North Pacific Anadromous Fish Commission

Established to promote conservation of anadromous stocks in the North Pacific Ocean.
Members are Canada, Japan, the Republic of Korea, the Russian Federation, and the United States of America.

NEWSLETTER

New Year Message from the President

Greetings! As we welcome in another new year I would like to express a heartfelt thanks to each and every one of you and the Parties you represent for your contributions to a very busy and successful milestone year at the NPAFC. During 2017 some of you supported the delivery of our routine annual activities, while others designed and/or participated in our special 25th Anniversary celebrations, organized and contributed to our Annual Meeting, strengthened our capacity to detect Illegal, Unreported and Unregulated fishing (IUU) in the high seas of the North Pacific, or supported the planning of our most ambitious program to date—*International Year of the Salmon (IYS)*. Big and small, your collective contributions have made a real difference to our understanding of the current status of salmon populations throughout the North Pacific and the factors that compromise their conservation. Together, we have energized teams of scientists, policy-makers, conservationists and salmon lovers throughout the northern hemisphere to join forces with us to ensure the sustainability of these iconic species for the benefit and enjoyment of future generations. I encourage you to take pride in these achievements—you made my inaugural year as President of this organization a real joy and I am excited at what we are positioned to achieve in the coming year.

Carmel Lowe has worked for the Canadian federal government for some 27 years. During this time she has occupied a variety of science-based positions and is currently employed as the Pacific Regional Director of Science in the Department of Fisheries and Oceans Canada and the Canadian Coast Guard. In this role she is responsible for managing an approximately 600-strong team of scientific and technical personnel to deliver the scientific products and advice required to support effective decision-making with respect to Canada's aquatic resources and habitats. Carmel is also a member of the PICES Governing Council and currently serves as Chair of its Finance and Administration Committee. Additionally, she is in her second and final year as Chair of the Pacific Salmon Commission's Committee on Scientific Co-operation. Carmel holds BSc and MSc degrees in Geoscience from University College Ireland Galway and a PhD in Geophysics from Trinity College, Ireland. She has broad interests in the outdoors and when not working likes to enjoy nature with family and friends. Carmel was elected NPAFC President in May 2016.

INSIDE THIS ISSUE

I do wish to pass along my very deepest appreciation to a few among you who dedicated much extra time and energy in making 2017 the very special year it was. Gary T. Smith and his international team of volunteers planned and delivered the historic celebration in Victoria, BC, Canada on May 15, 2017, that marked the 25th Anniversary of NPAFC's founding. From the inspiring welcome provided by the Lt. Governor of BC (the Honorable Judith Guichon) and the First Nations Le-La-La Dancers, to the keynote speeches by former Presidents (Vyacheslav Zilanov, and Fran Ulmer), past NPAFC Enforcement Committee Chair (Vincent O'Shea, USCG), and past NPAFC Science Panel Chair (Dick Beamish) among others, this event was truly a trip down memory lane. The speeches confirmed the importance of vision, hard work, collaboration and persistence to the conservation of salmon in our convention area over the last quarter century and reinforced their relevance for ensuring their future survival and productivity.

The messages of these notable NPAFC founders were reaffirmed by subsequent reports of the Committee for Enforcement (ENFO) and the Committee for Scientific Research and Statistics (CSRS) at the Annual Meeting. Under the leadership of Phillip Thorne (USA), ENFO members designed and delivered a very successful collaborative effort aimed at combatting Illegal, Unreported, and Unregulated (IUU) fishing on the high seas of the North Pacific in 2016 and 2017. Including more than 548 hours of aircraft patrols, 218 days of ship patrols and scrutiny of more than 2000 vessels by the fisheries enforcement representatives of member States. Their efforts in 2016 led to the arrest of one vessel and the watch-listing of two others. They also reported that Korea has acceded to the FAO Port State Measures Agreement on January 14, 2016 and that subsequent ratification of this Agreement by the USA on February 26, 2016. Japan deposited its instrument of accession to this Agreement on May 19, 2017. This has effectively added a new level of deterrence to IUU activity since this agreement prevents illegally caught fish from entering the market place.

Khabarovsk, Russia. Photo credit: Pavel Emelin

Under the Chairmanship of Igor Melnikov, the CSRS Committee was also very active in 2017. In addition to presenting salmon catch and hatchery statistics, the committee planned, reviewed and coordinated exchange of scientific data and samples, and assessed scientific studies of Pacific salmon and steelhead in international waters and adjacent areas of the North Pacific. Of particular note, they examined a preliminary proposal of an Interactive Mapping System (IMS) for a high seas salmonid tag-recovery database and agreed to further develop IMS as part of the NPAFC website. This new tool will provide a dynamic display of information on the ocean distribution and movement patterns of Pacific salmon and steelhead trout and empower users to easily search and display tag-recovery data by species, age class, maturity, origin, etc. As such, this tool is expected to become a powerful addition to our tool kit for future monitoring and assessment of anadromous stocks.

2017 marked the second year of formal planning for the IYS. Under the direction of Mark Saunders and with strong support from George Iwama, Madeline Young, the Secretariat and all Parties there were many noteworthy advances that are detailed later in this issue (see Page 24). For me personally, a highlight was a visit from Mr. Jóannes Hansen, President of the North Atlantic Salmon Conservation Organization (NASCO), to my office in Nanaimo, BC, Canada in August 2017. During the visit, the President re-affirmed NASCO's commitment to the IYS initiative and a desire to strengthen governance, planning, co-ordination and collaboration—commitments we anticipate will be further solidified when the IYS Coordinating Committee hold their first face-to-face meeting in London, UK in early February, 2018.

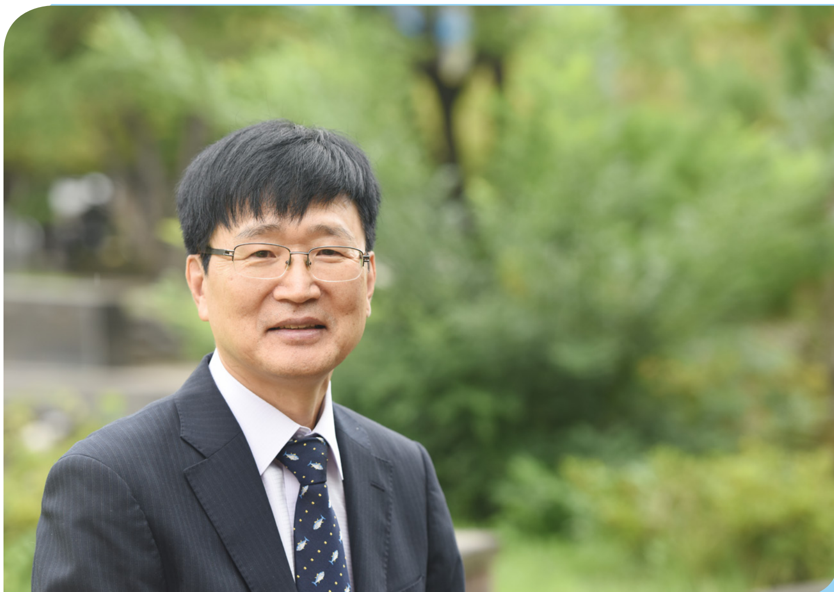
It cannot go without saying that none of our achievements this past year would have been possible without the exceptional management of our Executive Director, Vladimir Radchenko, the guidance of our Finance and Administration Committee and the ongoing and stellar support of our Secretariat staff and interns. We were sad to say goodbye to former Deputy Director, Nancy Davis at the beginning of 2017, but the arrival of our new Deputy Director, Jeongseok Park soon after brought welcomed skills, capacity and personality to the small but mighty Secretariat.

Thanks again to each and every one of you and until we meet again in Russia, I wish you continued success for 2018.

See you in Khabarovsk!

North Pacific Fisheries Commission Overview of Its Second Year of Operation

By Dae-Yeon Moon
Executive Secretary, NPFC

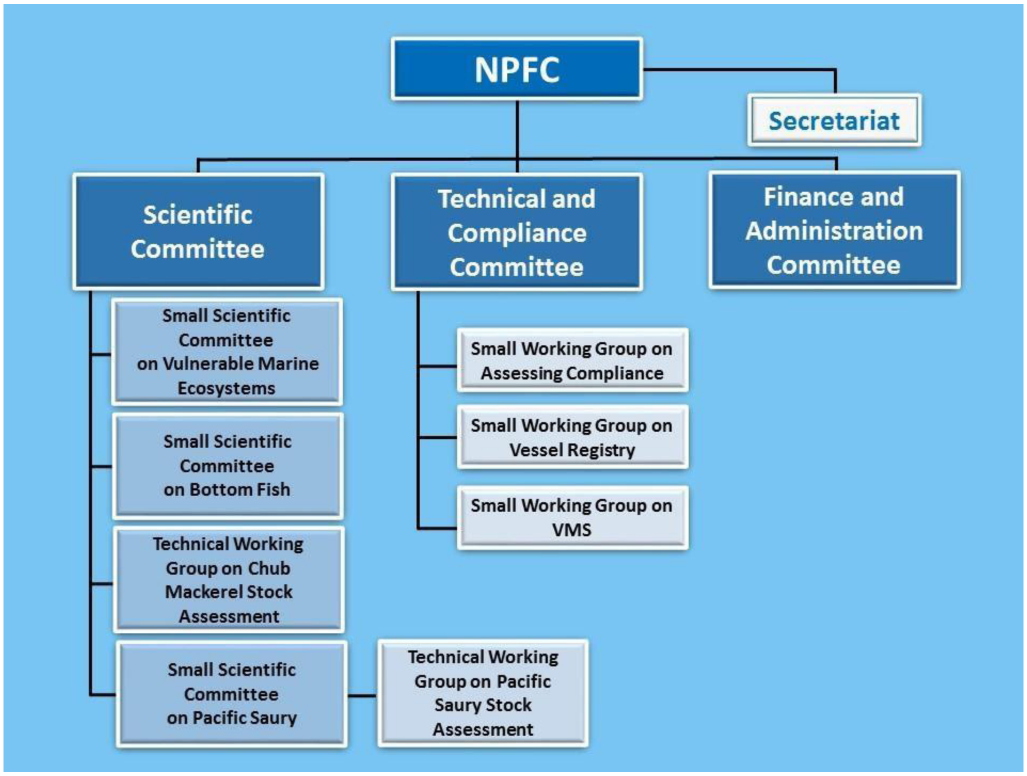


Dae-Yeon Moon is the first Executive Secretary of the North Pacific Fisheries Commission (NPFC) launched in 2015 and headquartered in Tokyo, Japan. Prior to joining the NPFC, he worked as a fisheries biologist and manager at the National Institute of Fisheries Science (NIFS) and the Marine Biodiversity Institute of Korea (MABIK) where he has devoted most of his career to the conservation and sustainable use of distant-water fishery resources over the past twenty years. He graduated from Busan National University, the Republic of Korea, with a bachelor's degree in biology in 1982 and received a PhD degree in marine biology from Texas A&M University, USA in 1992.

The North Pacific Fisheries Commission (NPFC) launched in 2015 and has been very busy in its first two years. It is now well on the road to successful establishment of its basic management principles to address its objective, namely the long-term conservation and sustainable use of the fisheries resources in the Convention Area while protecting the marine ecosystems of the North Pacific Ocean in which these resources occur. Simply speaking, the birth of the NPFC was to bridge the gap in the management of fisheries resources in the high seas of the North Pacific where its Convention Area overlaps with other Regional Fisheries Management Organizations (RFMOs) including NPAFC, IATTC, and WCPFC. This is to report the accomplishments of NPFC in its second year of operation through a series of official meetings the results of which are shown below.

In summary, the second year of the Commission was highlighted by activities to facilitate implementation of the Conservation and Management Measures (CMM) adopted at its 2nd Annual Session Meeting in 2016. Those include the initial development of a Data Management System, an initial Vessel Monitoring Systems (VMS) study of existing systems by the Secretariat, the hosting of NPFC official meetings including workshops and working group meetings for assessment of stocks on NPFC's priority species, and support to electronic meetings to advance compliance and CMM initiatives. Two new CMMs—Pacific saury and High Seas Boarding and Inspection Procedures—demanded Members' attention at the 3rd Annual Session of the Commission meeting in 2017 and were adopted to facilitate the Commission's move forward with a total of nine CMMs in force to date. Six came into force as of November 28, 2017 and the others remaining in force since January 16, 2016. Members have developed the first NPFC IUU vessel list and established several new policies and administrative documents. The Commission welcomed the United States of America and the Republic of Vanuatu as new Members of the Commission as of February 18, 2017 and June 11, 2017, respectively. A new Secretariat staff, our Data Coordinator, was recruited on April 1, 2017 and began to work on the Commission's data and information system. The Commission has been represented at meetings of NPAFC, PICES, UN BBNJ Preparatory Committee Meetings, UN SDG14 Conference, IOTC and International Fisheries Forum in Russia in order to become more involved in cooperative activities with existing organizations.

As in most RFMOs of the world, the NPFC also has subsidiary bodies to assist the Commission in attaining the objective of the Convention: the Scientific Committee (SC), the Technical and Compliance Committee (TCC), and the Finance and Administration Committee (FAC).



Scientific Committee (SC)

Scientific advice is provided to the Commission for fisheries resources caught by fishing vessels within the high seas of the North Pacific Ocean which is the most productive area in the world according to FAO. In fact, scientific activities began with formal negotiations back in 2006 through the Scientific Working Group Meetings which took place 13 times and continued until the Convention entered into force in 2015. This was succeeded by the Scientific Committee (SC), one of the three subsidiary bodies that support the Commission. Under the Scientific Committee, there are five specialist groups established to assist the SC: the Small Scientific Committee on Pacific Saury (SSC PS), the Small Scientific Committee on Bottom Fish (SSC BF), the Small Scientific Committee on Vulnerable Marine Ecosystems (SSC VME), the Technical Working Group on Pacific Saury Stock Assessment (TWG PSSA), and the Technical Working Group on Chub Mackerel (TWG CM). The outcomes of each group meeting are reported to the SC with the SSCs occurring each year just before the larger Scientific Committee Meeting.

The 2nd Scientific Committee (SC) Meeting, preceded by three meetings of Small Scientific Committees (SSCs)—vulnerable marine ecosystems (SSC VME), North Pacific armorhead (SSC NPA), and Pacific saury (SSC PS)—was held in Shanghai, China, on April 24–27, 2017. All Members attended with observers from Vanuatu, the Food and Agriculture Organization of the United Nations (FAO), the North Pacific Anadromous Fish Commission (NPAFC), and the North Pacific Marine Science Organization (PICES). The SC, accepting many of the SSC recommendations, further recommended to the Commission the revision for Conservation and Management Measures for bottom fishing and ecosystems in the Northwest and Northeast Pacific Ocean, including: possible additional measures for NPA stock, in light of the low levels of NPA catch; adoption of an Adaptive Management process for NPA; broadening the scope of the SSC NPA to encompass bottom fish stocks;

2nd Scientific Committee (SC) Meeting and Meetings of three Small Scientific Committees (SSC) of NPFC, Shanghai, China, April 17–27, 2017. Photo credit: NPFC Secretariat establishment of a Technical Working Group on Chub Mackerel (TWG CM) for the purpose of stock assessment; additional meetings such as a VME workshop and meetings of TWG CM and TWG PSSA. The SC also reviewed and endorsed the Research Plan for 2017–2021 and the list of scientific projects for 2017 and subsequent years. Intersessional scientific work would be progressed through Corresponding Groups on data collection templates, Information Security Guidelines, the NPFC Observer Program, and a Joint NPFC-PICES group.

Technical and Compliance Committee (TCC)

The compliance area is another essential component of the Commission, where rules and regulations are developed and enforced. To this end, Members discuss and, where possible, adopt Monitoring, Control and Surveillance (MCS) tools and conservation and management measures for NPFC Registry of Authorized Fishing Vessels, Transshipment Procedures, the establishment of an Observer Program, High Seas Boarding and Inspection Procedures, preventive action to address IUU fishing, establishment of a Vessel Monitoring System (VMS), reporting of Entry/Exit to the NPFC Convention Area, possible identification and use of market measures, and the establishment of a compliance monitoring scheme to enable the Commission to assess its progress in ensuring compliance with its management regime. At its 2017 meeting, TCC formed three SWGs to address specific areas of its multi-year work plan: the SWG on Assessing Compliance, including the development of detailed procedures for implementation of the high seas boarding and inspection CMM; the SWG on Vessel Registry to further address and fine tune this key information requirement through which the scientific and compliance management operations are based in all RFMO management regimes, and SWG on VMS to decide on the development, or not, of a regional vessel monitoring system. Recent activities and progress in the compliance area are summarized below.

The 2nd Meeting of the Technical and Compliance Committee (TCC) took place in Sapporo, Hokkaido, Japan, July 10–12, 2017, and was attended by all Members. Major topics discussed during the meeting included: overview of the fisheries in the Convention Area, progress in the first stage of VMS study, the outcomes of the TCC Webex preparatory meeting, review of MCS-related issues from SC, compliance work plan and priorities, Cooperating Non-Contracting Parties (CNCP), the Observer Program. Among the tasks identified by Members as a higher priority in terms of urgency included: mechanisms for assessing compliance, VMS, and vessel registry, each to be progressed intersessionally through SWGs comprised of designated subject focal contacts for each Member. The meeting reviewed current MCS-related CMMs and endorsed the following CMMs as edited: Vessel Registry, IUU fisheries, Interim Transshipment Procedures, Vessels without Nationality, Bottom Fisheries and VME Protection NW Pacific Ocean, Bottom Fisheries and VME Protection NE Pacific Ocean, and the conservation measures for Chub Mackerel, and Pacific saury. The outstanding proposed CMM for high seas boarding and inspection was discussed and endorsed at some later time following discussions with home officials. Members were very concerned by what they perceived as a high level of IUU fishing in the NPFC Convention Area and took an aggressive stance on this matter by endorsing a Provisional IUU Vessel list to the Commission, which was then adopted. Finally, the TCC recommended that the Commission consider Information Security Guidelines as a further priority for 2017.

2nd Technical and Compliance Committee (TCC) Meeting of NPFC, Sapporo, Japan, July 10–12, 2017. Photo credit: NPFC Secretariat

Finance and Administration Committee (FAC)

In 2016, the Commission established the Finance and Administration Committee (FAC) to assume the Commission's finance and administrative responsibilities. The 1st Meeting of the FAC took place in Sapporo, Hokkaido, Japan, on the afternoon of July 12, 2017, and was attended by all Members. Mr. Kenji Kagawa of Japan, Chairman of the Commission, also served as Chair of the FAC. The half-day meeting reviewed and endorsed the financial status for 2016 and 2017, budget estimates for 2017–2020, establishment of a special project fund, the Secretariat work plan for 2017, and several policies including: the NPFC Policy on support to experts, the policy on document rules, the media access policy, and a revised CNCP policy, all of which were endorsed and approved by the Commission.

Commission Meeting

The 3rd Annual Session of the Commission Meeting took place in Sapporo, Hokkaido, Japan, July 13–15, 2017, and was attended by all Members, and observers from Ukraine, the NPAFC, PICES, and the Organization for Regional and Inter-regional Studies (ORIS) of Waseda

University. The meeting was opened by Mr. Kenji Kagawa of Japan, who served as the Commission Chair. Mr. Takashi Koya, Director-General, Resources Management Department, Fisheries Agency of Japan, welcomed the participants on behalf of the Government of Japan. The Commission Members discussed and adopted the reports of the SC, TCC and FAC, including the SC Research Plan, the TCC Work Plan and the Commission's budget for 2017 and 2018. The Commission adopted four revised CMMs (a CMM on IUU Vessels, two CMMs on Bottom Fisheries and Protection of Vulnerable Marine Ecosystems in the Northwestern and Northeastern Pacific Ocean, and CMM on Chub Mackerel) and two new CMMs: a CMM on Pacific saury and a CMM on High Seas Boarding and Inspection Procedures. As noted in the TCC Meeting, in response to the perception of a high level of IUU fishing in the Convention Area, an extensive IUU Vessel List was recommended to the Commission, with strong support from Members, and it was adopted by the Commission. Several new policies and administrative documents were established, as noted earlier.

3rd Annual Session of the Commission Meeting of NPFC, Sapporo, Japan, July 13–15, 2017. Photo credit: NPFC Secretariat

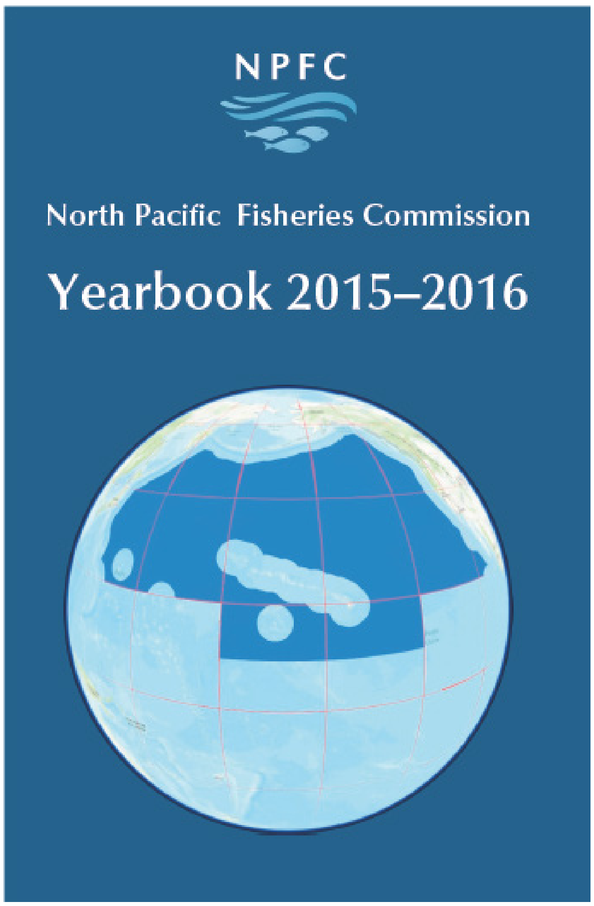
Cooperation Enhancement with the NPAFC, PICES and Other Organizations

As in the beginning of other existing RFMOs, the NPFC is also facing challenges in attaining its Convention objectives. Current challenges include: data collection and sharing of information for science and compliance, establishing a regional vessel monitoring system, establishing common standards amongst RFMOs to address IUU fishing in accordance with international practices, adopting existing MCS tools to ensure compliance with the CMMs, adopting a system to assess compliance levels of the Commission and its Members, and stock assessments for key species. To overcome these challenges in the short and long-term period, liaising and cooperating with other RFMOs will be crucial at this early developmental stage to enable exchange of pertinent information on research, processes and operational activities. To this end, and consistent with Article 21 of the Convention, Members at the 3rd Annual Session of the Commission Meeting agreed to enhance cooperation with other organizations and noted that such cooperation should complement the objectives and activities of the NPFC. To implement this decision and to assist Members in moving forward on this initiative, the Secretariat suggested the following two organizations to be the first to be considered for formal linkages of cooperation. First, the NPAFC—NPAFC is well recognized by the Commission for its geographical overlap and similar membership as a relatively small fisheries commission. The NPFC and NPAFC have cooperated by attending each other's meetings as observers for the past two years, and both sides at the Executive level have informally exchanged the idea that further cooperation would be mutually beneficial in various areas including science and compliance. It is notable that recently there has been on-going discussion of an NPAFC research survey with the possibility of inviting NPFC scientists on-board. This is scheduled for early 2019 in the North Pacific area, where the NPFC might be able to get valuable information on North Pacific armorhead in its early development stages, one of the NPFC's priority species. Second in targeted organizations for cooperation is PICES. As an intergovernmental scientific organization, PICES has also been well known to the Commission for its geographical overlap, almost common membership, and similarity in scientific interests in the North Pacific. The NPFC and PICES have already been cooperating since NPFC was established in 2015 and even before by attending each other's meetings. The NPFC co-sponsored the PICES International Symposium on *Drivers of Dynamics of Small Pelagic Fish Resources* in 2017 and agreed to co-sponsor the PICES International Symposium on *Understanding Changes in Transitional Areas of the Pacific* to be held April 24–26, 2018, La Paz, Baja California Sur, Mexico. More importantly, both sides agreed to establish a joint NPFC-PICES Group on Scientific Cooperation in the North Pacific Ocean to identify areas and ways of cooperation between the organizations and develop a framework for cooperation. At the last PICES meeting, the Science Board endorsed the NPFC's invitation to cosponsor the NPFC VME workshop. The NPFC-PICES Group was tasked to determine the form of cooperation, including possible formal arrangements such as a Memorandum of Understanding (MOU) a Memorandum of Cooperation (MOC), or another mechanism to share scientific information with others. In principle, however, regardless of the mechanism agreed on between Parties, relevant linkages may relate to common activities under the Convention, so the purpose of the cooperation will be to enhance the output of both Parties from the cooperation.

3rd Annual Session of the Commission Meeting of NPFC, Sapporo, Japan, July 13–15, 2017. Photo credit: NPFC Secretariat

Publications

NPFC Yearbook 2015–2016 (2017), 172pp.



The purpose of this publication is to record and highlight the results of the key activities and Commission meetings held from the 1st Annual Session of the Commission Meeting in September 2015 and all Commission meetings up to and including the 2nd Annual Session of the Commission Meeting in August 2016. This yearbook will be published annually, and it has been posted under Publications of the NPFC Website: www.npfc.int

NPFC News

Schedule of 2018 Meetings

- NPFC/FAO Workshop *Protection of Vulnerable Marine Ecosystems in the North Pacific Fisheries Commission Area*, March 12–15, 2018, Yokohama, Japan

- The 3rd Scientific Committee (SC) and three Small Scientific Committee Meetings of the NPFC, April 9–20, 2018, Tokyo, Japan

- The 3rd Technical and Compliance Committee (TCC) Meeting, 2nd Finance and Administration Committee (FAC) Meeting, and 4th Annual Session of the Commission, June 28–July 5, 2018, Tokyo, Japan

Further information will be uploaded on the website in due course. Please refer to our official website www.npfc.int for details on the above meetings or contact the NPFC Secretariat at secretariat@npfc.int

(Front row, left to right) Dae-Yeon Moon (Executive Secretary of NPFC), Kenji Kagawa (Chair of the Commission), Yuko Yoshimura-Takamiya (Executive Assistant), (Back row, left to right) Mervin Ogawa (Data Coordinator), Aleksandr Zavolokin (Science Manager), Peter Flewwelling (Compliance Manager), and Alexander Meyer (Rapporteur of the 3rd Commission Meeting).
Photo credit: NPFC Secretariat

The End of Anonymity at Sea with Space-based Technologies

By Sean Wheeler, Sr. Compliance Program Officer – International,
Fisheries and Oceans Canada

Sean Wheeler recently joined Canada's Department of Fisheries and Oceans as a Senior Program Officer within Conservation and Protection. Prior to DFO, Sean spent the last ten years with the Royal Canadian Mounted Police (RCMP) coordinating the RCMP's maritime security efforts in the Pacific. He was the Project Manager for the design and implementation of a number of technology programs which supported Canada and US law enforcement operations and maritime domain awareness. Prior to the RCMP, he obtained significant experience over seven years in marine Search and Rescue operations, has a BA in Criminology and a Masters Certificate in Project Management (PMP).

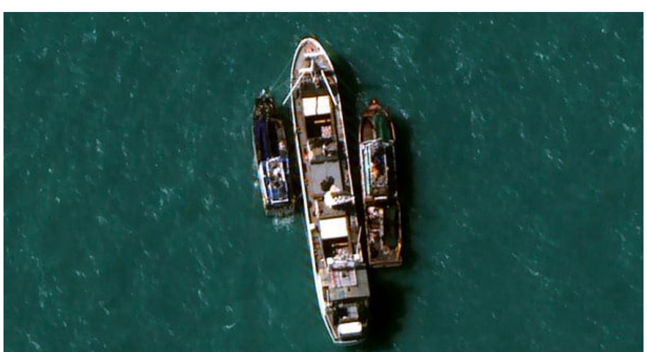
Since the dawn of seaborne navigation, the sheer vastness of the world's oceans has allowed criminality to flourish alongside legitimate trade, travel, and fisheries. The open space of an ocean has always provided a natural barrier to state monitoring and control. As the earliest vessels increased in range and capability, so did the ability to use them for ill intent. The civilizations of Ancient Greece were first to raise navies to counter piracy in 1400 BC. In 2018, detection remains the biggest challenge to countering illegal activity at sea. Although modern navies have largely secured the oceans from major threats, the ability of small vessels to move across the oceans anonymously continues to present an opportunity for criminals today. Piracy, trafficking of humans and drugs, illegal fishing and environmental destruction continue to exist, not due to a lack of laws or enforcement agencies, but on the simple ability to travel undetected on the high seas.

However, this anonymity is being squeezed between two forces. The first is the progression and proliferation of self-identifying transmitting devices. Since the 1990s, the adoption of Automatic Identification Systems (AIS) has increasingly illuminated vessels of all types, as costs declined. What began as an anti-collision system has developed into an asset for maritime domain awareness, with receiving stations and satellite coverage allowing governments and private citizens alike to monitor marine traffic thousands of miles away, even on their smartphones. Vessel Monitoring Systems (VMS), often regulated by fisheries agencies, have filled the gap for monitoring fishers who may prefer their location remain a trade secret. These systems have identified much of the legitimate traffic, and this is critical for the second force to be effective in identifying the remaining vessels. Simply, you must know who the good guys are before you can see the bad guys.

The second force is a game changer, and is driven by the proliferation of space-based technologies within the commercial realm. This industry is being propelled by the rapidly falling cost of sending objects into orbit. Elon Musk's Space-X has dropped the cost of sending a satellite into space from more than $10,000 per kilogram a decade ago to $2,500 today. He promises a goal of $1,000 per kilo in the coming years. Another factor is the continued miniaturization of processing and communications technology, allowing a small box sent into space by a start-up company to have the same capability once reserved for nation states; taken together, the space-based industry is on the cusp of a massive change. Thousands of satellites are planned for launch in the coming years. These satellites will take ever higher resolution imagery, will scan the surface of the planet with radars, collect signals from ships, and provide internet and communications to the most remote places on Earth.

Radarsat-2, Canadian Space Agency

Each proposed system has unique capabilities, and many will be able to detect small vessels at sea. Some designs aim for high resolution detection, some revisit the same location multiple times per day, and others focus on reducing cost. Ever accessible imagery may provide near real time intelligence of what activity a ship is engaged in. Some of these capabilities exist currently, but the sheer number of sensors promises accessibility in cost and, importantly, the ability to cue one sensor from another. An agency could be surveilling a marine protected area, for example, finding an anomaly, and using sensors of a separate constellation to identify and track. This is known in the industry as "cross-cueing". One design sees this decision making uploaded to the spacecraft themselves, where sensors in a constellation communicate with each other, cross-cueing on their own to detect, identify, and track bad actors, then send the results back to earth. It should be noted that similar innovations are happening in Unmanned Aerial Systems, which could provide even greater capabilities, due to their proximity to the surface and their ever greater autonomy. Many of these technologies lend themselves to detection of IUU vessels even more so than trafficking due to their relatively large size and slow speeds. The once invisible poacher may now be illuminated.



Digital Globe satellite image of two fishing trawlers loading slave-caught fish onto a refrigerated cargo ship off the coast of Papua New Guinea on July,14, 2015. Photo credit: Digitalglobe.com

To take advantage of these changes, governments and enforcement agencies will need a shift in thinking. Activities in maritime surveillance are more typically thought to be associated with military hardware and distant patrols, not achieved through service agreements and subscription models. This model may free governments from the risks of large scale procurements, but a change in mindset will be required in order to become an agile customer in a changing industry landscape. Designs of the constellations themselves will require a high level of engagement between government and industry that is not typical of the current planning cycle. For the systems to meet the unique requirements of enforcement agencies, planning and collaboration needs to start now. Hardware cannot be changed while traveling 7.5 km/second, 600 km above the Earth.

The challenge of the next decade will be handling the volume of data that may deluge enforcement agencies. The end of anonymity at sea could result in a problem of big data. As these systems are commercial, data will be flowing to both governments and non-governmental organizations. Analyses, intelligence, and services will proliferate. One benefit of commercial data is its open source nature allows for more convenient sharing between entities. Governments will be tasked with developing a common understanding of the maritime domain from multiple systems and partners. As detection becomes less of a challenge, additional pressure may be placed on the other elements in the enforcement chain. It remains a question of whether governments are prepared to really see what has been, up to now, "unknown". In comparison to past challenges of finding illegal activity at sea, having too much data is ultimately a good problem to have. As space-based technologies shrink the monitoring of the world's oceans, the ability for IUU fishers, poachers, pirates and smugglers to operate in high seas undetected is likely coming to an end.

SpaceX's Falcon 9 rocket launching from Space Launch Complex 40 at Cape Canaveral Air Force Station, Florida, on March 1, 2015.

Growing Fish for a Growing World: The Future of Salmonid Aquaculture

By Caroline Graham
2017 NPAFC Intern

Caroline Graham was born and raised in the landlocked United States but was always looking for opportunities to get out on the water, whether it was a lake, river, or pool. She graduated from a small school in the cornfields of Iowa, called Grinnell College, with a degree in Biology in 2016. During her time at Grinnell, she participated in a joint marine science and policy program run by the Sea Education Association, during which she sailed from Puerto Rico to Bermuda to New York on a tall ship studying microplastic pollution and high seas policy. This sparked her interest in marine/aquatic science, as well as international policy, which led to a string of other adventures. These included invasive fish removal in the Grand Canyon, tow net surveys in Puget Sound, salmon habitat assessments in the rivers of Alaska, and finally a year in Mexico studying the impacts of seaweed on coastal ecosystems. Although Vancouver is a bit colder than the Mexican Caribbean, Caroline is excited to spend her time hiking, skiing, swimming, and exploring all the area has to offer.

As wild fisheries decline, or remain stagnant, the global population continues to grow, with greater than nine billion people expected to be living on this planet in 2050, raising serious concerns about global food security (United Nations 2017). Increasingly, national and international government organizations are pointing to aquaculture as a solution (Food and Agriculture Organization 2016).

Aquaculture is defined by the Food and Agriculture Organization (FAO) of the United Nations as:

"The farming of aquatic organisms…farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated".

Commonly referred to as fish farming, fish are raised through their entire life cycle and then harvested. Aquaculture includes the rearing of many different aquatic organisms, ranging from molluscs to algae to finfish, and these facilities can take on different forms. In finfish farms, fish are often grown in net pens in the ocean, at least during the later life stages. There are also entirely land-based aquaculture systems, which do not allow farmed fish to interact with the external environment. FAO reports that aquaculture is the fastest growing food production sector globally and now provides over half of the world's fish for human consumption (Figure 1, FAO 2016).

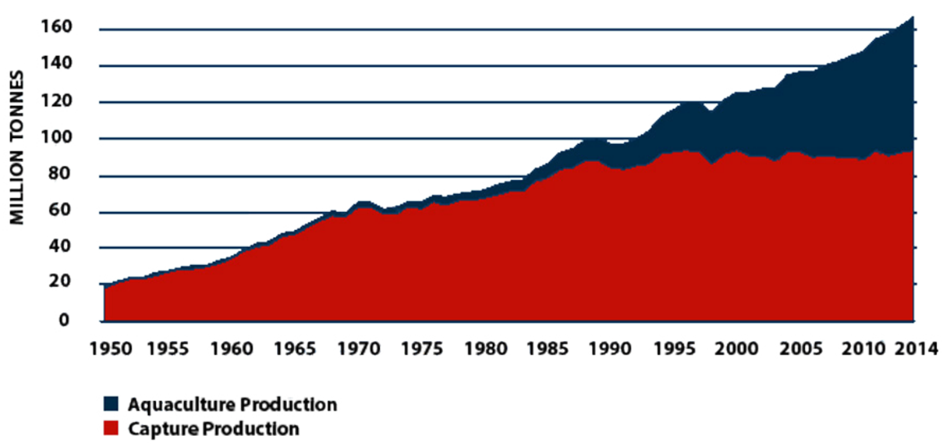


Figure 1. *Global aquaculture production versus global capture production from 1950–2014. Source: FAO 2016*

While wild salmon stocks face an unpredictable future due to climate change, salmonid aquaculture has seen a boom in production, starting from just 12,000 tons in 1980 and growing to over 2.4 million tons in 2011, which is a faster growth rate than overall aquaculture production (Schindler et al. 2008; Asche and Bjørndal 2011). Salmonid aquaculture is now the largest single aquaculture commodity by value, according to the latest report by FAO (2016), with the two largest producers of farmed salmonids being Norway and Chile (Asche et al. 2013). Farmed Atlantic salmon is the most common species, accounting for over 90% of salmonid aquaculture, followed by rainbow trout, coho, and Chinook salmon (Figure 2).

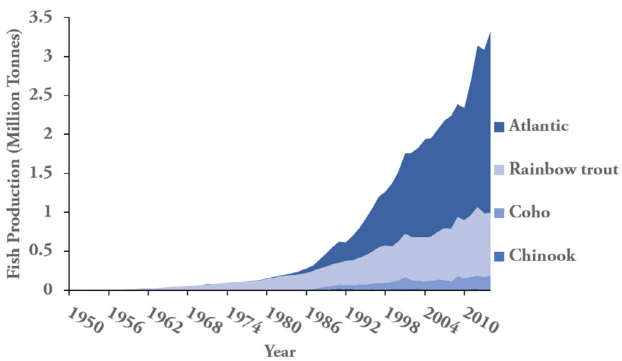


Figure 2. *Aquaculture production of salmonid species in million tonnes from 1950–2014. Data is extracted from FAO "Aquatic Species Fact Sheets" (Source: http://www.fao.org/fishery/species/search/en).*

While salmon aquaculture has seen tremendous growth over the past several decades, it has remained a highly controversial issue. Some praise aquaculture for decreasing dependence on endangered wild fish stocks while supplying a nutritious and affordable source of protein. Others condemn the practice for its potentially harmful impacts on the environment and wild fish populations. Recently, aquaculture has received a fair amount of attention, specifically in Canada and the United States, due to an escapement of thousands of Atlantic salmon from a fish farm in Puget Sound, where Atlantic salmon are an invasive species (Johnson 2017). This was followed by heavy criticism for the aquaculture industry from scientists, Indigenous Peoples, environmental advocacy groups, and the concerned public.

One of the major points of concern regarding aquaculture practices, and specifically salmonid aquaculture on a global scale, has to do with the spread of disease/parasites that may occur when many fish are grown in a confined space. This could be a threat to wild populations when fish are raised in ocean net pens where diseases can potentially spread from farmed to wild salmon. The increased prevalence of sea lice over the past 30 years has led to widespread concern and major losses for the industry. Costello (2009) estimated that the global

Adult Atlantic salmon. Photo Credit: E. Peter Steenstra, US Fish & Wildlife Service

cost of sea lice control in 2006 was over 300 million Euros. Some of the infectious diseases that can affect farmed salmonid species include infectious hematopoietic necrosis virus, furunculosis, bacterial kidney disease, and pancreas disease, among others (Toranzo et al. 2005; Lafferty et al. 2015; Jansen et al. 2017). To further exacerbate the issue, the use of antibiotics to treat some disease outbreaks can lead to increased antibiotic resistance, which may affect both farmed and wild fish, and can also negatively impact human health (Cabello 2006; Shah et al. 2014; Aaen et al. 2015).

Another controversial topic related to salmonid aquaculture is the widespread use of fishmeal and fish oil, harvested from wild fish, to feed carnivorous farmed fish. Most fishmeal and fish oil come from small pelagic fish species, such as anchovies, sardines, mackerel, capelin, and herring, which generally have short life cycles and mature and reproduce quickly (Péron et al. 2010). However, the aquaculture boom can even put a strain on fisheries such as these.

Mass production of fish in net pens has led to problems with nutrient loading and pollution in coastal areas. Some of the waste products and contaminants that can end up in surrounding waters are excess feed, excrement, waste from slaughtering and mortalities, chemicals, insecticides, anti-foulants, and antibiotics (Seymour and Bergheim 1991; Turcios and Papenbrock 2014). This presents a number of issues for coastal areas, ranging from oxygen depletion and changing benthic communities to the spread of disease and antibiotic resistance (Mente et al. 2006; Shah et al. 2014).

Finally, escapement of farmed fish from net pens can pose a threat to wild populations. In the case of the San Juan Islands escapement in August of 2017, Atlantic salmon were accidently released into Pacific salmon habitat. Even though Atlantic salmon have historically had trouble colonizing the North Pacific, this introduction of non-native fish can affect native populations without establishing a viable population (Naylor et al. 2005). Escaped farmed fish can compete for habitat and prey, and often have an advantage over wild fish, as they are able to grow more quickly due to selective breeding (Fleming et al. 2000; McGinnity et al. 2003; Jonsson and Jonsson 2006). However, even though farmed fish have been found to grow more quickly than their wild counterparts, they show overall reduced survival compared to wild fish (McGinnity et al. 2003).

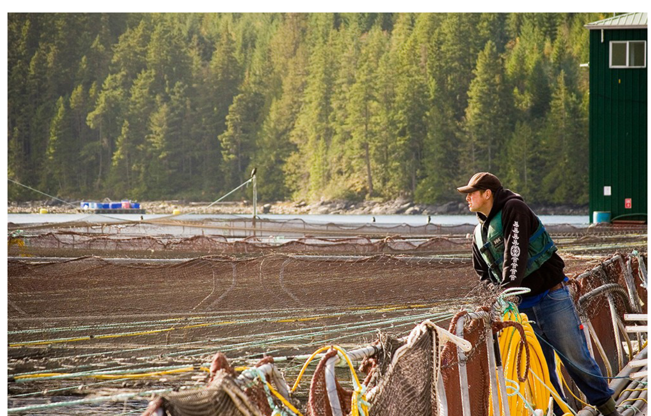
Salmon aquaculture in Norway

Keeping in mind the issues raised by salmonid aquaculture, the question becomes: How can we make informed policy decisions regarding the development of this industry that will ensure net positive outcomes in the environmental, social, and economic dimensions? With a growing global population and increasing demand for fish, aquaculture will continue to expand and have the potential to alter the natural environment by affecting wild fish populations and changing marine/aquatic ecosystems. Despite these drawbacks, fish farming has the potential to provide a solution to issues of global food security by increasing access to a nutritious source of protein. Aquaculture is also economically important to a growing number of coastal communities and estimated to provide between 27 and 56 million jobs globally (Phillips et al. 2016). With all of this in mind, where does the future of aquaculture, particularly salmon aquaculture, lie, and how can we arrive at a place where there are net positive outcomes in the environmental, social, and economic dimensions?

The answer is not simple and will certainly involve further investment into research and technology. The aquaculture industry has made some significant strides over the past several decades in reducing their environmental footprint. There has been a shift away from fishmeal and fish oil towards terrestrial-based feeds, which means less dependence on wild fish stocks to feed carnivorous farmed fish (Shepherd et al. 2017). Furthermore, with regards to disease outbreaks and increased antibiotic resistance, there has been increased research into treatment alternatives, such as vaccines, prebiotics/probiotics, immunostimulants, and genetically modified disease-resistant fish (Wetten et al. 2007; Forabosco et al. 2013; Ringø et al. 2014).

Another proposed solution to some of the environmental issues facing fish farms is the application of Integrated Multi-Trophic Aquaculture (IMTA). The objective of IMTA is to rear multiple species in aquaculture pens in order to mitigate some of the pollution issues caused by monoculture fish farms (Neori et al. 2004). For example, on the east coast of Canada, Atlantic salmon, kelp, and blue mussels are all farmed together in aquaculture pens (Troell et al. 2009). The kelp and mussels are able to use the excess nutrients and food provided by the fish waste to grow even faster than they would in the wild (Chopin et al. 2004; Lander et al. 2004). Although IMTA currently represents only a small portion of overall global aquaculture, it is one method of reducing nutrient inputs into the environment from fish farming and it minimizes the risk of harmful algal blooms and anoxia events (Neori et al. 2004).

To further mitigate the harmful impacts of aquaculture on the environment, some producers are turning to land-based aquaculture facilities known as Recirculating Aquaculture Systems (RAS). In these systems water is partially reused after treatment (Martins et al. 2010). These can be used in areas with limited water availability, can reduce waste discharge, allow for more controlled conditions, and decrease the potential for escapees and the spread of disease to wild fish stocks (Bostock et al. 2010; Badiola et al. 2012). However, it is challenging to constantly maintain appropriate water conditions and the steep startup and operational costs are often cited as the greatest limiting factors (Badiola et al. 2012). Most of these facilities are being built on relatively small scales and therefore are not often very profitable. For example, in British Columbia, the average salmon net pen yields 2,500 to 3,000 metric tons of fish while land based facilities average only 100–200 tons (J. Dunn, pers. comm., October 2017). These systems were originally developed and used mainly for freshwater fish that are less sensitive to poor water quality conditions, however, they are more recently being used for marine fish, like salmon, which has required greater technological innovation (Martins et al. 2010).



Salmon aquaculture in British Colombia.
Photo credit: BC Salmon Farmers Association

One of the most recent and promising strides made by the aquaculture industry is the advancement of offshore aquaculture, also referred to as open ocean aquaculture. While it is not yet well defined, the general consensus is that offshore aquaculture refers to farms situated away from the coastline, in the open ocean, which have more exposure to wind and waves and are less accessible than coastal farms (Bostock et al. 2010). This innovative strategy can take a number of forms, including net cages attached to the seafloor, diver-operated submerged cages, ships, and drifting net systems that can be anchored to existing wind and wave farms, or even abandoned offshore oil rigs (Holmer 2010).

While this strategy is in the testing and development stages, it is thought to have a number of advantages over coastal aquaculture. First, it is expected to reduce the impact of pollution and nutrient loading on coastal areas, since these farms are further from the coast and there is increased water circulation, so the waste can be diffused quickly over a large area (Goldburg and Naylor 2005). Some have also speculated that better water quality will mean fewer disease outbreaks in these farms, compared to coastal ones (Holmer 2010). Offshore aquaculture also reduces competition with other coastal activities since these farms usually lie kilometers away from the coastline (Bostock et al. 2010). This provides the potential for significant expansion and increased productivity of aquaculture. When combined with other innovative aquaculture techniques, such as terrestrial-based feeds and antibiotic alternatives, offshore aquaculture looks to be a very auspicious step towards environmentally-sound fish farming, but is it?

Of course, this new technology has disadvantages as well. One of these disadvantages is the high initial investment cost. Since these facilities will be remote, making them difficult and costly to reach, there is a need for automated production (Skladany et al. 2007). The technology is new and still under development, meaning that the startup costs are significant. However, with automation of production, labor costs would go down. While this would mean less jobs on fish farms, there would be new jobs available in the technology and construction sectors.

Juvenile coho salmon. Photo credit: Scott Creek, NOAA Fisheries West Coast

Other disadvantages may include interference with shipping, piracy, entanglement of marine creatures in nets, damage to nets by large predators, and the potential for damage by strong winds, waves, and storms. Unfortunately, since this technology is so new, there is a lack of research regarding the extent to which offshore aquaculture facilities may face these challenges. There are a lot of unknowns, not only due to the novelty of this technology, but also because there is less research on open ocean ecosystems and the organisms that reside there, such as salmon in the high seas. Therefore, while offshore aquaculture is predicted to minimize environmental impacts, there is sparse scientific evidence and there are many unanswered questions.

Despite these questions, the offshore aquaculture industry is forging ahead, most recently being led by a Norwegian company called SalMar. One of the world's largest producers of farmed salmon, SalMar just installed "Ocean Farm 1" in Frohavet, off the coast of Norway, in 2017. This offshore aquaculture facility is a highly-automated "full-scale pilot facility for testing, learning, research, and development" (SalMar ASA). The structure is 68 meters high, 110 meters in diameter, and has a total volume of 250,000 cubic meters (SalMar ASA), which is roughly the volume of 100 Olympic-sized swimming pools. SalMar claims that this structure can grow up to 1.5 million salmon for harvest in just 14 months (Hoyle 2017). While there is still a lot of testing and research required, salmon offshore aquaculture is already a reality. Jeremy Dunn, Executive Director of the British Columbia Salmon Farmers Association, says: "Everyone around the world is watching how SalMar's project is going to go".

Although SalMar's project is considered offshore aquaculture, the trial system lies within a few kilometers of the coast and the design is only suitable for water depths of 100 to 300 meters (SalMar ASA). An even newer project, that just received permits for development and construction in September of 2017, is called "Havfarm", which is a collaboration between Nordlaks and NSK Ship Design in Norway. This farm is intended to be the longest ship in the world (430 m long, 54 m wide), and is engineered for the sole purpose of producing farmed salmon in the open ocean. This massive vessel will be able to house over 2 million salmon and can travel to maintain appropriate water conditions and to avoid storms (NSK Ship Design).

Model of Havfarm. Photo credit: NSK Ship Design

Even if the technology and research exist, one of the biggest impediments to aquaculture development in many areas is public perception of this industry. Of course, public perception varies based on region, especially when looking at this issue from a global perspective. By analyzing over 1,500 newspaper headlines from both developed and developing nations, Froehlich et al. (2017) found significantly more positive headlines about aquaculture in developing nations than developed nations. Overall, they found a growing positive trend in general aquaculture coverage, while offshore aquaculture tended to be more negative. When Froehlich et al. (2017) examined only the headlines that included the term 'salmon', the sentiment was overall negative, with Canada contributing 69% of those negative headlines. Therefore, it is likely that salmon aquaculture will struggle even more than other types of aquaculture due to intense criticism in the media.

According to Michael Rust, Science Advisor for the Aquaculture Office of the National Oceanic and Atmospheric Administration (USA), aquaculture is struggling to make major advances in places like the United States because of a lack of understanding about what aquaculture entails. He states: "We probably have a farmer in our family tree, maybe a fisherman—as a culture we understand those industries. Very few of us have an aquaculturist in our background". Rust wants to remind the public that everything we do has an impact on the environment, and he says, "It's entirely possible to produce farmed seafood in the oceans using existing technologies and have a small environmental footprint".

With an exploding global population and the food security issues that go hand in hand, aquaculture has the potential to revolutionize the global food market. Currently, only 2% of the global food supply comes from the ocean, even though the ocean comprises 70% of the planet (FAO 2006). A recent study by Gentry et al. (2017) calculated the possible growth of aquaculture on a global scale and found it has the potential to produce 15 billion tons of finfish on a yearly basis. This is over 100 times the current global consumption of seafood (Gentry et al. 2017). Furthermore, finfish aquaculture production is considered more environmentally friendly in certain ways than farming terrestrial meat sources, like chickens, cows, and pigs. This is due to higher food conversion ratios and less greenhouse gas emissions associated with aquaculture as opposed to livestock production (Hall et al. 2011).

Interdisciplinary collaboration and research will be key to answering the question previously posed: How can we make informed policy decisions regarding the development of the aquaculture industry that will ensure net positive outcomes in the environmental, social, and economic dimensions? Aquaculture will surely continue to grow, and with this growth will come new and different challenges. If people are willing to work together—across disciplines, backgrounds, and ideologies—to meet these challenges, I believe we can generate net positive outcomes for the environmental, social, and economic dimensions.

Salmon aquaculture off the coast of British Colombia. Photo credit: BC Salmon Farmers Association

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I would like to thank Michael Rust (National Oceanic and Atmospheric Administration, NOAA) and Jeremy Dunn (British Columbia Salmon Farmers Association) for interesting and informative interviews on this topic, as well as Stanley Kolosovskiy for the initial conversation that helped me begin this article. I would also acknowledge NPAFC Secretariat staff including Nancy Davis for their insightful comments and editing expertise.

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Workers at a salmon processing plant in British Columbia. Photo credit: British Columbia Salmon Farmers Association

Salmon Genetic Stock Composition Analyses in Alaska

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Introduction

Alaska is a very large and beautiful state with over 80,000 km of shoreline along the Gulf of Alaska, Bering Sea, and Arctic Ocean (http://www.shorezone.org/learn-shorezone/shorezone-coverage). It offers both marine and freshwater habitat for a wide range of species in Alaska. Five species of Pacific salmon in addition to steelhead are commonly encountered in Alaskan waters that in the marine environment include stocks that originate from throughout their spawning distributions. Salmon are intercepted in Alaskan waters through directed and non-directed fisheries, where in the non-directed fisheries they are caught as bycatch. Because salmon are encountered at sea throughout Alaska as mixed stocks, genetic stock identification (GSI) is one of the techniques used to determine the impacts of catch on salmon stocks or groups of stocks. The purpose of this article is to describe how GSI techniques are implemented in the management of fisheries in Alaska. Two examples are provided, one for the analysis of salmon harvested in a state managed, directed salmon fishery, and another for the analysis of salmon incidentally caught in a federally managed fishery.

Population Structure of Pacific Salmon Lends Itself to Genetic Stock Identification

Salmon return to spawn in the same rivers where they were born with fairly high fidelity. Consequently, salmon within a spawning population are more genetically similar to each other than to salmon in other populations. Since straying among nearby populations is more likely than straying among more distant populations, nearby populations are often more genetically similar to each other than more distant populations, a characteristic known as isolation-by-distance. GSI takes advantage of these genetic patterns to group multiple closely-related populations into *reporting groups* or "stocks". By comparing the genetic characteristics of the catch with that from baseline spawning populations, stock composition of the catch can be estimated. One assumption for GSI is that the baseline contains adequate representation of all reporting groups that may be found in the catch sample.

State Managed Fisheries Example: Bristol Bay Sockeye Salmon Fishery

Sockeye salmon returning to spawn in tributaries of Bristol Bay, Alaska, sustain the largest sockeye salmon fishery in the world, with an average of 22.7 million fish caught annually in the last 20 years (Salomone et al. 2017). Fish returning to spawn are sought by commercial and subsistence harvesters (Figure 1). Within the commercial fishery, there are drift gillnet and set gillnet fisheries prosecuted in five management districts located near the mouths of the major rivers that drain into Bristol Bay (Figure 2). The commercial fishery harvests more than half of the returning adults (1996–2015 average was 52%; Salomone et al. 2017). Although most of the sockeye salmon caught in a given district originate from drainages within that district, some districts encompass multiple drainages and some districts catch fish that are destined to drainages in other districts. The subsistence fisheries, on the other hand, are much smaller and harvest most of their catch within the rivers or lakes in Bristol Bay and, therefore, are assumed to catch fish from the stock(s) that spawn in that drainage.

Figure 1. *Drift gillnet commercial harvesters vie for position in the Naknek River, subsistence harvest hangs to dry, and set gillnet harvester brings in catch of sockeye salmon in Bristol Bay. Photo credit: Alaska Department of Fish and Game (ADF&G)*

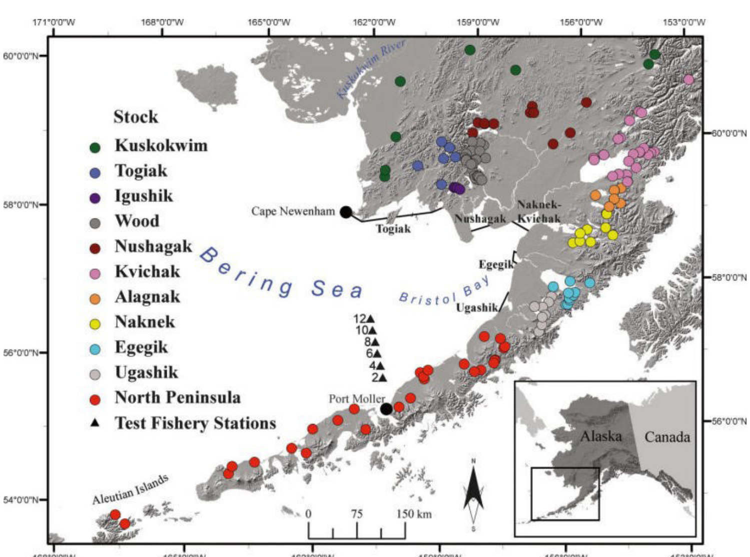

Figure 2. *Map showing the five Bristol Bay commercial fishing districts, Port Moller test fishing stations (triangles), baseline collection locations, and stocks identified using GSI. Source: Dann et al. (2013)*

Bristol Bay sockeye salmon fisheries are managed to ensure adequate numbers of salmon escape the fisheries and reach their spawning areas to maintain sustained yield, as is required by the State of Alaska Constitution, while meeting allocations set by the Alaska Board of Fisheries. The Board consists of seven members serving three-year terms. Members are appointed by the governor and confirmed by the legislature. Members are appointed on the basis of interest in public affairs, good judgment, knowledge, and ability in the field of action of the board, with a view to providing diversity of interest and points of view in the membership (http://www.adfg.alaska.gov/index.cfm?adfg=fisheriesboard.main).

Ensuring that adequate fish escape the fisheries means that the Alaska Department of Fish and Game (ADF&G) needs to determine the appropriate escapement goals and then control the harvest of each stock (drainage) to meet those escapement goals. Both of these objectives require an understanding of how many fish from each stock are harvested. This number is added to the number of fish that escape into rivers to spawn to come up with the total runs—a critical estimate for determining the spawner-recruit relationship to establish escapement goals. This understanding is also important for the managers to determine where and when user groups can harvest fish in order to target those stocks that are in excess to escapement needs.

Figure 3. *Sampling sockeye salmon from the Ualik Lake on the Igushik River that drains into the Nushagak District in Bristol Bay: Skiff used to access the beach, a proud biologist with a captured fish, and sampling the axillary process.*
Photo credit: Alaska Department of Fish and Game (ADF&G)

Because almost all sockeye salmon encountered in the Bristol Bay fishery are returning to spawn in Bristol Bay and surrounding area tributaries, sockeye salmon baselines have been developed from that region (Dann et al. 2012). Baseline sampling expeditions normally involve sending a group of trained people into the field to collect axillary processes from spawning populations, often in remote areas with difficult logistical operations (Figure 3). The salmon can be captured in a number of different ways, although the most common is with a small seine net where the fish can be immediately sampled and released unharmed to the river. When salmon are sampled on the spawning grounds they are assumed to represent the population from that location and are used to define the genetic "fingerprint" for that population within the larger baseline of populations from Bristol Bay. Samples are archived at ADF&G for current and future analyses (Figure 4).

Fish sampled from commercial fishery catches are genotyped for the same set of markers used in the baseline (Figure 4). Statistical programs are used to examine the genotypes of fish in the catch and compare those with the baseline to estimate the stock composition of the catch. ADF&G estimates stock composition for multiple geographic and temporal strata of the commercial fishery. These estimates of stock composition are then applied to the harvest that the catch sample represents to estimate the stock-specific harvest. As long as the catch samples represent the harvest well, a sample of 400 fish for each stratum is adequate to provide estimates that are within 5% of the true value 90% of the time.

ADF&G uses this genetic information to provide in-season and post-season estimates of stock proportions. In-season estimates are calculated for fish entering Bristol Bay captured in the Port Moller Test Fishery (Figure 2) and provide information to fishermen, processors, and ADF&G. This information, along with other information, is used by ADF&G managers to open and close fisheries on a daily basis. Post-season estimates are calculated for fish captured in multiple district/time strata to estimate the total run for use in spawner-recruit models used to establish escapement goals. This genetics program in Bristol Bay has been estimating stock composition of the commercial fishery since 2005. This long-term data series will allow for improved spawner-recruit relationships and provide insights into changes in productivity among stocks over time. ADF&G will continue to use GSI to inform managers as they seek to direct the harvest and distribute those harvests among user groups following the guidance of the Alaska Board of Fisheries.

Figure 4. *Genetics processing within the Alaska Department of Fish and Game's Gene Conservation Laboratory. Left: Extracting DNA in preparation for genotyping sockeye salmon commercial fishery catches. Right: Samples of both baseline and fishery catches are archived at Alaska Department of Fish and Game (ADF&G) for future analysis.*

Federally Managed Fisheries Example: Incidental Harvest of Chinook and Chum Salmon in the Bering Sea Pollock Trawl Fishery

In Alaska, mid-water and bottom-trawl fisheries take place for gadid, rockfish, flatfish, and other species. While not the target catch, Chinook and chum salmon are also taken as bycatch in these fisheries, primarily in the walleye pollock fishery, which is the largest single species fishery in the United States (Figure 5). The number of salmon captured relative to the target species is small; however, given the magnitude of the Bering Sea-Aleutian Island groundfish fisheries, approximately two million metric tons annually, the total number of salmon taken can be high. For example, in 2007, an estimated 130,000 Chinook salmon were taken as bycatch in the Bering Sea trawl fisheries, although the 20-year median is 29,585 (NMFS 2017a). Similarly, the number of chum salmon encountered in these fisheries peaked in 2005 at an estimated 715,000 fish with a 20-year median of 89,430 chum salmon (NMFS 2017b). Because salmon return to their natal streams to spawn, it is critical to know both the number of salmon taken as bycatch and the stock of origin to help us understand the impacts of capture. Salmon stock composition data has been used in recent years to help inform federally managed fisheries in the Bering Sea and the Gulf of Alaska (https://www.npfmc.org/bsai-salmon-bycatch/).

Figure 5. *The groundfish trawl fisheries in Alaska (top left) capture both the intended target of pollock (top right) and incidental catch of salmon (bottom). Photo credit: NOAA Fisheries*

In the management of Bering Sea trawl fisheries, the National Marine Fisheries Service (NMFS) utilizes fishery observers on more than 100 vessels that fish each year. The observer's primary purpose is to ensure catch accounting, but they also monitor catch of non-target species such as salmon, halibut, and crab (AFSC 2016). One of the first challenges for determining which salmon stocks are present in the bycatch, within the available management resources, was to develop a method to transport representative samples from the many vessels participating in the Bering Sea pollock fishery to a single laboratory for processing. This includes collecting samples at sea from catcher processors and motherships, and from catcher vessel offloads at processors in Dutch Harbor and Akutan, Alaska (Figure 6). Previously, allozyme-based GSI analyses of the salmon bycatch were completed by the NMFS (Wilmot et al. 1998, Seeb et al. 2004); however, allozyme-based analyses required logistically difficult tissue collection procedures. Today, sample collection procedures are simpler and more robust for DNA-based analyses, and genetic methods in recent years have enabled the analysis of large numbers of samples.

Figure 6. *Salmon bycatch samples from the Bering Sea are shipped from NMFS offices in Dutch Harbor (brown), Anchorage (green), and Seattle (yellow) for genetic stock identification at the NMFS Auke Bay Laboratories in Juneau, Alaska. Underlying map from www.google.com/maps.*

DNA-based sample collection methods were first tested in 2005 and 2006 when a special sampling project was established within the NMFS as a collaboration of scientists at the Auke Bay Laboratories and the North Pacific Groundfish and Halibut Observer Program. Through this special project, observers opportunistically collected an axillary process (part of the pelvic fin) for genetic analysis and scales for ageing from salmon encountered in the bycatch. The samples were placed in labeled coin envelopes and then stored frozen. At the end of the season, the Observer Program assembled the sample collections from multiple observers and sent the frozen collections via overnight delivery to Auke Bay Laboratories in Juneau, Alaska for analysis.

DNA was extracted from the samples by digesting a fragment of the axillary process with a protease and purifying over a silica-based column (Figure 7). For the chum salmon samples, 11 microsatellite markers (Beacham et al. 2009) were genotyped by using sizing standards on a polymer-based DNA sequencer (Life Technologies 3730*xl*) and GeneMapper software. Because of the complexity of genotyping microsatellite markers, each sample was independently genotyped by two people and the genotypes were compared to quantify consistency. For the Chinook salmon samples, 43 single nucleotide polymorphism (SNP) markers (Templin et al. 2011) were genotyped with either TaqMan™ (Applied Biosystems) (Figure 7, bottom right) or MALDI-TOF technologies; the genotyping concordance rate between these two technologies is greater than 99.5%. After genotyping, the data quality was evaluated; duplicate samples (very low number) and samples with genotypes at less than 80% of the markers were removed following previous standards (Dann et al. 2009).

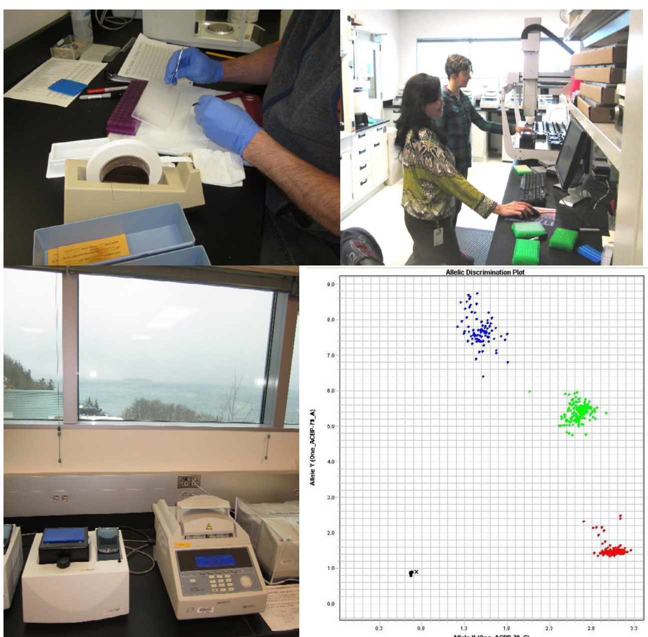

Figure 7. *Genetics Laboratory processing within NOAA's Alaska Fisheries Science Center's Auke Bay Laboratories. Top Left: Preparing samples for DNA extraction, Top Right: Plating DNA in the lab prior to genotyping, Bottom Left: PCR machines used to amplify quantity of specific DNA regions, Bottom Right: example plot output from SNP analyses.*

Stock compositions were estimated with Bayesian and frequentist software that maximizes the probability that the observed genotypes were derived from large regional aggregations of salmon baseline stocks. This methodology takes advantage of the genetic divergence of salmon that often exists in an isolation-by-distance pattern and produces regional differences. For the chum salmon bycatch, stock composition was estimated to six large regional aggregations including: Southeast Asia, Northeast Asia, Western Alaska, Upper/Middle Yukon, Southwest Alaska, and Eastern Gulf of Alaska/Pacific Northwest. For the Chinook salmon bycatch, stock composition was estimated to 11 large regional aggregations including: Russia, Coastal Western Alaska, Middle Yukon, Upper Yukon, North Alaska Peninsula, Northwest Gulf of Alaska, Copper River, Northeast Gulf of Alaska, Coastal Southeast Alaska, British Columbia, and Washington/Oregon/California. The stock compositions have been assembled into annual NOAA Technical Memoranda that are available on-line (see https://www.afsc.noaa.gov/Publications/techmemos.htm).

Tests showed that these samples contained viable DNA that could be successfully genotyped and compared to species-wide genetic baselines to determine the overall stock composition of the sample set. By using opportunistically collected samples, bycatch stock compositions were developed for the Chinook and chum salmon bycatch intercepted in the Bering Sea pollock trawl fisheries from 2005 through 2010 (e.g., Guthrie et al. 2012, Kondzela et al. 2012). These results showed that in the Bering Sea (1) the majority of Chinook salmon encountered were from stocks from river systems that flow into the Bering Sea, and (2) the chum salmon were from stocks from throughout their geographic distribution.

The analysis of opportunistically collected samples provided valuable information about the stock origin of the salmon bycatch, but the stock composition estimates were only as good as the available sample sets, which had the potential to be biased because not all vessels and plants were sampled at the same rate. To account for the number of salmon taken in the Bering Sea trawl fisheries, the NMFS restructured the Observer Program for the Bering Sea pollock fishery to enable the census of all salmon (counting each fish rather than estimating from basket samples) and the collection of representative samples. In 2011, a systematic sampling protocol was implemented whereby 1 out of every 10 Chinook salmon and 1 out of every 30 chum salmon were genetically sampled (Faunce 2015). These sampling rates were established to collect enough samples in a low-bycatch year to determine a reliable stock composition estimate. In years with higher bycatch, as in recent years for the chum salmon bycatch, the sampling rate of 1 of 30 yields more samples than is needed for analysis and the samples may be further sub-sampled.

Although the precision of the estimates is influenced by the number of samples, an acceptable degree of accuracy can be obtained with subsamples from large collections (Whittle et al. 2015).

The method of sampling is simple to explain; however, it can be difficult to execute given the hundreds of fishing trips, the large number of participating vessels, and the wide geographic area of the pollock fishery. Even with these obstacles, genetic sampling has been representative of the entire bycatch, a feat largely attributable to the professional fishery observers and cooperation of the fishing industry. For example, the plot of the 2015 chum salmon bycatch census versus the number of genetic samples collected for each fishing vessel closely matches the proposed sampling rate of 1 in 30 fish encountered (Figure 8). The stock composition estimates of samples collected systematically were generally similar to those from prior years when samples were collected opportunistically, a result likely reflective of the dispersion of stocks in the Bering Sea and the relative randomization of collection dates and locations for even the opportunistically collected samples. Systematic sampling for both the Chinook and chum salmon bycatch in the Bering Sea continues to this day.

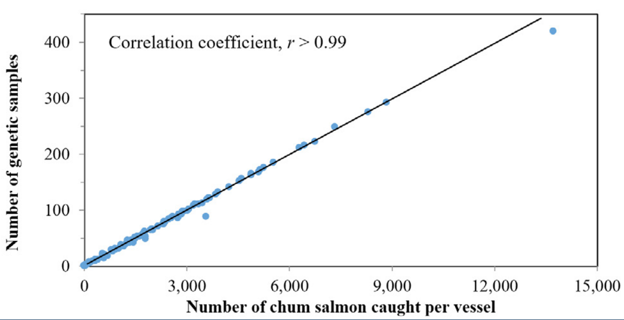

Figure 8. *Number of genetic samples collected from the number of chum salmon caught by fishing vessels (blue dots) during the 2015 Bering Sea pollock fishery. The diagonal line represents the expected sampling rate.*

In the United States, the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act) was first passed in 1976 and established a series of eight fishery management councils (Figure 9), with the NMFS the designated action agency. U.S. marine fisheries are scientifically monitored, regionally managed, and legally enforced under a number of requirements, including ten national standards. The National Standards are principles that must be followed in any fishery management plan to ensure sustainable and responsible fishery management (see https://www.fisheries.noaa.gov/national/commercial-fishing/national-standard-guidelines). These National Standards incorporate regulations for both the intended fishery and the associated bycatch.

North Pacific Fishery Management Council (picture from https://www.npfmc.org/joint-protocol-committee/).

The North Pacific Fishery Management Council (Council) has the primary responsibility for groundfish management of marine fisheries in Alaska that are conducted in the exclusive economic zone, between 3 and 200 nautical miles offshore. The stock composition results of the salmon bycatch are presented annually to the Council where we receive information requests that can help guide changes to fishery management plans. In recent years, the Council requested that stock compositions be completed for more refined temporal and spatial strata. This led to a collaboration with the Pacific States Marine Fish Commission to develop a graphical tool that we use to determine finer scale spatial and temporal strata of sample sets. The genotype data sets are now prepared for stock composition analyses based on the temporal and spatial strata of interest. In addition, new analyses are becoming possible as the ageing of scales is being completed at the Auke Bay Laboratories. In the future, age determination of the bycatch samples will enable additional stock compositions separated by year class.

Summary

The genetic stock composition analysis of the salmon bycatch from the Bering Sea pollock fishery is completed annually by the Alaska Fisheries Science Center and involves the collection of genetic samples through the Observer Program and the analysis of those samples at the Auke Bay Laboratories. The work has evolved from stock composition analyses of allozymes from opportunistic sampling, to a DNA-based approach of systematically collected samples. The need to understand the impacts of groundfish trawl fisheries on salmon stocks is not unique to the Bering Sea and our efforts have expanded into the Gulf of Alaska where annual stock compositions of the Chinook salmon bycatch have been developed since 2011. The analyses of Gulf of Alaska samples include samples collected by the Observer Program from the pollock trawl fishery (e.g., Guthrie et al. 2017), as well as by the fishing industry, which voluntarily collects genetic samples of Chinook salmon from the rockfish and arrowtooth flounder trawl fisheries.

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Winter ice melts in the new year

A Busy Fall for the International Year of the Salmon (IYS) Initiative

By Mark Saunders, IYS Director
and Madeline Young, IYS Coordinator
North Pacific Region

The fall has been a busy and productive one for the IYS initiative. It has been a true team effort for all Secretariat staff, including Caroline Graham, who joined us this fall as an intern and has contributed greatly. Working with our partners to explore potential collaborations has been an extremely positive experience. It seems every day we become aware of another person, organization, or event that fits well into the IYS. Even with the minimal media exposure we have had to date, we are routinely approached by people who are interested in engaging in the initiative.

A great example is an October visit from a Korean delegation to Canada including researchers and executives from a university and government agencies as well as a couple of film crew. We were able to participate in a day spent at a Qualicum hatchery on Vancouver Island where there were stimulating exchanges of information regarding hatchery practices and research projects related to high seas salmon. We were also interviewed by the film crew that was developing a segment on the IYS.

The Korean delegation at Big Qualicum Hatchery. Back row, left to right: Jeong-Seok Yu (Blue Korea Innovation Ltd.), Hyun Je Park (Gangneung-Wonju National University (GWNU)), Chung Il Lee (GWNU), Jim Irvine (Fisheries and Oceans Canada (DFO)), Mark Saunders (NPAFC), Young-Ja Yun (Ministry of Oceans and Fisheries (MOF)), Les Clint (DFO), Dave Willis (DFO). Front row, left to right: Do Hyun Lee (Korea Fisheries Resources Agency (FIRA)), Cheul Ho Lee (FIRA), Yeongha Jung (DFO).

Mark Saunders currently works for the NPAFC Secretariat as the Director for the North Pacific Region of the International Year of the Salmon (IYS) initiative. In 2016 he retired from the Canadian Department of Fisheries and Oceans (DFO) where he headed up a Salmon, Aquaculture and Freshwater Ecology Division at the Pacific Biological Station in Nanaimo, BC with staff working on salmon stock assessment, freshwater habitat, molecular genetics, fish health, and marine ecology. Mark has been active at NPAFC since 2009, serving as CSRS Chairperson from 2011–2014, and he is currently the Chairperson of the International Year of the Salmon Working Group.

Madeline Young began working as the North Pacific Coordinator for the International Year of the Salmon (IYS) initiative after completing an internship at the NPAFC Secretariat in March 2017. Prior to working with the NPAFC, Madeline obtained a BSc in Marine Biology from the University of British Columbia, Canada, and moved to Ísafjörður, Iceland, to complete her Master of Resource Managment at the University Centre of the Westfjords. During this time, she developed an interest in studying ways to reduce entanglements and bycatch in fisheries and aquaculture operations and completed a study of whale, porpoise, and turtle entanglements in mussel aquaculture gear for her thesis.

NPAFC and NASCO Presidents' Meeting

In August 2017, the NPAFC President, Carmel Lowe, and the NASCO President, Jóannes Hansen, met in Nanaimo, BC, Canada, with the aim of advancing the partnership of their organizations to implement the IYS. The meeting and associated visits to fisheries and scientific sites throughout southern BC were fun and constructive, including both formal and informal exchanges between the Presidents. A considerable amount of the informal exchanges emphasized the vast amount of potential synergies that exist between the two RFMOs, and the Presidents agreed to seek additional opportunities to determine how they might capitalize on these synergies to the mutual benefit of both organizations.

The Presidents confirmed the commitment of both NPAFC and NASCO to work collaboratively towards the IYS initiative and agreed that the focus of the IYS partnership would be at the salmosphere level and on activities in either the Pacific, Atlantic or Baltic regions that would add value to the efforts of the IYS. They also recognized that there could be benefits from improved exchanges among scientists and managers working in all regions of the salmosphere. The meeting concluded with an invitation from the NASCO President for a reciprocal visit from Carmel to continue the exploration of other collaborative opportunities.

NPAFC President Carmel Lowe and NASCO President Jóannes Hansen in Nanaimo, BC, Canada. Photo credit: NPAFC Secretariat

We very much appreciated the support of John Field, the Executive Director of the Pacific Salmon Commission (PSC) in Vancouver, who arranged to visit the Johnstone Strait sockeye salmon test fishery, and the Mission and Qualark hydroacoustic counting sites on the Fraser River. In particular, Jóannes had a memorable moment catching a coho salmon with rod and reel trolling gear off Nanaimo Harbour.

Jóannes Hansen with a coho salmon in Nanaimo Harbour. Photo credit: NPAFC Secretariat

Johnstone Strait sockeye salmon test fishery. Photo credit: NPAFC Secretariat

Planning a hemispheric-wide initiative is a challenging endeavor and the Presidents committed to convening face-to-face meetings of our Coordinating Committee to expedite implementation of the IYS. As a result, an IYS technical team, consisting of the Coordinating Committee Co-chairs and NPAFC and NASCO Secretariat representatives, met at the office of the United States National Marine Fisheries Service in Gloucester, MA, USA, in mid-December to develop discussion documents to inform meeting agendas for the North Pacific and North Atlantic Steering Committees and the Coordinating Committee. The three committees will meet in person between January 30 and February 7, 2018.

We anticipate that at these meetings we will be able to confirm approaches to complete our website, communications key messages, plans for the launch of the IYS, a social media strategy, as well as a plan to conduct outreach and research planning at the salmospheric scale.

This fall we have been working on planning potential research activities at both the basin and salmospheric scales that will address our IYS outcomes. Descriptions of several of these exciting projects follow.

IYS Technical Team in Gloucester, MA, USA. From left to right: Mark Saunders (NPAFC), Madeline Young (NPAFC), Kim Damon-Randall (NOAA Fisheries), Emma Hatfield (NASCO), Vladimir Radchenko (NPAFC). Photo credit: NPAFC Secretariat

North Pacific High Seas Expedition: This IYS Signature Project presents an opportunity to make significant progress in understanding the marine life history period of Pacific salmon through an intensive coordinated program of winter and summer expeditions utilizing up to five research vessels deployed simultaneously across the North Pacific Ocean. Information, including biological materials for salmon stock identification, data for abundance estimates, and structure of nektonic communities will be collected through the trawl surveys and supplemented by oceanographic, hydrobiological, and trophological studies in the summer–autumn season as well as the wintering period. The objective of these expeditions is to provide estimates of salmon spawning stock recruitment for 3–4 age cohorts of chum and sockeye salmon. These data can then be utilized for fishery forecasting in subsequent years. Cooperative high seas cruises represent a tremendous opportunity to collaborate on methods related to fisheries research in the field and for outreach through live-streaming of the exciting work being conducted onboard. Dick Beamish has been successful raising over $1M CDN towards chartering a Russian research vessel and we have made requests for ship time from the parties in Canada, Japan, Korea and the United States.

ROAM: One exciting new frontier to explore for salmon tracking in the open ocean is ROAM (RAFOS Ocean Acoustic Monitoring)—a concept being developed by a few Atlantic researchers, including Tim Sheehan (National Marine Fisheries Service), Simon Thorrold (Woods Hole Oceanographic Institute), and Jon Carr (Atlantic Salmon Federation). This novel idea uses existing SOFAR (Sound Fixing and Ranging) technology to track salmon in the high seas; however, it works in reverse so that instead of drifting tags emitting 'pongs' which are identified by moored receivers, drifting tags identify 'pongs' emitted from moored sound sources. Some advantages of this new method include increased ability to accurately track salmon through their entire marine phase, the enhanced potential for basin-level collaboration, and its overall cheaper price tag. In October 2017, the NPAFC Secretariat hosted a webinar with a presentation by Tim Sheehan for interested participants in the Pacific. While this approach is still in the development stage, there is a great amount of interest from both the Atlantic and Pacific basins to explore the use of this technology. A small workshop will be hosted by Tim Sheehan in Woods Hole in March 2018 to further explore this concept with Pacific researchers expected to attend.

Likely Suspects Framework: The Likely Suspects Framework is an accounting approach to identify likely bottlenecks across life history stages of salmon that is under development by the Atlantic Salmon Trust (AST). The Framework places candidate mortality factors within an overall spatio/temporal framework of Atlantic salmon throughout the smolt migration phase, both freshwater and marine, with a view to quantifying the potential of each factor to influence survival. Recognizing the significant benefits that could be realized from expanding the discussion to the wider salmosphere, Pacific colleagues were invited to attend a workshop hosted by the AST in Edinburgh in November 2017. Participants discussed further development and refinement of the Likely Suspects concept, taking into account previous and on-going related research in both the North Atlantic and North Pacific basins. For information on the outcome of the workshop, please visit Jim Irvine's article on Page 27.

The collaborative spirit experienced at all the above-mentioned meetings and planning sessions is infectious to say the least! We are eager for this energy to take us into the new year, which will be an exciting one for the IYS. The months leading up to the 2018 NPAFC Annual Meeting in May will be formative for the IYS launch, focal year of 2019, and other activities expected to take place for the duration of the initiative. We are looking forward to working with all of you in the coming days and months.

A Workshop on Atlantic Salmon Mortality at Sea: Developing an Evidence-based "Likely Suspects" Framework

By Jim Irvine
Pacific Biological Station,
Fisheries and Oceans Canada

James (Jim) Irvine has been a research scientist with Fisheries and Oceans Canada (DFO) since obtaining his PhD at the University of Otago in New Zealand in 1984. Based at the Pacific Biological Station in Nanaimo, BC, for the past 30 years, Jim's research shifted from a focus on salmonids in fresh water to ocean-related research about 20 years ago. He worked in Hokkaido, Japan, for six months and has mentored various Japanese scientists. Jim has held various positions at DFO including Chair of the Pacific Science Review Committee, Science lead during the development of Canada's Wild Salmon Policy, Co-Chair of the Fishery Oceanography Working Group, and lead for the International Year of the Salmon (IYS). Jim has authored approximately 250 scientific publications, of which about 80 are peer-reviewed. An active member of the NPAFC scientific community since 2003, particularly as Chair of the Stock Assessment Working Group, he currently represents Canada on the Science Sub-committee and IYS Working Group. Jim enjoys kayaking, fishing, curling, and skiing. He lives on a small island in Nanaimo Harbour from which he regularly commutes in a small powerboat and occasionally provides driving instructions to his grandson, Micah.

The International Year of the Salmon (IYS) is being led by NPAFC in the Pacific, and by its sister organization NASCO (North Atlantic Salmon Conservation Organization) in the Atlantic. Researchers have shown that certain Pacific Ocean climate anomalies, such as sea surface warming in the central western Pacific, often precede warming in the Atlantic. Perhaps not coincidentally, similarities have been noted between the production dynamics of Atlantic salmon and several Pacific salmon species in the southern portion of their natural range. Is it possible that teleconnections between the Pacific and Atlantic oceans are responsible for common survival patterns of Pacific and Atlantic salmon?

Clearly much can be learned by sharing information between Atlantic and Pacific salmon researchers, not only with respect to teleconnections, but also analytical approaches to better understand productivity time series, genetic approaches to discriminate amongst populations, and tagging and sampling approaches in the ocean, just to mention a few common interests. Such was some of the thinking preceding a workshop in Edinburgh in November 2017.

The "Likely Suspects" Framework, an accounting process designed to identify and quantify mortality factors within the salmon life cycle was discussed by 17 salmon researchers from the UK, Ireland, France, USA and Canada, including five from the Pacific (Michael Schmidt from Long Live the Kings, Seattle, Washington; Brian Wells from NOAA Fisheries, Santa Cruz, California; and Sue Grant, Kim Hyatt, and Jim Irvine from DFO, British Columbia). The November 2017 workshop was hosted by the Atlantic Salmon Trust while the IYS and DFO supported participation of Pacific researchers.

Significant benefits were realised from having joint Atlantic and Pacific representation at the workshop. Agreement was reached that specific follow up tasks should include developing a common language/currency, establishing an operating framework for working together (e.g., meetings/discussion forum), and sharing information to align approaches so that data are readily comparable. There is a need to isolate primary and contributing factors responsible for changing salmon survival/abundance/distribution patterns in order to understand mechanistic linkages. Testable hypotheses need to be clearly stated.

Interactions between bottom-up (e.g., prey changes, inability of salmon to adapt) and top-down (e.g., predation) drivers should be investigated while recognizing that multiple factors (cumulative effects of habitat loss, disease, contaminants etc.) are involved.

Hemispheric scale research themes of interest to the IYS include assessing similarities and differences in marine survival/abundance trends across salmon species and jointly investigating climate change drivers and impacts on salmon. Continued dialogue between Pacific and Atlantic researchers will benefit all.

Acknowledgements

Thanks to all participants at the workshop as well as the Atlantic Salmon Trust (especially Walter Crozier for chairing the workshop and Ken Whelan for being the rapporteur) and NASCO for hosting.

Atlantic and Pacific salmon researchers at the Workshop on Atlantic Salmon Mortality at Sea hosted by the Atlantic Salmon Trust (AST)—Edinburgh, UK, November 7–9, 2017.

What Can We Get Out of a High Seas Research Expedition in the Convention Area?

"I wrote an article once called 'Marvels and Miracles, Pass It On.'
… To remind you of your potential and how wonderful life is constantly"
Ray Bradbury, American writer

By Vladimir Radchenko
Executive Director, NPAFC

At the first International Year of the Salmon (IYS) North Pacific Steering Committee meeting in Richmond, BC, in February 2017, the Russian Party put forward a proposal for a signature project under the IYS framework. The proposed project is to conduct a synchronous trawl and oceanographic macro-survey in February and March in the upper pelagic layer of the North Pacific Ocean, from Asian to North American coasts, through efforts by the NPAFC member countries. The survey will be restricted to areas within the winter thermal limits of salmon.

The survey area will be divided into five sectors, based on the number of participating vessels that will be deployed simultaneously (Figure 1). Each research vessel will start survey operations in its designated sector at the same time to ensure a synchrony between the surveys. In total, there will be 18–20 survey sections from north to south. Each vessel will work for 30–40 days. Unified methods of trawl hauls, catch processing, and the spectrum of ecological research studies would be applied. The proposal by Russia is an expansion of the Gulf of Alaska Expedition that is being organized by Dick Beamish for February–March 2019 and independently funded by private donors and government agencies.

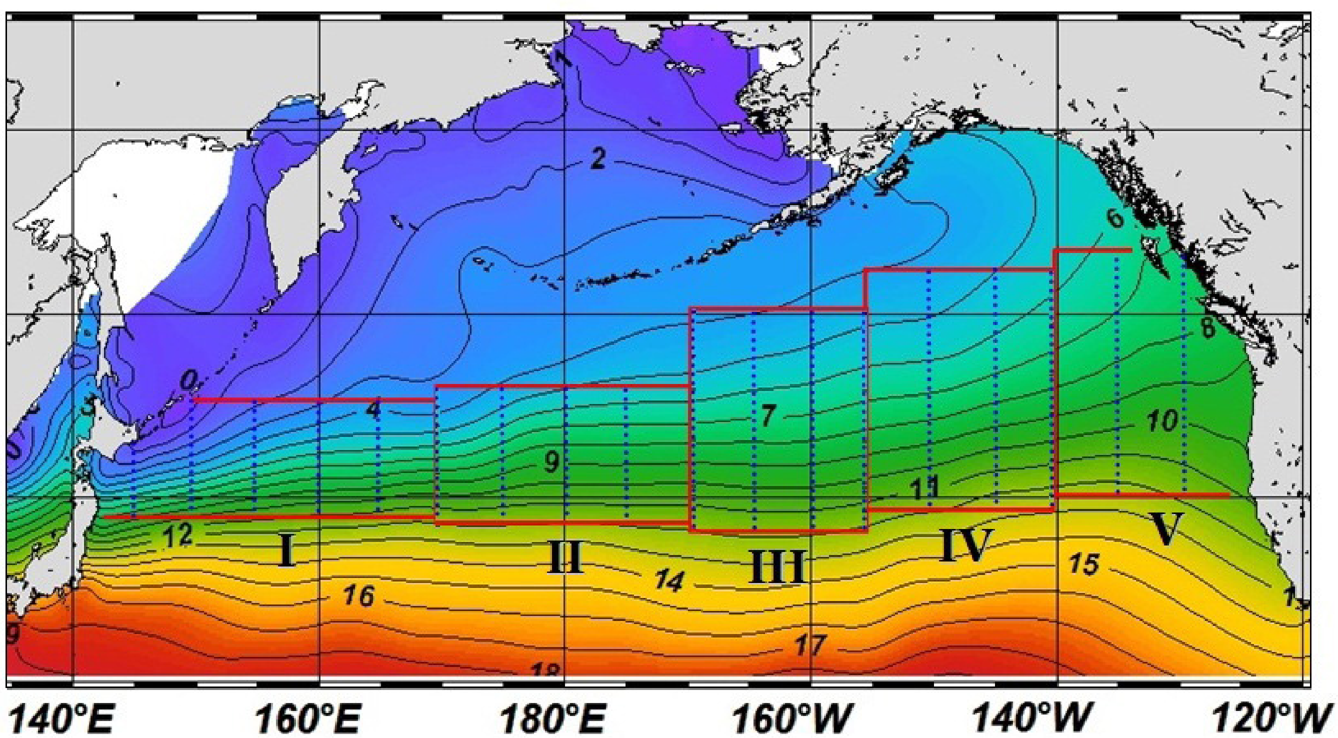


Figure 1. *Proposed trawl and oceanographic upper pelagic layer macro-survey grid throughout Pacific salmon wintering area in the North Pacific Ocean in February–March.*

Although the idea of including large-scale ocean studies in the IYS has been in the air since the initiative was first proposed by Dick Beamish in 2009 (see NPAFC Document #1425), not many of the experts involved have spoken out about it. The reason, in my opinion, is an understanding from these experts of the magnitude of costs and the extent of the organizational challenges related to the implementation of such a large project across the vast expanse of the North Pacific Ocean (Figure 2). In 2014, when ideas to initiate the IYS discussion were summarized by the Secretariat (see NPAFC Technical Report 10), a high seas scientific research expedition to the winter residence area of Pacific salmon was conceived with a cruise duration of "*no less than 30 days at sea*" and approximate costs of survey ship-time roughly estimated at about $600,000 CDN. However, research vessels cannot appear out of nowhere in the middle of the Pacific Ocean. There will be additional costs to prepare the vessel, for transit time to the survey area, and for supplies and additional equipment, which may double expenditures altogether. With these anticipated costs, the question in the title of this article is rather reasonable.

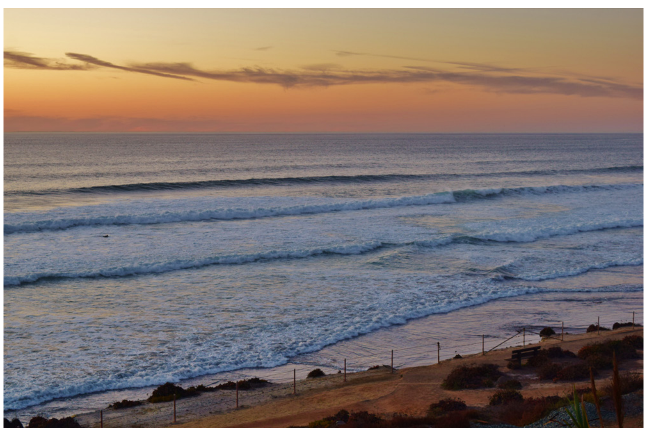


Figure 2. *Endless Pacific Ocean in the evening time. Photo credit: NPAFC Secretariat*

With my considerable experience in the field of marine expeditionary research, I can conclude that research cruises on specialized research vessels remain the most reliable, productive and history-making way to obtain new knowledge on composition, dynamics, and functioning of marine life and its surroundings. And this is not only true for the ocean itself. Until the end of the past century, ship-based observations provided virtually all the empirical information we had about the oceans' fundamental role in the evolution of the atmosphere, climate, and many important resources of our planet. Although many coastal countries have built ocean observing systems that reach some remote oceanic regions and the full depths of the water column, and satellite technologies that have interrogated the ocean surface, technologies have only been operational for the last two decades or so.

Figure 3. *Aerial view of the Marine Operation Center-Pacific in Newport, Oregon with NOAA research vessels, MacArthur II, Rainier, Oscar Dyson, Fairweather, and Bell M. Shimada alongside. Photo credit: US Coast Guard*

New robotic technologies, such as autonomous profiling floats and ocean gliders, have much more recently been revealing the secrets of the water column [*see Beamish, R.J., and B.J. Rothschild (editors). 2009. The Future of Fisheries Science in North America*]. Ship-based research remains vital to conduct oceanographic, hydrochemical, planktonic, trawl, and hydroacoustic surveys, and especially to collect integrated or spatially explicit data that cannot be remotely sensed. All remote sensing data needs to be validated, or compared with information collected onboard research vessels, to ground truth satellites. Therefore, if we really want to gather some new highly valuable data on Pacific salmon within the IYS framework, this information should be collected by research vessels on the "grounds" (Figure 3).

A winter high seas expedition in the North Pacific Ocean is a special opportunity to make significant progress in understanding the marine life history period of Pacific salmon. There were only seven trawl stations conducted by Japanese r/v *Kaiyo maru* along 145ºW between 48º and 54ºN in February 2006 (see NPAFC Document #957). Integrated trawl and oceanographic macro-surveys have never been conducted in the eastern part of salmon habitat during the winter, even though several important regional salmon stocks migrate then. All we know about Pacific salmon originating from the North American west coast in the winter is that they end up somewhere in that area, like the popular *X-Files* slogan "*The Truth is Out There*". Until now, the remote North Pacific Ocean during the winter is less understood than nearby outer space. While the orbit of the moon and other celestial bodies are carefully calculated, our understanding of the winter distribution of abundant salmon species is still not far enough matured from the first patterns suggested by K. Takagi et al. [1981, Bulletin INPFC #40, *Distribution and origin of pink salmon Oncorhynchus gorbuscha in offshore* *waters of the North Pacific Ocean. 195 p*.]. Many issues concerning Pacific salmon stock abundance dynamics have been attributed to processes occurring during the wintering period: en route salmon mortality, factors affecting it and their ranking, carrying capacity, winter survival strategies of different salmon species and different regional stocks, growth and energy dynamics, forage areas shifting under climate change, hypothesesother yet-unknown matters. Numerous hypotheses—a northern shift in the salmon stocks because of ocean conditions, salmon winter starvation, their strong competition for food with other planktivorous fish—which are not necessarily supported by data, have emerged on the mentioned research issues, while many uncertainties remain.

One of the most general problems is whether we will find salmon in "expected" areas of winter residence. Has their distribution shifted northward in response to observed climate warming and progressive growth of the ocean heat budget? If so, how do redistribution patterns vary by species and age? Clear answers to these questions will allow us to further understand how climate change influences salmon survival during their marine phase of life. Some might say it is obvious that salmon wintering areas would shift to the north. On both the Asian and American coasts, southernmost salmon stocks suffer from droughts, wildfires, high water temperatures, diminishing oxygen concentrations in rivers, and other effects related to a warming climate. While, in both the Russian and Canadian Arctic, salmon are expanding their habitat along the coasts and are being found in rivers and creeks where they have never been seen before. In the Yukon, Northwest Territories and Nunavut (Canada), members of a research group established by Karen Dunmall that study Arctic salmon bought more than 300 salmon from local fishermen in 2017 (Figure 4, see also https://www.facebook.com/arcticsalmon/). While this is all true, it is not known whether salmon behave in the same manner in the high seas in the winter.

Figure 4. *Sockeye salmon caught by nets under the ice on Victoria Island near Ulukhaktok, the Northwest Territories, Canada in November 2017. Photo credit: Arctic Salmon*

The fact is that salmon at sea can tolerate a wide range of water temperatures. Vyacheslav Shuntov in his recent article "*On the Persistence of Stereotypes Concerning the Marine Ecology of Pacific Salmon (Oncorhynchus spp.)*" [Russian Journal of Marine Biology, 2017, 43(7): 1–28] pointed out that undue ("absolute") importance has been given to the influence of sea surface temperature when considering salmon distribution patterns. The water column structure, i.e., landscape of salmon habitat, where each species may have their own preferred feeding spots, is more important than water temperature, which is likely a general index of hydrological conditions and seasonal phenological processes. While salmon in the western North Pacific prefer to overwinter in productive areas of oceanographic fronts (i.e., boundaries of ocean currents), they can not move far from that water domain, even if water temperature increases. The vicinities of oceanographic fronts, with all meanders, eddies, surface and subsurface (sometimes oppositely directed) flows, are a favorable habitat for salmon, since the inhomogeneities beneath the surface increase mechanical accumulation of forage plankton. Comparing oceanographic fronts and

Figure 5. *Enormously big pink salmon specimen at the fish processing facilities in Southeast Alaska. Photo credit: ADF&G*

their vicinities to terrestrial ecosystems, it is like a forest with several strata of plants, from grass to the tallest trees. Regardless of the air temperature increase in forest ecosystems, it will remain a forest (although with changed conditions). At the same time, vast ocean domains with a predominantly homogenous water column surface structure will remain practically two-dimensional, like a terrestrial prairie.

Unlike distribution, many aspects of salmon biology, including feeding, growth, and maturation, will undoubtedly change under the new thermal conditions of a warmer ocean (Figure 5). In the cited article, V. Shuntov, who does not support the idea of severe competition for food between fish in the ocean, including between species of Pacific salmon, mentions that many marine biologists loosely apply the results of studies of schooling fish to salmon. However, salmon operate independently in open waters and therefore, their ecological traits are distinct, and their feeding behavior ensures more opportunities to obtain food. This circumstance draws further attention to trophological studies not only of salmon but of ecologically-related species and the food supply. To address this need for new information on salmon ocean ecology during winter, the most experienced field specialists, who have a wide array of data for

Figure 6. *Daggertooth, Anotopterus nikparini in a trawl survey catch consisted mainly of pink salmon. Photo credit: TINRO-Center*

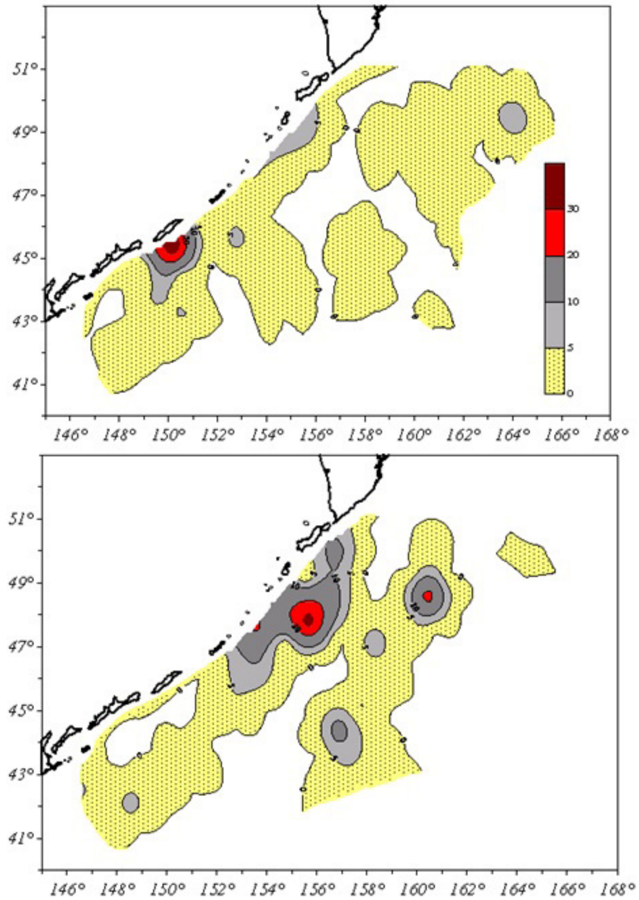


Figure 7. *Frequency of occurrence (% of total) of bites and wounds caused by marine mammals on Pacific salmon bodies: upper panel, pink salmon; lower panel, chum salmon.*
Data of TINRO-Center, Vladivostok, Russia

comparisons and interpolations, will lead the planktonic and trophology studies as an integral part of the proposed high seas expedition. And we can expect they will produce breakthrough findings. Based on data collected during the cruises, trophologists will test the hypothesis of whether there is a limited food supply for Pacific salmon in their over-wintering areas in the high seas. This is a key point in understanding the carrying capacity of the subarctic epipelagic zone of the North Pacific Ocean for Pacific salmon.

Salmon trophic linkages to upper levels of the oceanic food web are not any less important than their connections to the lower levels. Based on data collected during Russian expeditions in the western North Pacific, I. Melnikov [1997. *Pelagic predatory fish – consumers of Pacific salmon // Izvestiya* TINRO. 122: 213–228, in Russian] estimated that total losses of the anadromous pink salmon stocks in the Sakhalin-Kuril Islands region in July and August in recent years were as follows: 0.7–41.7 million fish from daggertooth *Anotopterus nikparini* predation, 0.1–0.5 million fish from lancetfish *Alepisaurus ferox*, and 1.0–7.0

million fish from salmon shark *Lamna ditropis* (Figure 6). These estimates ranged from 3.9–17.8% of the estimated pink salmon abundance in the adult return migration. Similar calculations were made for salmon shark predation by K. Nagasawa and co-authors [2002. *Impact of Predation by Salmon Sharks*… // NPAFC Tech. Rep. #4: 51–52]. The grand total of pink salmon losses for the western North Pacific was estimated at 73–146 million fish (113–226 thousand tons) in the pre-spawning run, which is a significant contribution to salmon mortality on the high seas. A comparison of survey results for pink salmon juveniles in the fall and returning adult salmon abundance revealed that the percentage of returns to the southwestern Bering Sea coasts varied from 16–33%, while returns to the Sea of Okhotsk coast varied from 25–33% on average. There are no similar estimates for the eastern North Pacific Ocean, even though the first evidence of a daggertooth attacking a salmon was collected at a salmon troll fishery near the British Columbia coast in 1990 [Welch et al. 1991. *Evidence for attacks by the bathypelagic fish Anotopterus pharao (Myctophiformes) on Pacific salmon* … // Can. J. Fish. Aquat. Sci. 48: 2403–2407]. A review of predatory fish impacts on salmon in the eastern North Pacific is long overdue, and not just for fish. In 2009, we were surprised to see how far from the coasts salmon specimens with wounds caused by pinnipeds occurred (Figure 7). Unfortunately, the ecology of predators and the consistency of their effect on Pacific salmon abundance dynamics are studied much less than Pacific salmon themselves.

Will we be able to estimate salmon abundance throughout the survey area? Without a doubt. Over the last 30 years, the available formulae for estimating nekton species abundance and biomass with trawl net catchability coefficients have been proven to be correct, time after time, with estimations validated by results from commercial fisheries and escapement. Contemporary methods of salmon stock identification allow us to distinguish between major regional groups with high accuracy. On the survey cruises, special attention will be paid to abundance estimates of immature and maturing chum and sockeye salmon to provide estimates for spawning stock recruitment for 3–4 age cohorts. On the other hand, nobody can say which part of investigated stock will be covered by the survey. Therefore, estimates will be relative rather than absolute. In Russian research practices, this problem is solved by maximizing the survey area across salmon migration pathways and conducting recurrent surveys with a similar grid over consecutive years. It would be most valuable for the IYS project if the NPAFC member countries (at least some of them) decide to have such an expedition every year, or every other year, after the first cruise. But even if it will be five or ten years before a repetition of such research, the advantage of possessing data collected in 2019 will be crucial for comparative analysis and assessments.

In this article, I will not outline the whole cruise plan. Group brainstorming yields better results, and the IYS Working Group will determine the details of the research cruise plans. Cooperative efforts by scientific organizations in the NPAFC member countries will ensure a comprehensive cruise plan and high efficacy of the work performed. The plans will be built on the extensive experience of the NPAFC member countries conducting salmon research on the high seas—especially based on the experience of coordinated research that was gained through the BASIS I and II projects (Figure 8). During the cruise, a comprehensive sampling program will give researches many opportunities to collect material for biological, trophological, bio-energetic, microchemical and genetic studies. These results will be jointly analysed with

Figure 8. *Collaborative work of international scientific group aboard Japanese research vessel during the BASIS I project implementation. Photo credit: NPAFC Secretariat*

Figure 9. *Smooth lumpsucker, Aptocyclus ventricosus (Pallas, 1769). Photo credit: NPAFC Secretariat*

a wide array of oceanological, hydrochemical and synoptic information, as well as data on ecologically related species including zooplankton and micronekton, predatory fish species, etc. I expect that collaborative adoption of designing cruise plans will allow us to develop an optimal sampling design. It is also important to note that it is not just the IYS/NPAFC that need a large-scale expedition on the high seas, and the expedition itself needs to be a sound project with the support of international organizations in order to be performed.

Cooperative high seas cruises also represent a tremendous opportunity to collaborate on methods used to study salmon ocean ecology onboard research vessels. Data collected during such an expedition will be of the highest quality **gathered through collective efforts**. Scientific results gained together will strengthen the feeling of belonging and partnership within the Committee on Scientific Research and Statistics (CSRS) that will help immeasurably to implement the NPAFC Science Plan successfully.

We believe that a marine research cruise, an endeavor attractive to the public, will create inexhaustible opportunities for outreach and education. Having some experience with blogging via social media as part of a research cruise in the western North Pacific Ocean, I can confirm it first-hand. Readers were interested in everything from my blog that was distinct from routine city life. The readers were especially interested in the everyday opportunities for crew members to swim in heated oceanic water of incredible clarity. On Russian research vessels, this water is heated by hot steam in a big wooden pool that offers the delightful a light aroma of seafood brine from small boiled planktonic crustaceans (calanuses, euphausiid larva, etc.). While rich people can swim in champagne, a hot spa with tons of clear oceanic water is only a seaman's privilege. Another "advertisement for health care" was related to the biological analyses of salmon. Ichthyologists, who sample many fish per day, have noted that the skin on their hands looks brighter and healthier at sea than it does after using expensive creams. This may be explained by the fact that salmon contain many biologically active substances, which help it to recover and regenerate after terrible wounds and bites from marine mammals, lampreys, daggertooth and lancetfish, etc. Successful healing occurs quickly in marine water and emphasizes the power of these biologically active substances. Cosmetologists should probably pay attention to this news in the future.

Another attractive topic related to ocean surveys are the exotic fish species that can be encountered. Imagine smooth lumpsucker, which, like salmon, reproduce in coastal environments and then migrate to the central part of the far-eastern seas to depths below 1,700 m (Figure 9). When captured, the smooth lumpsucker will swallow water and can more than double their body size and weight. Night-time trawl catches in the western North Pacific are rich with fish and squid species, whose names sound strange the first time you hear them. The most common are some myctophids, bathylagids, paperbones, ribbonfish, dragonfish, pearleye, dreamers, barracudinas, bristlemouths, pencil smelts, sunfish, squaretail, ragfish and prowfish, etc. Some specialists have been lucky enough to see these species in real life, not just in the pages of a fish guide. It's true that the Pacific Ocean is well studied only near the coasts and in the surface layer. These unique species would likely attract special interest from a diverse and general audience, leading to a successful outreach campaign.

Preparation and implementation of the trawl and oceanographic macro-survey requires external financing and additional efforts to attract the private sector to this project. Available funding may limit the survey capacity, including the number of research vessels involved at the same time. For such a case, priority should be given to designated eastern survey sectors based on current knowledge, expected distribution of Pacific salmon species and regional stocks, and logistics. The survey may be expanded, if additional ship-time resources become available. As reported previously, Dick Beamish is arranging for an international expedition to study the winter ecology of Pacific salmon in the Gulf of Alaska in February–March 2019. This has never been done before and is both privately funded and supported by government agencies. The Russian ship on charter will have an international team of scientists and all data will be publicly available.

Accepting Applications for the 2018 NPAFC Internship Program

APPLICATION DEADLINE: March 22, 2018

2017 NPAFC interns: Pavel Emelin (left) and Caroline Graham (right) in Vancouver, British Columbia. Photo credit: NPAFC Secretariat

The North Pacific Anadromous Fish Commission (NPAFC) invites citizens from its member countries (Canada, Japan, Republic of Korea, Russian Federation, and USA) to apply for the NPAFC Internship Program. One intern 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),
- assist in organizing and editing various NPAFC publications,
- coordinate international cooperative programs and assist Secretariat activities,
- assist with other work delegated by the Executive Director and/or his designates.

Internship period: Starts on or about September 1, 2018, for a period up to a maximum of 6 months. 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 citizens 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 $2,500 CDN per month. Travel cost to and from the intern's place of residence and the location of the Secretariat office and cost of medical insurance 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 the NPAFC.

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 22, 2018. The selected intern will be notified in early June of 2018.

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

APPLICATION DEADLINE: March 22, 2018

Congratulations to Dr. Suam Kim, as the Recipient of the 17th Wooster Award from PICES

Suam Kim, Vice-President of the NPAFC, received the 2017 Wooster Award on September 25, 2017, during the Opening Session of the 2017 PICES Annual Meeting in Vladivostok, Russia. We sincerely congratulate him on being a Wooster Award recipient. The following text, with some edits, is an excerpt from the PICES webpage (www.pices.int).

Suam Kim is a professor in the Department of Marine Biology at Pukyong National University in Busan, Korea. His career in examining fishery resources worldwide has spanned more than 35 years, including his chairmanship of international organizations related to science programs on fisheries and ocean studies such as PICES and NPAFC. He has published over 100 peer-reviewed articles on topics of climate change, fishery resource trends, ecosystem changes and forecasting of fish stocks. He has published six books in Korean, and contributed chapters to 28 books domestically and globally.

Suam's connection to the sea deepened when he entered the Department of Oceanography of Seoul National University in 1972. His education continued with a Master in Marine Biology in Korea, and a PhD in Fisheries Oceanography at the University of Washington. He did a postdoc at the Alaska Fisheries Science Center of NOAA. In 1989, as a young scientist still, he shifted his focus to studying the Antarctic. In 1992 he was the team leader of the Antarctic King Sejong Station, where he managed research operations and studied Antarctic biological resources. He later published "The Antarctic Science Story" in Korean for his daughter based on his experiences from this time.

Dr. Suam Kim received the Wooster Award on September 25, 2017 from Science Board Chair, Dr. Hiroaki Saito (right) and PICES Chair, Dr. Chul Park (left). Photo credit: PICES Secretariat

Along with his highly acclaimed papers in English, Suam has also played an active role in many international organizations in the areas of marine fisheries and oceanography, including for PICES and for the NPAFC, where he is currently Vice-President and a decade ago was the President (2008–2009). He was also vice chairman of the CCAMLR scientific committee. He currently serves as an Editorial Board member of the Marine Coastal Fisheries of the American Fisheries Society.

Since Suam moved to Pukyong National University (PKNU) in 2000, he has devoted great energy to fostering the next generation of marine and fisheries scientists. As a member of the Korean Committee of Global Ocean Ecosystem Dynamics (GLOBEC), he convinced an anonymous benefactor to provide funds that would enable young Korean scientists to attend and present their studies in international venues. This support enabled more than 50 young scientists to share their results in various venues, including PICES. Many of his students received Best Presentation Awards at four PICES Annual Meetings. He will officially retire from PKNU as of February 28, 2018. However, he will continue his commitment to marine and fisheries scientific studies and contributions to the NPAFC.

What is the Wooster Award, and who can win the Award?

In 2000, PICES Governing Council approved the establishment of an award named in honour of Professor Warren S. Wooster, a principal founder and the first Chairman of PICES, and a world-renowned researcher and statesman in the area of climate variability and fisheries production. The criteria for selection are: sustained excellence in research, teaching, administration or a combination of the three in the area of North Pacific marine science. Special consideration is given to individuals who have worked in integrating the disciplines of marine science, and preference is given to individuals who were or are currently actively involved in PICES activities (www.pices.int).

Baked Sockeye Salmon Ring Steak with Mushrooms

By Pavel Emelin
2017 NPAFC Intern

Ingredients:

Salmon Steak
3 Button Mushrooms
¼ Onion
1 Green Onion
3 sprigs Parsley
2 Tb Yogurt
Salt & Pepper to taste
¼ cup Cheddar Cheese
3 Tb Butter

Optional:

1 clove Garlic
¼ Lemon
1 slice Tomato

Method

1. Prepare the steaks: Add salt and pepper to taste and leave the steaks marinating while you prepare the stuffing. You can also sprinkle the steaks with lemon juice.
2. Preheat the oven to 400°F (200°C).
3. Stuffing: Chop the mushrooms and onions. Heat the frying pan to medium temperature. Fry the onions using butter. Add mushrooms and fry for a few more minutes. The filling will be baked with the steak, so the vegetables should be slightly undercooked. Turn the heat off, and mix in yogurt immediately while still warm.
4. Line a baking tray with foil or parchment paper. Place the steaks and spoon the stuffing into the centre, folding the steaks around for presentation. Cover and bake for 20 minutes.
5. Chop green onions and parsley. Mix with a small amount of yogurt. Grate cheese. Take the steaks out of the oven, and remove cover. Spread yogurt and fresh greens on steaks, cover with a slice of tomato (optional) and cover it with grated cheese. Bake until cheese is melted. Enjoy!

All types and species of salmon are a good source of beneficial omega-3 fatty acids.

If you want fewer calories and more protein, wild salmon comes out the winner.

Sockeye steak is pictured here, but no matter which species of Pacific salmon you may have—any species will result in success.

Some ingredients will depend on your choice of fish. If you are going to use steaks from fish that have a lot of fat in the tissues, like Chinook or sockeye salmon, they will have a rich and buttery flavour. With these fish, it is alright to exclude ingredients such as sour cream, because the dish will not turn out dry.

Serving Suggestions:

Green Beans
Avocado
Chilli Pepper

Pavel Emelin photographed all of these mouth-watering images.

Pavel Emelin was born and raised in Vladivostok, Russia and could never imagine being away from the sea. In 2011, being a third-year student of Far Eastern Federal University (FEFU), Pavel began to participate in marine expedition research of the Pacific Research Fisheries Center (TINRO-Center). Pavel graduated with a master's degree in Ecology—the main subject of his undergraduate thesis and graduate work was the composition and dynamics of abundance of the epipelagic nekton of the Bering and Okhotsk Seas. In 2013 he took up a full-time engineering position (now a research scientist). In the same year, Pavel started a full-time postgraduate study at TINRO-Center specializing in Ichthyology. The main direction of Pavel's work is the study of composition, structure and long-term dynamics of the epipelagic nekton of the Sea of Okhotsk. This work is important in the context of studying the biological environment of Pacific salmon, and their role in functional processes of the epipelagic nektonic community. Pavel has spent most of his time on the water aboard scientific research vessels. However, he also enjoys being on the water just on a board. If a good wave, on the surfboard; if the water is frozen, on a snowboard.

UPCOMING EVENTS

The 2nd IYS North Pacific Steering Committee & IYS Working Group Meetings

Dates: February 5–8, 2018, Vancouver, Canada
Venue: The Office of the Pacific Salmon Commission (PSC) on February 5
Blue Horizon Hotel from February 6–8

Committee on Enforcement Joint Patrol Schedule Meeting

Dates: March 2018
Venue: Email Meeting

ENFO Workshop

Dates: May 20, 2018
Venue: The House of Official Receptions of the Government of the Khabarovsk Krai
Khabarovsk, Russia

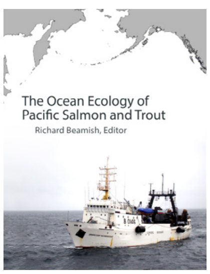
NPAFC 26th Annual Meeting

Dates: May 21–25, 2018
Venue: The House of Official Receptions of the Government of the Khabarovsk Krai
Khabarovsk, Russia

The First NPAFC-IYS Workshop on *Pacific Salmon Production in a Changing Climate*

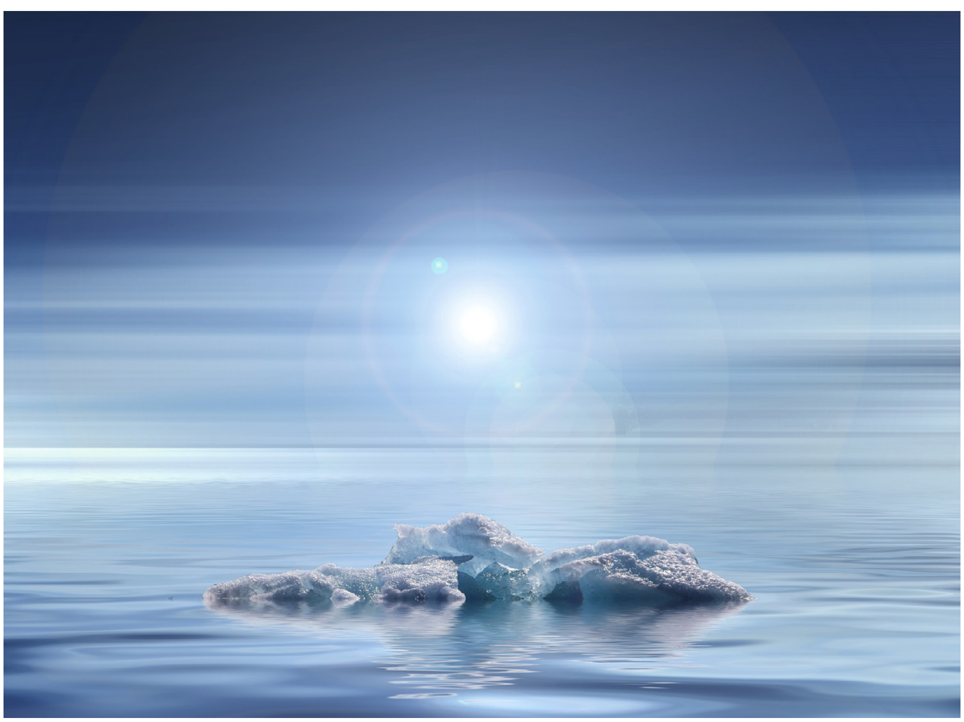
Dates: May 26–27, 2018
Venue: Boutique Hotel, Khabarovsk, Russia

UPCOMING PUBLICATION



Anniversary Book, titled "The Ocean Ecology of Pacific Salmon and Trout"

publication is anticipated soon in 2018 and will be announced when available.



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Visit the NPAFC website: www.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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