ACFFA AQUACULTURE RESEARCH, SCIENCE AND TECHNOLOGY FORUM

FINAL REPORT

OCTOBER 23 AND 24, 2019

HUNTSMAN FUNDY DISCOVERY AQUARIUM

ST. ANDREWS, NB

****PDF versions of power point presentations may be available upon request.**

ACKNOWLEDGEMENTS

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Thank you to DFO-ACRDP for their collaboration on this workshop.

A special thank you to all the speakers and presenters for their participation.

INTRODUCTION

The Atlantic Canada Fish Farmers Association hosted its annual Science, Research and Technology Forum on October 23 and 24, 2019 at the Huntsman Fundy Discovery Aquarium in St. Andrews, New Brunswick. The annual forum is designed to support the transfer of knowledge on aquaculture related research and development projects, as well as new innovative approaches being used in aquaculture. It creates a venue to share results, profile new technologies, determine knowledge gaps and inform industry priorities through a number of networking opportunities.

Presentations at the 2019 forum covered a variety of themes including wild salmon conservation activities, understanding wild -farmed interactions, and sea lice research. Two multi-country panels discussed containment standards and sea lice thresholds.

157 individuals registered for the forum. Participants included representatives from the aquaculture industry from across Canada, local, national and international researchers, pharmaceutical and feed companies, federal and provincial regulators as well as representatives of academia, traditional fishery and conservation interests.

AGENDA

WEDNESDAY, OCTOBER 23, 2019		
8:00	REGISTRATION AND REFRESHMENTS	
8:45	Welcome to the Forum	Susan Farquharson, Atlantic Canada Fish Farmers Association
9:00	Greetings	Minister Jeff Carr, NB Environment and Local Government
9:15	International Year of the Salmon - FSR 2019	Dr. Kurt Samways, University of New Brunswick and Tim Robinson, Fort Folly First Nation
10:00	Children's Book: Farming the Oceans	Deborah Irvine Anderson, Canteen Media
10:30	REFRESHMENT BREAK	
ENVIRONMENT – Moderator Tom Taylor		
10:50	Assessing the Effects of Multiple Stressors on the Estuarine and Early Marine Survival of Atlantic Salmon Post-smolts	Dr. Marc Trudel, DFO – St. Andrews Biological Station
11:15	Salmon farm-lobster/rock crab interactions in southwest New Brunswick	Dr. Chris McKindsey, DFO - Institut Maurice-Lamontagne
11:40	Potential Impacts of Elevated Temperatures and Hypoxia on Salmon Cultured in Atlantic Canada	Dr. Kurt Gamperl, Memorial University
12:05	New ROV Technologies aiding in Regulating Aquaculture Sites for a Sustainable Future	Sam Macdonald, Deep Trekker
12:30	LUNCH	
	TECHNOLOGY	
Country Panel (Norway, Scotland, US, Canada) Aquaculture Containment Standards: Respecting the Conditions Moderator – Jamey Smith		
1:15	Containment Standards in US Aquaculture – enforcement and compliance.	Conrad Powell, SGS Canada Inc
1:30	The Containment Standards for Sustainable Operations in Norway	Dr. Jon Arne Grøttum, Norwegian Seafood Federation
1:45	Development of a Scottish Technical Standard for Scottish finfish aquaculture	Dr. Iain Berrill, Scottish Salmon Producer's Organization
2:00	Why iteration, adoption, and legislation of containment standards is a key to building public trust in finfish aquaculture	Dean Steinke, Dynamic Systems Analysis (DSA)
2:15	Panel Discussion	
2:45	Break	
3:00	Sustainable Development of North Atlantic Ocean Food Systems in the Anthropocene	Dr. Barry Costa-Pierce, University of New England
3:30	Wrap Up	

THURSDAY, OCTOBER 24, 2019		
8:00	REGISTRATION AND REFRESHMENTS	
8:45	Welcome and Introduction to the Day	Susan Farquharson, ACFFA
New Sea Lice Research - Moderator David Seeley		
9:00	Sea lice vaccines: Chapter 30!	Dr. Ian Bricknell, University of Maine
9:25	Impacts of different moulting inhibitors across various life stages of sea lice	Dylan Michaud, University of PEI
9:50	Developing warm water shower technology to manage sea lice infections in Atlantic salmon farming: Experiences from the Bay of Fundy	Dr. Shawn Robinson, DFO – St. Andrews Biological Station
10:15	Connecting your Farm to the Future	Dr Tim Kniffen, Merck Animal Health
10:45	REFRESHMENT BREAK	
Modeling to Manage Sea Lice in the Bay of Fundy Moderator - Michael Ness		
11:00	Results of drifter releases from fish farms	Dr. Fred Page, DFO-St. Andrews Biological Station
11:25	Oceanographic Tools to Predict Sea Lice Infection Risk	Dr. Jon Grant, Dalhousie University
11:50	Developing an understanding of the early life history population ecology of sea lice (*Lepeophtheirus salmonis*) in and around Atlantic salmon aquaculture sites in the Bay of Fundy	Jonathan Day, DFO-St. Andrews Biological Station
12:15	Sea lice data - current uses and future possibilities	Dr. Larry Hammell, University of PEI
12:45	LUNCH	
1:30	COUNTRY PANEL (Canada, Norway, Scotland) Sea Lice Thresholds: Numbers or Science? Moderator – Ben Forward	
1:30	Sea lice regulation in the Scottish farmed salmon sector	Dr. Iain Berrill, Scottish Salmon Producer's Organization
1:45	Management Thresholds and Other Factors Influencing Variation in Salmon Louse *Lepeophtheirus salmonis* Abundance on Farmed Salmon *Salmo salar* in BC	Dr. Simon Jones, DFO-Pacific Biological Station
2:00	The Traffic Light Sea Lice Model – An Appropriate Tool to Regulate the Production	Dr. Jon Arne Grøttum, NSF
2:15	Perspectives on Sea Lice Thresholds and a Monitoring Plan for the East Coast.	Dr. Shawn Robinson, DFO-St. Andrews Biological Station
2:30	Panel Discussion	
3:00	REFRESHMENT BREAK	
	New Research – *Moderator Sue*	
3:20	Genomic Analysis of Tenacibaculum Species	Dr. Ahmed Siah, BC Centre for Aquatic Health Sciences
3:45	Research Priorities Discussion	Susan Farquharson
4:00	Closing	

Presentation Synopses and Speaker Biographies

Wednesday, October 23, 2019

Life Beyond the River: Applying Stable Isotopes to Identify the Primary Marine Feeding Grounds of Endangered Inner Bay of Fundy Atlantic Salmon
-presented by Kurt Samways, University of New Brunswick

Inner Bay of Fundy (iBoF) Atlantic salmon are a critically threatened population where repeat spawners are disproportionately important, and there is little known about the marine ecology of these returning adults. As a result of the Fundy Salmon Recovery Project, there were 13 repeat spawners in 2016 in the Upper Salmon River, 32 in 2017, and 2018 saw 70+ repeat spawners. However, there is no information about where they went while out in the marine environment or what they were eating. iBoF salmon have a different life history than other Atlantic salmon and with only ~200 repeat spawners, knowledge about this part of their life cycle may be important in recovery efforts. Determining salmon migration patterns is very complicated, and tagging is very expensive, usually including only a small subset of the group being investigated. Following the "you are what you eat" principle, this current research project is looking to isotopes to potentially answer some of these questions.

There are 5 commonly used isotopes in ecological research which can be used to infer different ecological relationships. Carbon and nitrogen from food sources becomes part of tissues so the ratios can be used to determine the food signature and identify prey items. This is a good way to trace feeding patterns through the environment. This project is using scale samples that have been taken from returning salmon because there are global archives that could be accessed for this process to help build the isotopic maps required of salmon and prey items. Initial concept data presented showed how the carbon to nitrogen ratios from different parts of a scale can be used to identify the freshwater versus saltwater food items. Using the correct portion of the scale is very important to ensure evaluation of correct time period in the life cycle.

Using this analysis, the project proposes to determine where iBoF salmon returning to Bay of Fundy rivers have been feeding and if this is a process that can be used to distinguish wild and farmed Atlantic salmon. Scale samples were first taken from wild salmon on the FSR wild salmon conservation farm, the New Brunswick commercially produced salmon and the salmon from Mactaquac Biodiversity Facility which could be easily identified as separate groups. When data for Saint John River salmon, an Irish river salmon and salmon caught in Atlantic Ocean off Nova Scotia were placed on the same C:N ratio plot there were some interesting overlap between these three groups. Salmon scales analysed from salmon in the Gaspereau River, for example, showed one fish like a Big Salmon River (iBoF) salmon, one like a Saint John River salmon, and the rest looked like the Irish salmon. This would suggest possible migration outside of the assumed area of Bay of Fundy / Gulf of Maine.

The results of isotope analysis to date shows that marine feeding locations can potentially be identified but more data is required. Stable isotopes appear to provide a quick and easy method to distinguish between wild and aquaculture raised salmon, but here too more data is required. The samples from eight additional rivers are currently being analyzed, along with plans to test scales from Canadian and European archives. Compound specific stable isotope analysis may then allow researchers to infer the marine diet of Atlantic salmon and better define migration routes and the various ecosystems used during this part of their life history.

Presentation Available Upon Request

Kurt Samways

Dr. Kurt Samways is an internationally recognized freshwater ecologist and fish biologist at the University of New Brunswick. He has worked extensively in applied ecology to restore river ecosystems and recover fish populations, particularly Atlantic salmon, in Canada and abroad. Dr. Samways currently leads UNB scientific monitoring of the Fundy National Park salmon restoration program, studying the effects of captive reared adults on fish fitness and ecosystem health. He was recently awarded the first-ever Parks Canada Research Chair. His Chair position will focus on river restoration and the study of ecosystem recovery processes associated with fish restoration programs. Dr. Samways has ongoing collaborations with academia, government, industry, First Nations, and NGO's, as well as being a representative in multiple government and local working groups and committees involved in Atlantic salmon restoration.

Post Causeway Construction Era - Ecological Stewardship and Activism on The Petitcodiac River
-presented by Tim Robinson, Fort Folly First Nation / Fort Folly Habitat Recovery

Pre and post construction pictures were shared showing the impact of the causeway built on the Petitcodiac River in 1968. The Petitcodiac River historically produced 20% of the entire inner Bay of Fundy (iBoF) Atlantic salmon population and post causeway construction the Petitcodiac River became extirpated of iBoF Atlantic salmon. Pictures also showed Chief Joe Knockwood and Robert F. Kennedy Jr. at an early Petitcodiac Riverkeeper meeting in June 1999 and more recently, Chief Rebecca Knockwood receiving the 2016 NB Lieutenant Governors Award for Salmon Conservation on behalf of Fort Folly Habitat Recovery.

In 2010 the causeway gates were permanently re-opened and Fort Folly Habitat Recovery (FFHR) lead efforts to re-establish and monitor iBoF Atlantic salmon in the Petitcodiac River supported by restocking from DFO's Live Gene Bank (LGB) maintained at the Mactaquac Biodiversity Facility (MBF). LGB fry stockings started in 2009 and LGB adult stockings started in 2012 in the Pollett River, a tributary of the Petitcodiac. This river has been the focus of the restocking program since the Pollett has a known history of being a very good juvenile salmon habitat.

Starting in 2014 the FFHR's efforts have been supported by an innovative, collaborative recovery program - the Fundy Salmon Recovery project (FSR). The FSR, has shown that maximized wild exposure increases the fitness of salmon released into the environment for conservation and recovery efforts. The FSR project works to support that on the wild salmon conservation farm on Grand Manan.

To help kick-start the natural process, fall parr are collected via electro-fishing and overwintered at MBF with non-target (wild exposed) smolt then released to become part of the FSR project the following spring. Meanwhile, wild smolt collections occur using counting fences on the Pollett and Little River tributaries of the Petitcodiac. All the smolt added to the conservation farm each year are cared for until they show indications of sexual maturity. During a sorting event in September each year, those maturing salmon are tagged and then released back to their natal rivers in October to naturally spawn. The objective is that wild produced smolt will increase over time, eventually eliminating the need for the non-target MBF smolt. The FSR Dark Harbour site has capacity to grow out twice the number of historic iBoF adult returns and currently holds approximately 2000 salmon for FFHR.

On October 1, 2019 the community of Fort Folly First Nation with Fort Folly Habitat Recovery personnel and all the FSR project partners celebrated the International Year of the Salmon and the latest and largest release of FSR adults to the Pollett. Including some adults that were released earlier in the summer from the Grand Manan farm, there were approximately 460 salmon returned from the FSR project to the river with the hope of more than doubling that number in the coming years of the project. Ultimately, the longer-term goal is a release of upwards of 5000 to 6000 adults providing there is continued increases in FFHR project capacity.

Pictures of the celebration were shared showing the ceremonial blessing, drumming and dancing that occurred along with those showing the participation of the youth of Fort Folly.

Presentation Available Upon Request

Tim Robinson
Tim has worked for Fort Folly First Nation since 1995, initially supervising community-based habitat restoration and stewardship projects. Since the early 2000's Tim has co-managed the Fort Folly Habitat Recovery program operating more extensively, on multiple rivers in southeastern New Brunswick, in many conservation and recovery actions benefiting endangered inner Bay of Fundy Atlantic salmon. Since 2010, the FFHR team has been leading recovery efforts on the Petitcodiac River which historically produced 20% of the entire iBoF Atlantic salmon population. Starting in 2014 Fort Folly has been a proud partner in Fundy Salmon Recovery, working collaboratively with Fisheries and Oceans, Parks Canada Agency (Fundy National Park), NB DAAF, Cooke's Aquaculture, ACFFA and University of New Brunswick to restore wild salmon in historic numbers back to inner Bay of Fundy Rivers.

Assessing the Effects of Multiple Stressors on the Estuarine and Early Marine Survival of Atlantic Salmon Post-Smolts
-presented by Marc Trudel, DFO – St Andrews Biological Station

Atlantic salmon have been extirpated from several of their native rivers and often fail to meet conservation requirements, particularly in the Bay of Fundy and Northeast United States. Although multiple factors likely contributed to these declines such has habitat destruction, overfishing, and climate change, the cumulative effects of multiple stressors on the survival of Atlantic salmon is poorly understood. The results of an acoustic telemetry project to assess the population response of Atlantic salmon to multiple stressors during a critical period of their life cycle, including passage through a hydropower system and bycatch mortality associated with in-river fisheries were presented. Also assessed in this project was the salmon migration routes and rates during their early marine life and whether there are any interactions with aquaculture.

A pilot project was undertaken in 2018 which saw 30 receivers placed in various locations within Passamaquoddy Bay and at exit points in order to follow two groups of 30 smolts as they left the Magaguadavic River basin. Most of the salmon post-smolts left the bay through the Western Passage (83-96%) with a residence time average of 4.1 days (1.5-9.8 d). Only 23 out of 53 fish that left the estuary were detected within the detection range of the receivers at aquaculture sites, with an average residence time near individual aquaculture site of approximately 16 minutes and the cumulative residence time near aquaculture sites at approximately 29 minutes. Some of the challenges identified with the 2018 project were that some areas were quite noisy possibly making it difficult to detect salmon, the receivers detect tags but those used do not provide any information to indicate if the fish is alive or dead (inside predator), and since the receivers have a detection range of 400-500m there is no way to know how far the fish was from the receiver when it was detected.

For the 2019 project, a total of 160 smolts (two groups of 80) were tagged with pressure and temperature sensors within the acoustic tags and released in May or June, above and below the hydropower dam, and before and during the commercial alewife fishery. A total of 129 acoustic receivers were placed in the river and estuary of the Magaguadavic River, at all the exit areas of Passamaquoddy bay, as well as at twenty-three salmon aquaculture sites located in three Bay Management Areas. The survival rate for the smolt released in May and June above the dam was 75% and 30% respectively. After arrival in the estuary, the survival rates for all groups of smolt as calculated separately within the estuary, inner bay, outer bay ranged between 73% and 100%. Overall, both smolt groups released below the dam had higher survival rates. Preliminary data from 2019 shows more variation in migration pattern than in 2018, with only 67% of the smolt leaving Passamaquoddy Bay by the Western Passage and a resident time in the inner bay of 3 to 4 days. About 5% of the smolt were consumed by a predator (marine mammal), mostly in the Western Passage. Of the 93 fish that entered the ocean 66 (71%) were detected near receivers (400m-500m) on aquaculture sites with a cumulative residence time of about 40 minutes.

Further work includes developing models of juvenile salmon migration in Passamaquoddy Bay and surrounding waters, and further assessment of the effects of multiple stressors on the estuarine and the early marine survival of Atlantic salmon post-smolts by collecting two more years of data. It is anticipated that this research will provide information necessary to develop effective mitigation strategies to limit associated threats, and aid in the recovery of wild salmon populations.

Presentation Available Upon Request

<u>Marc Trudel</u>
Dr. Trudel is a research scientist who leads multidisciplinary research program aimed at assessing the long-term effects of climate change on salmon productivity and the limits to marine ecosystems productivity for Pacific salmon. He has extensive experience in designing and managing large-scale field programs in coastal waters of British Columbia, and in studying the migration behavior of juvenile salmon. His research program has contributed to the development of leading indicators of marine survival that are used to forecast adult salmon returns in southern British Columbia and to understanding the interactions between wild and cultured salmon. He recently relocated to St. Andrews where his research will focus on aquaculture-ecosystem impacts and risk mitigation

Salmon Farm – Lobster / Rock Crab Interactions in Southwest New Brunswick
-presented by Chris McKindsey, DFO - Institut Maurice-Lamontagne

The way in which finfish aquaculture inputs (bio-deposition and waste food) affect the seafloor and the animals that live in it are generally known but the potential effects of salmon farms on lobsters and crabs is not well understood. The presentation gave an overview of research to evaluate variation in lobster/crab use between habitat types, their movement and fidelity to salmon farms relative to natural areas, and an evaluation of the uptake and effect of salmon farm-derived material by lobsters/crabs.

Crabs, in general, were more abundant below farm sites than outside of farm sites whereas lobsters were about equally abundant under farm sites as away from them with one exception where lobsters were mostly absent from under a farm site but abundant away from it.

Acoustic telemetry was used to evaluate lobster/crab use and movement below and around 3 farm sites in the Passamaquoddy Bay area over 5-6 months in 2016 and 2017. One site had a rocky bottom at about 15m water depth, one had a muddy bottom at 30m water depth, and one had mud directly under the pens but a mixed mud/rocky bottom around the edges and a 20m water depth. Rock crabs released at the deep muddy or the shallow rocky sites moved around extensively, both below and outside of the farm lease, rarely setting up territories below or around the farm. In contrast, most lobsters remained around the farm with the rocky bottom, at times setting up territories beneath it; all lobsters departed the study area around the deep muddy farm site within 24-48 hours, commonly going below farm site structures.

Lobster core areas (i.e. the area in which they concentrate their activities) were smaller under and within 100 m of the shallow rocky bottom farm than in areas at greater distances from it. This may be due to areas under and adjacent to the farm providing adequate food and good habitats. On the muddy/rocky farm site, none of the lobsters spent much time under the pens and several left the study area.

Farm energy uptake by lobsters and crabs was assessed at three farm and reference locations on Grand Manan by testing the muscle, gonad and hepatopancreas for fatty acid profiles of 29 lobsters and 62 rock crabs. Both lobster and crab made use of farm-derived (i.e. feed) nutrients at the farm locations, although assimilation was greater for crabs. Laboratory experiments have been initiated to evaluate the effect of this type of "farm" diet on lobster and crab versus other diets on time to moulting and size increase at moulting. Preliminary results indicate that crustaceans fed only on fish farm feed required increased time to moult and showed smaller increases in carapace length at moulting. Note that this type of diet is not observed around farms in nature; lobsters apparently feed on a more mixed variety of food types when given a natural choice.

Work initiated in 2019 is further evaluating lobster and crab use of the mud/rocky bottom farm site and how the distribution of lobster/crabs may be influenced by benthic conditions and farm activities. Lobster/crab habitat use is also being evaluated at two farm sites in Nova Scotia. Ongoing projects are examining long-term effects of different diets for lobster/crabs on the condition of the animals and their progeny (eggs and resulting larvae/juveniles).

Presentation Available Upon Request

Chris McKindsey

Chris McKindsey is a Research Scientist and Section Head with Fisheries and Oceans Canada at Institut Maurice-Lamontagne in Mont-Joli, Quebec. Chris' work focuses on anthropogenic stressors in coastal areas, with a focus on aquaculture-environment interactions, aquatic invasive species, and habitat-community relationships. His interdisciplinary research involves partners from various levels of government, academia, various organizations, and industry partners. He uses observational, manipulative, and laboratory studies with a strong emphasis on complex field experiments, to provide science advice for coastal zone management. He has ongoing collaborations on all Canadian coasts as well as in Europe and Tahiti but most of his work is focused on issues on the Atlantic coast of Canada.

Potential Impacts of Elevated Temperatures and Hypoxia on Salmon Cultured in Atlantic Canada
-presented by Kurt Gamperl, Memorial University

Data were presented which showed that ocean temperatures in Atlantic Canada change over a year from 0°C to 18°- 20°C, that the rate of temperature increase over the summer is approximately 1°C per week, and that high temperatures are often associated with moderate hypoxia (oxygen levels of 60% - 75% air saturation). Given these conditions, and that water temperatures are expected to increase by 1°C to 1.5°C by 2050, it is important to understand what the future will look like for salmon farmers. For example, salmon operations in Tasmania are already being challenged with high temperatures at the surface (22-23ºC) and low oxygen conditions in deeper parts of the cages (< 40% air saturation), and this forces the fish to select intermediate depths where environmental conditions are suboptimal.

A large project, *Mitigating the Impacts of Climate-Related Challenges on Salmon Aquaculture* (MICCSA), was developed in 2016 to provide a road map for adaptation of salmon aquaculture production to climate change, and to work collaboratively with Canadian industries to reduce disease-related mortalities and loss of production. Determining the sub-lethal and lethal environmental limits of current Atlantic Canadian farm stocks that originate from the Saint John River was the initial focus of the work. However, research is now being conducted to identify Atlantic salmon families that have an enhanced capacity to tolerate environmental challenges and mount robust pathogen-specific immune responses. Further, the project is developing functional tools and diagnostic assays for assessing fish health, welfare and immune function, and the efficacy of vaccine formulations as influenced by environmental conditions.

The impact of sub-lethal temperatures and hypoxia on various growth and somatic indices was investigated in three groups of salmon (initial weight ~ 150 g) fed to satiation and exposed to: 1) a constant temperature of 12ºC and oxygen levels of 100% air saturation (normoxia); 2) increasing water temperature up to 20°C (at 1°C per week) and then 3 more weeks at this temperature under normoxic conditions; and 3) the increase in temperature, but with the addition of moderate hypoxia (~ 70% air saturation). Results from five sampling dates during the test period indicated that the only consequence of the temperature increase to 20°C was an increase in the salmon's food conversion ratio (FCR). Whereas, the addition of hypoxia reduced growth, condition factor and FCR.

When genomics was used for the identification of potential stress and immune biomarkers in these three groups, the results showed that the first signs of temperature stress began at 16°C with the most extreme response at 20°C. Further, this research showed that while salmon may acclimate to being held for weeks at 20°C the response is small, and regardless of temperature, moderate hypoxia alone can affect stress gene expression.

In a second, similar, experiment on larger fish (~ 400 g initial weight) water temperature was not held at 20ºC, but continued to increase at 1ºC per week until 23°C. In this experiment, hypoxia again decreased growth and FCR, and food intake and growth starting to decrease in both experimental groups at 18°-19°C. Mortalities were first observed at 21° C, and by 23°C 33% of the fish had died. Surprisingly, moderate hypoxia had no effect on mortality during the incremental temperature increase.

Collectively, this data and that from other studies suggests that while salmon grown in Atlantic Canada can survive temperatures up to 20ºC (with or without moderate hypoxia) for several weeks, further reductions in water oxygen levels could dramatically increase mortalities at high water temperatures.

As a first step to understanding fish distribution and physiology under farm conditions, a lab-based study was first undertaken to validate the use of data loggers from Star-Oddi for the measurement of temperature, heart rate, activity (acceleration) and depth in Atlantic salmon. This involved both trials in a swim-tunnel and experiments in large tanks that lasted up to 6 weeks. This research showed that acceleration can be used to quantify swimming speed and characterize behaviours in Atlantic salmon, that at least 4 days of recovery are required before heart rate stabilizes post-surgery, and that heart rate provides a sensitive measure of alterations in the salmon's environment. For example, heart rate was directly related to swimming speed, sensitive to changes in temperature, and showed a clear diurnal (day / night) pattern that corresponded with changes in activity. On farm studies are being conducted to characterize the distribution and physiology of salmon in the cage-site environment.

Presentation Available Upon Request

Kurt Gamperl
Since completing his Ph.D. in biology at Dalhousie in 1994, Dr. Gamperl has studied various aspects of the stress, metabolic, exercise and cardiovascular physiology, and immunology, of fishes. However, his most significant contributions have been made in understanding how fishes respond and adapt to challenging environmental conditions such as hypoxia, changes in temperature, and temperature extremes. This research has been used to set water temperature criteria for redband trout (residents of the high desert regions of Oregon and Idaho), and has defined the thermal and oxygen limits of several fish species (e.g. cod, rainbow trout, Atlantic salmon, Arctic char, sablefish, lumpfish and cunner) used in aquaculture. Further, it has determined how elevated temperatures impact immune function and the capacity of fishes to respond to bacterial and viral pathogens. Kurt is currently the Program Co-Chair of the 2020 Aquaculture Association of Canada / WAS North America meeting, is co-lead of the 'Mitigating the Impact of Climate-Related Challenges on Salmon aquaculture' project and is lead scientist for two Ocean Frontier Institute aquaculture sub-modules.

Escapes and Collapse - Mitigating risks using Remotely Operated Vehicles
-presented by Sam MacDonald, Deep Trekker

New headlines provided show that fish escapes from farms have occurred globally. It was identified that in Norway mandatory net inspection are required after all farm operations involving the net and / or weighting system. This program of systematic monitoring and inspections ensures that holes caused by such operations are discovered and repaired as soon as possible. Remotely Operated Vehicles (ROVs) have been proven to be a safe, robust and cost-effective alternative to divers for this purpose.

ROVs are unoccupied, highly maneuverable underwater robots operated by someone at the water surface using a joystick and feedback from the unit. ROVs are equipped with a video camera and lights though equipment such as a manipulator or cutting arm can be added to the unit. The ROV pilot bases the steering on information from a forward-looking camera, a depth sensor and a compass. Images and any installed sensor data can also be recorded to an SD card in the controller or sent wirelessly to a remote station.

Video from Chile showed sealions that have breached the predator net and are accessing mortalities at the bottom of the main net. A net hole is inevitable and demonstrates the importance of timely removal.

External net and mooring inspections are more routinely being completed with ROVs to avoid depth and temperature considerations that make these tasks that were traditionally left to divers, situationally prohibitive. Deep Trekker ROVs, for example, can check moorings and benthic conditions to depths of 1000 ft.

The DTG3 is a mini observation-class underwater ROV built to provide operators the ability to quickly deploy and visually inspect within underwater environments. It has a speed of 2.5 knots and a depth rating of 200 m (656 ft)

The Deep Trekker REVOLUTION is a completely re-imagined ROV. The patented pending revolving head allows operators to rotate the camera, manipulators, and sonar all while station holding in moving water. It is well suited for offshore underwater inspections with a speed of 3.5 knots and a depth rating of 305 m (1000 ft).

<u>Sam MacDonald</u>
Sam MacDonald is the President of Deep Trekker a company which makes ROVs that are used for aquaculture farm inspections around the world.

Containment Standards in US Aquaculture – Enforcement and Compliance
-*presented by Conrad Powell, SGS Canada Inc.*

As in Canada, US regulations around containment for finfish farm operations may differ between states. Comparisons between regulations in Washington State and Maine were highlighted.

Maine's General Permit for Net Pen Aquaculture issued by the Maine Department of Environmental Protection (MDEP) has a Section 'O' entitled Protection of Atlantic Salmon. Part 6 discusses the requirement for each farm to have a Containment Management System (CMS) in place prior to the first entry of fish. The CMS plan must contain items such as predator control procedures, escape response procedures, unusual event management procedures and severe weather procedures. Within each of these procedures, the critical control points (CCP) where escapes could occur must be identified along with control measures that will be in place for each CCP. There is a requirement for an annual audit of the CMS by a qualified third party with a report submitted to MDEP by December 31st. If deficiencies are identified with the farm's CMS, the report must include a corrective action plan with time timetable.

An audit is also required within 30 days of a reportable escape or notification of a farmed salmon found in a river within the range of the Gulf of Maine Distinct Population Segment of Atlantic salmon. A reportable escape is the loss of 25% of a cage's population and/or more than 50 fish with an average weight of 2 kg or more. Escapes below this threshold must be included in monthly reporting to the Maine Department of Marine Resources (MDMR). Within 24 hours of becoming aware of a known or suspected escape MDEP, MDMR, Army Corps of Engineers, National Marine Fisheries Service, US Fish and Wildlife Service must be notified.

In Washington State the Washington Administrative Code (WAC) Title 220-370: Aquaculture includes a section entitled Marine Finfish Aquaculture which outlines the requirement for farms to have an Escape Prevention Plan (EEP). Like the Maine CMS plan, this EEP must include procedures to minimize escapes when pens must be moved, repaired or manipulated, and when stocking or harvesting pens. Best Management Practices (BMPs) must also be developed and documented to minimize risk of escape in day-to-day operations.

The WAC also has a detailed section entitled Escape Reporting and Recapture Plan which includes the requirement for an escape reporting procedure, recapture procedures, procedures to minimize the number of escaped fish and emergency contact list in the event of a significant fish release. For Washington, a significant fish release means the loss of 1,500 or more fish whose average weight is > 1 kg or 3,000 or more fish whose average weight is ≤ 1 kg. Annual fish escape reports are also required, and the Washington Department of Fish and Wildlife employees have the authority to visit farms to conduct inspections to determine conformity with laws and rules regarding escape prevention and/or recapture.

The Engrossed House Bill 2957 now places additional requirements on farms including farm inspection procedures, procedures for eradication of escapees and provisions "to facilitate the most rapid recapture" of escaped fish. Marine net pen operators must contract a government-approved marine engineering to conduct inspections of their farm every two years, including topside and mooring assessments related to escapement potential. The facility must be found to be in good condition to receive fish.

The definition of reportable escapes is not only defined differently by regulatory jurisdictions but also is addressed differently by certification programs. The ASC certification program is the strictest with the maximum number escapees allowed without losing certification is 300 fish per production cycle. The BAP Certification program will suspend certification of a farm if there is a single escape of over 5,000 fish, if there are ≥ 3 escapes of over 500 fish over two production cycles or if such escapes cumulatively add to more than 5,000 fish.

Presentation Available Upon Request

<u>Conrad Powell</u>
Conrad is a Seafood Auditor with SGS Canada Inc., the Canadian affiliate of SGS, the multinational inspection, verification, testing and certification company. Conrad has an M.Sc. in Biology from Memorial University and an M.Sc. in Food Science from the University of Manitoba. He has an extensive background in seafood, having worked with the Department of Fisheries and Oceans and the Canadian Food Inspection Agency for 18 years before leaving the government to take on senior quality assurance roles with companies such as Fishery Products International, Connors Bros. Ltd. and Ocean Choice International. In 2011, he struck out on his own as a consultant and auditor before joining SGS Canada in 2018. He has audited fish farms and related facilities on five continents. In his current role as Seafood Auditor, Conrad conducts audits for a wide range of standards pertaining to fisheries, seafood

and aquaculture: Best Aquaculture Practices (all standards), Aquaculture Stewardship Council Salmon Standard, Canadian Organic Aquaculture Standard and MSC/ASC Chain of Custody Standard.

The Containment Standards for Sustainable Operations in Norway
-presented by Jon Arne Grøttum, Norwegian Seafood Authority

There is a dispute in Norway, as in Canada, about aquaculture's environmental impact. The discussion is about four factors: escapees, sea lice, the release of nutrients, and accumulation of organic matter on the seabed, with escapes described as the most serious. Farmed fish escapes are no doubt a negative for the reputation and production cost. Farmers must recognise their responsibility to have a control of their fish and the industry must address the challenge by having a defined vision and goal. The aquaculture industry has a vision for zero escaped farmed fish, with an operational objective to reach a level where escaped farmed fish do not affect wild fish negatively. The goal in Norway is to have less than 4% escapees in river.

Data was presented to show Norwegian production since 1993 with the number of escapes. The main reasons for escapees are technical failure and human factor. The plan to update the existing technical standard was started in 2003, a committee was established in 2005 to review an escape event and then 2006 saw many severe windstorms so there were many escapes. Based on the various investigations another revision was developed in 2009. There was a discussion on how to best ensure the industry adopted the upgraded technical standard, and the pros and cons of inclusion as Best Practice, Regulation and National Standard were reviewed. Regulations are not suitable for complicated descriptions of exposure and technical details, so this became a National Standard. Norway saw the benefit of an international standard for supply companies and at the time was leading established technical standards.

The Norwegian Standard NS 9415, *Marine fish farms - Requirements for site survey, risk analyses, design, dimensioning, production, installation and operation* was developed with the aim of reducing the risk of escapes due to technical failure and improper handling of fish by having the standard sufficiently functional and unambiguous, practicable to comply with, and based on updated knowledge. NS-9415:2009 requires marine fish farms be designed by accredited inspection companies that will evaluate the site conditions, degree of exposure then decide the appropriate criteria for the mooring system and technical equipment to be used. Once the site is in place, another inspection confirms that everything is according to the design, the site with its equipment is certified. There must be a user manual for all components which includes risk-based and routines for surveillance of components, plus requirements for actions like an inspection after adverse weather event. The technical standard is linked to the NYTEK regulation as its "technical tool", so it is obligatory for the industry.

In 2018, there was significant technical development of new production systems due to the introduction of "development" licences in Norway requiring the use of more exposed sites and therefore larger, more robust farming systems. This created the need for the technical standard to be revised and adapted to the new technology, starting with a new approach to estimate and define acceptable exposure. This revision would also allow the inclusion of new and updated knowledge, the strengthening of the components risk assessment requirement, and the adequate safeguard of new constructions along with the usual clarification of existing details and definitions.

Revisiting the previous graph of salmon production with number of escapes over time, the data shows the decreasing trend in the number of escapees except for 2019. Unfortunately, to date in 2019, there has been almost 300,000 fish escape, but 2/3 of the escapees were from a closed containment system – a landbased smolt facility. There is a technical standard for landbased aquaculture, *NS9416:2013 Landbased aquaculture farms for fish - Requirements for risk analyses, design, running operation, user handbook and product data sheet.* Like the marine standard, there are requirements for inspections, maintenance and modifications of land-based aquaculture systems and components.

Regulations on the technical standard came into force in 2018 which set out the requirements for the holders of aquaculture permits and manufacturers, suppliers, certification bodies, engineering businesses and inspection companies related to land-based aquaculture facilities. Existing facilities must demonstrate compliance with standards through a technical report that includes an analysis of the condition of the plant, the construction works, the drain system, the fish transport system and maintenance plan along with a risk assessment. This standard and regulation are also under revision.

Presentation Available Upon Request

Jon Arne Grøttum

Jon Arne Grøttum is the Director of Aquaculture at the Norwegian Seafood Federation. The Norwegian Seafood Federation represents the interests of approximately 550 member companies. The member companies cover the entire value chain from fjord to dinner table in the fisheries and aquaculture sectors in Norway. The federation promote policies and legislation that benefit the members, members interests regarding exports, trade and other international issues, and advise the member companies on a wide range of other issues. Grøttum is responsible for the activities in the federation related to policies and legislation within the aquaculture sector. He has a PhD in fish physiology/aquaculture and has in his former work as a researcher published several publications within topics related to fish metabolism, live transport of fish and land based fish farming.

Development of a Scottish Technical Standard for Scottish Finfish Aquaculture
-*presented by Dr Iain Berrill, Scottish Salmon Producers' Organisation*

A statement of the obvious is that nobody wants escapes, we all want escape incidents to be zero, and we are not yet at that point, though generally the number of escape incidents and number of escaped fish are relatively low. In Scotland there has been legislation regarding the reporting of escapes since 2002 and the Aquatic Animal Health Regulations 2009 requires that Scottish Ministers be immediately notified where farmers suspect that an escape has occurred. In practice of course, the initial notification occurs as soon as practically possible with a follow up "Final" notification 28 days later, and the data is publicly available. The Scottish Aquaculture and Fisheries Act of 2007 also identifies the Ministers authority to access information around containment, escape and recovery efforts, as well as the of authority of Inspectors. Secondary legislation provides the detail of the records that must be kept by fish farming businesses.

Though there was some discussion of containment by a 2002 Ministerial Group on Aquaculture, it wasn't until the Ministerial Group on Sustainable Aquaculture was established in 2009 that various working groups, including an Improved Containment Working Group (ICWG), were put together to build on the

2002 vision. Made up of a diverse group of stakeholders, the ICWG identified various goals which led to the development of what would eventually become the Scottish Technical Standard.

The Scottish Aquaculture Research Forum was commissioned to provide an assessment of protocols and best practice guidance to improve containment through the identification of causes of escapes, knowledge of national and international protocols and understand the technologies and research required. With the key recommendation of this initial project being the development of a technical standard, the next project was to include recommendations of what the standard should include and how it should be implemented. The ICWG took the report and finalized the standard with the document *A Technical Standard for Scottish Finfish Aquaculture* published in 2015 (STS).

The STS covers items like site surveys, design and construction of freshwater and marine operations, design, construction and installation of all primary and secondary equipment, and fish transport. Equipment replacement frequency was acknowledged during the program development so the implementation process included a phased introduction such that all equipment will have to meet the requirements by no later than 2020. As this is an ever-changing sector, there is already new knowledge and technology that should be included so a revision is required.

The STS will be implemented by regulation under the Aquaculture and Fisheries (Scotland) Act 2013, which allows Scottish Ministers to require the fish farming industry to adopt a Technical Standard and train its workforce. The stumbling block is the need to establish a clear means of auditing farms and enforcing the standard as there is no regulatory authority / process. There are also questions around the resources required in people and financially to address this necessary function as the industry works towards the 2020 deadline for compliance.

Iain Berrill
Iain Berrill is currently the Head of Technical at the Scottish Salmon Producers' Organisation (SSPO). He has worked for the SSPO for over 9 years and was initially brought into the company to set up and manage an industry fish health database. Since then, Iain's role and responsibilities have expanded greatly, and he now provides technical input into all aspects of the company's activities. Before working for the Scottish salmon farming sector, Iain had a short career in academic research, then undertaking various studies surrounding farmed fish welfare at Institute of Aquaculture in Scotland. He holds an undergraduate degree in Marine Biology from the University of Swansea and a Master's degree in Applied Fish Biology from the University of Plymouth. He also holds a PhD from the Institute of Aquaculture in Stirling, which investigated the freshwater development of farmed Atlantic salmon, funded by both NERC and what was then Marine Harvest McConnell (now Mowi Scotland).

Why Adoption, Iteration, and Legislation of Containment Standards is a Key to Building Public Trust in Finfish Aquaculture
-presented by Dean Steinke, DSA

DSA provides ocean engineering services and technology to enable those working in marine environments to complete projects on time with reduced environmental and financial risk. Services include mooring analysis, site survey for engineering, front-end engineering design, and mooring system inspection. Video of the ProteusDS dynamic analysis software showed how nets and moorings respond to wind, waves, and current.

Standards, such as International standard ISO 16488, are documents that specify characteristics and technical details that must be met by the products, systems and processes for the item or activity in question. Whether it is steel toe boots (CSA) or a quality management system (ISO 9001) a standard should ensure acceptable performance, compatibility, and safety requirements are met. They may enable insurance coverage and can be a means to assess a product or service. In addition to all these criteria, a containment standard typically specifies processes, based on experience, that will prevent fish escapes, protect marine mammals, and ensure human safety. The development and or implementation of a standard can help build public trust in the industry, but its adoption and corresponding legislation are important to maintain that trust.

Under the Norwegian Standard NS 9415 marine fish farms are issued certificates by accredited organizations which state that the site has compliant site survey documentation, mooring analysis documentation and certified main components. These certifications are provided by accredited Norwegian inspection bodies and the farms are audited. Suppliers must issue a certificate stating materials provided are compliant and suppliers also must be accredited.

NS9415 cannot be simply applied in Canada because the Standard Council of Canada (SCC) doesn't recognize the Norwegian Standard and notes that the document has requirements for inspection and component certification in the same standard, which is not inline with IEC/ISO best practice. It is inflexible and more prescriptive compared with other marine standards recognized in Canada (e.g. ISO 19901-1) and any standard developed for the industry in Canada should include Canadian specific recommendations based on lesson's learned. The Scottish Technical Standard is less prescriptive that NS9415:2009 and has some improvements over NS9415 for high energy sites (e.g. current speed), but it is overly conservative in some areas and the regulatory framework is not defined.

The ISO 16488 standard *Marine Farms – Net Cage – Design and Operation* was developed by a group of international experts and ratified by Canada. This standard requires a detailed site "handbook", mooring analysis using suitable mooring standard (refers to ISO 19901-7), and sufficient documentation be maintained. It largely follows NS9415 guidelines for analysis. As with the STS, there needs to be organizations which can issue the required certificates of compliance, complete inspections, and these certifying, and inspection bodies must be accredited by SCC to issue certificates. Presently SCC doesn't have expertise in aquaculture design and operations so would have to hire experts to assist in accreditation. To establish a Canadian version of ISO 16488 a working group of government, consultants, suppliers, and growers would need to be established and there would need to be support from SCC to create accredited inspection and certification bodies. Along with updates and clarifications required, separate standards for the various components would have to be created.

Presentation Available Upon Request

Dean Steinke
Dean Steinke is a founder of DSA and a professional engineer with extensive experience in the aquaculture industry, including advisement to DFO on the development of ISO 16488 for the systematic analysis, design, and evaluation of net cage marine finfish farms. Dean, after spending 10-years in Nova Scotia, is now based in British Columbia, where he continues to lead a team of engineers focused on the aquaculture industry and in the development of DSA's ProteusDS software. DSA is presently active in

conducting mooring analyses and designs to NS9415 and performing site equipment inspections and risk analyses to prevent fish escapes and protect growers' fish.

Sustainable Development of North Atlantic Ocean Food Systems (esp AQUACULTURE) in the Anthropocene

-presented by Barry Costa-Pierce, UNE NORTH: The Institute for North Atlantic Studies, University of New England

Maine is a large rural state with a declining population, approximately 3000 km of coastline and 10 governments (2 state, 3 provincial, 5 federal). The University of New England (UNE) is a located in Biddeford with a Portland campus that contains most of the Universities health services. UNE also has a campus in Tangiers, Morocco. Maine is now considered "The New, Near-Arctic State" with two EIMSKIP ships per week coming from Reykjavik Iceland to Portland. Maine business are looking north now since the cost of sending shipments via EIMSKIP is to many EU locations is equivalent to trucking all the way to Georgia, USA. These sea routes are now moving to mixed energy fleets, reducing costs and environmental footprints. Importantly, we have a venue; the Arctic Circle Assembly was created to discuss our common destiny in the "New North". Maine had a 60-person group attending this year attesting to the importance of these new social-economic partners.

Along with a global goal of accelerating the supply and delivery of sustainable seafoods to humanity, we all are involved locally in many efforts are to save and enhance working waterfronts and the coastal economy. Sustainability, economic development, and jobs are always a focus of our local to global efforts.

How it is then that only 4% of total human foods come from the ocean? There's a enormous potential in the blue bioeconomy to not only increase seafood production locally, but also globally to make more efficient ocean food production value chains. An ever-increasing human population in Asia and Africa and the shift to a larger middle class in Asia and India present tremendous opportunities for us as high-quality producers of seafoods. Projections of demands from these countries cannot be met by terrestrial agriculture, which could destroy the Earth's remaining biodiversity in an effort to meet the increasing demands for food.

So, one question I have is, how can knowledge-based investments, our universities and government science centres, prioritize development of applied programs that are good for business and educate the next generation of seafood leaders?

Unfortunately, we are doing a very bad job at this. There are too many fisheries regulators making bad decisions on aquaculture issues as they have little to no aquaculture knowledge or training. It's very important for the future of food that we change this. Decision-makes in this space need to be educated on the latest advances in the aquaculture and fisheries industries and their vital connections in order to integrate their planning and management of the two sectors, essential to the future development and sustainability of ocean food systems. The FAO suggests that fisheries and aquaculture are interacting with increasing intensity as fishers shift to aquaculture and by competing in the same markets with similar products. For example, the marketplace cannot separate fisheries and aquaculture products in what they consider the generic "white fish" market. UNE has started a new program, a Professional Science Masters in Ocean Food Systems (OFS) to address this need; we have partnerships throughout the North Atlantic; we seek a strategic one with New Brunswick; and that's why I'm here!

There is a huge amount of opportunity in Atlantic salmon farming with us in the New North. As well, we need to diversify even more and invest in the value chains for these new products in our region - seaweeds, sea vegetables, Integrated Multi-trophic Aquaculture (IMTA), and aquaponics production are in their infancy of development in our region even after pioneering investments in science (e.g. CIMTAN). In summary, I call increased investments in the transdisciplinary sciences of aquaculture and fisheries, but under the broader rubrics of ocean foods systems and their essential contributions to human health and wellness, enhancing ecosystems goods and services, aligned to the U.N. Sustainable Development Goals.

Presentation Available Upon Request

Barry Costa-Pierce

Barry Costa-Pierce is the Executive Director of UNE NORTH: The Institute for North Atlantic Studies, Henry L. & Grace Doherty Professor of Marine Sciences, and the Program Coordinator of the UNE Graduate Program in Ocean Food Systems at the University of New England in Maine, USA. He has a Ph.D. in Oceanography from the University of Hawai'i and a M.Sc. from the University of Vermont. Dr. Costa-Pierce has worked as an aquaculture and fisheries research scientist and policy expert for education and research organizations, banks, and industries throughout the World, having lived long-term in Asia, the Pacific Islands, Africa, the Americas, and, more recently, in Europe. While Executive Director at UNE NORTH he has been a Fulbright scholar in Iceland and was selected as the 2018 Knut & Alice Wallenberg Professor at the University of Gothenburg, Sweden. He is a Fellow of the American Association for the Advancement of Science.

Thursday, October 24, 2019

Sea Lice Vaccines: Chapter 30!
-*presented by Ian Bricknell, University of Maine*

October 2nd, 1989 received first grant to work on a sea lice vaccine and since then many things have changed, except there is still no vaccine. These are a complicated organism and it was only five years ago that researchers finally understood the complete lifecycle of the sea louse. The initial focus for a vaccine was on pre-adults and adults and this is an important factor in why vaccine development has failed until now. Projects have looked for proteins associated with the digestive tract of the louse and screened 200 potential antigens involving many research groups over the last 30 years, with no results.

It wasn't until 2000 that a model was developed showing what happens in the sea lice gut as fish antibodies are ingested, degraded and used as nutrients. The diagram and data presented showed the internal structures of the sea lice gut, processes and gut environment as being low pH and high in salt content. Proteases used as part of the vaccine development like low salt conditions so that explains one factor in the lack of progress. Data also showed the relatively small amount of salmon blood ingested so parasite biology is very important to vaccine success.

The focus of work then changed to vaccination of salmon against the attached stages, Chalimus I & II. Inflammation response to sea lice attachment varies by species, with no response in Atlantic salmon and sea trout to a strong response in Coho salmon. Work began to investigate how the chalimus stages might be suppressing the immune response of the salmon and if there was anything in the saliva that could be identified. Chalimus have well developed salivary glands, so thousands were harvested, and their saliva analyzed. MALDI TOF analysis identified 13 potential antigens then amino acid sequencing of these proteins were used to predict gene sequence. From this process, eleven experimental vaccines were developed.

Fish trials indicated a good immune response and data provided showed that the antigens in the recombinant protein vaccines did induce an antibody response in the fish. A significant reduction in lice was seen in two formulations, with 31% and 33% reduction in chalimus, observed in a lice challenge post vaccination. Data presented indicated that Vaccine 1 is stimulating the mediated immune response, while Vaccine 2 is neutralizing the immunosuppression caused by the sea lice saliva. Most parasite vaccines are about 40% effective so sea lice vaccine trials are doing well. Testing is ongoing.

Presentation Available Upon Request

<u>Ian Bricknell</u>
Dr. Bricknell is a Libra Professor of Aquaculture Biology in the School of Marine Science and an active member of the Aquaculture Research Institute at the University of Maine. Ian joined School of Marine Science from his position as Group Leader, Immunological Diagnostics in the Fisheries Research Service Laboratory, Aberdeen, Scotland. He works on the developmental immunity of larval fishes and with host-pathogen interactions. His interests include: the interaction of parasites with their host and the mechanisms they employ to avoid the host's defence mechanisms; immunological detection of fish diseases; the development of the immune system of larval fishes and the onset of immunocompetence;

and, the mechanisms that larval fish use to contain or resist infection. His current project includes a new Patent for sea lice vaccines and a new project looking at mucosal vaccination of fish.

Impact of Different Benzoylphenylureas Across Various Life Stages of *Lepeophtheirus Salmonis*
-presented by Dylan Michaud, Atlantic Veterinary College, UPEI

Benzoylphenylureas (BPUs) are chitin synthesis inhibitors which disrupt the normal functioning of the ecdysis pathway resulting in an inability for a chitin-using organism to successfully moult to the next developmental stage. Chitin synthesis inhibitors are thought to directly impact the chitin synthase 1 (CHS1) gene of terrestrial arthropods, however we have demonstrated *L. salmonis* CHS1 does not appear to be influenced by various BPU treatments. Thus, BPUs are of particular interest as not only do they appear to operate differently within copepods, but they are also currently the only chemical class to which resistance has not yet been described in a louse species (*L. salmonis*/*C. rogercresseyi*).

The aim of this research was to characterize the chitin synthesis pathway of *L. salmonis* and utilize RNA sequencing on lice exposed to three different BPUs to aid in the elucidation of their mechanism of action in copepods.

Double-stranded RNA was prepared for nearly all enzymatic steps of the *L.sal* chitin synthesis pathway (CSP). Reduced expression of *LsGFAT, LsCHS1* and *LsCDA5* resulted in complete abrogation of the CSP and of infectivity potential. RNA sequencing was used to determine if various BPUs elicit differing transcriptomic signatures within *Lsalmonis.* Copepodids were exposed to two different concentrations of Lufenuron (50 and 1500ppb), Hexaflumuron (1500ppb) and Teflubenzuron (1500ppb) and dimethyl sulfoxide (DMSO) as the solvent and control. A subset of copepodids were sampled 24 hrs post BPU exposure and the remaining lice were used to infect Atlantic salmon (*Salmo salar*) and subsequently enumerated and sampled 3, 7- and 14-days post infection. Both concentrations of Lufenuron and Hexaflumuron significantly reduced lice numbers on the host and all BPUs appeared to reduce the rate of development compared to the DMSO control. RNA sequencing revealed surprisingly few transcripts were perturbed by BPU treatment many of which were shared between BPUs and concordant in differential expression. Furthermore, few transcripts from within the CSP appear to be influenced by differing BPU treatments supporting the hypothesis of a taxa-specific response in copepods. Lastly, the Lufenuron 1500ppb treatment had a significantly increased number of unique transcripts differentially expressed, only 55% of which are annotated.

Elucidation of the chitin synthesis and degradation pathway of *Lsal* will be essential for continued sustainability of salmonid aquaculture industry as currently the only chemotherapeutics with no described resistance in lice are BPUs. Furthermore, identification of the difference in the MoA of BPUs between Insecta and Copepoda (e.g., as *LsCHS1* and *CrCHS1* are not differentially expressed in response to BPUs) will crucial for resistance screening and management strategies. Additionally, a clear understanding the CSP in copepods will generate multiple targets for novel therapeutic discoveries.

Presentation Available Upon Request

<u>Dylan Michaud</u>
Dylan Michaud is a PhD candidate at the Atlantic Veterinary College under the supervision of Dr. Mark Fast. Dylan completed his BSc with honours and a specialization in biology at the University of Western

Ontario where his undergraduate projects primarily focused on immunology and genome evolution. Dylan's current research projects involve the salmon louse (*Lepeophtheirus salmonis*) an ectoparasitic copepod which parasitize both wild and farmed Atlantic salmon (*Salmo salar*). He utilizes multiple molecular techniques such as qPCR and RNA sequencing to investigate the chitin synthesis pathway and the impacts of benzoylureas (a chitin synthesis disrupting chemical class) across various life stages of Lepeophtheirus salmonis.

Tracing the Development of The Warm Water Shower Technology to Manage Sea Lice Infections in Atlantic Salmon Farming
-presented by Shawn Robinson, DFO- St. Andrews Biological Station

While it is intuitive that the abundance and survival of a cohort of larvae (nauplii etc.) is related to the future number of adults that ultimately develop to infect the fish and create sea lice populations, there is exceedingly little information on sea lice early life history stages in nature. In 2010, an Integrated Multi-Trophic Aquaculture (IMTA) project showed that while shellfish (mussels) had the ability to eat sea lice larvae, plankton samples showed larval sea lice densities less than 1 larvae /m3 at farms and reference sites while other similarly sized zooplankton were typically seen at densities over 10,000/m3. This implied that shellfish would have to eat a lot of zooplankton before they significantly affected the sea lice densities. Therefore, they were not going to be a solution to the sea lice problem.

It was identified from all the sampling effort that farms were point sources of sea lice release when activities such as harvests were performed without the benefit of sea lice collection processes or equipment that became overwhelmed with the water flow. Results showed that larvae densities were very high during harvest, but the day after harvest or other activities were complete, the larval densities were back down to reference levels. The question of where the older, infective larvae were going was highlighted.

The research and development of an alternative sea lice removal technology using a warm water shower technology was initiated in 2014. The laboratory results at SABS indicated the warm water shower was extremely effective and removed approximately 95% of all the mobile sea lice from the fish with virtually no mortality to the fish. Changing parameters such as the salinity of the spray did not make any difference to the already high removal rate. Evaluation of the first field version of the warm water prototype showed that a lot of lice were being lost from the initial dewatering point through the lice filter bag prior to the warm shower system decreasing the overall capture efficiency. The 2nd prototype (CookeR) had increased filtration capability at the dewatering points which effectively solved this problem. The slope of the slide was adjustable and could be set to maintain contact by the salmon with 32-34 °C water for 25-30 seconds.

Ongoing research is now evaluating the potential for sea lice to develop thermal tolerance to the temperatures used in the warm water shower. This research is examining whether the removal efficiency of the warm water shower goes down over time due to the development of genetic resistance by the sea lice to warmer water. If there is a decrease over generations, then the rate at which that happens will allow for the calculation of the lifespan of this technology, as it would ultimately become ineffective at some point.

The efficiency and relative ease of the warm water shower technology has some implications for regular sea lice counting operations on the farm. To make counting more objective and easier for the site workers when the weather is adverse or lice numbers are high, a portable warm water shower is being developed that can fit on a working skiff. Fish can be easily put through the shower and the sea lice that are removed are captured on a sieve that can be taken back and counted more comfortably on one of the tender vessels.

Presentation Available Upon Request

Shawn Robinson

Dr. Shawn Robinson has been working as a research scientist since 1988 with the Dept. Fisheries and Oceans at the Biological Station in St. Andrews, New Brunswick. He is also currently an adjunct professor at the University of New Brunswick and works closely with several other international colleagues. He is actively engaged in applied ecological research on a wide range of marine invertebrate species such as blue mussels, sea scallops, sea urchins, sea cucumbers, soft-shell clams, worms, sea lice and marine bacteria. His research team is studying the natural ecological processes by which these animals interact and utilise their environment so that better management decisions can be made and more sustainable culture techniques can be developed; such as the concept of integrated multi-trophic aquaculture or IMTA for example.

Connecting Farms to The Future - Automated Sea Lice Counting, And Machine Learning
-presented by Tim Kniffen, Merck Animal Health

The future of animal protein production includes the increased use of technology, increased monitoring and increased early intervention to potentially avoid various fish welfare issues. Animal Health Ventures, an investment arm of Merck Animal Health, has the key mission of addressing unmet customer problems and needs. One of the first challenges being addressed with technology is sea lice counting. Counting and monitoring sea lice has various challenges associated with it including the frequency and stress of fish handling, the accuracy of manual counts, and ensuring the sample being representative of fish in the pen. AHV has developed the Falcon which is ultimately a platform for monitoring many things within a pen of farmed salmon, including sea lice. It provides visualization and connectivity, connecting to the internet for access to real-time data for machine learning.

Development of the technology started in 2015 as an internal project using a bike tire rim that fish swam through with four Go-Pro cameras with version 2 evolving to a strait structure, high end diver's camera and bright lighting which caused poor image quality. Version 3 had many updates including optimized lighting package with horizontal and vertical LED lights, a motion detector, high-res camera and range finder. Unfortunately, this version was not sturdy enough for the farm and with lots of protruding pieces that could potentially create holes in netting it was not practical. The fourth and current version of the Falcon is cage friendly with a curved structure and ability to run 24 hours per day if required. It can be programmed to run at certain times, certain days or at night, and / or to collect a certain number of fish images. The high definition cameras will take multiple pictures of a fish and AI chooses the best quality one for sea lice enumeration. The lights are focused up and down to get the best picture.

Our proprietary machine learning algorithm then reviews and annotates those images to deliver results that are stored in the Cloud so that you can access them from wherever you are. Lice and fish must be annotated by 3+ trained humans, and then reviewed by an expert before being added to library, allowing for continuous improvement and machine learning. The Falcon allows for increased sea lice counts compared to manual events and farmers can see thousands of fish instead of only twenty. Production managers can view data from multiple sites in a simple user interface and output dashboards.

Initial findings from the Institute of Marine Research in Norway indicate that the Falcon system is capable of imaging and counting mobile and adult female lice, with increased accuracy over time expected as detector is improved and developed. The Falcon system is also not dependent on being used to count at a specific time of day.

Timothy S. Kniffen,

Dr. Tim Kniffen was raised on a family farm in the state of South Dakota that produced beef cattle, swine, and row crops. Tim graduated from the University of Illinois College of Veterinary Medicine in Urbana-Champaign and then completed a master's degree program in clinical medicine. Subsequently, Tim worked with food animals in private veterinary practice and integrated production systems and particularly enjoys food animal production system medicine and management. Tim has been a technical services veterinarian in Merck Animal Health's North American Aquaculture Business Unit since 2015.

Ocean Hydrodynamics and Sea Lice Management – How do we validate a model? Including Results from Fish Farm Drifter Releases

-presented by Fred Page, DFO-St. Andrews Biological Station

Models simulating the growth, reproduction, mortality, transport, dispersal and infection of sea lice are tools that, when calibrated, validated and used appropriately, can be useful for developing understanding of lice population and infestation dynamics. Models make predictions (qualitative and quantitative) such as the rate of sea lice exchange between aquaculture farms, the exposure of wild organisms to lice associated with the farms and the effectiveness of particular sea lice control measures and management strategies.

Lice models contain several components including biological, oceanographic and linkage sub models. The biological sub model(s) may include lice growth, reproduction, survival, behaviour, and sensitivity to management measures. The oceanographic component may include a hydrodynamic model or output from a separate hydrographic model. The hydrodynamic model is a numerical estimate of the spatial and temporal pattern in sea level, water current velocity, water temperature, water salinity and surface waves. The linkage component may include an individual based particle tracking model. The output from the hydrographic model is linked to biological lice growth and behaviour models to estimate the life stage and location of lice in space and time.

Like all models, lice models are simplifications of the real situation and range in complexity. For example, hydrographic models may be relatively simple and idealistic representations of situations to four dimensional (x,y,z,t) hindcast, nowcast and forecast data assimilation models that estimate real water velocity and water properties for specified periods of time.

Model outputs also have uncertainty and bias associated with them. Understanding and quantifying the model components, uncertainties and biases is an important component of model building and is essential to an informed use of a model for a particular purpose. Uncertainty and bias in models stem from multiple sources including those associated with the model itself and those associated with inputs to the model. Model uncertainties are associated with aspects such as simplifications and parametrizations, gaps in understanding, inadequate resolution. Coding and input uncertainties are associated with aspects such as initial conditions and external drivers of the models. The magnitude and form of uncertainty and bias differs between components while quantification of the uncertainty and bias is often lacking in model implementations.

Hydrodynamic model outputs are sensitive to the completeness of the physical processes included in the model and to the input forcings (e.g. tide, wind, river runoff, offshore flow, atmospheric heat-flux, air pressure) used to drive the model. The processes and inputs need to be appropriate to the situation being considered. The hydrodynamic and particle tracking outputs may also be sensitive to the spatial and temporal resolution of the model. In the coastal zone, where net pen aquaculture and the associated lice dynamics take place, hydrographic properties vary on small spatial and temporal scales so realistic modelling of site specific scenarios often needs a spatial resolution of 10-50m in the horizontal and 1m in the vertical, and temporal resolution of seconds to minutes.

To help ensure a model is appropriate for a specific task, the validation process needs to include checking if the model code contains all the necessary processes, they have been parameterized and coded properly and that assumptions are identified and understood. Test cases with known outputs need to be used to ensure the code is stable and gives reproducible results.

Models implemented in an attempt to simulate the lice dynamics of a specific location and situation should be calibrated and validated for the unique purpose and area. Calibration and validation require site specific information as well as evaluation of the processes contained within the model in relation to the specific objective(s) of the model implementation. Because a model name or type is recognized, has a good reputation and gave acceptable results in other implementations, does not guarantee it will give acceptable results for the present or next application / location.

Validation of hydrodynamic and trajectory models is challenging; it requires time series of current speed and direction at multiple horizontal locations and heights above the seabed. Most models of tidal currents often agree to within a few cm/second. Validation also requires information on horizontal and vertical mixing rates and rates of exchange between cages and the ambient environment. Work using dye tracers has shown that the flushing from cages and cage arrays is complicated; the outflow from one cage may be inflow to an adjacent cage, and the rate of flushing time of a cage may range from a few minutes to 2-3 hours. Although this information is useful for validating hydrodynamic models, the degree to which the dye represents lice transport and dispersal depends on the degree to which dye mimics lice behaviour.

Validation of trajectory models is also challenging. Often model predictions are compared to the trajectories of various surface and sub-surface drifters and dye. Work focused on implementing and testing models meant to simulate hydrographic and drift scenarios in the southwest New Brunswick area has suggested surface drifters often over-estimate distances travelled by dye and that models calibrated for one location does not imply accurate simulation of another region within the same model domain. The comparisons sometimes illustrate that model-observation differences may be related to differences in drifter design as well as model inaccuracies. Although the comparisons are useful, they are based on the limited behaviour of drifters and dye and one needs to consider how well drifters and dye mimic the behaviour of lice.

Although calibration and validation of models is essential, there are presently few, if any, extensively evaluated models (i.e. model evaluations that cover a wide range of space, time, location, input and issue scenarios); this may be related to the difficulties and costs associated with calibrating and validating models and to the relative immaturity of model development. Even with a perfect hydrodynamic model, given the uncertainties in sea lice biology, model results concerning sea lice dynamics should be considered cautiously. Work at DFO is continuing to evaluate hydrodynamic and trajectory models implemented to simulate various scenarios of relevance to the southwest New Brunswick area.

Presentation Available Upon Request

Fred Page

Dr. Fred Page is a research scientist within the Ocean Coastal Ocean Sciences Section of the Department of Fisheries and Oceans located at the Biological Station in St. Andrews and has been the Responsibility Center Manager for the Section and the Director of the DFO virtual national Center of Integrated Aquaculture Science (CIAS). He is a member of the DFO-NBDAFA Memorandum of Understanding Aquaculture Environmental Coordinating Committee (AECC) and a frequent scientific advisor to the salmon industry and government regulatory bodies (NBDAA, NBDENV, DFO Habitat) on oceanography in the area and aquaculture interactions. He is a bio-physical oceanographer specializing in the investigation of linkages between the physical characteristics and processes of the coastal and shelf seas and their living resources. He has been actively involved in the development of aspects of the environmental monitoring program for the salmon industry in SWNB and is presently evaluating the DEPOMOD model for its usefulness in indicating sulphide levels in the vicinity of some salmon farms in SWNB.

Oceanographic Tools to Predict Sea Lice Infestation risk

-presented by Jon Grant, Dalhousie University

Models are used to address regulatory issues of sustainability including particulate waste, pesticide dispersion and infection risk. The Finite Volume Community Ocean Model (FVCOM) is one of the physical models that are the basis of most predictions in the ocean (currents, winds, tides) to move particles around. When these models are being used for regulatory advice purposes, after the output results are provided and translated, the aim would be to leave the model behind.

Lagrangian analysis of the output of ocean circulation models allows that particles follow the fluid, but particles have no behaviour, so for an epidemiology model this lack of biological parameter in the model means that it does not include the decrease in particle number due to mortality, etc. Movies of trajectories are only a single indication of infestation risk so the ability to provide advice based on results on only a physical model is conservative. Risk decreases by having biology in the model.

Graphed data provided showed the difference in particle density using a physical model versus a model with mortality and maturation parameters included and showed how a bio-physical model can quantify connectivity between farms. Questions remain such as how much variation should be expected in farm connectivity as a result of weather and seasonal changes, how the time scale relates to the life cycle of different parasites and pathogens, and what measures are used to deliver advice. Results from a particle tracking experiment at one farm location were provided from times of low and high wind showing the significantly different trajectories and therefore connectivity. To use connectivity for any regulatory advice, measures such as particle concentration and residence time or how long particles spend in each location must be evaluated.

Farm Interactions with Natural Systems (FINS) is a mapping framework for farm siting and management being developed with collaborators in the United Kingdom. It integrates output from FVCOM, but there is the ability to move farms around by dragging and inserting new farms. Its initial submodel is ORGANIX which predicts farm deposits to sediments and then the DIAGENIX submodel predicts sediment sulfides. Graphics provided showed how the organics sedimentation model and import tools function. This model might be an appropriate base on which to add a sea lice infection risk model.

Presentation Available Upon Request

Jon Grant

Jon Grant is the NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture, a multi-year partnership with Cooke Aquaculture. He is a Professor of Oceanography at Dalhousie University. Trained as a benthic ecologist, he has a BSc from Duke University and PhD from the University of South Carolina. Jon has worked in aquaculture-environment interactions for 30 years and is co-editor of a new book entitled "Goods and services of marine bivalves". Working with both the shellfish and finfish farming industry, Jon has pioneered concepts and tools for assessing carrying capacity in field culture. This work has led to rigorous application of ecosystem-based management, marine spatial planning, and epidemiological approaches to aquaculture, including incorporation of ocean technology, remote sensing and GIS. Jon led the development of the Aquaculture theme in the new Ocean Frontier Institute, the largest marine science initiative in Canadian history

Developing an Understanding of the Early Life History Population Ecology of Sea Lice (*Lepeophtheirus salmonis*) In and Around Atlantic Salmon Aquaculture Sites in the Bay of Fundy
-presented by Jonathan Day, DFO-St. Andrews Biological Station

The planktonic larvae of sea lice have 2 different life history stages, nauplii (non-infectious) and copepodid (infectious). Both stages drift in the plankton, have temperature dependent development, live off internal energy reserves that were provided by their mother and as a result, have a limited amount of time to find a host. The planktonic phase of a cohort is the most abundant and small changes in its survival could have large effects on the later sea lice cohort. New Brunswick's aquaculture industry has an ongoing sea lice infestation cycle and, although we don't completely understand it yet, a physical process must exist for these cycles to persist. Research is being conducted to understand what processes are maintaining sea lice populations on salmon farms in New Brunswick.

Previous work has shown that farm locations have substantially more larvae (0.65 larvae/m3) than reference stations (0.08 larvae/m3) with nauplii comprising most sea lice larvae captured on salmon farms (93%) compared to copepodids (7%). Research studying dilution rates around salmon farms were conducted with aerial drones tracking a tracer in the water and showed that dilution occurs rapidly (up to 80% in 15 meters). It is quite likely that sea lice larvae are also being diluted at these rates with densities dropping quickly as they move away from the farm. In general, the larvae are being diluted by an order of magnitude every 100 meters.

Recent work has involved intensive sampling within and around salmon farms in southwest New Brunswick. The analysis revealed that all sites had similar patterns: mostly nauplii on farms, whose distribution is random and patchy, but highest adjacent to cages. Lower numbers of larvae were found at reference locations and were mostly copepodids. Since nauplii molt to copepodids in 2-3 days at 10°C, the question of where all the copepodids were still remained.

The research extended its scope and began searching for sea lice larvae on shorelines around the farms. This proved very successful. In an initial survey at one farm site in July, there were no mobile lice present on the fish during commercial counts, but larval copepodid densities on shore were more than ten times higher than those usually found on farms. Copepodid sea lice larvae were found up to 600m away from the farm and in far higher concentrations that would have been predicted by the dilution calculations. More intensive shoreline sampling was undertaken in 2019 at two salmon farms, the first being the same farm as the previous year (now in its second year of production) and a farm in a different bay management area during its first year of production. Most of the sample analysis is still pending, but initial results of a single date from the second farm in its first year of production showed that copepodid sea lice densities were significantly higher in samples on shore than those in the mid-shore or farm.

If infestations on farms are self-sustaining, then physical retention mechanisms must be present, otherwise the larvae would be swept into the open ocean and the population would slowly decline. This research is showing there are certain shorelines which possess physical traits that concentrate particles, and larval behaviour can likely enhance larval retention in these shorelines. Data from drifters and current meters are currently being analyzed to evaluate the shoreline transport mechanisms present at farm locations. As this work continues, the information will have implications for site selection, bay management, and may provide opportunities for a new early-warning sea louse monitoring system.

Presentation Available Upon Request

Jonathan Day

Jonathan Day (BSc.) is currently a biologist working for the Department of Fisheries and Oceans and completing his master's thesis with the University of New Brunswick on novel approaches to monitoring the environmental effects of salmon aquaculture. Since moving to St Andrews in 2011, Jonathan has had the opportunity to work on a wide variety of research projects related to aquaculture operations and how they interact with the marine environment. Since 2016, Jonathan has been working on a project in the Robinson lab at the St. Andrews Biological Station with the Aquaculture Collaborative Research and Development Program (ACRDP) to study the early life history ecology of sea lice (L. salmonis). During that time Jonathan has made key observations and discoveries that are starting to influence the way we approach managing sea lice.

Sea Lice Data – Current Uses & Future Possibilities in Atlantic Canada

-presented by Larry Hammell, Atlantic Veterinary College, University of Prince Edward Island

The Fish-iTrends (FiT) Decision Support System was created by the Atlantic Veterinary College (UPEI) for industry to assist with sea lice management data collection and analysis. Examples of various data outputs were presented including graphs for Atlantic Canada site reporting since the inception of the FiT, average sea lice burden by production cycle, and sea lice numbers and trends by BMA.

Since FiT currently has the data to provide outcome (lice count) trends and track movement of fish groups, there is the capacity to increase the data collected in order to provide other potentially important trend information such as cleaner fish health tracking. With more frequent sea lice counts and / or counting lice on more fish, FiT could be used to investigate impacts of neighboring cages, while inclusion of individual fish characteristics of fish used for lice counts could be used to evaluate associations for susceptibility to sea lice.

In providing historical and current data regarding the number and type of sea lice bath treatments, it was shown that starting in 2018 and continuing through 2019, there was a significant reduction in medicinal bath treatments in favour of warm water or water pressure treatment systems. The FiT program has built-in capacity to include hatchery treatment and cleaner fish data in addition to the marine treatment data.

Treatment efficacy, specifically for adult female removal as an example, was presented by product. Paramove continues to have variable results with approximately 21-24% of treatments experiencing only 80% removal of adult females over the past three years. Only 10-20% of Salmosan of treatments have 95% removal. Data for the Warm Water treatments showed approximately 56% of treatments had 20% adult females remaining on the salmon and the HydroLicer is similar with approximately 61% of treatments having 20% adult females remaining after treatment. This low removal could potentially promote resistance since 95% (or more) removal should be the target to reduce the reproductive success of lice with greater tolerance to any treatment. There is a need to examine variables contributing to treatment responses resulting in highly variable treatment success (relative change pre / post counts). As well, lice resistance trends should be incorporated into the industry lice monitoring programs.

Annual sea lice trends in 2019 were in the middle category of lice burdens, similar to 2012, 2017, and 2018. In other words, there have been worse years (2010, 2015, 2016) but there have also been substantially better years (2011, 2013, 2014). Marine chemical treatments (both in-feed and bath) were used with reduced frequency which may be partially attributable to hatchery treatments. Data are rigorous over time for count averages and pre/post treatments but much more can be done to boost predictor data, and more data is needed for resistance monitoring and predicting, while changing treatment practices require constant adaptation in the data management system.

Presentation Available Upon Request

Dr. Larry Hammell
As an aquatic veterinary epidemiologist, Dr. Larry Hammell has been the lead proponent on many large, clinical research projects and partnerships with industry and government agencies. Dr. Hammell's research focuses on aquatic food animal health studies including disease detection and surveillance, health management through identification of risk factors and disease prevention and biosecurity studies, and clinical trials for improved responses to disease treatment and prevention. Currently the Dean (Interim) of the UPEI Faculty of Graduate Studies & Research, he is also Professor and Associate Dean (Graduate Studies & Research) at the Atlantic Veterinary College, University of Prince Edward Island, and Co-Director of the Collaborating Centre for Epidemiology and Risk Assessment of Aquatic Animal Diseases (ERAAAD) for the World Organisation for Animal Health (OIE).

Sea Lice Regulation in the Scottish Farmed Salmon Sector
-presented by Iain Berrill, Scottish Salmon Producers' Organisation

Lice counts have been undertaken voluntarily on Scottish salmon farms for many years as it is a vital part of fish health management. It wasn't until 2006 that the process was formalised as part of the sector's Code of Good Practice Standard (CoGP). This is still voluntary but 100% of the sector is participating. The CoGP includes guidelines for lice counting and management, with the requirement to provide farm data to the SSPO and sets guidance to support treatment decisions. This treatment guidance revolves around preventing the escalation of adult females adjusted to the time of year. From February 1st to June 30th, the suggested criteria for treatment is an average 0.5 adult females per??? with the criteria increasing to an average of 1 adult female from July 1st to January 31st.

The Aquaculture and Fisheries (Scotland) Acts of 2007 and 2013 address sea lice management requiring farms to collect and store information as well as giving the regulator the right to carry out inspections. The Record Keeping Order of 2008 also requires farms to hold a range of information which may be audited using "enhanced" inspections. Those inspections draw from standards within the CoGP.

SSPO initiated public reports starting with area-based reporting in 2010. The average adult female level for 6 areas of Scotland were made available. 2013 saw the move to more focused regional reporting with 30 region reports developed with additional information that focused on wild / farmed interactions. The SSPO agreed in 2018 that the reporting commitment would be to publish data for each farm, providing a monthly average weighted by fish number. At that time the data was "lagged" by 3 months but commencing in 2019 that has been reduced to a 1-month lag.

In April 2017, a new regulatory framework for sea lice management was initiated but its approach is quite complex as it refers to a "Reporting" level of an average of 3 adult lice per fish and an "Action" level of an average of 8 adult lice per fish. A diagram from Marine Scotland was presented to illustrate the enforcement decision process indicating the need for an action plan above the reporting level, and when enforcement notices may be issued depending on the time taken to reduce the sea lice average below the action level.

In 2019, Marine Scotland and the Scottish Government undertook a review of this enforcement regime, and the aquaculture sector requested that levels be reduced to an average of 2 adult females for reporting and an average of 6 adult females for the action level. An updated enforcement diagram for the Sea Lice Policy was presented.

Sea lice data was provided for 2013 to 2019 and showed the continued variation in sea lice numbers indicating the difficulty in determining if the regulatory framework has helped reduce lice levels. The downward trend started in 2016 and it is likely the results of the additional tools the salmon industry gained for sea lice management. However, it was noted that the regulatory framework does keep pressure on the sector for continuous improvement and innovation. For this improvement and innovation to happen there must be support for the sector in the development of tools and medicines, and the flexibility and time for new tools to work.

<u>Iain Berrill</u>
Iain Berrill is currently the Head of Technical at the Scottish Salmon Producers' Organisation (SSPO). He has worked for the SSPO for over 9 years and was initially brought into the company to set up and manage an industry fish health database. Since then, Iain's role and responsibilities have expanded greatly, and he now provides technical input into all aspects of the company's activities. Iain is a Director

and Trustee of the Scottish Aquaculture Research Forum (SARF), a charity set up to provide funding support for research relating to Scottish aquaculture. He also a Steering Group member of the multinational Gill Health Initiative and a member of the Scientific Advisory Board of ARCH UK, a network that supports aquaculture research in the UK. Before working for the Scottish salmon farming sector, Iain had a short career in academic research then undertaking various studies surrounding farmed fish welfare, at Institute of Aquaculture in Scotland. He holds an undergraduate degree in Marine Biology from the University of Swansea and a master's degree in Applied Fish Biology from the University of Plymouth. He also holds a PhD from the Institute of Aquaculture in Stirling.

Management Thresholds and Other Factors Influencing Variation in Salmon Louse (Lepeophtheirus Salmonis) Abundance on Farmed Salmon in British Columbia
-presented by Simon Jones, DFO - Pacific Biological Station

Marine cultured salmon is British Columbia's largest agriculture product with a value of CAD 728 million and 85,608 tonnes produced in 2017. The industry is scrutinized by NGOs, the public, and government over the potential for interactions with wild salmon and other impacts to coastal ecosystems so the conservation of wild salmon is an important driver of sea lice management regulations in BC.

DFO issues licences for marine finfish aquaculture in BC with licence conditions including the requirement for a Health Management Plan, as well as requirements for sea lice monitoring. A management threshold of 3 three motile (pre-adult and adult) lice per fish was established in 2003 for Atlantic salmon farms. There was no scientific basis for this threshold, it was chosen as a precautionary management level while more data are collected. Counts are completed every 2 weeks during the wild Pacific salmon outmigration between March 1 to June 30 and monthly for the remainder of year. For counts exceeding the threshold during the outmigration period, licence holders are required to act (e.g., treatment, harvest) to lower sea lice numbers. Sea lice data are posted publicly.

DFO conducts quarterly sea lice audits with 50% of all active Atlantic salmon farm sites audited in the outmigration period and for the remainder of year there is 1 audit per zone on randomly selected sites chosen for fish health audit. The audit includes an assessment of industry's counting sensitivity, sampling procedures and records with audit results posted publicly.

The coast of BC is divided into seven fish health management zones. Data provided covering 2011 to 2016 provided a timeline for sea lice abundance, treatments and the timing of the fall wild Pacific salmon returns in relation to the management threshold. The Chum and Pink salmon are carrying a lot of lice when they return, and some of these lice or their progeny are transferred to farms. Data provided for each fish health zone showed how each zone is distinct regarding sea lice abundance due to differences in salinity, water temperatures, and wild salmon populations. Even which Pacific salmon species is dominant in the area i.e., Pink versus Sockeye was identified as a factor in sea lice abundance in the various fish health zones due to differences in sea lice susceptibility. Data for the estimated abundance and diversity of Pacific salmon by management zone (CPUE = salmon/vessel-day; 2005-2015) was provided.

Graphical data indicating the amount of active therapeutant used per tonne of salmon produced since 1996 was provided indicating that the amount used has increased since the inception of the 3 lice per fish threshold. Aquaculture licences state that when the threshold of three motile sea lice has been exceeded, the licence holder must implement a plan within 15 calendar days which will reduce the absolute sea lice inventory within the farm. As in the Atlantic region and in farming areas globally, SLICE (emamectin benzoate) resistance has now been documented in four areas in BC. Limited access to a wider range of medicines and therapeutants, and the lack of cleaner fish technology are challenges for the BC industry. Options being considered for future sea lice management in BC seek to minimize egg output per farm/area, while minimizing treatments. For example, area-based management with locally relevant outmigration periods or management thresholds.

In the future, area-based sea lice management in BC that is based on hydrological connectivity of farms and tailored to area-specific out-migration periods should be considered. The opportunity exists for the integration of wild salmon sea lice datasets.

Presentation Available Upon Request

<u>Simon Jones</u>
Simon completed his B.Sc. in Marine Biology and went on to obtain his M.Sc. and Ph.D. in aquatic parasitology from the University of Guelph. He took up an NSERC-funded postdoctoral fellowship in fish immunology at Wageningen University in the Netherlands. He then spent 8 years researching the development of commercial vaccines for use in salmon aquaculture against piscirickettsiosis, infectious salmon anaemia and cold water vibriosis, among others. In 2000, Jones accepted a research scientist position with DFO at the Pacific Biological Station in Nanaimo where he now leads the Marine Parasitology Program. Currently, he is interested in disentangling the roles of environmental, host and infectious factors in the occurrence of proliferative gill disease, which is emergent and of considerable significance to marine cultured salmon in BC. His long-term interest in salmon lice seeks to better understand mechanisms underlying the highly variable susceptibility to sea lice among species of Pacific salmon and the significance of the three-spine stickleback to the ecology of salmon lice in western Canada. In addition, he plays a central role in ongoing efforts to advise the Federal Government on the likelihood and consequences of risks to wild salmon in BC posed by infection and disease in marine-reared Atlantic salmon.

The Traffic Light Sea Lice Model – An Appropriate Tool to Regulate the Production?
-presented by Jon Arne Grøttum, Norwegian Seafood Federation

Sea lice are a challenge for the animal welfare of aquaculture salmon and for the possible negative effect on wild salmon. The strategy of the industry is to maintain a consistently low level of sea lice on farms to keep levels low which means less impact on neighbours and fewer treatments. Practically, sea lice regulate the production of salmon in Norway. There is legislation which defines a maximum level of sea lice on the sites as 0.5 adult female per fish, and regulation of the production capacity of farms is based on a traffic light system. The purpose of this system is to enable predictable and sustainable growth using environmental impact as a regulator for growth, specifically the effect of salmon lice on wild salmon stocks.

Each production license is connected to one production area of the 13 coastal areas in Norway, with the environmental impact in each production area evaluated as acceptable - green, moderate - yellow, or unacceptable - red. These evaluations / colours reflect the estimated wild salmon mortality in the production area of less than 10% mortality of wild salmon, 10%-30% or above 30% mortality and each require different responses by regulators and farmers.

There are several challenges to this type of system starting with a high degree of uncertainty at each step within the model used to run the traffic light system and the lack of appropriate methods for model validation. Validation attempts continue by trawling for salmon and counting lice which raises concerns about catching weaker fish etc. Sea lice data from captured rainbow trout is being used to validate the model as well, though they have different life histories.

The system is very complex, providing less flexibility for farmers and serious economic and social consequences for areas determined to be in the red zone, which impacts every farmer regardless of individual sea lice monitoring results / management. There has not been any verification of the effect of smolt mortality on the salmon population, so there are questions to what a 30% mortality level would mean to wild salmon population.

At its core, the traffic light model assumes that sea lice are causing a certain effect on the wild salmon mortality. References for papers involved in salmon research were provided that indicate that if 100 salmon leave the river, 95 will die in the sea even if no sea lice existed in the marine environment. Of the estimated 4 fish which return to a river, two will be caught by recreational fishermen or through the harvest of other wild fish. Another paper referenced provided an estimate of the effect of sea lice on salmon in Ireland using 56 experimental groups from 2000 – 2009. The wild salmon population data showed a continuous decrease throughout this survey period independent of the sea lice level within the farming industry, and at a rate as much as ten times greater than the detectable effect of sea lice on the salmon population.

Data provided for the nominal catches of salmon in the North Atlantic from 1960 to 2008 for nine countries showed the significant decline in salmon numbers starting around 1988-89, without any relation to changes in the aquaculture industry. In fact, the decrease was highest for countries without any aquaculture activity. Also, that the number and proportion of populations reaching their management targets in 199 rivers in Norway have increased markedly from 2006-2009 to 2015-2018 survey periods.

The industry agrees to be regulated based on environmental indicators, but this must be based on a better understanding of the effect on the social, economical and environmental sustainability.

Presentation Available Upon Request

Jon Arne Grøttum

Jon Arne Grøttum is the Director of Aquaculture for the Norwegian Seafood Federation. The Norwegian Seafood Federation represents the interests of approximately 550 member companies. The member companies cover the entire value chain from fjord to dinner table in the fisheries and aquaculture sectors in Norway. The federation promote policies and legislation that benefit the members, members interests regarding exports, trade and other international issues, and advise the member companies on a wide range of other issues. Grøttum is responsible for the activities in the federation related to policies and legislation within the aquaculture sector. He has a PhD in fish physiology/aquaculture and has in his former work as a researcher published several publications within topics related to fish metabolism, live transport of fish and land based fish farming.

Perspectives on The Sea Lice Thresholds and A Monitoring Plan for The East Coast
-presented by Shawn Robinson – DFO-S. Andrews Biological Station

Each of the Atlantic Provinces has had a slightly different developmental path with respect to sea lice infestations and as a result, farm management plans, pest management plans, fish health policies have slight differences. Sea lice monitoring on farmed salmon in the different regions is similar to each other and other parts of the world, but the data that result from this effort is more of a guideline than a predictive tool and is more important for fish welfare concerns. The problem is that we still don't know enough about the life cycle of the salmon sea louse with respect to salmon farms to predict the stock-recruitment relationship between the number of gravid females on a farm and the number of early juvenile sea lice returning to the fish.
A diagram was presented showing the evolution of the fish farming industry in the methods that have been employed to control pests. These are similar to the trajectories of agriculture and human health. Early strategies involve separation of the farms from pests, but as space becomes more limiting and the intensity of farming increases, chemicals based on natural products are used to kill the pests. Eventually, the pests develop a resistance to these chemicals and more sophisticated engineering techniques are employed. As the industry intensifies biotechnology becomes more prevalent as the animal and its physiology are adapted to new culture techniques. All of these components of development are paralleled in nature through evolution. Different areas of the world are on different parts of this continuum, including the Atlantic Canadian industry which is in the engineering/biotechnology stage.

The current monitoring strategy for sea lice management has certain limitations to the methodology as it relies heavily on visual observations of the various developmental stages of attached sea lice. The chalimus stage, the very earliest juvenile life stage attached to the salmon, is very small and can easily be underestimated or missed due to the eyesight of the observer and / or weather conditions. It is also difficult to count all the sea lice when numbers are high and there is obviously a limited time the fish can spend of water. This variability in the data creates problems for management as the warning sign of early infections is not always evident.

There are other potential methods for monitoring that may give more objective data on sea lice infestation cycles. These could include the use of a portable warm water shower, sampling the stomachs of sentinel shellfish that eat sea lice, light traps for sea lice larvae, high-tech computer aided counting cameras and genetic eDNA options to count larval stages. Data from a portable warm water shower that has been developed and used in the field in early 2019 consistently showed approximately 95-98% removal of the mobile sea lice on a fish and was easily handled from a commercial skiff.

The current state of knowledge on the spawner-recruit relationship for sea lice in the Atlantic provinces does not support the implementation of a sea lice threshold at this time, other than for fish health concerns. However, while the cause-effect relationships are not fully understood, this is improving through early life history field work and modeling.

Presentation Available Upon Request

Shawn Robinson

Dr. Shawn Robinson has been working as a research scientist since 1988 with the Dept. Fisheries and Oceans at the Biological Station in St. Andrews, New Brunswick. He is also currently an adjunct professor at the University of New Brunswick and works closely with several other international colleagues. He is actively engaged in applied ecological research on a wide range of marine invertebrate species such as blue mussels, sea scallops, sea urchins, sea cucumbers, soft-shell clams, worms, sea lice and marine bacteria. His research team is studying the natural ecological processes by which these animals interact and utilise their environment so that better management decisions can be made, and more sustainable culture techniques can be developed; such as the concept of integrated multi-trophic aquaculture or IMTA for example.

Genomic Analysis of Tenacibaculum Species Isolated from Both Canadian Coasts
-presented by Ahmed Siah, BC Centre for Aquatic Health Sciences

Infection with *Flexibacter* was first described in 1977 in Japanese flounder and sea bream with the species characterization and name, *Flexibacter maritimus*, proposed in 1986. Reference information from the Journal of Aquatic Animal Health was provided for the research that identified *F. maritimus* in British Columbia (BC) smolts reared in seawater between March 1994 and July 1995. Clinical signs were mainly focal yellow-colored plaques on the teeth and gums. Later, molecular analysis showed the detail of how this bacterium was re-classified from *F. maritimus* to *Tenacibaculum maritimum* in 2001.

The challenges to isolate this slow growing bacterium were discussed, only becoming somewhat described in 1996 when a marine media known as Flexibacter maritimus media (FMM) was developed. Salmon farming regions where *Tenacibaculum* has been found were identified along with pictures of moderate to severe clinical signs taken in BC mouth rot outbreaks. 2015 saw the first workshop dedicated to *Tenacibaculum* coordinated by the BC Centre for Aquatic Health Sciences. This health issue was costing the BC Atlantic salmon aquaculture industry approximately $3m/year and underlined the lack of knowledge about this bacterium.

Several diagrams, pictures and charts were presented to show the progress and results of *Tenacibaculum* isolation and sequencing work. Several local isolates of *Tenacibaculum species* have been identified in BC. Among the virulent factors, the *T. maritimum* from BC has the protein Internalin A, a virulence factor, which may play a role in host susceptibility to infection as shown in comparative studies with *Listeria* species. Information provided also showed that the isolates have antimicrobial resistance factors.

Work on *Tenacibaculum* lead to the first isolation and genomic identification of *T. finnmarkense* in BC as described in various charts, diagrams and graphs. Recent genome comparison work indicates that this isolate has genomic sequences related to the strain *T. finnmarkense* isolated from Chile. The BC strain causes mouth rot (yellow nodules) while the Nova Scotian strain typically only causes skin lesions. Genomic comparisons show Nova Scotian and Norwegian strains are similar. These *T. finnmarkense* isolates have gene encoding for resistance to tetracycline.

Presentation Available Upon Request

Ahmed Siah

As a Senior Scientist, Dr. Siah is leading numerous research projects at the BC Centre for Aquatic Health Sciences (British Columbia), 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 Prince Edward Island's Atlantic Veterinary College, he led and managed several projects on mollusk health management and the development of molecular diagnostic tools in salmonids. Dr. Siah is a well-published researcher in the field of fish and shellfish pathogens, their isolation, genomic sequencing and detection. His germane work in the area of genomics and bioinformatics has led to several advancements in the pathogen diagnostic capability in farmed and wild salmonids stocks.

Plenary Discussion - What are the R&D Priorities?

Additional research is needed on all fronts within the theme of fish health. There are still many questions around *Tenacibaculum*, the species and strains being found with various levels of pathogenicity. The multi-faceted challenges of sea lice remain a research priority, as well as the need for more and / or new tools and products. More work is need on sea lice vaccines, alternative treatments, and their effects on both the fish and sea lice. Hydrodynamic and sea lice models need further development to ensure the physics and biology are correct, and validation is required in each jurisdiction, relative to the information required and spatial scale. To aid with modeling in the Bay of Fundy specifically, more work needs to be completed on the shoreline collection and retention of larval sea louse stages.

Research that provides greater understanding of wild salmon migration and interactions near aquaculture sites can contribute to productive discussions and interactions with traditional marine users. Wild salmon smolt migration routes within Passamaquoddy Bay and potential interactions with salmon farms will continue as will work on smolt migration at sea and their marine prey items.

Research topics identified that were not part of the agenda themes included the freshwater health concern of Flavobacteriosis, and microbiomes in general. Technology developments present the ability to now find microbes at lower and lower resolutions, which could have various management implications.

Forum Wrap-up

Research and science remain essential to ongoing development of the aquaculture industry. It continues to provide the salmon farming industry and broader stakeholders with important information on a range of topics, while providing opportunities for collaborative projects intended to develop a sustainable industry in Canada. These include fish health, operational best practices, environmental monitoring as well as technological advancement.

The ACFFA is committed to continuing to work on behalf of our members to identify industry research priorities and facilitate collaborative research activities.

As always, we greatly appreciate the contributions of the public and private research community in supporting our annual forum.

PARTICIPANTS

Last Name	First Name	Company
ACHESON	JENNIFER	DEPT OF AGRI, AQUACULTURE & FISHERIES.
ARMSTRONG	TRAVIS	SKRETTING
BACKMAN	STEVE	SKRETTING
BARTLETT	CHRIS	MAINE SEA GRANT
BENFEY	TILLMAN	UNIVERSITY OF NEW BRUNSWICK
BENNETT	AARON	MOWI CANADA EAST
BERRILL	IAIN	SCOTTISH SALMON PRODUCERS ASSOCIATION
BERRY	NEAL	SIMCORP
BOURQUE	PETER	MITCHELL MCCONNELL INSURANCE
BRADFORD	HANNAH	FISHERIES AND OCEANS CANADA
BRAGDON	FIONA	DEPT OF ENVIRONMENT AND LOCAL GOV'T
BRICKNELL	IAN	UMIVERSITY OF MAINE
BRIDGER	CHRIS	HUNTSMAN MARINE SCIENCE CENTER
BURGETZ	INGRID	FISHERIES AND OCEANS CANADA
BURKE	MELISSA	DEPT. OF FISHERIES AND LAND RESOURCES
CALLAHAN	CYNTHIA	BIONB
CANAM	AMY	COOKE AQUACULTURE
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COFFIN	DAVID	FISHERIES AND OCEANS CANADA
COLLINS	JASON	BENCHMARK ANIMAL HEALTH
COOK	SARAH	SKRETTING
COOKE	TARA	KELLY COVE SALMON
COSTA-PIERCE	BARRY A.	UNIVERSITY OF NEW ENGLAND
CRANDALL	MARK	SEAPLAST
DAGGETT	TARA	SIMCORP
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DONKIN	ALAN	COOKE AQUACULTURE
DOUCET	RICK	AGW CONSULTING
DROST	TERRY	FOUR LINKS MARKETING LTD.
DULUDE	JULIE	CANADIAN FOOD INSPECTION AGENCY
ELSEMORE	MARSHALL	SIMCORP
EPWORTH	WENDY	FORT FOLLY FIRST NATION
FARHAD	AMINI	HUNTSMAN MARINE SCIENCE CENTER

FARQUHARSON	SUSAN	ACFFA
FILGUEIRA	RAMON	DALHOUSIE UNIVERSITY
FITZPATRICK	KAITLIN	KELLY COVE SALMON
FORWARD	BEN	RPC
FUERSTE	HEIDI	FUERSTE VACCINATION SERVICES CORP
GAGNE	JONATHAN	ENTREPRISES SHIPPAGAN
GAMEIRO	MARTA	ELANCO CANADA
GAMPERL	KURT	MEMORIAL UNIVERSITY - NL
GILLCRIST	ASHLEY	JEFO NUTRITION INC.
GLEBE	BRIAN	INDEPENDENT CONSULTANT
GRAHAM	BECKY	PARKS CANADA
GRANT	DR. JON	DALHOUSIE UNIVERSITY
GRIFFIN	RANDY	KELLY COVE SALMON
GROMAN	DAVE	AQUATIC DIAGNOSTIC SERVICES
GROTTUM	JON ARNE	NORWEIGAN SEAFOOD FEDERATION
HACHE	SEBASTIEN	VALORES
HACHE	BERNARD	FISHERIES AND OCEANS CANADA
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HARRISON	GEOFFRY	NORTHEAST NUTRITION INC.
HAWKINS	LEIGHANNE	KELLY COVE SALMON
HODGINS	LAURA	SIMCORP
HODKINSON	TIM	KELLY COVE SALMON
HOLMES	JASON	NORTHEAST NUTRITION INC.
HOUSE	BETTY	ACFFA
HOYT	MISTY	KELLY COVE SALMON
IRVINE ANDERSON	DEBORAH	CANTEEN MEDIA
JACKSON	TIM	NRC IRAP
JAMPANI	VARVIN	COOKE AQUACULTURE
JONES	DR. SIMON	FISHERIES AND OCEANS CANADA
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KENNEDY	TIM	CAIA
KIERSTEAD	TERRY	COASTAL FISH HEALTH SERVICES
KNIFFEN	DR. TIM	MERCK ANIMAL HEALTH
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KURKIMAKI	PETER	SKRETTING
LAKING	ERIN	FISHERIES AND OCEANS CANADA
LAMBERT	JEAN	AGRICULTURE & AGRI-FOOD CANADA
LANE	MARK	NAIA
LATENDRESSE	DANIELLE	PARKS CANADA
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LIVELY	ANDREW	COOKE AQUACULTURE

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MACKINNON	ALLISON	ELANCO CANADA
MAHER	KEN	ELANCO CANADA
MAXWELL	RYAN	COOKE AQUACULTURE
MCBRIARTY	GEOFFREY	KELLY COVE SALMON
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MCGRATTAN	JASON	ELANCO CANADA
MCKINDSEY	DR. CHRIS	FISHERIES AND OCEANS CANADA
MCLEOD	DAVID	TIER ONE CONSULTING INC.
MICHAUD	DYLAN	UNIVERSITY OF PEI
MISK	EHAB	HUNTSMAN MARINE SCIENCE CENTER
MITCHELL	KELLI	COOKE AQUACULTURE
MOHAMMED	RAEFEY	COOKE AQUACULTURE
MONEVA	EVGENIYA	CANADIAN FOOD INSPECTION AGENCY
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NICKERSON	JEFFREY	COOKE AQUACULTURE
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PEDERSEN	VICTORIA	CANADIAN FOOD INSPECTION AGENCY
PELLETIER	CLAUDE	VALORES
PIERSON	MARK	PHIBRO ANIMAL HEALTH CORP.
PILCHER	SCOTT	FISHERIES AND OCEANS CANADA
PIZARRO	RUBY	NORTHEAST NUTRITION INC.
POWELL	CONRAD	SGS CANADA
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RICHARDSON	JOEL	COOKE AQUACULTURE
ROBERTSON	BILL	RETINK INC.
ROBINSON	TIM	FORT FOLLY FIRST NATION
ROBINSON	SHAWN	FISHERIES AND OCEANS CANADA
ROGERS	BRIAN	ROGERS CONSULTING LTD.
ROUSSEL	HELENE	ENTREPRISES SHIPPAGAN
RYAN	CLAIRE	COOKE AQUACULTURE

SAMWAYS	KURT	UNIVERSITY OF NEW BRUNSWICK
SEELEY	DAVID	SKRETTING
SIAH	AHMED	BC CENTER FOR AQUATIC HEALTH SCIENCES
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STEPHENSON	CHRIS	COOKE AQUACULTURE
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UNDERWOOD	SCOTT	COOKE AQUACULTURE
von RONGE	FREDERICK	COOKE AQUACULTURE
WHITELAW	JOHN	PARKS CANADA
WILLIAMS	WENDY	FISHERIES AND OCEANS CANADA
WIPER	JENNIFER	COOKE AQUACULTURE
WONG	DAVID	FISHERIES AND OCEANS CANADA
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