“Implementation of an ecosystem approach to fisheries management”

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NPAFC report prepared in connection with the 15th round of informal consultations of State parties to the 1995 United Nations Fish Stock Agreement

14 March 2022

The North Pacific Ocean is home to multiple species of salmonid fishes, including anadromous Pacific salmon that regularly migrate from freshwater to the sea and back. Salmon provide economic benefits in the form of subsistence, commercial, and recreational fisheries, and contribute to the cultural enrichment of the regions where they occur. Their ecological role is complex as they facilitate energy transfer directly and indirectly at multiple trophic levels in many ecosystems.

Since the time of development of the First NPAFC Science Plan (1995-1996), a section on Salmon habitats and ecosystems was included into the scope of consideration. Thorough attention is paid to research on carrying capacity of the marine ecosystems to sustain salmon production, correspondence between salmon stock conditions and climate indices, trophic linkages and growth changes of juvenile salmon, primary production and salmon food resources, as well as climate-induced changes in distribution and abundance of salmon predator and prey populations.

The BASIS (Bering-Aleutian Salmon International Survey) Working Group was established in 2001. It was the NPAFC-coordinated program of cooperative research on Pacific salmon in the Bering Sea and adjacent North Pacific Ocean that was designed to clarify the mechanisms of salmon biological response to the conditions caused by climate changes. Specific issues that provide necessary direction to the research included:

- seasonal-specific migration patterns of salmon and their relation to the Bering Sea ecosystem,
- biological, climatic, and oceanographic factors affecting long-term changes in Bering Sea food production and salmon growth rates,
- similarities (or differences) in production trends between salmon populations in the Bering Sea and common factors associated with their trends in survival, and
- an overall limit or carrying capacity of the Bering Sea ecosystem to produce salmon.

The BASIS programme findings have been presented at six NPAFC workshops and three Symposia in 2008, 2010, and 2015. It was found that immature and maturing Pacific salmon originating from Asia and North America intermingle in both the Western Subarctic Gyre and Gulf of Alaska ecosystems while playing a very important role in their biological structure as a higher trophic level predator. While salmon occur in the North Pacific Ocean ecosystems during all seasons, winter was identified as a critical period that defines the biological characteristics and biomass of anadromous stocks. Better information on the status and trends in production and condition of Pacific salmon during the late fall to early spring period become needed for conservation and management of salmon resources, especially considering that observed climate change was the most prominently evidenced in the region in winter.

Since 2011, the NPAFC Science Plan was expanded to cover the fisheries management issues including, as one of the most important, an accurate forecast of returning salmon abundances. The Long-term Research and Monitoring Plan (LRMP) for Pacific Salmon in the North Pacific Ocean was adopted by the Commission in 2010. The LRMP highlighted several approaches to apply collaborative efforts in order to improve understanding of common mechanisms that regulate Pacific salmon production: precision monitoring of abundance and biomass in the ocean as the most reliable method for predicting changes in production of anadromous populations, accurate stock identification methods such as genetic and otolith mark analyses, and modeling to explain how Pacific salmon production will change in the ocean ecosystems affected by changing climate. The concept of the International Year of the Salmon (IYS) was first proposed in the LRMP.

After the 2015 Symposium, a new NPAFC Science Plan (2016–2022) was developed and integrated with a proposal for the IYS. The IYS was conceived as an intensive burst of internationally coordinated, interdisciplinary, scientific research and outreach focused on salmon, and their importance to people. Both the Science Plan and the IYS contain five overarching research themes including Human Dimension. Expected IYS outcomes include improved forecasting, understanding of temporal and spatial risks for Pacific salmon stocks in a changing climate and environment, and better planning given environmental uncertainties to improve wild stock sustainability and probability of success of hatchery propagation and salmon farming.

Throughout the course of the IYS five-year initiative, three High Seas Expeditions have been planned to study the winter ecology of salmon and try to identify the mechanisms regulating salmon abundance and production. The 2019 International Gulf of Alaska Expedition, which took place on the Russian research vessel *Professor Kaganovskiy*, was the first successful comprehensive study of the stock abundance, composition, and condition of the stocks of five species of Pacific salmon at the end of their first ocean winter in decades. The second expedition on F/V *Pacific Legacy* in March 2020 aimed to build off this research and was a continuation of the international scientific effort to establish greater international research capacity for understanding the consequences of future environmental conditions.

Two completed expeditions provided with a wide range of important results to clarify scientific fundamentals of salmon conservation and management. Several hypotheses on the limited carrying capacity of the pelagic zone of subarctic Pacific Ocean waters for salmon, the food shortage for salmon in the Ocean in winter, tough competition for food between and within salmon species, the “suppression” of other salmon species and own adjacent year-classes by pink salmon, the distortion of the structure of epipelagic communities in ecosystems of the North Pacific due to the large-scale hatchery enhancement of pink and chum salmon, etc. were tested. The technology for salmon stock identification on-board the vessel was verified and looks very promising for fishery enforcement application in high seas. Significant array of data and samples on salmon physiological condition and health was collected for the first time in high seas in winter.

The 2022 Expedition involves a full ecosystem survey with pelagic trawling and detailed sampling of marine life in the upper ocean performed from four research vessels and includes research on physical, biological and chemical oceanography. There is also a gillnet vessel deployed in the Gulf of Alaska, alongside the ships that will be trawling, to test the catch efficiency of different gear

types. Novel technologies such as gliders, environmental DNA and genetic stock identification are used to enhance research efforts. The 2022 Expedition brings together scientists from Canada, Japan, the Republic of Korea, the Russian Federation, and the United States — the five NPAFC member countries to build on research from the 2019 and 2020 International Gulf of Alaska Expeditions. More scientific results are to come from collected samples processing in laboratories and from the North Pacific Ocean-wide expedition in 2022. New genomic technology will facilitate the assessment of the impact of changing ocean conditions on the health of Pacific salmon. Using of autonomous glider will enhance understanding on fine-scale oceanographic structure of the ocean upper layer in winter and provide with additional information on marine life distribution there.

It is increasing recognized that the single biggest impediment to science and management of salmon and their associated ecosystems are timely access to data. Our collaborative high seas work has reaffirmed the need to establish standards and data sharing protocols to mobilize data associated with salmon and epipelagic ecosystems of the North Pacific Ocean that are consistent with the FAIR data principles (Findable, Accessible, Interoperable and Reusable) and create the data standards that define Essential Ocean and Essential Biological Variables for coastal areas and the open ocean. The NPAFC has established a Study Group to develop common standards for salmon and their ocean ecosystems and is working with international partners to test the application of emerging graph database technologies to facilitate the rapid discovery and synthesis of data. Data from the 2019 and 2020 International Gulf of Alaska Expeditions are now accessible to the scientific community from the partner's website.

Based on collected data and literature, mortality factors within an overall spatio/temporal framework covering the freshwater migration/sea entry phases and the marine phase of the salmon life cycle should be clarified. The concept of a Likely Suspects Framework (ICES 2016) is being developed to accomplish this. An international toolkit will be developed to synthesize current and future states of the open ocean and coastal ecosystems with understanding of salmon mortality factors for use in short-term projections of productivity and abundance for marine resources, including salmon. The next steps of the NPAFC development on that momentum are outlined in the project proposal submitted for the U.N. Decade of Ocean Science for Sustainable Development - *Basin Events to Coastal Impacts: An Ocean Intelligence System for Fish and People (BECI)*, which is particularly built on the IYS legacy.

Discussions are now underway within the voluntary fundraising group with participation of the NPAFC and the North Pacific Marine Science Organisation (PICES) to set out the management structure and implementation plan for BECI and to draft a full Special Project proposal to seek support from potential donors. Phase 0 planning for BECI to be conducted between January and June 2022, with the aim of producing an implementation plan for BECI. Fundraising efforts are underway to support the planning phase, with $125,000 CAD secured from PSF and the Canadian fishing industry as part of $450,000 CAD required in total.