WRITTEN TESTIMONY OF
Katrina Hoffman, President and CEO, Prince William Sound Science Center and
Executive Director, Prince William Sound Oil Spill Recovery Institute

HEARING ON
The State of our Salmon: A Review of the Science and Data Informing the Management of Alaska's Salmon Fisheries.

BEFORE THE
Subcommittee on Oceans, Atmosphere, Fisheries, and Coast Guard

submitted October 18, 2018

Introduction

Good morning Chairman Sullivan, Ranking Member Baldwin, and Members of the Subcommittee. Since our founding in 1989, the Cordova, Alaska-based Prince William Sound Science & Technology Institute (dba Prince William Sound Science Center, and referred to as "the Science Center" or PWSSC) has focused the vast majority of our work on ecosystem research and science education in our heavily spill-affected region. We are the only place-based research and education institute on Prince William Sound, and we now have three decades of experience studying the region. In our first 29 years, the organization has generated more than $90 million in direct expenditures related to our work. We are driven by our vision of communities that maintain socioeconomic resilience among healthy ecosystems.

Cordova remains economically the hardest hit community in the wake of the *Exxon Valdez* Oil Spill. Numerous species have yet to recover from the spill, and environmental conditions, including climate change, are impacting our region – including salmon – in unprecedented and unanticipated ways. To fully understand these changes and to help management agencies and communities adjust appropriately, more long-term research must be conducted in Alaska.

Conclusions from our current research:

- Rapid environmental changes are occurring in Alaska. Unprecedented ocean conditions have characterized the northeast Pacific Ocean in recent years including anomalously warm sea-surface temperatures 2-3 ºC above the long-term average, known as the "Warm Blob" or "the Blob".
- We know that Prince William Sound is changing: the North Pacific Ocean in general is warming at about a fifth of a degree per decade, we see that signal in the waters flowing

into the Sound from the Gulf of Alaska.

- Glaciers and ice sheets that surround the perimeter of Prince William Sound are melting at rates as high as anywhere else in the world – enough that we see marine waters near those glaciers becoming cooler and fresher as a result of the runoff. This impacts the typical function of the marine ecosystem.
- The recent marine heat wave, colloquially referred to as "the Blob," gives us a hint of what we can expect as the ocean continues to warm. We saw big changes in the surface ocean: productivity was down, nutrients were not used up by living organisms; plankton that are more common off Oregon and California became prevalent in the northern Gulf of Alaska; toxin-producing algae blooms appeared; and there were huge die offs in marine birds and mammals. Recent, unexpected declines in Alaska fisheries, including collapsing Pacific cod populations and historically low returns of salmon in the region, may be cascading effects of the Blob.
- Our research suggests that fish exposed to anomalously warm coastal waters in their first year in the ocean made them more likely to suffer effects from competitive interactions with pink salmon. We have also documented slower growth rate (as measured on scales) of several key populations of sockeye salmon in the Gulf of Alaska during the years influenced by the Blob.
- At-sea food web interactions among natural- and hatchery-origin salmon are important as they can shape salmon body size, overall quality, and survival and spawning success. This topic is a major knowledge gap. We are keen to extend our pilot work with future studies that will examine similar relationships between at-sea foraging and performance correlates, such as body condition, migratory timing, timing of residence in spawning streams, and investment in reproduction, among natural- and hatchery-origin Pink Salmon over multiple years including both high and low run years for Pink Salmon, as well as for Chum and Sockeye Salmon that return to the Prince William Sound region.
- We feel that further study of these issues and reduction of these knowledge gaps is highly relevant to the interests and needs of a variety of salmon stakeholders in the State of Alaska.
- In addition, we believe a new program of research focused on ecosystem shifts, especially those associated with the loss of glacial ice and subsequent ecosystem impacts, including those affecting salmon, is necessary for our region.

Ecosystem Shifts in the Face of Climate Change

Climate change is affecting ecosystems and salmon in Alaska in a variety of ways. One of the most dramatic changes is associated with the loss of glacial ice. The most obvious change is the exposure of new terrain as the glaciers recede. Less obvious, but just as important, are changes in freshwater flow, water temperatures, water chemistry, water clarity, and nutrient supplies downstream of the glaciers. The ecosystems from glaciers to the ocean thus have to adapt to the loss of ice. There is a recolonization of the land by a succession of plants. New lakes, rivers, and streams form that are eventually inhabited by macroinvertebrates and fish, including, potentially, salmon. As glaciers disappear, the source of water shifts from melting ice to snow melt and rain. This leads to altered stream and river flow regimes. The changes in streamflow affect organisms reliant on that water. Changes in freshwater input, minerals, and nutrients carried by the streams or released by glaciers also have impacts on ocean properties and ocean productivity due to changes in ocean chemistry and the physical structure and interactions of different seawater layers.

In the northern Gulf of Alaska region, including Prince William Sound and the Copper River basin, we have glaciers in all stages of loss, and changes in the cryosphere are driving changes in ecosystem function and ocean productivity. For example, the Columbia Glacier is a rapidly retreating tidewater glacier that is exposing miles of new land each decade. We also have hanging glaciers in which the ice is nearly gone, resulting in altered freshwater flow regimes as streams become more influenced by rainfall or rapid melting, flooding, and scouring. The human communities in the region are highly dependent on natural resources, particularly salmon, that must adapt to the changing environment. Changes in ocean chemistry may even influence the ability of salmon to home to their natal streams, and more acid ocean conditions complicate the matter further.

It would be beneficial to support further research focused on these ecosystem shifts, including those associated with the loss of glacial ice. While this is a very large and complex problem, there are many aspects that can be separated that will allow for a series of focused research projects to address the theme in an integrated fashion. Even when focusing on a single species, such as salmon, there is much to learn. The opening of new streams and lakes provide new spawning and rearing habitat. How long does it take for those new habitats to support new fish runs? How does the shift in source of freshwater affect the survival of salmon? Does salmon run timing have to shift with changes in the timing of river outflow cues? There are many unanswered questions. Additional knowledge gained can help humans continue to utilize the resources in a sustainable manner while adjusting to novel conditions.

Environmental Drivers

The deep waters of the Gulf of Alaska are the northern extent of a huge global conveyor belt that takes about 1,000 years to cycle. This source of seawater, combined with a constant rain of organic material from the surface, results in nutrient-rich waters upwelled to the surface. The nutrients drive the productive marine ecosystems of the Gulf of Alaska region, which in turn drive the many fisheries that are a cornerstone of the Alaska economy. Those deep waters are, however, lacking in one element, iron, a micronutrient that is required by marine producers to take up other nutrients and grow. Iron comes from the weathering of rock, and is present in high concentrations in the freshwater that washes out into the coastal margin of the Gulf of Alaska. In the central Gulf of Alaska, far from shore, iron must be delivered by atmospheric transport of aerosol dust. One potentially large source of aerosol iron from Alaska is glacial flour: the fine, powdery, crushed rock produced by ice grinding on bedrock. Wind storms are able to carry that glacial flour hundreds of miles out into the North Pacific, into the iron-limited region. Such storms are visible in satellite imagery, and in our region, the dust deposited from the Copper River basin into the northern Gulf of Alaska has a measurable effect on ocean productivity. The iron-rich dust provides an injection of nutrients that can support more robust growth of plankton, known as primary productivity. These plankton are the food upon which some salmon prey. There is a delicate interplay between ice, rock, weather, and water that actually supports marine life and salmon fisheries.

We know that the landscapes of our watersheds are changing. Glaciers and ice sheets are shrinking and receding; colonizing plants are moving into those new habitats. Those landscape changes will manifest in the ocean as a change in iron transport, and thus marine productivity. With the initial retreat of glaciers, as we are now seeing, we might expect an initial increase in iron transport as glaciers recede and glacial flour is mobilized. But as those colonizing plants move in, the glacial flour will become bound up in soils, and iron transport will decrease. It is unknown what the impact of this change will be on marine productivity.

Prince William Sound is the nursery to several hundred million salmon smolts that enter it each year from the numerous streams and hatcheries around its periphery. The environment that salmon smolts encounter is critical to their life history as they proceed to the Gulf of Alaska to continue their life cycle. We know that Prince William Sound is changing: the North Pacific in general is warming at about a fifth of a degree per decade. We see that signal in the waters flowing into Prince William Sound from the Gulf of Alaska. At the same time, the glaciers and ice sheets that ring the Sound are melting, at rates as high as anywhere else in the world – enough that we see marine waters near those glacier rivers cooling and becoming fresher. We suspect that this is changing the way the surface oceanography in Prince William Sound works, but don't have a good understanding of what this will do to the marine ecosystem and salmon productivity. Our oceanographic efforts right now are focused on observing Prince William Sound as it changes, using a combination of vessel surveys and automated robotic observations. We are watching how changes in the physical environment are changing the way nutrients move around, how material and energy moves through the food web, and how the major players in the upper trophic levels are responding to these changes.

Observing Marine Ecosystems

We are now able to observe marine ecosystems at unprecedented scales. Every spring, PWSSC deploys a robotic profiling float in the middle of Prince William Sound. It measures temperature, salinity, oxygen, nutrients, and plankton concentrations from a depth of 200 feet to the surface, taking measurements every two inches. The moored profiler does that twice per day. If ocean conditions permit, it will transmit some of that data after every profile. With that profiler we are able to watch the annual cycle of marine productivity in near real time. We see all the nutrients in the surface layer become depleted as the single-celled phytoplankton that drive the base of the marine food web use it up. We are able to watch as different types of zooplankton grazers come and go. Some are important food for species higher up in the food web – the cod, salmon, herring and halibut that consume plankton directly as young fish, not to mention the many other fish, birds and mammals that prey on these plankton consumers. The technology now exists to do this at much larger scales—to monitor the nutrients and productivity that makes up the base of our extraordinarily productive marine ecosystem. Understanding this base of the food web gives us a picture of how much of that productivity will be available to the players higher up in the food web—things like salmon, that in part drive our region's economy. Tracking every fish in the sea is hard; tracking how much food is available to them is much easier.

The recent marine heat wave, colloquially referred to as "the Blob," gives us a hint of what we can expect as the ocean continues to warm. We saw big changes in the surface ocean: productivity was down, nutrients were not used up; plankton that are more common off Oregon and California became prevalent; toxin-producing algae blooms appeared; there were huge die-offs in marine birds in Prince William Sound. We are now seeing what are likely cascading effects of “the Blob” in our fisheries: Pacific cod populations have collapsed, and there have been historically low returns of salmon in the regions impacted by the Blob.

Salmon Ecology

Via the NCEAS SASAP Working Group (Ocean/Climate effects on salmon), we have detected strong effects of ocean temperature (during 1st year in the ocean) and densities of pink salmon in the ocean on productivity of sockeye populations in the Gulf of Alaska. Further, we found an interaction between these two variables, suggesting that fish exposed to anomalously warm coastal waters in their first year in the ocean made them more likely to suffer effects from competitive interactions with pink salmon. We also documented slower growth rate (as measured on scales) of several key populations of sockeye salmon in the Gulf of Alaska during the years influenced by the Blob.

In addition, we have conducted research via funding we obtained in 2016 through the National Fish and Wildlife Foundation for a one-season pilot study focused on examining the at-sea foraging strategies of natural- and hatchery-origin adult Pink Salmon (Oncorhynchus gorbuscha) returning to the Prince William Sound region of Alaska using stable isotope analysis. This study was an initial effort that extended the work being conducted by the Alaska Hatchery Research Program (AHRP) to begin developing a mechanistic perspective regarding Pink Salmon fitness variation by considering at sea foraging determinants of performance in migration and reproduction. Our results indicate that in 2015, a high run Pink Salmon year, strong relationships existed between muscle $\delta 13C$ and $\delta 15N$ stable isotope values and the body size of Pink Salmon, with hatchery-origin Pink Salmon being smaller than natural-origin fish. However, relationships were not evident between marine foraging and body condition (size corrected body weight) of either natural- or hatchery-origin Pink Salmon. On-going analysis is examining relationships between tissue-specific stable isotope values and investment in reproduction such as gonad weight, fecundity and egg size.

Additionally, this pilot study begins to fill a major knowledge gap regarding overlap in at-sea food preferences by natural- and hatchery-origin Pink Salmon as density dependent impacts of ocean ranching practices in Alaska, particularly those occurring at-sea, have not been extensively considered and are not specifically addressed by the AHRP research program. At-sea food web interactions among natural- and hatchery-origin salmon are important as they can shape salmon body size, overall quality, and survival and spawning success. This topic is a major knowledge gap and PWSSC researchers are keen to extend our pilot work with future studies that will examine similar relationships between at-sea foraging and performance correlates, i.e., body condition, migratory timing, timing of residence in spawning streams, and investment in reproduction, among natural- and hatchery-origin Pink Salmon over multiple years including both high and low run years for Pink Salmon, but also similar relationships for sympatric Chum and Sockeye Salmon returning to the PWS region. Salmon food web relationships were recently highlighted as key, needed information. Thus, we feel studies such as ours are highly relevant for filling knowledge gaps that are currently of interest to a variety of salmon stakeholders in the State of Alaska.

Through funding support by Alaska INBRE (Idea Network of Biomedical Research Excellence) at the University of Alaska, PWSSC researchers are currently engaged in a pilot study that is exploring ecological dynamics between reductions in the body size of adult Sockeye Salmon (O. nerka) returning to spawn in the Copper River, Alaska, and energy density, pathogen loads, and reproductive fitness trade-offs among short and long distance Sockeye migrants.

Rapid environmental changes are occurring in Alaska. Unprecedented ocean-climate conditions have characterized the northeast Pacific Ocean in recent years including anomalously warm sea-surface temperatures 2-3 ºC above the long-term average. The impacts of ocean acidification are exacerbated in Alaska. In the Gulf of Alaska region, cold water temperatures and significant freshwater input from glacial discharge can influence alkalinity and carbonate ion concentrations in seawater, which has important implications for the structure and function of marine food webs. Stressful environments can magnify the impacts of infectious agents on fish populations. Recent scientific reviews highlight the increasing concern for understanding how environmental change might alter the severity or distribution of diseases in aquatic animals. It is notable that research focused on infectious agents has not been widely conducted on Alaskan salmon stocks, despite extensive hatchery aquaculture practices and the importance of robust salmon populations to Alaskan livelihoods.

To this end, PWSSC researchers are conducting pilot research that is a first of its kind for the State of Alaska by employing a recently developed, high throughput, molecular microfluidics approach to quantify globally-significant pathogens such as viruses, bacteria, fungal and protozoan parasites in Sockeye salmon of the Copper River. Copper River Sockeye are an economic cornerstone of the commercial salmon fishery in southcentral Alaska and also sustain active subsistence fisheries in the upper reaches of the watershed, some of which are moderately enhanced by the Gulkana hatchery. Since the mid-1990's, there has been a notable long-term decline in the size at age of adult Sockeye returning to the Copper River, with marked declines in body size occurring in recent years (2015 – 2018). Recent reductions in body size of returning adult Copper River Sockeye has coincided with an unprecedented oceanic heatwave throughout the northeast Pacific Ocean. Body size and energy density of adult Sockeye have been negatively related to warmer sea surface temperatures during the last year of ocean residency, and recent studies have confirmed growth impacts to Sockeye due to density-dependent competition at-sea. Research on salmon in British Columbia, Canada, has already revealed striking relationships between physiological variation and survival during spawning migration by Sockeye of the Fraser River, possibly as a result of viral infection. Thus, our pilot research aims to couple physiological variation in returning Copper River Sockeye, with information on the diversity and loads of pathogens that these fish carry to understand mechanisms contributing to spawning migration success and performance. This initial work on salmon pathogens will lead to important future research to be conducted on all salmon species in Alaska and at various life stages from young emerging in freshwater systems, to adults during their ocean residency and return spawning migration.

Finally, we are looking at reproductive traits in wild and hatchery pink salmon in PWS via a University of Alaska—Fairbanks collaborative study. In two streams in western PWS, we are quantifying stream life (the number of days adult pink salmon are alive and spawning in streams) and determining if there are differences among individuals that differ in their origin (natural- or hatchery-origin). Stream life is thought to be positively related to reproductive fitness. We conducted a pilot project in a single stream in 2017, and executed a full field program in 2018 in two separate streams. Results will be included in a UAF thesis. This work is important in that it may elucidate mechanisms that could explain fitness differences, and thus complements the larger AHRP effort.

Other Work

Salmon Monitoring For Management

The Science Center, in collaboration with the Copper River / Prince William Sound Marketing Association (a Regional Seafood Development Association funded by Area E permit holders) and with recent support from the NOAA Saltonstall-Kennedy program, deploys a pair of imaging sonars in the lower Copper River delta to count salmon during the start of the Copper River run. The sonars complement ADF&G sonars several miles up river and give state fisheries managers near real-time information on salmon escapement that they can use when deciding on the timing and duration of fisheries opportunities. Copper River salmon are the first major salmon fishery to market, and early season fish are exceedingly valuable. Each fishing opportunity generally means several hundred thousand, to over a million dollars added to the local economy alone.

ADF&G AHRP (H-W) Project

PWSSC just completed the 6th year of field sampling under contract to the ADF&G. This work included test fishing at the PWS entrances (Hinchinbrook and Montague) in addition to monitoring in over 30 streams across PWS. The focus of the project was on quantifying the fraction of hatchery-origin pink and chum salmon in the run (entering PWS) and in the spawning populations in streams. This work resulting in the most rigorous assessment to date of the scale and magnitude of straying of hatchery-origin salmon in this ecosystem. The project also involves sampling tissues to assemble DNA-based pedigrees to compare relative reproductive fitness in pink salmon families whose parents differ in origin. This work will provide some insight into whether families composed of hatchery-origin parents are less fit than those completing their entire life cycle in natural habitats. PWSSC have produced annual reports on this project (posted on the ADF&G website) and we are currently finalizing two manuscripts (on PWS and SE Alaska) that will be reviewed by the AHRP Science Panel and submitted to a scientific journal for peer-review.

Salmon Under Climate Change Impacts

The plumes of meltwater that stream out from tidewater glaciers are a double threat for ocean acidification: They do not contain much calcium or carbon dioxide. Being calcium poor, meltwater tends to be corrosive to calcium in general, and being low in carbon dioxide means that when those water do take up carbon dioxide from the atmosphere, they tend to become even more acidic as the carbon dioxide is converted to carbonic acid. That is bad news for any marine organism with a calcium carbonic shell, because their shell will be dissolved by those acidic waters. Prince William Sound alone has lost many cubic kilometers of ice in the last two decades, and glaciers and ice sheets continue to recede; this problem can be expected to get worse, not better as time passes.

The productivity in the marine ecosystem of the Gulf of Alaska each year is set up in part by the size and duration of the “spring bloom”: an explosion of growth by primary producers that proceeds until all the nutrients in the surface waters are used up. The size of that spring bloom in many ways sets up the amount of production that will make its way into higher trophic levels like fish. A better understanding of the timing and magnitude of that bloom will give us a better idea of the state of the ecosystem, and improve our ability to forecast fisheries productivity.

Conclusion

Rapid environmental changes are occurring in Alaska. Unprecedented ocean conditions have characterized the northeast Pacific Ocean in recent years including anomalously warm sea-surface temperatures 2-3 ºC above the long-term average. We know that Prince William Sound is changing: the North Pacific in general is warming at about a fifth of a degree per decade, we see that signal in the waters flowing into the Sound from the GOA. Our research suggests that fish exposed to anomalously warm coastal waters in their first year in the ocean made them more likely to suffer effects from competitive interactions with pink salmon. We also documented slower growth rate (as measured on scales) of several key populations of sockeye salmon in the Gulf of Alaska during the years influenced by the Blob. We feel more studies are highly relevant for filling knowledge gaps that are currently of interest to a variety of salmon stakeholders in the State of Alaska. In addition, we believe a new program of research focused on the ecosystem shifts, especially those associated around the loss of glacial ice and related to salmon, is necessary for our region.

As part of this research, we believe that to truly get a picture of what is happening we need to take in place measurements at different depths – not just remote-sensing. This will allow us to understanding interactions between wild and hatchery salmon - in PWS and GOA and on the spawning grounds. This needs to be broad, and include oceanographers, ecologists, pathologists, geneticists, fishery managers, and hatchery operators. More work on key fitness components (spawning, hatching and early life history, resistance to pathogens, etc.) should be undertaken to help elucidate any differences that might exists between wild, natural-origin, and hatchery-origin salmon in PWS. We must also look at ocean effects on salmon - growth and competitive interactions at sea. NOAA has substantial resources, and groups like PWSSC could collaborate, focusing on linkages between PWS and GOA, for example. In addition, we must look at migratory and reproductive performance of salmon in changing river conditions, including glacially-influenced rivers like the Copper or smaller coastal streams like many in PWS, while also engaging economic studies of salmon management practices, to maintain our regional resilience and presence as a global leader in salmon management.

Thank you.