

Reference for Pink Salmon Origins

Chairman Wood, Members of the board:

As per your request, please find the following five pages from the paper *titled "High Ocean Biomass of Salmon and Trends in Alaska Salmon in a Changing Climate"* authored by Alex Wertheimer and William Heard.

The reference for my testimony stating that hatchery pink salmon comprises 15% of all pink salmon, the remaining 85% are of wild origin, can be found on Page 5 of this document.

The full document was submitted at the October 15-17 2018 BOF work session as PC069. The link to the entire document can be found here:

<https://www.adfg.alaska.gov/static/regulations/regprocess/fisheriesboard/pdfs/2018-2019/ws/pcs50-99.pdf>

Thank you

Mike Wells

Board of Fisheries

October 15-16, 2018

Work Session Anchorage, Alaska

Dear Chairman Jensen and Board of Fish Members:

In the interest of understanding the complex topic of Ocean Carrying Capacity (OCC) this document written by two career fisheries research scientists is presented.

High Ocean Biomass of Salmon and Trends in Alaska Salmon in a Changing Climate

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EXECUTIVE SUMMARY

The abundance and biomass of wild and hatchery pink, sockeye, and chum salmon in the North Pacific Ocean has been higher in the past 2.5 decades (1990-2015) than at any time in the 90-year time series. The high biomass has been remarkably consistent from 1990-2015. There has been higher variability in numbers of salmon than in biomass due to the variability in pink salmon abundance. The high sustained abundance and biomass is driven in no small part by historically high abundance of Alaska salmon, and corresponds with the renaissance of Alaska salmon fisheries from their nadir in the 1970s. Statewide commercial catches of salmon were just 22 million fish in 1973; for 1990-2015, statewide catches have averaged 177 million salmon, an eight-fold increase.

This remarkable recovery and historically high abundance of Alaska salmon can be attributed to five major factors: (1) large expanses of relatively pristine and undeveloped habitats; (2) salmon management policies that have evolved since statehood; (3) the elimination of high seas drift-net fisheries; (4) production from large-scale hatchery programs designed and managed to supplement natural production; and (5) favorable environmental conditions associated with the 1977 “regime shift” affecting the ecosystem dynamics of the North Pacific Ocean. Habitat, management, and enhancement set and maintain the productive capacity that responds to marine environmental conditions: ocean “carrying capacity”.

Carrying capacity has been defined as the ability of an ecosystem to sustain reproduction and normal functioning of a set of organisms. Ocean carrying capacity for Pacific salmon is not a fixed productivity limit, and the considerable regional and temporal variability in salmon stocks is a response to non-homogeneous ocean conditions. Over the past few decades, conditions in the North Pacific Ocean have

been generally favorable to Pacific salmon as reflected by the sustained high abundances and catches. However, extremes in survival and production have occurred both temporally and geographically. Survival and year-class strength of salmon is the result of responses to local, regional, and basin scale conditions. Marine conditions vary geographically and temporally within a given year, interannually, and in the context of oceanographic regimes favorable or unfavorable to salmon production.

There are concerns that the high abundance in the North Pacific Ocean, coupled with high variability in stock performances, indicate that carrying capacity is being exceeded, and that competitive interactions are negatively affecting growth and survival. These concerns have been raised for over 20 years. Rather than indicate that carrying capacity has been exceeded, the trend of the past three decades show that the North Pacific Ocean has had the capacity for the recovery and sustained production of wild stocks while supporting the expansion of large-scale enhancement production from Japan (chum salmon) and Alaska (chum and pink salmon).

A proposed mechanism for negative impacts of high abundance of salmon in the ocean is that their feeding capacity alters the biomass of oceanic zooplankton, and in turn the phytoplankton biomass. In this scenario, this “trophic cascade” and alteration of food webs then negatively impacts other species, including coho and Chinook salmon. The record numbers and abundance of Pacific salmon can appear to be an imposing load on the North Pacific Ocean ecosystem. However, assessments of nektonic trophic structure in the Gulf of Alaska and the western North Pacific Ocean indicate that salmon have low to moderate impacts on oceanic food webs, and they respond to, rather than control, changes in ocean productivity.

Pink salmon have been identified as a keystone predator restructuring oceanic food webs to the detriment of other species. Four lines of evidence call this conclusion into question. First, Russian researchers report that in extensive ocean research programs, they have found typically no significant correlations occur among pink salmon growth rate, stock abundance, or zooplankton standing crop. Second, high numbers of pink salmon in the North Pacific Ocean have been associated with record run sizes and continued sustained biomass of salmon, rather than a reversal in these trends when pink salmon abundance increased. Third, pink salmon have shown the greatest variation in abundance among Alaska salmon, especially in response to anomalous ocean conditions. Thus rather than restructuring the food webs, they appear to be the most sensitive to changes in marine conditions. Finally, the high predation pressure of pink salmon in the context of epipelagic food webs is justified because other species, especially chum and sockeye salmon, switch to other, poorer quality prey items when pink salmon are abundant. However, the obvious implication is that these other species will “switch back” to the prey with higher nutritional value when pink salmon are at lower levels of abundance. Because chum and sockeye salmon comprise almost 80% of the oceanic biomass of salmon, salmon predation pressure on the “high value” prey remains relatively constant.

Effects of pink salmon abundance are often used as a proxy for deleterious effects of large-scale enhancement in general. In fact, while pink salmon are the most numerous of the salmon species in the North Pacific Ocean, wild stocks of pink salmon contribute some 85% of the overall abundance.

Density dependent interactions have been identified within and between species of salmon. These interactions have been observed during both periods of low and high abundance. Changes in size, survival and age at maturity have been attributed to these interactions. Despite the existence of

competitive interactions in the marine environment, high productivity of Alaska salmon has persisted during this period of high abundance. In general, size declines of pink and chum salmon occurred prior to the 1977 regime shift, and thus are associated with poorer ocean conditions rather than ocean abundance of salmon, and sockeye salmon size has been stable over the past 60+ years.

There is also concern that the high ocean abundance of the big three (pink, chum, and sockeye salmon) negatively impact coho and Chinook salmon in Alaska. For coho salmon, size declines in Southeast Alaska have been linked to pink salmon abundance in the Gulf of Alaska, while in Canada recent size increases in coho salmon have been positively associated with the combined biomass of pinks, chums, and sockeye salmon. The high correlation of run strength between coho and pink salmon in Southeast Alaska is strong evidence that their abundance is driven by similar overall response to shared marine conditions. Density-dependent mechanism other than competition may also play a role in pink salmon/coho salmon dynamics. These include such as predator sheltering of coho salmon juveniles by the more abundant pink salmon juveniles (decreasing predation on coho juveniles), predator aggregation (increasing predation on coho juveniles), and direct predation of coho juveniles and adults on pink salmon juveniles.

Chinook salmon stocks in Alaska have been depressed in recent years due to reduced marine survival, and have declined in size at age for older fish, and age at maturity. These changes are not likely driven by the high abundance of salmon in oceanic habitats. Chinook salmon, by their propensity to utilize deeper depth strata and distribute more broadly on shelf and slope areas during marine residency, are segregated to a large degree from other salmon in their use of ocean habitats with correspondingly different temperatures, prey fields, and predator complexes. Size of Chinook salmon at ocean age 2 has not declined, indicating no density-dependent effect on growth through the first two years at sea. Size declines at older ages are more consistent with selective removal of older, larger fish.

Survival declines of Chinook salmon occurred well into the period of high ocean biomass. There is substantial evidence that much of the variation in Chinook salmon marine survival is due to conditions in the first summer and winter at sea. Changes in the North Pacific ecosystem, such as increased killer whale predation, could introduce more mortality at older ages, and further depress realized survival during periods of poorer environmental conditions for Chinook salmon.

Favorable ocean conditions rather than density-dependent interactions seem to be driving both the high abundance at the basin-scale and the high variability in salmon populations at local and regional scales. Recent climatic and oceanographic events such as the marine heat waves of 2004/2005 and 2014/2015 in the Gulf of Alaska are demonstrative of the intrinsic variability of ocean conditions affecting salmon at local and regional scales. Will density-dependent interactions become increasingly important if and when ocean conditions become less favorable to salmon, with large releases of hatchery fish putting wild stocks in more jeopardy? Or will hatchery fish provide a buffer to sustain fisheries when wild stock productivity is low in response to varying environmental conditions? We conclude the latter, because there is empirical evidence that large releases and returns of hatchery pink salmon in years of both low and high wild stock abundance did not limit the production potential of the wild stocks.

Introduction

The Alaska Board of Fisheries (BOF) was recently petitioned to hold an emergency meeting asking the BOF to amend actions taken in Permit Alteration Requests (PARs) made by the Prince William Sound (PWS) Regional Planning Team and deny the increase in the number of pink salmon eggs taken in 2018 by 20 million eggs. One of the rationales the petitioners used for rescinding the PAR was "... 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." To support this concern, the petitioners provided references to record high abundance and biomass of salmon in the North Pacific, as well as possible density-dependent effects of pink salmon on the trophic structure in the North Pacific Ocean and intra-specific and interspecific competition of pink salmon with other species of salmon and seabirds.

The BOF held the emergency meeting on July 17, 2018, and denied the request for rescinding the PAR. The BOF determined there was no need for such an emergency action, and deferred further consideration to the review of the State's salmon enhancement program scheduled for the October 2018 work session. The intention of that review is for members of the BOF to educate themselves about the program and understand the science the enhancement program is predicated on and the current scientific evaluation.

This paper provides a brief, broad overview of the issue of record abundance and biomass of Pacific salmon and the implications for the status of Alaska salmon. We present this overview in six sections. The first is a review of the recent information on abundance of salmon in the North Pacific. The second is an examination of trends in harvest of Alaska salmon, including enhanced production. The third is a discussion of oceanographic conditions and the concept of "carrying capacity" for salmon in the North Pacific. The fourth is a perspective on the relative role of salmon as a component of the North Pacific ecosystem. The fifth looks at intra- and interspecific competition and density dependence among salmon species, and its possible impacts on growth and abundance. The sixth section summarizes our conclusions from this overview.

I. High Abundance and Biomass of Salmon in the North Pacific Ocean

In a recent paper, Ruggerone and Irvine (2018) published an excellent compendium of the available data on numbers and biomass of pink, chum, and sockeye salmon in the North Pacific Ocean over the time period 1925 through 2015. The authors have compiled 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 found 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, averaging 665 million adult salmon each year ($1.32 \times$ million metric tons) during 1990–2015 (Figure 1). During 1990–2015, pink salmon dominated adult abundance (67% of total) and biomass (48%), followed by chum salmon (20%, 35%) and sockeye salmon (13%, 17%). When immature salmon biomass was included in the biomass estimates, biomass was dominated by chum salmon (60% of the combined biomass of all three species),

followed by pink salmon (22%) and sockeye salmon (18%).

The high biomass has been remarkably consistent over the 1990-2015 time period. There has been higher variability in numbers of salmon than in biomass due to the variability in pink salmon abundance.

Alaska produced approximately 39% of all pink salmon, 22% of chum Salmon, and 69% of sockeye salmon, while Japan and Russia produced most of the remainder. Approximately 60% of chum salmon, 15% of pink salmon, and 4% of sockeye salmon during 1990–2015 were of hatchery origin. Alaska generated 68% and 95% of hatchery pink salmon and sockeye salmon, respectively, while Japan produced 75% of hatchery chum salmon. Salmon abundance in large areas of Alaska (PWS and Southeast Alaska), Russia (Sakhalin and Kuril islands), Japan, and South Korea are dominated by hatchery salmon. During 1990–2015, hatchery salmon represented approximately 40% of the total biomass of adult and immature salmon in the ocean.

In the context of concern for the impacts of hatchery fish on wild salmon and the North Pacific ecosystem, we reiterate three facts about pink salmon noted above. Pink salmon are the most abundant of the species, have the greatest temporal variability in abundance, and are mostly (85%) wild origin (Ruggerone and Irvine 2018). As we will discuss below, the high variability of pink salmon and differences in abundance between odd-year and even-year lines is often used to examine competitive interactions and ecosystem level impacts of salmon in the North Pacific. At the basin-scale, to the extent that such effects may occur, effects of pink salmon are predominately from wild-stock populations rather than from enhanced fish.

II. Trends in Harvest of Alaska Salmon

The high sustained abundance and biomass in the North Pacific Ocean reported by Ruggerone and Irvine (2018) is driven in no small part by historically high abundance of Alaska salmon. It is instructive to put the current levels of salmon harvest into perspective of the 115 year time series of Alaska commercial salmon harvests (Figure 2), to recognize the extent of recovery and extraordinary recent productivity of Alaska salmon. In the early 1970's, Alaska salmon harvests were at their nadir, with statewide catches of all species averaging just 22 million fish in 1973 and 1974 (Figure 2). In the “good old days” of the 1930s, catches sometimes exceeded 100 million. The State of Alaska initiated a number of management actions to address the decline and rebuild production (Clark et al. 2006), with a goal of once again reaching harvests of 100 million salmon. In 1971, the Alaska Legislature established the Division of Fisheries Rehabilitation Enhancement and Development (FRED) within the Alaska Department of Fish and Game (ADF&G) for hatchery development. In 1972, Alaska voters approved an amendment to the state Constitution (Article 8, section 15), providing for an exemption to the “no exclusive right of fishery” clause, enabling limited entry to Alaska’s state fisheries and allowing harvest of salmon for broodstock and cost recovery for hatcheries. In 1974, the Alaska Legislature expanded the hatchery program, authorizing private nonprofit (PNP) corporations to operate salmon hatcheries.

Alaska's modern salmon hatchery system started in the 1970s and grew out of depressed fisheries that reached record low harvest levels. At the same time a century old Japanese salmon hatchery system was undergoing dramatic improvements in performance with record high marine survivals of young salmon, increased releases of up to 2 billion juveniles per year, and returns of adult chum salmon ranging from