ACFFA AQUACULTURE RESEARCH, SCIENCE AND TECHNOLOGY FORUM

FINAL REPORT

OCTOBER 27 AND 28, 2021

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 27 and 28, 2021 virtually and 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 2021 forum covered a variety of themes including new farm technology, wild salmon conservation activities, farm management and the environment, and fish health and welfare.

160 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 and conservation interests.

AGENDA

WEDNESDAY, OCTOBER 27, 2021		
9:00	Welcome to the Forum	Susan Farquharson, Exe Director Atlantic Canada Fish Farmers Association
9:10	New Brunswick Aquaculture Act/Development Strategy	Minister Margaret Johnson - NB DAAF
9:30	Neptune III	Trond Waldemar Rosten, MOWI Norway
10:00	Sustainable Solutions for Fish Sludge Handling	Stig Amdam, Hyperthermics AS
10:30	**BIO BREAK**	
10:45	Introducing the VSI, or 'Voluntary Swim-In' system	Joel Halse, East Coast Innovation
11:15	LiftUP Clean-Up. Fish Waste Collection from Open Cages	Liam Heffernan, LiftUP AS
11:45	FishGLOBE: A Global Game Changer	Tor Magne Madsen, FishGLOBE AS
12:15	Guest Speaker	Dr Martin Jaffa
1:00	**LUNCH**	
1:45	Looking Under the Surface: Using Acoustic Telemetry to Understand the Interactions Between Wild Fish and Aquaculture	Marc Trudel, DFO-SABS
2:15	Fundy Salmon Recovery: Have We Turned the Corner in Restoration?	Kurt Samways, University of New Brunswick
2:45	Recovery Of Inner Bay of Fundy Atlantic Salmon in The Petitcodiac Watershed	Alanah (Annis) Bartlett, Fort Folly Habitat Recovery
3:00	The Return of Anadromous Fish Species to The Petitcodiac 2010-2021	Edmund Redfield, Fort Folly Habitat Recovery
3:30	Wrap up	Susan Farquharson, Atlantic Canada Fish Farmers Association

THURSDAY, OCTOBER 28, 2021		
9:00	Welcome and Introduction	Susan Farquharson, ACFFA
FISH HEALTH AND WELFARE		
9:10	Molecular Characterization of The Innate Immune Response Associated with Different Types Of Vaccines And Vaccination Strategies In Salmon	Juan Carlos Rodriguez-Lecompte, University of Prince Edward Island
9:40	Can We Decrease Disease Though Probiotics? The Importance of The Microbiome in Supporting Animal Health	Steve Leadbeater, DFO - SABS
10:10	AcuLice - Can Sound Prevent Lice on Atlantic Salmon?	Albert Imsland, Akvaplan-Niva
10:40	**BIO BREAK**	
11:00	Automatic Sea Lice Counting, Biomass Estimation, and Welfare Monitoring with Aquaculture AI	Bryton Shang, Aquabyte
11:30	Novel Microalgal Products as Alternatives for Antibiotic Use in Atlantic Salmon	Stefanie Columbo, Dalhousie University
12:00	Aquatic Diagnostic Capacity and Testing Quality Assurance: Are We Ready for the Projected Growth of Aquaculture in Atlantic Canada?	Dave Groman, Atlantic Veterinary College - UPEI
12:30	**LUNCH**	
ENVIRONMENT - FARM MANAGEMENT		
1:15	New DEPOMOD for Deposition Sampling	Iain Gatward and Stevie Brain, SAMS Enterprise
1:45	The Smart Energy Company: NOREASTER® Solar Energy Solution	Mark McAloon, The Smart Energy Company
2:15	Spatial Computing: Why Should I Care?"	Iain Whyte, Kognitiv Spark
2:45	Latest Developments in The Application of Genome Editing to Aquaculture	Xavier Lauth, Center for Aquaculture Technologies – San Diego
3:15	Implementing A Molecular Index for Monitoring Salmon Farms in New Zealand	Xavier Pochon Cawthron Institute, University of Auckland, and Nigel Keeley, Institute of Marine Research
4:00	Wrap- up	Susan Farquharson, Atlantic Canada Fish Farmers Association

Wednesday, October 27, 2021

Semi-closed Containment Systems – lessons learned from the 6G Neptune trials
-presented by Trond W. Rosten, MOWI ASA.

The focus for Mowi with its work with semi-closed containment systems (S-CCS) is for post smolt production - taking smolt from approximately 130g to 1kg, not for full grow-out. Once the post smolt reach the 1kg range they are transferred to traditional flexible net pens until they reach market size. The S-CCS unit called Neptune III has been stocked with six batches of smolt since 2013 and lessons learned from the 2013 - 2021 trials were discussed.

Fifteen years ago, the idea of S-CCS was not included in what experts thought would be the focus of the salmon aquaculture industry in 2021. Only 10 years ago did SINTEF identify 3 categories for closed fish farms and since 2018 the focus has been on RAS development. The SINTEF Category I and II closed farm units both have a solid barrier to keep the fish and marine environment separated, have controlled, deep water intakes and controlled water discharge. Category III units have filtration processes in place to remove sea lice and fish waste from the water. Neptune III is between category I and II closed farm unit. Some technical data on Neptune III was provided and included the following specifications:

- Circumference of the unit is 126 m, with a cage depth of 22 m and a gross Volume: 21.000 m3
- It is designed for a max wave height (HMax) of 1.8 m, and a current of 0.75 m/s
- With a flow of up to 400 m3/min, the unit's energy requirement is 240 kWa

To help avoid sea lice larvae, there is a deep-water intake of ~26m. There is no filter or UV system on the incoming water at this point, but the good water current limits the ability of the sea lice to complete its life cycle. The current unit will not be able to eliminate sea lice from the system, but they can be maintained below treatment thresholds. Addition of a sea lice filtering system with pre-filter and would increase the energy demand by 3-4 times. Concerns with Amoebic Gill disease (AGD) are site dependent, typically occurring 70 – 80 days post transfer in the autumn and the disease often "burns out" when temperature drops, though it can be a trigger for wounds and increased mortality in the smolt caused by handling during AGD treatment. Other pathogens are no bigger a risk in the Neptune III system than net pen farms but smolt need to be healthy upon entry.

Growth is temperature and water quality dependent especially within a S-CCS and excellent water quality has been demonstrated, though water temperatures in the winter may be somewhat lower than that of a Recirculation Aquaculture Systems (RAS). Results on a have indicated a relative growth index of approximately 2% higher than predicted for these post-smolts (predicting growth as a function of fish size, temperature, feed intake, feed type and season), and a biological Food Conversion Ratio (bFCR) below 1.0.

Survival within the Neptune III is normally close to 99 % over 6 months of on growing and is technically competitive with RAS if AGD treatments can be avoided and movement of post-smolt to net pens are allowed. After transferring the post smolt to net pens, survival has been documented at approximately 92% after seven transfers to five different farm sites, with good growth and acceptable bFCR.
Over a 170-day production cycle the S-CCS recaptured 151 tons of fish waste and discharged only 7.2 kg total phosphorus per day and 4.4 kg total nitrogen per day. Large volumes of water enable good water quality but also make treating the water more complicated.

Several alternatives available for S-CCS post-smolt systems are evolving and were discussed. Key performance indicators currently show that net pens continue to be lower cost than S-CCS and RAS, though competition is high to develop new systems with the best return on investment and sustainability metrics.

Trond Waldemar Rosten

Trond Waldemar Rosten is the Global Manager R&D and Technical at Mowi ASA. He has over 30 years of experience in management consultancy and research with a focus on seafood and is currently leading Mowi's Neptune semi closed cage technology project, which has been in development over the last few years. Mr. Rosten will share information on the development of that project, and the potential benefits of the technology that have been observed to date.

Sustainable Solutions for Fish Sludge Handling

-presented by Stig Amdam, Hyperthermics

The pioneering fermentation technology being developed by Hyperthermics AS since 2006, is seen as a sustainable solution for sludge created by large processing plants and land-based farming facilities. Hyperthermics uses hyperthermophile bacteria, some from hydrothermal vents pumping out extreme heat on the seabed, to transform biomass into renewable energy, in a fast and environmentally friendly way. These bacteria are found in the most hostile environments on the planet and are able to work faster and more efficiently than any other known fermentation technology.

Inputs into the system can include manure, energy crops (low-cost, low-maintenance crops grown solely for energy production by combustion), organic waste and fish sludge. The hygienisation (decomposition) within the Hyperthermics reactor occurs at 80°C over three to eight hours, depending on the material used. A high-quality protein for feed ingredients can be obtained at this time in the process, with the remainder of the material moving into a biogas reactor from which wet or dry fertilizer and biogas for power or heat can be derived. With the heat produced through the process, only approximately 10% is used within the operation, leaving the rest for use for energy and creating a low-cost product for fertilizer producers. Traditional plants require 20-30 days to produce similar outputs which enables a significant increase in plant capacity and efficiency.

The Hyperthermics plant at Lindum, Drammen has been operating since 2017 using food waste, sewage, pulp and salmon sludge, with a biogas capacity of 10,000 tonnes per year.

Process diagrams identifying individual components for a biogas plant, a protein plant and a dual recovery plant were presented. The units are highly scalable and can be tailored to meet various operational requirements, with a variety of financing option available to those interested in using the technology.

The Hyperthermics process uses marine bacteria so the conversion of sludge from saltwater fish farming into valuable feed ingredient, energy and fertilizer can be accomplished. The salt may be able to be removed to provide another salable product. The use of flocculant technology gives valuable and sustainable end-products and polymer free effluent with a very low number of biological particles. Other sustainability indicators include less waste handling as the process removes more than 85% of the water, it can convert 70% of sludge into biogas, and recover 50% of the dry matter into saleable proteins.

Presentation Available Upon Request

Stig Amdam

Located in west coast of Norway, Stig Amdam has been working with fish sludge handling solutions in Hyperthermics since 2019 as Sales Manager for the aquaculture solutions. Stig's background ranges from

project management in MOWI`s largest processing plant for farmed salmon to Project Manager in Kongsberg Maritime for several years, responsible for delivery of handling systems for the ship industry.

Introducing the VSI, or 'Voluntary Swim-In' System
-presented by Joel Halse, East Coast Innovation Inc

Fish Transfer Today – high density crowding. Density in cages 10-25kg/m3 but this is increased when transferring fish so stress and oxygen demand increases. Fish swim AWAY from the suction.
If the dynamic is changed such that fish participate in the transfer process, this changes the conditions in front of the pump with lots of water space, high oxygen, and lower stress.

The Voluntary Swim-in (VSI) is a new system that is designed to work with nature and respect the fish's natural instincts. Instead of forcing them to do what they don't want to do, the VSI works with the fish's natural behavioral instincts, resulting in a low-density population during the loading of a fish pump. When the VSI is added to current fish transfer technology, the result will be better survivability, quicker return to feed post transfer, and an improved bottom line.

With version 10 of the unit, fish have been transferred as proof of concept but now the system has to be incorporated into other production / service systems i.e., land based, and field trials with harvest / treatment boats within the region are being sought. The VSI has been tested at the Huntsman Marie Science Center. With patents pending, information is limited at this point, but the entire fish experience from how the device is introduced onward is part of the system.

The system could decrease vessel service timelines and increase efficiency, with fish moving continuously through the VSI, not in large infrequent groups.

Presentation Available Upon Request

Joel Halse
Joel Halse is a retired Captain from the Canadian Armed Forces where he served as an aerospace engineer. He subsequently spent more than a decade working as a Professional Engineer and hands on Corporate Engineer in one of the world's top ten aquaculture companies. He is the named inventor on two projects, taking them from product development to commercialization. He deployed more than $100 Million in capital to address business problems through technological solutions in all facets of the aquaculture industry. Joel is the CEO of East Coast Innovation Inc. (ECI) which uses its considerable aquaculture experience, technical skills, and hands-on approach to meet challenges and improve operations throughout the aquaculture sector; on land-based or ocean farms. The company's current focus is on developing an exciting new technology to transform fish transfer systems.

LiftUP Clean-Up. Fish Waste Collection from Open Cages
-presented by Liam Heffernan, LiftUP AS

Within the last three years, the interest in sludge removal / reuse at marine farms has increased due the perceived environmental impact on the seabed and the water quality, with potential limiting effect on fish production. LiftUp has been involved with several projects since 2012, working with farmers to develop technology that enables efficient collection and filtration of sludge at farm sites for reuse in other production systems.

Pilot farm with 14 cages used the Combi Collector to collect sludge and fish waste from open cages and pump the biomass through separate pipe systems to the feed raft on site. This project was started in June 2020 and followed the whole production cycle of fish until harvest in Autumn 2021. The piping system connects all cages for transport of sludge and mortalities back to barge through a one-way valve system, controlled by operators. A filter module on the feed raft increases the dry matter content to approximately 10%, then sludge is automatically pumped into a 50-200 M3 floating tank for storage. Companies that specialize in transport / collection of this type of material retrieve it for further product development. Diagrams of the components and overall system design were provided.

The LiftUp dewatering bin with inspection table includes a new software package called CreateView Diagnostics which enables the counting and scanning of dead fish before they are moved into the grinder. Information collected includes sea lice numbers, deformities, maturity, and seal bites. The software also enables farmers to monitor components like filters and pump status and to monitor the entire operation from a land-based facility.

Data was provided from the LiftUP system based on a farm with 750,000 salmon during the on-growing from an average weight of 50g to 5kg. Total sludge collected in the growth cycle was 3,800 tons. With the maximum feed fed at 31t per day, the average sludge collected was 24t per day, using the two-stage filtering system. The goal of the system is 80-90% sludge recovery. Sample waste collection using particle traps under the cages occurs once a month by the local Environment Department to monitor environmental health. The farm with the LiftUP system typically has 1 to 2cm of waste in the traps versus a reference farm next door that typically has 15 to 20cm in the traps each month. The seabed under the cages has been monitored using grab analysis by a neutral external company during the whole production cycle and demonstrated a very healthy seabed

The farm waste post collection is now being used for various renewable energy operations including the production of biogas, organic fertilizers, nutrition in insect and algae production. The purpose of this system is to reduce the environmental footprint of the fish farming cages, demonstrating that aquaculture can produce huge amounts of high-quality seafood in an environmentally sustainable fashion, by collecting and using all the fish waste for biogas and organic fertilizer. This system is now being installed on a number of cage sites in Norway

Presentation Available Upon Request

Liam Heffernan

Liam Heffernan has been the CEO of fish farm equipment producer LiftUP AS since 2005. Previous experience includes 10 years fish farming in cage farms for salmon in the fjords of Norway, 1 year land-based salmon farming in Northern Spain, 3 years managing an offshore salmon farm off the west coast in Ireland, 10 years managing an integrated fish farm for sea bass and sea bream in the Mediterranean composed of a hatchery and land based farm in Portugal and 3 sea cage sites in Spain, and 1 year on the construction and operation of a fish farm in the Caribbean.

FishGLOBE A Global Game Changer
-presented by Tor Magne Madsen, FishGLOBE

The vision for FishGLOBE is to develop new cost-effective solutions that makes it possible for the aquaculture industry to expand in a sustainable manner. A timeline for the development of the technology was provided showing the progress from 2013 to current.

In 2019, the fifth version of the FishGLOBE design, a 3500m3 post smolt unit that could produce 600T a year went into production. It was delivered for field trials and was in full operation for post smolt production by the end of the year. It is now growing its fourth generation of smolt.

In 2020 / 2021 the design for the FishGLOBE 10,000 m3 post smolt unit to produce 1800T a year was completed using the experience from the 3.5K design and became available to the market. Planning for 2023 includes using the experiences from 3.5K and 10K units to design a 30,000m3 unit for large scale post smolt production for use in large offshore farms or production up to market size. A video showing the basic design and operations of the FishGLOBE was presented.

FishGLOBE is a patented technology, but design elements include 100% containment, deep water intakes (33m down to 44m), sludge and particle control. The units are built from polyethylene (HDPE) so are 100% recyclable and provide a high health and safety standard for workers.

A graph was provided comparing the average post smolt growth from FishGLOBE units and two RAS facilities starting with smolt of between approximately 100g and 300g. The smolt in the FishGLOBE units showed approximately 25% better growth reducing production time by two months.

FishGLOBE is seen as part of a future salmon farming strategy where the units may be used to produce large post smolt (1kg-1.5kg) to lower exposure time in sea cages and shorten time to market. It has less technological risk compared to RAS facilities and is designed and proven for 75kg/m3 densities. The unit cannot be used in exposed locations but sea lice and escape prevention, welfare and growth results and the short lead time required for building the units are advantages for the Canadian industry. To serve Canada, building yard/partners to build and service the globes are required as well as a famer's help to develop the technology long term within the region.

Presentation Available Upon Request

Tor Magne Madsen
After spending more than 15 years in various management positions in the oil & gas industry within projects, sales and business development, Tor Magne Madsen started with the FishGLOBE team just before the pandemic. His job as Head of Sales and Project Execution includes managing current FishGLOBE projects: Building a new globe and engineering the larger and newer versions. As Head of Sales and Marketing, Tor Magne is responsible for introducing the Globe to new clients and new markets and leading the advancement process from a mach#1 prototype to a commercial technology with a system of units for the market. A Mechanical Engineering (B.Sc.) by training Tor Magne says: "I'm loving my job to try to make the aquaculture more sustainable and is passionate about our great technology that keeps everything it promises!"

In the Lion's Den
-presented by Martin Jaffa, Independent Researcher

After a negative response to a presentation at a Scottish event, using a recent paper to discuss the various reasons why salmon farming was not the cause for salmon declines in British Columbia, a decision to review available information and conduct independent research into salmon farming developed into a new career path. The information presented highlights concerns with some fundamental assumptions and blind focus on a single idea.

In November 1993, there was a one-day conference in Scotland with a presentation graph that was used showing the percentage difference from the mean in catch data from 1952 to 1992, to indicate the wild

Atlantic salmon population in the western highlands where salmon farming occurs, increasing while the sea trout population was decreasing. The presentation focused on the year 1985 when there was also a drop in mean salmon catch as well, relating this change to the start of salmon farming.

A graph from a paper by Butler and Walker in 2006 was discussed which showed the sea trout and brown trout catch in Lock Ewe from 1969 to 2001. The graph highlighted the year of 1987 as the start of salmon farming in the area with the inference that this was the start of the major trout population decline even though the data showed that the decline had started approximately 7 years prior to farms arrival in the area. The two salmon farms were approved in November 1987, to be sited 4km and 7km from the river mouth and with biomass limits of 919 and 950 tonnes. Other information including the removal of the 3-mile fishing limit in Scotland in 1985 due to the declining catch of marine species like cod, saith and whiting was not included in the paper's discussion. Data on this decline was presented and discussed.

A graph of the sea trout catches from 1952 to 2014 for the "Aquaculture Zone" of West Highland and Outer Islands was presented which showed the decline starting decades before the 1000t production level of Atlantic salmon was achieved in 1982. The government produced graph of the rod and line trout fishery catch for all of Scotland was also presented showing the decline starting in the mid-1960's, but the observations of sea lice on trout has focused attention on the farming industry.

Biologists assume that trout sea lice levels are representative of salmon lice loads and are responsible for declines in both species. Over 4000 fish were sampled by sweep net as part of a smolt monitoring project in 2012 but the data of the aggregated distribution of sea lice on fish, show very few fish being host to large numbers of the parasite, making these fish easy to catch, and most of the population have no parasites. The long tern data from the project was presented graphically. Since the collapse of the population In Loch Ewe over 6000 sea trout have been caught.

In turn to salmon, graphs presented for discussion included:

- Migration pattern of Atlantic salmon from UK
- Graph of 1952 to 2021 catches of salmon trout on the River Ewe and Lock Maree showing decline. Ewe salmon graph showing increasing trend, but trout declining
- Salmon and grilse catch in Ewe 1952-2012
- Salmon, grilse and trout catch on the Ewe and River Nith for 1952 to 2012. Both show decrease trout catches, increase salmon and grilse catches. Nith not in aquaculture zone.
- Official government graph of salmon returns and catch and release – total rod catch trend up.

The Scottish Government has little data on sea lice counts or impacts on wild salmon. Data has come from experimental modelling and catch data, which actually show the decline is small.

Graphs provided showed salmon catches up are up across Scotland and the west coast, while the wild salmon catches on east coast down, so farms are not the issue. West coast salmon catches have always been small relative to the east coast of Scotland, normally only 10% of total Scotland catch of salmon. If salmon netting data were included, all would decline as netting decreased, rod catches increased. There are 130 fishing districts, ~400 graphs, with water depth, size of rivers different so trends are down, up or stable.

A graph of historical data showed the ratio of salmon to grilse / grilse to salmon returning to the Tweed River for the time period of 1740 to 2004. Except for a timespan between 1870 and 1900 when the ration was around 1:1, a generally repeating pattern of more salmon than grilse returning several decades, then more grilse than salmon returning continues over time series. Data from 1990 onward shows the ratio cycle returning such that there are more grilse than salmon retuning to the river.

A number of graphs and tables were presented with numbers of salmon and grilse caught from 1952 to 2012, including trend lines, for all of Scotland and the aquaculture zone, show that if plotted separately the grilse numbers have been trading upwards and have been the higher proportion of the spring fish being caught since the 1990s.

The increase in grilse numbers does not support the assumption that farming is the root cause of population changes, but factors such as predators, dams, agricultural run off, and over exploitation by anglers are among other concerns continue to be ignored.

Presentation may be available upon request to speaker

Martin Jaffa

Dr. Martin Jaffa is best known for his weekly reLAKSation commentary that is now in its 21st year. Although originally intended as a platform for discussion about the consumption and the markets for aquaculture produce, it has become an antidote to the constant criticism about salmon farming from the wild fish sector. Martin is a long- time passionate advocate of aquaculture; an interest that developed in his early teens after reading about how food could be created out of waste in extensive warmwater fishponds in Asia, from which point he actively pursued a career in fish production. This journey eventually moved from production towards what happened to the fish after harvest. For the last twenty-five years, Martin has run a business involved in analysing fish consumption and the marketplace. This was disrupted in 2010 when he was dragged into the debate about the impacts of open pen salmon farming on the environment and especially wild fish. He has since become an outspoken defender of the modern salmon farming industry.

Looking Under the Surface: Using Acoustic Telemetry to Understand the Interactions Between Wild Fish and Aquaculture

-presented by Marc Trudel, DFO – St Andrews Biological Station

The ongoing research project has several key objectives including determining the migration route and residence time of Atlantic salmon in Passamaquoddy Bay, estimating stage-specific survival rates from the estuary to the open ocean and determining the extent of the interactions of juvenile salmon with marine salmon aquaculture sites. The 2018 pilot work concentrated on routes. Time, stress via dam, elver fishery, and predators were also explored in 2019 and 2021.

The study design 2018-2021 timeline diagram showed the Bay Management Area (BMA) included each year and where the BMA fit within the three-year production cycle. In 2020, COVID restrictions cancelled the Spring smolt releases and monitoring but in August receivers were deployed until November to see what other fish were in Passamaquoddy Bay. Receivers were also deployed in the Spring of 2021. As of October 2021, those receivers were still in the water so the focus of presentation will be the earlier work. In 2018 there were 60 fish tagged, 29 receivers deployed and in 2019 there were 160 fish tagged and 130 receivers deployed plus manual tracking. Drifters were also deployed to determine if smolt were moving with the current.

Data from the project showed that most Atlantic salmon post-smolts leave Passamaquoddy Bay through the Western Passage (60%-87%), primarily using the north shore, and residence time in Passamaquoddy Bay averaged 3.6-4.1 days. Freshwater mortality was high in June (70%) but not in May (25%), and though there was no mortality in fish that went through the bypass (10% of group), mortality through the hydropower system was 39%. Estuarine mortality and early marine mortality were low for all release groups (~10-23% and ~10-20%, respectively). Marine mammal predation accounted for 33% of the marine mortality. Understanding which predators were involved in the predation events may be determined with further analysis of dive pattern data.

Of the smolt released, 43% (2018) and 71% (2019) were detected near aquaculture sites (within ~400m 500 m). The residence time of smolt at an aquaculture site averaged ~15-16 min, with cumulative residence time at aquaculture sites averaged ~26-29 min.

The wild fish project is attempting to answer the question: "are farms acting as reefs for wild fish or are wild salmon / fish attracted to farms because of the activity, food availability?". The data collected was graphically presented comparing detections per fish per receiver in 2018 and 2019 from inside Passamaquoddy Bay, outside the bay (only 2019), and around salmon farms. Wild smolt were detected on the farm receivers (within 400m-500m) in both years, with the number of detections higher near aquaculture sites in 2018. For 2019 this pattern was not apparent.

While many wild fish species are being tracked through the Ocean tracking Network (OTN), only a handful of those are being detected on the project receivers. There have been several false positives, identifying fish such as walleye which are not found here, but others are providing interesting data such as that for sturgeon. Over 30 sturgeons, some from Quebec, were detected during the 2018 and 2019 field seasons, several close to farms (400m to 500m) both within and outside Passamaquoddy Bay. In 2019 there were more detected outside Passamaquoddy Bay.

Great white sharks are most typically seen in local waters in July and August. Project receivers detected 11 great whites in 2018 and 2019 from early July to late September. Most of these detections were outside Passamaquoddy Bay, but the picture isn't complete as most project receivers were removed before the typical time of arrival for great whites.

Acoustic telemetry work in 2021 includes tracking of Atlantic salmon, alewife, sturgeon, and sharks with receivers being removed in late November / early December so more data will be forthcoming. Collection of data from sonar imagery (Jul-Nov), acoustic zooplankton fish profilers and monthly eDNA (~May-Nov) sampling data in BMA1, 2a, and 3a (2020-2023) continues through 2023.

Going forward there are several study components being added to the current work, including pelagic and benthic wild fish collection that will occur from July to November starting in 2022 for tagging and acoustic telemetry tracking through 2023.

Presentation Available Upon Request

Marc Trudel

Dr. Trudel has been a research scientist at Fisheries and Oceans Canada for more than 20 years. He started his career at the Pacific Biological Station in 2000, where his research focused on the effects of ocean conditions and climate change on the distribution, migration, growth, and survival of Pacific salmon, as well as on the interactions between wild and farmed salmon. He relocated at the St. Andrews Biological Station in 2016 and has been conducting research on aquaculture and ecosystems interactions since.

Fundy Salmon Recovery: Have We turned the corner in Restoration?
-presented by Kurt Samways, University of New Brunswick

The inner Bay of Fundy (iBoF) Atlantic salmon are a special group in that they typically only migrate within the Bay of Fundy and Gulf of Maine. Historic runs of 40 thousand adult salmon across more than 45 iBoF rivers has declined to less than 200 individuals in total, with most rivers extirpated. If population dynamics remain the same and if there was no human intervention, it would take an estimated 200 years before the population would recover on its own.

The Big Salmon River (BSR) and Stewiacke River are index rivers for DFO monitoring, so these rivers can be used to compare their population numbers, environmental conditions with those rivers in Fundy National Park (FNP) which are involved in the Fundy Salmon Recovery (FSR) project.

Traditional stocking programs have involved the collection of broodstock, captive rearing of the juveniles until their release into the river at various life stages. The Live Gene Bank (LGB) program has followed the same basic plan, including the collection of smolt and captive rearing to various stages before release, including the release of adults. Though the release of these fish since program inception has not improved populations numbers, the LGB program has kept the iBoF population from extinction and is on life support, and it is why there are iBoF salmon to work with as part of the FSR program.

Fundy Salmon Recovery strategy began in 2014 with the majority of smolt collected originating from released unfed fry from the LGB program. Now the goal of the FSR program is to collect only wild run smolt to be reared in the marine conservation farm to produce mature adults for wild spawning.

The number of salmon released from the FSR program to FNP rivers since 2015 was provided, with the number of salmon returning to the USR since 1976 graphically presented showing the initial impact of the 2010-2012 pilot program. Lessons learned from that initial research included the importance of less captive exposure in any recovery program.

All adult salmon to be released from the FSR program are PIT tagged (Passive Integrated Transponder) for telemetry monitoring in the rivers. In 2020 FNP started releasing salmon in Point Wolfe River (PWR) with 674 salmon and in 2021 the program released 825 salmon. The PWR receiver array is 30m long and ~2m tall.

Monthly adult (June through August) return data to the USR and PWR 2021 was presented showing salmon returning to the rivers in late June, the earliest ever seen in rivers, and the largest adult salmon return in over 30 years with 116 total salmon counted.

The number of adult returns to Fundy National Park was graphically provided with data up to 2021 indicating when the first salmon from the pilot project were released and when the next large salmon releases began in 2015 as part of the FSR program. The estimated number of adults returning to the BSR for two years was also indicated on the graph. In 1990, the estimate was 975 salmon while in 2007 the estimate was 47 salmon.

The breakdown of origin data for the salmon returning in 2021 was presented indicating approximately 64% of the salmon returning were reared at the marine conservation farm and over 78% of those returning are females. Two of the salmon released in 2019 came back in 2021, and at least one of those salmon returned in 2020 as well, showing 16.5% of the salmon are repeat spawners. This is compared to 2018 BSR data indicating only 11% of the salmon returning are repeat spawners.

The USR is currently the only iBoF River with exclusively wild hatched juvenile salmon. Data of juvenile salmon densities in the USR from 1991 to current showed 1+ parr density of approximately 2 parr per meter squared. Considering the increase in density with the years of juvenile stocking program and the wild reared adult stocking program, indicates that the adults from the FSR program is the bases for the increase in juvenile density in the rivers with those returning adults contributing proportionally more (37.5%) to the next generation. The USR has exclusively wild hatched smolt for the last several years and had the highest wild salmon smolt run ever in 2021. So far there is only anecdotal evidence that adult salmon are in fact returning from wild produced smolt.

The rivers in FNP are also being monitored for ecosystem effects of adult releases.

Presentation Available Upon Request

Kurt Samways

Dr. Kurt Samways is a Research Associate at the University of New Brunswick and became the first ever Parks Canada Research Chair (in aquatic restoration) in 2019. Dr. Samways has worked extensively in applied ecology to restore river ecosystems and recover fish populations in Canada and internationally. Dr. Samways is the lead Research Scientist of the Fundy Salmon Recovery program for endangered inner Bay of Fundy Atlantic Salmon, studying the effects of captive reared adults on fish fitness and ecosystem health. With over a decade of food web and fish-related studies, Dr. Samways will be continuing his research on a larger scale, bridging salmon recovery and ecological restoration efforts currently underway across five Atlantic national parks.

Recovery of Inner Bay of Fundy Atlantic salmon in the Petitcodiac Watershed
-presented by Alanah Bartlett, Fort Folly Habitat Recovery

Historically, the Petitcodiac River with the Pollett and Little Rivers as its major tributaries, was home to ~20% of the entire inner Bay of Fundy Atlantic salmon population. The construction of a causeway in 1968 stopped the migration of many fish species and caused salmon to disappear from the river. The Petitcodiac causeway gates opened in 2010 and a bridge was eventually constructed, and the causeway was removed entirely this year.

The Petitcodiac Salmon Recovery program design was reviewed showing how DFO's Live Gene Bank (LGB) and the Fundy Salmon Recovery (FSR) programs are currently involved in activities on the Pollett and Little Rivers. Currently, the FSR marine conservation farm receives wild exposed smolt caught on the rivers, as well as wild exposed parr that are caught in the Fall and overwinter at the Mactaquac Biodiversity Facility.

In Spring 2021, smolt collections occurred on the Big Salmon River by rotary screw trap and on the Pollett River through the operation of a counting fence. Throughout the summer the rivers are monitored through snorkel and electrofishing surveys, as well as Passive Integrated Transponder (PIT tag) array monitoring. This PIT array monitoring on the Little River in 2020 revealed that returning salmon were entering Little River (likely since entry to this tributary is located before the salmon reach the Pollett) so previous numbers of returning salmon reported may be underestimated because this river wasn't previously being monitored. Adults are spawning and progeny are being seen in the river. This summer the highest number of returning salmon were detected in Pollett, with 14 salmon observed in one pool alone.

Fall 2021, 2003 wild exposed parr were captured and transported to Mactaquac Biodiversity Facility (MBF) to overwinter and will be moved to the Fundy Salmon Recovery's (FSR) conservation farm in spring 2022.

The number of adults released annually since 2015 from the FSR program to the Petitcodiac was presented, showing that 798 salmon were released from the FSR conservation farm in 2021. Other non target Live Gene Bank (LGB) adults from MBF will also be released later this year.

The overall Petitcodiac watershed recovery program success was discussed based on several outcomes in the freshwater environment. Fisheries and Oceans Canada and FFHR have released 936, 392 unfed fry into the watershed since 2011 and 8,170 adults have been released since 2012, with 2,673 of those adults having marine exposure at the FSR farm since the project started in 2014. The FSR project has also seen the wild exposed smolt inclusion numbers more than tripled since 2014 and over 5,000 wild exposed parr captured since 2018.

A graph of egg deposition estimates from 2012 to 2021 was presented showing that the 2021 egg deposition is estimated at 3.87M eggs based on fish size and sex ratio. In 2020, almost 4000 smolt were

caught on the Pollett from the 2017 salmon release. Based on the number of salmon that were released since then, the smolt run over the next few years is expected to be significant.

On the marine side, the Petitcodiac Program success has been shown through the adult salmon returns that have been detected since 2018. There were 6 adult salmon returns detected in 2020 and over 30 salmon in 2021. One salmon was presumed to be a true wild return based on morphology and lack of internal / external tags. This salmon would have been grown in the Petitcodiac and was a multi sea winter female. Genetic testing results are pending.

Presentation Available Upon Request

Alanah (Annis) Bartlett
Alanah is a senior technician at Fort Folly Habitat Recovery and is based out of Mactaquac Biodiversity Facility (MBF). She is responsible for providing care and maintenance to Fundy Salmon Recovery fish at MBF, supervising juvenile inner Bay of Fundy Atlantic salmon collections in the Petitcodiac watershed, and program coordinating with Fisheries and Oceans Canada. Alanah holds a BSc in Biology from the University of New Brunswick, and currently is a MSc candidate at the University of New Brunswick.

The Return of Anadromous Fish Species to the Petitcodiac River: Monitoring at the head of tide from 2010 to 2021
-presented by Edmund Redfield, Fort Folly Habitat Recovery

Historically Moncton was a seaport set in a wide river channel carved out more by the tidal prism than freshwater discharge. Conditions changed after construction of the Moncton to Riverview Causeway over the Petitcodiac River which closed off the river in 1968. Pictures displayed of river conditions pre and post causeway construction showed that below the causeway gates the river channel narrowed by 92%, channel infilling occurred up to 21 km downstream and the tidal bore declined to a fraction of a metre.

Due to these changes in the river, there was a loss of several anadromous fish species including Atlantic salmon, American shad, striped bass, Atlantic tomcod and a declined in Gaspereau (Alewife & Blueback herring) populations.

Since the gates were opened in 2010, the river has widened generally by 20 m in Moncton but 10 km downstream it has become 350 m wider. Data presented showed the tidal bore strengthened bringing stronger tides, so with all these changes on the river, monitoring commenced about 20 km upstream of the causeway at the head of tide to monitor the potential return of anadromous fish species.

In 2021, the first season with the new bridge, a new channel 160 m wide was created which allowed for improved tidal exchange and fish passage. A picket trap started fishing this year on May 21st and will be operated until October 31st but comparing the 2020 data and 2021 date to date, the total number of fish seen have increased. Data on specific species was presented showing striped bass and American eel numbers are increasing but Gaspereau are declining.

By October 27th three salmon were counted at the trap, including one adult captured October 4th with no tag and no wounds from prior sampling or shedding of a Floy or PIT tags, indicating the possibility that this is a wild return. Scale and tissue samples were sent to UNB for analysis.

Rainbow smelt are a crucial forage fish for salmon, but numbers of smelt were drastically reduced by the causeway. The smelt run has shown encouraging signs of recovery in recent years, but river conditions prevented the trap to be deployed in April in time for the 2021 smelt run though one was caught in the trap after the run, on July 27th. The smelt were observed in April moving up with the tidal bore so based

on the density of smelt visible against the river bottom and portion of river attracting gulls, it is estimated that thousands of smelt were present.

Unfortunately, some aquatic invasive species are being found in the trap on the Petitcodiac, though there is not enough data to determine population trends. In the 2018 season, 11 smallmouth bass were captured, the most since 2012 when 15 were caught. As they are a threat to salmon fry and redds, the FFHR license authorizes personnel to euthanize this species when encountered. Also, in the 2018 season 2 chain pickerel were caught. There have been none since that time but with 10 caught in 2015, and since they are a threat to salmon smolt, the FFHR licence also permits those fish to be euthanized when encountered.

Presentation Available Upon Request

Edmund Redfield

Edmund has an M.Sc. in Restoration Ecology (University of Alberta), B.Sc. in Forestry (University of Missouri), and is certified as a Fisheries Field Technician (Vancouver Island University). He has worked for Fort Folly Habitat Recovery (FFHR) since 2009. From 2011 onward he has been managing the Fish Net Trap at the Head-of-Tide that FFHR operates on behalf of the Province of New Brunswick as part of required monitoring according to the terms of the regulatory approval for the project building the new bridge linking Moncton and Riverview to partially replace the Petitcodiac Causeway. The trap targets anadromous fish species coming upstream as they enter the freshwater portion of the Petitcodiac River from the estuary in order to assess the results of changes being undertaken in the river. The first being the opening of the gates in 2010, and the second- completion of the bridge in 2021.

The Innate and Acquired Immune Response Associated with The Use of a Heterologous Vaccine with Immunomodulatory Potential in Salmon

-presented by Juan Carlos Rodriguez-Lecompte, Atlantic Veterinary College, UPEI

Renogen is a heterologous live vaccine which uses live *Arthrobacter davidanieli* as microbial stimulation for the immune system which shares antigenic determinants with Renibacterium salmoninarum and Piscirickettsia salmonis (salmon rickettsial septicemia (SRS). This vaccine is primarily used to prevent Bacterial Kidney disease (BKD), however, its ability to directly modulate the immune system aids in a more robust and sustained response against other diseases such as SRS.

The objective of the research project was to assess the immune response in fish after the use of this live vaccine by assessing the presence of cytokines during the initiation, maintenance, and amplification of the immune response to the vaccine antigen. Cytokines may act as effector substances against a specific agent, soluble mediators (messengers) of the immune system that have to ability to regulate different types of cells associated with the response. Data analysis considered several categories of cytokines and the sequence of events of what occurred when and or which were activated when exposed to the antigen. Cytokines included in the analysis were Pro-inflammation, antigen recognition/presentation and anti-pro-inflammation (IL-1β, IL-12 and IL-10); T Cells (IL-2, CD4 and CD8); and Polarization of T cells CD4 sub-sets (IFN-γ) Th1.

In a disease challenge for Bacterial Kidney Disease (BKD), fish were IP vaccinated twice and sampled seven times over 910-degree days, as per timeline shown. The anterior part of the kidney was used for the molecular immunology studies, which focused on the levels of mRNA gene expression for Interleukin (IL)-1 beta, IL-12, IL-2, CD4, CD8, IL-10, and Interferon (IFN)-gamma. The tests were performed using a real-time PCR test (RT-PCR). The expression increase (Upregulation) or decrease (Down-regulation) was considered from one (1) against the endogenous expression gene (housekeeping gene) (ELF1 + Bactin).

Graphs were provided showing the level of each cytokine over the timeline of the project, indicating the point of the initial vaccine and the booster. The results of this project showed that pro-inflammatory and anti pro-inflammatory effects associated with the use of Renogen are observed, the presence of Renogen at vaccination site helps the activation of macrophages improving the capture and phagocytosis of the other inoculated vaccine antigens; and the presence of Renogen activates cellular immunity, increasing the spectrum of the overall immune response, both cellular and humoral.

Results suggest a modulating/activating effect of Renogen's immune response upon immunization with heterologous antigens; presumably because they share similar antigens.

Presentation available upon request

Juan Carlos Rodriguez-Lecompte

Dr. Juan Carlos Rodriguez-Lecompte is a veterinarian, professor of Veterinary Immunology, at the Atlantic Veterinary College, University of Prince Edward Island. Followed to his Master of Sciences in immunology (Javeriana University, Colombia, 1997), Dr. Rodriguez-Lecompte did his PhD in Immunovirology at AVC-UPEI (2003). After that, he had the opportunity to conduct post-doctoral studies at McMaster University (2002-2007) in Cancer and Immunotherapy working on Chronic lymphocytic Leukemia. In 2007, he became Faculty at the Animal Sciences Department, University of Manitoba. Since 2012 he is a faculty Member at the AVC-UPEI, where he is a professor of Veterinary Immunology and principal investigator. Dr. Rodriguez-Lecompte is working in the nutritional immunology field; he is trying to understand the different immunological mechanisms associates with the

mucosal areas of the intestine in different species using viral and bacterial models. Currently he is working in innate nutritional immunomodulation in food animals to modulate and enhance the maturation of immune cells pre- and post-infection.

Can We Decrease Disease Though Probiotics? The Importance of The Microbiome in Supporting Animal Health

-presented by Steve Leadbeater, DFO-SABS

Health management in aquaculture is a continuous cycle of identifying pathogens / diseases of concern and managing the impacts. Often first action requires antibiotics to manage bacterial issues while vaccines can be developed and approved. Pathogens of concern can differ between sites, regions, and fish populations. There are also regional differences in the availability of therapeutant options, with those in Canadian aquaculture limited to treatment of disease by prescription. Globally antibiotic use has led to an awareness of the rise of antimicrobial antibiotic resistance genes, which is increasing pressure to reduce the use of medically important drugs, their fate in the environment and market concerns with residue in products for human consumption.

Hologenome refers to the microbiome plus the organism, a superorganism. The term microbiome refers to those microbial (bacteria, fungi, virus) communities external and internal to the fish, and with all these genes within these microbiomes there may be the potential to support health if the combination of these organisms is correct. The action of the microbiome can offset the need for action by the host immune system. For this question to be answered more information is required about the mechanism – how these communities are established, when and how do they work, is there a seasonal component and is there the potential for modulation of this community to strengthen its capacity for health promotion.

Bacteria are everywhere in the environment and so are found within the skin, gastrointestinal tract, and gills of fish. The ability of bacteria to move from the marine environmental through the gills into the blood allows bacteria to get to all organs but are some "invited" in and either add to the health of the organism or are inert. A pathogen would be disruptive or takes advantage of disruption. Does a breakdown in this community lead to disease? The question if there are potential differences between wild and farmed fish microbiomes, is asking if farming practices are eliminating beneficial microbiome components. Understanding this could help with future fish health management decisions.

A three-year ACRDP project commenced in 2021 evaluating a probiotic product as health support for both salmon and lumpfish in the farming sector. This is of interest especially as lumpfish are being used within cages as a biological control for sea lice in many regions and there is a limited conventional treatment options and vaccine limitations for lumpfish, so cohabitating these fish raises unknowns. There are variations in marine and fish microbiome communities depending on the environment so local knowledge is required to determine what organisms are included in these communities and increase the understanding of probiotic potential in supporting fish health. A survey of local wild and farmed salmon and lumpfish can provide information on the seasonality of various microbiome components and potential reduction in disease occurrences and sea lice attachment with the use of a probiotic called Stembiont™ in Canada.

The work plan for year one included a survey of wild salmon smolt, returning adult salmon to rivers and hatchery broodstock and salmon on farms. COVID 19 restrictions impacted logistics so farms and hatcheries could not be accessed, testing kit design took time and timing of funding approval resulted in small sample sizes of wild salmon and only two samples of wild lumpfish. This work will be attempted again in 2022. The second component of the 2021 work was the start of a year long sea lice repeat exposure study with salmon exposed to three pulse of sea lice in the fall and winter of 2021,

spring/summer of 2022. The experimental groups of salmon are being given the Previwo probiotic product Stembiont, and assessments of salmon condition / growth, lice load, and any lice deformities will be evaluated during each seasonal timeframe.

An assessment of pathogen protection in lumpfish and salmon given the Stembiont product, will also commence this year. For salmon, protection from ISAv and *Moritella* will be evaluated with negative control fish and test groups receiving the probiotic plus a standard production vaccine or a standard vaccine alone which will be exposed to pathogens. For Lumpfish, the health support provided during challenges with Vibriosis will be evaluated and are important as there are not yet widely available vaccines for this bacterial pathogen in lumpfish. In both work packages, microbiome sampling will be completed to understand potential changes in community structure in the presence of disease.

Within the work plan for year two and three, the microbiome survey analysis and pathogen/pest impacts will continue with the refinement of protocols and timing of sample collection. In year two and three, the analysis of health support provided by the probiotic product against the same pathogens, will be repeated to evaluate potential differences in protection with seasonal changes in water temperature. Other pathogen may also be included based on temperature profiles. The potential of extended protection will also be assessed repeating experiments with delayed pathogen exposure, 4 months after probiotic treatment.

Lessons learned should allow for increased knowledge on the response of microbial community to disease, assess the ability of a treatment to modulate the microbiome, and provide information for decision makers to improve fish health management.

Presentation available upon request

Steve Leadbeater

Steve Leadbeater has been involved in aquaculture science since 1996 follow graduation from the University of New Brunswick in Saint John. In 2008 Steve completed a master's degree in biology and in 2007 began work at the Saint Andrews Biological Station on aquatic animal health and salmon biology projects. He operates and oversees activities in the bio-containment lab designed for the study of diseases impacting salmonids, as well as other fish and invertebrate species. Current studies involve many partners from industry, academia, government groups working on projects involving ISAv, sea lice, bacterial kidney disease characterization, lumpfish behavior and microbiome health. It is Steve's responsibility to collaborate with research teams to help design and execute live animal trials to answer aquatic animal health research questions, while complying with the Canadian Food Inspection Agency (CFIA) requirements for holding laboratory certification.

AcuLice – Can Sound Prevent Lice on Atlantic Salmon?
-presented by Albert Imsland, Akvaplan-Niva

The rationale for this project has been to develop a method of preventing infection of sea lice (Lepeophtheirus salmonis) that is sustainable, cost-effective and would not lead to resistance. The AcuLice system uses a composite acoustic sound in seawater that is believed to reduce the ability of sea lice to feed on its host and therefore the louse falls off the salmon after about 3-4 weeks.

The research project consisted of the three different experiments. The five-month pilot study in 2018 at the Hessvik locality in Hardangerfjord was conducted as an initial field trial of AcuLice to prevent sea lice infections on post smolt versus a control site. There were lumpfish at both sites, otherwise, no mechanical and or drug treatment was required at the test site. There were some technical challenges with

unstable electricity at the test site such that the AcuLice units were periodically turned off. There was a higher total lice load on Hessvik (0.84) compared to the control site, Apalviknes (0.36), but at the last sampling there was less new lice on Hessvik (AcuLice) compared to Apalviknes (0.03 vs. 0.13). There was no difference in size, fitness, health, or welfare between the groups.

The large-scale testing of the AcuLice technology in 2019-2020, assessed the risk of sea lice infection at a regional level and the third experiment evaluated the effects of AcuLice on the welfare, stress, and health of salmon in intensive farming. This work involved over 20 sites, but the data presented represented nine test and three control sites with the Hardangerfjord.

With the large-scale trial there was of course variation between facilities with smolt stocking, lice load, and lice treatment (cleaner fish). In the second experiment, there was significantly longer production time in the AcuLice group before treatment for sea lice was required (7 weeks), and fewer treatments were needed during the production period, by half or more. The data presented on the salmon lice composition showed that the sites using the AcuLice had a higher number of small lice (2.8:1) prior to the trial, as in the pilot study, but at the end of the field trial there was a 37% higher level of mature sea lice in control fish.

February to March 2020, post-smolt at one facility with AcuLice were assessed for physiological stress response and welfare compared to a control site. In the first experiment, smolt were sampled prior to AcuLice treatment, then again one hour post treatment, and data was presented for each analysis completed. There was no significant difference in plasma cortisol concentration, a primary stress response indicator, between the groups of salmon. The secondary stress response indicators in the plasma of calcium, chloride, lactic acid, and magnesium also showed no significant differences between the groups. There was a significant difference in plasma glucose concentration between the smolt with AcuLice treatment versus control, but glucose levels could be influenced by other factors, such as food ingredients / feeding regime. Specific growth rate (SGR) data followed for longer period, used as a tertiary indicator, showed no significant differences between treatment and control groups of salmon. Overall, the Atlantic salmon group reared with low frequent sound treatment (AcuLice) in commercial open sea cages showed minor or no acute stress response compared to the control.

The results indicate that AcuLice treatment had a significant effect on reduction of the salmon lice burden in Atlantic salmon during commercial production. This was Phase 1 of the project with Phase 2 to begin in 2022 looking further into the technology, that will include testing with cleaner fish, and evaluation of potential effects within the marine environment, with marine mammals, etc.

Presentation Available Upon Request

Albert Imsland

Professor Albert Kjartan Dagbjartarson Imsland has a PhD degree in aquaculture (1997) from university of Bergen and MSc in applied statistics (2000) from the same university. He is the research manager in aquaculture (since 2001) at Akvaplan-Niva (https://www.akvaplan.niva.no/en/home/) and is also professor ii in marine developmental biology at the university of Bergen (since 2003). He has been working with marine species in culture since 1991 mainly focusing on environmental and genetical regulation of growth mechanisms and fish maturation. He works closely with people from the aquaculture industry in Norway, Iceland and abroad, where the aim is to make scientific findings and knowledge in aquaculture applicable in real “daily life” situations at the fish farm. Prof. Imsland has since 1995 authored and co-authored more than 190 scientific papers published in peer-review journals (h-index 36). Prof. Imsland has extensive management experience in administration of several European, Norwegian, Icelandic, and Nordic scientific projects and has coordinated over 40 research projects in aquaculture.

Aquaculture AI - Changing the Industry
-presented by Bryton Shang, Aquabyte

Aquabyte is combining advanced tech from the US with fish farming knowledge from Norway to help farmers do better, be more sustainable and more profitable. What is Aquaculture AI? Smarter Farming Decisions with Data. It follows the real time growth of the fish to allow farmers to feed better, make better feed choices and have weight distribution data for sales and harvest planning. Aquabyte's automated sea lice counting systems was the first to be approved in Norway to comply with regulations for reporting purposes and for monitoring of treatment effectiveness. The system can monitor fish quality and 14 welfare aspects for marketing advantages and better prices. It is currently in use in over 100 cages around the world with salmon and rainbow trout.

Expect Aquaculture AI suppliers to deliver systems that can do everything. Aquabyte's All-In-One Camera can monitor average weight, complete automatic lice counting, monitor fish welfare metrics and feeding by taking pictures within the cage 24/7 and are processed on the camera. The data is sent to a simple website for the farmers to access the data. So far there have been images of 250,000,000 fish processed.

For the Automatic Lice Counting program high-resolution pictures of fish are taken in the pen every day and a graph presented showed how farmers can track the lice level day-by-day. The graph also compared the weekly counting of ten fish per cage versus with the automated system counting 10 times that number of salmon every day to see real time infestation patterns of lice development. The program counts three life stages, both Caligus and Leps, with the machine learning component including different farming environments and validated through University of Bergen.

The system is also being used by farmers for precision treatments. An example of data graphically presented over several months on a site with five cages showed high lice pressure on pens 1-3, but initially low lice pressure on pens 4-5. Eventually pens 4-5 became infected and lice pressure increased such that Pens 4-5 reach same high lice pressure as pens 1-3. Treatment after this point did not reduce the lice load effectively.

The biomass and weight monitoring system provides real-time average weight and growth, so therefore real-time FCR, SGR estimates for better production control. A table of data comparing weights from a processing plant (harvest weight) and the Aquabyte system for various harvest dates showed deviations of between 0.21% and 1.96%. Graphical data presented showed how feeding with the actual growth rate versus the guidelines provided in feeding tables, could allow the farmer to feed more, or less, based on the data or change pellet size and get better SGR.

Several graphs were used to present data showing the use of Fish Identity Recognition (FishID), which increases the accuracy of weight estimates and aids to identify subpopulations of fish. The weight data and welfare data of these fish may enable changes in farm or feed management.

Dashboard views of data using the FishID component showed how farmers can easily assess salmon quality for example, maturity rate overall within a cage and proportion of salmon in the various stages of maturation via a maturation scoring system identified on the dashboard page. Similarly, the number of fish with body wounds and their severity can be easily evaluated by the farmer as either active wounds or healed wounds.

Presentation Available Upon Request from the Speaker

Bryton Shang

Bryton Shang is the founder and CEO of Aquabyte, a Silicon Valley and Norway-based venture-backed company applying machine learning and computer vision to aquaculture fish farming for biomass estimation, sea lice counting, and feed optimization and formulation. Bryton was named to the 2019 Forbes 30 Under 30 in Manufacturing & Industry. Graduating at the top of his engineering class at Princeton University, Bryton has led several venture-backed start-ups. Bryton built deep learning algorithms to diagnose cancer as CTO of HistoWiz, a biotechnology firm. He also co-founded iQ License, a brand licensing platform, and Nikao Investments, an algorithmic trading firm.

Novel Microalgal Products as Alternatives for Antibiotic Use in Atlantic Salmon
-presented by Stefanie columbo, Dalhousie University

Antimicrobial resistance (AMR) is a global human and animal health concern which has the potential for transmission in the ocean environment. It is complex and understudied in marine environments, likely influenced by many sources, including human use of antibiotics. Less understood is the effect of climate change and how this may impact salmon farming since the northward expansion of temperate species may involve new invasive species, including pathogens.

In Atlantic Canada, warming impacts on the Bay of Fundy salmon farming region has already been observed over the last 10 years with extended warm periods estimated to reduce the development time of sea lice to adult stage by 60%. Other salmonid pathogens of importance, like *P. salmonis* (causative agent of SRS), grow optimally at 14^{o}C-18^{o}C, creating the potential for greater geographic range and pathological impacts in the host.

A recent literature review found that of 51 antibiotics commonly used in aquaculture and agriculture, 39 (or 76%) are also of importance in human medicine. There is a need to develop innovative solutions to emerging diseases in aquaculture and the spread of invasives that avoid contributing to resistance of treatments already in use in terrestrial and aquatic systems. The aquaculture industry has greatly reduced the use of antibiotics over the last 10-20 years, so this project hopes to add to the tools to continue this trend over the coming years.

One Ocean Health is a large research consortium, part of the Ocean Frontier Institute, created to increase understanding and management of environmental and animal health threatened by climate change. This will enable the sustainable grow of fisheries and aquaculture sectors and support coastal communities in the North Atlantic. One proposed research output includes the measuring and mitigating antimicrobial usage (AMU)in ocean food animals by examining factors influencing farm level AMU, develop methods to monitor AMR in wild and farmed animals, and designing functional feeds that have potential to reduce AMU.

Over three years, this work package aims to develop alternative functional elements, specifically bioactive compounds from microalgae, to add to fish feeds to enhance protection of Atlantic salmon against infections, thereby reducing AMU. There are three experiments planned over the next three years. One of the bioactive being assessed is Astaxanthin (Ax) which is a carotenoid naturally occurring in shrimp and other prey items that give the naturally occurring pink/red coloration to salmon flesh but is also a potent antioxidant, involved in immunity and specifically promotes inflammatory control in skin cells.

The same signalling mechanisms involved with Ax in salmon as an antioxidant are also associated with salmon response to ectoparasite (i.e., sea lice) and bacterial skin ulcer disease (i.e., *Moritella viscosa*). This work will evaluate an algal product to potentially replace astaxanthin by examining if it provides equal pigmentation and flesh quality, if there is any extra benefit from the algal oil source as an

antioxidant and if the algal oil can improve inflammatory response and wound healing capability in Atlantic salmon under challenge with common skin infections that are normally controlled with antibiotics.

Haematococcus pluvialis (Hp) is a unicellular alga that is ubiquitous in freshwater environments and stores high amounts of Ax, though it is naturally difficult for fish to digest and so the Ax is not bioavailable. A novel product with weakened algal cell wall structure has been developed and might be the solution to this problem. The trial design using 1kg rainbow trout was outlined where the trout were fed one of three experimental diets to compare Ax digestibility, tissue Ax content, and flesh color between groups fed synthetic Ax (S-Ax), the Hp whole cell Ax and a control group with no Ax. After 10 weeks there was no significant differences in growth, Ax digestibility, fillet Ax content, retention or coloration observed between S-Ax and Hp-Ax treatment groups. SalmoFan™ color reading data of S-Ax and Hp-Ax fillets presented ranged from 28-34 and were significantly higher than the control group with no Ax.

A second project will test pigment effectiveness and wound healing capacity of Hp for salmon to determine if Hp-Ax can replace synthetic-Ax in Atlantic salmon feeds with additional benefit. In addition to evaluating performance-associated metrics and product quality, the experiment will include a microbiome assessment of salmon, correlated with changes in immune response and any potential impact on mucosal immunity and resilience of salmon in a wound-healing model.

Project design was presented. Atlantic salmon (300-500 g initial weight) are being fed one of seven diet treatments which will compare high and low doses of Ax from three sources against a control. Products derived from Hp include one with extracted Ax in a carrier oil and one with a spray-dried (extracted) Ax powder, will be compared with synthetic Ax as a control for 6 months for pigment effectiveness plus an additional month for wound healing challenge. After the 6-month sampling has been completed, three layers of skin from a biopsy punch will be removed from the salmon. Post-wounding sampling at 2, 7, 14 days will be completed encompassing transcriptomics (skin, head kidney), microbiomics (skin), histology (skin, gill) and proteomics (mucous) assessments.

The next project will involve the testing of other novel algal extracts for their potential effects on innate and adaptive immune parameters in Atlantic salmon. The objective will be to develop enhanced diets that impact clinical outcomes against viral (ISAv) or bacterial (BKD) infection, and enhanced diets that benefit immune function and improve clinical outcomes following bacterial infection, without the use of antibiotics.

Once effective algal extracts have been identified with antioxidant and immunological enhancement in salmon, studies will potentially be conducted in a non-salmonid finfish species such as halibut.

Presentation Available Upon Request

Stefanie Colombo

Dr. Stefanie Colombo is an Assistant Professor at Dalhousie and Canada Research Chair (Tier II) in Aquaculture Nutrition. She has published over 40 scientific papers and 2 book chapters. She has been an invited keynote speaker at several national and international conferences. Dr. Colombo has served as the President of the Aquaculture Association of Canada and is currently the Science Advisor for the Aquaculture Association of Nova Scotia. She was selected to highlight her research during visits from the Prince of Monaco, Speakers of the House from the G7 countries, the G7 Oceans Summit, and the Premier of Nova Scotia. She has received the Dalhousie's President's Research Excellence Award for an Emerging Investigator and the Faculty of Agriculture's Early Career Research Excellence Award.

Aquatic Diagnostic Capacity and Testing Quality Assurance: Are We Ready for The Projected Growth of Aquaculture in Atlantic Canada?
-presented by Dave Groman, Atlantic Veterinary College, UPEI

Maps of Canada were presented indicating the locations of aquatic diagnostic laboratories across the country, and more specifically in Atlantic Canada. Currently the Canadian Food Inspection Agency (CFIA) in conjunction with the Department of Fisheries and Oceans (DFO), provides diagnostic laboratory testing services for notifiable fish and shellfish pathogens under the umbrella of the National Aquatic Animal Health Laboratory System (NAAHLS). The Government of Canada utilizes the NAAHLS for routine testing in support or domestic and international trade, as well as for large-scale disease response testing activities. Laboratories in Canada other than the NAAHLS may be approved by CFIA to conduct official virus testing to assist with surge response as well as routine surveillance.

CFIA has proposed the development of a Canadian Aquatic Animal Health Laboratory Network (CAAHLN) which would include laboratories, external to the DFO NAAHLS. These labs would be required to maintain accreditation under the ISO 17025 system and would also be required to obtain and maintain certification with respect to national biocontainment standards for laboratories handling aquatic animal pathogens. To be approved by CFIA these labs must also enter into an agreement with the CFIA to provide testing services in support of the National Aquatic Animal Health Program (NAAHP), participate in training on the use of approved NAAHLS test methods, where applicable, and adhere to the operating policy and procedures specified by the CFIA for laboratories performing testing in support of the NAAHP. In addition, approved laboratories are required to successfully participate in a proficiency testing programs (PT) if available.

The mandate and focus for aquatic animal surveillance programs in Canada differ slightly nationally and regionally. CFIA, through the DFO NAAHLS, conducts national surveillance for diseases such as Infectious Salmon Anemia (ISA) and confirms outbreaks of other "Notifiable Diseases "as this is a World Organization for Animal Health (OIE) obligation. In addition, DFO in British Columbia (BC) routinely conducts fish health audits of the BC salmon aquaculture industry, in conjunction with the BC Ministry of Agriculture, Food and Fisheries Animal Health Centre. In Atlantic Canada surveillance and monitoring of private sector aquaculture facilities is conducted by the provinces using a program termed the Pan-Atlantic Certificate of Health for Transfer (COHFT). In Alberta, the province conducts Whirling Disease surveys of wild salmonid populations.

Currently, CFIA does not offer a mandatory National Aquatic Animal Pathogen Proficiency Testing Program. Because of this lack of PT there is no interlaboratory comparison program which allows the aquaculture industry in Canada two objectively evaluate lab testing and quality assurance. Many aquatic diagnostic laboratories do, however, conduct in-house Quality Assurance Programs (QAP's) and / or subscribe to international certification programs such as ISO 17025. This program, however, is not considered to be part of a PT scheme and independent PT programs for aquatic diagnostic labs are presently limited. At present, only the EU Reference Lab located in Denmark provides virology and shellfish pathology PT programs to EU Countries and Foreign National References Labs Only.

In North America, veterinary diagnostic labs are not mandated to participate in PT programs, though many labs voluntarily participate in commercial PT programs such as the Veterinary Laboratory Association Quality Assurance Program (VLAQAP). The VLAQAP is operated by the AVC as a private for-profit PT service, and currently offers 2 PT programs for aquatic testing for bacteriology and histopathology. The process for participating labs was presented.

All aquatic diagnostic labs operate on narrow margins, especially in Atlantic Canada. Flexibility to hire personnel is limited, primarily due to operational human resources policies in university, government and / or agency environments. As well, innovation and development of new testing protocols are both costly and

time consuming. As novel pathogens are found there is always a time-lag in developing quality assured diagnostic assays. In addition, workload is often unpredictable, and aquatic diagnostic labs do not always meet the expectations of clients due to many constraints such as personnel and protocol development.

Data was presented to demonstrate that the overall aquatic diagnostic testing workload trend has been increasing in Atlantic Canada since 2011 and is expected to increase significantly as new fish and shellfish production comes on-line. This includes viral diagnostics due to surveillance programs and histology testing for diagnostics and research. Currently, there is only one diagnostic aquatic histology lab currently servicing Atlantic Canada. The interpretive histopathology workload is extremely high in the Atlantic Region, often exceeding the interpretation of nearing five thousand (5000) histology slides per year.

The diagnostic case submission frequency can be highly variable on a weekly or monthly basis. This variability creates inefficiencies in diagnostic laboratory operations and can lead to delays in reporting results and laboratory human resources allocations. Due to this demand labs have developed into a triage situation, where diagnostic cases take precedent over research and surveillance cases.

With aquaculture production in Atlantic Canada set to expand and current diagnostic laboratory testing demand often exceeding capacity, the recruitment of qualified professional staff needs to be a priority. The Atlantic Provinces and private sector aquaculture companies need to work together with Provincial Aquaculture Departments and regional diagnostic labs to develop strategies and plans to expand and quality assure aquatic diagnostic capabilities in anticipation of the projected increase in both finfish and shellfish production.

Presentation Available Upon Request

David Groman

Dr. David Groman has been working in the field of wild and aquaculture fish pathology for over 40 years, having begun his training at the Northeast Wildlife Disease Center at the University of Connecticut in 1976-1980 and continued onto the US National Fisheries Academy in 1978-1979, University of Idaho 1979-1983 and the University of Iceland 1983-1984. He brings a wide variety of fish health and fish pathology experiences to his current job in Diagnostic Services at the Atlantic Veterinary College (AVC) having worked on fish health projects and diagnostic cases in Atlantic Canada & Worldwide since arriving to the AVC in 1988. For the last 25 years Dr. Groman has been Section Health of Aquatic Diagnostic Services at the AVC, and in this role has reviewed thousands of fish disease cases, including those from a large variety of wild finfish and shellfish. In this regard, Dr. Groman would offer the aquatic animal health clients and companies a breath of experience in the field of fish disease, which can be applied equally to both potential research projects.

Introduction to NewDEPOMOD

-presented by Iain Gatward and Stevie Brain, SAMS Enterprise

SAMS Enterprise is the commercial subsidiary of the Scottish Association for Marine Science (SAMS), whose products and services include marine environmental consultancy, NewDEPOMOD and Marine growth modelling / 3D photogrammetry. NewDEPOMOD is a particle-tracking modelling software designed to predict dispersion of fish farm wastes in the benthic environment, which can be used by industry and regulators to manage adherence to environmental quality objectives and safeguard the environment.

This software has been expanded from the original AutoDEPOMOD and DEPOMOD over 20 years and had an initial validation program carried out in 2014 in Canada. To increase confidence in the model,

NewDEPOMOD has been extensively validated in Scotland, and validation is underway in Chile and Norway.

A product video was presented outlining the uses for NewDEPOMOD which includes predicting farm site capacity, optimising feeding and disease treatments, and research. Individuals and organisations who want to predict near-field benthic deposition from caged fish farm can used the program under licence packages. SAMS Enterprise also provides modelling services for the industry including NewDEPOMOD, sea-lice connectivity and hydrodynamic modelling.

NewDEPOMOD incorporates a range of processes, which together simulate the fate of individual waste particles from farm cages. Through this simulation conducted over a period of weeks to years and including environmental factors such as bathymetry and water currents, NewDEPOMOD creates a picture of how waste products are likely to be distributed in the benthic environment.

The model does not currently incorporate a biogeochemistry unit; however, users can make associations between the calculated flux and the impacts of interest (e.g., regulator specified EQS). NewDEPOMOD is highly customisable, and the bed-model can be adapted for specific conditions.

The modelling process, which can use data from one ACDP for basic use or multiple ACDPs or a hydrodynamic model for more complex analysis, was described. With the basic use the model does not account for tides and waves. Cages in the model are represented by the appropriate shape and do not need to be at the water surface as NewDEPOMOD can allow for cages to be suspended at any height in the water column. This has allowed modelling work to be carried out with semi-enclosed systems with waste-capture capability simulated. This work has been accepted by the Scottish regulatory body (SEPA).

Presentation available upon request

Iain Gatward
Iain Gatward is Business Development Manager within SAMS Enterprise, the wholly owned subsidiary of the Scottish Association for Marine Science (SAMS), where he has worked since 2019 and is involved in both research and commercial engagement with the aquaculture sector. Iain has a BSc in marine biology and an MSc in aquaculture and over 15 years' experience working in consultancy, particularly focused on aquaculture, renewable energy, and international development. He has been involved in leading and delivering aquaculture projects internationally and works closely with clients to support their needs in NewDEPOMOD software services. He works closely with research colleagues and the aquaculture industry to improve our fundamental understanding and innovation in marine science.

Stevie Brain
Stevie Brain is an Environmental Modelling Analyst at the Scottish Association for Marine Science (SAMS), where since 2019 she has worked as a mathematical modeller for research and commercial projects within the aquaculture sector, with a primary focus on salmon farming. Stevie has a BSc in Mathematics and an MSc in Mathematical Biology. She has been involved in projects in Scotland to further validate and maximise the potential of NewDEPOMOD, and international collaborations to validate NewDEPOMOD in non-Scottish waters. She has completed modelling work on behalf of customers to support license applications to the regulatory body and works with users of the NewDEPOMOD software within industry to enable the continuous development of the software.

The Smart Energy Company™: NOREASTER® Solar Energy Solution
-presented by Joe Allison, The Smart Energy Company™

The Smart Energy Company™ installed it's first customer solar array on a private New Brunswick Dairy operation in 2016, and at 400 kW remains as the province's largest private solar farm. The company has installed New Brunswick's largest "net metered" solar farm (100 kW) and is responsible for developing over 50% of all solar energy systems installed in the province, totaling over 1 Megawatt of solar generation capacity. Our recent collaboration with NB Power on the 1.6 MW Shediac Community Solar Farm will create the first utility-scale solar array in the province when completed later in 2022.

Solar Energy Systems are energy producing assets that provide a return on investment versus a utility expense and enable companies to reduce GHG emissions. Our highly efficient solar energy products generate electricity at a reduced rate when compared to utility providers. A video and text explained how the solar panels absorb sunlight creating DC energy flow with the DC electricity then converted to usable AC electricity through inverter technology. The electricity, if unused, is transported to the grid through NB Power's net-metering program and like a battery system, are stored as electricity credits. These electricity credits are then consumed by electricity demand in off-peak solar periods.

Ground mounted solar has many advantages over roof mounted systems and ensures perfect placement, higher power production, and better snow shedding along with ease of installation and assembly. The use of bifacial solar panels allows energy to be produced from both direct and reflected light energy, increasing winter-time performance with an approximate 8%-10% gain in overall annual power production. Aggregates under the system may also improve reflected light energy which is being evaluated.

The NOREASTER® Ground Mounted Solar System was developed in New Brunswick for the harsh Atlantic Canadian climate and is offered in two separate packages: "In A Box" which is our customer-ready-to-assemble solution and "Turnkey", which is fully assembled and electrically installed. The "In A Box" option, launched Spring 2021, includes high performance bifacial solar modules, the patented NOREASTER® Solar Racking System, a code-compliant grid-tie inverter and all DC wiring and fasteners. The "Turnkey" package adds NOREASTER® assembly by certified installation professionals, trenching and materials for AC wiring, and electrical interconnection to the service entrance.

A table was presented detailing the lifetime savings, annual power production, lifetime GHG emissions, and environmental benefits based on the number of ground mounted systems employed produced from one to six units. The NOREASTER® "Six" at 96.1 kW is the largest system that can be implemented with NB Power's net-metering program and generates up to 140 MWh annually.

Presentation available upon request

Joe Allison

Joe Allison is the Business Development Manager at The Smart Energy Company and works to actively promote the exciting opportunities available through solar energy. Joe helps clients implement clean energy solutions that save costs, provide energy independence, and contribute to a sustainable environment by reducing greenhouse gas emissions. Prior to Smart Energy, Joe was a Senior Business Relationship Manager with Irving Oil Limited, a leader in refining and traditional energy, and has also held several product and marketing management roles with a variety of technology organizations including Bell Aliant, Blackberry and Alcatel (NOKIA). He holds a Bachelor of Business Administration from the University of New Brunswick, has a Lean Six Sigma certification, and considers himself a lifelong learner.

Spatial Computing: Why should I care?
-presented by Iain Whyte, Kognitiv Spark

Founded in 2016, Kognitiv Spark is a New Brunswick based technology company delivering cutting-edge Augmented Reality/Mixed Reality solutions to clients globally. These solutions enable remote users, wherever they are in the world, to access subject matter experts to facilitate complex task troubleshooting. Experts can deliver their knowledge to the point of need allowing them to support end-users in real time, without the requirement for travel. Kognitiv Spark's flagship solution is RemoteSpark, a mixed reality communication platform.

The platform creates a secure, low bandwidth, collaborative Mixed Reality digital communication environment designed specifically for the end-user or operator to access critical support to diagnose and resolve issues and ensure critical systems are operational. Current partners are found across the utilities sector, as well as oil and gas, aerospace and defense, the marine sector, industrial engineering, and healthcare. A video was presented showing how RemoteSpark can help an employee access a subject matter expert, and interact with images, documents, and 3D models to address problems and communicate with expert support in real time.

Spatial computing enables the computer's user interface to become a seamless part of the three-dimensional digital environment in which a person can visualise and interact directly with data to inform situational awareness and decision making, as well as collaborate on projects. It connects experts, researchers and or industry employees in remote locations to plan and design projects, collaborate and analyse data, provide technical support or transfer knowledge, and be able to visualize models in 3D while completing these tasks. The ability to take the water column as a 3D space, for example, and add data to that model to interact with it through a computer is a new way to experience and interact with that data.

Project HydroSpark is an Ocean Super Cluster project lead by Kognitiv Spark to enable 3D Visualisation of Sub-Sea Data Sets using Mixed Reality, providing the ability to take near real-time data and bring data to support situational and real time decision making. For fishing and aquaculture, the data already being collected is extensive so to be able to view the data in the environment in real time would be a tool for information integration, supporting day-to-day operations.

The RemoteSpark system is a digital enabler that can make a significant contribution to sustainability strategies. Environmentally, the system reduces the need for travel, with a positive impact in reducing carbon footprint/green house gas emissions and contributing to Net Zero aspirations and the long-term sustainability of the aquaculture industry. These reductions also translate into economic sustainability, along with faster resolution times and increased efficiency and productivity. An internally and externally a connected workforce aids in social sustainability with the ability to maintain and build knowledge and skills. Companies can also enhance stakeholder relationships, allowing 3D site visits without compromising operational restrictions.

Presentation Available Upon Request

<u>Iain Whyte</u>
Iain is a former Royal Navy Officer, with a background in operational planning, amphibious operations, and training. He has deployed worldwide, including on exchange with the US Navy, and with NATO. On leaving the Royal Navy, Iain was a Principal Consultant for a Leadership and Team Development company, established his own strategy and innovation consultancy, and held an Interim Directorship with the Marine Additive Manufacturing Centre of Excellence at the University of New Brunswick. Joining Kognitiv Spark in 2019, Iain is responsible for the Defence Sector portfolio, which also includes Public Sector and Marine Sector solutions. He is also the lead for Kognitiv Spark's Ocean Supercluster project with Kraken Robotics looking at the using mixed reality as a vehicle for visualising sub-sea data sets. He is a graduate of Loughborough University (BA (Hons), MSc.) and Kings College London (MA) in the

UK, a former Ridgway Fellow at the University of Evansville, USA, and a Fellow of the Institute of Leadership and Management (UK).

Latest Developments in The Application of Genome Editing to Aquaculture
-presented by Dr. Xavier Lauth, Center of Aquaculture Technologies

Artificial selection of naturally occurring mutations has been used for centuries in agriculture to produce animals and crops with desirable traits. The diversity of crops and of man's best friend are powerful illustrations of our ability to manipulate genes of the ancient species from which they were derived.

In 1970, the discovery of enzymes capable of cutting and splicing genetic material gave us new possibilities to engineer genetic materials in a directed way towards a desired end. Despite this breakthrough, the early enzymes were difficult to use for genetic manipulation of complex genomes. This hurdle was removed over the last two decades with the discovery of far more powerful, adaptable, and precise, programmable DNA scissors (e.g., Zinc Fingers, TALENs and CRISPR/Cas).

Currently, a variety of CRISPR/Cas-based therapeutics are being tested in clinical trials to correct pathogenic genetic variants and treat inherited human diseases such as sickle cell anemia, cystic fibrosis, and muscular dystrophy.

Furthermore, CRISPR genome-editing technology has been used to expedite sustainable genetic improvement in crops and livestock. Compared to conventional breeding, genome editing offers faster genetic gain for a beneficial trait per generation without undesirable side effects. The technique allows researchers to create one or multiple desired genetic variants directly to elite broodstock in a single generation. For example, the technique was used to accelerate the domestication of wild tomato, or to improve production traits in chickens, cattle, sheep, and pigs. Moreover, at least 20 economically important aquaculture finfish species have been successfully edited to create new valuable fish varieties with improved growth rate, increased food conversion ratios, enhanced flesh quality, greater resistance to disease or to stress and superior nutritional benefits.

Many experts believe that producing more fish will be an important part of the solution to addressing global hunger and malnutrition and to achieve a doubling of food production over the next 30 years to meet global food security.

Results were presented on how genome editing allows production of single-sex and sterile populations of fish and how the sterility trait can be propagated from one generation to the next.

The benefits of sterilization in finfish aquaculture include better fish performance and reduced risk of environmental impact on natural ecosystem from those fish that might escape cages. Data was provided showing the advantages of single-sex populations using tilapia as a model species. Nile tilapia are by far the most widely edited species accounting for more than 50% of all genes targeted to date in aquaculture species, and has sexual dimorphic traits, with culture of all male fish providing greater harvest weight and more uniform size. Preliminary economic analysis data of sterile male tilapia demonstrated a 10% increase in body weight gain which is expected to result in a shortened production timeline compared to conventional, non-sterile, male tilapia.

Diagrams were presented to detail the method used to inactivate genes controlling sex determination and production of eggs and sperm. The success rate of eliminating a targeted gene function with genome editing in tilapia is 10-30%, where with natural selection, obtaining the same desired trait would be found once in a million fish. Fish that have inactivated genes for sex determination are completely sex reverted. Diagrams were presented to explain the process to produce sterility in male and female tilapia, and data indicating the advantages of sterility technology when combined with single sex were also reviewed.

Data for growth and other preliminary economic analysis of sterile tilapia was presented. Genome editing for sterility is 100% effective with improved fish performance.

Canada is one of several aquaculture producing countries that have indicated there will be no new regulations for products of genome editing if no new DNA is added. Genome editing is a complimentary breeding tool that should accelerate genetic improvement.

Presentation Available Upon Request to CAT

Xavier Lauth

Dr. Xavier Lauth has expertise in the fields of immunity, host-pathogen interaction, developmental biology, and reproductive physiology. He has been with The Center for Aquaculture Technologies (CAT) since its inception and currently serves as Director of Innovation developing Genome-editing technologies to improve production traits of aquaculture species. Dr. Lauth has >20+ years of R&D experience, serving in several leadership positions at AquaBounty and Kent Sea Tech following his post-doctoral fellowship at UCSD. He holds a PhD in Cellular and Molecular biology from the University of Strasbourg (France).

A Validated Protocol for Fish Farm Monitoring Using Environmental DNA
-presented by Xavier Pochon, Cawthron Institute and University of Auckland, New Zealand.

This decade-long project has developed and validated an eDNA-based tool for monitoring benthic impacts of salmon aquaculture in New Zealand (NZ).

In NZ, the salmon farming industry is a growing sector, and its production does impact the surrounding benthic ecosystem below the farm due to high organic loading from fish feces and excess feed. This impact must be monitored by law under the *Resource Management Act*, and while many indices have been used internationally for measuring the degree of benthic impact, until recently it was not clear which one should be used in NZ.

Salmon farming is a relatively recent business in NZ, and it was only in the 2000s that the increase in aquaculture site applications fueled intense public and governmental scrutiny which led to the implementation of the Enrichment Stage (ES) index and the Benthic Standards Working Group (BSWG). This small group includes representatives from key government agencies, science providers, industry, and community stakeholders. It is this group that created, maintains, and updates the Best Management Practices (BMP) guidelines that guide monitoring efforts under the resource consent conditions set for high and low-flow salmon farms in the Marlborough Sounds.

The ES index is quite unique as it incorporates both biological and physio-chemical metrics. This method involves the collection of sediment along the enrichment gradient from control sites to the fish pens at regular distance intervals. Microscopy is used to measure changes in macrofaunal distribution along that gradient. This index provides a quantifiable scale of impact that ranges between 1 (natural state) to 7 (highly organically enriched), and along this gradient there exists a range of compliance thresholds which may vary depending on the farm resource consent conditions or the water flow environment where the farm is located. This method works well and is the gold standard in the BMP guideline, but it is costly and time consuming. It typically takes approximately 4 months from collection of sediment to reporting before any action can be taken, which is problematic for environmental managers as well as fish farmers.

About 10 years ago, eDNA metabarcoding was identified as a very promising alternative to microscopy. This method enables the capture of environmental DNA from living or dead organisms followed by high-throughput sequencing which produces a holistic map of the biological diversity present. Some of the obvious advantages over traditional methods discussed include faster turnaround time, the potential for

standardized processing between laboratories and the opportunity to explore difficult or new environments. Through work to develop a Metabarcoding Biotic Index (MBI), the bacterial MBI outperformed other indices and in 2017 the initial work on the b-MBI was presented to the BSWG, after which the group requested update protocols, refinement, and validation of the new method.

The details of the compliance study which compared the mean ES scores obtained with the traditional and b-MBI methods across a 9-year period was discussed with a data subset of five farms located in high water flow environments presented for discussion. Graphs showed the year, farm number, sample distance to the pen, mean ES score confidence limit, and difference between method scores at sampling stations. The results provided show the mean ES scores obtained with both methods were very similar to each other. The analysis of station-averaged ES scores showed a very high level of agreement between the molecular and macrofauna-based indices, and the mean ES score differences between methods were minimal.

The confidence intervals values around the mean ES scores are approximately half those typically obtained with the macrofauna-based ES. This indicates the new index is less variable when measuring enrichment levels within a given sampling station and suggests it is less influenced by spatial patchiness that can be evident in macrofaunal assemblages. This is a key advantage of the molecular-based index because it can provide more certainty around the results when there are instances of non-compliance.

The project data provided a much deeper understanding of the diversity, ecology, and spatio-temporal distribution of a range of taxonomic assemblages in NZ. This project also revealed the incredible value of bacterial assemblages as powerful indicators of environmental stress.

The final report has been submitted to the BSWG for assessment, the QA/QC protocols have been approved and it is expected that the group will incorporate this new tool into the BMP guidelines for routine monitoring next year.

Presentation Available Upon Request

Xavier Pochon
Xavier is a marine molecular ecologist in the Coastal & Freshwater group at Cawthron and an Associate Professor at the Institute of Marine Science of the University of Auckland. His research expertise focuses on developing multi-trophic molecular detection tools to analyse environmental DNA (eDNA) and measure biodiversity changes associated with natural and human-induced stressors in aquatic ecosystems. Xavier is involved in multiple research programmes using DNA and RNA proxies for monitoring New Zealand's aquatic health (e.g. Lakes380), emerging contaminants such as organics and microplastics, non-indigenous marine species (Marine Biosecurity Toolbox), and benthic impacts associated with aquaculture. Xavier is very passionate about his research and particularly enjoys interacting with the general public as well as regulators and industry partners, to find better ways of protecting our aquatic ecosystems.

Can eDNA Solve 'the Hard-Bottom Problem'?
-presented by Nigel Keeley, Institute of Marine Research, Norway

A problem with environmental monitoring programs is their reliance on being able to obtain soft sediment sample for analysis, but many sites have a mixed or hard bottom. Various published papers from 2015 to 2020 were identified that indicate marine sediments contain microbial communities that can be used to reliably describe benthic enrichment using metabarcoding (eDNA) and outline the development of the technology.

Images provided showed the conventional mud habitat along with other typical benthic habitats found in northern Norway and elsewhere including a mixture of rocks, boulders, gravel, bedrock, coarse sand, and shell sands. The only substrate that can be effectively grab sampled at present are sand / mud however, one thing all benthic environments have in common is a fine layer of organic and inorganic silt. This silt presumably contains the same benthic microbial communities as the sand / mud substrate, so a project was initiated to pursue this potential environmental monitoring solution. The first step was to address the technical challenges of extracting the flocculent layers and mobile substrate from steep rocky surfaces, often at depths of over 100m. Version 2 of the Substrate Independent Benthic Sampler (SIBS) included improved suction chamber engineering, and ability to sample in triplicate on single deployment.

The study sites used to test the SIBS and compare with conventional sediment grabs included three in northern Norway with a mixed bottom type (one gravel, two mixed) and depths between 50-120m deep. The three sites in southern Norway have steep sided, solid bedrock bottom, currently impossible to sample.

Methods and analysis process for conventional sediment grab for macrofauna, grab for eDNA and SIBS sampler for eDNA were compared. To help assess the SIBS microbial eDNA samples other criteria for describing the state of the seabed were used based on the video footage captured at the time of sampling. The substrate assessment categories included base substrate type, mobile substrate type, and the visual assessment of organic enrichment. The enrichment stage (ES) was also calculated based on environmental parameters by b-MBI. Graphs and charts were provided detailing the results of the comparison study. The SIBS eDNA results were consistent with the Grab eDNA results from the Northern farms, and the b-MBI ES calculated for each method all showed a clear relationship with distance. The microbial species used in this work were the same as those found in NZ, with the same roles and functions, showing how ubiquitous these bacteria may be in the benthic environment.

The SIBS b-MBI on hardbottom substrates from the southern farms provided invaluable information about waste distribution and enrichment status but further work needs to be completed to determine what the data reveals about such sites before and after farm installation. The data from the project showed that the microbial assemblages contain the same 'species' that are being used to assess benthic enrichment in conventional soft sediments, with relative abundance changing with distance from the farm, but many species' functions are yet to be determined.

This tool has potential for mapping the distribution footprint of farms irrespective of substrates.

Presentation Available Upon Request

<u>Nigel Brian Keeley</u>
Nigel Brian Keeley is a senior research scientist with the Institute of Marine research in Norway, working as well with the Cawthron Institute in New Zealand until early 2022, with 25 years' experience studying aquaculture and environment interactions with emphasis on benthic ecosystems, indicators of organic enrichment and the use of eDNA in benthic monitoring. Nigel has recently developed a method for applying molecular-based techniques that were developed for soft sediments, to hard and mixed bottom monitoring around salmon farms.

What are the R&D Priorities?

New technologies of all types require proof of concept work, field trials and commercially sized projects to ensure scalability for use on farms and so must be supported through that process, especially when being applied in a different environment. Technology that may advance regulatory requirements for monitoring requires comprehensive comparison studies with current systems. These processes can take many years and funding support needs to be available.

Research that provides greater understanding of wild salmon smolt migration and wild fish interactions near aquaculture sites can contribute to productive discussions and interactions with traditional marine users and regulators. These types of projects help address the many knowledge gaps with regard to potential wild / farmed interactions.

Additional research is needed on all fronts within the theme of fish health. Probiotics and alternatives for antibiotic use are a high priority globally. The importance and function of the microbiomes inside and outside fish are also part of this research. The multi-faceted challenges of sea lice remains a research priority and more work is always needed on alternative sea lice treatments and management technologies.

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 support the 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 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.

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McSporran	Duncan	Kognative Spark
Misk	Ehab	Huntsman Marine Science Centre
Moneva	Evgeniya	Canadian Food Inspection Agency
Mowatt	Pat	NB DAAF
Ness	Matthew	RPC
Ness	Michael	Zoetis
Ogah	Samuel	
O'Halloran	John	Veterinarian
Oldford	Vanessa	Fisheries And Oceans
Owens	Paul	ACOA
Parker	Edmund	Fisheries And Oceans
Peach	Randy	Pharmaq
Pennell	John	East Coast Innovation
Penney	Mark	Fisheries And Oceans
Penton	Norman	Gov of Newfoundland and Labrador
Pereira	Giulia	
Peterson	Brian	USDA
Pietrak	Michael	USDA
Polinski	Mark	USDA
Proude	Dale	ACOA
Quayle	Taylor	Sustainable Blue
Rae	Aimee	CAIA
Redfield	Edmund	Fort Folly First Nation
Reid	Gregor	Perennia
Richardson	Joel	Cooke Aquaculture
Richardson	Beth	ACFFA
Richardson	Joel	Gov of New Brunswick
Roberts	Ian	Mowi
Robinson	Tim	Fort Folly First Nation
Robinson	Shawn	Fisheries And Oceans
Rouse	Michael	ACOA
Rousel	Helene	Enterprise Shippagan
Ryan	Claire	Cooke Aquaculture
Samways	Kurt	University Of New Brunswick

Seeley	David	Skretting
Shang	Bryton	Aquabyte
Sherwood	Todd	Cooke Aquaculture
Smith	Sean	Fisheries And Oceans
Smith	Jamey	Consultant
Stirling	David	Aquatech Center
Storey	Andrew	Open Ocean Systems
Strowbridge	Zachery	Mowi
Sullivan	Andrew	NB DAAF
Sun	Jinghan	Marine Thinking Inc.
Swanson	Andrew	Cooke Aquaculture
Sweeney	Bob	SIMCcorp
Synard McInnis	Stephanie	Gov of Newfoundland and Labrador
Sypher	Suzanne	ACOA
Szemerda	Michael	Cooke Aquaculture
Taylor	Tom	Cooke Aquaculture
Taylor	Tobi	ACFFA
Tetegan Simon	Marion	University Of Moncton
Thiruvengadam	Vaitheeswaran	
Trudel	Marc	Fisheries And Oceans
Turner	Adam	Cooke Aquaculture
Underwood	Scott	Cooke Aquaculture
Underwood	Jonathan	Fisheries And Oceans
Vautour	Lindsay	ACFFA
Vera	Ana	Cooke Aquaculture
Verge	Darrin	ROMOR Ocean Solutions
Viegas	Ivan	
Von Ronge	Frederick	Cooke Aquaculture
Weaire	Ted	Cooke Aquaculture
Wiper	Jennifer	Cooke Aquaculture
Wiper	Philip	Huntsman Marine Science Centre
Whitelaw	John	ACOA
Wyngaarden	Nell	East Coast Innovation
Young	Alice	Fisheries And Oceans