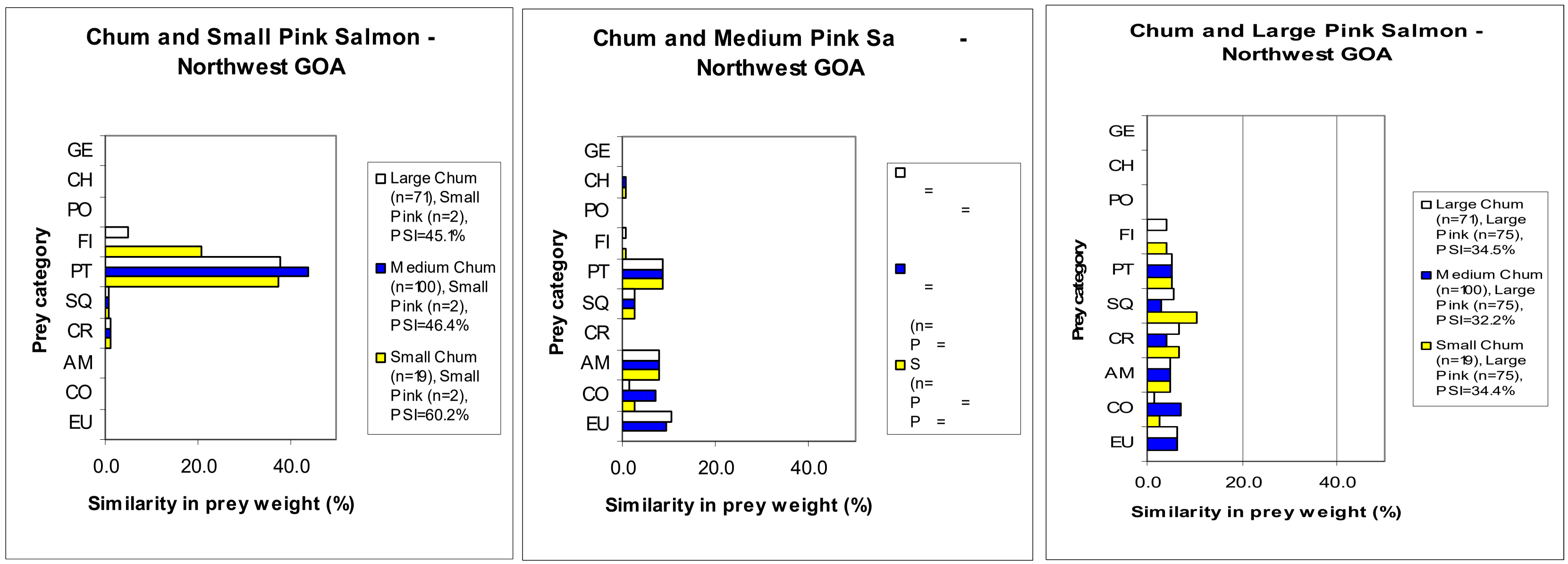
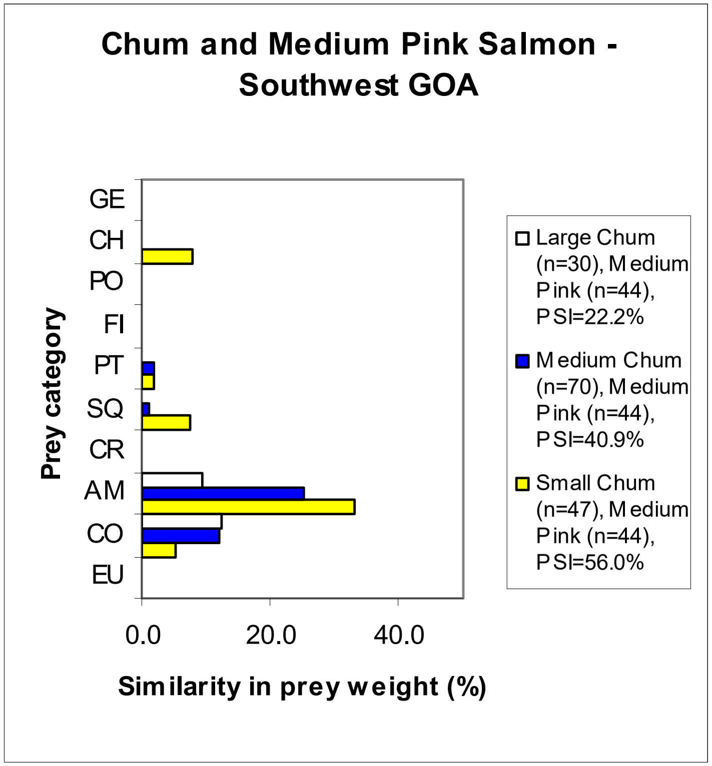


Fig. 11. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum and pink salmon in the Northwest region of the Gulf of Alaska (GOA; north of and including the sea surface temperature minimum and between 157°-165°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).



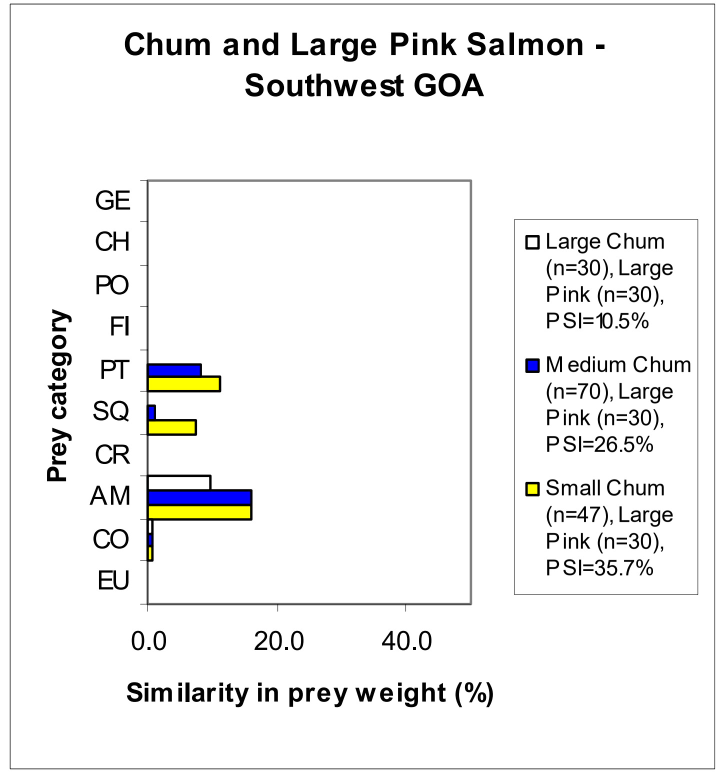


Fig. 12. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon and two size groups of pink salmon in the Southwest region of the Gulf of Alaska (GOA; south of the sea surface temperature minimum and between 157°-165°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

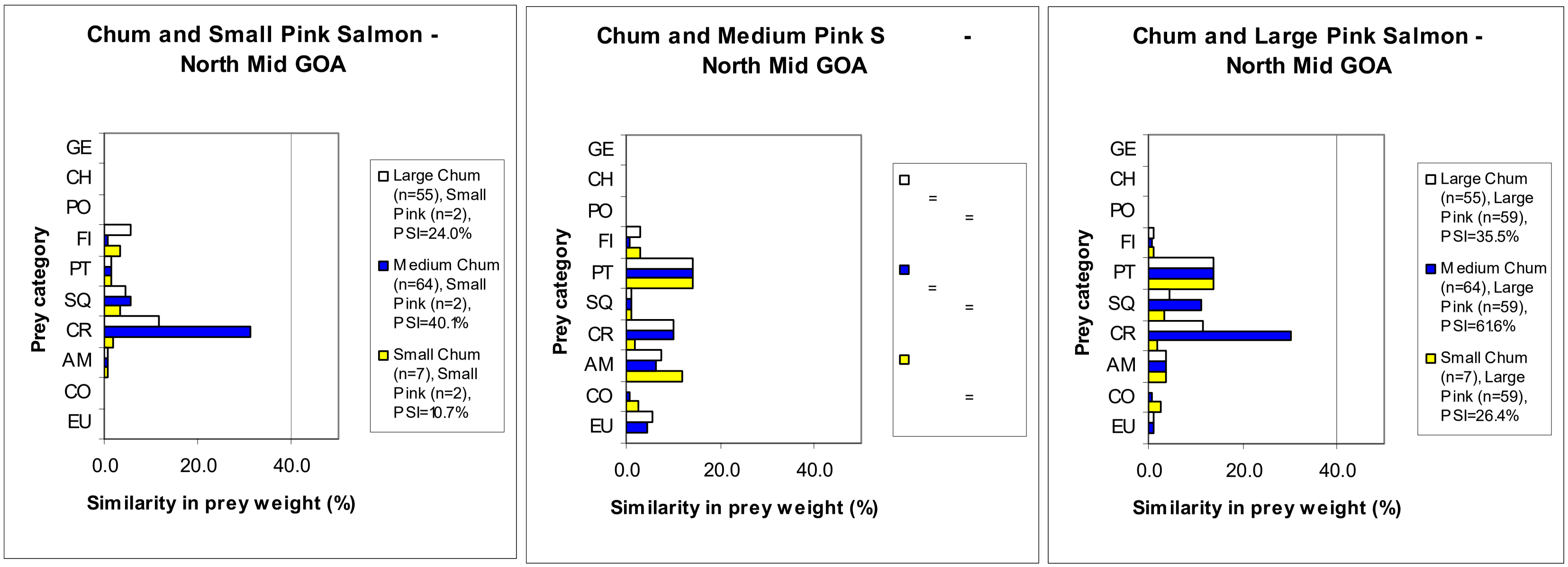
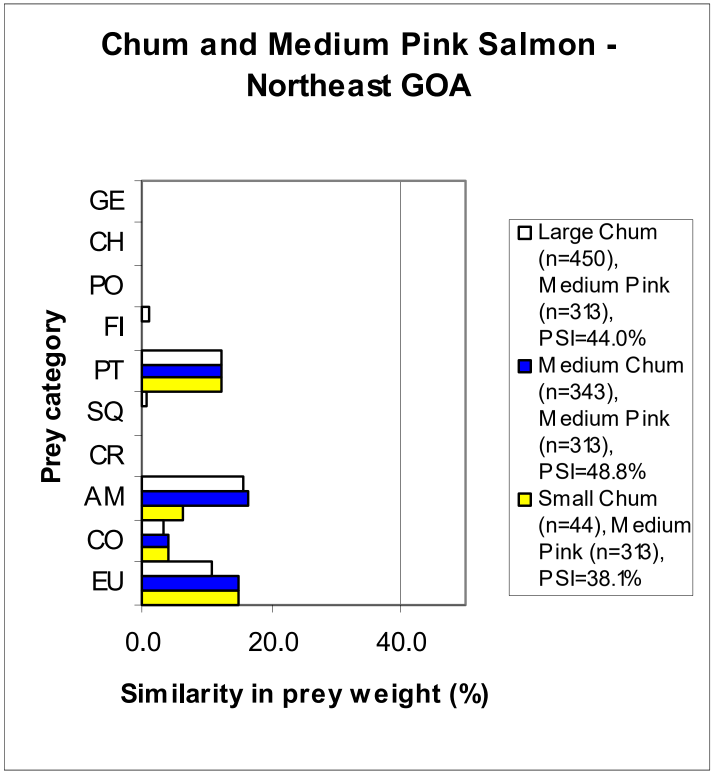


Fig. 13. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum and pink salmon in the North Mid region of the Gulf of Alaska (GOA; north of and including the sea surface temperature minimum and between 149°-156°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).



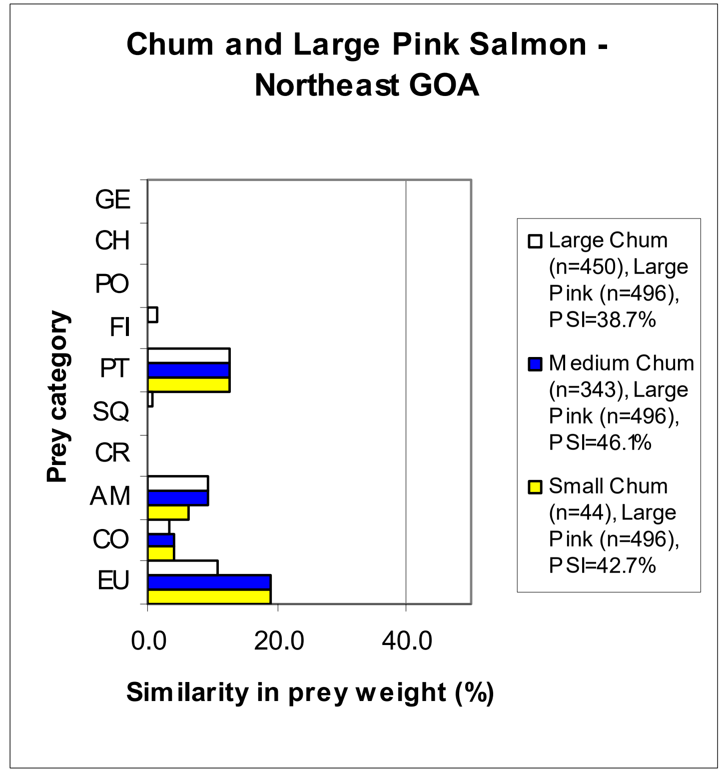


Fig. 14. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon and two size groups of pink salmon in the Northeast region of the Gulf of Alaska (GOA; north of and including the sea surface temperature minimum and between 139°-148°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

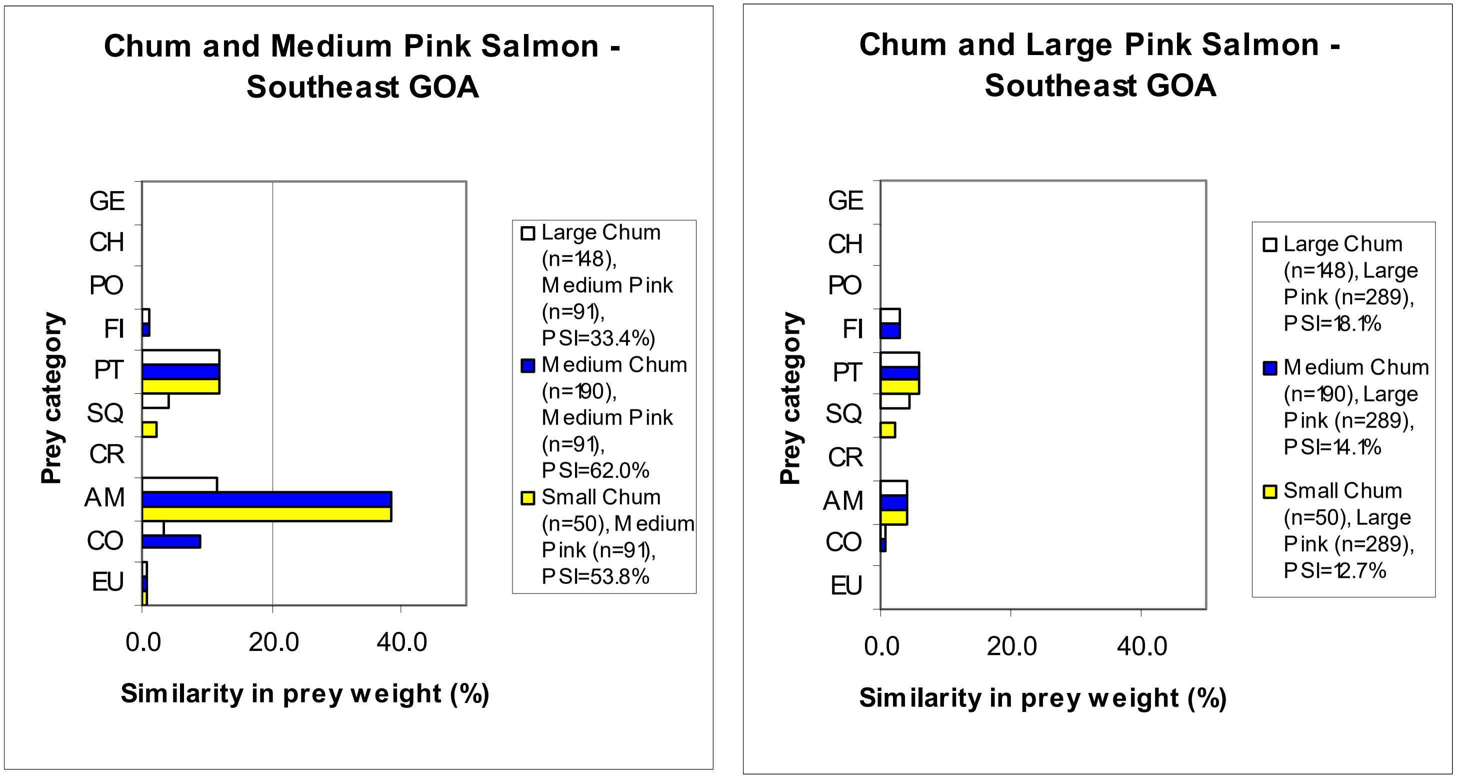


Fig. 15. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon and two size groups of pink salmon in the Southeast region of the Gulf of Alaska (GOA; south of the sea surface temperature minimum and between 139°-148°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

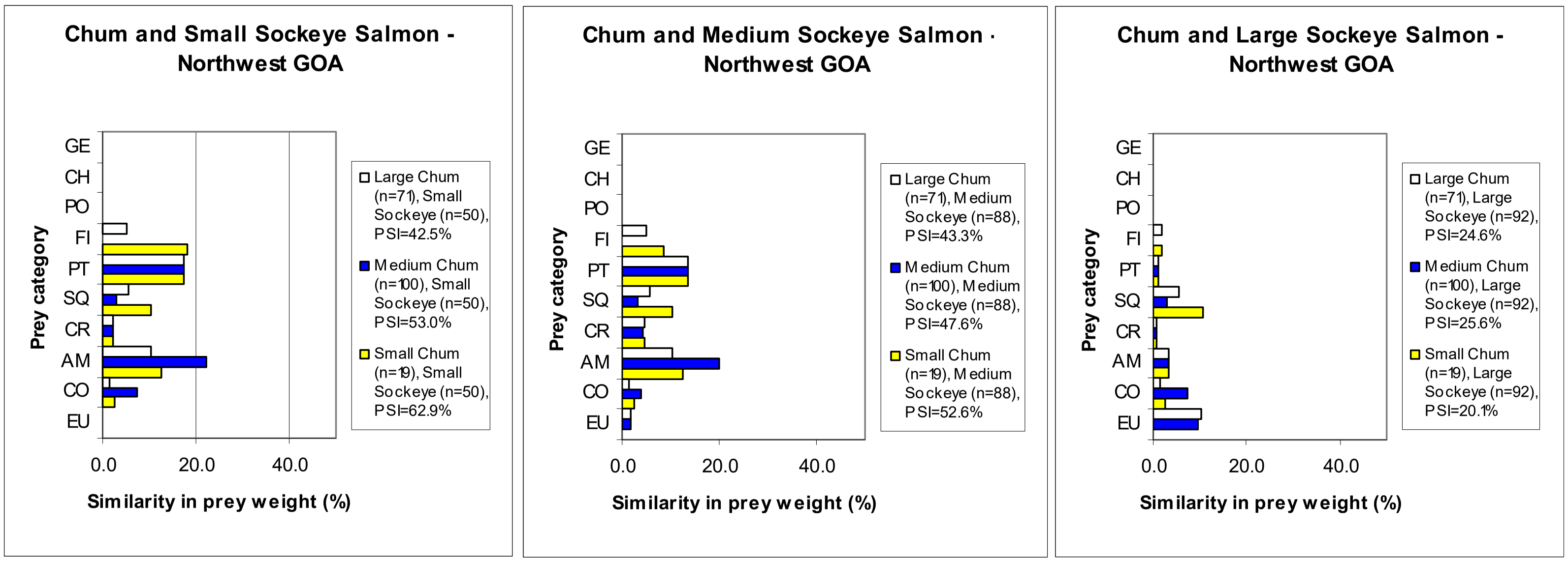


Fig. 16. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum and sockeye salmon in the Northwest region of the Gulf of Alaska (GOA; north of and including the sea surface temperature minimum and between 157°-165°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

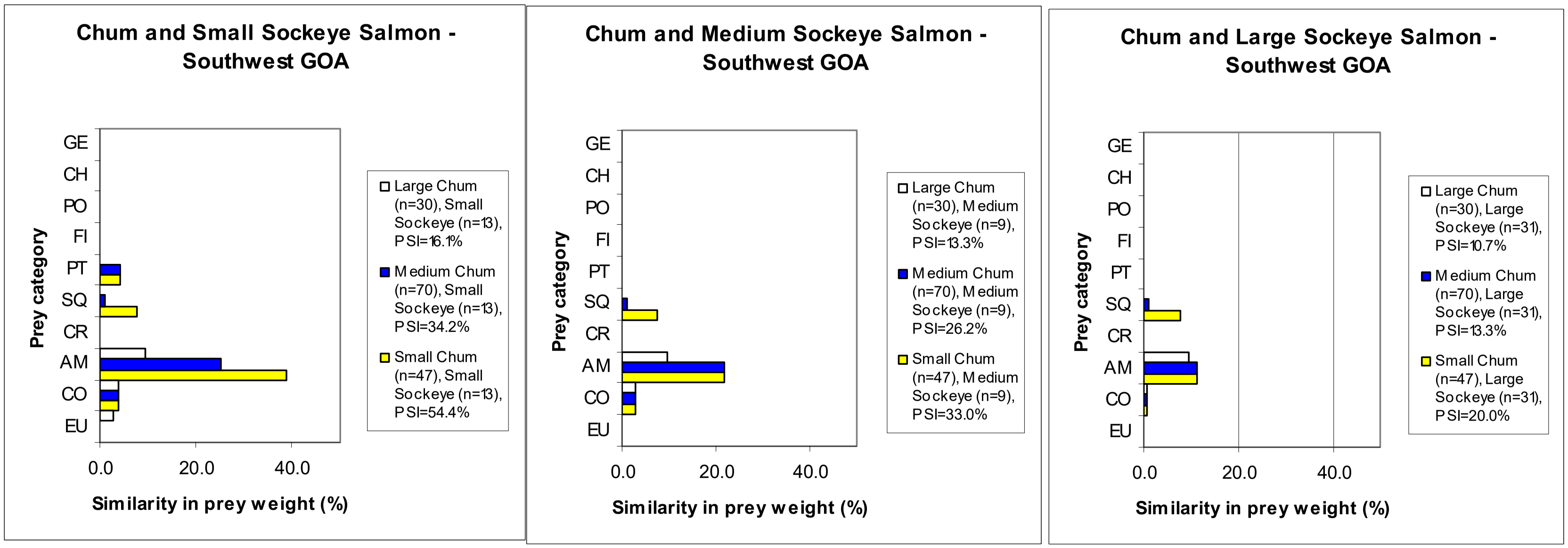


Fig. 17. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum and sockeye salmon in the Southwest region of the Gulf of Alaska (GOA; south of the sea surface temperature minimum and between 157°-165°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999); low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

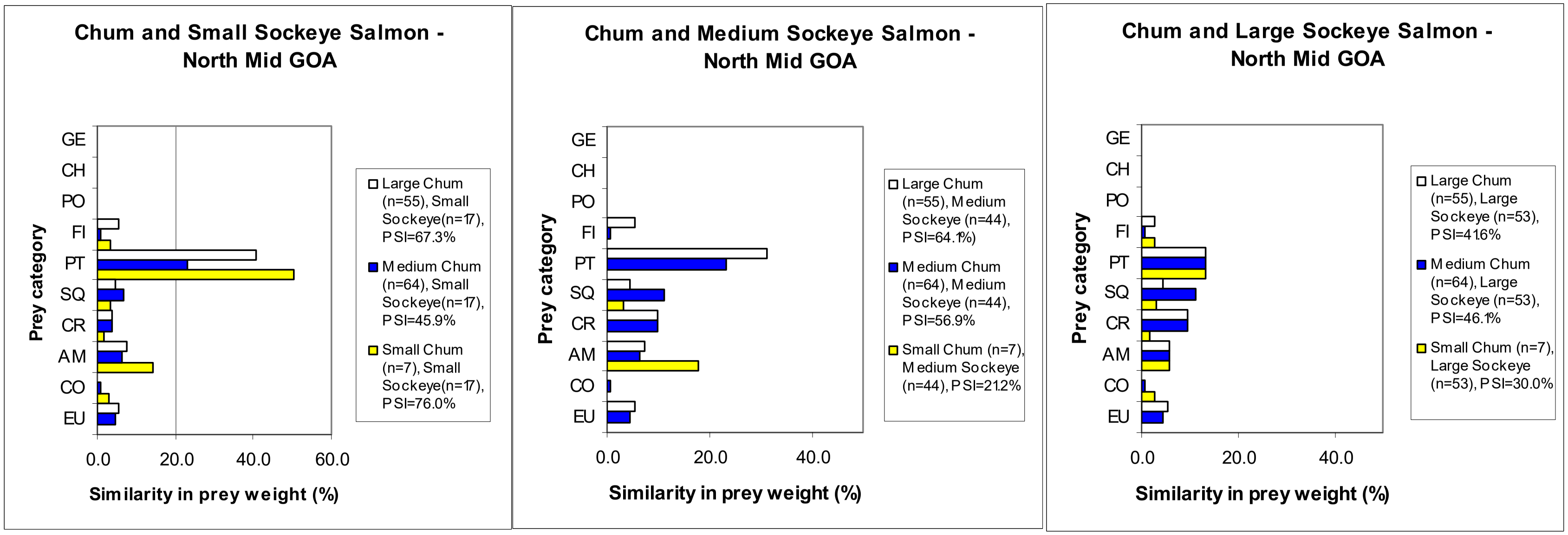


Fig. 18. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum and sockeye salmon in the North Mid region of the Gulf of Alaska (GOA; north of and including the sea surface temperature minimum and between 149°-156°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

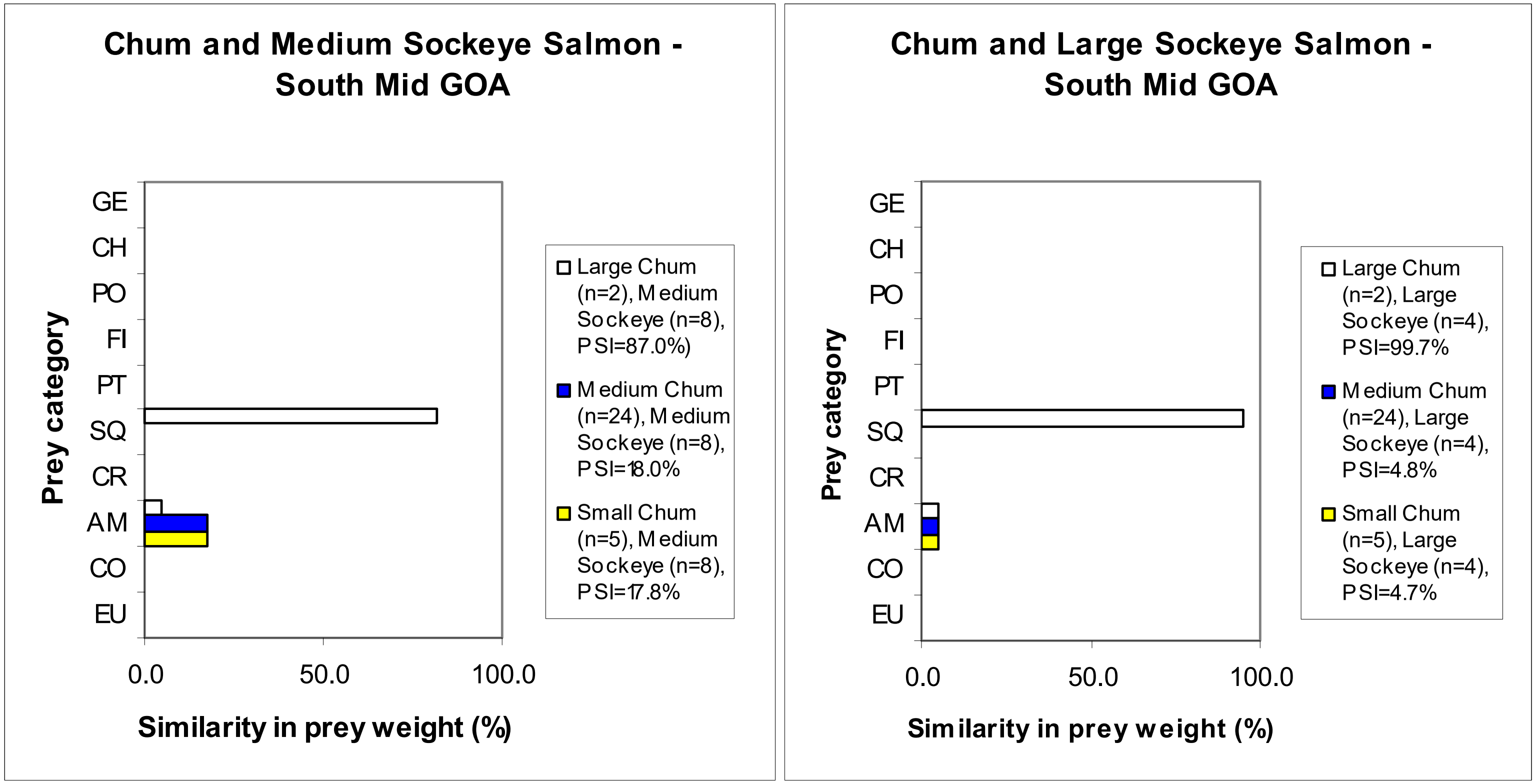


Fig. 19. Percent Similarity Index (PSI; values shown in figure legends) and pairwise comparisons of similarity in the summer diets of three size groups of chum salmon and two size groups of sockeye salmon in the South Mid region of the Gulf of Alaska (GOA; south of the sea surface temperature minimum and between 149°-156°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

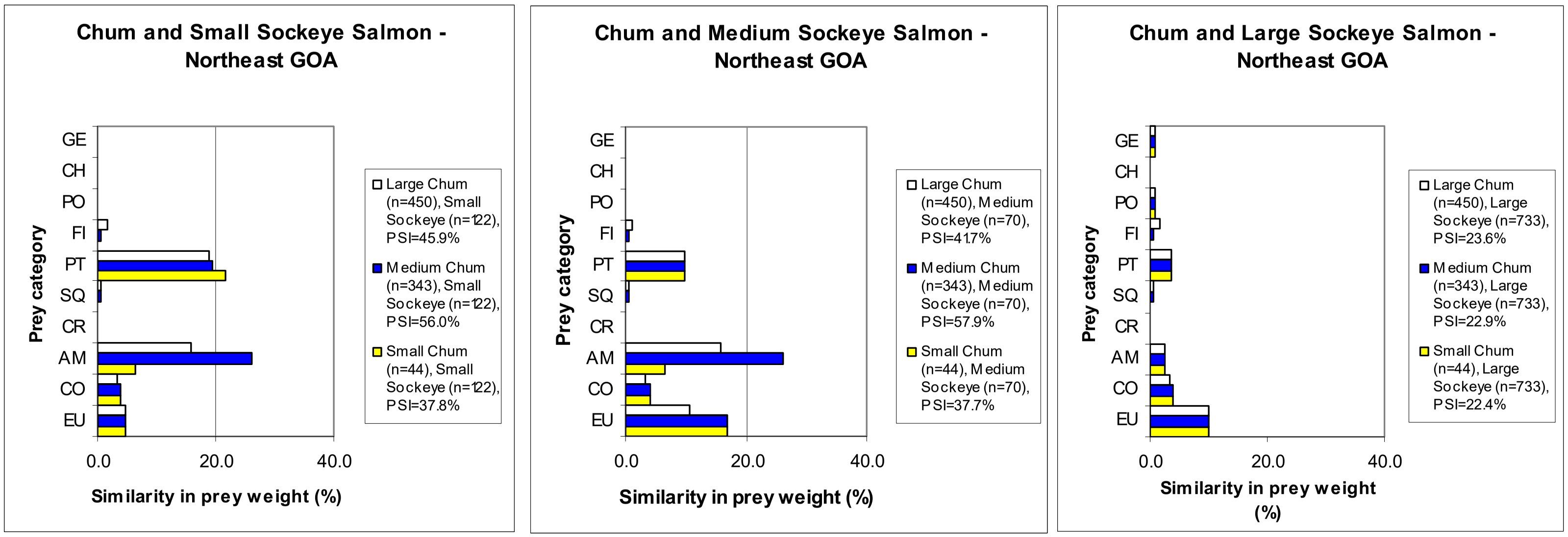


Fig. 20. Pairwise comparisons of similarity in the summer diets of three size groups of chum and sockeye salmon in the Northeast region of the Gulf of Alaska (GOA; north of the sea surface temperature minimum and between 139°-148°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

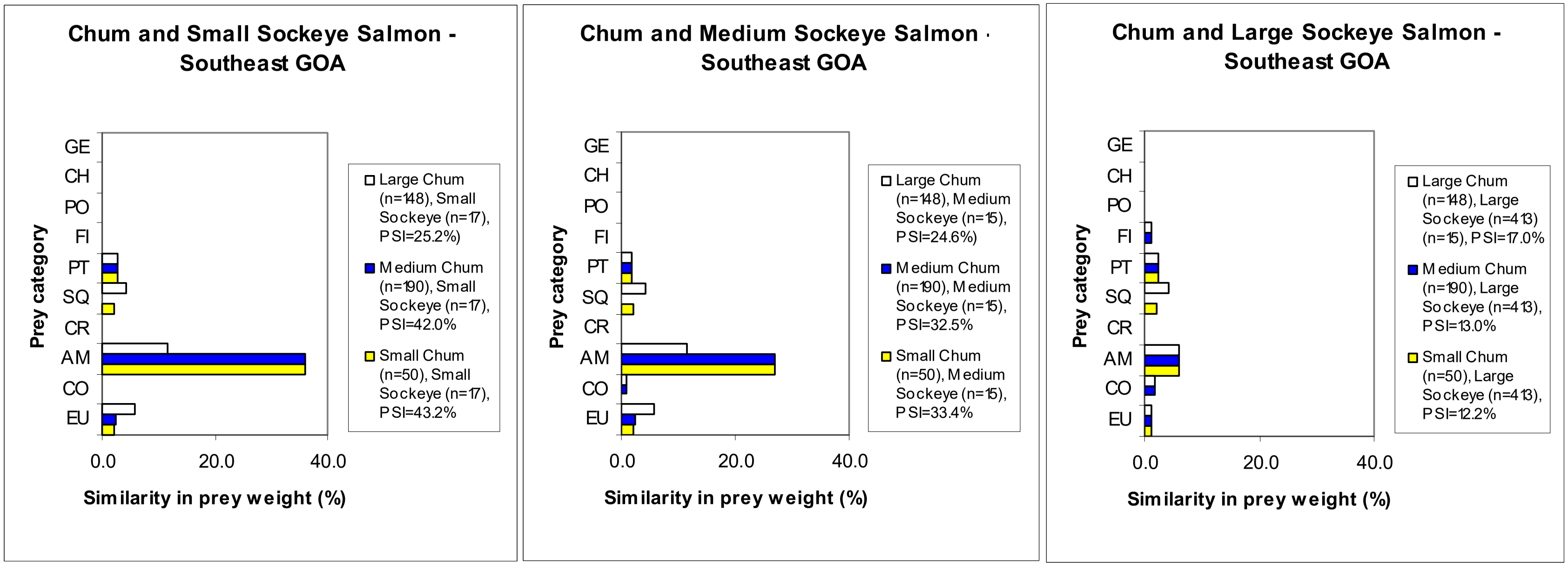


Fig. 21. Pairwise comparisons of similarity in the summer diets of three size groups of chum and sockeye salmon in the Southeast region of the Gulf of Alaska (GOA; south of the sea surface temperature minimum and between 139°-148°W longitude, Fig. 2). Size group categories: small = <600 g body weight, medium = 600-1200 g, and large = >1200 g. PSI = Percent Similarity Index (Buckley et al. 1999; low similarity = 0-24%, moderate = 25-49%; high = 50-74%, very high = 75-100%). Prey categories include: EU = euphausiids, CO = copepods, AM = amphipods, CR = larval crab, SQ = squid, PT = pteropods, FI = fish, PO = polychaetes, CH = chaetognaths, GE = gelatinous zooplankton (medusae and ctenophores).

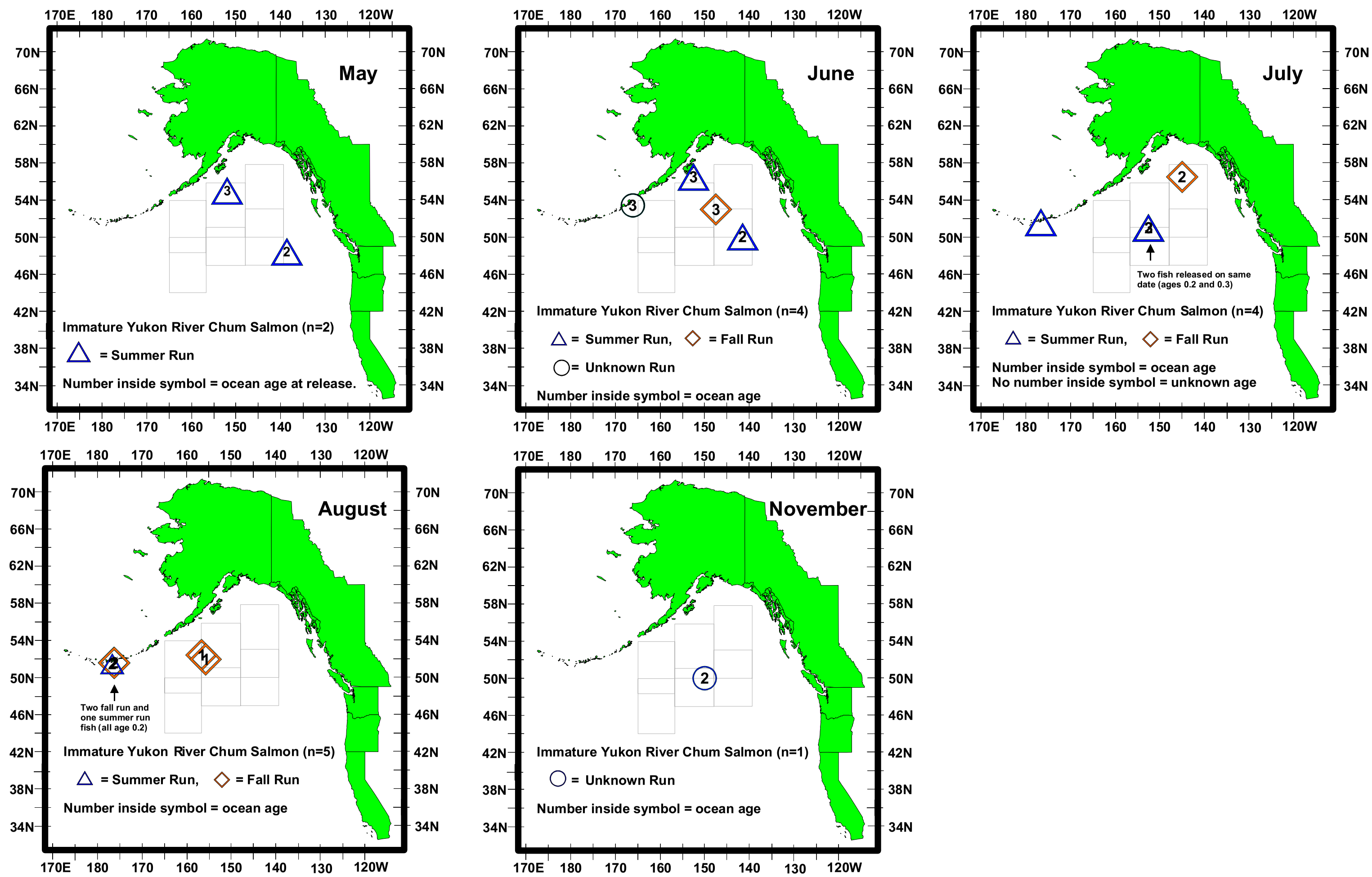


Fig. 22. The high seas distribution of seasonal races (summer and fall) of immature Yukon River chum salmon by month, as shown by tagging experiments (1956-2003). The symbols indicate the ocean release locations (May-November; no data for September and October) of tagged fish that were recovered one or more years later in the Yukon River. Summer-run chum salmon were caught in the Yukon River on or before July 15, and fall-run chum salmon were caught in the river after July 15. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged fish recovered.

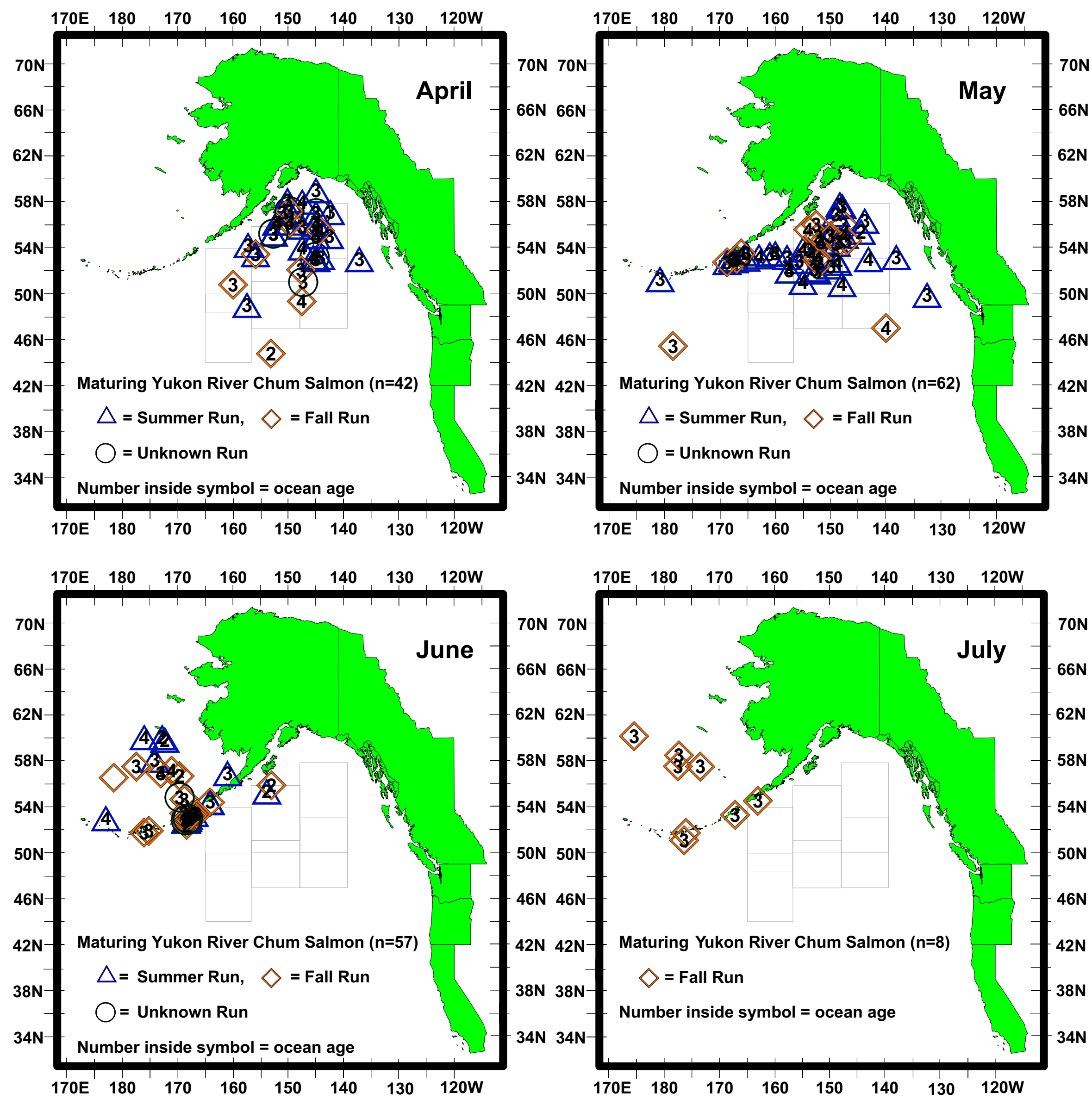


Fig. 23. The high seas distribution of seasonal races (summer and fall) of maturing Yukon River chum salmon by month, as shown by tagging experiments (1956-2003). The symbols indicate the ocean release locations (April-July) of tagged fish that were recovered during the same year in the Yukon River. Summer-run chum salmon were caught in the Yukon River on or before July 15, and fall-run chum salmon were caught in the river after July 15. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged fish recovered.

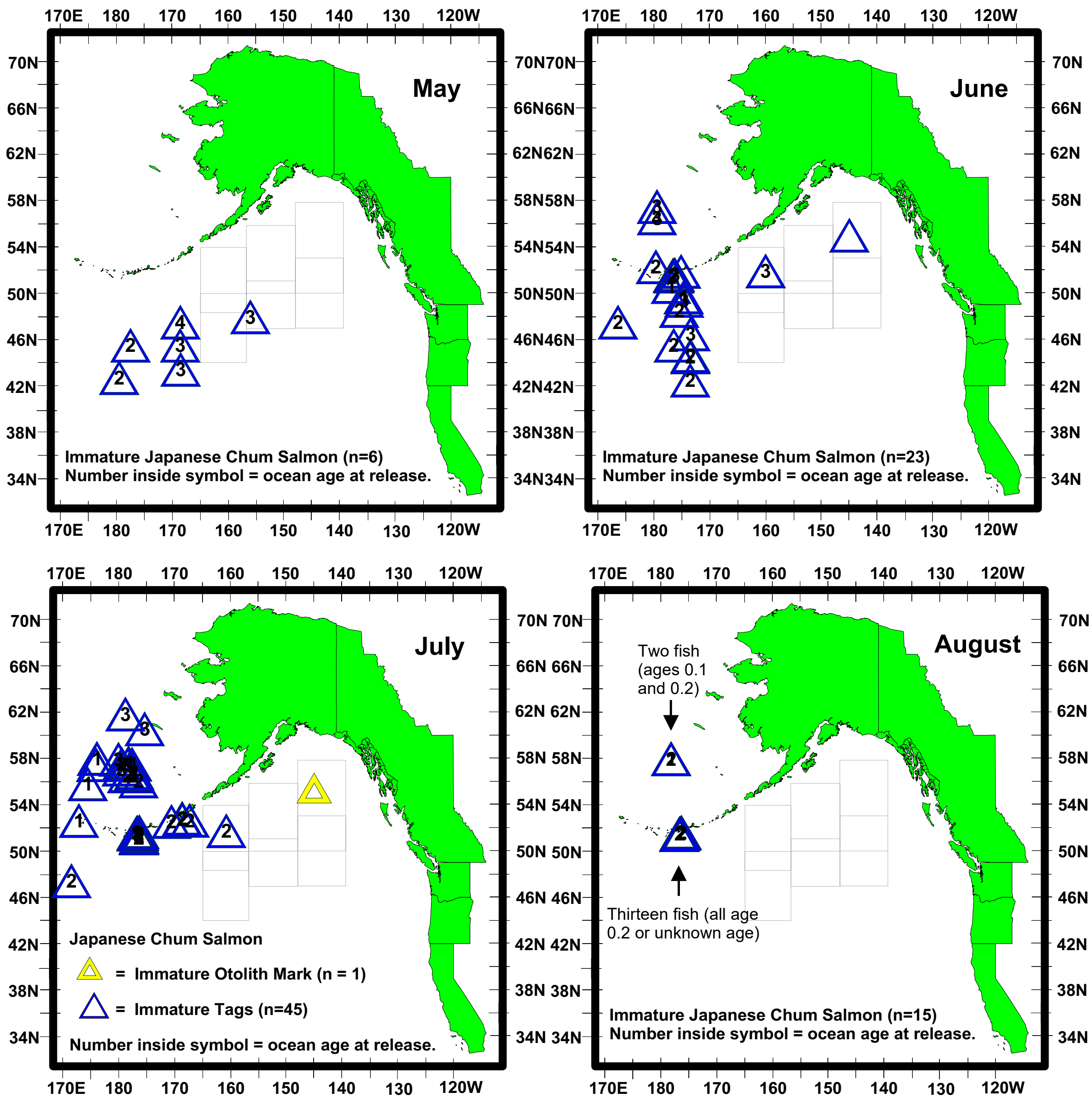


Fig. 24. The high seas distribution of immature Japanese chum salmon by month, as shown by tagging experiments (1956-2003) and otolith mark recovery experiments (2002). The symbols indicate the ocean release locations (May-August) of tagged fish that were recovered one or more years later in Japan or the ocean recovery location of otolith marked fish. Recoveries in Japan from release locations west of 170°E are not shown. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged or otolith marked fish recovered.

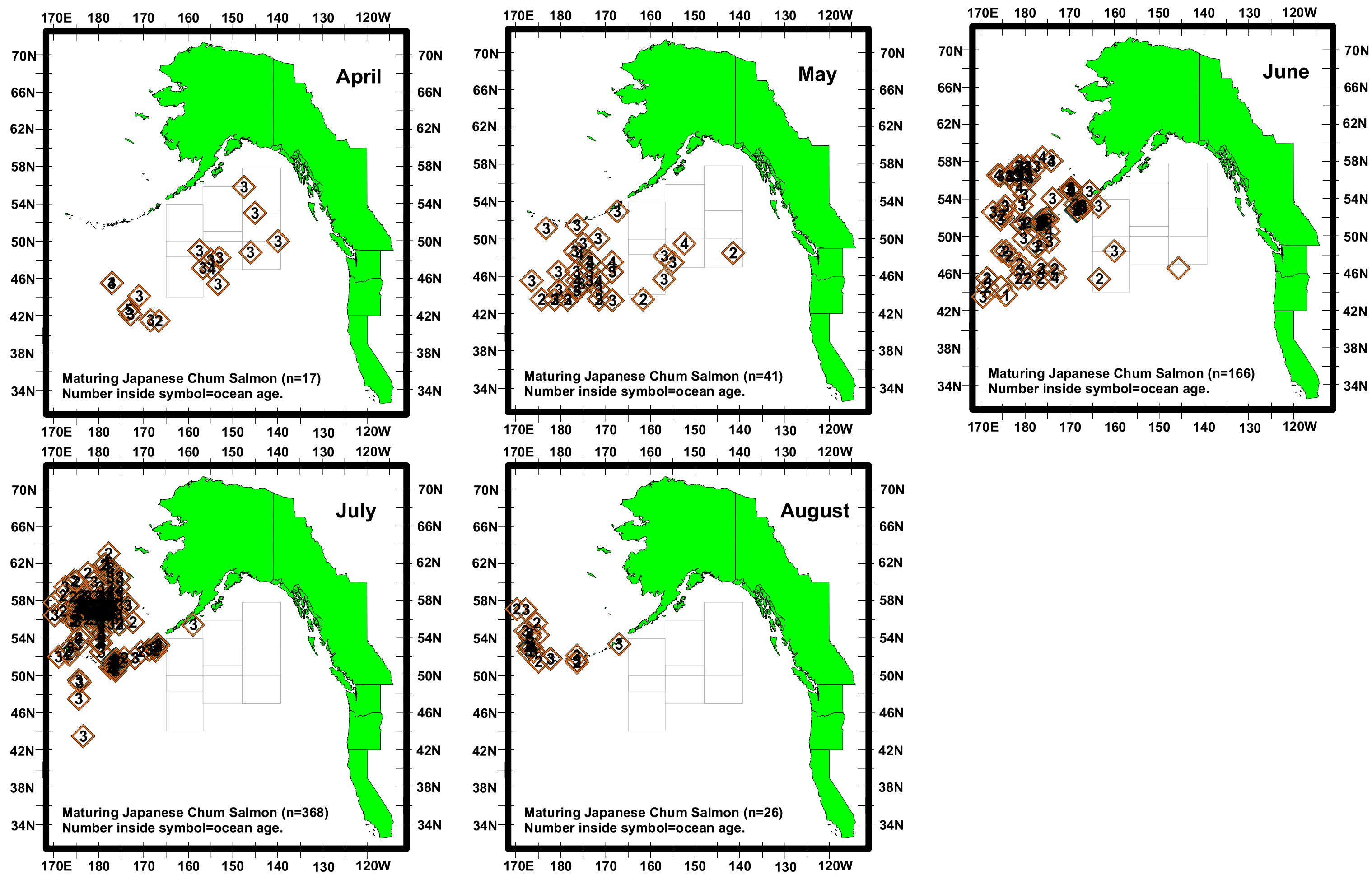


Fig. 25. The high seas distribution of maturing Japanese chum salmon by month, as shown by tagging experiments (1956-2003). The symbols indicate the ocean release locations (April-August) of tagged fish. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged fish recovered.

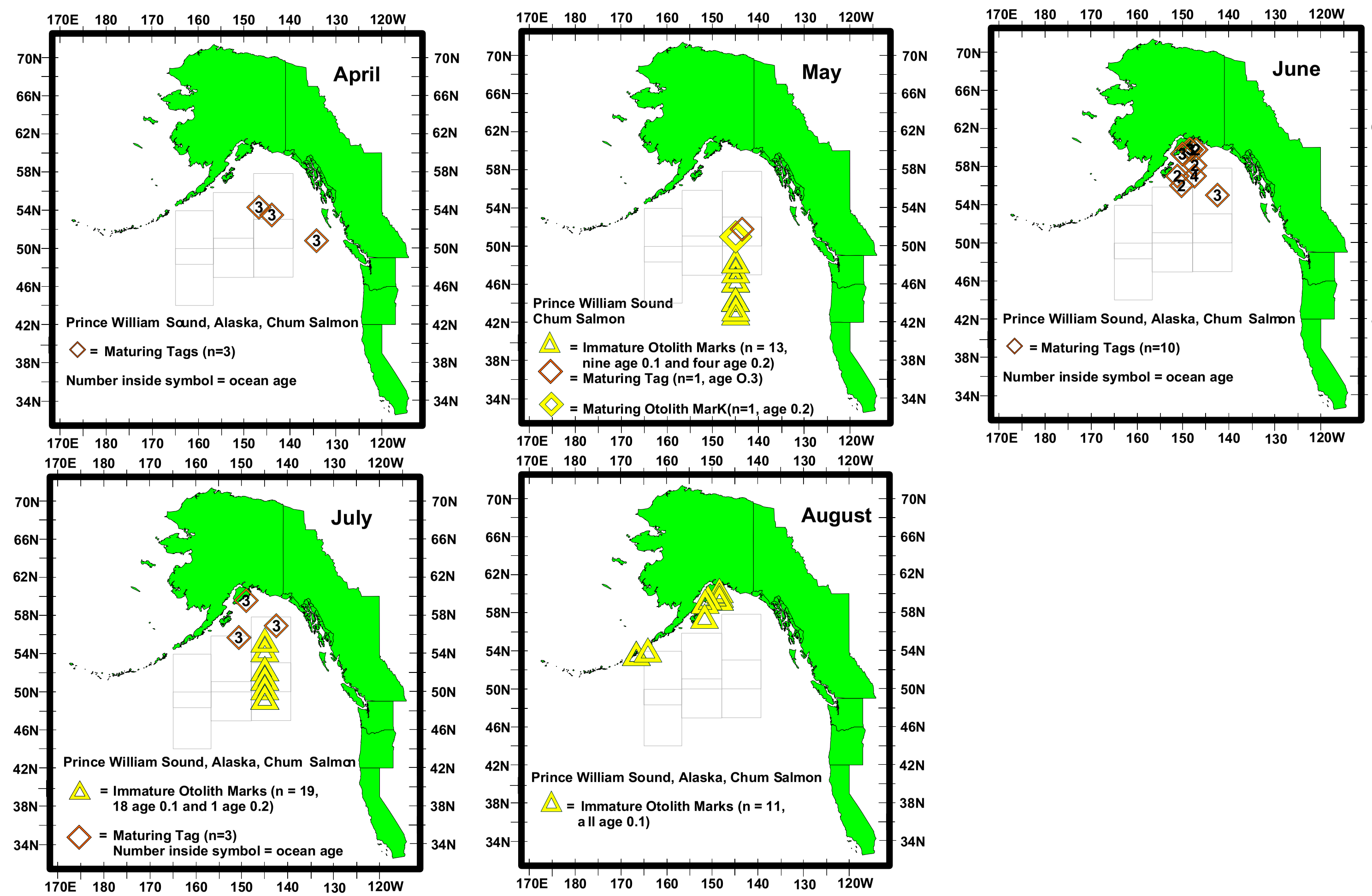


Fig. 26. The high seas distribution of immature and maturing Prince William Sound, Alaska, chum salmon by month, as shown by tagging experiments (1956-2003) and otolith mark recovery experiments (1997-2002). The symbols indicate the ocean release locations (April-August) of tagged fish or recovery locations of otolith marked fish. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged or otolith marked fish recovered.

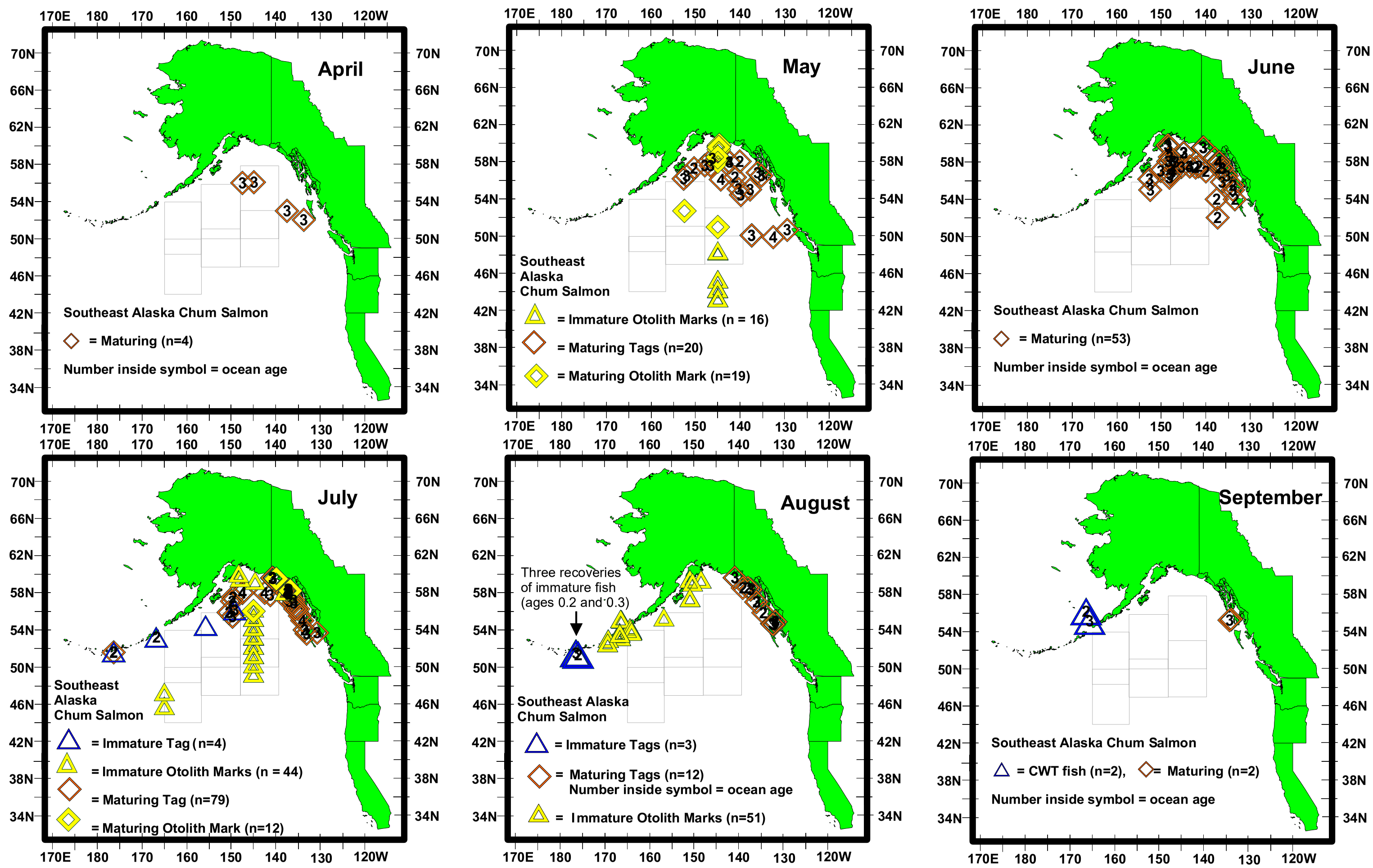


Fig. 27. The high seas distribution of immature and maturing southeastern Alaska chum salmon by month, as shown by tagging experiments (1956-2003) and otolith mark recovery experiments (1997-2000). The symbols indicate the ocean release locations (April-August) of tagged fish and recovery locations of otolith marked fish. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged or otolith marked fish recovered. CWT = recovery locations of two coded-wire tagged hatchery chum salmon in the Bering Sea in September.

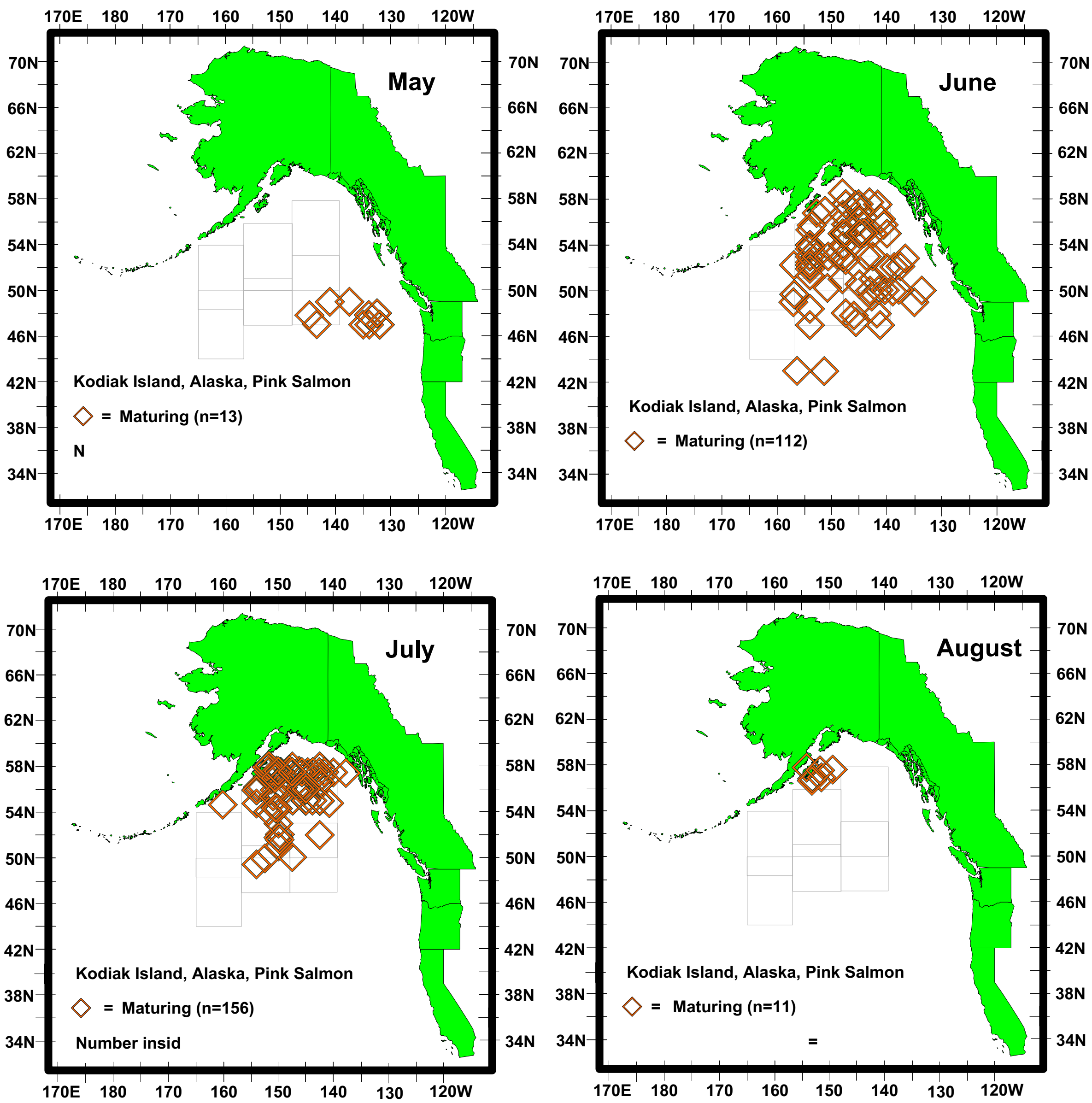


Fig. 28. The high seas distribution of maturing Kodiak Island, Alaska, pink salmon by month, as shown by tagging experiments (1956-2003). The symbols indicate the ocean release locations (May-August) of tagged fish. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged fish recovered.

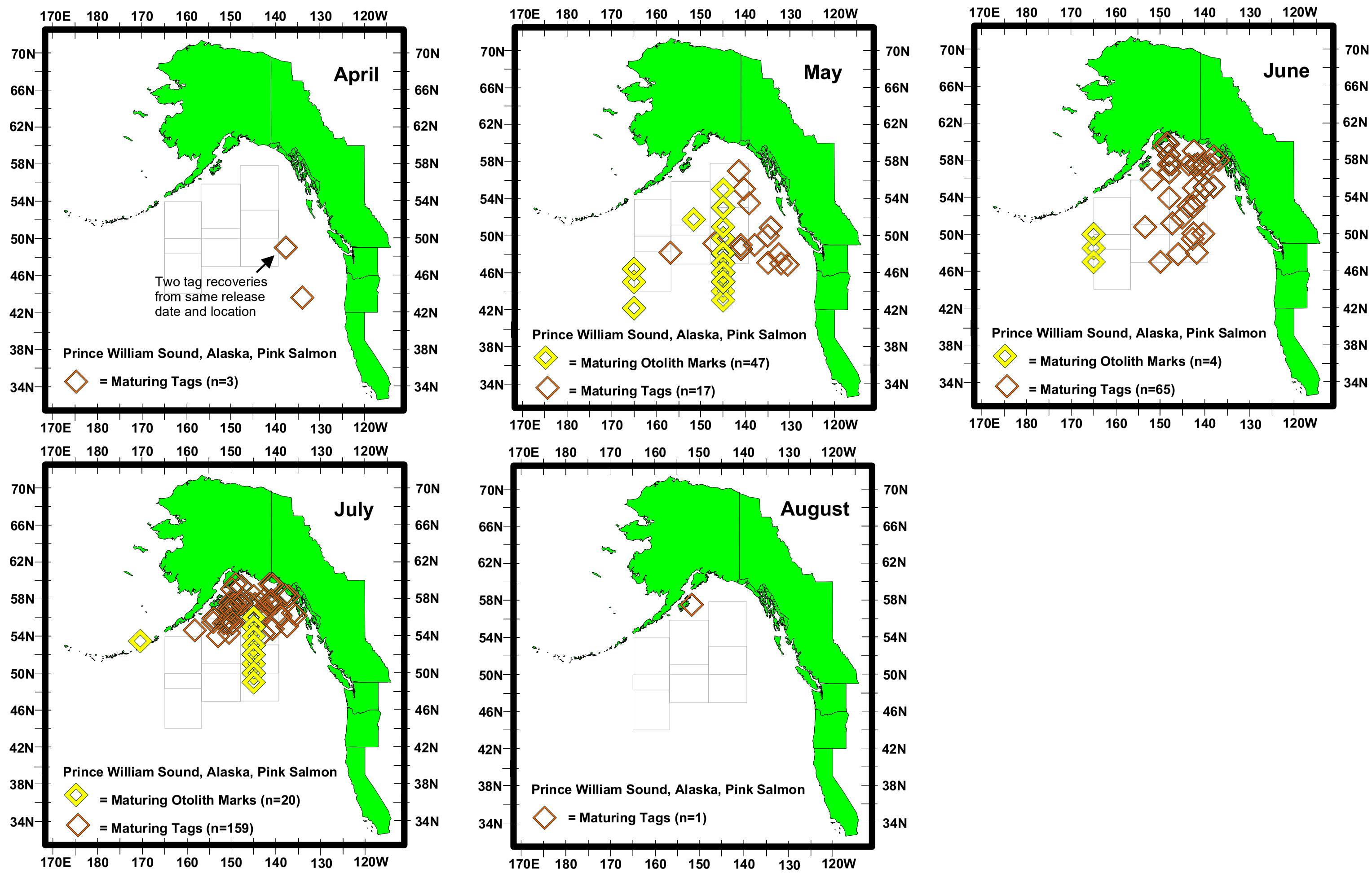


Fig. 29. The high seas distribution of maturing Prince William Sound, Alaska, pink salmon by month, as shown by tagging experiments (1956-2003) and otolith mark recovery experiments (1998-2002). The symbols indicate the ocean release locations (April-August) of tagged fish and recovery locations of otolith-marked fish. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged and otolith marked fish recovered.

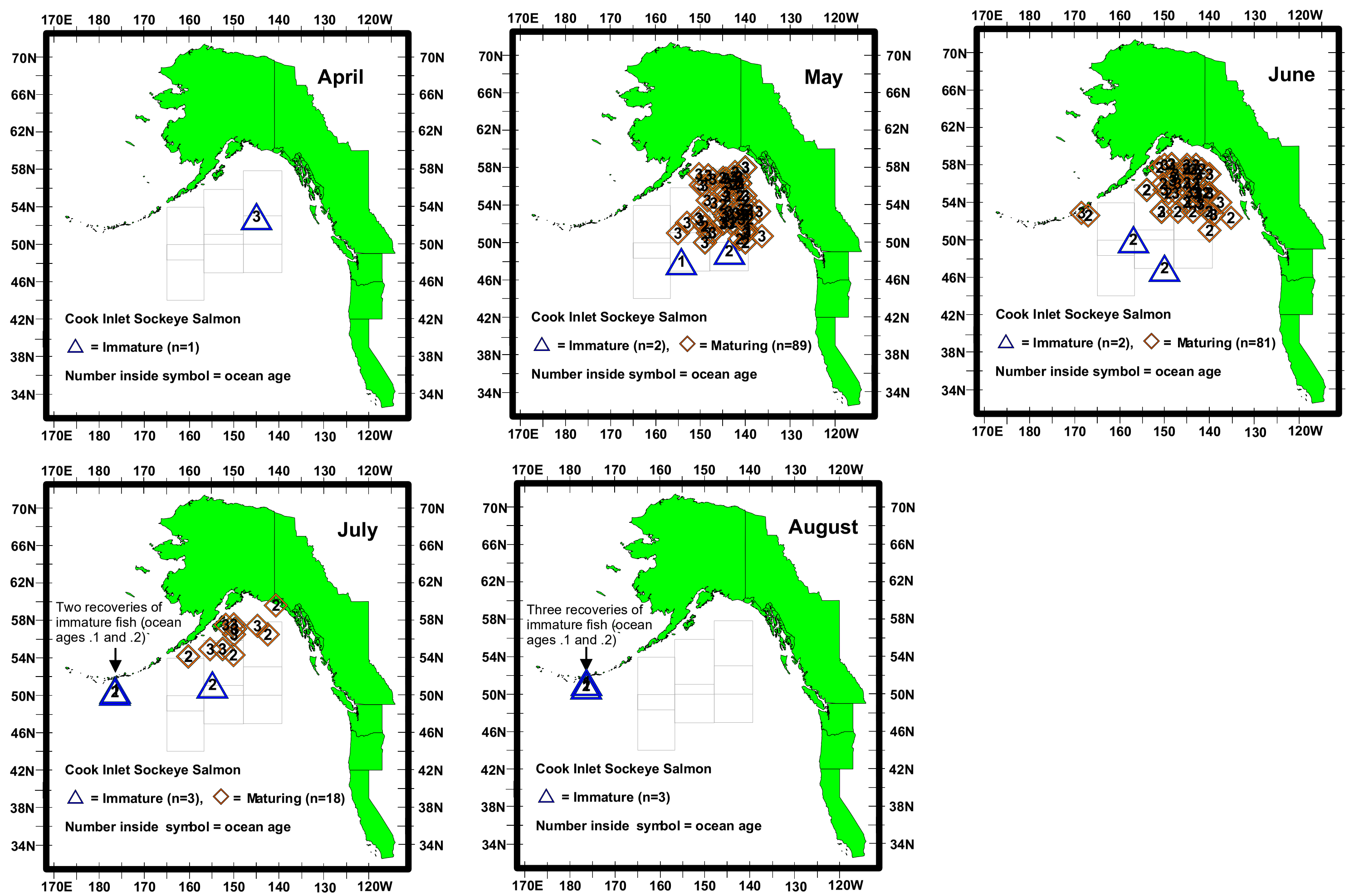


Fig. 30. The high seas distribution of Cook Inlet, Alaska, sockeye salmon by month, as shown by tagging experiments (1956-2003). The symbols indicate the ocean release locations (April-August) of tagged fish. The food habits study area is indicated by dotted lines (Fig. 2). n = total number of tagged fish recovered.

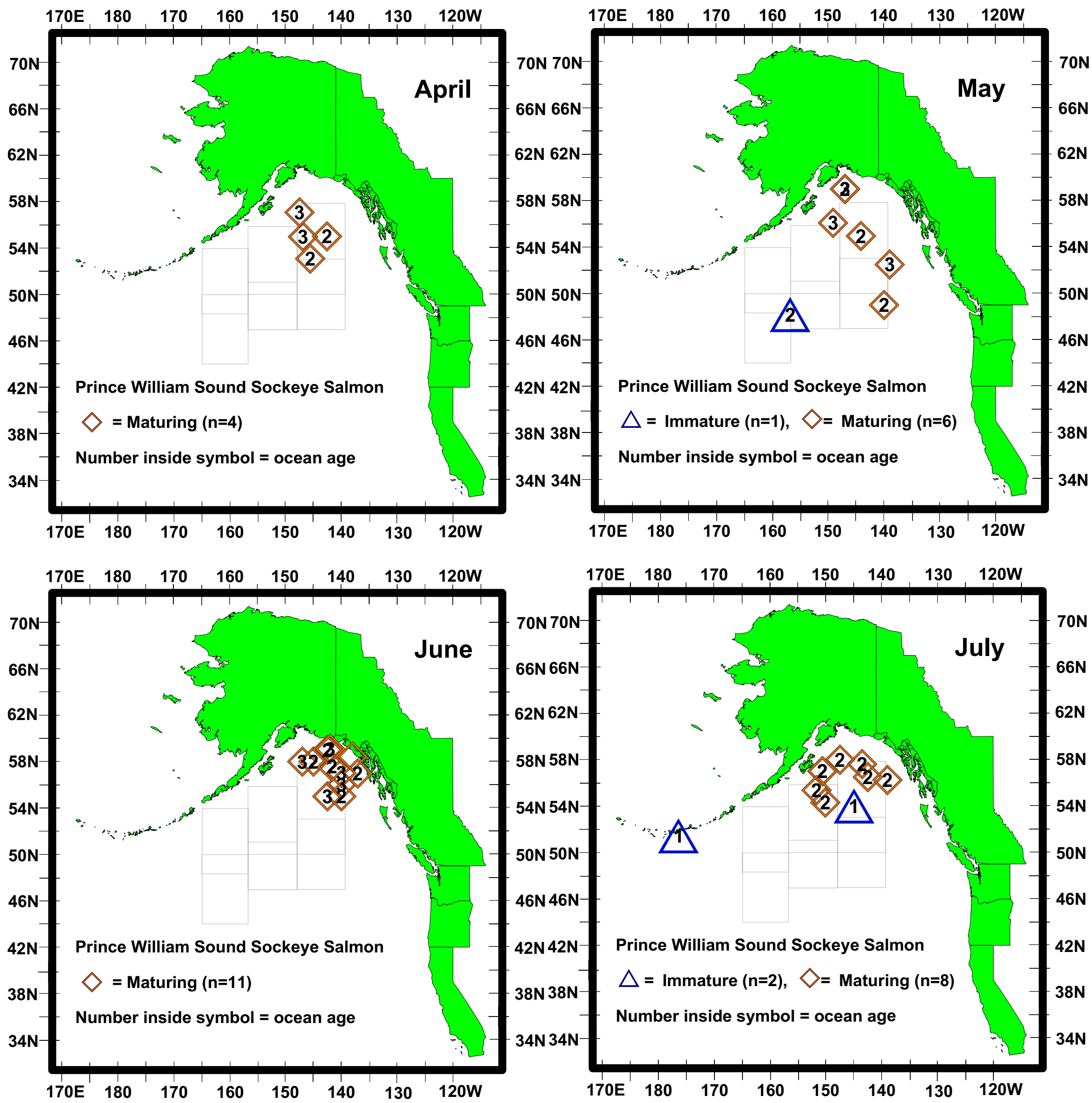


Fig. 31. The high seas distribution of Prince William Sound, Alaska, sockeye salmon by month, as shown by tagging experiments (1956-2003). The symbols indicate the ocean release locations (April-August) of tagged fish. The food habits study area is indicated by dotted lines (Fig. 2). In July, one immature fish is a CWT hatchery fish recovered in the northeast sector of the study area. n = total number of tagged fish recovered.

Appendix Table 1. List of prey animals and food items of Pacific salmon in the Gulf of Alaska in 1994-2000. Source: Kaeriyama et al. (2004).

EU	Euphausiids	
		Thysanoessa longipes
		Thysanoessa inermis
		Thysanoessa spp.
		Euphausia spp.
		Other euphausiids
CO	Copepods	
		Neocalanus cristatus
		Eucalanus bungii
		Other copepods
AM	Amphipods	
		Hyperia medusarum
		Hyperia spp.
		Themisto pacifica
		Themisto japonica
		Themisto spp.
		Primno macropa
		Phronima sedentaria
		Other amphipods
DE	Decapods	
		Decapods
SQ	Squids	
		Berryteuthis anonychus
		Gonatus middendorffi
		Other squids
PT	Pteropods	
		Limacina spp.
		Clio spp.
		Clione spp.
FI	Fishes	
		Anoplopoma fimbria
		Myctophids
		Other fish eggs and larvae
PO	Polychaetes	
		Polychaetes
CH	Chaetognaths	
		Chaetognaths
GE	Gelatinous zooplankton	
		Coelenterates
		Ctenophores
		Salps
OT	Other animals	
		Halocyprids
		Cumacea
		Octopoda
		Ostracods
		Barnacles
		Debris

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Climate Change and a Dynamic Ocean Carrying Capacity: Growth and Survival of Pacific Salmon at Sea

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Abstract.—Studies have documented reduced growth of salmon in response to competition with conspecific salmon and with other salmon species during early and late marine life stages. However, key questions remain as to whether density-dependent growth translates to reduced survival of salmon at sea and whether changes in ocean regimes, similar to that of 1976/1977, can alter this relationship. These questions are particularly important with respect to annual releases of numerous hatchery salmonids into the ocean. Few studies have tested these questions because the capacity of the ocean to support salmon is dynamic and reduced growth in Pacific salmon is often associated with great abundance of smaller fish which infers a higher overall survival rate, thereby confounding traditional statistical fisheries harvest modeling efforts. We review evidence from several recent studies suggesting that, when the density-dependent effect on growth at sea is large, salmon survival is lower with lower reproductive potential from survivors, and that the salmon carrying capacity of the ocean is influenced by climate change. We conclude that salmon growth and survival responses to oceanic changes can vary with season and life stage and that density-dependent growth at sea is an important, yet often elusive, mechanism affecting salmon survival. Pacific salmon life history models should account for these relationships.

Introduction

Impacts of climate change on salmonid fishes have been characterized in recent decades by their significant effects on interrelated biological and physical relationships including growth, survival, and abundance of salmon in the North Pacific Ocean. Transitions from one climatic state to another are called regime shifts, and there is significant literature linking such shifts in ocean condition to the distribution and abundance of aquatic organisms (Francis et al. 1998; Anderson and Piatt 1999; Hare and Mantua 2000 and 2001; Welch et al. 2000; Benson and Trites 2002; Clark and Hare 2002; Zamon and Welch 2005). There is still controversy on the true nature of “regime shift” in the North Pacific Ocean even though there is substantial support for regime-like behavior in these marine ecosystems (Hsieh et al. 2005; Mangel and Levin 2005). Pacific salmon in marine environments have faced changes in sea surface

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temperature and ocean condition associated with shifts in the Pacific Decadal Oscillation (PDO), Arctic Oscillation Index, and the El Nino-Southern Oscillation (ENSO) (Mantua et al. 1997; Hare and Mantua 2000; Minobe 2000). A well-documented climatic regime shift altered conditions in the North Pacific Ocean in 1976–1977 (Minobe 1997). A less pervasive regime shift occurred again in 1989 (Hare and Mantua 2000). Ocean conditions can significantly affect salmon growth and survival (Holtby et al. 1990; Friedland 1998; Beamish et al. 2004). Abundances of all species of Pacific salmon in the North Pacific Ocean and the Bering Sea increased after the marine climate shift during the mid-1970s (Figure 1; Rogers 1984; Beamish and Bouillon 1993; Hare et al. 1999; Mueter et al. 2007). Salmon production in the period from 1951 to 1976 averaged approximately 280 million salmon per year; after the mid-1970s climate shift, adult runs nearly doubled to approximately 520 million salmon per year (Rogers 2001; Eggers et al. 2005). Hatchery production of Pacific salmon also increased dramatically during this period contributing to confounding impacts among species, populations at sea, and recruitment (Beamish and Noakes 2002; Orsi et al. 2004; Ruggerone and Goetz 2004; Beamish et al. 2004; Spies et al. 2007).

Salmon from different regions or continents of origin can overlap at their ocean feeding grounds in the North Pacific Ocean, but the extent of overlap among species is not easily determined (McKinnell 1995; Myers et al. 1996). Density-dependent growth has been observed in Pacific salmon (Peterman 1984; Rogers and Ruggerone 1993; Bigler et al. 1996). Competition for limited resources in marine habitats has been recognized as an important factor in growth of Pacific salmon at sea (McKinnell 1995; Ishida et al. 2002; Ruggerone and Nielsen 2004; Holt and Peter-

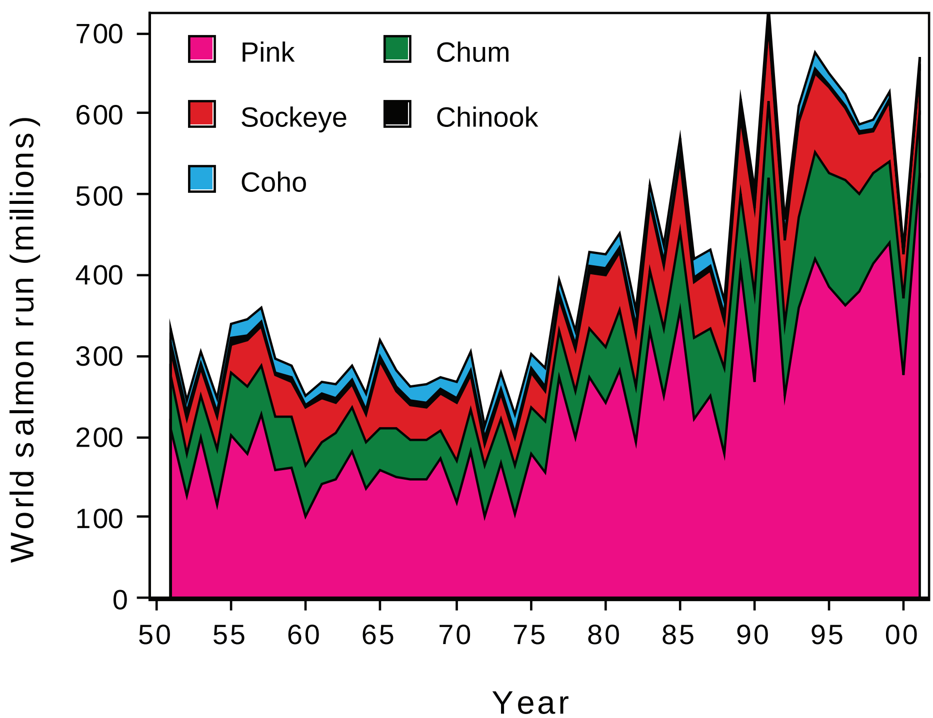

FIGURE 1. World salmon run size 1951–2001 (adapted with permission from Rogers 2001).

man 2004). Over the last quarter century, the apparent abundance of salmon in the ocean has doubled with a large component of that productivity based on artificial propagation from hatcheries with approximately 5 billion salmon fry released annually into the Pacific Ocean (Mahnken et al. 1998). In Japan, hatchery release programs for pink salmon have been credited with a significant increase in the Japanese commercial salmon harvest at sea (Hiroi 1998; Kaeriyama 1999), but Morita et al. (2006b) question their benefits in relation to loss of wild salmon production.

The ability of natural ocean systems to sustain large numbers of fish and the concept of an ocean carrying capacity for salmon remains controversial (Shuntov and Temnykh 2005). However, few studies have looked at the actual increase in net population growth for adult salmon at sea when the effects of density dependence and climate change are taken into account (Hilborn 1999; Morita et al. 2006a). Environmental and oceanic conditions at various sea-ages have been correlated with patterns in growth and survival in juvenile salmon (Mason 1974, Holtby et al. 1990; Pearcy 1992; Farley et al. 2007) and in later marine life stages where growth-related mortality appears less important (Rogers and Ruggerone 1993; Ruggerone et al. 2003).

Several life history models have been published on the impacts of climate change on marine species (Giske et al. 1992; Nonacs et al. 1994; Mangel 1994; Hilborn and Mangel 1997; Tian et al. 2004). Although many excellent papers have associated variation in Pacific salmon growth and abundance with climate change (Mantua et al. 1997; Hare et al. 1999; Beamish et al. 1999 and 2000; Wells et al. 2005), few have directly focused on the implications of a changing marine environment on salmon life history characteristics. Climate change may influence the important trade off between somatic growth and reproductive investment since salmonid life history variation is a trade off between the optimal allocation of resources to maximize growth during early life stages and facilitate reproduction in later life stages (Fleming and Gross 1989; Thorpe 1990). Marine growth has been associated with age-at-maturity in Pacific salmon (Bigler et al. 1996; Pyper and Peterman 1999; Pyper et al. 1999; Morita et al. 2005). Older, maturing salmon are usually larger adults (Friedland and Haas 1996; McGurk 1996: Hobday and Boehlert 2001); fish size has been directly correlated with egg number and size (Fleming and Gross 1990; Mangel 1994; Quinn et al. 2004) and reproductive success (Gross 1991; Beacham and Murry 1993; Quinn et al. 1995). Therefore, salmon that are impacted by climate variation and/or density-dependent factors, leading to reductions in growth and development, may lose individual reproductive potential despite increases in total abundance. In this paper we review 1) the productivity-climate change relationship documented for salmon in the North Pacific Ocean in relation to growth-at-sea for different life stages, and 2) the effects of the mid-1970s regime shift on salmon growth and abundance. We explore potential causes of density-dependent salmon growth in marine habitats and discuss the implications that reduction of growth-at-sea may have on life history trade offs.

Early Growth and Movements at Sea

Anadromous Pacific salmon typically spend 1–5 years at sea where the majority of their growth and development takes place (Groot and Margolis 1991). Some salmon migrate over great distances to feed in the ocean while others remain relatively close to shore during their whole ocean cycle (Quinn and Myers 2005). Survival during the first year at sea is most difficult for Pacific salmon, and growth and survival appear to be linked (Pearcy 1992; Beamish and Mahnken 2001; Farley et al. 2005, 2007). During their early weeks at sea, growth-mediated survival may define year-to-year variability and patterns of recruitment in salmon populations (Friedland 1998; Welch et al. 2000; Beamish and Mahnken 2001).

Physiological adaptation to the marine environment, the need to discover previously unknown food resources, and a gauntlet of active predators take their toll on young marine salmon. Changes in climate can affect survival during any of these activities. Although salmon species have feeding tendencies, salmon select a variety of prey at different life stages which may represent several trophic levels (Kaeriyama et al. 2004). Significant changes in chlorophyll and zooplankton abundance and distribution have been associated with patterns of climate change (Napp and Hunt 2001; Gregg 2002; Zamon and Welch 2005). Major zooplankton assemblages have shifted their composition since the early 1990s (Kang et al. 2002). Recent increases in gelatinous zooplankton in the Bering Sea have been linked to climate change (Brodeur et al. 1999). Anomalous blooms of coccolithophores *Emiliania huxeyi* in the Bering Sea have been suggested as disruptive ecosystem components affecting the distribution and abundance of marine fauna (Napp and Hunt 2001). Large oceanographic models such as PICES' Carrying Capacity and Climate Change BAsin Scale Studies (CCCC BASS; Aydin et al. 2003) have been developed to facilitate understanding of the impacts of climate change and climate variability on physical and lower trophic level biological processes in the North Pacific Ocean, but these models are not yet connected to upper trophic level fishes. Also, in some regions, such as the Bering Sea, the mid-1970s climate shift did not lead to a significant change in zooplankton biomass (Napp et al. 2002).

Significant changes in the distribution and abundance of predators such as marine birds, sea lions, baleen whales, walleye pollock, and Pacific salmon have recently been recorded in the eastern Bering Sea, most likely linked to changes in the availability of different prey (Merrick 1997; Hunt et al. 2002). Empirical data show that ocean regime shifts influence the composition and productivity of both higher and lower tropic levels in marine habitats (Francis and Hare 1994; Francis et al. 1998; Anderson and Piatt 1999; Gregg 2002). Our own studies indicate that sockeye growth during their first two years at sea tended to be greater after the mid-1970s (Ruggerone et al. 2005). Greater growth in the first year at sea was most pronounced in salmon from Bristol Bay which occupy the Bering Sea, while growth in the second year at sea was greatest in salmon from the Chignik River which inhabit the North Pacific Ocean (Figure 2).

Mechanisms supporting marine growth and survival for young salmon are poorly understood in part because stock-specific salmon distributions span exceptionally broad areas that include multiple ocean habitats. Therefore, it is understandable that the concept of a food competition-related ocean carrying capacity has long been controversial (Cushing 1975; Joyner 1975; Aydin 2000; Azumaya and Ishida 2000; Achord et al. 2003; Ruggerone and Nielsen 2004; Shuntov and Temnykh 2005). Evidence is growing that greater prey availability during early marine life of salmon contributed to greater salmon abundance following the 1977 regime shift in the North Pacific Ocean (Brodeur and Ware 1992; Ruggerone et al. 2005). In Puget Sound, salmon prey availability was greater prior to the 1982/83 El Niño. The 1982/83 El Niño and subsequent events appeared to reduce prey abundance, thereby enhancing competition between juvenile pink salmon *Oncorhynchus gorbuscha* and juvenile Chinook salmon *O. tshawytscha*, which experienced significantly reduced growth and a 62% reduction in survival when pink salmon were present during 1984–1997 (Ruggerone and Goetz 2004).

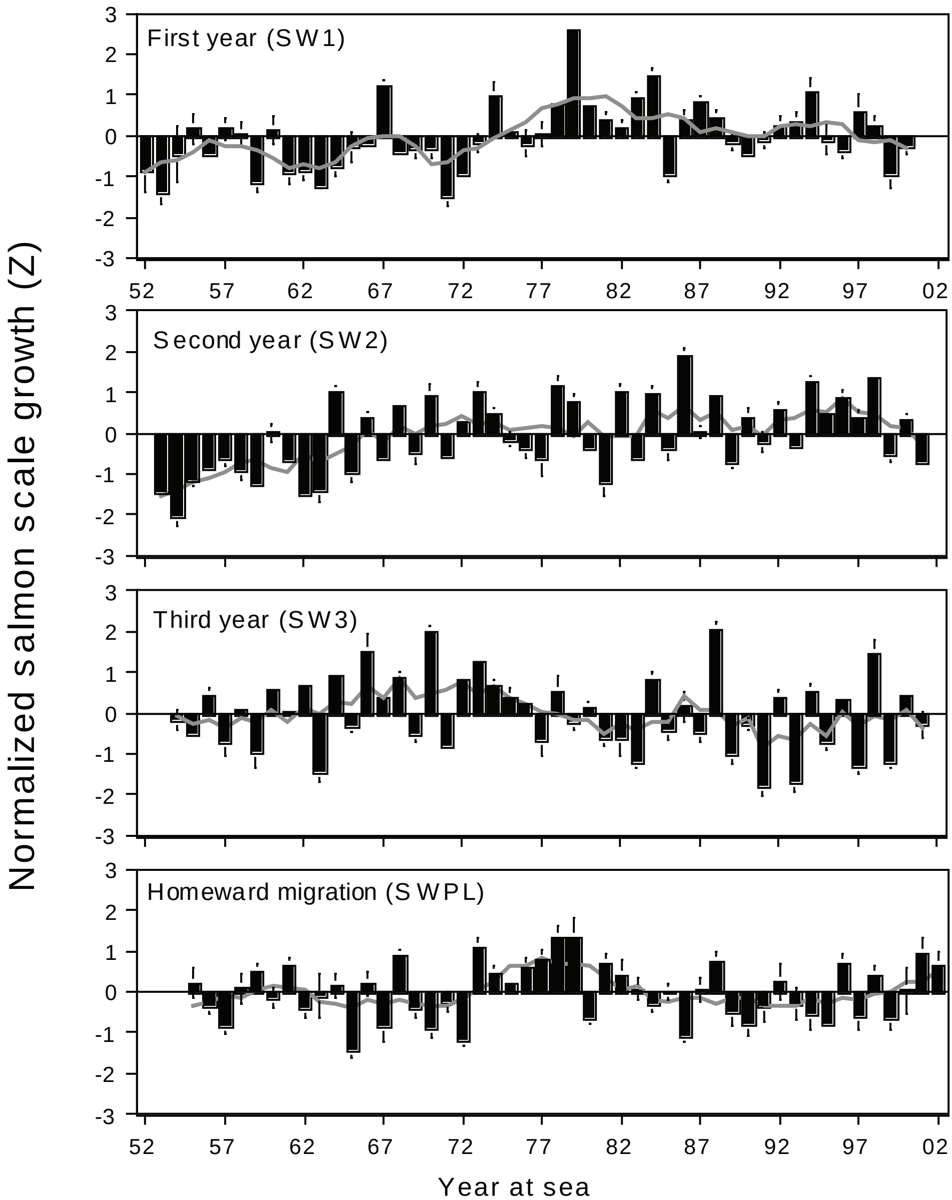

FIGURE 2. Trends in sockeye salmon *O. nerka* scale growth 1952–2002 in: a. Bristol Bay sockeye and b. Chignik River sockeye populations (with permission Ruggerone et al. 2007). Growth is normalized to the population mean.

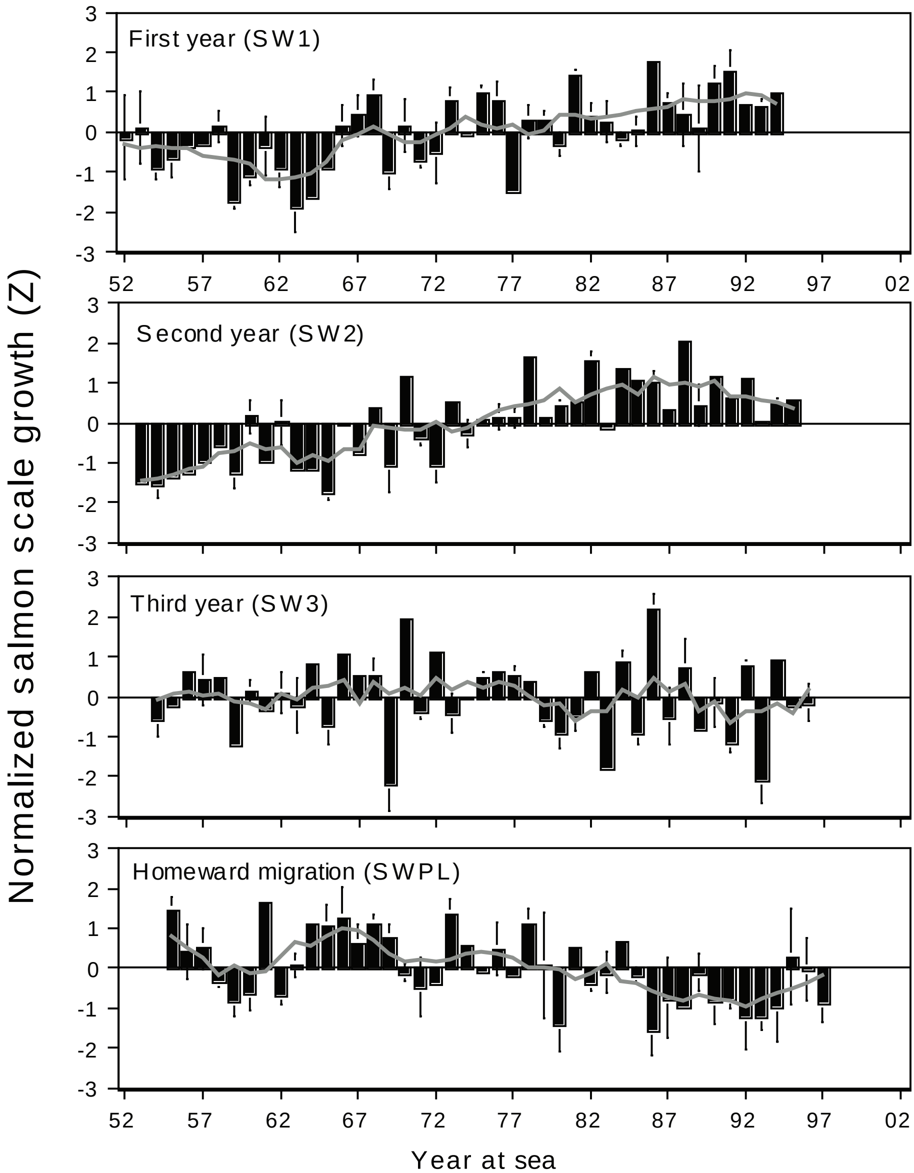

FIGURE 2. Continued.

Most studies of early-marine salmon responses to climate change have focused on bottom-up control of salmon abundance. However, some evidence suggests predation by salmon sharks *Lamna ditropis*, North Pacific daggertooth *Anotopterus nikparini* and other predators may influence juvenile salmon abundance in oceanic habitats (Welch et al. 1991; Yodzis 2001; Nagasawa 1998). Beamish and Neville (1995) reported that river lamprey *Lampetra ayresii* attack and kill a significant portion of Chinook and coho salmon *O. kisutch* in the Fraser River plume. In Puget Sound, abundances of most salmon predators were much greater prior to the series of El Nino events beginning in 1982/83 and predation rather than competition appeared to be the primary mechanism of mortality affecting Chinook salmon during 1972–1983 (Ruggerone and Goetz 2004). Changes in salmon predator abundances in the North Pacific Ocean have not been directly linked to climate change, although salmon shark abundance increased sharply in 1996 and thereafter compared with 1984 to 1993 (Nagasawa et al. 2002). Size-dependent predation has been suggested as a key mechanism linking climate change and salmon growth to salmon survival and abundance, but few data are available on size-dependent predation after salmon leave nearshore marine areas (Holtby et al. 1990). Ultimately, the relative importance of mechanisms leading to mortality of salmon at sea, such as predation, delayed density-dependent effects, starvation, or disease, are rarely quantified.

Salmon Maturation at Sea

Life at sea for anadromous salmonids serves two purposes—one to grow rapidly and survive in marine habitats; the other to develop gonadal material for reproduction. Aquaculture has provided a large literature on the growth/reproductive trade offs measured in terms of the gonosomatic index (GSI) necessary for salmonid reproduction (Hoar et al. 1983). In general, age at maturity in Pacific salmon has been linked to marine growth with faster growing progeny generally maturing at younger ages (Hankin et al. 1993; McGarvey et al. 2007). Somatic growth rates in apparently similar individuals, however, often vary widely producing dynamic effects in reproductive potential (Sebens 1987; Bacon et al. 2005). At a specific point in adult development, most energetic inputs cease to contribute to somatic growth and, instead, begin to contribute to reproductive development. However, the turning point in the trade off between these two physiological processes has not been well described for adult Pacific salmon at sea. A smooth progression through reproductive cycles at sea depends on the continuing interplay between an individual endrocrine system and the environment (Lam 1983). We can therefore assume that hormonal, environmental, and behavioral aspects of salmonid gametogenesis may be influenced by climate change.

Photoperiod and/or temperature are generally recognized as the most important cues in the timing of gametogenesis in temperate fishes. Typically, oocytes progress into early vitellogenesis when a fish is exposed to low temperatures and short photoperiod, but warmer temperatures are required for final oocyte maturation and spawning (Scott 1990). In addition to temperature cues, the primary growth phase of oocytes in salmonid females, i.e. yolk vesicle formation and endogenous vitellogenesis, requires significant exogenous input of energy for lipid development. Viable salmon eggs contain over 80% lipid stores in the form of yoke material (Lam 1983). Gonadal development in marine environments—in females particularly—requires significant energy which in turn is linked to the availability and quality of food at sea (Aydin 2000).

Neutral lipids (as opposed to cellular or polar lipids) are used by salmon as an energy source while at sea (Davis et al. 1998; Nomura et al. 1999; Myers et al. 2000). Lipid levels can vary from 3% to 23% during spring and summer in chum and pink salmon (Nomura et al. 2000), and significant differences in lipid levels have been found between younger (lower) and older (higher) chum salmon white muscle tissues (Nomura et al. 2001). Lipid-rich squid provide an important resource for salmon at sea (Lordan et al. 1998; Yatsu et al. 2000; Davis et al. 2001). Changes in lower trophic levels, i.e. zooplankton biomass and composition, have been positively associated with squid production (Nesis 1997; Kang et al. 2002). Therefore, we speculate that variation in bottom-up ocean conditions resulting from climate change (Brodeur and Ware 1992; Sakurai et al. 2000) may have a significant effect on salmonid development and subsequent reproductive success.

We examined age at maturation of Bristol Bay salmon in relation to climate shifts during 1952 to 1998. Total age at maturation of westside and eastside Bristol Bay sockeye salmon stocks remained relatively constant throughout three climate regimes (Figure 3, bottom panel). However, the number of

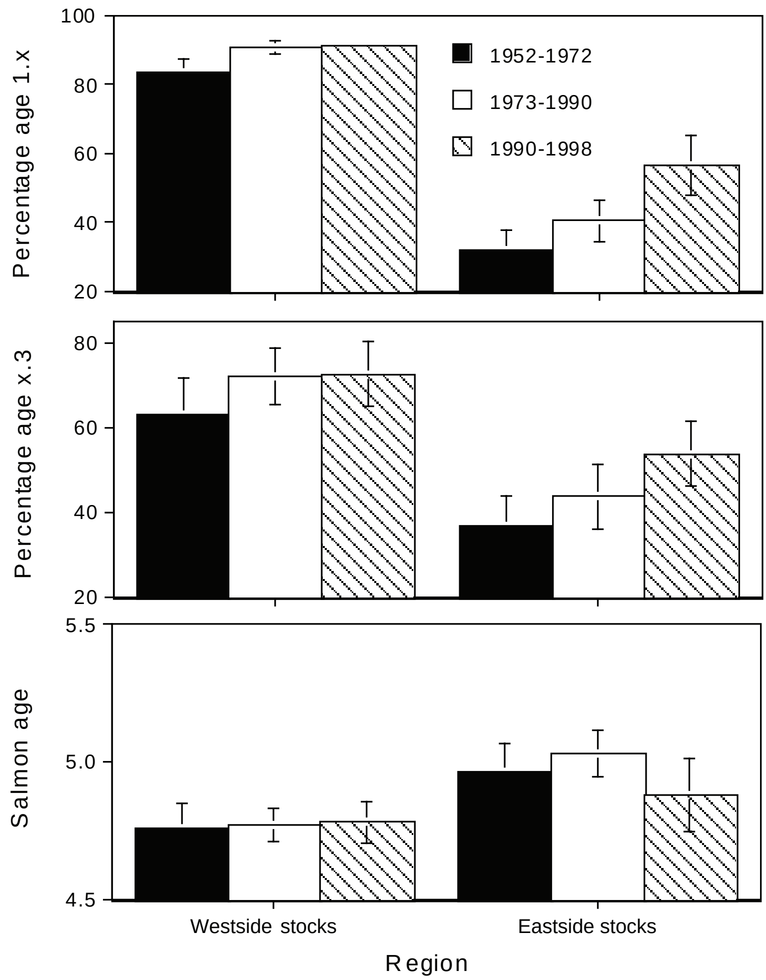

Figure 3. Freshwater and marine age composition and total mean age of eastside and westside Bristol Bay sockeye salmon *O. nerka* stocks during three climate regimes, 1952–1998. Values are mean ± 1 SE (with permission Ruggerone and Link 2006).

years spent in freshwater versus marine areas changed markedly between each regime, except for westside stocks during the recent 1989 climate shift. Among eastside sockeye salmon stocks, the percentage of freshwater age 1 (1.x) and ocean age 3 (x.3) salmon increased over time and during each regime (Ruggerone and Link 2006). Reduced salmon residence time in freshwater (in likely response to increasing temperature during the past 45 years) was associated with increased time in the ocean, leading to little change in total age at maturation (Peterman et al. 2003; Ruggerone and Link 2006). Thus, Bristol Bay sockeye salmon have tended to experience a relatively fixed age at maturation, which is achieved through trade offs of residence in freshwater versus marine environments (Rogers 1987). Warming temperatures can have a marked effect on residence in lakes and the ocean, especially among populations such as those on the eastside of Bristol Bay where fish formerly tended to spend two winters in freshwater and two winters at sea. Changes in the ocean age may affect reproductive potential and success of salmon through changes in fecundity or by affecting the ability of salmon to successfully spawn in habitats where size affects reproductive success, e.g., large rivers, shallow creeks, and areas with size-dependent predation by bears.

Climate Change and Late Ocean Life Stages

Marine fish populations have been shown to be responsive to climate variability with strong regional and local patterns (Mueter et al. 2002; McGinn 2002 and literature therein). Since adult salmon at sea are influenced by climate on multiple temporal and spatial scales, it is important to link questions and data to the same scale. Climate drivers have large-scale regional footprints. Data collected from sediments in sockeye-bearing lakes suggest that climate and salmon runs may have a long correlated history (Finney et al. 2000). Several studies have shown that the distribution and abundance of anadromous salmon returning to freshwater to spawn are vulnerable to the influences of climate change on a more local scale (Beamish and Bouillon 1993; Clark and Hare 2002; Meuter et al. 2002; Beamish et al. 2004; Pyper et al. 2005). Changes in ocean temperature may affect the migration timing and behavior of locally adapted spawning stocks (Bernatchez and Dodson 1987; Hodgson and Quinn 2002; Ruggerone 2004). However, inter-decadal and even shorter patterns in climate variation have had associated fisheries impacts (McGinn 2002).

Several recent climate simulation models and empirical models predicted a phase shift in fisheries productivity from northern to southern Pacific Ocean habitats based on cyclical climatic fluctuations (Francis and Sibley 1991; Peterson et al. 1993; Peterman et al. 1998; Francis et al. 1998; Anderson and Piatt 1999; Hare and Mantua 2001; Botsford et al. 2002). Under this concept, salmon in northern British Columbia and Alaska are thought to be on an alternate trajectory of abundance compared with southern stocks (Hare et al. 1999; Pyper and Peterman 1999). Furthermore, productivity of salmon populations tends to be more correlated among nearby compared with distant stocks, implying that regional climate affects salmon populations in addition to large-scale effects (Pyper et al. 2005).

Although large scale and regional oceanographic features are important to salmon production, the interactions between species originating from distant regions is also important. For example, multivariate time series analyses indicated that Bristol Bay sockeye growth during the second year at sea was negatively related to abundance of Eastern Kamchatka pink salmon and positively related to winter sea-surface temperature in the North Pacific Ocean (Ruggerone and Nielsen 2004).

Additionally, McKinnell (1995) reported that growth of northern British Columbia sockeye salmon during their last year at sea may be negatively influenced by abundance of Bristol Bay sockeye salmon.

Fisheries harvest data supporting negative sockeye growth at sea in relationship to abundance, however, remain controversial. A PDO phase shift thought to contribute to this effect was documented in 1998, but recent recruitment to Pacific salmon stocks in different geographic regions has been mixed (Beamish et al. 2004). Significantly larger runs of salmon have been reported in recent years in some Pacific Northwest rivers, but not in others (Keefer et al. 2004). Salmon in Alaska have also experienced variable productivity with declines in some Bristol Bay stocks, but not in other geographically proximate rivers (Ruggerone and Nielsen 2004; Ruggerone and Link 2006). Local variations in natural productivity or effects of fisheries are likely superimposed on broad-scale, climate-driven production variations. Little data are available for salmon growth at sea throughout each life stage. Our studies concluded that Bristol Bay and Chignik River sockeye salmon *O. nerka* growth declined during their third year at sea and during their homeward migration after the mid-1970s (Ruggerone et al. 2007). Reduced growth during their third year at sea was especially great during odd-numbered years when Asian pink salmon were most abundant (see below).

Local, fine-scale environmental conditions in both near-shore marine and freshwater outflow habitats may play an important role in the climate-salmon relationship (Mueter et al. 2002). Global change effects may impact estuarine migration patterns and oxygen consumption requirements for migrating salmon (Stevenson et al. 2002; Roessig et al. 2004). Additional research is needed on salmon life histories at the freshwater-marine interface during upstream and downstream migrations under different patterns of climate change.

Climate Change and Population Distribution

The most abundant North American salmonid populations in the Pacific Ocean are thought to have colonized freshwater habitats from more southern refugia populations since the end of the last ice cover, less than 10,000 years before present (Macdougall 2004). Warming climate may increase or accelerate the movement of aquatic species including spawning salmon populations further north (Welch et al. 1998; Rahel 2002; Roessig et al. 2004; Perry et al. 2005; Wing 2006). All five Pacific salmon species have been recently reported in previously unoccupied riverine habitats in the Canadian arctic (Babluk et al. 2000; Beamish and Noakes 2002). Incidental reports of coho, pink and chum salmon *O. keta* are available from rivers draining into the North Bering and Chukchi seas in Alaska, north of the current limits of each species' range (Craig and Haldorson 1986; Beamish and Noakes 2002). In 2004 and 2005, unprecedented numbers of pink salmon returned to the Norton Sound region, apparently in response to warm ocean temperatures in recent years (G. Sandone, Alaska Department of Fish and Game, personal communication) and the most northerly sockeye population in Port Clarence has expanded dramatically over the past five years (E. Knudsen, C. Lean, K. Dunmall and G. Sandone, personal communications). Natural colonization of novel habitats by Pacific salmon has been facilitated in Alaska by glacial retreat (Milner et al. 2000). Novel colonizations of new glacial streams have resulted in highly variable ecosystem structure and research has shown that colonization pathways can differ significantly across ecosystems (Milner and Bailey 1989; Burger et al. 2000; Milner et al. 2000; Pavey 2004; Quinn and Myers 2005). There is a clear need to study shifts in life history characteristics of salmon in relation to climate change and colonization of new habitats (Field and Francis 2002; Pavey 2004).

Asian Pink Salmon Affect Sockeye Growth and Survival at Sea

The mechanisms linking Pacific salmon growth and abundance in the ocean and climate change are very complex and often nonintuitive since most salmonid literature has focused on the freshwater phase of these fish. One aspect of the overall productivity for salmon at sea has clearly increased extensively over the last three decades, artificial propagation and release of hatchery fish into marine habitats. Salmon hatcheries across the North Pacific Ocean, in the U.S., Canada, and throughout Asia, release up to five billion salmon a year (Mahnken et al. 1998). Natural salmon production in wild riverine habitats, such as the Kamchatka Peninsula, has also increased substantially over the last three decades (Sinyakov 1998). Differentiation of hatchery and wild fish at sea is sometimes problematic since not all hatchery fish are marked at their hatchery of origin (Heard 1998). Interactions between wild and hatchery-produced salmon at sea have only recently been studied (Levin et al. 2001; Orsi et al. 2004; Wertheimer et al. 2004). However, the rapid increase in hatchery and wild salmon abundance in the North Pacific Ocean following the 1977 regime shift led to food limitations with intra-specific (Rogers and Ruggerone 1993; Bigler et al. 1996) and nonlinear inter-specific effects (Burkett et al. 2005) on salmon growth.

In northern latitudes where wild salmon have been especially abundant, the 1976/1977 regime shift appeared to enhance growth and survival of salmon during early marine stages, leading to density-dependent effects during older stages when survival is less influenced by growth (Ruggerone et al. 2002, 2007). During 1958–1999, annual growth of Bristol Bay sockeye salmon was low during odd-numbered years of the second and third years at sea (Figure 2), a pattern that was opposite from that of Asian pink salmon abun-

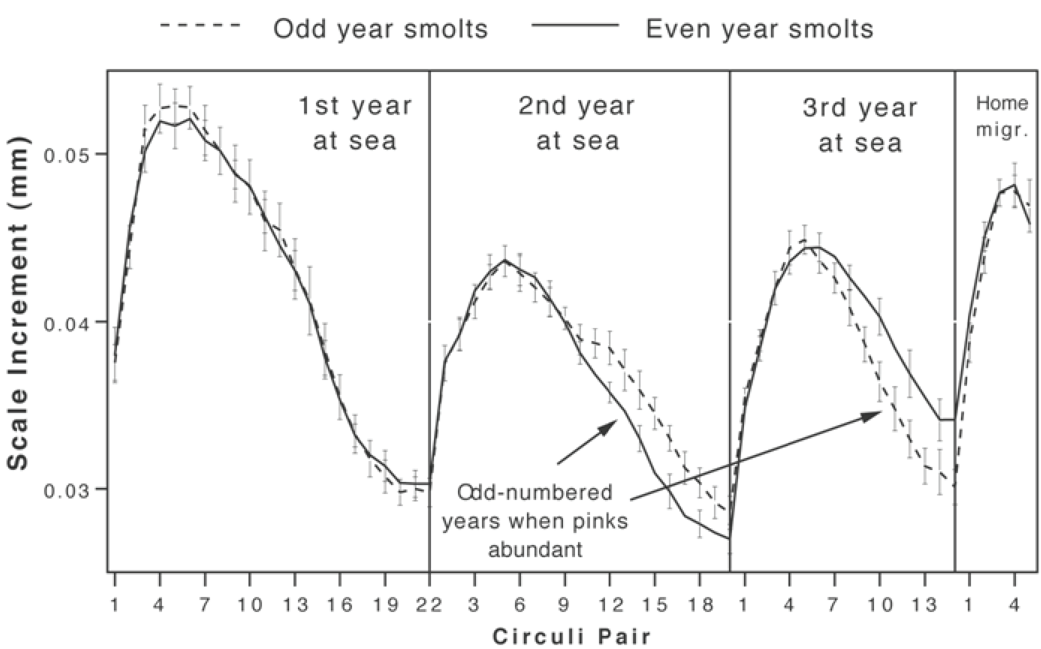

FIGURE 4. Seasonal growth at sea of Bristol Bay sockeye salmon during odd- and even-numbered years, based on circuli measurements from adult scales (with permission Ruggerone et al. 2005).

dance (Ruggerone et al. 2003). Competition with pink salmon occurred after peak sockeye growth in spring (Figure 4). The effect of competition on sockeye salmon growth appeared to transcend the 1976/1977 ocean regime shift because both salmon species responded similarly to the large scale climate change and increased over time (Ruggerone et al. 2005). No competition was detected during the first year at sea when there was little or no overlap with Asian pink salmon. First year competition may not be expressed in growth if all smaller fish died during their first year at sea (Farley et al. 2007). Interspecific competition was also not evident in the homeward migration of sockeye salmon when there was no overlap with Asian pink salmon.

Adult Bristol Bay sockeye length decreased in years with large Bristol Bay sockeye runs and in years following large Asian salmon runs indicative of density-dependent growth (Ruggerone et al. 2003). Sockeye salmon lengths in Bristol Bay stocks were greater in 1977–2000 compared to 1958–1976 at a given abundance of adult sockeye and pink salmon (Figure 5). However, recent evidence indicates the mid-1970s and 1989 climate shifts affected sockeye salmon size at age in addition to inter- and intraspecific competition (Ruggerone et al. 2007). The decline in size at age of Bristol Bay sockeye salmon after the 1989 climate shift may have reduced individual reproductive success of ocean age-2 sockeye salmon and contributed to the observed decline in productivity of stocks associated with a high proportion of ocean age-2 sockeye salmon (Ruggerone and Link 2006).

Recent research on species interactions in the ocean has provided evidence that competition can lead to reduced survival of salmon. During 1977–1997, sockeye salmon smolts from Bristol Bay, Alaska, experienced 26–45% lower survival at sea when migrating during even-numbered years and competing with Asian pink salmon (Ruggerone et al. 2003). Age-1 smolts experienced greater mortality compared with age-2 smolts. Adult returns from even-year smolt migrations were 22% lower, on average, leading to 482 million fewer adult sockeye salmon produced by smolts during 1977–1997 (Ruggerone and Nielsen 2004). Prior to the 1976–1977 ocean regime shift, scale growth of sockeye salmon was reduced during years of great pink salmon abundance but a reduction in sockeye salmon abundance was not detected, possibly because the high seas salmon fishery captured many Bristol Bay sockeye salmon.

In the Pacific Northwest, an analysis of 53 million coded-wire-tagged Chinook salmon demonstrated that juvenile Chinook salmon survival declined 62% when entering Puget Sound and lower Strait of Georgia in even-numbered years along with the large migration of juvenile pink salmon, 1984–1997 (Ruggerone and Goetz 2004). No odd-even pattern of survival was detected among Chinook salmon released in coastal areas where few pink salmon originate. Coastal data and age-specific adult recoveries of Puget Sound Chinook salmon indicated that mortality occurred in Puget Sound and the lower Strait of Georgia during the first year at sea. Growth of Chinook salmon was significantly reduced and age at maturation was extended when competing with pink salmon. During 1972–1982, the odd-even year pattern of survival was reversed. The authors provided evidence that the mechanism of Chinook salmon mortality switched from primarily predation to competition in response to climate change and associated declines in piscivores and prey availability and an increase in pink salmon abundance.

Summary

Environmental change in critical marine habitats has had a significant impact on salmonid populations throughout the Pacific Rim. This review of studies exploring ocean

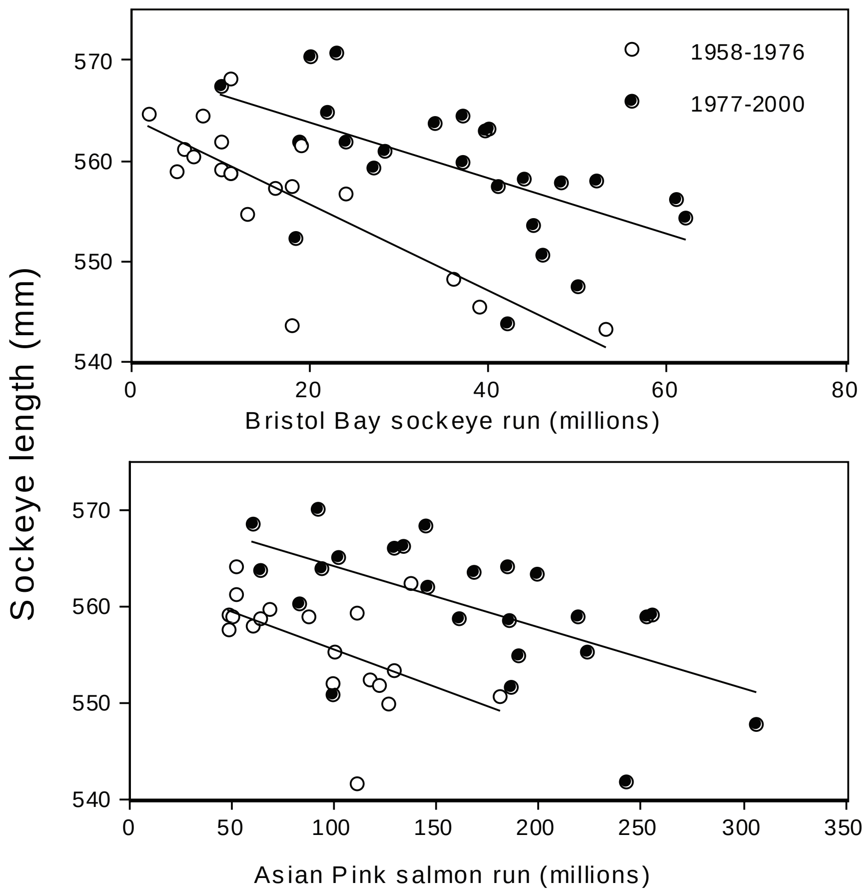

FIGURE 5. Regression-corrected plots of adult, age 1.3, female, Bristol Bay, sockeye salmon *O. nerka* lengths in relation to adult abundance of Bristol Bay sockeye salmon (A) and Asian pink salmon abundance during the previous year (B). Salmon lengths are partial residuals based on the following multivariate equation (adapted with permission Ruggerone et al. 2003): Length (mm) = 571.7 – 0.0339 (sockeye run) – 0.067 (pink run) + 8.76 (period); r^2 = 0.059, where period is coded as "1" after the 1976/1977 regime shift or "0" prior to 1977.

condition and physical forces that shape the North Pacific system showed significant relationships with salmon growth and productivity. However, the effects of climate change on other life history traits, such as age at maturation and fecundity, have not been well-documented and impacts of ocean regime change on community ecology are even less well known (see Mangel and Levin 2005). Anadromous salmonids demonstrate diverse behavior in their passage through coastal and marine habitats with important physiological trade offs required for survival and reproduction during these transits. Our research has shown that density-dependent growth in sockeye salmon varies with life stage and season. These patterns in marine growth can be associated with climate change and density-dependent factors that are both natural and human-induced. Greater abundance and productivity of Alaskan salmon following the 1976/77 ocean regime shift was associated with greater salmon growth during the first two years at sea. However, density-dependent growth was significant at later life stages when growth-related mortality was less important and maturation and reproduction became primary functions affected by growth. Further research needs to be done on the relationship between growth-related changes in fecundity and maturity with total returns of North Pacific salmon in relationship to climatic variation. Hatchery and wild pink salmon production in the North Pacific Ocean has grown significantly following the 1976/77 regime shift. Our research suggests that greater pink salmon abundance has affected growth, survival, and abundance of Bristol Bay sockeye salmon over the last several decades. Salmon life history models developed for this time of dynamic ocean and climatic conditions should not ignore density-dependent growth at sea when modeling the often elusive mechanisms affecting salmon survival.

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Seasonal marine growth of Bristol Bay sockeye salmon (*Oncorhynchus nerka*) in relation to competition with Asian pink salmon (*O. gorbuscha*) and the 1977 ocean regime shift

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Abstract—Recent research demonstrated significantly lower growth and survival of Bristol Bay sockeye salmon (*Oncorhynchus nerka*) during odd-numbered years of their second or third years at sea (1975, 1977, etc.), a trend that was opposite that of Asian pink salmon (*O. gorbuscha*) abundance. Here we evaluated seasonal growth trends of Kvichak and Egegik river sockeye salmon (Bristol Bay stocks) during even- and odd-numbered years at sea by measuring scale circuli increments within each growth zone of each major salmon age group between 1955 and 2000. First year scale growth was not significantly different between odd- and even-numbered years, but peak growth of age-2. smolts was significantly higher than age-1. smolts. Total second and third year scale growth of salmon was significantly lower during odd- than during even-numbered years. However, reduced scale growth in odd-numbered years began after peak growth in spring and continued through summer and fall even though most pink salmon had left the high seas by late July (10–18% growth reduction in odd *vs.* even years). The alternating odd and even year growth pattern was consistent before and after the 1977 ocean regime shift. During 1977–2000, when salmon abundance was relatively great, sockeye salmon growth was high during specific seasons compared with that during 1955–1976, that is to say, immediately after entry to Bristol Bay, after peak growth in the first year, during the middle of the second growing season, and during spring of the third season. Growth after the spring peak in the third year at sea was relatively low during 1977–2000. We hypothesize that high consumption rates of prey by pink salmon during spring through mid-July of odd-numbered years, coupled with declining zooplankton biomass during summer and potentially cyclic abundances of squid and other prey, contributed to reduced prey availability and therefore reduced growth of Bristol Bay sockeye salmon during late spring through fall of odd-numbered years.

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Competition among Pacific salmon (*Oncorhynchus* spp.) for food resources in the North Pacific Ocean and Bering Sea is a potentially important mechanism affecting salmon growth and population dynamics. Reduced growth at sea may lead to delayed maturation (Rogers, 1987), lower reproductive potential (Groot and Margolis, 1991), or greater risk of predation (Juanes, 1994).

Density-dependent growth in the ocean has been observed among sockeye (*O. nerka*), pink (*O. gorbuscha*), and chum salmon (*O. keta*), which are the most abundant species among Pacific salmon (Rogers[1]; Eggers et al.[2]). Density-dependent growth may occur during early marine life (Peterman, 1984) or during the homeward migration period when the potential for high growth rate (Ishida et al., 1998) may be influenced by high concentrations of salmon (Rogers and Ruggerone, 1993).

Since the early 1970s, salmon abundance in the North Pacific Ocean has increased, whereas body size for many populations of all salmon species has declined (Bigler et al., 1996). However, greater abundance of adult sockeye salmon returning to Bristol Bay, Alaska, was associated with increased growth during the first and second years at sea, followed by relatively low growth during the third year at sea, and greater adult size at a given abundance (Ruggerone et al.,

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2002). Increased growth of Bristol Bay sockeye salmon during the first two years at sea was associated with greater adult returns, but high abundance apparently led to increased competition and reduced growth during the third year.

The potential for competition for food between Asian pink salmon and Bristol Bay sockeye salmon stocks is great in the North Pacific Ocean and Bering Sea. Trophic level, diet, and feeding behavior of pink salmon overlap significantly with sockeye salmon (Welch and Parsons, 1993; Davis et al., 2000; Kaeriyama et al., 2004). Asian pink salmon are highly abundant, averaging approximately 162 million adults in odd-numbered years and 104 million adults in even-numbered years, 1955 to 2000 (Rogers[1]). Bristol Bay sockeye salmon and Asian pink salmon overlap in the central North Pacific Ocean and the Bering Sea. Greatest overlap is with pink salmon from the eastern Kamchatka Peninsula and Sakhalin Island (French et al., 1976; Takagi et al., 1981; Myers et al.[3]), which are especially abundant, as shown by average harvests of 79,000 metric tons (t) in odd-numbered years and 33,000 t in even-numbered years, 1955–99 (Sinyakov, 1998; Anonymous[4]).

Evidence for competition between Asian pink and Bristol Bay sockeye salmon was provided in a recent investigation by Ruggerone et al. (2003). During 1955–97, annual sockeye salmon scale growth during the second and third years at sea was significantly reduced during odd- compared to even-numbered years. Adult sockeye salmon length was relatively low when sockeye salmon overlapped with abundant odd-year pink salmon during the year prior to homeward migration. Furthermore, smolt-to-adult survival of Bristol Bay sockeye salmon was significantly lower when they encountered odd-year pink salmon during the second year at sea. However, Bristol Bay sockeye salmon encountered relatively few pink salmon during their first year at sea and no competition effect was observed during this early marine period.

In our study we examined the seasonal growth of Bristol Bay sockeye salmon scales in an effort to determine the approximate timing and duration of reduced growth during odd-numbered years at sea that was observed by Ruggerone et al. (2003). Scale circuli increments and annuli are correlated with salmon body size (Clutter and Whitesel, 1956; Fukuwaka and Kaeriyama, 1997; Fukuwaka, 1998). We compared seasonal scale growth before and after 1977 to examine seasonal growth trends associated with the twofold increase in Bristol Bay sockeye salmon abundance and the 1977 ocean regime shift (Rogers, 1984; Beamish and Bouillon, 1993; Rogers[1]). We also examined the hypothesis that seasonal growth during the second growing season was dependent on previous marine growth (Aydin, 2000). These hypotheses were tested by using scales from Kvichak River and Egegik River sockeye salmon, which averaged approximately 16 million fish per year or approximately 57% of the annual sockeye salmon run to Bristol Bay, 1955–2000.

Methods

For our study, we used scales from four age groups of Kvichak River sockeye salmon and three age groups of Egegik River sockeye salmon collected from the late 1950s through 2000 (Fig. 1). Adult salmon scales were obtained from the Alaska Department of Fish and Game (ADFG) archive in Anchorage, Alaska, and from the School of Aquatic and Fishery Sciences, University of Washington. Scales have been collected annually for measuring and quantifying age composition for management of the fisheries in Alaska. We selected scales from salmon sampled in the Kvichak and Egegik rivers rather than in the ocean fisheries to reduce the possibility of mixed stocks in the scale collection. Scale collections from the Kvichak River began in 1955, whereas collections from Egegik River began in 1960. Major freshwater and ocean age groups from Kvichak (ages 1.2, 1.3, 2.2, 2.3) and Egegik (ages 1.3, 2.2, 2.3) sockeye salmon were measured. Age was designated by European notation, i.e. the number of winters spent in freshwater before going to sea (1 winter=age-1. or two winters=age-2.) followed by the number of winters spent at sea (two winters=age-.2 or 3 winters=age-.3.). Nearly all Bristol Bay sockeye salmon mature after spending two or three winters at sea.

Scales were selected for measurement in this study only when 1) we agreed with the age determination previously made by ADFG, 2) the scale shape indicated that the scale was removed from the "preferred area" (Koo, 1962), and 3) circuli and annuli were clearly defined and not affected by scale regeneration or significant resorption along the measurement axis. We measured up to 50 scales per year, representing equal numbers of male and female salmon from each age group within each stock.

Scale measurements followed procedures described by Davis et al. (1990) and Hagen et al.[5] After selecting a scale for measurement, the scale was scanned from a microfiche reader and its image was stored as a high resolution digital file. High resolution (3352×4425 pixels) allowed the entire scale to be viewed and provided enough pixels to be seen between narrow circuli

[3] Myers, K. W., K. Y. Aydin, R. V. Walker, S. Fowler, and M. L. Dahlberg. 1996. Known ocean ranges of stocks of Pacific salmon and steelhead as shown by tagging experiments, 1956–1995. Report FRI-UW-9614, 159 p. School of Aquatic and Fishery Sciences, Univ. Washington, Seattle, WA

[4] Anonymous. 2002. Biostatistical information on salmon catches, escapement, outmigrants number, and enhancement production in Russia in 2001. Doc. no. 646, 14 p. NPAFC, 889 Pender Street, Vancouver, Canada.

[5] Hagen, P. T., D. S. Oxman, and B. A. Agler. 2001. Developing and deploying a high resolution imaging approach for scale analysis. Doc. 567, 11 p. North Pacific Anadromous Fish Commision, 889 Pender Street, Vancouver, Canada.

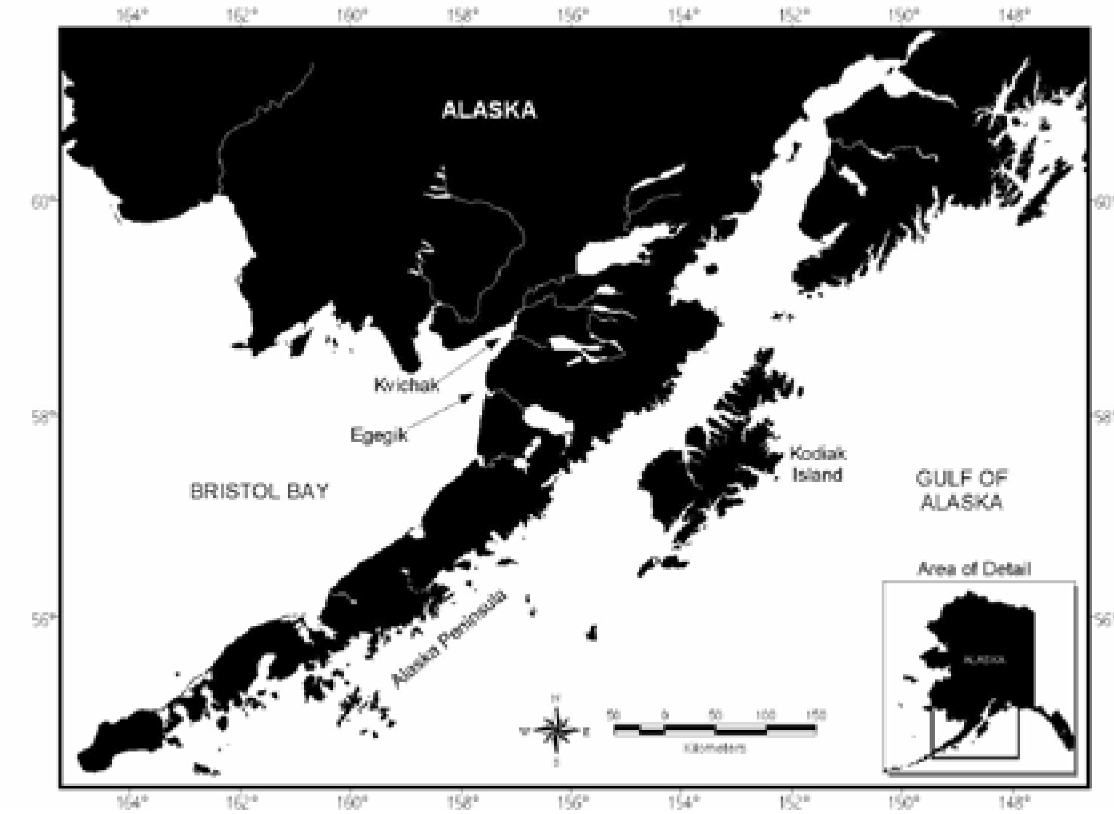

Figure 1
Map of Bristol Bay, Alaska, and the location of the Kvichak and Egegik river systems.

to ensure accurate measurements of circuli spacing. The digital image was loaded in Optimas 6.5 (Media Cybernetics, Inc., Silver Spring, MD) image processing software to collect measurement data with a customized program. The scale image was displayed on a digital LCD flat panel tablet. The scale measurement axis was determined by a perpendicular line drawn from a line intersecting each end of the first saltwater annulus. Distance (mm) between circuli was measured within each growth zone (i.e., from the scale focus to the outer edge of the first freshwater (FW1) annulus, between the first and second freshwater (FW2) annuli, within the spring plus (FWPL) growth zone, within each annual saltwater (SW1, SW2, SW3) growth zone, and from the last ocean annulus to the edge of the scale (i.e., the saltwater plus [SWPL] growth zone).

Data analysis

Mean scale circuli increments (distance between adjacent circuli pairs) of each age group and stock were calculated for each year when 10 or more scales were available. Typically, 40 to 50 scales of each age group and stock were measured in a given year. To facilitate evaluation of trends between odd- and even-numbered years at sea, scale circuli measurements were described in terms of the odd- or even-numbered year when the salmon entered the ocean. Thus, a salmon smolt entering the Bering Sea during an even-numbered year interacted with abundant odd-year Asian pink salmon during its second growing season (SW2) and less abundant even-year pink salmon during its third year, if it remained at sea. The number of circuli pairs considered in our analysis differed by growth zone, ranging from 22 circuli (SW1) to 20 circuli (SW2) to 15 circuli (SW3) in order to represent the majority of salmon. Analyses of seasonal scale growth trends were based on the mean of annual mean scale circuli increments, percentage change in scale circuli increments during odd- versus even-numbered years, and percentage change in odd- and even-year growth during periods before and after the 1977 ocean regime shift. A two-sample *t*-test was used to test for differences between odd- and even-numbered year scale growth at each circuli pair. Correlation was used to determine whether an individual's growth during the second growing season was related to previous growth at sea.

Results

First year (SW1) growth of ocean age-3 sockeye salmon

Kvichak and Egegik river sockeye salmon scale growth (distance between adjacent circuli) increased rapidly

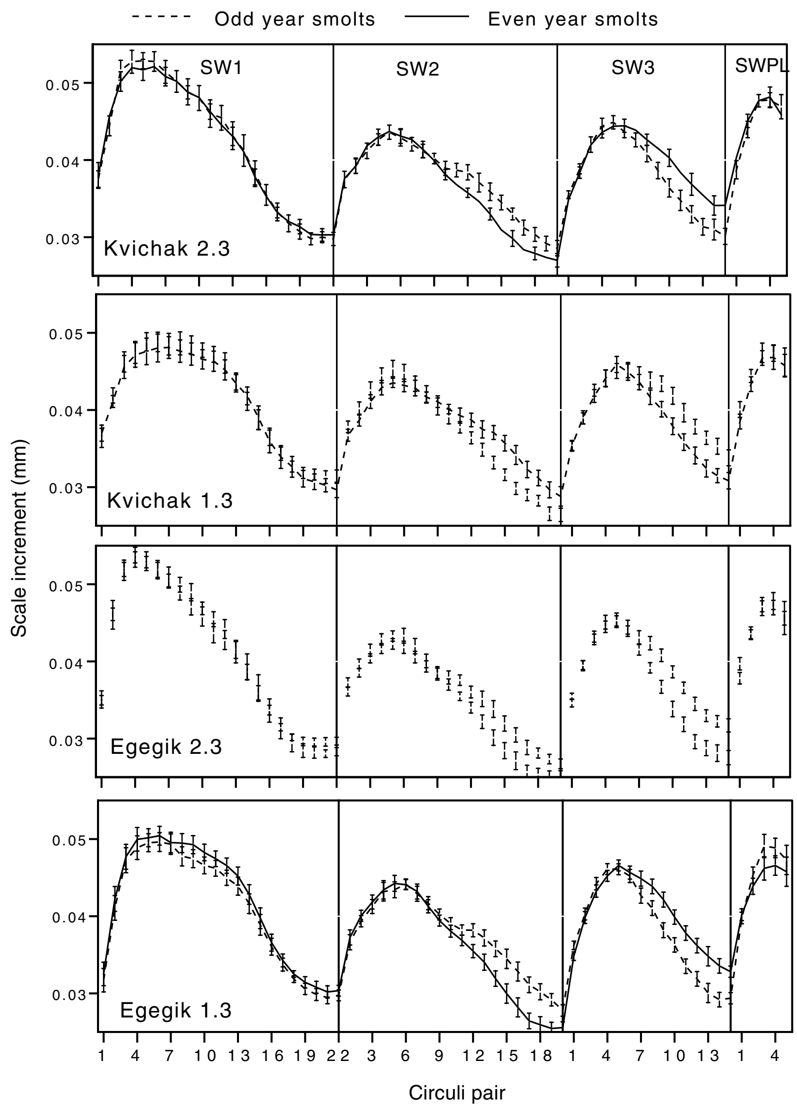

Figure 2

Average seasonal scale growth for Kvichak and Egegik ocean age-3 sockeye salmon (*Oncorhynchus nerka*) that entered the ocean as smolts during odd (- - - - -) and even (———) numbered years, 1952–2000. Growth of salmon spending one (age 1.3) and two years (age 2.3) in freshwater are shown separately. Circuli pair ordering restarts at the beginning of each new growing season (SW1, SW2, SW3, SWPL). 95% confidence intervals (CIs) are shown at each measurement.

after the fish entered Bristol Bay during May and early June, reaching peak growth near the fifth circuli (Fig. 2). Thereafter, growth declined steadily to a minimum at the first ocean annulus (circuli 18–22).

Peak scale growth of age-2. smolts was significantly greater compared with that of age-1. smolts for both Kvichak (df=79, t=5.757, P<0.001) and Egegik salmon (df=73, t=4.667, P<0.001). During the first eight circuli, age-2. smolts averaged 6.5% greater growth than age-1. smolts. Thereafter (circuli 11–20), growth of age-2. smolts declined more rapidly and averaged 2.3% (Kvichak) to 6.1% (Egegik) less than growth of age-1. smolts.

Within the SW1 growth period, no statistically significant difference in circuli growth was detected between smolts entering the ocean during odd- and even-numbered years (P>0.05). However, there was a trend for greater growth among even-year smolts in some

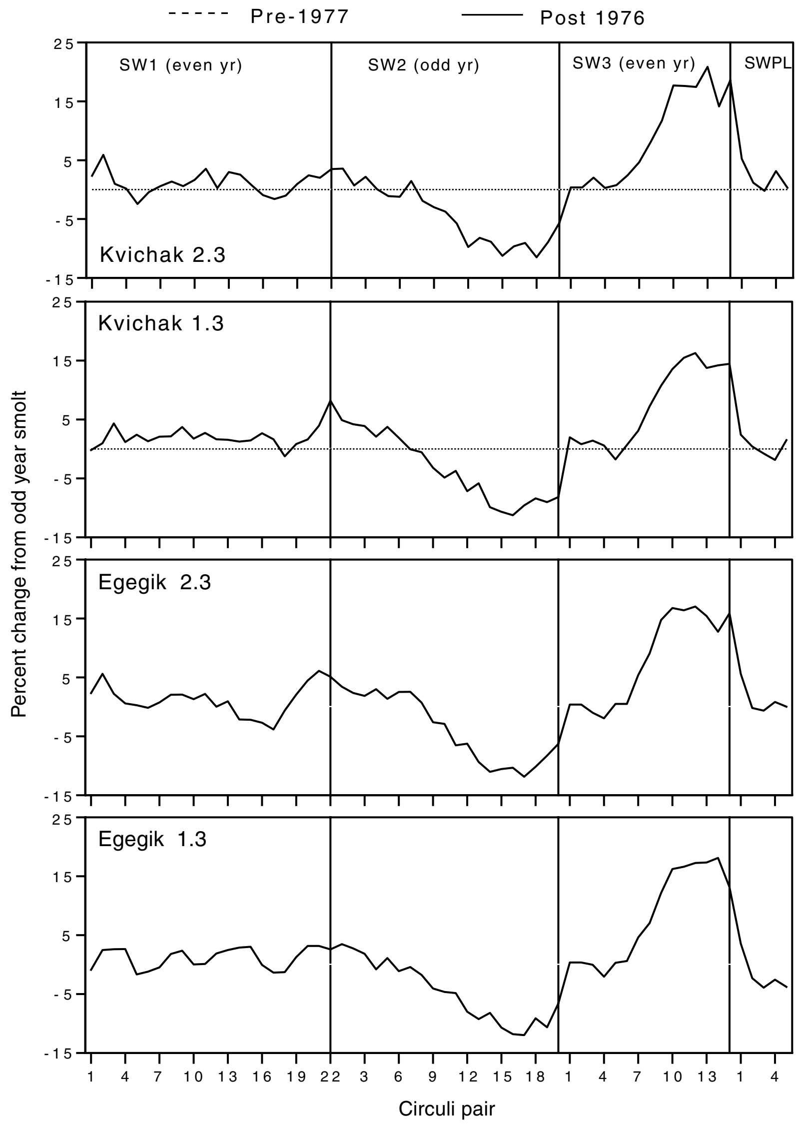

Figure 3

Percent change in scale growth of ocean age-3 sockeye salmon (*O. nerka*) entering the ocean during even-numbered years compared to odd-numbered years. Growth patterns represent ocean developmental periods prior to 1977 (- - - - -) and after 1976 (———). Even-year smolts encountered odd-year pink salmon (*O. gorbuscha*) during their second year at sea (SW2), but they encountered even-year pink salmon during their third year at sea (SW3). Age 1.3=1 year in freshwater and 3 years in saltwater; age 2.3= 2 years in freshwater and 3 years in saltwater.

portions of SW1, including the annulus (circuli 18–22) and immediately after peak growth (circuli 7 to 13) (Figs. 2 and 3).

SW1 growth of both even- and odd-year smolts tended to be greater after the 1977 climate shift than prior to this period, except for the last few circuli (Fig. 4). The greatest difference in growth between these two periods occurred immediately after entry into Bristol Bay (circuli 1–3) and during the last part of the SW1 growth period (circuli 13–19). This bimodal pattern of growth between the two periods was somewhat consistent among both stocks and freshwater age groups. However, Kvichak age 2.3 salmon experienced especially high early marine growth that was 17% greater, on average, after 1976. Following peak scale growth in spring, Egegik age 1.3 sockeye salmon experienced a

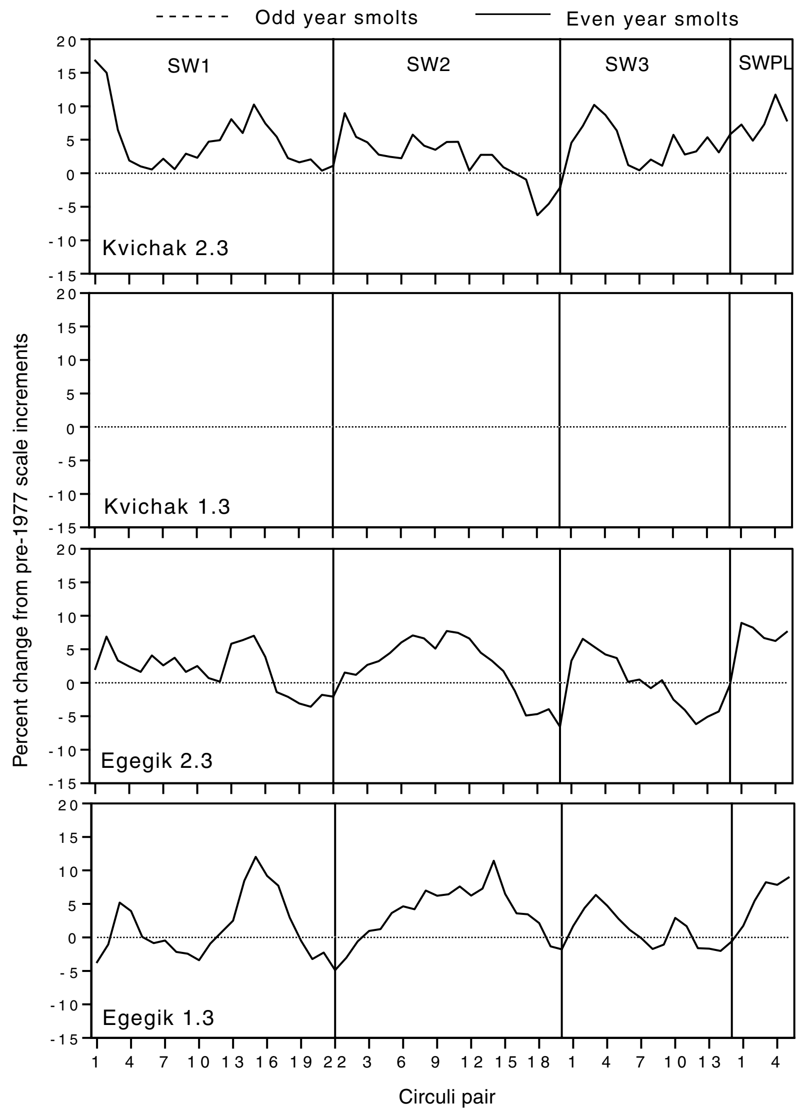

Figure 4

Percent change in scale growth of ocean age-3 sockeye salmon (*O. nerka*) entering the ocean during 1977–97 from those entering the ocean during 1952–76. Growth patterns represent smolts entering the ocean during odd- (- - - - -) and even-numbered years (———). Even-year smolts encounter odd-year pink salmon (*O. gorbuscha*) during their second year at sea (SW2), but they encountered even-year pink salmon during the their third year at sea (SW3).

15% increase in growth after 1976. In contrast, growth near the winter annulus (circuli 20–22) was up to 5% lower after the 1977 climate shift.

Second year (SW2) growth of ocean age-3 sockeye salmon

At the beginning of the second growing season (SW2), when Bristol Bay sockeye salmon are farthest south in the North Pacific Ocean (French et al., 1976), scale growth of both stocks and age groups increased rapidly, but the rate of increase was 59% less than that of SW1 and 37% less than SW3 growth (Fig. 2). Peak growth occurred near circuli 5 or 6 and it averaged 15% lower than that of SW1 growth.

During their second year at sea, even-year sockeye smolts inhabited the North Pacific and Bering Sea when Asian pink salmon were abundant in offshore waters

Table 1

Summary of two sample *t*-tests for evaluating the circuli number at which sockeye scale growth began to differ between odd- versus even-numbered years of the second and third seasons at sea. Between-year differences in circuli growth were greater after the circuli number shown in this table. No consistent pattern of differences between odd- and even-numbered years was observed during the first season at sea. Age "1.2" is a fish that has spent one year in fresh water and two years in salt water. SW2=2 years in saltwater.

Age	Ocean period	Stock	Circuli no.	df	*t*-value	*P* (two tailed)
1.2	SW2	Kvichak	C11	43	2.412	0.020
2.2	SW2	Kvichak	C11	44	3.283	0.002
2.2	SW2	Egegik	C11	39	3.434	0.001
1.3	SW2	Kvichak	C12	42	3.068	0.004
	SW3	Kvichak	C8	42	3.126	0.003
1.3	SW2	Egegik	C11	38	2.140	0.038
	SW3	Egegik	C7	38	2.527	0.016
2.3	SW2	Kvichak	C11	43	2.711	0.010
	SW3	Kvichak	C8	43	2.384	0.022
2.3	SW2	Egegik	C11	39	3.061	0.004
	SW3	Egegik	C7	39	2.728	0.010

(i.e., during odd-numbered years). Initial scale growth prior to the SW2 peak in spring was the same between odd- and even-numbered years, although there was a tendency for greater growth following the SW1 annulus of even-year smolts (Fig. 3). Immediately after peak growth near circuli 11, scale growth of even-year smolts became significantly less than that of odd-year smolts (Table 1). The growth differential continued through the end of the SW2 growing season and it reached a maximum reduction of –10% to –18% near circuli 14 to 18 (Fig. 3). This pattern was consistent before and after the 1977 climate shift and among each stock and age group. The reduced growth of even-year smolts during SW2 corresponded with high abundance of pink salmon in the central North Pacific Ocean during odd-numbered years.

Scale growth during SW2 of both odd- and even-year smolts tended to be greater after the 1977 climate shift (Fig. 4), a period when abundance of Bristol Bay sockeye salmon and Asian pink salmon was great. This pattern was consistent among both age groups of Kvichak and Egegik River sockeye salmon. Greatest growth differential between the two periods (up to 10%) occurred just after peak growth (circuli 5 to 15), a pattern that differed markedly from both SW1 and SW3. In contrast to the relatively large increase in growth shown in the central portion of SW2 after 1977, growth at the beginning of SW2 was similar during both periods and growth at the end of SW2 was relatively low after the climate shift.

Third year (SW3) growth of ocean age-3 sockeye salmon

Scale growth at the beginning of the third year at sea increased rapidly, peaked near circuli 5–6, then declined steadily through the year (Fig. 2). Peak growth during SW3 was intermediate to the relatively high peak growth during SW1 and relatively low peak growth during SW2.

During their third year at sea, even-year sockeye smolts inhabited the North Pacific and Bering Sea when relatively few Asian pink salmon were in offshore waters (i.e., even-numbered years). Prior to peak growth, SW3 growth of even-year smolts was similar or below that of odd-year smolts (Fig. 3), a pattern that continued from the previous season. Immediately following the peak, growth of even-year smolts significantly increased in relation to odd-year smolts (Table 1), and growth remained relatively high throughout the remaining season (Fig. 2). Growth of even-year smolts was approximately 5% to 15% greater than that of odd-year smolts from circuli 8 to the annulus (Fig. 3). Differences in growth during even- versus odd-numbered years tended to be greater after 1976 when both pink and sockeye salmon were relatively abundant.

Peak SW3 scale growth was up to 10% greater after the mid-1970 regime shift during both odd- and even-numbered years (Fig. 4). However, after the peak growing season, scale growth was typically lower after 1976. The relatively low growth after 1976 was especially pronounced among odd-year smolts that inhabited the ocean during odd-numbered years when Asian pink salmon were abundant in offshore waters. Scale growth of odd-year smolts during SW3 was as much as 10% lower than that prior to 1977.

Scale growth during both SW3 and SW2 were significantly reduced during odd-numbered years at sea (Table 1). However, SW3 scale growth during odd- versus even-years diverged immediately after the peak, whereas

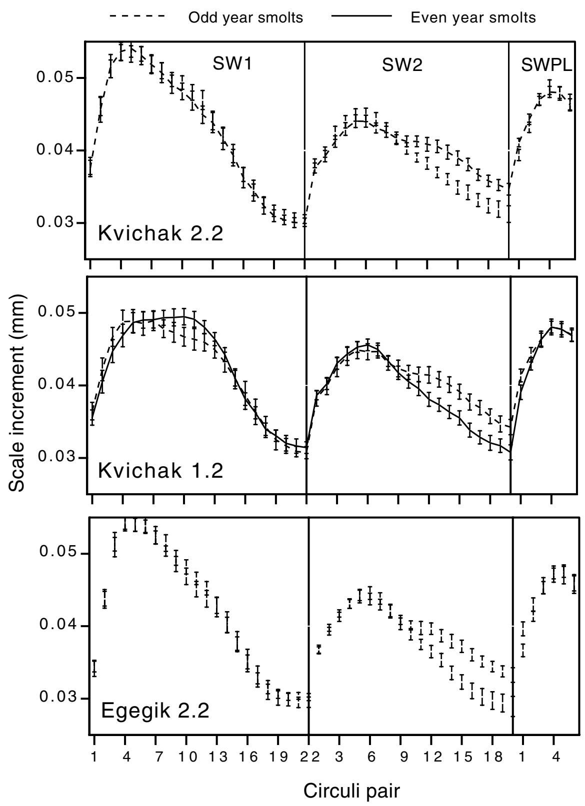

Figure 5

Seasonal scale growth of Kvichak and Egegik ocean age-2 sockeye salmon (*O. nerka*) that entered the ocean as smolts during odd- (- - - - -) and even- (———) numbered years, 1952–2000. Growth of salmon spending one (age 1.2) and two years (age 2.2) in freshwater are shown separately. Circuli pair ordering restarts at the beginning of each new growing season (SW1, SW2, SWPL). 95% CIs are shown at each measurement. Age 1.2=1 year in freshwater and 2 years in saltwater.

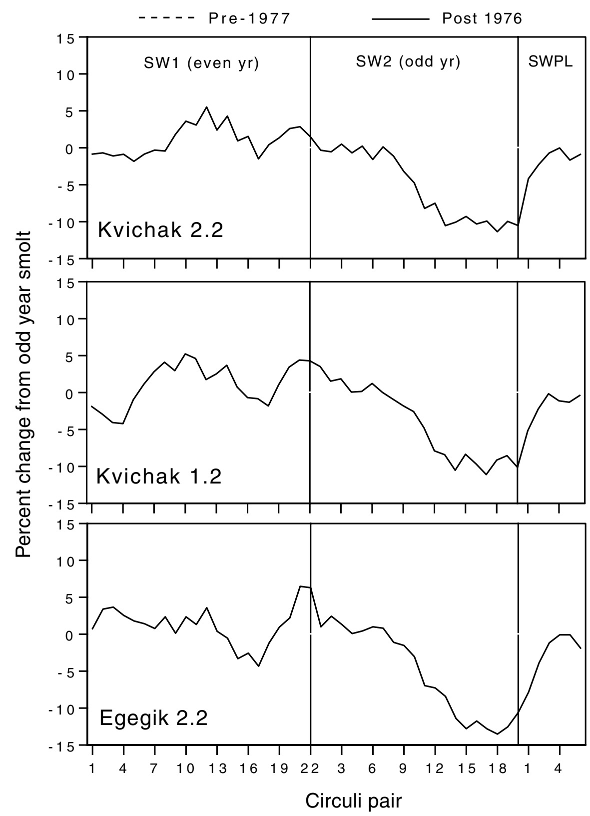

Figure 6

Percent change in scale growth between ocean age-2 sockeye salmon (*O. nerka*) entering the ocean during even years and those entering during odd-numbered years. Growth patterns represent ocean rearing periods prior to 1977 (- - - - -) and after 1976 (———). Even-year smolts encountered odd-year pink salmon (*O. gorbuscha*) during the second year at sea (SW2).

growth during SW2 diverged two or three circuli after the peak (Fig. 2). Late season growth of even-year smolts during SW3 was greater than late season growth during SW1 and SW2, whereas growth of odd-year smolts during SW3 was intermediate to SW1 and SW2 growth. These relatively large, older fish experienced a longer growing season, especially during even-numbered years, when few pink salmon were present.

Growth during homeward migration (SWPL) of ocean age-3 sockeye salmon

The peak return of sockeye salmon to Bristol Bay occurs near 3 July. Scale growth during the homeward migration peaked at circuli 3 and 4, then declined (Fig. 2). Peak growth was less than that of SW1, but greater than SW2 and SW3 growth. No growth difference was detected between odd- and even-year migrants during the period of homeward migration. Spring growth after 1976 was 5–10% greater than that during the earlier time period (Fig. 4).

First year ocean (SW1) growth of ocean age-2 sockeye salmon

Scale growth patterns of ocean age-2 Kvichak and Egegik sockeye salmon were remarkably similar to that of ocean age-3 sockeye, especially among those having the same freshwater age (Fig. 5). Sockeye salmon that had spent two winters in freshwater had significantly greater SW1 peak growth compared with those spending one winter in freshwater (Kvichak stock: df=85, t=6.772, P<0.001). Growth of age-2. smolts during the first eight circuli averaged 9% higher compared to age-1. smolts. However, as with ocean age-3 salmon, postpeak growth of age-2 smolts averaged 3.5% less than that of age-1.

smolts. Growth of even- and odd-year smolts during the first growing season was not significantly different but even-year smolts tended to have somewhat greater growth immediately following peak growth (circuli 7–13) and at the end of the growing season (circuli 19–22) (Fig. 6).

SW1 growth was markedly greater after 1976 when salmon abundance was relatively high compared with the growth during 1952–1976 (Fig. 7). Greater growth during the recent time period was most pronounced immediately after entry to Bristol Bay and after peak growth (circuli 13–18), but it was relatively low at the end of the growing season (circuli 20–22). These patterns were generally consistent between odd- and even-year smolt years.

Second year (SW2) growth of ocean age-2 sockeye salmon

SW2 scale growth patterns of ocean age-2 sockeye salmon were similar to SW2 patterns of ocean age-3 sockeye salmon. Scale growth of odd- and even-year smolts was similar until scale growth of even-year smolts significantly declined approximately three circuli after peak growth (Fig. 5, Table 1). Lower growth of even-year smolts continued to the end of the growing season. Scale growth of even-year migrants during their second year at sea was approximately 10% to 15% less than that of odd-year migrants (Fig. 6). Low growth of even-year migrants was associated with odd-numbered years at sea—a trend that was observed among SW2 and SW3 growth periods of ocean age-3 sockeye salmon.

Scale growth during SW2 was greater after 1976 when salmon abundance was relatively high compared with the growth before 1977, especially during the middle of the growing season (Fig. 7). However, after 1976, growth near the end of the growing season (circuli 17–20) tended to be below average. These patterns were consistent among the two stocks and three age groups.

Late season growth of ocean age-2 sockeye salmon during the second year at sea differed from that of ocean age-3 sockeye salmon (Figs. 2 and 5). Growth after circuli 8 of SW2 was significantly greater among ocean age-2 compared with ocean age-3 sockeye salmon (df=283, t=12.81, P<0.001), averaging 11% greater growth.

Growth during homeward migration (SWPL) of ocean age-2 sockeye salmon

Scale growth of ocean age-2 sockeye salmon during the homeward migration peaked at circuli 4, then declined. Prior to peak growth, even-year migrants experienced approximately 5% less growth than odd-year migrants, a pattern that was similar prior to and after the climate shift (Fig. 6). Low initial growth during SWPL appeared to be a continuation of relatively low growth during SW2. No difference in peak growth between odd- and even-years was apparent. Growth tended to be higher after the mid-1970s (Fig. 7).

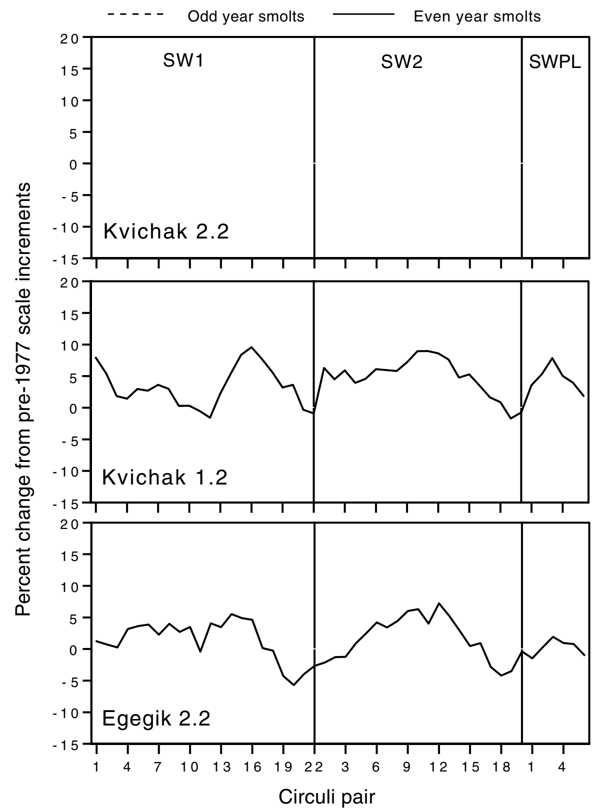

Figure 7

Percent change in ocean age-2 sockeye salmon (*O. nerka*) scale growth entering ocean during 1977 to 1998 compared with 1952–1976. Growth patterns represent smolts entering ocean during odd- (- - - - -) and even-numbered years (———). Even-year smolts encountered odd-year pink salmon (*O. gorbuscha*) during the second year at sea (SW2).

Relationship between early marine and late SW2 scale growth

We examined correlations between early marine scale (SW1 growth through the first eight circuli of SW2) and late SW2 growth (circuli 11 to annulus), corresponding with periods before and after the divergent scale growth pattern observed between odd- and even-numbered years. Negative correlations between early marine and late SW2 scale growth were observed among each stock and age group, before and after the 1977 regime shift, and among fish inhabiting the ocean during odd- or even-numbered years (Table 2). Only one of the 28 correlations (Egegik age-2.2, early period, odd SW2 year) was statistically insignificant. Thus, individual sockeye salmon that experienced somewhat low growth during early marine life tended to have somewhat high growth during later portions of their second year at sea, regardless of whether they competed with pink salmon. The strength of the

Table 2

Correlation between early marine scale growth (SW1 through SW2, circuli 1–8) and SW2 scale growth after growth difference in odd and even numbered years (SW2, circuli 11 to annulus). Measurements based on individual fish (n). Correlation coefficient and statistical significance are shown for each age group and stock during early (pre-1977) and recent (post-1976) periods for odd- and even-numbered years at sea. SW2=2 years in saltwater.

Age	Stock	Period	SW2 year	r	n	F-value	P-value
1.2	Kvichak	Early	Even	–0.11	408	5.18	<0.025
		Early	Odd	–0.20	429	18.20	<0.001
		Recent	Even	–0.22	550	27.84	<0.001
		Recent	Odd	–0.24	596	36.07	<0.001
2.2	Kvichak	Early	Even	–0.14	592	12.17	<0.001
		Early	Odd	–0.14	523	10.16	<0.002
		Recent	Even	–0.31	549	56.23	<0.001
		Recent	Odd	–0.17	568	16.78	<0.001
2.2	Egegik	Early	Even	–0.14	428	8.61	<0.004
		Early	Odd	–0.06	441	1.33	0.249
		Recent	Even	–0.14	551	10.21	<0.002
		Recent	Odd	–0.09	599	4.81	<0.030
1.3	Kvichak	Early	Even	–0.15	270	6.53	<0.020
		Early	Odd	–0.15	333	7.50	<0.010
		Recent	Even	–0.35	517	71.18	<0.001
		Recent	Odd	–0.20	504	21.89	<0.001
1.3	Egigik	Early	Even	–0.15	191	4.32	<0.040
		Early	Odd	–0.22	210	10.51	<0.002
		Recent	Even	–0.23	453	24.67	<0.001
		Recent	Odd	–0.27	479	38.60	<0.001
2.3	Kvichak	Early	Even	–0.15	347	7.78	<0.010
		Early	Odd	–0.16	376	10.12	<0.002
		Recent	Even	–0.24	438	25.86	<0.001
		Recent	Odd	–0.18	407	13.38	<0.001
2.3	Egegik	Early	Even	–0.16	460	12.35	<0.001
		Early	Odd	–0.23	416	23.94	<0.001
		Recent	Even	–0.18	546	17.94	<0.001
		Recent	Odd	–0.17	543	16.11	<0.001

correlations was low, but the consistent pattern among stocks, age groups, and time periods indicates that the negative correlations were not spurious.

Discussion

Previous research documented reduced annual scale growth of Nushagak Bay (Bristol Bay) sockeye salmon during odd-numbered years of their second and third years at sea (Ruggerone et al., 2003). The primary finding of our investigation was that salmon scale growth reduction during odd-numbered years did not occur throughout the second and third years at sea. During the second year at sea, scale growth reduction began three to five circuli after peak scale growth. During the third year at sea, scale growth reduction began immediately after peak growth. This finding was consistent among all age groups of both Kvichak and Egegik sockeye salmon prior to and after the mid-1970s regime shift that led to greater sockeye salmon abundance. Comparison of seasonal scale growth patterns before and after the regime shift indicated that the recent period of high sockeye salmon abundance was associated with relatively high growth 1) immediately after entry to Bristol Bay, 2) after peak scale growth during the first growing season, 3) during the middle of the second growing season, and 4) during the third spring but followed by below average growth during the remaining summer and fall.

Timing of peak scale growth and differences in scale growth between odd- and even-numbered years

The approximate time period of peak scale growth can be estimated from previous studies of salmon circuli formation at sea and timing of peak prey production. Bilton and Ludwig (1966) reported that sockeye salmon in the Gulf of Alaska tended to form annuli during December and January, whereas salmon sampled farther west in the relatively cold waters below the Aleutian Islands appeared to form annuli during March (Birman, 1960). For example, sockeye salmon collected from the eastern range of Bristol Bay sockeye salmon in the Gulf of Alaska (e.g., 152–160°W) averaged 1.2 circuli beyond the winter annulus during January and 3.6 circuli in April. We observed peak circuli growth of Kvichak and Egegik sockeye salmon to occur near circuli 5 to 6 (all ages), indicating that peak scale growth occurred from approximately early May to mid-June. This finding is consistent with scale growth in the year of homeward migration when Bristol Bay sockeye salmon averaged approximately 1 to 2 circuli after peak circuli growth before reaching Bristol Bay, on average, during the first week in July. The estimated date of peak scale growth is also consistent with observations of peak biomass of zooplankton in the Gulf of Alaska and Bering Sea, which typically occurs during May or June (Brodeur et al., 1996; Coyle et al., 1996; Mackas et al., 1998; Mackas and Tsuda, 1999). However, Ishida et al. (1998) reported that salmon growth was greatest between June and July, a period apparently later than peak scale growth and peak zooplankton biomass. Furthermore, scale growth may lag behind body growth (Bilton, 1975). Based on these observations, the observed divergence in scale growth between odd- and even-numbered years likely began after zooplankton biomass declined and during a period of high potential body growth of salmon.

Differences in SW2 scale growth between odd- and even-numbered years at sea began three to five circuli after peak growth, rather than immediately after the peak as shown among fish during their third year at sea (SW3). Because younger salmon begin circuli formation earlier in winter than do older salmon (Bilton and Ludwig, 1966; Martinson and Helle, 2000), it is likely that the differences in time of SW2 scale growth was only slightly later than that scale growth during SW3. The reason for the somewhat later differences between odd and even years of younger sockeye salmon might relate to the degree of diet overlap with pink salmon. In the central North Pacific Ocean and Bering Sea, pink salmon in their second growing season have greater diet overlap with larger sockeye salmon (Davis, 2003), such as sockeye salmon in their third season at sea. Thus, competition for prey may be greatest between pink salmon and the larger, older sockeye salmon, leading to earlier growth differences between the SW3 than the SW2 growth period. Alternatively, this pattern may reflect differences in the distribution of age-2 and age-3 sockeye salmon: age-3 salmon maybe distributed farther west where overlap with Asian pink salmon is greater.

Interactions with pink salmon and prey

Spatial and temporal overlap between Asian pink salmon and Bristol Bay sockeye salmon are important factors that affect the degree of competition. Little or no overlap occurs between these stocks during the first growing season (SW1) and there are typically small numbers of pink salmon originating from Bristol Bay (Rogers[1]). Little sampling has occurred during winter (Myers[6]), but data collected during fall and spring indicate that some overlap between Asian pink salmon and Bristol Bay sockeye begins in the central North Pacific Ocean during winter (French et al., 1976; Takagi et al., 1981; Myers et al.[3]). The degree of overlap likely increases into spring when both species reach their southernmost distribution, which is somewhat farther south for pink salmon. As the temperature begins to increase, both species migrate northwest—pink salmon leading the migration. Both species enter the Bering Sea but many Bristol Bay salmon and some Asian pink salmon remain in the North Pacific Ocean. In June, some Asian pink salmon leave the high seas for coastal areas, whereas others remain offshore through July (Myers et al.[3]; Azumaya and Ishida, 2000). During odd-numbered years, pink salmon are more broadly distributed on the high seas and catch per effort in the Bering Sea remains high through at least mid-July (up to 400 fish per 30 tans (1.5 km) of gill net) compared with that during even-numbered years (Azumaya and Ishida, 2000). Catch per effort of pink salmon during July is somewhat lower in the central North Pacific Ocean. Most pink salmon in the Bering Sea likely originate from the eastern Kamchatka Peninsula, which supports a major Asian population that is dominated by odd-year pink salmon. Thus, the period of overlap between Asian pink salmon and Bristol Bay sockeye salmon is from approximately winter through July and greatest overlap likely occurs during late spring through at least mid-July.

The relatively slow growth of sockeye salmon scales during odd-numbered years at sea began in the period of overlap with pink salmon and continued for months after pink salmon left the high seas. This finding indicates that prey availability was reduced for months after most pink salmon left the high seas. Sugimoto and Tadokoro (1997) examined zooplankton biomass during June and July, 1950–81 and concluded that Asian pink salmon caused the observed alternating pattern of zooplankton biomass in the central North Pacific Ocean and the eastern Bering Sea. Shiomoto et al. (1997) examined macrozooplankton biomass in the central North Pacific Ocean during 1985–94 and also concluded that Asian pink salmon, especially those from the eastern Kamchatka Peninsula, reduced the biomass of macrozooplankton. Shiomoto et al. (1997) noted that lower zooplankton biomass was still apparent in the central North Pacific Ocean after many pink salmon had migrated into the Bering Sea. These findings support the hypothesis that predation by pink salmon altered zooplankton biomass from spring through at least July.

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[6] Myers, K. 1996. Survey on overwintering salmonids in the North Pacific Ocean: Kaiyo Maru, 5 January–29 January 1996. Report FRI-UW-9607, 54 p. Univ. Washington, Seattle, WA.

Timing of peak zooplankton biomass occurs later in the year in northern regions, but zooplankton biomass typically declines during summer and fall (Batten et al., 2003). Declining zooplankton biomass in epipelagic waters is related, in part, to the ontogenetic migration to deep waters of some major zooplankton species, such as *Neocalanus* spp. (Mackas and Tsuda, 1999). Declining zooplankton biomass during summer likely enhanced the effect of competition exerted by pink salmon during odd-numbered years. July through at least September is a period of high potential salmon growth (Ishida et al., 1998); therefore sockeye salmon may be especially influenced by prey reduction during this period. During early spring, when scale growth of sockeye salmon was great and did not differ between odd- and even-numbered years, prey availability was apparently sufficient to minimize the effects of competition. Walker et al. (1998) reported that density-dependent growth of Asian pink salmon occurred after late June—a finding that is consistent with our study.

The transition from foraging on zooplankton to foraging on squid for both pink and sockeye salmon may also contribute to the alternating-year pattern of sockeye salmon growth. Aydin (2000) suggested that pink and sockeye salmon may begin to feed intensively on micronekton squid after reaching sufficient size during their second growing season. Pink salmon reportedly begin feeding on squid during spring, whereas sockeye salmon may not begin to feed on squid until summer because sockeye salmon are smaller. During odd-numbered years, pink salmon may have reduced the availability of squid to sockeye salmon and influenced the observed differences in scale growth after spring. In support of this hypothesis, sampling of sockeye and pink salmon during a recent 10-year period in the Bering Sea (June and July) indicated a 58% reduction among sockeye salmon and 32% reduction among pink salmon in the weight of squid consumed during odd- compared to even-numbered years (Davis, 2003). Few annual estimates of squid abundance are available, but Sobolevsky (1996) estimated that epipelagic squid biomass in the western Bering Sea was approximately five times greater in an even-year (1990) than in an odd-year (1989). Population dynamics and life history of squid are not well known (Nesis, 1997; Brodeur et al., 1999), but their apparent one- or two-year life history, in conjunction with predation by pink salmon, may lead to an alternating-year pattern of squid abundance that re-enforces the alternating-year pattern of sockeye salmon growth.

Ruggerone et al. (2003) reported that Bristol Bay sockeye salmon that inhabited the ocean in odd-numbered years of their second year at sea experienced lower smolt-to-adult survival compared with sockeye salmon that were present during even-numbered years. Lower survival was believed to be related to competition with Asian pink salmon. Our findings suggest that this mortality was likely related to reduced growth during late spring through fall, rather than during the first winter. We hypothesize that reduced sockeye salmon growth during the second year at sea led to lower energy reserves and to greater mortality during the second winter, but predation on smaller salmon may also be an important factor (Nagasawa, 1998). Bioenergetic modeling of salmon by Aydin (2000) indicated the greatest difference between the need for prey and prey availability is during winter. Nagasawa (2000) reported exceptionally low prey availability and corresponding low lipid content for salmon in the North Pacific Ocean during winter. Ishida et al. (1998) examined salmon on the high seas and determined that condition factor of all salmon species was lowest during late winter. Beamish and Mahnken (2001) provided evidence that relatively low growth of salmon during summer and fall can lead to significant growth-related mortality during the first winter at sea. Growth-related mortality appears to occur among Bristol Bay sockeye salmon in response to competition with pink salmon, but this competition-related mortality primarily occurs during the second winter at sea.

Bristol Bay sockeye salmon are broadly distributed across the North Pacific Ocean and Bering Sea. They occur in several oceanographic regions in which dominant prey may vary (e.g., the Bering Sea [euphausiids, squid, fish], subarctic current [squid], ridge domain [small zooplankton], the Alaska stream [small zooplankton, squid, fish], and the coastal domain [fish, euphausiids]) (Pearcy et al., 1988; Aydin, 2000). The alternating-year pattern of scale growth was persistent among adult Kvichak and Egegik sockeye salmon of all age groups returning to Bristol Bay even though many of these fish likely inhabited different ocean habitats. Thus, the observed scale growth pattern is either highly persistent in most of these ocean habitats or it is especially important in certain key regions inhabited by Bristol Bay sockeye salmon.

Salmon growth in relation to the regime shift of the mid-1970s

Several studies indicate that a significant change in the species assemblage of the North Pacific Ocean began near 1977 and concurrent with a dramatic shift in physical oceanic regimes (Francis et al., 1998; Anderson and Piatt, 1999). Pacific salmon abundance, including Bristol Bay sockeye salmon, more than doubled after this period (Rogers[1]). Zooplankton and squid biomass have appeared to increase substantially, especially in coastal regions, since the mid-1970s (Brodeur and Ware, 1992; Brodeur et al., 1996). Furthermore, Mackas et al. (1998) reported that the period of maximum zooplankton biomass shifted one or two months earlier after the mid-1970s. In comparison, seasonal scale growth of Kvichak and Egegik sockeye salmon during the first and second years at sea tended to be high after the regime shift. This pattern was also observed in annual scale measurements of sockeye salmon (Ruggerone et al., 2002). Spring scale growth of sockeye salmon after the regime shift was relatively high immediately after entry of sockeye salmon into Bristol Bay and during their third year at sea, but spring growth was relatively low during the second year. Growth during the second year was relatively high during summer, a pattern that was different from SW1 and SW3 growth. Seasonal scale growth patterns of sockeye salmon indicate that the response of salmon to the 1977 ocean regime shift varied with age and season but that the greater growth during early marine life was associated with greater adult returns. The shift in seasonal growth patterns of sockeye salmon likely reflected their opportunistic forging behavior and the changes in prey species abundances caused by climate change (Kaeriyama et al, 2004).

Greater growth of sockeye salmon when they initially entered the Bering Sea after the 1977 ocean regime shift may reflect differences in seaward migration patterns. Prior to the 1977 regime shift, juvenile sockeye salmon were observed in a narrow band that extended from the shore along the Alaska Peninsula to as far as 50 km offshore (Straty, 1981; Hartt and Dell, 1986). However, recent survey results indicate that juvenile sockeye salmon are broadly distributed in the eastern Bering Sea from the Alaska Peninsula to north of 58°N and that the highest catch rates occur beyond 50 km offshore (Farley et al.[7]). Zooplankton are more abundant in offshore, deeper waters of Bristol Bay than within near shore waters (Straty, 1981; Napp et al., 2002), indicating that the recent northerly seaward migration patterns of juvenile sockeye salmon may place them in areas of higher prey densities and lead to higher early marine growth rates.

Sockeye salmon scale growth during the third year of growth (SW3) was relatively low after 1977, indicating that density-dependent growth was most apparent during this late life stage when mortality is likely relatively low (Ruggerone et al., 2002). Our study indicated the reduced SW3 growth after the 1977 regime shift occurred after peak spring growth, indicating that interspecific competition was most apparent during summer and fall. During the spring homeward migration (SWPL) period, scale growth was above average after 1977. Age-specific size of adult sockeye salmon returning to Bristol Bay was density dependent, but size at a given density was greater after 1977 (Rogers and Ruggerone, 1993; Ruggerone et al., 2003).

[7] Farley, E. V., Jr., R. E. Haight, C. M. Guthrie, and J. E. Pohl. 2000. Eastern Bering Sea (Bristol Bay) coastal research on juvenile salmon, August 2000. Doc. 499, 18 p. North Pacific Anadromous Fish Commission, 889 Pender Street, Vancouver, Canada.

Farley, E.V., Jr., C.M. Guthrie, S. Katakura, and M. Koval. 2001. Eastern Bering Sea (Bristol Bay) coastal research on juvenile salmon, August 2001. Doc. 560, 19 p. NPAFC, 889 Pender Street, Vancouver, Canada.

Farley, E.V., Jr., B.W. Wing, A. Middleton, J. Pohl, L. Hulbert, M. Trudel, J. Moss, T. Hamilton, E. Parks, C. Lagoudakis, and D. McCallum. 2002. Eastern Bering Sea (BASIS) Coastal Research (August–2002) on Juvenile Salmon. Doc. 678, 27 p. NPAFC, 889 Pender Street, Vancouver, Canada.

Salmon survival and scale growth

Biologists have suggested that rapid growth early in life can lead to greater growth in subsequent periods because larger animals have a greater variety of prey and prey size available to them (Pearcy et al., 1999). Aydin (2000) hypothesized that rapidly growing salmon in their first year at sea would more quickly reach a threshold size for feeding on abundant, energy-rich micronekton squid, leading to even greater growth in their second year. However, comparison of early marine scale growth (SW1 through SW2, circuli 8) with late season SW2 growth of individual Kvichak and Egegik sockeye salmon indicated a negative rather than positive relationship. Individual salmon having relatively great early marine scale growth tended to experience reduced scale growth during the later portion of their second year when sockeye salmon reach the size needed to readily consume larger prey such as squid. This finding reflects the growth of sockeye salmon survivors and not those that died at sea. Thus, we interpret this counterintuitive finding as an indication that slow growing sockeye salmon during late SW2 survived primarily when their early marine growth was relatively high. Salmon that experienced both low early marine growth and low SW2 growth apparently did not survive and were not represented in the scale collection. These observations do not necessarily reject the hypothesis that high early marine growth leads to high subsequent growth. In fact, other analyses of sockeye scales indicate spring growth is positively correlated with fall growth within a given year (G. Ruggerone, unpubl. data).

Effect of freshwater age on seasonal scale growth

Scale growth during the first year at sea was different among salmon spending one versus two winters in freshwater. Early SW1 scale growth of sockeye salmon spending two winters in freshwater (age-2.) was significantly greater than that of salmon spending only one winter in freshwater. This trend might reflect differences in migration timing or size (or both) of age-2 versus age-1 smolts. Age-2 smolts are approximately 17 mm longer than age-1 smolts and most age-2 smolts enter marine waters before age-1 smolts (Crawford and West[8]). After peak growth in spring, scale growth of age-1. smolts exceeded that of age-2. smolts. The different early marine growth patterns of age-1. and age-2. smolts did not appear to significantly affect the size of the fish at the end of the growing season. For example, during 1958–72, age-2.1 sockeye salmon sampled immediately south of the Aleutian Islands were 25 mm longer than age-1.1 sockeye salmon (French et al., 1976). The size difference between age-2. and age-1. smolts declined to 8 mm during the second growing season.

[8] Crawford, D. L., and F. W. West. 2001. Bristol Bay sockeye salmon smolt studies for 2000. Reg. Info. Rept. 2A01-12, 164 p. Alaska Dept. Fish Game, 333 Raspberry Road, Anchorage, AK.

Difference in growth by ocean age

Barber and Walker (1988) reported that peak SW2 scale growth for Bristol Bay sockeye salmon (Ugashik stock) was less than peak growth during SW1 and SW3. They suggested that this trend reflected lower prey availability for sockeye salmon in the North Pacific Ocean than in the Bering Sea (Mackas and Tsuda, 1999). But Bristol Bay sockeye salmon also develop in the Bering Sea during their second growing season (French et al., 1976; Myers et al.[3]). Kvichak and Egegik sockeye salmon scales, 1955–2000, exhibited relatively low growth throughout SW2 year compared to SW1 and SW3 years. We suggest that low SW2 growth may also be related to the inability of sockeye salmon to efficiently capture large prey (Aydin, 2000) and to a lower bioenergetic efficiency when consuming smaller prey. Salmon in their third year at sea may experience greater prey availability and capture efficiency because they are larger.

Late season growth of ocean age-2 sockeye salmon during SW2 was significantly greater than that of ocean age-3 sockeye salmon. This finding indicates that the greater size-at-age of ocean age-2 sockeye salmon compared to ocean age-3 sockeye salmon at the end of the second growing season (French et al., 1976) may be largely related to increased growth during the later portion of the second growing season at sea.

Conclusions

Seasonal scale growth patterns of Kvichak and Egegik sockeye salmon exhibited significant differences in SW2 and SW3 scale growth during odd- versus even-numbered years. Differences in scale growth did not begin until after peak scale growth and difference began somewhat later for younger SW2 sockeye salmon. The persistence of this pattern over the past 45 years may be caused by pink salmon, especially those from eastern Kamchatka that are highly abundant during odd-numbered years. During odd-numbered years, pink salmon reduced prey abundance prior to migrating to coastal areas in June and July (Shiomoto et al., 1997; Sugimoto and Tadokoro, 1997). This prey reduction, coupled with declining abundance and ontogenetic vertical migrations of some zooplankton (Mackas and Tsuda, 1999), appears to have influenced (reduced) growth of sockeye salmon from early summer through fall of odd-numbered years. We hypothesize that the alternating odd- and even-year growth pattern of sockeye salmon may be reenforced by the one- or two-year life cycle of prey, such as squid, whose abundance may be out-of-phase with the two-year cycle of pink salmon. These data, coupled with previous findings of reduced smolt-to-adult survival of sockeye salmon that interacted with odd-year pink salmon during the second year at sea (Ruggerone et al., 2003), indicate that reduced growth of salmon during the second year at sea can lead to measurable salmon mortality. Sockeye mortality associated with pink salmon likely occurs during winter when demand for prey by salmon exceeds the low availability of prey (Aydin, 2000), but it may also occur in response to size-selective predation. Our study indicates that salmon growth and survival are influenced by complex food web interactions, which are likely to significantly shift under various scenarios of climate change that affect temperature, CO_2, and phytoplankton community structure of the Bering Sea (Hare et al.[9]).

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Evidence for competitive dominance of Pink salmon (*Oncorhynchus gorbuscha*) over other Salmonids in the North Pacific Ocean

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Key words: climate change, competition, food web, growth, North Pacific Ocean, salmon, survival

Abstract

Relatively little is known about fish species interactions in offshore areas of the world's oceans because adequate experimental controls are typically unavailable in such vast areas. However, pink salmon (*Oncorhynchus gorbuscha*) are numerous and have an alternating-year pattern of abundance that provides a natural experimental control to test for interspecific competition in the North Pacific Ocean and Bering Sea. Since a number of studies have recently examined pink salmon interactions with other salmon, we reviewed them in an effort to describe patterns of interaction over broad regions of the ocean. Research consistently indicated that pink salmon significantly altered prey abundance of other salmon species (e.g., zooplankton, squid), leading to altered diet, reduced total prey consumption and growth, delayed maturation, and reduced survival, depending on species and locale. Reduced survival was observed in chum salmon (*O. keta*) and Chinook salmon (*O. tshawytscha*) originating from Puget Sound and in Bristol Bay sockeye salmon (*O. nerka*). Growth of pink salmon was not measurably affected by other salmon species, but their growth was sometimes inversely related to their own abundance. In all marine studies, pink salmon affected other species through exploitation of prey resources rather than interference. Interspecific competition was observed in nearshore and offshore waters of the North Pacific Ocean and Bering Sea, and one study documented competition between species originating from different continents. Climate change had variable effects on competition. In the North Pacific Ocean, competition was observed before and after the ocean regime shift in 1977 that significantly altered abundances of many marine species, whereas a study in the Pacific Northwest reported a shift from predation- to competition-based mortality in response to the 1982/1983 El Nino. Key traits of pink salmon that influenced competition with other salmonids included great abundance, high consumption rates and rapid growth, degree of diet overlap or consumption of lower trophic level prey, and early migration timing into the ocean. The consistent pattern of findings from multiple regions of the ocean provides evidence that interspecific competition can significantly influence salmon population dynamics and that pink salmon may be the dominant competitor among salmon in marine waters.

Introduction

Pink salmon (*Oncorhynchus gorbuscha*) are unique among Pacific salmon in many ways, but a key characteristic is their invariable two-year life cycle that leads to genetically distinct stocks that can differ significantly in abundance during odd- versus even-numbered years. Large alternating-year abundances of pink salmon are most apparent at the northern and southern range of the species, including the Pacific Northwest and the Russian Far East. Pink salmon grow rapidly and they are the most abundant species of Pacific salmon (Heard, 1991), therefore they have potential to significantly affect other salmon species in the ocean.

The alternating-year pattern of pink salmon abundance provides a unique natural experimental control to test for interactions between pink salmon and other species of salmon in the ocean. The natural experimental control provided by the alternating-year abundance of pink salmon is important because environmental variables in the ocean are often correlated and salmon species often respond similarly to environmental conditions. For example, all species of salmon in northern regions increased significantly after the 1977 ocean regime shift (Rogers, 1984; Beamish and Bouillon, 1993; Mantua et al., 1997). Such correlations confound attempts to evaluate the nature and importance of species interactions, such as competition, as a mechanism that regulates population abundance in offshore marine communities. Competition has been widely described in terrestrial, freshwater, and some marine communities (Schoener, 1983; Bertness et al., 2001) and some scientists have assumed that interspecific competition may influence abundances of offshore marine fish populations (Cushing, 1975; National Research Council, 1999), whereas others have downplayed its importance in regulating these populations (Sinclair, 1988). Quantification of species interactions is important given the growing desire to manage marine fisheries using the concept of ecosystem management (National Research Council, 1999). This is especially important for Pacific salmon because up to five billion juvenile salmon are released from hatcheries each year (Mahnken et al., 1998), often in regions where natural salmon populations are depressed, and concern has been raised about the capacity of the ocean to support these salmon (Pearcy et al., 1999).

A number of recent investigations have utilized the natural experimental control provided by pink salmon to examine interactions between pink and other species of salmon. We reviewed these studies in an effort to document patterns of species interactions and to evaluate whether interspecific competition is an important mechanism influencing salmon population dynamics in marine waters. Since competition often involves a shortage of prey resources, we were particularly interested in competitive interactions before and after periods of climate change.

Findings

Pink salmon abundance and distribution

Pink salmon are the most abundant species of Pacific salmon, representing approximately 58% of all anadromous Pacific salmon (Rogers, 2001). Abundance of adult pink salmon in the North Pacific Ocean averaged approximately 156 million

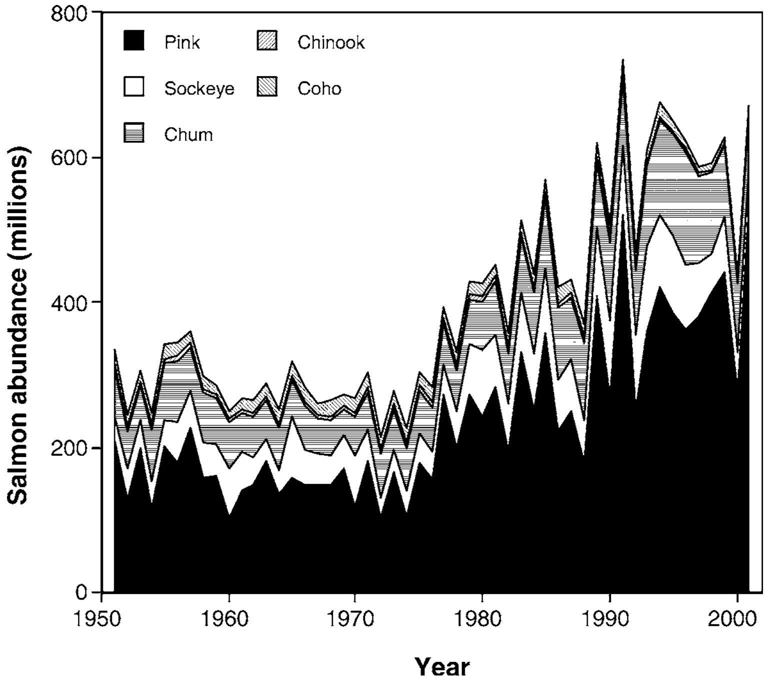

Figure 1. Time series of adult Pacific salmon abundance in Asia and North America, 1951–2001 (Rogers 1987, 2001).

fish per year during 1951–1976, increasing to 323 million fish per year during 1977–2001 (Figure 1). Asian pink salmon represented approximately 56% of the total adult return of pink salmon. In Asia, large runs of pink salmon originated from the Kamchatka Peninsula and Sakhalin Islands, whereas in North America most pink salmon originated from Kodiak Island, Alaska, south to the Fraser River in British Columbia (Heard, 1991).

Large pink salmon populations dominated by odd-year adults are located primarily at the northern and southern range of pink salmon, such as the eastern Kamchatka Peninsula and the Strait of Georgia/Puget Sound. Catch of eastern Kamchatka pink salmon is approximately 380% greater during odd- compared with even-numbered years, i.e., average 5 million fish in even-years versus 24 million fish in odd-years (Sinyakov, 1998). More than 99% of runs in Puget Sound and southern British Columbia (Fraser River) occur during odd-numbered years. Western Kamchatka historically produced primarily odd-year pink salmon runs, but the dominant run abruptly switched to even years after 1983 (Bugaev, 2002). The southeastern Bering Sea produces relatively small runs that are dominant during even-numbered years. Regions in the central portion of the pink salmon range in North America (southeastern and central Alaska and northern British Columbia) tend to produce large pink runs in both odd- and even-numbered years.

Juvenile pink salmon enter coastal marine waters in early spring after minimal feeding in freshwater, then disperse counter-clockwise along the coast and into the North Pacific Ocean or Bering Sea (Heard, 1991). Ocean migration patterns and distribution of regional pink salmon assemblages have been described from extensive high seas tagging and sampling (Takagi, 1981; Myers et al., 1996). In general, pink salmon disperse broadly across marine waters and may travel up to approximately 7400 km during their 14–16 month stay. For example, pink salmon originating from eastern Kamchatka have the eastern-most distribution of Asian stocks, extending eastward to approximately 155°W (south of Alaskan Peninsula) and south to approximately 44°N. Pink salmon from Washington and British Columbia migrate north into the Gulf of Alaska (up to ~58°N) and westward to approximately 148°W. Thus, pink salmon disperse broadly into the ocean, but they have little overlap with distant populations. Pink salmon, like other salmon species, typically occupy the upper 30 m of the water column (Heard, 1991).

Sockeye and pink salmon interactions

Diet overlap and prey availability

Pink and sockeye (*O. nerka*) salmon are opportunistic foragers that have similar diets in offshore marine waters (Davis et al., 2000; Kaeriyama et al., 2000, 2004). Their diet includes prey from several trophic levels, including zooplankton and micronekton such as squid and small fishes. Stable isotope analyses demonstrated that the trophic position of pink and sockeye is similar (Welch and Parsons, 1993; Kaeriyama et al., 2004), as expected from diet data. However, during the second season at sea, pink salmon may begin foraging on larger prey, such as squid, at an earlier date in spring compared with sockeye salmon (Aydin, 2000).

Field research in the central North Pacific Ocean recently demonstrated that zooplankton

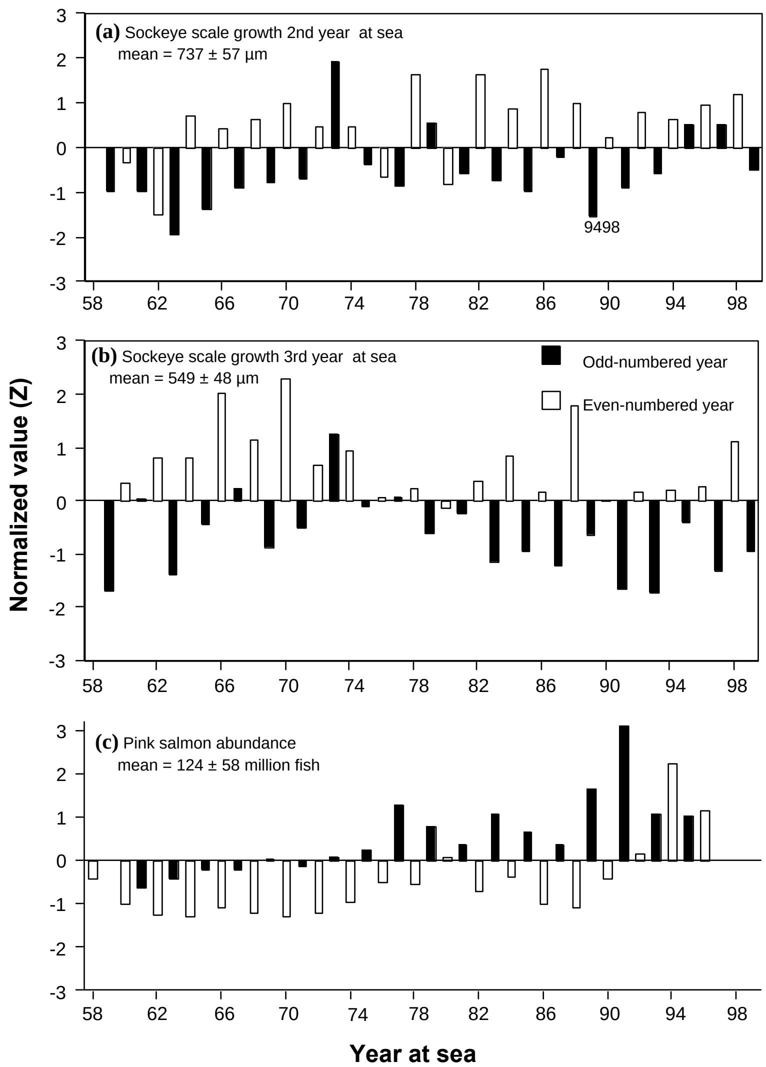

Figure 2. Bristol Bay (Egegik stock) sockeye salmon growth during the second (a) and the third growing seasons at sea (b) and the corresponding abundance of maturing Asian pink salmon (c), 1958–1999. Open bars are even years at sea, and closed bars are odd years at sea. Values are normalized, i.e., standard deviations above and below the long-term mean. Revised from Ruggerone et al. (2003) using a different stock of Bristol Bay salmon.

biomass was significantly reduced during June and July of odd-numbered years (Sugimoto and Tadokoro, 1997; Shiomoto et al., 1997). These researchers concluded that Asian pink salmon, which are abundant during odd-numbered years, had reduced zooplankton abundance over this large region. Sano (1963) reported that prey consumption of both pink and sockeye salmon in the western Pacific Ocean during May through August, 1955–1962, significantly declined during odd-numbered years, corresponding to years when Asian pink salmon were most abundant. The reduction in total prey weight (primarily squid and euphausiids by both species) consumed by sockeye salmon during odd-numbered years (61% reduction) was greater than that of pink salmon (52% reduction). During 1991–2000, stomach contents of pink and sockeye salmon collected in the central Bering Sea declined 24 and 36%, respectively, during odd-numbered years (high pink salmon abundance) (Davis, 2003; Ruggerone et al., 2003). However, two key prey of both species (squid and fish) declined more in sockeye salmon (27% reduction) than in pink salmon (7% reduction), suggesting pink salmon were more efficient at exploiting key prey.

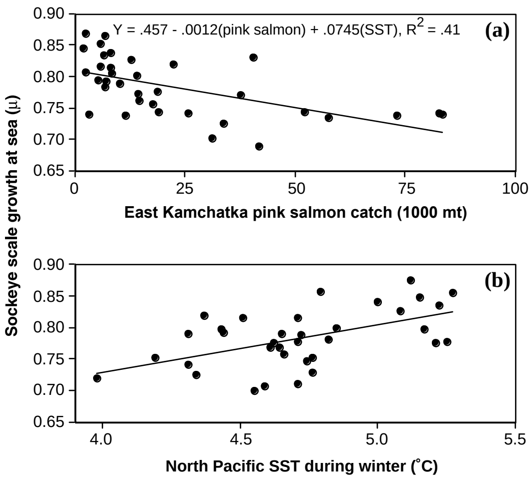

Figure 3. Multi-variate analysis showing the partial effects (Larsen and McCleary, 1972) of pink salmon abundance (A) and winter sea surface temperature (SST; B) on second-year scale growth of Bristol Bay sockeye salmon, 1966–2000. Sockeye scale growth (μ) = 0.457–0.0012 (pink salmon catch) + 0.0745 (temperature); R^2 = 0.41, overall $P < 0.001$, P (pink salmon catch) < 0.001, P (SST) < 0.002; P (autocorrelation of residuals at lags 1–10) > 0.05. Ruggerone, unpublished data.

Bristol Bay, Alaska

Ruggerone et al. (2003) provided evidence that Asian pink salmon, primarily those from the eastern Kamchatka Peninsula, reduced the growth and survival of Bristol Bay, Alaska, sockeye salmon. Annual sockeye salmon scale patterns, 1955–2000, exhibited an alternating-year pattern of growth during the second and third years at sea that was opposite that of Asian pink salmon abundance, which was 56% greater in odd-numbered years (Figure 2). Sockeye growth during the first growing season at sea was not reduced because overlap with Asian pink salmon did not begin until the second season at sea and relatively few pink salmon originate in Bristol Bay. Ruggerone and Nielsen conducted a multi-variate regression analysis and found that scale growth of Bristol Bay sockeye during the second year at sea, 1966–2000, was negatively associated with harvests of eastern Kamchatka pink salmon ($P < 0.001$), but positively associated with winter sea surface temperature in the North Pacific Ocean ($P < 0.002$; Figure 3). This finding suggests pink salmon abundance influenced year-to-year variation in sockeye salmon growth whereas sea-surface temperature influenced the long-term trend in early marine growth shown in Figure 2.

Age-specific length of adult sockeye salmon returning to Bristol Bay, 1958–2000, was inversely

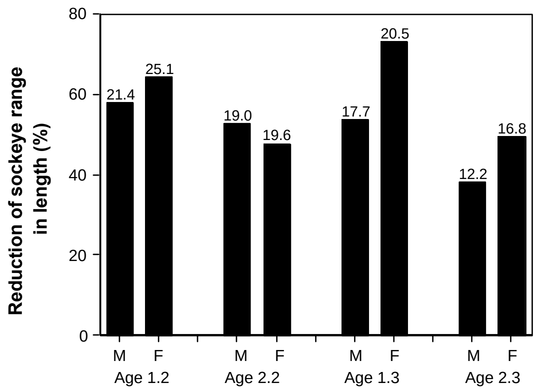

Figure 4. Effect of maximum Asian pink salmon abundance on the observed range in Bristol Bay sockeye lengths during 1958–2000. Maximum effect of Asian pink salmon abundance based on sockeye length change when pink salmon abundance increase from zero to 300 million pink salmon. Estimates based on empirical models of sockeye length (age and sex) presented by Ruggerone et al. (2003). Values at top of each bar are the estimated reduction in sockeye length (mm) associated with maximum pink salmon run.

related to Asian pink salmon abundance during the year prior to homeward migration (Ruggerone et al., 2003). This pattern was consistent among all four major age groups and both sexes of sockeye salmon. Pink salmon tended to have the greatest effect on growth of younger age groups (e.g., ages 1.2 and 2.2) and female salmon. Using the empirical relationships between sockeye length and pink salmon abundance described by Ruggerone et al. (2003), we calculated the maximum potential effect of Asian pink salmon on sockeye length (i.e., sockeye length during maximum versus zero pink abundance) using the approach described by Bugaev et al. (2001). A change from zero to maximum Asian pink salmon abundance may account for up to approximately 38–73% of the observed range in mean Bristol Bay sockeye length, depending on age and sex (Figure 4). Although these analyses demonstrated pink salmon could exert a significant effect on size of Bristol Bay sockeye salmon, the multi-variate analyses indicated that intraspecific competition during the homeward migration had a greater effect on sockeye salmon size.

Ruggerone et al. (2005) examined seasonal scale growth patterns of Bristol Bay sockeye salmon in relation to pink salmon abundance during 1955–2000. They demonstrated that the reduction in salmon growth observed during the second and third years at sea (Figure 2) began immediately after peak prey availability in spring and continued to the end of the growing season, well after pink salmon had left the high seas. The researchers noted that prey population dynamics that influenced the observed alternating-year pattern in sockeye growth are poorly understood. They hypothesized that high consumption rates of pink salmon during spring through mid-July of odd-numbered years, coupled with declining zooplankton biomass during summer (Mackas and Tsuda, 1999; Batten et al., 2003) and potentially cyclic abundances of squid (Sobolevsky, 1996; Nesis, 1997), contributed to reduced prey availability and to reduced growth of Bristol Bay sockeye salmon during spring through fall of odd-numbered years.

A key finding of recent pink/sockeye interaction research was that reduced growth of Bristol Bay sockeye salmon during odd-numbered years was associated with a significant reduction in smolt-to-adult survival during 1977–1997 (Ruggerone et al., 2003). This analysis was based on annual estimates of salmon smolts that migrated to sea during odd- versus even-numbered years and subsequent age-specific returns of adult salmon. On average, smolt survival declined 35% (from 18.6 ± 3.1 (SE) to 12.1 ± 2.5% survival) when they entered Bristol Bay in even-numbered years and competed with Asian pink salmon during their second year at sea (odd-numbered year). Younger age-1.2 sockeye salmon experienced the greatest reduction in survival (59%), age-1.3 and age-2.2 experienced intermediate reduction in survival (30%), and the older age-2.3 salmon experienced the least reduction in survival (19%) when interacting with Asian pink salmon during their second season at sea. Some of the reduction in ocean age-2 sockeye salmon may be explained by delayed maturation associated with reduced growth, but analyses demonstrated that overall mortality was greater when sockeye interacted with abundant pink salmon during their second season at sea. It was hypothesized that reduced growth during spring through fall of the second growing season at sea led to greater mortality during winter when demand for prey can exceed prey availability (Nagasawa, 2000; Beamish and Mahnken, 2001; Ruggerone et al., 2005).

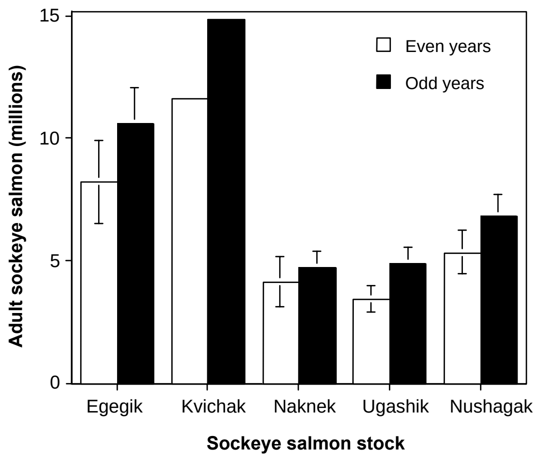

Figure 5. Comparison of adult Bristol Bay sockeye salmon stocks returning from smolts entering the ocean during odd- versus even-numbered years (means ± 1 SE), 1977–1997 (updated from Ruggerone et al., 2003). Sockeye salmon entering ocean during even-numbered years began their interaction with relatively abundant odd-year pink salmon during first winter at sea. Adult returns of Kvichak salmon is strongly influenced by the five-year spawning cycle, therefore the mean reduction from other stocks (22%) was applied to Kvichak returns.

The findings of the smolt-to-adult survival analysis were further supported by an analysis of age-specific adult sockeye salmon returns to Bristol Bay. This analysis included stocks that did not have annual smolt enumeration programs. Adult returns were compared based on whether they entered the Bering Sea as smolts during odd- versus even-numbered years. Adult returns of four major sockeye salmon stocks declined 22% (from 6.76 ± 0.59 to 5.29 ± 0.62 million fish per stock), on average, during 1977–1997, when they competed with abundant odd-year pink salmon during their second season at sea (Ruggerone et al., 2003). This effect represented a cumulative loss of 59 million adult sockeye salmon, excluding the Kvichak River stock whose returns are strongly influenced by a five-year spawning cycle. In light of previous findings that most salmon mortality at sea occurs during early marine life (Pearcy, 1992), it is noteworthy that the analyses of Bristol Bay adult sockeye return data and smolt-to-adult survival data indicate significant mortality also occurred during the second year at sea.

The Kvichak sockeye salmon stock is a major component of the Bristol Bay salmon population and survival of Kvichak smolts was significantly reduced when they interacted with odd-year pink salmon (Ruggerone et al., 2003). Therefore, we applied the average reduction in adult returns to Bristol Bay (22%) to the average adult return of Kvichak salmon (average 13.25 million salmon per year) in order to calculate the cumulative total loss of Bristol Bay sockeye salmon. This analysis indicated approximately 32.8 million fewer adult Kvichak sockeye salmon returned to Bristol Bay when interacting with odd-year pink salmon during their second season at sea, 1977–1997. The total reduction in Bristol Bay sockeye salmon abundance associated with odd-year Asian pink salmon was approximately 91.8 million fish during 1977–1997 (Figure 5). Thus, Asian pink salmon abundance, including the 380% increase in eastern Kamchatka pink salmon abundance between even- and odd-numbered years, was associated with a 35% reduction in sockeye smolt-to-adult survival and a 22% reduction in adult returns.

Prior to the ocean regime shift in 1977, no effect of competition on Bristol Bay sockeye abundance was detected from an analyses of adult returns even though growth reduction was observed (Ruggerone et al., 2003). Harris (1989) noted that many Bristol Bay salmon were harvested on the high seas during this early period and were not counted in Bristol Bay catch statistics. Thus, it is possible that catches of salmon on the high seas by international fisheries confounded the analysis prior to 1977.

Kamchatka, Russia

Asian pink salmon have been shown to have a significant adverse effect on the growth of Russian sockeye salmon (Krogius 1964, 1967; Bugaev et al., 2001). Bugaev et al. (2001) examined age and sex-specific mature body weights of Ozernaya River sockeye salmon (eastern Kamchatka Peninsula), 1970–1994, and found that weight of sockeye salmon was inversely related to abundances of local eastern and western Kamchatka pink and sockeye salmon. They estimated that an increase in Kamchatka pink salmon from zero fish to average abundance (~75 million fish) would cause a 20% reduction in sockeye body weight, whereas an increase from zero fish to the peak observed pink salmon run (~170 million fish) could reduce body weight of some sockeye age groups up to 50%. Although the relationships were weak, Bugaev et al. (2001) suggested that on a per capita basis sockeye salmon had a greater effect on sockeye weight than pink salmon, but that pink salmon ultimately had a greater effect on sockeye salmon because pink salmon were much more abundant.

Krogius (1967) examined annual scale patterns of sockeye salmon collected from the Ozernaya River, 1945–1957, and reported scale growth at sea was inversely related to pink salmon abundance. He hypothesized that competition for food was greatest during mid-summer and thereafter when prey availability was less. This hypothesis was recently substantiated by analyses of seasonal scale growth patterns of Bristol Bay sockeye salmon in which growth reduction began immediately after peak scale growth in spring (Ruggerone et al., 2005). However, the alternating-year growth pattern of Ozernaya sockeye salmon was not consistent for all age groups of salmon, leading Krogius to suggest sockeye migration patterns varied among the groups. Although somewhat speculative, he further suggested that increased high seas fishing effort on pink salmon during the study period led to greater growth of sockeye salmon as a result of less competition. Similar findings of interactions with pink salmon were found for Lake Dalnee (eastern Kamchatka Peninsula) sockeye salmon (Krogius, 1964).

Bugaev and Dubynin (2000) examined a variety of factors potentially affecting the abundance of adult Ozernaya River sockeye salmon, 1976–1998, and hypothesized that Kamchatka pink salmon negatively influenced sockeye abundance. More recently, Bugaev (2002) commented on the potential relationship between an 88% increase in Asian sockeye salmon abundance and the sudden collapse in 1985 of odd-year pink salmon runs in western Kamchatka (97% reduction from approximately 60 million pink salmon during 1975–1983). The pink salmon collapse appeared to be influenced by the exceptionally large spawning escapement and overcrowded spawning grounds in 1983 ($\sim$110 million spawners). Since 1983, even-year pink salmon runs to western Kamchatka increased substantially to approximately 61 million salmon per year and odd-year runs declined to less than two million fish per year. In eastern Kamchatka during this same period, odd-year runs of pink salmon increased from approximately 40 to 72 million salmon whereas even-year runs increased only slightly from 11 to 15 million salmon. Annual Kamchatka pink salmon abundance increased approximately 5% from 1976–1983 to 1984–1998. Bugaev hypothesized that the recent de-synchronization of the western and eastern Kamchatka pink salmon runs led to greater growth and survival of Kamchatka sockeye salmon because Kamchatka pink salmon are presently spread between both odd- and even-year lines rather than concentrated in the odd-year line.

In contrast to the hypothesis suggested by Bugaev, there is evidence that the significant shift in Kamchatka pink salmon abundance may have influenced the recent decline of Bristol Bay sockeye salmon that began with the 1991 brood year. Abundance of eastside Bristol Bay salmon (Kvichak, Naknek, Egegik, Ugashik stocks) declined 48% during brood years 1991–1998 compared with those in 1973–1990 (Ruggerone, unpublished analysis). Coincidentally, the 1991 brood year produced age-1 smolts that entered Bristol Bay in 1993 and competed with Asian pink salmon in 1994, the year that marked the beginning of relatively large runs of both odd- and even-year pink salmon. Instead of competing primarily with odd-year pink runs, eastside Bristol Bay sockeye salmon have been competing with continuously large Kamchatka pink salmon runs since the early 1990s. In contrast with eastside Bristol Bay salmon, westside Bristol Bay sockeye salmon (Nushagak District, Togiak stocks), whose ocean distribution is further east and overlaps less with Asian pink salmon (Rogers, 1987; Myers, 1997), increased slightly in abundance (17% increase). Further research is necessary to determine the validity of these hypotheses.

British Columbia

In contrast to the aforementioned studies, Peterman (1982) reported that smolt-to-adult survival of Babine Lake (British Columbia) sockeye salmon was positively correlated with the abundance of pink salmon fry entering the ocean with juvenile sockeye salmon, 1961–1978. He hypothesized that juvenile pink salmon, which were similar in size to sockeye smolts in marine waters, may have swamped predators. However, sockeye salmon survival was also inversely related to adult pink salmon abundance, suggesting adult pink salmon might be a potential predator or possibly a competitor species. No data were collected from the marine waters to test these competing hypotheses.

Chum and pink salmon interactions

Diet overlap and prey availability

Pink and chum salmon (*O. keta*) have similar life histories during early marine life and both species can be highly abundant. Pink salmon enter marine waters after minimal feeding or rearing in fresh and estuarine waters, whereas chum salmon feed briefly on freshwater and estuarine prey before entering nearshore marine areas (Healey, 1980; Heard, 1991). Chum salmon tend to enter nearshore marine areas after pink salmon, but both species rear in nearshore waters for weeks to months before moving offshore. In the Pacific Northwest, large and small mixed-species schools of chum and pink salmon have been observed (Heard, 1991). Juvenile pink and chum salmon are opportunistic foragers and their diet can be similar in coastal waters (Kaczynski et al., 1973; Beacham and Starr, 1982; Duffy, 2003).

Diet of chum salmon can be altered by pink salmon in offshore marine waters. Sano (1963) reported that total prey weight consumed by chum salmon in the Western North Pacific Ocean during May through August, 1955–1962, was approximately 27% lower during odd-numbered years when pink salmon were abundant. Ivankov and Andreyev (1971) reported that feeding rates of immature chum salmon near the Kuril Islands were lower in years of high juvenile pink salmon abundance. Tadokoro et al. (1996) examined the diet of pink and chum salmon from the Bering Sea and central North Pacific Ocean during June and July and reported that dominant prey of chum salmon changed from gelatinous zooplankton (pteropods, appendicularians, jellyfishes, etc) in 1991 when numerous pink salmon were present to crustaceans (euphausiids, copepods, amphipods, etc.) and some micronekton (squid and fish) in 1992 when few pink salmon were present. Local biomass of crustaceans in 1991 was inversely related to catch per effort of pink salmon, further indicating pink salmon reduced prey availability. In 1992, crustacean biomass was inversely related to chum salmon abundance, indicating intraspecific competition was also important. Other researchers have documented a shift in the diet of chum toward less nutritional prey in years of high pink salmon abundance (Salo, 1991). On the high seas, chum salmon appear to minimize competition with pink and sockeye salmon by consuming gelatinous zooplankton that are seldom consumed by other salmon (Welch and Parsons, 1993; Azuma, 1995).

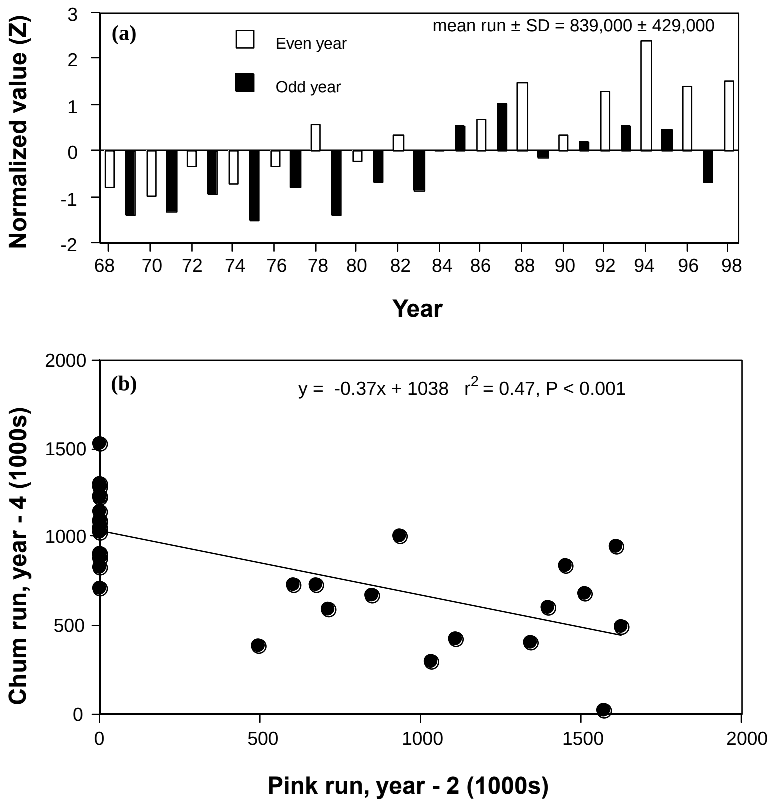

Figure 6. Time series of normalized Puget Sound chum runs during even- (few pink salmon) versus odd-numbered years, 1968–1998 (a), and the relationship between standardized Puget Sound chum and pink salmon runs (b). Chum and pink salmon runs standardized to the level in 1979 (time series mid-point) because both runs increased over time. Pink and chum runs lagged back in time to parent spawning year, i.e., four years for chum salmon (Gallagher, 1979) and two years for pink salmon. Run size data provided by J. Packer, Washington Department Fish and Wildlife, Olympia, WA.

Pacific Northwest

Phillips and Barraclough (1978) reported that chum salmon fry in the Strait of Georgia near the Fraser River estuary were larger in 1967 and 1969 (when pink salmon fry abundance was low) compared with those in 1966 and 1968 (when pink salmon fry were abundant), indicating consumption of prey by chum fry was reduced by pink salmon. Pratt (1974) reported that adult chum salmon in Puget Sound, 1954–1970, were smaller when they returned with the abundant odd-year pink salmon. Thus, during odd-numbered years in the Pacific Northwest, growth of juvenile chum salmon was greater (few juvenile pink salmon present), whereas size of adult chum salmon was less (numerous adult pink salmon present).

In Puget Sound and the Fraser River, large odd-year runs of adult pink salmon produce large numbers of pink salmon fry that enter marine waters in even-numbered years. Adult abundance, productivity (return per spawner), and survival of chum salmon is reportedly lower when juvenile chum salmon enter Puget Sound and Strait of Georgia in even-numbered years with numerous juvenile pink salmon (Gallagher, 1979; Beacham and Starr, 1982; Salo, 1991; Fresh, 1997). For example, during 1968–1998, adult chum salmon returns to Puget Sound exhibited an alternating-year pattern and their abundance was inversely correlated with pink salmon abundance (Figure 6). Beacham and Starr (1982) reported that fry-to-adult survival of Fraser River chum salmon declined 44% (from 1.53 to 0.85% survival) when they entered marine waters in even-numbered years with numerous juvenile pink salmon, 1961–1979. Beacham and Starr (1982) also reported that survival of chum salmon was greater when the median downstream migration timing of chum fry was earlier relative to pink salmon. Early migration timing appeared to reduce competition with pink salmon, thereby enhancing survival.

The odd/even year cycle of chum salmon abundance in the Pacific Northwest is maintained, in part, by a regular alteration in the age-at-maturity that appears to be an evolutionary response to competition with pink salmon (Gallagher, 1979; Smoker, 1984). In Puget Sound, odd-year broods of chum salmon, which produce fry that compete with numerous pink salmon fry, mature at a 50:50 ratio of age-3 and age-4 adult salmon (Salo, 1991). In contrast, even-year broods, whose fry experience little competition, produce approximately 35% age-3 and 65% age-4 chum salmon. Chum salmon returning to the Fraser River also exhibit this pattern of maturation. This unique pattern of maturation by chum salmon, along with a reduction in survival of odd-year broods, led to a greater number of adult chum salmon returning during even-numbered years. Progeny of these adults experienced less competition with pink salmon and greater survival.

Smoker (1984) used a simulation modeling approach to examine whether the alternating age of maturation of Puget Sound chum salmon was related to environmental versus genetic factors. He concluded that age-at-maturation was highly heritable and that genetic factors led to the alternating pattern of maturity in response to competition with odd-year pink salmon. This finding suggests competition may have been a significant factor for many generations, leading to a genetically influenced pattern of maturation that reduced competition. A key assumption in this analysis was that differences in age and size of chum salmon originating from odd- versus even- brood years led to little interbreeding between the two brood lines. It is noteworthy that the alternating-year pattern of chum salmon abundance was consistent before and after the 1982/1983 El Nino event that appeared to mark a shift in the interaction between pink salmon and Puget Sound Chinook salmon (see below). This consistency might reflect the influence of genetics on altering age-at-maturation as suggested by Smoker. "Alternatively, greater survival of even-year brood chum salmon in response to pink salmon and greater intraspecific competition among chum salmon at older life stages might have led to delayed maturation and the observed alternating-year pattern of chum run size."

No pink salmon are produced along the Oregon and Washington coasts, yet chum salmon stocks exhibit an alternating-year pattern of run size and age at maturity (Salo, 1991). For example, our updated analysis indicated chum salmon abundance in the Columbia River was 50% greater during even- compared with odd-numbered years, 1960–2000 (df = 1, 39; $F = 4.88$, $P = 0.033$; data source: ODFW/WDFW, 2002). The cyclic pattern of chum abundance was consistent throughout the 40-year period and did not change in response to climate patterns. The pattern of chum salmon abundance, which is consistent with Puget Sound and Fraser River chum salmon populations, might be explained by either a lingering genetic effect (Smoker, 1984) established when pink salmon were possibly abundant in this area or by competition with pink salmon in the ocean after chum salmon migrate north. Further research is needed to isolate the cause of this pattern of abundance in chum salmon along the Oregon and Washington coasts.

Kamchatka, Russia
Sinyakov and Ostroumov (1998) evaluated the return per spawner of northeast Kamchatka pink salmon, 1957–1993, as a means to predict adult returns of chum salmon to this region. They suggested that interspecific competition between pink and chum salmon was much less important than intraspecific competition and that environmental factors during spawning, downstream migration, and marine periods similarly affected pink and chum salmon. The researchers did not evaluate alternating-year age-at-maturation.

North Pacific Ocean
The shift in the diet of chum salmon in the North Pacific Ocean in response to pink salmon (see previous discussion) may affect growth of chum salmon. Walker and Myers (1998) examined scale growth of chum salmon collected south of the Aleutian Islands and concluded that chum growth during their third year at sea was inversely related to both Asian pink and chum salmon abundances. The inverse correlation between chum scale growth and Asian pink salmon abundance was observed before and after the 1977 regime shift. Competition with Asian pink salmon was not apparent during the first two years at sea.

Azumaya and Ishida (2000) examined the density and distribution of chum salmon in relation to pink salmon density in the North Pacific and Bering Sea using monthly gill net operations, 1972–1998. They reported that the distribution patterns of chum salmon in offshore waters shifted between even- and odd-numbered years and was opposite that of pink salmon density. Chum salmon were concentrated to the west in even-numbered years and were relatively abundant in the Bering Sea (i.e., years of low Asian pink salmon abundance in this region). During odd-numbered years, when pink salmon were abundant in the Bering Sea, density of chum salmon declined in the Bering Sea and increased in the eastern North Pacific Ocean. In contrast to findings of other studies, Azumaya and Ishida (2000) reported that age-specific growth of chum and pink salmon (change in mean length from year to year) was not related to the density of the other species, but growth was dependent on abundance of conspecifics. The authors suggested that growth of chum salmon was indirectly influenced by pink salmon because pink salmon altered the distribution of chum salmon, leading to high densities of chum salmon in specific ocean regions and density-dependent growth.

Laboratory study
Beacham (1993) conducted a laboratory study in order to evaluate competition between pink and chum salmon fry in a controlled environment. In contrast to the aforementioned studies, he found that mean weight and survival of chum salmon did not decline in response to increasing density of pink salmon. Instead, weight of pink and chum fry declined in response to increasing density of chum salmon. The results of this experiment may have been influenced by relatively large size of chum salmon (50% larger than pink salmon) and the low daily growth of pink salmon in the aquaria under monoculture and multiple species conditions. This experiment highlighted the influence of body size on species interactions.

Chinook and pink salmon interactions

Diet overlap
Juvenile and immature Chinook salmon (*O. tshawytscha*) are opportunistic in their prey selection, but they tend to feed on higher trophic level prey at earlier life stages compared with pink salmon, based on diet (Brodeur, 1990) and stable isotope analyses (Welch and Parsons, 1993; Kaeriyama et al., 2004). Some diet overlap exists between juvenile pink and Chinook salmon that recently enter marine waters, but it is much less than that between pink and chum salmon (Healey, 1980, 1991; Duffy, 2003). In the Pacific Northwest, the size of juvenile pink and subyearling Chinook salmon do not differ significantly at the time chinook enter marine waters since pink fry have been growing in marine areas for weeks to months.

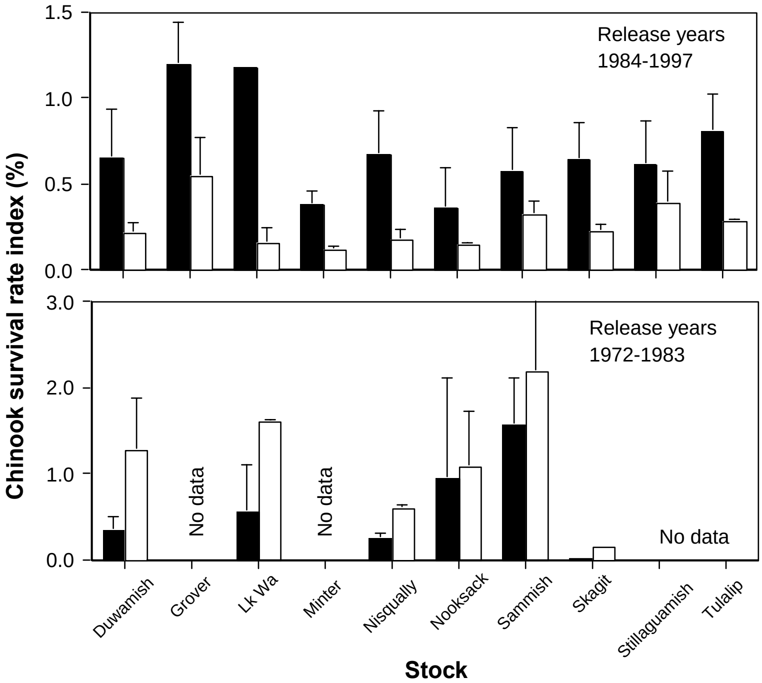

Figure 7. Release to recovery survival of coded-wire-tagged subyearling chinook salmon released into 10 Puget Sound watersheds during odd (■) and even (□) numbered years. Survival analysis split into periods before (lower graph) and after the 1982/1983 El Nino (upper graph), which led to significant changes in the marine environment (Pearcy, 1992). Values are mean + 1 standard error. Figure reproduced from Ruggerone and Goetz (2004) by permission.

Pacific Northwest

In the Pacific Northwest, where adult pink salmon are highly abundant in odd-numbered years, the release of 53.5 million coded-wire-tag (CWT) Chinook salmon was used to examine potential competition between subyearling pink and Chinook salmon (Ruggerone and Goetz, 2004). Coded-wire-tagged subyearling Chinook salmon released into streams and entering Puget Sound during even-numbered years experienced 62% lower survival than those entering the sea during odd-numbered years, 1984–1997 (Figure 7). This pattern was consistent for 10 Puget Sound stocks (range: 36–86% survival reduction depending on stock) and three lower mainland British Columbia stocks near the Fraser River (45–61% survival reduction). Analysis of age-specific recovery rates of Chinook salmon indicated that lower survival from even-year releases was established during the first year at sea. Furthermore, Chinook salmon entering Puget Sound and the eastern Strait of Georgia with numerous juvenile pink salmon in even-numbered years experienced significantly reduced growth during the first year at sea (average 17 mm reduction among survivors) and delayed maturation (average 12% increase in age-4 and older salmon). In contrast, few pink salmon originate from streams along coastal Washington and lower Vancouver Island and survival of tagged Chinook salmon released into these streams (9 stocks) did not vary between even- and odd-numbered years ($P > 0.05$). The lack of an alternating-year pattern in coastal stocks and the observation that growth and survival of Chinook salmon were reduced during the first year at sea indicates survival and growth were primarily influenced in Puget Sound and the lower Strait of Georgia.

The survival pattern of Puget Sound Chinook salmon in relation to pink salmon appeared to be influenced by climate-induced changes in the marine environment. During 1972–1983 and immediately prior to the exceptional 1982/1983 El Nino (Pearcy, 1992), the odd/even year survival pattern of Puget Sound Chinook salmon tended to be opposite that during 1984–1997 (Ruggerone and Goetz, 2004; Figure 7). Prior to the 1982/1983 El Nino, sea surface temperatures along the coast were relatively cool, upwelling was more frequent, prey availability was greater, and Puget Sound Chinook salmon experienced relatively high survival when they entered Puget Sound with numerous juvenile pink salmon. The researchers provided evidence that salmon predators and prey in the Puget Sound region were much more abundant during 1972–1983. They hypothesized that prior to the 1982/1983 El Nino, growth of juvenile Chinook salmon was relatively high and pink salmon provided a buffer to abundant predators rather than competition for prey.

The investigation of pink and Chinook salmon interactions in the Puget Sound region provided evidence that climate can alter predator-prey interactions and competition between species (Ruggerone and Goetz, 2004). From 1972–1983 to 1984–1997, Chinook survival in Puget Sound declined 50%, juvenile herring (Chinook prey) and piscivorous seabird abundance declined substantially (PSWQAT, 2002), but pink salmon abundance nearly doubled. A factor contributing to competition and the inverse relationship between pink and Chinook salmon was believed to be the observed earlier peak zooplankton production during the recent period (Bornhold, 1999) that favored early-arriving juvenile pink salmon over Chinook salmon. Ruggerone and Goetz (2004) suggested that the primary mortality source for Chinook salmon switched from predators to competitors in response to climate change and associated changes of marine species in the Puget Sound region.

Kamchatka, Russia

Grachev (1967) analyzed annual and seasonal scale patterns of stream-type Chinook salmon returning to the Kamchatka River, Russia, 1935–1955. The translated manuscript indicated that scale growth was inversely related to pink salmon abundance during the first and second growing seasons at sea, but not during subsequent years. Growth of juvenile Chinook salmon in their first ocean year was less during even-numbered years, corresponding with abundant juvenile pink salmon produced by the dominant odd-year broods (Sinyakov 1998). During the second year at sea, chinook growth was reportedly greater during odd-numbered years, a trend that was opposite that observed in Bristol Bay sockeye salmon (Ruggerone et al., 2003) and opposite that of Chinook salmon captured in the central Bering Sea during the 1990s (K. Myers, unpublished data, University of Washington, personal communication). Although there were some inconsistencies in the translated manuscript, the findings suggest Kamchatka Chinook salmon may be distributed westward of most Asian pink salmon during their second growing season.

Coho and pink salmon interactions

Coho salmon (*O. kisutch*) feed at a higher trophic level (e.g., fishes and squid) than pink salmon during the first season at sea, but diet overlap increases during the second season as pink salmon switch to larger prey such as fish and squid (Brodeur, 1990; Ogura et al., 1991). Stable isotope ratios suggested some overlap in the trophic level of pink and coho salmon (Welch and Parsons, 1993; Kaeriyama et al., 2004). Consistent with the observation of diet overlap during the second growing season, Ogura et al. (1991) reported that final year growth rates of coho salmon were lower in years of high pink salmon abundance (odd-numbered years) in the western North Pacific Ocean. We are aware of no other studies that examined interactions between pink and coho salmon in the marine environment.

Intraspecific competition

Pink salmon are highly abundant and their rapid migration and dispersal as fry from streams through the estuary and into nearshore marine waters may be a mechanism to minimize intraspecific competition during early life. In offshore waters of the Bering Sea and central North Pacific Ocean, reduced consumption of prey and alteration of diet has been documented during odd-numbered years when pink salmon abundance is great (Tadokoro et al., 1996; Davis, 2003). Walker and Myers (1998) examined scale growth of pink salmon collected south of the Aleutian Islands and found second year scale growth was density-dependent prior to the 1977 climate shift when zooplankton and pink salmon abundance was less (Brodeur and Ware, 1992; Mantua et al., 1997). After 1977, when salmon abundance and prey production was relatively great, Walker and Myers found that both first and second year growth were positively correlated with pink salmon abundance.

This analysis included both even- and odd-year lines of pink salmon, which may have confounded density-dependent relationships. After excluding the genetically distinct and smaller even-year pink salmon (see below), Azumaya and Ishida (2000) demonstrated that size of odd-year pink salmon in the Bering Sea was inversely related to their abundance during 1973–1997. We examined average weight of odd-year adult pink salmon in Puget Sound, 1959–1999, and found that their weight was inversely related to total abundance of pink salmon returning to the Fraser River and Puget Sound ($n = 21$, $P = 0.013$, $R^2 = 0.28$).

The relationship between pink salmon growth and density may be confounded by the unique genetic characteristic of odd- versus even-year pink salmon, which are genetically distinct (Heard, 1991). For example, Azumaya and Ishida (2000) documented that length of pink salmon in the Bering Sea during July was significantly greater during odd-numbered years when pink salmon were highly abundant compared with length in even-numbered years (few smaller-sized pink salmon were captured in even years). These authors attributed greater size of odd-year pink salmon to genetic factors. Heard (1991) reviewed adult size of pink salmon from North America and concluded that the odd-year line of pink salmon tended to be larger than the even-year line. This pattern was consistent in areas where odd-year pink salmon were dominant (e.g., Puget Sound) and in areas where both odd- and even-year pink salmon were relatively abundant (e.g., central and northern British Columbia). In contrast, in some areas of Russia, pink salmon size was inversely related to abundance (Heard, 1991).

Birman (1976) argued that the two-year life cycle of abundance shown by pink salmon and other salmon species in Russia was related to a variety of factors other than interspecific competition. Birman (1976) suggested that abundances of zooplankton and salmon in the North Pacific Ocean was related, in part, to two-year cycles in ocean currents and wind, which in turn were influenced by a two year solar cycle. He also suggested that a two-year cycle in river flows influenced pink and chum salmon in the Amur River, Russia, and interactions between seaward migrating juvenile salmon and returning adults maintained two-year cycles of abundance. We are not aware of other studies that support Birman's ideas on two-year cycles in the North Pacific Ocean.

The genetically distinct odd-and even-year lines of pink salmon can lead to significantly different levels of abundance that is maintained, in part, by the invariable two-year life cycle of pink salmon. Ricker (1962) and Heard (1991) reviewed possible mechanisms that might lead to dominance of one line. Potential mechanisms included depensatory mortality where small populations suffer disproportionately greater mortality, depensatory fishing, cannibalism of adults on juvenile pink salmon, fouling of the spawning grounds by dead eggs produced by the dominant line, and food competition. Ultimately, Ricker could find no strong evidence for any single mechanism and suggested that multiple factors likely interact to develop and maintain dominance. It is noteworthy that considerable attempts to establish or enhance off-year lines of pink salmon through supplementation have failed (Heard, 1991). It is also noteworthy that the off-year line in western Kamchatka rebounded immediately following the collapse of the dominant odd-year line in response to significant over-crowding of the spawning grounds (Bugaev, 2002). These findings suggest that the odd-year line was somehow suppressing the even-year line, but not by fouling of the spawning grounds or cannibalism. Intraspecific competition remains a possible mechanism leading to dominant pink salmon cycles, possibly by influencing cyclic patterns in production of prey species at critical early life stages (Ruggerone et al., 2005).

Interactions with pink salmon in freshwater

Juvenile pink salmon spend little time in freshwater habitats prior to migrating to sea (Heard, 1991), therefore effects of competition with other species in fresh water is likely negligible. However, as described below, several studies indicate pink salmon benefit other salmon species, primarily by providing an important source of food.

A variety of studies have documented significant predation on pink salmon as they migrate down river to marine waters (Heard, 1991). Coho salmon, steelhead (*O. mykiss*), cutthroat trout (*O. clarki clarki*), and char (*Salvelinus* spp.) are key predators that benefit from the abundance of pink salmon fry. Pink salmon fry are also consumed by other salmonids in nearshore marine waters.

In the Skagit River, Washington, the adult return per spawner of coho salmon was positively correlated with pink salmon spawners co-occurring with subyearling life stage coho salmon (Michael, 1995). Juvenile coho salmon reportedly consumed pink salmon eggs and flesh of carcasses, leading to greater growth and survival.

In the Keogh River, British Columbia, steelhead smolt abundance and size were positively correlated with the abundance of spawning pink salmon during the previous fall (Ward and Slaney, 1988). During the fall, steelhead parr fed intensively on dislodged pink salmon eggs and possibly carcasses, leading to enhanced growth and survival in freshwater. Steelhead survival at sea was positively correlated with smolt size, suggesting that consumption of pink salmon in streams also had a beneficial effect on survival at sea.

Pink salmon typically spawn prior to most other species of Pacific salmon, therefore their redds may be subjected to superimposition by other salmon spawning in the same reaches. Gallagher (1979), who documented lower returns of Puget Sound chum salmon that competed with juvenile pink salmon in marine waters, provided evidence that pink salmon returns declined with increasing abundances of chum salmon on the spawning grounds. Other than interactions involving predation, this is one example where pink salmon were adversely affected by other Pacific salmon.

Discussion

Interspecific competition has long been thought to be one of the more important processes determining the structure of natural communities, and many studies have documented competition in terrestrial, freshwater, and marine communities (Schoener, 1983; Bertness et al., 2001; Chase et al., 2002). Still, the role of interspecific competition in structuring populations has been controversial, largely because many factors may influence populations and because ''ghosts of competition past'' may or may not have been important in partitioning of species niches and reducing competition during the current period. The variety of studies presented here utilized the natural experimental control provided by alternating-year abundances of pink salmon to show that prey abundance, diet, growth, and survival of salmon varied inversely to pink salmon abundance. These studies provide evidence that competition can be an important process in offshore marine waters where the lack of experimental controls and vast area occupied by migratory species often inhibit evaluation of interspecific competition (Cushing, 1975; Sinclair, 1988).

The variety of studies from the North Pacific Ocean, Bering Sea, and adjoining coastal waters indicates pink salmon influenced each species of salmon by reducing availability of prey. Chum and sockeye salmon experienced lower prey availability, reduced food consumption and growth, and lower survival in years when pink salmon were abundant (e.g., Salo, 1991; Ruggerone et al., 2003). Puget Sound Chinook salmon experienced reduced growth and survival when pink salmon were abundant (Ruggerone et al., 2004), and one study indicated growth of coho salmon on the high seas was reduced during years of high pink salmon abundance (Ogura et al., 1991). In the North Pacific Ocean, consumption of key prey changed more in sockeye and chum salmon than in pink salmon when abundance of pink salmon was great (Salo, 1991; Tadokoro et al., 1996; Davis, 2003), suggesting that pink salmon were efficient foragers. We are not aware of studies indicating other salmon species adversely affect pink salmon in marine waters through competitive interactions, although a laboratory study suggested growth of pink salmon fry declined in the presence of large chum salmon (Beacham, 1993). The consistency in findings presented here suggests that pink salmon may be the dominant competitor among salmonids in the North Pacific Ocean.

Competitor characteristics of pink salmon

The ability of pink salmon to affect other salmonids stems from their great abundance, rapid growth, high feeding rates, and their unique life history (LeBrasseur and Parker, 1964; Heard, 1991). Pink salmon enter the marine waters, such as Puget Sound, before many other subyearling salmon and begin foraging on small, lower trophic level invertebrates (Healey, 1980). This life history trait enables pink salmon to avoid competition in freshwater and estuarine areas while allowing access to marine prey before most other salmon. Subyearling Chinook and chum salmon tend to follow pink salmon from nearshore to epipelagic habitats and they experience reduced prey availability or growth in years of high pink salmon abundance (Salo, 1991; Ruggerone and Goetz, 2004). In the North Pacific Ocean, sockeye salmon from Bristol Bay appear to follow pink salmon as both species migrate northwest during spring (Myers et al., 1996), leading to reduced growth of sockeye salmon. In spring of their second season at sea, pink salmon appear to begin exploiting large prey, such as squid, earlier in the season compared with smaller sockeye salmon (Aydin, 2000). Pink salmon also appear to exploit key prey more efficiently than sockeye and chum salmon (Tadokoro et al., 1996; Davis, 2003). Thus, pink salmon compete with other species by directly altering prey availability of other salmon or indirectly by feeding on smaller prey and altering food web dynamics.

Climate change and competition

Competition between pink and other salmon species was observed before and after the 1977 ocean regime shift, suggesting the influence of competition can transcend recent climatic events. Competition was observed before and after 1977 among Bristol Bay and Russian sockeye salmon (Krogius, 1967; Bugaev et al., 2001; Ruggerone et al., 2005) and chum salmon in the North Pacific Ocean and Puget Sound (Sano, 1963; Tadokoro et al., 1996; Salo, 1991). However, in the Puget Sound region, coded-wire-tag data indicated mortality of chinook salmon switched from predation-based to competition-based mortality in response to the 1982/1983 El Nino that influenced predator, competitor, and prey abundances (Ruggerone and Goetz, 2004). Thus, competition can be an important factor affecting salmon populations in multiple climatic regimes or, in some cases, it may only occur during periods of low prey reduction.

Climate has a long-term effect on salmon populations, as indicated by the 1977 ocean regime shift that led to substantial increases in abundances of all salmon species in northern regions (Rogers 1984, Mantua et al., 1997; Figure 1). If population trends of salmon species are positively correlated, how can competition be an important factor regulating salmon populations in the marine environment? We propose that the answer lies in the temporal and spatial scales of competition and other factors that influence salmon abundance. Although mechanisms leading to greater salmon abundance after 1977 are not well known, greater prey production during early marine life may have been a key factor (Brodeur and Ware, 1992; Ruggerone et al., 2002). Apparently all species of salmon benefited by this change because they are opportunistic foragers and their diets are often similar (Welch and Parsons, 1993; Kaeriyama et al., 2004). However, the rapid increase in salmon after 1977 led to food limitations, as indicated by studies of intraspecific competition effects on salmon growth at sea (Bigler et al., 1996; Rogers and Ruggerone, 1993). Thus, while climate change enhanced salmon survival during a critical life stage of salmon, prey availability at some life stages was limited and competition continued to influence growth and survival of salmon. The finding of competitive dominance of pink salmon across multiple climate regimes seems to be somewhat unique in the ecological literature because other studies suggest climate change may alter competition and favor one species over the other (Skud, 1982; Jiang and Kulczycki, 2004).

Management implications

The finding that interspecific competition in marine waters can affect salmon population levels has important implications for management of salmon harvests and hatcheries. Competition is a function of species abundances and salmon hatcheries have released up to five billion salmon per year into the North Pacific Ocean in order to enhance or maintain harvests (Mahnken et al., 1998). In some regions, such as the Pacific Northwest, numerous hatchery salmon are released into streams with depressed native salmon runs. Although interactions between hatchery and native salmon have rarely been directly studied in marine waters (Levin et al., 2001), concerns have been raised about effects of competition (Bigler et al., 1996; Pearcy et al., 1999). These concerns have raised the controversial question of whether hatchery salmon production should be allocated among countries (Joyner, 1975; Heard, 1998), but actions are unlikely without more data indicating competition can limit population abundances.

Competition from conspecific salmon can be greater than that from other species because niche overlap is greater among conspecific salmon (Azumaya and Ishida, 2000; Bugaev et al., 2001; Ruggerone et al., 2003). Studies of intraspecific competition, however, typically lack the experimental control, such as that offered by cyclic pink salmon abundances, needed to evaluate the effects of competition on population levels. Effects of intraspecific competition are typically based on changes in growth or habitat utilization. Given the greater per capita effect of intraspecific competition, our review of interspecific competition provides evidence that intraspecific competition may significantly influence salmon growth and survival, especially when numerous hatchery fish are released into the environment during periods of low prey production (Achord et al., 2003).

Future research

Mechanisms linking pink salmon to reduced growth and/or survival of other salmon is not well known in some regions. For example, in Puget Sound, where Chinook salmon exhibited a strong alternating-year pattern of growth and survival that was opposite pink salmon abundance, juvenile Chinook salmon feed more on larger and higher trophic level prey compared with juvenile pink salmon, and the linkage between pink and Chinook salmon was not obvious (Ruggerone and Goetz, 2004). The researchers suggested that pink salmon might indirectly reduce availability of Chinook salmon prey by altering food web dynamics. Although diet of salmon has been frequently examined, food web dynamics supporting foraging salmon are not well known because salmon continually change habitats and prey preferences as they grow and because prey population dynamics are rarely studied.

In Alaska, Bristol Bay sockeye salmon exhibited a strong alternating-year pattern in growth at sea from 1955 to 2000 (Ruggerone et al., 2003). This pattern was persistent even though sockeye are broadly distributed and forage in ocean regions having different dominant prey species (Aydin, 2000). Examination of seasonal sockeye scale growth indicated growth reduction began after peak growth in spring and continued well after pink salmon had migrated to coastal waters (Ruggerone et al., 2005). These researchers hypothesized that two-year life cycles of key prey, in conjunction with predation by cyclic pink salmon, may help maintain cyclic patterns in prey abundances and the observed cyclic patterns of salmon growth and survival.

Observations of competition between pink salmon and other salmon were facilitated by alternating-year patterns of pink salmon abundance. These observations suggest new hypotheses about food web dynamics, life history patterns of prey species, and mechanisms in which climate change influences species assemblages in the ocean. In addition to the natural experimental control provided by the alternating-year pattern of pink salmon abundance, Pacific salmon provide a unique research tool because they migrate across large expanses of the North Pacific Ocean, then return to natal streams where data can be readily gathered on their seasonal growth at sea, survival and abundance. These characteristics of salmon and relatively long time series of data for some salmon stocks provide opportunities to investigate relationships among physical oceanographic and climatic conditions, community structure and population dynamics, and anthropogenic activities that affect fish and fisheries. Studies should attempt to incorporate the natural experimental control provided by alternating-year abundances of pink salmon.

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ARTICLE

Productivity and life history of sockeye salmon in relation to competition with pink and sockeye salmon in the North Pacific Ocean

Gregory T. Ruggerone and Brendan M. Connors

Abstract: Sockeye salmon (*Oncorhynchus nerka*) populations from Southeast Alaska through British Columbia to Washington State have experienced similar declines in productivity over the past two decades, leading to economic and ecosystem concerns. Because the declines have spanned a wide geographic area, the primary mechanisms driving them likely operate at a large, multiregional scale at sea. However, identification of such mechanisms has remained elusive. Using hierarchical models of stock–recruitment dynamics, we tested the hypothesis that competition between pink (*Oncorhynchus gorbuscha*) and sockeye salmon for prey has led to reduced growth and productivity and delayed maturation of up to 36 sockeye populations spanning the region during the past 55 years. Our findings indicate the abundance of North Pacific pink salmon in the second year of sockeye life at sea is a key factor contributing to the decline of sockeye salmon productivity, including sockeye in the Fraser River where an increase from 200 to 400 million pink salmon is predicted to reduce sockeye recruitment by 39%. Additionally, length-at-age of Fraser River sockeye salmon declined with greater sockeye and pink salmon abundance, and age at maturity increased with greater pink salmon abundance. Our analyses provide evidence that interspecific competition for prey can affect growth, age, and survival of sockeye salmon at sea.

Résumé : Les populations de saumons rouges (*Oncorhynchus nerka*) du sud-est de l'Alaska à la Colombie-Britannique, jusqu'à l'État de Washington ont connu des baisses semblables de productivité au cours des deux dernières décennies, suscitant des inquiétudes d'ordre économique et écosystémique. Étant donné la vaste étendue géographique de ces baisses, les principaux mécanismes à l'origine de celles-ci s'opèrent vraisemblablement en mer, à une échelle multirégionale. La nature de ces mécanismes demeure toutefois difficile à cerner. À l'aide de modèles hiérarchiques de la dynamique stock–recrutement, nous avons testé l'hypothèse selon laquelle la concurrence pour les proies entre les saumons roses (*Oncorhynchus gorbuscha*) et rouges a mené à des réductions de la croissance et de la productivité et a retardé la maturation de jusqu'à 36 populations de saumons rouges à l'échelle de la région au cours des 55 dernières années. Nous observations indiquent que l'abondance du saumon rose du Pacifique Nord durant la deuxième année en mer du saumon rouge est un facteur clé de la baisse de productivité des saumons rouges, dont ceux du fleuve Fraser, où il est prédit qu'une augmentation de 200 à 400 millions de saumons roses entraînera une réduction du recrutement de saumons rouges de 39 %. En outre, la longueur selon l'âge des saumons rouges du fleuve Fraser a diminué parallèlement à l'augmentation de l'abondance des saumons rouges et roses, et la maturité selon l'âge a augmenté parallèlement à l'abondance des saumons roses. Nos analyses indiquent que la concurrence interspécifique pour les proies peut avoir une incidence sur la croissance, l'âge et la survie des saumons rouges en mer. [Traduit par la Rédaction]

Introduction

Sockeye salmon (*Oncorhynchus nerka*) is one of the most economically, ecologically, and socially important Pacific salmon species. This is particularly true for Fraser River sockeye salmon, which support major international commercial and First Nations fisheries, spawn in hundreds of unique locations throughout the 220 000 km² Fraser River basin, and are a cultural icon. The Fraser sockeye fishery has been monitored and managed for many decades with the key objectives of meeting spawning objectives and achieving sustainable runs and harvests (Roos 1991). Nevertheless, the abundance of Fraser sockeye salmon has decreased substantially since the late 1980s, leading to considerable concern. In 2009, the run of 1.5 million adult sockeye salmon was the lowest since 1947, and it achieved only 14% of the preseason forecast of 10.5 million salmon (Peterman et al. 2010). This large and unexpected decline led to a judicial inquiry and a scientific workshop to uncover factors that might have influenced the long-term decline and the unexpected collapse in 2009 (Peterman et al. 2010), which was followed by an unexpectedly large return in 2010 and higher, though variable, abundances in 2011–2014. Initial scientific analyses indicated the long-term decline in abundance was likely associated with a decline in productivity at sea rather than low parental spawner abundances or other factors in fresh water. Factors in fresh water are known to adversely impact Fraser sockeye salmon (e.g., Hinch et al. 2012), but the observed long-term decline in productivity could not be explained by freshwater processes alone (Peterman et al. 2010; Connors et al. 2012). Recently, a number of investigations have explored early marine factors associated with the unexpectedly small sockeye salmon return in 2009 (Rensel et al. 2010; Miller et al. 2011; Beamish et al. 2012; Thomson et al. 2012; McKinnell et al. 2014).

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As a means to further identify potential factors influencing Fraser sockeye salmon, Peterman and Dorner (2012) examined the population dynamics of sockeye salmon populations extending from Puget Sound (Washington) through British Columbia (BC) and into western Alaska. They found that the productivity (adult recruits produced per spawner) of sockeye populations from Washington through Southeast Alaska, including the Yakutat region, was positively correlated and exhibited a shared declining trend in recent decades. They recommended that future research on declines in sockeye productivity focus on mechanisms that operate at large multiregional scales, such as marine areas where the sockeye populations overlap.

One potential mechanism that operates at large spatial scales is competition at sea between Fraser sockeye salmon and pink salmon (*Oncorhynchus gorbuscha*) (Peterman et al. 2010). Fraser sockeye salmon and pink salmon from distant regions are broadly distributed and overlap in the North Pacific Ocean (Myers et al. 2007; Beacham et al. 2014). Adult pink salmon returning from the North Pacific Ocean are exceptionally abundant, averaging approximately 4.7 times more adults than sockeye salmon during 1952–2005 (Ruggerone et al. 2010). A review of studies indicated that pink salmon can influence the diet, growth, distribution, age at maturation, and survival of other Pacific salmon (Ruggerone and Nielsen 2004; Atcheson et al. 2012). Sockeye salmon may be especially vulnerable to competition with pink salmon because they share common prey at sea (Pearcy et al. 1988; Kaeriyama et al. 2000; Bugaev et al. 2001; Davis et al. 2005). For example, growth of sockeye salmon originating from Bristol Bay, Alaska, was inversely related to abundance of Russian pink salmon, and sockeye salmon survival at sea and adult abundance was substantially reduced when they overlapped with pink salmon during odd-numbered years of their second year at sea (i.e., when pink salmon were exceptionally abundant owing to their biennial cycle; Ruggerone et al. 2003, 2005). A number of studies have shown that reduced growth of salmon at sea can lead to lower survival (Moss et al. 2005; Friedland et al. 2009; Farley et al. 2011) and delayed age at maturation (Pyper et al. 1999; Healey et al. 2000; Morita and Fukuwaka 2007; Wells et al. 2007). These studies, and the observation that annual pink salmon abundance has increased over time to approximately 640 million adults in 2009, provide initial evidence that Fraser River sockeye salmon may be influenced by pink salmon.

An examination of broad-scale factors that may have adversely affected the productivity of Fraser and other sockeye populations in BC during the past 50 years concluded that the abundance of pink salmon had the strongest negative relationship with sockeye productivity of the variables examined (Connors et al. 2012). In addition, regional sea-surface temperature appeared to have a moderate effect on sockeye productivity, and exposure to farmed salmon early in marine life (via an unknown mechanism) appeared to exacerbate the influence of competition with pink salmon later in sockeye marine life (Connors et al. 2012). The hypothesis of delayed density dependence in response to high parent spawner abundances was not supported as a common factor responsible for declining productivity across the sockeye populations considered (Connors et al. 2012; Peterman and Dorner 2012). While these analyses provided the most comprehensive examination of correlates of declining productivity in Fraser sockeye to date, they only considered a single line of evidence (lifetime productivity) for a group of populations originating from a smaller portion of the region of shared declines in sockeye productivity (Peterman and Dorner 2012).

Here we use comparisons between odd and even years and hierarchical statistical models of stock–recruitment dynamics to test the hypothesis that competition with pink salmon from across the North Pacific has led to declines in productivity of sockeye populations ranging from Washington State through Southeast Alaska. In addition, we test the hypothesis that pink salmon abundance influenced length-at-age and age at maturation (years at sea) of Fraser sockeye salmon. These analyses consider the density-dependent effects of sockeye salmon abundance in the North Pacific, as well as the potentially confounding effects of sea-surface temperature and farmed salmon production. We did not test for potential competition between chum (*Oncorhynchus keta*) and sockeye salmon because their diets are often markedly different (Azuma 1995; Davis et al. 2005), and a previous study did not find evidence of competition between chum and sockeye salmon (Rogers and Ruggerone 1993), but we note that stable isotope research suggests trophic overlap of pink, chum, and sockeye salmon (Johnson and Schindler 2009). This examination of multiple lines of evidence provides the most extensive evaluation to date of the hypothesis that competition at sea can influence the population dynamics of Pacific salmon.

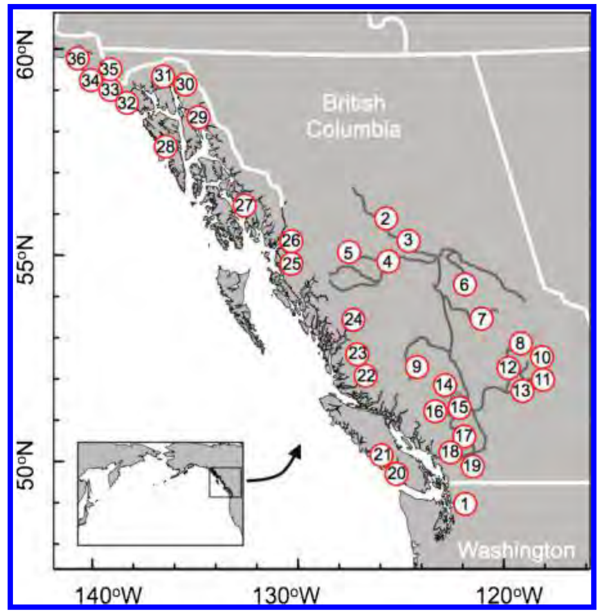


Fig. 1. Map with locations of sockeye salmon populations considered in the analyses. See Table 1 for details of the populations corresponding to each number.

Materials and methods

Sockeye salmon data

To test hypotheses related to the influence of competition with pink and sockeye salmon on sockeye salmon productivity, we used time series of the abundance of sockeye salmon spawners and adult recruits (the total number of adults, including those caught in fisheries) from one population in Washington State, 25 populations in BC, and 10 populations in the Southeast Panhandle and Yakutat regions of Alaska (Fig. 1 and Table 1). These 36 sockeye populations span a region of shared declining trends in productivity, suggesting that mechanisms that operate at this large, multiregional spatial scale are (at least partially) responsible for the declines in productivity observed in the Fraser River (Peterman and Dorner 2012). Details of the sockeye productivity time series can be found in Connors et al. (2012) and Peterman and Dorner (2012). Most time series extended back to the 1950s and 1960s, and many of the populations are dominated by salmon spending 1 year in fresh water and 2 years at sea, thereby maturing as 4-year-old salmon (age-1.2). For a subset of Fraser River populations, we analyzed data provided by the Pacific Salmon Commission on the standard length of 4-year-old male and female sockeye on the spawning grounds to test hypotheses related to the influence of competition on sockeye growth (15 populations). Only years with 50 or more individual measurements of each sex per

Table 1. Sockeye salmon populations (stock) considered.

Number	Jurisdiction	Region	Population	Brood years	Male length	Female length	Proportion ocean-age-3
1	Washington	Washington	Lake Washington	36	—	—	—
2	BC	Fraser	Early Stuart	55	35	35	55
3	BC	Fraser	Late Stuart	54	29	29	54
4	BC	Fraser	Stellako	55	—	—	55
5	BC	Fraser	Nadina	30	12	12	30
6	BC	Fraser	Bowron	55	14	14	55
7	BC	Fraser	Quesnel	55	20	20	55
8	BC	Fraser	Raft	55	29	29	55
9	BC	Fraser	Chilko	55	44	44	55
10	BC	Fraser	Seymour	55	39	39	55[a]
11	BC	Fraser	Late Shuswap	53	22	22	53[a]
12	BC	Fraser	Fennell	36	14	14	36
13	BC	Fraser	Scotch	22	—	—	22
14	BC	Fraser	Portage	39	21	21	39
15	BC	Fraser	Gates	35	25	25	35
16	BC	Fraser	Birkenhead	55	35	35	55
17	BC	Fraser	Harrison River	55	—	—	39[a]
18	BC	Fraser	Weaver	37	26	26	37
19	BC	Fraser	Cultus	49	24	24	36[a]
20	BC	Barkley Sound	Great Central Lake	25	—	—	—
21	BC	Barkley Sound	Sproat Lake	25	—	—	—
22	BC	Central Coast	Long Lake	33	—	—	—
23	BC	Central Coast	Owikeno Lake	33	—	—	—
24	BC	Central Coast	Atnarko	31	—	—	—
25	BC	North Coast	Skeena	35	—	—	—
26	BC	North Coast	Nass	22	—	—	—
27	Alaska	Southeast	McDonald	22	—	—	—
28	Alaska	Southeast	Redoubt	15	—	—	—
29	Alaska	Southeast	Speel	14	—	—	—
30	Alaska	Southeast	Chilkoot	28	—	—	—
31	Alaska	Southeast	Chilkat	24	—	—	—
32	Alaska	Yakutat	Klukshu	30	—	—	—
33	Alaska	Yakutat	East Alsek	26	—	—	—
34	Alaska	Yakutat	Alsek	30	—	—	—
35	Alaska	Yakutat	Italio	26	—	—	—
36	Alaska	Yakutat	Situk	22	—	—	—

Note: Brood years refer to the total number of brood years available from each population for the analysis of productivity. Values in "length" columns are the number of brood years in which there were at least 50 length measurements of 4-year-old male and female sockeye on the spawning grounds. Values in "Proportion ocean-age-3" column are the number of brood years for which we could calculate the proportion of total recruits from a given brood year that spent 3 years at sea.

[a]These populations have, on average, less than 5% of the adult return that spend 3 years at sea and so were excluded from age at maturity analyses because mean age at maturity changed very little from year to year, possibly in response to other factors such as physical constraints imposed by spawning habitat.

population were used in the analyses of growth in relation to pink and sockeye salmon abundance (Table 1). For those Fraser River populations for which we had detailed brood tables (18 populations), we also calculated the proportion of total recruits that spent 3 years at sea to test hypotheses related to the influence of competition on sockeye age at maturity (Table 1). Fraser River populations having less than 5% of the adult return spending 3 years at sea (ocean-age-3), on average, were excluded from this analysis because mean age at maturity changed very little from year to year, possibly in response to other factors such as physical constraints imposed by spawning habitat (Quinn 2005).

Total abundances of sockeye salmon in the North Pacific that may compete with Alaska, BC, and Washington State sockeye salmon were obtained from Ruggerone et al. (2010) for years 1952 to 2005. These data included sockeye salmon returning to Russia, Alaska, BC, and Washington. The dataset was updated using reported runs (catch and escapement) of Russian sockeye salmon during 2006–2010 (www.npafc.org) and a regression of North American sockeye salmon abundance on sockeye catch in Alaska (www.npafc.org) from 1952 to 2005 (North American sockeye abundance in millions = [1.4 × Alaska catch in millions] + 19.8; R^2 = 0.92; n = 58).

Pink salmon data

We derived indices of the abundance of pink salmon that may compete with sockeye salmon from a dataset of the total number of adult pink salmon from key populations across the North Pacific Ocean from 1952 to 2005. These populations were from Japan, Russia (western Kamchatka, eastern Kamchatka, mainland, and islands), Alaska (Prince William Sound, Kodiak, Alaska Peninsula, and Southeast Alaska), BC (southern and northern BC and the Fraser River), and Washington (Puget Sound) (Ruggerone et al. 2010). These data were updated through 2010 (Japan: North Pacific Anadromous Fish Commission Doc. 1344, www.npafc.org; Russia: North Pacific Anadromous Fish Commission Doc. 1269, www.npafc.org; Prince William Sound: S. Moffitt, Alaska Department of Fish and Game (ADF&G), Cordova, Alaska; Kodiak: ADF&G staff, Kodiak, Alaska; Southeast AK: Piston and Heinl (2011); Fraser: S. Latham, Pacific Salmon Commission). Pink salmon originating in southern BC and Puget Sound from 2006 onwards were estimated from Fraser pink salmon adult recruits by regressing southern BC and Puget Sound pink salmon on Fraser River pink salmon from 1958 to 2005 (southern BC + Puget Sound pink salmon in millions = [1.06 × Fraser pink salmon in millions] + 3.69; R^2 = 0.86; n = 48).

Hypotheses

First, since pink salmon tend to be more abundant across the North Pacific in odd-numbered years owing to their 2-year life cycle (Ruggerone et al. 2010), we examined the hypotheses that sockeye productivity and length-at-age were less, and age at maturity later, in odd versus even years. These comparisons between even and odd years were then complimented with more detailed analyses that examined the evidence for four separate hypotheses related to the intensity of interactions between sockeye salmon and abundances of pink and sockeye salmon in the ocean. The first three hypotheses examined the potential influence of competition with pink salmon and conspecifics on sockeye salmon productivity, age at maturity, and growth at sea at two temporal scales (i.e., interactions beginning during first versus second year at sea). The sensitivity of these findings to the spatial scale of pink and sockeye salmon (i.e., North Pacific versus North American populations) and the potentially confounding influences of sea surface temperature (SST) and farm salmon production (Connors et al. 2012) were also examined (see section on Sensitivity analyses). The fourth hypothesis examined the potential role that predation on juvenile sockeye salmon in coastal areas by returning pink salmon plays on sockeye productivity (e.g., Peterman 1982). Below we describe the analyses testing each of these hypotheses in detail.

1. Odd–even year patterns in sockeye characteristics

As an initial examination of the potential effects of pink salmon on sockeye salmon, we plotted sockeye survival (residuals from Ricker stock–recruitment relationship), length of age-1.2 male and female sockeye salmon, and proportion of ocean-age-3 sockeye salmon in adult returns to determine whether there were alternating year patterns consistent with the difference in abundance between even- and odd-year pink salmon. The plots were generated for the entire period of data availability, as well as for the period after the mid-1970s ocean regime shift when abundance of pink salmon in the ocean doubled (Ruggerone et al. 2010). These comparisons between odd and even years provide a first pass examination of the evidence for differences in productivity, growth, and age at maturity between years of lower and higher pink salmon abundance. However, these initial plots do not account for the magnitude of differences in pink salmon abundance between years or other potentially confounding factors (e.g., intraspecific competition). Therefore, we complemented these initial plots with more comprehensive statistical evaluations of the influence of pink salmon as described below.

2. Competition effects on sockeye productivity

We tested whether competition between pink salmon and sockeye salmon in their first and second year at sea leads to reduced sockeye productivity. To formalize this hypothesis, we fit a modified Ricker stock–recruitment relationship (Ricker 1975) to the data as a hierarchical model:

$$\ln\left(\frac{R_{i,t}}{S_{i,t}}\right) = (\mu_\alpha + \alpha_i + \alpha_t) - b_i S_{i,t} + (\mu_j + \delta_{i,j})E_{j,i,t+x} + \varepsilon_{i,t} \quad (1)$$

where $R_{i,t}$ is the total number of adult sockeye recruits to population i produced by spawners ($S_{i,t}$) in brood year t, μ_α is the intrinsic rate of population growth (i.e., productivity at low spawner abundance) common to all populations, and b_i is density dependence in relation to the carrying capacity of population i. E is one or more of j time series of independent variables experienced in year x of the sockeye salmon life cycle that represent how pink and sockeye salmon might compete with sockeye salmon during each year of sockeye residence in the ocean (see below), μ_j is the overall effect of variable E on productivity, and $\delta_{i,j}$ is the random population-specific effect. The terms α_i, α_t, and $\delta_{i,j}$ are assumed to be population- (i) or year- (t) specific deviations from the mean response μ_α and μ_j, where $\alpha_i \sim N(0, \sigma^2_{\alpha_i})$, $\alpha_t \sim N(0, \sigma^2_{\alpha_t})$, and $\delta_{i,j} \sim N(0, \sigma^2_{\delta_{i,j}})$ (Pinheiro and Bates 2000; Mueter et al. 2002*a*), and $\varepsilon_{i,t}$ is residual error with mean of zero and variance that is estimated (i.e., $\sim N(0, \sigma^2_\varepsilon)$). These terms are often referred to as random effects and in our case the location-dependent random effect (α_i) captures natural variation among populations in productivity. The time-dependent random effect (α_t) captures variation in productivity among years common to all populations and accounts for the nonindependence of observations within years in relation to indices of ocean basin-scale competitors that are the same for all populations within a year. The location-dependent random effects on the slope of the relationships ($\delta_{i,j}$) captures intrinsic differences in how each population responds to an independent variable as opposed to constraining the model to assume all populations respond in the same way (i.e., magnitude and direction) to a given independent variable.

We considered three possible indices of pink and sockeye salmon competitors (i.e., the E_j values in eq. 1). First, as an index of the number of juvenile pink salmon that may begin competing with sockeye salmon in their first year at sea (McKinnell and Reichardt 2012), we used the abundance of adult pink salmon from the Northeast Pacific (northern BC and Alaska) 3 years after each sockeye brood year for sockeye that spent 1 year in fresh water before migrating to sea. For those sockeye populations that spent more than 1 year in fresh water, we used the number of adult pink salmon in years t + 3 and t + 4 weighted by the proportions of juvenile sockeye entering the ocean each year, as determined by age-specific abundances of adult sockeye salmon. Second, as an index of the potential number of pink salmon that may begin to compete with sockeye in their second growing season at sea, we used the total abundance of adult pink salmon across the North Pacific 4 years after each sockeye brood year (Ruggerone and Nielsen 2004; Connors et al. 2012). These pink salmon would have likely interacted with the sockeye brood beginning in the late portion of their second year at sea, continuing through winter and into the third growing season. In the third growing season, the sockeye would have either matured and returned to fresh water after 2 years at sea (e.g., age-1.2) or delayed maturation until 3 years at sea (e.g., age-1.3). Third, we used the total abundance of sockeye salmon across the North Pacific as an index of potential conspecific competitors during marine life. Additional independent variables were evaluated in the sensitivity analyses described below.

Considering multiple populations simultaneously can increase the chance of finding true relationships by allowing for common responses to be more easily isolated from random demographic noise and sampling errors (e.g., Myers and Mertz 1998). Two possible alternatives to considering all populations simultaneously are the following: (1) no pooling of data and separate tests of the hypotheses for each individual population or (2) complete pooling of data and a single test on aggregated data across all the populations. No pooling ignores information and can give highly variable inferences, while complete pooling of data can be misleading by ignoring among-population variation (Gelman and Hill 2007). While both approaches can provide useful preliminary analyses, we chose to take an approach that allows for the estimation of a common response and that models among-population variation in the response. This approach offers a balance between the overly noisy individual population estimates in alternative 1 and the overly simplified estimate in alternative 2.

All independent variables were standardized in the analyses by subtracting the mean of the time series from each observed value and dividing by the standard deviation. Prior to fitting the models, with the exception of proportion data (see point 5 below), we removed linear time trends from dependent and independent variables to reduce the potential for spurious correlations due to similar underlying time trends that may arise because of large-scale, longer-term climatic conditions. We present the findings for both detrended and raw data below, but the details of the raw data analyses are shown in the online supplementary material[1].

We compared models fit by maximum likelihood (ML) with and without pink and sockeye salmon abundance as independent variables at both spatial and temporal scales (i.e., the fixed effects) using small-sample Akaike information criteria (AIC$_c$; Burnham and Anderson 2002). The random effects were kept the same across all models (Zuur et al. 2009). To account for model uncertainty, we generated multimodel averaged estimates of the influence of pink and sockeye salmon abundance across the hypotheses considered according to the "natural average" method (Burnham and Anderson 2002) based on parameter estimates re-estimated by restricted estimate maximum likelihood (REML). The parameters were re-estimated prior to model averaging because REML standard deviation estimates are typically less biased than corresponding ML estimates (Bolker et al. 2009). To capture uncertainty in parameter estimates across models, we calculated unconditional standard error according to eq. 4.7 in Burnham and Anderson (2002). This model selection approach allowed us to consider the relative support for multiple competing hypotheses instead of focusing on whether a single null hypothesis is accepted or rejected. Specifically, we based our inference about the importance of competition on the sign, magnitude, and uncertainty of the multimodel averaged parameter estimates for the relationships between the response variable (sockeye productivity) and pink abundance in the first and second year of sockeye life at sea and sockeye abundance in the second year at sea. This approach to quantifying the influence of pink and sockeye salmon abundance was repeated for each of the hypotheses described below.

3. Competition effects on sockeye growth at sea

We fit a hierarchical model to test the hypothesis that competition between pink salmon and sockeye salmon in their first and second year at sea results in reduced Fraser sockeye growth in years of high pink and sockeye salmon abundance:

$$(2)\qquad L_{4,i,t} = (\mu_{\text{length}} + \alpha_i + \alpha_t) + (\mu_{k,j} + \delta_{k,j,i})E_{j,i,t+x} + \varepsilon_{\text{length},i,t}$$

where $L_{4,i,t}$ is the mean standardized fork length of 4-year-old male or female sockeye from population i and brood year t, and μ_{length} is the predicted mean standardized fork length across all populations at mean pink and sockeye salmon abundance (the intercept). The shared response of sockeye length to pink or sockeye competitor index E_i is $\mu_{k,j}$, while intrinsic variation in body length among populations (α_i) and common to all populations among years (α_t), as well as population-specific variability in responses to pink and sockeye salmon abundance (the $\delta_{k,j,i}$ values), were modeled as random effects as described for eq. 1. We fit these models separately for each sex.

4. Competition effects on sockeye age at maturity

To test the hypothesis that competition between pink salmon and sockeye salmon results in delayed Fraser sockeye maturity and a higher probability of spending an extra year at sea, we fit a hierarchical model similar to eq. 2:

$$(3)\qquad \text{logit}\left(\frac{R_{3,i,t}}{\sum_{x=1}^{3} R_{x,i,t}}\right) = (\mu_{\text{age}} + \alpha_{\text{age},i} + \alpha_{\text{age},t}) + (\mu_{l,j} + \delta_{l,j,i})E_{j,i,t+x} + \varepsilon_{\text{age},i,t}$$

where $R_{3,i,t}$ is the number of recruits that spent 3 years at sea, $\Sigma_{x=1}^{3} R_{x,i,t}$ is the total recruits from population i and brood year t (i.e., the sum of sockeye that matured after 1, 2, and 3 years at sea), μ_{age} is the logit-transformed mean proportion of ocean-age-3 recruits at mean pink and sockeye salmon abundance (the intercept), and $\mu_{l,j}$ is the common response to pink or sockeye competitor index E_i. Intrinsic variation in the logit-transformed proportion of age-3 recruits among populations ($\alpha_{\text{age},i}$) and common to all populations among years ($\alpha_{\text{age},t}$), as well as population-specific variability in responses to pink and sockeye salmon abundance (the $\delta_{l,j,i}$ values), were modeled as random effects as described above in eq. 1. We fit eq. 3 as a generalized linear mixed model with binomial error and a logit link function (Zuur et al. 2009), and to account for overdispersion, we included an observation-level random effect in the model (Warton and Hui 2011). We did not detrend the proportion data for these analyses because detrending the time series of proportions would result in a nonsensical dependent variable (i.e., one that was not bound between 0 and 1).

5. Pink predation and sockeye productivity

To test the hypothesis that predation by returning adult pink salmon on out-migrating juvenile sockeye results in reduced sockeye productivity, we fit a modified version of eq. 1, which included an independent variable providing an index of potential pink salmon predators returning to the coast in the year sockeye smolts migrate to sea. This index was the abundance of pink salmon from southern BC and Washington state (for explaining productivity of sockeye populations 1–24), from northern BC and Southeast Alaska (sockeye populations 25–26), Southeast Alaska (sockeye populations 27–31), and the Yakutat region (sockeye populations 32–36). All pink salmon abundances were lagged by 2 years.

Predicted reduction in sockeye returning to Fraser River as a function of pink salmon abundance

We also estimated the number of sockeye that would be predicted to return to just the Fraser River as a function of pink salmon competitors in the second and third sockeye growing seasons at sea:

$$(4)\qquad \sum_{i=1}^{18} R_t = S_i e^{(\mu_\alpha + \alpha_i + \alpha_t) - b_i S_i (\mu_j + \delta_{i,j}) E_{j,i,t+4}} e^{\text{MSE}/2}$$

where $R_{i,t}$ is the total number of recruits to population i (18 sockeye populations total in the Fraser River) in year t, S is the mean spawner abundance in population i, E_j is a particular value from the range of North Pacific pink salmon abundances observed from 1952 to 2010 (118–643 million fish), MSE is the mean squared error from the model fit applied as a bias correction (Newman 1993), and the remaining terms are the same as those estimated in eq. 1. By estimating the total number of recruits returning to the Fraser River across a range of pink salmon abundances, we could illustrate the predicted change in total adult sockeye salmon recruits, that is, those returning to the Fraser River in a given year to both spawn and be available for commercial, recreational, and First Nation's fisheries as a result of competition with pink salmon in the second and third sockeye growing seasons at sea. These predictions are at long-term mean North Pacific sockeye abundance in the second sockeye year at sea and North Pacific pink abundance in the first sockeye year at sea.

[1]Supplementary data are available with the article through the journal Web site at http://nrcresearchpress.com/doi/suppl/10.1139/cjfas-2014-0134.

Sensitivity analyses

Our main analyses were based upon detrended datasets as a means to reduce the potential for time trends in the data to confound our interpretation of the results. However, removing low-frequency variation in the data (i.e., the time trends) means that any longer-term, slowly changing true relationships between sockeye salmon and the independent variables we considered may not be detected if they exist. Therefore, we reran the analyses using raw data and examined the results for consistency with the findings based on detrended data.

Our main analyses assume that sockeye salmon from BC, Southeast Alaska, and Washington State interact in the open ocean with pink salmon originating from North America, as well as Russia and Japan. Therefore, we included pink salmon abundance from all these populations as an index of competitors in the second year of sockeye life at sea. Although there is evidence for overlap in the distribution of pink salmon from the Far East and sockeye salmon from southern BC (Takagi et al. 1981; Myers et al. 2007; Beacham et al. 2014), the extent of overlap is uncertain. Therefore, we repeated our analyses with an index of pink and sockeye salmon competitors in the second year of sockeye life at sea that was composed of only salmon originating from North America.

It is well known that climate and oceanographic conditions can influence sockeye salmon growth (Cox and Hinch 1997; Hinch et al. 1995) and productivity (Mueter et al. 2002*a*, 2002*b*, 2005). It has also been recently suggested that exposure to farmed salmon early in sockeye marine life may increase the influence of subsequent competition with pink salmon on sockeye productivity (Connors et al. 2012), though we note that this correlative relationship is uncertain and the underlying mechanism(s) unknown. Our initial analyses did not account for these other factors, which could potentially confound the relationships we describe. To evaluate whether the conclusions of our main analyses were sensitive to the inclusion of these other factors, we reran the analyses described above to include terms for SST in the winter preceding juvenile sockeye marine entry (e.g., Mueter et al. 2002*a*; Connors et al. 2012) and farmed salmon production along juvenile sockeye migration routes (as a proxy for potential pathogen exposure; Connors et al. 2012). These factors were considered in models both individually and together. In addition to these individual factors, the analyses also included interactions between farmed salmon production and pink salmon abundance as previously identified and described (Connors et al. 2012). We fit all models, calculated their AIC_c weights, and then generated multimodel averaged parameter estimates for each factor. The multimodel parameter estimates for the influence of pink salmon and sockeye salmon abundance could then be compared with those from the baseline analyses we conducted to evaluate if the relationships quantified in our baseline analyses were sensitive to the inclusion of other potential influential explanatory factors.

All analyses were performed in R (2012) using the lme4 (for the linear mixed effects modeling) and MuMIn (for multimodel inference) packages. The lme4 package is the only R package that supports crossed random effects (i.e., non-nested time and location dependent random effects) but does not allow for autocorrelated errors. Therefore, we examined the assumption that within-population residuals were not temporally autocorrelated by examining the correlation between residuals within populations from the models in eqs. 1–3 at a 1-year lag. In instances where there was significant lag-1 autocorrelation in residuals (at α = 0.05), we reran our analysis after removing those populations to determine how influential their results were to the overall conclusions.

Results

Odd–even year patterns

The annual mean abundance of maturing pink salmon returning to natal watersheds from across the North Pacific increased from approximately 209 million fish during the 1950s and 1970s to approximately 385 million fish after the mid-1970s ocean regime shift. Maturing pink salmon were approximately 38% more abundant in odd- versus even-numbered years during both the entire study period and after the mid-1970s ocean regime shift. In North America, pink salmon abundance increased approximately 2.5-fold after the regime shift (from 65 to 170 million fish), and they were 37% more abundant in odd-numbered years of the recent period. Across all years, pink salmon in North America averaged 18% more fish in odd-numbered years.

Sockeye survival rates (residuals from Ricker stock–recruitment relationship) were markedly lower during odd- versus even-numbered brood years for the entire study period and after the regime shift. During the recent period, sockeye survival rates were approximately 20% lower in odd-year broods than even-year broods, on average. Lower survival from odd-numbered broods was observed, on average, in 20 of the 24 sockeye populations (Fig. 2*a*).

Length-at-age of returning male and female sockeye salmon was markedly lower in odd- versus even-numbered brood years for the entire period of data and for the period after the regime shift. This pattern was consistent among all sockeye populations for both male and female salmon (Figs. 2*c*, 2*d*).

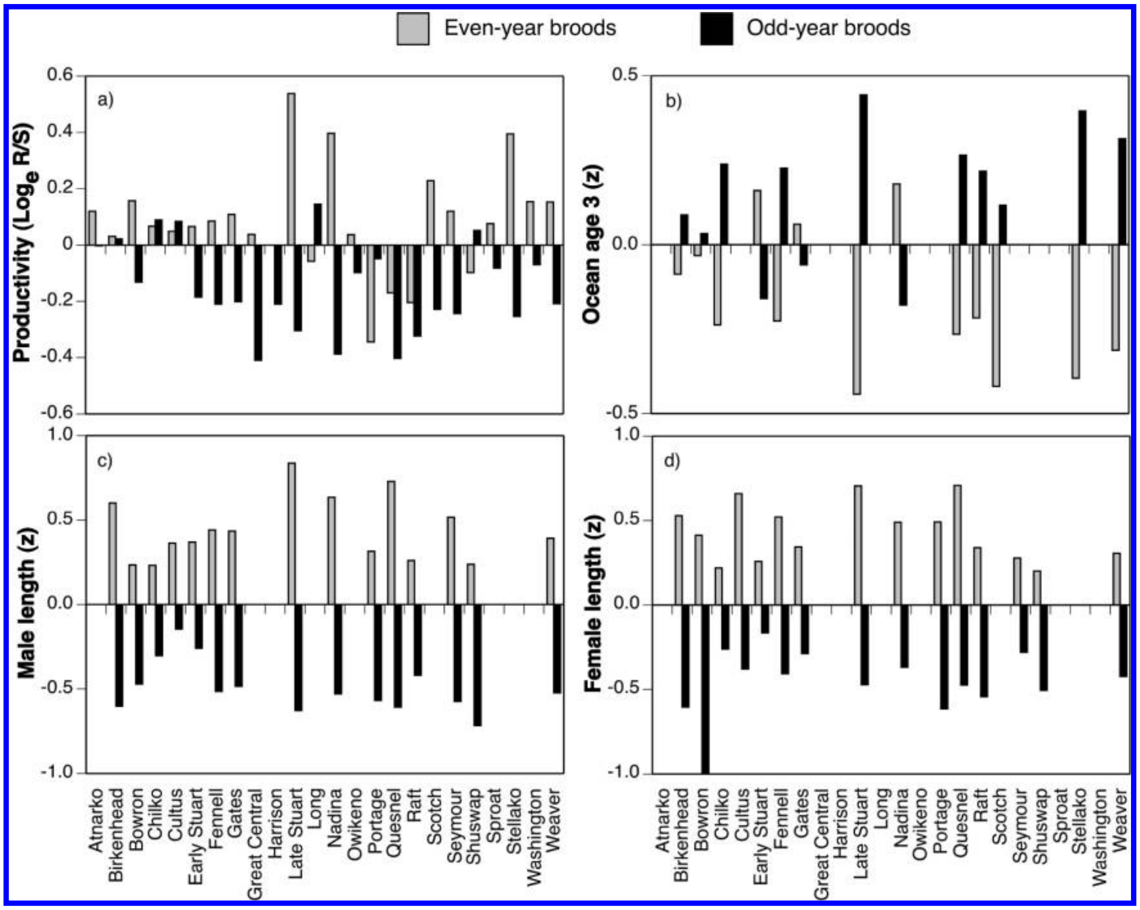
The proportion of sockeye salmon in each population spending 3 years at sea tended to be greater among odd-numbered brood years for the entire study period and after the regime shift, as hypothesized. Delayed maturation was more common in odd- versus even-numbered brood years in 10 of 13 populations (Fig. 2*b*).

Hypotheses

Sockeye survival rates were typically negatively correlated with the abundance of pink salmon in the North Pacific in the second sockeye growing season at sea (Fig. 3). The hypothesis that competition with pink salmon in the second year of sockeye life at sea leads to reduced productivity had strong data support (i.e., a term for this competition occurred in almost all models that had support as indicated by a relative variable importance close to 1; Table 2 and "Productivity" row in Table 3) and had the strongest predicted negative relationship with sockeye productivity ("Productivity" row in Table 3). There was little data support for inverse relationships between sockeye productivity and pink salmon abundance in the first year, as opposed to second year, of sockeye marine life or the abundance of sockeye in the North Pacific (Tables 2 and 3). These findings suggest that it is competition with pink salmon in the second and later years of marine life, as opposed to conspecific or pink salmon in the first year of marine life, that leads to reduced survival.

For those Fraser River sockeye populations for which we had data, mean male and female length was typically negatively correlated with the abundance of pink salmon in the North Pacific during the second sockeye growing season at sea (Figs. 4 and 5). However, of the hypotheses considered, North Pacific sockeye abundance was predicted to have the strongest negative influence on adult male and female sockeye length, and sockeye abundance appeared in all models that had data support ("Standard fork length" rows in Tables 2 and 3). The abundance of pink salmon across the North Pacific in the second year of sockeye marine life had the second strongest predicted negative influence on adult male and female sockeye length of the hypotheses considered and was more negative for male than female sockeye (Tables 2 and 3). In contrast with the support of the hypothesis that competition with sockeye and pink salmon in the second year of sockeye marine life leads to reduced sockeye growth, there was little support

Fig. 2. Survival (*a*), proportion of ocean-age-3 (*b*), and length-at-age of male (*c*) and female (*d*) sockeye salmon populations from British Columbia and Washington during odd- versus even-numbered brood years, 1978–2005. Values are normalized (*Z*) relative to the entire data time series, except survival, which is the mean residual from the recruitment relationship.



for the hypothesis that competition with pink salmon in the first year of sockeye marine life leads to reduced adult male and female sockeye salmon length (Tables 2 and 3). These findings suggest that competition with conspecifics as well as pink salmon in the second and later years of marine life leads to reduced growth at sea and smaller sockeye salmon on the spawning grounds.

The proportion of total sockeye recruits from a given brood year that spent 3 years in the ocean was positively related to the abundance of pink salmon in the North Pacific for most of the sockeye populations we considered (Fig. 6). Of the hypotheses considered, there was strong data support for the hypotheses that North Pacific pink salmon abundance in the first and second year of sockeye ocean life had a positive influence on the proportion of sockeye that delayed maturation and returned at ocean-age-3 (Tables 2 and 3). This effect was weaker for pink salmon abundance in the first, as opposed to second, year of sockeye ocean life, and there was much less support for an effect of North Pacific sockeye abundance (Tables 2 and 3).

The estimated magnitude of the relationships between productivity, length, and age at maturity of sockeye salmon and North Pacific pink salmon abundance based on the hierarchical analyses varied by population (Fig. 7), with Harrison productivity being the most anomalous (Fig. 7*a*).

We did not find support for the hypothesis that returning adult pink salmon predate upon juvenile sockeye, which would have resulted in reduced productivity in years when sockeye migrated to sea as large numbers of pink salmon returned to spawn. The inclusion of adult pink salmon abundance as an index of potential predators did not improve model fit relative to the null model without an index of predators (Table 2).

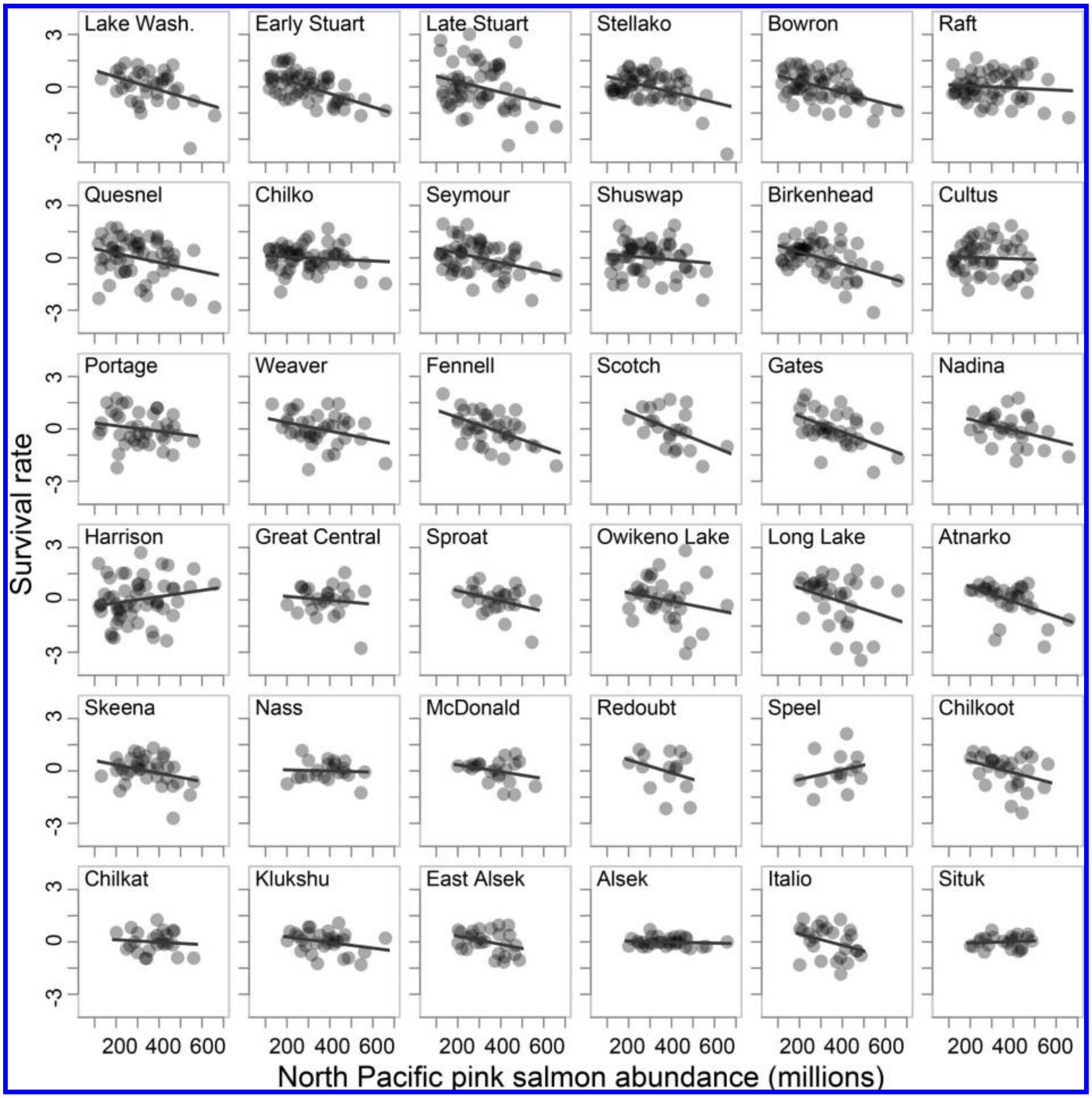
Predicted reduction in sockeye returning to Fraser River as a function of pink salmon abundance

Based on the relationship between North Pacific pink salmon abundance and sockeye productivity quantified in our analyses, across the range of pink salmon abundance observed since the 1950s to present (see eq. 4), competition with pink salmon is predicted to reduce the number of adult sockeye that return to the Fraser River before the onset of fisheries by up to 67% (i.e., from mean recruits of ~16 million sockeye at low pink salmon abundance (150 million pinks) to ~5.3 million sockeye at high pink salmon abundance (600 million pinks); Fig. 8). Following the mid-1970s ocean regime shift, annual pink salmon abundance increased from approximately 200 million to 400 million fish, resulting in a predicted reduction in Fraser River sockeye salmon of ~5.5 million (39%).

Sensitivity analyses

Our finding that pink salmon abundance in the second year of sockeye marine life influenced sockeye productivity was consistent when using either detrended (see above) or raw data (see online Supplementary Tables S1*a*, S1*b*[1]). Likewise, when using raw data, both North Pacific sockeye and pink salmon abundances during the second year of sockeye marine life had support for their negative relationship with Fraser River sockeye length though the support was weaker for North Pacific pink salmon abundance using the raw data. In contrast with these relatively

Fig. 3. Relationship between sockeye salmon survival rates (residuals of population specific Ricker stock–recruit relationship in $\log_e$ space) and North Pacific pink salmon abundance in the second year of sockeye life at sea.



consistent findings, our results involving pink salmon abundance in the first year of sockeye marine life were inconsistent, as shown by the change in the direction of the parameter estimate when using raw versus detrended data, in addition to being weak relationships.

Our finding that sockeye salmon productivity was negatively related to pink salmon abundance during the second year of sockeye life at sea was sensitive to the use of North Pacific versus North American pink salmon abundances when considering the detrended data (Tables S3*a*, S3*b*[1]) but not the raw data (Tables S2*a*, S2*b*[1]). Specifically, there was little support for a negative relationship between detrended North American pink salmon abundance and sockeye productivity, but there was strong support for the negative relationship when raw pink salmon data were used. In addition, there was still support for negative relationships between North American pink salmon abundance and the size of male and female sockeye returning to spawn in the Fraser River at 4 years of age (Tables S2*a*, S2*b* and S3*a*, S3*b*[1]). When considering just North American salmon abundance, sockeye salmon continued to have the strongest predicted influence on the size of male and female sockeye returning to spawn. Lastly, when considering North American pink salmon abundance, there was still support for the hypothesis that the proportion of ocean-age-3 recruits was positively related pink salmon abundance (Tables S2*a*, S2*b*[1]).

When the analyses were repeated in a framework that included other potentially influential factors, including oceanographic conditions (e.g., sea surface temperature), potential exposure to pathogens from salmon aquaculture, and a mediating effect of exposure to farmed salmon on the relationship between sockeye productivity and pink salmon abundance during the second year of sockeye life at sea, our findings remained largely the same (Tables S4*a*, S4*b* and S5*a*, S5*b*[1]). Specifically, multimodel averaged predicted effects of pink salmon abundance on sockeye productivity and length-at-age were consistently negative and similar in magnitude to those estimated in analyses without these additional factors (Tables S4*a*, S4*b* and S5*a*, S5*b*[1]). Also, there was still

Table 2. Summary of model selection statistics for analyses of hypotheses related to interactions between pink and sockeye salmon.

Hypothesis	Model	LL	ΔAIC$_c$	Weight
1. Productivity	P_{t+4} + P_{t+3}	−1594.68	0.00	0.60
	P_{t+4} + Sx_{t+4}	−1595.93	2.50	0.17
	P_{t+4}	−1597.43	3.34	0.11
	P_{t+4} + P_{t+3} + Sx_{t+4}	−1595.35	3.51	0.10
	Null	−1601.21	8.74	0.01
	P_{t+3}	−1600.42	9.32	0.01
	Sx_{t+4}	−1600.82	10.13	0.00
	P_{t+3} + Sx_{t+4}	−1600.43	11.49	0.00
2. Standard fork length (males)	P_{t+4} + Sx_{t+4}	−396.74	0.00	0.70
	P_{t+4} + P_{t+3} + Sx_{t+4}	−396.64	1.99	0.26
	Sx_{t+4}	−401.12	6.60	0.03
	P_{t+3} + Sx_{t+4}	−400.94	8.40	0.01
	P_{t+4}	−406.66	17.68	0.00
	P_{t+4} + P_{t+3}	−406.32	19.17	0.00
	Null	−414.58	31.36	0.00
	P_{t+3}	−414.48	33.32	0.00
2. Standard fork length (females)	P_{t+4} + Sx_{t+4}	−403.59	0.00	0.55
	P_{t+4} + P_{t+3} + Sx_{t+4}	−403.24	1.47	0.26
	Sx_{t+4}	−406.17	2.98	0.12
	P_{t+3} + Sx_{t+4}	−405.82	4.45	0.06
	P_{t+4}	−412.47	15.58	0.00
	P_{t+4} + P_{t+3}	−411.70	16.22	0.00
	Null	−417.72	23.93	0.00
	P_{t+3}	−416.83	24.32	0.00
3. Proportion ocean-age-3 recruits	P_{t+4}	−103.99	0.00	0.43
	P_{t+4} + P_{t+3}	−103.56	1.25	0.23
	P_{t+3} + Sx_{t+4}	−104.07	2.27	0.14
	P_{t+4} + P_{t+3} + Sx_{t+4}	−103.44	3.12	0.09
	P_{t+3}	−105.83	3.69	0.07
	P_{t+4} + Sx_{t+4}	−105.66	5.44	0.03
	Null	−108.08	6.08	0.02
	Sx_{t+4}	−108.90	9.82	0.00
4. Productivity (predation)	Null	−1601.75	0.00	1.00
	$P_{predators}$	−1601.72	12.38	0.00

Note: All models were fit to data with linear time trends removed with the exception of the proportion of ocean-age-3 recruits (see Table S1 for analyses with raw data[1]). The dependent variable in each hypothesis is denoted by "Variable" and includes sockeye productivity ($\log_e$(recruits/spawner)), the mean standardized length of 4-year-old male and female sockeye on the spawning grounds, and the proportion of total recruits from a given brood year that spent 3 years in the ocean. Independent variables in the hypotheses (Model) are North Pacific pink salmon abundance (P_{t+4}) lagged 4 years later from the corresponding sockeye brood year to reflect the abundance of potential pink salmon competitors in the second sockeye growing season at sea, Northeast Pacific pink salmon abundance (P_{t+3}) lagged by 3 years to reflect the abundance of potential pink salmon competitors in the first sockeye growing season at sea, and North Pacific sockeye salmon abundance (Sx_{t+4}) lagged by 4 years to reflect the number of potential conspecific competitors in the second and third sockeye growing seasons at sea. $P_{predators}$ is the abundance of potential pink salmon predators returning to the coast in the year sockeye smolts enter the marine environment. Models for each set of hypotheses are ordered by increasing values of the small-sample Akaike information criterion (AIC$_c$). Also shown are the log likelihoods (LL), differences in AIC$_c$ from the AIC$_c$ of the top model (DAIC$_c$), and Akaike model weights (w_i). The null model is simply within-population and within-brood-year density dependence.

support for the hypothesis that the proportion of ocean-age-3 recruits was positively related to pink salmon abundance (Tables S4*a*, S4*b* and S5*a*, S5*b*[1]).

Collinearity among the independent variables was weak to moderate for detrended (0.0 to 0.33) and raw variables (0.2 to 0.56; Table S7[1]), and all independent variables had variance inflation factors of <2, suggesting that correlations among these independent variables were unlikely to substantially inflate the standard errors of our parameter estimates (Zuur et al. 2009). Overall, there was little evidence of temporal correlation in the population-specific residuals from the best-fit models in both the initial and sensitivity analyses. Rerunning the analyses without those few populations that exhibited significant lag-one correlation in residuals did not affect our conclusions.

Table 3. Multimodel averaged parameter estimates, unconditional standard error (SE), and relative variable importance (RVI) of parameters appearing in the hypotheses in Table 2.

Hypothesis	Variable	Coefficient (in SDU)	SE (in SDU)	RVI
1. Productivity	P_{t+4}	−0.153	0.048	0.98
	P_{t+3}	0.049	0.036	0.45
	Sx_{t+4}	0.001	0.022	0.25
2. Standard fork length (males)	P_{t+4}	−0.224	0.073	0.96
	P_{t+3}	−0.033	0.076	0.27
	Sx_{t+4}	−0.347	0.069	1.00
2. Standard fork length (females)	P_{t+4}	−0.181	0.078	0.81
	P_{t+3}	−0.062	0.074	0.33
	Sx_{t+4}	−0.365	0.074	1.00
3. Proportion ocean-age-3 recruits	P_{t+4}	0.552	0.227	0.88
	P_{t+3}	0.298	0.246	0.41
	Sx_{t+4}	0.017	0.303	0.26

Note: All models were fit to data with linear time trends removed. Parameters include the abundance of potential pink salmon competitors beginning in the first (P_{t+3}) and second sockeye growing seasons at sea (P_{t+4}) and well as the number of potential conspecific competitors in the second and third sockeye growing seasons at sea (Sx_{t+4}). Parameter estimates were measured in standard deviation units (SDU) on dependent variables with linear time trends removed.

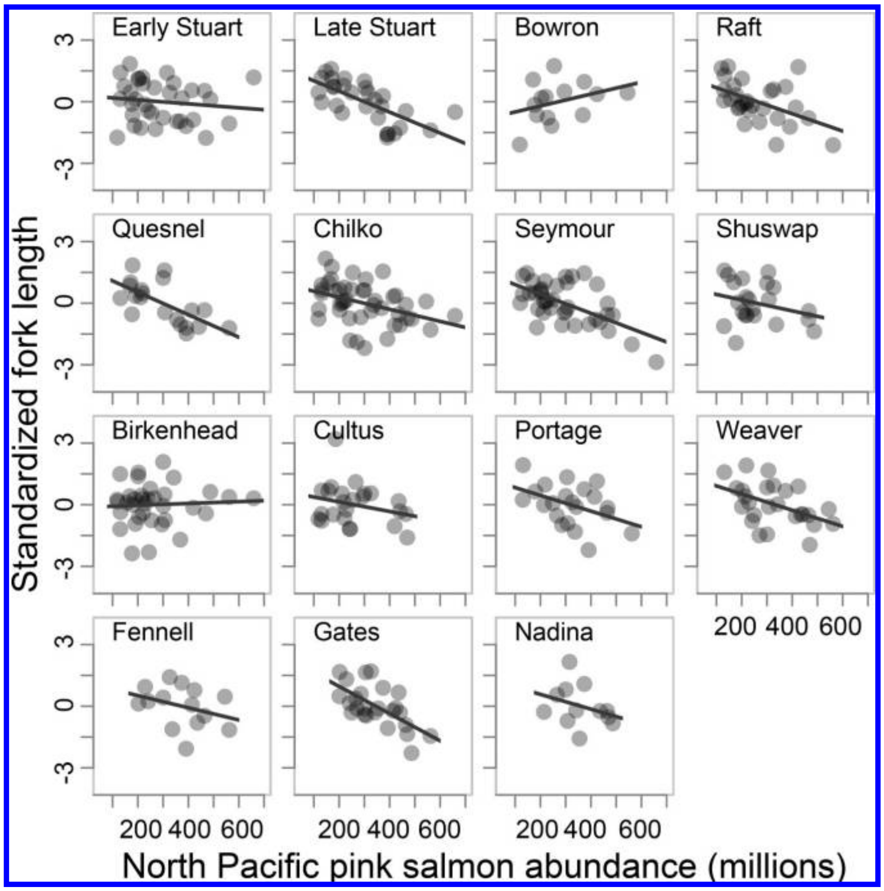
Discussion

The productivity of sockeye salmon populations in BC, Southeast Alaska, and Washington has declined similarly over time and intensified in recent years, suggesting that the primary causal mechanism driving this decline operates at a large, multiregional spatial scale at sea (Peterman and Dorner 2012). We examined the productivity and life history characteristics of up to 36 sockeye populations — including 18 Fraser River populations — spanning this region of similar trends in productivity over the past 55 years to test whether competition between pink and sockeye salmon for resources at sea may have contributed to these declines. We found consistent evidence that productivity of these sockeye salmon populations has declined in response to increasing abundance of pink salmon in the North Pacific Ocean. Furthermore, length-at-age of male and female Fraser River sockeye salmon was inversely correlated with both pink and sockeye salmon abundance, and age-at-maturity of Fraser River sockeye salmon was positively correlated with pink salmon abundance. These findings were consistent for both detrended and raw datasets involving North Pacific pink salmon, indicating that the influence of pink salmon was detected across both short and long time scales. The abundance of pink salmon in the North Pacific alternates from high (odd-numbered years) to relatively low abundance (even-numbered years), and this alternating-year pattern was also observed in sockeye salmon productivity, length-at-age, and age at maturity. Thus, the evidence for competition between pink and sockeye salmon comes from both hierarchical modeling of patterns over time and the natural experiment provided by the 2-year life cycle of pink salmon and its alternating-year abundance. Our analyses predict that an increase in pink salmon abundance from 150 million to 600 million fish (i.e., the observed range) would lead to a ~67% reduction in total abundance of returning Fraser River sockeye salmon (catch and spawning escapement combined) after controlling for other variables in the model such as parental spawning abundance.

Temporal and spatial influence of pink salmon

Sockeye salmon may be influenced by competition with pink salmon throughout their life at sea. Early marine scale growth of two Fraser River sockeye salmon populations (Chilko, Birken-

Fig. 4. Standardized fork length of 4-year-old male sockeye salmon spawners in relation to North Pacific pink salmon abundance in the second year of sockeye life at sea.



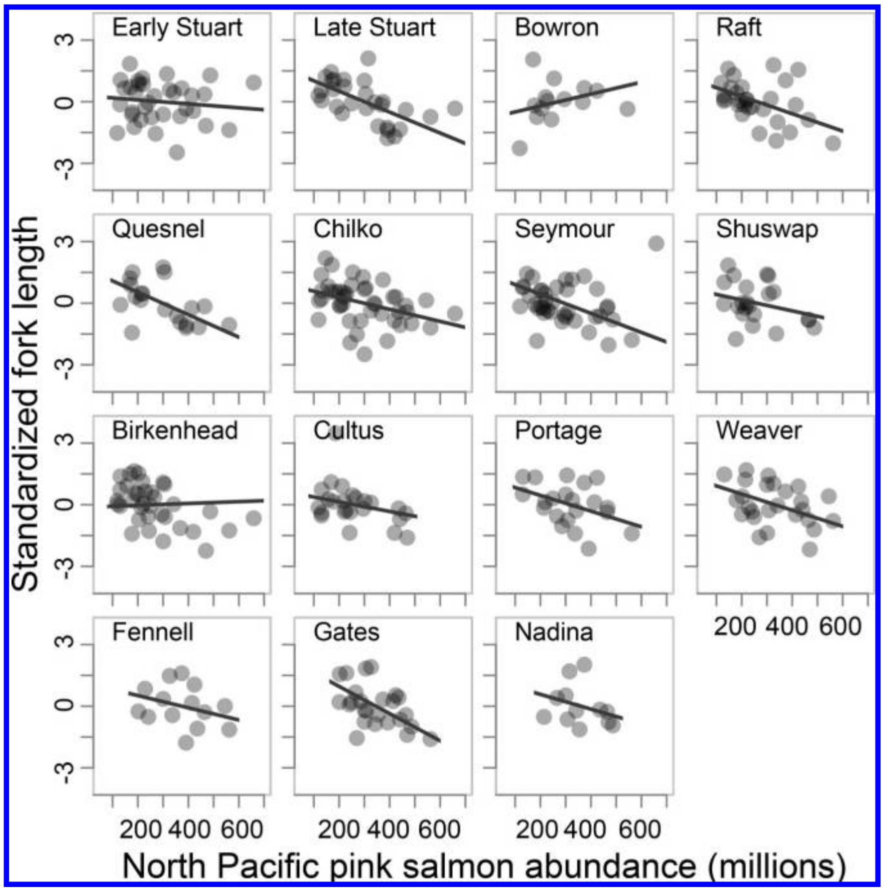
head) during their first year at sea tends to be negatively correlated with regional abundances of juvenile pink salmon estimated from adult returns during the following year (McKinnell and Reichardt 2012). In contrast, survival of Babine sockeye salmon at sea is positively correlated with an index of juvenile pink salmon abundance, possibly because juvenile pink salmon may swamp predators of sockeye salmon (Peterman 1982). Our analyses indicated weak and inconsistent support for interactions between pink and sockeye salmon in the first year of marine life. This inconclusive finding may stem, in part, from the opposing effects of competition for prey and predator swamping.

Our analyses provide consistent support for the hypothesis that competition between pink and sockeye salmon begins (or intensifies) during the second year of sockeye marine life. This finding is consistent with the period of interaction between Bristol Bay sockeye salmon and Russian pink salmon (Ruggerone et al. 2003, 2005; Ruggerone and Nielsen 2004). This research in Bristol Bay used scale growth measurements to show that sockeye growth was reduced during their second and third years at sea of odd-numbered years, corresponding with high pink salmon abundance. Scale circuli measurements revealed that sockeye growth reduction in odd-numbered years occurred shortly after peak growth in spring and continued into the fall of their second and third years at sea. Interaction with abundant pink salmon in odd-numbered years led to reduced adult length-at-age and 26%–45% lower smolt to adult survival depending on smolt age. No pink–sockeye salmon interaction was detected during the first year at sea because relatively few pink salmon are present in the southeastern Bering Sea (Ruggerone et al. 2010).

Our analyses support the hypothesis that the combined abundances of both North American and Asian pink salmon influenced the productivity and life history of Fraser River sockeye salmon, while there was support for hypotheses that included the abundance of only pink salmon from North America when using raw but not detrended data (Tables S2*a*, S2*b* and S3*a*, S3*b*[1]). The lack of support when using detrended data probably reflects the relatively small differences between odd- and even-year abundances of North American pink salmon across all years of the investigation. However, Asian pink salmon are approximately 50% more abundant than pink salmon in North America (Ruggerone et al. 2010), and the limited tagging and genetic data that have been collected demonstrate overlap between Asian pink salmon and sockeye salmon originating from BC (Takagi et al. 1981; Myers et al. 2007; Beacham et al. 2014).

Recent genetic analyses indicate that sockeye salmon originating from BC migrate farther west and overlap to a greater extent with Asian pink salmon than previously indicated by tagging studies (Takagi et al. 1981; Myers et al. 1996). Sockeye salmon from BC have been captured in their first year at sea along the Alaska Peninsula during summer and fall (Tucker et al. 2009), near the Aleutian Islands during winter (Farley et al. 2011), and Fraser River sockeye salmon have been captured in the Bering Sea (Beacham et al. 2014). Juvenile sockeye salmon originating from the Fraser River and adjacent areas dominate the stock composition of sockeye along the Alaska Peninsula during fall, suggesting that these stocks migrate westward as far as 175°E during their first year at sea (Beacham et al. 2014). Asian pink salmon have been reported to migrate eastward to as far as 155°W based on tagging (Takagi et al. 1981), which provides additional evidence to suggest sympatry between BC sockeye and Asian pink salmon. Furthermore, overlap between these species may be greater during odd-numbered years when pink salmon are more broadly distributed

Fig. 5. Standardized fork length of 4-year-old female sockeye salmon spawners in relation to North Pacific pink salmon abundance in the second year of sockeye life at sea.



on the high seas, based on Japanese gillnet surveys across the North Pacific during 1972–1998 (Azumaya and Ishida 2000). We hypothesize that sympatry between Asian pink salmon and North American sockeye salmon is facilitated by the counterclockwise movement of the Alaska Gyre and the westward flow of the Alaska Current along the Alaska Peninsula (Mann and Lazier 2006).

Unique sockeye life history

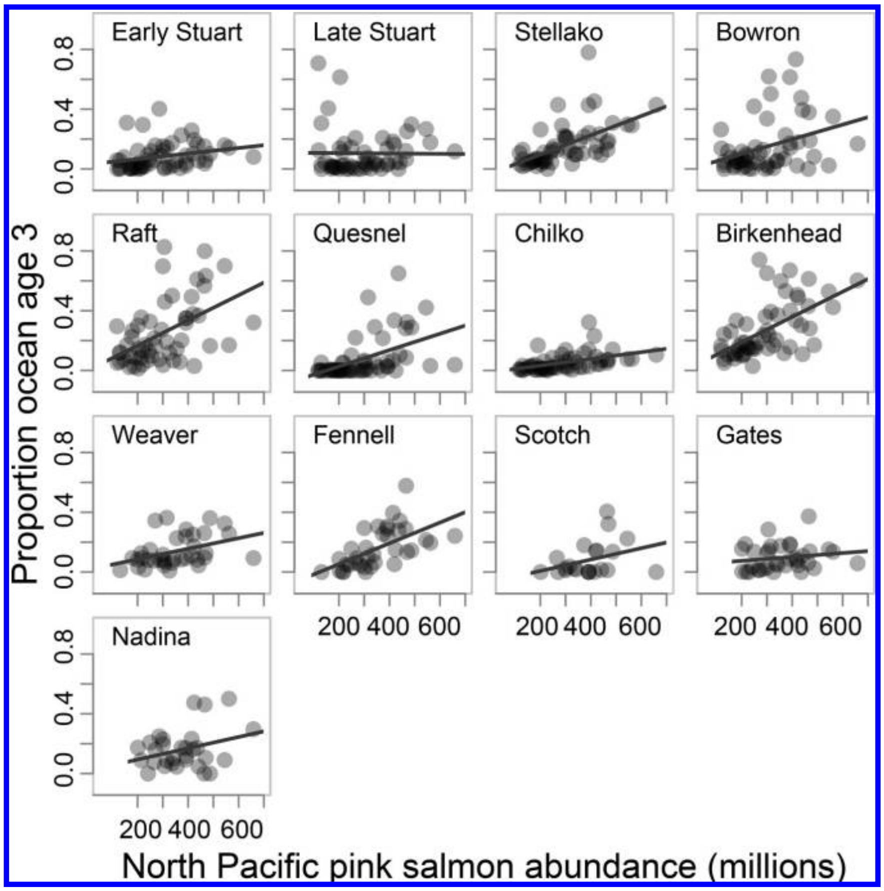
Our hierarchical analyses suggest that the productivity of all but one of 36 sockeye populations considered was inversely related to North Pacific pink salmon abundance. The single outlier, Harrison River sockeye salmon, is noteworthy because these sockeye have a unique life history among the populations we considered and their productivity has trended in the opposite direction of other Fraser River sockeye salmon populations (Tucker et al. 2009; Beamish et al. 2010; Peterman and Dorner 2012). Harrison River sockeye are primarily "ocean-type" salmon that emigrate to sea as subyearlings rather than yearlings that overwinter in lakes, as do most sockeye populations we considered. Harrison River sockeye salmon enter the Strait of Georgia approximately 6–8 weeks after "lake-type" yearling sockeye smolts, initially inhabit inlets rather than offshore areas of the Strait, delay emigration to the ocean until winter, and primarily emigrate through the Strait of Juan de Fuca rather than through Johnstone Strait (Tucker et al. 2009; Beamish et al. 2010; Beacham et al. 2014). These life history characteristics may reduce the extent to which Harrison River sockeye interact with pink salmon in the North Pacific, but odd-year broods may compete with local juvenile pink salmon during the first summer in the Strait of Georgia, leading to reduced productivity and delayed maturation (Beamish et al. 2010).

Oceanographic, prey life history, and predation effects

A variety of factors at sea undoubtedly affect sockeye growth, maturation, and productivity in addition to the species interactions we identify here (e.g., Mueter et al. 2002*a*, 2002*b*, 2005; Wells et al. 2007; Healey 2011; McKinnell et al. 2014). These other factors could confound our analyses. However, when we considered the potentially confounding influence of SST and farmed salmon production in the analyses (Connors et al. 2012), our conclusions did not change and species interactions remained the primary factor of influence. Our findings support the hypothesis put forward by Holt and Peterman (2004) that density dependence and its effect on growth and delayed maturation (Healey et al. 2000) may have a greater influence than physical oceanographic features (Cox and Hinch 1997). Irvine and Akenhead (2013) also concluded that the smolt to adult survival of Chilko sockeye salmon (Fraser River population) was more related to indices of total salmon abundance at sea, including Asian salmon, than to oceanographic conditions. Physical oceanographic conditions are important to salmon and they set the baseline for growth and survival, but the dynamic and complex food web and salmon interactions are likely to be equally important though perhaps more elusive to detect and evaluate.

Most salmon mortality at sea is thought to occur during the first year at sea (Ricker 1976; Beamish and Mahnken 2001; Farley et al. 2007). In response to the unexpectedly low return of adult Fraser sockeye salmon in 2009 from the 2007 smolt emigration, investigators reported anomalous oceanographic conditions encountered by sockeye salmon during early marine life. Low sockeye survival was associated with unfavorable winds, high river runoff, and pronounced surface stratification that appeared to cause

Fig. 6. The proportion of all sockeye salmon recruits from a given brood year that matured after 3 years in the ocean in relation to North Pacific pink salmon abundance in the second year of sockeye life at sea.



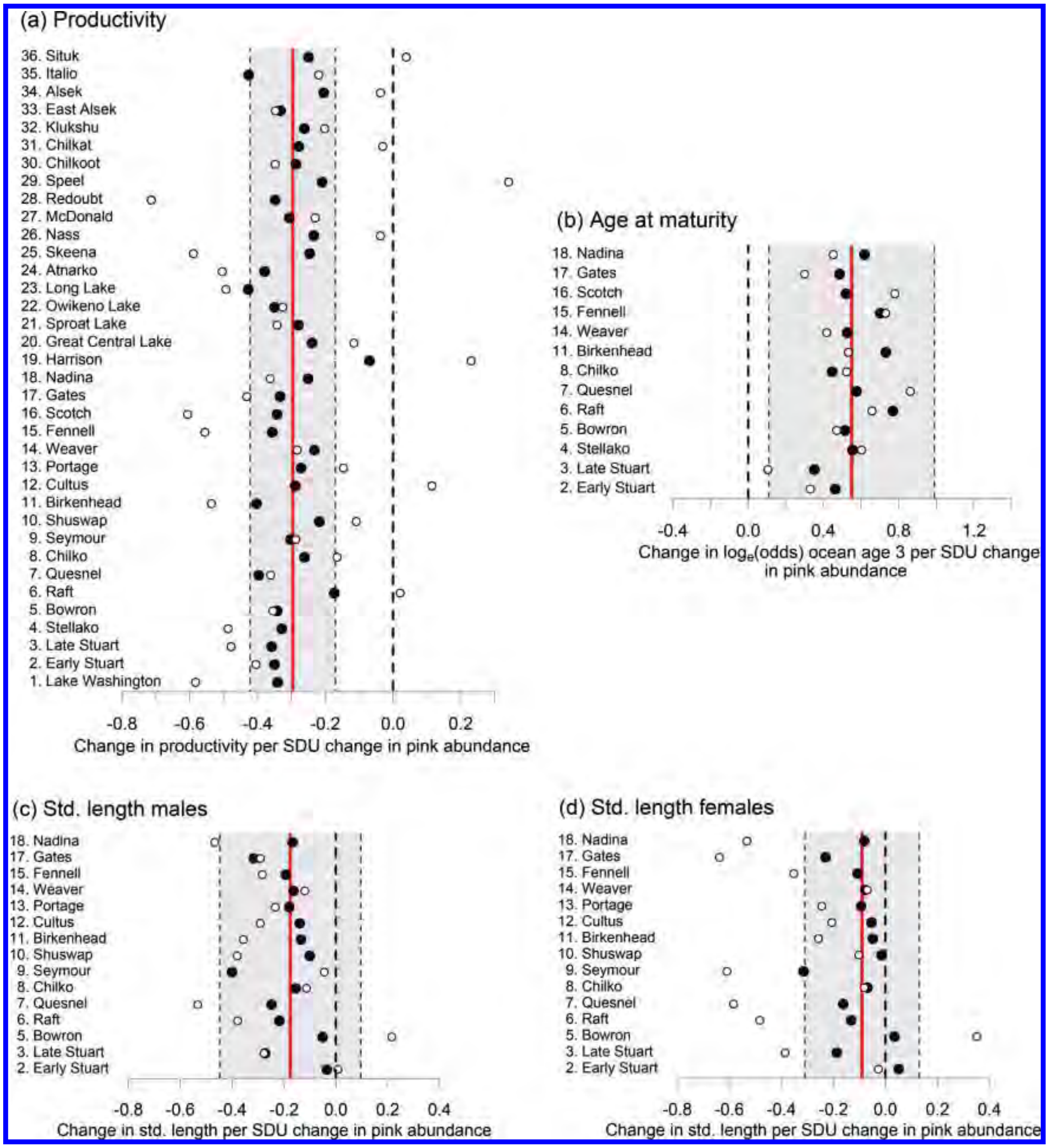
low prey production and reduced growth (Beamish et al. 2012; Thomson et al. 2012; McKinnell et al. 2014). Other investigators reported disease and toxic algae blooms in the Strait of Georgia as possible factors (Rensel et al. 2010; Miller et al. 2011).

Although mortality during early marine life is unquestionably important to salmon production, recent evidence also indicates that mortality later in marine life may also be important (Bradford 1995). For example, Welch et al. (2011) reported that most mortality of Fraser sockeye salmon occurred after sockeye exited the Salish Sea, based on large acoustically tagged Fraser River sockeye salmon smolts and detection arrays set along the coast and at the mouth of the Fraser River. In western Alaska, adult returns of Chinook (*Oncorhynchus tshawytscha*), chum, and coho (*Oncorhynchus kisutch*) salmon declined abruptly during the 1997–1998 El Niño event, suggesting that El Niño related processes late in marine life (as opposed to early in marine life when El Niño had not yet occurred) contributed to reduced survival and abundance (Agler 2010). Our investigation, and investigations of Bristol Bay sockeye salmon (Ruggerone et al. 2003), provide additional evidence that significant mortality of salmon may also occur after early marine life. Additional research is needed to improve our understanding of the relative importance of mortality rates early in marine life versus those later in marine life in shaping the dynamics of salmon populations.

The abundance of both sockeye and pink salmon in Alaska has been relatively high since the mid-1970s (Ruggerone et al. 2010), likely as a result of favorable (warmer) oceanographic conditions during the first year of marine life (Mueter et al. 2002*a*, 2002*b*; Stachura et al. 2014), which are correlated with increased early marine growth and survival (Ruggerone et al 2007). At first glance, this pattern may seem to contradict the hypothesis that competition between pink and sockeye salmon for prey has led to reduced sockeye growth and productivity. However, while the survival and abundance of Alaska sockeye has been shown to be correlated with increased early marine growth and SST, length-at-age, survival, and abundance of Alaskan sockeye have also been shown to be inversely related to pink salmon abundance later in marine life (Ruggerone et al. 2003, 2007). This suggests that while the survival and abundance of Alaskan sockeye has been strongly positively influenced by favorable oceanographic conditions during early marine life in recent decades, competition for resources with pink salmon may still occur later in marine life. We hypothesize that the balance between these opposing processes may tilt in favor of increased survival and abundance for Alaskan sockeye populations but not those to the south that have, on average, experienced less favorable early marine oceanographic conditions.

The life history of key prey shared by pink and sockeye salmon likely contributes to the strong species interaction shown in this and other studies (Ruggerone et al. 2005). Pink salmon reportedly influence the standing crop of macrozooplankton (Shiomoto et al. 1997; Sugimoto and Tadokoro 1997), which are also consumed by sockeye salmon. Squid (e.g., *Berryteuthis anonychus*) are an exceptionally important prey of both species, and squid abundance in their diets is reduced in odd-numbered years when pink salmon are abundant (Aydin 2000; Kaeriyama et al. 2004; Davis et al. 2005; Aydin et al. 2005). These squid (*B. anonychus*) exhibit a 2-year life cycle and predation by pink salmon may be a key factor controlling squid abundance (Nesis 1997; Jorgensen 2011). Predation by pink salmon on prey with biennial life histories (Tsuda et al. 2004) may enhance the alternating-year pattern of prey abundance, leading to the alternating-year pattern of sockeye salmon growth, productivity, and age at maturation. Furthermore, advection and

Fig. 7. Multimodel averaged predicted relationships (solid vertical line ± 2 unconditional standard errors — dashed lines) between North Pacific pink salmon abundance during the second sockeye growing season at sea and (*a*) sockeye productivity ($\log_e$(recruits/spawner)), (*b*) the proportion of total sockeye recruits that matured after 3 years in the ocean, and the standardized length of 4-year-old male (*c*) and female (*d*) spawners. A dashed vertical line at "0" highlights the observed relationship relative to no effect. The *x* axis in each plot is the response of each dependent variable to a one standard deviation unit increase in pink salmon abundance (~120 million pink salmon). For the coefficients in panel (*b*), the response is the $\log_e$(odds) of maturing after 3 years in the ocean instead of 2 years. For example, a $\log_e$(odds) of 0.5 is equivalent to a 1.65 greater chance of maturing at ocean-age-3. Solid circles corresponding to each individual population are multimodel averaged estimates of population-specific responses to a one standard deviation unit increase in pink salmon abundance based on hierarchical models fit to all populations simultaneously. Open circles are corresponding multimodel averaged parameter estimates based on models fit to each population independently. All parameter estimates are based on models fit to data without linear time trends removed.



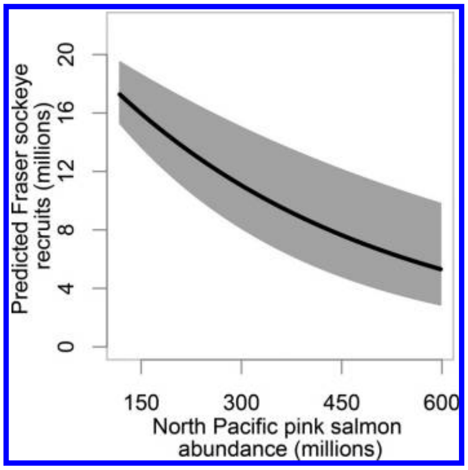
active migration of key prey, such as squid, in the eastward-flowing Subarctic Current (Mann and Lazier 2006) may indirectly enhance the interaction between Asian pink salmon and sockeye salmon in this study.

Predation is often a key factor affecting salmon survival (Quinn 2005), but we found no evidence that predation by returning adult pink salmon influenced sockeye salmon productivity. This finding is consistent with observations of few juvenile salmon consumed by returning adult pink salmon in Southeast Alaska (Sturdevant et al. 2012).

Management implications

Our study has important implications for policy and management of salmon hatcheries because it provides strong evidence that salmon species compete for prey at sea, leading to potentially important effects on salmon productivity and life history characteristics. Approximately 1.4 billion hatchery pink salmon are released into the North Pacific each year, of which 70% are from hatcheries in North America (Ruggerone et al. 2010). A key goal of hatcheries is to maintain and stabilize high levels of salmon harvests. However, even though overall abundance of wild pink

Fig. 8. Predicted Fraser River adult sockeye recruits (black line ± 2 standard errors) as a function of the abundance of potential North Pacific pink salmon competitors in the second sockeye growing season at sea.



salmon has been exceptionally high during the past 30 years, hatchery operators have proposed substantial increases in hatchery pink salmon in Prince William Sound, Kodiak, Yakutat, Southeast Alaska, and Russia (http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesPlanning.enhance). The greatest production of hatchery pink salmon occurs in Prince William Sound, Alaska, where hatchery pink salmon reportedly reduced the growth of wild pink salmon because of food limitations in near-shore and oceanic areas (Cross et al. 2005), and hatchery pink salmon reduced wild pink salmon abundances from up to 17 million fish per year (Hilborn and Eggers 2000, 2001) to between 0 and 4.6 million fish per year (Wertheimer et al. 2004).

Pink salmon, including those produced in hatcheries, appear to have a strong influence on the North Pacific ecosystem. Seabird diet, body mass, and reproductive success near the Aleutian Islands are reduced in odd-numbered years when pink salmon abundance is exceptionally high (Toge et al. 2011; Springer and van Vliet 2014). In Prince William Sound, recovery of Pacific herring (*Clupea pallasii*) populations during the 20-year period after the *Exxon Valdez* oil spill may have been inhibited by competition with juvenile hatchery pink salmon for prey (Pearson et al. 2012). Additionally, salmon migrate long distances from their natal rivers, and abundant hatchery fish in Asia may compete with depleted wild populations in Norton Sound, Alaska, more than 2000 km away (Ruggerone et al. 2012). In response to the growing evidence for ecological interactions of salmonids at sea, scientists have argued for international cooperation among nations in the North Pacific to reduce competition among hatchery and wild salmon at sea (Peterman 1984; Holt et al. 2008; Peterman et al. 2012) and among hatchery salmon and other ecosystem components, including seabirds (Springer and van Vliet 2014).

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Productivity and life history of sockeye salmon in relation to competition with pink and sockeye salmon in the North Pacific Ocean

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Supplementary tables

These supplementary tables provide model selection summaries and parameter estimates for models fit to the raw data without time trends removed (S1a, b), models that only considered North American pink and sockeye abundance (raw data: S2a, b; de-trended data: S3a, b) and models that included additional hypotheses (raw data: 4a, b; de-trended data: S5a, b). A correlation matrix of all independent variables used in the main and sensitivity analyses is shown in Table S6.

Table S1a. Summary of model selection statistics for analyses of hypotheses related to interactions between pink and sockeye salmon using data **without linear time trends removed**. The dependent variable in each hypothesis is denoted by "Variable" and includes sockeye productivity ($\log_e$[recruits/spawner]), the average standardized length of four-year old male and female sockeye on the spawning grounds and the proportion of total recruits from a given brood year that spent three years in the ocean. Terms in the hypotheses (Model) are **North Pacific** pink salmon abundance (P_{t+4}) lagged by four years from the corresponding sockeye brood year to reflect the abundance of potential pink salmon competitors in the second sockeye growing season at sea, Northeast Pacific pink salmon abundance (P_{t+3}) lagged by 3 years to reflect the abundance of potential pink salmon competitors in the first sockeye growing season at sea and **North Pacific** sockeye salmon abundance (Sx_{t+4}) lagged by 4 years to reflect the number of potential conspecific competitors in the second and third sockeye growing season at sea. $P_{predators}$ is the abundance of potential pink salmon predators returning to the coast in the year sockeye smolts enter the marine environment. Each set of hypotheses is ordered by small-sample Akaike Information Criterion (AIC_c). Also shown are the log likelihoods (LL), differences in AIC_c from the AIC_c of the top model (ΔAIC_c), and Akaike model weights (w_i).

Hypothesis	Model	LL	Δ AICc	Weight
1. Productivity	P_{t+4}	-1704.67	0.00	0.51
	$P_{t+4} + P_{t+3}$	-1704.43	1.68	0.22
	$P_{t+4} + Sx_{t+4}$	-1704.59	2.00	0.19
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-1704.38	3.74	0.08
	Sx_{t+4}	-1710.72	12.10	0.00
	$P_{t+3} + Sx_{t+4}$	-1710.50	13.81	0.00
	P_{t+3}	-1712.95	16.56	0.00
	null	-1714.07	16.64	0.00
2. Std. fork length (males)	Sx_{t+4}	-434.61	0.00	0.38
	$P_{t+4} + Sx_{t+4}$	-433.94	0.82	0.25
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-433.23	1.57	0.17
	$P_{t+3} + Sx_{t+4}$	-434.32	1.59	0.17
	P_{t+4}	-438.03	6.84	0.01
	$P_{t+4} + P_{t+3}$	-438.02	8.99	0.00
	P_{t+3}	-441.44	13.66	0.00
	null	-442.94	14.51	0.00
2. Std. fork length (females)	Sx_{t+4}	-426.03	0.00	0.52
	$P_{t+4} + Sx_{t+4}$	-425.91	1.93	0.20
	$P_{t+3} + Sx_{t+4}$	-425.93	1.97	0.19
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-425.71	3.70	0.08
	P_{t+4}	-430.72	9.38	0.01
	$P_{t+4} + P_{t+3}$	-430.39	10.88	0.00
	P_{t+3}	-431.90	11.73	0.00
	null	-434.24	14.28	0.00
3. Proportion ocean-age-3 recruits	P_{t+4}	-103.99	0.00	0.43
	$P_{t+4} + P_{t+3}$	-103.56	1.25	0.23
	$P_{t+3} + Sx_{t+4}$	-104.07	2.27	0.14
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-103.44	3.12	0.09
	P_{t+3}	-105.83	3.69	0.07
	$P_{t+4} + Sx_{t+4}$	-105.66	5.44	0.03
	null	-108.08	6.08	0.02
	Sx_{t+4}	-108.90	9.82	0.00
4. Productivity (predators)	null	-1715.23	0.00	1
	$P_{predators}$	-1714.33	12.05	0

Table S1b. Multimodel averaged parameter estimates, unconditional standard error (SE) and relative variable importance (RVI) of parameters appearing in the hypotheses in Table S1a. Parameters include the abundance of potential **North Pacific** pink salmon competitors in the first (P_{t+3}) and second and third sockeye growing season at sea (P_{t+4}) and well as the number of **North Pacific** potential conspecific competitors in the second and third sockeye growing season at sea (S_{t+4}). Parameter estimates were measured in standard deviation units (SDU) on dependent variables with **without linear time trends removed**.

Hypothesis		**Coefficient (*in* SDU)**	**SE (in SDU)**	**RVI**
1. Productivity	P_{t+4}	-0.296	0.063	1.00
	P_{t+3}	-0.034	0.079	0.26
	Sx_{t+4}	-0.019	0.057	0.27
2. Std. fork length (males)	P_{t+4}	-0.176	0.136	0.43
	P_{t+3}	0.107	0.137	0.34
	Sx_{t+4}	-0.394	0.101	0.99
2. Std. fork length (females)	P_{t+4}	-0.081	0.136	0.29
	P_{t+3}	0.051	0.141	0.27
	Sx_{t+4}	-0.400	0.097	0.99
3. Proportion ocean-age-3 recruits	P_{t+4}	0.552	0.227	0.88
	P_{t+3}	0.298	0.246	0.41
	Sx_{t+4}	0.017	0.303	0.26

Table S2a. Same as Table S1a but based on **North American** pink and sockeye salmon abundance and models fit to data **without linear time trends removed**.

Hypothesis	Model	LL	Δ AICc	Weight
1. Productivity	P_{t+4}	-1705.82	0.00	0.52
	$P_{t+4} + Sx_{t+4}$	-1705.65	1.84	0.21
	$P_{t+4} + P_{t+3}$	-1705.78	2.09	0.18
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-1705.64	3.98	0.07
	Sx_{t+4}	-1709.97	8.31	0.01
	$P_{t+3} + Sx_{t+4}$	-1709.75	10.04	0.00
	P_{t+3}	-1712.27	12.92	0.00
	null	-1713.44	13.10	0.00
2. Std. fork length (males)	Sx_{t+4}	-430.50	0.00	0.52
	$P_{t+3} + Sx_{t+4}$	-430.27	1.70	0.22
	$P_{t+4} + Sx_{t+4}$	-430.49	2.15	0.18
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-430.20	3.74	0.08
	P_{t+4}	-436.73	12.46	0.00
	$P_{t+4} + P_{t+3}$	-436.59	14.36	0.00
	P_{t+3}	-438.13	15.27	0.00
	null	-440.03	16.91	0.00
2. Std. fork length (females)	Sx_{t+4}	-426.29	0.00	0.53
	$P_{t+3} + Sx_{t+4}$	-426.19	1.95	0.20
	$P_{t+4} + Sx_{t+4}$	-426.27	2.13	0.18
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-426.10	3.95	0.07
	P_{t+4}	-431.08	9.58	0.00
	$P_{t+4} + P_{t+3}$	-430.92	11.42	0.00
	P_{t+3}	-432.41	12.23	0.00
	null	-434.79	14.85	0.00
3. Proportion ocean-age-3 recruits	P_{t+4}	-107.08	0.00	0.33
	P_{t+3}	-107.36	0.57	0.25
	$P_{t+4} + P_{t+3}$	-106.64	1.23	0.18
	$P_{t+3} + Sx_{t+4}$	-107.48	2.91	0.08
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-106.57	3.20	0.07
	$P_{t+4} + Sx_{t+4}$	-108.01	3.97	0.05
	null	-110.80	5.35	0.02
	Sx_{t+4}	-109.88	5.61	0.02

Table S2b. Same as Table S1b but based on **North American** pink and sockeye salmon abundance and models fit to data **without linear time trends removed**.

Hypothesis		Coefficient (*in* SDU)	SE (in SDU)	RVI
1. Productivity	P_{t+4}	-0.264	0.065	0.99
	P_{t+3}	-0.069	0.092	0.25
	Sx_{t+4}	-0.019	0.060	0.29
2. Std. fork length (males)	P_{t+4}	-0.027	0.146	0.26
	P_{t+3}	0.087	0.131	0.30
	Sx_{t+4}	-0.413	0.092	1.00
2. Std. fork length (females)	P_{t+4}	-0.054	0.154	0.25
	P_{t+3}	0.054	0.140	0.27
	Sx_{t+4}	-0.409	0.098	1.00
3. Proportion ocean-age-3 recruits	P_{t+4}	0.481	0.223	0.63
	P_{t+3}	0.353	0.245	0.58
	Sx_{t+4}	0.094	0.284	0.21

Table S3a. Same as Table S1a but based on **North American** pink and sockeye salmon abundance and models fit to data **with linear time trends removed**.

Hypothesis	Model	LL	Δ AICc	Weight
1. Productivity	null	-1600.44	0.00	0.22
	P_{t+3}	-1599.55	0.40	0.18
	P_{t+4}	-1599.61	0.51	0.17
	$P_{t+4} + P_{t+3}$	-1598.59	0.62	0.16
	Sx_{t+4}	-1600.33	1.95	0.08
	$P_{t+3} + Sx_{t+4}$	-1599.45	2.35	0.07
	$P_{t+4} + Sx_{t+4}$	-1599.58	2.60	0.06
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-1598.55	2.72	0.06
2. Std. fork length (males)	$P_{t+4} + Sx_{t+4}$	-401.62	0.00	0.51
	Sx_{t+4}	-403.53	1.67	0.22
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-401.58	2.10	0.18
	$P_{t+3} + Sx_{t+4}$	-403.46	3.67	0.08
	P_{t+4}	-412.51	19.63	0.00
	$P_{t+4} + P_{t+3}$	-412.19	21.14	0.00
	null	-418.22	28.89	0.00
	P_{t+3}	-417.62	29.84	0.00
2. Std. fork length (females)	$P_{t+4} + Sx_{t+4}$	-404.15	0.00	0.57
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-403.88	1.64	0.25
	Sx_{t+4}	-406.77	3.07	0.12
	$P_{t+3} + Sx_{t+4}$	-406.38	4.45	0.06
	P_{t+4}	-413.77	17.07	0.00
	$P_{t+4} + P_{t+3}$	-413.14	17.98	0.00
	P_{t+3}	-419.03	27.59	0.00
	null	-420.15	27.68	0.00

Table S3b. Same as Table S1b but based on **North American** pink and sockeye salmon abundance and models fit to data **with linear time trends removed**.

Hypothesis		**Coefficient (*in* SDU)**	**SE (in SDU)**	**RVI**
1. Productivity	P_{t+4}	-0.063	0.047	0.44
	P_{t+3}	0.050	0.037	0.43
	Sx_{t+4}	-0.001	0.002	0.27
2. Std. fork length (males)	P_{t+4}	-0.145	0.074	0.69
	P_{t+3}	-0.026	0.072	0.26
	Sx_{t+4}	-0.386	0.073	1.00
2. Std. fork length (females)	P_{t+4}	-0.177	0.077	0.82
	P_{t+3}	-0.061	0.075	0.31
	Sx_{t+4}	-0.375	0.078	1.00

Table S4a. Same as Table S1a but with additional hypotheses including sea surface temperature anomalies in the winter preceding sockeye marine entry from the 1950-2010 average (SST, in °C), farmed salmon production in 1000s of metric tons (F), and an interaction between farmed salmon production and **North Pacific** pink salmon abundance (*FxP*). All models were fit to data **without linear time trends removed** and only models within 4 Δ AICc of the top model are shown. Each model is as described in equations 1-3 except for the inclusion of the $\delta_{i,j}$ terms because with their inclusion models routinely failed to converge.

Hypothesis	Model	LL	Δ AICc	Weight
1. Productivity	$SST + F + FxP + P_{t+4}$	-1680.36	0.00	0.44
	$SST + F + FxP + P_{t+4} + Sx_{t+4}$	-1680.11	1.65	0.19
	$SST + F + FxP + P_{t+4} + P_{t+3}$	-1680.28	1.99	0.16
	$SST + F + FxP + P_{t+4} + P_{t+3} + Sx_{t+4}$	-1679.97	3.54	0.07
2. Std. fork length (males)	$F + P_{t+4} + Sx_{t+4}$	-437.20	0.00	0.18
	Sx_{t+4}	-439.96	1.31	0.09
	$SST + F + P_{t+4} + Sx_{t+4}$	-436.98	1.67	0.08
	$F + FxP + P_{t+4} + Sx_{t+4}$	-437.14	2.00	0.07
	$P_{t+4} + Sx_{t+4}$	-439.26	2.01	0.07
	$F + P_{t+4} + P_{t+3} + Sx_{t+4}$	-437.16	2.03	0.07
	$F + Sx_{t+4}$	-439.38	2.26	0.06
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-438.48	2.56	0.05
	$P_{t+3} + Sx_{t+4}$	-439.64	2.77	0.05
	$SST + Sx_{t+4}$	-439.68	2.84	0.04
	$SST + P_{t+4} + Sx_{t+4}$	-438.95	3.50	0.03

	$SST + F + FxP + P_{t+4} + Sx_{t+4}$	-436.93	3.71	0.03
	$SST + F + P_{t+4} + P_{t+3} + Sx_{t+4}$	-436.98	3.80	0.03
	$SST + F + Sx_{t+4}$	-439.15	3.89	0.03
2. Std. fork length (females)	$F + P_{t+4} + Sx_{t+4}$	-424.76	0.00	0.15
	$F + Sx_{t+4}$	-425.98	0.33	0.12
	Sx_{t+4}	-427.13	0.53	0.11
	$SST + F + P_{t+4} + Sx_{t+4}$	-424.53	1.66	0.06
	$F + FxP + P_{t+4} + Sx_{t+4}$	-424.58	1.76	0.06
	$F + P_{t+4} + P_{t+3} + Sx_{t+4}$	-424.67	1.94	0.06
	$SST + F + Sx_{t+4}$	-425.74	1.95	0.06
	$SST + Sx_{t+4}$	-426.82	2.00	0.05
	$F + P_{t+3} + Sx_{t+4}$	-425.88	2.24	0.05
	$P_{t+3} + Sx_{t+4}$	-427.01	2.38	0.04
	$P_{t+4} + Sx_{t+4}$	-427.02	2.41	0.04
	$SST + F + P_{t+4} + P_{t+3} + Sx_{t+4}$	-424.30	3.33	0.03
	$SST + F + FxP + P_{t+4} + Sx_{t+4}$	-424.32	3.36	0.03
	$SST + F + P_{t+3} + Sx_{t+4}$	-425.49	3.57	0.02
	$SST + P_{t+4} + Sx_{t+4}$	-426.70	3.88	0.02
	$F + FxP + P_{t+4} + P_{t+3} + Sx_{t+4}$	-424.58	3.88	0.02
3. Proportion ocean-age-3 recruits	P_{t+4}	-104.55	0.00	0.38
	$P_{t+4} + P_{t+3}$	-103.85	0.66	0.27
	$F + P_{t+4} + P_{t+3}$	-103.18	1.39	0.19
	$SST + F + P_{t+4} + P_{t+3}$	-103.29	1.61	0.17

Table S4b. Same as Table S1b but with additional parameters for sea surface temperature anomalies from the 1950-2010 average (SST, in °C), farmed salmon production in 1000s of metric tons (F), and an interaction between farmed salmon production and **North Pacific** pink salmon abundance (*FxP*). All models were fit to data **without linear time trends removed**. Note for models pertaining to productivity the SST parameter was estimated separately for populations north and south of the Skeena watershed in Northern BC to allow for opposite responses to SST between the two regions (Mueter et al. 2002).

Hypothesis	Parameter	Coefficient (*in* SDU)	SE (in SDU)	RVI
1. Productivity	P_{t+4}	-0.204	0.053	1.00
	P_{t+3}	-0.021	0.054	0.27
	Sx_{t+4}	0.035	0.046	0.31
	SST (south)	-0.162	0.044	0.99
	SST (north)	0.018	0.073	0.99
	F	-0.076	0.072	0.98
	FxP	-0.123	0.047	0.88
2. Std. fork length (males)	P_{t+4}	-0.263	0.149	0.68
	P_{t+3}	0.062	0.155	0.30
	Sx_{t+4}	-0.348	0.114	0.97
	SST	0.065	0.104	0.30
	F	0.217	0.138	0.62
	FxP	-0.029	0.105	0.14
2. Std. fork length (females)	P_{t+4}	-0.199	0.153	0.52
	P_{t+3}	-0.033	0.168	0.29
	Sx_{t+4}	-0.406	0.115	0.99
	SST	0.080	0.109	0.31
	F	0.228	0.139	0.68
	FxP	0.061	0.110	0.12
3. Proportion ocean-age-3 recruits	P_{t+4}	0.580	0.215	1.00
	P_{t+3}	0.284	0.051	0.62
	Sx_{t+4}	-	-	-
	SST	0.179	0.221	0.17
	F	0.012	0.092	0.36
	FxP	-	-	-

Table S5a. Same as Table S4a but with models fit to data **with linear time trends removed**.

Hypothesis	Model	LL	Δ AICc	Weight
1. Productivity	$SST + P_{t+4} + P_{t+3}$	-1580.20	0.00	0.30
	$SST + P_{t+4} + P_{t+3} + Sx_{t+4}$	-1579.46	0.66	0.21
	$SST + F + P_{t+4} + P_{t+3}$	-1579.88	1.50	0.14
	$SST + F + P_{t+4} + P_{t+3} + Sx_{t+4}$	-1579.10	2.10	0.10
	$SST + FxP + P_{t+4} + P_{t+3} + Sx_{t+4}$	-1579.68	3.27	0.06
	$SST + P_{t+3}$	-1583.17	3.78	0.05
	$SST + F + FxP + P_{t+4} + P_{t+3} + Sx_{t+4}$	-1578.86	3.78	0.04
2. Std. fork length (males)	$SST + F + FxP + P_{t+4} + Sx_{t+4}$	-398.57	0.00	0.15
	$F + FxP + P_{t+4} + Sx_{t+4}$	-399.72	0.18	0.14
	$P_{t+4} + Sx_{t+4}$	-401.89	0.29	0.13
	$SST + P_{t+4} + Sx_{t+4}$	-401.35	1.31	0.08
	$SST + F + FxP + P_{t+4} + P_{t+3} + Sx_{t+4}$	-398.39	1.79	0.06
	Sx_{t+4}	-403.73	1.89	0.06
	$F + P_{t+4} + Sx_{t+4}$	-401.71	2.04	0.05
	$F + FxP + P_{t+4} + P_{t+3} + Sx_{t+4}$	-399.71	2.29	0.05
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-401.85	2.33	0.05
	$SST + F + P_{t+4} + Sx_{t+4}$	-400.86	2.47	0.04
	$SST + Sx_{t+4}$	-403.10	2.72	0.04
	$SST + P_{t+4} + P_{t+3} + Sx_{t+4}$	-401.19	3.12	0.03
	$F + P_{t+4}$	-403.62	3.75	0.02
	$P_{t+3} + Sx_{t+4}$	-403.67	3.85	0.02

2. Std. fork length (females)	$P_{t+4} + Sx_{t+4}$	-404.15	0.00	0.16
	$SST + F + P_{t+4} + Sx_{t+4}$	-402.19	0.30	0.13
	$SST + F + FxP + P_{t+4} + Sx_{t+4}$	-401.29	0.64	0.11
	$SST + P_{t+4} + Sx_{t+4}$	-403.70	1.21	0.08
	$P_{t+4} + P_{t+3} + Sx_{t+4}$	-403.88	1.57	0.07
	$SST + F + FxP + P_{t+4} + P_{t+3} + Sx_{t+4}$	-400.73	1.66	0.07
	$F + P_{t+4} + Sx_{t+4}$	-404.05	1.91	0.06
	$F + FxP + P_{t+4} + P_{t+3} + Sx_{t+4}$	-401.97	1.99	0.06
	$SST + P_{t+4} + P_{t+3} + Sx_{t+4}$	-403.19	2.29	0.05
	$SST + P_{t+4} + F + Sx_{t+4}$	-403.40	2.71	0.04
	Sx_{t+4}	-406.77	3.14	0.03
	$F + P_{t+4} + P_{t+3} + Sx_{t+4}$	-403.79	3.51	0.03
	$SST + F + P_{t+4} + P_{t+3} + Sx_{t+4}$	-402.83	3.70	0.02

Table S5b. Same as Table S4b but **with linear time trends removed**. Parameter estimates for sockeye abundance, pink abundance in the first year of marine life and SST are not presented under hypothesis 3 because they were not in the top model set (i.e., within 4 Δ AICc of the top model).

Hypothesis		**Coefficient (*in* SDU)**	**SE (in SDU)**	**RVI**
1. Productivity	P_{t+4}	-0.091	0.035	0.91
	P_{t+3}	0.097	0.034	0.95
	Sx_{t+4}	0.042	0.035	0.41
	SST (south)	-0.178	0.041	1.00
	SST (north)	0.004	0.067	1.00
	F	-0.035	-0.042	0.11
	FxP	-0.029	0.04	0.39
2. Std. fork length (males)	P_{t+4}	-0.132	0.073	0.81
	P_{t+3}	-0.030	0.072	0.28
	Sx_{t+4}	-0.377	0.074	1.00
	SST	0.123	0.092	0.46
	F	-0.028	0.013	0.58
	FxP	0.014	0.020	0.39
2. Std. fork length (females)	P_{t+4}	-0.167	0.077	0.88
	P_{t+3}	-0.067	0.076	0.34
	Sx_{t+4}	-0.364	0.078	1.00
	SST	0.123	0.100	0.43
	F	0.011	0.021	0.56
	FxP	-0.028	0.014	0.37

Table S6. Correlation matrix of all independent variables used in the main and sensitivity analyses of sockeye salmon productivity, length at age, and age at maturity. Correlations below the diagonal are for detrended time series while those above the diagonal are for raw values. Variables include the abundance of adult pink salmon (P_{t+3}) from the Northeast Pacific (Northern BC and Alaska) three years after each sockeye brood year as an index of competitors early in the first year of sockeye marine life, the abundance of adult pink salmon (P_{t+4}) from the North Pacific (BC through Russia) four years after each sockeye brood year as an index of competitors in the second year of sockeye marine life, and the abundance of sockeye salmon (Sx_{t+4}) from the North Pacific (BC through Russia) four years after each sockeye brood year as an index of conspecific competitors in the second and third year of sockeye marine life. Also included are the two additional variables from the sensitivity analyses: sea surface temperature anomaly in the winter preceding juvenile sockeye marine entry (SST), and farmed salmon production along sockeye salmon early marine migration routes (Farm).

	P_{t+3}	P_{t+4}	Sx_{t+4}	SST	Farm
P_{t+3}	-	0.46	0.45	0.38	0.51
P_{t+4}	-0.15	-	0.56	0.24	0.44
Sx_{t+4}	0.12	0.26	-	0.28	0.22
SST	0.33	0.08	0.19	-	0.21
Farm	0.01	0.09	-0.22	-0.08	-

Competition between Asian pink salmon (*Oncorhynchus gorbuscha*) and Alaskan sockeye salmon (*O. nerka*) in the North Pacific Ocean

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ABSTRACT

The importance of interspecific competition as a mechanism regulating population abundance in offshore marine communities is largely unknown. We evaluated offshore competition between Asian pink salmon and Bristol Bay (Alaska) sockeye salmon, which intermingle in the North Pacific Ocean and Bering Sea, using the unique biennial abundance cycle of Asian pink salmon from 1955 to 2000. Sockeye salmon growth during the second and third growing seasons at sea, as determined by scale measurements, declined significantly in odd-numbered years, corresponding to years when Asian pink salmon are most abundant. Bristol Bay sockeye salmon do not interact with Asian pink salmon during their first summer and fall seasons and no difference in first year scale growth was detected. The interaction with odd-year pink salmon led to significantly smaller size at age of adult sockeye salmon, especially among younger female salmon. Examination of sockeye salmon smolt to adult survival rates during 1977–97 indicated that smolts entering the ocean during even-numbered years and interacting with abundant odd-year pink salmon during the following year experienced 26% (age-2 smolt) to 45% (age-1 smolt) lower survival compared with smolts migrating during odd-numbered years. Adult sockeye salmon returning to Bristol Bay from even-year smolt migrations were 22% less abundant (reduced by 5.9 million fish per year) compared with returns from odd-year migrations. The greatest reduction in adult returns occurred among adults spending 2 compared with 3 years at sea. Our new evidence for interspecific competition highlights the need for multispecies, international management of salmon production, including salmon released from hatcheries into the ocean.

Key words: Alaska, Bering Sea, Bristol Bay, growth, hatchery, interspecific competition, Kamchatka, management, marine survival, *Oncorhynchus*, Pacific salmon, Russia, scale annuli

INTRODUCTION

The role of interspecific competition in structuring terrestrial, freshwater, coral reef, and marine intertidal communities has been widely investigated (Schoener, 1983; Bertness *et al.*, 2001), but the nature and importance of interspecific competition as a mechanism that regulates population abundance in offshore marine communities is largely unknown. This uncertainty stems from the difficulty in testing competition between species that inhabit broad regions of the world's oceans. Some scientists have assumed that interspecific competition may influence abundances of marine populations (Cushing, 1975; National Research Council, 1999), whereas others have downplayed its importance in regulating populations (Sinclair, 1988).

Intraspecific competition in epipelagic waters of the North Pacific Ocean can lead to density-dependent growth within the highly abundant species of Pacific salmon (*Oncorhynchus* spp.) such as sockeye (*O. nerka*), pink (*O. gorbuscha*) and chum (*O. keta*) salmon (Peterman, 1984; Ishida *et al.*, 1993; Rogers and Ruggerone, 1993; Welch and Parsons, 1993). Pacific salmon are highly migratory and competition may occur between conspecifics originating from distant

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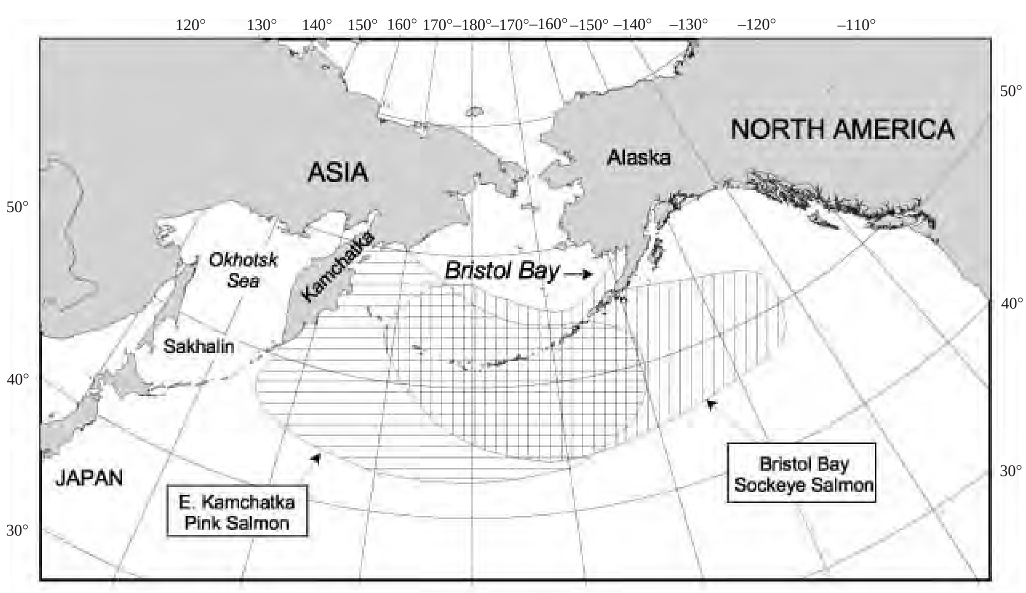
natal rivers (McKinnell, 1995; Pyper and Peterman, 1999). Additionally, several studies have reported evidence of interspecific competition among Pacific salmon leading to reduced growth of the species foraging at the slightly higher trophic level. Asian pink salmon reportedly reduced the length of Russian sockeye salmon (Krogius, 1964; Bugaev *et al*., 2001) and Asian coho salmon (*O. kisutch*) (Ogura *et al*., 1991) and altered the diet of Asian chum salmon (Tadokora *et al*., 1996). These observations of density-dependent growth have led to concerns about salmon carrying capacity in the ocean, especially in the light of increased artificial propagation (Pearcy *et al*., 1999). However, there is little evidence that competition leads to reduced survival of salmon, although researchers have suggested that pink salmon from Washington and British Columbia may reduce the abundance of chum salmon through competition in nearshore waters (Salo, 1991).

Here we evaluated offshore competition between pink salmon originating from Asia and sockeye salmon originating from Bristol Bay, Alaska, using the unique biennial abundance cycle of Asian pink salmon from 1955 to 2000. Several attributes of Asian pink salmon and Bristol Bay sockeye salmon make them ideal for testing the competition hypothesis. First, pink salmon have a unique 2-year life cycle that can lead to significant differences in abundance during odd- versus even-numbered years, thereby providing a natural experimental control for environmental conditions that similarly influence both species. Asian pink salmon are most abundant in odd-numbered years, averaging approximately 55% more fish (162 million adults, i.e. catch and spawning abundance) compared with even years (105 million adults) during 1955–2000 (INPFC Secretariat, 1979; Rogers, 1987a, 2001). In comparison, annual pink salmon runs to Alaska are nearly equal during odd- and even-numbered years, and they are less abundant than Asian pink salmon. Furthermore, adult pink salmon distribution is broader in the western and central North Pacific Ocean and Bering Sea in odd-numbered years compared with even-numbered years (Azumaya and Ishida, 2000).

A second attribute that supports tests of the competition hypothesis is that the distribution of Asian pink salmon overlaps that of Bristol Bay sockeye salmon in the North Pacific Ocean and Bering Sea, based on extensive high seas tagging studies since 1956 (French *et al*., 1976; Takagi *et al*., 1981; Myers *et al*., 1996). Pink salmon from eastern Kamchatka migrate the farthest east and have the greatest overlap (Fig. 1), but other Asian stocks also overlap with Bristol Bay sockeye salmon. Overlap in offshore waters begins during winter after the spring seaward migration of

Figure 1. Known range of immature Bristol Bay sockeye salmon and maturing eastern Kamchatka Peninsula pink salmon, based on the international tag recovery database, 1956–95 (French *et al*., 1976; Takagi *et al*., 1981; Myers *et al*., 1996). Area of known overlap is approximately 2 million km^2 and represents high densities of both species. Actual overlap is probably broader than that shown. Sakhalin and Okhotsk pink salmon migrate to approximately 177 E and overlap with the western distribution of Bristol Bay sockeye salmon.



juveniles and continues through July when adult pink salmon return to coastal waters and enter spawning streams (Fig. 2). Pink salmon invariably spend one winter at sea whereas sockeye salmon typically spend two or three. The trophic level, diet, and feeding behaviour of pink salmon overlap significantly with sockeye salmon (Welch and Parsons, 1993; Davis *et al.*, 2000; Kaeriyama *et al.*, 2000). Macrozooplankton abundance in the central North Pacific is lower during odd-numbered years, apparently due to the high abundance of Asian pink salmon in odd years (Shiomoto *et al.*, 1997). Consumption of prey by individual sockeye and pink salmon tends to decline during years when pink salmon are most abundant; however, the decline in the dominant prey may be greater for sockeye salmon than pink salmon (58% versus 31% reduction) (Davis *et al.*, 2000). Pink salmon are the most abundant salmonid, and Asia (Russian Far East) supports the largest pink salmon runs in the world. Bristol Bay supports the largest sockeye salmon runs in the world. Thus, competition between Asian pink salmon and Bristol Bay sockeye salmon was expected to be greatest during odd-numbered years when Asian pink salmon were most abundant.

To establish the mechanism by which pink salmon might reduce Bristol Bay sockeye salmon survival, we first compared annual scale growth of sockeye salmon at sea and their final adult length in odd- and even-numbered years. A reduction in sockeye salmon growth in offshore waters during odd-numbered years (high pink salmon abundance) would support the hypothesis that competition for food might lead to reduced sockeye salmon survival. The effect of Asian pink salmon on survival of adult sockeye salmon was evaluated by comparing smolt-to-adult survival rates and total adult returns of sockeye salmon resulting from even- versus odd-numbered year smolt migrations.

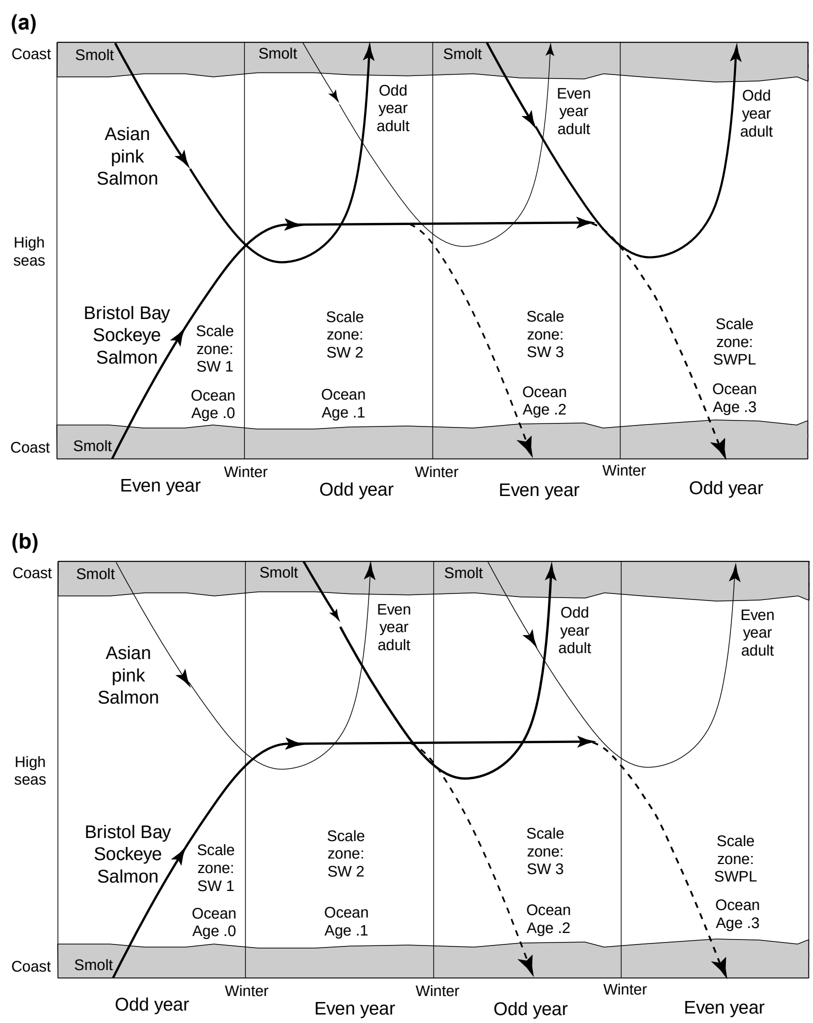


Figure 2. Diagram of temporal overlap between Asian pink salmon and Bristol Bay sockeye salmon. Sockeye salmon smolts entering the ocean during even-numbered years first encounter abundant odd-year pink salmon (bold line) during the first winter at sea and the second growing season, i.e. primarily during SW2 (a), whereas sockeye salmon smolts entering the ocean during odd-numbered years do not encounter abundant odd-year pink salmon until the second winter at sea and the third growing season, i.e. during SW3 (b). Interaction between Asian pink salmon and maturing sockeye salmon may be minimal because maturing sockeye salmon are distributed farther north during fall, winter and spring compared with immature sockeye salmon (French *et al.*, 1976). Pink salmon spend one winter at sea, whereas most sockeye spend two (age-.2) or three (age-.3) winters at sea. Period of overlap between species is from winter to July, but the effect of interaction may continue until prey populations recover.

Sockeye salmon first interact with Asian pink salmon during the second season (Fig. 2). Therefore, a reduction in survival or abundance of sockeye salmon smolts entering the ocean during even-numbered years would support the hypothesis that Asian pink salmon affect survival of Alaskan sockeye salmon.

MATERIALS AND METHODS

Sockeye salmon scale and adult length measurements

An index of annual Bristol Bay sockeye salmon growth at sea was estimated by measuring distances between scale annuli using the methodology developed by the University of Washington's High Seas Salmon Research Program (Davis *et al*., 1990; Zimmermann, 1991). Scale annuli measurements are correlated with salmon length (Fukuwaka and Kaeriyama, 1997). Sockeye salmon scales were obtained from commercial harvests of adult fish in Nushagak Bay, a major fishing district within Bristol Bay. Scales of both age-1.3 and age-1.2 sockeye salmon, corresponding to the dominant age groups in this fishing district, were measured at a magnification of 56× (age is designated by European notation, i.e. the number of winters spent in freshwater before going to sea, one winter = age-1.x or two winters = age-2.x, followed by the number of winters spent at sea, two winters = age-x.2 or three winters = age-x.3). Sample size was 100 adult salmon scales (equal sex ratio) per year per age group; 1955–97 for age 1.3 and 1955–90 for age 1.2 fish. Average length of adult Bristol Bay sockeye salmon was determined for each sex and age, based on regular sampling of adult returns by the Alaska Department of Fish and Game (ADFG) in each river system during 1958–2000 (Rogers and Ruggerone, 1993).

Salmon abundance and survival statistics

Abundance of Bristol Bay sockeye salmon by age and river system (stock) was obtained from a database previously used to reconstruct annual runs of Pacific salmon throughout their range since 1950 (Rogers, 1987a, 2001). Age-specific adult sockeye salmon returns in a given year were used to estimate adult salmon returns from smolt migrations occurring in odd- versus even-numbered years where even-year smolts interacted with abundant odd-year pink salmon during the second growing season.

Abundances of Asian (Japanese and Russian) pink salmon after 1991 were based on annual estimates of catch and spawning density provided by the North Pacific Anadromous Fish Commission in documents and statistical yearbooks (NPAFC, 2001). Prior to 1992, abundances of Asian pink salmon were calculated from catch statistics provided by the International North Pacific Fisheries Commission, the Food and Agriculture Organization of the United Nations (FAO), and by the USSR (Fredin *et al*., 1977; INPFC Secretariat, 1979; Fredin, 1980; Harris 1989), and a 60% harvest rate, which was estimated from catch and spawning abundance statistics in the early 1990s (Rogers, 2001). Commercial catches by Japan on the high seas and inside the Russian 200-mile zone are included in the abundance estimates. These estimates represent an index of Asian pink salmon abundance on the high seas that largely reflects catch trends. Actual harvest rates may have been higher during even-numbered years when pink salmon were less abundant (Semko, 1969), a trend that helped to maintain the dominance of odd-year pink salmon runs.

Sockeye salmon smolt to adult survival rates were based on reported age-specific smolt abundance estimates and subsequent age-specific adult returns (Crawford and West, 2001). Smolt estimates were available for the Kvichak (1977–97), Egegik (1982–97), and Ugashik (1983–97) rivers, all of which enter into Bristol Bay. Earlier years of Kvichak smolt data were not used because they were based on a different sampling methodology and represented a period of lower salmon production.

Statistical analysis

Time series analysis with transfer function models (Liu and Hudak, 1992) was used to develop multivariate relationships between adult sockeye salmon length and the independent variables – Asian pink salmon abundance and Bristol Bay sockeye salmon abundance. An intervention model approach was incorporated to model a level shift during the mid-1970s, as this approach reduced residual error more than incorporation of an autoregressive error term. Model assumptions were examined and validated using autocorrelation, cross correlation and collinearity analyses. Additionally, correlation between sockeye salmon scale growth and pink salmon abundance used the procedure recommended by Pyper and Peterman (1998) to control for type I error resulting from autocorrelation.

Analysis of variance (ANOVA) was used to test for differences in sockeye salmon size, abundance and survival during odd- compared with even-numbered years at sea. An arcsine transformation was applied to sockeye salmon survival estimates.

RESULTS

Pink salmon effects on sockeye salmon growth

Since the mid-1950s, Bristol Bay sockeye salmon scale growth exhibited a distinct alternating year pattern of growth during the year prior to homeward migration (Fig. 3). Scale growth was typically below average during odd-numbered years at sea and above average during even-numbered years for both ocean age-2 and age-3 sockeye salmon. This unique time series of sockeye salmon growth highlights the effect of Asian pink salmon, which exhibit a distinct odd- and even-year pattern of abundance that is opposite to that of sockeye salmon growth (Fig. 3c).

Long-term trends in sockeye salmon growth in relation to pink salmon abundance were also apparent. During odd-numbered years and, to a lesser extent, in even-numbered years, sockeye salmon scale growth during the third growing season (SW3) decreased after pink salmon abundance increased during the mid-1970s (Fig. 3b), leading to an inverse correlation between sockeye salmon scale growth and pink salmon abundance ($r = -0.59$, $P < 0.05$). This transition in scale growth corresponds with the mid-1970s North Pacific Ocean 'regime shift' that had a strong effect on climate, sea surface temperature and abundance of marine species (Anderson and Piatt, 1999). The strong response of sockeye salmon growth to pink salmon abundance is further shown by reduced sockeye salmon growth during recent (1992–96, except 1994) even- and odd-numbered years when Asian pink salmon abundance was large compared with earlier years

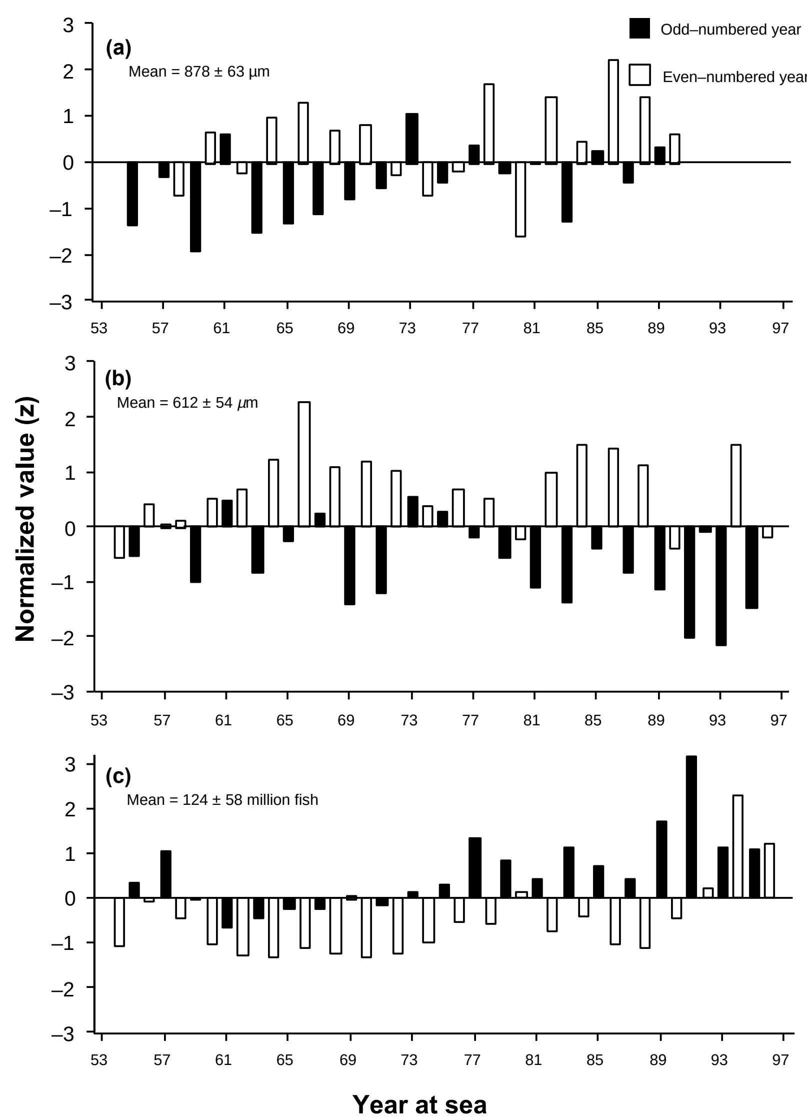


Figure 3. Bristol Bay sockeye salmon growth during the second (a) and the third growing season at sea (b) and the corresponding abundance of maturing Asian pink salmon (c), 1954–96. Growth measurements are based on scales of age-1.2 (a) and age-1.3 (b) sockeye salmon. Age-1.2 scale measurements after 1990 were not available. Open bars are even years at sea, and closed bars are odd years at sea. Values are normalized, i.e. standard deviations above and below the long-term mean.

(Fig. 3). Sockeye salmon scale growth during the second growing season (SW2) was also inversely correlated with pink salmon abundance before and after the mid-1970s ($r = -0.35$, $P < 0.05$), but ocean age-2 growth tended to be greater after the mid-1970s.

Bristol Bay sockeye salmon scale growth was significantly lower during odd-numbered years at sea [i.e. years of high pink salmon abundance; two factor ANOVA (odd/even year, scale zone); age-1.3: df = 1, 2, 123; $F = 14.255$; $P < 0.001$; age-1.2: df = 1, 1, 71; $F = 4.124$; $P < 0.05$]. Reduced growth during odd-numbered years occurred during both the second [3.7% (age-1.3) to 5.6% (age-1.2) reduction] and third (12.8% reduction) growing seasons ($P < 0.05$). No differences in sockeye salmon scale growth were observed during the first growing season at sea, corresponding to the period when little or no overlap occurs with Asian pink salmon (French *et al.*, 1976; Takagi *et al.*, 1981; Myers *et al.*, 1996). Scale growth during the homeward migration (SWPL) was confounded by resorption of the outer scale margin.

Previous research demonstrated that the length of adult Bristol Bay sockeye salmon was smaller during years when they were abundant, primarily due to intraspecific competition during the spring migration back to Bristol Bay when they concentrate in a relatively small migration corridor and time period (Rogers and Ruggerone, 1993). Multivariate time series analysis indicated that lengths of adult male and female sockeye salmon (each of four age groups) during 1958–2000 were also inversely related to Asian pink salmon abundance during the previous year (Table 1). Sockeye salmon length was not related to Asian pink salmon abundance during the year of homeward migration ($P > 0.05$), indicating little interaction with maturing sockeye salmon. Standardized model coefficients indicated that pink salmon abundance affected lengths of female, more than male, sockeye salmon. Maximum percentage reduction in average sockeye salmon length as a result of pink salmon ranged from 1.8% (age-2.3 males) to 4.2% (age-1.2 females), indicating a greater effect on the youngest age group.

Sockeye salmon abundance during the homeward migration period tended to influence final sockeye salmon length more than pink salmon abundance during the previous year. Thus, intraspecific competition had a greater effect on adult salmon length than interspecific competition. Time series analysis indicated a shift in the relationship between final adult length and salmon abundance: beginning with adults returning in 1977, sockeye salmon length was greater at a given abundance of pink and sockeye salmon.

Pink salmon effects on sockeye salmon survival and abundance

Survival was significantly lower for sockeye salmon entering the ocean during even-numbered years [three factor ANOVA (odd/even year, freshwater age, sockeye salmon stock); df = 1, 1, 2, 89; $F = 6.208$; $P < 0.02$]. These fish interacted with abundant odd-year Asian pink salmon during the first winter and second growing season at sea, whereas odd-year smolts did not interact with odd-year pink

Table 1. Multivariate time series analysis showing the effect of pink salmon abundance (X3) on lengths (mm) of adult sockeye salmon returning to Bristol Bay (model for each sex and age class), 1958–2000. Asian pink salmon abundance is run size (millions) during the previous year ($t-1$), corresponding to the last year of interaction throughout much of the growing season. Pink salmon abundance during the year of return (t) was not significant ($P > 0.05$), indicating little interaction with maturing sockeye salmon. Other variables in the models are abundance of Bristol Bay (BB) sockeye run (X1; millions) and time period (X2: 0 if 1958–76; 1 if 1977–2000). Age-1.2 level shifts began in 1978. Pink and sockeye salmon run sizes were statistically significant factors for each age group and sex; critical $t_{0.05(2),39} = 2.023$. Standardized model coefficients are shown.

					Std model coefficients			*t* value		
Age	Sex	Multivariate equation	N	R^2	BB run	Period	Pink run	BB run	Period	Pink run
1.3	Male	$L = 594.3 - 0.289(X1) + 6.40(X2) - 0.058(X3_{t-1}) + \varepsilon$	43	0.49	−0.619	0.415	−0.492	−4.55	2.75	−3.78
1.3	Female	$L = 571.7 - 0.339(X1) + 8.76(X2) - 0.067(X3_{t-1}) + \varepsilon$	43	0.59	−0.710	0.556	−0.551	−5.88	4.14	−4.76
2.3	Male	$L = 596.8 - 0.310(X1) + 6.03(X2) - 0.040(X3_{t-1}) + \varepsilon$	43	0.46	−0.697	0.411	−0.355	−5.00	2.65	−2.66
2.3	Female	$L = 578.8 - 0.315(X1) + 8.31(X2) - 0.055(X3_{t-1}) + \varepsilon$	43	0.48	−0.715	0.574	−0.485	−4.93	3.54	−3.56
1.2	Male	$L = 524.9 - 0.211(X1) + 6.75(X2) - 0.070(X3_{t-1}) + \varepsilon$	43	0.26	−0.340	0.332	−0.467	−2.15	1.84	−3.01
1.2	Female	$L = 508.8 - 0.198(X1) + 9.87(X2) - 0.082(X3_{t-1}) + \varepsilon$	43	0.31	−0.362	0.550	−0.593	−2.20	2.94	−3.87
2.2	Male	$L = 538.5 - 0.404(X1) + 14.50(X2) - 0.062(X3_{t-1}) + \varepsilon$	43	0.50	−0.712	0.777	−0.433	−5.29	5.19	−3.35
2.2	Female	$L = 523.8 - 0.424(X1) + 14.21(X2) - 0.064(X3_{t-1}) + \varepsilon$	43	0.47	−0.704	0.715	−0.419	−5.10	4.66	−3.17

salmon until their third growing season. Lower survival of even-year migrating juveniles occurred in each of the three sockeye salmon populations for which survival data were available. Survival of both freshwater age-1 and age-2 juvenile sockeye salmon was less during even-year migrations, but the reduction was greatest for the smaller and younger age-1 salmon (45% versus 26% reduction) (Fig. 4). Examination of age-specific contributions to the survival rates indicated that the youngest sockeye salmon (age-1.2) experienced the greatest reduction in survival (59%), whereas the oldest age group (age-2.3) was affected the least (19% reduction). Intermediate age groups (age-1.3 and age-2.2) experienced intermediate reductions (30%).

The effect of Asian pink salmon on the abundance of Bristol Bay sockeye salmon was evaluated by comparing adult returns from juvenile sockeye salmon entering the ocean during odd- versus even-numbered years during 1956–76 and 1977–97, corresponding to periods of relatively low and high adult salmon production (Beamish and Bouillon, 1993; Mantua *et al.*, 1997). All major Bristol Bay stocks were analysed except for the Kvichak stock, which is strongly influenced by a 5-year cycle of spawning density that causes the large 5-year cycle of adult returns. Prior to the mid-1970s regime shift when pink and sockeye salmon were less abundant, no difference was detected in odd- and even-year sockeye salmon abundance ($P > 0.05$). After the mid-1970s, the Bristol Bay sockeye salmon return from juveniles entering the ocean during even-numbered years averaged 1.48 million fewer fish per stock per year or a 22% reduction compared with returns from odd-year juveniles (df 1, 3, 76; $F = 3.97$; $P = 0.049$). The reduction occurred in each of the four stocks (Fig. 5), resulting in 5.9 million fewer sockeye salmon per year returning to Bristol Bay from even-year smolt migrations.

Analysis of age-specific sockeye salmon returns after 1976 indicated 1.04 million fewer ocean age-2 sockeye salmon per Bristol Bay stock per year returned from juveniles entering the ocean during even-numbered years compared with odd-numbered years [two factor ANOVA (sockeye salmon stock, odd/even year), df 1, 3, 76; $F = 8.724$; $P < 0.005$]. The return of ocean age-3 sockeye was not statistically different between odd- and even-numbered years ($P = 0.35$), but fewer age-3 sockeye salmon tended to return

Figure 4. Average smolt to adult survival of freshwater age-1 and age-2 Bristol Bay sockeye salmon entering the ocean during odd versus even years, 1977 to 1997. Even-year smolts first interact with relatively abundant odd-year Asian pink salmon during their first winter and second spring at sea, whereas odd-year juveniles first interact with odd-year pink salmon during their second winter and third spring at sea. Contribution of ocean age-2 and age-3 sockeye salmon to the survival estimates is shown. Estimates represent Kvichak, Egegik and Ugashik sockeye salmon populations, which constitute 67% of the adult Bristol Bay sockeye salmon population since 1978 (on average). Error bars show ± 1 SE.

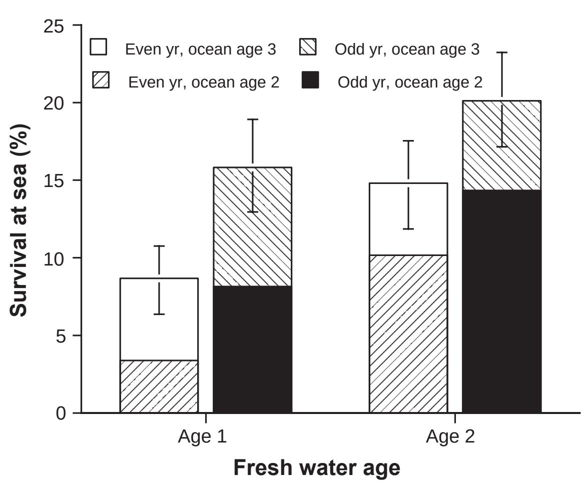
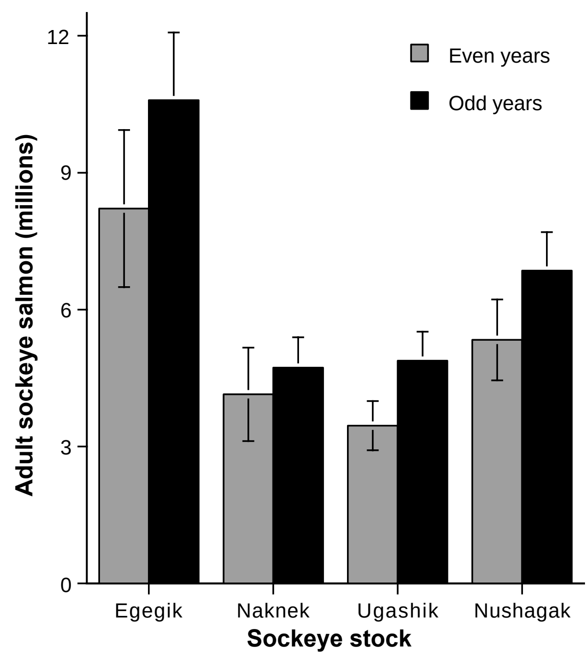


Figure 5. Annual number of adult sockeye salmon returning from juvenile sockeye salmon entering the ocean during odd versus even years (mean ± 1 SE), 1977 to 1997. All major Bristol Bay sockeye salmon stocks are shown except Kvichak (see text).



from juveniles entering the ocean during even-numbered years (average reduction: 0.44 million adults per stock). Ocean age-3 sockeye salmon returns from even-year migrations of juveniles experienced large numbers of pink salmon during their second growing season at sea (SW2 scale zone) but fewer pink salmon during their third season (SW3 scale zone). These results indicate that sockeye salmon abundance was primarily affected during their second growing season at sea.

DISCUSSION

Our analyses show that growth and survival of Bristol Bay sockeye salmon were inversely related to Asian pink salmon abundance, indicating that pelagic marine species can compete and affect population levels over broad regions of the North Pacific Ocean and the Bering Sea. This finding is contrary to the opinion that competition may have little effect on the regulation of populations in the ocean (Sinclair, 1988), a belief founded in part by the difficulty in testing the competition hypothesis. In this study, detection of competition was facilitated by the unique odd/even year cycle of Asian pink salmon abundance. The 2-year cycle is important to the detection of competition because both species appear to respond similarly to decadal-scale cycles, as shown by the significant overall increase in abundance of both species beginning in the mid-1970s (Beamish and Bouillon, 1993). Interspecific competition effects on sockeye salmon growth occurred throughout the 45-year period of investigation, but competition effects on sockeye salmon survival and abundance were most apparent after the mid-1970s when overall survival rates and abundances of both species were relatively high. Further research is needed to evaluate survival prior to the mid-1970s.

The mechanism leading to lower sockeye salmon abundance and survival in this study is reduction in food availability and salmon growth as a result of the relatively high abundance of Asian pink salmon during odd-numbered years. These species are sympatric on the high seas, share similar prey, and Asian pink salmon can reduce prey availability in the central North Pacific Ocean during odd-numbered years (Shiomoto *et al.*, 1997). Size-selective predation on slower growing sockeye salmon by salmon sharks (*Lamna ditropis*) and other large predators is probably a key source of mortality (Nagasawa, 1998). Sockeye salmon is reportedly the dominant prey of salmon sharks in the central North Pacific and Bering Sea, representing up to 40% of their diet.

Other environmental or biological factors cannot explain the observed sockeye salmon abundance pattern exhibited over decades. Bristol Bay sockeye salmon spawning density is largely controlled by the fixed spawning density policy of the ADFG, and it does not vary on a 2-year cycle (two factor ANOVA; odd/even year, stock; df = 1, 4, 205; $F = 0.000$; $P > 0.99$). Furthermore, a 2-year cycle originating from freshwater sources would be inhibited by the variable residence time of sockeye salmon in lakes (either 1 or 2 years), which is partially influenced by growth rate (Burgner, 1991). In marine waters, other species having life history characteristics that might influence the odd/even year pattern observed in Bristol Bay sockeye and Asian pink salmon are not known (Heard, 1991). Predation by returning adult pink salmon on emigrating juvenile sockeye salmon may influence a biennial cycle of sockeye salmon in British Columbia (Peterman, 1982), but pink salmon returning to Bristol Bay are not abundant and they are distributed offshore from juvenile sockeye salmon (Straty, 1981). Abundance of North American pink salmon stocks cannot explain reduced growth and abundance of Bristol Bay sockeye salmon during odd-numbered years as Alaska pink salmon abundance is nearly equal during odd- and even-numbered years, and pink salmon originating from British Columbia and Washington have little overlap with Bristol Bay sockeye salmon (French *et al.*, 1976; Takagi *et al.*, 1981; Myers *et al.*, 1996). Thus, we conclude that Asian pink salmon influenced the growth and survival of Bristol Bay sockeye salmon.

We believe the effect on sockeye salmon abundance and growth shown in this investigation was largely related to the eastern Kamchatka population of pink salmon and secondarily to other Asian pink salmon populations. The international tag recovery database shows that eastern Kamchatka pink salmon have the greatest eastward migration and largest overlap with Bristol Bay sockeye salmon (Fig. 1). From 1955 to 1999 eastern Kamchatka pink salmon were relatively abundant, supporting an average harvest of approximately 24 million fish in odd-numbered years and 5 million fish in even-numbered years (Sinyakov, 1998). The relatively high odd-year abundance of eastern Kamchatka pink salmon has continued throughout the 1990s, whereas even-year abundances of other Asian pink salmon populations increased during the early 1990s. These other Asian pink salmon stocks are also abundant but they overlap with Bristol Bay sockeye salmon to a lesser degree. North American pink salmon from Alaska probably compete with Bristol Bay sockeye salmon but detection of this effect is confounded by the similar odd- and even-year abundances of central and southeast Alaska pink salmon.

Previous researchers have suggested that most salmon mortality occurs during the first few months of marine life (Pearcy, 1992). This study indicated that sockeye salmon abundance was reduced during the second year at sea, corresponding to the period when Bristol Bay sockeye and Asian pink salmon first overlap (French *et al.*, 1976; Takagi *et al.*, 1981; Myers *et al.*, 1996). The salmon interaction probably begins during the first winter at sea of both species when they are primarily located in the central North Pacific (Fig. 2). During spring and early summer, many immature sockeye salmon and maturing Asian pink salmon migrate northwest and enter the central Bering Sea. Many maturing pink salmon coexist with immature sockeye salmon in the Bering Sea until mid-July. Although most pink salmon leave offshore rearing areas by August for coastal spawning streams, the effect of pink salmon probably continues until prey populations increase. Thus, the period of salmon interaction occurs from winter to at least summer.

Sockeye scale growth during the third year at sea was strongly influenced by pink salmon abundance. This reduction in growth, however, did not correspond to a reduction in sockeye salmon abundance. Instead, ocean age-3 sockeye salmon abundance was slightly greater after interacting with odd-year pink salmon in their third year at sea. This suggests that sockeye salmon abundance, in relation to interactions with pink salmon, is established during the second year at sea, but sockeye salmon growth during the third year continues to be influenced by large numbers of pink salmon. Furthermore, these data show that the potential increase of ocean age-3 sockeye salmon, resulting from reduced growth during the second year at sea and delayed maturation (Rogers, 1987b), did not offset reduced returns of ocean age-2 siblings.

The reduction in sockeye salmon scale growth during the second growing season (SW2) was less than that during the third season (SW3). This result may reflect greater overlap between the older ocean age-3 sockeye salmon and Asian pink salmon, and/or size-selective predation on smaller individuals during the second compared with the third year at sea. McKinnell (1995) examined sockeye salmon scale growth patterns and concluded that older salmon from northern British Columbia migrated farther and overlapped to a greater degree with Bristol Bay salmon compared with younger fish. Size-dependent mortality in the present study is supported by the observation that pink salmon had the greatest effect on the youngest sockeye salmon, leading to less differential SW2 scale growth during odd- and even-numbered years. In contrast to annual sockeye salmon scale growth, differential size of adult sockeye salmon was most apparent among the younger ocean age-2 compared with older ocean age-3 sockeye salmon because ocean age-3 sockeye salmon interact with both odd- and even-year pink salmon populations, whereas ocean age-2 sockeye salmon interact with only one pink salmon population.

Bristol Bay supports one of the most valuable salmon fisheries in the world. During smolt years 1977 to 1997 approximately 59 million fewer sockeye salmon returned to Bristol Bay from even-year compared with odd-year smolt migrations. This reduction represents approximately $310 million less to sockeye salmon fishermen, based on the average ex-vessel value of Bristol Bay sockeye salmon during 1980–99.

This study indicates that interspecific competition can occur among salmon species originating from different continents that feed in broad regions of the North Pacific Ocean and Bering Sea. Thus, salmon management actions taken in one region can affect species abundance in distant regions. These effects can have significant economic consequences for harvesters of impacted stocks, as indicated by Bristol Bay sockeye salmon, or they may potentially inhibit the recovery of salmon listed under the US Endangered Species Act. Salmon hatcheries have been a primary management tool for maintaining or supplementing salmon harvests in many regions of the North Pacific. Most Asian pink salmon are native, but significant hatchery production occurs in Russia (Sakhalin and Iturup islands) and Japan. During the 1990s, up to 1.6 billion juvenile pink salmon per year were released from hatcheries into the North Pacific Ocean, of which approximately 45% were from Asia (Mahnken *et al.*, 1998). All Bristol Bay sockeye salmon are native. Although the interactions between hatchery pink salmon and native populations of sockeye salmon in the open ocean remain unknown, our results may raise the controversial idea that hatchery salmon production should be allocated among countries (Joyner, 1975; Bigler *et al.*, 1996; Heard, 1998).

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Pink and Sockeye Salmon Interactions at Sea and Their Influence on Forecast Error of Bristol Bay Sockeye Salmon

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Abstract: Total sockeye abundance in Alaska tends to be positively correlated with North Pacific pink salmon abundance, leading to questions about the importance of competition at sea between these two species. We examined annual scale growth of Bristol Bay sockeye salmon at sea and quantified forecast error of Bristol Bay sockeye stocks over the past 40 years to test the hypothesis that competition with pink salmon reduces the growth and survival of sockeye salmon. Sockeye growth during the second and third years at sea exhibited a strong alternating-year pattern and was negatively correlated with pink salmon abundance from eastern Kamchatka and central Alaska. In addition, forecast error of sockeye stocks from southeastern Bristol Bay (Kvichak, Naknek, Egegik, and Ugashik) exhibited an alternating-year pattern suggesting competition with pink salmon also affected survival. After standardizing forecast error relative to adjacent years, forecasts in even-years were too high and forecasts in odd-years were too low, likely reflecting competition with pink salmon during the year prior to the return year. Sockeye salmon from northwestern Bristol Bay (Wood River) exhibited weaker growth and forecast error relationships with pink salmon abundance, which is consistent with their more easterly distribution at sea. Sockeye scale growth during the first year at sea was not related to pink salmon abundance, as expected, and the observed greater growth during this early marine period in recent decades likely contributed to the greater abundance of Bristol Bay salmon. These findings highlight sockeye growth and survival dynamics that cannot be explained by physical oceanographic patterns and support the hypothesis that competition with pink salmon adversely affects the growth and survival of Bristol Bay sockeye salmon.

Keywords: Bristol Bay, Fraser River, sockeye, pink salmon, forecast, competition, food web, density dependence

INTRODUCTION

To evaluate whether declines in Fraser River sockeye salmon survival occurred across a broader area than the Fraser watershed, Peterman and Dorner (2012) examined the productivity of 64 sockeye salmon populations spanning 17 regions from Puget Sound, Washington, to western Alaska. Sockeye spanning a large multi-regional area, from Puget Sound through British Columbia and into Southeast Alaska, were characterized by declining productivity since the early 1980s. In contrast, the productivity of sockeye populations in central and western Alaska was either stable or increasing over time. Peterman and Dorner (2012) concluded that future research into the factors driving broad-scale variability in sockeye dynamics should focus on mechanisms that operate at large, multi-regional spatial scales encompassing the two regions of correlated sockeye productivity patterns.

Competition at sea with increasingly abundant pink salmon is one possible large-scale process that could contribute to the pattern described above. Ruggerone and Connors (2015) tested the hypothesis that competition at sea with pink salmon contributed to declines in productivity among the 36 sockeye populations spanning the large southern area identified by Peterman and Dorner

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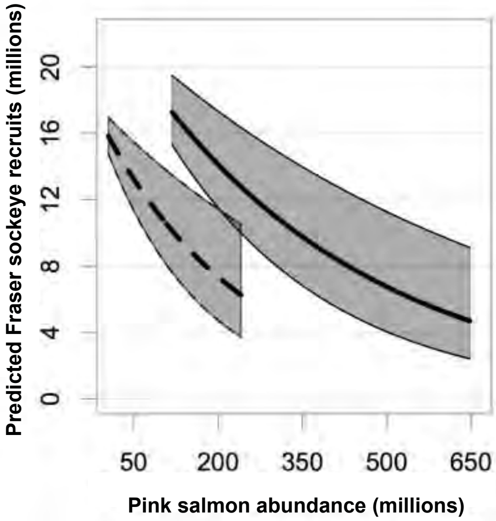

Fig. 1. Predicted Fraser River adult sockeye recruits (± 2 SE) as a function of pink salmon abundance returning to North America (dashed line) or to both North America and Asia (bold line). Other variables in the model, such as sockeye spawning abundances and sea surface temperature, were held at mean values. See Ruggerone and Connors (2015) for modeling methods and results.

(2012). They found that sockeye productivity was negatively correlated with the combined abundance of pink salmon from Asia and North America as well as the abundance of pink salmon from only North America. Also, sockeye length-at-age was negatively correlated with pink salmon abundance, whereas sockeye age-at-maturity was positively correlated with pink salmon abundance. Evidence supported the hypothesis that the interaction primarily occurred during the second year at sea rather than the first year at sea (but see McKinnell and Reichardt 2012). Furthermore, sockeye productivity, growth, and maturation exhibited alternating-year patterns consistent with the hypothesis that increasing pink salmon abundance leads to increased competition for food. Statistical modeling predicted that an increase in North Pacific pink salmon abundance from 200 to 400 million fish resulted in a 39% decline in the recruitment of Fraser River sockeye salmon. The investigators did not provide a prediction for the effect of North American pink salmon on Fraser sockeye salmon. However, using modeling results from the original investigation, a 50 to 250 million increase in pink salmon abundance from North America only is predicted to result in a 56% decline in Fraser sockeye recruitment. This suggests that the per capita effect of North American pink salmon was approximately 1.4x greater than that of pink salmon from both Asia and North America (Fig. 1). Most hatchery pink salmon are produced in Alaska, and approximately 50 million adult pink salmon returned to hatcheries in North America each year from 2000 to 2010 (primarily Prince William Sound and Kodiak; Ruggerone and Irvine 2015). The predicted decline in Fraser sockeye recruitment from an increase of 50 million pink salmon (150 to 200 million) salmon was 18% (or 1.83 million sockeye salmon), assuming an equal effect of pink salmon from each region of North America.

In contrast with sockeye populations in the southern half of their range, Peterman and Dorner (2012) showed that sockeye productivity in western and central Alaska was either stable or increasing. The overall abundance of these stocks tended to be positively correlated with the abundance of North Pacific pink salmon (Ruggerone et al. 2010), which begs the question: how can sockeye abundance in western and central Alaska be positively correlated with pink salmon when sockeye abundance in southern areas is negatively correlated with pink salmon abundance? First, it has been hypothesized that high abundance and survival of salmon in general is largely due to favorable early marine conditions (e.g., Mueter et al. 2002; Beamish et al. 2004; Farley et al. 2007; Stachura et al. 2014). In support of this hypothesis, sockeye abundance in Alaska (all regions combined) was positively correlated with growth of Bristol Bay (Bering Sea) and Chignik (Alaska Peninsula; Gulf of Alaska) sockeye salmon during their first and second years at sea (Ruggerone et al. 2007). Likewise, survival of pink salmon was linked to favorable growth during early marine life (Moss et al. 2005). This evidence suggests that favorable ocean conditions during early marine life enhanced survival and consequently adult abundances of both sockeye and pink salmon. Second, research also indicated that Asian pink salmon affect the growth and survival of Bristol Bay sockeye salmon in western Alaska during their second and third years at sea, but not during the first year at sea (Fig. 2; Ruggerone et al. 2003, 2005; Ruggerone and Nielsen 2004). Therefore, for northern sockeye populations such as those in Bristol Bay, the evidence suggests that both early marine conditions and competition between pink and sockeye salmon in the 2nd and 3rd years at sea influenced marine survival and adult sockeye salmon abundances. In contrast, declining sockeye salmon productivity in the southern area over the past two decades may be related to both unfavorable ocean conditions during early marine life (Rensel et al. 2010; Beamish et al. 2012; Thomson et al. 2012; McKinnell et al. 2014), and competition with abundant pink salmon beginning in the second year at sea (Ruggerone and Connors 2015), perhaps compounded by changing ocean productivity (Nielsen and Ruggerone 2009; Irvine and Akenhead 2013).

The goal of this paper is to further evaluate the evidence for competition between Bristol Bay sockeye salmon and pink salmon originating from Russia and central Alaska. Our objectives involve the testing of four hypotheses: (1) scale growth of Bristol Bay sockeye salmon stocks exhibit alternating-year patterns consistent with patterns of competition with pink salmon, (2) scale growth of Bristol Bay sockeye stocks during the second and third years at sea, but not the first, are negatively correlated with the abundance of pink salmon, (3) forecast error of Bristol Bay sockeye salmon is related to the alternating-year pattern of pink salmon abundance, and (4) evidence for hypotheses 1–3 is strongest for sockeye salmon having the greatest geographic overlap with pink salmon stocks that exhibit strong alternating-year patterns of abundance. Distribution at sea of sockeye salmon from northwestern Bristol Bay (e.g., Wood River; Fig. 3) is east of stocks originating in southwestern Bristol Bay (e.g., Kvichak, Naknek, Egegik, Ugashik) (Rogers 1988; Habicht et al. 2010). This results in less overlap with Russian pink salmon that exhibit strong alternating-year patterns of abundance, such as those from eastern Kamchatka.

MATERIALS AND METHODS

Sockeye Scale Measurements and Analyses

Scales collected from adult sockeye salmon that returned to the river to spawn were used to characterize annual growth during the first, second, and third years at sea from 1965 to 2009. Scales were measured from four southeastern Bristol Bay sockeye stocks: Kvichak, Naknek, Egegik, and Ugashik, and one northwestern Bristol Bay stock: Wood River (Fig. 3). The goal was to measure 50 scales (equal male and female salmon) from each of the

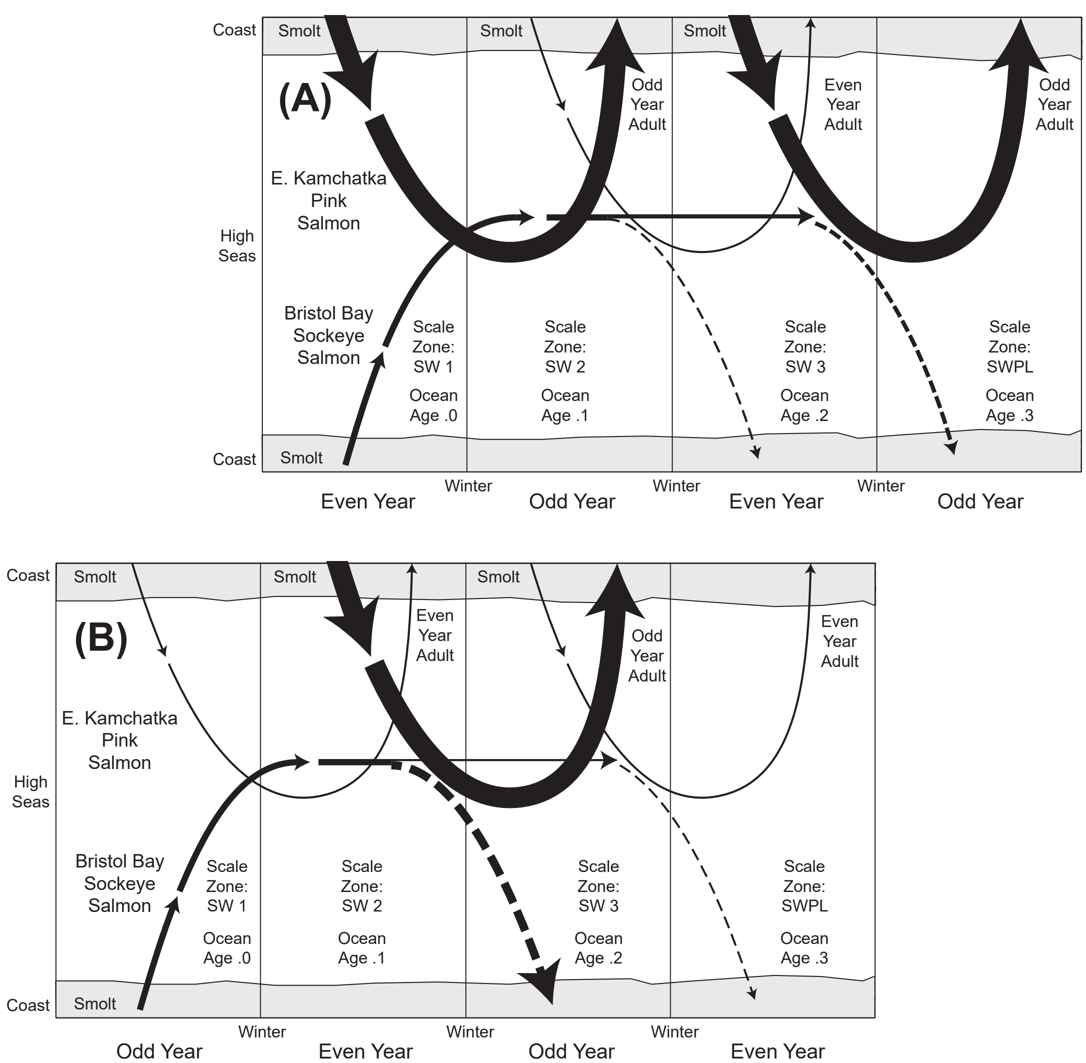

Fig. 2. Diagram of temporal overlap between Asian pink salmon and Bristol Bay sockeye salmon based on seasonal scale growth patterns (Ruggerone et al. 2005). (A) Sockeye salmon smolts entering the ocean during even-numbered years first encounter abundant odd-year pink salmon (bold solid line) during the first winter at sea and the second growing season, i.e., primarily during SW2, leading to reduced growth and abundance of maturing age-x.2 sockeye salmon in even-numbered return years (thin dashed line). (B) Sockeye salmon smolts entering the ocean during odd-numbered years do not encounter abundant odd-year pink salmon until their second winter at sea and the third growing season, i.e., during SW3, leading to relatively greater growth and abundance of maturing age-x.2 sockeye salmon in odd-numbered return years (bold dashed line). Odd-even abundance patterns of age-x.3 sockeye salmon are less distinct, as described in the text and Fig. 9. Sockeye scale growth (SWPL zone) indicates little interaction between Asian pink salmon and maturing sockeye salmon presumably because maturing sockeye salmon are distributed farther north during fall, winter, and spring compared with immature sockeye salmon (French et al. 1976). Period of overlap between pink and immature sockeye salmon is from approximately winter through July, but the effect of interaction may continue until prey populations recover. Redrawn from Ruggerone et al. (2003).

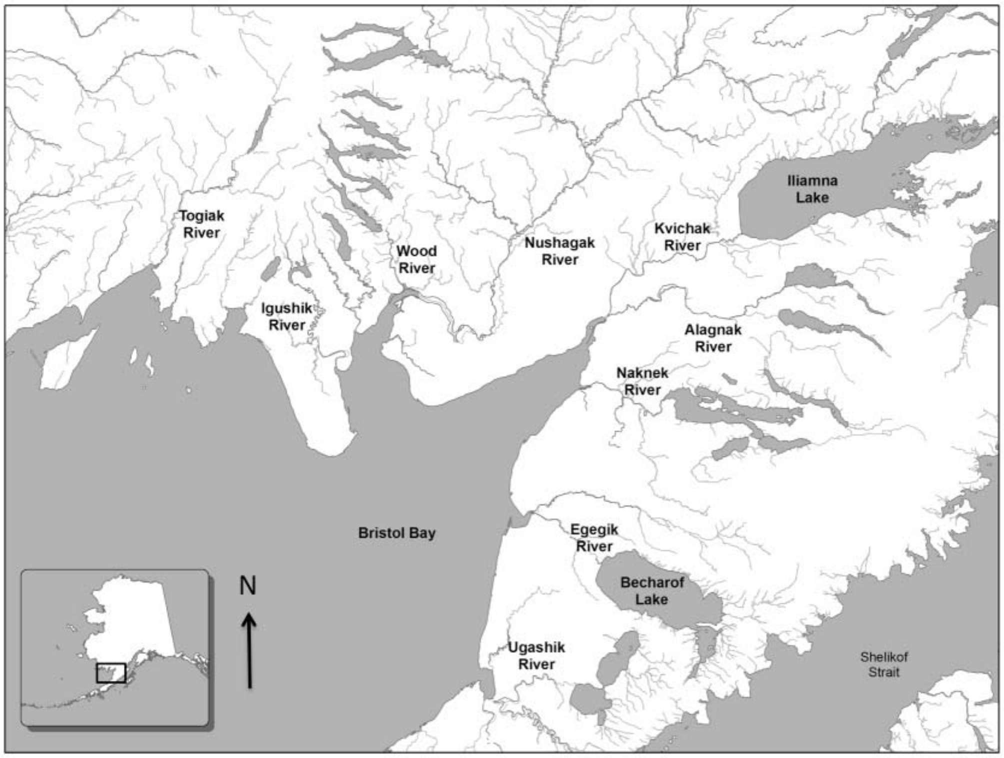

Fig. 3. Map of Bristol Bay and the eight sockeye salmon stocks considered in this investigation. Southeastern stocks include Naknek, Kvichak, Egegik, and Ugashik. Northwestern stocks include Wood River and smaller stocks (Nushagak, Igushik, and Togiak) not individually considered here.

four dominant age groups (1.2, 2.2, 1.3, 2.3), where the first digit represents the number of winters in fresh water and the second digit represents the number of winters at sea. Thus, up to 200 scales were measured per year per stock, and up to 1,000 scales were measured per year for all stocks combined.

Scale measurements were made by the Alaska Department of Fish and Game (ADF&G) Mark, Tag, and Age Lab following procedures described in Hagen et al. (2001) and Ruggerone et al. (2007). Scales were selected for measurement only when: (1) we agreed with the age determination previously made by ADF&G; (2) the scale shape indicated that the scale was removed from the "preferred area" (Koo 1962); and (3) circuli and annuli were clearly defined and not affected by scale regeneration or significant resorption along the measurement axis. The scale measurement axis was determined by a perpendicular line drawn from a line intersecting each end of the first saltwater annulus. Scale measurements included both circuli and annuli measurements within each growth zone in fresh water and the ocean but only annual growth during each of two or three years at sea are reported. Overall, 32,957 sockeye scales were measured. A few age groups in a given year contained fewer than 10 scales and were excluded from the analyses. Sufficient high quality scales were not available for Egegik age-1.2 and Ugashik age-2.3 sockeye salmon because these age groups were relatively rare for these stocks.

Median annual scale growth at sea was calculated for each year and stock and then normalized to the mean of the southeastern Bristol Bay sockeye salmon stocks, 1965–2009, to facilitate comparison of Wood River and southeastern Bristol Bay sockeye scale growth. A Model II two-factor ANOVA (factors: odd/even year, stock) was used to test for scale growth differences related to these factors during each year at sea. A Model II ANOVA was used to reduce degrees of freedom in the F-statistic and the likelihood of rejecting the null hypothesis as a result of large sample size (Zar 1996). Autocorrelation in annual median scale growth was quantified to test whether there was an alternating year pattern that was consistent with autocorrelation in pink salmon abundance. Only lag 1 and lag 2 partial autocorrelation was presented because the strength of autocorrelation declined rapidly after lag 2. Partial autocorrelation was shown at lag 2 because it describes autocorrelation after accounting for lag 1 autocorrelation. Ordinary least squares linear regression was used to test whether median annual scale growth was negatively correlated with pink salmon abundance after the dependent and independent values were detrended to remove linear time trends. Diagnostic tests, including serial autocorrelation of model residuals and plots of residuals on predicted values, were conducted to evaluate model assumptions. Analysis of covariance was used to test whether the relationships between annual median sockeye growth and pink salmon abundance were of a similar magnitude and direction between the Wood River and southeastern Bristol Bay sockeye salmon stocks. This test helped to evaluate whether Wood River sockeye, which are distributed farther east in the North Pacific Ocean, might exhibit less competition with Asian pink salmon.

Salmon Stock Data

Annual numerical abundances of adult pink salmon by region of the North Pacific were available from Ruggerone and Irvine (2015). The abundance of pink salmon from the eastern Kamchatka region was used as the primary index of potential pink salmon competitors with Bristol Bay sockeye salmon because the eastern Kamchatka stock is very large and appears to have the greatest degree of overlap with Bristol Bay sockeye salmon among large Asian and North American stocks (Takagi et al. 1981; Myers et al. 1996). Additionally, we compared sockeye growth with the combined abundances of pink salmon from central Alaska (southern Alaska Peninsula, Kodiak, Cook Inlet, Prince William Sound) and Eastern Kamchatka because the distribution of Bristol Bay sockeye salmon also overlaps these North American stocks to some extent.

Forecast Error of Bristol Bay Sockeye Salmon

Pre-season forecasts of sockeye salmon abundance (catch plus spawning escapement) as estimated by the ADF&G were tabulated by dominant age group and watershed from 1968 to 2010 (e.g., Pennoyer 1970; Baker et al. 2009). Dominant age groups included age-1.2, age-2.2, age-1.3, and age-2.3 salmon. Age-specific abundances of adult sockeye salmon returning to each watershed in Bristol Bay were provided by the ADF&G (T. Baker, tim.baker@alaska.gov, pers. comm.). These adult return data included estimates of Bristol Bay sockeye salmon harvested outside of the Bristol Bay management area. Forecast error (e) was calculated as:

$$e_{i,t} = \hat{R}_{i,t} - R_{i,t}, \tag{1}$$

where $\hat{R}$ is the forecasted run size (i.e., pre-fisher abudance), R is the observed run size and e is the forecast error for stock i in year t. We also calculated forecast error relative to error during the previous and following years as a means to examine whether there was an alternating-year pattern of forecast error:

$$Relative\ e_{i,t} = e_{i,t} - \left(\frac{e_{i,t-1} + e_{i,t+1}}{2}\right), \tag{2}$$

where relative error for population i in year t is the forecast error minus the average of the forecast error in the preceding and following year. This approach removed the autocorrelation associated with forecast error that stemmed in part from under-forecasting of sockeye runs following the ocean regime shift in the mid-1970s (Ruggerone and Baker 2011).

RESULTS

Alternating-year Patterns in Sockeye Growth

Second (two factor ANOVA: df = 1, 4; F = 355; P < 0.001) and third year (df = 1, 4; F = 657; P < 0.001) scale growth of sockeye salmon was significantly less during odd-numbered years, but there was no evidence of a difference in growth between odd- and even-years during the first year at sea (Fig. 4, df = 1, 4; F = 1.99; P > 0.05). This pattern supported the hypothesis that maturing pink salmon, which are most abundant in odd-numbered years, compete with sockeye salmon for food.

Growth varied by sockeye salmon stock during each year at sea (Fig. 4; df = 1, 4; $F \geq 22.6$; P < 0.02). During the first year at sea, Wood River sockeye growth was significantly less than each of the four southeastern stocks

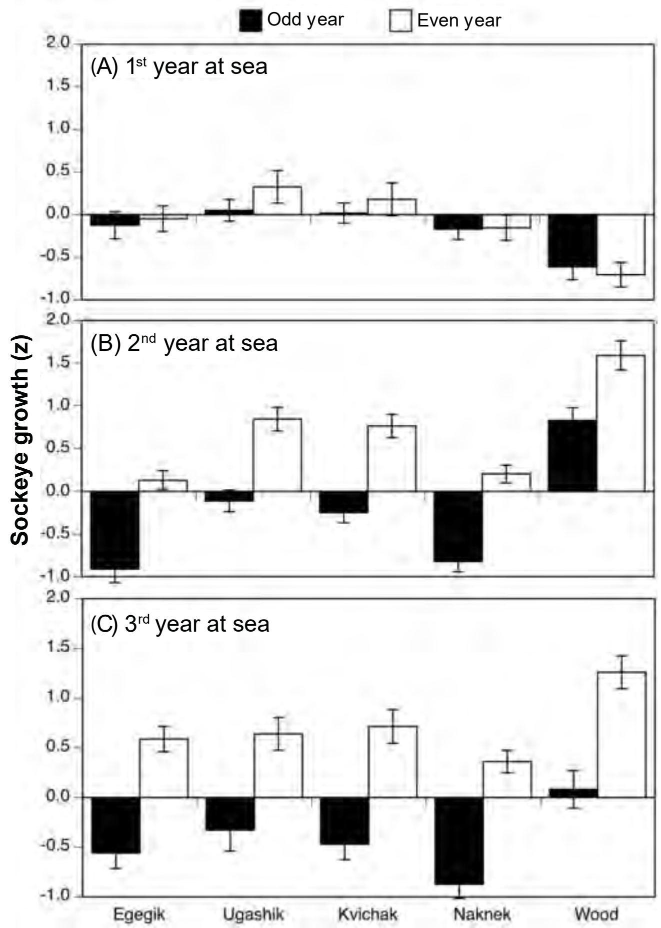

Fig. 4. Comparison of mean (± 1 SE) of annual median scale growth of sockeye salmon originating from each of five watersheds in Bristol Bay, Alaska, during odd- versus even-numbered years of the first (A), second (B), and third years (C) in the ocean. Scale growth values were normalized to mean growth of the southeastern stocks (Egegik, Ugashik, Kvichak, and Naknek) to facilitate comparison with Wood River sockeye growth, 1965–2009.

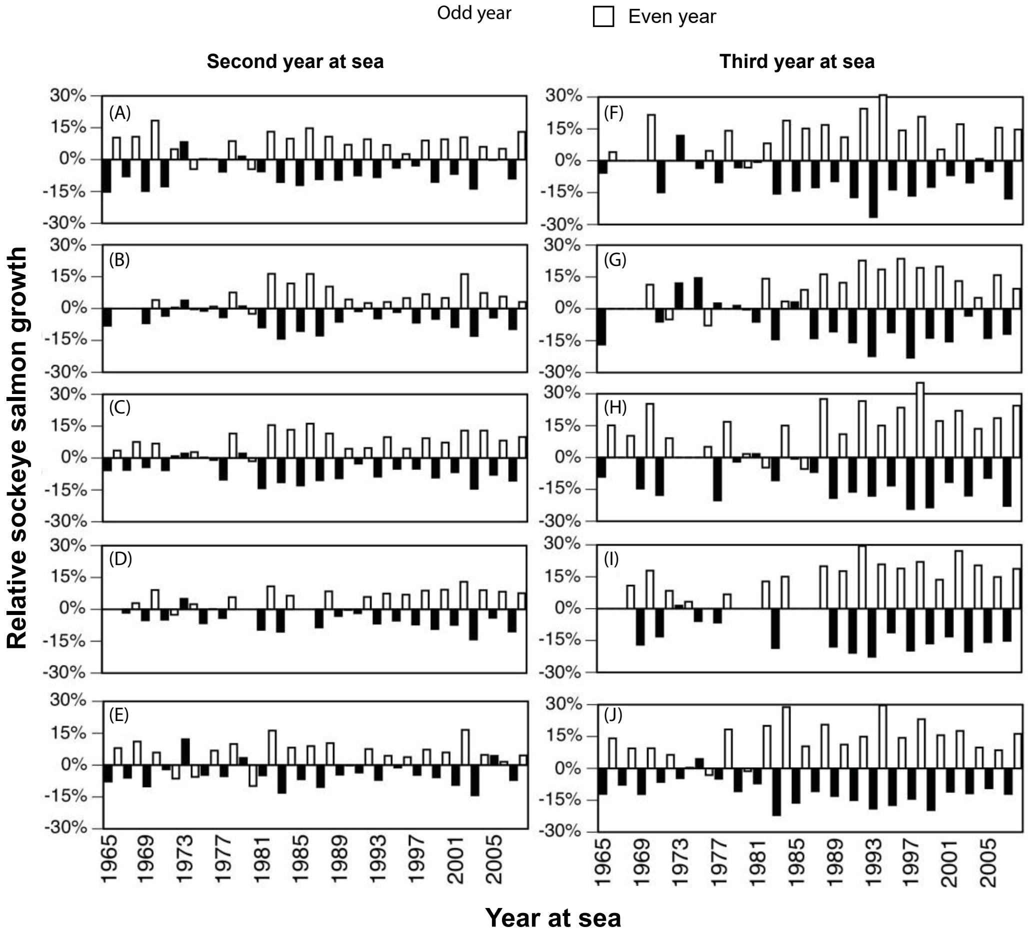

Fig. 5. Annual mean scale growth of sockeye salmon during each year at sea as a percentage of mean growth during the previous and following years at sea, 1965–2008: Egegik (A, F), Ugashik (B, G), Kvichak (C, H), Naknek (D, I), and Wood River (E, J). Growth during odd-numbered years is shown in black bars and growth in even-numbered years is shown in white bars to highlight the pattern of higher than average growth in even versus odd years.

($P < 0.01$). However, during the second and third year at sea, growth of Wood River sockeye salmon was significantly greater than each of the four southeastern stocks ($P < 0.005$). The interaction term (stock x odd-even year) was non-significant for growth during each year at sea ($P > 0.05$), indicating the odd-even pattern was consistent among the five stocks.

Lower scale growth during odd-numbered years compared with adjacent even-numbered years was observed in nearly all years for each of the five Bristol Bay sockeye stocks from 1965 to 2008 (Fig. 5). Odd-year growth during the second year at sea averaged 6.2% ± 0.2% (SE) less than adjacent even-year growth. During the third year at sea, odd-year growth averaged 10% ± 0.4% less than adjacent even-year growth. In odd-numbered years, annual growth was up to 15% or 24% less than growth in adjacent even-number years for second and third years at sea, respectively. For all stocks, the alternating-year pattern of sockeye growth was somewhat less consistent during the 1970s compared with subsequent years (Fig. 5).

Partial Autocorrelation of Pink Salmon Abundance and Sockeye Growth

Autocorrelation of eastern Kamchatka pink salmon abundance during 1965 to 2009 was negative at lag 1 ($r = -0.4$, $P < 0.01$) and partial autocorrelation was positive at lag 2 ($r = 0.5$, $P < 0.01$), reflecting the alternating-year abundance pattern of this major pink salmon stock (Fig. 6). Pink salmon abundance was relatively high during odd-numbered years and low during even-numbered years at sea, resulting in the negative autocorrelation at lag 1 and positive partial autocorrelation at lag 2. The somewhat stronger partial autocorrelation at lag 2 than lag 1 presumably reflects the stronger effect of parent abundance than the potential negative interaction between broodlines of pink salmon. Partial autocorrelation of total pink salmon from central Alaska and eastern Kamchatka was positive at lag 2 ($P < 0.01$) but non-significant at lag 1 ($P > 0.05$).

Growth of each sockeye stock displayed consistent patterns of autocorrelation during the second and third years at sea, reflecting their alternating-year growth patterns (Fig. 6). Consistent with the hypothesis that competition with eastern

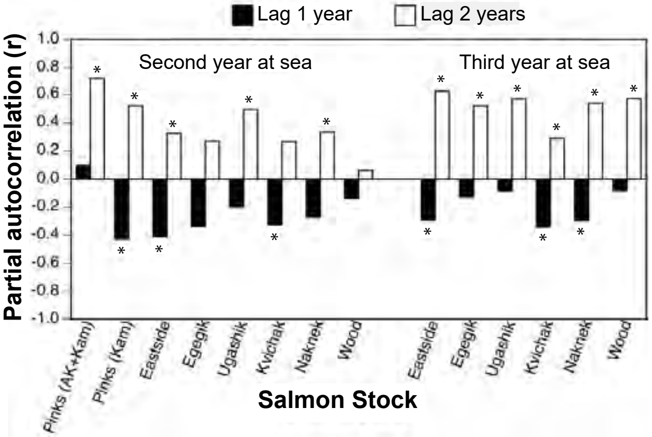

Fig. 6. Partial autocorrelation of median annual sockeye salmon scale growth at lags one-year and two-years during the second and third years at sea (1965–2009). Partial autocorrelation of pink salmon abundances from eastern Kamchatka (Kam) and from central Alaska plus eastern Kamchatka (AK+Kam) are shown for comparison. Partial autocorrelation and autocorrelation are identical at lag 1. Statistically significant values are identified (*$P < 0.05$).

Kamchatka pink salmon reduces sockeye growth, autocorrelation of sockeye growth was negative at lag 1 and partial autocorrelation was positive at lag 2. The magnitude of lag 2 partial autocorrelations was typically greater (avg. $r = 0.29$ to 0.52) than lag 1 autocorrelations (avg. $r = -0.28$ to -0.20) for sockeye in their second and third years at sea, respectively (Fig. 6). This pattern of larger magnitude lag 2 partial autocorrelation was also observed in eastern Kamchatka and central Alaska pink salmon, reflecting the fixed two-year life cycle of pink salmon. Growth of Wood River sockeye salmon exhibited less lag 1 and lag 2 partial autocorrelation ($P > 0.05$) than growth of each southeastern Bristol Bay stock during the second year at sea, but this difference was less apparent during the third year at sea.

In contrast to these patterns, growth of each sockeye stock during the first year at sea displayed positive autocorrelation at lag 1 ($P < 0.05$), and none of five stocks exhibited significant partial autocorrelation at lag 2 ($P > 0.05$). Thus, growth during the first year at sea did not reflect potential interaction with pink salmon, as expected (Fig. 4A). Instead, the positive serial autocorrelation reflected increased early marine growth over time, especially after the mid-1970s (Ruggerone et al. 2007).

Negative Correlation of Sockeye Growth and Pink Salmon Abundance

Detrended median annual scale growth of southeastern sockeye salmon stocks during the second and third years at sea was negatively correlated with the abundance of eastern Kamchatka pink salmon during 1965 to 2008 ($P < 0.001$). Approximately 33% and 58% of the annual variability in southeastern Bristol Bay salmon scale growth was explained by pink salmon abundance during the second and third years at sea, respectively (Fig. 7). Likewise, median annual

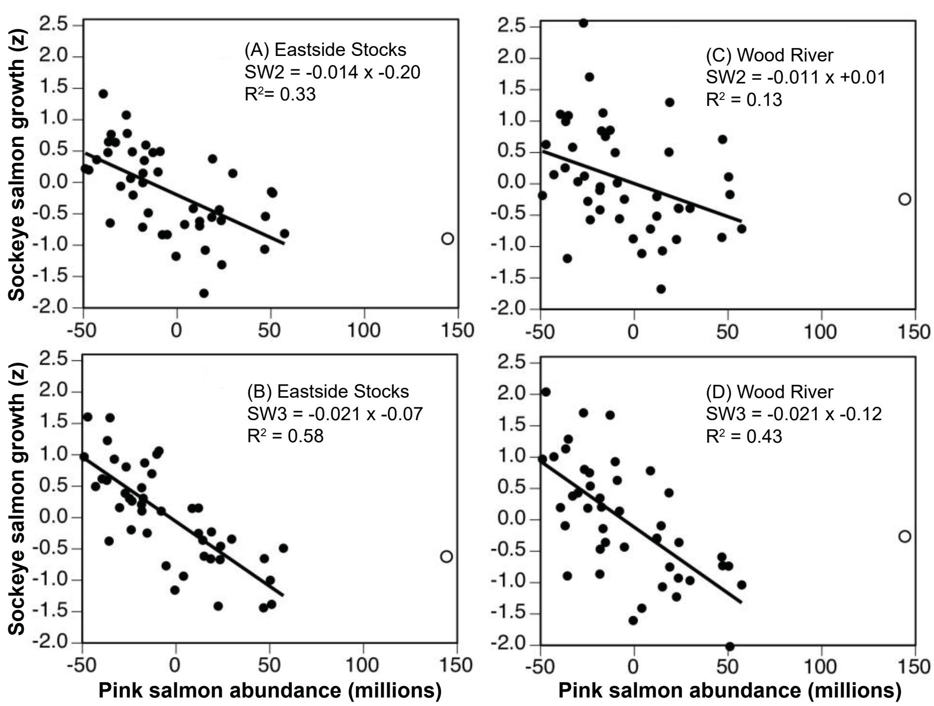

Fig. 7. Linear regression of median annual detrended, normalized growth in the 2nd (A, C) and 3rd (B, D) year at sea for southeastern Bristol Bay stocks (A, B) and Wood River sockeye salmon (C, D) in relation to detrended eastern Kamchatka pink salmon abundance, 1965–2008. Values in 2009 are shown (open circle) but not included in the regression because pink salmon abundance was exceptional. Average pink salmon abundance during 1965-2009 was 43 million fish.

growth of Wood River sockeye salmon stocks during the second and third years at sea was negatively correlated with the abundance of eastern Kamchatka pink salmon during 1965 to 2008 (SW2: $P < 0.016$; SW3: $P < 0.001$). Approximately 13% and 43% of the annual variability in Wood River scale growth was explained by pink salmon abundance during the second and third years at sea, respectively (Fig. 7). Serial autocorrelation of the model residuals was non-significant for all stocks and ocean ages ($P > 0.05$). Examination of model residuals plotted on predicted values did not reveal patterns, indicating no need for data transformations or alternative models. Analysis of covariance indicated that the detrended southeastern and Wood River regressions on eastern Kamchatka pink salmon were coincident for ocean ages -2 and -3; there was no statistical difference in the slopes or intercepts (Fig. 7, $P > 0.05$). Regressions performed using raw rather than detrended scale growth and pink salmon abundance led to the same findings: sockeye growth declined with increasing abundance of pink salmon ($P < 0.05$) and serial autocorrelation of the model residuals was non-significant ($P > 0.05$). Analysis of covariance using raw data also indicated that the slopes of the southeastern and Wood River regressions were coincident ($P > 0.05$), but growth of Wood River sockeye salmon was greater than growth of southeastern Bristol Bay stocks at each abundance level of eastern Kamchatka pink salmon during the second and third years at sea ($P < 0.001$). The finding of greater growth of Wood River sockeye salmon is consistent with the ANOVA presented above (Fig. 4).

Scale growth of Bristol Bay sockeye salmon was also compared with the combined abundances of pink salmon returning to central Alaska and eastern Kamchatka. During the second year at sea, detrended scale growth of southeastern Bristol Bay ($R^2 = 0.18$) and Wood River ($R^2 = 0.12$) sockeye salmon were negatively correlated with detrended abundance of central Alaska and eastern Kamchatka pink salmon ($P < 0.05$). During the third year at sea, the negative correlations ($P < 0.001$) were stronger for both southeastern Bristol Bay ($R^2 = 0.48$) and Wood River sockeye salmon ($R^2 = 0.37$).

Forecast Error of Bristol Bay Sockeye Salmon

Forecast error of southeastern Bristol Bay sockeye salmon (Kvichak, Naknek, Egegik, and Ugashik stocks) relative to adjacent years was positive during even-numbered years (avg. 6.1 million fish per year), and negative during odd-numbered years (avg. -6.3 million fish per year), 1968–2010 (Fig. 8). A positive forecast error occurs when the pre-season forecast is too high relative to the observed run. After standardizing forecast error relative to adjacent years, forecasts in even-numbered years were too high in 86% of the years, whereas forecasts in odd-numbered years were too low in 81% of the years. This finding is consistent with the observation that abundant odd-year pink salmon compete with sockeye salmon during the year prior to their return to Bristol Bay (Fig. 2). In other words, high positive forecast error in even-year runs reflects potential competition with abundant pink salmon in the previous odd-numbered year. In even-numbered years, forecasts of southeastern Bristol Bay sockeye salmon tended to be too high.

Relative forecast error of northwestern Bristol Bay sockeye salmon (Wood River, Nushagak, Igushik, and Togiak stocks combined) was positive during even-years (avg. 0.48 million fish per year) and negative during odd-years (avg. -0.48 million fish per year), but this pattern was not as consistent nor as strong as it was for the southeastern stocks (Fig. 8). After standardizing forecast error relative to adjacent years, forecasts in even-numbered years exceeded zero in 64% of the years, whereas forecasts in odd-numbered years were below zero in 62% of the years.

The alternating-year pattern in forecast error was not consistent among ocean age-2 and -3 sockeye salmon. For all stocks combined, relative forecast error of ocean age-2 sockeye salmon was 1.9–3.0 million (± 1.2 million) fish too high in even-numbered years (Fig. 9), or approximately 30% too high, on average. In contrast, relative forecast error in even-numbered years of ocean age-3 sockeye salmon was only 0.5–1.2 million (± 0.8 million) fish too high, or 13% too high. The lower relative forecast error of ocean age-3 sockeye salmon likely reflected their interaction with

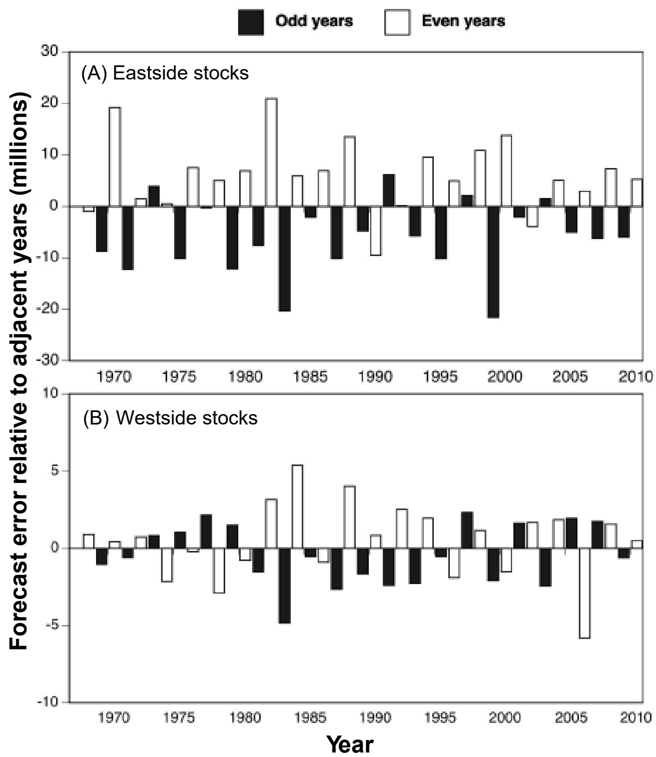

Fig. 8. Annual relative forecast error of southeastern (A) and northwestern (B) Bristol Bay sockeye salmon abundance (millions of fish) relative to mean error in the previous and following years. Northwestern stocks include Wood River and the smaller stocks shown in Fig. 2. Positive values indicate that the pre-season forecast was larger than the observed abundance.

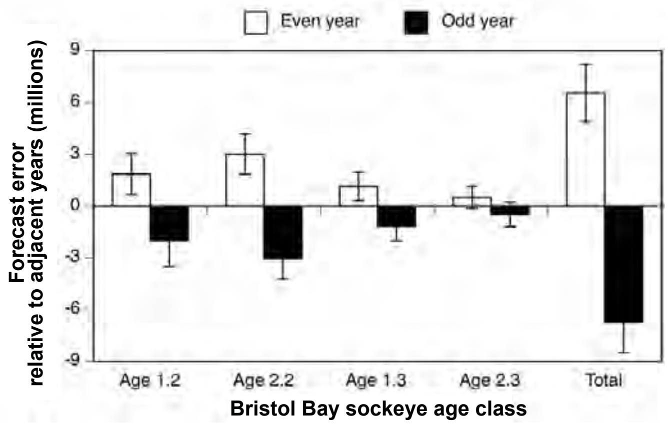

Fig. 9. Mean forecast error (± 1 SE) of Bristol Bay sockeye salmon abundance by age group (millions of fish) relative to mean error in the previous and following years.

pink salmon during both even- and odd-numbered years; ocean age-2 sockeye salmon only interact with pink salmon during their second year at sea, based on scale growth measurements (Fig. 2; Ruggerone et al. 2005).

DISCUSSION

Sockeye Growth

Growth of all five major Bristol Bay sockeye salmon stocks during the second and third years at sea exhibited a strong alternating-year pattern that is consistent with the hypothesis that sockeye salmon compete with abundant pink salmon for food on the high seas. From 1965 to 2009, sockeye growth at sea was low during odd-numbered years when pink salmon abundance was high (Irvine et al. 2014), whereas sockeye growth was high in even-numbered years when pink salmon abundance was low. Evidence for competition was further supported by the significant positive partial autocorrelation at lag two-years of eastern Kamchatka and central Alaska pink salmon abundance and scale growth of all five sockeye stocks during the third year at sea and three of five stocks during the second year at sea. Autocorrelation of pink salmon abundance and sockeye growth was stronger at lag two-years compared with lag one-year, as expected because pink salmon have a fixed two-year life cycle. Both the lag one-year autocorrelation of eastern Kamchatka pink abundance and the lag one-year autocorrelation of sockeye growth were negative, as predicted by the competition hypothesis. Lastly, detrended scale growth of Bristol Bay sockeye salmon was negatively correlated with the detrended abundances of pink salmon originating from eastern Kamchatka and from central Alaska/eastern Kamchatka during the 44-year period. The natural experimental control provided by the alternating-year abundance pattern of pink salmon, the negative correlation between sockeye growth and pink salmon abundance, the high diet overlap of the two species (Davis et al. 2005), and the observed 36% reduction in sockeye stomach fullness during odd-numbered years at sea (Davis 2003) provide strong support for the competition hypothesis.

Sockeye Salmon Forecast Error

Salmon forecasts in Alaska contribute to pre-season and early-season management of the fisheries and to pre-season planning by the salmon industry (Munro 2015). Salmon forecasts do not consider potential effects of pink salmon on the abundance of other salmon species. However, we found that the forecast error of Bristol Bay sockeye salmon from 1968 to 2010, especially those from southeastern Bristol Bay, exhibited an alternating-year pattern that is consistent with the growth of sockeye salmon in relation to competition with pink salmon. The forecast error pattern is also consistent with the alternating-year pattern observed in sockeye smolt-to-adult survival and adult returns from smolt migrations (Ruggerone et al. 2003). The forecast error pattern largely stems from interactions with pink salmon during the previous full year at sea rather than the year of return because relatively few pink salmon inhabit the southeastern Bering Sea (Ruggerone et al. 2010) and because sockeye scale growth during the homeward migration period did not reveal an alternating-year pattern (Ruggerone et al. 2005). Therefore, during even-numbered years of sockeye return, Bristol Bay sockeye interacted with abundant odd-year pink salmon during the previous year; whereas, during odd-numbered years of return, sockeye interacted with relatively few pink salmon. Sockeye forecasts tended to be too high in even-numbered return years and too low in odd-numbered return years. For example, in 2015, the pre-season inshore Bristol Bay sockeye forecast was exceptionally large—approximately 52 million sockeye salmon—yet the observed run was even larger (58 million fish; ADF&G 2015). This single observation is consistent with the findings presented here and with the dramatic decline in the abundance of eastern Kamchatka pink salmon beginning in 2013 (Klovach et al. 2014, 2015).

The strength of the alternating-year forecast error pattern varied with ocean age of sockeye salmon. The pattern was relatively weak for ocean age-3 sockeye and strong for ocean age-2 sockeye salmon. This pattern reflects interaction with both even- and odd-year abundances of pink salmon by ocean age-3 sockeye and interaction with only even- or odd-year pink salmon by ocean age-2 sockeye salmon (Fig. 2). The somewhat lower than expected return of ocean age-3 sockeye salmon in even-numbered years likely reflects the complex effects of growth at sea on both maturation and survival. For example, Bristol Bay and Fraser River sockeye salmon delayed maturation when encountering numerous pink salmon during their second year at sea of odd-numbered years (Ruggerone and Baker 2011; Ruggerone and Connors 2015).

Southeastern versus Northwestern Sockeye Patterns in Relation to Pink Salmon

Studies of Bristol Bay sockeye migration and distribution at sea, including genetic stock identification analyses, indicate that northwestern stocks are distributed farther east in the ocean than southeastern stocks (Rogers 1988; Habicht et al. 2010; Seeb et al. 2011), suggesting that northwestern stocks overlapped less with Asian pink salmon, including eastern Kamchatka pink salmon. For example, based on the protracted smolt emigration through a series of five nursery lakes, the average timing of Wood River smolts at the outer boundary of Bristol Bay was estimated to be 10 weeks behind that of Egegik and Ugashik sockeye salmon (Rogers 1988).

Our findings support the hypothesis that Wood River sockeye salmon, a large northwestern Bristol Bay stock, interact less with Asian pink salmon than the southeastern sockeye stocks. During the first year at sea, Wood River scale growth was significantly less than that of southeastern sockeye stocks, reflecting the protracted entry of Wood River smolts into the Bering Sea and less time to grow in the ocean. However, during the second and third years at sea, scale growth of Wood River sockeye salmon was greater than that for southeastern sockeye stocks, presumably reflecting a more easterly marine distribution compared with southeastern sockeye stocks (Habicht et al. 2010) and so reduced overlap with abundant Asian pink salmon. Greater growth during the second and third years at sea may reflect less competition of northwestern stocks with Asian pink salmon, as also suggested by weaker autocorrelation of scale growth and weaker forecast error in relation to pink salmon. Although Asian pink salmon may have less effect on Wood River sockeye salmon than on southeastern stocks, all sockeye stocks exhibited negative relationships with pink salmon abundance, including pink salmon from central Alaska. However, we found no evidence that Wood River sockeye salmon were more strongly influenced by pink salmon from central Alaska. Correlations between sockeye growth and the combined abundances of pink salmon from eastern Kamchatka and central Alaska tended to be weaker than those involving only eastern Kamchatka pink salmon.

Pink Salmon Effects and Prey Life History

The life history of key prey shared by pink and sockeye salmon likely contributes to the strong alternating-year patterns shown in this and other studies (Ruggerone and Connors 2015). Pink salmon appear to influence the standing crop of macrozooplankton and create an alternating-year pattern in their biomass (Shiomoto et al. 1997; Sugimoto and Tadokoro 1997). These macrozooplankton are also consumed by sockeye salmon. Squid, such as *Berryteuthis anonychus*, are an exceptionally important prey of both pink and sockeye salmon in some regions, and squid abundance in pink and sockeye diets is reduced in odd-numbered years when pink salmon are abundant (Kaeriyama et al. 2004; Davis et al. 2003, 2005; Aydin et al. 2005). These squid (*B. anonychus*) exhibit a two-year life cycle and so it has been hypothesized that predation by pink salmon may be a key factor controlling squid abundance (Arkhipkin et al. 1996; Jorgensen 2011). Predation by pink salmon on prey with biennial life histories (Tsuda et al. 2004) may enhance the alternating-year pattern of prey abundance, leading to the alternating-year pattern of sockeye salmon growth, productivity, and age-at-maturation.

Sockeye scale growth analyses indicated that the effect of pink salmon on sockeye growth was greater during their third compared with second year at sea. This finding may reflect more intense predation on higher trophic level prey, such as squid that exhibit a biennial pattern, compared with zooplankton that are consumed more frequently by smaller salmon (Davis 2003). Greater growth-related mortality of sockeye salmon during the second compared with third year at sea may also contribute to the observed pattern (Ruggerone et al. 2007).

CONCLUSION

The growth and forecast error analyses presented here are consistent with, and build upon, previous investigations into competition between Bristol Bay sockeye stocks and pink salmon at sea (Ruggerone et al. 2003; Nielsen and Ruggerone 2009). They are also consistent with an investigation of Russian sockeye growth in relation to pink salmon abundance (Bugaev et al. 2001), and recent analyses of 36 sockeye populations ranging from Puget Sound through British Columbia and into Southeast Alaska (Ruggerone and Connors 2015). Collectively, these studies support the hypothesis that pink and sockeye salmon compete for food on the high seas, leading to reduced growth, survival, and abundance of sockeye salmon, and increased age-at-maturity. In Alaska, favorable marine conditions since the mid-1970s, as indicated by greater growth during early marine life (Ruggerone et al. 2007), have likely masked the effects of competition on sockeye survival. In contrast, abundances of sockeye salmon in the southern region, including the Fraser River, have declined because marine conditions during early life appear to have been unfavorable and increasing abundance of pink salmon has lead to greater competition for food on the high seas.

The evidence for food competition suggests that the high abundance of pink salmon in recent decades has significantly influenced the epipelagic food web of the North Pacific Ocean. It seems highly unlikely that physical oceanographic conditions in the ocean could produce the strong alternating-year patterns observed in sockeye salmon across much of their range. Given this evidence for a strong effect of pink salmon on the food web, it is noteworthy that Chinook salmon abundance has declined throughout Alaska and British Columbia, and length-at-age

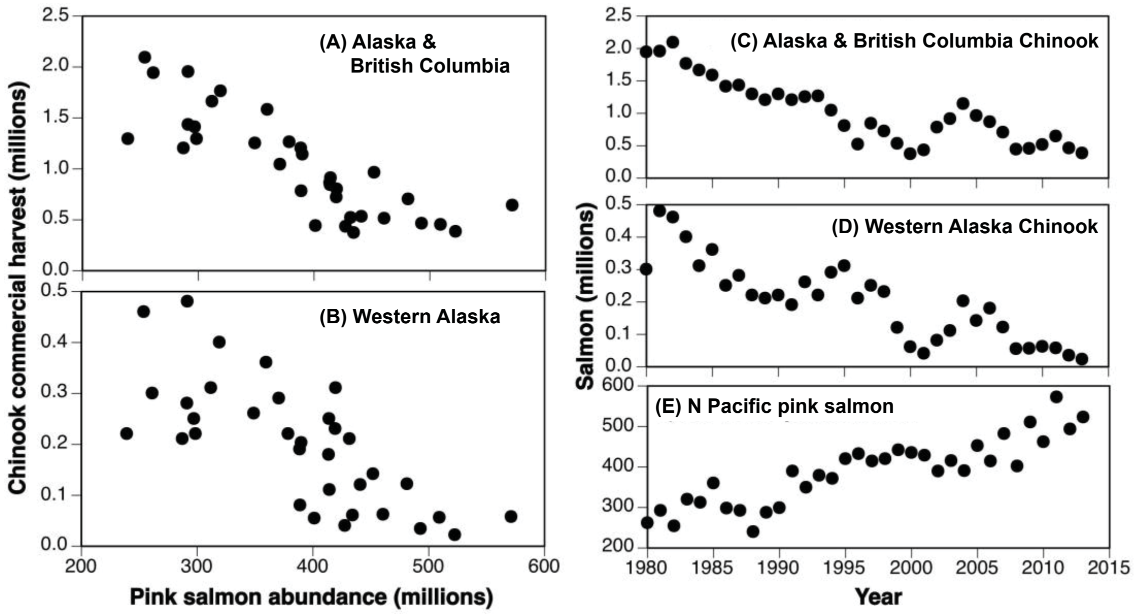

Fig. 10. Commercial harvest of Chinook salmon in (A) Alaska and British Columbia and (B) western Alaska (1980 to 2013) in relation to adult pink salmon abundance in the North Pacific Ocean. Similar relationships were produced if pink salmon from only North America were used. Chinook salmon harvest and pink salmon abundance trends over time are shown in plots C, D, and E. Pink salmon abundance was the three-year mean abundance corresponding to the year of Chinook harvest and the two previous years when Chinook may have potentially interacted with pink salmon in the ocean. Western Alaska includes Bristol Bay, Kuskokwim, Yukon, and Unalakleet Chinook salmon. Commercial Chinook catch estimates for Alaska and British Columbia were from NPAFC catch records (e.g., Irvine et al. 2012). Commercial Chinook harvest statistics reflect management decisions in recent years to greatly reduce harvests rates. Hatchery Chinook salmon produced in Alaska (Vercessi 2014) were subtracted from the total commercial Chinook catch estimates.

of many Alaskan Chinook populations has declined over time (Lewis et al. 2015). Analysis of the Chinook salmon diet in the central Bering Sea revealed a 56% reduction in stomach fullness and a 68% reduction in weight of fish and squid consumed during odd- versus even-numbered years, 1991–2000 (Davis 2003). Furthermore, the commercial catch of Chinook salmon in western Alaska and throughout Alaska and British Columbia have been negatively correlated with pink salmon abundance since 1980 (Fig. 10), leading to an intriguing and important question: could pink salmon play a role in the decline of Chinook salmon in Alaska and British Columbia?

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Evidence for competition at sea between Norton Sound chum salmon and Asian hatchery chum salmon

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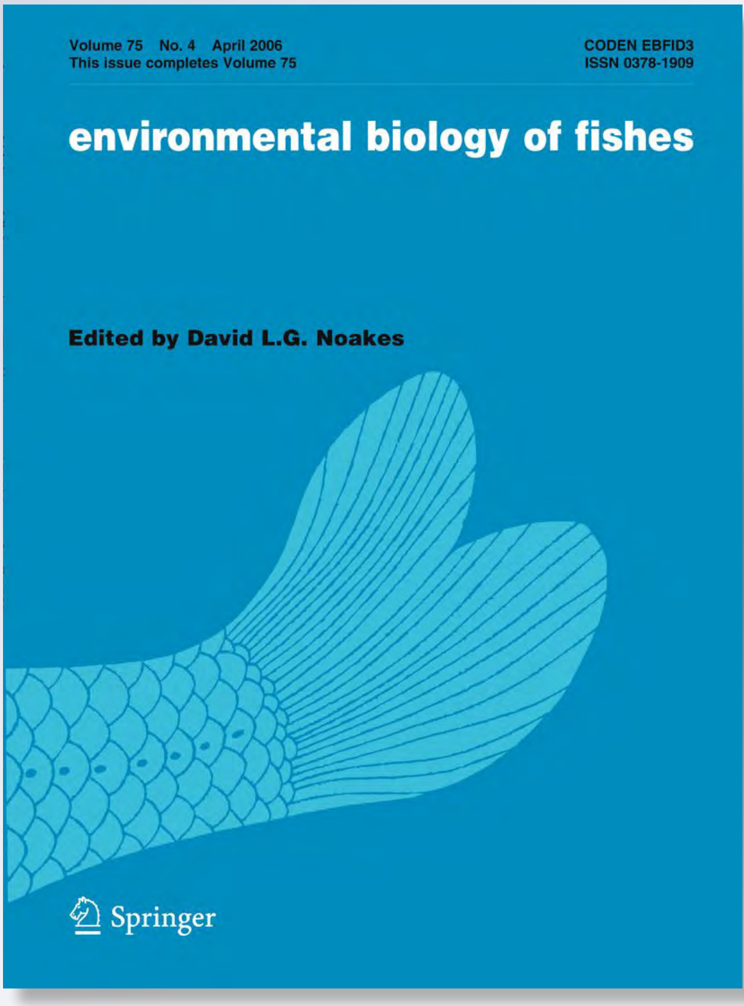

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Evidence for competition at sea between Norton Sound chum salmon and Asian hatchery chum salmon

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Abstract Increasing production of hatchery salmon over the past four decades has led to concerns about possible density-dependent effects on wild Pacific salmon populations in the North Pacific Ocean. The concern arises because salmon from distant regions overlap in the ocean, and wild salmon populations having low productivity may compete for food with abundant hatchery populations. We tested the hypothesis that adult length-at-age, age-at-maturation, productivity, and abundance of a Norton Sound, Alaska, chum salmon population were influenced by Asian hatchery chum salmon, which have become exceptionally abundant and surpassed the abundance of wild chum salmon in the North Pacific beginning in the early 1980s. We found that smaller adult length-at-age, delayed age-at-maturation, and reduced productivity and abundance of the Norton Sound salmon population were associated with greater production of Asian hatchery chum salmon since 1965. Modeling of the density-dependent relationship, while controlling for other influential variables, indicated that an increase in adult hatchery chum salmon abundance from 10 million to 80 million adult fish led to a 72% reduction in the abundance of the wild chum salmon population. These findings indicate that competition with hatchery chum salmon contributed to the low productivity and abundance of Norton Sound chum salmon, which includes several stocks that are classified as Stocks of Concern by the State of Alaska. This study provides new evidence indicating that large-scale hatchery production may influence body size, age-at-maturation, productivity and abundance of a distant wild salmon population.

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Introduction

Competition among salmon for food in the ocean can lead to reduced growth and survival (Zaporozhets and Zaporozhets 2004; Ruggerone and Nielsen 2009). Salmon may compete with local salmon populations during early marine life in coastal areas (Peterman 1984a; Levin et al. 2001) or during late marine life when maturing salmon concentrate along the migratory pathway to their natal river (Rogers and Ruggerone 1993). Salmon may compete in the ocean with salmon of the same species (Rogers 1980; Peterman 1984a, b; Kaeriyama 1998; Pyper and Peterman 1999; Helle et al. 2007) and with salmon of different species (Peterman 1982; Ruggerone et al. 2003, 2005; Ruggerone and Nielsen 2004). Competition in offshore waters often involves populations originating from distant regions and even different continents because salmon migrate long distances and are broadly distributed at sea (McKinnell 1995; Ruggerone and Nielsen 2004, 2009; Myers et al. 2007).

Scientists have raised concerns about increasing abundances of hatchery salmon and their possible density-dependent effects on wild salmon (Peterman 1991; Beamish et al. 1997; Cooney and Brodeur 1998; Hilborn and Eggers 2000; Kaeriyama and Edpalina 2004; Zaporozhets and Zaporozhets 2004). Concerns arise because hatcheries release numerous juvenile salmon into the ocean each year even though ocean conditions vary and may not provide sufficient prey to fully support both hatchery and wild salmon. For example, production of adult hatchery chum salmon from Asia increased rapidly beginning in 1970, and hatchery chum salmon began to exceed total production of wild adult chum salmon from Asia and North America in the early 1980s (Kaeriyama et al. 2009; Ruggerone et al. 2010). Unlike sockeye and pink salmon, whose abundance doubled after the ocean regime shift in the mid-1970s, the abundance of wild chum salmon in the North Pacific remained relatively stable (Ruggerone et al. 2010). Since 1980, approximately 2.2 billion hatchery chum salmon per year were released from Asian hatcheries into the North Pacific Ocean and adjacent seas compared with approximately 0.7 billion chum salmon from North American hatcheries (Ruggerone et al. 2010). Hatchery chum salmon are much more numerous than other species of hatchery Pacific salmon. The large production of hatchery chum salmon in Asia was associated with a significant reduction in growth of Asian chum salmon (hatchery and wild) and delayed age-at-maturation (Ishida et al. 1993; Kaeriyama 1998; Kaeriyama et al. 2007; Zavolokin et al. 2009). However, while some Russian scientists (Klovatch 2000; Zaporozhets and Zaporozhets 2004) claim that wild chum salmon in Russia have declined in response to increasing production of hatchery chum salmon in Asia, Morita et al. (2006a) noted that there is little empirical evidence to support this claim.

Asian hatchery chum salmon, most originating from Japanese hatcheries, are broadly distributed in the Bering Sea and North Pacific Ocean and their distribution at sea overlaps with that of wild chum salmon originating from the Arctic-Yukon-Kuskokwim (AYK) region of western Alaska (Myers et al. 2007, 2009; Beacham et al. 2009; Urawa et al. 2009). The great abundance of Asian hatchery chum salmon and their distribution overlap with western Alaska chum salmon led Myers et al. (2004) to hypothesize that Asian hatchery chum salmon compete with AYK chum salmon for prey. Hatchery and wild chum salmon from North America may also compete with AYK chum salmon, but their overlap at sea and abundance is less compared with that of Asian hatchery chum salmon (Myers et al. 2007, 2009; Beacham et al. 2009; Urawa et al. 2009).

Potential competition between Asian hatchery salmon and AYK chum salmon is a concern to communities in this large region because abundances of AYK chum salmon have been low since the mid-1990s or earlier (Krueger and Zimmerman 2009). Abundance of some AYK stocks, such as Norton Sound chum salmon in northwestern Alaska, have declined since the late 1980s, leading to restrictions on commercial fisheries (e.g., an 80% decline in commercial harvests after 1988), reduced harvests of salmon for subsistence, and significant hardship for people in the region (AYK SSI 2006; Banducci et al. 2007; Menard et al. 2009; Wolfe and Spaeder 2009). Three chum salmon stock aggregates in Norton Sound are currently classified as “Stocks of Concern” by the State of Alaska because harvests have been consistently low compared with previous harvests (AYK SSI 2006; Menard and Bergstrom 2009). Subsistence fishing in the Nome subdistrict of Norton Sound has been restricted since the mid-1980s. Additionally, chum salmon in the Yukon River (summer and fall runs) and Kuskokwim River were classified as “Stocks of Concern” until recently (Brannian et al. 2006). Factors causing the decline of AYK chum salmon are largely unknown and a major initiative was undertaken in the region to identify potential factors (AYK SSI 2006; Krueger and Zimmerman 2009). Stock-recruitment analyses indicated that the declining productivity of AYK chum salmon was synchronous and indicative of a region-wide factor of decline that has yet to be identified (Hilborn et al. 2007).

We examined the hypothesis that large-scale production of hatchery chum salmon from Asia has influenced the growth, age-at-maturation, productivity, and abundance of chum salmon originating from Norton Sound, Alaska. We also tested for potential effects of density-dependent interactions with abundant Eastern Kamchatka pink salmon (Radchenko et al. 2007) that may affect chum salmon (Tadokoro et al. 1996; Morita et al. 2006b; Khrustaleva and Leman 2007) and whether seasonal sea surface temperature and ocean regime shifts influenced abundance. Chum salmon in Norton Sound are not highly productive (adult returns per spawner is low), and their distribution in the Bering Sea and North Pacific Ocean overlaps that of hatchery chum salmon originating from Asia (Myers et al. 2009). This investigation addresses the question of whether large-scale hatchery production limits the productivity of a distant wild salmon population.

Methods

Our approach for evaluating the potential effects of hatchery chum salmon on wild Norton Sound chum salmon involved regression analysis and three response variables: length-at-age, age-at-maturation, and productivity of Norton Sound chum salmon. The primary explanatory variable considered in the analyses was abundance of Asian hatchery salmon. Potential effects of total chum salmon abundance (hatchery and wild), pink salmon abundance, parent chum spawners, seasonal sea surface temperature, air temperature at Nome, ice cover in the Bering Sea, and ocean regime shifts were also evaluated as a means to explain variability in the response variables.

Norton Sound chum salmon

The wild chum population that served as a response variable in this investigation spawns in the Kwiniuk River, a tributary to Norton Sound in northwestern Alaska (Fig. 1). The Kwiniuk River drains into the north side of Norton Sound just east of Moses Point, approximately 160 km east of Nome, Alaska. Kwiniuk chum salmon were the major contributor to the commercial fishery that began in 1962 near Moses Point. However, significant commercial harvests of Kwiniuk chum salmon have not occurred since 1988 in spite of achieving sufficient parent spawners (Kent 2007; Volk et al. 2009), indicating that the productivity of the population had declined. Subsistence fishing occurs in the Kwiniuk River and in nearshore marine waters without significant restrictions to limit harvests needed for food (Menard et al. 2009; Wolfe and Spaeder 2009). Tagging studies indicated few Kwiniuk chum salmon were captured in adjacent harvest areas in Norton Sound (Gaudet and Schaefer 1982).

The Kwiniuk chum salmon population was selected for this investigation because it has the most comprehensive dataset in Norton Sound and the trends in Kwiniuk chum salmon abundance are representative of other stocks in the region (Hilborn et al. 2007; Menard et al. 2009). Therefore, in this investigation, we used the Kwiniuk chum salmon population as a proxy for chum salmon in Norton Sound. The Alaska Department of Fish and Game (ADF&G) has estimated age-at-maturation, spawner abundance, and total abundance of Kwiniuk chum salmon since 1965. Norton Sound chum salmon migrate to sea immediately after emergence from gravel (age-0.X), typically spend three (age-0.3) or four (age-0.4) winters at sea, and return to spawn as four or five-year old fish, respectively (Ruggerone and Agler 2008). Age-specific adult returns and spawning abundances were used to calculate the number of adult chum salmon returning from parent spawners (R/S), brood years 1965–2001 (T. Hamazaki, S. Kent, ADF&G, pers. comm.). The R/S data incorporated adult returns from 1965–2007.

Length-at-age of Kwiniuk chum salmon was obtained from the ADF&G. Approximately 350 age-0.3 and age-0.4 chum salmon were measured each year, 1974–2005, except 1984 and 1992 which had less than 20 measured fish and were excluded from the analysis. Prior to 1974, length data were collected infrequently. The index of chum salmon growth was based on the mean of male and female salmon maturing at age-0.3 and age-0.4 in each year of return. This mean of mean approach accounted for differences in length associated with gender and age while providing a single robust index of chum salmon growth given that large numbers of fish in each category were not measured each year.

Average age of maturing Kwiniuk chum salmon produced by each brood year was calculated from age-specific returns to the river. Kwiniuk chum salmon mature at age-0.2, age-0.3, age-0.4 and

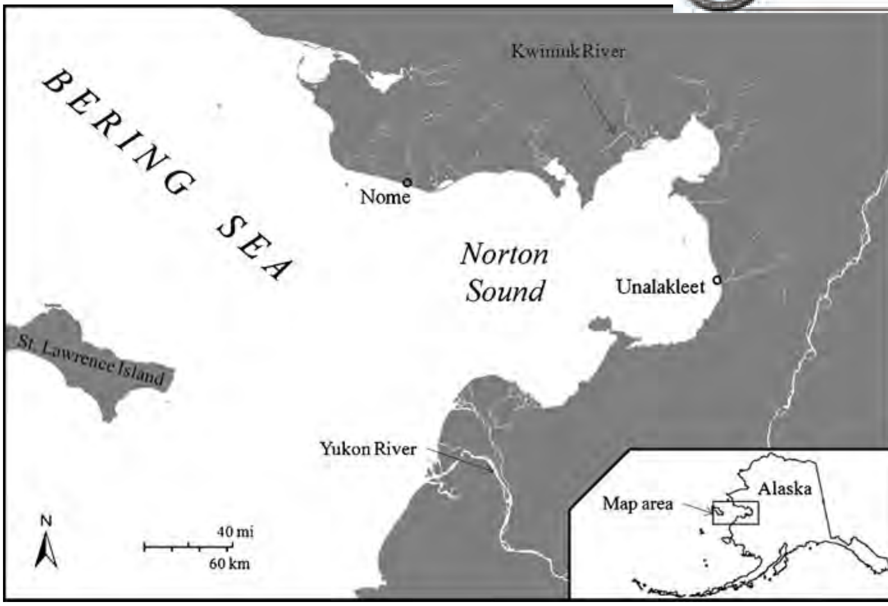


Fig. 1 Map of Norton Sound, Alaska, showing the location of the Kwiniuk River

age-0.5, corresponding to three- to six-year old fish, respectively.

Salmon and environmental data

Estimates of annual abundances of hatchery- and wild-origin salmon in Asia and western Alaska were obtained from Ruggerone et al. (2010). The large majority of Asian hatchery chum salmon originated from Japan, but some were from Russia. Negligible hatchery chum production (<1% of total) occurs in western Alaska (e.g., a few years of production in Kotzebue). Hatchery and wild stocks from central and Southeast Alaska were excluded from this analysis because the degree of overlap and influence on growth was much less than that of Asian and western Alaska chum salmon (Myers et al. 2007, 2009; Beacham et al. 2009; Urawa et al. 2009). Potential density-dependent interactions at sea were examined by comparing length-at-age, age-at-maturation, and productivity (see below) of Kwiniuk chum salmon with abundances of 1) Asian hatchery chum salmon, and 2) total chum salmon (hatchery and wild) returning to Asian and western Alaska (watersheds draining to the Bering Sea) since the mid-1960s. Each brood year of Kwiniuk chum salmon overlapped with other chum salmon stocks two, three and four years after the parent spawning year of Kwiniuk salmon. Therefore, mean abundances of adult chum salmon returning to Asia and western Alaska were calculated for these three years for comparison with productivity of Kwiniuk chum salmon (see below).

Eastern Kamchatka pink salmon are highly abundant in the Bering Sea, especially during odd-numbered years (Radchenko et al. 2007). Adult pink salmon returning two years after the chum parent spawning year were compared with productivity of Kwiniuk chum salmon. These pink salmon would overlap with Kwiniuk chum salmon during their first winter and second spring in the ocean.

Environmental data were tested as potential variables to explain characteristics of Kwiniuk chum salmon. Seasonal sea surface temperature (SST) data and ice cover indices were obtained from http://www.beringclimate.noaa.gov. Additional sea surface temperature (SST) data were derived from COADS data provided by the US National Center for Atmospheric Research and the US National Oceanic and Atmospheric Administration (Woodruff et al. 1998; http://dss.ucar.edu/datasets/ds540.1/data/msga.form.html). Monthly air temperature at Nome was obtained from http://climate.gi.alaska.edu. Large scale shifts in ocean productivity of the Bering Sea and North Pacific Ocean occurred in 1976/1977, 1989, and 1997 (Kruse 1998; Hare and Mantua 2000). The effect of these shifts on productivity of Kwiniuk chum salmon was tested using dummy variables (0, 1) in the statistical model (see Eq. 1) whereby the years within the shift period were coded as "1" and other years were coded as "0". For example, since chum salmon fry enter the ocean during the spring following parent spawning, the 1976/1977 ocean regime shift in relation to other regime shift periods was examined by coding the dummy variable as "1" during brood years 1976–1987, 1976–1995, or 1976–2001.

Data analysis

We extended the linear form of a Ricker recruitment curve (Hilborn and Walters 1992; Peterman et al. 1998) to determine whether abundance of hatchery chum salmon (H_i) and other factors explained the variability in Kwiniuk chum salmon productivity (Log_e R/S) during brood years 1965–2001 after accounting for density-dependent effects associated with parent spawners (S_i):

$$\mathrm{Log_e}\, R_i/S_i = \alpha - \beta(S_i) - \Psi(H_i) + \delta(E_i) + \varepsilon_i, \qquad (1)$$

where R_i is the adult return of progeny produced by parent spawners (S_i) during brood year i, H_i is hatchery or total chum salmon abundance, E_i is an environmental variable, and ε_i is the unexplained residual or deviation from expected recruitment. Stepwise and multiple regression, estimates of autocorrelation among model residuals, and collinearity between independent variables (Variance Inflation Factor [VIF]) were used to evaluate whether the independent variables explained variability in the productivity of Kwiniuk chum salmon (Kutner et al. 2005). Statistical significance of a variable in the model was determined when both the partial p-value (P) was <0.05 and the Akaike's Information Criterion (AIC) was reduced by at least three points (Burnham and Anderson 1998). A maximum VIF of 10 or more was used to indicate unsatisfactory collinearity among independent variables (Kutner et al. 2005). Partial residual analysis was used to examine the effect of each independent variable in a multiple regression while accounting for the effect of other variables in the model (Larsen and McCleary 1972).

Preliminary analyses indicated that productivity of Kwiniuk chum salmon was related to abundance of hatchery chum salmon and other factors, as shown in Eq. 1. Therefore, the effect of hatchery chum salmon on the abundance of Kwiniuk chum salmon was estimated by solving Eq. 1 for adult returns (R):

$$R = S e^{\alpha - \beta(S) - \Psi(H) + \delta(E)} e^{\varepsilon} \qquad (2)$$

Kwiniuk spawner abundance (S) and other environmental variables in this model were set at their mean value during the study period, whereas abundance of hatchery chum salmon (H) was allowed to to vary by the approximate range in abundance since 1965 (10 million to 80 million fish).

Linear regression analysis was used to test whether adult length-at-age of Kwiniuk chum salmon was correlated with chum salmon abundance and environmental variables. Generalized least squares (GLS) regression with restricted maximum likelihood estimation (R Development Core Team 2010) was used to evaluate the relationship between average age of Kwiniuk chum salmon and abundance of chum salmon because preliminary analysis indicated significant autocorrelation among the residuals. The GLS regression model has the same form as the linear model (e.g., Eq. 1) except the error values (ε_i) are assumed to be correlated and are accounted for in the model.

Results

Kwiniuk chum salmon length

Length-at-age (mean of age-0.3 and age-0.4 male and female salmon) of adult Kwiniuk chum salmon was negatively correlated with both Log_e Asian hatchery chum salmon and Log_e total abundance of Asian and western Alaska chum salmon that returned to their natal stream during the same year, 1974–2005 (Fig. 2). Chum salmon abundance (total or hatchery) explained approximately 36% of the variability in length-at-age of Kwiniuk chum salmon. Autocorrelation at lags 1–6 years was non-significant ($P>0.05$). Adult chum length was negatively correlated with SST during the winter prior to adult return ($r=-0.47$, $P<0.05$), an unexpected pattern. However, environmental variables, including seasonal SST, Nome air temperature, and Bering Sea ice index, did not improve the model that included chum salmon abundance ($P>0.05$).

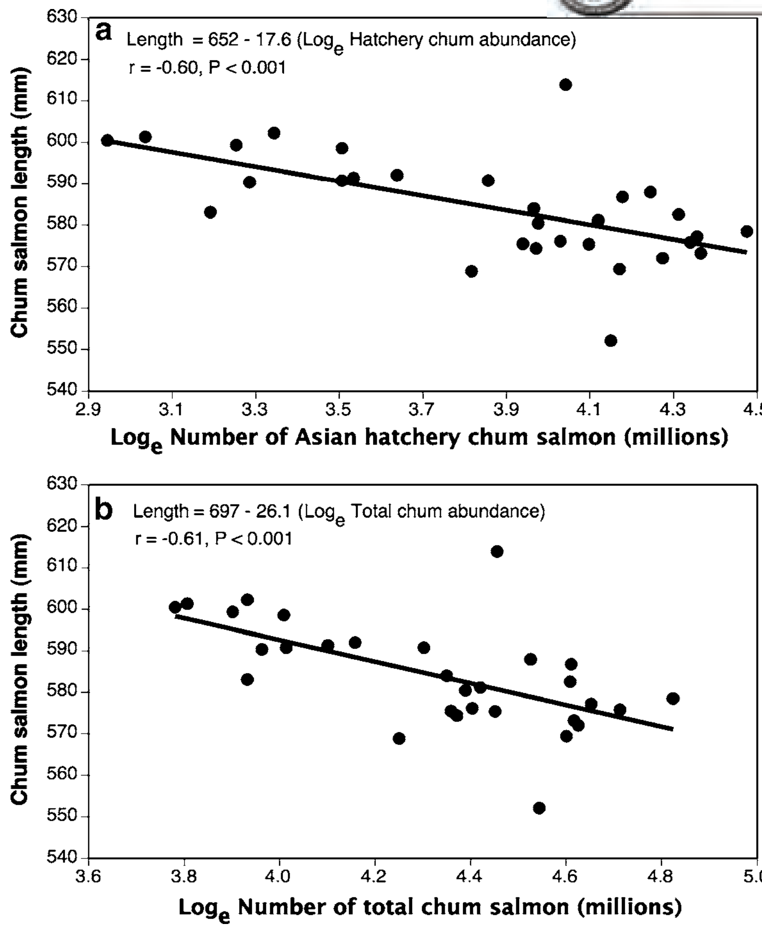


Fig. 2 Mean length-at-age of Kwiniuk River (Norton Sound) chum salmon in relation to **a**) Log$_e$ abundance of Asian hatchery chum salmon, and **b**) Log$_e$ total abundance of Asian and western Alaska chum salmon during the same year of return, 1974–2005

Kwiniuk chum salmon age at maturation

The dominant age of Kwiniuk chum salmon returning from brood years 1965–2001 was age-0.3 (59% of total) followed by age-0.4 (36%), age-0.2 (3%), and age-0.5 (2%). Average age of chum salmon in the brood return to Kwiniuk River ranged from 3.9 to 4.8 years, and age increased with greater abundance of Asian hatchery chum salmon (P=0.004). The relationship between average age of chum salmon and abundance of Asian hatchery chum salmon during the 37-year period was explained by the following GLS model (Fig. 3a):

$$\text{Chum salmon age (years)} = 3.76 + 0.166(\text{Log}_e \text{ Hatchery chum abundance}). \quad (3)$$

This GLS regression incorporated second order autoregressive (AR2) terms (ϕ_1=0.39, ϕ_2=−0.39) as a means to account for residual memory when estimating model parameters. The AIC of this model was at least 3.6 points lower than the AR1 and AR3 models and the model that assumed no autocorrelation. Average age of Kwiniuk chum salmon also increased with greater total abundance of Asian and western Alaska chum salmon, based on the same GLS regression approach (Fig. 3b).

Kwiniuk chum salmon productivity

Adult runs of chum salmon to the Kwiniuk River averaged 35 671±22 034 (SD) fish per year, 1965–2007. Adult returns per spawner (R/S) averaged 1.8±1.6 fish during brood years 1965–2001. Residuals from the Ricker recruitment curve were relatively high

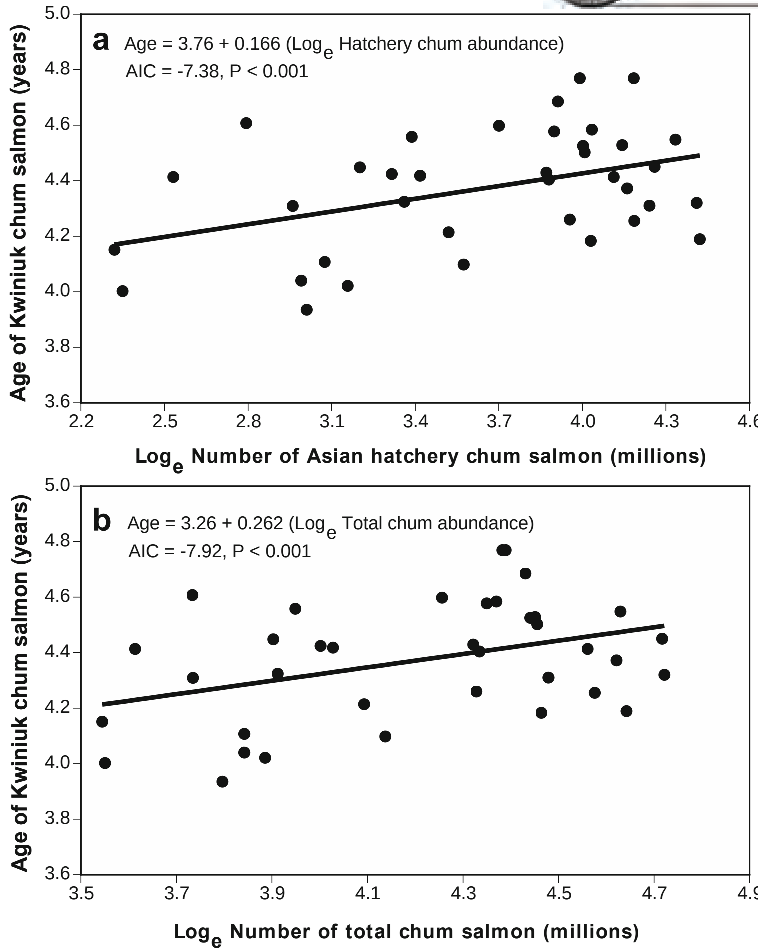


Fig. 3 Average age of adult chum salmon returning to the Kwiniuk River (Norton Sound) from each brood year (1965–2001) in relation to **a**) Log_e average Asian hatchery chum salmon abundance, and **b**) Log_e average total chum salmon abundance two to four years after the Kwiniuk salmon brood year. The regression equations reflect a fit to the data using generalized least squares regression with autoregressive (AR2) correlation structure (AIC values decreased by at least 3.6 over the AR1 model and by 5.0 over the simple linear model that assumed no autocorrelation)

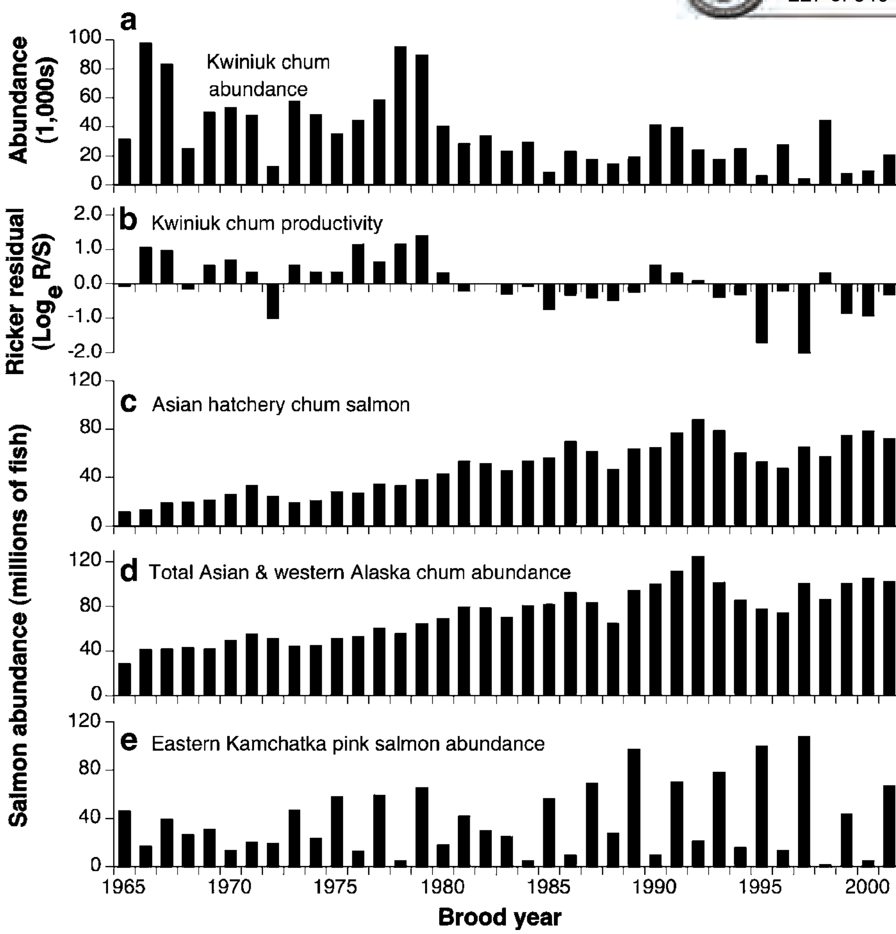
during 1965–1980, low from 1981 to 1994, and very low from 1995 to 2001 (Fig. 4). Since 1965, 37% of the broods failed to produce sufficient adult returns (catch and escapement) to replace the parent spawning escapement (R/S<1). Since 1980, 57% of the broods failed to replace themselves.

Approximately 48% of the variability in the productivity (Log_e R/S) of Norton Sound chum salmon during brood years 1965–2001 was explained by the following model (Table 1):

$$\text{Log}_e\text{R/S} = 2.69 - 0.016(\cancel{\text{T}}\text{otal chum abundance}) - 0.009(\cancel{\text{K}}\text{amchatka pink salmon}) - 0.039(\cancel{\text{S}}\text{pawners}). \quad (4)$$

This model indicates that productivity decreased with greater total adult abundance of Asian and western Alaska chum salmon two to four years after the Kwiniuk chum salmon brood year (millions), decreased with greater adult abundance of Eastern Kamchatka pink salmon two years after the chum salmon brood year (millions), and decreased with greater abundance of parent spawners (1000s). AIC values decreased by at least 4 points with the inclusion of each new variable into the previous best-fit model, indicating that all explanatory variables in Eq. 4 were important (Table 1). Autocorrelation among residuals at lags of one to six years was non-significant ($P>0.05$). Collinearity among the independent variables was negligible, as indicated by Variance Inflation Factor (VIF) values of 1.09-1.10. Environmental variables (e.g., seasonal SST, ice cover,

Fig. 4 Time series of **a**) adult chum salmon recruitment to Kwiniuk River, Norton Sound, **b**) productivity of Kwiniuk River chum salmon, **c**) abundance of adult Asian hatchery chum salmon four years after the brood year, **d**) abundance of adult Asian and western Alaska chum salmon (hatchery & wild) four years after the brood year, and **e**) abundance of pink salmon returning to Eastern Kamchatka two years after the brood year



winter and spring air temperature in Nome) did not improve the fit of the model.

Asian hatchery chum salmon averaged approximately 61% of total chum salmon production in Asia and western Alaska during the study period, but the contribution of hatchery salmon increased to 68%, on average, after 1980. Productivity of Kwiniuk chum salmon was negatively correlated with abundance of hatchery chum salmon, as shown in the following model (Fig. 5):

$$\begin{aligned}\mathrm{Log_e R/S} &= 2.37\\ &- 0.018(\cancel{\mathrm{H}}\text{atchery chum abundance})\leftarrow\\ &- 0.009(\cancel{\mathrm{K}}\text{amchatka pink salmon})\leftarrow\\ &- 0.039(\cancel{\mathrm{S}}\text{pawners}).\end{aligned} \qquad (5)\leftarrow$$

This model explained 50% of the variability in productivity of Kwiniuk chum salmon. Productivity of Kwiniuk chum salmon declined with greater abundance of hatchery chum salmon two to four years after the Kwiniuk chum salmon brood year, greater abundance of Eastern Kamchatka pink salmon two years after the chum salmon brood year, and greater abundance of parent chum salmon spawners in Kwiniuk River (Table 1). Autocorrelation among residuals at lags of one to six years was non-significant ($P>0.05$). The AIC values decreased by at least 4 points with the inclusion of each new variable into the previous model (Table 1). Collinearity among the independent variables was negligible, as indicated by Variance Inflation Factor (VIF) values of 1.09–1.1. Standardized regression coefficients indicated that Kwiniuk spawner abundance was the most influential independent variable followed by hatchery chum salmon abundance (Table 1).

Abundance of wild Asian and western Alaska chum salmon did not improve the model ($P>0.05$), indicating that abundance of hatchery chum salmon

Table 1 Standardized model coefficients, AIC, and partial P-values of multivariate models used to explain the variability in adult chum salmon returns per spawner in the Kwiniuk River, Norton Sound, Alaska, brood years 1965–2001 (see Eq. 1). Numerical superscript values identify the independent variables (V) in the model

Model variables	P-value	adj R^2	AIC	Std model coefficients			Partial P-values		
				V1	V2	V3	V1	V2	V3
Spawners[1]	0.004	0.19	−18.5	−0.46			0.004		
Total chum salmon									
Spawners + Total chum[2]	<0.001	0.40	−28.7	−0.58	−0.48		<0.001	<0.001	
Spawners + Total chum + Pink salmon[3]	<0.001	0.48	−33.0	−0.65	−0.43	−0.31	<0.001	0.002	0.02
Hatchery chum salmon									
Spawners + Hatchery chum[2]	<0.001	0.42	−29.9	−0.56	−0.50		<0.001	<0.001	
Spawners + Hatchery chum + Pink salmon[3]	<0.001	0.50	−34.0	−0.64	−0.45	−0.30	<0.001	0.002	0.02

was more important than wild chum salmon abundance in explaining variability in productivity of Kwiniuk chum salmon. Environmental variables did not improve the model ($P>0.05$). Most ocean regime shift variables did not improve the model ($P>0.05$), but the regime shift period incorporating brood years 1976–1995 was statistically significant (partial $P=0.018$, AIC change: −4.0), suggesting that productivity of the 1976–1995 broods may have been somewhat more productive after accounting for other factors in the model. However, the regime shift variable was the least influential variable in the model and it was moderately collinear with other variables, therefore this complex model was not considered further.

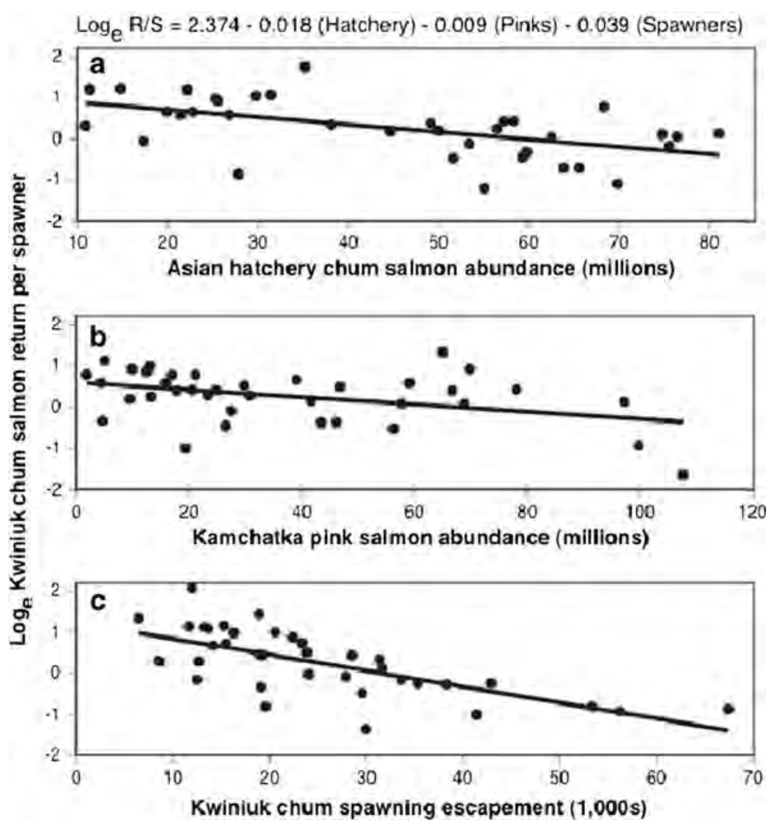


Fig. 5 Multivariate relationship showing the effect on Kwiniuk River (Norton Sound) chum salmon return per spawner (Log$_e$) of **a**) average Asian hatchery chum salmon abundance two to four years after the Kwiniuk salmon brood year, **b**) abundance of Eastern Kamchatka adult pink salmon abundance two years after the Kwiniuk chum salmon brood year, and **c**) spawning escapement of parent chum salmon in the Kwiniuk River, 1965–2001. Plots are based on partial residual analysis (Larsen and McCleary 1972)

Kwiniuk chum salmon abundance

The effect of hatchery chum salmon on the abundance of Kwiniuk chum salmon was examined by solving for returns (R) of adult Kwiniuk chum salmon in Eq. 5. For this analysis, the mean number of both parent spawners in Kwiniuk River (24 800 fish) and pink salmon returning to Eastern Kamchatka (37.6 million fish) were held constant in the equation, but the number of Asian hatchery chum salmon was allowed to vary from 10 million to 80 million adult salmon, a range that spanned the observed hatchery salmon production during the study period. This analysis indicated that increasing hatchery chum salmon from 10 million to 80 million fish would cause abundance of Kwiniuk chum salmon to decline from 60 900 fish to 17 100 fish, representing a 72% reduction (Fig. 6).

Discussion

Kwiniuk chum salmon, a key population in Norton Sound, Alaska, have experienced reduced adult length-at-age, greater age-at-maturity, lower productivity (Ricker residual), and lower abundance since the early 1980s, corresponding with the period of increased production of hatchery chum salmon in Asia. Age-at-maturation of Kwiniuk chum salmon tended to be delayed in relation to increasing abundance of hatchery chum salmon, potentially contributing to the observed lower productivity of the wild chum salmon because older salmon have a higher risk of mortality. Productivity and adult length of Kwiniuk chum salmon were inversely correlated with abundance of hatchery chum salmon (avg. 59 million salmon), which represented approximately 68% of total adult chum abundance in Asia and

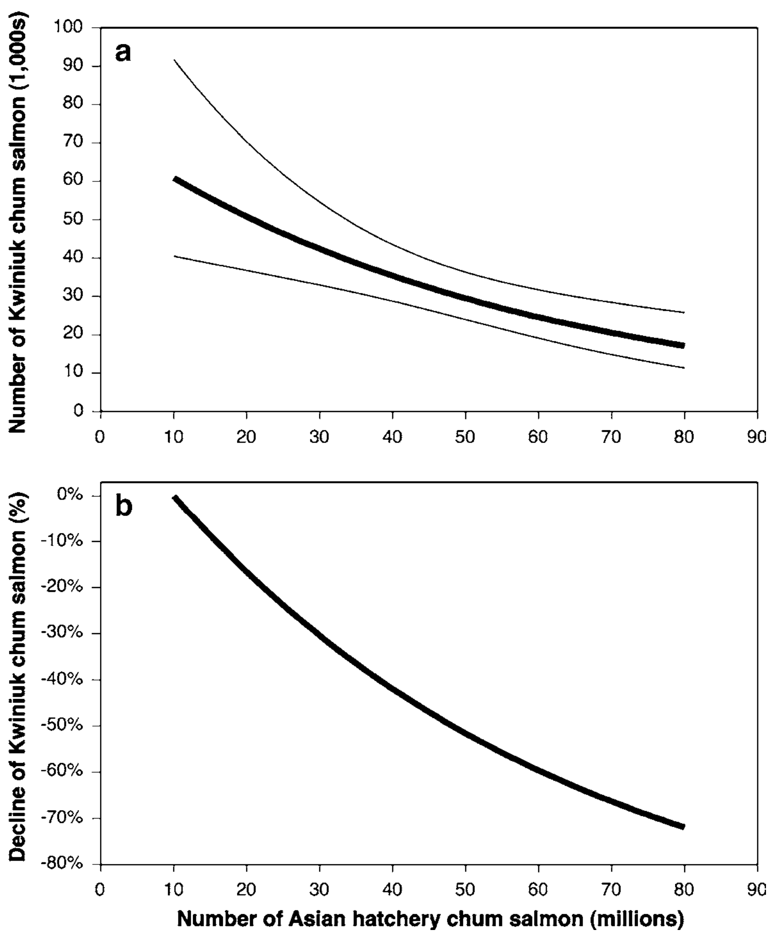


Fig. 6 The modeled effect of Asian hatchery chum salmon on abundance of Kwiniuk River chum salmon, based on Eq. 5 (see text) and mean values for Kwiniuk spawner abundance (24 800 fish) and Eastern Kamchatka pink salmon abundance (37.6 million fish). The response of Kwiniuk chum salmon is shown in **a**) numbers of fish, and **b**) percentage decline relative to the baseline of 10 million hatchery chum salmon. Confidence limits (95%) bounding the mean abundance prediction are shown

western Alaska since 1980 (Ruggerone et al. 2010). Inclusion of wild chum salmon abundance in Asia and western Alaska did not improve the statistical model, suggesting that Asian hatchery salmon was the primary stock correlated with the decline of chum salmon productivity and abundance in Norton Sound. The relationships involving age-at-maturation, length-at-age and productivity of Kwiniuk chum salmon since 1965 are consistent with the hypothesis that highly abundant hatchery salmon compete with distant wild salmon stocks in the ocean, leading to reduced growth and productivity of the distant wild salmon stock. This analysis provides evidence that the previously documented decline in AYK chum salmon (Hilborn et al. 2007) was associated with hatchery production.

The analyses presented here were based on correlations between variables that were not controlled within an experimental framework. The analyses suggest adverse interactions between hatchery and wild salmon at sea, based on the known overlapping distribution and diet of the chum salmon stocks at sea, but the correlations do not necessarily prove the hypothesis. Nevertheless, there were multiple lines of evidence suggesting that hatchery salmon influenced key characteristics of wild chum salmon. In addition to the relationships involving adult length, age-at-maturation and productivity, we found that length-at-age was negatively correlated with SST, rather than positively correlated as expected based on studies involving salmon in northern latitudes (Mueter et al. 2002a, b; Ruggerone et al. 2007). This unexpected finding suggests that density-dependent effects involving abundance of hatchery chum salmon may have overwhelmed favorable growth conditions associated with warmer SST. Our results were consistent with other studies showing reduced length-at-age and delayed maturation of Japanese and Russian chum salmon during the past several decades in response to increasing abundance of hatchery chum salmon (Ishida et al. 1993; Kaeriyama 1998; Zavolokin et al. 2009). In contrast to total abundance of wild sockeye and pink salmon in the North Pacific Ocean, abundance of wild chum salmon did not increase after the ocean regime shift in the mid-1970s, possibly because the increasing abundance of hatchery chum salmon in the ocean led to reduced productivity of wild chum salmon (Kaeriyama et al. 2009; Ruggerone et al. 2010). Together, these studies provide consistent support for the hypothesis that large-scale hatchery production can affect the growth, age, and productivity of wild salmon in the ocean.

The statistical model (Eq. 5) indicated that an increase from 10 million to 80 million hatchery chum salmon would lead to a 72% decline in the abundance of Kwiniuk chum salmon, assuming all other factors were held constant. The statistical model explained only 50% of the variability in Kwiniuk chum salmon productivity during the 37-year period, so other factors were also important and contributed to variability. Nevertheless, abundance of Kwiniuk chum salmon declined 60%, on average, from brood years 1965–1979 to 1990–2001, a period in which hatchery chum salmon production increased 190% (from 23 million to 67 million fish, on average).

The decline in productivity of Kwiniuk chum salmon is a special concern because the Kwiniuk population had relatively low productivity before large scale hatchery releases began in the early 1970s, e.g., $R/S=1.8$. Six wild chum salmon populations in the AYK region of western Alaska, which typically inhabit relatively pristine habitats, have been depressed during the past 15 or more years, leading to "Stock of Concern" designations by the State of Alaska (Brannian et al. 2006). Our findings provide evidence that increasing production of Asian hatchery chum salmon may have contributed to the decline of these chum salmon stocks, whose distribution at sea overlaps that of Kwiniuk chum salmon (Myers et al. 2007, 2009; Urawa et al. 2009).

Our findings indicated that productivity of Kwiniuk chum salmon also declined in response to the abundance of Eastern Kamchatka pink salmon, which were exceptionally abundant in the Bering Sea during odd-numbered years. These pink salmon were wild fish, but production of hatchery pink salmon was also increasing in Asia and North America (Ruggerone et al. 2010). The influence of pink salmon on Kwiniuk chum salmon was less than that of hatchery chum salmon, as expected. This finding is consistent with other studies that have reported negative relationships between highly abundant pink salmon versus chum salmon (Tadokoro et al. 1996; Morita et al. 2006b; Khrustaleva and Leman 2007), other species of salmon (Bugaev et al. 2001; Ruggerone and Nielsen 2004), and marine birds in the Bering Sea (Toge et al. 2011).

In recent decades, scientists have raised concern about the increasing abundance of hatchery salmon and density-dependent effects on wild salmon populations (Peterman 1991; Cooney and Brodeur 1998; Myers et al. 2004; Mantua et al. 2009). The concern becomes more critical when the underlying productivity of the wild population is low, as in populations in the AYK region of Alaska and in the Pacific Northwest (Good et al. 2005; AYK SSI 2006; Krueger and Zimmerman 2009). Salmon stocks originating from distant regions and adjacent continents overlap in the North Pacific Ocean and Bering Sea, and they share a common food resource (Myers et al. 2004, 2009). For example, genetic data show numerous Japanese and Russian origin chum salmon overlap with western Alaska chum salmon in both the Bering Sea and in the Gulf of Alaska (Beacham et al. 2009; Urawa et al. 2009). The growing evidence for competition for food among conspecific salmon and between species of salmon has led some scientists to suggest the need for international dialog among organizations that produce numerous hatchery salmon so that the productivity of wild salmon can be preserved (deReynier 1998; Holt et al. 2008). Our findings represent another example of the "tragedy of the commons" (Hardin 1968) in that production of hatchery salmon has unintended effects on salmon and people in distant regions.

Conclusions

Smaller adult length-at-age, delayed age-at-maturation, and reduced productivity and abundance of Kwiniuk chum salmon in Norton Sound, Alaska, were associated with greater production of Asian hatchery chum salmon, which have been exceptionally abundant since the early 1980s. These findings, together with other observations of density-dependence involving Asian hatchery and wild chum salmon, provide multiple lines of evidence supporting the hypothesis that large-scale hatchery production may adversely affect growth and productivity of distant wild salmon populations.

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Effects of Climate and Competition for Offshore Prey on Growth, Survival, and Reproductive Potential of Coho Salmon in Southeast Alaska

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Abstract: In the offshore Gulf of Alaska (GOA), coho salmon exhibit strong dependence upon a single prey species, the minimal armhook squid (*Berryteuthis anonychus*). We propose and then test elements of the general hypothesis that coho salmon adult size in Southeast Alaska reflects predator-prey interactions among coho salmon, pink salmon, and squid, where squid are the main prey of coho salmon while pink salmon mediate squid abundance as both competitors and predators of squid. The majority (65%) of variation in size of coho salmon over a 45-year period was explained equally by the catch biomass of pink salmon in the GOA and by the PDO index during squid emergence and development, averaged at lags in 2-year increments (matching the life cycles of pink salmon and squid) of up to four years. We extend the analysis to examine effects on marine survival, sex ratio, and per capita reproductive potential and examine evidence for growth-related late-marine mortality. Our results lend support for an important late-marine period for coho salmon survival and for the role of pink salmon as a keystone predator that controls the trophic structure of salmon forage and the flow of energy in the offshore GOA ecosystem. Our findings also indicate that the capacity of the GOA to produce pink salmon for harvest, while maintaining stable adult coho salmon weight (based on inferred stable squid prey populations), is highly variable and closely linked with atmospheric forcing.

Keywords: coho salmon, *Berryteuthis anonychus*, squid, pink salmon, growth, survival, climate, competition

INTRODUCTION

The relationship among salmon species (*Oncorhynchus* spp.) and their prey in the offshore Gulf of Alaska (GOA) has been described as a "trophic triangle" in which flexible planktivores (pink *O. gorbusha* and sockeye *O. nerka* salmon) function as intra-guild predators that both prey upon minimal armhook squid (*Berryteuthis anonychus*) and compete with them for zooplankton prey (Aydin 2000; Uchikawa et al. 2004; Fig. 1). *Berryteuthis anonychus* is also the predominant prey of obligate nektivores (coho *O. kisutch* and Chinook *O. tshawytscha* salmon, and steelhead *O. mykiss*) that feed primarily on squid and (to a lesser extent) fish in these same waters (Kaeriyama et al. 2004; Atcheson et al. 2012). Here, we examine this relationship through size and survival of coho salmon in Southeast Alaska.

Coho salmon exhibit features that, compared with other salmon species, reduce the range of plausible mechanisms determining their growth at sea, where most spend approximately 16 months. Southeast Alaska coho salmon are limited to the northeast Pacific (Myers et al. 1996) where they are dependent upon a single calorie-rich prey species to fuel an exceptionally rapid growth rate during their second season at sea (Ishida et al. 1998). *Berryteuthis anonychus* has been shown to be the primary offshore prey of maturing coho salmon across varying climate regimes (LeBrasseur 1966; Pearcy et al. 1988; Davis 2003; Kaeriyama et al. 2004). Davis (2003) found that coho salmon in subarctic waters in the central North Pacific consumed almost exclusively large subadult and adult *B. anonychus*, which comprised the majority of the diet of all size classes larger than 500 g, and was highly correlated with stomach fullness. Coho salmon feeding in summertime increased their stomach contents index (SCI) with increasing size, as larger fish were able to catch larger squid, thereby further increasing their capacity for growth. While squid comprised 83% of the prey weight consumed by

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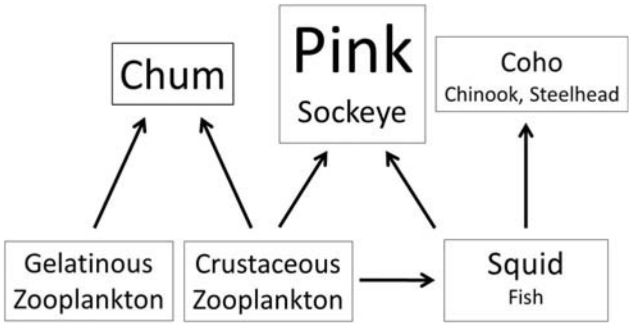

Fig. 1. Primary trophic connections between zooplankton and six species of maturing salmon in offshore waters of the Gulf of Alaska (modified from Aydin 2000).

maturing coho salmon, their contribution to digestible calories was even greater (93%), after accounting for their high caloric density and digestibility (Davis et al. 1998).

Although its rapid early growth rate and small size at maturity have led most investigators to conclude that *B. anonychus* has a 1-year lifespan (Nesis 1997; Katugin et al. 2005; Drobny et al. 2008), Jorgensen (2011) presents compelling evidence for a 2-year lifespan based upon a consistent biennial cycle (over a 19-year period) in abundance of paralarvae in the northwestern GOA that was correlated with abundance of pink salmon. Pink salmon, which also have a 2-year lifespan, have increased in abundance in odd years while even-year returns have remained more stable (Fig. 2A).

Average weight of troll-caught coho salmon in Southeast Alaska shifted from odd-year to even-year dominance in 1982–1983 (Fig. 2B), two cycles after an opposite shift in cyclic dominance in the commercial catch of pink salmon populations in the GOA (Fig. 2A). Coho salmon averaged 5.4% larger in odd years during the first decade of the 45-year series (1970–1979) but 14.1% smaller during 2005–2014. While average weight in odd years declined from a peak of 3.64 kg in 1977 to 2.45–2.60 kg in 2011–2013, even-year weights have remained more stable, increasing from a 1970s average of 3.07 kg to a peak in 1984–1988 (average 3.55 kg) followed by a stable trend (average 3.20 kg) during 1990–2010, before dropping abruptly to 2.69–2.93 kg in 2012–2014.

Climatic variability may also be important for growth of coho salmon, either through temperature mediated effects on growth or food web effects on prey (Aydin et al. 2005; Beauchamp 2009). Studies of covariation between coho salmon length and ocean environmental variables have generally found poor correlation in Alaska populations at time lags considered to be most important (Hobday and Boehlert 2001; Wells et al. 2006). However, Wells et al. (2008) observed a direct positive relationship between growth and the Aleutian Low Pressure Index (ALPI) in a Southeast Alaska population of Chinook salmon, a species with an offshore diet comprised primarily of squid (similar to coho salmon; Kaeriyama et al. 2004). Intensification of the Aleutian Low, and associated positive phase in the related Pacific Decadal Oscillation (PDO) index, has been shown to be potentially important to growth and survival in early stages in GOA fish populations, through increased phytoplankton and zooplankton production (Brodeur and Ware 1992), potentially as a result of shallowing of the mixed layer (Polovina et al. 1995). In addition, the same climatic pattern is also thought to have an important positive effect on transport by currents and subsequent survival of larvae of some marine fish species (Bailey and Picquelle 2002). Although less studied, atmospheric forcing may similarly affect growth and survival of cephalopod larvae.

Review of literature on offshore salmon feeding ecology and climatic effects on salmon growth led us to hypothesize that the observed history of average adult weight (Fig. 2B) was influenced by availability of maturing squid, which we hypothesized was influenced by bottom-up climate-related processes controlling squid recruitment and by direct competition for squid by pink salmon. However, initial exploration

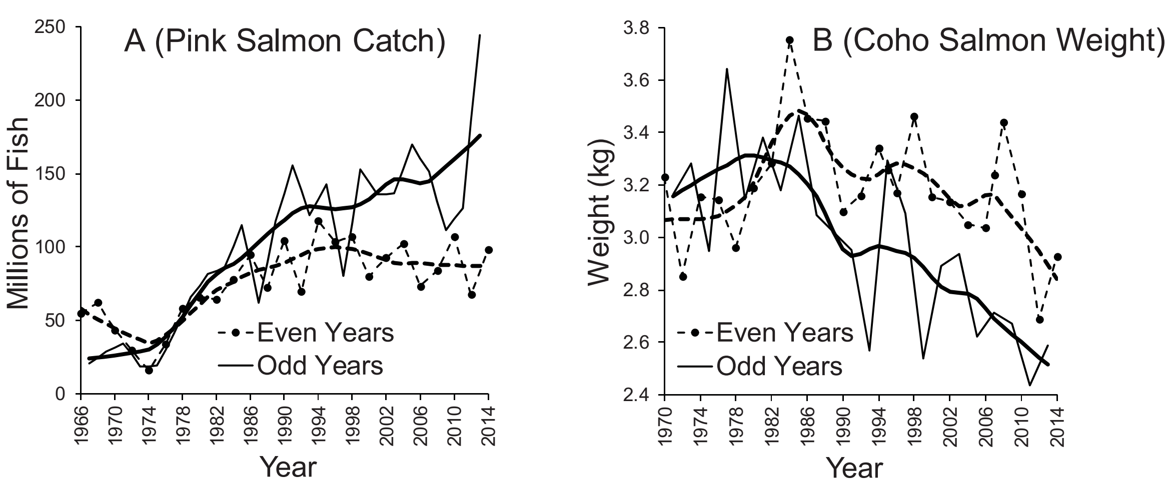

Fig. 2. Commercial catch of pink salmon in North America (A—excluding the Aleutian Islands and Bering Sea) and the average dressed weight of troll-caught coho salmon in Southeast Alaska (B) in even and odd years with 0.3 LOESS trends. Data sources are shown in Table 1.

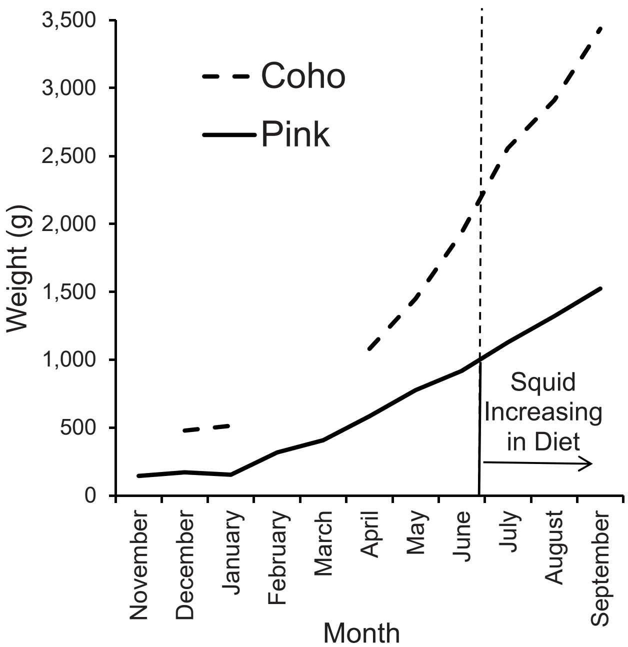

Fig. 3. Monthly average weight of coho and pink salmon during their final months at sea (Ishida et al. 1998) and the approximate threshold weight (1,000 g) for pink salmon to begin preying on maturing *Berryteuthis anonychus* (Aydin 2000; Davis 2003).

of the data produced regression models that were not parsimonious, indicating strongly contradictory relationships between even- and odd-year series. We observed that coho weight was positively correlated with the PDO Index in even years but not in odd years, while coho weight was negatively correlated with the catch of pink salmon in odd years but not in even years (Shaul et al. 2011). The need for a parsimonious explanation for coho weight, based on a consistent relationship with potential causal factors, led us to use multiple regression techniques to explore the hypothesis that pink salmon abundance and atmospheric forcing are both influential, but that the effects on coho growth are lagged. A lagged competitive relationship would be consistent with research findings pointing to an ontogenetic shift in the diet of maturing pink salmon from zooplankton to squid at a weight of about 1,000 g (Aydin 2000; Davis 2003), a size not achieved until late June, on average, after coho salmon have already fed for several months on the same prey cohort and have achieved nearly two-thirds of their final weight (Ishida et al. 1998; Fig. 3). The effect of this late transition in diet by pink salmon likely limits the effect on coho salmon growth of direct competition for the current-year squid cohort by the current-year pink salmon cohort, suggesting that the observed intensifying biennial cycle in coho size may reflect changes in prey populations that have developed over sequential generations.

We then extended the analysis to examine evidence for growth-related late-marine mortality through effects on marine survival, sex ratio, and per capita reproductive potential. Several studies have pointed to an early marine critical period for survival of coho salmon within the first weeks or months of marine residence (e.g. Holtby et al. 1990; Pearcy 1992; Beamish et al. 2004). However, evidence of such a period has remained elusive in studies of growth and survival of coho salmon in Southeast Alaska, where indirect evidence has instead favored an important late period for growth and survival after juveniles leave coastal waters late in their first summer at sea. Hobday and Boehlert (2001) found that environmental conditions when adults were returning explained more variance in survival of Alaska populations compared with the first season at sea. In northern Southeast Alaska, LaCroix et al. (2009) found no relationship between indices of juvenile coho salmon size, condition, abundance, or biophysical variables and subsequent marine survival and harvest. Although marine survival of adult pink salmon and age-.0 jack coho salmon from Auke Creek was correlated with Southeast Alaska coastal ocean response metrics, adult coho salmon marine survival was not, suggesting that different factors likely influence survival of adults beyond their seaward migration phase (Orsi et al. 2013). The biennial cycle in size of adult coho salmon was not evident in juveniles on 24 July, after approximately 2 months at sea (LaCroix et al. 2009), indicating that the difference in apparent growth likely occurs in offshore waters. Scale growth of Auke Creek adults also indicates that size-at-maturity is determined in the offshore GOA and is not significantly influenced by growth in early-marine or strait habitats (Briscoe 2004).

Findings from these studies led us to extend the analysis from a single growth-related response variable (adult size) to explore relationships with survival-related response variables including marine survival, sex ratio, and the per capita reproductive capacity of a coho salmon population. We tested the set of predictive variables that best explained adult coho weight with growth and survival-related response variables specific to the Berners River in Southeast Alaska. We also examined relationships between growth-related and survival-related variables for evidence of growth-related late-marine mortality to further test the hypothesis that there exists an important growth-related late-marine period for survival.

METHODS

In the first stage of the analysis, multiple regression models were constructed to explore relationships between adult coho salmon weight (1970–2014) and potential explanatory variables at various lags to test our hypothesis that variation in coho weight can be explained by lagged effects of climatic variation and top-down control on squid prey populations. Software used to run the analysis was R (version 3.2.3) (R Core Team 2015).

Data Sources

Response variables used in the analysis were obtained from two sources, (a) commercial catch data showing the av-

Table 1. Description of explanatory and response variables and data sources.

Explanatory variables	Description/Source
Pacific Decadal Oscillation (PDO) index	April-March average of monthly PDO index values ending in the year of maturity for coho salmon. The monthly data series is maintained by Nate Mantua (University of Washington): http://research.jisao.washington.edu/pdo/PDO.latest
Commercial catch of pink and sockeye salmon	Commercial catch by species in North America (excluding NPAFC area W-AK, the Aleutian Islands and Bering Sea) in metric tons; 1964–2011 data are available in Irvine et al. (2012); 2012–2014 catches for Canada, Washington and Oregon were downloaded as a statistical data file from the NPAFC: www.npafc.org/new/science_statistics.html
	Alaska catches in 2012–2014 (excluding the Aleutian Islands and Bering Sea) were provided by Kurt Iverson, Alaska Department of Fish and Game, Commercial Fisheries Division, Juneau.
Response variables	**Description/Source**
Coho weight	The weekly total weight of head-on, gutted coho salmon landed by the Southeast Alaska troll fishery divided by the number of fish reported in the landings. Weekly average weights were averaged over a period of 11 statistical weeks (weeks 28-38) from early July to mid-September. Data were accessed from the catch data base using the Alaska Department of Fish and Game's ALEX program and are reported by Shaul et al. (in press).
Adult length	Average mid-eye to fork length of male and female age-.1 coho salmon spawners in the Berners River estimated prior to the gillnet fishery. (Shaul et al. in press).
Sex ratio	Number of females-per-male estimated prior to the gillnet fishery. (Shaul et al. in press).
Marine survival	Total return (harvest plus escapement) of age-.1 coho coho salmon returning to the Berners River divided by the number of smolts emigrating in the prior year. (Shaul et al. in press).
Egg biomass per female	Average egg biomass of female Berners River coho salmon (prior to the gillnet fishery) based on an estimated relationship between female length and egg biomass reported by Fleming and Gross (1990) and Shaul et al. (in press).
Per Capita Egg Biomass (PCEB)	Estimated egg biomass per female Berners River coho salmon multiplied by the estimated proportion of females in the population prior to the gillnet fishery. (Shaul et al. in press).

erage weight of troll-caught coho salmon in Southeast Alaska during 1970–2014 and (b) growth and survival-related variables specific to the Berners River population for adult returns in 1990–2014 (Table 1; Shaul et al. in press).

Coho weight was calculated by dividing the weight of head-on, gutted coho salmon landed by the Southeast Alaska troll fishery by the associated number of fish reported on sales slips. There is a seasonal trend of increasing average weight, as well as substantial inter-annual variation in the temporal distribution of the troll catch (Shaul et al. 2011). Therefore, average weight was calculated weekly and averaged across 11 statistical weeks (weeks 28–38), spanning a period from early July through mid-September, in order to obtain a temporally stable measure of average coho salmon weight in coastal waters.

Marine survival and the size and sex composition of age-.1 returning adults were estimated annually for 1990–2014 adult coho salmon returns to the Berners River, located 65 km north of Juneau, Alaska (Shaul et al. in press). A target sample of 600 spawners was captured from upper river pools using a 13.7-m beach seine and sampled for age, sex, and mid-eye to fork (MEF) length. Returns to the Berners River are comprised almost entirely of age-.1 adults that have spent one year at sea, with age-.0 jacks being rare. Marine survival was estimated by dividing the total age-.1 adult return (combined catch and spawning escapement estimates) by the estimated smolt migration in the prior year.

Returning fish are exploited intensively by two major fisheries, including a troll fishery in outer coastal waters and passages, and a gillnet fishery conducted near the river. In order to account for size selection in the latter fishery, we reconstructed the pre-fishery length distribution and computed average length (following Kendall and Quinn 2012), using length measurements from an average of 339 coded-wire tagged Berners River fish sampled annually from the catch. Sex was not determined for the catch, so estimation of the effect of the harvest on the sex ratio required an assumption that fish of the same length were equally vulnerable to the fishery, independent of sex.

Per capita reproductive potential was assumed to be proportionate to the per capita egg biomass (PCEB). We used an average relationship between egg biomass (*EB*) and female length from two British Columbia coastal streams, Mamquam River and Tenderfoot Creek (Fleming and Gross 1990). Letting *MEF* denote the mid-eye to fork length (mm), the following is the conversion relationship applied to females in the Berners River:

$$EB = 2.33 \times 10^{-7}[MEF]^{3.39}.$$

Estimates of egg biomass for individual females were averaged and multiplied by the proportion of females in the adult population to estimate PCEB, which was then converted to a PCEB index by dividing the annual value by the average for all 25 years.

Explanatory variables included the commercial catch of pink and sockeye salmon (in metric tons) as a measure of the biomass of maturing salmon (Table 1) and, by inference, the potential for each species to influence availability of squid prey for coho salmon. Biomass of the catch was selected over numerical abundance as an explanatory variable because biomass includes elements of both abundance and size. Evidence of a strong positive relationship between the individual size of pink and sockeye salmon and the amount of squid in their diet (Aydin 2000; Davis 2003) suggests that total biomass is a more accurate measure of the potential for both species to influence squid prey populations of importance to coho salmon. Salmon biomass variables tested included separate values for pink and sockeye salmon, as well as the combined biomass of both species. We used the combined commercial catch in North America, excluding fishing areas in the Aleutian Islands and Bering Sea, with the objective of indexing the biomass of pink and sockeye salmon maturing primarily within the GOA.

North Pacific climate was represented by a single variable, the 12-month (April–March) average monthly PDO index ending in the coho salmon catch year. This period was targeted to encompass the period of hatching and development for *B. anonychus*, based on the occurrence of new paralarvae in the northern GOA beginning in April and assuming a 2-year lifespan (Jorgensen 2011).

Models

Multiple regression analysis was used to explore relationships between coho salmon weight, as the response variable, and the PDO index and pink and sockeye salmon catches at various lags ranging from 0 to 6 years from the catch year for adult coho salmon. Each predictive series was tested for obvious autocorrelation structure using conventional time-series analysis tools, including calculating the sample autocorrelations and partial autocorrelations out to at least 12 lags. Cross-correlation values were generated between the coho weight series and each of the other variables to see at which lags the variables might be most useful for predicting dependent variables. In cases with correlation at more than one lag, we considered averages across lags to develop new explanatory variables. We tested models that included sockeye salmon catch as a separate variable from pink salmon catch, as well as the pooled catch of both species under the assumption of an equal effect (per unit of weight) on the prey species of interest. Each predictive time series was standardized (the mean of the values actually used in the regression relationship was subtracted and the result was divided by the sample standard deviation). Model residuals were tested for autocorrelation using a Durbin-Watson test and by examining the sample autocorrelations. Models were ranked in order with the change in Akiaike Information Criterion differences (ΔAIC; Burnham and Anderson 1992). Models with ΔAIC ≤ 2 were considered to have equivalent support.

We tested the combination of predictive variables for coho weight with the lowest ΔAIC score in models explaining adult length, sex ratio, PCEB index, and marine survival for the Berners River population. Multiple regression models were developed for length of adults of each sex and the mean-average of both sexes prior to exposure to the gillnet fishery. Additional models were developed for marine survival, ratio of females-to-males, and the PCEB index. Single-variable regression models were also used to explore relationships between the catch of pink salmon and variables representing adult length, sex ratio, PCEB index, and marine survival for the Berners River population, as well as relationships among growth and survival-related variables. Additionally, these variables were also differenced so as to show the relationship between pink salmon biomass and the year-to-year change in adult length, sex ratio, PCEB index, and marine survival for the Berners River population. Relationships among response variables were plotted and examined separately for the second half of the series (2002–2014), which occurred after a shift to a cooler North Pacific climate (Peterson and Schwing 2003).

We rearranged the top-ranked predictive model for coho weight to examine the effects of salmon biomass separately from climate, and to estimate a climate-based

Table 2. Model selection statistics for analyses of hypotheses for average weight of troll-caught coho salmon, 1970–2014. Terms in the hypotheses are the commercial catch of pink salmon or pink and sockeye salmon combined (in millions of fish) and the April–March average monthly Pacific Decadal Oscillation (PDO) index ending in the coho salmon return year. The independent variables are lagged from 0 to 4 years (denoted 0, -2 or -4). Models are ranked by the Akiaike Information Criterion differences (ΔAIC). Models with ΔAIC ≤ 4 are listed, with the best model shown at the top.

Hypothesis	Coefficient weights		R^2	Adjusted R^2	ΔAIC
	Salmon	PDO			
Pink (average -2, -4) + PDO (average 0, -2, -4)	0.508	0.492	0.646	0.629	0.00
Pink & Sockeye (average -2, -4) + PDO (average 0, -2, -4)	0.483	0.517	0.644	0.627	0.29
Pink (-2) + Pink (-4) + PDO (average 0, -2, -4)	0.522[a]	0.478	0.651	0.625	1.72
Pink & Sockeye (-2) + Pink & Sockeye (-4) + PDO (average 0, -2, -4)	0.497[a]	0.503	0.648	0.623	2.00
Pink & Sockeye (average 0, -2, -4) + PDO (average 0, -2, -4)	0.504	0.496	0.625	0.608	2.53
Pink (-2) + PDO (average 0, -2, -4)	0.494	0.506	0.618	0.600	3.38
Pink & Sockeye (-2) + PDO (average 0, -2, -4)	0.474	0.526	0.615	0.597	3.75
Pink (average 0, -2, -4) + PDO (average 0, -2, -4)	0.504	0.496	0.615	0.597	3.76

[a] Coefficient weights at specific lags are: Pink (-2): 0.329, Pink (-4): 0.193, Pink & Sockeye (-2): 0.312, Pink & Sockeye (-4): 0.185.

carrying capacity for the GOA to produce pink salmon for harvest, given an objective of maintaining a constant average coho salmon size. The regression model describing coho weight (W) as a function of the pink salmon catch biomass (*Pink*), the PDO index (*PDO*), and a random (uncorrelated) normally distributed error (ε), where b_1 and b_2 are respective variable coefficients and c is a constant, is shown as follows:

$$W = (b_1)\ Pink + (b_2)\ PDO + c + \varepsilon.$$

By ignoring the error and fixing coho weight (W) at a constant value (in this case the 45-year average of 3.09 kg), we can rearrange the model to estimate the capacity (K) of the GOA to produce pink salmon for harvest while achieving the coho weight target under observed climatic conditions (PDO index) associated with the same coho return year:

$$\hat{K} = \frac{3.09 - (b_2)\ PDO - c}{b_1}.$$

RESULTS

Coho Weight Model

Positive autocorrelation was detected in the data series at lags of 1, 2, 3, 4, and 6 years for pink salmon biomass, 1–5 years for sockeye salmon biomass, and 1–7 years for combined biomass of the two species, while the PDO index had significant positive autocorrelation only at lag 1. The best models explaining troll coho weight included salmon abundance and climate variables only in the current year and at lags in 2-year increments up to 4 years (Table 2). Diagnostics for the best models were generally acceptable, with no detected autocorrelation in the residuals (diagnostic checks included calculating the autocorrelation in the residuals out 12 lags, plotting the fitted variables against the residuals, examining Q-Q plots, looking for large leverage in the residuals, and calculating the Durbin-Watson statistics). Models that included salmon biomass or climate variables for the alternate biennial cycle (at lags of 1 or 3 years) ranked poorly, consistent with a 2-year life cycle in *B. anonychus* (Fig. 4). Models that included sockeye salmon as a variable separate from pink salmon did not rank high. Among the four top-ranked models considered to have equivalent support (ΔAIC ≤ 2), two that included the combined biomass of pink and sockeye salmon as a single variable ranked slightly below similar models that included only pink salmon. Highest ranked models consistently indicate a nearly even split in influence (regression coefficients) between salmon abundance and the PDO (Table 2). All highly-ranked models (ΔAIC ≤ 4) included the average PDO lagged at 0, 2, and 4 years. Salmon biomass was most influential at a lag of 2 years, followed by 4 years, while biomass at lag 0 was substantially less influential. The third highest ranked model included pink salmon biomass at separate lags of 2 and 4 years, with the lag 2 coefficient weight (0.329) comprising 63% of the total coefficient weight assigned to salmon (0.522) while the lag 4 coefficient weight (0.193) accounted for 37%. The top ranked model (hereafter this predictor set will be referred to as the Pink-PDO predictors) included the pink salmon catch biomass averaged over the two prior cycles (lag 2 and 4 years; Fig. 5). No significant autocorrelation was detected in the residuals for this model at lags of 1–15 years and the Durbin-Watson statistic was not significant ($p = 0.474$). Partial residual plots indicate a strong negative relationship with pink salmon biomass (Fig. 5C) and a strong positive relationship with the PDO index (Fig. 5D), with 1995 and 1999 appearing as principal outliers.

Climate-Based Capacity

PDO-based estimates of the climate-based capacity of the GOA to produce pink salmon biomass for harvest while maintaining a constant average target coho salmon weight (3.09 kg) are highly variable, ranging over an order of magnitude from a low of 24.1 thousand metric tons in 1976 to 245.7 thousand metric tons in 1998 (Fig. 6). The relationship between the estimated climate-based capacity ($\hat{K}$) for pink salmon harvest (in metric tons) at the 3.09 kg

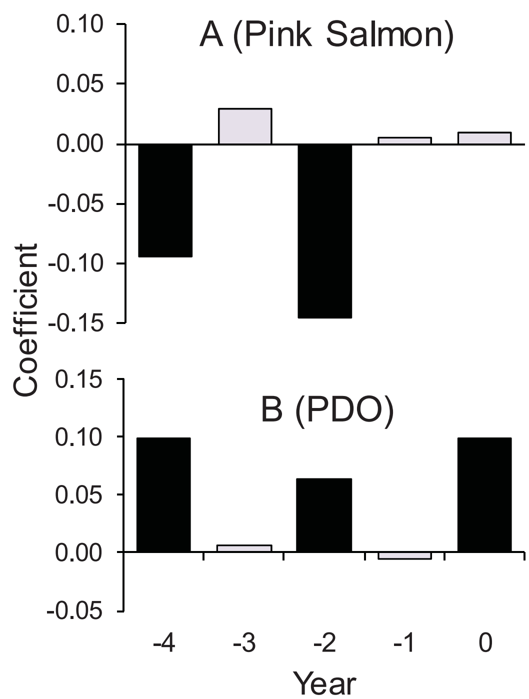

Fig. 4. Annual predictive variable coefficients for coho weight, including (A) pink salmon catch biomass and (B) PDO fitted at lags from 0 to 4 years in a regression model with 10 variables (5 lags each for pink salmon and PDO). Years that were averaged for the respective predictive variables in the top-ranked model (Table 2) are shaded black.

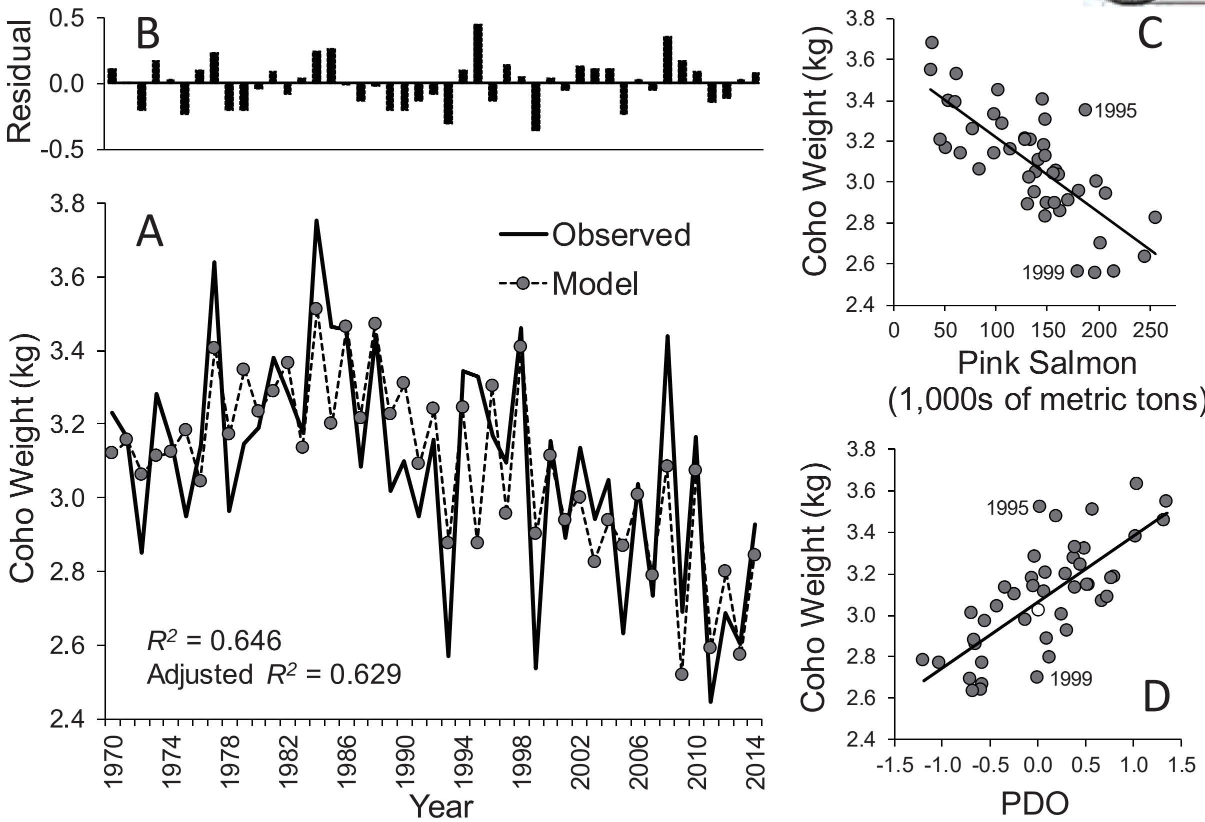

Fig. 5. Southeast Alaska troll-caught coho salmon average dressed weight compared with modeled weight (A) based on a multiple regression model with two variables: the standardized April–March PDO Index (average for lag 0, 2, and 4 years; 0.492 weighting based on the regression coefficient) and the standardized average commercial catch of pink salmon in North America (excluding the Bering Sea and Aleutian Islands) lagged by 2 and 4 years (0.508 weighting). The model residual is shown (B), as well as partial residual plots for pink salmon (C) and the PDO index (D).

target coho weight is shown by the following relationship with the PDO index:

$$\hat{K} = 86.928(PDO) + 128{,}066,$$

where K at a neutral (0) PDO index value is estimated at 128,066 metric tons, an amount that has been consistently equaled or exceeded by the lagging pink salmon catch biomass variable since 1987.

Although not significantly correlated over the full time series ($r = 0.264$; $p = 0.079$), pink salmon catch biomass and estimated climate-based capacity (i.e., scaled PDO index variable) showed strong positive correlation during 1970–1990 ($r = 0.809$; $p < 0.001$), with capacity exceeding catch biomass in all but 2 years. However, pink salmon biomass and estimated capacity were essentially uncorrelated in the subsequent period from 1991–2014 ($r = -0.148$; $p = 0.490$), as biomass remained high while the PDO index trended lower. This change was associated with a substantial (43%) increase in variation in annual coho weight (Fig. 5A). However, the model fit was consistent between the periods (Fig. 5B), with no meaningful change in the average residual between 1970–1990 (-0.014) and 1991–2014 (0.012), or in coefficients of variation (*CV*) in the residuals (0.164 and 0.188, respectively).

Climate-based capacity estimates based on the target coho weight were exceeded only a few times in even years and by modest percentages prior to 2012, when a series of low trailing PDO index values and substantial even-year pink salmon returns were associated with biomasses that exceeded capacity estimates by 102% in 2012 and 83% in 2014 (Fig. 6). Coho weight was the lowest on record for an even year in 2012, and third lowest in 2014 (Fig. 2). Since the early 1990s, differences between pink salmon biomass and estimated capacity have been greater in odd years as odd-year biomass transitioned from being consistently below estimated capacity during 1971–1991 (by an average of 26%) to consistently above capacity by an increasing margin since 1993 (158% in 2009, 205% in 2011, 364% in 2013; Fig. 6).

Adult Length

During 1982–2014, Berners River spawners of both sexes declined in length by an average of 1.6 mm/year for males and 1.1 mm/year for females (Fig. 7). Variation in length among spawners returning in the same year increased for both sexes. Males showed substantially greater intra-annual variation in length among individual spawners (average $CV = 0.109$) compared with females (average $CV = 0.059$) as well as greater in-

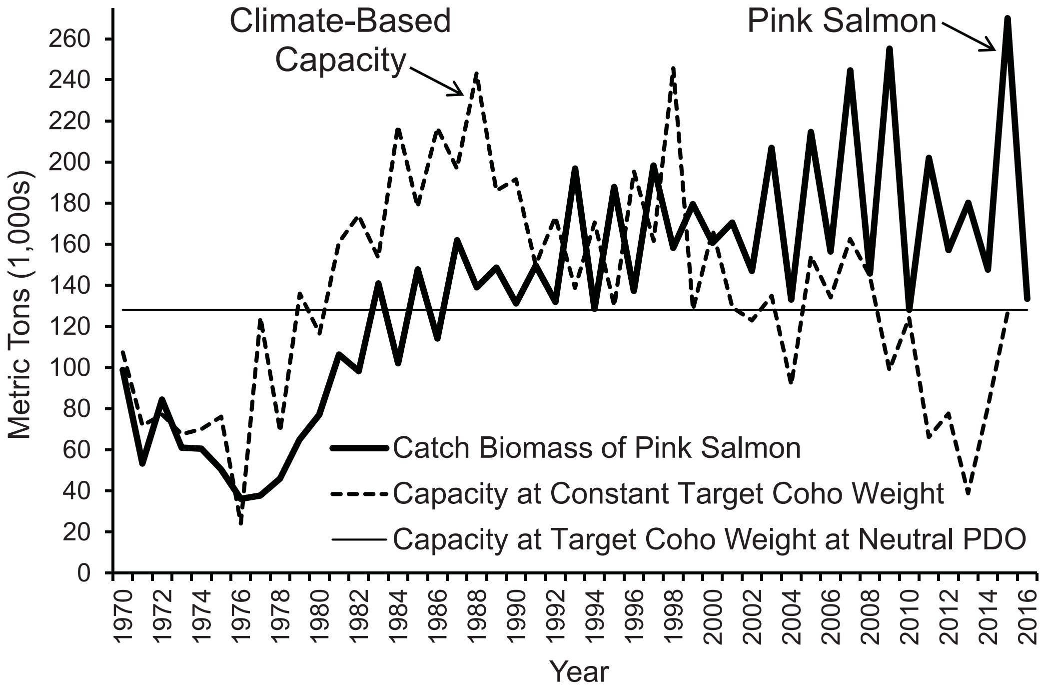

Fig. 6. Average Gulf of Alaska pink salmon catch in the preceding two cycles (lag 2, 4) compared with the estimated catch at a constant target coho salmon weight of 3.09 kg (45-year average) at both the trailing 3-cycle average PDO index (lag 0, 2, 4) and at a constant neutral PDO index. The PDO variable is converted to an estimate of the climate-based capacity of the Gulf of Alaska to produce pink salmon for harvest while also achieving a target coho salmon weight.

ter-annual variation in average length ($CV = 0.044$) compared with females ($CV = 0.028$). During 1998–2010, average length of both sexes became increasingly cyclical, declining in odd years while remaining relatively stable in even years until 2012, when even-year length decreased sharply.

The linear selection differential (LSD), the difference in average length before and after the gillnet fishery, averaged -12.3 mm for males and -3.7 mm for females during 1990–2014 (Shaul et al. in press). On average, the estimated effect of the gillnet fishery on the ratio of females-to-males was not meaningful, with the average ratio before and after the fishery decreasing from 0.80 to 0.75.

Relationships Between Population Variables

There was a moderate correlation between marine survival and adult length (Spearman's rho = 0.669, $p < 0.001$; Fig. 8A). The correlation between adult length and the ratio of females-to-males was lower, with greater variability in the female-to-male ratio at larger adult length (Fig. 8B). The correlation between marine survival and the female-to-male ratio was considerably lower, and did not reach statistical significance (Fig. 8C). The PCEB index, which has as factors both female length and the proportion of the adult population comprised of females, had a small to moderate correlation with marine survival (Fig. 8D).

The regression slope for the 2002–2014 length-survival relationship did not differ from the slope for the entire series (Fig. 8A), but recent relationships between length and sex ratio and between marine survival and PCEB index exhibit greater slope. Variation in the length-survival relationship decreased at smaller adult sizes, suggesting a more limited range of survivals for cohorts with slower growth, as a potential consequence of size-selective mortality (Fig. 8A).

During 1990–2014, there were important differences between even and odd years in the length of age-.1 adults, the female-to-male ratio, and the PCEB index (Fig. 9). Average marine survival estimates in odd years (14.6%) were not significantly different from even years (17.9%; $p = 0.157$). However, the relative survival of females (female-to-male ratio) was lower in odd years ($p = 0.012$) with a pre-gillnet female-to-male ratio of 0.71 compared with 0.88 in even years (assuming a 1:1 sex ratio in smolts; Spidle et al. 1998). The PCEB index was also significantly different, averaging 18% lower in odd years prior to the gillnet fishery ($p = 0.002$) and 23% lower in the spawning escapement ($p < 0.001$).

Pink Salmon and PDO Predictors

The Pink-PDO predictors consistently explained at least a moderate amount of the variation in average size of returning coho salmon of both sexes in 1990–2014 (Table 3; Fig. 9A). Results were consistent with troll weight (1970–2014) in indicating an approximately equal split between pink salmon biomass and climate (PDO) as factors influencing

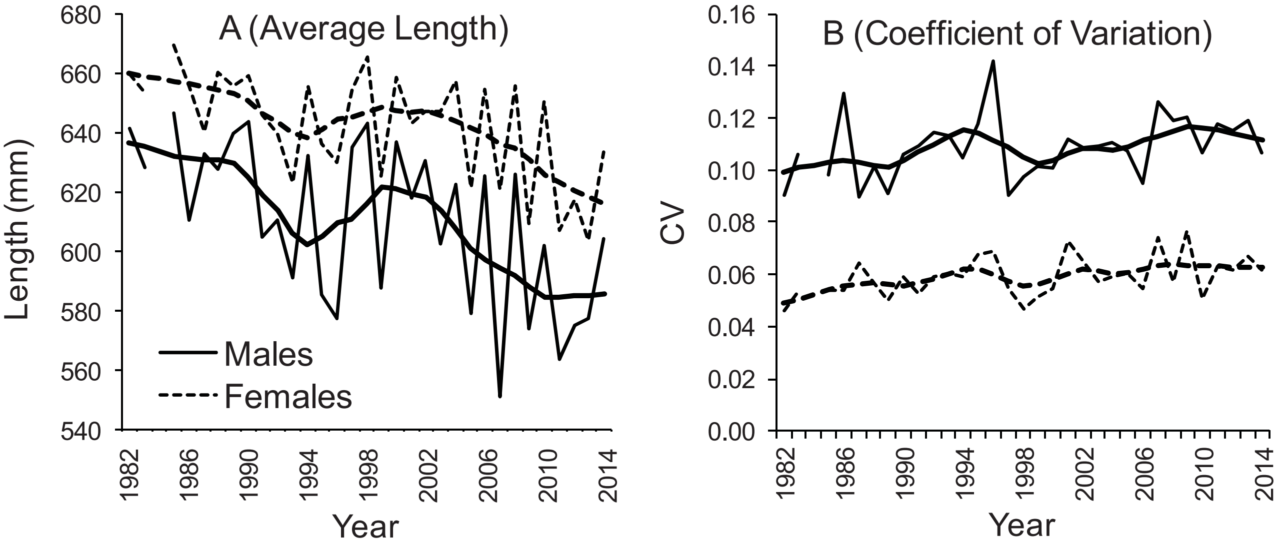

Fig. 7. Average mid-eye to fork length (A) and coefficient of variation of length (B) of age-.1 male and female coho salmon spawners in the Berners River with 0.3 LOESS trends (data are from Shaul et al. in press).

coho salmon size-at-maturity. The proportion of variation in size explained by the Pink-PDO predictors was lower for Berners River adults (0.508 for males and 0.610 for females) compared with troll weight (0.646).

Neither predictive variable was significant in models with the sex ratio of returning adults as the response variable (Table 3; Fig. 9B). The Pink-PDO predictors accounted for about a third of variation in the PCEB index for adults prior to the gillnet fishery ($R^2 = 0.356$) but the PDO variable missed statistical significance (Table 3; Fig. 9C). These predictors also explained over a third of the variation in marine survival ($R^2 = 0.378$; Fig. 9D) but the coefficient of the PDO again failed to reach statistical significance.

Although the pink salmon variable that best predicted adult size (average lags 2 and 4) did not explain a significant amount of the variation in the sex ratio (Fig. 10A), there was a small-to-moderate negative correlation with the PCEB index (Fig. 10C). However, pink salmon biomass showed a moderate-to-strong negative correlation with year-over-year change in both the sex ratio (Figs. 10B, 11A) and the PCEB index (Figs. 10D, 11B).

While pink salmon biomass alone was negatively correlated with marine survival, explaining about a third of variation ($R^2 = 0.332$; Fig. 10E), significant autocorrelation was detected in the residuals at lag 1 and the Durbin-Watson statistic was significant ($p = 0.029$). In other words, although there is an obvious negative correlation between marine survival and pink salmon biomass, we are not able to produce a good predictive model for marine survival. However, a proportion of the difference, or year-to-year change, in the marine survival rate was explained by pink salmon biomass with acceptable model diagnostics ($R^2 = 0.376$; Figs. 10F, 11C).

Results of studies conducted at Auke Creek and in nearby waters have led to the hypothesis that abundant wild pink salmon and hatchery chum and pink salmon juveniles have a positive effect on coho survival by providing food or a "predation shelter" (Briscoe 2004; LaCroix et al. 2009), indicating a potential countervailing positive effect at lag 0 that, combined with biennially autocorrelated pink salmon returns, might offset a negative influence on late-marine growth at lags 2 and 4. We examined similar early marine predictor variables for Berners River coho salmon survival, including (a) the number of fish harvested in four local commercial fishing districts (111, 112, 114 and 115) where pink salmon are likely to intermingle as juveniles with Berners River coho salmon, and (b) combined releases of pink and chum fry by the local DIPAC (Douglas Island Pink and Chum) hatchery. However, regression results did not support a positive interaction, either with predominantly wild pink salmon ($r = -0.072$; $p = 0.733$) or with combined releases of pink and chum salmon in the common sea-entry year ($r = -0.078$; $p = 0.713$). In contrast with the lagged GOA pink salmon catch (pink-PDO predictors), the un-lagged pink salmon catch in local districts did not explain much variation in the year-to-year change in marine survival ($R^2 = 0.033$). The same was true for the un-lagged GOA pink salmon catch.

DISCUSSION

Coho Weight Model

The Pink-PDO predictors explain a substantial amount (65%) of the variation in Southeast Alaska coho salmon weight over a 45-year period spanning both warm and cold North Pacific regimes. Because the predictors were standardized, the estimated regression parameters are compara-

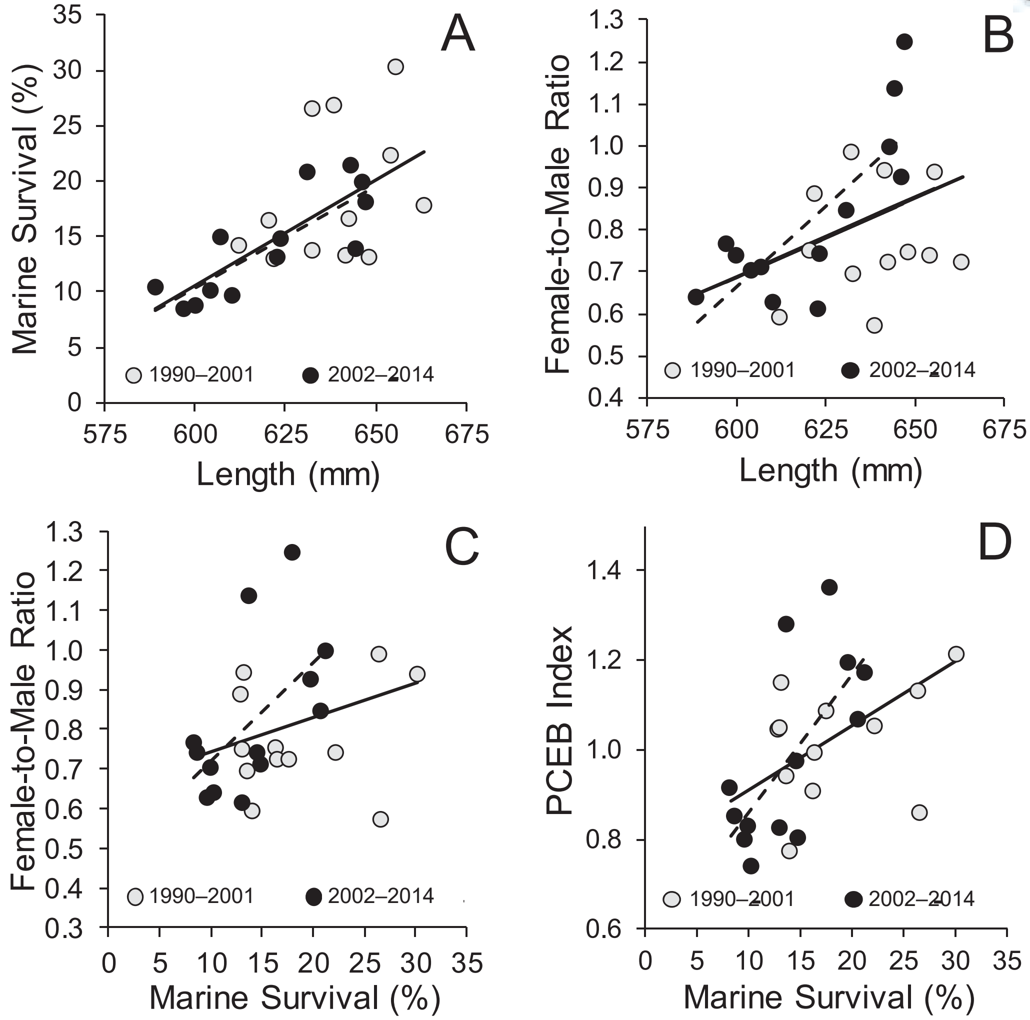

Fig. 8. Regression relationships for age-.1 Berners River coho salmon: marine survival *vs.* length (A), sex ratio *vs.* length (B), sex ratio *vs.* marine survival (C), and PCEB index *vs.* marine survival (D). Earlier years (1990-2001) are shown with gray dots and later years (2002–2014) with black dots. Linear relationships for the entire data series are shown with solid lines while relationships for 2002-2014 only are indicated with dashed lines. Length, sex ratio and PCEB index values are estimated prior to the gillnet fishery and length values are the mean-average for both sexes. Spearman's rho correlations are significant ($p \leq 0.05$) for all relationships except for sex ratio *vs.* survival for the full data series (1990–2014). Note: sex ratio (C) and the PCEB index (D) include elements of survival and are, therefore, not entirely independent from marine survival.

ble, with approximately equal weighting indicated for top-down control (0.508) and climate (0.492) variables targeted at squid recruitment and survival. Our results are in strong agreement with Jorgensen's (2011) hypothesized 2-year lifespan for *B. anonychus*, as well as our hypothesis that coho salmon size reflects a lagged response by reproductively isolated even- and odd-year populations of *B. anonychus* to variable intensity of top-down control by pink salmon. The most likely explanation for the lagged response (Fig. 4) is a related delay in predation on maturing squid by maturing pink salmon that limits the effect on coho salmon growth of direct competition for the current prey cohort. Pink salmon appear to influence coho salmon growth primarily through predation on the parents and grandparents of the current squid cohort, with the parent generation being most important (accounting for 63% of the combined pink salmon coefficients).

One obvious criticism of our approach is that both the predictive and response variables contain autocorrelation. The important effect of this is to potentially produce misleading error rates in statistical hypothesis tests of zero correlation (e.g., Pyper and Peterman 1998). However, our intent was never to simply test the hypothesis that there was zero correlation between any two variables. Rather, we were looking for consistent relationships between coho salmon size and environmental and competition metrics—consistent over a period of improving environment (from 1970 to the early 1990s) and a period of declining environment (mid-1990s to the present, Fig. 6). We did not attempt to adjust error rates or *p*-values, but rather we were guided by the notion that we were especially skeptical of any hypothesis tests that were not highly significant using conventional *p*-value calculations. In the end, we found essentially the same Pink-PDO predictor signal in different measures of coho size, and coho size consistently trended upwards with increases the PDO metric and downwards with increases in the pink salmon metric, in a way that was consistent along both even- and odd-year lines.

The two predominant outlying years when coho salmon weighed substantially more (1995) and less (1999) than indicated by the model (Fig. 5) occurred during a period when salmon were sampled in July in the offshore GOA from the research vessel *Oshoro maru*. Neither outlier is evident in average coho salmon length reported by Kaeriyama et al. (2004) which was more closely correlated with modeled Southeast Alaska coho weight ($r = 0.844$) than with observed weight ($r = 0.444$; Fig. 12), suggesting that growth of mature adults may have been heavily influenced by food availability in geographic areas not sampled during the cruises, likely including the coastal forage fish community which continues to support growth of maturing coho salmon after they arrive in coastal fishing areas. The strong correlation with offshore size provides further support for the hypothesis that the Pink-PDO predictive variables in the Southeast Alaska coho weight model represent the principal climatic and top-down factors affecting *B. anonychus*, the dominant prey species in the diet of fish in the offshore sample (Kaeriyama et al. 2004).

Late Marine Effects

Studies in northern Southeast Alaska have generally failed to support an early-marine critical period for growth and survival of coho salmon in that region and have instead pointed toward an important late-marine period after juveniles leave coastal waters late in their first summer at sea (Briscoe 2004; LaCroix et al. 2009; Orsi et al. 2013). Our results are consistent with these studies in a number of ways. Our predictive model explains the majority of variation in adult size with variables targeted at recruitment of the predominant prey species found in the offshore diet of coho salmon. This finding is consistent with research on coho

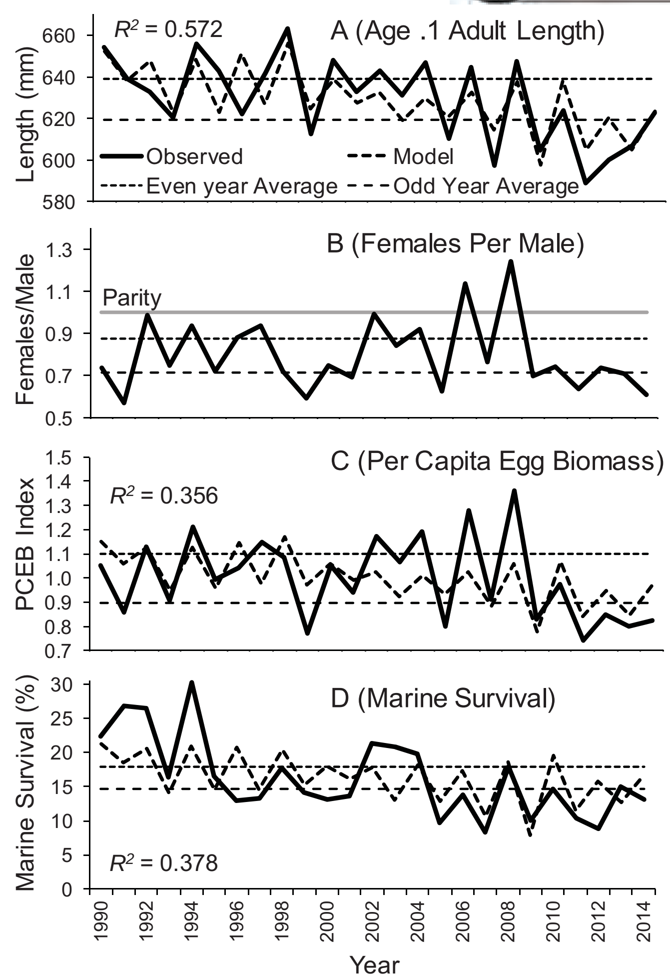

Fig. 9. Average adult length (males and females averaged), females per male, per capita egg biomass (PCEB) index, and marine survival rate of age-.1 Berners River coho salmon. All response variables are prior to exposure to the drift gillnet fishery. Also shown are even- and odd-year averages and significant fits ($p \leq 0.05$) for combined Pink-PDO predictors. Differences between even- and odd-year averages were significant ($p \leq 0.05$) for length, sex ratio, and PCEB index but not for marine survival.

Table 3. Coefficient weights (with 95% confidence intervals), R^2 and adjusted R^2 values, and variable p values for multiple regression models correlating adult size, sex ratio, marine survival, and predicted egg biomass per adult (PCEB index) with the catch of pink salmon in North America (excluding Bering Sea-Aleutian Islands areas) averaged for lags of 2 and 4 years, and the Pacific Decadal Oscillation (average for lags of 0, 2, and 4 years). Variables that are not significant ($p > 0.05$) are marked with an asterisk.

Response variable	Pink salmon			PDO			R^2	Adjusted R^2
	p	Coefficient Weight (C.I.)		*p*	Coefficient Weight (C.I.)			
Troll weight (1970–2014)	<0.001	0.508	(0.363–0.653)	<0.001	0.492	(0.347–0.637)	0.646	0.629
Berners River (1990–2014):								
Length (Males)	0.004	0.536	(0.192–0.880)	0.010	0.464	(0.120–0.808)	0.508	0.463
Length (Females)	0.003	0.454	(0.174–0.734)	0.001	0.546	(0.266–0.826)	0.610	0.574
Length (Average)	0.002	0.501	(0.199–0.803)	0.002	0.499	(0.197–0.801)	0.572	0.533
Females per male	0.151*	0.691	(-0.272–1.654)	0.513*	0.309	(-0.654–1.272)	0.126	0.047
PCEB index	0.027	0.539	(0.069–1.009)	0.054*	0.461	(-0.009–0.931)	0.356	0.298
Marine survival	0.005	0.709	(0.235–1.182)	0.215*	0.291	(-0.182–0.765)	0.378	0.321

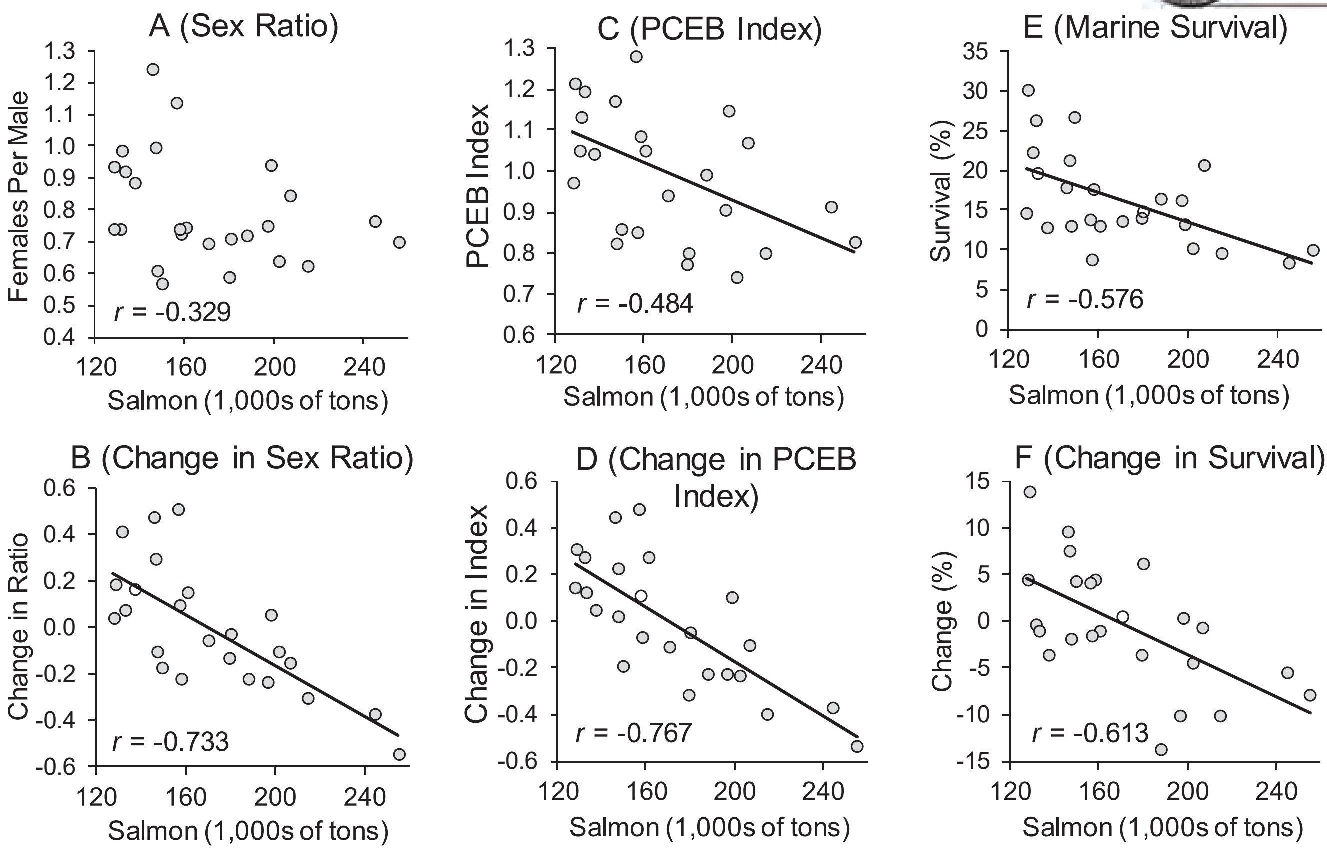

Fig. 10. Relationship between the average pink salmon harvest (lag 2 and 4 years) and the sex ratio (females per male; A), the year-over-year change in sex ratio (B), the PCEB index (C), the change in the PCEB index (D), the marine survival rate (E), and the change in marine survival (F) for coho salmon returning to the Berners River, 1990–2014. Sex ratio and PCEB index values are prior to exposure to the drift gillnet fishery.

scale growth (Briscoe 2004) in indicating that adult size is influenced primarily by conditions encountered in offshore waters of the GOA.

The moderately strong positive correlation between marine survival and size of Berners River adults is, therefore, consistent with the hypothesis that overall survival in the ocean is related to late-marine growth. The evident decrease in variation in survival at smaller adult sizes (Fig. 8A) suggests that slower late-marine growth may reduce both average survival and the potential range of survival rates. This suggests that as the rate of growth slows in the offshore environment, growth-related late-marine mortality may become a proportionately more important influence on marine survival compared with other factors.

Our model indicates about half of the nearly two-thirds of variation in adult size explained by the coho weight model is attributed to the biomass of pink salmon in the GOA while the other half is attributed to climatic factors related to atmospheric forcing (measured by the PDO index). However, when the same Pink-PDO predictors from models explaining adult size were applied to survival-related response variables, only the pink salmon biomass variable showed a consistent statistically significant influence. For example, marine survival for the Berners River population was poorly explained by the Pink-PDO predictors that explain much of the variation in adult size. The model containing these variables together accounted for over a third of variation in marine survival ($R^2 = 0.378$) but the PDO coefficient was not significant. Although the pink salmon predictor alone was significant ($r = -0.576$; Fig. 10E), model diagnostics were poor with the variance of the residuals decreasing with increases in the predictor and with significant autocorrelation in the residuals. In contrast, a direct relationship with adult length explained somewhat more of the variation in marine survival and the model diagnostics were better. This may mean that variation related to late-ocean growth accounted for some of the variation in marine survival for the Berners River population, but that the link to the PDO and pink salmon is less direct. Potential countervailing effects (perhaps less growth-related) by the predictive variables on survival should be considered, however, we found no evidence of a positive relationship with indicators of abundance of pink salmon (or hatchery chum salmon) in near-shore environments.

The pink salmon catch (average for lags of 2 and 4 years) included in the pink-PDO predictors explained much of the year-to-year change in marine survival, sex ratio and PCEB index (with acceptable model diagnostics) suggesting that while trends in marine survival may be influenced by other factors, the biomass of pink salmon has an important effect on year-to-year variation in survival of coho salmon. We infer that the probable underlying mechanism is control of squid prey populations by pink salmon.

More recently (2002–2014), variables associated with growth were more strongly correlated with marine survival (Fig. 8). This suggests that growth-related late marine mortality may have increased in importance as a component of overall marine mortality and has become more sex-specific as adult size has continued to trend lower with increased inter-annual variation (Fig. 7A, 8B). Climate may also have been a factor in this change, as the earlier part of the series (1990–2001) occurred primarily during a warm North Pacific regime that appears to have ended in 1998 (Peterson and Schwing 2003). The return to a colder regime may have influenced both growth and survival of maturing coho salmon in a number of potential ways, including through changes in prey and predator abundance and distribution, and through temperature-related physiological processes.

Different populations of squid may be affected differently by top-down control and climate. Those migrating toward the shelf during summer months (Bower et al. 2002) face an increasing density of increasingly effective predators as growing and maturing salmon concentrate in the northern gulf during their return to coastal streams and hatcheries. A highly regular biennial cycle in *B. anonychus* in the northwestern GOA, with odd-year peaks in paralarvae density averaging over 20 times off-peak density in 1991–2009 (Jorgensen 2011), is consistent with an even-year dominant pattern in the stomach contents index (SCI) of coho salmon in the Alaska Gyre in 1994–2000, but inconsistent with an opposite odd-year dominant pattern in the SCI index to the south in the Subarctic Current (Kaeriyama et al. 2004). Increased variation in size among maturing coho salmon and evidence of a proportionately greater decline in adult size in less migratory fish (Shaul et al. 2011) is consistent with a change in the spatial distribution of squid prey in favor of the more distant Subarctic Current over more northern areas. We hypothesize that the typically high abundance of *B. anonychus* reported in salmon diets in the Subarctic Current, including in odd-numbered years, includes distinct populations that are less exposed to the gauntlet of maturing salmon compared with populations that spawn near the shelf.

A higher female-to-male ratio among coho salmon returning in even years and a moderate positive correlation between this ratio and average length at maturity (Fig. 8B) are consistent with the hypothesis of increased risk-taking by female coho salmon nearing maturity and in poor feeding conditions (Holtby and Healey 1990) and with an apparent strong even-year dominant cycle in mature *B. anonychus* in the northern gulf (Jorgensen 2011). Aydin et al. (2005) observed that, while pink and sockeye salmon switch diets from squid to zooplankton as they move northward from the Subarctic Current, coho salmon appear to consume little during this migration before reaching abundant forage fish populations near the coast. In odd years, females that

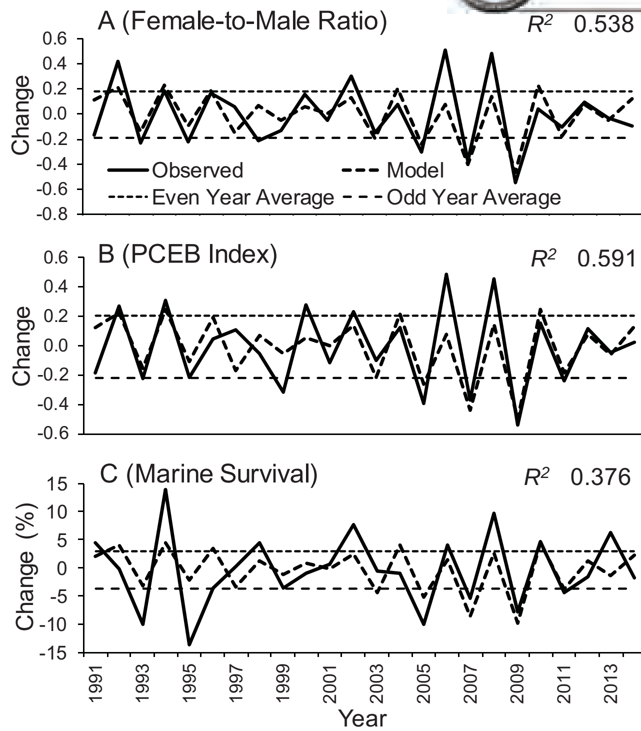

Fig. 11. Year-over-year change in the sex ratio, PCEB index, and marine survival rate for Berners River coho salmon compared with the modeled change based on the average pink salmon catch (lag 2 and 4 years).

may have benefited from abundant forage in the relatively squid-rich Subarctic Current must still cross an increasingly prey-barren expanse of water during their northward migration, potentially inducing them to take increased risk through energy expenditure and exposure to predators in pursuit of food. An increase in correlation between the sex ratio and length and marine survival after 2001 (Fig. 8) suggests that the spatial and temporal distribution of coho salmon mortality, and potentially the underlying mechanisms, may have changed during the study period.

Fishery managers should note that variation in factors affecting late-ocean growth and survival tends to magnify variation in effective spawning escapement. That is, our results show that the usual assumption of stable per capita reproductive capacity is simply wrong. Variation in the PCEB index of the Berners River spawning escapement was substantial (range 0.74–1.39). That means that a typical measured or nominal escapement of 12,000 spawners could represent a potential effective escapement ranging from 8,900–16,700 spawners. Spawner-recruit analysis used to establish escapement goals may be improved by accounting for such variation and the associated variation in marine survival (Fig. 8D). That is, low adult returns lead to potentially low nominal escapement, and this condition will likely coincide with even lower effective spawning escapement, and *vice versa*.

Other studies have pointed to increased growth-related late-marine mortality related to competition for prey with

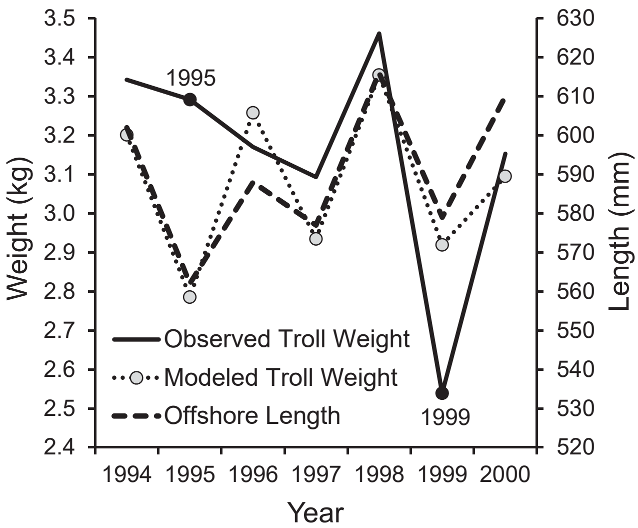

Fig. 12. Observed and modeled average weight of troll-caught coho salmon (with 1995 and 1999 outliers indicated; see Fig. 5) compared with average fork length of fish sampled at offshore stations along longitude 145°W (Kaeriyama et al. 2004).

pink salmon. Ruggerone et al. (2003, 2005) and Ruggerone and Connors (2015) presented evidence indicating that growth and survival of sockeye salmon returning to Bristol Bay and the Fraser River, respectively, was reduced by a competitive interaction with pink salmon occurring primarily in the second year at sea. The reduction in apparent growth in odd years for Bristol Bay sockeye salmon occurred in summer after highly abundant Russian pink salmon populations had migrated to coastal areas, an effect that may have been reinforced by a biennial cycle in prey, including squid (Ruggerone et al. 2005; Ruggerone and Connors 2015).

Wide-spread declines in abundance of Chinook salmon populations have occurred throughout Alaska since 2007 (ADF&G 2013) concurrent with consistent over-prediction by sibling-based forecast models for stocks contributing to Southeast Alaska fisheries (CTC 2014). Broad declines since the early 1980s have been documented in size-at-age and age-at-maturity of Alaska Chinook salmon populations (Kendall and Quinn 2011; Lewis et al. 2015). The steepest declines in size-at-age have occurred in older fish, primarily those that have spent four years at sea, while age-.2 fish have shown little change. A combination of decreasing size-at-age and decreasing age-at-maturity is unexpected, as Chinook salmon have been shown to delay maturity when growth is poor (Healy 1991; Wells et al. 2007).

As in coho salmon, the decrease in apparent growth and survival of Chinook salmon is potentially related to a decline in gonatid squids, which are typically the dominant prey of older Chinook salmon in offshore waters of the northeast and north-central Pacific and the Bering Sea (Davis 2003; Kaeriyama et al. 2004; Davis et al. 2009). Evidence pointing to an increase in late-ocean mortality as a factor in declines in Chinook salmon abundance since the mid-2000s is consistent with an increase since 2002 in the correlation between marine survival and size-at-maturity for Berners River coho salmon.

The timing and mechanisms underlying late-marine mortality remain unclear. While maturing squid (*B. anonychus*) have been found to comprise the majority of the summer diet of coho salmon above a weight of 500 g (Davis 2003), a size that is reached on average in January (Ishida et al. 1998), *B. anonychus* may also be important in the diet of coho salmon during winter months when growing squid are also smaller (Aydin 2000). If so, variation in growth-related mortality linked to squid abundance may begin during winter from a physiologically based process (Beamish and Mahnken 2001). Unfortunately, this hypothesis is difficult to assess because of a scarcity of information on the winter diet and condition of coho salmon in offshore waters.

Predation appears to be the most likely cause of mortality of maturing fish during summer. While females may take greater risks with predators when food is scarce because of their greater energy and growth requirement for successful reproduction (Holtby and Healey 1990), a substantial proportion of males may be motivated by similar pressures. The large amount of variation in size of age-.1 males appears to stem from disruptive selection associated with the option of two viable breeding strategies: stealth (satellite) or dominance (alpha; Healey and Prince 1998). The largest (as well as smallest) individuals returning to the Berners River are invariably males, suggesting that larger males have also expressed a willingness to trade survival for growth in order to be competitive as dominant spawners, even as a substantial proportion of males may pursue an opposite strategy in years of poor growth when a reduced female-to-male ratio likely enhances the advantage to middle-sized males of trading growth for survival, thereby accepting a stealth role over dominance in a more competitive breeding environment.

Specific mechanisms behind risk-taking as a cause of late-marine mortality are poorly understood but may include some combination of increased metabolic cost relative to reward and increased exposure to salmon predators while undertaking searching movements or while pursuing prey in the vicinity of "patches" of food that may concentrate biota at multiple trophic levels (Benoit-Bird and Au 2003). Spatial variation in food and risk factors may occur across different geographic scales, from intensive patches of mesozooplankton (Russell et al. 1992) to the scale of oceanographic domains. Salmon dietary studies indicate that *B. anonychus* typically appears in higher density in the Subarctic Current compared with other North Pacific domains (Davis 2003; Kaeriyama et al. 2004), while on a smaller scale, the species has been found concentrated above seamounts (Nesis 1997). Depending upon their persistence, such aggregations may attract not only higher trophic level salmon species, but species such as salmon sharks, which are abundant and effective predators on maturing salmon (Nagasawa 1998) and also feed extensively on *B. anonychus* and other squids (Kubodera et al. 2007).

Climatic Effects

The occurrence of biennial lags in both of the Pink-PDO predictors (Fig. 4) leads us to infer that the connection between the PDO and coho weight likely occurs through a climatic link to recruitment of squid. The positive association between coho weight and the PDO index across multi-generational lags, with no evidence of influence during off-cycle years, suggests that *B. anonychus* survival is closely coupled with atmospheric forcing in the North Pacific. Potential mechanisms include improved early survival in response to more abundant food associated with a shallower mixed layer (Polovina et al. 1995) and improved transport of larvae by currents to locations favorable for survival (Bailey and Picquelle 2002) during conditions associated with a strong Aleutian Low and high PDO index values. The distribution of squid within the Alaska Gyre, as well as their abundance, may be linked to physical oceanographic variables (Aydin et al. 2000).

However, other plausible mechanisms may contribute to the observed positive relationship between adult coho weight and the PDO. Exceptionally warm climatic conditions in the northeast Pacific in 1997 and 2015 were associated with peaks in average size of juvenile coho salmon sampled during late-July in trawl surveys in northern Southeast Alaska (J. Orsi, joe.orsi@noaa.gov, pers. comm.), suggesting that warm conditions associated with high PDO index values are favorable for early-marine growth of coho salmon prior to when they move offshore and begin feeding on *B. anonychus*. In addition, results of bioenergetics simulation indicate that optimal temperatures for growth are positively related to daily rations (Beauchamp 2009), indicating that warmer temperatures associated with high PDO index values may reinforce the effect of an increase in prey availability by also increasing the growth response in coho salmon. Aydin (2000) estimated that a systemic 10% increase in sea surface temperature in the vicinity of the squid-rich Subarctic Current would favor squid-feeders like coho salmon, as they currently find enough food to benefit from increased metabolic activity associated with warmer water.

Although specific mechanisms behind the inferred connection between the PDO and recruitment of *B. anonychus* await further study, it seems likely that other subarctic cephalopods with similar life histories may be similarly influenced by climate, a factor that should be considered when investigating causes of variation in growth of other higher trophic level species known to consume cephalopods. For example, Wells et al. (2008) found a direct positive relationship between apparent growth of Chinook salmon from the Taku River in Southeast Alaska and the Aleutian low pressure index (closely related to the PDO index used in this study) during their 3rd and 4th ocean years, when Chinook salmon are known to feed heavily upon squid (Davis 2003; Davis et al. 2009).

Our findings do not appear applicable to more southern coho salmon populations that do not feed extensively in offshore subarctic waters. In contrast with our results, size variation of coho salmon stocks south of Alaska has been shown to be negatively correlated with warm conditions (positive PDO; Wells et al. 2006), while recruitment of natural coho salmon from Oregon coastal rivers showed a strong negative correlation with the spring/summer PDO averaged over a period of four years prior to the return year (Rupp et al. 2012).

Interactions with Pink Salmon

An important feature of the relationship between pink salmon biomass and estimates of climate-based capacity (i.e., scaled PDO index variable) is their transition from being strongly correlated with each other during 1970–1990 to being uncorrelated afterward (Fig. 6). The marked change in the relationship between atmospheric forcing and pink salmon returns in the northeast Pacific was associated with a substantial increase in variation in annual coho weight. We infer from these results that a decrease in synchrony between variables representing bottom-up (positive) and top-down (negative) influences has increased vulnerability of epipelagic squid populations to steep declines during periods when both factors are unfavorable for survival. Our model for estimating the climate-based capacity of the GOA ecosystem to produce pink salmon for harvest while maintaining coho salmon at a historical average weight provides a potential template for evaluating some of the ecosystem trade-offs associated with ocean ranching.

Other investigators have found evidence of control of squid populations by pink salmon, based on opposing biennial cycles in the western North Pacific and Bering Sea (Ito 1964; Davis 2003). Ogura et al. (1991) observed an even-year dominant pattern in length of coho salmon in the western North Pacific that developed during the second summer at sea when diet overlap with pink salmon increases. Our results indicate that a similar interaction exists and has been intensifying in the northeast Pacific.

Wild pink salmon populations appear to have benefited from recent climatic patterns and effective fishery management practices. These salmon have remained at high abundance, particularly in odd years, despite a recent turn in the North Pacific climate cycle to cold conditions that have historically been associated with poor returns (Beamish and Bouillon 1993). Interest in further increasing utilization of offshore salmon forage through ocean ranching of pink salmon (Stopha 2013) underscores the importance of understanding the trade-offs at higher trophic levels. Chum salmon, which have the most distinctive diet among species of Pacific salmon (Welch and Parsons 1993) and consume few maturing squid (Kaeriyama et al. 2004), offer an alternative to pink salmon for aquaculture that may substantially reduce the negative effects on higher trophic level species indicated by this study.

We hope that our findings help clarify which species (pink salmon or *B. anonychus*) holds the commanding position in the offshore trophic triangle (Fig. 1). Aydin (2000)

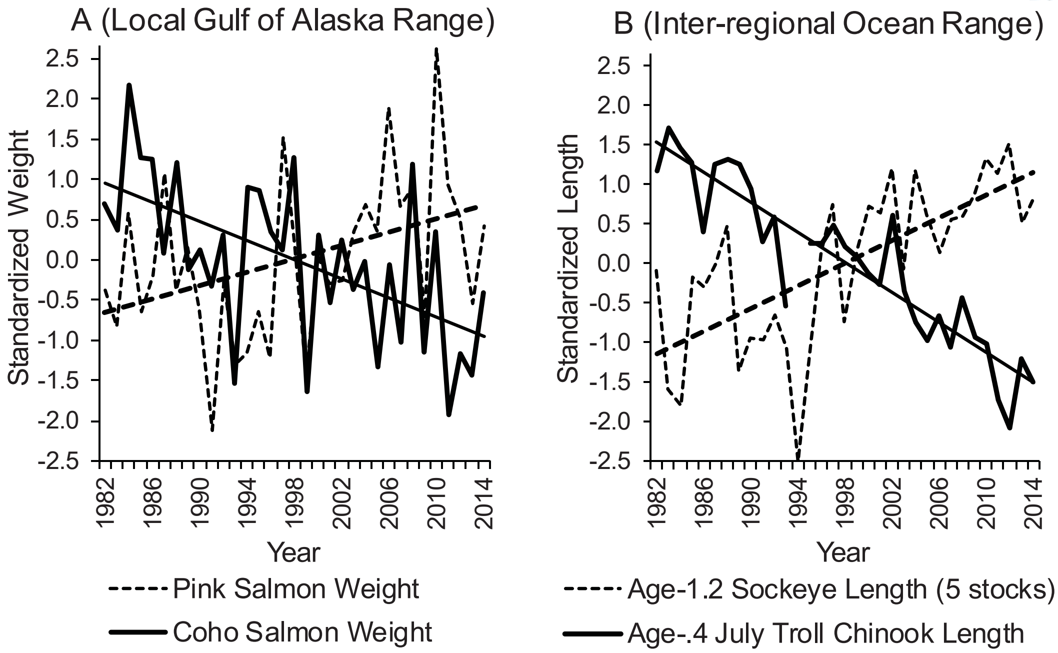

Fig. 13. Standardized size of salmon in harvests and escapements in Southeast Alaska including (A) weight of commercially-caught pink salmon and troll-caught coho salmon, and (B) length of age-1.2 sockeye salmon spawners (male and female average for Chilkoot River, Situk River, Ford Arm Creek, McDonald Lake, and Hugh Smith Lake) and troll-caught age-.4 Chinook salmon (mean-average for ages 0.4 and 1.4). All slopes are significant ($p \leq 0.05$).

has suggested that the trophic position and presumed high productivity of *B. anonychus* may give it a controlling position in the ecosystem. However, our findings suggest that *B. anonychus* is less productive and more vulnerable to intensive predation by salmon than had been presumed. We infer from our results that the pink salmon is a keystone predator that exerts top-down control (over squid) and thereby directs energy flow in the ecosystem.

Aydin (2000) produced from his extensive investigation of trophic dynamics and bioenergetics relationships a conceptual model of salmon carrying capacity in the GOA that predicts that adding more small salmon to the ecosystem through ocean ranching may be self-defeating. He hypothesized that introducing increasing numbers of small salmon may, through density-dependent effects, reduce their early growth rate, thereby delaying their ontongenetic shift to squid prey while placing further pressure on zooplankton. Release of squid from top-down control by their intra-guild predator (pink salmon) may lead to an increase in squid abundance, placing further demand on zooplankton and leading to further decline in salmon growth in a self-defeating cycle.

Our findings, supported by trends in size-at-age for various salmon species in Southeast Alaska (Fig. 13), are consistent with the feed-back loop proposed by Aydin (2000) but suggest that the mechanism has been operating in direct reverse of his hypothesized self-defeating response. Flexible planktivores (age-.1 pink salmon and age-.2 sockeye salmon) have increased in size during 1982–2014 while obligate nektivores (age-.1 coho salmon and age-.4 Chinook salmon) have decreased, suggesting that increased top-down control by salmon (combined with recent unfavorable climatic conditions for squid) may be reducing the mean trophic level of prey in the forage base in a way similar to the phenomenon of "fishing down marine food webs" (Pauly et al. 1998). A shortened food chain, with squid reduced as an intermediate trophic component, may have instead increased energy transfer efficiency between primary production and salmon. Thus, increased top-down pressure by pink salmon on micro-nektonic squid occupying an intermediate trophic level may actually increase the capacity of the GOA to produce salmon biomass, in direct reversal of the self-defeating hypothesis. A key element determining the direction of the feed-back response to increasing pink salmon abundance lies in squid populations, which appear substantially less resilient and more vulnerable to top-down control by salmon than has been assumed.

An important area for future investigation is to explain how flexible planktivores have been able to increase in adult size in the face of indications of decreased squid abundance, and in apparent contradiction with bioenergetics results reported by Aydin et al. (2005) indicating that the zooplankton found in the diet of maturing pink salmon do not have the caloric density needed to support the apparent growth trajectory of pink salmon as they approach maturity. Although untested, one mechanism that could potentially explain an increase in average size of salmon in the face of a decline in squid is a temporal advance in the growth curve resulting from an increase in abundance or nutritional quality of available zooplankton prey beginning earlier in marine life that may allow pink salmon and age-.2 sockeye salmon to achieve larger adult size even while experiencing a smaller boost near maturity from an ontogenetic shift to calorie-rich squid. Under this hypothesis, pink salmon may have become less dependent upon squid for growth while at the same time increasing their per capita impact on squid populations during a longer window of time when they are of sufficient size to be effective predators on maturing squid.

Although a simplified forage base may benefit overall salmon biomass production in the GOA, it is important to emphasize that the inferred transition in the trophic structure of the salmon forage community can be expected to entail offsetting losses among a wide range of higher trophic level species that utilize epipelagic squid (Nesis 1997), including coho, steelhead, and Chinook salmon that occur in far lower abundance than benefiting planktivores but have high per capita value to fisheries. Our results indicate that for Berners River coho salmon, the trade-offs entail not only a reduction in size of maturing fish, but a decrease in their rate of survival and therefore their total number.

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Evaluating Alaska's Ocean-Ranching Salmon Hatcheries: *Biologic and Management Issues*

Environment and Natural Resources Institute
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EXECUTIVE SUMMARY

This review of the biologic and management issues surrounding ocean-ranching hatcheries summarizes both the documented and theoretical threats that these facilities pose to Alaska's wild salmon. It focuses on North Pacific Rim hatchery production and examines the topics of genetics, straying, ecological interactions between wild and hatchery fish, fish-culture practices, biological concerns associated with managing mixed wild and hatchery stock fisheries, questions of the ocean's carrying capacity, and global climatic regime shifts together with associated management implications.

Alaska's ocean-ranching salmon hatcheries operate amidst considerable uncertainty. Perhaps the most striking feature uncovered by this review was the many gaps in the scientific data from which one could fairly draw conclusions of the effects hatcheries may or may not have on wild salmon. Alaska has been successful in augmenting salmon harvest with hatchery-produced fish, but whether or not salmon biodiversity has been adequately protected in the process is unanswered. Data necessary to evaluate interactions between hatchery and wild salmon populations have not, in most cases, been collected. Better data are needed to bring consensus among scientists and managers on how to figure uncertainties into the management equations, such as ocean carrying capacity and genetic risk to wild fish from hatchery straying.

After more than 30 years of debate about the impact of hatchery fish on the genetic diversity of wild salmon populations, there is still no definitive answer to this concern (even given the increase in the body of knowledge). While it may be easy to identify potential risks that hatcheries pose for natural populations, it is not so easy to predict whether deleterious effects have occurred or how serious the consequences may be. However, the documented high incidence of straying of hatchery fish (especially pink and chum salmon in Prince William Sound and Southeast Alaska, respectively) suggests that large-scale ocean ranching has the potential to severely disrupt the extensive population genetic structure that exists among wild salmon populations—a structure that many biologists believe correlates to adaptive traits. To date, there is insufficient data from genetic studies monitoring wild stocks proximal to hatcheries to resolve such issues. But, if such impacts are of a significant magnitude, the operations of certain hatcheries may not be in line with the State of Alaska's Sustainable Salmon Fisheries, Finfish Genetics, and Salmon Escapement Goal Policies nor with its wild-stock priority.

The need to conserve genetic information is fundamental to salmon biodiversity. Both commercial fishing and hatchery production can adversely affect genetic diversity. Alaska's Finfish Genetics Policy recommends designation of hydrologic basins or geographic areas as gene preserves—perpetual repositories of genetic information for all plant and animal species inhabiting such areas. Currently, there are no officially recognized gene preserves in Alaska specifically established for salmon. The state's Finfish Genetics Policy came about as a result of concern that the development and operation of a hatchery system could have a detrimental impact on wild salmon populations. The policy has not been revised since 1985.

Management of a mixed-stock fishery is complex. Factoring hatchery fish into this management equation only makes a hard job more difficult. It is important not to overharvest small salmon populations that may contain unique adaptive traits (and genes). Given the number of streams in Alaska (and the corresponding number of salmon stocks), coupled with the size of the Alaska Department of Fish and Game's staff and budget, conducting the monitoring required to ensure that no wild salmon stocks are being negatively impacted by overfishing or invasion of hatchery strays is nearly impossible. In Prince William Sound alone, the Department currently monitors 150 to 200 of the approximate 800 streams for escapement. In order to monitor all 800, more staff and budget would be needed. The use of thermal marking is a significant advance in technology that enables a closer and more thorough monitoring of mixed-stock fisheries and consequently better protection of wild stocks. At present, there is inadequate information to provide for reliable and timely estimates of wild-stock escapements and run sizes that are needed to direct management of the mixed-stock fisheries, especially for those that harvest chum salmon in Southeast Alaska.

Competition for resources between hatchery and wild salmon stocks has become a significant concern. Based on a review of the literature and discussions with biologists, geneticists, and fishery managers, it is widely believed that extensive ocean ranching may pose a threat to the ocean's carrying capacity and the protection of salmon biodiversity. This may be the most important issue for assessing risks to wild salmon, especially for populations with comparatively small numbers of individuals, and it may be more significant than the risk of loss or change in genetic diversity due to hatchery practices. The potential for hatchery-bred salmon to displace wild fish in the ocean, coupled with the overall lack of knowledge about complex dynamics of the North Pacific ecosystem, suggests that it would be prudent to manage the hatcheries in Alaska conservatively, especially in years of lower ocean-productivity indices.

Fisheries management currently has little data on the effects of ocean variability on marine survival of salmonids even though salmon stocks clearly respond to shifts in climate. Ongoing scientific pursuits should help pinpoint which physical and biological processes lead to changes in salmon growth and survival so that, as the ocean enters a new climate regime, we are able to predict and account for changing trends of fish growth and survival due to marine variables.

With respect to fish-culture practices, Alaska's hatcheries are among the best in North America. The main reasons for this are both fortuitous and purposeful. By concentrating on pink and chum salmon, Alaska's ocean-ranching program has avoided many of the attenuated problems (e.g. domestication and ecological) with long-term rearing species like steelhead trout and coho salmon. Given the late date at which Alaska's ocean-ranching program was established, the state was able to benefit from mistakes made elsewhere. The program started on better footing by having genetic oversight of operations through fish transport permits, hatchery siting, egg takes, broodstock development, etc. Oversight of fish diseases by the state's pathology department has been exemplary and closely follows Alaska's Fish and Shellfish Health and Disease Control Policy.

Given the biologic and management questions of ocean ranching, prioritizing research objectives can help narrow existing information gaps. The State of Alaska has an extensive permitting procedure for starting a hatchery, thorough pathology guidelines, and an adequate genetics policy. However, once operating, hatcheries do not face stringent supervision, monitoring, or evaluation. As can be seen by perusing the reports or plans currently available, it is difficult if not impossible to gauge whether hatchery programs are impacting wild stocks.

Monitoring of hatchery practices is a duty and responsibility of each of the Regional Planning Teams established by the Alaska Department of Fish and Game. Judging from the type of reports they produce (e.g., annual hatchery management plans), their primary concern is development of hatchery-production plans and evaluating the resulting contribution to fisheries. Extensive documentation exists for egg takes, incubation, rearing, and broodstock, as well as for fisheries management for hatchery returns including common property fisheries, special harvest areas, cost recovery, and marking/tagging studies. While this is useful information, it is difficult to ascertain whether the Regional

Planning Teams perform any substantive review of hatchery operations as is specified in the description of planning team duties. For instance, there is virtually no information about whether the egg take reflects the run-timing characteristics of the stock, the degree to which adequate numbers of spawners are used for hatchery broodstock, how often a stock has been used as a brood source, straying rates, or the number and final destination of fish that escape the cost-recovery harvest. Some plans have information that addresses the protection of wild stocks, however, there is almost no information on how effective any of the proposed measures have been. As to whether a site for a hatchery is appropriate (one of the public benefit criteria), there is no published documentation addressing this point.

This report concludes that industrial-scale hatchery salmon production, which releases billions of smolts into the North Pacific Ocean, could be jeopardizing Alaska's wild salmon. Additionally, there are legitimate management questions as to whether hatchery operations in Alaska are in line with current Alaska Department of Fish and Game policies, including the Sustainable Salmon Fisheries Policy.

INTRODUCTION

Today there is much concern over the status and fate of wild salmon populations. Fueling this are recently published reports by several preeminent scientists questioning the degree to which human activities have impacted the overall biodiversity of wild salmon. In response, Trout Unlimited launched its Alaska Salmonid Biodiversity Program in Alaska in January 2000. Soon thereafter, the Program published a survey of its concerns about Alaska salmon and salmon fisheries (Konigsberg 2000). One concern focused on the future management and protection of wild salmon biodiversity and specifically identified Alaska's ocean-ranching program as a potential threat to wild salmon biodiversity. To further investigate this, Trout Unlimited contracted with the University of Alaska Anchorage's Environment and Natural Resources Institute (ENRI) in October 2000 to review and summarize information on both the documented and theoretical threats associated with ocean-ranching programs to Alaska's wild salmon populations.

This report is the result of that investigation. It begins with an overview of North Pacific Rim hatchery production and then reviews specific scientific and management issues associated with hatchery production. Topics addressed include straying and the potential genetic impacts of introgression and hybridization versus the demographic effects of displacement. Data germane to the ecological interactions between wild and hatchery fish are presented, such as density-dependent competition for resources, predation, and altered behaviors of hatchery-produced salmon compared to wild salmon. Marine concerns, such as understanding the ocean's carrying capacity and predicting global climatic regime shifts, are considered as well as management implications. Finally, it provides an in-depth look at Alaska hatchery management and fish-culture practices, policies, and the biologic concerns associated with managing mixed wild and hatchery stock fisheries. This report does not address the socioeconomic issues associated with the ocean-ranching industry.

Note that the terms *stock* and *population* are used interchangeably throughout this report as are the terms *ocean ranching* and *salmon ranching*. With the exception of sockeye salmon *(Oncorhynchus nerka)* aquaculture, where juvenile sockeye are released into natural freshwater environments for rearing, the preponderance of Alaska hatcheries are located adjacent to the sea and produce pink salmon *(Oncorhynchus gorbuscha)* and chum salmon *(Oncorhynchus keta)* that are released directly into marine waters. Rather than use the terms *enhancement* and *supplementation*, which have imprecise meanings, this report simply distinguishes between hatchery-produced and wild or naturally-produced salmon.

NORTH PACIFIC RIM HATCHERY PRODUCTION

Since 1991 Canada, Japan, Russia, and the United States have annually released 5 to 6 billion hatchery-reared salmon into the Pacific Ocean (Beamish, et al. 1997; North Pacific Anadromous Fish Commission [NPAFC] 1995). A brief overview of hatchery production of the North Pacific salmon fishery by major areas of production is presented below to help establish the scale of these activities. A more detailed section covering Alaska management, regulations, and policies is presented later in this report.

BRITISH COLUMBIA, CANADA

The joint federal/provincial Salmonid Enhancement Program (SEP) of Canada was initiated in 1977 with the long-term objective of doubling the catch of Pacific salmon *(Oncorhynchus spp.)*, steelhead trout *(Oncorhynchus mykiss)*, and sea-run cutthroat trout *(Oncorhynchus clarki)* by protecting, rehabilitating, and enhancing fish stocks throughout British Columbia. Projects were designed to restore depressed stocks through improved management and employment of various restoration and enhancement techniques. The methods used have included improvement of fish habitat, removal of barriers to fish migration, construction of both in-river spawning channels and groundwater side channels for spawning habitat, placement of cover to increase rearing habitat, enrichment of streams and lakes, stabilization of stream banks, and fish culture. Fish culture plays a major role in SEP. Its annual stocking programs are intended to accelerate recovery of severely depleted wild stocks and to sustain major sport and some commercial fisheries. Fish culture methods include hatcheries, spawning and rearing channels, and instream incubation boxes (Kelly et al. 1990).

Hatcheries built under SEP provide well over 10% of the total British Columbia catch of coho salmon *(Oncorhynchus kisutch)* and chinook salmon *(Oncorhynchus tshawytscha)*. SEP fish production in 1984 was over 375 million juveniles (including the six Pacific salmon species and cutthroat trout) from all enhancement techniques. Major production in 1984 was from 32 hatcheries, four spawning channels, and two side channel improvement projects. Over one-half of fish production in 1984 came from three facilities: the Big and Little Qualicum spawning channels and hatcheries and the Babine spawning channels. The Babine facility produces over 100 million sockeye salmon juveniles annually and the Big and Little Qualicum facilities produce over 80 million juveniles, most of which are chum salmon (Kelly et al. 1990).

British Columbia currently has 38 federal hatcheries, and there are also 150 public involvement projects ranging from classroom incubators to hatcheries producing about 2 million juveniles. Peak production from SEP facilities occurred in 1990 when just over 650 million fish were released including 66 million chinook, 189 million chum, 21 million coho, 283 million sockeye, and 88 million pink salmon. Since then there has been a declining trend, with significant reductions of released juvenile chum salmon into the rivers of the Georgia Basin. Approximately 429 million fish were released in 1998; chum (154 million) and sockeye (186 million) salmon were the most numerous (R. Cook, pers. comm.). Up to 80% of the juvenile coho salmon in southern British Columbia coastal waters have been attributed to enhancement projects (Noakes et al. 2000a).

JAPAN

Japan operates the most extensive ocean-ranching program in the world both in terms of the number of hatcheries and the number of juveniles released annually. There are 150 hatcheries on Hokkaido and 165 on Honshu (Heard 1996), most of which are operated by private fisherman cooperatives.

From the mid-1980s to the mid-1990s, over 2 billion juvenile salmon were released annually from these hatcheries. Most were chum salmon, and a little over 100 million pink and 10 million masu *(Oncorhynchus masu)* salmon were released as well. In 1995 Japanese hatcheries released just over 2 billion chum, 118 million pink, and 13 million masu salmon (NPAFC 1995).

All Japanese stocks of salmon except for masu are maintained by artificial propagation. For management purposes there is basically one stock of chum salmon, which is supported by an extensive hatchery program. Any adult fish returning in excess to those needed by Japanese hatcheries are generally harvested and not allowed to spawn naturally (Moberly and Lium 1977). Thus, any possible conflict between wild and hatchery chum salmon stocks in Japan is moot as the species exists there almost solely as a result of artificial fish culture.

SOUTH KOREA

South Korea has a small hatchery program that began in 1913. Hatchery-produced chum salmon are released in 12 streams on the east coast of South Korea. Between 1970 and 1995 the number of juvenile chum salmon released annually increased from 8 thousand to 16 million (Seong 1998).

RUSSIA

The first salmon hatcheries in Russia were built by the Soviets in the 1920s at Teplovka Lake (a tributary to Amur River) and at Lake Ushkovskoye (a tributary to Kamchatka River). The Japanese also built a number of salmon hatcheries in the late 1920s in the northern part of Sakhalin Island and in the Kurile Islands that came under Russian control following World War II. A total of 25 hatcheries were in operation by 1964. Subsequently, the more inefficient hatcheries were abandoned. There are currently 22 operating in the far east of Russia: 17 on Sakhalin Island, 4 on Amur River tributaries, and 1 on a Kamchatka River tributary. The number of juveniles released from these hatcheries between 1985 and 1990 was between 600 and 700 million; about 450 million were pink salmon and 200 million were chum salmon (Dushkina 1994). In 1995, approximately 478 million hatchery fish were released; almost all were pink and chum salmon along with a few million sockeye and coho salmon (NPAFC 1995). About 500 to 550 million Pacific salmon fry are released annually; about 52% are pink and 48% are chum (Radchenko 1998).

U.S. PACIFIC NORTHWEST

Development of salmon hatcheries in the U.S. Pacific Northwest began in the late nineteenth century. Hatcheries have played an increasingly prominent role in salmon supplementation and enhancement in the region ever since. Most public hatcheries were built to mitigate for extensive losses of natural habitat due to industrial development, urbanization, and especially to damming of major river systems like the Columbia. In the Columbia River Basin alone, for example, there are now nearly 100 hatcheries producing about 200 million juveniles each year (Flagg et al. 2000).

Chinook was the first salmon species to be artificially propagated in western North America; this occurred in 1872 on the McCloud River in California. More chinook salmon have been produced from hatcheries than any other species in the Pacific Northwest. Today, the Columbia River Basin is the center of chinook hatchery production, with approximately 27% of the world's chinook salmon being cultured there (Mahnken et al. 1998). Hatchery production of chinook salmon in Washington State began in 1895 at the Kalama (a Columbia River tributary) hatchery. Production grew to about 50 million released fish by the late 1930s. By the early 1980s, more than 300 million chinook salmon were being released from Pacific Northwest hatcheries.

Coho salmon are among the most successful of hatchery-cultivated species in the Pacific Northwest.

In the 1960s advances in feed, disease prevention, and better understanding of the early life-history culture requirements of coho salmon led to improved survival of hatchery fish. Increased reliance on hatchery coho salmon led to rapid expansion of production through the 1970s. In 1981 a record 198 million hatchery coho salmon were released from Pacific Northwest hatcheries. In the following years coho salmon production in the Pacific Northwest stabilized and then began to decline. By 1995 only 72 million coho were released from Pacific Northwest hatcheries (NPAFC 1995).

In 1995 approximately 470 million fish were released from hatcheries in four Pacific Northwest states: California, Idaho, Oregon, and Washington. About 64% of the hatchery fish in this region are produced in Washington, where hatchery enhancement has been an integral part of salmon management programs since the early 1900s. By 1976 there were 52 separate salmon enhancement projects operating statewide, 39 of which were hatcheries. The total 1976 enhancement effort resulted in release of over 151 million chinook, coho, chum, and pink salmon. By 1985 this program had grown to 111 projects statewide including 70 hatcheries. The total release for 1985 was over 365 million fish; over 99% of these were chinook, coho, and chum salmon (Kelly et al. 1990). In 1995 Washington hatcheries released just over 300 million fish: 159 million chinook, 57 million coho, 59 million chum, 16 million sockeye, and 11 million steelhead. In the same year Oregon released 80 million fish, California 67 million, and Idaho 17 million; most of these fish were chinook salmon (NPAFC 1995).

ALASKA

There was a flurry of private hatchery construction in Alaska during the early 1900s (primarily in Southeast, Prince William Sound, and Kodiak Island), but it was short-lived and with little apparent success. An amendment in 1900 to the Alaska Salmon Fisheries Act required any person, company, or corporation taking salmon for commercial purposes in Alaska waters to establish a hatchery (Roppel 1982). This amendment was poorly conceived and not stringently enforced. A number of canning companies did construct hatcheries, but they were poorly sited. Water was often of poor quality and quantity, and insufficient numbers of salmon returned to provide eggs for incubation. Two major company hatcheries were built in Southeast Alaska near Ketchikan: one at Boca de Quadra and the other at Heckman Lake. The latter was eventually enlarged to a capacity of 110 million eggs and at the time was the largest in the world (Roppel 1982). By 1936 all hatcheries in Alaska had closed.

Only one attempt was made to propagate salmon in Alaska between the 1930s and 1950s. It was an experimental pink salmon hatchery operated by the U.S. Fish and Wildlife Service (FWS) at Little Port Walter on south Baranof Island in Southeast Alaska. By then a complete reversal of management philosophy had taken place since the federal government first mandated artificial propagation. A policy of regulating the fisheries replaced that of artificial propagation and remained in effect in Alaska until the 1970s.

In the mid-1970s, commercial salmon harvests in Alaska reached near historic lows (20 to 25 million fish) compared with the very high salmon harvests of the 1930s (100 to 126 million fish). To counteract declining commercial salmon harvests, the state embarked on an ambitious salmon enhancement program. By 1988 the Alaska Department of Fish and Game (ADF&G) was operating 16 hatcheries throughout Alaska, which were annually producing more than 300 million juvenile salmon (Kelly et al. 1990). There are currently 2 state hatcheries, 27 private hatcheries, and 3 federal hatcheries operating in Alaska (Figure 1). The state hatcheries primarily produce salmonid species targeted for sport fisheries. Private hatchery corporations are permitted to operate salmon hatcheries and recoup their operational costs from the harvest of adult fish. Two of the federal hatcheries are generally used for

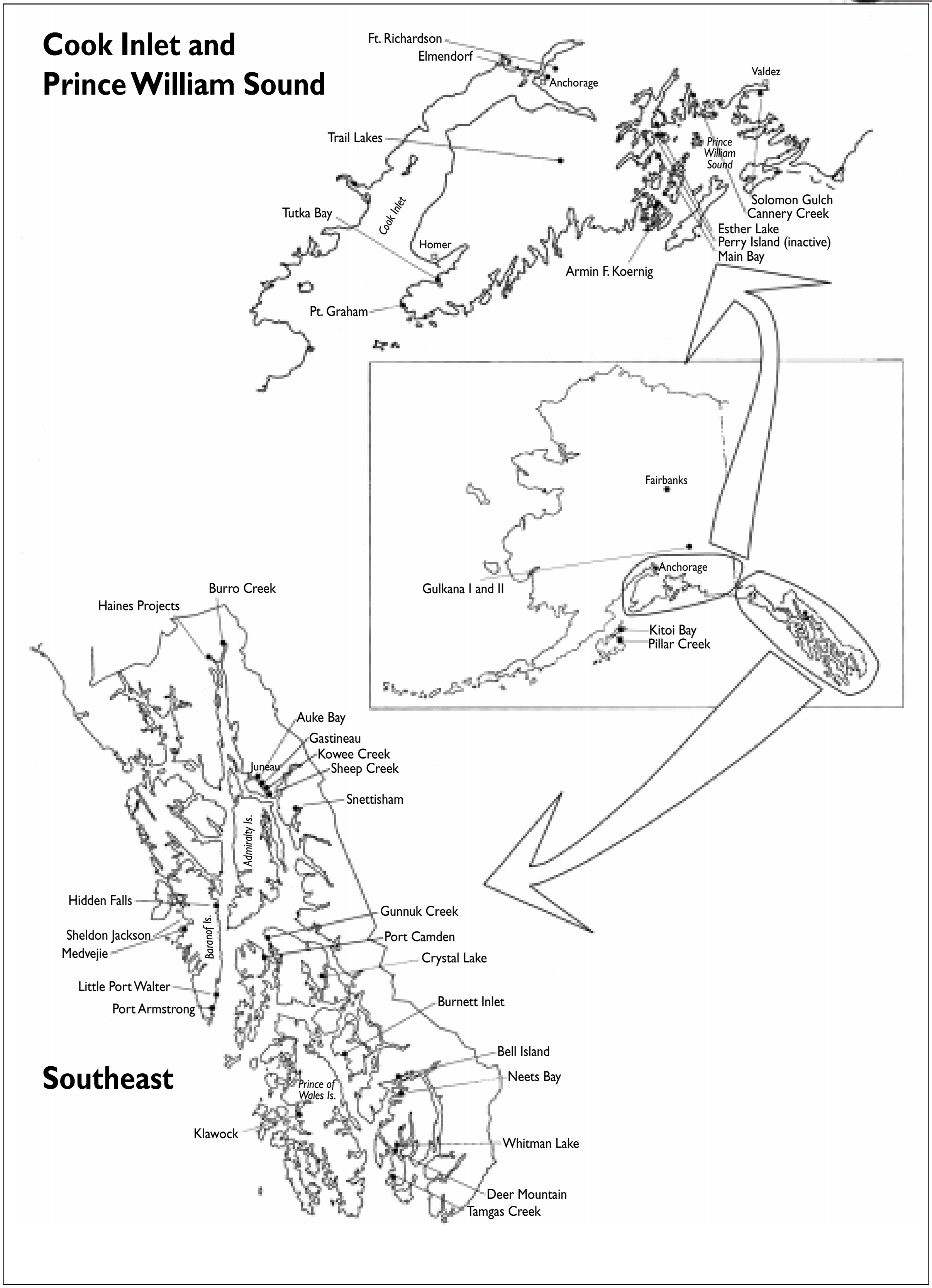

Figure 1. Hatchery locations in Alaska (McNair 2001).

research and the third is operated by the Metlakatla Indian Community with oversight by the U.S. Bureau of Indian Affairs (McNair 2001).

Pink and chum salmon make up the largest proportion of salmon produced in Alaska hatcheries and all come from private hatcheries. Prince William Sound and Southeast Alaska are the predominant regions in which hatchery production occurs. The Prince William Sound Aquaculture Corporation (PSWAC) operates the largest hatchery program in North America, releasing more than 400 million pink salmon each year. A little over 1.4 billion salmon were released from Alaska hatcheries in 2000, including nearly 600 million pinks in Prince William Sound and 385 million chums in Southeast. Production levels, in terms of egg take and releases, were at about this level throughout the 1990s (McNair 2001).

Hatchery-produced fish accounted for roughly 34% of the commercial common property harvest of salmon in 2000 (McNair 2001). Of these, 64% were chum; 42% were pink; 24% were coho; 4% were sockeye; and 19% were chinook (Table 1). Regionally, the relative hatchery contribution varied considerably from a high of nearly 80% of all salmon caught in Prince William Sound; 27% in Southeast; 10% in Cook Inlet; 32% in Kodiak; and 0% in the Chignik/Alaska Peninsula, Bristol Bay, and Arctic-Yukon-Kuskokwim areas (Table 1).

Table 1. Alaska commercial harvest of hatchery-produced fish in 2000.

Region	Percentage of Hatchery-Produced Fish in Commercial Harvest by Species					Percent of Total Harvest
	Chinook	Sockeye	Coho	Pink	Chum	
Southeast	30	16	20	1	73	27
Prince William Sound	0	34	65	82	88	80
Cook Inlet	8	15	3	2	0	10
Kodiak	0	16	40	37	26	32
Chignik/Alaska Peninsula	0	0	0	0	0	0
Bristol Bay	0	0	0	0	0	0
Arctic-Yukon-Kuskokwim	0	0	0	0	0	0
Statewide	*19*	*4*	*24*	*42*	*64*	*34*

BIOLOGIC ISSUES

Salmon hatchery operations have a long history and figure prominently in the fisheries programs of all of the states, provinces, and nations that have indigenous salmon populations. From the outset hatcheries have been surrounded by controversy, and their perceived benefits have waxed and waned periodically with changing public attitudes and with scientific advances in their operations. This section of the report focuses on the fundamental biologic issues associated with salmon hatcheries: genetics, homing/straying, ecological interactions, and limitations of the marine environment.

GENETICS

Populations of many fish species, particularly the salmonids, are characterized by complex structures of subpopulations representing historically developed population aggregates. Such aggregates share common spawning areas and times, yet maintain independent morphologic and behavioral characters and a high degree of genetic isolation. These population systems as a whole are characterized by long-term genetic stability due to reciprocal balance between dynamic factors, such as random genetic drift and migration and the stabilizing influence of natural selection (Ryman and Utter 1987). In other words, wild fish are adapted to their environment.

In general, declines in population productivity from habitat degradation and the nongenetic effects of overfishing have caused greater losses in productivity or population resilience than has genetic degradation. In the long term (e.g., over scores of generations), however, the harmful effects of accumulated genetic degradation within populations, loss of populations and the associated genetic diversity, and the accompanying hindrance of genetic adaptation to changing environmental conditions may equal or exceed the effects of habitat degradation and overfishing. The productivity of populations and their resilience to environmental change is a result of their genetic diversity (Busack and Currens 1995). Even a modest loss of adaptiveness for already degraded populations may cause extinction in the absence of rapid genetic recovery or favorable human intervention (Reisenbichler 1996). Furthermore, different salmonid populations use spawning, rearing, migratory, and oceanic resources in a variety of ways and can be expected to show a similar diversity in response to changing environmental conditions. This diversity therefore can be expected to buffer total productivity for the resource against periodic or unpredictable changes. Events of the recent past, in particular the eruption of Mount St. Helens and the strong El Niño events, remind us that, on an evolutionary time scale, sudden and drastic change is the rule rather than the exception. Loss of interpopulational diversity thus may lead to a reduction in overall productivity and a greater vulnerability to environmental change (Waples 1991).

Conservation of genetic resources and minimization of genetic risks from artificial propagation are emerging as a central fisheries management issue, and discussion about the role of genetics in fishery management has increased markedly since the 1970s. This can be seen by the numerous papers, symposia, and workshops on the topic (Allendorf and Waples 1996; Busack and Currens 1995; Campton 1995; Kelly et al. 1990; National Research Council 1996; Reisenbichler 1996; Reisenbichler and Rubin 1999; Scientific Review Team 1998; Sound Science Review Team 1999; Waples 1991, 1999).

Many lines of evidence suggest that hatchery production may adversely affect wild stocks. In the last 100 years, at least 27 species and 13 subspecies (40 taxa) of North American fish have become extinct. Among possible contributing factors that have been suggested to have led to such extinctions are effects of introduced species (27 of 40 taxa), hybridization (15 of 40 taxa), and overharvesting (6 of 40 taxa) (Williams et al. 1989). These results can be linked at various levels to hatchery operations or fish stockings, justifying widespread concern among many biologists about loss of genetic diversity. However, while it is easy to identify risks that hatcheries pose for natural populations, it is not so easy to predict whether deleterious effects will occur or, if they do, how serious the consequences will be (Waples 1999).

Stock or fish transfers among hatcheries or watersheds are well documented. This is especially true for salmon and steelhead in the Pacific Northwest where artificial gene flow and mixing of previously isolated gene pools have historically been standard practices. In the Columbia River, similar gene frequencies characterize several hatchery populations of chinook salmon (Utter et al. 1989). All hatchery summer steelhead for Washington State comes from just two stocks. Campton (1995) feels that any genetic effects caused by the importation of exogenous fish or gametes should not be considered caused by hatcheries per se, but rather an effect caused by a management process that used too few donor stocks.

The indefinite perpetuation of a population of fish is contingent upon maintenance of sufficient genetic diversity to allow adaptation to environmental changes (Thorpe et al. 1981). The extinction of a discrete population (or stock) is tantamount to a loss of genetic diversity within the species. The need for genetic material preservation is a universally accepted concept and is a fundamental purpose of the International Biosphere Reserve Program initiated by the United Nations. Virtually all biologists agree that a wide range of genetically diverse traits exists in naturally spawning wild stocks and that these are worth protecting (Kelly et al. 1990).

Genetic variability within and among fish populations constitutes the resource base that enables a species to survive and adapt to changing environmental conditions (Gharrett and Smoker 1993a, b; Gharrett et al. 1999b; Philipp et al. 1986). This variability is derived from a combination of many heritable traits developed and maintained through a complex set of long-term natural selective processes. Within a population, the number, frequency, and diversity of alleles present can measure genetic variability. Alleles are the variant forms of genes that are the basic units of heredity; the particular set of alleles present gives a stock its genetic uniqueness. In order to determine the extent to which two fish stocks differ genetically, scientists examine their genotypic and phenotypic structure. Genotypes can be studied qualitatively by molecular biologic techniques such as DNA sequencing, DNA and protein electrophoresis, and analyses with histochemical stains. Phenotypic differences between stocks can be teased apart to reveal the underlying genetic and environmental components by comparing phenotypes of individuals from different stocks raised in similar environments and measuring phenotypes of related individuals raised in contrasting environments. Both molecular/genotypic and phenotypic approaches can be used to estimate actual gene differences between stocks and the adaptive significance of those differences.

A great deal of protein electrophoretic information has been collected on salmon and on steelhead, rainbow, cutthroat, and brown trout *(Salmo trutta).* These data have been of value in a variety of ways and have enabled large genetically distinct groups of salmon to be identified. It is now known that three major, genetically distinct groups of sockeye salmon occur: one in Asia, one in Alaska to mid-British Columbia, and one ranging from mid-British Columbia south (Varnavskaya et al. 1994). These large genetically distinct groups may be comprised of many stocks. For example, a survey of electrophoretic diversity of 52 sockeye populations throughout Southeast Alaska identified three geographic groupings corresponding to the southern inside waters, the far southeastern islands (including Prince of Wales Island), and inside waters of northern and central Southeast Alaska (Wood et al.

1994). In British Columbia, five distinct groups of chum salmon, consisting of 83 separate stocks, have been identified (Kondzela et al. 1994).

A primary concern with hatcheries is their role in influencing genetic change (Utter 1998; Waples 1991). Indeed several studies have detected genetic differences between hatchery-produced and wild populations (Nielsen et al. 1994; Skaala et al. 1990, 1996). Unintended changes in allele frequencies or gene combinations in populations can potentially depress productivity (Busack and Currens 1995).

More recent studies have demonstrated that genetic changes may occur in farmed Atlantic salmon *(Salmo salar).* Altered allele frequencies and lowered heterozygosities in these fish relative to wild source populations have been recorded in Scotland and Ireland (Crozier 2000). An issue with farmed salmon involves the potential effects of interactions between them and the wild populations they come in contact with after escaping from sea pens. In Northern Ireland, the genetic status of a small wild population of Atlantic salmon was studied after an escape of farmed salmon from nearby sea cages led to interbreeding. Juvenile salmon in the first generation after interbreeding showed significant differences in the frequency and occurrence of some alleles. Observations of temporal change, the presence of a previously absent allele, and the genetic disequilibria reinforce a general conclusion that genetic change in the wild Atlantic salmon population reflects the influence of one or more episodes of escaped farmed salmon breeding in the river (Crozier 2000).

Direct genetic effects from hatchery production may occur if cultured fish hybridize with wild fish. Hybridization of different gene pools can theoretically have two important genetic consequences: loss of interpopulational genetic diversity and outbreeding depression (Waples 1991). According to Campton (1995), the natural spawning of hatchery fish in the habitat of wild populations can potentially lead to one or more of several outcomes: decreases in between-population genetic variation, decreases in within-population genetic variation, and decreases in fitness of the wild population (outbreeding depression).

Although hybridization typically increases the average gene diversity within the hybridizing populations, it also results in loss of gene diversity between populations (Waples 1991). With salmonids, the concern is that a variety of locally adapted stocks will be replaced with a smaller number of relatively homogeneous ones (Allendorf and Leary 1988). This process of consolidation tends to limit the evolutionary potential of the species as a whole (Waples 1991). The principal mechanisms leading to hybridization of hatchery and wild fish are (1) unintentional straying of hatchery fish into wild spawning grounds and (2) deliberate releases of hatchery fish to either increase population size or as conservation measures intended to save populations at risk or reintroduce native populations that have been eradicated. The reproductive effectiveness of hatchery-reared salmonids in the wild has been analyzed in several systems (Fleming and Petersson 2001; Garcia-Marin et al. 1999; Williams et al. 1996).

Decreases in fitness can occur when two genetically diverged or reproductively isolated populations interbreed (outbreeding depression). Extensive arguments have been made regarding the potential for outbreeding depression in Pacific salmon (Gharrett et al. 1999a). While many studies have demonstrated phenotypic differences between hatchery and wild fish, relatively few are clearly genetic. Examples of local adaptation appearing to have a genetic basis are rate of embryo development, homing ability, rheotactic swimming ability in emerging fry, outmigration timing of smolts, timing of returning adults, and variations of fecundity and egg size (Campton 1995; Hebert et al. 1998; McGregor et al. 1998; Smoker et al. 1998, 2000).

One often-mentioned negative effect from artificial propagation is a genetic change that reduces fitness for natural reproduction. Apparent loss of fitness in hatchery populations of resident trout has been demonstrated and widely accepted (Ryman and Utter 1987). However, this potential hazard has not been universally accepted as real or relevant to management of salmon. Skepticism stems from the anadromous life history of salmon. Culture of salmon involves rearing in captivity during freshwater stages and then release to use marine food supplies. Accordingly, measuring genetic changes and corresponding loss of fitness becomes complicated for populations experiencing natural conditions for much of their life cycle (Reisenbichler and Rubin 1999). Consequently, there is a reluctance to accept the argument that the genetic fitness of hatchery fish to produce viable fry declines substantially under natural conditions. There are also examples of hatchery fish successfully spawning in the wild like the chinook salmon in the Umatilla and Walla Walla tributaries to the Columbia River where they had been extirpated by dams, indicating that hatchery production is not necessarily correlated with a complete loss of fitness.

In Alaska, there exists a correlation in Prince William Sound of marine survival (one important component of fitness) in hatchery pink salmon and wild pink salmon. The high productivity estimated in both components suggests no measurable depression of saltwater fitness in either after more than ten generations of hatchery culture (W. Smoker, pers. comm.). However, Reisenbichler and Rubin (1999) argue that published information, along with studies in progress, collectively provide evidence that artificial propagation of steelhead trout, chinook and coho salmon, and probably other Pacific salmon results in significant genetic changes that lower fitness. At least eight studies have shown genetic differences between hatchery (ocean-ranched) and wild populations of Pacific salmon in behavioral or physiological traits that could reduce the fitness of hatchery fish (Reisenbichler and Rubin 1999). For example, development rate may change in response to novel water temperature regimes (Lannan 1980); time of spawning and growth rate may change due to either artificial or natural selection (Nickelson et al. 1986); and antagonistic behavior may increase (Swain and Riddle 1990), territorial behavior decrease (Norman 1987), and predator avoidance decrease (Berejikian 1995) in response to unnatural conditions in the hatchery.

Two published studies (Leider et al. 1990; Reisenbichler and McIntyre 1977) and three in progress (according to Reisenbichler and Rubin 1999) found the survival of naturally spawning hatchery fish was less than that for wild fish. The reproductive success of hatchery adults was lower than that of wild adults, and relative survival of hatchery fish consistently declined through successive life-history stages. These studies suggest the same conclusion: hatchery programs that rear steelhead trout or chinook salmon before release may genetically change the population and thereby reduce reproductive success when these fish spawn in natural systems (Reisenbichler and Rubin 1999). Reisenbichler and Rubin (1999) suggest that genetic change in fitness results from traditional artificial propagation of anadromous salmonids held in captivity for extended periods. In similar studies, Fleming and Gross (1989, 1992, 1993) demonstrated many changes in coho behavior, wherein hatchery coho were less able to compete for mates and had less ability to spawn successfully in the wild than did wild-origin fish. No comparable data are available for sockeye salmon, but it seems prudent to assume that the same conclusion holds. No comparable data are available for species (pink, chum) held in captivity for shorter portions of their life cycle, nevertheless similar though smaller genetic changes may be expected (Reisenbichler and Rubin 1999).

The potential for genetic interactions between hatchery and wild salmonid populations in the North Pacific has increased considerably since the 1970s. This is because efforts to mitigate losses to wild stocks from overfishing, destruction of habitat, and blockage of migratory routes have been focused on artificial production from hatcheries. This increases the pool of hatchery fish capable of breeding in the wild due to straying, and thus increased the opportunities for genetic interactions between wild and hatchery fish. Waples (1991) identifies three issues of concern: (1) direct genetic effects (caused by hybridization and introgression); (2) indirect genetic effects (principally due to altered selection regimes or reductions in population size caused by competition, predation, disease, or other factors); and (3) genetic changes to hatchery stocks (through selection, drift, or stock transfers) that magnify the consequences of hybridization with wild fish. Busack and Currens (1995) recognize four different types of genetic hazard: (1) extinction, (2) loss of within-population variability, (3) loss of among-population variability, and (4) domestication. According to Campton (1995), the potential genetic effects of hatcheries and hatchery fish can be grouped into three categories: (1) the genetic effects of hatcheries and artificial propagation on hatchery fish, (2) the direct genetic effects of hatchery fish on wild populations due to natural spawning and potential interbreeding, and (3) the direct genetic effects of hatchery fish on wild populations due to ecological interactions or management decisions that affect abundance.

One of the risks associated with hatcheries is domestication. Busack and Currens (1995) define domestication as the changes in quantity, variety, or combination of alleles within a captive population or between a captive population and its source population in the wild as a result of selection in an artificial environment. Waples (1999) defines it as any genetic change that results directly or indirectly from human efforts to control the environment experienced by a population. Considerable improvements have been made in both fish culture and fisheries management such as improved broodstock collection and mating protocols, more natural rearing conditions, focus on local broodstock, and release strategies more friendly to wild fish (Waples 1999). Although it may be possible to eliminate intentional selection from hatchery programs, it generally will not be possible to eliminate nonrandom broodstock sampling and unintentional selection that occurs in the hatchery environment.

The hatchery environment is different from the natural environment, and a successful hatchery program changes the mortality profile of the population and results in more fish surviving to enter the wild. Because of these factors, Busack and Currens (1995) concluded that some level of domestication is inevitable in a captive population. The management significance is simple: changing mating protocols will not eliminate genetic change from artificial propagation, and genetic changes in cultured populations cannot be avoided entirely. Although many factors can help reduce the nature and extent of the resulting genetic changes, they cannot be avoided entirely. Alternative mating protocols have been identified and more natural rearing systems are under development, but their effect on domestication has yet to be evaluated (Waples 1999).

A serious hatchery management concern is inbreeding, as it reduces the amount of genetic variation in a hatchery population. Repeated inbreeding may lead to inbreeding depression, the reduction of the mean phenotypic value. This may be greatest for traits that are components of fitness such as fertility, sperm viability, and survival of various life stages (Schonewald-Cox et al. 1983). Inbreeding depression and subsequent reductions in genetic variability have been demonstrated in cutthroat (Allendorf and Phelps 1980), brown (Ryman and Stahl 1980), and rainbow (Kincaid 1976) trout. The cited studies demonstrated several undesirable effects of inbreeding such as reductions in development, growth rate, survival, hatching, and fertility. Because traits related to fitness are susceptible to inbreeding depression, managers try to limit inbreeding. Salmon hatchery stocks have not generally experienced inadvertent inbreeding or measurable inbreeding depression as demonstrated in some wild and hatchery trout species (Lannan and Kapuscinski 1984). This is likely due to the comparatively large founder populations used in salmon hatcheries versus the limited broodstock used in trout hatcheries. A consensus of biologists is that the goal of hatcheries involved in fishery enhancement should be to make every effort to avoid inbreeding and maintain high fitness of the hatchery stock. However, many believe it is not possible to adequately mimic the successful reproductive strategies fish use in nature to maintain their genetic viability (Gharrett and Shirley 1985). Fish culturists, thus, have been encouraged to compensate for inadvertent loss of genetic variability by avoiding mating practices that foster loss of variability and by following certain procedures to minimize inbreeding. Best hatchery practices use a large founder or effective population size, provide crosses between wild and hatchery fish every season, use random mating, mate fish from all parts and age classes of a run, and avoid intentional selection of any given trait (e.g., large size, brightness) to help conserve genetic variability.

HOMING/STRAYING

What do homing and straying mean? For a wild fish, home is the natal stream where it incubated, hatched, and emerged. Nearly all salmon return reliably to their natal stream to spawn. Homing is a well-known feature of their biology; through it local populations are genetically isolated and are able to adapt to local environments. It is known that there is extensive variation among populations in many traits and this variation often has adaptive value. Such local adaptations have presumably arisen because homing fidelity leads to reduced levels of gene flow between populations using specific habitats and because there is genetic control of the traits that adapt the salmon for those habitats (Quinn 1997). For hatchery fish released at a remote location, the hatchery where they are reared and the release site could both be considered homes. While there is some tendency to return to the ancestral area, hatchery-reared salmon generally return to the site where they were released (Quinn 1997).

The other side of homing is straying. During straying, a small portion of salmon return to spawn in a stream different from their natal stream, maintaining genetic communication among local populations and, in turn, genetic diversity (Heggberget 1994). Patterns of straying vary between species and among populations and are poorly understood. Salmon move into non-natal streams for a variety of reasons. Upstream migration is characterized by a certain amount of exploratory movement. It is technically difficult to study straying, and it requires observations of marked fish. Consequently, most data come from observations of artificially cultured salmon (Quinn 1993).

Homing and straying have adaptive value for populations; the relative advantages may depend on environmental conditions, other life-history traits, and possibly the relative frequencies of homing and straying (Quinn 1997). A long-term balance between homing and straying is important to the fitness of salmon populations (Heggberget 1994). Straying from hatchery populations poses a risk to wild salmon populations because, if it results in interbreeding, genes from hatchery populations can be introduced into wild populations and adaptive gene complexes in wild fish can be disrupted (Gharrett 1994; Reisenbichler 1996).

There is concern that gene flow from hatchery strays may dilute the gene pool in populations of locally adapted wild fish. If a hatchery produces a large number of salmon, straying by even a small percentage of them has the potential to compromise the genetic makeup of nearby small wild populations. For example, in the 1980s strays from an ocean-ranching facility in Oregon were considered low (about 6%), but these strays accounted for about 74% of the fish in nearby streams (Quinn 1997). The absolute number of strays, a small percentage of the hatchery population, was large relative to the local wild population. While most concern is that strays will influence wild gene pools, wild salmon may also stray into a hatchery. One year an estimated 65% of wild coho salmon returning to the Yaquina River watershed in Oregon entered a local hatchery (Quinn 1997). Decoying of wild salmon into hatcheries can both reduce the number of wild fish and contribute to genetic mixing. Nonetheless, inclusion of wild salmon in hatchery broodstocks has often been practiced as it theoretically slows domestication and thus the potential effects of outbreeding depression (W. Smoker, pers. comm.).

Some natural colonization by salmon occurs. The relationship between straying and natural colonization is not well understood and little research has been done. In Alaska, new habitat appears as glaciers recede and this habitat is colonized as it becomes suitable for spawning (Milner 1987), hence colonization is now and recently has been important and frequent in most of the range of Pacific salmon. It is readily observed in recently glaciated landscapes and as a consequence of catastrophic landslides, volcanic eruptions, etc. It appears that soon after colonization straying rates may be high and that after populations become established only modest straying occurs (Quinn 1997). Nonetheless, in recent times translocation has been more common than natural colonization. Most translocations of salmon have been unsuccessful. There are, however, several successful examples: the inadvertent translocation of pink salmon into the Great Lakes as well as deliberate introductions of chinook and coho salmon into the Great Lakes resulted in rapid colonizations. The translocation of chinook salmon into one river in New Zealand led to unaided colonization of several river systems (Quinn 1997). There have also been successful and purposeful introductions of sockeye salmon into the upper Frazer River in British Columbia, Fraser Lake in Alaska, and Lake Washington in Washington. Evidence of reproductive isolation was found in Lake Washington sockeye after fewer than 13 generations (Hendry et al. 2000).

Little information exists on comparative straying rates between fish species. Straying is often thought to be greater in pink salmon than in other species, but definitive evidence is lacking. The most data exist for coho and chinook salmon and indicate large amounts of homing variability among populations, even within small geographical areas (Quinn 1997). Coho salmon straying rates are thought to be low in undisturbed populations (Dittman and Quinn 1996; LaBelle 1992). Most tagging occurs in hatchery fish; wild salmon are tagged less frequently and the data are seldom analyzed to produce estimates of straying. Consequently, most estimates of straying come from hatcheries. The overall estimate of homing in hatchery fish is 80% to 100% (Quinn 1997). Hatchery-produced salmon may or may not stray with the same frequency as wild salmon. Few studies have been conducted on hatchery and wild fish in the same area. Many experiments also suffer from a number of technical shortfalls, such as being poorly controlled, not being replicated, the study of homing variability being incidental to other goals, and failing to account for straying into and out of a population (only the dispersal of strays from the marking site is documented) (Quinn 1997). Quinn (1997) specifically mentions three studies of straying rates in salmon. In one case, wild chinook salmon in Washington State homed at a higher rate than did members of a hatchery population. On the other hand, hatchery and wild coho on Vancouver Island, British Columbia, did not significantly stray at different rates nor did Atlantic salmon in England.

Coded-wired tagging has provided a large database that can be used in homing studies. It is interesting to note that these data show a wide variation in spatial and temporal patterns of straying. The proportion or distance salmon stray is not the same in all hatcheries or regions, and the proportion of salmon straying into and out of a hatchery can vary considerably. Straying rates between 0% and 30% have been documented (Quinn 1997). In addition to differences in straying among rivers, straying can also vary from year to year. Straying variability can be associated with environmental changes like the eruption of Mount St. Helens or El Niño. Age at return can also contribute to straying variability, as older chinook salmon tend to stray more than younger fish (Quinn 1997). Even though chinook salmon hatcheries in Southeast Alaska are sited more than 50 kilometers from wild chinook rivers, tagged hatchery chinook have been detected among some wild spawning salmon in the region (Heard et al. 1995). One important study of wild pink salmon straying in Prince William Sound was not published because of concerns over direct effects of wire tags on homing and because it indicated very large rates of straying among populations. It is reviewed in the context of a later study of whether or not wire tags affect homing (Thedinga et al. 2000). This is more evidence that straying among pink salmon populations in western Prince William Sound is probably naturally large.

Some hatchery practices may promote straying. The most obvious is the transporting of fish from one locality to another. This is often referred to as "seeding" new habitat. Improper or incomplete imprinting may increase the straying rate of populations released from hatcheries. Fish released too long before or after the critical parr-smolt transformation may not experience the appropriate combinations of temporal, spatial, and physiological stimuli necessary for successful homing (Unwin and Quinn 1993). The site of release for hatchery fish can affect the amount of straying. Generally, local populations home better than transplanted ones; salmon home better to their natal site than a new site; and transplanted populations may show some tendency to return to their ancestral location (Quinn 1997).

Studies of small chum salmon populations on Vancouver Island indicate that degrees of genetic exchange between strays was lower than that inferred by the number of strays in the spawning area. Simply counting stray hatchery fish on spawning grounds may not provide a reliable estimate of the genetic interaction between hatchery and wild populations (Quinn 1997). It is not known whether straying hatchery salmon spawn successfully with wild salmon or if any loss of fitness and productivity occurs, but the potential risk is a strong concern within Alaska's ocean-ranching program (Smoker et al. 1999).

ECOLOGICAL INTERACTIONS

There exist many layers of biological diversity: within population, between population, behavioral, physiological, molecular, and ecological. Some stocks that have no obvious molecular differences may still have substantial ecological differences (e.g., run timing, preferences of substrate or habitat for redd construction and for incubation, intertidal versus upstream spawning, etc.). There are a number of ecological interactions that can take place between hatchery and wild fish. They can take the form of competition for food or space, predation, and negative social interactions when large numbers of hatchery fish are released in association with small numbers of wild fish. Given the controlled environmental conditions in a hatchery, it is not surprising that fish reared under these conditions are markedly different than their wild counterparts in behavior, morphology, survival, and reproductive ability. Artificial culture environments condition fish to respond to food, habitat, conspecifics, and predators differently than do wild fish (Flagg et al. 2000). Seemingly, the only similarities in hatchery and wild environments for salmonids are water and photoperiod (Reisenbichler and Rubin 1999). Flagg et al. (2000) summarized the major differences between hatchery and wild salmonids (Table 2).

Phenotypic differences observed between cultured and wild fish are both genetically and environmentally controlled. There is a positive relationship between smolt size and survival of hatchery fish that has encouraged hatchery managers to release larger smolts to maximize hatchery returns. The problem is that wild salmon life-history strategies have evolved based on the sizes they have been able to achieve under the temperature and nutrient limitations of the natural environment. Two potential negative impacts can result from this hatchery management scenario. One is the immediate impact on the ability of wild fish to avoid competition and predation pressures compounded by the presence of abundant, larger hatchery fish. The other, and perhaps more serious, is the long-term selective pressure being exerted on wild fish to accommodate the larger conspecifics in the ecosystem (Scientific Review Team 1998).

Salmon species that spend more time rearing in hatchery environments (coho, sockeye, chinook) are more

Table 2. Relative differences between wild and hatchery salmonids (Flagg et al. 2000).

Wild Salmonid		Hatchery Salmonid
Lower survival egg to smolt *Higher* survival smolt to adult	***Survival***	*Higher* survival egg to smolt *Lower* survival smolt to adult
Efficient forager *Lower* aggression *Lower* social density *Higher* territorial fidelity *Disperse* in migration *Bottom* habitat preference *Flee* from predators	***Behavior***	*Inefficient* forager *Higher* aggression *Higher* social density *Lower* territorial fidelity *Congregate* in migration *Surface* habitat preference *Approach* predators
More variable shape *Brighter* color *Larger* kype	***Morphology***	*Less* variable shape *Duller* color *Smaller* kype
Smaller eggs *Fewer* eggs *Higher* breeding success	***Reproduction***	*Larger* eggs *More* eggs *Lower* breeding success

susceptible to subtle environmental changes than are those that do not (chum, pink). Although hatchery rearing increases egg-to-smolt survival, the post-release survival of cultured salmonids is often lower than wild-reared fish. Research conducted since the 1960s suggests that post-release survival of hatchery fish represent both adaptive differences between hatchery and wild populations and environmental differences between hatchery and natural rearing environments (Flagg et al. 2000). Poor survival of both hatchery strains in natural environments and wild strains in hatchery environments were found in steelhead trout (Reisenbichler and McIntyre 1977). In other steelhead studies, naturally spawned and reared hatchery offspring experienced greater mortality than offspring of wild fish during all three major life-history stages (Chilcote et al. 1986; Leider et al. 1990). These studies suggest that adaptive differences occurred between hatchery and wild populations in a relatively short time period.

Many studies have indicated that the hatchery-rearing environment can influence the behavior of salmon. Levels of aggression and antagonistic behavior appear to differ between domesticated and wild populations. Juvenile salmonids from domesticated and wild populations appear to demonstrate adaptive differences in antagonistic behavior, and the behavioral development of domesticated and wild fish appears dependent upon their rearing environment (Flagg et al. 2000). Cultured and naturally-reared salmonids respond differently to habitat. In most cases wild fish use both riffles and pools in streams, while hatchery fish primarily use pool environments. Hatchery strains are typically more surface oriented than are wild fish. Most of the innate surface orientation of hatchery fish is likely an adaptive response to the practice of introducing food at the surface of the water (Flagg et al. 2000). Predation is a major factor affecting the survival of hatchery-reared fish. Experimental evidence indicates that hatchery strains of salmonids have increased risk-taking behavior and lowered fright responses compared to wild fish (Flagg et al. 2000).

Another impact of hatchery management on the ecological status of wild fish involves pre-smolt releases on stream carrying capacity through added competition. Hatchery fish are seldom released in numbers that are related to the carrying capacity of the receiving stream. The pre-smolt juveniles and any residuals will compete with their wild counterparts and lower the wild fish success by changing optimum habitat use of the wild fish (Scientific Review Team 1998). Hatchery coho releases into naturally seeded streams in British Columbia led to little demonstrable increase in smolt production on the east coast of Vancouver Island. Irvine and Bailey (1992) evaluated the success of outplanted coho juveniles and concluded that supplementation prior to summer low-flow periods did little to increase production. Thus, for releases to be successful in increasing smolt yield, releases would need to be timed to take advantage of available habitat after summer low-flow periods had ended (summer low flows created survival bottlenecks).

Hatchery practices have altered reproductive behavior by relaxing selection pressure on secondary sexual characteristics (kype) used in breeding competition in the wild, while increasing selection pressure on primary sexual characteristics (such as quantity and quality of eggs). Relaxation of breeding competition led to hatchery coho salmon with less pronounced kypes and breeding colors while developing larger and more numerous eggs than comparably sized members of the wild stocks from which they were derived (Fleming and Gross 1989). The same researchers found that hatchery male coho allowed to spawn naturally were less aggressive and less active than wild males. Either inadvertently or intentionally, hatcheries often develop strains that spawn at different times than their ancestral stock. The most common practice is to select for early run timing by spawning a disproportionate higher percentage of the early returning fish. An advantage of a temporal separation from a management perspective is to separate stocks in a fishery and minimize interbreeding. A disadvantage is that if interbreeding does take place, the progeny of domestic strains and wild-domestic crosses may emerge prior to peak abundance of natural aquatic food sources and thus suffer higher mortality rates. Granath et al. (2000) found significant differences in hatch times for crossed coho salmon in Southeast Alaska.

MARINE ENVIRONMENT

Climatological Influences

Despite increased awareness of the marine effects on salmonid growth and survival, scientists still have a rather poor understanding of the ecology of salmon once they leave freshwater (Brodeur et al. 2000). There exists a lack of comparable understanding of the marine environment to that of freshwater despite evidence that this habitat may be more significant to population variability. An incomplete understanding about the basic aspects of salmon biology in marine waters has hampered the ability to predict natural variability in salmon production (Brodeur et al. 2000).

Although climatological factors such as precipitation affect freshwater systems as well as salmon survival, scientists believe that ocean conditions contribute to variability in salmon survival and growth, particularly in the first few months after leaving freshwater. Early marine survival is governed in part by both water temperature and salinity. This period of ocean entry is a critical one in the life history of salmonids. The timing of ocean entry has evolved through natural selection to minimize predation and maximize growth (Pearcy 1992). Although the most visible part of a salmon's life cycle is completed on the freshwater spawning grounds, most growth and about one-half of mortality occurs in the ocean.

Following entry into the ocean, most North American salmon begin a rapid and highly directed migration north and west. They remain exclusively upon the narrow coastal shelf, migrating up and around at least as far as the Aleutian Islands and do not enter the open ocean for many months. The confinement of the entire North American population of juvenile salmon to a narrow strip of coastal ocean makes them especially vulnerable to problems resulting from competition for food or climate change (Welch 1999). The climate of the North Pacific alternates between two general ocean states. One is dominated by a weak winter Aleutian Low (pressure) resulting in negative sea-surface temperature anomalies (cooling). The second occurs in response to an eastward displacement and intensification of the Aleutian Low and is characterized by positive sea-surface temperature anomalies (warming) (Cooney and Brodeur 1998).

Numerous recent studies indicate that fluctuations in climate are the major source of widespread, regionally, coherent changes in the marine survival rate for many salmon species (Hare et al. 1999). Mysak (1986) showed that El Niño affected both Bristol Bay and Fraser River sockeye salmon populations. Several studies have connected dramatic changes in Alaska and West Coast salmon production to decadal scale climate regime shifts in the North Pacific (Beamish and Bouillon 1993; Francis and Hare 1994; Francis and Sibley 1991; Hare 1996; Hare and Francis 1995). This climate phenomenon is known as Pacific Decadal Oscillation or PDO. It is described as a pan-Pacific, recurring pattern of ocean-atmosphere variability that alternates between climate regimes every 20 to 30 years (Hare et al. 1999). Hare et al. (1999) found that salmon catches in Alaska have varied inversely with catches from the U.S. West Coast during the past 70 years. Results of their analysis suggest that the spatial and temporal characteristics of this inverse catch/production pattern are related to climate-forcing events associated with the PDO.

Clues left by decaying salmon at the bottom of lakes in Alaska point to climate change and overfishing as causes of the large swings in the size of the state's salmon runs. Records of prehistoric salmon abundance have been reconstructed from analysis of stable nitrogen isotopes in sediment cores (Finney 1998). Cores from Karluk Lake show minimum salmon escapement occurring during the mid-1900s, early 1800s, early 1700s, and mid-1500s. Relatively high values were observed from the early 1900s, late 1700s, mid-1600s, and late and early 1500s. In general, sockeye salmon runs were larger during periods of warm climates and smaller during cold periods.

There is increasing evidence of persistent patterns and synchronous changes in the ocean environment in the Pacific Ocean. Evidence is also accumulating to show that large-scale trends in Pacific salmon abundance are linked to trends or regimes in climate and resulting ocean conditions (Beamish et al. 1999). The fluctuations in salmon abundance have been shown to correspond to shifts in zooplankton abundance that can be linked to physical changes in the ocean. The trends in salmon abundance are not necessarily the same for all areas of the ocean, as climate shifts can cause large-scale oscillations in ocean productivity with regional impacts. Fluctuations in Pacific salmon abundance in this century are synchronous with large fluctuations in Japanese sardine abundance, a relationship that can be traced back to the early 1600s. The synchrony in the fluctuations suggests that Pacific salmon abundance may have fluctuated for centuries in response to climate (Beamish et al. 1999).

Since 1976 a major change has occurred in the Northeast Pacific Ocean, with unfavorable ocean conditions for salmonids in the Coastal Upwelling Domain and highly favorable conditions farther north in the Coastal Downwelling and Central Subarctic Domains and the Bering Sea. High sea levels and warm temperatures along the coast, an intense Aleutian Low, and weak upwelling are associated with these changes (Pearcy 1996). In the late 1970s, an intensification of the Aleutian low-pressure system in the North Pacific Ocean apparently resulted in a warming of the sea surface along the northern North America coast and cooling farther offshore (Cooney and Brodeur 1998). This event was associated with exceptionally strong year-classes of many marine and anadromous fishes and signaled the beginning of a period of increasing productivity for salmon north of British Columbia. Conversely, this shift in ocean climate produced an opposite effect on fish off the Pacific Northwest, most notably on coho salmon (Mantua et al. 1997). Coded-wire tagging studies indicate that changes in ocean conditions could be partially responsible for survival declines of coho and chinook salmon in the Pacific Northwest (Coronado and Hilborn 1998a).

Favorable ocean conditions, growing enhancement operations, and improved management practices have led to dramatic increases in Pacific salmon production over the last 20 years. Production in 1994 was about double the amount in the mid-1970s. The largest increases have been for pink and sockeye salmon. Evidence exists for at least two previous ocean states or regimes affecting Alaska salmon, one ending in the 1940s after which production fell and the other concluding in the late 1970s and followed by increasing production for two decades (Beamish 1993; Beamish et al. 1999).

Salmon sensitivity to temperature is widely recognized and any climate change is likely to affect survival rates. Long-term impacts from any carbon dioxide-induced global warming may prove to have major implications for sustainability of salmon. If salmon continue to maintain the sharp thermal limits that they have been shown to follow over the past 40 years, then any global warming could adversely affect them. Warming oceans could force salmon to migrate farther north in search of suitable temperatures or force them deeper out of the sunlit surface water where food is greatest (Welch 1999).

Ocean Carrying Capacity

Large-scale climatic factors affect ocean productivity and thus carrying capacity for salmon (Cooney and Brodeur 1998). Review of research on the physical and biologic factors affecting ocean production indicated that climate-induced variation in productivity and fishing are the two major factors affecting ocean production of salmon (Myers et al. 2000).

Carrying capacity is a measure of the biomass of a given population that can be supported by a given ecosystem. It changes over time with the abundance of predators and resources. Carrying capacity is determined by several processes including primary productivity, food-web dynamics, number of trophic links, ecological efficiencies, fraction of production consumed by competitors, and predation. In addition, the carrying capacity of a species is modulated by the size of the region inhabited, which in turn is influenced by temperature and availability of food (Pearcy et al. 1999). All of these factors are dynamic, fluctuating over seasons, years, decades, and millennia.

Dramatic changes have occurred in the North Pacific Ocean in recent years. Some recently documented changes are significant warming of the ocean during the 1990s, shallower winter mixed-layer depth and reduction of nutrients entrained into the euphotic zone, changes in seasonal maxima of a dominant subarctic copepod with peak biomass occurring earlier in the upper water column, unusual coccolithophore blooms in the Bering Sea, and regions of depleted nitrate during the 1990s (Pearcy et al. 1999). All of these changes may affect the carrying capacity of the North Pacific. The ocean's carrying capacity for salmon is dynamic in time and space, constantly changing on interannual, decadal, centennial, and millennial time scales.

Humans impact estuarine and coastal regions through activities that may exacerbate global warming, by introducing exotic species, by creating chemical pollution, and by physically altering habitats (e.g. clear-cut logging practices, building subdivisions, dredging, etc.) and bottom fishing (Brodeur et al. 2000). When these anthropogenic factors are set against the backdrop of natural variability, their effects on ocean carrying capacity may be further exaggerated (Brodeur et al. 2000). The estuarine and ocean carrying capacity for salmon may be compromised by the attempt to make up for declining natural runs by increasing hatchery production, thus leading to density-dependent food limitation in winter months (Pearcy et al. 1999).

Density-Dependent Competition

A fundamental assumption of ocean ranching has been that salmon use only a small fraction of available coastal and ocean forage. Food limitations in these environments were not given serious consideration until salmon began returning at smaller sizes and older ages (Cooney and Brodeur 1998). Several investigators in the 1970s estimated that salmon consumed only a few percent of the zooplankton and that salmon production could be increased significantly. Since these early studies, several salient estimates have changed. Even though only a fraction of the primary production is used by salmon, as recognized in earlier studies, the high trophic level of salmon and the complex food web with many other consumers and competitors suggest that substantial increases in the production of salmon in ocean waters of the Pacific are unlikely (Pearcy et al. 1999). Declines in both the size and size at age of salmon harvested and increases in the age of maturity have been documented over the past 20 years around the Pacific Rim (Bigler et al. 1996). This is important evidence for density-dependent growth and may suggest that the carrying capacity of oceanic waters of the North Pacific is being approached for salmonids (Pearcy et al. 1999).

Competition for food among salmon has been shown. The diet of pink salmon may change between years of strong and weak year classes, with a shift from zooplankton to more nutritious prey like squid. Squid compete with immature salmon for zooplankton, while providing a food source for maturing salmon. Both the growth and diet of chum salmon have been correlated with the abundance of pink salmon; when pink salmon are less common, chum salmon may shift their diet from gelatinous zooplankton to more nutritious prey (Pearcy et al. 1999).

Releases of hatchery fish increased rapidly after the 1960s and are presently between 5 and 6 billion, about 25% of the total number of juvenile salmon entering the ocean (Heard 1998). According to Beamish et al. (1997), of the total number of juvenile salmon entering the ocean, about 84% of chum, 23% of pink, and 5% of sockeye salmon are produced at hatcheries. Estimates of annual food consumption by pink salmon in Prince William Sound rose from less than 100,000 metric tons prior to 1976 to more than 300,000 metric tons after 1988, when hatchery production began dominating returns (Cooney and Brodeur 1998). Recent levels of wild and hatchery production in the North Pacific Ocean have placed substantial forage demands on ocean-feeding domains (Pearcy et al. 1999). Recent studies in Prince William Sound found Dungeness crab megalopae composed 35% to 65% of the stomach contents of pink salmon. Despite the curtailment of fishing on these crabs in Prince William Sound, their productivity remains low. The large numbers of hatchery pink salmon being released in Prince William Sound could be having a significant and unintended impact on other ecosystem components like crab (Boldt et al. 2001).

Evidence for a limited ocean carrying capacity comes from negative relationships between numbers of fish and their rates of growth. Density-dependent growth of some stocks has been suggested (reviewed by Pearcy 1996). Klovach and Gritsenko (1999) suggested that limited ocean carrying capacity might explain why fish became smaller during periods of high salmon abundance. There has been a decrease in mean body length, mean weight, and fecundity and an increase in the mean age of matured fish. A decrease in size of the fish may lead to corresponding decreases in fecundity and energy reserves available for the freshwater migration. In 1994 a mass softening of chum salmon tissue was discovered in Asian salmon. Some of these fish also had unusual elongated body shapes. The causes behind this appear to be dietary. Studies have documented a shift in the diet of Asian chum salmon to include a large quantity of low-caloric forage like salps, jellyfish, and ctenophores, which were only rarely found in other salmon. In the 1960s, when salmon abundance was much lower, these organisms were not so prevalent in the diet of chum salmon. Previously, these organisms were part of chum salmon diets only in years of high pink salmon abundance (Klovach and Gritsenko 1999). Klovach and Gritsenko (1999) concluded that the high numbers of Japanese hatchery chum salmon feeding in the ocean creates densities of fish which, if not exceeding carrying capacity, then at least considerably exceed an optimal density. Some Russian scientists believe that competition with the chum juveniles of Japanese hatchery origin during the marine-rearing phase has prevented the recovery of wild Russian chum stocks (Radchenko 1998). These studies are consistent with the hypothesis that hatchery releases by one country along the Pacific Rim may affect the size, number, and value of adult salmon returning to other countries thereby creating scientific and management problems of international concern.

In contrast to growth, survival does not appear to be as density dependent. Survival of hatchery-produced pink and chum salmon in Alaska appears to mirror that of wild fish from the area surrounding the hatchery: when survival of hatchery salmon is high, wild stocks from the surrounding area also survive in greater numbers. In some years, this appears to be a localized phenomenon with different survival rates within a region. Coronado and Hilborn (1998b) presented data summarizing ocean survival over time and hatchery releases for Pacific coho populations. The graph of ocean survival for southern British Columbia coho showed a strong inverse relationship to the total number of hatchery-produced salmonids released. Salmon survival shifts appear to be caused by changes in local environmental conditions, possibly related to fluctuations in climate (ADF&G 1999; Coronado and Hilborn 1998a, b).

FISHERY MANAGEMENT IMPLICATIONS

Forecasting future trends in the abundance of fish populations has not been particularly successful. Historically, many hypotheses about the relationship between fish populations and marine environmental parameters have been suggested. Only in the last several years have these hypotheses become more refined. It is possible that improved forecasting will result from an increasing understanding of the synchronicity between persisting trends in climate/ocean conditions and patterns of marine survival of salmon (Beamish et al. 2000).

Beamish et al. (1999) and others have noted persistent trends in the dynamics of fish populations in relation to climate/ocean conditions and term these regimes, which they define as a multiyear period of linked recruitment patterns in fish populations. If natural trends in Pacific salmon abundance occur, then fisheries management should account for this phenomenon when developing strategies. Beamish et al. (2000) found that survival of coho salmon from California to British Columbia decreased after 1989 in synchrony. This large-scale synchronous change over the southern range of coho salmon distribution indicates linkage with a common event. Shifts in the pattern of April flows in the Fraser River and the intensity of the Aleutian Low appeared to be indices to this change in survival. The trend towards low marine survival may persist as long as the trends in the climate indicators do not change.

Survival rates for coho salmon were estimated for all coded-wire tagged fish in the Pacific Northwest between 1971 and 1990. During this time there was considerable geographic variation, with most regions south of northern British Columbia showing declining survival and more northern areas showing increasing survival. According to Coronado and Hilborn (1998b), ocean conditions have been the dominant factor affecting coho survival since the 1970s and a major reduction in exploitation rates is necessary to maintain the populations. Moreover, during lower productive regimes there is concern as to what impact large numbers of hatchery-produced salmon may have on wild populations, and it has been suggested that prudent management practices be adopted during less productive regimes. High harvest rates in ocean fisheries targeted toward abundant hatchery stocks make conservation of wild stocks especially difficult when ocean productivity is low (Beamish et al. 1997).

Environmental indices changed around 1990, indicating the productive North Pacific Ocean regime of the 1980s was changing. There were continued increases in much (but not all) of Alaska marine productivity and a concomitant sharp drop in southern British Columbia—but not northern British Columbia ocean productivity (Welch et al. 2000). Hatchery enhancement has contributed to increased salmon production in the late 1900s, especially in Japan and Alaska. If the ocean carrying capacity is being reached, increased hatchery releases may not increase the biomass of salmon produced. Catches of pink, chum, and sockeye salmon by the major salmon-producing countries in the 1900s shows high catches in the early and late 1900s and low catches in the mid-1900s (Beamish et al. 1997). The early and late 1900s correspond to favorable ocean/climate conditions and the mid-1900s to unfavorable. The high catches in the early 1900s were almost entirely wild fish, while those of the late 1900s included a significant number of hatchery fish.

Given the two favorable ocean environmental regimes, about the same number of fish were produced but hatchery-produced fish appeared to replace wild fish in the late 1900s. Estimates of the percentage of hatchery-produced coho salmon in the Strait of Georgia have been made over time. The percentage of hatchery fish has increased from about 25% in the early 1980s to nearly 50% in 1990 to approximately 75% in 1998 (Noakes et al. 2000b). These estimates suggest a gradual replacement of wild fish with hatchery fish over time. Evidence from Prince William Sound also suggests that hatchery pink salmon replaced rather than augmented wild production (Hilborn and Eggers 2000). A critique of this analysis, based on different assumptions and statistical analysis, questions the rate at which hatchery-produced pink salmon may be replacing wild salmon (Wertheimer et al. 2001).

MANAGEMENT ISSUES

The reassessment of management's fundamental assumptions about the role of hatchery production has led to much public debate, most recently over the federal proposal to breach or remove the four Snake River dams to aid in the recovery of salmon. This would have been an unthinkable action just a few years ago. To avoid the problems of the past, fundamental assumptions need continuous examination and management programs must be flexible to change, when warranted, in response to new information (Lichatowich et al. 1999). Throughout their history, hatchery programs have exhibited a chameleonic behavior, changing to match the social and economic environment while retaining the same conceptual foundation. In the nineteenth century fish culture offered a means to restore eastern U.S. fisheries, provide an income for farmers, and increase the food supply of an expanding nation. The agricultural goals of the U.S. fish culture movement dictated the kinds of scientific questions that were relevant and may explain why fisheries science developed its own ideas and theories distinct from those of systems ecology (Bottom 1996). These ideas emphasized the improvement of fish through hatchery selection as well as the introduction and acclimatization of species in new environments.

New understanding about fish adaptations to their environment along with the recent collapse of salmon production in the Pacific Northwest have undermined the old agricultural model of applied fisheries science (Bottom 1996). Presently, there is a continuing search for an analytical solution to a value-based problem. According to Bottom (1996), a more important role for fisheries than ecosystem management will be to foster a better understanding and appreciation of human ecosystem dependence.

Throughout their history, hatchery programs have been implemented under the assumption that relationships among reproduction and harvest could be manipulated through human intervention to be simpler and more predictable. Production has largely been brought under control in some watersheds like the Columbia River, where 80% of the salmon is of hatchery origin. Even though most of the salmon are of hatchery origin, less salmon are returning to the Columbia River Basin today than at any time in recorded history. The hatcheries have failed to achieve their original objective of replacing production (Lichatowich et al. 1999).

The use of hatcheries to supplement depleted stocks has generated nearly endless disagreement. Faced with the general collapse of salmon in the Pacific Northwest, four independent scientific advisory boards have or are currently examining restoration programs in various parts of the region (Independent Science Group 1996; National Fish Hatchery Review Panel 1994; National Research Council 1996; Scientific Review Team 1998). The conclusions and recommendations of these different groups were almost identical and the following points were identified as common denominators (Flagg and Nash 1999):

- Hatcheries have generally failed to meet their objectives.
- Hatcheries have imparted adverse effects on natural populations.
- Managers have failed to evaluate hatchery programs.
- Hatchery production was based on untested assumptions.
- Hatchery production should be linked with habitat improvements.
- Genetic considerations have to be included in hatchery programs.
- More research and experimental approaches are required.
- Stock transfers and introductions of non-native species should be discontinued.

- Artificial production should have a new role in fisheries management.
- Hatcheries should be used as temporary refuges, rather than for long-term production.

The Northwest Power Planning Council's Independent Science Advisory Board concluded that it is skeptical of the efficacy of hatcheries in fisheries enhancement but does not discount their functionality in fish and wildlife restoration (Independent Science Group 1996).

The above evaluations and conclusions are focused on hatchery operations in the Pacific Northwest, and it remains to be seen to what degree they apply to Alaska's ocean-ranching program. Proponents of Alaska's system are quick to claim that hatchery programs in Alaska have either met their objectives or have been closed down. They note that about a quarter of all hatcheries have been closed, that mixed hatchery and wild stock fisheries have been managed based on the productivity of wild stocks, and that sufficient resources have been devoted to evaluation of hatchery efficacy. Alaska has, to some degree, learned from mistakes made elsewhere and Alaska's management reflects this.

Recently, there has been a growing appreciation that long-term sustainability of salmon requires conservation of natural populations and their habitats (National Research Council 1996). As a result of this paradigm shift, many hatcheries are now being asked to minimize impacts to natural populations (Waples 1999). The recent examination of salmon management's conceptual framework has led to the recommendation that it be replaced with an alternative (Independent Science Group 1996). The new framework proposes that restoration activities must consider the entire ecosystem. It recognizes the complexity of salmon life history and that the biodiversity of wild stocks must be conserved (Independent Science Group 1996). Biodiversity has become a familiar term outside of scientific circles. Ways of measuring and mapping it are advancing and becoming more complex, yet a consensus about how to conserve biodiversity is still developing and the resources available to manage diminishing biodiversity are scarce. One problem is that policy decisions are frequently at the local scale, whereas biodiversity issues are more often regional or national in scope.

Many have argued that critics of hatcheries often confound biologic factors intrinsic to hatcheries with effects of fisheries management. One should be careful not to exaggerate the dichotomy between biology and management. No fish hatchery exists in a vacuum, and they are usually designed to meet one or more management objectives. Many management factors involve both fisheries management and fish culture. For example, selective breeding, when it occurs, is carried out by fish culturists to achieve a fisheries management objective. Two factors that are primarily a function of management are mixed-stock fisheries and stock transfers (Waples 1999).

In an analysis of salmon and steelhead hatchery production, Miller (1990) studied over 300 projects in North America. Among his observations was that evidence for the successful rebuilding of runs was scarce. Projects were more successful at just returning fish. Adverse impacts to wild stocks had been shown or postulated from about every type of hatchery introduction. He concluded that there were no guarantees that hatchery production could replace or consistently augment natural production. Miller found that most supplementation projects have been so poorly documented that it is impossible to determine what has happened. Cuenco et al. (1993) also examined historical cases of successful and unsuccessful supplementation and found quite a few successful supplementation projects. Among the best known is the case of successful supplementation of the Lake Washington sockeye, which were originally from the Skagit River. Repeated stocking of Skagit sockeye started the current run of Lake Washington sockeye.

MIXED-STOCK FISHERIES

A major management concern involves different exploitation rates between hatchery and wild stocks mixed in commercial and/or sport fisheries. Overharvest of wild stocks in mixed-stock fisheries could have a profound impact on survival of wild stocks. When abundant hatchery stocks are targeted for high harvest, less abundant wild stocks cannot withstand the high exploitation rates, resulting in underescapement of wild fish. The optimum harvest rate of wild stocks is much lower (generally 40% to 75%) than that of hatchery stocks (90% to 95%) (Wright 1981). It also should be noted that depressed stocks, such as the interior Fraser River coho, could not withstand exploitation rates in excess of 10%. The protected hatchery environment generally allows a high rate of fertilized egg to fry or juvenile survival while, in contrast, the average overall survival rate of wild salmonids from fertilized egg to adult is lower. Subsequently, fewer fish (or eggs) are needed to maintain a hatchery population. In mixed-stock fisheries, it is difficult (if not impossible) to harvest one stock at the optimum level without over- or underharvesting other stocks (Ricker 1973). Where overfishing of wild stocks has been permitted, adverse effects have been measured. Some examples are disappearance of the summer chinook stock in the Columbia River, disappearance of coho stocks in the Columbia and Snake Rivers, and decline of wild stocks caught in the highly productive channel-raised sockeye fishery of Babine Lake, British Columbia.

Ideally, establishment of separate fisheries on wild and hatchery stocks (usually involving geographically separate terminal fisheries) is the preferred management technique. This usually involves manipulations through reprogramming of hatchery production that would directly impact harvest in specific fisheries. This can involve changes in stocks reared at a hatchery or changes in the hatchery environment that would affect migration behavior and availability of returning adults to a fishery. The most common technique is establishment of a terminal fishery. The goal is to allow as much exploitation in mixed-stock fisheries as practical and then to harvest all remaining hatchery adults in a terminal single-stock fishery (Evans and Smith 1986). However, a terminal fishery is not always possible because of geographic or socioeconomic barriers. When a mixed-stock fishery is inevitable, the recommended first priority is to reduce exploitation rates to accommodate the less productive wild stocks (Argue et al. 1983; McDonald 1981; Ricker 1973). Risks to wild stocks from overharvest can be reduced by siting facilities where harvests are not mixed or by using tags to identify hatchery fish in mixed harvests. In areas of mixed-stock fisheries, large-scale marking programs (thermal otolith marks) have been initiated to contain the risk (Smoker et al. 1999).

Patterns of salmon migration complicate management. Conservation of weak stocks by time and area closures may not be a good option for stocks that pass through numerous fisheries over an extended period en route to their spawning streams. Artificial production of salmon stocks through hatcheries has the potential to adversely affect wild runs via overexploitation. This concern can be amplified by the geographic location of hatcheries and release sites. Long-term declines have occurred in coho stocks with high exploitation rates from Georgia Strait, British Columbia (Shaul 1994).

The generic management goal of maximizing harvest underscores hatchery management philosophy. The management concept of maximum sustainable yield has not only impacted escapements of wild fish in mixed-stock fisheries, but has also affected nutrient input from carcasses that enriched otherwise nutrient-impoverished streams. The dependence on artificial production in the Pacific Northwest has exaggerated the deficit in nutrient transfer of many drainages from that historically experienced. Consequently, reduction of carcass contribution to nutrient loads in salmon-spawning streams is an indirect ecological impact of hatchery management (Scientific Review Team 1998). Nutrients delivered from the ocean by salmon are important in the nutrient-poor streams of Alaska.

ALASKA'S HATCHERY PROGRAM

HISTORY

Due to the depressed state of Alaska's salmon fishery in the late 1960s and early 1970s, many (including fishermen, processors, and legislators) felt it was time to attempt to propagate fish by means of hatcheries. The public and the Alaska legislature seemed more enthusiastic about the program than professional fishery biologists. State and federal fishery management agencies often expressed concerns about adverse biologic consequences. The biologists stated a preference for rehabilitating wild stocks over the propagation of hatchery stocks. Questions such as genetic intermingling, disease, and competition were raised, but it was decided to proceed with an eye toward protecting wild stocks. Concerns were known to legislators but seemed speculative in the face of cries for relief from communities. It was hoped that potential problems could be mitigated by exercising reasonable precautions, such as regional management plans and careful siting of hatchery facilities to segregate hatchery and wild stocks (Alaska Senate 1992).

By 1968 public concern over the depressed salmon fishery was high, and a general obligation bond authorization for $3 million to build hatcheries was passed by the Alaska legislature and overwhelmingly approved by the public. In 1971 the legislature created the Fisheries Rehabilitation, Enhancement, and Development Division (FRED) of ADF&G to operate public hatcheries and coordinate fish enhancement activities. In 1973 the United Fisherman's Association (UFA) was formed, organizing commercial fishermen at the state level. Fishermen's groups like UFA were a driving force behind the state's salmon hatchery programs (Alaska Senate 1992), and they soon lobbied for private nonprofit (PNP) hatchery programs. In 1974 the Alaska legislature passed the Private Salmon Hatchery Act. It was amended in 1976 and 1977 to add the Fisheries Enhancement Loan Program, which provided for low-interest loans to regional aquaculture associations and added a provision for the formation of regional associations that would own and operate the PNP hatcheries (Olsen 1994).

It soon became evident that the costs of developing private salmon hatcheries were far greater than anticipated. New methods of financing construction and operation were sought (Alaska Senate 1992). Accordingly, the 1974 law was amended the following year to allow proceeds from the sale of salmon or salmon eggs to be applied to debt retirement as well as to operating costs. In 1975 another state low-interest financial source was made available to hatcheries when the commercial fisheries loan program was expanded to include hatcheries. In 1977 legislation was passed to create a Fisheries Enhancement Revolving Loan Fund that relaxed conditions for obtaining loans. In 1988 legislation was passed to allow private aquaculture corporations to take over operations of state hatcheries. FRED was combined with the Division of Commercial Fisheries by executive order in 1993 and subsequently most FRED hatcheries were transferred to regional associations under long-term cooperative lease arrangements (Heard 1996). ADF&G closed 3 hatcheries and transferred 13 to the PNP corporations. Except for the Deer Mountain hatchery, these were owned by the state but operated for ADF&G under contract with various PNPs. Deer Mountain was owned by the City of Ketchikan and operated by ADF&G; today it is owned by the Ketchikan Indian Corporation. The four state hatcheries that produced fish for recreational fisheries were transferred to the ADF&G Division of Sport Fish in 1993. In 2000 the state's Crystal Lake Hatchery was contracted to the Southern Southeast Regional Aquaculture Association, leaving only the two sport fishery hatcheries near Anchorage directly under ADF&G's control.

Since 1980, five state hatcheries have been closed that were not taken over by PNPs: East Creek, Russell Creek, Big Lake, Sikusuiliaq, and Clear. East Creek was an experimental sockeye hatchery in Bristol Bay that encountered infectious hematopoietic necrosis virus (IHNV) disease problems and was shut down in 1981. Russell Creek was a chum hatchery in the False Pass area that was closed in 1992. It was poorly sited from a management perspective, causing allocation conflicts between sockeye and chum salmon and between different management-area chum salmon runs. The Big Lake hatchery was a sockeye hatchery that had a history of low cost-recovery harvest and closed in 1993. Sikusuilaq was an experimental chum hatchery near Kotzebue above the Arctic Circle that was closed in 1995. The Russell Creek, Big Lake, and Sikusuilaq hatcheries were all ultimately closed as cost-reduction measures by ADF&G (S. McGee, pers. comm.). The Clear hatchery was a Division of Sport Fish hatchery that was closed in 1997; its mission was absorbed by the Division's hatcheries in Anchorage. Table 3 summarizes significant events in Alaska's fishery enhancement program.

PLANNING

The commissioner of ADF&G is authorized to designate regions of Alaska for the purpose of salmon enhancement and to develop and maintain Regional

Table 3. Time line of fishery enhancement events in Alaska (McNair 2001).

Year	Event	Number of State Hatcheries	Number of PNP Hatcheries	Number of Federal Hatcheries
1934	Federal research station Little Port Walter constructed			1
1950	Federal hatchery at Auke Creek constructed			2
1953	1 territorial hatchery constructed (Kitoi Bay)	1		
1954	1 territorial hatchery constructed (Deer Mountain)	2		
1958	1 territorial hatchery constructed (Ft. Richardson)	3		
1965	1 state hatchery constructed (Fire Lake)	4		
1969	1 state hatchery constructed (Crystal Lake)	5		
1971	Fisheries Rehabilitation, Enhancement, and Development (FRED) Division created by legislature			
1973	2 state hatcheries constructed (Crooked Creek and Gulkana) State enhancement projects at Starrigavan and Halibut Cove started	7		
1974	2 state hatcheries constructed (Beaver Falls and East Creek) Legislature authorizes permits for PNP hatchery operators to salmon ranch	9		
1975	4 PNP permits issued (Sheldon Jackson (#3), Port San Juan (#2), Perry Island (#1), and Sandy Bay (#4) 2 state hatcheries constructed (Big Lake and Tutka)	 11	4	
1976	AS 16.10.375 passed, designating regions for Regional Planning Teams and enhancing salmon 1 state hatchery constructed (Elmendorf) 2 PNP permits issued (Burnett Inlet (#5) and Kowee Creek (#6)	 12	 6	
1977	1 PNP permit issued (Gunnuk Creek (#7) 2 state hatcheries constructed (Klawock and Russell Creek) State enhancement project at Karluk Lake started	 14	7	
1978	1 PNP permit issued (Whitman Lake (#8) 2 state hatcheries constructed (Cannery Creek and Hidden Falls)	 16	8	
1979	3 PNP permits issued (Sheep Creek (#11), Meyers Chuck (#10), Salmon Creek (#9) 1 state hatchery constructed (Snettisham) 1 state hatchery closed (Fire Lake)	 17 16	11	
1980	1 PNP permit issued (Burro Creek (#12) 2 state hatcheries constructed (Clear and Main Bay) 1 hatchery at Tamgas Creek constructed (Metlakatla Indian Community/BIA)	 18	12	 3

Planning Teams (RPTs). RPTs currently have three primary duties: (1) develop and update regional comprehensive salmon plans, (2) review hatchery permit applications, and (3) review hatchery operations. RPTs comprise three members of the local aquaculture association and three members of ADF&G. Criteria that are used to determine public benefit from the hatchery program include: (1) whether or not the hatchery makes a significant contribution to the common property fishery, (2) whether or not the

Year	Event	Number of State Hatcheries	Number of PNP Hatcheries	Number of Federal Hatcheries
1981	1 state hatchery closed (East Creek) 2 state hatcheries constructed (Sikusuilaq and Trail Lakes) 4 PNP permits issued (Medvejie (#16), Port Armstrong (#13), Solomon Gulch (#15), Salmon Creek (#14) 1 PNP permit revoked (Salmon Creek (#9)	17 19 	 16 15	
1982	2 PNP permits issued (Eklutna (#17) and Favorite Bay (#18)		17	
1983	3 PNP permits issued (Neets Bay (#19), Crittenden Creek (#22), and Esther (#20) 1 state hatchery completed (Broodstock Development Center)	 20	20 	
1984	1 PNP permit issued (Santa Ana (#21)		21	
1985	1 PNP permit issued (Port Camdem (#23)		22	
1986	1 PNP permit issued (Beaver Falls (#24)		23	
1987	State enhancement projects at Starrigavan and Halibut Cove started			
1988	Aquatic Farm Act signed; statute passes allowing contracting of hatchery operations 4 state hatcheries contracted to private sector (Kitoi Bay, Trail Lakes, Cannery Creek, Hidden Falls) 4 PNP permits issued (Hidden Falls (#28), Cannery Creek (#26), Trail Lakes (#27), Kitoi Bay (#29) 1 state hatchery constructed (Pillar Creek) 2 PNP permits revoked (Sandy Bay (#4) and Salmon Creek (#14)	 16 17 	 28 26	
1990	CSHB432 becomes law prohibiting finfish farming in Alaska 1 PNP permit issued (Bell Island (#30)		 27	
1991	5 state hatcheries contracted to private sector (Main Bay (#31), Tutka, Gulkana (#30), Pillar Creek (#38), and Beaver Falls (#24) – Beaver Falls and Tutka tallied elsewhere Portions of 6 state hatcheries paid for by private or federal funds	 12 	 30	
1992	1 state hatchery closed (Russell Creek) 2 PNP permits issued (Haines projects (#34) and Port Graham (#33) 1 PNP permit revoked (Meyers Chuck (#10) FRED Division merged with the Commerical Fisheries Division to form the Commercial Fisheries Management and Development (CFMD) Division	11 	 32 31 	
1993	3 state hatcheries transferred from CFMD Division (Broodstock Development Center, Elmendorf, & Ft. Richardson) 2 state hatcheries contracted to private sector (Crooked Creek and Klawok) 1 state hatchery closed (Big Lake)	 9 8		
1994	4 PNP permits issued (Tutka (#32), Crooked Creek (#35), Klawok (#36), Deer Mountain (#37) 1 state hatchery contracted (Deer Mountain) Ft. Richardson Hatchery merged with Broodstock Development Center	 7 6	35 	
1995	1 PNP hatchery under new management (Klawok (#38) 1 state hatchery transferred from CFMD to Division of Sport Fish (Crystal Lake) 1 state hatchery closed (Sikusuilaq)	 5		
1996	1 state hatchery contracted (Snettisham (#39) 1 state hatchery transferred from CFMD Division to Division of Sport Fish (Clear) 3 PNP permits revoked (Crittenden Creek (#22), Santa Ana (#21), and Favorite Bay (#18)	4 	36 33	
1997	1 state hatchery closed (Clear) 2 state contracted PNP hatcheries closed (Beaver Falls (#24), and Crooked Creek (#35) 1 PNP hatchery closed & reopened under new management (Burnett Inlet (#5), now #40)	3 	 31 31	
1998	1 PNP hatchery closed (Eklutna (#17)		30	
2000	1 state hatchery contracted to private sector (Crystal Lake Hatchery)	2	31	3

Note: Perry Island, Kowee Creek, Port Camden and Bell Island are not active PNP sites (total = 27 active operational PNPs) hatchery production protects wild stocks, (3) whether or not the hatchery operation is compatible with the regional comprehensive salmon plan, and (4) whether or not the site for the hatchery is appropriate (Alaska Board of Fisheries 1999).

Regional comprehensive salmon plans have been completed by RPTs for the following regions: Southern Southeast, Northern Southeast, Yakutat, Prince William Sound/Copper River, Cook Inlet, Kodiak, Chignik, Alaska Peninsula/Aleutian Islands, Bristol Bay, Yukon River, and Norton Sound/Bering Strait. Regional comprehensive planning progresses in stages. Phase I sets the long-term goals, objectives, and strategies for the region. Phase II identifies potential projects and establishes criteria for evaluating the enhancement and rehabilitation potentials for salmon in the region (McGee 1995). Many regions, including Northern and Southern Southeast, Prince William Sound/Copper River, Yakutat, Cook Inlet, Kodiak, and Bristol Bay completed their plans in the 1980s. Others, like Chignik, Alaska Peninsula/Aleutian Islands, and Norton Sound/Bering Strait, completed their plans in the 1990s. Most of these plans were written for a 20-year period and some, like Northern and Southern Southeast were updated in the 1990s. One region, Prince William Sound/Copper River, developed a third planning phase in 1994 that incorporated the allocation and fisheries management plans of the Board of Fisheries with hatchery production plans. Each region approached the development of its regional comprehensive plan differently and the resulting documents reflect this (Krasnowski 1997).

PNP statutes provide for regional aquaculture associations comprised of representative fishery resource user groups within regions. In order to obtain a hatchery permit, these groups must be PNP corporations. Aquaculture associations can (1) build and operate hatcheries, (2) assist ADF&G in developing regional salmon plans, (3) authorize tax assessments on commercially caught salmon to support ranching (a 1%, 2%, or 3% assessment is chosen by vote of the members), and (4) provide for the sale of a portion of returning hatchery fish to help cover operational costs and repay state loans (Heard 1996). Before an aquaculture association or other PNP corporation can build and operate a hatchery, it must obtain the necessary hatchery permits from ADF&G.

PERMITTING

The permit application procedure for a PNP hatchery is described in Title 5 of the Alaska Administrative Code (AAC 40.100–40.990). Application procedures include pre-application assistance, management feasibility analysis, application form and fees, determination of acceptance by ADF&G for formal review, RPT review, completeness determination by the commissioner, and a provision for reconsideration. The ADF&G Divisions of Commercial Fish, Sport Fish, and Habitat and Restoration; the principal pathologist; and the principal geneticist review the hatchery permit. A public hearing and full review by other state and federal agencies is required through the coastal zone consistency process. A basic management plan (BMP) is developed as part of the permit. The BMP includes a description of the facility, special harvest areas, broodstock description and development, and hatchery stock harvest management. The permit application process is shown in Figure 2. In 1975 the first PNP permits were issued for four locations: Perry Island, Port San Juan, Sheldon Jackson, and Sandy Bay. Forty PNP permits have been issued since inception of the program. The PNP permit process usually takes one to two years to complete (McGee 1995). A hatchery permit is nontransferable.

When a permitted hatchery becomes operational, an annual management plan (AMP) is developed for each year of operation. Specific plans for egg takes, cost recovery, harvests, fry and smolt releases, and marking and recovery are included and approved in this plan. AMPs are developed by ADF&G in conjunction with the operator and are reviewed by the fisheries management divisions and RPT before approval by the commissioner (McGee 1995). Any PNP permit holder is to submit an annual report to

ADF&G, which is to include but not be limited to information pertaining to species; broodstock source; and number, age, weight, and length of adult returns attributable to hatchery releases (ADF&G 1996). Even though statutes permit inspection of a hatchery by ADF&G personnel at any time the hatchery is operating, the annual reports along with the AMPs constitute the primary PNP-monitoring vehicles. The PNP regulation process is shown in Figure 3.

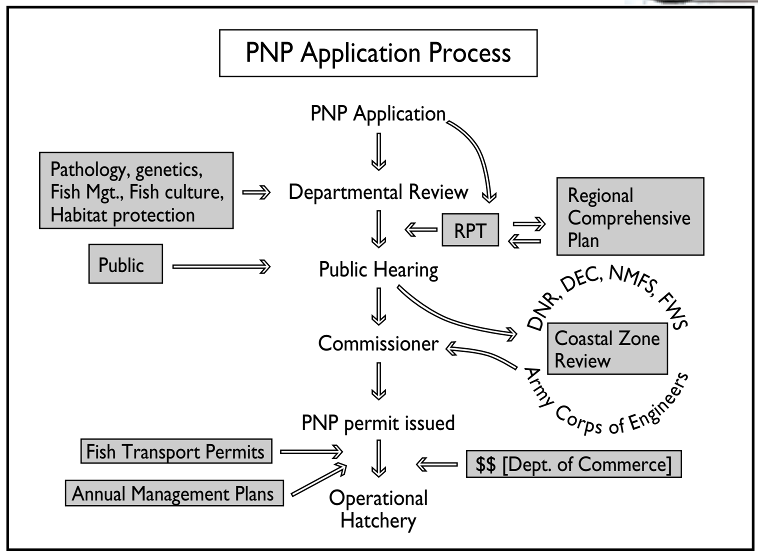

Figure 2. PNP application process chart (McGee 1995).

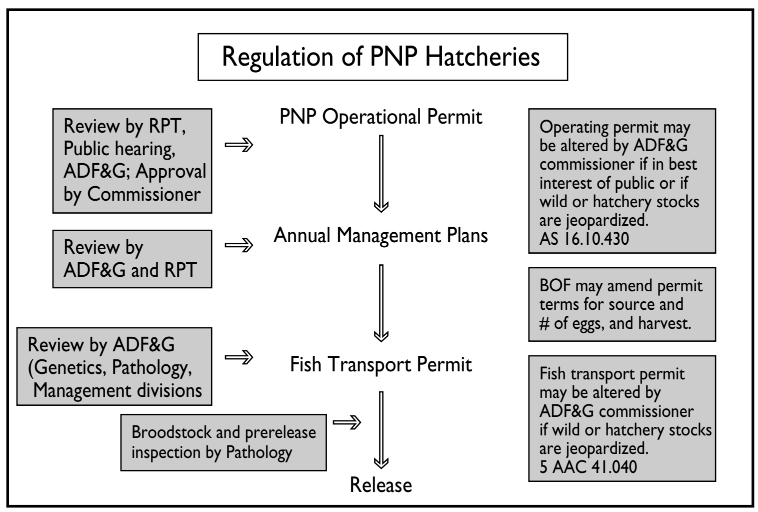

Figure 3. Regulation of PNP hatcheries (McGee 1995).

Alaska statutes (AS 16.10.400–430) place responsibility for the PNP program with the commissioner of ADF&G. It is the exclusive authority of the commissioner to issue permits for the construction and operation of salmon hatcheries. The commissioner may place conditions on a permit. All PNP permits include a fish transport permit (FTP). Title 5 ACC 41.005 states that no person may transport, possess, export from the state, or release into the waters of the state any live fish unless that person holds an FTP issued by the commissioner (McGee 1995). The principal pathologist and geneticist, as well as the region's regional supervisors for the ADF&G divisions review all FTPs. Additional PNP permit conditions may include the following: no placement of salmon eggs or resulting fry into waters of the state except as designated in the permit, restrictions on the sale of eggs or fry, no release of salmon before ADF&G approval, destruction of diseased fish, and ADF&G control of where salmon are harvested by hatchery operators.

The commissioner of ADF&G has the power to revoke a hatchery permit if he or she determines that after five years from the date of issue, the permit holder has not undertaken substantial work to operate a facility in compliance with the terms and conditions specified in the permit. Seven hatchery permits have been revoked to date: Salmon Creek #9 and #14, Crittendon Creek, Santa Anna, and Favorite Bay due to lack of progress toward operating a facility; Sandy Bay as the result of a natural disaster (landslide); and Meyers Chuck because of a violation of the terms of the permit when an un-authorized habitat alteration in an anadromous stream took place (S. McGee, pers. comm.).

The commissioner can also consider a permit alteration, suspension, or revocation based on an internal review that deems the hatchery operation performance is inadequate. RPTs use the following criteria to review, evaluate, and make recommendations to the commissioner: (1) hatchery survival standards, (2) the transport of broodstock from wild sources, (3) hatchery contribution to common property fishery, (4) hatchery impact on wild stocks, (5) fulfillment of production objectives, and (6) mitigating circumstances (ADF&G 1996). More recently, several of the amendments have resulted in a downward adjustment of allocated egg takes due mostly to lack of facility capability or use. Since 1999 the hatcheries in Prince William Sound have had their permits adjusted downward about 150 million pink salmon eggs. Also in 1999, the hatchery at Solomon Gulch lost its allocation for fall chums due to nonutilization and a concern for potential overfishing of local wild coho salmon stocks (S. McGee, pers. comm.). Permitted hatchery capacity for chum salmon in Southeast Alaska was reduced by 119 million eggs between 1997 and 1998 and by another 90 million in 2000.

POLICIES

As described below, various policies were implemented in Alaska to guide hatchery development and to protect wild stocks.

In 1975 ADF&G formulated a provisional Finfish Genetics Policy, which was revised in 1978 following legislative approval of the PNP program. It was revised again in 1985 by a review team comprising scientists from ADF&G, PNP organizations, the University of Alaska, and the National Marine Fisheries Service. The policy represents a consensus of opinion and is intended to be reviewed periodically to ensure the guidelines maintain consistency with current knowledge (McGee 1995). The revisions clarify the rationale for the guidelines and reduce ambiguity in the policy. The current policy contains recommendations designed to protect the genetic integrity of wild stocks. It restricts stock transport, calls for identifying significant or unique stocks and establishing wild stock sanctuaries, and helps maintain adequate genetic variability in hatchery-produced stocks to enable them to adapt to changing environmental conditions (Genetic Policy Review Team 1985). The policy includes considerations for selective breeding practices to ensure diversity within hatcheries and from donor stocks.

Alaska's Fish Resource Permits Policy was approved in 1994 to replace an outmoded 1983 policy. This policy covers the various types of permits required for the collection and/or transportation of live fish in any life stage used for scientific, educational, propagative, or exhibition purposes (McGee 1995).

Alaska's Fish and Shellfish Health and Disease Control Policy was completed in 1988. Its purpose is to prevent the dissemination of infectious diseases to fish and shellfish without creating impractical constraints for aquaculture (McGee 1995). Regulations require that the state pathologist approve any transfer of live salmon and that all salmon eggs brought into any hatchery be disinfected. The policy also includes a separate fish culture document (Sockeye Salmon Culture Manual) that outlines breeding and hatchery protocols for sockeye salmon (Smoker et al. 1999). These special considerations for sockeye salmon were deemed necessary because of the persistent threat of IHNV disease in culture facilities. ADF&G may inspect hatchery facilities at any time they are operating. Each facility is inspected at least every other year by state pathology staff, and each broodstock is examined for disease prior to use in a hatchery (McGee 1995).

In 1992 Alaska's Salmon Escapement Goal Policy was approved to establish the basis and mechanisms for setting escapement goals for the state's wild salmon stocks. Then, in 2001 the Board of Fisheries adopted a revised policy as regulation.

It is intended to support the statute to provide for a wild-stock priority while managing fishery resources on a sustainable yield basis. In 1992 the Board of Fisheries also adopted the Policy for the Management of Mixed Stock Salmon Fisheries (5 ACC 39.220). This regulation makes conservation of wild stocks and sustained yield the highest priority when allocating salmon resources (McGee 1995).

In 2000 the Board of Fisheries adopted the Sustainable Salmon Fisheries Policy to further effect sustainable fisheries management. The policy is based on five central principles: (1) protect wild salmon and habitat, (2) maintain escapements, (3) apply effective management system, (4) encourage public support and involvement, and (5) manage conservatively when there is uncertainty (ADF&G and Alaska Board of Fisheries 2000). This policy recognizes the need to protect wild salmon stocks, as well as to conserve and maintain normal ecosystem functions.

SITE SELECTION

According to various ADF&G salmon plans, hatchery sites and remote release sites were to be selected to minimize the chance of returning hatchery stocks mixing with wild stocks. During the early 1970s, some biologists testified in legislative resource hearings concerning PNP hatcheries that intermingling of returns of wild and hatchery stocks could be minimized if barren systems were used as hatchery sites. By this time, however, several hatcheries (Ft. Richardson, Fire Lake, Deer Mountain, Kitoi) had already been placed on producing streams. In addition, the then director of the FRED Division felt siting was not a problem and that it was better to have the problem of too many fish returning (regardless of where they came from) than not enough (Alaska Senate 1992).

In general, the siting of the PNP hatcheries was determined in the permit review process by ADF&G and PNP staff. In 1974 an ADF&G policy on permitting PNP hatcheries in Alaska addressed permitting on streams depleted of salmon or for insignificant producers. Most early decisions were based on the reviewers' knowledge of the area and relevant fisheries. Hatchery siting decisions were often determined by who owned the land and the reliability of the water source. In the case of chinook salmon, however, guidelines were written in 1983 to minimize the chance of hatchery and wild stock mixing. No hatcheries in Southeast Alaska were to be built on streams with natural runs of chinook salmon (Denton et al. 2000). Current permit regulations state that a hatchery is to be located in an area where a reasonable segregation from natural stocks occurs. However, when feasible, it is also to be placed in an area where returning hatchery fish will pass through traditional salmon fisheries (ADF&G 1996). Given the nearly statewide distribution of salmon in Alaska, it is nearly impossible to avoid siting a facility close to a salmon stream.

STOCK SELECTION

In general, the broodstock for hatcheries is to come from stocks as close to the facility as practical. The 1985 Finfish Genetics Policy prohibits transport if there would be significant interaction with "significant or unique wild stocks." Just what "significant" or "unique" stocks are is rather vague and is left up to ADF&G interpretation. The policy prohibits transport of salmon between regions of Alaska and from outside the state; it permits transport within regions only with consideration of the risks. The policy has been enforced with rigor in preventing transfers of salmon to Alaska from outside of the state. Coho and chinook are the only species of salmon that have been transplanted in Alaska from outside the state. Several coho and chinook stocks were brought into the state from Washington in the 1960s and 1970s. Most of these fish came from either the Green River or Carson hatcheries and were placed in Alaska hatcheries at Crystal Lake, Fire Lake, Starrigavan, and Fort Richardson. The last egg transfers to come into Alaska from outside the state were chinook from Carson, Washington, in

1971 to Little Port Walter; coho from Green River, Washington, in 1972 to Crystal Lake; and coho from the Columbia River in 1979 to Tamgas Creek. There were also a few uses of broodstock from inside the state but outside of the region. For example, coho eggs were taken in the 1970s from Bear Lake (Seward) and Ship Creek (Anchorage) and used at Crystal Lake (Southeast). (See Appendix A for broodstock source for hatcheries).

In Southeast Alaska, eight ancestral chinook salmon broodstocks (Andrew Creek, Big Boulder Creek, Chickamin River, Farragut River, Harding River, King Salmon River, Tahini River, and Unuk River) have been used in hatchery production. Presently five of these broodstocks are being used, with two (Andrew Creek and Chickamin River) accounting for the majority of releases since 1988. The Broodstock Development Project at Little Port Walter maintains Chickamin and Unuk stocks in isolation from each other (and all are wire tagged) (W. Smoker, pers. comm.). Andrew Creek stock has been used at five hatcheries (Crystal Lake, Gastineau, Hidden Falls, Medvejie, and Sheldon Jackson). Most hatcheries in Southeast are 50 to 240 kilometers from any endemic chinook salmon stock (Denton et al. 2000).

Numerous coho broodstocks have been used in Alaska hatcheries; over 30 have been used in Southeast. Sashin Creek, a stock from the southern end of Baranof Island, is one of the more common and farthest traveled stocks. It is found at four hatcheries: three on Baranof Island (Hidden Falls, Medvejie, Port Armstrong) and one near Juneau (Auke Creek). However, there is no hatchery production of coho at Auke Creek. Sashin Creek coho were transferred to Auke Creek as part of a "norms of reaction" experiment in the early 1980s, but all were marked and none were allowed entry to Auke Creek (W. Smoker, pers. comm.). Also, Sashin Creek coho are not released at Medvejie. They are transported from the hatchery back to several hanging lakes (inaccessible to naturally-spawning salmon) on the east side of Baranof Island between Port Armstrong and Hidden Falls. Ketchikan Creek fish (originally from Reflection Lake) are used as broodstock for three hatcheries: Deer Mountain, Tamgas Creek, and Burnett Inlet. Most of the other hatcheries use stocks in close proximity to the hatcheries.

There are over 20 stocks being used for chum salmon broodstock, most in Southeast Alaska. All chum salmon broodstock sources have come from within the same region as the hatchery. Hidden Falls hatchery is the most used broodstock by other hatcheries and originated with three stocks: Kadashan, Clear, and Seal Bay. In turn, this broodstock has been used at the Medvejie Creek, Gastineau, Gunnuk Creek, and Indian River hatcheries. The three Gastineau hatcheries have the most complex mixture of broodstock, with at least six stocks being incorporated. The Whitman Lake and Neets Bay hatcheries both used the same three stocks (Carroll, Cholmondelay, and Disappearance) to start their broodstock. Cholmondelay and Disappearance Creeks are fall-run stocks and Carroll River is a summer-run stock.

Pink salmon are raised at fewer hatcheries in Alaska than are coho or chum. In Southeast, pinks are being raised at four hatcheries with about 10 stocks being used as broodstock. Most of these have come from sources close to the hatcheries and, with the exception of the Gastineau hatcheries, little broodstock interchange has taken place among hatcheries. In Prince William Sound, pinks make up the largest number of salmon being cultured. They are raised at four hatcheries with broodstock coming from Cannery Creek and Solomon Gulch, both of which are in close proximity to the hatcheries. The Koernig hatchery used three principal sources for broodstock (Duck/Galena Bay, Larson, and Ewan). This broodstock was also used for the Norenberg hatchery. Of these only Duck/Galena Bay made any significant contribution in even years. Larson (the site of Koernig hatchery) is an intertidal waterfall with a few fish spawning below it. Only Ewan contributed significantly in odd years. The broodstocks at Koernig have been moved to the Noerenberg hatchery on the western side of Prince William Sound.

Sockeye salmon are the least cultured salmon in Alaska due to a difficulty in culturing them because of their high potential for disease. There are currently five hatcheries plus two incubation box facilities raising sockeye salmon. Most of the hatchery sockeye broodstock come from remote sites (distant from the hatchery location), and the progeny are released back at these sites.

STRAYING

Straying rates for pink salmon from hatcheries in Prince William Sound specifically, and among wild pink salmon populations generally, may be significantly higher than for other salmon species (Sharp et al. 1993). Joyce and Evans (1999) used recoveries of thermally marked otoliths to determine if pink salmon strays from hatcheries could be detected adjacent to three Prince William Sound hatcheries (Noerenburg, Koernig, and Cannery Creek) in 14 selected streams in Prince William Sound. They purposefully studied streams where straying from the hatcheries would be most likely detected and did not systematically sample streams across Prince William Sound. The proportion of hatchery salmon in stream escapements ranged from 26% to 97%.

An obvious explanation for the large contribution of hatchery salmon to wild escapements in Prince William Sound lies in the numerical dominance of hatchery over wild salmon runs. In 1997 the commercial fishery in Prince William Sound harvested about 25 million hatchery pinks and 1.2 million wild pink salmon (Joyce and Evans 1999). The proportion of hatchery salmon in stream escapements may become large even when straying rates are small. The study also showed that straying was highly correlated with distance between the hatchery and donor stream origin. The Noerenburg and Koernig hatcheries had straying rates five times those for the Cannery Creek hatchery. The broodstock from the Noerenburg hatchery was obtained from pink salmon spawning streams located distant from the facility, while the Cannery Creek hatchery stock was obtained from Cannery Creek. Broodstocks from the Koernig and Noerenburg hatcheries originated from streams considered unstable, and they may have more tendencies to stray (Joyce and Evans 1999). This is probably due to the fact that these broodstocks were from intertidal spawning stocks that probably have intrinsically much lower homing fidelity than do upstream stocks (W. Smoker, pers. comm.). High rates of straying in Prince William Sound relative to other locations may reflect recent geologic instability in the Sound. The 1964 earthquake caused widespread habitat destruction in the intertidal zone of streams. A large proportion of Prince William Sound pink salmon are intertidal spawners, and a high level of straying was likely among returning salmon that found natal streams no longer accessible (Halpuka et al. 2000).

In another study using thermal mark recoveries in Southeast Alaska, returning pink salmon of Prince William Sound hatchery origin were found over 450 direct distance miles away from the hatchery (Agler et al. 2000). Thermally marked otoliths from chum salmon originating in Gastineau hatchery near Juneau have been recovered in watersheds near the hatchery (Smoker et al. 1999).

FISH CULTURE

In order to help maintain genetic variance in hatchery stocks, several guidelines for fish culture were outlined in the Finfish Genetics Policy. These include the following: a single donor stock cannot be used to establish or contribute to more than three hatchery stocks; a minimum effective population *(Ne)* of 400 should be used for broodstock development and maintained in hatchery stocks (however, small population sizes may be unavoidable with chinook and steelhead); and to ensure all segments of the run have the opportunity to spawn, sliding-scale egg takes for donor stock transplants will not allocate more than 90% of any segment of a run for broodstock. There is also a caution in the policy to keep the male-to-female sex ratio as close to 1:1 as possible (Genetic Policy Review Team 1985).

The AMP for each hatchery outlines their respective fish culture procedures and is reviewed by ADF&G genetics staff for adherence. The FTP is used to authorize the broodstock and stocking location requested by each PNP in their respective AMPs. Prior to 1998 there was a potential for genetics review of the FTP without knowing what was in the AMP. ADF&G altered its review procedures and now staff geneticists routinely review both the FTPs and AMPs prior to their being approved by the commissioner (D. Moore, pers. comm.).

GENETIC DIVERSITY

Identification of the origins of salmon harvested from a mixed-stock fishery is a management concern as well as a conservation concern for biological diversity. The ADF&G Gene Conservation Laboratory has successfully used genetic data to identify regional stock components for selected populations of chinook, chum, pink, and sockeye salmon.

Data have been collected throughout the North American range for chinook salmon. Allele frequency differences are sufficient to identify differences among chinook stocks from eight large regions: Western Alaska, Southeast Alaska, British Columbia (non-Frazier), Fraser River, Washington Coastal, Puget Sound, Columbia River, and California-Oregon. At least two distinct lineages of chinook are present in Alaska: one composed of populations from Southeast and one of populations from west and north of the Copper River. Populations within Southeast Alaska are more divergent than those in the Western region. Three distinct groups are apparent within Southeast Alaska: Chilkat River, King Salmon River, and remaining Southeast populations (Crane et al. 1996).

A comparison of allele frequency data collected in western Alaska with data available for Pacific Rim chum populations suggests that populations of the Alaska Peninsula-Gulf of Alaska lineage were derived from Cascadia (the Pacific Refugium) and belong to a larger southern lineage, which includes populations from Southeast Alaska, British Columbia, and the Pacific Northwest. In contrast, populations from Northwest Alaska appear to be derived from a northern lineage with affinities to Asian populations. Populations of the northwest lineage occur in the largely unglaciated areas of Alaska north of the Alaska Peninsula, and the more southern lineage occurs in the glaciated and unglaciated areas of the Alaska Peninsula, Kodiak Island, and Southcentral Alaska (Seeb and Crane 1999).

ADF&G has conducted a pilot study of pink salmon from Northwest Alaska to Northwest Washington using DNA markers. Populations were found to be organized by latitude; populations that are geographically farthest apart are also genetically most divergent. In Prince William Sound, ADF&G found genetic differences between even- and odd-year fish and within-year differences between early and late spawning aggregates. Genetic differentiation has been found among streams and within streams, as well as between tidal and upstream spawning fish. These differences indicate that pink salmon in Prince William Sound are not one randomly interbreeding population, but rather a collection of populations with restricted gene flow (ADF&G 2001).

ADF&G has developed a sockeye salmon database of genetic information for the Upper Cook Inlet and Chignik River drainages and is currently working to expand the database to include Kodiak Island and the Bristol Bay drainages.

DISEASE PROTOCOLS

Risks of infectious disease dissemination have been reduced by rigorous enforcement of Alaska's Fish and Shellfish Health and Disease Control Policy (Holmes and Burkett 1996), which restricts transfer of salmon and requires inspection of facilities and examination of salmon. There have been several instances where IHNV disease has been detected in hatchery sockeye, and the fish have been destroyed. Because of this threat, Alaska has a sockeye-breeding protocol for hatcheries.

FISHERIES MANAGEMENT

Management of Alaska's salmon fishery began when Congress passed the Alaska Salmon Fisheries Act in 1889 to protect and regulate Alaska's fisheries; it was amended several times between 1900 and 1906. The Act prohibited obstruction of spawning streams and any fishery above tidewater in streams less than 500 feet wide (Pennoyer 1979). Prohibiting fishing out of stream mouths adversely affected fishery efficiency in order to reduce the prospect of overharvesting, but it necessarily established mixed-stock fisheries that are prone to overharvesting the weak stocks. With Alaska statehood in 1959, the legislature invested authority for management of Alaska's fisheries to ADF&G and the Alaska Board of Fish and Game (later separated into the Board of Fisheries and Board of Game). ADF&G was given authority to promulgate emergency orders to summarily open or close seasons or areas or to change weekly closed periods (Pennoyer 1979). The governor appoints members to the Board of Fisheries (also known as the Board of Fish). The Board of Fisheries has no administrative, budgeting, or fiscal powers but is charged with allocating salmon within and among different user groups and promulgating management regulations that are enforced by ADF&G. The Board of Fisheries holds hearings regarding regulations and policies affecting Alaska's fisheries throughout the state and maintains a system of advisory committees to obtain local input in making regulations.

Management of resources in waters within three nautical miles from shore is the responsibility of the State of Alaska (Pennoyer 1979). ADF&G manages the salmon fishery in discrete management areas. These include six fish and game resource management regions (Southwest, Southcentral, Southeast, Arctic, Interior West, and Interior Central) and four commercial fisheries management regions (Southeast, Central, Arctic-Yukon-Kuskokwim, and Westward). Because of the discrete nature of these areas, there is no comprehensive salmon management plan for the entire state and each management area has its own goals and objectives. In addition, ADF&G may promulgate certain statewide management policies that are signed by the commissioner of ADF&G, such as its Finfish Genetics Policy.

The mixed-stock and mixed-species nature of the Alaska fishery, as well as its system of allocation to specific user groups, creates complicated management issues. Even though the commercial fishery is by far the largest, the recreational, subsistence, and personal use fisheries all target on salmon. Meeting the needs of these diverse user groups while maintaining salmon population levels can be problematic. Although goals and objectives may differ from management area to management area, the ultimate salmon management goal statewide is to harvest surplus salmon from each stock while providing adequate escapement levels.

Article VIII of the Alaska Constitution mandates that renewable state resources be managed in a sustainable manner. This is the guiding principle behind the state's current fisheries management, whose goal is to produce maximum sustained yield. According to Alaska Statute (Title 16), it is the policy of ADF&G to manage for wild salmon stocks by ensuring adequate escapement. The commissioner approved the Salmon Escapement Goal Policy in 1992 to establish the basis and mechanisms for setting escapement goals for wild salmon stocks. The Alaska Board of Fisheries adopted a revised Salmon Escapement Goal Policy in 2001. This policy affirms the mandate to manage fishery resources on a sustainable yield basis.

A further relevant historical point is to note the growing dependency of commercial fisheries in Southcentral and Southeast on hatchery production. For example, salmon fisheries in the Gulf of Alaska are notable because hatcheries produce the majority of some salmon species in some areas and, in specific fisheries, the majority of salmon harvested.

Within this region, 56% of the salmon in the traditional commercial harvest were of hatchery origin in 1999, and the percentage is higher if cost-recovery fisheries are included. In Prince William Sound in particular, hatchery production provides a majority of the pink and chum salmon harvested and a substantial fraction of the sockeye and coho salmon harvested. In 1999 hatchery pink salmon contributed 84% of the number of pink salmon harvested by commercial fisheries in Prince William Sound (P. Mundy, pers. comm.).

Special Harvest Area

The harvest of salmon in Alaska, regardless of whether the fish were naturally or artificially propagated, may be conducted only pursuant to regulations adopted by the Board of Fisheries. The harvest of salmon returning to a PNP hatchery is governed by regulations adopted by the Board of Fisheries and is a common property fishery. The operation of PNP hatcheries brings with it the obligation to provide the hatchery operator with a certain portion of the hatchery run for recovery of operational costs and broodstock to sustain production. Cost-recovery harvests and broodstock collection take place within a designated area termed the special harvest area (SHA). Where hatchery returns enter a segregated location near the release site and can be harvested without significantly affecting wild stocks, a SHA is designated for each hatchery by regulation adopted by the board or by emergency orders issued by the commissioner. A PNP permit holder may harvest salmon for the hatchery only in the applicable SHA. However, this does not prevent a SHA from being open to commercial, sport, or subsistence fishing. Harvesting of salmon within the SHA, whether by the hatchery or the common property fishery, is opened or closed by regulation or emergency order. SHA boundaries are set in 5 AAC 40 or in a PNP permit issued by the commissioner (ADF&G 1996). A SHA is very similar to a terminal harvest area, except that a terminal harvest area is solely a common property fishery and does not have to be related to a hatchery.

Cost-recovery requirements and broodstock needs are determined in advance of the season and published in the AMPs. Based upon returns to the SHA, interception of hatchery returns by the common property fishery is adjusted to meet the hatchery's goals. Management strategies are developed each year based upon the specific cost-recovery and broodstock requirements, the forecast returns, and other factors as appropriate. These management strategies are formalized annually for each hatchery in the AMP (Prince William Sound - Copper River RPT 1994).

Mixed-Stock Fisheries

In Alaska, the ocean-ranching program has complicated management since its inception by the intermingling of hatchery and wild fish in the common property fishery. The regions where this has become a major concern are Kodiak, Cook Inlet, Prince William Sound, and Southeast (Krasnowski 1997). The mixed-stock fishery has apparently recently reduced some wild stocks below desirable numbers as evidenced by low wild pink salmon returns to the Coghill District in northwest Prince William Sound (Smoker et al. 1999). A few wild stocks of chum salmon in Southeast Alaska have probably experienced some detrimental effects of large-scale enhancement efforts, and at least one (Sheep Creek) may have been extirpated (Halupka et al. 2000).

The concern of overexploitation of wild fish can be amplified by the geographic location of hatcheries and release sites. For example, the Neets Bay and Whitman Lake hatcheries in Southeast Alaska are located along the migration pathway of numerous wild Behm Canal stocks (Halupka et al. 2000). The sustainability of high exploitation rates for southern Southeast Alaska and Lynn Canal coho and chum salmon is a concern. Declines in the early-run coho salmon in the Skeena and Taku Rivers may be caused by overharvest in the fishery directed at sockeye salmon. A similar concern exists for late-run coho salmon from Lynn Canal that are harvested in a fishery directed at chum salmon runs to the Chilkat River (Halupka et al. 2000). Wild coho salmon returning to Salmon Lake are of special concern due to increased fishing pressure targeting hatchery-produced (Medvejie) chum and coho salmon in the Deep Inlet SHA (Schmidt 1996).

Attempts to reduce risks to wild stocks from overharvest have been implemented by siting facilities where harvests are not mixed (e.g., Hidden Falls) and by using tags to identify hatchery fish in mixed harvests (e.g., Nakat Inlet). In areas of mixed-stock fisheries, large-scale marking programs (thermal otolith marks) have been initiated to contain the risk (Smoker et al. 1999).

Escapement

Wild Stocks. In order to achieve biological escapement goals (BEG) to ensure maximum sustained yield, managers depend upon in-season assessment of relative annual abundance. BEGs have been formulated by ADF&G for salmon by major river system. The in-season assessment is accomplished by using numerous methods including catch data from ongoing fisheries, test fisheries, aerial surveys, and weirs. The effectiveness of in-season management is evaluated by spawning escapements and exploitation rate estimates for indicator stocks. To monitor escapements ADF&G uses weirs, aerial surveys, towers, sonar, mark-recapture studies, and ground counts of spawners or carcasses on index streams. The methods may vary from region to region. Escapement goals for Alaska streams were established in the 1960s and 1970s and revised in 1991 for Prince William Sound, Cook Inlet, and Bristol Bay (Fried 1994). In Prince William Sound, for example, there are over 800 pink salmon streams. ADF&G seasonally monitors between 150 and 200 of these (which serve as the index streams) with weekly aerial surveys. ADF&G also enumerates escapements of two major sockeye systems in Prince William Sound by daily weir counts. Escapement was met for all index streams between 1990 and 2000 except in 1992, a year with very low returns in Prince William Sound for all stocks (Sharp et al. 2000).

In Southeast Alaska, there are over 5,000 streams producing anadromous fish. About 3,000 of these are principal salmon-producing streams and coho, pink, and chum salmon are found in most all of them. Most escapement estimates in Southeast are done by aerial survey along with some weir data and mark-recapture estimates. Escapement trends for coho salmon are primarily monitored for 34 streams in six stock groups (Yakutat, Lynn Canal, North-Central, Taku, Stephens Passage, Southern Inside), and none of these streams showed declining trends in escapement between 1981 and 1996 (Van Alen 2000). Helicopter surveys and weirs are used to count chinook escapements at 27 locations in 11 river systems. ADF&G is in the process of developing new spawner-recruit (S-R) escapement goals for chinook in Southeast to replace those established prior to 1985. New S-R escapement goals have been established for six systems (Situk, Alsek, Unuk, Chickamin, Blossom, Keta), and chinook escapements to these six systems have generally been within or above goal ranges since 1981 (Van Alen 2000). Reliable indices, or estimates, of annual escapements are available for just a handful of the over 200 systems in Southeast that produce sockeye salmon. Total run size is estimated for nine systems primarily using weir counts with mark-recapture studies as backup. Two systems (Chilkoot and Italio) have shown a downward trend in sockeye escapement counts over the 1980 to 1996 period (Van Alen 2000).

Since 1960, ADF&G has intensively monitored pink salmon escapements in 1,588 Southeast streams, but usually fewer than half are surveyed in any given year. Most counts are by aircraft and foot with occasionally counts by helicopter, weirs, or mark-recapture studies. Escapement trends were estimated using peak aerial survey counts from 652 streams between 1960 and 1996. Overall, escapement indices showed an upward trend for both northern and southern Southeast Alaska pink stocks. Florence Creek (Admiralty Island) was the only one of the 652 index streams to show a significant downward escapement trend (Van Alen 2000). ADF&G does not have a standardized program for indexing the escapement of chum salmon in Southeast, but aerial and foot escapement survey counts dating back to 1960 are available in its database. Baker et al. (1996) evaluated escapement trends for 45 chum salmon stocks and found declining escapements in 10. A decline in escapements of Chilkat River chum salmon has been an ADF&G concern since the mid-1980s (Van Alen 2000).

There are approximately 800 streams on Kodiak Island where salmon have been documented. Of these, 4 support chinook, 39 support sockeye, 150 support chum, 174 support coho, and all support pink salmon. The majority of sockeye and all chinook salmon escapement counts are obtained from weirs that are located on 12 spawning systems. Some pink, chum, and coho salmon escapement counts are also obtained from weirs, but most come from aerial surveys. Since the 1980s, the BEG has been met or exceeded for chinook, sockeye, pink, and coho salmon on Kodiak Island. Chum salmon production has been variable and low since 1992, nevertheless, the BEG has been achieved in 9 of 10 years between 1988 and 1998 (Prokopowich 2000).

There are approximately 582 documented spawning streams within the Alaskan Peninsula and Aleutian Islands. Most salmon escapement estimates are derived from aerial surveys plus five weirs that are used for monitoring sockeye salmon. Escapement estimates for the area are indexed totals and are limited to chinook, sockeye, pink, and chum salmon. Since 1989, average indexed total escapements have been above the escapement goal range for all species (Shaul and Dinnocenzo 2000). The Chignik River on the Alaskan Peninsula is in a separate management area and is monitored by a weir. Chinook and sockeye salmon escapements were above the BEG in 1997.

In general, Upper Cook Inlet salmon stocks are in good condition insofar as assessments of spawning escapements have been conducted. The best assessments are sonar counts of sockeye entering the larger watersheds (Kasilof, Kenai, Crescent, Susitna), followed by weirs. The majority of salmon spawning localities in Upper Cook Inlet have no direct assessment of escapements. The overall return of sockeye salmon in 1998 was low. Since the late 1980s, the Crescent River sockeye salmon run has declined and ADF&G is reducing the BEG for this system to reflect a decreased capability of the system to rear fish. Recent returns of sockeye to Fish Creek in Knik Arm have been poor and in 1998 produced less than 50% of the desired escapement. Chum salmon production has been relatively poor in recent years for the Susitna Basin. Coho stocks have generally produced strong runs throughout the 1980s and 1990s except for 1997, which was a substandard year in most drainages. After experiencing a significant downturn in the early 1990s, chinook salmon escapements continue to trend upward (Ruesch and Fox 1999).

In Bristol Bay, several indicators of run size are used including the False Pass fishery, Port Moller test fishery, tower counts, sonar, and aerial surveys. Sockeye salmon dominate the fishery in Bristol Bay and spawning escapement requirements have been defined by ADF&G for eight river systems there (Naknek, Kvichak, Egegik, Ugashik, Nushagak, Togiak, Wood, Igushik). Sockeye escapement goals were met or exceeded in all of these systems in 1999. Two of these systems (Kvichak and Nushagak) had difficulty meeting escapement goals for the 10-year period from 1989 to 1998. The 10-year escapement average for the Kvichak system was 12% below the goal (ADF&G 2000).

The vast size and remoteness of the Kuskokwim, Yukon, and Norton Sound areas present challenges to monitoring salmon escapements. Aerial spawning surveys have been the principal means of monitoring salmon escapements but over the past few years the use of weirs, counting towers, and sonar operations has increased. Most of the BEGs for these areas are based on average annual escapements from aerial surveys. Many of these are being reviewed and modified. Seven projects using weirs, counting towers, or sonar were operated in the

Kuskokwim area in 1999 to better monitor escapement. Escapement at the Kogrukluk River weir in 1999 was just over half of the BEG for chinook, under 50% for coho, and 54% for chum salmon (Burkey et al. 2000).

Most monitoring in the Yukon Drainage is for chum or chinook salmon and includes sonar (hydroacoustic), ground surveys, counting towers, and mark-recapture projects. Chinook salmon minimum escapement goals were generally achieved in the Alaskan, but not the Canadian portion, of the Yukon Drainage in 1999. The 1999 run was larger than the very weak 1998 run but below that of 1997. Escapements of summer chum in the Anvik River, the largest producer of summer chum in the Yukon Drainage, were above the escapement goal from 1991 to 1997. In 1998 no escapements in monitored tributaries met escapement goals and ranged from 27% to 81% below average. In 1999 the summer chum run in the Anvik was 12% below the minimum escapement goal. The 1998 and 1999 fall chum runs into the Yukon River were 46% and 44% of normal run size expectations. With the exception of the upper Tanana River, spawning escapements were below average but still within minimum escapement goals. In the Toklat River (Tanana Drainage), the 1999 escapement estimate was 86% below the minimum escapement goal and the lowest on record since 1982 (Bergstom et al. 2001).

Escapement projects in Norton Sound include counting towers on seven rivers, a test net on the Unalakleet River, and a weir on the Nome River. Overall, in 1998 returns of chinook salmon were average to above average, coho salmon were average to below average, and chum salmon were below average. Several streams in the northwest area (Pilgrim, Sinuk, and Nome) had chum escapements below goal. Escapement indices for Shaktoolik and Unalakleet were also below escapement goals in 1998 (Brennan et al. 1999). Also of concern in the Nome area was the fact that no chum salmon returned to the Penny and Cripple Rivers in recent years, causing concern for the extirpation of these populations (Clark 2000).

A recent review of salmon escapement data and estimation methods in western Alaska was conducted by a group of scientists who were asked by the commissioner of ADF&G to assist the Alaska Board of Fisheries (Independent Scientific Review Committee 2001). The group concluded "…the basic data on stock and recruitment are not as precise as would be desirable." Of particular concern was the general inability in many instances to allocate catches to river of origin, which precluded keeping track of trends in productivity by river system.

Hatchery Stocks. Ideally, one does not want escapement of hatchery fish but sufficient returns to the facility for the purpose of cost recovery and broodstock use. In most years, this is what takes place at PNP hatcheries. Occasionally, especially during broodstock development, there have been insufficient returns or a hatchery has harvested into its broodstock and not ended up with enough eggs. There have also been a few instances when too many fish returned and hatchery fish spilled over into adjacent streams and beaches. In 1998 a huge return of pink salmon in Prince William Sound flooded the processors and an unknown number went unharvested. In 1996 a large chum salmon return went underharvested in Southeast and many dead chums were noted on beaches. When this happens, there is a greater potential for hatchery fish to migrate to nearby streams and spawn with wild stocks. This is an undesirable scenario and ADF&G will take appropriate action including adjusting fishery openings or modifying hatchery permits to rectify the situation.

Discriminating Hatchery Fish in the Harvest

Understanding the relative impact of fisheries on wild stocks requires knowing what proportion of the harvest is of hatchery origin. This is akin to the need for managers to know the origin of wild salmon by watershed in order to track trends in productivity and to set escapement goals. Recognizing hatchery fish in the harvest has recently become much easier due to advances in mass tagging technologies.

The first major breakthrough in distinguishing between large numbers of hatchery and wild fish came with the use of coded-wire tags (Riffe and Evans 1998; Sharr et al. 1996). Coded-wire tags allowed reasonably precise estimates of the proportion of hatchery salmon in each harvest by the end of the season. However, its use for in-season management was limited by technical difficulties that have since been solved by thermal mass-marking. Thermal marking of otoliths was initiated in Prince William Sound in 1995, and since 1997 all hatcheries there are so marking released fish. This tool has greatly increased ADF&G's ability to manage the fishery, for within 24 hours managers can determine what percent of the catch is hatchery and to a degree of precision not possible with the previous marking technology. This information gives managers the basis for opening, closing, or otherwise modifying the fishery to control the proportion of wild salmon in catches to ensure wild salmon escapement. Since 1997, all escapement goals in Prince William Sound have been met or exceeded and the thermal-marking tool is likely responsible for this success.

In Southeast Alaska, it is felt that better segregation of the chum salmon runs has made the fishery easier to manage than in Prince William Sound; nevertheless, ADF&G is encouraging all hatcheries to thermally mark all chum salmon (S. McGee, pers. comm.). Currently, most Southeast hatcheries are thermally marking chum and sockeye salmon and all pink salmon are marked at the Gastineau hatcheries. Northern Southeast and Douglas Island PNPs have been doing so since 1997, and the Southern Southeast Regional Aquaculture Association is in the process of implementing structural changes to its facilities that will enable marking 100% of released chum salmon. Some smaller operations, like the Gunnuk Creek hatchery, have not yet been able to comply with this request due to complex water quality and allocation problems. Due to ongoing research projects and complex U.S.-Canada treaty considerations, coded-wire tagging operations are still used for chinook and coho salmon marking.

CONCLUSIONS

There has been little systematic evaluation of the effects of hatcheries on natural systems. Most evaluations of hatcheries are economic rather than biologic, as might be expected given the commercial purpose of large-scale hatchery production. Another commonly recognized benefit from hatcheries is stocking with trout and salmon throughout the United States for sport fisheries. The most common and accepted biological benefits attributed to hatcheries are their use for research and as possible refuges for threatened or endangered species. Critics of hatcheries often do not agree among themselves on the nature and severity of the risks hatcheries pose or on ways to minimize them (Waples 1999). Various scientific reports have asserted that hatchery-produced salmon stocks have reduced or replaced wild stocks (Eggers et al. 1991; Hilborn and Eggers 2000), while others offer differing views (Smoker and Linley 1997; Wertheimer et al. 2001). Some argue that genetic diversity can be reduced by artificial propagation (Reisenbichler and Rubin 1999), others diminish the risk (Campton 1995), and others minimize it (Cuenco 1994). Given these divergent views and the lack of data that prove any one view, research is needed to shed light on the issues and hopefully provide practical solutions.

Alaska's ocean-ranching salmon hatcheries operate amidst considerable uncertainty. Perhaps the most striking feature in conducting this review was encountering so many gaps in the available scientific data from which one can fairly draw conclusions on the effects hatcheries may or may not have on wild salmon. Alaska has been successful in augmenting salmon harvest, but in accomplishing this, the question of whether salmon biodiversity has been adequately protected is unanswered. The robust and reliable data necessary to evaluate interactions between hatchery and wild salmon populations have not, in most cases, been collected. Decisions regarding the efficacy of hatcheries or ocean ranching should be based on sound science. Unfortunately, due to uncertainties and gaps in the available data, management decisions are more often based on short time frames and focused on local concerns rather than on long-term time frames and whole ecosystems. Better data are needed to bring consensus among scientists and managers on how to figure uncertainties, such as ocean carrying capacity and genetic risk to wild fish from hatchery straying, into the complex management equations. Until such data are available and algorithms for using them developed, the prudent course for management is a conservative one.

In the comprehensive salmon plan for Prince William Sound, one of the recommendations is that the proportion of hatchery salmon straying into wild stock streams must remain below 2% of the wild-stock escapement over the long term (Prince William Sound - Copper River RPT 1994). This recommendation is obviously not being followed. Straying of hatchery fish in Prince William Sound and Southeast is a major concern that is not being adequately addressed and needs to be brought fully into the light. Without proper monitoring, it cannot be said with certainty what impact high hatchery straying rates are having on wild fish. Potentially it is of significant magnitude and may not be in line with Alaska's Sustainable Salmon Fisheries, Finfish Genetics, and Salmon Escapement Goal Policies, or with the wild stock priority statute as it relates to the protection of wild stocks.

After more than 30 years of debate about the impact of hatchery fish on the genetic diversity of wild salmon populations, there still is no definitive answer to this concern (even given the increase in the body of knowledge). It may be easy to identify risks that hatcheries pose for natural populations; it is not so easy to predict whether deleterious effects have occurred or, if they have, how serious the consequences will be. One problem with genetics research is that it can be costly and lengthy. Regardless, it is prudent to continue investigations in this area. Given the documented incidence of straying of hatchery fish, especially pink and chum salmon in Prince William Sound and Southeast Alaska, an increased commitment to genetic studies and monitoring of wild stocks proximal to hatcheries for any detectable genetic changes is warranted. Elucidation of salmon population structure is always important information for developing management programs designed to conserve biologic and genetic diversity.

Is Alaska's Finfish Genetics Policy sufficient to protect the state's wild salmon? Protection of wild stocks is a principal objective of the policy, which is considered to be one of the more conservative policies in the country (Davis and Burkett 1989). That said, the policy has not been revised since 1985 and could be updated to ensure that the most recent molecular genetic knowledge and technologies are used. There are examples of hatchery practices that are out of compliance with this policy and accepted practices elsewhere. The policy calls for a single donor stock to be used in no more than three hatcheries. Five Andrew Creek chinook and four Sashin Creek coho stocks have been used at Southeast hatcheries. It is difficult to follow the trail of chum salmon hatchery stocks in Southeast, but it appears that the Hidden Falls hatchery is made up of at least three separate stocks that in turn have been used (albeit to a limited extent) in four other hatcheries. The restriction on stock transport to within regions sounds good, but Southeast Alaska is a big region and stocks are transported over large distances. It is a recommended practice in other parts of the country and in Canada to occasionally infuse wild gametes into a hatchery population for conservation purposes. This is currently not being done in Alaska, although most hatcheries have outbred their broodstocks in one way or another, either from the inclusion of strays (e.g. Prince William Sound pinks) or from wild stock egg take programs (e.g. Gastineau coho, Neets Bay coho).

The Finfish Genetics Policy came about as a result of a concern that the development and operation of a hatchery system could, if not done properly, have a detrimental impact on wild salmon populations. A provisional policy was developed in 1975 and the most current revision was published in 1985. The policy contains guidelines that provide for the application of genetic principles to the development and management of hatchery broodstock. ADF&G applied the existing body of population genetics knowledge to the development of the Finfish Genetics Policy, but at that time there was little, if any, information on genetic impacts of hatchery-produced fish on wild populations.

The need to conserve genetic information is fundamental to salmon biodiversity conservation. Both commercial fishing and hatchery production can adversely affect conservation of genetic diversity. The Finfish Genetics Policy recommends designation of hydrological basins or geographic areas as gene preserves—perpetual repositories of genetic information for all plant and animal species inhabiting such areas. Currently, there are no officially recognized gene preserves in Alaska specifically established for salmon species. This issue has been examined by several of the RPTs. For example, the Cook Inlet RPT considered several streams on the Kenai Peninsula in the early 1990s as stock reserves or gene preserves for one or more salmon species. Unfortunately, this process was not completed due to funding constraints (G. Fandrei, pers. comm.). This is an oversight of long standing and should be addressed.

Another example of where a well-informed genetics policy is essential can be seen in evaluating hatchery-siting criteria. The majority of PNP hatcheries were permitted prior to 1992; the two large hatcheries in western Prince William Sound were permitted in 1975 and 1983. Most Alaska hatcheries were sited with land ownership and water quality as preeminent criteria, with less attention given to biologic concerns. Considerable biologic and managerial knowledge has accumulated since these hatchery sites were permitted. Many state hatcheries are located in areas that make straying into wild stock waters and complicated mixed-stock fisheries management inevitable. Both RPTs and the Finfish Genetics Policy address hatchery siting. In view of the mandate to protect wild stocks, the hatcheries in western Prince William Sound (as well as others, especially some in Southeast) may be less than ideally sited with regard to wild-hatchery interaction.

The question is often asked: To what extent are wild salmon stocks overexploited in mixed-stock fisheries? Management of a mixed-stock fishery is a complex problem even without hatcheries. Factoring hatchery fish into the management equation only makes a hard job more difficult. It is important not to overharvest small salmon populations that may contain unique adaptive traits (and genes). Given the number of streams in Alaska (and corresponding number of salmon stocks) coupled with the size of the ADF&G staff and state budget, conducting the monitoring required to ensure that no wild salmon stocks are being negatively impacted by overfishing or invasion of hatchery strays is nearly impossible. In Prince William Sound alone, ADF&G currently monitors 150 to 200 of the approximate 800 streams found there for escapement. In order to monitor all 800, a much larger staff and logistics budget would be needed. The advent of thermal marking is a significant advance in technology that will enable a much closer and more thorough monitoring of mixed-stock fisheries and subsequently better protection of wild stocks. Hatcheries are moving in the direction of marking all released fish, which will improve mixed-stock management.

Management of fisheries and of hatcheries must be integrated and adaptive. There is a need to change the expectations of managers and harvesters to coincide with the natural variation and uncertainty in the abundance of salmon populations (Knudson 2000). More reliable and timely estimates of wild-stock escapements and run sizes are needed to direct management of the mixed-stock fisheries, especially for those that harvest chum salmon in Southeast Alaska.

There is significant concern over competition for resources between hatchery and wild salmon stocks. Based on a review of the scientific literature and discussions with biologists, geneticists, and fishery managers about protecting salmon biodiversity, the potential impacts of extensive ocean ranching appear to pose a great concern for the ocean's carrying capacity. This may become the most important issue for assessing risks to wild salmon populations, especially for those with comparatively small numbers of individuals. It will likely become a higher risk than loss or change in genetic diversity due to hatchery practices. It has been hypothesized that hatchery-produced chum salmon from Southeast Alaska may be having a negative impact on wild stocks of chum salmon in Western Alaska through density-dependent interactions like competition for food in the marine environment. ADF&G believes that there is no conclusive evidence to link hatchery production in one part of Alaska with declines of wild salmon in another and, in fact, has seen indications of the opposite for chum salmon, where survival of both wild and hatchery chum salmon are high in Southeast Alaska (although this may not be true for fall run chums in Lynn Canal). Nevertheless, there is evidence (smaller size, soft flesh) that Asian salmon have suffered deleterious effects leading some researchers to conclude that the carrying capacity of the western North Pacific for pink and chum salmon has been exceeded. It is also thought that high numbers of pink salmon (many of them hatchery derived) may lead to lower numbers of chum salmon.

Environmental conditions favorable for producing salmon are (and have been for several years) on a decline in the northern portion of the North Pacific. Consistent with this are results of several studies indicating declines in the size of harvested salmon. Although increased competition may not lead directly to increased mortality, wild fish that survive to spawn may have fewer eggs, less energy to reach spawning grounds, and smaller bodies to contribute to the ecosystem. According to Myers et al. (2000), underlying mechanisms of the processes linking climate, ocean productivity, and salmon production are not well understood and better information is needed on salmon distribution, abundance, and migration patterns with respect to environmental conditions.

The potential for hatchery-bred salmon to displace wild fish in the ocean, coupled with the lack of knowledge about complex dynamics of the North Pacific ecosystem as a whole, suggests that it would be prudent to manage Alaska's hatcheries conservatively. In other words, it would be better to reduce the state's hatchery release numbers in years of lower ocean-productivity indices. This would comply with Alaska's Sustainable Salmon Fisheries Policy requirement to manage in accordance with the precautionary principle (manage conservatively). The state's PNP hatcheries have reached a plateau of about 1.4 billion fish released into the marine environment and since 1997 have had about 150 million pink and 200 million chum salmon egg take removed from their permits. Given the various concerns and indicators that ocean carrying capacity for salmon in the northern North Pacific is likely on a decline, the number of hatchery releases may still be high (especially for pink and chum salmon in Prince William Sound and Southeast, respectively) and may be contrary to the Sustainable Salmon Fisheries Policy.

There is a need for greater scientific and public understanding of the climatic influences on fisheries and aquatic resources. Aquatic ecosystems are vulnerable to a range of climate change impacts including temperature changes, altered stream flows and ocean patterns, reduced water quality, and coastal changes. Addressing these impacts has not yet become a priority for scientists, as well as policymakers. It is incumbent upon scientists to determine which physical and biological processes lead to changes in salmon growth and survival so that when the ocean enters a different climate regime, the role ocean conditions play in changing trends of fish growth or survival can be ascertained (Brodeur et al. 2000).

With respect to fish-culture practices themselves, Alaska's hatchery practices as a whole are among the best in North America. The main reasons for this are both fortuitous and purposeful. By choosing to concentrate on pink and chum salmon, Alaska's ocean-ranching program has avoided many of the attenuated problems (e.g. domestication and ecological) with long-term rearing species like steelhead trout and coho salmon. Given the late date at which Alaska's ocean-ranching program was established, the state benefited from mistakes that had been made elsewhere and got the program started on better footing by having genetic oversight of operations through fish transport permits, hatchery siting, egg takes, broodstock development, etc. Oversight of fish diseases by the state's pathology department has been exemplary and closely follows the Fish and Shellfish Health and Disease Control Policy.

Given the concerns surrounding the biologic and management issues of ocean ranching, prioritizing research objectives can help narrow existing information gaps. Evaluation of hatchery operations have been inadequate. The State of Alaska has a rigorous permit procedure for starting a hatchery, outstanding pathology guidelines, and a good genetics policy. These tools are all very good in getting a hatchery properly started. However, hatcheries do not face sufficient supervision, monitoring, or evaluation once they are operating. As can be seen by perusing the reports or plans currently available, it is difficult if not impossible to gauge whether hatchery programs are impacting wild stocks or not. Hatchery programs should be evaluated rigorously on an ongoing basis by independent teams of scientists to determine whether they are achieving their goals and are not compromising other worthy goals.

Monitoring of hatchery practices is a duty and responsibility of the RPTs. Judging from the type of reports they produce (e.g. AMPs), their primary concern is development of hatchery-production plans and evaluating the resulting contribution to the fisheries. There is extensive documentation regarding egg takes, incubation, rearing, and broodstock, as well as regarding management of fisheries on hatchery returns including common property fisheries, SHAs, cost recovery, and marking/tagging studies. However, there is virtually no information about whether egg takes reflect the run-timing characteristics of the stock; the degree to which adequate numbers of spawners are used for hatchery broodstock; how often a stock has been used as a brood source; straying rates; or the number and final destination of fish that escaped the cost-recovery harvest. There is some information in certain plans that addresses the protection of wild stocks, but there is almost no information on how effective any of the proposed measures have been. As to whether a hatchery site is appropriate (one of the public benefit criteria), no published documentation addressing this point was found.

In recent years, several research initiatives have been suggested that are germane to the ocean-ranching issue. The Sound Science Review Team (1999) prioritized information needs regarding fishery ecosystems, focusing on Prince William Sound, and highlighted the need to evaluate interactions between hatchery and wild salmon. The reviewers identified three areas of concern: conservation, ecology, and management and suggested 18 specific research objectives (see Appendix B). As the present evaluation of biologic and management issues relating to ocean-ranching has made clear, there is insufficient data to ascertain the consequences of interactions between wild and hatchery-produced salmon. Unresolved questions involve a range of topics: fish culture, genetics, ecological interactions, competition between hatchery and wild salmon, and climatic change. Further, how all these factors affect salmon productivity is puzzling and deserves the attention of scientists and managers alike. Alaska's Sustainable Salmon Fisheries Policy mandates that, in light of uncertainty, a precautionary approach to management will best ensure the long-term protection of salmon biodiversity. Protection of biodiversity is the best insurance policy for survival of Pacific salmon, especially in the event of significant future environmental change.

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GLOSSARY

Adaptation. Evolutionary process resulting in an organism becoming optimally suited to its environment.

Aleutian Low. A winter weather pattern over the North Pacific that influences ocean productivity.

Allele. One of two or more alternate forms of a gene or other segment of DNA.

Anadromous. Fish that migrate from freshwater spawning areas to ocean waters and return to freshwater to spawn.

Aquaculture. The cultivation of fish or shellfish for food.

Artificial propagation. Any fish-culturing activity involving modification of natural spawning, incubation, or rearing habitat.

Biodiversity. Variety and variability among living organisms and the ecological complexes in which they occur at many biological levels, ranging from genes to species to ecosystems.

Broodstock. Adult fish retained for artificial propagation.

Carrying capacity. The maximum number or biomass of organisms that can be supported by a given habitat over the long term.

Conspecific. Belonging to the same species.

Deoxyribonucleic acid (DNA). Molecule that contains the genetic code consisting of a sequence of nucleotides.

Ecosystem. A community of organisms and their environment forming an interrelated unit.

Effective population size *(Ne).* Size of an ideal population that would have the same rate of increase in inbreeding or decrease in genetic diversity by genetic drift as the population being studied.

Electrophoresis. Technique for separating molecules based on their different mobility in an electric field.

Endemic. Refers to an organism that is either indigenous in or restricted to a specific geographic locality.

Fitness. Relative survival value and reproductive capability of a given genotype in comparison with others of a population.

Fry. Juvenile salmon at the time of yolk absorption and initiation of active feeding.

Gene. Basic unit of inheritance transmitted as part of the chromosome.

Gene flow. Exchange of genes (in one or both directions) between populations.

Gene pool. Sum total of genes in a breeding population.

Genetic diversity. Totality of genetic information that exists in a stock.

Genetic drift. Variation of allele frequency from one generation to the next due to chance fluctuations.

Genetic integrity. Population genetic structure in an unimpaired or sound condition.

Genotype. Genetic identity of an individual.

Hatchery fish. Any fish resulting from artificial spawning and rearing regardless of the history of the parent stock.

Hybridization. A cross between two genetically dissimilar individuals resulting in hybrid offspring.

Inbreeding. Mating of related individuals.

Inbreeding depression. Permanent or temporary reduction in fitness due to inbreeding.

Introgression. The incorporation of genes from one species or distinct population into the gene pool of another.

Linkage. Genes are linked when they are transmitted as pairs or sets because they are located close together on a chromosome.

Migration. Movement of any number of individuals or populations from one geographic location to another.

Mixed-stock fishery. A fishery where more than one stock of fish is harvested simultaneously.

Native. Fish stocks or populations indigenous to an area resulting from natural spawning.

Natural selection. Natural process by which organisms leave differentially more/less descendents than other individuals because they possess certain inherited advantages/disadvantages.

Ocean ranching. The process of artificially hatching and releasing juvenile fish into the ocean with the intent of later harvest as adults.

Otolith. Ear bone in fish that can be sectioned for the purpose of aging and can be imprinted with characteristic markings by modulating water temperature during culture for later use in identifying fish from a particular hatchery.

Outbreeding. Mating pattern in which mating between close relatives does not usually occur.

Outbreeding depression. Decrease in fitness resulting from hybridization between distant, isolated populations.

Parr. The freshwater stage of juvenile salmon between fry and smolt.

Pacific Decadal Oscillation (PDO). A pan-Pacific, recurring pattern of ocean-atmosphere variability that alternates between climate regimes every 20 to 30 years.

Phenotype. Visible properties of an individual produced by the interaction of the genotype and the environment.

Population. Group of organisms of the same species that occupy a well-defined locality and exhibit reproductive continuity from generation to generation.

Regime. A multiyear period of linked recruitment patterns in fish populations.

Run. Seasonal migration upriver to spawn.

Selection. Process (either natural or artificial) whereby select individuals, based either on fitness or other predetermined criteria, serve as broodstock for the next generation.

Smolt. Juvenile salmon at time of physiological adaptation to life in saltwater.

Special harvest area. An area, designated by the commissioner or the Board of Fisheries, where hatchery returns are to be harvested by the hatchery operators, and in some situations, by the common property fishery.

Species. Group of individuals that can interbreed successfully with one another but not with members of other groups.

Stock. Population sharing a common environment and participating in a common gene pool that is sufficiently discrete to warrant consideration as a self-perpetuating system, which can be managed.

Strain. Group of individuals coming from a particular location or produced by a particular breeding program.

Straying. The behavior of returning to a location other than the location of origin.

Terminal harvest area. An area where hatchery returns have achieved a reasonable degree of segregation from naturally-occurring stocks and may be harvested in the common property fishery without overharvesting wild stocks.

Translocation. Moving an individual or progeny from individuals outside its indigenous geographic range.

Wild (naturally-produced) fish. Fish or stock naturally spawned and reared.

APPENDIX A

BROODSTOCK HISTORY

(Adapted from various ADF&G files)

Table A1. Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: NSRAA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: HIDDEN FALLS					
Chum	Kadashan River	77–80	Same region	Kasnyku Bay	
	Clear River	78–79	Same region	Kasnyku Bay	
	Seal Bay	80–81	Same region	Kasnyku Bay	
	Hidden Falls	81–99	proximate	Kasnyku Bay, Baranof Bay, Takatz Bay	
Coho	Deep Cove	88–90	SE/nearby district	Kasnyku Bay	
	Sashin Creek	89–93	SE/nearby district	Kasnyku Bay	
	Hidden Falls	91–98	proximate	Kasnyku Bay	
Chinook	Andrew Creek	81–88	SE/nearby district	Kasnyku Bay	
	Tahini River	83–91	SE/nearby district	Kasnyku Bay, Lutak Inlet	
	Crystal Creek	85–91	SE/nearby district	Indian River, Eliza Lake, Kasnyku Bay	Hatchery stock/Andrew Creek
	Farragut River	89–90		Farragut Lake	
	Medvejie	90–93	SE/nearby district	Kasnyku Bay	Hatchery stock/Andrew Creek
	Hidden Falls	90–99	proximate	Taiya Inlet, Kasnyku Bay, Indian River	
LOCATION: MEDVEJIE CREEK					
Chum	Medvejie Creek	81–99	proximate	Deep Inlet, Bear Cove	
	Nakwasina River	82–84	SE/same district	Deep Inlet	
	Salmon Lake	82–85	SE/same district	Deep Inlet	
	Deep Inlet	85–91	proximate		
	Hidden Falls	89–99	SE/same district	Deep Inlet	

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: NSRAA cont.					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: MEDVEJIE CREEK cont.					
Coho	Sealion Cove	81–84	SE/same district		Broodstock for lake stocking
	Sashin Creek	81–99	SE/nearby district	Deer Lake	Broodstock for lake stocking
	Deep Cove	81–97	SE/nearby district	Banner Lake	Broodstock for lake stocking
	Falls Creek	82–84	SE/same district	Elfendahl Lake	Broodstock for lake stocking
	Indian River	88–98	SE/same district	Deep Inlet, Bear Cove, Shamrock Bay	
	Medvejie	91–97	proximate	Bear Cove, Shamrock Bay, Wrinkleneck Creek	
	Hidden Falls	93–97	SE/nearby district	Deer Lake	Hatchery stock/Sashin Creek
Chinook	Andrew Creek	82–83	SE/nearby district	Bear Cove	
	Crystal Lake	84–94	SE/nearby district	Bear Cove	Hatchery stock/Andrew Creek
	Medvejie	86–99	proximate	Bear Cove	Current primary source
	Little Port Walter	88–89	SE/nearby district	Bear Cove	Hatchery stock/Chickamin River
	Ohmer Creek	89	SE/nearby district	Bear Cove	
	Whitman Lake	89–90	SE/nearby district	Bear Cove	Hatchery stock/Chickamin River
	Hidden Falls	94–96	SE/nearby district	Bear Cove	Hatchery stock/Andrew Creek
LOCATION: HAINES					
Chum	Slough	84–93	proximate	31 Mile Creek	Incubation boxes
	Spawning Channel	90–97	proximate	17 Mile	Spawning channel
	Herman Creek	94–99	proximate	Herman Creek, 17 Mile, 31 Mile	
	31 Mile Incubator	98–99	proximate		
Sockeye	Spring Pond	90–98		Chilkat Lake	
	Garrison Creek	95		Garrison Creek	
	Chilkat Lake	97		Chilkat Lake	

OPERATOR: SSRAA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: WHITMAN LAKE					
Chum	Carroll River	79–97	Same region	Nakat Inlet, Earl West Cove, Kendrick Bay	Summer chum
	Cholmondelay	86–92	Same region	Nakat Inlet, Earl West Cove, Kendrick Bay	Fall chum
	Disappearance Creek	80–94	Same region	Neets Bay, Nakat Inlet	
	Nakat Inlet	82–86	Same region	Nakat Inlet	
	Burnett Inlet	90	Same region	Earl West Cove	Hatchery stock
	Neets Bay	98–99		Nakat Inlet, Earl West Cove, Kendrick Bay	Summer chum

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: SSRAA cont.

Species	Source	Years	Distance	Remote Release	Comments
LOCATION: WHITMAN LAKE cont.					
Coho	Indian Creek	78–82	SE/same district	Herring Cove, Neets Bay	
	Whitman Lake	81–98	proximate	Herring Cove, Nakat Inlet, Earl West Cove	
	Karta River	95–96	SE/nearby district	Old Frank Lakes	
	Ward Lake	95–97	SE/same district	Herring Cove, Neck Lake	
Chinook	Unuk River	80–90	SE/nearby district	Herring Cove, Neets Bay, Carroll Inlet	
	Chickamin River	81–99	SE/same district	Carroll Inlet, Herring Cove	
LOCATION: NEETS BAY					
Chum	Carroll River	83–97	Same region	Neets Bay, Kendrick Bay	Summer chum
	Cholmondelay	84–97	Same region	Neets Bay, Nakat Inlet	Fall chum
	Disappearance Creek	89–94	Same region	Neets Bay	
	Neets Bay	98–99	proximate		
Coho	Neets Bay	81–90	proximate		
	Whitman Lake	89–98	SE/same district	Neets Bay	Hatchery stock/Indian Creek
Chinook	Ketchikan Creek	83–99	SE/same district	Neets Bay	Hatchery stock/Unuk River
	Whitman Lake	91–99	SE/same district	Neets Bay	Hatchery stock/Chickamin River
LOCATION: BURNETT INLET					
Coho	Big Creek	84–88	SE/same district	Burnett Inlet	
	Burnett Inlet	87–92	proximate		
	Ketchikan Creek	96–98	SE/nearby district	Burnett Inlet	Hatchery stock/Reflection Lake
Sockeye	Hugh Smith Lake	98–99	Hugh Smith Lake		

OPERATOR: AKI

Species	Source	Years	Distance	Remote Release	Comments
LOCATION: PORT ARMSTRONG					
Pink	Sashin Creek	83–96	Same region	Port Armstrong	
	Port Armstrong	85–99	proximate		
Coho	Blanchard Lake	88–90	SE/same district	Jetty Creek	
	Deer Lake	89–92	SE/same district	Jetty Creek	Hatchery stock/Sashin Creek
	Port Armstrong	91–98	proximate		
	Hidden Falls	93–96	SE/nearby district	Port Armstrong	

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: BCF					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: BURRO CREEK					
Pink	Sawmill Creek	80–82	Same region	Burro Creek	
	Howard Bay Creek	83–89	Same region	Burro Creek	
	Burro Creek	83–98	proximate		
	Pullen Creek	90	Same region	Burro Creek	
	Gastineau	93			Hatchery stock
Chum	Howard Bay Creek	80–88	Same region	Burro Creek	
	Burro Creek	85–98	proximate		
	Taiya River	86–88	Same region	Burro Creek	
Coho	Taiya River	86–96	SE/same district	Burro Creek	
	Pullen Creek	87–92	SE/same district	Burro Creek	
	Sheep Creek	88–90	SE/same district	Burro Creek	Hatchery stock/Montana Creek
	Burro Creek	91–97	proximate		
Chinook	Hidden Falls	90-95	SE/nearby district	Burro Creek	Hatchery stock/Tahini River
	Burro Creek	94-97	proximate		

OPERATOR: DIPAC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: GASTINEAU					
Pink	Kowee Creek	77–86	proximate		3 hatcheries along Gastineau Channel: Gastineau, Kowee and Sheep Creeks
	Sheep Creek	80–92	proximate		
	Salmon Creek	90	Same region	Gastineau	
	Kadashan River	88	Same region	Gastineau	
	Gastineau	87–98	proximate		
Chum	Kowee Creek	76–83	proximate		
	Hidden Falls	88–93	Same region	Gastineau, Boat Harbor	
	Sheep Creek	81–96	proximate		
	Gastineau	87–98	proximate	Amalga Harbor, Boat Harbor, Limestone Inlet	
Coho	Montana Creek	85–87	SE/same district	Gastineau, Sheep Creek	
	Snettisham	86–87	SE/same district		Hatchery stock/Speel Lake
	Gastineau	89–97	proximate	Gastineau, Sheep Creek	
	Sheep Creek	88–90	proximate	Gastineau, Sheep Creek	
	Steep Creek	89–97	SE/same district	Gastineau, Sheep Creek	
Chinook	Snettisham	84–92	SE/nearby district		Hatchery stock/Andrew Creek
	Crystal Lake	84–92	SE/nearby district		
	Little Port Walter	93–96	SE/nearby district		Hatchery stock/King Salmon River

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: DIPAC cont.					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: GASTINEAU cont.					
	Gastineau	95–97	proximate	Gastineau, Auke Creek, Twin Lakes, Fish Creek, Taiya Inlet	No wild stock used for broodstock since 1988. All chinook may have originated from Andrew Creek or King Salmon River
LOCATION: SNETTISHAM					
Sockeye	Speel Lake	88–98	Same region	Speel Lake, Sweetheart Lake, Speel Arm, Snettisham Inlet	
	Crescent Lake	90–95	Same region	Crescent Lake, Sweetheart Lake, Gilbert Bay	
	Chilkat Lake	93–96	Same region	Chilkat Lake	
	Snettisham	96–99	proximate	Sweetheart Lake	

OPERATOR: KNFC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: GUNNUK CREEK					
Chum	Security Bay	82–83	Same region	Gunnuk Creek, Portage Bay	
	Hidden Falls	84–88	Same region	Gunnuk Creek, Kake Sha, Southeast Cove	
	Gunnuk Creek	88–99	proximate		
Coho	Portage Creek	94–96	SE/same district	Portage Creek	

OPERATOR: SJC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: INDIAN RIVER					
Pink	Indian River	75–99	proximate		
	Starrigavan Creek	76	Same region	Indian River	
Chum	Katlian River	75	Same region	Indian River	
	Nakwasina River	76–84	Same region	Indian River	
	Sandy Creek	79–85	Same region	Indian River	
	Deep Inlet	85	Same region	Indian River	
	Indian River	80–99	proximate		
Coho	Indian River	75–98	proximate	Crescent Bay	
Chinook	Crystal Creek	84–90	SE/nearby district	Sitka Sound	Hatchery stock/Andrew Creek
	Andrew Creek	85–87	SE/nearby district	Sitka Sound	
	Indian River	89–99	proximate	Sitka Sound, Crescent Bay	

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: POWHA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
		LOCATION: KLAWOCK			
Coho	Klawock River	78–98	proximate		
	Cable River	86–92	SE/same district	Cable River	
	Thorne River	88–92	SE/nearby district	Rio Roberts	
	Karta River	93-95	SE/nearby district	Old Frank Lakes	
Sockeye	Klawock Lake	86–99	proximate	Klawock Lake	

OPERATOR: MIC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
		LOCATION: TAMGAS CREEK			
Chum	Tamgas Creek	93–98	proximate		BIA Hatchery
Coho	Nadzaheen Creek	78–81	SE/same district	Tamgas Harbor	
	Columbia River, WA	79–81	Washington (state)	Tamgas Harbor	
	Ketchikan Creek	80–82	SE/same district	Tamgas Harbor	
	Tamgas Creek	81–97	proximate	Tamgas Harbor, Tent Lake	
Chinook	Ketchikan Creek	82–85	SE/same district	Tamgas Creek	Hatchery stock/Unuk River
	Hybrid	85–88		Tamgas Creek	Hatchery hybrid stock/ Unuk & Chickamin Rivers
	Neets Bay	86–87	SE/same district	Tamgas Creek	Hatchery stock/Unuk River
	Unuk River	87–88	SE/same district	Tamgas Creek	
	Little Port Walter	87–89	SE/same district	Tamgas Creek	Hatchery stock/Unuk River
	Tamgas Creek	87–99	proximate	Tamgas Creek	

OPERATOR: FEDERAL					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
		LOCATION: AUKE CREEK			
Coho	Auke Creek	78–86	proximate		
	Sashin Creek	82–85	SE/nearby district	Auke Creek	
		LOCATION: LITTLE PORT WALTER			
Chinook	Carson, WA	71–73	Washington (state)	Little Port Walter	Washington state hatchery stock
	Chickamin River	76–95	SE/nearby district	Little Port Walter	
	Unuk River	76–95	SE/nearby district	Little Port Walter	
	King Salmon River	88–92	SE/nearby district	Little Port Walter	
	Little Port Walter	93–99	proximate		

Table A1 *cont.* Broodstock history (hatcheries operating in 1999): Southeast Region.

OPERATOR: ADF&G					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: CRYSTAL LAKE					
Coho	Green River, WA	72–73	Washington (state)	Ward Lake	Washington state hatchery stock
	Blind Slough	73–78	SE/same district	Crystal Creek, Mendenhall, Salmon Creek, Sheep Creeks	
	Bear Lake	74–76	SC/Seward	Crystal Creek	
	Ship Creek	74–77	SC/Anchorage	Mendenhall River	
	Duncan Salt Chuck	78–81	SE /same district	Crystal Creek	
	Crystal Creek	79–98	proximate	Crystal Creek, Ohmer Creek, Irish Creek, Sumner Creek, Slippery Creek, St Johns Creek	
	Slippery Creek	86–87	SE/nearby district	Slippery Creek	
	St Johns Creek	86–87	SE /same district	St Johns Creek	
	Mitchell Creek	92–96	SE /same district	Mitchell Creek	
	Portage Creek	92–93	SE/nearby district	Portage Creek	
Chinook	Chignik River	71–73	AP/Chignik	Crystal Creek	
	Ship Creek	71–75	SC/Anchorage	Crystal Creek	
	Chickamin River	75–76	SE/nearby district	Crystal Creek	
	Nakina River	75–76		Crystal Creek	
	Andrew Creek	75–79	SE/nearby district	Crystal Creek	
	King Salmon River	76–77	SE/nearby district	Crystal Creek	
	Farragut River	83–93		Farragut Lake	
	Tahini River	84–86		Tahini River	
	Harding River	86–92		Harding River	
	Crystal Creek	81–99	proximate		

OPERATOR: KHC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: DEER MOUNTAIN					
Coho	Ketchikan Creek	74–98	proximate	Ketchikan Creek, Ward Lake	
	Reflection Lake	86–94	SE/same district	Ketchikan Creek, Ward Lake Reflection Lake, Margaret Lake	
	Ward Lake	90–95	SE/same district	Bold Island Lake, Ketchikan Creek, Ward Lake	
Chinook	Unuk River	77–82	SE/same district	Ketchikan Creek	
	Ketchikan Creek	81–99	proximate		

Table A2. Broodstock history (hatcheries operating in 1999): Cook Inlet Region.

OPERATOR: PGHC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: PORT GRAHAM					
Pink	Port Graham River English Bay River	90–00	proximate	Port Graham	
Sockeye	English Bay River	89–00	proximate	English Bay	
Coho	Port Graham River	96-98	proximate	Port Graham	

OPERATOR: CIAA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: TRAIL LAKES					
Coho	Bear Lake	89–99		Bear Lake	
Sockeye	Tustemena Lake	90–99		Tustemena Lake, Kirschner Lake, Leisure Lake, Hazel Lake	
	Packers Lake	90–97		Packers Lake, Grouse Lake	All Trail Lakes hatchery fish for remote release
	Hidden Lake	89–99		Hidden Lake	
	Chelatna Lake	89–95		Chelatna Lake	
	Big Lake	98–99		Big Lake	
	Upper Russian Lake	89–91		Bear Lake	
	South Fork Big River	89–92		Bear Lake	
	Bear Lake	92–99		Bear Lake	
LOCATION: TUTKA BAY					
Pink	Tutka Creek		proximate		

OPERATOR: ADF&G					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: FT. RICHARDSON					
Coho	Ship Creek		proximate	Ship Creek, Bird Creek, Campbell Creek	
	Little Susitna River			Ship Creek, Bird Creek, Campbell Creek	
	Jim Creek Bear Lake			Eklutna Homer, Seward	
Chinook	Deception Creek			Willow Creek	
	Ninilchik			Ninilchik	
LOCATION: TUTKA BAY					
Chinook	Ship Creek		proximate	Ship Creek	
	Moose Creek			Eklutna	
	Crooked Creek			Crooked Creek	
	Ninilchik			Halibut Cove, Seldovia, Homer, Seward	
	Deception Creek			Whittier, Valdez, Cordova	

Table A3. Broodstock history (hatcheries operating in 1999): Prince William Sound.

OPERATOR: PWSAC					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: KOERNIG					
Pink	Duck River	76	PWS/same district		Even year source
	Larson Creek	75–76	PWS/same district		Both odd and even year source
	Ewan Bay	75	PWS/same district		Odd year source
	Koering	78–99	proximate		Wild fish mixed with hatchery broodstock
LOCATION: NOERENBERG					
Pink	Koering	85–89			Hatchery source
	Noerenberg	89–99	proximate		
Chum	Wells River		Same region		
Coho	Mile 18 Creek		Same region		
	Power Creek		Same region		
	Corbin Creek		Same region		VFDA hatchery stock
LOCATION: CANNERY CREEK					
Pink	Cannery Creek	78–99	proximate		
LOCATION: MAIN BAY					
Sockeye	Eyak Lake		Same region		Early Run
	Coghill Lake		Same region		
	Eshamy Lake		Same region		
LOCATION: GULKANA					
Sockeye	Gulkana River	73–99	proximate		Onsite incubation boxes

OPERATOR: VFDA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: SOLOMON GULCH					
Pink	Valdez Arm	81–82	PWS/same district		
	Solomon	83–99	proximate		
Coho	Corbin Creek		proximate		

Table A4. Broodstock history (hatcheries operating in 1999): Kodiak Island.

OPERATOR: KRAA					
Species	**Source**	**Years**	**Distance**	**Remote Release**	**Comments**
LOCATION: KITOL BAY					
Pink	Big Kitoi Creek	72–99	proximate		
Chum	Sturgeon River	81–85			
	Big Kitoi Creek	86–99	proximate		
Coho	Buskin River	82–85			
	Little Kitoi Lake	83–92	proximate		
	Big Kitoi Creek	93–99	proximate		
LOCATION: PILLAR CREEK					
Coho	Buskin River	93–00			Stocked in Kodiak road system lakes
Sockeye	Afognak Lake	91–00		Hidden Lake, Big Waterfall Lake, Little Waterfall Lake, Crescent Lake	All for remote release sites
	Laura Lake	93–00		Laura Lake	
	Malina Lake	91–00		Malina Lake	
	Saltry Lake	94–00		Spiridon Lake Ruth Lake	

APPENDIX B

SOUND SCIENCE REVIEW AND PLANNING TEAM RESEARCH OBJECTIVES

CONSERVATION

1. Estimate the extent and causes of migration (straying) between Prince William Sound salmon local populations.

2. Describe microclimate environmental differences and connection to genetic differences.

3. Evaluate hatchery management and fish cultural effects on straying.

4. Determine extent of outbreeding depression by appropriate controlled experimentation.

ECOLOGY

1. Determine distribution and abundance of prey, species composition, and ocean temperature along the migratory pathway.

2. Estimate growth rate of the early life stages of pink salmon.

3. Monitor bioenergetic model of growth and describe changes in optimal growth conditions over time.

4-7. Four proposals having to do with various aspects of monitoring primary production in Prince William Sound.

8. Monitor predation models focused on how predator distribution responds to localized, short-term aggregations of vulnerable prey (hatchery releases).

9. Monitor the effect of pink salmon production on regional predator population size.

MANAGEMENT

1. Identify and characterize the effects of harvest management on hatchery and wild populations.

2. Identify locations outside of hatchery terminal areas that will exploit hatchery populations with low exploitations of wild stocks.

3. Determine geographic areas that are affected by straying.

4. Determine the relationship of run entry timing and straying potential of hatchery stocks.

5. Improve precision and accuracy of forecast methods to identify run strengths of individual hatcheries.

Submitted By
Kenneth Carlson
Submitted On
7/8/2018 12:17:12 PM
Affiliation

Chairmen Jensen and Board members, I am a commercial fishermen of the Prince William Sound and Copper River District. I have been following the attack on Prince William Sound Hatcheries since the beginning of the year. While out fishing on the grounds, I became aware of a 3rd Emergency Petition on the subject, the second filed by KRSA. This petition resulted in a hearing in the middle of the fishing season, when I cannot fully participate in the public process laid out for our fisheries. This same issue has now come before Board of Fish and ADFG on 4 occasions, in a 6 month time span. ADFG has stated that there is no finding of an emergency each time. The Board of Fish has set a date for an October work session in Anchorage to address the subject, when they have more data and more time to review said data. The filers of the petitions are berating the Board into making a decision in their favor, when they are unsatisfied with the answer. It is an abuse of public policy that a 3rd Emergency Petition is being brought to you once again, after it was already determined there was no finding of Emergency, and after it was decided that this issue would be taken up at the October work session in Anchorage. I am strongly opposed to this petition, and ask the Board to once again to take no action, and continue forward with the plan to meet in October on the subject. Thank you,

Submitted By
Kenneth Jones
Submitted On
6/26/2018 5:49:25 AM
Affiliation

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64%of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Additionally, I believe it is prettt obvious that the petitioners are abusing use of the emergency petition., I wish to voice a concern about this process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion onhatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed, Kenneth Jones

Alaska Board of Fisheries

Juneau, Alaska

Gentlemen:

I am writing as a board member of the Prince William Sound Aquaculture (PWSAC) board member regarding the most recent emergency petition that was filed. I am one of 45 board members that represents a large section of the region with diverse interests. As a board member and resident of the State of Alaska I am deeply concerned with the current effort to reverse a decision that was years in the making through a collaborative effort between the Alaska Department of Fish and Game, Regional Planning Team and Valdez Fishermens Development Association. The Alaska hatchery program is important to state, regional and local economies, they help provide for a stable community by supporting sport fishing, tourism, personal use fishing, commercial fishing, seafood processing, along with other economic benefits that spread throughout the state.

It is important to remember that our board discusses production changes with great detail. These discussions are first vetted by our Production Planning Committee, then past to the full board for a vote even before being submitted to the Alaska Department of Fish and Game. Through the years PWSAC has submitted Permit Alteration Requests that have been denied for various reason, which is proof the process in place works.

I ask that the board fully consider the whole process regarding the Permit Alteration Request, as I attest that the effort put into these is significant. We are in the middle of the salmon season and should be focusing our time on the fishing season before us.

Holding a meeting during the salmon fishing season is poor public process when the topic has been addressed several times this winter and spring. At this point you are now limiting the opportunity for impacted users to support the hatchery program. The board of fish established a committee to address these concerns in October, and should stick to that plan. This will be an opportunity for fishermen, processors, public, and hatchery operators to devote the attention to the topic and help explain the program and what it means to them.

Our Hatcheries are backed by years of experience, science, and by people who have a true interest in bettering the communities.

Please deny this emergency petition request

Thank you,

Kenneth Roberson, PWSAC Board Member

1284 Rainbow Lane, Fernley, Nevada 89408

Submitted By
kevin timm
Submitted On
7/8/2018 9:22:49 AM
Affiliation
buyer/processor

Phone
9075180801
Email
kevint@icicleseafoods.com
Address
PO Box 1147
Petersburg, Alaska 99833

I have worked for Icicle Seafoods for over 30 years and my livelyhood as well as the town of Petersburg are reliant on salmon.

BOF must be open and transparent in order to protect our resources and communities.

I do not approve of special interest groups using the emergency petition process to force a meeting in the middle of the summer when everyone in the industry is too busy to comment or participate.

Kevin Timm

Submitted By
Kimberly Collins
Submitted On
6/26/2018 5:38:57 PM
Affiliation

Chairman Jensen and Board members,

I am a commercial fisherwoman in Prince William Sound. I would like to voice my concern with the fact that a 3rd Emergency petition is being brought before the Board. It is unacceptable that this meeting is taking place after it has been determined that there is no emergency and the issue was suppose to be re-examined in October. I am stongly opposed to this petition and ask the Board to once again take no action and keep the plan to meet in October. Regards,

Kimberly Collins

Submitted By
Kirby Green
Submitted On
7/6/2018 9:40:41 PM
Affiliation
Commercial Fisherman

Phone
206-817-5033
Email
Shirt50@yahoo.com
Address
418 Highland Dr. #3
Seattle, Washington 98109

To The Board of Fisheries,

My name is Kirby Green, I have been a commercial fisherman operating out of Petersburg for approximately 35 years. Currently my wife and I own the F/V Miss Sherri and participate in the Southeast Alaska Salmon Purse Seine Fishery. I am writing to voice my concern over this emergency meeting, and particularly over the timing of the meeting. I am a conservationist and I 100% support managing fisheries in a way that ensures that future generations of fishermen and women have access to this resource. I do not approve of special interests using an emergency petition to promote their interests during a time of year when it is financially impossible for commercial fishers to adequately prepare and respond. These meetings and the decisions that come out of them are extremely important to our industry and to the future of the entire state. As such the meeting process must be open and accessible for all involved parties. Thank you for your time and consideration.

Kirby Green

Owner/Operator F/V Miss Sherri

KODIAK REGIONAL AQUACULTURE ASSOCIATION
104 Center Avenue, Suite 205
Kodiak, AK 99615

Phone: 907-486-6555
Fax: 907-486-4105
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Alaska Department of Fish & Game
Alaska Board of Fisheries
P.O. Box 115526
1255 W. 8th Street
Juneau, AK 99811-5526

July 7, 2018

Chairman Jensen and members of the Board of Fish,

This letter is in response to the emergency petition to halt the implementation of a PAR for increased pink salmon production at Valdez Fisheries Development Association's (VFDA) Solomon Gulch Hatchery. **I would like to encourage you to take no action on the request of the signatories on this petition to rescind the PAR awarded to VFDA**. The current petition attempts to subvert the established hatchery permitting process and cycle and brings to bear as evidence alarmist references to a list of scientific articles. Additionally, it runs counter to good public policy to hold an emergency meeting mid-summer, when those most likely to be affected by any decision have limited ability to participate in the public process.

At the outset it is important to realize there is a fact-based, scientific counter-narrative to the one that has recently been presented to you in public and written comment and in the media. Armed with the knowledge that there is a supportive base of information for the approved increase at VFDA, and the fact that essentially the same petition has already been submitted and rejected as not constituting an emergency within weeks of the current petition, the Board must reject this petition and proceed with the objective of gaining greater knowledge of the Alaska Hatchery Program as scheduled at the October work session.

Closer examination of the list of articles provided by the petitioners has demonstrated two basic findings: 1) much of the information that is highlighted by the petition signatories is neither new, nor unexpected, demonstrates no clear threat to the resource, and overall does not meet the stipulated criteria for an emergency; and 2) the petitioners rely on list of titles that they would have you believe condemn hatchery production and practice, but they themselves make no effort to demonstrate where these articles provide such conclusive evidence. Examination of the list of articles reveals that certain of these papers contain serious flaws and unsupported conclusions. In these instances, the articles often rely on weak correlations with low statistical significance which do little to support the authors' suppositions and conveniently ignore other factors that have been investigated as drivers of population dynamics and marine survival.

Despite the contention of the petitioners that the modest increase in production at VFDA's Solomon Gulch Hatchery presents an emergency, the information provided neither supports the assertion nor meets the Board's criteria for an emergency. Recent claims that hatchery production, and pink salmon production in particular, has been greatly on the rise for over two decades are not supported through the data. Following the increased production of the early 1990s, hatchery production in the State of Alaska and in the North Pacific has been relatively stable over the last 2.5 decades (Figures 1-3). The North Pacific Anadromous Fish commission tracks hatchery production and provides extensive information related to number and species. You can see (Figure 1) that US hatchery production represents only about 20% of the whole and has remained stable for an extended period. No distinction is made here to separate Alaska Hatchery production from that of Oregon, Washington, California, and Idaho.

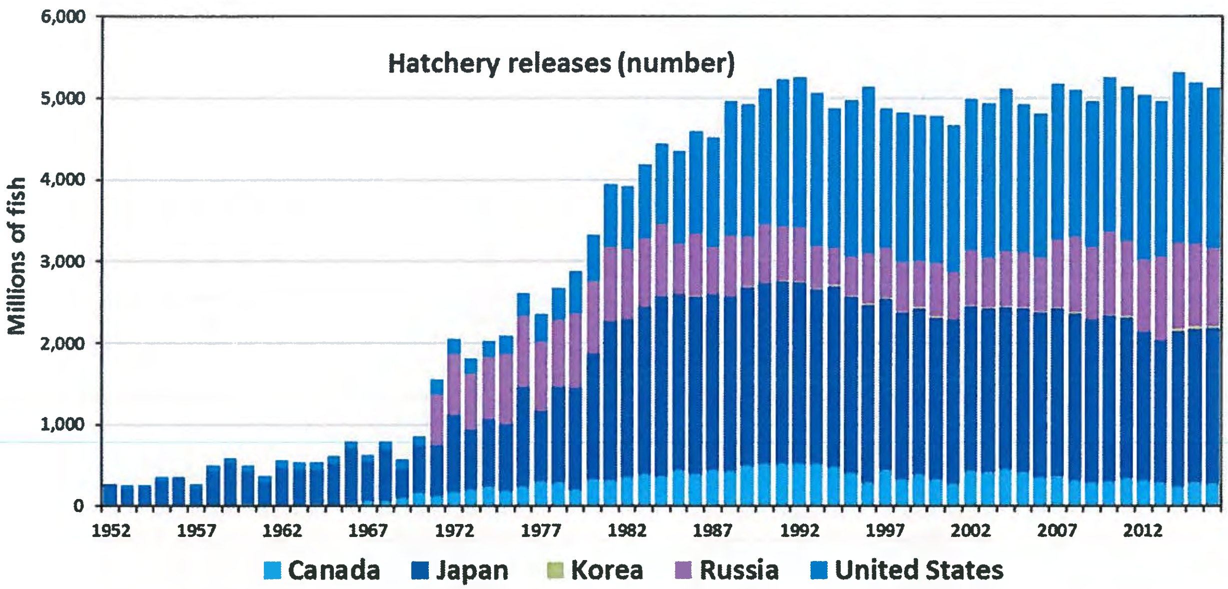

Figure 1. Hatchery releases, 1952-2016, Source: North Pacific Anadromous Fish Commission (NPAFC). 2017. NPAFC Pacific salmonid hatchery release statistics (updated 31 July 2017). North Pacific Anadromous Fish Commission, Vancouver. Accessed Month, Year. Available: www.npafc.org.

Of the hatchery releases to the North Pacific, Pink salmon appear to represent around 25% of the total hatchery releases (Figure 2). In Alaska, pink salmon represented just over half (53.8%, 894 million) of the overall hatchery releases in 2016 (ADF&G Alaska Salmon Fisheries Enhancement Annual Report, 2017, RIR No. 5J18-02), and in the context of overall hatchery production in the North Pacific, this represents approximately 18.8% of all hatchery releases to the North Pacific. Again, this figure further

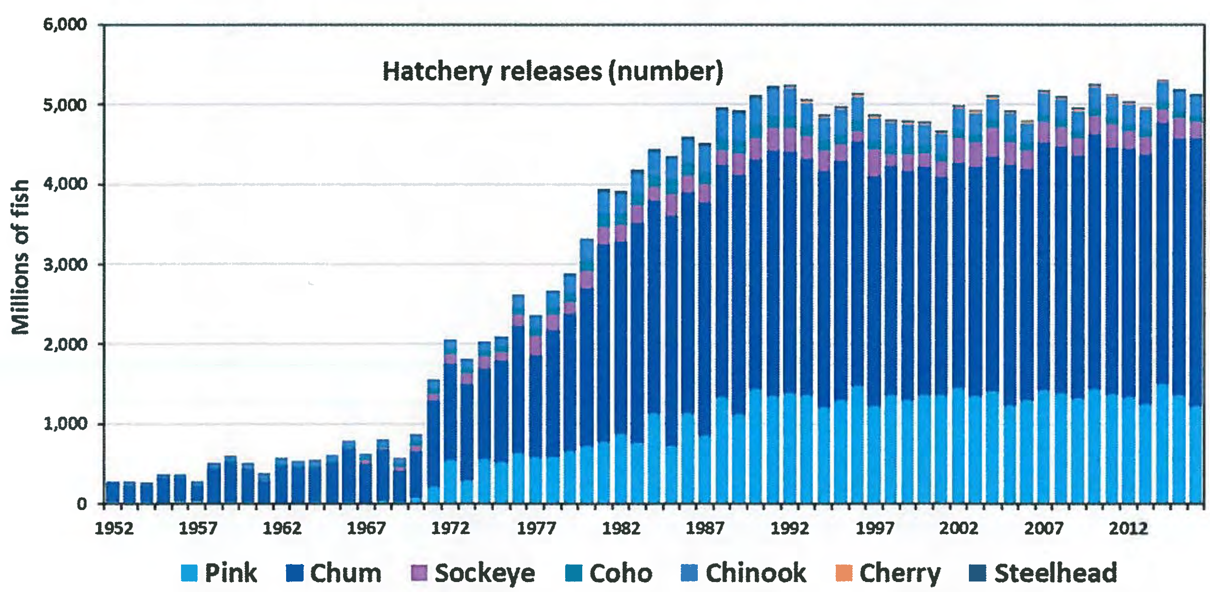

Figure 3. Hatchery Releases by Species, 1952-2016; Source: North Pacific Anadromous Fish Commission (NPAFC). 2017. NPAFC Pacific salmonid hatchery release statistics (updated 31 July 2017). North Pacific Anadromous Fish Commission, Vancouver. Accessed Month, Year. Available: www.npafc.org.

demonstrates the consistent trend in hatchery production over the last 2.5 decades. This trend of steady production has persisted and echoes a period of record high salmon abundance (hatchery and naturally produced) in the North Pacific as a whole. That there have been variable trends over time for various species in terms of body size, size at age, marine survival, abundance, etc. throughout this period of sustained high abundance is fair evidence that the relative constant of hatchery production is not the primary driver of those trends.

For Alaska taken alone and factoring in variability in survival at various life stages, Alaska Hatchery production for all species again reflects this relatively stable trend in production since the early 1990s (Figure 3).

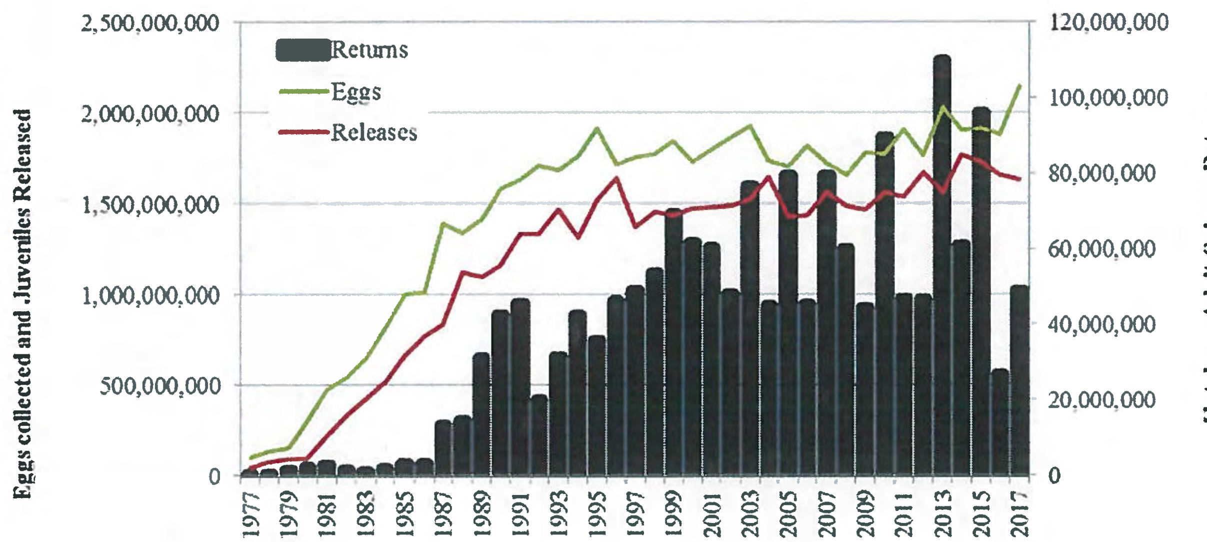

Figure 3. Total salmon eggs collected, juveniles released and adult return for Alaska salmon hatchery programs, 1977-2017; ADF&G Alaska Salmon Fisheries Enhancement Annual Report, 2017, RIR No. 5J18-02

Certainly, an increase in production of 20 million seems quite large, but taken in the context of the above figures, consider this: hatchery pink salmon from all countries make up approximately 15% of the pink salmon biomass in the North Pacific (Ruggerone, 2018). The increase in that percentage by the addition of the resultant juveniles (estimated at 18 million) from the approved PAR for VFDA represents a fraction of a percent. Through other lenses, this increase represents less than a 10% increase in the facility's production, less than a 3% increase in releases to the Prince William Sound, approximately 2% increase in the total pink salmon releases from Alaska Hatcheries, and as little as 0.1% of the pink salmon biomass in the North Pacific.

Further claims against hatchery production, such as those by the petitioners, imply that increases in hatchery pink salmon production threaten to upset the balance in ocean carrying capacity. The list of articles supplied by the petitioners does not establish with any credibility that the approved increase at VFDA constitutes an emergency by this means. The articles contain no conclusive evidence to confirm that a 2% increase Alaska hatchery pink salmon releases will have a negative impact on Alaska fishery resources now or in the future. For more detailed information please reference **"Scientific Analysis &**

Review of Journal Articles Submitted by Petitioners KRSA et.al." Submitted by Alaska PNP Aquaculture Associations" as included with the written comment submitted by VFDA in relation to the emergency petition.

In an effort to support their claims, the petitioners provide numerous statements on hatchery production and regulation but make no statement as to how the approved PAR has not met the established process or policies (Factors 1-6 of the emergency petition). Subsequently, they make two contentions, one related to hatchery pink salmon presence (straying) observed in Lower Cook Inlet Streams in 2017 and another related ocean carrying capacity in relation to hatchery pink salmon production. In response to these contentions:

On Straying:

1) Straying of pink salmon an acknowledged consideration in the development of the Alaska Hatchery Program and is inherent to all salmon species—pink salmon especially. Discussion and investigation of hatchery straying is an ongoing part of the programs.
2) An understanding of the distinctions between stray rates and hatchery fractions is important to understanding both the hatchery otolith marks recovered in LCI in 2017 and the Hatchery-Wild Interaction study. Without that understanding, the LCI information has little relevance.
3) The collection of hatchery-marked otoliths collected by ADF&G in Lower Cook Inlet streams was conducted as a result of opportunistic sampling events in 2017. The sampling conducted was not a formal straying study structured to conduct representative sampling of a statistically significant portion of the returning population throughout the spawning period. The percentages indicated are not representative of stray rate or even hatchery fraction present in the overall escapement for 2017.
4) Furthermore, there is documented assessment of overall stray rates in the Prince William Sound for the initial years of the Hatchery-Wild Interaction study (2013-2015). This is the best science available in relation to potential straying trends associated with pink salmon stocks in the Prince William Sound.
5) Finally, an important factor in the approval of this par is the notable temporal separation between the early pink stock used by VFDA and other PWS stocks. This type of separation in run and spawn timing mitigates concerns related to straying. The local derivation of the early SGH stock as well as the existing temporal separation in the hatchery bloodstock made it ideal for hatchery use.

On Ocean Carrying Capacity:

1) A number of the scientific articles offered as evidence by the petitioners contain weak if not unsupportable correlations and conclusions while others, though sound science, don't carry the dire implications the authors of the petition imply. For example:
2) Ruggerone and Irvine, 2018, "Numbers and Biomass of Natural- and Hatchery-Origin Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean, 1925-2015"
    a. This article indicates that 1990-2015 has been a sustained period of high salmon abundance of all species; pink salmon abundance has been more variable than other species and thus unlikely to be driving abundance of other species; and
    b. The fact that hatchery pink salmon represent only 15% of the total pink salmon biomass in the North Pacific supports that pink salmon likely have only a low-to moderate impact on the food web.
    c. This information, pulled from a single article provided by the petitioners is further indication that the petitioners' claims are sensational rather than substantial and should be discounted until such a time that the Board has gained better understanding of the hatchery programs and hatchery science. In the meantime established practice and process should stand.

3) There are many potential drivers of ocean carrying capacity, marine survival, size at age, etc. such as climate regimes or climate events, sea surface temperature, increased marine mammal populations & etc. The following are two such examples of investigations that look at other drivers of abundance and survival of Chinook salmon:
    a. Siegel, J.E. M.V. McPhee and M.D. Adkison (2017) "Evidence that Marine Temperatures influence growth and Maturation of Western Alaska Chinook Salmon, Marine and Coastal Fisheries Dynamics, management, and Ecosystem Science 9:441-456, 2017."
    b. Chasco, B.E. et.al (2017) "Competing tradeoffs between increasing marine mammal predation and fisheries harvest of Chinook salmon. Scientific Reports 1, Article number: 15439 (2017)."

Hatchery Operators from across the state are looking forward opportunity increase the knowledge and awareness of Alaska Hatchery programs and the foundational scientific principles with which they were conceived. The Board has scheduled time during the October 2018 work session to begin to better familiarize itself with the Alaska Hatchery programs and should not consider taking action in limiting or altering approved Hatchery permitting without greater knowledge of the programs and the science that supports them.

Sincerely,

Tina Fairbanks
Executive Director
Kodiak Regional Aquaculture Association

Submitted via email: dfg.bof.comments@alaska.gov

Submitted By
Korry Vargo
Submitted On
6/27/2018 10:34:44 AM
Affiliation
Area E Permit Holder

Phone
6037157348
Email
korryrv@gmail.com
Address
PO Box 242
Cordova, Alaska 99574

June 27, 2018
Korry R. Vargo, Fisherman
F/V Katya Dawn
Cordova, Alaska

To: Alaska Board of Fisheries
RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Respectfully Submitted,

Korry R. Vargo

Submitted By
kyle
Submitted On
6/27/2018 12:21:24 PM
Affiliation

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Kyle Richard Moss

Submitted By
Larry Bell III
Submitted On
6/27/2018 11:45:00 AM
Affiliation

Phone
(907)715-4167
Email
larryman27@gmail.com
Address
480 S Glacier Dr
Wasilla, Alaska 99654

I believe that science and annual reports show that nothing but benefits come from these hatchery fisheries. We are not only providing food for the ecosystem but food for the population in a very humane way. To eliminate these hatcheries would have an immense and abrupt effect on the whole ecosystem which we would regret in the years to come. I respect the people against these hatcheries and their opinions and believe they have the right to take it to court when both parties could be present. To hold it while the population most affected is out working and unable to attend is uncivil and cruel. I vote to deny this request for a emergency petition meeting.

Submitted By
Laura Beam
Submitted On
7/9/2018 9:28:53 AM
Affiliation

Chairman and member of the Board of Fish,

My husband and I make our living from commercial fishing and have done so since the early 1980s. I am writing to you in support of the hatcheries in Prince William Sound which are under attack by the Kenai River Sportfishing Association. Their attack appears to have no basis in fact. Where is the research that supports their belief that hatchery fish is causing a decrease in king salmon returns? I implore you to deny their emergency petition that is being considered in the middle of everyone's fishing season. Let's address this when all sides can be present.

At one time, there was a research project planned to study the king salmon in Cook Inlet. It was to be conducted by the Canadian firm Kintama, but Gov Parnell cut the funding for the project. If we had the results of that research, we would know more about the migratory patterns of these fish among other things.

Thank you for you time,

Laura Beam

Submitted By
Lauren Wolford
Submitted On
6/27/2018 11:45:35 AM
Affiliation

Phone
9073998083
Email
Lauren.a.wolford@gmail.com
Address
PO Box 942
Homer, Alaska 99603

I am a third generation commercial fisherman. I have relied on the income of the PWS hatchery fisheries throughout my lifetime. The sustainabiliy and success of this fishery is shown in the data. I am currently working on a boat and believe it is completely unethical for this meeting to be held while the majority effected will be unable to attend due to being away for our jobs. I vote to deny this emergency petition request.

Submitted By
Leroy Cabana
Submitted On
7/3/2018 5:10:09 PM
Affiliation

Phone
9072021029
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llcabana@yahoo.com
Address
Box 49
Homer, Alaska 99603

I am writing this comment while engaged in commercial salmon seining in PWS, I am disappointed to say the least to hear the BOF is having another emergency meeting on the very same issue while the commercial salmon fishermen whom will be directly affected by the action the BOF may take are committed to being out fishing. July could not be described as a time when PWS seiners and ginnetters can leave their fishing to tend BOF hearings. The issue of possible effects of hatchery production on wild salmon and other environmental questions is far from new or considered an "emergency" . In fact as the BOF and the groups requesting the emergency meeting are fully aware, there is the largest study on exactly this question currently ongoing and the first published results on pink salmon hatchery impacts are expected to be available in 2019, yup, next year. This study encompasses both pink and chum salmon, it has what most people would consider the best scientific and biological minds in North America and possibly the world. It has been going on for years and has cost tens of millions of dollars. So here we are, having another emergency meeting with the intent of the petition to convince the BOF to take action this summer, voiding an existing 20 million pink egg increase to the Valdez hatchery. The folks involved in this emergency are for all practical purposes regular folks, sport fishermen, business owners and a research person. In contrast, the folks conducting the scientific evaluation are lifelong scientists and biologists. This begs the question, is the intended action being requested looking for the best possible answer to possible effects from hatchery salmon or is the intent to have the BOF take action before the study is released. As far as this being described as an emergency, lets visit actual facts. PWS currently collects in ball park numbers about 700 million pink eggs yearly. I could provide the exact number but I am out fishing and am without the benefit of my computer. Now the emergency is supposed to do what? There are already 700 million eggs being collected and the petition folks say we need to stop this already approved 20 million egg collection at the Valdez hatchery. This represents about 3%of the existing hatchery pink production in PWS. None of this makes any sense, you are having an emergency meeting in the middle of the commercial salmon season to void an existing 20 million egg collection, which represents 3% of current PWS pink egg production. The folks whom are requesting the emergency meeting have by any measure very limited scientific and biological experience. Meanwhile the worlds largest, most expensive, salmon straying study which is being overseen by Alaska's fisheries department is due to have published results in 2019.. I have much more to say on this topic, but as I have said, I am currently harvesting PWS hatchery chum salmon in SW PWS and have no internet, no computer and little time to deal with a BOF meeting in July.

Submitted By
Leslie Allen
Submitted On
7/5/2018 1:24:07 PM
Affiliation

Phone
907 8310694
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lcallen@gci.net
Address
Box 984
Valdez, Alaska 99686

Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria.

I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families.

The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions.

I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session.

Thank you, Leslie Allen

Submitted By
Liam Corcoran
Submitted On
6/27/2018 10:12:16 AM
Affiliation

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Address
P.o. Box 1371
Cordova, Alaska 99574

I am writing as a fisherman in response to the Alaska Board of Fisheries decision to hold a hearing on the Emergency Petition filed May 16, 2018. Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria. I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families. The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions. I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session. Thank you, Liam Corcoran

RE: Comments on KRSA et. al Hatchery Emergency Petition

Dear Alaska Board of Fish, Chairman Jensen and members of the board.

My name is Lillian Connor, I've been a commercial fishing deckhand for 10years from 16-26, and a Commercial seine deckhand for 7years. I am part of the community of deckhands working to own and operate my own vessel. Providing the next generation of Alaska with jobs and the world with a good sustainable source of protien.

Without hatchery production commercial operations around the state would suffer, causing a dip in a very important sector of Alaskan Economy.

I support the findings of the Alaskan Deparment of Fish and Game that no emergency exists and ask you to act in accordance with that.

I am looking forward to entering a healthy fishery, thank you for considering my testimoney

— Lillian Connor

[illegible], Homer, AK
99603

RE: Petition concerning Prince William Sound Hatchery Management Plans

Dear Chairman Jensen and Members of the Board of Fisheries,

My name is Malcolm Milne. I am a Lower Cook Inlet Salmon Seine permit holder and actively participate in that fishery among others. I am also the President of the North Pacific Fisheries Association (NPFA) which is a Homer based commercial fishing group representing over sixty fishermen who are involved in fisheries throughout the state. Given the time of year I am unable to get a quorum of NPFA board members to take an official position on this petition so the comments in this letter are my own.

The first comment is that the timing of this meeting is terrible for the participation of a huge number of stakeholders who are busy fishing this time of year. I am certain that NPFA would take a position but we are unable to as our members are scattered throughout the state working long hours and largely out of easy communication range. The information that the petition is based on has been available since February and to wait this long to act on it is unacceptable. The Board has already decided to review these issues in October and that will allow broad participation.

The second comment concerns the information that the petition sites as grounds for an emergency. Page 2 of the Petition states "7. Pink salmon that showed up in streams across Lower Cook Inlet in 2017 weren't all local stocks, up to 70 percent were releases from PWS hatcheries. ... In Fritz Creek, 70 percent of the 96 fish sampled were from PWS hatcheries. In Beluga Slough, 56 percent of the 288 fish sampled were from PWS" First of all, the samples that are referenced were small, lacking in methodology and taken in one year without any sort of study plan that I'm aware of. Secondly the sample sites are not even salmon streams. I don't have time to see if they are in the Anadromous Stream Catalog but anyone with knowledge of the area will tell you that Beluga Slough is certainly not a salmon stream and Fritz Creek may have a few salmon some years. The percentages cited are not relevant. The petition seems to be largely based on this small sample and I respectfully request that the Board fully examine the data before making such a drastic decision.

My final statement is that I hope the Board of Fisheries will respect the decision by the Alaska Department of Fish and Game to grant the 2014 amended Permit Alteration Request (PAR) to the Valdez Fisheries Development Association and subsequently deny this petition. I also hope the Board will realize that this is not an emergency and allow for all of the stakeholders to participate in the scheduled meeting in October. In my opinion granting this petition would be a huge disservice to the public process. I would write more but I have to get back out to the fishing grounds. Thank you for your consideration and I look forward to discussing this with you in October.

Respectfully,

Malcolm Milne

Malcolm Milne

PO Box 1846 , Homer, Ak 99603

Submitted By
Marguerita McManus
Submitted On
7/9/2018 2:03:27 PM
Affiliation
none

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Seward, Alaska 99664

I support the emergency petition from the Kenai River Sportfishing Association regarding restriction of additional hatchery production, however the issue is larger than Prince William Sound, and I urge the Board, on it's own motion, to view the big picture and address the issue statewide.

I have been interested in all aspects of fishing since I moved to Alaska in 1978. I sport fish, commercial fish and have subsistence fished.

I remember when hatcheries were built, and why – to restore depleted natural stocks. I am deeply opposed to what they have become: hatcheries have turned into aquaculture **businesses** that neither citizen owners of the natural resources of Alaska, nor fishermen harvesting natural resources, have any say or control over. This road was paved with good intentions, but it's now a road that's creating repeated emergency issues with finances, wild stocks, natural runs, and with the environment (as documented in the KRSA Petition attachments) and as seen with past actions by Cook Inlet Aquaculture Association.

An emergency exists because overproduction by hatcheries poses a threat to the general welfare of commercial fishermen who rely on natural runs and are limited by the capacaties of processing facilities that they sell and deliver to. As more and more hatchery fish are created, commercial fishermen of natural wild run salmon are precluded from fishing when canneries are swamped with Alaska's version of hatchery-bred-ocean-fed farmed fish.

Alaska's Wild Salmon are a thing of beauty and I treasure them. *The whole world treasures them*. Overproduction harms our special market. We cannot, and should not, try to compete with the worldwide farmed fish market, not in any way–including via PNP's, which are acting more like big businesses and less like non-profits every year.

I beg the Board to rein in overproduction of pinks and direct Alaska's hatcheries to return to what they were intended to do–assist with depleted stocks and other man-made issues and STOP acting like salmon farmers; stop competing with commerical fishermen; stop diluting the unique market that only Alaska wild salmon have.

Overproduction could easily backlash against our precious market via social media when the world sees Alaska participating in policies that harm the oceans, other stocks and birds.

I urge the Board to see this as a **statewide PNP Aquaculture Association crisis**, not a PWS/Cook Inlet issue. Overproduction needs to be addressed as a whole, in every single area, with all PNP aquaculture association in this state.

From ADF&G's Website: *Alaska's hatchery program is designed to advance the science of fisheries enhancement in Alaska as well as to increase consumer confidence in Alaskan salmon by assuring the marketplace that these products come from sustainable and responsibly managed systems.*

*(*http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.main*)*

This is not what's happening now and it's up to the Board to return hatcheries and PNP's to their original intent. PNP (over)production not responsibly managed–it's out of control; overproduction harms the natural/wild fish market; overproduction is not sustainable; overproduction has the potential to destroy the reputation of Alaska's truely wild salmon.

From the same website: *Alaska's modern salmon fishery enhancement program is stakeholder driven, with provisions for planning and oversight by representatives of regional user groups.*

This is patently not true. PNP's are being governed by themselves, for their own benefit, to the exclusion and harm of the public and commercial fishermen. Regional Planning Teams are made up of the same people on the board of the PNP's. The Board of Fish has been addressing these issues for several years as Cook Inlet Aquaculture repeatedly files motions and petitions attempting to grow the PNP as a business and shut down commercial fishing and even sport fishing! I wholeheartedly concur with the statement in the Petition on page 3, #3: *The RPT is about as closed, opaque and esoteric as any process deemed "public" can be. Whereas the BOF process is open, transparent and accessible to the public, both in person and online, the RPT is the opposite.*

Please deny an increase of 20 million pink salmon eggs taken by the PNP's in PWS and please deny past increases as well. Please bring all PNP's back to the starting line, to protect truly wild stocks, the commercial fishing industry, the public reputation of Alaska's Wild

Salmon, and to protect the oceans and wildlife so dependent upon healthy seas.

Submitted By
Marina Carroll
Submitted On
7/7/2018 2:36:14 PM
Affiliation
PWS commercial fishermen

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I am part of a commercial fishing family in Prince William Sound. I have grown up fishing with my dad and salmon provides the income for our family and my future. I was disappointed to hear that a hearing on this petition would be held in July right during the middle of our season. It seems that we are being ambushed by a special interest group at a time when we should be focused on making a living. The prudent thing would be to wait until the scheduled meeting in October when the facts can be presented and discussed in a more productive and meaningful way. PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Submitted By
Mark Hazeltine
Submitted On
7/6/2018 12:33:10 PM
Affiliation
Area E permit holder, lifelong Alaska resident

Phone
907-440-2594
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Address
3200 staysail dr
Anchorage, Alaska 99516

I am writing as a fisherman in response to the Alaska Board of Fisheries decision to hold a hearing on the Emergency Petition filed May 16, 2018.

Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria.

I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families.

The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions.

I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session.

Thank you, Mark hazeltine

Submitted By
Mark Meadows
Submitted On
7/1/2018 11:14:20 AM
Affiliation
Meadows Fishing Corp

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skateskipper@hotmail.com
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PO Box 1510
Valdez, Alaska 99686

o: Alaska Board of Fisheries

RE: Comments on KSRA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I have been a commercial fisherman in Prince William Sound 1976 to the present. My family has depended on Prince William Sound Salmon fishery all my adult life. In that time the hatchery program has evolved from a cafe napkin dream to one of the most successful fishery projects in the States history.

In conversations recently, the declining returns of King salmon and Sockeye salmon in recent years has been linked to the rise in Hatchery pink production. This is a case where people are using corelation as causeation. Many other natrural factors have changed over the time period, Ocean water temps have risen and many predtory species numbers have increased also.

Having served on the PWSAC Board of Directors for a number of years I have seen the time and energy it takes to have changes to hatchery plans approved. In Alaska where politics is not supposed influence biology decisions this petition smacks of politics. The Fish and Game has determined this is not an emergency. To have meeting when one of the major stake holders is not able to adequately represent itself is not good for the decision making process especially in light of the meeting scheduled for October 2018 to discuss this topic.

Please deny this emergency petition which the Fish and Game determined was not an emergency and is planned for a time when one of the major stake holders is prevented from attending

Thank You

Mark Meadows

F/V Ruth M

Valdez, Alaska

MATANUSKA-SUSITNA BOROUGH
Fish & Wildlife Commission
350 East Dahlia Avenue • Palmer, AK 99645
Phone (907) 861-7833 • Fax (907) 861-7876

July 9, 2018

Alaska Board of Fisheries
ADF&G-Boards Support Section
PO Box 115526
Juneau, AK 99811-5526
Dfg.bof.comments@alaska.gov

RE: KRSA Emergency Petition regarding Hatchery Production in Prince William Sound

Dear Alaska Board of Fisheries Members,

The Matanuska-Susitna Borough Fish & Wildlife Commission (MSBFWC) supports the Kenai River Sportfishing Association (KRSA) petition to find for an emergency and scheduling a hearing on the recent changes to Prince William sound hatchery Management Plans for adding 20 million Pink salmon eggs to the existing permitted capacity. MSBFWC concurs with KRSA's requested relief that the Alaska Board of Fisheries PAUSE any increased authorization of pink salmon production until adequate consideration can be given to all the issues associated with this action.

As referenced in KRSA's petition, and as previously documented in Nancy Hillstrand's BOF petition, (RC 027), hatchery pink salmon are showing up in greater numbers in streams in Lower Cook Inlet; in 2017, in Fritz Creek, 70 % of fish sampled were from Prince William Sound (PWS) hatcheries, and in Beluga Slough 56% were from PWS hatcheries. There is excessive straying from PWS hatcheries into Cook Inlet wild spawning salmon streams. It is imperative to maintain populations of wild spawning salmon and not allow further introduction of non-wild hatchery salmon in Cook Inlet.

On a related issue, there is a growing body of evidence, to include the peer-reviewed study by Greg Ruggerone and Jim Irvine, ("Numbers and Biomass of Natural and Hatchery-Origin Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean, 1925-2015"), that in Alaska declines in size and abundance of Chinook salmon and Coho salmon and a decrease in age at maturation of Chinook salmon may be related to the alteration of the food web by highly abundant pink salmon and higher mortality during later marine life.

Both of these issues justify putting a pause on further production of PWS hatchery pink salmon until further comprehensive research directed at better understanding of total hatchery and wild stock returns, stock identification, and other factors influencing ocean survival of salmon are understood.

Though no statute expressly grants the Board regulatory authority over hatchery production *per se*, the Board may exercise considerable influence over hatchery production through its authority to directly amend hatchery permit terms relating to fish and egg harvesting (AS 16.10.440(b)). The Mat-Su Borough Fish & Wildlife Commission strongly recommends that the BOF act immediately to preclude any further disbursement of hatchery pink salmon at this time.

Respectfully,

Terry Nininger

Terry Nininger, Chair
Mat-Su Borough Fish & Wildlife Commission

cc: John Moosey
Brianne Blackburn

Submitted By
Matthew Alward
Submitted On
7/9/2018 3:42:45 PM
Affiliation
commercial fishermen

Chairman John Jensen

Alaska Board of Fisheries

Boards Support Section

P.O. Box 115526

Juneau, AK 99811-5526

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members,

I am an Alaskan commercial salmon fishermen and I am opposed to the emergency petition to stop the expanded egg take at the Valdez hatchery.

The expanded egg take at the Valdez hatchery was approved and permitted four years ago and has gone through multiple public meetings with many opportunities to express opposition to the permit. There was also the same emergency petition submitted and taken up by the Board of Fisheries (BOF) in May which the board rejected. There is no scientific evidence that shows hatchery fish cause harm to wild stocks and the department of fish and game has determined that there is no emergency finding so I believe that it would be unjustified for the BOF to take action.

According to a brief form the Alaska Attorney General the BOF does not have the authority to change a hatchery permit, and it is my belief that if the BOF takes action on this petition it would in fact change the Valdez hatchery permit. There is already hatchery issues scheduled for the October BOF work session and I feel that is the appropriate time and place for this discussion.

It is a breach of the public trust to hold this meeting during the salmon season, especially given that this same petition was just denied by the BOF. The emergency petition process was set up for actual emergency's and it is an abuse of the process to be holding a meeting during the fishing season on an issue that already went through the process.

I ask that you take no action on this emergency petition and we wait to have the conversation at the fall work session.

Sincerely,

Matthew Alward

Owner-Alward Fisheries LLC

Submitted By
maura obrien-phillips
Submitted On
7/9/2018 10:35:28 AM
Affiliation

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po box 1315
603A vesta street
petersburg, Alaska 99833

My name is Maura O'Brien-Phillips. I have been involved in the fishing industry for over 40 years. In my younger days, I fished for many, many years. My grown children (in their 30's) are 100% dependent upon fishing and are literally life long Alaskan fisherman. They are 3rd generation fishing dependent families. We all live in Petersburg. My son and I have F/VPacific Knight. As younger generation fisherman, it is getting harder and harder for them to make it in the fishing industry. I am sure a few of you who have young adult fishrman can relate. We see them selling out and opting for other ways to make a living. Unfortunately, both of my sons are presently out fishing salmon and can not be available to comment on they way you are sneaking in the interests of select, specific groups by add items to your original emergency petition adgenda. This is NOT THE TIME to bring the emergency closure of Area M and Kodiak sockeye to the table!!! The only reason it it being presented now is because 100% of the fleet is out trying to make a living and are unavailable to comment or offer 1st hand knowledge as to these adgenda items. Be a fair and transparent working board and represent the majority rather than the select minority and move these adgenda items to the fall time and give those 100% dependent on the fishery a chance to use their voice. Thank you.

Maura

Submitted By
maxwell Harvey
Submitted On
7/8/2018 2:44:47 PM
Affiliation

I am a commercial fisherman in Prince William Sound.

I oppose the May 16, 2018 Emergency Petition filed with the Alaska Board of Fisheries.

The Prince William Sound hatchery program is crucial to the local economy and the lives of many commercial fishermen and sport fishermen. The hatchery is well run and based on science.

It is absolutely unnacceptabe that the board would hold a meeting and require comment at a time that is peak season in the commercial fishing season in PWS.

I strongly recommend you deny this emergency petition. The Board should use sound science in making its decision. The May 16, 2018 Emergency Petition is not based on sound science.

Max Harvey

Submitted By
Megan M Corazza
Submitted On
6/28/2018 9:35:43 AM
Affiliation
PWS seiner

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PO Box 732
40953 Knott Circle/732
Homer, Alaska 99603

Hello from the fishing grounds with just enough service to submit a comment. i am a PWS seiner. This will be my 19th year with my own operation, and 32nd year seining in the sound. I have been following this issue and am very concerned that the BOF is responding to emotional politics rather than science. The papers being cited as 'evidence' for an emergency petition state very clearly that their stance is only hypothetical and require much more research before being considered factual. This by no means meritd an emergency petition. In addition, the meeting is going to take place during the peak of the Valdez run, and much of the fishermen who would like to be present will be busy fishing. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries. Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually. Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation. PLEASE DENY THIS EMERGENCY PETITION REQUEST Signed, Megan Corazza

Submitted By
Michael Baccari
Submitted On
6/27/2018 12:47:50 PM
Affiliation
Commercial Fisherman

To: Alaska Board of Fisheries

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Michael Baccari

Mike Adams
F/V Red Pack
PO Box 961
Cordova, AK 99574
907-253-5160

July 5, 2018

Board of Fisheries,

I am writing as a PWS Commercial Fisherman in response to the Alaska Board of Fisheries decision to hold a hearing on the Emergency Petition filed May 16, 2018.

Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria.

I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families.

The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions.

I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session.

Thank you,

Mike Adams

Submitted By
Mike Durtschi
Submitted On
6/27/2018 3:09:55 PM
Affiliation
PWS Purse Seiner

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Girdwood, Alaska 99587

BOF,

Back in the 80's there was a similar discussion regarding salmon. Then it was, wild versus Farm raised salmon. Alaska chose to stick with wild and it has proven to be a wise choice. Hatcheries propagate salmon and release them to the wild for their life cycle. The market accepts them as wild and proven that Alaska is still the preferred source for salmon.

For nearly 4 decades Prince William Sound hatcheries have provided a harvestable surplus for the Commercial and Sport fishermen. At the same time wild naturally propagated runs have flourished in the same waters setting new production records

At this time I see no reason to try and fix something that is obviously not broken and in fact is tremendously successful.

In addition to this opinion the fact remains that I personally am responsible for providing employment and creating wealth that percolates through the Alaskan community I reside as well as the general economy

Hatcheries in Alaska should be expanded, not diminished

Sincerely, Mike Durtschi

Owner/Operator. F/V Halberd

July 3, 2018

To: Alaska Board of Fisheries
By email to: dfg.bof.comments@alaska.gov

Re: Emergency Petition by the Kenai River Sportfishing Association, May 16, 2018 regarding additional hatchery production in Prince William Sound

Commenter: Michael J. Frank, Anchorage, Alaska

Dear Board Members:

Please accept these comments in support of the Emergency Petition.

The ADF&G Commissioner's Decision ("Decision") dated January 14, 2018 is in error. It would allow another significant increase in hatchery pink salmon fry production at the Solomon Gulch Hatchery ("SGH") in the face of the potential for great harm to other species of wild Pacific salmon that return to Alaska's waters from the high seas. The Decision is not properly attuned to the intent of applicable statutes and regulations and downplays certain very significant facts. The Board of Fisheries ("BOF") should therefore direct the Commissioner to reconsider and reverse his Decision.

FACTUAL BACKGROUND

The Decision indicates that the SGH first released fry in 1982. The hatchery's output grew from an initially permitted 50 million eggs to 230 million eggs in 1991. There it remained until 2014 when ADF&G granted it permission to incrementally progress to a production level of 300 million eggs. Currently SGH is authorized at 270 million eggs. The effect of the Decision rejecting the Petition is to affirm an ADF&G staff decision to grant SGH's permission to increase that level by 20 million eggs.

While approving the increase of egg production, the Decision nonetheless acknowledges the need for an after-the-fact evaluation of the potential adverse impacts from the increase. The Decision states "Further increases were not recommended until more comprehensive research directed at better understanding of total wild stock returns, stock identification, and run timing are implemented." *Id.* at 1. The Decision also acknowledges the ongoing problem of hatchery fish straying from Prince William Sound ("PWS") and mixing with wild stocks in both PWS and in Cook Inlet. It indicates, however, that "[an] incremental approach will allow time for assessment of straying proportions in Eastern District streams and provide for evaluation of potential effects on fishery management prior to consideration of additional increases." *Id.* at 1-2. The Decision also indicates that there the "[r]esults of … [an ongoing] study will improve understanding of recent results showing presence of PWS hatchery- produced pink salmon in some Lower Cook Inlet (LCI) streams." *Id.* at 2. Notably, the Decision does not mention ADF&G's *Genetic Policy*, under which wild stocks are to be protected from straying hatchery salmon.

Nonetheless, while the Decision acknowledges that "there were relatively high numbers of PWS hatchery-produced salmon found in several recent sampling events in LCI streams," it concludes that "not enough information is currently available to determine whether their presence threatens a fish or game resource." *Id.* at 3.[1]

In sum, the Decision would allow an increase of egg production at the SGH in the face of acknowledged uncertainties about its potential adverse impacts and notwithstanding the problems associated with the straying of hatchery fish.

BOF AUTHORITY

Before addressing the substance of the Decision, the BOF's authority concerning the Petition needs to be addressed.

The Decision makes somewhat oblique comments concerning the BOF's authority over hatcheries, implying (but without stating so directly) that this authority is limited and therefore the BOF should defer to the Commissioner in this matter. *Id.* at 2.

The BOF's base authority is in AS 16.05.251. That statute gives the BOF authority to adopt regulations for, among other things,

> **(7)** watershed and habitat improvement, and management, conservation, protection, use, disposal, propagation, and stocking of fish;
> **(8)** investigating and determining the extent and effect of disease, predation, and competition among fish in the state, exercising control measures considered necessary to the resources of the state … .

Id. (emphasis added). The Legislature also expressly gave the BOF authority to promulgate regulations "necessary to implement" hatchery management. AS 16.40.440(b). Implicit in the BOF's right to address these subjects and to adopt regulations concerning them is the right to collect information, and to direct the Commissioner and ADF&G to abide by legitimate regulatory directives. Thus, the BOF

[1] Compare this statement to Richard E. Brenner et al., *Straying of hatchery salmon in Prince William Sound, Alaska*, Environmental Biology of Fishes, Vol. 94, Issue o. 1, pp. 179-195 (May 2012) ("The straying of hatchery salmon may harm wild salmon populations through a variety of ecological and genetic mechanisms. Surveys of pink … chum … and sockeye … salmon in wild salmon spawning locations in Prince William Sound … since 1997 show a wide range of hatchery straying…. 0–98% of pink salmon, 0–63% of chum salmon and 0–93% of sockeye salmon in spawning areas are hatchery fish, producing an unknown number of hatchery-wild hybrids. Most spawning locations sampled (77%) had hatchery pink salmon from three or more hatcheries, and 51% had annual escapements consisting of more than 10% hatchery pink salmon during at least one of the years surveyed … streams throughout PWS contain more than 10% hatchery pink salmon…. . The level of hatchery salmon strays in many areas of PWS are beyond all proposed thresholds (2–10%), which confounds wild salmon escapement goals and may harm the productivity, genetic diversity and fitness of wild salmon in this region" (emphasis added)).

implicitly has the authority to, at the very least, recommend, if not directly require, that the Commissioner reconsider or reverse a decision if it is inconsistent with statutes, regulations, or policies under which the BOF and ADF&G operate.

BURDEN OF PROOF

An additional matter that deserves mention is the "appropriate placement of burden of proof."[2]

The Decision indicates that

> <u>The petition does not demonstrate</u> that approval a 20 million increase in the number of pink salmon eggs to be harvested by VFDA in 2018 is an unforeseen, unexpected event threatening a fish or game resource. Therefore, based on the information available to me I cannot conclude that an emergency under 5 AAC 96.625(f) exists. Accordingly, I deny the emergency petition pursuant to AS 46.62.230.

Decision, at 3 (emphasis added). The quotation suggests, without any explanation, that the entirety of the burden of proof is on the petitioners. Moreover, because the level of the burden is unspecified, it is not clear what petitioners would have to show to satisfy the emergency petition regulation (discussed below).

This seems unfair to citizen petitioners, who ordinarily have neither the expertise nor the resources of ADF&G staff, whose job it is --- who are in fact obliged by law --- to protect state fishery resources. It is ADF&G staff members, not Alaska citizens, who must keep the BOF well informed of problems facing the state's fisheries. After all, it is the ADF&G staff that must implement the "policy for management of sustainable fisheries" in 5 AAC 39.222. ADF&G staff must assess environmental impacts on wild stocks before, not after, permitting activities that might harm fisheries.[3]

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[2] 5 AAC 39.222 requires that

> Management of salmon fisheries by the state should be based on the following principles and criteria …
>
> (5) <u>in the face of uncertainty, salmon stocks, fisheries, artificial propagation, and essential habitats shall be managed conservatively as follows</u>
>
> (v) <u>appropriate placement of the burden of proof</u>, of adherence to the requirements of this subparagraph, on those plans or ongoing activities that pose a risk or hazard to salmon habitat or production … .

Id. (c)(v).

[3] ADF&G regulations require that:

> (1) wild salmon stocks and the salmon's habitats should be maintained at levels of resource productivity that assure sustained yields as follows:

The BOF also has adopted a "precautionary approach"[4] to the management of salmon stocks.[5]

Given that regulatory context, citizen petitioners should not be forced to prove with certainty that there is an "emergency" before ADF&G looks into the matter and brings it to the attention of the BOF.

To the contrary, since the ADF&G's managers of the fishery resources have been directed to use a precautionary approach and to manage the resources conservatively,

---

> (A) salmon spawning, rearing, and migratory habitats should be protected as follows:
> *   *   *
> (iii) adverse environmental impacts on wild salmon stocks and the salmon's habitats should be assessed;
> *   *   *
> (D) effects and interactions of introduced or enhanced salmon stocks on wild salmon stocks should be assessed; wild salmon stocks and fisheries on those stocks should be protected from adverse impacts from artificial propagation and enhancement efforts … .

Id. (emphasis added).

[4] The "precautionary approach" is derivative of the "precautionary principle" under which "the existence of scientific uncertainty regarding the precise effects of human activities on the natural environment constitutes legitimate grounds for constraining such activities rather than pursuing them." Grant Thompson, *The Precautionary Principle in North Pacific Groundfish Management,* NOAA, Alaska Fisheries Science Center REFM Division, at 1, available at http://www.afsc.noaa.gov/refm/stocks/grant/precaut.html

[5] 5 AAC 39.322(c)(1)(a)(iii), (D) reads in part:

> (5) in the face of uncertainty, salmon stocks, fisheries, artificial propagation, and essential habitats shall be managed conservatively as follows:
>
> (A) a precautionary approach, involving the application of prudent foresight that takes into account the uncertainties in salmon fisheries and habitat management, the biological, social, cultural, and economic risks, and the need to take action with incomplete knowledge, should be applied to the regulation and control of harvest and other human-induced sources of salmon mortality; a precautionary approach requires
>
> (i) consideration of the needs of future generations and avoidance of potentially irreversible changes;
> (ii) prior identification of undesirable outcomes and of measures that will avoid undesirable outcomes or correct them promptly;
> (iii) initiation of any necessary corrective measure without delay and prompt achievement of the measure's purpose, on a time scale not exceeding five years, which is approximately the generation time of most salmon species;
> (iv) that where the impact of resource use is uncertain, but likely presents a measurable risk to sustained yield, priority should be given to conserving the productive capacity of the resource … .

5 AAC 39.222(c)(5) (emphasis added).

they should not be allowed to deflect their responsibilities away by refusing to act when citizen-petitioners have allegedly failed to carry some unspecified burden of proof. Instead, the burden on citizen petitioners should be relatively light. Given what might be at stake in an emergency resource situation, it should be enough that petitioners bring a significant, imminent resource issue to the ADF&G's attention, accompanied by some relevant supporting information of a credible nature. As shown immediately below, the Petition easily satisfied that burden here.

THE DECISION ON THE EMERGENCY PETITION

The Decision asserts that the Petition does not satisfy the Joint Board Petition Policy concerning emergences. 5 AAC 96.625(f) defines "emergency" as follows:

> an emergency is an unforeseen, unexpected event that either threatens a fish or game resource, or an unforeseen, unexpected resource situation where a biologically allowable resource harvest would be precluded by delayed regulatory action and such delay would be significantly burdensome to the petitioners because the resource would be unavailable in the future.

Id. The Decision claims that the petition does not identify an "emergency" under this regulation because straying of hatchery fish has long been acknowledged as a potential issue and was considered by ADF&G staff in 2014 when the SGH sought an increase in egg production limits. Decision, at 2-3.

Because the relevant data on straying in Cook Inlet is more recent than 2014, however, ADF&G staff could not have taken that data into account when it authorized SGH an increase of egg production to 300 million eggs. ADF&G has not shown, and the Decision does not reflect, that the actual amount of straying that occurred was predicted (foreseen) and expected, or even discussed as part of ADF&G's decision-making process. And of course, excessive straying can "threaten[] a fish … resource" as that phrase is used in the definition of what is an "emergency." 5 AAC 96.625(f).

Beyond the problems posed by straying, petitioners have cited scientific studies, published after 2014, which identify other deleterious impacts hatchery-bred pink salmon in particular may be having, specifically on the populations of other species of Pacific salmon on the high seas. Plainly, these impacts also "threaten[] a fish … resource" as that phrase is used in the definition of what is an "emergency." *Id.*

It also seems obvious that in making its decision, ADF&G did not follow the "precautionary approach" prescribed by regulation. *See* 5 AAC 39.222(c)(5), quoted above. In other words, in the face of uncertainties that the Decision itself identifies, ADF&G has not managed "artificial propagation [at SGH] … conservatively." *Id.* ADF&G's "incremental approach" of approving additional salmon egg production in stages is not adequately protective given the environmental risks.

Perhaps most importantly, ADF&G has not identified a compelling public need that outweighs the risks and uncertainties and that justifies allowing the SGH to process a higher volume of eggs than already authorized. It must be remembered that it is the "bests interests of the public" that are at stake, not the best interests of private hatcheries or fishing interests. *See* As 16.10.430(b) (ADF&G Commissioner given the authority to "find[] that the operation of the hatchery is not in the best interests of the public … [and to] alter the conditions of the permit to mitigate the adverse effects of the operation" (emphasis added)). In assessing whether ADF&G's decision serves the "best interests of public," it must be borne in mind that the Legislature authorized the creation of privately owned hatcheries for one purpose:

> It is the intent of this Act to authorize the private ownership of salmon hatcheries by qualified nonprofit corporations for the purpose of contributing, by artificial means to the rehabilitation of the state's depleted and depressed salmon fishery. The program shall be operated without adversely affecting natural stocks of fish in the state and under a policy of management which allows reasonable segregation of returning hatchery-reared salmon from naturally occurring stocks.

1974 SLA Ch. 111, Sec. 1 (emphasis added). It is long past the time anyone can reasonably claim that either PWS or Cook Inlet is a continuously "depleted and depressed salmon fishery" in need of "rehabilitation." Hatcheries in those areas now function almost exclusively to provide a reliable source of fish, produced by "artificial means," for commercial salmon fishing interests and not to "rehabilitate" any particular fishery.

In short, the "best interests of the public" would not be served by allowing additional egg production at the SGH in face of the uncertainties and risks that hatchery-bred salmon may be posing to wild stocks.

COOK INLET BELUGA WHALES

In assessing the merits of the Petition and the Decision, the BOF also should take into account one other consideration not mentioned in either document. That consideration relates to the status of the Cook Inlet beluga whale population. Known as the "canaries of the sea" because of the chirping sounds the whales make, the Cook Inlet beluga whale population truly may be the apocryphal "canary in the coal mine" warning of disaster for Cook Inlet's fisheries.

Cook Inlet beluga whales are genetically distinct from beluga whale populations resident elsewhere in Alaska's waters. They do no intermingle with other populations. Thus, if the Cook Inlet beluga whale population ceases to exist, beluga whales will no longer appear in Cook Inlet.

The Cook Inlet beluga whale population suffered a rapid decline in the early 1990s. Because of that decline, citizen groups petitioned the U.S. Department of Commerce's National Marine Fisheries Service ("NMFS") to list the whale population as endangered under the federal Endangered Species Act ("ESA"). In 2000 NMFS rejected the ESA petition but listed the population as "depleted" under the federal Marine Mammal Protection Act ("MMPA"). NMFS then severely restricted Alaska Native hunting of the whale under that Act. At the time, both NMFS and State officials predicted that hunting restrictions would allow the population to recover. The population did not recover, however. In response to a new ESA petition, in 2008 NMFS listed the population as endangered under the ESA. Today, the estimated population hovers around 300, where it has remained for well over the last decade. The population still shows few positive signs that it is recovering.

For most of the year, the Cook Inlet beluga whale population is confined to the far reaches of upper Cook Inlet, principally in Knik Arm and Turnagain Arm. Historically this was not the case, as beluga whales were plentiful throughout Cook Inlet.

Among other food sources, Cook Inlet beluga whales traditionally have hunted eulachon ("hooligan") in the spring and salmon in the summer at the mouths of Cook Inlet's anadromous streams, often traveling far upstream in search of their prey.[6]

While many have attributed the Cook Inlet beluga whale population decline almost entirely to Alaska Native hunting, the increase in commercial fishing and boat traffic in Cook Inlet and the associated commercial harvest of salmon in the 20th century likely was a contributing factor. Presumably beluga whales may be deterred from fishing areas with a high concentration of boats and nets notwithstanding the plenitude, or lack thereof, of returning salmon. During a commercial salmon fishing period one summer in the 1990s off the Kenai Peninsula, NMFS engaged in an acoustical study to determine if noise impacts from boat traffic were influencing the behavior of beluga whales. So few whales were sighted, however, it was not possible to reach any defensible conclusions. Today the reduced opportunities for Cook Inlet beluga whales to feed on salmon may be a factor in the population's failure to recover.

If the beleaguered population of the remaining Cook Inlet beluga whales had a way to do so, they would naturally ally with petitioners. Many recreational fishing interests have been advocating for the opportunity to catch a bigger share of the larger species of salmon returning to Cook Inlet's anadromous streams. If there were more of the bigger, fattier salmon in the mouths and streams of Cook Inlet, they would not only be available for recreational fishermen but also for Cook Inlet beluga whales. A well-fed breeding beluga whale population could trigger a slow rise in the size of the population out of its endangered status.

To date, neither NMFS nor ADF&G has taken into account the specific food needs of the whales. In its ESA Recovery Plan for the whale population, NMFS explicitly rejected any need to more fully engage in advocacy for the whale during BOF fish allocation decision-making.

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[6] NMFS has reported that in the 1960s, when Cook Inlet beluga whales were plentiful, Kenai area residents would participate in an annual beluga whale hunt in the Kenai River as part of a day of fishing festivities.

ADF&G declined to list the population under Alaska's own Endangered Species Act and has been inactive in advocacy for the whale before the BOF. Presumably ADF&G fishery managers believe that if in-stream escapement goals are met that will be enough to ensure that there are adequate salmon for the Cook Inlet beluga whale population's consumption and its eventual recovery.

Unfortunately, NMFS and ADF&G's failure to grapple openly with the question whether the whales can opportunistically access an adequate amount of salmon leaves one without any assurance that there are enough salmon available for the whales' harvest in the areas where they would traditionally feed. And there are significant warning signs that the whale population may be food stressed. A recent study found that Cook Inlet beluga whales might have begun relying in greater proportion on freshwater species for sustenance. *See* Mark A. Nelson, et al., ADF&G, UAF, NMFS, *Fifty years of Cook Inlet beluga whale feeding ecology from isotopes in bones and teeth*, June 2018, published in Endangered Species Research, Vol. 36, pp. 77-87, abstract and pdf available at https://www.int-res.com/abstracts/esr/v36/p77-87/ ("This study represents the first evidence for a long term (~50 yr) change in feeding ecology.") The study noted that the NMFS had previously "found that while the threat of a reduction in prey was of medium concern," but that "little was known about prey availability and how availability has changed over time. … " *Id.* at *78.*

So, what does the plight of the Cook Inlet beluga whale population have to do with hatcheries and the issue of the SGH's salmon egg volume that is now before the BOF? The connection may be indirect but upon reflection, it should be obvious.

In addition to evidence of straying, petitioners cite a growing body of scientific evidence concerning the adverse impacts that hatchery bred salmon may be having on wild stocks of other species of Pacific salmon. This recent scientific evidence suggests that hatchery salmon may be crowding out wild salmon species, especially on the high seas, reducing the size of these species' returns to their spawning grounds and therefore threatening their long-term productivity. This in turn could be having a cascading negative effect on threatened marine mammal species, like the Cook Inlet beluga whale as well as the MMPA-protected Steller sea lion, and seals, which may be dependent on the larger species of salmon for their own productivity.

Putting aside the question whether hatchery-bred salmon may be indirectly causing adverse impacts on marine mammal populations, the petitioners have made an adequate showing that there is considerable risk in continuing on the path of enabling even more production of salmon at hatcheries in PWS and Cook Inlet in the face of increased evidence of straying of PWS hatchery fish into Cook Inlet. The BOF should not allow ADF&G to take that risk without further scientific studies and a careful evaluation of their results.

CONCLUSION

The BOF should take this opportunity to begin rethinking the role of private salmon hatcheries in Alaska's fisheries.

Some of these hatcheries have been heavily subsidized by an investment of public monies and struggle under large financial obligations. Their operation has led to the creation of artificial salmon fisheries upon which some fishermen and processors have come to depend for their annual incomes and business survival. And yet when salmon returns are too low, public monies are also used to diminish the impacts from any income losses. *See, e.g., Seafood News*, Susan Chambers, "Commerce Department Announces $200 Million Fishery Disaster Funding Allocations, " June 21, 2018 ("Alaska's disastrous pink salmon runs in 2016 led NMFS to declare that fishery a failure last year. Alaska will receive more than $56 million.") As a matter of sound financial public policy, this situation does not seem to make much sense. It makes even less sense if, as the recent scientific research seems to show, salmon from hatcheries are having deleterious impacts on wild stocks.

The BOF should, therefore, acknowledge the legitimacy of the Emergency Petition. Guided by the "precautionary approach," it should direct the Commissioner to reverse ADF&G's decision allowing additional egg production at the SGH until more definitive studies determine that the "best interests of the public" would be served by an increase in egg production.

Thank you for considering these comments.

From: Mike Kramer
To: DFG, BOF Comments (DFG sponsored)
Subject: Comments on KRSA proposal re: additional PWSAC hatchery production
Date: Tuesday, July 3, 2018 5:08:38 PM

We are in a statewide wild salmon crisis. Poor ocean survival is the primary cause. Warm water in the Pacific feeding grounds reduces food production and when increasing numbers of juvenile salmon compete for scarce food, the more aggressive hatchery produced pinks and chums outcompete wild reds and kings. The science supporting the conclusion that hatchery overproduction is contributing to the demise of our wild red and king stocks cannot continue to be ignored in these times of unprecedented wild run failures.

PWSAC has a long history remaining unaccountable and failing to live up to various commitments made to ADFG over the years. Not only should the board take action to prevent the proposed increase in hatchery production, it should also implement some measures to ensure future accountability and reduced production until the Pacific feeding conditions improve.

The fact that some segments of the commercial fishing industry have become reliant on hatchery fish is irrelevant to whether there exists an emergency in the form of failed wild runs with poor ocean survival being the primary cause. You cannot simply blame the problem on the "blob". The blob may have reduced the forage available, but if hatchery fish were taken out of the food chain, the reduced forage is much more likely to sustain our wild fish.

For many years, at the urging of Commercial fish interests, the Board failed to reduce the size of Yukon river gill nets despite the science proving that size selectivity was having a drastic negative effect on larger Yukon kings and consequently, the overall health of the run. The board waited far to long to acknowledge the science on size selectivity, and allowed our Yukon kings to become further depressed.

Please respect the emerging science about negative hatchery impacts on wild fish following another disastrous year in the Copper River. Please do not be overly influenced by commercial interests and proactively manage PWS wild stocks for long term sustainability by reducing hatchery production.

Mike Kramer
216 Sacia Ave
Fairbanks AK 99712

Submitted By
mnowickiitchell
Submitted On
6/30/2018 11:58:49 AM
Affiliation
pws comm fisherman

the pws salmon hatcheries are a vital component to the viability of the commercial salmon fisheries in area E. wild runs are are much more volatile and would hurt not only fisherman if the hatcheries did not exist, but also all the local towns and all businesses and services....we all live off what we can harvest from the sea...really....esp in cordova, with minimal tourism. i also understand that all salmon reared in hatcheries here are from local stock not alien stocks....i think that until we can run a study that definitely shows that there is no straying of pure wild stocks from their native streams...this may indeed be an allowable natural way of salmon repopulating weak streams or starting up in new streams....or perhaps just keeping the gene pool from becoming stagnant as we see in all populations...anyways it is premature to say the sky is falling , please defer any action until much,much more facts can be brought to light.........also as a fact only pws hatcheries tag their fry so it is unknown until we tag other hatcheries and wild fry what is really happening...too easy to just point a finger at pws.....thank you for your time

July 9, 2018

Nancy Hillstrand
Pioneer Alaskan Fisheries Inc.
4306 Homer Spit
Homer, Alaska 99603

Dear Alaska Board of Fisheries,

As the owner / operator of Pioneer Alaskan Fisheries (established in 1964) in Homer, Alaska, we have harvested and processed finfish and shellfish, such salmon, halibut, rockfish, lingcod, herring and crab, for both wholesale and retail markets. I also have 21 years of experience working for F. R. E. D. division of the Alaska Department of Fish and Game (ADFG), retiring in 1999. I am writing in support of the emergency petition submitted to halt the 20 million in further egg take and rearing of hatchery pink salmon in Prince William Sound (PWS), at the Solomon Gulch Hatchery (SGH). Thank-you for your time to address this crisis affecting our wild salmon stocks and for your understanding of my comments.

Please quarantine PWS hatchery pink salmon production, to protect wild salmon stocks and remove the impacts from straying hatchery fish. ADFG has documented unacceptably high levels of unharvested PWS hatchery fish reproducing with wild salmon in Lower Cook Inlet streams, which is glutting, suffocating and contaminating wild pink salmon. Consider: There are equal amounts of Hatchery pinks as Sockeye in the Pacific.

We are witnessing very serious indicators of stress to our wild salmon fisheries and distress in the Gulf of Alaska (GOA). **Significantly reduced yields of high value salmon species such as sockeye, Chinook, and coho salmon** is affecting GOA coastal communities.

Is it a coincidence the ADFG 2010 PWS PAR denial warned of these reduced yields[1]:

> A multitude of studies indicate that competitive interactions from large numbers of hatchery pink and chum salmon is occurring in and around PWS and these interactions are likely having a detrimental impact to wild stocks of salmon and herring in the PWS region. Also, of concern to department biologists is evidence showing these **competitive interactions can significantly reduce yields of high value salmon species such as sockeye, Chinook, and coho salmon.**
>
> Department research and management biologists, consistent with statutory and regulatory requirements to maintain a precautionary approach to salmon management, **advise against additional increases to PWS hatchery pink and chum salmon production.**

[1] State of Alaska ADFG Memo April 19th, 2010 comments summarizing PWS PAR requests

These indicators of oceanic distress form an unforeseen and unexpected emergency, which demands immediate attention without delay, to detect, scrutinize, and remove **all** detrimental impacts to wild stocks, that we can control, without exception, per existing statutes and regulations.

Additional increases to PWS hatchery production are a detrimental competitive stress to wild fish; this must cease until oceanic stressors are comprehensively investigated.

It is fashionable to blame this stress on the Blob, a concentration warm waters in the Gulf of Alaska from 2014 - 2016. These reports come with the caveat that "fresh water survival seems fine, it is something mysterious out in marine waters." Is there a mysterious accomplice to the Blob and its repercussions in migratory pathways?

When we consider 2013 and 2015 both record returning adult hatchery pink salmon to PWS, is it a coincidence that GOA hatchery pinks crashed in 2016? There seems to be an ongoing sockeye and Chinook crash this year which is of the same 2015 brood year, in many areas of the GOA. Consider: pinks exceeded wild sockeye numbers these years.

Can we see a pattern of wild salmon survival and abundance between the odd and even year pink salmon cycles? Is it a fluke that cod crashes, king salmon depletion, murre starvation, sockeye weigh a pound less, and Chignik and Yakutat sockeye showing significant signs of stress during these one-two punches?

Some now glorifying the more than 310,000,000 million pounds of hatchery-origin, additional introduced predator pink salmon that grow 500 percent in the last four months of their lives while circulating in the out-migratory paths of newly emerging wild fish in the GOA. However, this is not what I would call success, and it violates state statutes and regulations that are intended to provide the highest of protection to Alaska's wild salmon populations.

Is there any way possible that these domesticated eating machines have no detrimental impact on wild salmon? As this enormous biomass of hatchery-origin adult pink salmon returns to spawn along coastal areas of the Gulf of Alaska, it is gorging on 6,000,000 pounds of seafood each day or 180,000,000 million pounds of seafood each month. Can we say with certainty that there is no impact in the overlapping timeframe when, during their tender early marine life stages, juvenile wild salmon are out-migrating through these very same coastal areas to the ocean? Is there no impact, no cause and effect of this magnitude of introduced hatchery-origin biomass?

We have indicators. We have impacted coastal communities that depend upon healthy stocks of wild salmon. The state has a responsibility to the public trust. Everything is on the table, no exceptions.

The glut (at harvestable surplus levels) of straying PWS hatchery-origin pink salmon some 200 miles in too many LCI streams means permitted egg capacity and rearing is way too high. Alaskans should not have to withstand this damage to our significant wild stocks, to be subservient to a corporate business plan for marketing purposes. Alaskan fishery statutes and regulations place protection of wild salmon above industry hatchery production and financial consideration.

In terms of the time concern that this proposed increase must occur in 2018, a memorandum from PNP program employees dated May 6th, 2014 appeared not very concerned about any delays in this 2018 increase. It states:

> An additional increase of 20 million pink salmon green eggs will occur in 2018, once VFDA is able to demonstrate the required physical capacity **or delayed** until hatchery modifications required to reach physical capacity are completed.

This memo continues:

> **Incremental permit increases also allow for further evaluation of management feasibility and potential effects on the areas wild stocks.**[2]

It was unforeseen and unexpected that this **further evaluation phase of potential effects on wild stocks** has manifested itself outside of the PWS area, with impacts of an inter-regional area (Cook Inlet) now documented with the LCI otolith studies. Also, as per this memo, since there seemed to be no real concern with delay if the SGH is not ready, then it is now logical that SGH can easily delay until there is some serious discussion and evaluation about this straying situation. Delay should be mandatory until management feasibility is assured and the evaluation is complete, including an expansion of the impact area to include Lower Cook Inlet.

The Regional Planning Teams (RPT) of both Cook Inlet and PWS refused to take this massive straying situation up at their respective December 2017 and April 2018 meetings, despite multiple requests to do so. Any delay of SGH additional increases rests squarely on a seriously broken State of Alaska RPT process.

As courtesy to the public trust, we now have the opportunity through the Board of Fisheries, that (hopefully) is still intact and not broken, to get this serious issue on the table, into the hands of scientists, biologists and managers, to be discussed, considered and resolved before any further eggs are allowed to be taken.

<u>Let's take a more in-depth look at the unforeseen and unexpected nature of the massive straying of PWS hatchery-origin pink salmon into LCI streams.</u>

[2] Memo from Larraine Vercessi and Sam Rabung with attached Notice of Permit Alteration for SGH May 6th 2014

In August of 2014, it was unforeseen and unexpected that **three months after the 2014 Solomon Gulch hatchery PAR was signed, SGH strays were detected in 6 out of 8 streams sampled in Lower Cook Inlet.**

It was unforeseen and unexpected that SGH pinks would stray 200 miles into LCI. As then ADFG chief scientist Eric Volk stated[3]:

> Hatchery salmon strays may have both ecological and genetic impacts to wild salmon stocks…. …these (SGH) fish appear to have a lower propensity to stray than pink salmon from other PWS hatcheries.

Another example of surprise is from ADFG LCI manager Glenn Hollowell, who uses SGH as an example of a hatchery having a stellar reputation for low straying rates to be used as a model:

> Because we don't fully understand all the factors that contribute to straying, a common-sense approach would be to mimic the characteristics of hatchery releases that demonstrate low stray rates…In PWS the SGH has the lowest observed pink salmon straying rates….

Beginning in 2014, ADFG LCI staff took heads from pink salmon to remove the otoliths (ear bones) that show the distinct mark depicting which hatchery these pinks were straying from. This distinct mark is created by raising the water temperature during the incubation stage in hatcheries.

The reason for the expense, time, effort and money, of mass thermal otolith thermal mark is written in the PWS Comprehensive Plan Phase III:

> Since there is a priority for protecting wild stocks in the management of salmon fishery harvest (AS16.05.730), harvests in traditional common property fisheries are based on the abundance of wild stocks consistent with the Escapement Goal Policy.
>
> Mass thermal otolith marking determines the presence and percentage of hatchery fish in the spawning escapements of wild stocks and identifies which hatchery they originated from.
>
> The ADF&G Escapement Goal Policy provides the mechanism for establishing biological escapement goals for wild salmon stocks to allow management of fisheries based on biologically-established escapement goals.

ADFG LCI staff related the percentage of PWS hatchery fish incidence by facility and abundance. This otolith sampling was continued in 2015, 2016, and 2017 and will commence in 2018.[4]

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[3] SGH Permit Alteration Request comments from Eric Volk chief fishery scientist, salmon
[4] 2016 Lower Cook Inlet Finfish Management Report number 17-26 beginning on page 167
The 2017 Reports were not available at this time.

<u>In **2014** – **SGH hatchery strays were detected in 6 out of 8 streams studied.**</u>

The unforeseen and unexpected otolith sampling revealed an extremely concerning 92.6 percent hatchery straying in Barabara Creek, a significant stock of LCI.

By facility SHG came in 4th by abundance detected.

- AFK won taking 38.7 percent of the PWS straying hatchery fish detected in LCI.
- WNH took second at 32.2 percent.
- CCH took third at 36.1 percent.
- SGH took fourth at 3 percent.

<u>**In 2015**</u> - <u>**SGH hatchery strays were detected in 7 out of 12 streams.**</u>

By facility, in this year **SGH the winner, number1 in PWS facilities to stray!**

- **SGH won** taking 38.3 percent **of the straying hatchery fish detected in four significant stocks Barabara, China Poot, Humpy, English Bay River at 35 percent a significant stock for sockeye salmon. Pinks have proven to cause suffocation in sockeye[5].**
- AFK took second at 26.8 percent **straying into ancestral stock - hatchery contamination prohibited. These are seed banks of pure unadulterated genetics, which is now contaminated.**
- CCH took third at 19.5 percent **yet strayed into an into ancestral stock, which is now contaminated.**
- WNH took fourth prize at 15.4 percent **yet strayed into an ancestral stock, which is now contaminated.**

<u>In **2016 - SGH hatchery strays were detected in 7 out of 10 streams.**</u>

By facility SGH lost first place by only by 7.5 percent!

- AFK won taking 37.7 percent of the hatchery fish detected.
- SGH took second at 30.2 percent! **detected primarily <u>Barabara Creek a significant stock.</u>**
- CCH took third at 24.5 percent.
- WNH took fourth prize at 7.5 percent.

In **2017** - <u>**SGH hatchery strays were detected in 13 out of 16 streams.**</u>

- <u>**SGH in second place Dogfish Lagoon a high of 34.3 percent in a significant stock.**</u>

<u>**Hatchery-marked pink salmon (Prince William Sound and Lower Cook Inlet combined) outnumbered unmarked pink salmon on 5 of the 16 streams sampled!**</u>

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[5] High Salmon Density and Low Discharge Create Periodic Hypoxia in Coastal Rivers. Ecosphere 8(6):e01846. 10.1002/ecs2.1846

It must be unforeseen and unexpected that we are replacing our wild fish with hatchery fish, as Alaska's fishery statutes and regulation have prohibitions from this occurring.

Since these unacceptable straying results have been made public by ADFG, the RPT's have refused to even discuss this critical issue or put it on their agenda, which in and of itself creates another very dangerous unforeseen and unexpected event.

The RPTs are not abiding by the laws of the State of Alaska. They are not showing consideration for the public, repercussions to other regions, or due regard to the Genetics Policy, which is designed to protect significant or ancestral salmon stocks, many of which in LCI now have SGH and other PWS hatchery strays.

The Alaska Genetics Policy states:

- Interaction with or impact on significant stocks: **Priority is given to protection of significant wild stocks from harmful interactions with introduced stocks. Stocks cannot be introduced to sites where they may impact significant or unique wild stocks**.
- Use of Indigenous stocks in watersheds with significant wild stocks: **A watershed with a significant wild stock can only be stocked with progeny from the indigenous stocks. The policy also specifies that no more than one generation of separation from the donor system to stocking of the progeny will be allowed. This means that only progeny from eggs taken from natural broodstock from the watershed may be used, and not progeny of broodstock returning to a hatchery or release site.**

State of Alaska Law is to protect self-sustaining wild stocks:

The State of Alaska was founded on guiding principles for wild self-sustaining salmon. They have very clear legislative mandates, policies, and constitutional authority, for wild stock priority and protecting the public trust.

The PWS Comprehensive Plan Phase III is full of points to protect wild fish and details protection for <u>significant stocks:</u>

In addition, RPTs develop and maintain regional comprehensive salmon plans. The locations of hatcheries are given prime consideration in the planning process. **Criteria include <u>isolation from significant wild stocks</u>.**

1.22 Biological Constraints:

Increases in enhanced salmon production in PWS are possible only if shown to be biologically feasible. Intensified research is being integrated into the enhancement program to detect impacts on wild stocks and ecosystem carrying capacity, and thereby will determine upper levels of hatchery production by species.

1.17 Research must encompass biological and ecological issues:

Again, the PWS/CR RPT supports a wild stock conservation priority. We must be certain that in our efforts…that production and harvest strategies minimize impacts to wild stocks.

The intent of the original 1974 PNP hatchery legislation mirrors these guiding principles:

> **…for the purpose of <u>contributing</u> by artificial means…to the <u>rehabilitation</u> of the state's depleted and depressed salmon fishery.**
>
> **The program shall be operated <u>without adversely affecting natural stocks of fish in the state…</u> and under a policy of management which allows reasonable segregation of returning hatchery-reared salmon from naturally occurring stocks.**

NOTE: Natural wild stocks are clearly differentiated from artificial hatchery fish.

<u>Definitions:</u>

Rehabilitation defined by AAC 39.222 means efforts applied to a salmon stock to restore it to an otherwise natural level of productivity. Rehabilitation does not mean enhancement.

Enhancement defined in AAC 39.222 means intended to augment production above otherwise natural levels.

In addition to the PNP Hatchery legislation intent of **contributing** to **rehabilitate**, it has a mandated caution that demands heed… **wild natural fish must be kept safe and separate** from man produced artificially propagated hatchery programs.

While ADFG notes that straying is a natural phenomenon in salmon, hatchery policy states that no more than 2 percent straying of hatchery-origin salmon to areas outside the designated recovery area is acceptable.

<u>Straying rates above this 2 percent baseline does not reasonably segregate returning hatchery-reared salmon from naturally occurring stocks. In 2017, straying PWS hatchery-origin pink salmon accounted for 15 percent of the total pink salmon abundance in LCI streams, at levels much higher than 2 percent in the vast majority of streams sampled.</u>

With no validation, no science, and no consideration of the public trust, aquaculture advocates use **The Four D's** strategy to attest their operations have no adverse effects:

- Deny
- Delay
- Disagree
- Denigrate

The Four D's have no merit in the fisheries public policy process that puts protection of wild salmon as its highest conservation and allocation priority.

What is designed to have merit is the Regional Planning Teams as stated in the PWS Comprehensive Salmon Plan phase III:

> The key component for implementing hatchery management policies are the Regional Planning Teams (RPT). The RPTs are to invite input from management and research biologists, scientists from universities and federal agencies, commercial and recreational fishery groups, and local community representatives.

Unforeseen and unexpected is the extent of our lack of knowledge and grave uncertainty pertaining to hatcheries, hatchery fish, corporate sea ranching operations, and these massive magnitudes of artificially produced, hatchery-origin fish impacts on wild salmon, seabirds and other pelagic fish.

The PWS Comprehensive Plan phase III again eloquently states this:

> **Mixed Stock fisheries and protection of wild stocks**
>
> The impact of large scale hatchery returns on the PWS wild stocks could be devastating if knowledge of the interactions between hatchery and wild fish is not gained and applied to production planning and fisheries management.[6]
>
> **Recognizing optimum production of enhanced stocks**...during the early marine life stage, compensatory mortality may occur when large numbers of fry compete for a limited food resource. If so, marine survival rates will decline (mortality will increase) as fry release numbers are increased.

Apply this statement to include optimum production on wild stocks and...mortality will increase as fry release numbers are increased.

What is unforeseen and unexpected is this **key component to implement the laws,** the Regional Planning Teams, refuse to acknowledge any science, refuse to put this massive straying issue on their agenda, and refuse to concede to ADFG, its management and fisheries biologist who are on record with alarming PWS Internal Reviews and memos using science foretelling damage.[7],[8]

What compounds this unforeseen and unexpected event is the realization that the guardians are off track from the original intent to serve the public trust of salmon, and one of the very reason Alaska became a state is in jeopardy. Hatcheries are modern day fishtraps.

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[6] PWS Comprehensive Salmon Plan phase III – PWS CR Regional Planning Team

[7] ADFG PWS Internal Review 2009

[8] ADFG Memo PWS Permit Alteration Requests- regional and area staff comments April 9 2010

Continual bullying and promotion of increased production with paltry evaluation for wild fish is like a runaway train with a heavy weight of indicators barreling down, while the public trust frozen like deer in the headlights, just waiting for the impact, instead of shouting caution, stop, slow down, before more damage can occur.

Why would further expansion even be considered, when the PWS RPT and Aquaculture Boards have a history of non-compliance and until this infection of hatchery stray fish contaminating LCI wild salmon ceases?

Currently the Comprehensive Salmon Plans that guide enhancement activities in each region are not being followed. With no consistent and comprehensive evaluations of impacts, the five criteria are being ignored and show non-compliance.

Thus, all increases in egg take and rearing for hatchery production must cease. There are more ongoing state studies in addition to the narrow focus of the industry paid for and designed PWS studies. There is 30,000 miles of coastline, a much larger area than just PWS, home to the 99 percent Alaskans living in the rest of the state.

Currently, peer reviewed scientific research on the impacts of hatchery-origin fish on wild salmon is ongoing: as an example, the otolith studies are continuing in LCI and the GOA wild salmon systems. A much more comprehensive inter-regional picture of straying propensity is being formed, to say nothing on the ever-increasingly clear picture documented in scientific reports on the impacts of pink salmon (wild and hatchery) on the food chains of the North Pacific Ocean, to sockeye, Chinook, coho and steelhead as well as seabirds and other pelagic species.

As these various studies continue and as the indicators of stress to our wild fisheries become comprehensively understood, the precautionary principle holds additional increases at abeyance for hatchery production.

I strongly recommend that the BOF make a finding on emergency and take action to halt the additional 20 million egg take and rearing of PWS hatchery pink salmon.

Thank-you kindly again for your time and effort.

With Sincere Regards,

Nancy Hillstrand

Nancy Hillstrand
Pioneer Alaskan Fisheries Inc. (since 1964)
907-399-7777

Submitted By
Nathan doll
Submitted On
6/27/2018 10:20:33 AM
Affiliation

Phone
907-428-8066
Email
Nathan.doll@yahoo.com
Address
607 4th st
Cordova, Alaska 99574

Sample text #3 - Sent out by Silver Bay Seafoods to their fishermen

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST

Signed,

Nathan S Doll

6-27-18
NATHAN TUELLER
F/V GOLDEN PACIFIC
GIRDWOOD, AK.

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and B.O.F. Members:

My family and I depend on fish produced by PWSAC and VFDA for our entire livelihood. Without the longstanding hatchery programs in P.W.S. there would not be a sustainable seine fishery for the 250 boats that participate here. The hatcheries are critical to all Seiners, Gillnetters, and Setnetters in P.W.S.

THERE IS NO EMERGENCY! There is a long and well thought out process that has and continues to govern the hatcheries of our area. The board already has plans to discuss this issue in the October 2018 work session.

This is a deliberate political maneuver by special interests, with the goal of eliminating hatchery production whenever possible. The timing designed specifically to reduce or eliminate participation of my user group. July 17 is the middle of the seine season. It is the best time to have a meeting if the goal is to silence the opposition. Regardless of the final outcome I strongly object to this being decided at a time that I am unable to participate in the process.

I urge you to address these concerns in October, when all the parties directly involved can fully participate.

Thank you for your time,

Nathan Tueller

Submitted By
Nikita Kuzmin
Submitted On
6/30/2018 10:06:22 PM
Affiliation
Commercial and personal use fisherman

I live in Delta Junction alaska fishing is my source of income supporting my family, personal use we harvest to have food for cold long winters Our beautiful state is cold we cant really grow much food relying on whats brought in is not a good option Fish is most important for Alaska Alaskans without abundant fish the economy will fall less tourism people will not have opportunities to harvest fish. Fish in Alaska is the talk of the world so much excitement for people to visit Alaska to go catch fish Hatcheries in Alaska are providing abundant fish for all user groups communities around the state started releasing by harbors now people come from all over the world to catch fish in Alaska If all be shut down only few fish will return every year only subsistence harvests will participate that will drive the economy in rural communities to suffer most Please keep the hatcheries open that were operating for decades we saw no scientific problems On the emergency meeting during a busy season people are out working fishing, their livelihoods are at stake would be ruined by opposing group is not what Alaska board of fish should be discussing is outrageous. Please move the meeting to other date winter be the time to discuss hear from both groups not just one opposing group. Thanks

NORTHERN *NSRAA* *SOUTHEAST REGIONAL AQUACULTURE ASSOCIATION, INC.*

(907) 747-6850
FAX (907) 747-1470
EMAIL steve_reifenstuhl@nsraa.org

1308 Sawmill Creek Road Sitka, Alaska 99835

July 9, 2018

Board of Fisheries

July 17, 2018
Emergency Meeting Anchorage, Alaska

Re: Comments Regarding Emergency Petition to Rescind VFDA 20m Pink Salmon

Dear Chairman Jensen and Board of Fish Members:

I respectfully submit comments, which follow the format and progression, point by point in the petitioners' argument. Fundamentally and succinctly, there is no justification for an emergency finding considering that every year from 1988-2018 five billion pink and chum fry have been released by e Japan, Canada, Russia, Korea, and the U.S. into the North Pacific Ocean. Twenty million eggs or 18 million fry represent a 0.36% increase in biomass. Furthermore, based on Pauley et.al. (1996) Pacific salmon make up only 7% of the epipelagic fish biomass or 3% when squid are included. A review of the literature attached demonstrates ocean carrying capacity is complex and salmon are a minority in the nektonic competition for zooplankton.

Factors refuting finding of emergency:

1. Petitioners state the permitting requirements for a hatchery correctly but omit that these conditions are under the regulatory authority of ADF&G.

2. **AS Sec. 16.10440(b)** (circa 1979) specifies source and numbers of eggs. This statute refers to the original wild salmon stock and number of eggs that may be taken from a wild donor source. This authority has been delegated to ADF&G, evaluated by local AMB's and granted or denied by ADF&G since 1979. The department develops a 'sliding eggtake' scale based on biological criteria, with the first and most important being adequate wildstock escapement. Second, providing for hatchery development of a brood source. In 1979, there were no large-scale hatchery programs, but rather development of brood sources from local wildstocks. Generally, it took two generations of hatchery releases to obtain large-scale egg takes. Section 16.10.440(b) was thoroughly discussed during the BOF 1999 to 2002 sessions resulting in the Joint Protocol BOF #2002-FB-215.

   Therefore, the number of source eggs is within BOF authority but not number of eggs that are taken from hatchery returns. Established hatchery programs are prevented from going back to the original wild source due to the **Genetics Policy (pg. 4).**

http://www.adfg.alaska.gov/fedaidpdfs/fred.geneticspolicy.1985.pdf?_ga=2.149217652.352854699.1530561433-1681060088.1530561433

3. **Joint Protocol #2002-FB-215** – it is true the BOF in 2002 recommended a public forum on hatcheries, but each board makes choices on how to utilize their time and apparently annual public forums did not reach that threshold. To have or not have a public forum on enhancement is a BOF decision, and not within the PNP's authority and therefore had no input into whether such forums were scheduled. The BOF did have annual presentations and reports from ADF&G at BOF meetings both at statewide and area finfish venues. However, lack of a forum in no way makes for an emergency as all subsequent production was permitted through publically noticed regional planning meetings, and fully vetted by numerous ADF&G biologists, managers, and scientists. These meetings are attended by members of the public, and often by federal land managers. Public records of RPT meetings are maintained and available.

   The current BOF has decided they want to have a review of the state's enhancement program at the October 2018 work session. The intention of that review is for the board to educate themselves about the program and review the science upon which the enhancement programs are predicated. In addition, the board would see the most recent data on the hatchery/wild research program and NPAFC ocean carrying capacity science. Further, the board has outlined a path for better understanding local enhancement programs by focusing on specific areas during the regularly scheduled regional finfish meetings. The petitioners seem to be attempting to short circuit that public process.

4. **5 AAC 39.222 Natural stock protection** – There is no emergency defined here by the petitioners. Protection of natural stocks is being done via significant policy and regulatory elements of the enhancement program. In addition, the department launched into a massively ambitious research program in 2012 costing $16 million, over two salmon life cycles spanning eleven years.

   Policies and regulations for protection of wild stocks – genetics policy, fish pathology, transport of fish policy, use of local stocks, restrictions on cross-geographic regions, regional salmon enhancement plans, limnology protocols, 100% marking of salmon, management feasibility analyses, and more insure those protections.

   Hatchery Wild Interaction Research – this study will answer the hypothesis: do hatchery strays breeding with natural spawners (introgression) reduce the reproductive success and productivity of the wild spawners? This innovative research employees recent genetic techniques that will be able to establish pedigrees of parents and their offspring for two generations of wild/wild, wild/hatchery, and hatchery/hatchery crosses in four discrete streams in PWS.
   http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.findings_updates

   Straying Assessment – some 34 randomly selected ADF&G index streams have been

assessed for extent of hatchery straying in PWS. Research results have been presented at American Society of Fisheries in Anchorage, May 2018. Preliminary results were reported in 2016 and 2017
http://www.adfg.alaska.gov/static/fishing/PDFs/hatcheries/research/2017_annual_report_pwssc_hw.pdf
Peer reviewed journal articles are expected in press later this year or in early 2019.

5. **Pink salmon eggs and fry released to PWS in 2016** – reporting the numbers of release and returns does not present an emergency, nor is there any rationale presented as to what the stand-alone numbers are supposed to mean. Context would be helpful. Since 1990 about five billion hatchery fry from Japan, Russian, Canada, and the U.S. have been released into the ocean annually. In addition, there are billions of **wild pink fry** from Alaska, Canada, and Russia entering the North Pacific each year. The petitioner's cited number of pink fry (643 million) is 12.9% of five billion. If you included fry from wild systems in Russia, Canada, and U.S. the percentage would be much lower.
https://npafc.org/new/publications/Annual%20Report/PDFs/Annual%20Report%202016.pdf

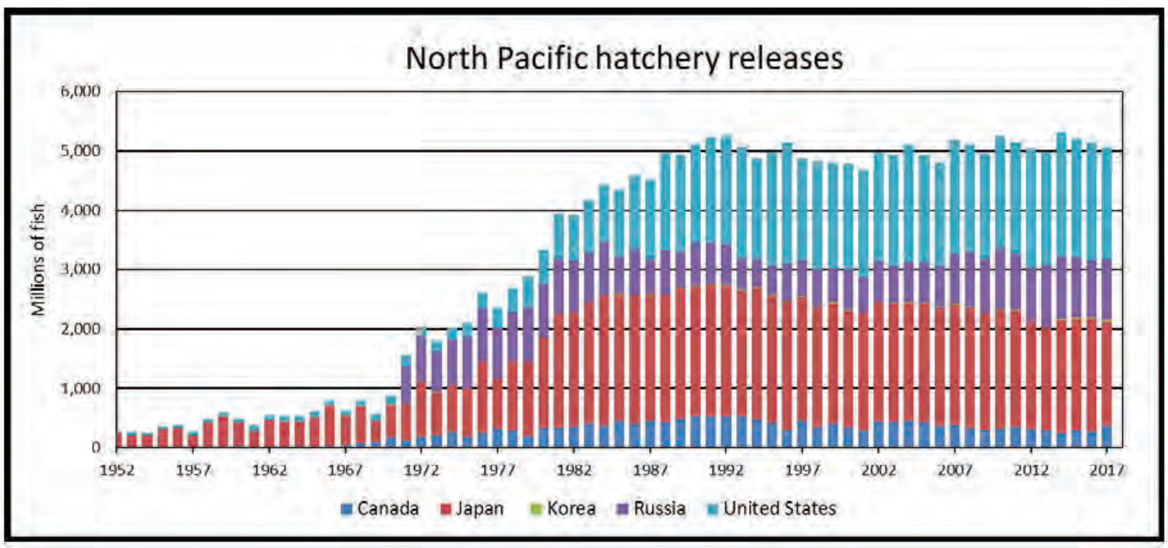

Figure 1. Source: North Pacific Anadromous Fish Commission

Again, in the interest of context for understanding, the permit in question is for 20 million eggs or 18 million resultant fry, which is 0.36% of the five billion fry from North Pacific Ocean enhancement.

6. **High pink salmon catches in PWS** - The petitioner, I suppose inadvertently, points out

the specific purpose of the enhancement program – harvest high percentage (up to 92%) of hatchery salmon except for a small proportion that are necessary to perpetuate the program as broodstock. Furthermore, the department manages wildstock harvest of salmon only when the return is in excess to ADF&G escapement requirements. Maximizing enhanced fisheries' harvest and protecting wildstocks from over-exploitation is a State of Alaska mandate. The pink and chum harvest numbers that the petitioner cites are a small proportion of harvests in Russia, Japan, and Canada (see Figure 2).

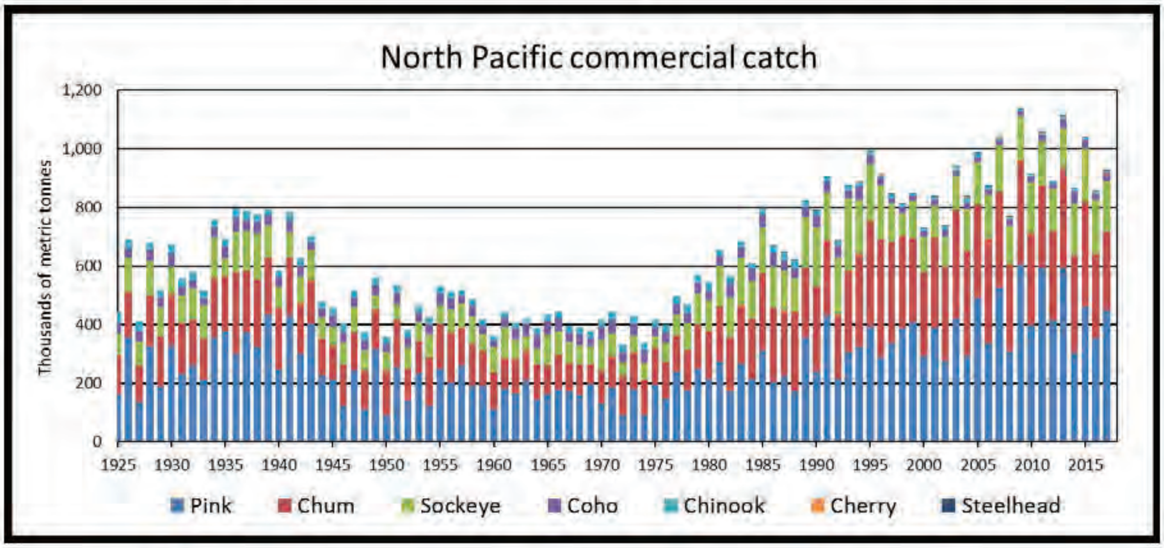

Figure 2. Source: North Pacific Anadromous Fish Commission

Many sport fisheries benefit from the same PNP hatchery programs across the state, including chinook, coho, and chum salmon in S.E. Alaska and pink, sockeye, chinook, and coho in PWS and Cook Inlet. ADF&G has a state of the art $100,000,000.00+ hatchery near downtown Anchorage that produces coho & chinook for the public.

7. **Pink salmon straying into Cook Inlet in 2017** – All salmon stray and pink salmon stray more than any other salmon. Russian pink salmon have now strayed into Scotland most likely due to Arctic ice melt during the summer months. All of Alaska was recolonized by Pacific salmon after the last ice age due to straying. The extent of straying that occurred in 2017 was anomalous and unfortunate. It appears these late returning pink salmon were pushed into Cook Inlet by strong winds and currents, and they became energy depleted and unable to continue on their journey.

   The ADF&G report presented by the petitioner represents a small sample size and does not truly represent the proportion of stray pink vs natural spawners. The proper sampling protocol requires sampling spawners through the entire spawning run, usually 3 to 4 weeks, rather than a onetime grab sample. Straying salmon generally arrive later to the spawning grounds than progeny born there, as that is the nature of colonizing or straying from home territory. Therefore, a onetime sample late in the run would certainly over-represent the straying proportion. The Hatchery-Wild Investigation for example has a sample protocol that samples the target stream every few days for the entire run.

8. **Journal article submissions** – There are nine journal articles presented and each can be debated for scientific rigor and significance. The petitioner makes no attempt to explain the significance of each paper but rather throws down a sheaf of documents as if to say it proves something. Some of these journal articles represent good work and even support some of my contentions. For example, Ruggerone and Irvine (2008) document the high-sustained abundance of pink and chum salmon. They show the harvest data for the low harvest era in 1974, 22 million salmon to an average of 177 million from 1990-2015 (Stopha 2018). Based on the discussion, recent changes in abundance, survival, and size of coho and Chinook salmon have NOT been in response to recent changes in aggregate salmon numbers or biomass. These analyses will be submitted in a separate document and are the work of a retired career scientist with National Marine Fisheries Service, PNP biologists, and science panel members. These analyses are critical to understanding the petitioners' cited journal articles.

Please reject the petition that would rescind ADF&G's NPA for 20 million VFDA pink eggs. The petitioners' fall far short of the BOF criteria. Rather, the board is to be commended for scheduling a hatchery committee meeting at the October work session in order to become more educated on the state's enhancement program. Making an affirmative decision on the petition prior a full vetting of the HWI research and other relevant information would be premature.

Respectfully,

Steve Reifenstuhl

Steve Reifenstuhl
General Manager, Northern Southeast Regional Aquaculture Assoc.

PSPA
PACIFIC SEAFOOD PROCESSORS ASSOCIATION
Est. 1914

July 9, 2018

Alaska Board of Fisheries
John Jensen, Chair
Via email dfg.bof.comments@alaska.gov

RE: Emergency Petition on Valdez Hatchery Permit

Chairman Jensen and Board Members:

Thank you for the opportunity to comment on an emergency petition before the Alaska Board of Fisheries (board) on July 17. The KRSA petition requests that the board reverse a 2014 ADFG decision to modify an existing permit to allow an increase in the number of pink salmon eggs taken by Valdez Fisheries Development Association (VFDA) at the Solomon Gulch Hatchery in 2018. **PSPA opposes the petition and requests that the board deny the petition request.**

PSPA is a nonprofit seafood trade association representing seafood processing businesses and their investment in coastal Alaska, including three shorebased processors located in Cordova and Valdez. Seward, Valdez, and Cordova have multiple large and small seafood processing operations, and VFDA directly benefits harvesters and processors in the region by providing a relatively stable supply of pink salmon. The commercial fishery brings over 900 seine captains and crew members to Valdez for the VFDA pink fishery, and hundreds more processing workers. In 2017, 28.5 million hatchery-produced salmon harvested in the Prince William Sound commercial common property fishery accounted for 57% of the total common property commercial catch in the region, with an ex-vessel value of about $76 million.

Hatchery pink and chum salmon are crucial for Prince William Sound processors because they represent the volume necessary to keep plants operating, in addition to wild stock salmon and other species such as halibut, black cod, and Pacific cod. In addition to shorebased processors, commercial fishermen, tenders, support vessels, support businesses, transportation companies, sport fishermen, and the communities in Prince William Sound and the State of Alaska (through fish taxes) are dependent on the direct and indirect economic activity that the VFDA hatchery program provides.

The board's action at this meeting is to determine whether the petition meets the regulated criteria for an emergency action, meaning it demonstrates that the approved increase in 2014 of the number of pink salmon eggs to be harvested in 2018 is an unforeseen, unexpected event that threatens a fish or game resource, or a biologically allowable resource harvest would be precluded by delayed regulatory action and such delay would be significantly burdensome to the petitioners because the resource would be unavailable in the future. The ADFG Commissioner has already determined that the petition does not meet the criteria for an emergency under 5 AAC 96.625(f) and has demonstrated this in letters to the petitioners as of May 10 and June 14, and in responses to the board.

An increase of 20 million eggs in 2016 and 2018 was approved in 2014 as an incremental increase over a four-year period, with no previous production increases since 1991. The approval of the permit alteration in 2014 recognized that policies and regulations were adopted to mitigate concerns associated with straying of hatchery fish, and significant, multi-year, inter-agency research implemented by the Prince William Sound Science Center and Sitka Sound Science Center has been underway to determine the degree to which hatchery pink and chum salmon straying is occurring, including the range of interannual variability in the straying rates, and an examination of the genetic structure of pink and chum salmon in Prince William Sound and Southeast Alaska and the impact on productivity of these salmon.[1] This research is a direct response to the value that hatchery production provides to Alaska and the mandate that hatchery production be compatible with sustainable productivity of wild stocks, and thus was instigated and supported by ADF&G, the university, the fishing industry, and private hatchery operators. The research plan and objectives were developed by a science panel with broad experience in salmon management, and wild and hatchery interactions, comprised of current and retired scientists from ADF&G, the University of Alaska, aquaculture associations, and National Marine Fisheries Service.

Annual progress reports on data collection and analysis are provided on the ADFG website relating to the three overall research objectives described above. For example, PWS field research in 2017 was focused on pink salmon fitness (relative survival of hatchery-origin and wild-origin offspring following natural spawning). The final 2017 report on PWS pink salmon fitness was published in late April 2018, which indicates that hatchery fractions calculated for 2017 were overall generally consistent among high run years for pink salmon in sampled streams in PWS (2013, 2015, and 2017).[2] The report also notes that results comparing the relative survival of hatchery and wild-origin offspring will be available after the last PWS pink salmon field season in 2018 and subsequent DNA tissue analyses are completed in 2019. This is the type of recent, credible, long-term scientific information that the board should rely on in assessing impacts of the state's hatchery program.

The benefits of the state's salmon enhancement program are wide-reaching and include commercial, sport, personal use, and subsistence fishermen and Alaska communities dependent on fishing. The 2017 Alaska Salmon Fisheries Enhancement Annual Report[3] produced by ADFG states that **in 2017, the commercial fleet caught about 47 million hatchery-produced salmon worth an estimated $331 million in first wholesale value.** Hatchery fish contributed 21% of the statewide commercial salmon harvest, which is the lowest percentage of hatchery fish in the harvest since 1995, and due largely to a very high wild stock harvest that was the 3rd highest in Alaska history (the report notes that 2013, 2015, and 2017 were three of the four highest wild stock returns in Alaska's history dating back to the late 1800s). An additional 194,000 Alaska hatchery fish were caught in the sport, personal use, and subsistence fisheries in 2017.

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[1] http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.current_research
[2] http://www.adfg.alaska.gov/static/fishing/PDFs/hatcheries/research/2017_annual_report_pwssc_hw.pdf
[3] http://www.adfg.alaska.gov/fedaidpdfs/rir.5j.2018.02.pdf?_ga=2.16801777.93909972.1530292352-686289217.1523643770

Particular to Valdez and Prince William Sound hatchery operations, studies[4] have shown that:

- VFDA generated an average of $80.1 million in economic output per year within Alaska's economy during 2008 – 2012
- Between 2008 and 2012, the cumulative first wholesale value of VFDA salmon is estimated to be $266 million (an average of over $53 million per year)
- VFDA salmon accounts for 30% of PWS seiners' annual average gross earnings
- 74% of VFDA's commercial salmon harvest value goes to Alaskan residents (37% to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to Anchorage, and 4% to Kodiak, Mat-Su, Sitka, Wrangell, Petersburg combined)
- VFDA salmon accounts for 75% of all coho salmon and 90% of all pink salmon caught by sport fish anglers in the Valdez area; total sportfish economic output for VFDA is estimated at $6.6 million annually
- Shoreside processing plants in the Prince William Sound region employ roughly 1,600 workers and generate $19 million in annual labor income
- PWSAC salmon accounts for 64% of PWS seiners' and gillnetters' annual average gross earnings
- 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough

Finally, it is clear that convening an emergency meeting on this issue is at best a misuse of the system created to address truly unforeseen, unexpected events, where delaying action by the board would be significantly burdensome to stakeholders or threaten the viability of a fish or game resource. This issue has been addressed twice previously, with no finding of emergency, and is relative to a permit alteration deliberated on and approved in 2014. This meeting is also being convened during commercial salmon season, when many affected harvesters and processors cannot participate in a meaningful way. Any action taken under these circumstances, in light of the non-emergency status, would constitute very poor process. We note that the board has already scheduled a review and discussion of hatchery production for its October 2018 work session, and we look forward to engaging in that process.

Alaska's commercial fisheries have been sustainable and diverse over time because of our commitment to sound science through the use of best available data and the expertise of our fishery scientists and managers to develop and implement needed research to regulate fisheries appropriately. Please continue to uphold these overarching tenets, and rely on current, relevant, robust science while supporting a state program that provides widespread benefits to Alaskans.

Please deny this emergency petition. Thank you for your consideration and your public service.

Sincerely,

President

---

[4] Economic Impact of the Prince William Sound Aquaculture Corporation, McDowell Group, October 2012; Economic Impact of the Valdez Fisheries Development Association, McDowell Group, December 2013.

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www.pspafish.net

Submitted By
Pahisi Reutov
Submitted On
6/30/2018 2:14:31 PM
Affiliation

I am writing as a fisherman in response to the Alaska Board of Fisheries decision to hold a hearing on the Emergency Petition filed May 16, 2018. Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria. I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families. The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions. I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session. Thank you,

From: Patrick Wilson
To: DFG, BOF Comments (DFG sponsored)
Subject: Emergency Petition process during mid fishing season
Date: Friday, July 6, 2018 5:56:54 PM

To whom it may concern:

It is totally inappropriate to have interest groups using the emergency petition process right in the middle of the Alaska salmon season when all commercial fishing participants are preoccupied trying to make a living with many far removed from having access to appropriate communications. It is important that the Board of Fisheries remain open and transparent for all participants that are active in the state salmon fisheries. Issues should be address at the Bard of Fish in the fall when everyone has an opportunity and or the option to attend and provide their input.

Sincerely yours

Patrick Wilson
Plant Manager and past gillnetter
40 years in the industry
Petersburg, AK

From: Peter Hamre
To: DFG, BOF Comments (DFG sponsored)
Subject: Comments for Emergency Petition regarding VFDA
Date: Sunday, July 8, 2018 1:12:59 PM

Dear Board of Fisheries Members,

As a purse seine permit holder, and new commercial fisherman in Prince William Sound, I am very concerned about the upcoming emergency petition meeting. For one, besides sending this letter, I have no ability to show my support of commercial fisherman and their causes. The emergency petition was designed to steamroll a user group without allowing them to participate in the process. This is wrong.

I take issue with many parts of this petition, namely the hypocrisy of the user group that submitted it. I don't understand how they can make the case that pink salmon hatchery production is disproportionately affecting wild king salmon survival rates when they are absolutely willing to harvest Columbia River hatchery Chinooks by the troves, and yet these fish are surreptitiously absent from the discussion. It is absolutely clear that there is an agenda here. Let us be clear, this is about the low returns of Chinook salmon to the Kenai River, and upper Cook Inlet. Perhaps the Board of Fish should look at some other sources of Chinook mortality more carefully; let me give some examples.

- The bag limit in Lower Cook Inlet is two Chinook per day, all winter long. There are individuals I know of that harvest literally hundreds of Chinook per year. Is it fair for an individual to so disproportionately affect a troubled resource, for minimal economic benefit, if any?

- Cook Inlet gill netters harvest king salmon in great numbers for home pack, yet don't report them, as they know it will shut down their fishery. This is understandably a cause for contempt for Kenai area sport fisherman, yet it remains unaddressed.

- The way that king salmon bycatch is measured on pollock boats in the Gulf of Alaska. They use a basket to take up to five samples throughout the cod end. There is nothing even remotely scientific about taking a <1% by volume sample of hundreds of thousands of pounds, and then extrapolating that data to represent the entire catch. Not to mention, the observer coverage remains around 30%. I'm not advocating shutting down the pollock fishery, I'm just saying the the king salmon mortality rate on pollock boats is more or less a complete unknown. Perhaps the State needs to work with NMFS to address this issue.

Let's talk a bit about the sources and studies the petition references. One of them is about hatchery coho competition with wild stock salmon. I'm not sure how this is relevant to increasing pink salmon egg harvest at VFDA. Another document is a 9 year old review of PSWAC, again, completely irrelevant. Yet another study is 20 years old; it's pretty safe to say that anything that old is also irrelevant to the discussion, as wild stock pink salmon have also dramatically increased in the last 20 years. It is clear that the signers of the petition went with the shotgun approach - throw anything with the keywords *pink salmon, hatchery, wild stock competition*, into a ledger and see if it sticks.

Straying was mentioned as a detrimental effect of hatcheries, one that necessitated an emergency proposal. For one, VFDA fish have notably lower rates of straying than many other hatcheries, so it would be for everyone's benefit, if straying is indeed an issue, to increase production at VFDA, rather than somewhere else. However, I must take issue, with the argument that all straying is a problem. Wild pink salmon have very high rates of straying as it is; this is just the nature of the species, and the types of streams that they spawn in. It doesn't make much sense to use a survival mechanism of a species as an argument to decrease their propagation. Simply put, this is not a new issue, and it doesn't meet the criteria for an emergency.

I would like to address the issue of precedent. If the line of logic that hatchery pink salmon negatively affect wild chinook salmon is followed, and the egg increase is overturned, it will set a dangerous precedent for our fishery. In all likelihood, given the current trends, Chinook salmon will continue to decline; a species hit from many different user groups, not to mention the unknown effects of climate change, ocean acidification, and evolving parasites and diseases. If this precedent is allowed to move forward, our hatcheries will continue to be strangled, until they are obsolete, yet in all likelihood, it will have no effect on the survival of king salmon. The livelihood of thousands of people will be destroyed because of a flawed line of reasoning that *it must be the other guy*. I sincerely hope the Board of Fisheries recognizes that the passage of this emergency petition represents the beginning of the end of our fishery.

Please do not pass this emergency petition. Thank you for your time.

Sincerely,

Peter Hamre

F/V Alaskan Belle

July 8, 2018

Alaska Department of Fish and Game
Board of Fisheries
PO Box 115526
Juneau, AK 99811
Via email: dfg.bof.comments@alaska.gov

RE: Comments on July 17th Emergency Petition regarding VFDA egg take

Dear Chairman Jensen and Board of Fisheries Members,

Petersburg Vessel Owner's Association (PVOA) is composed of over 100 members participating in a wide variety of species and gear type fisheries in state and federally managed waters. An additional thirty businesses supportive to our industry are members.

While our organization is primarily Southeast Alaska based, we have members that participate in the Prince William Sound purse seine fishery and would like to comment on the emergency petition regarding egg take permitting of Valdez Fisheries Development Association and straying of salmon.

Along with the Alaska Department of Fish and Game, PVOA does not believe the 20 million egg take increase to be harvested by VFDA is an unforeseen or unexpected event that could threaten wild fish returns in Prince William Sound and therefore does not meet emergency criteria. We ask the issue be stalled until the October Work Session meeting, as previously scheduled, to allow the public more time to evaluate production and allow fishermen currently on the water participating in salmon fisheries to access the meeting.

Enhanced salmon is produced for public benefit and governed by the State to increase access to for subsistence, personal use, sport, and commercial fishermen. In the case of some sport fish programs, ADF&G and private non-profit hatcheries share the cost of raising fry.

As with wild fish, a small amount of enhanced salmon stray from their stream of origin. For the last 20 years, hatcheries have been marking their fry to track movement of enhanced fish and ensure the sustainability of near-by wild salmon runs. Straying is a genetic disposition in salmon and influenced by weather factors such as wind, rain, drought, and other environmental drivers. Otolith marking is a frequently used technique that aids ADF&G and hatcheries in identifying wild and enhanced fish composition in harvest and stream escapement.

To further limit interactions of wild and enhanced salmon in streams, great care is taken in operations of and choosing sites for hatcheries through the public Regional Planning Team process and oversight from the Alaska Department of Fish and Game, Department of Natural Resources, and Department of Environmental Conservation.

Hatcheries are also primarily developed using non-anadromous streams as water sources. As another precaution, only local stocks can be used to create a hatchery program. The Alaska Hatchery program was created by the State in 1971 during historic low harvests to supplement fisheries, not to replace wild fisheries. Today, this is still the primary objective of the program.

If you take one thing away from our letter, we ask you recognize that commercial fishermen are currently harvesting salmon and unable to communicate and participate. The issues of Board of Fisheries authority over egg take permitting for private non-profit hatcheries, and hatchery production levels by region are best considered at the October Work Session meeting or March Statewide meeting and not during the salmon season.

Respectfully,

Megan O'Neil

Megan O'Neil
Executive Director

Phyllis M. Day
2020 Muldoon Rd. #317
Anchorage, AK 99504-3668

RECEIVED
JUL 03 2018
BOARDS

June 29, 2018

John Jensen, Chairman
Members of the Board Alaska Board of Fisheries
P. O. Box 115526
Juneau, AK 99811-5526

RE: Emergency Petition: Kenai River Sportfishing Association

Please accept this written comment speaking AGAINST this petition to limit and/or reduce PNP pink salmon enhancement production in Prince William Sound.

- It is widely known that wild pink salmon have an inherent incidental straying factor. This has been nature's way to guarantee the survival of specific stream wild run returns. This occurs in hatchery-enhanced wild pink salmon as well.
- This protects fish survival in the sometimes turbulent years when the ocean gyre has been adversely affected by abnormal conditions such as severe storms or other events, and it might be attributed to our current increased ocean water temperatures too. It seems possible that if there truly is a straying factor, these fish are reacting to other natural ocean events.

The production of enhanced wild salmon in PWS has been responsibly developed by the Prince William Sound Aquaculture Corporation and the Solomon Gulch Hatchery since their inception in the early 1970's. Production decisions are not made without consideration for the long-standing needs of the natural returns and their protection. The PNP's management plans are also developed within the parameters of the ADF&G hatchery regulations and after review, are approved by the ADF&G annually.

It seems foolish to make snap decisions for management practices that ignore the long-standing practices for hatchery management. If the habit of such reactionary decisions are allowed, it will ultimately end up having to micro-manage the wild stock run returns for every "bump in the road" that comes along and it will detract from the far reaching goals which are to protect the permanency of state's natural resources.

The PNP's need to make long-term management plans. If it was requested and approved to increase the Solomon Gulch incubation goals, then it should not be rescinded on the basis of perceived fears of endangerment to other wild stock returns. It is not a matter of "stop and go" planning; the PNP production planning is far reaching and encompasses the well-being of all the communities and their fishers that make their living from these production plans.

Please keep a level-headed approach to these long-range issues: do not be swayed to "fix" what is not broken. Thank you for your consideration.

Respectfully,

Phyllis M. Day

Phyllis M. Day

June 30, 2018

Prince William Sound
Aquaculture Corporation
DEVELOPING SUSTAINABLE SALMON FISHERIES
FOR ALASKA AND THE WORLD

Alaska Board of Fisheries
John Jensen, Chair
Via email: dfg.bof.comments@alaska.gov

Dear Chairman Jensen,

The Prince William Sound Aquaculture Corporation (PWSAC) is a regional nonprofit hatchery organization operating five hatcheries, four on the westside of Prince William Sound and one on the Gulkana River, raising all five salmon species. **We are responding to the Emergency Petition filed by Kenai River Sportfish Association on May 16th, 2018. The board previously found a virtually identical petition did not meet the emergency criteria, and this most recent petition was determined not to meet the emergency criteria by the Commissioner of the Alaska Department of Fish and Game on June 24th, 2018. We ask you once again deny this emergency petition as it does not meet the criteria for an emergency.**

PWSAC was founded in 1974 by local fishermen to support the local and regional economies after several years of low salmon returns prevented commercial fishing. The organization is governed by a board of forty-five members who represent diverse users. Our board has representation from the following groups:

- Commercial Fishermen (Seine, Drift Gillnet and Set Gillnet)
- Sport Fishermen
- Subsistence Fishermen
- Personal Use Fishermen
- Prince William Sound Municipalities
- Alaska Native Organizations
- Scientists
- Salmon Processors

P.O. Box 1110 · Cordova, Alaska 99574
P. 907 424 7511 · F. 907 424 7514

www.pwsac.com

Today PWSAC is Alaska's largest hatchery organization employing 45 full time staff members and 75 located in Cordova, Anchorage and at our remote hatcheries in Prince William Sound and Gulkana. The organization has

a total budget of $14.2 million which is funded by Salmon Enhancement Tax and cost recovery fish sales. PWSAC employs many professionals with advanced scientific degrees in and provides early career opportunities for those interested in fisheries science and management. Salmon reared by PWSAC are harvested by all user groups in Prince William Sound and on the Copper River including commercial, sport, personal use and subsistence.

The Regional Planning Team (RPT) process for salmon fishery enhancement planning is described in law (AS 16.10.375) and is the responsibility of RPTs. RPTs operate as described in regulation (5 AAC 40.300-370) and prepare comprehensive salmon fishery enhancement plans, provide recommendations on PNP hatchery permit alterations and applications for new hatcheries, and may also review hatchery annual management plans. PWSAC is very familiar with this process., The process is collaborative, provides opportunities for stakeholder engagement, and results in well-vetted, scientifically sound decisions. Permit requests are regularly modified from their original submission in response to concerns raised, or in some cases denied. The integrity of this process should be maintained.

There appears to be a misconception that pink salmon production has been on the rise in recent years and permitted production is continually increasing. We refer you to the written comments submitted by VFDA for factual information about pink salmon production at their facility. In the case of PWSAC, production levels stabilized in 1981 and have remained stable for many years. In 1997, PWSAC was permitted to take 566 million pink salmon eggs, today PWSAC is permitted to take 525 million pink salmon eggs, a 7% ***decrease*** over the last 30 years. There have been several changes in permits over the years and actual annual production varies depending on whether egg take thresholds were met..

Board members should be aware hatcheries are periodically evaluated for consistency with statewide policies and regulations for protection of naturally spawning wild salmon, genetics, fish health, and disease by ADFG and the results can be found on the ADFG website at: http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesOtherInfo.reports

The petitioners cite ten papers as support for the petition not one of which presents conclusive evidence supporting significant changes to the Alaska Hatchery program. Many of the statements in the papers are taken out of context or contradicted by available data. For example:

> **"Pink Salmon induce a trophic cascade in plankton populations in the southern Bering Sea and around the Aleutian Islands"**
>
> This indicates pink salmon populations have an impact on zooplankton in the Bering Sea and Aleutian Islands. This is not new or unexpected information. When a population increases, the primary food source is reduced. The report does not analyze how quickly zooplankton populations rebound and replenish from depths outside preferred foraging zones. Nor is any evaluation provided of long term trends.
>
> At hatcheries in PWS, 33 years of zooplankton data collected in the near shore environment indicates zooplankton populations have been stable or increasing. Since 2007, zooplankton data show an increasing trend within PWS.

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"Numbers and Biomass of Natural- and Hatchery-Origin Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean, 1925–2015"

This paper cites historic statistics regarding total salmon production, stating that ocean conditions are favorable to salmon production and have resulted in historic high natural production. It also shows that hatchery raised pink salmon represent 15% of the total pink salmon, indicating that wild production is dominant. Correlations are made by the authors regarding pink salmon abundance and changes in other species weight composition. However, many of the correlation statistics cited are 0.50 or less, indicating only a moderate correlation This indicates other factors are present and that pink salmon abundance alone does not explain the observed changes. I Moderate correlation does not imply causation due to the presence of confounding variables (variables a researcher failed to control or eliminate damaging the internal validity of an analysis or experiment). This report also makes three management recommendations:

(1) Mark or tag hatchery salmon so that they can be identified after release.
(2) Estimate hatchery- and natural-origin salmon in catches and escapement.
(3) Maintain these statistics in publicly accessible databases.

All three recommendations were implemented by the hatcheries in Prince William Sound over a decade ago.

Pink salmon straying has also been a topic raised by the petitioners. "Straying" is a known and expected biological phenomenon that allows for colonization, not an aberration. Pink salmon straying has been expected and discussed since the hatchery program began. It is understood that stray rates differ among species. Pinks are known to have the highest stray rate among salmon due to their intertidal spawning and the propensity of their habitat to change quickly. Additionally, stray rates are known to be influenced by climate, water temperature and population density. , Biologists agree that the life cycle of salmon which spend little time rearing in fresh water has a higher stray rate than other species such as Chinook, coho and steelhead which were the basis for the ADF&G genetics policy. . The Marine Stewardship Council reviewed straying in PWS as part of their certification and developed specific guidelines and criteria for pink and chum.

The State of Alaska Hatchery Research project "Interactions of Wild and Hatchery Pink and Chum Salmon in Prince William Sound and Southeast Alaska" study completed ocean sampling at the entrance of PWS during 2013, 2014 and 2015 to establish an un-biased stray rate and a hatchery fraction in the total return of pink and chum salmon in PWS. It is important to understand the difference between "stray rate" and "hatchery fraction". A "stray rate" is an overall rate of hatchery fish present in all streams compared to the total run. A "hatchery fraction" is a measurement of hatchery fish in a particular river system. Results from the State of Alaska Hatchery Research Project's Ocean Sampling project (State of Alaska Hatchery Research Project: Project Synopsis June 2018) indicate in PWS 99%, 98% and 95% of the hatchery fish returning in 2013, 2014 and 2015 respectively were accounted for by common property harvest, cost recovery and brood stock collection. This indicates that the overall stray rate during those years would be 2.6% over the three-year period. Many of the statistics cited by petitioners are actually "hatchery fractions" measuring the number of fish in a given stream and determining the percentage of those fish that are of hatchery origin.

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PWSAC feels it is important that the Alaska Board of Fisheries understands the Alaska Hatchery prog end, we look forward to providing detailed information during the upcoming October Work Session. The topic is complex and cannot be adequately summarized in an emergency petition or addressed at a rushed emergency meeting. **We urge you to follow the commissioner's guidance and again decline the emergency petition before you, as it does not meet the criteria as set out in regulation.**

Sincerely,

Casey Campbell

General Manager/CEO

Prince William Sound Aquaculture Corporation mission statement: *"To ethically and professionally optimize salmon production in Area "E" for the long-term well-being of all user groups."*

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www.pwsac.com

ALASKA'S
PRINCE WILLIAM SOUND
ECONOMIC DEVELOPMENT DISTRICT
Chenega Bay Cordova Tatitlek Valdez Whittier

ADMINISTRATIVE OFFICE:
Prince William Sound
Economic Development District
610 East 5th Avenue, Suite 104a
Anchorage, Alaska 99501
(907) 222-2440

pwsedd@gmail.com
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July 9, 2018

Chairman John Jensen
Alaska Board of Fisheries
Boards Support Section
PO Box 115526
Juneau, AK 99811
Submitted via email: dfg.bof.comments@alaska.gov

RE: Comments on KRSA et al. Emergency Petition on VFDA

Dear Chairman Jensen and Alaska Board of Fisheries Members:

On behalf of the board of directors of the Prince William Sound Economic Development District (PWSEDD), its member communities, and affiliates, I am writing to urge your support for Commissioner Cotten's findings under Alaska Statute 16.05.270, Board of Fisheries policy 2015-277-FB, and 5 AAC 96.625(f) with regard to an emergency petition by the Kenai River Sportfishing Association and other signatories.

The petition seeks to curtail permitted pink salmon egg take by the Valdez Fisheries Development Association. In a review by the Alaska Department of Fish and Game and by the Commissioner, no emergency circumstances were found that would justify such a modification. PWSEDD urges the Board of Fisheries to take no action on the emergency petition.

Salmon enhancement programs make significant contributions to the economy of the Prince William Sound region. In this regard, these programs have fulfilled the role envisioned by the State of Alaska when it began fisheries rehabilitation and enhancement programs nearly fifty years ago.

We urge the Board of Fisheries to uphold a thoughtful, deliberative, and science-based approach to decisions of this nature. In this regard, please take no action to countermand the recommendations of the Department of Fish and Game and Commissioner Cotten.

Respectfully,

PRINCE WILLIAM SOUND
ECONOMIC DEVELOPMENT DISTRICT

Wanetta Ayers

Wanetta Ayers
Executive Director

PSVOA
PURSE SEINE VESSEL OWNERS' ASSOCIATION
1900 W Nickerson St., Ste. 320 ■ Seattle, WA 98119 ■ Tel: (206) 283-7733 ■ Fax: (206) 283-7795 ■ www.psvoa.org

July 6, 2018

VIA E-MAIL

John Jensen, Chair
Alaska Board of Fisheries
P.O. Box 115826
Juneau, AK 99811

Re: Kenai River Sportfishing Ass'n Emergency Petition Concerning PWS Hatchery Egg Take

Dear Chair Jensen Board of Fisheries Members:

The Purse Seine Vessel Owners Association ("PSVOA") submits the following comments in opposition to the Kenai River Sportfishing Association's (KRSA) emergency petition. PSVOA represents purse seine vessel owners throughout Alaska and the Northwest, including seiners who participate in the Prince William Sound salmon seine fishery.

KRSA's petition asks the Board of Fisheries (Board) to asks the BOF to "amend actions taken in Permit Alteration Requests made by the PWS Regional Planning Team and deny the increase in the number of pink salmon eggs taken in 2018 by 20 million."

First, KRSA's petition fails procedurally because the petition does not describe an "emergency," which is required before a Board can even consider a petition on an emergency basis. *See* 5 AAC § 96.625. As KRSA correctly points out in its petition, according to state policy, the Board should consider emergency petitions on a limited basis, and should limit the use of the Board's emergency authority to situations where an emergency truly exists. *See* AS 44.62.270. Salmon hatcheries, including pink salmon hatcheries, have operated in Alaska for many years and are closely regulated by ADF&G. Moreover, this Board previously denied a nearly identical emergency petition filed by KRSA based on the absence of a true emergency. Instead, at the March 2018 Statewide meeting, the Board voted in favor of conducting a review of hatchery production at the October 2018 work session in response to concerns raised by KRSA and others. PSVOA urges the Board to deny this current petition for the same reason. KRSA and other like-minded groups have knowingly attempted to circumvent the usual Board process to their advantage by attempting to use the emergency petition procedure. Such tactics should be rejected by the Board.

Second, Alaska's hatcheries, including the hatchery which is the purported subject of KRSA's petition, are managed through a collaborative and public process involving ADF&G, the Regional Planning Team, and the Valdez Fishermen's Development Association. This process involves input from interested stakeholders. Any action taken by the Board in response to KRSA's petition will only serve to undermine the collaborative efforts of these organizations and the individuals they represent.

Third, the science underlying the theory that Alaska's salmon hatcheries are somehow responsible for the recently observed decline in some salmon species in certain regions of Alaska is speculative, at best. In contrast, the tremendous economic benefits Alaska's salmon hatcheries provide commercial fishing families and Alaska's coastal communities are well-documented.

For the reasons stated above, PSVOA respectfully requests that the Board deny this position. Any review of hatchery production or hatchery practices by this Board must be held during a regularly scheduled meeting to facilitate a broad and thorough review of the underlying scientific theories, and to provide an opportunity for all affected stakeholders to be heard on this very controversial subject.

Very truly yours,

/s/ Robert Kehoe

Robert Kehoe, Executive Director
Purse Seine Vessel Owner's Ass'n

Submitted By
Randal J Gregg
Submitted On
7/8/2018 9:58:00 PM
Affiliation
commercial fisherman

Phone
907`723`4439
Email
fvpatriot@gmail.com
Address
PO Box 20373
Juneau , Alaska 99802

Hello, I am writing in regards to the emergency meeting being called in Anchorage, July 17th regarding VDFA hatchery fish. I am currently in the middle of commercial fishing for Salmon in Prince William Sound and cannot attend this meeting. The ADF&G have stated twice, there is no need for an emergency closure of salmon in this region. A meeting in October when all user groups can convene and discuss the issue is sufficient. These requests are distracting and unnessacary during the time in which my family (and our fellow fishermen) trying to make a living.

Kind Regards,

Randy Gregg

F/V Patriot

Submitted By
Regan mann
Submitted On
7/7/2018 3:50:24 PM
Affiliation
Gillnet

Phone
907-424-5740
Email
reganmmann@gmail.com
Address
1.5 mile whiteshed road
Cordova , Alaska 99574

Let it be known that all of the silvers that are harvested by sports fishermen in Valdez are all hatchery raised silvers.

The hatcheries in prince William are 100 percent self sustained. Unlike the William Jack Hernandez sport fish hatchery which is subsidized by the tax payers of Alaska. The hatchery system in the sound provide an economic benefit to hundreds of families. From fishermen process workers and merchants in the coastal communities they serve(Cordova Whittier Valdez and Seward). The dead loss from these hatcheries also provide an important food source for shrimp halibut and rockfish which benefits many sport fisherman in the sound. If there where no hatcheries in prince William sound, it would be a devistating loss to hundreds of families economic livelihoods and a devastating loss to marine life as well. Price William sound would be sterile. Void of salmon shrimp halibut rockfish and all the wildlife that depend on it. Sport fishermen benefit more than anyone from these hatcheries. Sport fisherman need to rethink what they are trying to destroy before it is too late for all of us.

Submitted By
Reiker Durtschi
Submitted On
6/27/2018 2:22:51 PM
Affiliation
Owner/Crewman of purse seine Operation

Phone
907-441-0077
Email
reikerdurtschi@gmail.com
Address
P.O Box 1012
Girdwood, Alaska 99587

Dear Board of Fisheries members,

As a second generation commercial fishermen in the state of Alaska I would like to voice my concern about the purposed reduction of released pink salmon fry from hatcheries around for the Prince William Sound. Our salmon industry here is one of the last in the world and has remained sustainable due to the work of the hatcheries propagating salmon runs. To reduce to the number of fish released by these hatcheries would be directly reducing economic opportunity to many of our state's residents. The same economic opportunity that has supported families, paid for college educations, and left all who are involved in the industry with a unique and special appreciation for our state. I firmly do not believe that the reduction of released salmon fry is a solution to any problem and would infact do more harm than good.

PC140
1 of 2

RECEIVED
JUL 06 2018
BOARDS

TO: ALASKA BOARD of FISHERIES

RE: Comments on KRSA et.al. Hatchery Emergency Petition

DEAR CHAIRMAN Jensen and Board of Fisheries MEMBERS

I Live in Homer AND AM A COMMERCIAL fisherman in Prince William Sound, We depend on the Areas commercial salmon fishing for our families Livelihood. Our family has been commercial fishing in ALASKA since 1938. My children are 3rd generation commercial fishermen. Both my daughter, Megan And son, Rick, own their own PWS seine permits and operations. Between the 3 boats we employ 14 crew every year. Over 42 years, our boat F/V Malamute Kid, has employed over 160 Alaskan crew members. All these crew men AND women depend on this fishery for their college And Living needs. None of us would be Able to make A Living without PWS hatchery production.

We Are the face of Alaskan communities and contribute positively to every Aspect of the Alaskan Life. Both Economically and Socially.
We Are proud to be A part of managing Alaskan salmon and highly value the efforts AND conclusions of ADF+G.

We support the ADF&G finding that an emergency does not exist. No Action warranted.

Finally, my feelings on process. I personally lost 11 valuable mining claims twenty years ago because the BLM purposefully set a deadline for the middle of mining season when no one could leave their work to comply.

Convening an emergency meeting on this issue during the middle of our commercial salmon fishing season is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria.

My concern is that by holding this meeting in Anchorage on July 17 you have denied me and my fellow fishermen an opportunity for meaningful participation. I don't want to be burned again because I can't devote my time to defending my position properly.

Please Deny this Emergency Petition Request

Signed

Richard A. Curazza
F/V Malamute Kid
P.O. Box 1320
Homer, AK 99603

Submitted By
Richard s corazza
Submitted On
6/26/2018 1:56:59 PM
Affiliation

Phone
907-202-2662
Email
Fvgodspeed@gmail.com
Address
200 w 34th ave #932
Anchorage , Alaska 99503

I am a 3rd generation Alaskan commercial fisherman. Me and my entire family depend on prince William sound hatchery production to be able to stay in business and survive in Alaska. Please deny this petition with extreme prejudice. It is very serious attack on my livelihood and many Alaskans.

Submitted By
Robert & Bambi HOCHMUTH
Submitted On
7/8/2018 7:27:06 PM
Affiliation

Phone
907-847-2329
Email
hunter99624@yahoo.com
Address
PO Box 74
Larsen Bay, Alaska 99624

I am Robert Hochmuth, owner of the commercial F/V LONI-K. My family has lived on the West side of Kodiak and depended on Kodiak salmon for subsistence and income for 7+ generations. We depend on the honesty and clarity of the public due process of Board of Fish. We do not approve of interest groups using emergency petitions in the middle of our fishing season to avoid public process.

Submitted By
Robert Moran
Submitted On
6/30/2018 5:39:21 PM
Affiliation
PWS Drift Gillnet Crewman

I am a commercial drift gillnet crewman in the Prince William Sound and a part-time resident of Cordova. I urge you to deny the KRSA Emergency Petition filed May 16th, 2018 and explore the issue in depth at the October Work Session.

Hatcheries are vital to the continued prosperity of Alaskan commercial fishermen. Hatcheries allow fishermen to continue to make a living and support their families in the absence of strong wild fish returns. In fact, hatchery fish have been my main source of income over the past three seasons due to weak natural runs, such as the failed early run of the Copper River this year. It goes even further than that: the main economic driver of Cordova is commercial fishing and without enhanced fish returns, every small business in town would be in jeopardy. I am certain the same assertation can be made for small towns throughout Southern Alaska.

I urge you to explore this issue in October, when you will have ample time and resources to do so, and when commercial fishermen will be done with fishing for the summer and can actively partcipate in the process. KRSA is, in my opinion, abusing Emergency Petitions to force the issue at a time when the most affected stakeholders--commercial fishermen--are working 24/7 to keep our businesses afloat. Thank you for your time and consideration.

Submitted By
Ron Thomson
Submitted On
6/27/2018 9:59:50 AM
Affiliation
PWS drift dillnet

Phone
907-354-5589
Email
rdthomson907@gmail.com
Address
26735 Paradis Lane
Chugiak , Alaska 99567

As a long-time commercial fisherman in Prince William Sound I would ask the board to consider the long history of successful hatchery production in PWS and the fact that the wild stocks in general have faired well. While King salmon stocks have been showing decreased returns for a few years to my knowledge there have been no studies to link these declines to competition with hatchery produced fish. I would ask the board to look to science to resolve this issue and not be swayed by emotion or politics.

Submitted By
Ryan Carroll
Submitted On
7/7/2018 2:38:13 PM
Affiliation
PWS commercial fishermen

Phone
9074060752
Email
ryancarroll514@gmail.com
Address
PO Box 3013
2043 Jakes Little Fireweed Ln
Homer, Alaska 99603

I am part of a commercial fishing family in Prince William Sound. I have grown up fishing with my dad and salmon provides the income for our family and my future. I was disappointed to hear that a hearing on this petition would be held in July right during the middle of our season. It seems that we are being ambushed by a special interest group at a time when we should be focused on making a living. The prudent thing would be to wait until the scheduled meeting in October when the facts can be presented and discussed in a more productive and meaningful way. PLEASE DENY THIS EMERGENCY PETITION REQUEST.

From: Ryan Rogers
To: DFG, BOF Comments (DFG sponsored)
Subject: PWS fisherman
Date: Saturday, June 30, 2018 9:12:57 AM

I, Ryan Rogers, am in my 36 season seining in PWS. I have struggled through tremendous adversity in my fishing career, and am now enjoying the rewards with a strong market, and reasonable stable returns, thanks mostly to our hatchery programs,

After living in Homer for many years, I chose to raise my kids back in my home town in Oregon. However, my home port is Valdez. I don't ship provisions north, but am proud to spend a lot of money in Valdez to support the services that are necessary for our fleet. There are many businesses in Valdez that rely heavily on the commercial fleet. And the community is very welcoming to me and all those who do not call Valdez home. VFDA has a huge impact on the Valdez community, and I cannot image any of it is negative.

Furthermore,
I am writing as a board member of the Prince William Sound Aquaculture (PWSAC) board member regarding the most recent emergency petition that was filed. I am one of 45 board members that represents a large section of the region with diverse interests. As a board member and resident of the State of Alaska I am deeply concerned with the current effort to reverse a decision that was years in the making through a collaborative effort between the Alaska Department of Fish and Game, Regional Planning Team and Valdez Fisheries Development Association. The Alaska hatchery program is important to state, regional and local economies, they help provide for a stable community by supporting sport fishing, tourism, personal use fishing, commercial fishing, seafood processing, along with other economic benefits that spread throughout the state.
It is important to remember that our board discusses production changes with great detail. These discussions are first vetted by our Production Planning Committee, then past to the full board for a vote even before being submitted to the Alaska Department of Fish and Game. Through the years PWSAC has submitted Permit Alteration Requests that have been denied for various reason, which is proof the process in place works.
I ask that the board fully consider the whole process regarding the Permit Alteration Request, as I attest that the effort put into these is significant. We are in the middle of the salmon season and should be focusing our time on the fishing season before us.
Holding a meeting during the salmon fishing season is poor public process when the topic has been addressed several times this winter and spring. At this point you are now limiting the opportunity for impacted users to support the hatchery program. The board of fish established a committee to address these concerns in October, and should stick to that plan. This will be an opportunity for fishermen, processors, public, and hatchery operators to devote the attention to the topic and help explain the program and what it means to them.
Our Hatcheries are backed by years of experience, science, and by people who have a true interest in bettering the communities.
Please deny this emergency petition request

Thank you,

Ryan Rogers
F/V Cat-Bil-Lu

Submitted By
sam moss
Submitted On
6/27/2018 1:25:39 PM
Affiliation
wife of commercial fisherman

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Samantha Moss

Submitted By
Samson Reutov
Submitted On
6/30/2018 2:26:31 PM
Affiliation

I am writing as a fisherman in response to the Alaska Board of Fisheries decision to hold a hearing on the Emergency Petition filed May 16, 2018. Alaska has an admirably open public process for amending fisheries regulations, but that process is being abused by a special interest group. This will be the fourth time this topic has been addressed by the Board of Fisheries or the Alaska Department of Fish and Game in less than 6 months. There is no new information to warrant holding a special meeting to discuss a petition that has been already been determined, by both the board and the Commissioner of Fish and Game, not to meet the emergency petition criteria. I am very disappointed that the board has elected to hold a meeting in the middle of the summer fishing season when the participants most affected do not have the opportunity to participate. Alaska's hatcheries are vital to my business, and we are amid a busy fishing season which is our only opportunity to make an income and support our families. The board has already established a committee, scheduled to meet in October, to address hatcheries. This is the appropriate time to address the topic, allowing the department, hatcheries, and salmon users to present information that will help the board make informed decisions. I strongly encourage the board to once again find that this emergency petition does not meet the criteria and vote it down. I further encourage you to take no action at this meeting and follow the plans you've already set forth to convene a hatchery committee at the October Work Session. Thank you, Samson Reutov

Submitted By
Shirley A Monroe
Submitted On
7/9/2018 12:56:44 PM
Affiliation
1936

Phone
9074863656
Email
whitneycreek@gci.net
Address
720 Thorsheim Street
P.O. Box 1202
Kodiak, Alaska 99615

My family and I have been fishing in the Kodiak Area sence Summer of 1961, both seine boat and set net sites in Larsen Bay and around the Island. These additional emergency petitions should not be accepted or voted on without public comment. When this type of action is taken, during a season and busy time of the year, it makes one feel that our Board of Fisheries is not open and transparent to everyone just a few.

I disapprove of letting any group use the emergency petition to advoid public process.
Shirley A Monroe

Silver Bay SEAFOODS
Sitka ✦ Craig ✦ Valdez ✦ Naknek ✦ Metlakatla

P.O. Box 1742 Cordova, AK 995
Phone: (907) 738-7202

July 9, 2018

Chairman John Jensen
Alaska Board of Fisheries
Boards Support Section
PO Box 115526
Juneau, AK 99811
Submitted via email: dfg.bof.comments@alaska.gov

RE: Comments on KRSA et al. Emergency Petition on VFDA

Dear Chairman Jensen and Alaska Board of Fisheries Members:

Silver Bay Seafoods, LLC (Silver Bay, or SBS) is opposed to the Kenai River Sportfishing Association (KRSA) et al.'s petition for a finding of emergency and their request to deny the previously approved 20 million increase in the number of pink salmon eggs taken at Valdez Fisheries Development Association's (VFDA) Solomon Gulch Hatchery in 2018. **Silver Bay Seafoods recommends that the Alaska Board of Fisheries confirms Alaska Department of Fish and Game's (ADF&G) findings for a lack of emergency with regards to this petition, and requests that the board take no action to reduce the permitted capacity of the Solomon Gulch Hatchery by 20 million pink salmon eggs in 2018.**

Silver Bay Seafoods is a vertically integrated, primarily fishermen-owned processor of frozen salmon, herring, and other seafoods products for both domestic and export markets. Silver Bay began in 2007 as a single salmon processing facility in Sitka, Alaska, and has since grown into one of the largest seafoods companies in Alaska. Silver Bay has state of the art, high volume processing and freezing facilities throughout Alaska, currently operating in Sitka, Craig, Valdez, Naknek and Metlakatla. The Company is also active in the California Loligo squid fishery. Silver Bay began participating in the Prince William Sound (PWS) commercial salmon fishery in 2010, maintains a significant market share in the fishery, and is interested in ensuring its long-term sustainability and viability.

Following the record-setting season of 2015 in which the PWS management area's salmon harvests and estimated ex-vessel values were among the best in the state for the third time in a handful of years (2010, 2013, and 2015), Silver Bay embarked on an expansion of its operations in Valdez. Hundreds of Alaskan electricians, fabricators, general contractors, and other skilled trades workers constructed a 65,000-square foot processing facility with a daily capacity to process 2.7 million round pounds of salmon per day. Complete with an ikura processing mezzanine and salmon oil plant, the company also constructed an adjacent 17,00 square foot 206-bed bunkhouse, thereby increasing its capacity to house a 400-person workforce to operate the facility. Altogether, Silver Bay invested many tens of millions of dollars in its new facilities in Valdez. As part of this expansion, Silver Bay also grew its harvesting fleet to a total of 60 fishermen-owners who have invested in the company and their Valdez plant, and who share in the company's success. Silver Bay's fleet and their families are provided with an opt-in health insurance plan, and participate directly in the company's management decision-making processes.

Silver Bay Seafoods and its fishermen-owners pursued this expansion based in part on their shared experiences in the PWS salmon fishery, and a faith in ADF&G's consistent science-based management of the areas salmon fishery resource. Silver Bay and its fishermen-owners participate in many of the forums associated with this fishery, including service on boards of directors for the area's hatchery operators, and engagement with private-public collaborations which exist between commercial fishery participants and ADF&G. This includes participation in the local regional planning team process.

Likewise, Silver Bay's fishermen-owners have been active participants in the Alaska Board of Fisheries' open, thoughtful, and deliberative public process. Silver Bay believes that this emergency petition process constitutes a significant deviation from historical practices. Specifically, Silver Bay Seafoods and its fishermen-owners believe that convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. By holding this meeting in Anchorage on July 17, we believe that the board has denied those most impacted a reasonable opportunity for meaningful participation in the discussion surrounding salmon hatchery production in PWS.

With regards to the petitioners' reference to recent scientific publications which they argue cause great concern for the biological impacts associated with PWS hatchery production, we refer you to the Alaskan hatchery operators' critique of the petitioners' cited publications. As you will read, many of the publications cited are irrelevant to the discussion at hand, with some deserving of little credibility within the scientific community. Silver Bay strongly urges that the Alaska Board of Fisheries familiarizes itself with and supports the ongoing Alaska Hatchery Research Project (AHRP) which was designed and is conducted at great expense to explore potential interactions between hatchery and wild salmon in PWS. The AHRP may be found further described at:

http://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheriesResearch.current_research

With regards to the petitioner's criticism of the local regional planning team process, Silver Bay refers board members to the many materials posted to the meeting's web site regarding the 2014 Solomon Gulch Hatchery Permit Alteration Request (PAR). As described in these materials and in written testimony elsewhere, this process was well vetted and involved a precautionary compromise as witnessed in the RPT's recommendations to ADF&G's Commissioner.

Starting in 1991, VFDA's Solomon Gulch Hatchery was permitted to take 230 million green pink salmon eggs, and did so for the following 23 years. In this time, industry and management successfully developed innovative and effective approaches to ensuring that ADF&G's wild stock objectives have been met while maximizing the value of the available resource. This success allowed VFDA to diversify and expand its operations to benefit the area's sport fish user groups. For example, it is estimated that VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually. These programs are largely paid for through the cost recovery harvest of hatchery pink salmon, the revenue from which comprises an overwhelming proportion of VFDA's budget. Thus, any decrease in pink salmon production as is recommended by KRSA et al. may reduce VFDA's capacity to support those hatchery programs which benefit noncommercial fishery participants the most.

It is estimated that salmon harvested in the VFDA pink salmon fishery represents 30–40% of the seafoods product produced annually at the SBS Valdez plant. If the petition discussed in this letter were to be acted on by the board during its July 17 meeting, individuals and entities associated with Silver Bay Seafoods' Valdez plant operations, including 60 seine vessel captains; 210 seine crew members; 25 tender operators and their 100 crew members; over 400 seafood processors; local shipping companies, such as Alaska Marine Lines and Samson Tug and Barge, and their employees; 6 spotter pilots; local restaurants, coffee shops, grocery stores, bars, hotels, gear stores, fuel docks, rental cars and taxi companies, would be harmed. Further, the City of Valdez would see significant reductions in revenues to their electrical and harbor departments, and would see declines in revenues from raw fish taxes and sales taxes as well.

Again, Silver Bay Seafoods recommends that the Alaska Board of Fisheries confirms Alaska Department of Fish and Game's (ADF&G) findings for a lack of emergency with regards to this petition, and requests that the board take no action to reduce the permitted capacity of the Solomon Gulch Hatchery by 20 million pink salmon eggs in 2018. Instead, Silver Bay urges the board to continue with its previous plans to convene an informative meeting at its October Work Session in Anchorage, as had previously been discussed and conveyed to the public.

We hope that the points raised in these comments provide you with additional information to aid you in your final determinations regarding this petition. Thank you for your service to this valuable resource and the communities that depend on it.

Sincerely,

Tommy Sher

Tommy Sheridan
External Affairs Officer
Silver Bay Seafoods
tommy.sheridan@silverbayseafoods.com

Submitted By
Siope Niusini
Submitted On
7/9/2018 3:34:45 PM
Affiliation
Commercial Fisherman

My name is Siope Niusini, I have been commercial fishing in Kodiak for the past serveral years in Uyak bay. I depend on being able to fish in the summers in order to put myself through college and the winter. It is highly important that the board of fisheries consider and listen to the people who actually live and depend upon the Kodiak fishery. It is also highly disruptive to attempt something of this nature in the middle of the season when many fisherman and people in the community are busy FISHING!

Submitted By
skyler smith
Submitted On
7/1/2018 1:58:46 PM
Affiliation

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Skyler Smith

Submitted By
Sonja Corazza
Submitted On
6/27/2018 4:55:51 PM
Affiliation
PWS Seine Permit Holder

Phone
907-202-1104
Email
sonja907@gmail.com
Address
P.O. Box 1320
62124 Skyline Drive
Homer, Alaska 99603

To the Board of Fisheries,

I am a seine permit holder in Prince William Sound and have fished there since 1985, before that drifting in Cook Inlet and halibut fishing. My family has been fishing out of Homer since 1938 so we have long experience with both the fisheries and the Board process.

First, I question the validity and need of this meeting being held in the summer when all the fishermen who are most affected by this petition are on the fishing grounds and most are finding it very difficult to comment much less to attend the meeting. In the view of being fair to local Alaskan communities and fishermen I think this meeting should never have taken place or if it did that it should be held in Valdez where we would have at least had an opportunity to attend. I have always supported the Board process as I know it is a lot of work but I have also always believed that it was supposed to be set up to be fair and legitimate for all parties and I do not consider the timing of this meeting either one.

The hatchery program in PWS was created first to help save the salmon runs after the earthquake and the subsequent uplift of the area that destroyed many salmon streams along with the local economies of the communities who participated in that fishery. It was started by fishermen but ultimately benefited everyone in the State in one way or another, from local businesses to tenders, processors, crew members and even sports fishermen who themselves catch pink salmon in the Sound.

Just to give you an idea of how important the PWS hatchery system is to our communities in Alaska, my family has three seiners and we employ ten young deckhands between us. Our deckhands are all young Alaskans, graduated from local high schools and are paying their way through college by working for us by earning a percentage of our catch. No other businesses in Alaska offer them that kind of opportunity as partners in the fisheries. We have a long list of young people who fished with us and used that experience to go on and become professionals in many areas of life here in Alaska. It is quite an impressive list which I can supply you with should you wish me to verify that information. WE are the faces of our Alaskan communities and we need a well run and strong hatchery program along with healthy natural runs. They supplement each other in a very positive way.

At present much research is being done in Alaska concerning the science of hatchery fish and those are ongoing studies which are not complete at this time and therefore this meeting is jumping the gun trying to come to conclusions that cannot yet be made and may never be made. Since last summer in PWS was a fabulously strong wild run of all species I believe that represents the best marriage of both wild and hatchery fish and shows the success of the program.

Considering the fact that an illegal Chinese fishing vessel was just caught with 80 tons of chum salmon I believe that the hatchery program should be not made the scapegoat for many issues that are at play in the fisheries. I lived through the years before the Magnuson Act was implemented and the Russians were fishing those six mile long nets and taking the majority of our salmon and I know the difference of the fish runs once that was stopped. We may have the same things at play here, not to mention bycatch by our own factory trawlers. So I would suggest that we consider focusing on a few larger pictures and see if in fact the hatcheries are a help to us all and not a hindrance. Why destroy the hatcheries that help all Alaskans when we have known destruction going on in other ways?

In conclusion, I ask that this meeting be postponed and that the petition be denied. The October meeting for PWS has already been scheduled for our area and should take place at that time when all concerned can participate in a valid way at the meetings.

Thank you for taking time to consider my comments.

Sonja Corazza

Southeast Alaska Fishermen's

9369 North Douglas Highway

Juneau, AK 99801

Phone: 907-586-6652 Email: seafa@gci.net

Fax: 907-523-1168 Website: http://www.seafa.org

July 7, 2018

Alaska Dept of Fish and Game
Board of Fish
John Jensen, Chairman
PO Box 115526
Juneau, AK 99811

RE: KRSA Emergency Hatchery Petition

Dear Chairman John Jensen, and Board of Fish members,

Southeast Alaska Fishermen's Alliance (SEAFA) agrees with ADF&G that the emergency hatchery petition submitted by Kenai River Sportfishing Association (KRSA) does not meet the criteria of an emergency as being an unforeseen event or an event that threatens a fishery resource. This subject of hatcheries has been reviewed several times already this year including at the SE meeting in January, Statewide meeting in March and at the May 14th meeting on emergency petitions. Holding a meeting in the middle of the fishing season allows for limited participation.

The Regional Planning Team (RPT) is a very public process, very deliberative and strongly influenced by ADF&G. The increase of pink salmon was actually approved in 2014 but with the condition that it be done in two increments of 20 million eggs at a time. ADF&G requested that VFDA postpone the first increase to 2016 because of the salmon hatchery study being conducted so it didn't influence the results. The 2018 increase was conditionally approved in 2014 pending completion of the hatchery infrastructure necessary to handle the increased capacity. The RPT received an update at the Spring 2017 on the progress of infrastructure for the conditional 20 million increase for 2018 and that a PAR would be submitted in the spring of 2018. **If there was this much concern on behalf of the KRSA, why didn't they participate at the RPT meetings rather than going outside of the traditional hatchery permit public process?**

The petitioners provided some hatchery studies trying to justify their request for an emergency action. Some of these studies imply that it's possible the ocean has reached it's carrying capacity. I attended a North Pacific Anadromous Fish Commission (NPAFC) Third International Workshop: *Migration and Survival Mechanisms of Juvenile Salmon and Steelhead in Ocean Ecosystems.* During the meeting summary for this workshop given by William (Bill) Heard stated, "I have this sense our Russian colleagues, based on their research in the western Pacific involving extensive year round ocean surveys in documenting high standing crops of macro-zooplankton and other micronekton foods of salmon, pretty much hold in abeyance any current concerns about carrying capacity of salmon in these waters."[1] There are plenty of other information that present different information but is not possible in the middle of the fishing season to research and provide the information.

The Board of Fish developed a plan this past winter/spring to hold hatchery committee meetings with the public every year at the work session and final statewide meeting after the annual enhancement report is produced. The upcoming work session (Oct 2018) will cover all hatchery issues statewide with subsequent years focused on hatchery production within that year's meeting cycle[2]. It is important that the Board of Fish members get a complete briefing on the hatchery process for permitting, authorities of the various agencies as was planned for the October work session before taking any action. **Taking action on this emergency petition will be precedent setting and is questionable on whether the Board of Fish actually has the authority[3] to override the decision to grant a PAR for the 20 million egg increase.**

Please do not take up this emergency petition submitted outside any of the normal public processes, that ADF&G has notified you that it doesn't meet the criteria for an emergency. Follow the plan you developed this spring by holding a meeting at the October work session that educates the Board members about hatcheries. Alaskans depend upon open and transparent public processes, for hatchery operations and permitting this is the RPT as well as an open and transparent public process for the Board of Fish. We encourage you to take no action or cancel the Board of Fish meeting as fishermen are busy with the summer salmon season. Taking up this petition after already acting on it is poor process and a bad precedent.

Sincerely,

Kathryn Hansen

Kathy Hansen
Executive Director

[1] NPAFC workshop on juvenile salmon William Heard wrap up meeting comments; https://npafc.org/presentations-workshop-2013/ ; https://npafc.org/presentations/
[2] Board of Fish March 2018 meeting summary page 5
[3] ADF&G Memo to Board of Fish from Sam Cotton RE: Emergency Petition June 14, 2018

SSRAA
Southern SE Regional Aquaculture Association
14 Borch Street, Ketchikan, AK 99901; Phone: 907-225-9605; FAX 907-225-1348

July 9, 2018

Alaska Board of Fisheries
Mr. John Jensen, Chair

By Electronic Copy Only: dfg.bof.comments@alaska.gov

Re: SSRAA comments regarding emergency petition: *Petition for finding of emergency and scheduling hearing on the adverse biological impacts that will result from recent amendments to Prince William Sound Private Non-Profit Hatchery Management Plans that add an increment of 20 million pink salmon egg take to existing permitted capacity.*

Dear Chairman Jensen and members of the Board of Fisheries,

Southern Southeast Regional Aquaculture Association (hereafter "SSRAA") is a regional non-profit salmon hatchery organization formed under state and federal law, which was originally incorporated in 1976. SSRAA, along with the other regional hatchery associations in the State, along with the associated Private Non-Profit (hereafter "PNP") salmon hatcheries in Alaska, have a substantial interest in the outcome of the above-referenced petition.

SSRAA vigorously opposes this emergency petition and urges the Alaska Board of Fisheries to take no action to reduce the lawfully permitted capacity of the Solomon Gulch Hatchery operated by the Valdez Fisheries Development Association, Inc.

The hatchery community is science-based and ecologically focused: we make our decisions in close coordination with exceptionally well-qualified ADF&G biologists, geneticists, pathologists and other science professionals, along with fisheries managers that are renowned as the best in the world. Collectively, the Alaska salmon hatchery community has worked for over 50 years to craft a well-functioning system that has robust regulatory oversight and a common understanding of what it takes to lead the world in sustainable, environmentally friendly salmon culture practices. We have a long and successful track record on this subject, and we agree with the ADF&G Commissioner and his staff when he correctly opined that the above-referenced petition did not rise to the "emergency" threshold. It bears mentioning that a substantially similar emergency petition was submitted just prior to this current iteration as well, which may well be considered an abuse of the Board's public process.

In preparation for the July 17 special meeting you will read many comments by others, including those with stellar reputations in the field of fisheries science and management, which rebut or disprove the analyses offered by the petitioners. SSRAA agrees with the comments offered by all regional hatchery associations, PNPs, commercial fishing groups and the paper entitled *Scientific Analysis & Review of Journal Articles Submitted by Petitioners KRSA et.al.* submitted to your attention for this meeting and appends them to SSRAA's comments by reference. The Alaska salmon hatchery community is united in concern for our industry, a primary economic and cultural driver for the State of Alaska.

In addition to our assertion that the referenced petition does not constitute an emergency, SSRAA would also like to reinforce the following points, in summary:

1. Reversal of a previously-approved Permit Alteration Request (hereafter "PAR") is bad public policy. PARs are only granted after a rigorous scientific and public review, not to mention the respective hatchery board processes (with representation from all user and interest groups). The RPTs (Regional Planning Teams) are the proper venue for PARs and have worked exceptionally well in bringing the industry together with the department and the public to make critical decisions regarding siting and production. Each PAR is extensively vetted and voted upon by the group, and none are final until signed by the Commissioner. But that is the end of the process. If the Board of Fisheries is now the final arbiter of each PAR, in our opinion there will be no respite from repeated and damaging so-called emergencies. A pattern has been established, and the fact that we are now facing the second of two substantially similar petitions provides proof of this assertion.

2. The Board has already decided to review salmon hatchery production. After the March 2018 Statewide Meeting, the Board decided to become educated on the details of Alaska's salmon hatchery system starting in October 2018. As a hatchery community, we will respond to this call, along with the Department and diligently communicate details of our industry to the Board. However, an early decision by the Board to get out ahead of that comprehensive review and carve out the previously-approved VFDA PAR is a chilling message to send to the Department and to Alaska's salmon hatchery industry. The science surrounding all aspects of hatchery production and related topics, including natural straying and ocean carrying capacity is incredibly complex and deserves to be heard in detail by the Board in this previously-identified venue.

3. The Hatchery/Wild Interaction project will provide many answers. As some of you have been made aware of rather recently: there is an ambitious, expensive ongoing study that will answer many questions surrounding straying impacts particularly. This is data that the associations and PNPs are quite anxious to learn, since our industry and the sustained production of wild fish are so inextricably intertwined. We urge the Board to take a similar stance the sustainability certification agencies such as the Marine Stewardship Council

(MSC) have taken and adopt a cautious wait-and-see approach in conjunction with the completion of the Hatcher/Wild Interaction Study.

4. Practice the precautionary principle thoughtfully. We urge the Board to consider this concept only when there is no legitimate science or historical data speaking to the other side of the issue. In this case, as we have done with the *Scientific Analysis & Review of Journal Articles Submitted by Petitioners KRSA et.al.* there are abundant and robust counter-arguments to be reviewed. It is possible that the Board has never heard these counterpoints in detail, and again we urge that you do so before acting on the petition. To do otherwise is to ignore that the system of salmon hatcheries was begun nearly 50 years ago, and, the Pacific food web has been essentially unchanged in terms of hatchery biomass for nearly three decades – encompassing many enormous runs of all species of salmon.

Thank you for your consideration of these comments. As a final thought, please consider the fact that coincidences between biological phenomena do not automatically equal causation from one to the other. Science and practice both bear out this maxim, and enormous credibility accrues to those who realize it, take it to heart and make critical decisions based on it, as opposed to emotion or public pressure.

Again, SSRAA vigorously opposes this emergency petition and urges the Alaska Board of Fisheries to take no action to reduce the lawfully permitted capacity of the Solomon Gulch Hatchery operated by the Valdez Fisheries Development Association, Inc.

Sincerely,

David Landis
SSRAA General Manager

Submitted By
Stephanie Carroll
Submitted On
7/7/2018 2:27:43 PM
Affiliation
PWS commercial fishermen

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PO Box 3013
2043 Jakes Little Fireweed Ln
Homer, Alaska 99603

I am part of a commercial fishing family in Prince William Sound. My husband and children and I make up our crew and we depend on this summer fishery for our livlihood. This fishery not only supports our family but allows us to live in Homer where we are active volunteers in our community, church and schools as well as coaching youth athletics. I was disappointed to hear that a hearing on this petition would be held in July right during the middle of our season. It seems that we are being ambushed by a special interest group at a time when we should be focused on making a living. I support responsible management when the science is there to justify it but am sceptical that PWS hatcheries are the reason for the decline in Kenai river King Salmon. The prudent thing would be to wait until the scheduled meeting in October when the facts can be presented and discussed in a more productive and meaningful way. PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Submitted By
Stephen Day
Submitted On
6/27/2018 12:15:46 PM
Affiliation
1988

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hoistedsails@gmail.com
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Anchorage, Alaska 99502

This is in regards to the measure to reduce hatchery production in Prince William Sound. As a first year permit holder a large part of my decision to buy into the PWS fishery was the success of it's hatcheries. When wild runs are unproductive (this year is a great example) we are able to still recoup our costs from the more reliable returns of hatchery fish. Please consider those of us that make our living out here in your decision. Also please plan these meetings at a time that is accessible for every user group. July 7 is mid run for several commercial fisheries across the state. On a side note, for all management of the huge resource our state enjoys in ocean fish I support a scientific management plan. If properly delegated there is enough fish for all user groups into perpituity. Another consideration is the investment made by permit holders in the comm fish arena. If drastic changes that effect the income of thousands of people are made I think it is imperative that financial compensation is somehow provided. Thank you for your time and diligence in protecting our unique and priceless resource.

6-27-2018
Steve Tutt
F/V Redemption and F/V Mighty Wind
Homeport: Homer, Alaska

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am writing these comments as a dual permit holding(seine and gillnet) commercial fisherman in Prince William Sound in response to the Alaska board of Fisheries decision to hold a hearing on the emergency petition filed May 16, 2018.

Alaska's open public process for hearing and amending fisheries regulations is being abused by a special interest group that has had this topic addressed by the Board and ADF&G four times in the past six months. There is no new information to warrant holding a special meeting prior to the October 2018 work session already scheduled.

I am very disappointed the board has decided to schedule a meeting in the middle of July when all the affected commercial fishermen are on the grounds and unable to participate in what is intended by statute to be accessible and timely for all affected individuals.

The Board has already scheduled an October meeting to address hatcheries, and salmon users to present information that will help the board make informed decisions.

I strongly encourage the board to once again find this emergency petition does not meet the criteria and vote it down. I also strongly encourage that no further action be taken at this meeting and you follow plans you've already set to convene a hatchery committee at the October work session.

My family has a long history in the commercial and sport fisheries in south central Alaska. My wifes father and grandfather began commercial fishing in lower Cook Inlet in 1939, seining and gillnetting supplemented long-shoring, gathering and selling coal, sawmilling etc. By 1958 instability in the fisheries compelled them to buy the Chevron jobbership from Tom Shelford on Homer Spit and commercial fish summers.

My father, Jim Tutt, started commercial fishing the seine and gillnet fisheries out of Cordova the summer of 1966, he was a school teacher the rest of the year.

I first fished with my dad in 1970 as an eight year old, seining Prince William Sound. There were a number of seasons in the 70's that had little to no returns resulting in no seine fishery in PWS. Most participants supplemented their fishing with other occupations.

In the 1970's it was apparent changes needed to take place and the FRED division of Fish and Game along with fisherman like my dad, Bill Webber, Armin Koenig, and others worked for free with the state to gather brood and set up hatchery infrastructure and develop net pen systems for fry. These pioneers were working for a better future for all user groups of salmon in South Central Alaska. By the late 1970's pink salmon were returning in numbers that allowed consistent harvests year to year alongside wild stocks that had significant cyclical fluctuation.

At 19 years old, I was able to buy my first gillnet boat and begin what has been a 36 year fisheries career, all three of my sons started their careers at 17 years old having grown up fishing with me. They all currently own seine operations in PWS.

Without the hard work, foresight, and ingenuity of ADF&G, commercial fisherman and others to establish fish hatcheries, the path of our family would not have been possible.

My grandson is almost 2 years old and I know he will represent the Tutt/Edens tradition which began in 1939 with pioneering great great grandparents whose motivation to get on a steamship to go to the ends of the earth to work hard and make a better life for their children and grandchildren for generations.

My grandson has as much right to participate and prosper from the mutually beneficial hatchery fisheries of PWS and Cook Inlet that continue to supplement and ensure stable returns of salmon that all user groups in Alaska benefit from.

Prince William Sound has enjoyed the largest returns of wild stock pink salmon in its history in recent years right alongside abundant hatchery stocks of pink,chum,red, and silver salmon.

My Family's 79 year history in the commercial fisheries of South Central Alaska is a wonderful example of how hard working, pioneering, and determined families can benefit for generations in fisheries that are enhanced with hatchery runs. I have no doubt that without hatcheries my families story would be dramatically different, owning other types of businesses no doubt, but we love what we do, the salmon produced by the hatcheries of

PWS and the wild stocks that return with them have provided food on our tables and roof over our heads and an occupation that is rewarding to the pioneering and hardworking men and women of our family and Alaska for generations.

Here are some statistics to support my point: Studies show:

*1500 active salmon permit holders in PWS and their crew depend on hatcheries for their livelihood.

*VFDA hatchery harvests contributes 74% of its harvest value to Alaskan families;37%to Cordova and Valdez, 23%to the Kenai Peninsula, 9% to Anchorage, 4% to other areas of the state.

*According to the McDowell group PWSAC red salmon benefit Alaskan sport fish, subsistence, and personal use fisheries with 73% of these fish going to residents of Anchorage, Fairbanks, and the Mat-Su.

*VFDA hatchery production accounts for 75% of all Coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area generating an estimated annual revenue of 6.6 million dollars.

And Finally, I want to express my concern about process. Convening an emergency meeting on this issue during the middle of our commercial fishing season is unreasonable for the following reasons:

*The same petition has been heard and denied due to not meeting criteria.

*The Board has scheduled a discussion on hatchery production at the October 2018 work session.

*By holding this meeting in Anchorage on July 17, you have denied me and my fellow fishermen in PWS the opportunity for meaningful participation on this important issue.

Please deny this emergency petition request again as you have already done!

Sincerely, Steve Tutt

F/V Redemption-seine
F/V Mighty Wind-gillnet

Submitted By
Steve Zernia
Submitted On
7/1/2018 7:38:00 PM
Affiliation
President Seward Charterboat Association

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Address
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Seward, Alaska 99664

Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am the president of the Seward Charter Boat Association. We have 22 member businesses that operate in Prince William Sound and depend on the area's salmon fishery for my family's livelihood. Our members, Captains and their crew would not be able to make a living in PWS without hatchery production. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our charter halibut and salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Steven Zernia, President Seward Charterboat Assocation

Submitted By
Steven Gildnes
Submitted On
7/7/2018 8:24:06 AM
Affiliation

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Cordova , Alaska 99574

From birth till present I grew up on tenders, seiners and gillnetters in prince William Sound during summer. I haven't missed a Seine season since 1980. This will be my 21st year as captain and it's my 28th year as owner and captain of a prince William Sound gillnet operation. I'm a 3rd generation fisherman here out of Cordova Alaska, I'm 45 years old, I support a child and his mother. My son is 11 I have high hopes he will be a 4th generation fishermen. Over my career my crews ranging in ages from 16 - 50 years of age have been able to finance and graduate from college debt free, learn invaluable life helping skills such as cooking, working as a team, maintaining engines, working on nets, working hard long hours, forcing themselves to do what they thought they couldn't accomplish and succeeding with hard work and determination. These types of skills are lost in a lot of the country's typical careers and although it's not a life style for everyone it's good for a lot of us Americans. Our hard work is appreciated by the world for we supply a healthy protein to feed the soldiers who defend our great nation and the children growing to be successful young entrepreneurs who will one day lead this great nation. Our hatcheries support a wide range of American jobs and careers. The sport fish organization is a treacherous group who have studied and paid big money to end our careers. They have succeeded in ending commercial fisheries across this country. This is our heritage our history our life style. We need our hatcheries the country needs its healthy protein. It is imperative to release as many or more salmon fry in the future. Thank you. Steven Gildnes.

Submitted By
Steven Roth
Submitted On
7/9/2018 2:05:55 PM
Affiliation

July 8, 2018

Chairman John Jensen

Alaska Board of Fisheries

Boards Support Section

P.O. Box 115526

Juneau, AK 99811-5526

RE: KRSA petition on VFDA

My name is Steve Roth, I am a Kodiak salmon fisherman and Kenai Peninsula resident and so are my two sons, Richard and William, also vessel owners. Our respective families, crew, and vessels rely on sustainable salmon runs for our livelihoods and abilities to contribute to our coastal communities and Alaskan economy.

Salmon hatcheries were established decades ago to take the "valleys" out of fluctuations in salmon stocks. Over time, our Alaskan salmon hatcheries have become more and more professional and have developed commendable best practices. Alaskans should be proud of the hatchery program and thankful for it considering how many user groups (guided and un-guided sport, dipnetters, drifters, set gillnetters, seiners and subsistence) harvest hatchery fish on a regular basis in many regions across the state.

There are only three things we would like to comment on. First, the hatchery program is not new. Experienced hatchery managers, biologists and researchers armed with up-to-date science applicable to current Alaskan hatchery operation and best practices (not in Canada and Washington) are not "shooting from the hip". **The claim that hatchery operations are causing an unforeseen or unexpected resource situation which would make wild salmon unavailable in the future lacks validity.** Second, is to echo the importance of KRSA et al's own comments about the public process on page 3, section 3, "Whereas the BOF process is open, transparent and accessible to the public, both in person and online, the RPT is the opposite" – the timing of this emergency petition has required the recruitment of family members back home, our "shore support", to make our voices heard from the fishing grounds in Shelikof Strait. Not every fisherman has shore support and thus **the Board will not hear from many in opposition to this petition as a result of the inequitable and overly burdensome timing to a large number of stakeholders in this issue**, one cannot help but wonder if this was orchestrated as such. **Finally, Page 2, section 7 is citing an opportunistic sampling of an event in Homer which renders makes the findings questionable, at best.**

We respectfully ask that the Board of Fish take no action on this petition,

Steve Roth, F/V Sea Grace

Richard Roth, F/V Kelly Girl

William Roth, F/V Sea Chantey

Submitted By
Stuart Deal
Submitted On
7/6/2018 12:15:52 AM
Affiliation
CDFU, Silver Bay Seafoods

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P O Box 1975,
Cordova , Alaska 99574

I ask the board to stick by its plan to address this subject at a work session in October. If the board weighs in on this matter under the heading of an emergency it will be overlooking the finding of ADF&G that there is no “emergency”. The July meeting will be very difficult for commercial fishermen, stakeholders like myself, to participate in because of being occupied with our business. We are in the middle of our season. I am sure the members of the Board of Fish know well that their deliberations and actions must be informed by science and follow due process. Without these we would all be loosing our way. Thanks. See you in October.

Submitted By
Susan Bourgeois
Submitted On
7/9/2018 1:44:15 PM
Affiliation

I am extremely dismayed at the process being used by the Board of Fish in hearing this emergency petition at all, let alone on a date during the middle of the PWS commercial salmon seine season when very few commercial fishermen will be able to be in attendance. An October 2018 work session on hatchery production has already been scheduled, that is a perfectly appropriate time to discuss this when all interested parties can be in attendance and/or be well-represented. The ADF&G had denied this petition and then the process was hi-jacked and the petition found it's way to an actual meeting, contrary to the rules in place concerning petitions.

As far as the content of the petition, I believe the VFDA increased hatchery production has been handled appropriately. Plenty of science was used in the decision and the increase was approved in an incrmental manner and very conservatively.

Submitted By
Susan Harvey
Submitted On
7/7/2018 1:06:28 PM
Affiliation

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Address
PO Box 771026
Eagle River , Alaska 99577

I am a commercial fisherman in Prince William Sound.

I oppose the May 16, 2018 Emergency Petition filed with the Alaska Board of Fisheries.

The Prince William Sound Alaska hatchery program is critical to state, regional, and local economy and commerical and sports fishermen. The hatchery program is implemented based on solid science and is carefully monitored by expert teams of state biologists.

I am very disappointed that the Board would hold a meeting on this issue and require comment by July 9th at the peak of our commercial fishing season, and hold a meeting on July 17 when we are all out commercial fishing trying to earn a living for our families. This is poor public process.

I strongly recommend you deny this emeregency petition. The Board should use sound science in making its decision. The May 16, 2018 Emergency Petition is not based on sound science.

Susan Harvey

Submitted By
Tania Harrison
Submitted On
6/29/2018 9:29:56 AM
Affiliation

I am a young commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery. My fellow Cordova citizens and I would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries. In addition, focusing the fishery on hatchery fish relieves pressure on wild stocks.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST

Signed,

Tania Harrison

Submitted By
Terry Nininger
Submitted On
7/6/2018 3:35:07 PM
Affiliation
MSB Fish & Wildlife Commission

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Alaska Board of Fisheries ADF&G-Boards Support Section PO Box 115526
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MATANUSKA-SUSITNA BOROUGH

Fish & Wildlife Commission

350 East Dahlia Avenue□Palmer, AK 99645 Phone (907) 861-7833□Fax (907) 861-7876

RE: KRSA Emergency Petition regarding Hatchery Production in Prince William Sound

Dear Alaska Board of Fisheries Members,

The Matanuska-Susitna Borough Fish & Wildlife Commission (MSBFWC) supports the Kenai River Sportfishing Association (KRSA) petition to find for an emergency and scheduling a hearing on the recent changes to Prince William sound hatchery Management Plans for adding 20 million Pink salmon eggs to the existing permitted capacity. MSBFWC concurs with KRSA's requested relief that the Alaska Board of Fisheries PAUSE any increased authorization of pink salmon production until adequate consideration can be given to all the issues associated with this action.

As referenced in KRSA's petition, and as previously documented in Nancy Hillstrand's BOF petition, (RC 027), hatchery pink salmon are showing up in greater numbers in streams in Lower Cook Inlet; in 2017, in Fritz Creek, 70 % of fish sampled were from Prince William Sound (PWS) hatcheries, and in Beluga Slough 56% were from PWS hatcheries. There is excessive straying from PWS hatcheries into Cook Inlet wild spawning salmon streams. It is imperative to maintain populations of wild spawning salmon and not allow further introduction of non-wild hatchery salmon in Cook Inlet.

On a related issue, there is a growing body of evidence, to include the peer-reviewed study by Greg Ruggerone and Jim Irvine, ("Numbers and Biomass of Natural and Hatchery-Origin Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean, 1925-2015"), that in Alaska declines in size and abundance of Chinook salmon and Coho salmon and a decrease in age at maturation of Chinook salmon may be related to the alteration of the food web by highly abundant pink salmon and higher mortality during later marine life.

Both of these issues justify putting a pause on further production of PWS hatchery pink salmon until further comprehensive research directed at better understanding of total hatchery and

wild stock returns, stock identification, and other factors influencing ocean survival of salmon are understood.

Though no statute expressly grants the Board regulatory authority over hatchery production *per se*, the Board may exercise considerable influence over hatchery production through its authority to directly amend hatchery permit terms relating to fish and egg harvesting (AS 16.10.440(b)). The Mat-Su Borough Fish & Wildlife Commission strongly recommends that the BOF act immediately to preclude any further disbursement of hatchery pink salmon at this time.

Respectfully,

Terry Nininger, Chair
Mat-Su Borough Fish & Wildlife Commission

cc: John Moosey Brianne Blackburn

Submitted By
Thea Thomas
Submitted On
7/1/2018 9:11:37 AM
Affiliation
Commercial Fisherman

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112 South 2nd St.
Cordova , Alaska 99574

Dear Chairman Jensen and Board members, I am a long time commercial fisherman in Prince William Sound. I have served on the Prince William Sound Aquaculture Corporation(PWSAC) board and have followed the PWS hatchery programs since the early 80's. I am writing to ask the board to once again turn down the KSFA's emergency petition concerning the VFDA permitted egg take increase. First, there is no scientific evidence that straying PWS pink are negatively impacting Kenai wild stocks. The ongoing PWS Hatchery Research Project was was initiated to answer just this question. This is a robust, long term project which after 6 years has failed to show any negative impact of hatchery pink salmon on wild stocks. In fact, PWS has had record wild stock pink salmon returns, with almost 40 years of hatchery production. Second, hatchery production is overseen by the Regional Planning Teams, made up of ADFG, hatchery personnel and industry members. They review all requested production increases. This is a rigorous and open public process. Please do not set any precedent taking this important job out of their hands. And last as a Copper River and Prince William Sound fisherman, this year has shown more than ever, with the sockeye salmon decline on the Copper River, how very, very important, the hatchery production is for the region. This year without PWSAC sockeye and chum hatchery salmon harvested by the gillnet fleet, we would be facing an economic disaster. Thank you for all your time and effort serving on the board, and for consideration of these comments. Sincerely, Thea Thomas

Submitted By
Thomas M Buchanan
Submitted On
7/9/2018 2:13:16 PM
Affiliation
none

Phone
907-491-0508
Email
tmbfish@gmail.com
Address
PO Box 925
Seward, Alaska 99664

I support the emergency petition from the Kenai River Sportfishing Association to limit and reduce hatchery releases in Prince William Sound. I

I have been commercial fishing in Lower Cook Inlet for 47 years, seining from Resurrection Bay to Katchemak Bay.

I can remember when we used to have over a 4 pound average to wild pink salmon, and it was not uncommon to catch a 10-12 pound pink.

The studies and research I've read indicate that overproduction of pinks is harming wild runs, the environment, and other species. There's only so much food in the ocean and man-made pinks are devouring too much, to the detriment of wild pink salmon, other salmon species and even birds.

Over production of pinks harms me financially, as a commercial fisherman of WILD stocks. I have been shut down by canneries who are swamped with too many hatchery fish - they won't send a tender to my area because the tenders are all tied up working at the hatcheries. This effectively puts me out of business and harms me financially, which is exactly opposite of what hatcheries were intended to do, or should be doing.

This issue is definitely an emergency to my commercial fishing, and to other permit holders in the Lower Cook Inlet area who have had to stop fishing wild runs because of canneries being at over-capacity due to hatchery returns. This creates over-escapement in areas of natural runs and harms the wild runs for years. This issue is definitely and economic emergency to myself and other seiners and an emergency to the health and sustainability of wild fish stocks.

I request the Board of Fish to view the KRSA petition as broadly as possible and consider it a statewide issue for all hatcheries, not just the ones in Prince William Sound.

I support strong reductions of hatchery production.

I urge the Board to adopt emergency regulations under AS 16.10.440(b) to amend all hatchery permit terms and drastically reduce production levels immediately.

Submitted By
Thomas Tomrdle
Submitted On
6/26/2018 5:30:06 PM
Affiliation
PWS GILLNETTER

Phone
9079872254
Email
Coolbreeze223@hotmail.com
Address
35745 walker st
Soldotna, Alaska 99669

To whom it may concern, My Name is Thomas Tomrdle. I was born and raised in Soldotna Alaska thirty eight years ago and have been a commercial fisherman my entire life. Being a resident of the Kenai Peninsula I am well aware of Krsa's political games and relentless attacks on commercial fishing. Without the PWS hatcheries my family would be in dire straights financially this year. KSRA and specifically Bob Penny, have been using any means necessary to further their agenda. The importance of these hatcheries in PWS cannot be understated especially for Cordova, Valdez, Tatitlek, Whittier and Chenega. Hacheries across this state employ hundreds and give revenue to thousands of Alaskans. KRSA relentless propaganda, false science and unrelenting hate towards commercial fishing, via their web site is a testament to their true cause... to further KSRA's own agenda at the cost of Alaskan families like my own.

Submitted By
tim cabana
Submitted On
6/27/2018 11:19:09 AM
Affiliation

Phone
9076328467
Email
timcabana1@yahoo.com
Address
box 201
girdwood, Alaska 99587

This is not the time or place for this discussion, there has been a meeting on this on the books for October and that is the time to take this up. Shame on the board members using this process to leave out the most effected group by calling this an emergency. The only emergency I see the need to reconsider the appointments of the 2 board members that started this waste of public time and money.

06/26/18

Timothy J Moore
Seascape Inc.
PO Box 1646
Homer, AK. 99603

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman John Jensen and Alaska Board of Fisheries Members:

I am a commercial salmon seiner in Prince William Sound (PWS) and have depended on the area's salmon resources for almost all of my family's livelihood for the last 28 years.

I want to voice my concern and objection to the emergency petition submitted by the Kenai River Sport Fishing Association and others. Alaska has a respected open public process for managing fish resources and strong regulations managing the salmon hatcheries. The Alaska Department of Fish and Game (ADF&G) has clearly met it's responsibility for managing the hatcheries which were established since the hatchery programs were started. The Commissioner of ADF&G has submitted his recommendation to the Board of Fish which firmly establishes that no emergency exists which should cause the meeting on July 17th to include actions to take place on the VFDA Hatchery Management Plan.

The ADF&G Commissioner's authority over managing the hatcheries is firmly stated and the VFDA hatchery management plan for 2018 has been fully vetted by all the ADF&G appropriate Departments.

I am very disappointed that two members of the BOF have elected to hold a meeting in the middle of the summer on July 17th. Although written comments are being accepted commercial fishermen have limited opportunity to participate in person. We are all required to be fishing for the limited fishing season that occurs each year.

Studies have shown the Valdez Fisheries Development Association (VFDA) salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. In many years in PWS, harvests by our fleet would be minimal if only relying on wild salmon returns. Before hatcheries were started in the late 70's entire PWS salmon seine seasons were canceled. Since that time the hatchery production has supplemented the wild priority stocks and a wonderful success story has been created. Recently we have experienced some of our largest wild pink salmon runs since ADF&G has taken records.

Alaska salmon hatchery programs are economic drivers for Alaskan communities. Studies have shown the 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka and Wrangell-Petersburg.

According the a McDowell Group study almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011. Seventy-three percent of these salmon were caught and used by Alaskans. VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area. The total sport fish economic output for VFDA is estimated at $6.6 million annually.

PLEASE DENY THIS EMERGENCY PETITION REQUEST

Thank you for considering these comments.

Timothy J. Moore

F/V Marandah

Submitted By
TOM LOVROVICH
Submitted On
7/6/2018 9:55:14 PM
Affiliation

Phone
2539057200
Email
fvtradition@gmail.com
Address
9705 Jacobsen Ln.
Gig Harbor, Washington 98332

Tom a Lovrovich purse seine vessel Tradition I am a 3rd generation fisherman we need hatchery production to remain intact for our fishery to be viable. We do not need out side interest groups using the emergencey petition process while we are out fishing.

From: Tom Manos, and the Families and crew of the fishing vessels***, Scotch Cap, Alaskan Lady, Cape Saint Elias, and the Alaskan Belle***

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition and Area M June Time restrictions

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Prince William Sound salmon fishing plays an important economic role in many communities in South Central Alaska and especially so in Girdwood the community that is home to a large number of fishermen and fishing families. The timing of this meeting makes it impossible for most of us to respond to this process however a number of us have asked our families that are not on the water to be present at the process as an expression of our concern. It is crazy that another user group is able to trigger a process that will have substantial consequences on many Alaskans livelihoods. The attempt to define as an emergency, a plan that has had substantial discussion and scientific review over a number of years seems like a corruption of the Board process. I have respect for the Board process and the accessibility that it provides fisher stakeholders to help us be effective stewards of the resource and a means to address the inevitable allocation issues that arise. I personally attended my first Board of Fish meeting in Juneau in 1980 and have been involved since, I now have two sons that own commercial Alaska fishing businesses and support their families from their catch.

Two seiners that I own with my sons are fishing this year in Area M on the Southwest end of Unimak Island. They have been experiencing decent fishing and based on the last decade of even years it is likely that the rest of our Salmon season will offer limited opportunity. The June fishery will be more than half of our Salmon Season. The time restrictions implemented this June could represent 40% of our 2018 Salmon income and by my estimate reflected 6 and a half million dollars of forgone opportunity for Area M fishermen. This forgone opportunity will have significant negative impact for the fishing communities in Southwest Alaska

We are stakeholders in Alaskan Salmon and as such we strongly support sound resource management policy even when it entails sacrifice. The time restrictions implemented in this case do not reflect sound management which it seems has been confused with great sacrifice. Zero risk terminal area weak stock management applied to mixed stock intercept fishery is wrong and that simple-minded management fails to consider net benefit. The parent year ocean conditions have created extreme hardship for a number of Salmon runs in the state over the last few years. It is time for the Department to put their heads down and look for a balanced effective way to rebuild these runs. We have done that in the past and I am confident we can do it now. I have no doubt this will involve restricted fishing and the support of the stakeholders will be crucial. The current management policy that calls for great sacrifice with little or no positive effect will not garner fishermen support in the future, Good management policy is going to come from knowledgeable experienced and balanced decision making and I do not believe that is what we are seeing right now, Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Tom Manos, and the Families and crew of the fishing vessels***, Scotch Cap, Alaskan Lady, Cape Saint Elias, and the Alaskan Belle***

From: Tom N
Sent: Sunday, June 24, 2018 10:29 AM
To: Sonja Nelson
Subject: Fw: Opposition to emergency petition

RECEIVED
JUL 03 2018
BOARDS

From: Tom N <icybay@live.com>
Sent: Sunday, June 24, 2018 8:16:48 AM
To: dfg.bof.comments@alaska.gov
Subject: Opposition to emergency petition

Members of the Board of Fisheries,

I would like to voice my strong opposition to the boards hearing of this petition again. There is no evidence that hatchery production is harming wild stock fish, the individuals behind this petition cite junk science, conjecture and flat out lies in their reasoning. A simple example is their statement that 2017 in PWS pink return was 90% hatchery origin which can be easily refuted by looking at the ADFG catch data which shows only 48% hatchery fish. If you factor in escapement wildstock pinks probably comprised 60-70% of the return. This petition is a purely political power play and should have been rejected immediately by the board. Hatchery releases comprise a micro percentage of all the YOY fishes in the ocean each spring, pollock alone dwarfs salmon outmigration wild and hatchery by many times. The hatchery system is also very important to the economic stability of Alaska salmon fishery's, and not just where the fish are caught. Production from PWS hatcheries could benefit Bristol Bay salmon prices as the same companies buy in both locations and the volume of pink salmon can lower statewide production costs allowing more competitive ex-vessel prices. I closing I want to reiterate my strong opposition to the board hearing this petition, this type of misinformation doesn't belong before the board. Thank you.

Tom Nelson Box 1392
Homer, AK
99603

Tom Nelson

PWS BOAT owner + Skipper

UNITED FISHERMEN OF ALASKA

Mailing Address: PO Box 20229, Juneau AK 99802-0229
Physical Address: 410 Calhoun Ave Ste 101, Juneau AK 99801
Phone: (907) 586-2820 **Fax:** (907) 463-2545
Email: ufa@ufafish.org **Website:** www.ufafish.org

July 6, 2018

Alaska Board of Fisheries
P.O. Box 115526
Juneau, Alaska 99811-5526

Re: KRSA Et Al. Emergency Petition on VFDA

Dear Chairmen Jensen and the Alaska Board of Fisheries,

United Fishermen of Alaska (UFA) is the statewide commercial fishing trade association, representing 35 commercial fishing organizations participating in fisheries throughout the state, and the federal fisheries off Alaska's coast.

We ask that you deny the emergency petition from Kenai River Sportfishing Association (KRSA) regarding the hatcheries in Prince William Sound based first, on the fact that this is not an emergency, which is the sole purpose of an emergency petition. Second, hatcheries are managed through a collaborative, public process in involving the Alaska Department of Fish and Game, the Regional Planning Team, and the Valdez Fishermen's Development Association. This process is years in the making and undergoes strict scrutiny to determine hatchery production. Third, the issue of ocean carrying capacity is not just a statewide issue—it is an international issue which lacks scientifically tested empirical evidence. Lastly, holding a meeting that directly impacts commercial fishermen and their livelihoods during a time when they cannot participate is detrimental to the process and purposefully excludes their participation and presence. It is a gross negligent wasting of limited ADF&G funds and resources when this topic has already been discussed at two prior board meetings.

The Alaska hatchery program is important to state, regional and local economies, they help provide for a stable community by supporting sport fishing, tourism, personal use fishing, commercial fishing, seafood processing, along with other economic benefits that spread throughout the state.

One of the key documents, *"Numbers and Biomass of Natural- and Hatchery-Origin Pink Salmon, Chum Salmon, and Sockeye Salmon in the North Pacific Ocean,1925–2015"* by Ruggerone and Irvine has repeatedly been cited as the document leading to conclusions that hatcheries are bad for our wild salmon stocks. The authors conclude with the three following management changes:

1) Mark or tag hatchery salmon so that they can be identified after release
2) Estimate hatchery- and natural-origin salmon in catches and escapement
3) Maintain these statistics in publicly accessible databases.

Currently all three of these practices are required and followed in the State of Alaska. We do not see an emergency at this time.

We cannot let fear and assumptions dictate sustainable fishery practices. There is not enough time, information, and scientific data to warrant the conversation that is on the table. At the March 2018 Statewide meeting, the board voted to review hatchery production at the October work session, allowing ample time to gather data and facts before the board makes a decision.

We ask that you do not succumb to the pressure to take action on this petition just for the sake of production and accomplishment. We urge you to deny this petition based on the fact that it does not meet the criteria for an emergency petition.

Respectfully,

Matt Alward
President

Frances H. Leach
Executive Director

MEMBER ORGANIZATIONS

Alaska Bering Sea Crabbers • Alaska Independent Tendermen's Association • Alaska Longline Fishermen's Association • Alaska Scallop Association • Alaska Trollers Association • Alaska Whitefish Trawlers Association • Armstrong Keta • At-sea Processors Association • Bristol Bay Fishermen's Association • Bristol Bay Reserve • Cape Barnabas, Inc. • Concerned Area "M" Fishermen • Cook Inlet Aquaculture Association • Cordova District Fishermen United • Douglas Island Pink and Chum • Freezer Longline Coalition • Golden King Crab Coalition • Groundfish Forum • Kenai Peninsula Fishermen's Association • Kodiak Regional Aquaculture Association • Kodiak Seiners Association • North Pacific Fisheries Association • Northern Southeast Regional Aquaculture Association • Petersburg Vessel Owners Association • Prince William Sound Aquaculture Corporation • Purse Seine Vessel Owner Association • Seafood Producers Cooperative • Southeast Alaska Herring Conservation Alliance • Southeast Alaska Fisherman's Alliance • Southeast Alaska Regional Dive Fisheries Association • Southeast Alaska Seiners • Southern Southeast Regional Aquaculture Association • United Cook Inlet Drift Association • United Southeast Alaska Gillnetters • Valdez Fisheries Development Association

TO: Alaska Board of Fisheries
FOR: Emergency Meeting, July 17, 2018, in Anchorage, AK
July 9, 2018

RE: Comments Regarding Emergency Petition to Rescind VFDA 20 million Pink Salmon

Dear Chairman Jensen and Board of Fisheries Members:

The Kenai River Sport Fishing Association submitted an emergency petition on May 1, 2018, asking the department to stay its decision to allow the Valdez Fisheries Development Association, a Valdez-based salmon hatchery, to increase its production of pink salmon brood stock. The board did not find it an emergency by a vote of 3-3. Now, two months later, stakeholders are asked to again expend time, effort, and financial resources because the petition filer wants a different answer. We appreciate the opportunity to make these comments yet this request comes at a time when hatcheries, processers and fishermen, are fully engaged in the summer season. Many fishermen do not have consistent or any internet services to enable them to fully participate in the BOF process; thus we find the timing of this meeting egregiously circumvents the public process.

Southeast Alaska Seiners Association (SEAS) and United Southeast Alaska Gillnetters (USAG), collectively represent the interests of over 650 seine and gillnet fishermen; we utilize and believe in the public process that sets the regulations that manage our salmon resources. Regional Planning Teams (RPTs) in each region offer the best notification and overview of enhancement activities and include the ability for rigorous public review. Twice each year, this region's RPT meets in a southeast community and members include pertinent divisions of ADF&G, the Forest Service, fishermen, and enhancement representatives. There are strict guidelines in regulation and statute that are read, reviewed and followed during agenda items that deal with new hatcheries and production increases. All voting records are documented (with comments when applicable) and given as recommendations to the Commissioner of Fish and Game who then makes the final decisions.

The RPT, much like the BOF, is mandated to follow statutes and guidelines carefully designed to eliminate political and personal bias from the decision making process. This process demands oversight by experts that rely on biology and sound data in their decision making process, along with specific criteria. We believe this separation in oversight that was built into the Alaska system has no equal. To undermine one divisions' oversight, or interject due to political pressure, is something Alaska built into its master plan to explicitly avoid. Re-evaluating this petition insinuates the BOF has a better understanding of this specific issue and is more qualified, less bias, and better informed to make this decision, which we find insulting to the RPT and its process.

In Alaska, we are fortunate to have documents developed over decades that have been reviewed and updated like the "The Comprehensive Salmon Plan", which are referred to frequently when the RPT is reviewing applications. Alaska has learned from the mistakes of the lower 48 and has specifically developed a process of decision making that has more biology and comprehensive science built into the system than anywhere else in the world. We sincerely hope the BOF will uphold its past decision and deny this petition, acknowledging your previous purview and recognizing and valuing the RPT's role and responsibilities.

Respectfully,

Southeast Alaska Seiners Association
Susan Doherty, Executive Director
PO Box 714
Ward Cove, AK 99901
(907) 220-7630
dohertyktn@gmail.com

United Southeast Alaska Gillnetters
Cynthia Wallesz, Executive Director
PO Box 2196
Petersburg, AK 99833
(253) 237-3099
usag.alaska@gmail.com

CITY OF VALDEZ, ALASKA

RESOLUTION NO. 18-24

A RESOLUTION OF THE CITY COUNCIL OF THE CITY OF VALDEZ, ALASKA, SUPPORTING THE VALDEZ FISHERIES DEVELOPMENT ASSOCIATION INC. SOLOMON GULCH HATCHERY PERMITTED INCREASE OF 20 MILLION PINK SALMON EGGS

WHEREAS, the City of Valdez benefits greatly from Prince William Sound salmon fisheries enhancement programs through hatchery propagation; and

WHEREAS, both sport and commercial fisheries enhancement efforts of the Valdez Fisheries Development Association, provide sustainable direct economic and social benefit to the community of Valdez; and

WHEREAS, this benefit is realized through the creation of local seafood processing jobs, fisheries business tax, increased commerce through the Port of Valdez and seafood industry investment in our community; and

WHEREAS, the enhancement of the sport fishery by VFDA provides significant fishing opportunity for both Pink and Coho salmon creating the largest Pink salmon sport fishery in Alaska; and whose efforts greatly support the annual Valdez Silver Salmon Derby and the Valdez Women's Silver Salmon Derby, a Kids Pink Salmon Derby; and

WHEREAS, this sport fishing activity significantly increases summer tourism by bringing an estimated 15,000 visitors annually to sport fish in Valdez; further benefiting local commerce through the sale of sporting goods, boat rentals, custom processing, lodging and RV camping, fuel, harbor moorage, fishing charters and other purchases estimated to be $6.6 million annually; and

WHEREAS, the sport fish enhancement program provided by VFDA is substantially funded through the sale of cost recovery pink salmon; and

WHEREAS, salmon hatchery programs like VFDA are permitted using a public process, employ strong scientific methodology and are built upon sound and sustainable fisheries policies intended to protect wild salmon populations.

NOW, THEREFORE, BE IT RESOLVED, BY THE CITY COUNCIL OF THE CITY OF VALDEZ, ALASKA, that

Section 1. The City of Valdez affirms its support for the Valdez Fisheries Development Association's salmon fishery enhancement programs.

Resolution No. 18-24
Page 2

<u>Section 2.</u> The City of Valdez supports the Alaska Dept. of Fish & Game's approval of VFDA's permitted increase of 20 million pink salmon eggs to be taken in 2018 at the Solomon Gulch Hatchery.

PASSED AND APPROVED BY THE CITY COUNCIL OF THE CITY OF VALDEZ, ALASKA, this 3rd day of July, 2018.

CITY OF VALDEZ, ALASKA

Jeremy O'Neil, Mayor

ATTEST:

Sheri L. Pierce, MMC, City Clerk

VALDEZ FISHERIES DEVELOPMENT ASSOCIATION, INC.
SOLOMON GULCH HATCHERY

P.O. Box 125 Valdez, AK. 99686 1815 Mineral Creek Loop Road Valdez, AK 99686
(907) 835-4874 Fax (907) 835-4831 Mike.Wells@valdezfisheries.com

July 6, 2018

Alaska Dept. of Fish & Game
Alaska Board of Fisheries
PO Box 115526
1255 W. 8th Street
Juneau, AK 99811-5526 via email: dfg.bof.comments@alaska.gov

RE: Petition for finding of emergency and scheduling hearing on the adverse biological impacts that will result from recent amendments to Prince William Sound Private Non-Profit Hatchery Management Plans that add an increment of 20 million pink salmon egg take to existing permitted capacity

Chairman Jensen, Members of the Alaska Board of Fisheries:

Thank you for the opportunity to provide written comments on the emergency petition submitted by the Kenai River Sportfishers Association *et al* on May 16th 2018. This petition requests the board take, by emergency action without oral testimony or full presentation of all related science on the biological factors being considered; measures to reduce the 2014 ADF&G decision to permit the taking of 20 million Pink salmon eggs at VFDA's Solomon Gulch hatchery this year.

VFDA objects in the strongest possible manner to the board considering this petition on an emergency basis. VFDA recommends in the strongest terms that the board take no action to amend our ADF&G approved permit and reduce its permitted pink salmon egg capacity at Solomon Gulch hatchery.

Record of finding for a lack of emergency:

Previous evaluations of the merits of the petition have concluded they do not meet the standard for finding of emergency under AS 44.62.270 which states: *"It is state policy that emergencies are held to a minimum and rarely found to exist"*. The board rejected a similar petition RCO27 in January that used the same arguments presented here. The board rejected again on May 14th the same petition filed by KRSA *et al*. In his June 14th ADF&G Memo re Emergency Petition, Commissioner Cotten concluded that the KRSA petition *"does not satisfy the criteria described in 5 AAC 96.625(f) because it is not unforeseen that some level of straying occurs in pink salmon stocks and concerns over straying effects and potential fishery management complications arising from increased pink salmon production levels were discussed by the RPT and department when the 2014 SGH PAR was considered and approved."* 5 AAC 96.625(f) reads: *"In this section, an emergency is an unforeseen, unexpected event that either threatens a fish or game resource, or an unforeseen, unexpected resource situation where a biologically allowable resource harvest would be precluded by delayed regulatory action and such delay would be significantly burdensome to the petitioners because the resource would be unavailable in the future."* The Commissioner reiterated that position in a June 14 letter to KRSA, *"This letter is to formally notify you pursuant to AS 44.62.230, that based on the information available to me I cannot conclude that an emergency under 5 AAC 96.625(f) exists and I deny the emergency petition."*

It should not be any clearer to the Board of Fisheries that this petition does not qualify as an emergency and should not even have been granted an emergency hearing.

This petition provides no new evidence that hatchery pink salmon create harm to Alaska's fisheries resources, or adversely impact the marine environment. The scientific research, when taken in context, does not conclude that hatchery pink salmon hinder the sustainability of Alaska's fisheries resources in any way. As an example, an attempt to link pink salmon as a root cause of reduced reproductive success of short tailed shearwaters falls well short upon further evaluation of its scientific method, which cannot overcome the contradictions contained in the analysis. The report also concludes the species is not in peril. Two studies correlating pink salmon abundance to the decline of size and maturity at age in other salmon species are also provided. However when taken in context, the study *"Changes in Body Size of Canadian Pacific Salmon"* provides a perplexing counter in which the mean weight of Chinook salmon declined by 3kg from 1951-1970, before hatchery production in Alaska began; then increased in weight back to the former mean through the 1980's and 1990's, after large hatchery production began. Coho salmon followed a similar pattern. In the study *"Changes in Size and Age of Chinook Salmon Oncorhynchus tshawytscha Returning to Alaska"*, the authors state that the number of salmon in the North Pacific is at an all-time high due in large part to large scale hatchery production. This means all species propagated by hatchery production, not just pink salmon from North America. The study does not call out Alaska hatchery pink salmon production specifically as the overwhelming cause of decline of size, and age at maturity. In addition it clearly states *"Beyond correlations, it has proven difficult to directly link specific biotic and environmental mechanism to the changes observed here, because of the ocean wide scale of these interactions and the many confounding mechanisms"*.

The research included in support of the petition states a common theme. However, the papers relied upon to support their concerns require considerable understanding of scientific evaluation and cannot simply be relied upon based on blind acceptance of a theory. At this time, the board has heard one side of the argument based on the aspersions of the petitioners, using only journal articles and a portion of the available information on the topics. In rebuttal, VFDA supports additional evaluation on the statistical methodology and conclusion of the reports referenced by the petitioners for the board to consider.

Ocean carrying capacity is a complex and an international global science studied by the North Pacific Anadromous Fish Commission for over two decades. It brings into consideration significant alternating oceanic and atmospheric effects on a broad scale. Research is ongoing, however it is premature to point to hatchery production, and specifically PWS pink salmon, as the primary source of reduced ocean survival impacting other salmon species. Hatchery production has remained stable in PWS for decades. The increase approved by the state is the first at Solomon Gulch since 1991. Considering the amount of pink salmon from all sources currently found in the North Pacific basin, an anticipated release of 19 million pink salmon fry and the correlating numbers of returning adults constitutes an increase of approximately 0.1% percent. When considered in context to total biomass of all salmon species rearing annually in the North Pacific the percentage is significantly lower at <0.02 %This minimal increase will have no measurable impact to the current conditions in the ocean.

The proclivity of pink salmon to stray has been known since well before the inception of Alaska's hatchery program. It is likely that PWS pink salmon, of both natural and hatchery origin, have been straying into Lower Cook Inlet systems and vice versa for many years. This is due in large part to the North Gulf coast being the primary migratory corridor for salmon returning to PWS. The Phase III PWS Comprehensive Salmon Management Plan (1994), recommends as a conservative number to maintain hatchery stray rates at 2%. This largely arbitrary number was developed for management of hatchery programs in the Pacific Northwest for other salmon species which proposed 2% for Coho; but also cited consideration of rates of 5% and 10%. In fact the PWS CSMP states *"The PWS/CR RPT recognizes that the present estimate of the acceptable threshold of hatchery-salmon straying is not well supported. Further research is needed to improve our confidence in the estimate of acceptable hatchery-salmon stray rates"*

Today, we have gained significant understanding of true rates of pink salmon straying of both hatchery and natural origins. Stray rates have been shown to be much higher in nature. Because of this, leading sustainability certification programs, including those currently reviewing hatchery impacts in PWS recognize that rates of hatchery straying are expected to be higher and accepted. To further address concerns of the public and scientific community, significant research is being conducted by ADF&G, hatchery associations and the seafood industry to understand the impacts of hatchery strays on natural stocks. Results of this ongoing research show that the overall fraction of hatchery pink salmon in PWS spawning systems is very low. After 40 years of hatchery production in PWS, natural stocks of pink salmon continue to be abundant and sustainable and initial results show that both hatchery and natural pink salmon stocks continue to maintain discreet identity.

The presence of hatchery strays in natural streams is being successfully managed by the department, resulting in achieved escapement goals and robust returns of natural fish to the sounds spawning systems. It can be reasonably ascertained that the presence of strays, even at a rate higher than 2% does not equate to harm. The fact that pink salmon stray and their feeding patterns overlap with other species is given considerable deference in approving hatchery production requests such as the one for Solomon Gulch hatchery. In addition, unlike previous denial of permit alteration requests in 2010, the department finds that SGH pink salmon stray at a much lower rate than other sound stocks. Brenner et al (2012) attributed this to SGH stocks being of early run timing, and sourced in close proximity to the hatchery site. The department has a long history of successfully managing SGH pink salmon returns to reduce straying to natural systems in the area. All of these factors contributed to the approval of the 2014 PAR.

The board is being asked to take action on what the petitioners believe is the board's regulatory authority to amend by emergency action VFDA's approved and existing hatchery permit. Exercising this perceived authority now, would be unprecedented and overwhelmingly political in nature; considering the board is limiting oral testimony and scheduled a hearing during the commercial fishing season limiting participation. The decision to grant further hearing, after repeated rulings against the finding of emergency, reflects negatively the political nature of the board process which may yield action that is neither grounded in scientific fact, based on a valid need to address allocative concerns or consistent with Alaska law.

The petitioners assert that the board and the department continue to ignore the Joint Protocol on Salmon Enhancement (#2002-FB-125) and therefore the public is owed an intervention in the matter on an emergency basis. VFDA supports a healthy public process. However, the joint protocol is irrelevant to the finding of emergency. The choice to ignore the joint protocol has been the boards, not VFDA's.

Regulatory permitting processes provide ample opportunity for public engagement on several levels. VFDA's permit increase was discussed openly at the RPT for four years. Simply because the petitioners have been unaware or have failed to participate in the process in a meaningful way are not grounds for amending our permit on an emergency basis. The board is on record to convene a full committee hearing to discuss hatchery policy at its October 2018 meeting. That is a better forum to address overarching matters of process and provide a balanced presentation of the science surrounding this issue. Adjudicating this petition, without a complete understanding of all factors, and adopting a position before then, without the opportunity for full public participation, is unfair and subverts the public process.

VFDA has followed the regulatory process available to it. The permit alteration request was well planned and discussed with the department prior to submittal. The application was vetted internally by the department, including reviews by the divisions of sport and commercial fisheries, the genetics and pathology departments and the chief fisheries scientist. The application was further reviewed by the RPT and found to warrant amendment before approval because of concerns of a lack of hatchery capacity and potential effects to ongoing straying research. This demonstrates an effective and transparent process. This scrutiny, in its totality, actually considered the same concerns brought forward by the petitioners and the permit alteration request was ultimately approved after being found to be reasonable, manageable and consistent with the state's sustainable fisheries policy. This is a matter of public record contained within the April 7th 2014 PWS RPT minutes and the department's comments of March 27th 2014.

The petitioners argue that sustainability of Alaska's resources takes priority over private investment. However, the board must consider this important factor when it has consistently been upheld that this increase constitutes a lack of emergency. VFDA has invested significant financial resources in this process to renew its infrastructure to accommodate this increased production. Approximately $1 million has been invested just to implement this specific increase of 20 million eggs this year and does not include operational costs for additional supplies and staffing. It has relied upon the state's approval to plan its finances and operations and is ready to begin its full approved permitted egg take within one week of the hearing date. Reducing or delaying the implementation of this increase will create unnecessary uncertainty for VFDA's production planning. Staying this increase is anticipated to result in a loss of approximately $2 million in annual revenue to the common property fishery assuming an average marine survival. Of much greater concern are the consequential financial impacts the finding of an unsubstantiated emergency ruling may have on the public's perception of Alaska's salmon hatchery programs.

VFDA has a long and successful history of salmon enhancement in Prince William Sound. This is well documented in the department's review titled the *"Evaluation of the Solomon Gulch Hatchery for Consistency with Statewide Policies and Prescribed Management Practices"*. VFDA operates its enhancement programs in a responsible and sustainable way and in cooperation with the State of Alaska for the benefit of many users.

VFDA strongly opposes this emergency petition and we strongly recommend that the board reject it and take no action to reduce the permitted capacity of the Solomon Gulch hatchery by 20 million pink salmon eggs in 2018.

Thank you for your consideration.

Sincerely

Mike H. Wells
Executive Director

Submitted By
Wade Quigley
Submitted On
6/27/2018 2:24:13 PM
Affiliation
Crew member on purse seine fishing vessel

Dear Board of Fisheries members,

As a crew member on a purse seining vessel I would like to voice my concerns on the proposal of reducing hatchery productions. The hatchery fisheries are the cornerstone that maintains our renewable salmon runs. Reducing the production of the salmon hatcheries in the Prince William Sound would jeopardize this and my education. Purse seining during the summer months is how I am able to afford college tuition. A diminution of hatchery production would place the future of salmon in the Prince William Sound as well as my own future in uncertainty. In the interest of the thousands who rely on salmon fisheries in the Prince William Sound do not reduce hatchery production.

Respectfully,

Wade Quigley

Submitted By
wayne smith
Submitted On
7/1/2018 2:01:14 PM
Affiliation

Phone
9072533640
Email
tebaydms3400@hotmail.com
Address
po box 419
cordova, Alaska 99574

To: Alaska Board of Fisheries

RE: Comments on KRSA et al. Hatchery Emergency Petition

Dear Chairman Jensen and Board of Fisheries Members:

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries.

Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually.

Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

PLEASE DENY THIS EMERGENCY PETITION REQUEST.

Signed,

Wayne Smith

Submitted By
Weston Carroll
Submitted On
7/7/2018 7:20:19 PM
Affiliation

Phone
907 406 0501
Email
wjcarroll72@gmail.com
Address
PO box 3013
2043 Jakes little fireweed ln
Homer, Alaska 99603

To:Alaska Board of Fisheries RE:Comments on KRSA et al. Hatchery Emergency Petition I am a life long Alaskan born in Homer in 1972 and second generation commercial fisherman in Prince William Sound. The hatcheries are a vital part of the salmon fishery and my family depends on pink salmon to make a living. I grew up fishing with my Dad in the 80's and 90's and began running my own seine boat in 1997 and have made a living as a salmon fisherman all my life, and now my own kids are now fishing to put themselves through college. I am concerned that this issue is coming up again right in the middle of our season at a time when fishermen can't attend. I am concerned that a special intetest group is trying to undermine our livelihoods and sneak the meeting in during summertime. I am concerned that there is no science to back up the claims. Seems to me if any wild stocks were going to be adversely affected by hatcheries it would be the wild stocks in Prince William sound. However in recent years we have had good wild returns. I believe Alaska has done a great job protecting and managing Alaska's salmon resources. I believe Alaska has developed successful salmon hatcheries Thank you for your time. Please protect our hatcheries. PLEASE DENY THIS EMERGENCY PETITION REQUEST Weston Carroll F/V Amber Dawn

Submitted By
William Deaton
Submitted On
6/26/2018 4:58:23 PM
Affiliation
Commercial Fisherman

Phone
907519-8469
Email
Williamgdeaton@gmail.com
Address
PO Box 874
Cordova, Alaska 99574

Board of Fish,

I oppose the emergency petition. I oppose reducing the number of fish the hatcheries can release. It is vital to the continuation of our livelihood that you oppose this as well. Do not cave to the workings of a special interest group! We are real people who will be effected by this change big time. Please do NOT support this! Thank you!

Submitted By
William Lindow
Submitted On
7/7/2018 12:41:33 PM
Affiliation

Phone
9074293000
Email
williamlindow@gmail.com
Address
PO Box 1612
Cordova, Alaska 99574

With respect to the Kenai Sportfishing emergency petition regarding Prince William Sound hatchery production, I ask that you deny to consider the petition because there is no emergency regarding the issue. It is very important that a BOF meeting to consider this issue be held in the offseason, when fishermen can prepare and attend to give their input on the subject. Thanks for considering my request.

Submitted By
William Potter
Submitted On
7/3/2018 6:29:57 PM
Affiliation

I am a commercial fisherman in Prince William Sound and depend on the area's commercial salmon fishery for my family's livelihood. 1,500 active salmon permit holders and their crew would not be able to make a living in PWS without hatchery production. Studies have shown that VFDA salmon account for 30% of PWS seiners' annual average gross earnings, while PWS seiners and gillnetters derive 64% of their gross earnings from harvesting PWSAC salmon. On many years in PWS, there would not be much fish at all if it weren't for the hatcheries. Hatchery programs are economic drivers for Alaskan communities. Studies have shown that 74% of VFDA's commercial salmon harvest value goes to Alaskan residents, with 37% going to residents of Cordova and Valdez, 23% to the Kenai Peninsula, 9% to residents of Anchorage, and 4% combined to residents from Kodiak, Mat-Su, Sitka, and Wrangell-Petersburg. It should be noted that these hatchery fish are not just benefiting commercial fisherman. According to the McDowell Group, almost 700,000 PWSAC sockeye salmon were harvested in subsistence and personal use fisheries between 1999 and 2011, with 73% of these fish going to residents of Anchorage, Fairbanks North Star Borough, and the Matanuska-Susitna Borough. Further, VFDA hatchery production accounts for 75% of all coho and 90% of all pink salmon caught by sport fish anglers in the Valdez area, and the total sport fish economic output for VFDA is estimated at $6.6 million annually. Finally, I wish to voice a concern about process. Convening an emergency meeting on this issue during the middle of our commercial salmon fishing is unreasonable and poor process, especially when the same petition has already been denied due to not meeting emergency criteria. The board has scheduled a discussion on hatchery production at the October 2018 work session. By holding this meeting in Anchorage on July 17, you have denied me and my fellow PWS fishermen an opportunity for meaningful participation.

Submitted By
William Roberts
Submitted On
7/8/2018 1:29:16 PM
Affiliation
Crew Member

Phone
9072309009
Email
freebillo17@hotmail.com
Address
11851 Galloway Loop
Eagle River, Alaska 99577

I strongly oppose decreasing hatchery production. I have been commercial fishing in Prince William Sound for the last 7 years and I depend on these hatcherys to provide a living for myself and my family.

Submitted By
Wyatt Hamilton
Submitted On
7/9/2018 3:42:12 PM
Affiliation
Commercial Setnetter

My name is Wyatt Hamilton and my family has been setnetting in Larsen Bay, Kodiak for 20+ years. To shut down the fishery would affectively inhibit me from being able to make a living, pay for college, and much more. I depend on these fish and this fishery. It is imperative that the board of fisheries hearout the Kodiak fisherman before considering such rash and irrational actions. It is even more disturbing that this even be considered amidst a busy summer of fishing when many community members do not have access to internet or the ability to comment or even time to protest and make our voices heard.

Submitted By
zachary burris
Submitted On
6/27/2018 2:22:18 PM
Affiliation
Crew member

Phone
9079523033
Email
Zcburris@gmail.com
Address
2200 northstar street
Anchorage, Alaska 99503

My name is Zachary Burris and I am a crewman on a seine vessel in the Prince William Sound. Seining has been a way for me to support myself and at the same time pay for a college education. The hatcheries fish are the majority of our catch and make up most of our profit for the year. The closure of hatcheries in the sound would result in a huge economic loss to myself and thousands of other fisherman like me. Please take this into account before jeprodizing the livelihood of the Prince William Sound fishing community.

From: Zachary Nelson
Sent: Sunday, June 24, 2018 10:43 AM
To: tsnelson6@hotmail.com
Subject: Fwd: Petition Oposition

RECEIVED
JUL 03 2018
BOARDS

Sent from my iPhone

Begin forwarded message:

> **From:** Zachary Nelson <zwn.polaris600@gmail.com>
> **Date:** June 24, 2018 at 10:32:13 AM AKDT
> **To:** dfg.bof.comments@alaska.gov
> **Subject: Petition Oposition**
>
> Members of the Board of Fisheries,
> I am sending this email to strongly oppose the petition to limit pwsac hatchery production. The hatcheries in Prince William Sound and around the state are extremely important for run stability and creation of revenue for the fisherman, processors, and the state. There is no proven science that hatchery pinks affect any other species or runs around the state. Until such science is proven and verifiable there is no reason to limit pwsac output and production, the hatcheries are only benefits to all involved.
>
> Zachary Nelson Box 1392
> Homer, Alaska
> 99603
>
> Zach Nelson
>
> PWS Crew Member