New Year Message from the President

Happy New Year!

The Year of 2019 was a fantastic and successful year with a lot of achievements and significant progress. Above all, the Gulf of Alaska Expedition 2019 as one of the International Year of the Salmon (IYS) activities was successfully completed with 21 scientists from five NPAFC member countries aboard the Russian R/V Professor Kaganovskiy. An international expedition like this one is the first in decades to study salmon in the high seas and has made many exciting discoveries. When we first heard the idea several years ago, it sounded like an unachievable dream. For the last two years, however, we have seen the impressively advocated activities by the IYS with support from many nations and organizations. I have read an interesting article about “Investigating salmon mysteries on the high seas” relating to the 2019 Signature survey published in Canada’s National Observer in December 2019, and you can see it at https://www.nationalobserver.com/2019/12/16/features/investigating-salmon-mysteries-high-seas.

As part of the IYS initiative, the NPAFC, along with the North Pacific Fish Commission (NPFC) and the North Pacific Marine Science Organization (PICES), co-hosted a two-day workshop which took place in Victoria (Canada) on October 19–20, 2019 at the PICES Annual Meeting. Many NPAFC/NPFC/PICES scientists including Mr. Mark Saunders (IYS Director, North Pacific Region), Dr. Vladimir Radchenko (NPAFC Executive Director) and myself attended this workshop. It brought together salmon/fish specialists, oceanographers, climatologists,
and resource managers from around the Pacific Rim to explore findings from the ground-breaking 2019 winter expedition in the Gulf of Alaska and to recommend the core elements of a Pan-Pacific High Seas Expedition in 2021 which will provide a platform for international collaborative ecosystem research to monitor the distribution, abundance and productivity of salmon. Considering the output extracted from this workshop, the North Pacific Steering Committee and the IYS Working Group meetings will take place in Vancouver (Canada) on February 25‒28, 2020. A key topic will be research planning for a 2021 multi-vessel Pan-Pacific High Seas Expedition. Working hypotheses and the overview of the High Seas Expedition Cruise Plan including logistics and equipment will be discussed. In addition, we will review the progress made on IYS activities in 2019 and the current and upcoming activities for the IYS through 2021. Update on the IYS strategic plan and the IYS communication and outreach strategies are also expected to be addressed during the February meetings.

Another big step made in terms of extension of cooperation with an international organization is that NPAFC and NPFC have signed a Memorandum of Cooperation (MOC) on May 13, 2019 at the 27th NPAFC Annual Meeting in Portland, Oregon. It will foster and strengthen the long-term relationship between the two intergovernmental organizations. As agreed in the MOC, a five-year (2021–2025) work plan that identifies key activities to deliver on the strategy during this time period will be cooperatively developed this year by both the commissions focusing on collaborative research efforts and implementation of conservation and management measures relating to stocks and species of mutual interest in the North Pacific Ocean.

Conservation of anadromous stocks in the Convention Area is the primary objective of the NPAFC and efficient conservation evenly requires both scientific knowledge and enforcement activity. The development of a common understanding of threats and knowledge gaps is an essential element for the management of salmon in the high seas. In this regard, I would like to express my special thanks to the enforcement people for a series of successful ENFO workshops in recent years. There will also be a one-day ENFO/CSRS workshop on “Threats and knowledge gaps related to Pacific salmon conservation on the high seas” on May 17, 2020 in Hakodate (Japan) before the start of the 28th NPAFC Annual Meeting. The workshop will focus on the exchange of information between the enforcement and science communities. I expect that the workshop will further improve the coordination between the ENFO/CSRS committees to enhance the enforcement effectiveness and the collection of scientific data. A draft program about topics and potential keynote speakers is being discussed and will be determined soon.
The NPAFC will hold its annual meeting in Hakodate, Hokkaido, Japan and will host its third NPAFC-IYS Workshop on *Linkages between Pacific Salmon Production and Environmental Changes* on May 23‒25, 2020. Convened jointly with several partners including the Fisheries Agency of Japan, the Hokkaido Research Organization, the Japan Fisheries Research and Education Agency, the Japan Salmon and Trout Resources Enhancement Association, the Tohoku Ecosystem-Associated Marine Sciences, and the PICES, it will provide an opportunity for scientists and researchers to present studies and findings on all five IYS research themes. There will be an emphasis on three topics—salmon production in changing environments, new technologies/integrated information systems for salmon research and management, and resilience for salmon and people: lessons from the Great East Japan Earthquake in 2011 as a special session.

With regard to scientific publications, I congratulate everyone for publishing four NPAFC technical reports relating to the IYS workshops last year: Technical Report No. 12 (Proceedings for the IYS workshop on Toward Effective Coupling of the Science of a Changing Climate with Salmon and People), No. 13 (Proceedings for the IYS workshop on Salmon Status and Trends), No. 14 (Proceedings for the IYS workshop on First International Salmon Data Laboratory), and No. 15 (the Second NPAFC-IYS workshop). The NPAFC Technical Report No. 15 includes extended abstracts of oral and poster presentations at the Second NPAFC-IYS Workshop on *Salmon Ocean Ecology in a Changing Climate* held on May 18‒20, 2019 in Portland, in a partnership with SOEM (Salmon Ocean Ecology Meeting). I would like to thank the NPAFC Secretariat and the Workshop Organizing Committee members for all your efforts to put the reports together and publish them, which will be a good legacy from the workshops.

I hope to see you all again in Hakodate, Japan, and I wish you and your family all the best.
Among the whole Pacific salmon family, pink salmon are a special fish. Its regional stocks often underwent unexpected sharp abundance fluctuations, when “humpy years” turned to lean years everywhere, even including regions with large-scale hatchery programs. While fishermen wait for the plentiful salmon run on a particular seacoast sector, it may reveal itself hundreds of miles away, e.g., on the eastern Sakhalin instead of the Kurile Islands. In other cases, pink salmon have appeared in places where they were considered not numerous, and in such high abundances that break the capacity limits for fish processing facilities and spawning grounds. Due to these erratic scenarios, pink salmon have always been considered a trustless fish by fishermen, and pink salmon fisheries can be a risky venture. One sentence in particular about the unpredictability of pink salmon at the fishermen’s forum stayed on my mind: How many fishermen went bankrupt due to this wonderful fish!

For fishery scientists, forecasting the magnitude of a pink salmon run is a challenging task. Canadian colleagues (Haeseker et al. 2005) showed that the best-performing model for 43 pink salmon stocks on the North American West Coast explained only an average of 20% of the observed variation in recruitment. My mentor in salmon ecology, Professor Vyacheslav Shuntov likes saying: Nobody made a greater mistake than he who forecasted pink salmon run. One scientific article written by Russian colleagues on pink salmon abundance dynamics modelling is titled as Ungrateful pink salmon of deterministic chaos? (Ostrovsky and Ponomarev 2009). The main idea of this article is that we usually do not know what to expect from any pink salmon stock under consideration. Back in the mid-1980s, Drs. Glubokovsky and Zhivotovsky (1986) developed a pink salmon concept of fluctuating stocks with conclusion that a local stock of pink salmon could not be considered as an independent unit for the fishery forecasting purposes due to large-scale oscillations of its abundance and spawning area dimensions.

From my own experience, I was convinced of pink salmon’s trickery in 2006. My colleagues and I at SakhNIRO made a bold fishery yield forecast of approximately one and a half times the historical records for even years due to the promising evidence that pointed to a great pink salmon run in the Aniva Bay. The fishery season came, and pink...
salmon approached in such massive quantities that fishermen at Aniva Bay harvested more than 5.5 times the previous historical record and four times more than our forecast, over 54,000 metric tonnes (mt). As the SakhNIRO Director, I was almost dismissed for that big mistake in the pink salmon forecast, but Sakhalin fishermen were satisfied by the profitable fishery season, and the senior management’s frustration faded away little by little. Soon after 2006, several fishing companies started to build additional salmon processing facilities along the Aniva Bay coast. I tried to tell them that miracles would not happen on a regular basis, but that advice was not heeded. Since that year, even-year pink salmon run magnitude and fishery harvest values have progressively declined to less than 300 mt in 2018. In 2020, the commercial fishery will be prohibited in the Aniva Bay completely due to the low productivity in the region.

When TINRO scientists under V. Shuntov’s leadership started a series of integrated research surveys focussing on pre-anadromous pink salmon abundance estimates, some colleagues considered that research to be as elusive as the quest for El Dorado. Nevertheless, the first two years were very successful. Survey outcomes realized the exact pink salmon run times and magnitudes, and the resulting estimates have been highly praised by fishermen and senior industry management. Unfortunately, a sudden failure occurred in 1993, when the last part of the pink salmon aggregation migrating to the Sea of Okhotsk drastically changed a line of migration and disappeared somewhere northwards. Some fish from that migration flow have likely reached the eastern Kamchatka coast after the traditional pink salmon run timing. The circumstances of that survey are described in detail in V. Shuntov’s memoir *Zigzags of Fisheries Science* (1994). Down the line, the experiences gained have resulted in large discrepancies between survey estimates and fisheries outcomes to become exceptionally rare. However, until the last day of each fishery season, scientists usually wait in breathless expectation to see whether pink salmon bring another surprise.

One of the main tasks of the Gulf of Alaska expedition in February–March 2019 was a “proof of concept” for the application of trawl studies to determine the abundance and distribution of Pacific salmon stocks that return to North American rivers (Pakhomov et al. 2019). Survey-based abundance estimates were expected to be used to forecast salmon returns using trawl catches as it is routinely done throughout the Russian Far East. Generally, fishing for salmon by Russian pelagic trawl was not bad during the survey. Pacific salmon occurred in 48 out of 58 trawl catches, and 425 salmon consisting of five species were caught. From the other side, catches were not as big as in the western North Pacific. Twelve of 48 salmon catches contained just one fish, the biggest catch was 52 salmon. Only two catches contained four salmon species, nine catches—three species, 18 catches—two species, and 19 catches were represented by a single salmon species. Most of the multi-species catches occurred southward of 50ºN and westward of 140ºW.

As usual, tricky pink salmon displayed itself in all its glory. At the first four stations, from one to eight pink salmon were consistently caught during one-hour trawl hauls. We expected that we would quickly be catching pink salmon by the dozens, but this was not the case. For the next 25 survey stations, when the vessel went northwards and returned back, no pink salmon were present in the catches since station #5. After all, the first four most southeastern

![Figure 1](https://example.com/figure1.jpg)  
**Figure 1.** Salmon catches in the Gulf of Alaska during the cruise in February–March 2019. An ‘x’ indicates zero catch. After Pakhomov et al. 2019.
survey stations brought us more than a half of total pink salmon catch in a course of survey—16 of 31 fish. Consequently, pink salmon abundance and biomass estimates were considered negligible. It appears that the winter area of pink salmon, unlike other salmon species, was shifted to the south of these longitudes, and the survey grid covered only a small part of it (Figure 1).

The Gulf of Alaska survey grid development was based on historical research of salmon distribution in winter mostly conducted by gillnets and pelagic longline. Canadian researchers worked there aboard R/V G. B. Reed in 1963–1965. In January–February 1964, when the most extensive longline survey was performed, no pink salmon were caught southward from 47°N or eastward from 132°W. That is why we expected to delineate the southern part of pink salmon distribution domain in vicinities of 47°N by our southernmost survey section. Meanwhile, Japanese R/V Kaiyo maru completed a seven-station section along 145°W with the southernmost station approximately 48°N in February 2006. In addition, there were priority tasks to find a pattern of winter migrations for sockeye salmon further northwards and for Chinook salmon presumably closer to continental slope.

One of our hypotheses we tested on the cruise was about a northern shift of salmon distribution in winter due to ocean water warming. All this explains why the survey area could not be stretched to the south. After 1986–1992, the Russian scientists resumed winter surveys, focusing on Pacific salmon in the western and central North Pacific in 2009–2010. It was found that the boundary of pink salmon distribution in winter 2009 was shifted several degrees of latitude northwards (Shuntov and Temnykh 2011). This observation fitted hypothesis on the northern shift of salmon forage areas in the warming Pacific Ocean. Otherwise, expectations were not met in the northeastern North Pacific in 2019.

As it was revealed in the western and central parts of the North Pacific, pink salmon overwinter in the Subarctic Current Domain. It mostly occurred along the frontal zones as between relatively cold subarctic waters and diluted waters as between diluted waters and relatively warm waters of subtropical origin. When plotting pink salmon distribution relative to sea surface temperature (SST) at high seas in winter, the plot has a two-peak curve, where the peaks correspond to the southern and northern fronts of the Subarctic Current Domain (Radchenko et al. 2018).
Closer to the end of the R/V Professor Kaganovskiy cruise, the TINRO colleague Aleksander Figurkin provided us with the OSCAR (Ocean Surface Current Analysis Real-time) map for the Gulf of Alaska and surrounding vicinities on March 2–7, 2019. The OSCAR model formulation combines geostrophic, Ekman and Stommel shear dynamics, and a complementary term from the surface buoyancy gradient. It was provided by the NASA Jet Propulsion Laboratory of the California Institute of Technology (https://podaac.jpl.nasa.gov/dataset/OSCAR_L4_OC_third-deg). According to satellite altimetry data, one of the well-expressed Subarctic Current branches was located just in the southeastern corner of the survey area, where about 90% of all pink salmon were caught during the survey. Based on this current chart, we estimated that some pink salmon were aggregated between 46°N and 47°30’N within limits of 133°W–148°W during the survey time (Figure 2). Going back to Russia after the Nanaimo port call, R/V Professor Kaganovskiy made a test trawl haul at 45°02’N 144°19’W on March 26, 2019. However, it was too far south of the Subarctic Current front and no salmon were caught there.

In the mid-2000s, the TINRO scientists summarized and mapped data on salmon distribution in different seasons and layers for a study period ranging from 1979 to 2004. When maps of pink salmon distribution for winter and spring seasons are compared, it appears that their distribution area in the northwestern Pacific Ocean shifts southward in spring compared to the winter position (Atlas ... 2005). Likely, pink salmon still continue to migrate oceanward in winter while moving from one place with favorable forage conditions to another. If maps of pink salmon distribution in the northwestern Pacific Ocean in winter are compared with our survey results, salmon distribution density throughout the 2019 survey area (from 11.4 to 107.4 fish per km²) will be similar to the periphery of pink salmon main aggregations on the western side (Figure 3). However, not enough information is available to put together the whole puzzle of pink salmon distribution on the right panel. It is difficult to assess whether that piece of the potential pink salmon distribution area of approximately 350,000 km² between 46°N–47°30’N and 133°W–148°W is enough to hold all wintering fish of the North American stocks, which were fairly abundant in 2019.

Figure 3. Estimated pink salmon distribution density (fish per km²) in the Gulf of Alaska in comparison with historical winter data from the northwestern Pacific Ocean obtained by the same trawl survey method in 1979–2004, after Atlas ... 2005.
Pink salmon fishery season was very productive throughout the Alaskan coasts besides Southeast as well as in the eastern and western Kamchatka regions in Russia (Figure 4). According to the preliminary data, 129.1 million fish (or 191,700 mt) of pink salmon were harvested in Alaska State. Historically, the highest amounts of pink salmon were harvested in the eastern Kamchatka—227,200 mt (or about 174.8 million fish). On the western Kamchatka, the catch record for odd years since 1953 was overwritten—60,200 mt (or about 46.3 million fish). In total, slightly more than 350 million humpies were taken in Alaska and Kamchatka altogether that allowed estimating a “catch plus escapement” pink salmon abundance in 610 million fish. Combined with the Canadian and Japanese coasts salmon run (roughly by 20 million fish), the overall pink salmon abundance in pre-spawning approaches to the coasts totaled 650 million fish. Using estimated natural mortality rate—about 58.6% from wintering to the spawning run time (Radchenko 2012)—we concluded that approximately 1.57 billion of pink salmon overwintered in the North Pacific in February–March 2019.

The North American populations contributed approximately 47.7% of total pink salmon run abundance, i.e., there should be approximately 750 million overwintering pink salmon belonging to the North American stocks. The Gulf of Alaska survey covered roughly 11.6% of potential pink salmon wintering area, but estimated abundance (4.2 million fish) reached only 0.3% of estimated total overwintering pink salmon abundance or about 0.6% of the estimate for the North American stocks. Assuming the rest of the pink salmon dwelt the mentioned area southwards from the survey grid in winter, its distribution density there should be equal to 2,143 fish per km$^2$. If that area had been covered by the survey, average trawl catch values should be equal to 200 fish·hour$^{-1}$ if calculated with the trawl net catchability coefficient 0.3. Such catches are not at all impossible. For example, the average nonzero pink salmon catch was 500 fish·hour$^{-1}$ during trawl surveys in the Sea of Okhotsk in October–November 2017 while the survey area was one-and-a-half times larger than 350,000 km$^2$. However, such dense salmon aggregations are usually surrounded by peripheral zones with catches that can be an order of magnitude lower. Our survey catches were two orders of magnitudes lower.

In April–May 1990, pink salmon distribution was farther southward than the 2019 survey grid (Welch et al. 1990) and was considered a seasonal shift due to continuing migrations. Based on data collected from the same type of research vessel, R/V TINRO, pink salmon catches varied there from 1 to 168 fish·hour$^{-1}$, and the average nonzero catch...
was 35 fish·hour⁻¹ (Figure 5). Larger trawl net (RT 108/528) was used aboard the R/V TINRO in 1990 with horizontal net mouth opening at 60 m. Over a surveyed area of over 625,000 km², pink salmon abundance was estimated at 134.6 million fish, and the distribution density was estimated at 215 fish per km². As for the pink salmon run magnitude in 1990, the pink salmon fishery season was below average for 1980–2019. Total commercial fishery catches throughout the Alaska and Kamchatka coasts were threefold less than in 1999.

In February–March 2009, R/V TINRO conducted a similar survey in the central North Pacific Ocean southward of the U.S. EEZ in the middle part of the Aleutian Islands chain (Starovoytov et al. 2009). Pink salmon were widely distributed throughout the survey area, except for the few southernmost stations in the western part of the grid. Its distribution density was estimated at 104 fish per km² with an average catch of 19 fish·hour⁻¹. In that year, total pink salmon fishery catch in Alaska and Kamchatka was 1.8 times higher than in 1990 but 1.7 times lower than in 2019. There was a great pink salmon run in 2009 on the Sakhalin Island, which had a total catch of 229,400 mt on the eastern Sakhalin coast. On the contrary, pink salmon catches on the eastern Sakhalin were poor in 2019—less than 5,800 mt, or less than 1.8% of the total Russian pink salmon harvest. Meanwhile, the central North Pacific area was previously considered as a wintering ground for the Kamchatkan pink salmon stocks while the western North Pacific in limits of 39°N–44°N and 150°W–170°W—for the Sakhalin and Kurile Islands stocks.

In January 2019, R/V Professor Kaganovskiy performed a trawl survey along the Russian EEZ in the northwestern Pacific Ocean. Pink salmon occurred in seven out of 23 catches (30%) in numbers from 1 to 23 fish·hour⁻¹. The average nonzero catch was equal to 5.6 fish·hour⁻¹. It was considered that the bulk of migrating pink salmon still had not left the Russian EEZ at the time of the survey. Then, in February 2019, the vessel crossed the area of the 2009 survey with a section of nine stations. Pink salmon catches varied from 0 to 14 fish·hour⁻¹, with an average catch of 6 fish·hour⁻¹, which was double the average catch of the Gulf of Alaska survey, which had an average nonzero catch of 3 fish·hour⁻¹ and ranged up to 8 fish·hour⁻¹. In conclusion, there were no pink salmon aggregations found in abundance that could provide a high pink salmon harvest in Alaska and Kamchatka coasts in 2019, neither in the northwestern nor in the northeastern Pacific Ocean.

This situation relates to an unexpected wintering pink salmon encounter in the deep-sea part of the Sea of Okhotsk in the winter of 1990 (Radchenko et al. 1991). Then, pink salmon were found there in the winter season of 1991–1995 and 2003 (Shuntov and Temnykh 2008). Favorable conditions for pink salmon wintering were formed on the iceless part of the Sea of Okhotsk under the influence of inflowing relatively warm oceanic waters and usually persisted until
March of each of the listed years. After March, pink salmon left from the Sea of Okhotsk to the ocean, demonstrated by their shrinking area of occurrence at sea from November to March (Figure 211 from Shuntov and Temnykh 2008). In early January 2003, pink salmon were met in the Sea of Okhotsk from 1 to 26 fish·hour⁻¹ in trawl catches immediately near the Kurile Islands’ coasts while no salmon were found there during the survey repeated in late February–mid-March.

Over the last two years, ice cover has been greatly reduced in the Bering Sea—more than in order of magnitude below of winter 2013, where ice covered about 679.6 km² in late April (Stein 2019). This suggests that favorable conditions for pink salmon wintering could be formed in the deep-water Bering Sea basins, similar to the situation in the Sea of Okhotsk (Figure 6). This hypothesis should be tested during the Pan-Pacific research survey in February–March 2021, and the southern Bering Sea area should be included in the combined survey grid.

Note: This article partly consists of a fragment of review on Pacific salmon distribution in the Gulf of Alaska in February–March 2019 that was recently published as Radchenko, V.I., A.A. Somov, and A.N. Kanzeparova. 2019. Abundance and biomass of Pacific salmon in the Gulf of Alaska based on results of the NPAFC expedition in winter 2019 // Bulletin of Pacific Salmon Studies on the Far East. No. 14 (In Russian). The authors thank the expedition organizer, Dr. Richard J. Beamish, Emeritus Scientist at the Pacific Biological Station, DFO, Nanaimo, Canada, the expedition leader, E.A. Pakhomov, IOF Director at the University of British Columbia, Vancouver, Canada, the captain of the R/V Professor Kaganovskiy A.V. Pakker and crew (BIF TINRO, Vladivostok, Russia), as well as all members of the scientific team and, especially, the ichthyological squad, who shared with the authors the whole difficulty of processing of trawl catches, but remain with their views on salmon abundance and biomass estimates and their interpretation.

References


The Response of Pacific Salmon and their Prey to Changing Ocean Conditions and Acidification

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Pacific salmon are an important cultural and economic resource around the Pacific Rim. In British Columbia (BC) they are a crucial economic resource both provincially and globally and are also relied upon by First Nation and coastal communities as a high priority food source. Economically, BC fisheries generate 1.0 billion CAD annually, from combined sources of aquaculture, wild stocks, commercial and recreational fisheries. Unfortunately, many vital wild salmon populations are currently at risk and average returns are dwindling. In particular, Fraser River coho (Oncorhynchus kisutch) and Okanagan Chinook (O. tshawytscha) salmon have been listed as threatened, while Cultus and Sakinaw sockeye salmon (O. nerka) are endangered (DFO 2016).

Many factors contribute to the declines in Pacific salmon including pollution, habitat destruction (e.g., barriers to spawning areas), over-fishing, over-harvesting, and climate change. These factors are all predicted to have negative impacts on BC fisheries. However, despite knowledge of those stressors, many questions about the responses of Pacific salmon to extreme climate variability remain unknown. As global temperatures continue to rise and unprecedented changes in the environment are observed, information regarding these questions is crucial. Many scientists throughout the North Pacific are working to find answers. The North Pacific Anadromous Fish Commission (NPAFC) is currently working on a multi-vessel high seas expedition plan in 2021 to investigate Pacific salmon distribution, migration, growth, and fitness under present oceanic conditions. This endeavor may help to elucidate responses to climate change of these vitally important fish and what this will mean for the individuals and communities that depend on them.

To predict how Pacific salmon and their prey will respond to climate change, an understanding of how climate change and ocean acidification affect seawater habitats is required. The ocean is a dynamic and complex environment, especially along the west coast of Canada. This region is sensitive to acidification because its pH is already relatively low (Haigh et al. 2015). Multiple seawater parameters are affected by changing ocean conditions including temperature, salinity, dissolved oxygen, primary production, pH, and alkalinity. Coastal regions are
especially vulnerable, as they are subjected to the cumulative effects of freshwater and marine variations, urbanization, and waste disposals (Hare and Mantua 2000; Overland et al. 2006). Temperatures in the Strait of Georgia have been rising > 1°C per century, and the Fraser River has also been experiencing an increase in the number of days that temperatures exceed the limit for safe salmon migrations (> 18°C; Riche et al. 2014). It would be remiss not to briefly mention the North Pacific marine heatwave of 2014, colloquially termed ‘The Blob,’ where sea surface temperatures rose 3°C above normal levels (Bond et al. 2015). It is predicted that anomalies such as this will occur more frequently and generate even more extreme conditions—due to greenhouse gas emissions—as climate change progresses.

Increases in temperature affect the amount of oxygen than can be dissolved into sea water. The partial pressure of oxygen, commonly referred to as \( P_{\text{O}_2} \) (mm hg), is an accurate way to determine oxygen levels in the water, not influenced by temperature or solubility. Oxygen diffuses more readily into cooler water than warm. Therefore, increasing ocean temperatures resulting from climate change can reduce the overall amount of oxygen available to aquatic organisms. Increases in ocean temperatures can also impact coastal and freshwater salmon habitats.

Decreases in oxygen saturation are positively correlated to higher salmonid embryo mortality rates (Malcolm et al. 2010). This is vital information concerning the development of salmonid embryos which subsequently affect the success of hatch rates and fry survival. Salmonid eggs are buried and incubated in redds for a period of 58 to 260 days (Sparks et al. 2019), with northern and southern salmon populations spawning at different times to optimize the conditions the eggs will be exposed to during the gestation period (Brannon 1987; Hodgson and Quinn 2002; Brannon et al. 2004). Additionally, an increase in temperature may shorten the development time of the salmonid embryos (Sparks et al. 2019) by increasing metabolic rates and activities to adapt to increasing temperatures, but this is not necessarily favourable. The shorter incubation time may lead to more synchronized spawning and decrease the portfolio effects of salmon—a diverse "portfolio" with variable spawn and hatch time increases resilience to climate change, similar to a diverse investment stock portfolio (Adelfio et al. 2019). Additionally, higher temperatures during incubation of pink salmon resulted in smaller fry and alevins compared to lower temperatures (Murray and Beacham 1985). However, temperature selection may also drive changes in developmental phenology. Warmer waters could result in a shift in spawning phenology so that the fry hatch when conditions are most favourable for their survival (Sparks et al. 2019). However, optimal temperature and oxygen conditions may not be the only factor involved in fry survival. Other factors that impact hatch rates and fry survival include \( \text{pH} \), yolk-to-egg ratios, food availability, and predation.

Temperature is not the only variable that is being influenced by climate change. Since pre-industrial times, the concentration of atmospheric carbon dioxide (\( \text{CO}_2 \)) has been increasing exponentially, driving ocean acidification. Carbon dioxide reached the highest recorded levels, approximately 400 ppm, after 800,000 years, in 2015 (Luthi et al. 2008; Dlugokencky and Tans 2015). These levels are predicted to reach over 900 ppm by 2100 (Meinshausen et al. 2011). A significant amount of this excess \( \text{CO}_2 \) has been absorbed by the ocean, which has thus far acted as a carbon sink and reduced further consequences of climate change from occurring. However, by removing \( \text{CO}_2 \) from the atmosphere, the partial pressure (\( P_{\text{CO}_2} \)) of marine systems is increased. As a result, ocean \( \text{pH} \) decreases, driving ocean acidification and environmental degradation (Doney 2010).

It is essential to measure ocean \( \text{pH} \) to monitor the rate of ocean acidification as climate change progresses. However, the additional ions present in saltwater make measuring and reporting \( \text{pH} \) significantly more complex than in freshwater (Brewer 2013), and the chemistry of the ocean’s carbon state must be considered when examining ocean acidification. The carbon state refers to the concentration of each chemical in the form of dissolved inorganic carbon (DIC). Atmospheric \( \text{CO}_2 \) (> 1%) dissolves into the ocean where it forms carbonic acid (\( \text{H}_2\text{CO}_3 \)) in the presence of \( \text{H}_2\text{O} \). \( \text{H}_2\text{CO}_3 \) will further dissociate into bicarbonate (\( \text{HCO}_3^- \)) and a proton (\( \text{H}^+ \)), lowering the ocean \( \text{pH} \) and increasing the partial pressure of \( \text{CO}_2 \) (\( P_{\text{CO}_2} \)). At the most acidic end, \( \text{HCO}_3^- \) forms carbonate ions (\( \text{CO}_3^{2-} \)) and \( \text{H}^+ \) (Figure 1). Quantifying the ocean’s carbon state requires knowing temperature and salinity along with two of the following four variables: DIC, \( \text{pH} \), total alkalinity, and \( P_{\text{CO}_2} \). Including phosphate and silicic acid concentrations would further improve the accuracy of this measurement (Dickson et al. 2007).

As \( \text{pH} \) decreases, marine organisms that use \( \text{CaCO}_3 \) to build and maintain carbonate structures (e.g., seashells) will be negatively impacted, as less is available to them (Haigh et al. 2015). Aragonite is a soluble form of \( \text{CaCO}_3 \), commonly used by marine calcifiers to build their shells or other structures. The effects that ocean acidification will have on their ability to build and maintain these structures is
based on the aragonite saturation state ($\Omega$). This can be calculated using the following equation:

$$\Omega = \frac{[Ca^{2+}][CO_3^{2-}]}{K_{sp}}$$

In this equation, $[Ca^{2+}]$ is the concentration of calcium in the water, multiplied by the concentration of carbonate $[CO_3^{2-}]$ and divided by the equilibrium constant, $K_{sp}$. When $\Omega$ decreases to 3 or below, shelled organisms become stressed. At levels of $\Omega < 1$, their shells will begin to dissolve (Figure 1). In the Bering Sea, aragonite undersaturation is expected to exceed historic variability by 2044, and by 2062 it will become chronic (Mathis et al. 2015 as cited by Crozier 2016).

Carbonate ion concentrations can be quantified, making it a useful measurement for tracking ocean acidification. The aragonite saturation state is closely linked to pH, decreasing as pH decreases. The impacts of ocean acidification are not only experienced by calcifying organisms. Though they possess no shells at risk of dissolving, with increasing ocean acidification, other marine organisms such as fish, will need to expend more energy to remove metabolic waste products such as CO$_2$. The removal of these waste products is partially dependent on diffusion and ambient P$_{CO_2}$ gradients (Hoffmann et al. 2013). Thus, with an increase in P$_{CO_2}$ in the water, the gradient will be decreased—and in severe cases—CO$_2$ may not readily diffuse across the gill into the ambient water as easily. As a result, acid-base regulation becomes a challenge and fishes may experience difficulties with cardiorespiratory control as well (Ishimatsu et al. 2008).

Freshwater systems are known to have larger pH variations than oceanic systems. Freshwater pH ranges from 6.5–9.0, whereas the typical pH range of marine environments is more strictly regulated, varying between 7.8–8.1. Ocean pH generally decreases as DIC and P$_{CO_2}$ increase with depth (Haigh et al. 2015), although the North West Pacific Ocean is known for its upwelling regions which contribute to increasing pH variability by transporting cooler, deep water to the ocean surface (Feely et al. 2010; Figure 2). There is also a seasonal variation in pH, as it is typically lower in the winter and higher in summer. In marine ecosystems, normal variation is expected, and water must not be outside of 0.2 pH units from its typical range (USEPA 1976). However, overall CO$_3^{2-}$ has decreased by 16% and in open ocean surface waters by approximately 0.1 pH units (Orr et al. 2005). This trend is predicted to continue, with approximately 50% CO$_3^{2-}$ and 0.3–0.4 pH unit decreases estimated to occur by the end of this century alone (Orr et al. 2005).

Changes in freshwater pH systems may have important implications for salmon during their early life stages, as well as the success of their spawning periods, due to their complex life cycles. After hatching and developing as fry, the juvenile salmon
must undergo smoltification to prepare for their next life stage in a marine ecosystem. Typically, the juveniles will begin their seaward migration and move back and forth as they acclimatize to increasing salinity until they reach the ocean. The effects of pH disruptions may become especially relevant during this sensitive life stage. These sublethal effects can include reduced growth, yolk-to-tissue conversion, and maximal O₂ uptake capacity (Ou et al. 2015). Additionally, increased exposure to CO₂ has been shown to reduce juvenile growth rates in Atlantic salmon (Fivelstad et al. 2015), although some models have alternatively predicted ocean acidification to have a neutral or positive effect for Pacific salmon in the high seas (Reum et al. 2015). However, those models fail to consider the physical responses of Pacific salmon when exposed to aquatic acidification.

Ocean acidification may have the capability to disrupt additional physiological processes beyond smoltification. The ion gradients that control cognitive signaling and behavior are extremely sensitive to water chemistry, and those neural membranes may become damaged when exposed to conditions outside of the normal range (Schild and Restrepo 1998; Tierney et al. 2010). The olfactory cues in salmonids are also sensitive to disruptions in pH, particularly when caused by increases in CO₂ (Williams et al. 2018). A previous study by Williams et al. (2018) determined that juvenile coho salmon exposed to elevated CO₂ experienced significantly disrupted neural pathways on a physiological level. This has potential implications for a salmon’s ability to home to its natal stream for spawning following the oceanic developmental phase of the life cycle (Dittman and Quinn 1996; Gerlach et al. 2007). Adult salmon unable to locate their natal streams may “stray” to new territories. Wild fish that stray into hatchery territory will have their eggs and milt collected, which increases the genetic diversity of the hatchery-origin fish. However, straying of hatchery fish into wild populations increases the chances of them breeding with wild salmon and can lead to decreased genetic diversity and fitness of the next generation of wild fish. Additionally, damage to the olfactory bulb of juvenile coho salmon caused by excessive CO₂ exposure has been shown to decrease their ability to respond to alarm cues (Williams et al. 2018). The failure to elicit an avoidance response to an alarm cue may make juveniles more susceptible to predators as well as increasing challenges experienced in locating and capturing prey (Dixson et al. 2010; Cripps et al. 2011; Williams et al. 2018).

In addition to affecting a salmonid’s ability to successfully capture prey, ocean acidification also threatens the survival of the prey species. For example, Pacific salmon typically feed on pteropods, whose swarming behavior allows salmon to feed on large clusters without having to exert much energy to find them (Armstrong et al. 2005, 2008). Ocean acidification decreases pteropod populations by limiting their ability to grow and maintain their shells. As P_co₂ and temperatures increase, pteropods allocate more resources into a protective coating that prevents shells from being dissolved in waters that are undersaturated with aragonite (Byrne et al. 1984; Lischka and Riebesell 2012). Even so, reduced calcification under these conditions takes a toll on pteropod populations. In the Gulf of Alaska, there is a clear relationship between pteropod abundance and pink salmon survival (Doubleday and Hopcroft 2015). Therefore, under these conditions of heightened ocean acidification and decreased prey abundance, salmon must spend more time and energy foraging, which in turn reduces growth rates and ultimately survival.

Climate change may also increase competition for prey with other species, although more research is required to confirm the correlation between changes to inter-species and intra-species competition for Pacific salmon as a direct result of variables associated with changing ocean conditions. The previously described decrease in pteropod prey abundance due to ocean acidification will increase competition for all Pacific salmon that rely on them. Other organisms also compete with Pacific salmon for resources, although how climate change will influence their populations remains unclear. For example, during the International Year of the Salmon (IYS) winter 2019 Gulf of Alaska Expedition, a notable increase in northern sea nettles population (Chrysaora melanaster) was detected (Hunt et al. unpublished), likely originating from the Aleutian shelf. Their dry weight was approximately five times that of Pacific salmon, and since this sea nettle species are known to feed on zooplankton, they are likely a source of competition to Pacific salmon during the critical winter period for the salmon life cycle. How their responses to climate change may influence their competition for prey with Pacific salmon should be investigated, along with interactions between other species.

Invasive species are now common within aquatic communities and their introductions and survival in new ecosystems may be facilitated by the effects of climate change. In the Columbia Basin, invasive zooplankton have outcompeted native species in both reservoirs (Emerson et al. 2015) and the estuary (Bowen et al. 2015). The effects these invasive planktonic crustaceans have within the food web once they become established remain unclear. The invasive Asian copepod Pseudodiaptomus forbesi are now the dominant zooplankton during late
summer in the Lower Columbia River (Adams et al. 2015). The invasive zooplankton are still prey for the Chinook salmon, but not the preferred prey (Adams et al. 2015) and may not have the same caloric content and benefits as the native zooplankton population. When preferred prey species are in decline, predatory fish may also switch to preying on smaller juvenile salmon (Willette et al. 2001). Additionally, in freshwater systems, increasing temperatures may also lead to increased predation on young salmon. The habitat range of predatory smallmouth bass is predicted to expand and overlap with that of Chinook juveniles with increasing aquatic temperature (Lawrence et al. 2015).

The ecosystem-based threats ocean acidification poses are amplified by those of economic importance. Shelled organisms are not only prey for salmon but are often harvested by humans for consumption as well. Thus, geoducks, oysters, and clams specifically, will negatively impact aquatic-based economies as their populations decline due to ocean acidification (Figure 3). Along with shelled organisms, salmon are contributors to the Canadian economy. Commercially and recreationally harvested wild salmon species include Chinook, coho, sockeye, pink and chum, but unfortunately more data is needed to understand the full extent of how ocean acidification will affect their populations (Figure 3). Concerning pink salmon, it is predicted that decreasing ocean pH will likely have a negative impact, due to its impacts on their pteropod prey.

Due to the economic and conservational consequences of ocean acidification, there are water quality guidelines to assist policy managers in making decisions to decrease the effects of ocean acidification. Unfortunately, air pollution is a major source of CO₂ emissions that are driving ocean acidification. This makes regulating water quality guidelines a challenge since it is air quality that must first be addressed. Air quality is impacted through a variety of anthropogenic activities, such as driving cars and burning fossil fuels. Regulations to control emissions must be enforced on a global scale in order to have the greatest impact on preventing further ocean acidification. In the meantime, there are federal laws in Canada and the United States, such as the Clean Air Act which regulate the sources of air pollution, along with the Clean Water Act which regulate water pollutants (Craig 2015). However, as previously noted, clean water and air are intricately linked and may influence each other.

Regulations tend to focus on guidelines for single parameters, forming guidelines based on individual standards. It is important to consider the cumulative effects of multiple stressors on organisms, as they may become more sensitive to changes in water quality parameters when more than one condition is outside of their typical range. While an organism may be more tolerant to changes in water quality separately (e.g., temperature stress), if this happens in occurrence with another stressor (e.g., pH), then the combined stress of temperature and pH may have a synergistic effect with a greater impact than predicted. The United States Environmental Protection Agency (USEPA) now recognizes pH as one of its water quality standards, along with a variety of other regulations such as specific contaminate levels. As one of its water quality standards, this means that there is an acceptable range that must be maintained, and this value is region-specific with seasonal variations. In marine
ecosystems, normal variation is expected, but water must not vary more than 0.2 pH units from the typical range of 6.5–8.5 (USEPA 1976). Above or below this range can result in damage to the ecosystem, which could include bleaching corals, a variety of physiological impacts to fish and/or shelled organisms, or risks of toxic algal blooms.

Rapidly developing environmental changes, like ocean acidification and climate change, have the potential to negatively impact our oceans and underline the imperative need to increase our understanding of the implications they may have on Pacific salmon. The anadromous nature of these already threatened fish may make them more susceptible to climate change and the resulting lower ocean pH, since they rely on both freshwater and marine ecosystems to complete their life cycles (Crozier et al. 2008). Southern populations, such as the declining Puget Sound Chinook, are not doing well and many salmon are decreasing their ranges along the California Current System as they cannot survive the increased temperatures (Cheung et al. 2015). However, there are some positive salmon populations and production trends worth mentioning. Pacific salmon species in Northern regions are found to be increasing in areas that were previously unfavourable for them (Logerwell et al. 2015) and there may be phenological changes that would favour migration (Kovach et al. 2015; Sergeant et al. 2015; Stich et al. 2015; Crozier 2016) and spawn timing (Lyons et al. 2015) under these new conditions. Predicting how Pacific salmon will respond to their changing environment presents a formidable challenge, and thus it is imperative that we understand the mechanisms behind those responses to effectively make decisions for their conservation and sustainability.

References


International Year of the Salmon

Proven Potential of Integrated Ecosystem Research in Expanding Human Understanding of the High Seas Environment

By Moronke Harris
Assistant IYS Coordinator, North Pacific Region
2019 NPAFC Intern

Moronke Harris was born and raised in land-locked Richmond Hill, Ontario, and joins the NPAFC from the Environmental and Community Health Services sectors of the Regional Municipality of York. In 2017, she graduated with a BSc (Honours) in Biological Science at the University of Guelph (Guelph, Ontario), where she completed studies on furunculosis and cold-water disease diagnosis in brook and rainbow trout. An aspiring oceanographic biogeochemist, Moronke strongly believes that observation of the largely unexplored ocean offers unmatched opportunity for revolutionary discoveries and scientific advances. Her research placements have taken her from studying climate engineering tactics in the Bermudian ocean, to the hydrochemical effects of Floridian seagrass beds on ocean acidification mitigation. Moronke is positioned at the NPAFC as Assistant International Year of the Salmon Coordinator. As a Supporting Member of the British Columbia High Seas Research Council, she facilitates 2019 International Gulf of Alaska High Seas Expedition hydrochemical data processing, and preparation for the 2021 International Pan-Pacific High Seas Expedition. Moronke aims to pursue a MSc and PhD in Oceanography.

In the autumn of 2019, the North Pacific Anadromous Fish Commission (NPAFC; npafc.org) successfully completed three days of meetings (October 19–21) associated with the 2019 annual the North Pacific Marine Science Organization (PICES) conference in Victoria, BC, Canada. Significant funding was provided by the British Columbia Salmon Restoration and Innovation Fund (BCSRIF). As an integral part of the International Year of the Salmon (IYS; yearofthesalmon.org) initiative led by the NPAFC in the North Pacific and the North Atlantic Salmon Conservation Organization (NASCO; nasco.int) in the North Atlantic, two workshops during the three days convened oceanographers, ichthyologists, climatologists, and resource managers from around the Pacific Rim and abroad to: (i) explore findings from the ground-breaking 2019 winter expedition to the Gulf of Alaska (GoA), the first comprehensive winter expedition examining Pacific salmon in the GoA that successfully established a baseline of environmental and ecosystem-level measurements for future comparisons; and (ii) plan for an expanded Pan-Pacific expedition in March of 2021.

2019 International GoA Expedition

The high seas pelagic ecosystems of the North Pacific support six species of Pacific salmon; chum (Oncorhynchus keta), coho (Oncorhynchus kisutch), sockeye (Oncorhynchus nerka), pink (Oncorhynchus gorbuscha), Chinook (Oncorhynchus tshawytscha) and masu (Oncorhynchus masou) salmon. During winter, approximately 55 million salmon, spanning all species but the Asian endemic masu, inhabit the GoA. Despite the importance of this region, the vast majority of previous salmon research has focused solely on freshwater and coastal habitats. The present scarcity of baseline data on salmonids in the GoA adds uncertainty to the already challenging task of forecasting returns and predicting salmon behavior and responses to the changing North Pacific ecosystem. Communities and resource managers around the Pacific Rim are challenged to understand the impacts of an increasingly uncertain climate on the distribution and productivity of these culturally and economically important fish. New knowledge is required to determine how climate uncertainty is affecting distribution and productivity across scales.
from coastal to high seas, as well as how human intervention through hatchery production impacts the structure of North Pacific ecosystems in relation to carrying capacity.

To bridge the knowledge gap concerning salmon overwintering conditions, the NPAFC as part of the IYS and along with NGOs, governments, academic and private partners, conducted a high seas expedition with scientists from around the Pacific Rim in winter 2019. The International GoA Expedition was completed with 21 scientific personnel from the five NPAFC member countries (Canada, Japan, the Republic of Korea, the Russian Federation, and the United States of America) aboard the chartered 62 m Russian R/V Professor Kaganovskiy (Figure 1, Figure 2). Organized by Richard J. Beamish, the Pacific Salmon Foundation (PSF) and NPAFC with funding from private individuals, government agencies and NGOs, it was the first in decades to study salmon in the winter high seas and set a precedent for addressing gaps in our knowledge through survey work concerning salmon, plankton, hydrochemical and physical conditions in the central GoA (Figure 3). The expedition covered an area of approximately 700,000 km² between February 16 and March 18, 2019 (Figure 1). In total, 425 salmon (223 chum, 95 coho, 73 sockeye, 31 pink, and three Chinook salmon) were caught during the trawl surveys.

Though the overarching objective was to test key hypotheses on factors regulating salmon survival in the open ocean during the critical overwintering period of their life history, the intent of the expedition was threefold:

i. to demonstrate that international collaboration among scientists from salmon producing countries could be used to effectively investigate factors regulating marine survival of Pacific salmon in shared international waters;

ii. to identify the stock specific rearing areas for all species of salmon, as well as their abundances and condition in order to test the hypothesis that the survival rate of salmon is mostly determined by conditions experienced during the first ocean winter; and

iii. to provide baseline measurements of environmental parameters and major pelagic

![Figure 1. Left: R/V Professor Kaganovskiy. Photo credit: PSF. Right: 58 expedition survey stations sampled between February and March 2019 in the GoA (Pakhomov et al. 2019).](image1)

![Figure 2. Members of the 2019 International GoA scientific team on board the R/V Professor Kaganovskiy at the departure event in Vancouver, BC, Canada (February 16, 2019). Left: From the left, Gennady Kantakov (Russia), Shigehiko Urawa (Japan), Evgeny Pakhomov (Canada) and Igor Shurpa (Russia). Right: From the left, Laurie Weitkamp (USA), Chrys Neville (Canada), Christoph Deeg (Canada) and Hae Kun Jung (Korea). Photo credit: PSF](image2)
ecosystem components including the abundance of Pacific salmon in the GoA in the winter season.

With these findings, scientists hope to create a strong research baseline for future expeditions leading to a program of coordinated integrated surveys across the entire North Pacific that will investigate the mechanisms affecting salmon distribution and productivity. The results of the 2019 survey will directly inform planning for tentative surveys in the GoA in March 2020 and across the full breadth of the North Pacific in 2021. In time, these efforts will provide communities and resource managers with the timely scientific advice needed to manage salmon and ecosystems in a rapidly changing world.

GoA Survey Results: PICES 2019 W16

W16: Developing a collaborative, integrated ecosystem survey program to determine climate/ocean mechanisms affecting the productivity and distribution of salmon and associated pelagic fishes across the North Pacific Ocean

On October 19–20, 2019, the NPAFC co-hosted a two-day workshop, which was co-sponsored by the PICES, NPAFC and the North Pacific Fisheries Commission (NPFC; npfc.int). W16 centered around results of the 2019 International GoA Expedition. Presentations were given by representatives from a wide variety of expedition partner organizations including Fisheries and Oceans Canada (DFO), National Oceanic and Atmospheric Administration (NOAA) Fisheries, NPAFC, the Pacific Branch of the Russian Federal Research Institute of Fisheries and Oceanography (TINRO), PSF, the University of British Columbia (UBC), the University of Victoria (UVic) and Hokkaido National Fisheries Research Institute (HFRI) of Japan Fisheries Research and Education Agency (FRA), and included members of the 2019 GoA scientific team. In total, W16 brought 24 researchers and multiple participants from over six countries together to network, discuss, and share their respective research (Figure 4).

I. Water Dynamics and Chemistry

Spanning approximately 10° latitude (47 to 57°N) and longitude (138 to 148°W), the GoA study area encompassed the eastern extreme of the North Pacific Current, the Sub-Arctic Current, and the beginning of the northbound Alaskan Current. These dynamics produced clear spatial variation in water conditions and biota catches across the study area (Figure 5). Temperature and salinity showed inverse N-S gradients. The cooler, saltier waters were located at the northwestern part of the grid and the warmest, freshest waters in the southeastern grid.
corner (Figure 6).

Two domains were determined within the surveyed area. The first domain was located in the northwestern part of the area, where the cyclonic circulation of the Subarctic gyre provided high concentrations of dissolved oxygen and nutrients. The second domain was influenced by both Subarctic front and the coastal processes that forms its transformed waters of the GoA. In this area, oxygen content and pre-vegetative concentrations of nutrients were lower. Below the thermocline (~200 m), the maximum concentrations of silicate, ammonium, dissolved phosphate and nitrogen were observed within thecentre of Subarctic gyre, therefore being the highest at the northwestern section of the grid. Concentrations of these macronutrients decreased southward, being lowest at the southeastern parts of the grid. Highest and lowest nutrient concentrations closely tracked the coldest and warmest parts of the survey, respectively (Figure 6; Figure 7).

Figure 6. Surface temperature and salinity of the GoA survey area from February to March of 2019. Colder and warmer parts of the survey were demarcated by a surface 7°C isotherm boundary (Pakhomov et al. 2019).

Figure 7. Surface distribution of macronutrients during February–March 2019 in the GoA (Pakhomov et al. 2019).
II. Salmonid Distributions and Genetic Stock Identification

The scientific results of the winter 2019 survey also revealed that salmon species distributions in the GoA differed and appeared to correlate with the environmental characteristics of water masses such as higher or lower ambient temperatures as well as productivity, mesozooplankton composition and macroplankton/micronekton distributional patterns (Table 1). Most surprising was the abundance of coho within the center of the GoA, given they were previously thought to be coastal in distribution, and the appearance of North American sockeye in the small set of western North Pacific samples taken as the R/V Professor Kaganovskiy made the journey from Russia to Canada to begin the 2019 expedition. Novel genomic tools allowed researchers to conduct at-sea DNA analyses for stock identification as well as assess physiological condition and test for the presence of pathogens for the first time. Interestingly, stock composition was largely independent of capture site, suggesting that distant stocks do not segregate according to origin but instead readily mix within the open ocean. For example, chum salmon of both Asian and North American origin co-mingled in the survey area (Figure 8). Genetic stock identification (GSI) using a Pacific-wide single nucleotide polymorphism baseline indicated a mixture of 20% Japanese, 20% Russian and 60% North American chum salmon.

III. Future Directions

Several discussions on new perspectives and ideas generated by the presentations were held between sessions. Participants suggested additional considerations and improvements for future expeditions including sampling eDNA at greater depths to better understand vertical distribution of species, installing cameras in the trawl nets to determine if predators enter and exit the net during sets, having dedicated marine mammal and bird observers on board and determining the vertical migration of salmon during the day and night. More on the preliminary results of the 2019 International GoA Expedition can be found at yearofthesalmon.org/gulf-of-alaska-expedition.

2021 International Pan-Pacific Expedition

Building on the successful single vessel expedition conducted from February to March 2019 in the GoA, a 2021 International Pan-Pacific Expedition has been proposed. If implemented, it will employ up to five research vessels operating simultaneously to survey the full breadth of the North Pacific Ocean (NPO) in winter 2021. These vessels will carry leading scientists from Canada, Japan, the Republic of Korea, the Russian Federation, and the United States of America committed to answering questions concerning mechanisms affecting the productivity and distribution of salmon. This expedition will provide a platform for international collaborative ecosystem research to monitor the distribution, abundance, and productivity of salmon—information that will directly inform fisheries management and enforcement decisions to be made in an increasingly uncertain future.

At the present time, notional requests for vessels are being considered by the five NPAFC member countries. Three or four vessels will cover a pan-Pacific grid, consisting of five regions for simultaneous sampling of biophysical oceanography and biota on a grid of stations that are spaced at 60 nautical mile intervals, while it has been proposed to have another vessel conduct fine-scale research to provide greater detail on our

Table 1. Survey area dominance, frequency of occurrence in trawl catches, estimated numbers and biomass of Pacific salmon species in the upper epipelagic layer (0–30 m) throughout the investigated area in the GoA during winter 2019 at a catchability coefficient (q) of 0.3 (Pakhomov et al. 2019).

<table>
<thead>
<tr>
<th>Salmon Species</th>
<th>Survey Area Dominance</th>
<th>Frequency of Occurrence (%)</th>
<th>Numbers (million fish)</th>
<th>Biomass (thousand tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chum (Oncorhynchus keta)</td>
<td>widely distributed</td>
<td>55.2</td>
<td>24.17</td>
<td>26.96</td>
</tr>
<tr>
<td>Coho (Oncorhynchus kisutch)</td>
<td>southern and westerly stations</td>
<td>37.9</td>
<td>13.59</td>
<td>10.37</td>
</tr>
<tr>
<td>Sockeye (Oncorhynchus nerka)</td>
<td>northern stations</td>
<td>31.0</td>
<td>8.94</td>
<td>10.28</td>
</tr>
<tr>
<td>Pink (Oncorhynchus gorbuscha)</td>
<td>southern and westerly stations</td>
<td>17.2</td>
<td>4.21</td>
<td>1.63</td>
</tr>
<tr>
<td>Chinook (Oncorhynchus tshawytscha)</td>
<td>rarely and sporadically occurred</td>
<td>5.17</td>
<td>0.37</td>
<td>1.32</td>
</tr>
</tbody>
</table>
understanding of how salmon interact with the high seas environment (Figure 9). In conjunction with the 2021 winter surveys, the NPAFC member countries will conduct coastal and high seas salmon surveys during the spring, summer, and fall of 2020–2021. Several hypotheses will be employed to examine how increasingly extreme climate variability in the NPO and the associated changes in the physical environment will influence the population distribution patterns, migration, growth, survival and fitness of Pacific salmon, and dependent human populations.

The 2021 Expedition is being planned primarily by agencies of the five NPAFC member countries. However, successful implementation of the Canadian role in the 2021 Pan Pacific High Seas Research Expedition will be facilitated by the British Columbia High Seas Research Council. Members include invited scientific and executive representatives from IYS partner organizations spanning academia, governments, First Nations and industry.

**2021 High Seas Planning Workshop**

On October 21, 2019, a third day of meetings
hosted by the NPAFC at Ocean Networks Canada (ONC) resulted in preliminary survey plans involving a minimum four vessels operating simultaneously in the winter of 2021. Similarly to the successful workshop held at PICES 2019, invited participants included scientific, government, and NGO personnel from the five NPAFC member countries.

Central to the 2021 International Pan-Pacific Expedition initiative is the intention that all five countries will develop the overarching program in conjunction, with scientific collaborators from all countries pursuing a survey design that will enable testing of hypotheses regarding mechanisms affecting the current and future salmon distribution and productivity in the North Pacific. This includes the provision of ship time, hypotheses and standardized methods of data collection, analysis, and storage.

At ONC, following the presentations of key aspects of the planned expedition by facilitators, Mark Saunders (IYS, NPAFC) and Mark Winston (Simon Fraser University), attendants readily contributed to discussions for the following development points:

i. Formulate highest priority hypotheses for the 2021 Expedition

ii. Evaluate current survey logistics (consider the efficacy of potential designs and their capability in providing accurate forecasts)

iii. Advise the redesigning of expedition logistics if necessary (identify new data, new analyses, new participants, and new research to include in the process)

iv. Strategize specific methods for international data integration and coordinated analysis

v. Clarify the compelling connection between 2021 efforts and management in survey rationale

The workshop and associated activities were intended to increase collaboration and build linkages and synergies among scientists from around the Pacific Rim. Ultimately, multi-nation surveys of the high seas will provide the missing science that will allow humans to both understand the mechanisms that drive salmon productivity and effectively manage salmon in a highly uncertain future.

Effectiveness of International Collaboration

The defining feature of both the PICES 2019 and ONC high seas expedition workshops, as well as the 2019 survey was the enthusiasm that the international team of ocean and salmon scientific experts from around the Pacific Rim displayed. The excitement was palpable as they revealed novel findings from winter 2019 and began planning for an unprecedented suite of surveys to cover the entire NPO in 2021:

“This has been a really wonderful experience [because of] how well everyone is working together...the level of enthusiasm [displayed by] everybody has been fantastic”—Laurie Weitkamp, NOAA, USA

“We have a baseline that has never been available before, we have observations about species distributions that we cannot explain right now.”—Richard Beamish, DFO Emeritus, Canada

“I believe that [aside from] our scientific findings, this will bring our nations closer [diplomatically].”—Arkadii Ivanov, TINRO, Russia

“Being able to work in real time with [international] scientists, looking at similar questions [of interest] from around the North Pacific is fabulous…it’s very, very exciting.”—Chrys Neville, DFO, Canada

Pacific salmon are an important cultural, commercial and biological resource for British Columbia and countries of the North Pacific Rim. As a changing climate and associated anomalous events within the large marine ecosystems of the NPO progressively expose Pacific salmon to conditions that are outside standard climate cycles, society will be confronted by new, augmented resource management issues. International collaboration facilitates a large-scale exchange of information, experience and capacity to most efficiently and effectively address the significant gap in our understanding of rapidly changing climate/ocean processes in the high seas and how they impact salmon. With high seas monitoring and research capacity there is the potential to understand mechanisms affecting survival across the full life history and make sound short term (in-season) or longer-term decisions that can utilize climate projections of changing marine distribution and productivity. In addition, knowledge of changing distribution will be important to effective and affordable high seas enforcement and informing
investments in restoration and hatcheries.

**IYS: Salmon and People in a Changing World**

Both the 2019 and 2021 expeditions are Signature Projects of the IYS. The IYS is a five year initiative (2018–2022) of the NPAFC and its North Atlantic partner, NASCO, aiming to establish a new hemispheric-scale partnership of governments, Indigenous Peoples, academia, NGOs and industry to effectively address the scientific and social challenges facing salmon and people in an increasingly uncertain environment. The IYS can be found on [Twitter](https://twitter.com), [Facebook](https://facebook.com) and [Instagram](https://instagram.com).

**Acknowledgements**

**References**


*Chinook and coho salmon collected during the 2019 International GoA Expedition. Photo credit: Chrys Neville, DFO and Svetlana Esenkulova, PSF*
Accepting Applications for the 2020 NPAFC Internship Program

APPLICATION DEADLINE: March 19, 2020

The North Pacific Anadromous Fish Commission (NPAFC) invites citizens from its member countries (Canada, Japan, the Republic of Korea, the Russian Federation, and the USA) to apply for the NPAFC Internship Program. One or two interns will be accepted upon approval of the Commission. The intern will work at the NPAFC Secretariat office in Vancouver, BC, Canada.

The intern will gain experience and knowledge in operations of the NPAFC and will have the opportunity to test his/her interest in international governmental organizations, fisheries management, salmon biology & ecology, and fisheries enforcement. The intern will work under the supervision of the Executive Director and/or his designates. In general, the intern will assist in a variety of tasks, including:

- plan, develop, and complete an individual project in enforcement, science, communication, fisheries management, or administration;
- prepare information for and provide support to special projects including the International Year of the Salmon (IYS) initiative;
- assist in organizing and editing various NPAFC publications;
- coordinate international cooperative programs and assist Secretariat activities; and
- assist with other work delegated by the Executive Director and/or his designates.

Internship period: Up to a maximum of 6 (six) months, with the start date to be negotiated. Start date must occur between the period of July–December 2020. The intern is expected to perform his/her tasks at the Secretariat office on a daily basis, Monday–Friday, 7.5 hours per day.

Qualifications: Applicants must be a citizen of an NPAFC member country, have a university degree, the ability to read, write, and speak English, the ability to use computers and the Internet, and demonstrated personal initiative. Applicants must currently be a part of the government or academic sector, a recent graduate, or currently enrolled in school for an advanced degree.

Financial support: NPAFC will provide a stipend of CDN $2,500 per month. Travel costs for the intern to and from his/her place of residence and the location of the Secretariat will be at the intern’s own expense or by home country support. Travel expenses associated with the intern’s work in the Secretariat will be covered by NPAFC. The intern’s medical insurance and benefits are not covered by the NPAFC Internship Program.

Applications: Completed applications must include all of the following:

- A cover letter describing the applicant’s interests and qualifications
- Resume showing academic and/or work experience
- Three professional letters of reference
- Personal Data Page of passport as citizenship proof

Email the completed application to secretariat@npafc.org by March 19, 2020. The selected intern will be notified in early June of 2020.

For complete information: Go to https://npafc.org and contact the NPAFC Secretariat for questions at secretariat@npafc.org.

APPLICATION DEADLINE: March 19, 2020
Technical Editors: Jeongseok Park and Laura Tessier

Organizing Committee: Richard Brodeur, Ed Farley, Jr., Jim Irvine, Ju Kyoung Kim, Svetlana Naydenko, Mark Saunders, Michael Schmidt, Shigehiko Urawa, Brian Wells, and Jeongseok Park

Proceedings of the second NPAFC-IYS Workshop on *Salmon Ocean Ecology in a Changing Climate*, May 18–20, 2019, Portland, Oregon, USA. Full PDF extended abstracts are available online.

**Topic 1: Current Status of Salmon and Their Environments**

**Status of Salmon in a Changing Environment: A Perspective from Alaska**
Andrew R. Munro, Richard E. Brenner, and William D. Templin
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**Changing Productivity, Variability, and Synchrony within Stock Aggregates can Limit Management Effectiveness**
Cameron Freshwater, Sean C. Anderson, Kendra R. Holt, Ann-Marie Huang, and Carrie A. Holt
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**Unprecedented Far East Salmon Catches in 2018: What Should We Expect in Future?**
Andrey S. Krovnin, Nataliya V. Klovach, and Kirill K. Kivva
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**Temporal Forms of Pink Salmon in Sakhalin-Kuril Region and their Abundance Dynamics**
Alexander M. Kaev
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**Current Status of Chum Salmon Populations in the Rivers with and without Hatchery Stock Enhancement on the Sanriku Coast, Japan**
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**Variation in Out-migration Timing and Estuary Reliance of “ocean-type” Chinook Salmon in the Fraser River Estuary, BC**
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**Direct and Carryover Effects of Freshwater, Marine and Fish Conditions on Juvenile, Ocean, and Adult Survival of Snake River Chinook Salmon**
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**Juvenile Salmon Migration Observations in the Discovery Islands and Johnstone Strait in 2018 Compared to 2015–2017**
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Topic 1-2. Migration and distribution

What can We Learn About the Return Migration of Fraser River Sockeye Salmon from Catches in Alaska?
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Inter-annual, Stock-specific Distribution and Migration of Juvenile Sockeye Salmon (Oncorhynchus nerka) from 1997–2017
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Long-term Trends of Distribution and Regional Composition of Hatchery-released Juvenile Pink and Chum Salmon in the Sea of Okhotsk during the Fall of 2011–2017
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Timing of Spawning of Wild Chum Salmon in a Non-enhanced River and their Seaward Migration in Northern Honshu, Japan
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Genetic Characterization of Juvenile Chum Salmon (Oncorhynchus keta) Migrating out of the Yukon River Delta
Genevieve M. Johnson, Christine M. Kondzela, Jacqueline A. Whittle, Katharine Miller, and Jeffrey R. Guyon
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Morphological and Genetic Subdivision of Sockeye Salmon Samples, Oncorhynchus nerka, Collected within the Period of Spawning Migration in Outfalls of Kamchatka Rivers
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Trace Elements Content in the Pink Salmon (Oncorhynchus gorbuscha Walbaum, 1792) from Sakhalin-Kuril Region
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Migration and Homing Behavior of Chum Salmon Tagged in the Okhotsk Sea, Eastern Hokkaido
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A Model of Smolt-to-adult Survival in Terms of Salmon Growth through the Size Distribution of Predators
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Changes in Juvenile Salmon Prey Fields Associated with a Recent Marine Heat Wave in the Northern California Current
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Southeast Alaska Pink Salmon Growth and Harvest Forecast Models
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Effect of Temperature and Amount of Food on the Growth Rate/Aerobic Scope of Juvenile Chum Salmon
Yuki Iino, Takashi Kitagawa, Takaaki K. Abe, Tsuyoshi Nagasaka, Yuichi Shimizu, Katsuhiko Ota, Takuya Kawashima, and Tomohiko Kawamura
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Spatial and Temporal Trends in Juvenile Sockeye Salmon Diets across Oceanographic Regimes on the Coast of British Columbia
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The Role of Environmental Conditions in Various Types of Estuaries for the Productivity of Pacific Salmon Populations of Kamchatka
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Is Juvenile Salmon Condition Driven by the Nutritional Quality at the Base of the Plankton Food-web?
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Trophic Relationships between Juvenile Salmon during a 22-year Time Series of Climate Variability in Southeast Alaska
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Neala W. Kendall, Benjamin W. Nelson, and James P. Losee
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Bottom-up Links to Juvenile Salmon Growth and Survival in Puget Sound, WA, USA
Julie E. Keister, Amanda K. Winans, BethEiLee Herrmann, Julia Bos, and Iris Kemp
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Quantifying Juvenile Salmon Prey Quality and Exploring Trophic Linkages in Puget Sound, WA, USA
Amanda K. Winans, BethEiLee Herrmann, Minna Hiltunen, Ursula Strandberg, Michael Brett, and Julie E. Keister
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Topic 2: Salmon in Changing Ocean Conditions

Sustainable Conservation and Use of Chum Salmon under Warming Climate and Changing Ocean Conditions
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Topic 2-1. Linkage between salmon production, climate and ocean changes

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Competitive Interactions between Natural Populations of Pink and Chum Salmon from Puget Sound and Coastal Washington, USA
Marisa N.C. Litz, Aaron M. Dufault, Andrew M. Claiborne, James P. Losee, and Tyler J. Garber
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Ecosystem Indicators Development for Coho and Chinook Salmon
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Patterns of Synchrony and Environmental Thresholds in the Performance of Forecast Models Used for U.S. West Coast Chinook and Coho Salmon Stocks
William H. Satterthwaite, Kelly S. Andrews, Jennifer L. Gosselin, Correigh M. Greene, Chris J. Harvey, Mary Hunsicker, Stuart H. Munsch, and Jameal F. Samhouri
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Long-term Shifts of Chum Salmon (Oncorhynchus keta) Distribution in the North Pacific and the Arctic Ocean in Summer 1982–2017
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A Compound Specific Stable Isotope Analysis of Chinook Salmon Stocks Caught in the Northern and Southern Strait of Georgia
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Detecting the Effects of Management Regime Shifts in Dynamic Environments Using Multi-population State-space Models
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State of the Salmon: Improving Predictions of Salmon Survival during a Period of Rapid Change
Sue C.H. Grant, Bronwyn L. MacDonald, David A. Patterson, Kendra A. Robinson, Jennifer L. Boldt, Keri Benner, Jackie A. King, Lucas Pon, Chrys M. Neville, Joe A. Tadey, Mike Hawshaw, and Dan T. Selbie
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Evaluating Impacts of Time-varying Productivity in Stock-recruit Relationships on Biological Benchmarks
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Improving Terminal Abundance Estimates of Spring- and Summer-run Age 5+ Fraser River Chinook Salmon by Incorporating a Second CPUE Dataset from the Albion Test Fishery
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Assessing the Early Marine Ecology of Juvenile Chinook Salmon in a Warming Bering Sea
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Topic 3-1. New Technologies

Comparison of Coded-wire Tagging with Parentage-based Tagging and Genetic Stock Identification in Large-scale Coho Salmon Fisheries Applications in British Columbia, Canada
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Developing an Inter-individual Communication Biotelemetry System and Application to Chum Salmon Returned to off Japanese Waters
Takashi Kitagawa, Nobuhiko Sato, Shigenori Nobata, Hiromichi Mitamura, Yoshinori Miyamoto, Nobuaki Arai, Keiichi Uchina, Hokuto Shirakawa, and Kazushi Miyashita
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A PIT Tag Based Method for Investigating Survival of Juvenile Cowichan River Chinook during their First Year of Life
Kevin A. Pellett, Will Duguid, Jeramy Damborg, and Jamieson Atkinson
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Integrating Multiple Intrinsic Markers to Infer Habitat Use of Sockeye Salmon Stocks (Oncorhynchus nerka) in the North Pacific Ocean
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A Compilation and Meta-analysis of Salmon Diet Data in the North Pacific Ocean
Caroline Graham, Evgeny A. Pakhomov, and Brian P.V. Hunt
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Topic 3-2. Integrated information and management systems

Supplementation of Atlantic Salmon in the Southern Extent of their Range: Evaluation of Age-1 Hatchery Smolt Stocking in a Small Coastal Watershed
James P. Hawkes, Graham S. Goullete, Alejandro M. Moctezuma, Ernie J. Atkinson, and Oliver N. Cox
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Dynamic Ocean Management for Salmon: Integrating Spatially-explicit Environmental and Fishery Datasets to Describe and Predict Fish Distributions
Jordan T. Watson, Rob Ames, Camille Kohler, Robert Nigh, Robert Ryznar, and Jenny Suter
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The International Salmon Data Laboratory (ISDL)
Scott A. Akenhead
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The Third NPAFC-IYS Workshop on Linkages between Pacific Salmon Production and Environmental Changes will be held in May 23–25, 2020, Hakodate, Japan. Workshop and hotel registration will be open in early March. For details, please visit the NPAFC website (https://npafc.org).
Enjoy this twist on a classic by adding your favourite smoked Pacific salmon! This recipe uses smoked wild sockeye salmon for the filling and pink salmon caviar as a garnish. The saltiness from the salmon and caviar pair well with the creamy yolk filling, and if desired, a sprig of dill or cornichon pickles on the side can enhance the delicate flavours. This finger food is a perfect hors d’oeuvre for a special occasion, and is so simple to make.

**Ingredients**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Extra-large eggs</td>
</tr>
<tr>
<td>3 tbs</td>
<td>Chopped fresh chives, plus more for garnish</td>
</tr>
<tr>
<td>2 oz</td>
<td>Red caviar (salmon roe)</td>
</tr>
<tr>
<td>4 oz</td>
<td>Smoked wild salmon, minced</td>
</tr>
<tr>
<td>1 tsp</td>
<td>Dijon mustard</td>
</tr>
<tr>
<td>½ cup</td>
<td>Mayonnaise</td>
</tr>
<tr>
<td>3–4</td>
<td>Small cornichon pickles or spring of dill (optional)</td>
</tr>
</tbody>
</table>

~ Salt and pepper to taste

**Method**

1. In a large pot, arrange the eggs in a single layer and add enough cold water to fully cover them. Slowly bring to a boil over medium heat. Boil for 5–8 minutes, then strain and fill the pot with ice-cold water and allow the eggs to cool.

2. Once eggs have cooled, peel the shells and slice eggs in half lengthwise. Carefully remove the yolks and place into a medium mixing bowl. Arrange the eggs cut side up on a serving platter in a single layer. Sprinkle the eggs with a pinch of salt and refrigerate while you make the yolk mixture.

3. In the medium mixing bowl, add the mayo and mustard to the yolks. Mix well with a fork until an even consistency is achieved.

4. Gently add the minced salmon and chives, mix until combined.

5. Season the yolk mixture with salt and pepper to taste.

6. Carefully spoon the yolk mixture into the eggs. Cover loosely and refrigerate for at least 30 minutes to allow the flavours to blend.

7. Add a sprig of dill or cornichon pickles on the side, and garnish with a dollop of red caviar and chopped chives before serving.

8. Enjoy!
Smoked Salmon Rice Paper Rolls
With mint sweet chili dipping sauce

A Canadian twist on a Vietnamese classic, these smoked salmon rice rolls are sure to delight family and guests. Yellow bell pepper, butter lettuce, garden radish and smoked salmon—brightened with scallion, and combined with mint sweet chili dipping sauce—make for a fresh and savory filling with just the right notes of sweetness. This versatile dish can be served as an appetizer or paired with a mixed-greens salad for a spread that is guaranteed to have a recurring spot within your weekly meal plan.

Preparation Time: 40 minutes

Yield: 10 to 12 Portions

Suggested Pairing:
Appetizers are often served with light white wines. The fresh, rich flavours of these rice rolls call for something crisp, refreshing and light-bodied—like a Pinot Grigio or Sauvignon Blanc.

Three Impressive Health Benefits of Salmon

1. Reduces inflammation markers in people at risk for chronic diseases (e.g., heart disease, diabetes and cancer). Inflammation is the root cause of most chronic diseases.

2. Contains carotenoid antioxidant astaxanthin, which prevents skin damage and lowers heart disease development risk by reducing LDL ("bad") cholesterol oxidation and increasing HDL ("good") cholesterol.

3. 100 grams of salmon provides 59–67% of the recommended daily intake of selenium, a mineral that protects bone health.

Ingredients

<table>
<thead>
<tr>
<th>Smoked Salmon Rolls</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 g Cold smoked salmon</td>
</tr>
<tr>
<td>½ English cucumber</td>
</tr>
<tr>
<td>½ Yellow bell pepper</td>
</tr>
<tr>
<td>3 Scallions</td>
</tr>
<tr>
<td>8 Garden radishes</td>
</tr>
<tr>
<td>6 Leaves of butter lettuce</td>
</tr>
<tr>
<td>½ Package of small rice noodles</td>
</tr>
<tr>
<td>1 Package of rice paper</td>
</tr>
<tr>
<td>2 tbsp Sesame seed oil</td>
</tr>
<tr>
<td>~ Seasoning salt</td>
</tr>
<tr>
<td>~ Red pepper flakes (optional)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sweet Chili Dipping Sauce</th>
</tr>
</thead>
<tbody>
<tr>
<td>½ cup Sweet chili sauce</td>
</tr>
<tr>
<td>¼ cup Lime juice</td>
</tr>
<tr>
<td>1 tbsp Chopped fresh mint leaves (optional)</td>
</tr>
</tbody>
</table>

Cold smoked salmon, English cucumbers, yellow bell pepper slices, and scallions all contribute to this wonderful meal
Method

**Smoked Salmon Rolls**

1. Boil rice noodles in a large pot. Season water with seasoning salt.

2. Meanwhile, wash, deseed/devein, and julienne the yellow bell pepper, cucumber, and butter lettuce.

3. Slice the garden radishes widthwise into thin circles.

4. Chop scallions into ½ inch diagonal pieces.

5. When rice noodles are complete, drain the water and gently fold in sesame seed oil. Let cool.

6. Place 1 roll of rice paper in a bowl of warm water until just softened; lift from the water carefully and place on a board.

7. Place rice noodles, lettuce, 1–2 slices of salmon, cucumber, bell pepper, radish and scallions in middle of the sheet. Dress with a sprinkle of red pepper flakes.

8. Roll rice paper once, fold in sides and roll up.

9. Repeat with the remaining ingredients and serve with dipping sauce.

**Sweet Chili Dipping Sauce**

10. In a small bowl, combine the lime juice with sweet chili sauce of your choice. Add finely chopped mint leaves. Mix.

11. Enjoy!
Vladimir Belyaev, the current Chairperson of the Committee on Finance and Administration (F&A) of the NPAFC, was elected as a new Chairperson of the North Pacific Fisheries Commission (NPFC) at the 5th NPFC Commission Meeting in July 2019, held in Tokyo, Japan. He is Head of the Center for International Fishery Cooperation, Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), Moscow, Russia. Since the NPAFC and NPFC signed a Memorandum of Cooperation (MOC) on May 13, 2019—which opened a new era of cooperation and promises to strengthen the long-term relationship between the two commissions—it is expected that he, as NPFC Chairperson, will continue to enhance cooperation between the two organizations during his term.

Bill Templin was elected as a new Chairperson of the NPAFC Working Group on Stock Identification (WGSI) at the 27th Annual Meeting in May 2019. He is the Chief Fisheries Scientist for Salmon in the Commercial Fisheries Division, Alaska Department of Fish and Game (ADF&G), Anchorage, AK, USA. The primary goal of the WGSI is to provide a forum for developing, standardizing, and disseminating genetic and biological data of Pacific salmon and steelhead trout in the North Pacific Ocean and to increase knowledge of anadromous stock-specific ocean distribution and migration.

Sean Wheeler and Andy Gray were elected Co-chairpersons of the Small ENFO/CSRS Working Group on Intercommittee Coordination (WGIC) at the 27th Annual Meeting in May 2019. Sean is a Senior Program Officer within Conservation and Protection at Canada’s Department of Fisheries and Oceans (DFO). Andy is the Supervisory Marine Biologist, Auke Bay Laboratories, Ted Stevens Marine Research Institute, Alaska Fisheries Science Center, Juneau, Alaska, USA. The primary goal of the WGIC is to improve the coordination between the two committees with the objective of enhancing enforcement effectiveness and the collection of scientific data.
People at the Secretariat

William (Bill) Stanbury joined the NPAFC Secretariat as Web/Publication Manager in October 2019. He was born in Vancouver, British Columbia, and graduated from both the University of British Columbia with a BA in History and from the British Columbia Institute of Technology with a Technical Diploma in Fish, Wildlife, and Recreation. Bill has completed invasive species mapping projects and mapped local trails with community groups. He has worked in a turtle hatchery enhancement program to rehabilitate sub-populations of the Western Painted Turtle, a protected species in BC, and reared hatchery coho salmon. Bill worked as a hydroacoustics technician with the Pacific Salmon Commission (2015–2017), an organization formed by Canada and the United States to cooperatively manage Pacific salmon, where his responsibilities included enumerating and sampling returning adult Fraser River sockeye salmon. Bill was one of the two 2016 NPAFC Interns, and wrote the article, “Biological monitoring of key salmonid populations: steelhead trout in BC” in Newsletter No. 41. Bill has a passion for sports, his dog Kona, and beer. He spent his youth heavily involved in soccer and hockey, activities he continues as an adult. He kayaks, hikes, and had the exciting experience of bobsledding at the Olympic Sliding Centre in Whistler, BC. His dog Kona, a Bernedoodle, often accompanies him on hikes and activities across Vancouver. Finally, Bill loves a pint of beer. You can often find him at a local craft brewery sampling some of the finest beers Vancouver has to offer.

Jeongseok Park, NPAFC Deputy Director, became a father to a healthy baby boy. Bomi, his wife, gave birth to Jaemin on Saint Patrick’s Day, March 17, 2019 in Vancouver. Jaemin has a very quiet and calm personality and loves to smile. He looks like Jeongseok and is growing so fast. Jaemin is struggling to stand up alone and it will take a bit more time before he can finally stand. Jeongseok and Bomi are enjoying day-to-day life with their baby. We wish Jeongseok and his family all the best.
Upcoming Events

2020 IYS North Pacific Steering Committee and Working Group Meetings
Dates: February 25–28, 2020
Venue: Blue Horizon Hotel, Vancouver, Canada

Committee on Enforcement Joint Patrol Schedule Meeting
Dates: March, 2020
Venue: Email Meeting

ENFO/CSRS Workshop
Dates: May 17, 2020
Venue: Hakodate Arena, Hakodate, Japan

NPAFC 28th Annual Meeting
Dates: May 18–22, 2020
Venue: Hakodate Arena, Hakodate, Japan

The Third NPAFC-IYS Workshop on Linkages between Pacific Salmon Production and Environmental Changes
Dates: May 23–25, 2020
Venue: Hakodate Research Center for Fisheries and Oceans, Hakodate, Japan

Recently Published

NPAFC Technical Report 15
Includes extended abstracts of oral and poster presentations at the second NPAFC-IYS Workshop (on Salmon Ocean Ecology in a Changing Climate) in May 2019. It is now available at https://npafc.org.

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Visit the NPAFC website: https://npafc.org for more information on events, publications, scientific documents, and salmon catch statistics.

The Commission encourages submission of ideas, articles, and images on NPAFC-related activities for publication in the newsletter.

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