2018 BC Salmon Farmers Association Collaborations on the Coast Workshop Report

Vancouver Island Conference Centre
Nanaimo, British Columbia

February 28 & March 1, 2018

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Acknowledgements

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Introduction

The BC Salmon Farmers Association held its third annual Collaborations on the Coast workshop at the Vancouver Island Conference Centre in Nanaimo, BC on February 28th and March 1st, 2018. The annual event highlights the many collaborative research projects between industry, government, academia and conservation organizations that contribute to a better understanding of fish health – wild and farmed-raised salmon and the health of the marine environment. As well, the workshop highlights the projects from the BCSFA's Marine Environmental Research Program (MERP)[1]. The gathering provides an opportunity to share new research, keep current with ongoing projects and identify research gaps. Additionally, the workshop brings together a variety of participants to share information and build collaborations. Altogether, 110 people attended the workshop representing fish health, regulatory, academic, conservation and industry.

This report provides an overview of the workshop with summaries of presentations and future plans to identify relevant research and development priorities forwarding BC's coastal research agenda.

[1] **About the MERP:** BCSFA is committed to providing strong support for new research and development and cutting edge technologies to improve the competitiveness and sustainability of the salmon aquaculture industry. In December 2014, BCSFA committed to $1.5 million in research funding to the BCSFA Marine Environmental Research Program between 2015 and 2020. Through the BCSFA workshop series and the BCSFA Science Advisory Council, research priorities were developed in an effort to gain a better understanding of the marine environment and BC's wild marine species, particularly wild salmon stocks. Research funds are utilized in partnership with government, academic and independent research institutions. To date, the program has funded 11 projects with a value of $800,000.

Workshop Program

Wednesday, February 28 2018

Time	Topic & Speaker
5:00 – 6:00 pm	*Registration Open*
6:00 – 6:10 pm	**Opening Remarks** *Jeremy Dunn, Executive Director, BCSFA*
6:10 – 6:25 pm	**Canada's Research Collaboration Potential in Aquatic Animal Health** *Ian Gardner (moderator), University of Prince Edward Island*
6:25 – 7:00 pm	**2018 International Salmon Research Expedition** *Richard Beamish, Emeritus Scientist, Fisheries and Oceans Canada*
7:00 – 7:40 pm	**Spatial and temporal patterns of sea lice infestations on wild and farm-raised salmon on the British Columbia coast.** *Crawford Revie, University of Prince Edward Island*
7:40 – 9:30 pm	***Networking reception – appetizers and drinks***

Thursday, March 1 2018

Time	Topic	Speaker
8:00 – 8:30 am	Registration and Networking - Coffee, muffins	
Introduction		
8:30 – 8:45 am	Introductions, Overview	Ian Gardner, UPEI, Moderator; Jeremy Dunn, Executive Director, BCSFA
Understanding the Marine Environment		
8:45 – 9:10 am	Studying micro-plastics in the marine environment.	Sarah Dudas, VIU

Time	Topic	Speaker
9:10 – 9:35 am	The Salmon Farm Reef and Building Collaborative R&D on the Coast	Steve Cross, NIC
9:35 – 10:00 am	Ocean Deoxygenation: Trends, Variability and Causes	Roberta Hamme, UVic
10:00 – 10:15 am	Break (Shaw Lobby)	
Wild Interactions		
10:15 – 10:40 am	Juvenile Salmon Acoustic Monitoring in the Discovery Islands, British Columbia –2015-2017	Shani Rousseau, DFO
10:40 – 11:05 am	Migration Routes, Residence Time and Survival of Juvenile Salmon in the Strait of Georgia and Discovery Islands Region: 2015-2017	Erin Rechisky, Kintama Research
11:05 – 11:30 am	Seals & Sea Lion and Marine User Interactions on the BC Coast.	Andrew Trites, UBC
Fisheries and Oceans Pacific Region Research Strategy		
11:30 – 12:00 pm	Research Strategy on Aquaculture Research in the Pacific: Progress-To-Date and Future Plans	Jay Parsons, DFO
12:00 – 1:00 pm	Lunch (Nanaimo River Room A/B)	
Fish Health		
1:00 – 1:25 pm	PRv Fitness Challenges and International Collaborative Studies	Mark Polinski, DFO
1:25 – 1:50 pm	Isolation of Aeromonas salmonicida and Piscirikettsia salmonis from farmed and wild salmonids in BC to support diagnostic test evaluation and epidemiological studies	Ahmed Siah, BC CAHS
1:50 – 2:15 pm	Marine reservoirs of infectious agents associated with proliferative gill disorders in farmed salmon.	Simon Jones, DFO
2:15 – 2:30 pm	Break (Shaw Lobby)	
2:30 – 2:55 pm	Does the fish gut microbiome signature reflect fish health?	Julie LaRoche, Dalhousie University
Production Management Investigations		
2:55 – 3:20 pm	Pile Perch as a Cleaner Fish Research Initiatives	Sam Ferguson, BC CAHS
3:20 – 3:55 pm	Research on Atlantic salmon and Coho in RAS facilities	Christian Damsgaard, UBC

Time	Topic	Speaker
Closing Discussion and Next Steps		
3:55 - 4:15 pm	Wrap up and Next Steps	Ian Gardner, Moderator

Speaker Biographies

Dr. Ian Gardner, University of Prince Edward Island

Dr. Ian Gardner is the Canada Excellence Research Chair (CERC) in Aquatic Epidemiology at the University of Prince Edward Island (UPEI). The CERC aquatic epidemiology research program has a strong ecosystem health focus. Prior to moving to Canada, Dr. Gardner was a Professor of Epidemiology at the University of California, Davis for 23 years. Dr. Gardner obtained his veterinary degree at the University of Sydney in 1975 and completed post-graduate training (Master of Preventive Veterinary Medicine and PhD) at the University of California, Davis in 1988. His research interests include validation of diagnostic tests for aquatic infectious diseases in the absence of perfect reference tests, and host-pathogen-environmental risk factors for fish diseases.

Dr. Richard Beamish, Emeritus Scientist Fisheries and Oceans Canada

Dr. Beamish C.M., O.B.C, Ph.D., D.Sc., F.R.S.C. is an Emeritus Scientist at the Pacific Biological Station in Nanaimo, B.C. He finished his Ph.D. at the University of Toronto in 1970 and went directly to Woods Hole Oceanographic Institute for a Post Doctoral Fellowship. He was the Head of the Groundfish Section at the Pacific Biological Station from 1977-1979 and Director from 1980-1993.

His research interests have included the discovery of acid rain in North America, new methods of ageing fish that included the discovery that many species of fish were much older than previously thought. He has published over 350 articles with about half in peer-reviewed journals. Dr. Beamish has been honoured with a number of awards including the Order of Canada and the Order of British Columbia. He was made a Fellow of the Royal Society of Canada and became the first foreign scientist to be made an honorary member of the fisheries centre, TINRO in Vladivostok, Russia. Recently, he received the first award given by the North Pacific Anadromous Fish Commission for significant contributions in scientific research, on Pacific salmon, and the Wooster award given by PICES for career achievements in fisheries and ocean science.

Dr. Crawford Revie, University of Prince Edward Island

Dr. Revie holds a Canada Research Chair in Epi-Informatics, which can be defined as "the use of techniques from informatics – such as data mining and data-driven modeling – to better understand disease at a population level". His research explores novel methods to extract and organize knowledge that exists in large/complex epidemiological data sets. A focus over the past decade has been the application of data-driven models to better understand host-parasite population dynamics in aquatic settings – particularly sea lice on salmon farms, in all of the major Atlantic salmon producing regions.

Dr. Sarah Dudas, Fisheries and Oceans Canada

Dr. Dudas is a Biologist at Fisheries and Oceans Canada, a Biology Professor at Vancouver Island University and an adjunct Professor at the University of Victoria. For the last seven years, she has led the 'Ecological Interactions Research Program' working with federal and provincial governments, industry and non-profit organizations to study the effects of human activities on coastal ecosystems. Her research has included examining marine biodiversity across regional and local scales and investigating the effects of historical and contemporary shellfish farming practices on the surrounding ecological community. Recently, her work has focused on the issue of microplastics and their presence in the marine environment and our seafood. She is a member of the United Nations led 'Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection' microplastics working group.

Dr. Stephen Cross, North Island College

Dr. Stephen Cross received his M.Sc. at the University of Victoria (Canada) in marine quantitative ecology/ oceanography and his Ph.D. at the Aquaculture Institute, University of Stirling (Scotland). He is currently the NSERC Industrial Research Chair for Sustainable Aquaculture at North Island College's Centre for Applied Research, Technology and Innovation, an Associate Professor at the University of Victoria, and an Adjunct in VIU's Department of Fisheries and Aquaculture. His current research program focuses on various aspects of environmental sustainability/ management of coastal aquaculture, with his real passion linked to the design, engineering and commercial-scale testing of Sustainable Ecological Aquaculture (SEA) systems.

Dr. Roberta Hamme, University of Victoria

Dr. Hamme is a chemical oceanographer who uses observations of dissolved gases to study the marine oxygen and carbon cycles. Her lab makes high precision measurements of both bioactive gases like oxygen and inert gases like neon, argon, and krypton. Her research group also uses robotic profiling floats to survey ocean oxygen concentrations. Ongoing projects include measuring ocean productivity rates and quantifying absorption of gases just before waters move from the surface into the interior ocean. Dr. Hamme also led a high profile study showing that the 2008 eruption of Kasatochi volcano led to a widespread bloom of phytoplankton in the subarctic NE Pacific. She holds a Canada Research Chair in Ocean Carbon Dynamics at University of Victoria's School of Earth and Ocean Sciences.

Ms. Shani Rousseau, Fisheries and Oceans Canada

Shani Rousseau works as an acoustics biologist as part of the fisheries acoustics group at Fisheries and Oceans Canada in Sidney. She holds a M.Sc. in physical oceanography from the University of Victoria and has more than 10 years of experience using acoustic technology to detect and study marine organisms, from marine mammals to zooplankton. At DFO, she currently focuses on the use of fixed, inverted echo-sounders to study Pacific juvenile salmon, and the development of automation methods for long term acoustic monitoring.

Dr. Erin Rechisky, Kintama Research Services

Dr. Erin Rechisky is the Research Manager at Kintama Research Services in Nanaimo, where they are working to develop cost-effective, large-scale telemetry array designs to address critical fishery issues, specifically regarding salmon survival in the ocean. She has 19 years of experience conducting telemetry studies. The first marine animal she ever tracked was a North Atlantic right whale in the Bay of Fundy, but since then her focal species have gotten noticeably smaller...from sharks...to reef fish....and now salmon smolts.

Dr. Andrew Trites, University of British Columbia

Dr. Trites is a Professor and Director of the Marine Mammal Research Unit in the Fisheries Centre at UBC. He is also the Research Director for the North Pacific Universities Marine Mammal Research Consortium, which is based at the Fisheries Centre. His main area of research is the interaction between marine mammals and commercial fisheries. This includes the population biology and bioenergetics and seals,

sea lions and whales, and involves a combination of field, captive and computer studies (data analysis and simulation modeling).

Dr. Jay Parsons, Fisheries and Oceans Canada

Dr. Jay Parsons has been involved in the aquaculture sector for over 30 years and has extensive experience in aquaculture research and management. Since 2003, Dr. Parsons has been with the Aquaculture, Biotechnology and Aquatic Animal Health Science Branch of Fisheries and Oceans Canada (Ottawa) where he is the National Director responsible for Aquaculture, Biotechnology & Genomics, and Aquatic Animal Health R&D programs and research coordination. From 1995-2003 he was a researcher at Memorial University (St. John's, Newfoundland, Canada) where he taught graduate courses in shellfish aquaculture and directed several graduate students involved in projects on culture, feeding and reproduction in shellfish. He is past President of the World Aquaculture Society (WAS), National Shellfisheries Association (NSA) and twice past President of the Aquaculture Association of Canada (AAC).

Dr. Mark Polinski, Fisheries and Oceans Canada

Dr. Polinski is a Research Scientist at the Fisheries and Oceans Canada Biological Research Station in Nanaimo and adjunct faculty in the Department of Biology at Vancouver Island University. His research focuses on elucidating host-pathogen interactions and the interplay of molecular responses that underlie disease and susceptibility within a context of aquatic animal health. His work also focuses on developing and refining molecular diagnostic tests for new aquatic pathogens.

Dr. Ahmed Siah, BC Centre for Aquatic Health Sciences

Dr. Siah is involved with numerous research projects developing new technologies in the field of aquatic health diagnostics and implementing and validating molecular biology technologies for diagnostics. Dr. Siah pursued his Postdoctoral studies in Molecular Ecotoxicology at the University of Le Havre in France after earning his PhD in Oceanography at the Institute of Marine Sciences in Rimouski, Quebec. As a Research Associate at PEI's Atlantic Veterinary College, he led and managed several projects on mollusk health management and the development of molecular diagnostic tools. He has extensive experience in developing and implementing diagnostic methods for emerging pathogens of interest.

Dr. Simon Jones, Fisheries and Oceans Canada

Dr. Jones has a Ph.D. in parasitology from the University of Guelph with post-doctoral training in fish immunology at Wageningen University. For several years, he was a researcher in the aquaculture vaccine industry. Since 2000, Dr. Jones has led the Marine Parasitology Program at the Pacific Biological Station in Nanaimo. Research in this program focuses on the structural and genomic characterization of parasites, defense responses of fish during parasite infections, and the development and application of treatment and immunisation strategies mainly in salmonids. The Marine Parasitology Program is highly collaborative with industry and academic partners in Canada and overseas. Under Jones' leadership, the program has delivered advice in the form of over 235 peer-reviewed scientific publications, reports and book chapters, and presentations at national and international conferences and workshops.

Dr. Julie LaRoche, Dalhousie University

Dr. LaRoche is a professor in the department of Biology at Dalhousie University. Her research has contributed significantly to promoting the application of molecular biological techniques to study marine biogeochemistry. She currently holds a Canadian Research Chair (tier 1) position with a focus in assessing the impact of microbial communities on marine biogeochemistry, for now and in the future. Her expertise lies in phytoplankton, marine microbes, microbial genomics, biogeochemistry, nutrient cycling and biodiversity. She is a member of the NSERC Banting postdoctoral review committee, and has published 107 papers, which have been cited over 16,000 times.

Mr. Sam Ferguson, BC Centre for Aquatic Health Sciences

Sam graduated from the University of Victoria in 2011 with a BSc in biology and then again subsequently in 2015 with an MSc in biology, specializing in marine invertebrate zoology and evolutionary developmental biology. As a research assistant and graduate student at the University of Victoria, he studied the larval development and evolution of a group of tropical marine snails. Sam joined the BC CAHS team as a research assistant on the sea lice cleaner fish project in January 2017. This research is being carried out at the Centre for Aquaculture and Environmental Research in West Vancouver where he has worked previously as a fish culturist for the Department of Fisheries and Oceans Canada.

Dr. Christian Damsgaard, University of British Columbia

Christian Damsgaard received his PhD in fish physiology from Aarhus University Denmark in 2016 and is currently a post-doctoral fellow at the University of British Columbia (UBC). In his research he uses genetic, molecular and whole organism techniques to investigate how aquatic organisms cope with environmental change with a strong focus on implementing these results in aquaculture practices. During his PhD, he worked on assessing the effects of high temperature and high CO2 levels on catfish production in tropical aquaculture in order to predict future sustainability of this industry. From 2017, he has worked with the InSEAS group at UBC that aims to determine the optimal rearing conditions for salmon in recirculation aquaculture systems, where he is particularly focused on how salinity and hypoxia affects growth and animal performance.

Presentation Summaries

Wednesday, February 28

Presentation 1. Canada's Research Collaboration Potential, Dr. Ian Gardner, University of Prince Edward Island

Dr. Gardner moderated the workshop. He opened the evening session by giving an overview of the collaborations his Canada Excellence Research Chair position in Aquatic Epidemiology at UPEI has prioritized. For more information, visit the group's website here http://projects.upei.ca/cerc/

Research priorities have included:

1) sea lice modelling
2) strengthening salmon health management
3) evidence synthesis and systematic reviews.

The group consists of 9 post-docs and 2 PhD students, and the current program ends in March 2019.

Collaborations in salmon and ecosystem health have included the Strategic Salmon Health Initiative (partnership with Genome BC and the Pacific Salmon Foundation, and

DFO), partnerships with other universities, industry, governments, both federal and provincial, and international collaborations including Chile, Norway and Scotland.

Some examples of programs have included epidemiological field investigations, tank-based challenge studies, collaborations with physical oceanographers in disease modelling, and collaborations on metagenomics. The group has published on many areas pertinent to the health of salmon in BC, including several on sea lice modelling.

Dr. Gardner also provided an overview of the Ocean Frontier Institute program, through Dalhousie University. The Institute integrates ocean science, engineering, data science, ocean governance and social science to aid in safe and sustainable development of ocean resources, including aquaculture. The initial focus of the Institute has been on projects to assess changes in atmosphere ocean interactions, develop sustainable aquaculture, marine safety, assess shifting ecosystems, ocean data analytics and sustainable fisheries. This work is being housed under two overarching umbrella programs of Atmosphere-Ocean Interactions, and Shifting Ecosystems.

Presentation 2. 2018 International Salmon Research Expedition, Dr. Richard Beamish, Emeritus Scientist, Fisheries and Oceans Canada

Dr. Beamish provided an overview of historical salmon stock trends, supporting the idea that understanding overall salmon production is an international problem.
He overviewed trends of several long time series, some as far back as 1925 - including the North Pacific commercial catch of chum salmon by country, and in Alaska specifically, populations of hatchery versus wild chum populations, trends for Coho marine survival in the Strait of Georgia and Puget Sound, the commercial catch of Chinook salmon in the Pacific subarctic, escapement data of the Taku River in Northern BC, North Pacific pink salmon catches, Fraser River sockeye productivity and halibut biomass. In every case, there were notable increases at some point in the time series and in most cases, declines over time – in many cases noted from the mid-1990s onward. The one difference in this trend has been seen in pink salmon catches, which have generally increased with time, in both even and odd year populations (with odd year catches being larger in all cases). (Wechter et al, 2017, found that even-year stock allocates more energy to storage, as opposed to growth, than does the odd-year stock).

Dr. Beamish summarized that production trends occur in different ecosystems and over large areas indicating that there is a common mechanism causing the trends. Identifying the mechanism will improve forecasting and stewardship and can best be accomplished by treating the issue as an international problem. The ability to reliably forecast return abundance does not currently exist.

To provide some insight into what is happening in terms of ocean conditions and their relation to salmon productivity trends, Dr. Beamish discussed the increasing temperature trends of the North Pacific and how this may relate to population changes. Dr. Beamish is part of a larger, long term research and monitoring program planned by the North Pacific Anadromous Fish Commission, in 2019 – the International Year of the Salmon, and has helped to organize a research expedition to the Gulf of Alaska in 2019, to further investigate the relationship between salmon production in the North Pacific, and the changing environment.

Presentation 3. Spatial and temporal patterns of sea lice infestations on wild and farm-raised salmon on the British Columbia Coast, Dr. Crawford Revie, University of Prince Edward Island

Dr. Revie summarized some of the work that he and Dr. Patanasatienkul have been engaged in over the past 18 months. This began with the Wild Salmon Sea Lice Integration Project (WSSLIP) in 2016 which aggregated data from around 70 different sources and has led to the largest collection of sea lice records relating to wild salmon collected to date anywhere in the world. By the end of 2017, data had been collected from almost 1 million wild Pacific salmon at over 300 sampling locations along the BC coast over the previous 16 years. From these, almost 250,000 fish captured at around 12,000 separate events had been assessed for sea lice infestation. This research was followed by a project funded through the BCSFA's Marine Environmental Research Program (MERP): "Spatial and temporal patterns of sea lice infestation (wild/farmed)", which will be completed in the next few months. The initial work focused on collecting comparative data from BC salmon farms over a similar period. In addition to sea lice levels on around 220,000 farmed fish from over 100 sites, data on around 550 cycles of Atlantic salmon production and 675 treatment events have been integrated into the data set.

Work is now underway to complete a peer-reviewed manuscript which will summarize this work and analyses trends and associations within these data. Dr. Revie illustrated ways in which patterns could be established, associations explored and, where appropriate, models developed. In particular, he indicated that some of the key risk levels that had been published over the past decade would be applied to this novel data set to explore where challenges had arisen and how models could be used to make predictions as to whether and where likely risk might occur in the future.

Thursday, March 1

Presentation 1. Studying microplastics in the marine environment, Dr. Sarah Dudas, Fisheries and Oceans Canada

Dr. Dudas presented her research on mircoplastics in the marine environment. Plastic is the most prevalent type of debris found in the ocean and plastics that are less than 5 mm are called microplastics (GESAMP Report 90). Microplastics come from a variety of sources including microbeads, very tiny pieces of manufactured polyethylene plastics that are added as exfoliants to health and beauty products. Additionally, microplastics come from larger plastic debris that degrades into smaller pieces. Macro-sized plastic debris accounts for the larger portion of plastic in the ocean by mass (kg km2), but micro-debris accounts for the larger proportion of plastic by number (items km2).

Microplastic is an emerging field of study and studies show that microplastics are ingested by zooplankton, mollusc, crustaceans, finfish sea birds and marine mammals etc. The ingestion of microplastics can cause abrasions, blockages and inflammation and lead to reduced fecundity and survival rates for species. Further, there is potential for microplastics to serve as vectors for the bioaccumulation of chemical pollutants. Further, microplastics provide habitat for pathogens and disease such as Vibrio which is a pathogen of concern for the aquaculture industry.

Dr. Dudas spoke about the potential food safety and security issues for the fisheries and aquaculture industries due to microplastics in the marine environment. And, she shared

her results from her research examining BC wild and farmed clams and oysters in the Baynes Sound area for microplastic concentrations. The results show 77 % of oysters have microplastics and fibres are the dominant microplastic type. As well, microplastic concentrations do not differ between wild and cultured clams or oysters or cultured type. Lastly, microplastic concentrations in shellfish are unrelated to proximity to aquaculture.

Presentation 2. The Salmon Farm Reef and Building Collaborative R&D on the coast, Dr. Steve Cross, North Island College

Dr. Cross discussed his MERP project "The Structure and Function of the Salmon Farm Reef". Four farm sites were chosen to conduct the research located on the west coast, the Broughton Archipelago and Okisollo Channel. The farms were selected based on differing oceanographic conditions, assuming these conditions would support different biological reef communities. Artificial substrates were placed at each farm site to get estimates of species diversity, dominance and biomass. The results of the project to date show a very clear difference in the reef community depending upon oceanographic conditions (water quality and flow) and the exposure of each farms physical structures to the environment (orientation to flow, sunlight, etc.). The final steps of the project include the completion of the taxonomic work, data analysis of the community structure and to assess functional characteristics of the "reef" in terms of farm interactions and management implications.

Dr. Cross also talked about the potential for developing a seaweed aquaculture sector in BC. Globally, the seaweed production values $10 billion. Seaweeds provide a food source and are used as alginates, bioethanol, emulsifiers, fertilizers, bioplastics and in cosmetics etc. In BC, there are 633 species of seaweeds, 20,000 km of coastline and a growing multi-cultural society with diverse appetites. Between 2013 to 2018, through an NSERC-Funded initiative, Dr. Cross conducted a study looking at integrating kelp with finfish production. Thirty salmon farms were chosen for the performance study. Preliminary results show that some farms can grow approximately 200 MT of kelp per year and more depending on the growing conditions at the site.

Presentation 3. Ocean deoxygenation: Trends, variability and causes, Dr. Roberta Hamme, University of Victoria

Dr. Hamme provided an overview of ocean deoxygenation in terms of trends, variability and causes. The North Pacific has unusually low oxygen concentrations. Long time series show decreasing concentrations of oxygen in the North Pacific since the 1950s. Dr. Hamme also overviewed trends indicating that deoxygenation is a global phenomenon. The amount of oxygen in water masses depends on how much organic matter there is to respire, how fast the water travels, and the starting oxygen content of the water. Water recharges with oxygen in the West Pacific, and then takes about a decade to cross the ocean. Numerical computer simulations of deoxygenation indicate that slower water circulations and lower initial oxygen concentrations are at the center of the deoxygenation phenomenon. As a result of declining open ocean oxygen and local wind directions, low oxygen waters creep up on to the Vancouver Island shelf, especially in summer months. These then enter interior waters at the base of the straits of Juan de Fuca and Georgia.

Dr. Hamme also discussed that existing coastal oxygen records are highly variable, and investigations through the Marine Environmental Observation Prediction and Response Network (MEOPAR), hope to answer questions on why this is. OxyNet, a collaborative effort between several organizations, and funded through MEOPAR seeks to:
1) Synthesize existing data to better quantify changes
2) Implement methods to calibrate oxygen sensors
3) Interpret patterns of variability in new and existing data
4) Improve simulations of present deoxygenation (causes) and make future predictions
5) Conduct an economic analysis of impacts of changing hypoxia on wild and aquaculture fish populations.

This work will utilize robotic floats and gliders observing the ocean. Significant data has been collected to date using Argo floats, globally, and these will help to estimate the de-oxygenation occurring as water approaches the shelves.

Dr. Hamme also overviewed a study on the east coast of Canada relating Atlantic monkfish habitat to oxygen levels.

In summary, the North Pacific is a region of naturally low oxygen, and dissolved oxygen levels are declining globally. This trend is likely caused by circulation slowdown and declining surface oxygen concentrations. Observations have shown extreme variability, especially near the coast. OxyNet seeks to better quantify trends and understand patterns of variability. It also seeks to make better projections of future oxygen decreases, and relate changing oxygen levels to impacts on fish habitat.

Presentation 4. Juvenile salmon acoustic monitoring in the Discovery Islands, British Columbia – 2015-2017, Shani Rousseau, Fisheries and Oceans Canada

Shani Rousseau described her work, in collaboration with, Stéphane Gauthier, Stewart Johnson, Chrys Neville and Marc Trudel on the use of inverted echo-sounders to monitor Pacific juvenile salmon. Several autonomous, multi-frequency echo-sounders (AZFP) were deployed in the Discovery Islands and in Johnstone Strait, British Columbia, from May to September of 2015, 2016 and 2017 to study the abundance, distribution and migration timing of Pacific juvenile salmon. Juvenile salmon migration timing observed acoustically was in good agreement with data obtained from net samples. The migration period was longer and more variable in 2015 and in 2017, when chum and sockeye dominated the juvenile salmon population, in comparison to 2016, a year dominated by sockeye. That year, the migration period was short (mid-May to mid-June), and the abundance was consistently high throughout. Vertical distribution showed that juvenile salmon were mainly found in the upper 20 m of the water column during day time, and that at night they spread into a thin and dense layer at the surface. An empirical logarithmic relationship between juvenile salmon length and $\Delta MVBS_{67\text{-}125kHz}$, the difference in acoustic signal of the fish aggregations at 67 and 125 kHz, was derived from acoustic and fish net data, allowing for an acoustic estimation of mean juvenile salmon length.

This study shows that inverted echo-sounders offer a cost-effective, non-intrusive option for long-term monitoring of juvenile salmon populations in the area, and provide high temporal and vertical resolution of the juvenile salmon aggregations.

Presentation 5. Migration routes, residence time and survival of juvenile salmon in the Strait of Georgia and the Discovery Islands region, Dr. Erin Rechisky, Kintama Research Services

Since 2015, Kintama has been using a large-scale acoustic telemetry array to track salmon smolts during their freshwater and early marine migration. Fish have been tracked with a network of acoustic sensors positioned in the Fraser River basin and throughout the greater Salish Sea area. By reconstructing the movements of each individual recorded by the array, it has been possible to estimate survival through the Strait of Georgia (SOG) and as far as the north-east end of Vancouver Island. Changes in array locations and detection frequencies prevented comparisons of survival in identical regions over all years, but they had made comparisons where possible. Residence time, travel rate, and route selection in these areas were also determined. In 2017, Kintama deployed additional receivers near salmon farms in the Discovery Islands to evaluate fish exposure time to salmon farms.

During the study, three major mortality trends were observed: high mortality in the small freshwater tributaries leading to the Fraser, low mortality in the Fraser River mainstem, and higher mortality in the northern marine area relative to the SOG. Travel times through the Strait of Georgia were generally longer for age-1 Chilko Lake sockeye which is partly due to smaller body size.

In 2017, receivers were deployed in Hoskyn and Okisollo channels and at two fallowed salmon farms (on the east and north side of Quadra Island), to monitor juvenile sockeye exposure time to salmon farms. In addition to Chilko Lake Sockeye tagged and released at Chilko Lake, juvenile Sockeye were captured in Okisollo Channel, tagged with acoustic transmitters, and released in the northern SOG. Both groups were included in the exposure time study. Sockeye migrated rapidly through Hoskyn and Okisollo Channels therefore exposure time to salmon farms was short. Median exposure at both salmon farms was short, approximately 4.5 minutes.

Presentation 6. Marine User Interactions with seals and sea lions on the BC coast, Dr. Andrew Trites, University of British Columbia

Interactions between marine mammals and marine users have been increasing since seal, sea lions and whales were protected in the early 1970s. As marine mammal

numbers have increased, so too have incidences of ship strikes, loss of fish, and damage to gear. Most of the negative interactions reported occur between fisheries and seals and sea lions, although humpback and grey whales are easily entangled in slack lines such as those attached to crab pots. There are increasing reports outside of BC of whales taking commercially caught fish, such as killer whales taking halibut from fishing lines in Alaska, and sperm whales removing hooked sablefish. In British Columbia, recreational fishermen commonly report harbour seals damaging or removing salmon throughout BC coastal waters, while depredation events from Steller sea lions tend to be more prevalent in outer coastal areas near major sea lion haulouts. Harbour seal numbers have been stable since 2000, and are likely controlled by transient killer whales. In contrast, Steller and California sea lions are continuing to increase and are having increasingly frequent interactions with fish farmers and commercial fishermen.

The key to deterring seals and sea lions from taking fish, both caught in the commercial fishery and farm-raised, is to ensure this undesired behaviour is not positively reinforced. Predator nets and electrified wire have helped to reduce the numbers of fish that seals and sea lions take from fish farms, but they are only part of the solution. Negative interactions with marine mammals is of concern to all fisheries in BC, and will require a concerted effort by all sectors working together to find amenable solutions that meet public approval.

Presentation 7. Research strategies on aquaculture research in the Pacific: Progress to date and future plans, Dr. Jay Parsons, Fisheries and Oceans Canada

Dr. Parsons provided the audience with an overview of the national aquaculture science programs at Fisheries and Oceans Canada. There are three distinct programs delivered nationally which are interconnected and interrelated, however, they have different mandates and clients etc. and are managed separately. The three programs include:

- Program for Aquaculture Regulatory Research (PARR)
    - This program supports research that advances an understanding of interactions between aquaculture and the aquatic environment and seeks to answer regulatory or policy questions received by the client.
    - It is a DFO internal research funding program. Results from the research are peer reviewed (e.g. Canadian Science Advisory Secretariat (CSAS)).

- Priority research was conducted in areas of fish pest and pathogen management, interactions with wild salmon populations, release of organic matter and cumulative effects and ecosystem management. Some current funded research in the Pacific region related to marine salmonids includes:
    - Investigation of piscine reovirus (PRV) in the development of disease
    - Epidemiological analysis and modeling of aquatic pathogens.

- Aquaculture Collaborative Research and Development Program (ACRDP)
    - DFO research funding program with priorities driven by industry and aligned with DFO mandate.
    - Research is led by DFO Science in DFO labs.
    - Research questions addressed are related to optimal fish health, environmental performance and fresh water and sustainability. Some current funded research in the Pacific region related to salmonids includes:
        - Marine reservoirs of infectious agents associated with proliferative gill disorders in farmed salmon.
        - Acoustic monitoring of wild fish interactions with aquaculture sites.

- Aquaculture Ecosystems Interactions Research
    - This program provides funding that advances an understanding of longer-term ecosystem level interactions of aquaculture.
    - It is a DFO internal research funding program. Results from the research are peer reviewed (e.g. Canadian Science Advisory Secretariat (CSAS)), and formal science advice is used to support management decisions.

Presentation 8. PRv fitness challenges and international collaborative studies, Dr. Mark Polinksi, Fisheries and Oceans Canada

Dr. Polinski overviewed on-going studies on Piscine reovirus (PRV) led by Fisheries and Oceans Canada, in partnership with the University of British Columbia. In 2017, a Norwegian research group published evidence that PRV is the cause of Heart and

Skeletal Muscle Inflammation (HSMI) in Atlantic salmon, in Norway (Wessel et al 2017). In Norway, on a farm experiencing HSMI, most fish in an affected sea cage show histopathological lesions, and mortality varies, from almost insignificant up to 20% (Kongtorp et al 2004) . It is also one of the most common diseases in farmed Atlantic salmon in Norway, and in 2010, was diagnosed at more than 90% of farms, at least once (Løvoll et al 2012).

By contrast, in BC, PRV has been known to be in the marine environment for some time, and one publication presented evidence of a diagnosis of HSMI through a longitudinal farm study, in 2017 (DiCicco et al 2017). However, unlike in Norway, laboratory studies have been unable to demonstrate a causal relationship between the BC PRV genotype and HSMI in Atlantic salmon and sockeye infected with PRV (Garver et al 2016).

DFO has been leading a collaborative study on testing whether there is harm to the respiratory physiology and capacity of juvenile Atlantic salmon and sockeye smolts infected with PRV. Dr. Polinski presented an overview of the challenge design, and initial results. Publication of these results is underway.

Additionally, Dr. Polinski discussed new studies underway to assess the mechanism for pathogenesis of PRV genotypes from Norway and BC. These studies are undertaking a side-by-side comparison of BC-PRV and Norway PRV challenges in the same environment and fish so that differences are directly comparable.

Presentation 9. Isolation of Aeromonas salmonicida and Piscirikettsia salmonis from farmed and wild salmonids in BC to support diagnostic test evaluation and epidemiological studies, Dr. Ahmed Siah, BC Centre for Aquatic Health Sciences

This project aimed at characterizing Aeromonas sp and Piscirickettsia salmonis infecting farmed and wild salmonids in British Columbia waters. More than 80 samples collected from 17 farmed sites of both coasts in Vancouver Island were tested for P. salmonis. Samples were tested by cell culture and more than 17 isolates were stored in glycerol and -80C. Different non cell culture media: Cystein Heart Agar Blood (CHAB) (Mikalsen et al., 2007), Blood Agar with 2% salt (BAS), SRS-BA SRS blood agar (Otterlei et al. 2016) and Hemoglobin Blood Agar (HB-Agar) were tested on some isolated bacteria. Results showed that isolates were mainly growing on BAS and HB-Agar. PCR targeting ITS (Internal Transcribed Spacer) marker was performed on the isolated bacteria. Amplicons

were sequenced and phylogenetic analysis showed that BC isolates are related to LF89 Chilean strains.

More than 47 Aeromonas sp were isolated from both fresh and saltwater sites. Isolates were re-streaked on TSA media and stored in glycerol and -80C. PCR targeting gyrase b marker was performed on the isolated bacteria. Phylogenetic analysis showed that the majority of the isolates were Aeromonas salmonicida although some isolates were clustered with A. bestarium, A. sobria and A. allosaccharophila. Antibiotic resistant analysis was also performed and some isolates presented some resistance to antibiotic compounds such as oxytetracyclin.

Future studies will be focusing on sequencing the full genome of some selected P. salmonis and Aeromonas species. Sequences will allow to identify virulent factors and antibiotic resistance genes. The sequence information will also assist in developing specific diagnostic tools to screen Aeromonas species and P. salmonis in farmed and wild salmonids.

Presentation 10. Marine reservoirs of infectious agents associated with proliferative disorders in farmed salmon, Dr. Simon Jones, Pacific Biological Station

Proliferative gill diseases (PGD) among marine-reared farmed Atlantic salmon are a globally-emergent and important cause of losses. The causes of PGI appear to be multifactorial and include both environmental and infectious factors. The incidence and significance of PGD in BC is poorly documented and there is a need for improved understanding of gill-associated pathologies in farmed and wild salmonids. This presentation summarised a 2-year research project in which gills from wild and farmed salmon were examined for morphological evidence of PGD. In addition, the gills were examined for evidence of infection with agents that have been associated with PGD elsewhere. In gills from farmed salmon, histopathology revealed epithelial hyperplasia and lamellar fusion in up to 90% of samples. There was no histological evidence of amoebic gill disease (AGD) however the prevalence of the flagellated protozoan parasite *Ichthyobodo salmonis* ranged as high as 93%. Molecular tests of farmed gills revealed the presence of *Ichthyobodo* and a microsporidian parasite *Desmozoon lepeophtherii* both at relatively high prevalence levels. *Paramoeba perurans*, the cause of AGD was not detected. The severity of *D. lepeophtherii* markedly increased in populations of farmed salmon experiencing clinical disease associated with recent exposures to

adverse environmental conditions such as a harmful algal bloom. In contrast, histological lesions were observed in a very small proportion of gills from juvenile wild salmon. In the wild salmon, *P. perurans* was detected in only 1 of nearly 200 juvenile chum salmon, whereas *I. salmonis* and *D. lepeophtherii* were present in up to 50% of juvenile chum and pink salmon tested. The available information indicate that gill-related lesions and/or infections occur in wild and farmed salmon in BC with greater frequency than previously known and with spatial and temporal patterns suggesting complex interactions with one or more environmental variables.

Presentation 11. Does the fish gut microbiome signature reflect fish health?, Dr. Julie LaRoche, Dalhousie University

Dr. LaRoche provided an overview of the linkages between fish gut biome and overall fish health. The North Pacific Ocean waters are particularly productive, as indicated by chlorophyll concentrations. The ocean microbiome is vast – from an ecological and evolutionary point of view, the Earth is a microbial planet. The microbiome is integrated with every biological process and organism on the planet. For example, the human microbiome is at least 10 times larger than the number of human cells in our bodies. An active research program called the human microbiome project has identified many aspects of human health that are greatly influenced by our microbiome. This includes immunity, food absorption, and moods. For the most part, gut bacteria play a positive role and also provide us with the ability to degrade foods that we otherwise would not be able to digest. And this depends greatly on where you live and what you eat. For example, Japanese people have acquired genes from marine bacteria that live on seaweed through lateral gene transfer, a way by which bacteria can exchange their genetic material. These new genes can degrade seaweed important in their diets and provide a more complete assimilation of nutrients.

It can be assumed that fish and shellfish are similar to humans and other organisms in that they are colonized by microbes, that form their microbiomes. More importantly for marine or aquatic species, these animals are drinking the water that they inhabit, and are assimilating the bacteria that are prevalent in the environment. Diet and environment will affect microbiome composition. In times of global warming, ocean acidification and increased eutrophication, it is important to know the composition of healthy microbiome of fish and shellfish, and know their metabolic potential, i.e. what

type of enzymes they have that are beneficial to the nutrition and survival of fish. Direct transfer of the techniques and analyses used for the human genome project are possible investigatory tools – high throughput sequencing and bioinformatics analyses of the bacterial genome without the need to isolate and cultivate the microbes.

Dr. LaRoche discussed collaborative research with Cermaq Canada to investigate the salmon microbiome on one salmon farm to test the effects of probiotic use in feeds on the overall health of the fish, and determine the salmon "healthy core microbiome". Investigations are also underway to look at the microbiome of cultivated oysters in BC in the context of ocean acidification.

Future work and recommendations include defining the salmon gut core microbiome including the need to combine results from as many farms and wild salmon populations as possible – to ideally build an international database, and then standardize the data being collected.

Presentation 12. Pile perch as a cleaner fish research Initiative, Sam Ferguson, BC Centre for Aquatic Health Sciences

Mr. Ferguson discussed the potential for local perch species as cleaner fish for the BC salmon farming industry. Over the past couple of years, trials were conducted using both Pile perch (Rhacochilus vacca) and Kelp perch (Brachyistius frenatus). Moving forward, the trial will focus on Pile perch as the most appropriate cleaner fish for BC. Pile perch have a longer life span than Kelp perch and live ~ 10 years, are larger which is important for net pen mesh size, and have a higher fecundity rate. Wild perch were collected for broodstock trials, and a broodstock program is in the planning stages. Also, the team is developing a fish health management plan for wild perch.

Several different cleaning trials were conducted for comparison including species trials - Pile vs Kelp perch, perch size – smaller vs larger fish for cleaning, different stocking densities, sea water temperatures – 12 vs 9 degrees Celsius and perch fed vs perch starved. Preliminary results for stocking ratios show a 5 percent perch to salmon ratio at 84.9 percent cleaning efficiency and a 10 percent perch to salmon ratio at a 94.9 percent cleaning efficiency. Feeding perch does not impact cleaning activity. Perch infection trials were conducted with sea lice showing some short-term attachment initially with repeated trials showing no attachment. Ongoing work includes research

assessing perch breeding and fecundity, perch health and disease, perch nutrition and deployment trial in larger tanks.

Presentation 13. Research on Atlantic salmon and Coho in RAS facilities, Dr. Christian Damsgaarrd, University of British Columbia

Dr. Damsgaard discussed Recirculating Aquaculture Systems (RAS) and growing Atlantic salmon. The costs of the systems for both startup and operational are substantial which leads to small profit margins. Profitability of RAS depends on maximizing growth and increasing the feed conversion efficiency ratio. The system does allow growers to optimize environmental conditions for growing salmon which should increase the profitability of the business. Optimal conditions for growing salmon (e.g. temperature, salinity and photoperiod etc.) are still under investigation.

Dr. Damsgaard talked about his RAS research with the InSeas RAS Research Facility to determine the optimal salinity and photoperiod for growth and performance on Atlantic and Coho salmon reared in RAS from smolt to adult. During the 400-day study, the salmon were measured for growth, effects on early maturation and fitness in response to salinity and photoperiod. The results for the trials are as follows:

<u>Coho salmon</u>

- 10 PPT improved growth in Coho salmon and reduced metabolic rate until day 150.
- No effect of photoperiod on growth.
- Early maturation was observed at low level in 24 hours of light but not 12 hours of light.
- Hypoxia tolerance was greater at intermediate salinities.

<u>Atlantic salmon</u>

- 10 PPT appeared to improve growth in Atlantic salmon
- 24 hours of light had a positive effect on the growth in Atlantic salmon
- 24 hours of light resulted in high levels of maturation (up to 30%). This was eliminated during 12-hour photoperiod

- High prevalence of cataracts.

Research and Development Priorities for the Future – Next Steps

During the 2018 BC Shellfish and Seafood Festival and in partnership with the BC Seafood Expo, the BCSFA will host a workshop on June 11th and 12th to discuss and set future priorities for the Marine Environmental Research Program. Focus groups will discuss research priorities on fish health, management of wild salmon stocks, the changing ocean climate and science communications. The discussions will help form the next iteration of this important program into the future.

The workshop will provide an opportunity for researchers, government and industry stakeholders to share their expertise and evaluate research priorities, and generate ideas important to forwarding BC's coastal research agenda.

About the Organizers

BC Salmon Farmers Association

The BC Salmon Farmers Association is a forum for communication and cooperation within the salmon farming sector, and the focal point for liaison between the industry and government. BCSFA also provides information to the public and stakeholders about salmon farming, and coordinate industry-wide activities, research, and community events. Members include both farmed salmon producers and many of the companies who provide services and supplies to them. The BCSFA was established in 1984 and is based in Campbell River, British Columbia.