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Wrap-Up Presentation Given at the Conclusion of the Workshop

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I think it is only fitting to start this wrap-up session by first expressing gratitude and thanks to each of the presenters, both oral and poster, for the wide range of excellent presentations focused on migrations and survival mechanisms of juvenile salmon and steelhead in ocean ecosystems. Such presentations are not easy, and what sometimes seems a thankless task involving long hours, weeks, months, even years of research, analysis, and focused effort is needed to make such good presentations. I think it is appropriate that we extend our sincere thanks to all those who have worked so long and hard to make this workshop a success.

This is the third NPAFC workshop on juvenile salmon, and the first to include a focus on steelhead. The first workshop held in Tokyo in 2000 was followed by an in-depth research review of the early marine period of Pacific salmon by Canada, Japan, Russia, and the United States, which was published in 2003 as NPAFC Bulletin 3. The second workshop on juvenile salmon was held in 2006 in Sapporo. And, given the amount of research completed since then, the timing of this workshop is very appropriate as evidenced by the breadth of significant new information we have heard over the past two days. While it is impossible for me to cover all the new findings and insights presented at this workshop, not to mention new insights into some older concepts, I will try to summarize some salient issues covered by keynote presentations from Asia and North America, and touch on a few key ideas covered under the six workshop topics.

My head is still spinning over the extent of information Vladimir Radchenko presented about new Asian research on juvenile salmon. Among other things, he reviewed Russian trawl surveys that described concentrations and migration patterns of juveniles for many stock groups of Asian salmon in the Okhotsk and Bering seas. Those surveys were especially effective for Asian pink salmon stocks by providing a strong basis for making annual forecasts of adult returns to Kamchatka and Sakhalin rivers. Russian surveys in winter and early spring have expanded our knowledge of juvenile and immature salmon biology during these periods, and additional surveys in late spring and summer have provided data for differentiation of stock groups and forecasting updates. Increased abundance of pink salmon from eastern Kamchatka has not changed the role of salmon in the trophic structure of epipelagic nekton communities in the western Bering Sea. Some changes in prey were noted in years of high salmon abundance, but this did not influence growth and survival of juvenile salmon. The food supply for juvenile salmon and micronekton in waters of far-eastern seas and the northwestern Pacific is much higher than the total food consumed by all epipelagic nekton. Food resources consumed by juvenile salmon represent a minor part (1-2%) of the total macro-zooplankton biomass.

I sense that our Russian colleagues, based on their research in the western Pacific involving extensive year-round ocean surveys 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. This doesn't mean, however, it can't change in the future.

Marc Trudel's survey of North American research since the 2006 workshop indicated that Chinook and coho salmon have received the most attention. This also turns out to be true for many North American presentations and posters at this workshop, a reflection of increasing concern over population and stock declines of these species over broad geographic regions, including Alaska. Marc reported progress in understanding stock–specific migration behavior of juveniles, and showed how DNA analyses, tags, and biophysical attributes provide tools for studying ocean distribution and behavior. In British Columbia, the role of sea lice parasites transferred from salmon farms to wild fish has received much attention as potential mortality agents on juvenile salmon. Unlike the western Pacific, few studies have been conducted in the eastern Pacific during winter periods. This leaves a huge gap in our understanding of North American salmon ecology during this critical life history period.

An important and continuing theme under the topic of distribution was the application of multiple technologies identifying stock-specific migratory patterns in juvenile salmon. Two Japanese papers using otolith marks and single nucleotide polymorphism markers documented dispersal and migration patterns of specific stocks of chum salmon on the Pacific coast of Hokkaido. North American scientists using variations of 14 DNA microsatellites followed individual Fraser River and central British Columbia (BC) sockeye salmon stocks migrating out of BC and tracked them northwestward throughout much of Gulf of Alaska. Russian scientists identified mixed-stock aggregations of 24 Okhotsk Sea even-year pink

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salmon stocks using restriction fragment length polymorphism analysis and found by September most juveniles originating from the southern part of the basin had migrated into the northern Okhotsk Sea. Otolith microstructure was used in another Russian study to identify mixed stock groups of Okhotsk Sea pink and chum salmon.

Migration behavior was another important theme. In the northern Bering Sea, juvenile Chinook salmon from western Alaska rivers migrated in opposite directions along the coast during a series of warm and cold years, affecting survival. Late migration timing and ocean entry were shown to have significant beneficial effects on populations of Fraser River Chinook and sockeye salmon. And a study on persistent age-specific homing and return timing of Columbia River Chinook salmon provided a basis for inferring different ocean distribution patterns in age groups of fish.

A presentation related to homing behavior was the first empirical evidence of geomagnetic imprinting in any animal determined from analyzing divergences in geomagnetic field drift at the mouth of Fraser River. Geomagnetic imprinting could account for the two different entry routes of returning sockeye salmon migrating around Vancouver Island.

Presentations on the physical and biotic environments of salmon habitats covered a range of eastern Pacific regions. In the Strait of Georgia, survival of hatchery coho salmon has decreased from 8-10% to 1% over a 30-year period, leading to new research focused on staggered smolt release dates along with plankton monitoring to assess food quality and availability. The study also has a fish health component to test if a marine bacterium is affecting survival. Increased primary and secondary production indicated favorable conditions for juvenile salmon.

In the northern California Current, a study on spatial associations from shipboard acoustic surveys of distribution and abundance of krill, satellite-derived indices of Chlorophyll-*a*, and occurrences of juvenile Chinook salmon showed persistent high krill and salmon abundance associated with Chlorophyll-*a* hot spots.

A study conducted along the Gulf of Alaska coast demonstrated juvenile salmon migrating through the perimeter of the Sitka Eddy have increased foraging opportunities and elevated growth rates that could mitigate for increased competition in years with high salmon abundance.

The session on trophic linkage, growth rates, and predation rates produced new information. A California Current study demonstrated a strong positive relationship between growth and survival in coho salmon during the first summer at sea with little mortality occurring during the following winter period. Researchers conducting a study along coastal British Columbia reported stock-specific predation on juvenile salmon by rhinoceros auklets at different nesting colonies, indicating there are important spatial-temporal salmon migration patterns. Concurrent coast-wide trawl surveys for juvenile salmon supplied evidence for size-selective predation, as the salmon consumed at each auklet colony were smaller than salmon caught in the surveys.

To better understand coast-wide declines in Chinook salmon, a continental-scale analysis of juvenile salmon feeding ecology from northern California to the eastern Bering and Chukchi seas found large gradients in carbon isotopic data corresponding to regional variations in zooplankton and forage fish in diets, especially in smaller Chinook salmon up to 200 mm in body length.

A presentation described results by utilizing a food supply index to examine relationships among biomass of nekton species, zooplankton, and juvenile salmon in the western Bering and Okhotsk seas. Diets changed somewhat during years of high salmon abundance, but there were no strong negative consequences for juvenile salmon in those years.

Several presentations related ecological interactions among pink salmon and other species. A Southeast Alaska study examined interactions between pink and chum salmon and suggested high brood-line returns of adult pink salmon influenced feeding and growth of juvenile chum salmon. To investigate the possibility that cannibalism by returning adult pink salmon contributes to brood-line oscillations in pink salmon abundance, a study in Southeast Alaska and Prince William Sound examined adult pink salmon predation on juvenile pink salmon and herring. Results indicated that over the 16-year data set, cannibalism rarely occurred, i.e., in less than 1.1% of more than 2000 adult pink salmon stomachs analyzed. I note, however, that Vladimir Radchenko showed an interesting photo of an adult pink with a large number of juvenile pink salmon in its stomach. A study conducted in Puget Sound found likely competition between juvenile salmon and Pacific herring due to similarities in their diets and to greater population biomass of herring.

The topic session with the most number of presentations was related to juvenile salmon survival rates and survival mechanisms. Researchers conducting a Strait of Georgia study reported that years of poor ocean productivity and biological stressors, such as harmful algal blooms and pathogens, may weaken the immune systems of juvenile salmon, which is associated with higher levels of mortality.

An analysis of high-seas food habits revealed salmon and steelhead consume a variety of types and forms of plastic debris. The study explored potential mechanisms of marine mortality due to ingestion of plastic debris and emphasized the need for field and laboratory process studies on this issue.

Two separate modeling studies considered the influence of large-scale climatic patterns such as the Pacific Decadal Oscillation and North Pacific Gyre Oscillation on survival rates of Pacific Northwest coho salmon. Both studies found large-scale events have strong influence on physical and biological components of ecosystems, but effects were more uncertain at local and regional levels. For example, in one case spatial comparisons of large scale events and ocean sea surface temperatures were better predictors for survival of coastal populations than temperatures inside Puget Sound.

Two other studies took a salmon life-history perspective. The life-history of Southeast Alaskan juvenile coho salmon "nomads" was highlighted as providing substantial life history diversification for efficient use of discontinuous freshwater habitats and a population buffer against survival shocks. The nomad coho salmon life history is one where pre-smolts rear in estuaries and return to natal or non-natal streams to overwinter before smolting in the spring and migrating to the ocean. Another presentation examined critical periods in the marine life history of Pacific salmon and argued for the need to consider all phases of the life history rather than focusing on the assumption that one "critical" period is of overriding importance.

In a study examining fish scales of out-migrating smolts and returning adult Bristol Bay sockeye salmon, authors concluded size-selected mortality was dependent on ocean conditions and biological characteristics of the smolts, and that productivity of these stocks was largely dependent on the degree of size-selective ocean mortality.

In a Gulf of Alaska study, mesoscale eddies were shown to be drivers of stable carbon isotopes in oceanic copepods and it appears these eddies can account for some of the interannual variability of Prince William Sound pink salmon survival.

Another presentation suggested that increased competition at sea, in part related to continued release of large numbers of hatchery salmon (here read pink and chum), may have played a significant role in reduced BC sockeye salmon survival since 1991.

There were several presentations related to salmon survival and salmonid ecology during the first winter at sea. Russian studies on the food supply of pink salmon during winter and spring of 2009-2011 in the upper epipelagic layer of the western Subarctic frontal zone estimated the total biomass of nekton along with the consumption of various zooplankton groups by pink salmon and other organisms. Estimates showed that consumption of zooplankton by pink salmon and all nekton was a minor fraction of the available food in the upper epipelagic zone. Feeding by pink salmon during winter and spring was not low, as was previously reported.

In summary, from my perspective these were some of the highlights of the workshop:

- Major new and continuing improvements in discerning stock-specific migration routes of juvenile salmon based on genetic stock identification techniques, otolith microstructure, otolith marking, and other stock identification technologies.
- Growing evidence regarding the importance of early marine growth in juvenile salmon and the significance of size-selective mortality in marine life stages as a key determinate of overall survival and a cornerstone of the critical size hypothesis. We even learned that rhinoceros auklets can be added to the list of juvenile salmon predators, and the birds seem to target the smaller fish. Looking at this from the salmon's point of view, I guess we might summarize this whole concept as "getting bigger quicker is better".
- Possible mismatch of juvenile salmon migration timing and production of suitable marine prey resources from changes in freshwater and marine environments due to global warming and differential climatic effects.
- New insights into salmon homing migratory behavior based on empirical evidence of geomagnetic imprinting.
- Potential deleterious impacts of marine debris on salmon ecology and survival.

In conclusion, I would like to add a comment regarding a future research direction involving Pacific salmon. Because we are in a period of fairly rapid climatic changes, it is important for us to collectively do whatever we can to maintain important long-term data sets, marine surveys, and long-standing observations that give us critical tools to help us better understand what is going on. I know this is tough in times of budget shortfalls and sequesters, but we must persevere and strive to keep the need for these valuable long-term data sets front and center in the minds of administrators and others.

I thank you for your attention and apologize for the many subjects and issues from both oral and poster presentations I was unable to touch on during this wrap-up.