Atlantic Canada Fish Farmers Association

Providing a strong, regional voice on behalf of the salmon farming industry

ACFFA Aquaculture Research, Science and Technology Forum

FINAL REPORT

October 24 and 25, 2018

Huntsman Fundy Discovery Aquarium

St. Andrews, NB

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

A special thanks 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 24 and 25, 2018 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 2018 forum covered a variety of themes including new off-shore and land-based technologies, wild salmon conservation activities, understanding wild -farmed interactions, new eDNA research as well as fish health and welfare.

140 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 First Nations, academia, traditional fishery and conservation interests.

AGENDA

WEDNESDAY, OCTOBER 24, 2018		
8:00	**REGISTRATION AND REFRESHMENTS**	
8:30	Welcome and Introductions	Susan Farquharson, Atlantic Canada Fish Farmers Association
8:45	Opening Remarks: Aquaculture in Canada	Doug Wentzell, Associate Regional Director General, Fisheries and Oceans Canada
9:10	Public Perceptions of Salmon Aquaculture	Steven Hedlund, Global Aquaculture Alliance
9:35	Public Perceptions of Aquaculture in Nova Scotia	Christina Waddy, Corporate Research Associates
10:00	Blue Salmon: Engaging Youth	Deborah Irvine Anderson, Canteen Media
10:30	**REFRESHMENT BREAK**	
	TECHNOLOGY SESSIONS – Lead David Seeley	
10:50	Offshore farming and how to increase global salmon production sustainably	Steven Rafferty, Global Maritime AS
11:15	Overview of Oceanographic Characteristics of Potential Relevance to Offshore Aquaculture within the Bay of Fundy	Fred Page, DFO – SABS
11:40	Aquafarm Equipment - aquaculture solutions for sustainable, cost-effective fish-farming	Egil Bergersen, Aquafarm Equipment AS
12:15	**LUNCH**	
	Session lead – Bob Sweeney	
1:15	Current Trends in Sustainable RAS: Zero Water Change	Jesper Lund, AKVA Group
1:40	The paradigm shifts in Salmon production: challenges and potential of large industrial land-based plants for Post Smolts and market size fish	Christian Scott, Veolia Water Technologies Canada Inc
2:05	The Emergence of Land-Based Atlantic Salmon RAS Facilities in Maine	Jennifer Fortier, Whole Oceans
2:30	Recirculating Aquaculture Systems: Are we there yet?	Steve Backman, Skretting
3:00	**REFRESHMENT BREAK Sue to lead**	
3:15	The status of offshore and land-based salmon aquaculture in Norway	Knut Hjelt, Norwegian Seafood Federation
3:45	FSR update	Kurt Samways, CRI / UNB and Becky Graham, FNP
6 pm	**Reception and Banquet** **Shaunessey Room, Algonquin Hotel**	

THURSDAY, OCTOBER 25, 2018		
8:00	**REGISTRATION AND REFRESHMENTS**	
8:30	Welcome and Introduction	Susan Farquharson, ACFFA
SCIENCE AND RESEARCH SESSIONS		
Animal Welfare – session lead Tim Kennedy		
8:40	Fish Welfare Code of Practice for Canada – An Update	Tim Kennedy, CAIA
8:45	Aquacare 365 – Practical Approach to Fish Welfare	Michael Bolton and Kasha Cox, Merck Animal Health
9:20	How to Achieve Big/Healthy Smolt with GIS Technology	Michael Beattie, GIS
9:40	Veterinary oversight of medically important antimicrobials	Jean Szkotnicki, Canadian Animal Health Institute
10:05	Sea lice monitoring and control in Atlantic Canada	Larry Hammell, AVC - UPEI
10:30	**REFRESHMENT BREAK**	
Alternatives – session lead Tom Taylor		
10:45	"Greening" fish health treatment: alternatives and innovations	Joel Halse, Cooke Aquaculture
11:10	Fish farm health issues: perspectives, politics, and the precautionary principle	Hugh Mitchell, AquaTactics Fish Health
11:35	Why are 'Autogenous Vaccines' needed	Kalena Statutiak, Gallant Custom Laboratories
12:00	Decoding important regulators of sea lice physiology using gene silencing techniques	Laura Braden, adjunct UPEI /AquaBounty
12:30	**LUNCH**	
1:30	**<u>eDNA Panel: What Is Its Role? What Does It Tell Us?</u>** *Moderator – Ben Forward, RPC*	
• Fish Microbiome and eDNA: Setting the scene for the aquaculture industry - Dr. Julie LaRoche, Dalhousie University • Using Microbial eDNA to Assess Organic Loading Impacts to Benthic Habitat in the Vicinity of Salmon Aquaculture in the Bay of Fundy - Shawn Robinson, DFO- SABS • The Use of Metagenomics in Fish Health - Tony Manning, RPC • Modernizing population and community monitoring with environmental DNA (eDNA) -Anaïs Lacoursière-Roussel, DFO-SABS		
3:05	**REFRESHMENT BREAK**	
3:20	A Pilot Study in Passamaquoddy Bay to Investigate the Migration of Juvenile Salmon and their interactions with Aquaculture	Marc Trudel, DFO-SABS
3:45	Plenary Discussion - What's next for R&D Priorities?	Susan Farquharson
4:00	Wrap up /Adjournment	

Presentation Synopses and Speaker Biographies

The following synopses were approved by the speakers.

Wednesday, October 24, 2018

CONSUMER PERCEPTION OF SALMON AQUACULTURE AND WHY SALMON IS BEST POSITIONED TO CAPITALIZE ON EMERGING TRENDS

-p*resented by Steven Hedlund, Global Aquaculture Alliance*

The Global Aquaculture Alliance (GAA) started as a voice for responsible aquaculture, primarily in industry located within mangroves. From there the GAA launched a magazine, an e-learning platform and eventually developed the standards for the Best Aquaculture Practices (BAP) third party certification process. Diagrams provided information on the benefits of membership including social media analytics and participation in the annual GOAL conference.

After identifying the top six public misperceptions around the salmon aquaculture industry, data was presented from a 2017 National Aquaculture Survey, administered by the University of Maine. There were 1,210 responses total, spanning the United States. When asked questions about their willingness to support aquaculture research, policies to expand the industry and look for aquaculture products, these consumers were undecided. It was suggested that this should be viewed as an opportunity, not a challenge.

A consumer survey administered by the Washington Fish Growers Association in April 2018 with 700 respondents, spanning western Washington state indicated that 68% supported the statement that salmon farming is an activity that can be done sustainably. 66% of respondents supported the statement that local aquaculture production of finfish is an important source of healthy seafood and 60% supported the statement that finfish aquaculture, the farming of fish in marine net pens, is something we should be doing more of in Washington. These data were gathered about one month after Washington state banned finfish farming for non-native species, which was a highly charged, political decision that obviously did not line up with opinion of the public. Again, an opportunity.

Most consumers are interested in answers that confirm that they are getting what they paid for and that it is a quality product. The majority of the seafood sector are now third party certified, so producers need to look to the "3rd dimension" – strategies for broadening and improving the customer experience from pre to post purchase to maintain relevance. Lifestyles, realities of work routines, home logistics, and the changing social context around the food experience were some areas producers need to keep in mind as these approaches are developed.

See Attached Presentation

Steven Hedlund

Steven Hedlund is the communications manager for the Global Aquaculture Alliance, a Portsmouth, N.H.-based non-profit dedicated to promoting responsible aquaculture through education, advocacy and demonstration. For the past six years, Steven has forged the communications and marketing strategy for the 21-year-old organization, which is experiencing tremendous growth. GAA has launched four new pre-competitive offerings (online community, film initiative, e-learning platform and restructured membership) to complement its well-established annual conference and weekly online magazine, which are his primarily responsibilities, in addition to PR and media monitoring and outreach. Steven's background is in journalism. Prior to GAA, he was the founding editor of SeafoodSource, a daily news website, and associate editor of SeaFood Business, a monthly print magazine. Steven is a 2003 graduate of the National Fisheries Institute's Future Leaders program. A 1998 graduate of the University of Maine, he worked for newspapers in Central Massachusetts after graduation and before finding a career in seafood with Diversified Communications in Portland, Maine, in 1999.

PUBLIC PERCEPTIONS OF AQUACULTURE IN NOVA SCOTIA

-presented by Christina Waddy, Corporate Research Associates Inc.

The ACFFA contracted Corporate Research Associates to complete a survey of Public Perceptions of Aquaculture in Nova Scotia. The questions were commissioned on the Atlantic Quarterly – CRA's quarterly telephone survey and occurred between May 1 and May 15, 2018. The survey was a random sample of adults aged 18+ years from Nova Scotia with 401 interviews completed during the dedicated time period.

When asked about buying local, most Nova Scotians consider buying food that is grown or produced in the province as important. This positive response was provided by 87 percent of respondents in 2018 compared to 80 percent in 2016.

There is strong support for the aquaculture industry in Nova Scotia, with 78 percent either mostly or completely supporting the industry. The main reasons for supporting the industry are that it provides employment in rural areas, is good for the economy, or helps protect fish stocks in the ocean.

Respondents were asked to rate the overall reputation of the aquaculture industry on a scale of 1 to 10. Of those that provided a response (89%) the mean was 6.0, for a moderate rating. Ratings of 8 to 10 were given by 20 percent the Nova Scotia residents.

When asked their opinion on four statements about the aquaculture industry in Nova Scotia, there was widespread agreement that the provincial aquaculture industry provides employment opportunities in the province and is an important contributor to the Nova Scotia economy.

The survey asked, if federally and provincially approved aquaculture sites and related infrastructure resulted in significant new employment opportunities in rural Nova Scotia how would that affect your view of new aquaculture? Four in ten (39%) residents indicated it would have no effect, while over one-half (55%) indicated it would increase their support of the industry.

One-third of Nova Scotians recalled seeing or hearing something about the aquaculture industry in Atlantic Canada. Among those who had heard something about the industry, the items identified were generally negative and included fish escapes, disease, or environmental concerns. The awareness of this news had little impact on opinion of the aquaculture industry. Residents identified the internet as the most convenient way to find information about aquaculture in Nova Scotia (68%), followed by television (18%) and social media (9%).

A minority (about one in three) residents recalled any issues related to Atlantic Canada farmed salmon in recent times. Meanwhile, most residents (64%) believe that in most respects, farming salmon is the same as farming other animals.

A large minority (44%), indicated their confidence would increase in the management of salmon farming if regulations were the same Atlantic-wide, while 39 percent said their confidence wouldn't change.

When asked what they would like to know about salmon farming, 32 percent of Nova Scotians indicated "nothing", and 21 percent did not offer a response. A small number (15%) would like to know more about how it works and how fish are raised/fed.

Finally, it was noted that consumer confidence varies across Atlantic Canada, and job insecurity continues to be identified as the most important issue facing Atlantic Canada.

See Attached Presentation

Christina Waddy

Christina Waddy is Managing Director of CRA's operations in New Brunswick. During her 12 years tenure in the marketing research industry, Christina has provided strategic marketing research expertise to a varied number of public and private sectors clients in New Brunswick and elsewhere in Atlantic Canada. Christina's expertise expands across various industries, including medical systems, information technology, manufacturing, and education. As past president of the Atlantic Chapter of the Marketing Research and Intelligence Association, she has played a key role in ensuring high standards of market research in the region. Having grown up on a dairy farm in New Brunswick, Christina continues to enjoy an active lifestyle in her native province.

ENGAGING YOUTH

-presented by Deborah Irvine Anderson, Canteen Media and Communications

Coming from a "potato province", information presented during Open Farm Day hosted by ACFFA, and subsequent visits to several salmon farms in the area provided information on the size and complexity of the industry, along with the value to the province of New Brunswick. It inspired me to think big about what we are teaching youth about the salmon farming industry and its role in the economy.

Salmon farming and Norway are synonymous in most people's minds, so the idea that other people must also be unaware of salmon farming's importance here became obvious. The "find a need and fill it" mission for a communications person was given a final push when on one farm visit a blue coloured salmon was seen and curiosity grew. The idea to write a children's book began with the realization that this would do more to help people understand salmon farming that other types of publications.

The goals of the book would be to educate children and their parents about aquaculture, to strengthen ties in our communities through partnerships, and to encourage children to read and spark their interest in aquaculture as a career.

In Phase 1 of this project, the book will be developed, and the first run of printing and initial distribution will occur. Phase 2 will include the development of curriculum tools with distribution in Nova Scotia, and complimentary media tools. The 3rd phase of the project will see the book translated for use in other jurisdictions where salmon farming occurs and international distribution.

See Attached Presentation

Deborah Irvine Anderson
Deborah Irvine Anderson worked for the CBC from coast to coast for more than two decades. She now runs Canteen Media and Communications a boutique consultancy in Quispamsis. cell/text: 506-639-5378 deborah@canteen.media

OFFSHORE FARMING - HOW TO INCREASE GLOBAL SALMON PRODUCTION SUSTAINABLY

-presented by Steven Rafferty, Global Maritime

Global Maritime is a consulting company that was founded in 1979 and is now present in 16 cities in 14 countries, involved in all sea-based industries. The company started working with the oil and gas industry initially, branching out into many service areas, and therefore has many highly qualified people to compliment offshore aquaculture development. Global Maritime Norway has an experienced team to assist clients in all the phases of an aquaculture project including Project Risk, Technical Safety / Emergency Preparedness, Advanced Hydrodynamic Analyses & Design, Advanced Structural Analyses & Design, Mooring analyses / Design of Mooring System and Marine Operations.

In 2013, collaboration began with SalMar and many others to develop Ocean Farm 1 (OF1) the first offshore farm in Norway. It was noted that collaboration is very important in the development of offshore systems as there is a large amount of intellectual property involved in designing equipment to retrieve mortalities, clean nets, monitor the environment and feed fish in these large systems. The OF1 structure has an overall height of 68 m, a diameter of 110 m and volume of 250,000 m3 to provide an annual production of 8,000 tonnes of salmon. It was built to withstand a significant wave of ~ 5m, and house four employees.

The farm started its trial production in 2017 with the addition of 200,000 smolt. The fish grew well, and were harvested earlier than anticipated, so plans are to stock a larger number of smolt in 2019. During the initial trial the fish were found to have some sea lice, but this initial deployment location is near the coast and it is believed that this situation will be avoided in future when OF1 is in its final location and the nets can be fully lowered.

Salmon is only 3-4% of global aquaculture production. Salmon farming was growing ~7% per year during the first 20 years of development but currently is growing less then 2% per year. Norway has 56% of the salmon market and recognizes aquaculture as a major industry within the country. Salmon production is limited by surface water temperatures and needs protected coast lines for current seawater pens in use. The offshore can create new production areas but will require a huge technological leap, and countries like Canada will fall behind if not provided with incentives to innovate.

Global Maritime Aqua Analytics provides the tool to evaluate the marine environment proposed for offshore development and aids fish farmers in the search for new exposed locations. The data is presented in Google Earth for easy use with good satellite imaging.

The new offshore system that Global Maritime is involved with is 160 m wide and will hold 13,000 t of salmon. It is a design that could work in Atlantic Canada. The development of offshore salmon farming in Canada is also dependent on several factors including a clear definition of what offshore is regarding environmental factors like wave height; investment, innovation and patience; improved infrastructure in some areas; and new legislation might be required on location of sites (shipping routes and safety of workers will follow similar route as Oil and Gas sector).

See Attached Presentation

Steven Rafferty

Steven Rafferty works at Global Maritime, a marine, offshore and engineering consultancy company that designed and engineered the first large scale offshore fish farm for salmon in Norway. Over the last 25 years he has worked in the aquaculture industry and has been CFO and CEO in some of the world's largest aquaculture companies, including Marine Harvest, Cermaq and Skretting, based in UK, Chile, USA, The Netherlands and Norway over that period. Global Maritime aim is to expand aquaculture farming and seafood production in a sustainable way by providing new offshore solutions to utilise more of the ocean and to provide the world's growing population more access to healthy seafood proteins.

OVERVIEW OF OCEANOGRAPHIC CHARACTERISTICS OF POTENTIAL RELEVANCE TO OFFSHORE AQUACULTURE WITHIN THE BAY OF FUNDY

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

The Bay of Fundy may present some unique challenges for the development of offshore fish farming. The Bay is 200m at its deepest near the mouth around Grand Manan and is shallow near shore with the highest tides in the world. The tidal range is 16m in height (low to high) at the head of the Bay, ~9m in the mid-Bay and ~6m at the entrance to the Bay. There is no ice offshore though icing of structures and equipment will be an issue plus the fog is particularly

bad in spring and summer significantly reducing visibility. There are many sources of freshwater input into the Bay creating seasonal and variable turbidity, brackish water conditions.

Water temperatures recorded are moderate (~1-14C) though are generally cooler on the Nova Scotia side of the Bay. The data charts presented suggest that a large amount of data exists for use, but the data is not representative of what is happening in the winter and spring, and most data collections are from good weather conditions. Fixed location data shows the water temperature overall has increased by about ~1°C per 100 years with warming trend strongest in winter. Within the Bay in the area of farming activity there can be an 8°C range in water temperatures between locations and pH data in the marine environment is limited.

Hydrodynamic models are now producing information accurate to observations. The models show that in addition to the residual current there is a strong diurnal M2 tidal current with magnitude of order 0.5 to 1m/s (1 to 2 knots), meaning this current is regular but not constant. There are no data for shore-based surface currents and there is limited information regarding waves. The wind is predominantly from the mouth of the Bay to the southwest, but there are multi-directional wave fields all the time and this changes the shape of the wave. Waves are often steep and choppy creating a challenging environment for mariners. The significant wave height 100-year prediction is 10m but currently 98% of significant waves heights are calculated to be less than 2m.

There are forecasting tools, but they are not very good at the moment so real-time, accurate data is needed for any future planning. Outside of environmental factors there are also considerations given how biologically rich the Bay of Fundy is and the many activities, including biological and anthropogenic activities, that take place in the Bay. A series of maps provided identification of various fishing and spawning areas, shipping traffic route and important areas for species at risk (Right whales, inner Bay of Fundy salmon). A composite map of all the activities discussed showed little room for potential offshore farm locations which will add to the complexity this type of industry development.

See Attached Presentation

Fred Page

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

AQUACULTURE SOLUTIONS - SEMI CLOSED CONTAINMENT SYSTEMS

-presented by Egil Bergersen, Aquafarm Equipment

The Aquafarm is a semi-closed system that is designed to hold up to 1 million, 100g smolt up to 1kg in 21,000m^3 of water. The eight pumps can move 50m^3/minute with high flow capacity for a changeover within the system every hour. The incoming water from 20-40m depth is sterilized, and the waste is collected and transferred to a sludge treatment barge located close by. The cage is 40m in diameter and escape proof with two hard barriers on all inlets and outlets. It can withstand a significant wave height of up to 2m.

Designing the Aquafarm system began in 2008. The first Aquafarm system went into the water in 2013. A hurricane in 2015, which did some damage, lead to significant reinforcements, and commercial units are now available.

The system has been tested with three generations of post-smolt grown in the system. The most recent group of 400,000 smolt had to have one treatment for AGD and sea lice were observed but were flushed out of the system during the 1-hour changeover. The mortality rate in the unit was 0.34% and the salmon also did well after being transferred into regular next pens for further grow out. Other test results provided included a food conversation ratio of 0.85 to 1 and growth from 100g to 1.2kg in 6.5 months. The latest generation of smolt were stocked 2 weeks before the presentation, the system being tested to nearly 60% of the tank capacity with 540 000 smolt. The commercial unit capacity is 800,000 smolt. The internal and external monitoring systems are extensive with operational and production support Cloud-based.

As part of the business case, the Aquafarm units are used on a farm site for the initial rearing period in conjunction with traditional pens, with one unit holding enough post smolt salmon to fill 4 or 5 pens. Use of the system will reduce the time the smolt spend in the open marine environment from 77 weeks to 40 weeks. Results to date indicate a 10% reduction in production costs and 30% increase in operational profit for post smolt phase.

See Attached Presentation

Egil Bergersen

Egil Bergersen is General Manager at Aquafarm Equipment AS, a tech-company providing aquaculture solutions for sustainable, cost-effective fish-farming. The Aquafarm closed-containment system (CCS) eliminates lice challenges, reduces diseases and mortality drastically and not the least produces healthy and high-quality fish.
Before starting in aquaculture, Egil worked mainly in the oil industry with technology development and project management, ranging from qualification and installation of new well equipment, to management within large scale green field offshore-developments. Egil has a M. Sc. within Mechanical Engineering and an intermediate university degree in History.

SUSTAINABLE RAS SOLUTION

-presented by Jesper Lund, AKVA group Land Based

AKVA group has been involved in recirculating aquaculture system (RAS) development for the last 12-13 years. The basics of a RAS system with inputs and outputs were identified. If good freshwater is not available, filters (20-30µm), ozone and high dose UV light can be used to treat the incoming water.

The general design concept of a basic RAS system as shown in a diagram provided would include a 40-60µm mechanical filter, a parallel up streamed fixed bed biofilter system with low velocity to get most of the small particles out, an ozone unit, carbon dioxide degassing, and an oxygen system (low pressure cone) before water re-enters a fish tank. The design is based on the system being gravity fed so that the water is only pump one time, and there is 1% system exchange per hour, complete system exchange in 4 days. After sludge treatment there is only 10% dry matter, but this product can be used on farms or as biogas.

A RAS facility with zero waste change (ZWC) is a more technical system as per the diagram presented. This design concept would add a plate separator, a denitrification unit and then a phosphorus reduction system since this element now becomes water quality a concern. With these changes this system now only requires a total water exchange every 40 days with only 0.1% of total system water volume added to the system per hour. This is 10 times less water than basic RAS. Also, everything is captured in sludge treatment with this system compared to a basic RAS so that there is 90-95% dry matter which is used as compost, as shown in diagram calculations. The need for ~~highly~~ qualified people to operate these systems was noted.

In land-based aquaculture, the technology definitions are primarily related to the type of water used (fresh water and/or salt water) and the amount of new water required per 1 kg of feed. The basic recirculation design concept discussed use 300-500 litres per kg of feed. A RAS with Fixed Bed and a De-nitrification unit alone would use 100-150 litres of water per kg of feed, while a RAS with Fixed Bed plus ZWC technology uses 30-40 litres of water.

Over the last 10 years, 40 RAS ZWC projects have been or are being constructed. Five examples of AKVA ZWC facilities were provided. The other benefits of Zero Water Change system were identified including increased production using existing water source, lower operating costs for sterilizing intake water, sludge treatment, and heating and the ability to place a fish farm facility almost anywhere.

See Attached Presentation

Jesper Lund
Jesper Lund is a Marine Engineer from Denmark who has been working for 11 years with Aquatec Solutions A/S, part of AKVA group. His extensive experience includes project management, project design/development and sales of land-based facilities. He currently holds the position of Sales Director, for the Nordic and America's areas.

THE PARADIGM SHIFT IN SALMON PRODUCTION: CHALLENGES AND POTENTIAL OF LARGE INDUSTRIAL LAND-BASED PLANTS FOR POST SMOLTS AND MARKET SIZE FISH

-presented by Bradley Young, Veolia Water Technologies Canada

Veolia, as a large company in the water business, can cover the entire range of environmental solutions including activities in water services and technologies, energy optimization, waste management and resource recovery. With a mission of "Resourcing the world" Veolia contributes to increasing access to resources as well as preserving and renewing them. Examples of Veolia projects were presented to highlight the flexibility of their technology, including information on the largest European underground wastewater treatment plant (WWTP) below the soccer stadium in downtown Marseille, France.

Over the last ten years the salmon farming industry's interest in the production of large smolts and post smolts on land using recirculating aquaculture systems (RAS) is driving the investment in new large RAS facilities. There are many challenges to scaling up RAS hatchery systems to these much larger fish and high production volumes. Some of these are with the equipment such as tank design, flow, hydraulics, functionality, instrumentation and controls, auxiliary system requirements, particle management and water quality. Larger salmon also provide challenges for transport, handling, and harvesting. Large projects mean more project management for construction scheduling and quality control, as well as, larger investments. Each of these challenges of industrial sized RAS facilities were discussed in further detail to show how to prevent risks through the proper design.

Combining its large capital project experience, its water treatment expertise and its aquaculture know-how, Veolia has developed two (2) industrial size RAS concepts: the Kaldnes enhanced conventional RAS and the Krüger A/S RAS 2020.

The former has been designed to avoid the easiest flaw of large land-based facilities with the piping systems, namely the "spaghetti syndrome". To avoid this situation, the design pays attention to factors like slope, bends/fittings and pressure loss, and the ability to always allow draining/cleaning/drying of all pipes. For the large tanks alternative designs are needed to accomplish the goals by including items such as multiple inlets, dual drain outlet to optimize tank hydraulics, reduce piping by decentralizing the carbon dioxide stripping, and using a moving bed biofilm reactor (MBBR).

Kaldnes enhanced conventional RAS builds upon standard sized modules placed together to create the large RAS facility required to meet production needs. One standard unit would include two RAS compartments, each containing three 2,500 m3 tanks with the capacity to handle a maximum of 6000 kg feed /day.

The innovative Krüger A/S RAS2020TM concept has a standard foot print of 3340 m2 (66,8 x 50), a tank volume of 6700 m3, two purge tanks each holding 385 m3, a system flow of 10.000 m3/h and a maximum capacity of 4000 kg feed /day. It has a tailored WWTP for any level of discharge required for the specific location. RAS2020TM has a combination of high quality and easy to use technology starting with Hydrotech Microscreens and an AnoxKaldnes MBBR. This MBBR has media providing a large surface area per volume for sheltered biofilm, prevents clogging and so no back flushing is required. The unit also includes a medium bubble aerator that is anchored at the bottom of the tank, and with no moving parts and requires no maintenance. The oldest in operation has been in place since 1989 and has never required any tank drainage for maintenance or repair. The drum filter operation was reviewed in detailed diagrams, noting low maintenance, and an easy access system with innovative durable, self-cleaning nozzles.

Smarter management of this large system includes RAS functions as well as management of all chemical dosing, heat pump and energy plant, intake treatment and disinfection, back-up generator lights and cameras. The fully integrated feeding system has centralized management, integration of data to RAS water quality management, a predictive tool for proactive intervention in case of deviation, and a management tool for FCR and growth performances optimization. With AQUAVISTA™, a client digital portal manages all the data, provides 24/7 support, generates reports, has an alarm system, as well as many other features increasing the ease of operation and the reliability of the system.

Bradley Young

Bradley Young is a professional engineer and has a Ph.D. in environmental engineering from the University of Ottawa. Bradley worked in the process engineering department at Veolia and is now the product manager for AnoxKaldnes. In his role he works with multiple departments to develop AnoxKaldnes technologies in the Canadian market. A significant portion of his work has been in R&D to develop the AnoxKaldnes MBBR at low temperatures.

THE EMERGENCE OF LANDBASED ATLANTIC SALMON RAS FACILITIES IN MAINE
-presented by Jennifer Fortier, Whole Oceans

The UN estimations of population growth lead to the calculation indicating the potential of a global protein deficit by 2050. Aquaculture was identified as an underutilized means of protein production and the source of most seafood by 2030. In the United States (US), Americans consume approximately 1.1 trillion pounds of Atlantic salmon per year, with almost 100% of that being farmed but also over 90% imported. Maine is the largest marine aquaculture state in the US and increasing domestic aquaculture production here can provide advances such as lower transportation costs and lower carbon footprints

Recirculating aquaculture system (RAS) technology has been used for decades for salmon smolt production. It has become more economically feasible for use with larger smolt and full grow-out ($/kg cost) in some jurisdictions due to several factors including advances in technology, increasing costs of net pen ocean licenses in Europe, and more efficient use of water (90%+ recirculation efficiency). Maine has unused industrial sites with existing infrastructure that can be retooled for land-based RAS production. It is here that Whole Oceans, a company with Maine roots, saw the potential for revitalization of distressed properties in Bucksport and a way to bring new markets and technologies to the region. The old papermill site has many of the criteria required for a land-based RAS including water discharge capacity, access to saltwater and freshwater, logistics infrastructure and proximity to a skilled labor force.

While many of the decisions are being finalized such as the type of RAS system to be used, a potential schematic was presented, and groundbreaking is planned for Spring 2019. Phase I will see a 5,000 MT full salmon grow-out

recirculating aquaculture facility developed that is expected to create 50-75 jobs. The hatchery will be stocked with eggs in winter 2019 and after the first three production cycles have been completed with positive results, the next phase will commence that will see the facility ultimately produce 20,000 MT of salmon. The estimated daily water usage of the RAS is 3 million gallons of Penobscot River water and 1 million gallons of Silver Lake water, which is a lot less than the previously operated paper mill. There will be complete control of feed, water and biosecurity with full traceability of seafood produced. There is a 10-year offtake agreement for up to 100% of the facility's production of Head on Gutted (HOG) whole Atlantic salmon at 4-6 kg. The fish viscera and wastewater sludge will be used for composting.

Whole Ocean identified many groups with which they are already working and those with whom they are pursuing partnerships within academia, the community, research sector and industry circles including the AIM Development Action Plan for Tomorrow and the University of Maine. The Whole Oceans executive team were profiled.

Jennifer Fortier

At Whole Oceans, Jennifer Fortier focuses on communications and local outreach, as well as workforce development and building academic partnerships for the future. She attended the University of Maine in Orono, Maine and received Bachelors' degrees in Marine Science and Microbiology in 2009. She received a master's degree in Marine Biology from UMaine's Aquaculture Research Institute in 2014, where she studied diseases of finfish aquaculture under Dr. Ian Bricknell. Most recently she worked for Acadia Harvest, a land-based aquaculture startup at UMaine's Center for Cooperative Aquaculture Research producing California yellowtail for the New England sushi market.

RAS: ARE WE THERE YET?

-presented by Steve Backman, Skretting

Innovation does not happen without some failures. Learning from failure is what pushes us beyond the boundaries of our current abilities. When we look at our tiny blue marble in space, it is clear that this is a closed life support system with only energy as an external input. Modern RAS systems attempt to mimic what happens in nature and these processes that have developed and been refined by Nature over millions of years Their complexity is well beyond our current understanding but serve as the template. With this template there is no limit to the scale RAS can be built. Reasons to reuse and recirculate water have been frequently identified to include control for the optimal growing environment, ability to grow fish where there is insufficient water supply available, reduced water treatment costs and discharge, recovery of nutrients, culturing fish in close proximity to market and ability exclude specific pathogens and parasites.

A RAS is essentially a terrestrial version of an integrated multi-trophic aquaculture operation (IMTA), using the same principles but with greater intensity and more technical applications. RAS and IMTA schematics were presented. Recirculating aquaculture systems are intricately associated with Biofilms. These are present everywhere touched by water within a RAS not just the bio filter. They become more complex with age, comprised of a large group of organisms in a complex ecosystem. When we ignore this relationship, considering only those organisms involved in ammonia breakdown we do so with risk of catastrophic failure. There is a strong need to better understand both their basic biology and the potential for beneficial relationships with fish populations as well as risks associated with passing of resistance genes within biofilm was highlighted.

The salmon farming industry has changed over the years from almost exclusively using flow through hatcheries and small ocean-based pens for 35-gram smolts, to almost exclusively using to RAS hatcheries, producing large 300 – 1000g smolt in these facilities, and use of large offshore farming systems or land-based RAS grow out operations to complete lifecycle. This change in technology and production processes leads to many other changes in the way designers, operators and feed suppliers must approach their technology and products. Feed is an example of a product

that steadily evolved from frozen trash fish to sophisticated formulations built around species and life stage. It too requires new focus for the unique characteristics of RAS. What is optimal to feed fish in the ocean is not necessarily optimal to use in a RAS because the technology and ecosystem that is developed. Sinking speed of pellets now becomes more important as well as dry matter loss, fecal size and quality as these characteristics will affect other factors such as phosphorus leaching, water quality and solids / nutrient removal. In RAS systems, our goal is to supply the correct balance of nutrition for the fish raised, but also understand that there is a complex eco-system impacted by any material addition.

RecircReady Concept (RC) is a new diet range that ensures the best pellet quality characteristics for RAS and provides many benefits including improved fecal consistency, less nutrient leaching and improved bio filter performance. Data was provided comparing RC to standard feeds used on marine farms and indicating the effective use of stabilizers to decrease dry matter loss and reducing phosphorus accumulation.

There are many other new developments in RAS technology, so this is a major focus of research occurring within Skretting. We have constructed new purpose-built RAS facilities to support our research goals based on customer needs. Our global RAS team was built to bring diverse expertise and experience together to address the many needs of RAS. These include increasing the knowledge base on RAS and fish biomes, nutrient processing, pellet technology, waste management, ingredient quality, and nutrient impacts on system efficiency, fish performance and RAS systems.

See Attached Presentation

Steve Backman

Dr. Steve Backman has been the Manager of Technical Services for Skretting since 1988 and just celebrated his 30th anniversary. He received his Diploma of Agricultural Science from Nova Scotia Agricultural College in 1982, then attended the University of Guelph where he received his Doctor of Veterinary Medicine in 1987 and a Diploma in Anatomic Pathology in 1989. Steve has been a member of the NB Fish Health Technical Committee and the NB Fish Health Policy Committee since 1996. He holds multiple veterinary licenses and memberships in a number of professional organizations, which includes being Charter President of the Canadian Association of Aquatic Veterinarians. He is also the owner of Magellan Aqua Farms Inc.

OFFSHORE AND LAND-BASED SALMON AQUACULTURE IN NORWAY

-presented by Knut A. Hjelt, Norwegian Seafood Federation

The Norwegian Seafood Federation is an industry association representing most companies within the seafood sector in Norway, promoting the interests of members with regards to exports, legislation and industrial policies as well as advising member companies on a wide range of issues.

News stories about what is happening in Norway regarding salmon aquaculture portray the industry as moving to offshore and land based full grow out production. An analogy was presented of the reality of the situation as "selling the fur before the bear was shot or even known to be in the area." Where the industry is really going is still in question. The term "Offshore" still has no official definition so if this refers to any farm located outside the coastal baseline or an operation that is in an area with a specific significant wave high has yet to be determined. The aquaculture industry has 70-80 years of land based smolt production experience, so this term is now most often used to only refer to a facility for the full grow out of salmon to market size.

The Norwegian regulatory system was discussed, including the fact that the government has to offer licences to the industry. There has been no regularity in licence offers and when offered have had limited production capacity and a high price. In 2017, the last time licenses were offered, the basic price for one license (780mt maximum allowed biomass) was set by the government at 93,6 mill NOK (≈ 15 mill. CAD).

The process for Development Permits were opened for applicants November 20, 2015 to November 17, 2017, with the understanding that technology developed in the projects must be shared so it benefits the entire industry. Of those submitted, 104 applicants were approved for further investigation. The permits are for a 15-year duration and can be converted to ordinary licenses for approximately 10 million NOK. Currently there are 49 applications still under consideration (461 licenses @ 360,000mt MAB), 8 development permits have been granted (54 licenses @ 42,000mt MAB) and 47 been rejected. Only three of those granted are off-shore installations (37 licenses @ 29,000mt MAB). Information on the three operations was provided.

In October 2017, Ocean Farm 1 was stocked with one million, 250g average weight smolt and harvested 4.5-5kg salmon in October 2018. The unit 68m high, 110m in diameter, has a pen volume of 250,000m3 and was designed to withstand a 9m significant wave height. There was an escape which was identified as human error. The HavFarm comes in two design versions: one is stationary, and one is a dynamic facility with an engine. The stationary farm is designed to withstand a 10m significant wave height and requires an approximate 1 billion NOKs (≈160 mill CAD) investment. It will be 385m in length, 59.5m in width and with net depths of 56 m has a water volume of 69,000 m3 per net. Requiring 21 licences for the estimated biomass, it will cost $4 billion NOK, if the licences are approved. Fishermen are protesting where the farm is to be located. First stocking of salmon in the HavFarm is scheduled to be during Spring 2020. Construction of Artic Ocean Farming's submersible farming facility hasn't started to date. Estimated to produce 3,000 tonnes per unit, it will require 8 licenses (5,990mt MAB) and it will be 79m outside diameter. Significant wave height 5m-15m.

As opposed to off-shore farming, licenses for production of salmonids for human consumption in land-based facilities is not limited and the licenses are free, though production volumes do have an approved maximum allowed biomass (MAB). There are only seven licences approved for on land production of market salmon currently and none are in operation. For most, planning continues but financing is not available. RAS are a high biological risk and those planning to use these types of facilities are assuming constant production and prices. The technology must be developed to help support and optimize the biology and not the other way around. Information was provided on the seven operations with three highlighted.

One facility is scheduled to stock fish in late 2018 starting with a capacity of 2,000 ton and increasing to 5,500 ton plus smolt-production. One company that currently has existing facilities for production of cod and Ballan wrasse is planning a pilot facility to produce 200 ton of salmon with plans to increase to 10,000 ton. The cost of the pilot is 40 mill NOKs (≈6,3 mill CAD) and the main project 850 mill NOKs (≈135 mill CAD). The expected start-up 2019 with fish stocked in 2020. Another company has recently decided to move forward with their plans for the first phase of a fresh water RAS operation with an annual production 5,000 tons and second phase facility with production of 10,000 tons. The investment of 500 mill. NOKs (≈ 80 mill. CAD) has not been fully committed to date. The success or failure of what is happening currently in the United Sates with the new facilities planned or in operation will help determine the growth direction of full grow out operations.

The 5-year horizon for salmon aquaculture in Norway may see land-based production facilities for market salmon providing 1-3% of todays capacity, and off-shore facilities providing 2-3% of todays capacity. Marine salmon faming as it is currently operating will remain the dominant method of production.

See Attached Presentation

Knut Hjelt

Knut Hjelt is the Regional director aquaculture, Norwegian Seafood Federation. Educated from University of Bergen, Cand.real. (PhD equivalent), zoological ecology 1982. Knut has been in the aquaculture sector since 1984, started as an executive aquaculture adviser in Mid-Norway under the Directorate of Fisheries, then director of the Norwegian Smolt producers Association from 87, which was merged into Norwegian Fish Farmers Association from 1991, Director of Terra Salmon Group 94-96, a cooperation of salmon producers in close cooperation with a seafood exporter. Since -96 been in the association, now Norwegian Seafood Federation, in different positions. Member of numerous working groups, research programs, steering groups etc. Among others: The Research Council of Norway – board member of different research programs (1990 – 2014), the Norwegian Veterinary Institute; board member 2005-2016, The Norwegian Biotechnology Advisory Board; board member 2000 – 2013. Been representing the industry in the European Aquaculture Association (FEAP), ISFA and NASCO.

FUNDY SALMON RECOVERY: AN INNOVATIVE COLLABORATION RESTORING WILD SALMON TO THE INNER BAY OF FUNDY

-presented by Becky Graham, Fundy National Park and Kurt Samways, University of New Brunswick

The inner Bay of Fundy (iBoF) Atlantic Salmon spawn exclusively in the inner Bay of Fundy rivers and only migrate to Bay of Fundy and Gulf of Maine, with most spawners as one sea-winter fish (grilse). The iBoF had historic runs of 40k adult salmon in ~ 40 rivers where now there are less than 200 wild adults returning and most rivers are extirpated. The Live Gene Banking program has done a great job of staving off extinction although the population remains at critically low numbers, being listed as Endangered under Species at Risk Act (SARA) in 2003.

The Fundy Salmon Recovery (FSR) Model was discussed with partners identified as to their role in the various steps of the recovery project process. Partners include: Parks Canada, Department of Fisheries and Oceans, Cooke Aquaculture, the Village of Grand Manan, the Atlantic Canada Fish Farmers Association, Fort Folly First Nation's Habitat Recovery, New Brunswick Department of Agriculture, Aquaculture and Fisheries, the University of New Brunswick and the inner Bay of Fundy Atlantic Salmon Law Enforcement Initiative members. Generally, the FSR model includes reducing captive exposure as much as possible such that the smolts that are produced in the wild are caught and delivered to the project's conservation farm to grow to sexual maturity at which time they are released into their natal river to spawn and repeat the process. To kickstart the process, smolt are currently obtained directly from the rivers by partners and through smolts not required by the live gene back program. These smolt are generally wild exposed meaning they may have been wild hatched or released as fry to the river then later caught as parr for inclusion in the live gene banking program or transfer to the marine conservation farm.

The number of adults released in Fundy National Park, as part of the FSR project, have increased over time since this phase started in 2014 to a high in 2017 of 927 adults. In 2018 the number was lower but with the ability to hold the salmon until maturity at the conservation farm, the biomass was the highest released to date.

Ecological monitoring is major part of the research that accompanies the FSR program in order to assess the ecosystem impacts of these adult releases. Monitoring aims to show if the nutrients (eggs, excretory products, mortalities) added to the river from adult releases are impacting the ecosystem, and ultimately benefiting salmon population dynamics.

Adult return data collected on the Upper Salmon River (USR), calculated from snorkel surveys (2002-2004, 2007-2008) and PIT antenna (2016-2018) was presented. After a high of 40 adult returns in 2012 from the pilot project, the

numbers again decreased until 2016 when the numbers started to increase, more than doubling each year, ending with a 29 year high of approximately 70 salmon returning in 2018.

To assess ecosystem services, river productivity is being measured along with records of when salmon are observed at various points on the USR and Point Wolfe River (PWR), where adults are currently not being released. Data show that there was a marked production increase that first started after the releases in 2016 and this was maintained into January 2017. Productivity increased more in 2017 post adult release and remined high into February. Observations indicate the salmon have been returning to the rivers earlier in the summer since the 2015 monitoring started.

With more food at base of food web, this energy is working its way up to the juvenile salmon as the salmon smolt in the USR are on average 2 cm longer and 4.5g heavier than the control river Point Wolfe. Data provided from 22 electrofishing sites on the USR shows that fry were captured at all sites surveyed with a density ranging from 1.9 to 11.3 fry/100m2. Testing has reveled that the returning adults contribute proportionally more offspring and the USR is only iBoF River with exclusively wild hatched salmon, exceeding the collapse period densities. The salmon are also providing food for those animals further up the food chain as evidenced by a 23mm pit tag found in coyote scatt 2km in bush.

See Attached Presentation

Kurt Samways

Dr. Kurt Samways is a Research Associate at the University of New Brunswick. Dr. Samways has 15 years of experience working in aquatic ecology related to natural and impacted rivers and stream fishes, particularly Atlantic salmon, across Canada, in both academia and government (Department of Fisheries and Oceans). Dr. Samways is currently leads UNB scientific monitoring of the Fundy National Park smolt-to-adult supplementation program, studying the effects of stocking adults on fish fitness and ecosystem health. He also currently leads fish passage studies in the Mactaquac Aquatic Ecosystem Study. Dr. Samways has ongoing collaborations with academia, government, industry, First Nations, and NGO's, as well as being a representative in multiple government and local working groups and committees involved in Atlantic salmon restoration.

Becky Graham

Becky Graham has been the ecologist at Fundy National Park since June 2018. Prior to that, she worked for Fisheries and Oceans at the Mactaquac Biodiversity Facility, where she worked on the gene bank component of the Fundy Salmon Recovery project.

CODES OF PRACTICE: FOR THE CARE AND HANDLING OF FARMED FISH

-presented by Tim Kennedy, Canadian Aquaculture Industry Alliance

To provide an introduction for the session theme of Animal Welfare, information was provided on CAIA activities to develop a national fish welfare program and the process being followed.

The Eastern Aquaculture Veterinary Association (EAVA) in consultation with the rest of Canadian aquatic vet community, asked CAIA to undertake the development of fish welfare standards in 2017. After consultation with members, CAIA contacted the National Farm Animal Care Council (NFACC) to begin the process. They applied to AgCanada for a grant to compete the work required which was approved in September 2018.

Farm care and animal welfare are critically important aspects of livestock production and it is something many Canadians, from farmers to consumers, care about. Other countries involved in salmon farming have completed similar guidelines, for example Scotland's RSPCA Fish Welfare Guidelines and Norway's NOFIMA Fishwell Handbook.

The development of animal welfare codes is coordinated by the National Farm Animal Care Council which involves a broad range of stakeholder groups and ensures credibility and transparency through scientific rigour, stakeholder collaboration and a consistent approach.

The timeline presented identified the various steps in the process to be completed and the intention for the final Code of Practise to be released in the summer of 2021 at the latest, and perhaps sooner.

See Attached Presentation

Timothy Kennedy

Timothy Kennedy brings a wealth of strategic and leadership experience in the non-profit, government and corporate sectors to the role of Executive Director of CAIA. After a period of time working in the non-profit sector and as an Advisor to the Official Opposition in Ottawa, he worked for ten years as a senior government relations consultant in Ottawa, advising clients in the natural resources and sustainability sectors, before being named in 2011 as Vice President, Government and Aboriginal Affairs for Spectra Energy, a Houston-based energy pipeline and delivery company. He served in this position for six years until beginning his role with CAIA in April 2017.

AQUA CARE 365 - A PRACTICAL APPROACH TO FISH WELFARE

-presented by Michael Bolton and Kasha Cox, Merck Animal Health

Created in 2010, Dairy Care 365 is a collaboration between Merck Animal Health, dairy organizations and key subject-matter experts, and is designed for dairy producers, calf ranchers, farm employees, veterinarians and every stakeholder involved in the care and well-being of dairy animals. The program provides tools to empower employees to provide the best care for their animals, but the farm owners need to be committed to the program. Dairy Care 365 now has eight training modules that uses photos and video to show people how to address welfare standards.

There are similarities between all animal agriculture, but we are three generations removed from understanding food production, and customers are far removed from aquaculture. Most people don't understand farming in a water

environment, so for the aquaculture sector the bad news stories become perceived as "normal". The identified welfare issues are like those of cattle including handling, and transport, euthanasia methods, antibiotics and parasiticides.

The AQUA CARE 365 journey started with the industry veterinarians recognizing they needed a fish welfare code / welfare program and at the Eastern Aquaculture Veterinary Association (EAVA) annual meeting an introduction to Dairy Care 365 was provided. They were shown the Dairy program with its training tools and agreed the program could work. Meetings were held with fish health teams to determine the need for fish welfare training, then again for the introduction of Dairy Care 365 and discuss survey results.

An AQUA CARE 365 Advisory Council has been organized to provide direction for modules, review content and provide sites / locations for videos. A key subject matter expert was identified, and in early October 2018 the video for the first two modules, Basic Introduction to Salmon Behaviour and Sea Pen Handling, was completed. Future modules will include transportation, mechanical and bath treatments, seining and harvesting.

As suggested above, AQUA CARE 365 is a practical approach to fish welfare and is focused on training for aquaculture producers, fish hatchery personnel, farm employees, veterinarians and other stakeholders involved in the production and care of fish. There will be an animal commitment form for people to sign, along with tests and certificate upon completion. It is designed to support aquaculture producers and their employees to demonstrate their commitment to animal welfare, especially as other third-party certification programs are working on welfare standards. The program will provide SOP templates which companies can revise, complete and design as needed for their specific type of operation.

As with Dairy Care 365, the AQUA CARE 365 program is a collaboration between Merck Animal Health, aquaculture organizations, production companies and key subject matter experts across a wide range of aquatic animal care topics.

Mike Bolton

Dr. Mike Bolton is a Senior Technical Services Specialist with Merck Animal Health. Mike received his D.V.M., at Michigan State University, 1978 becoming a Bovine practitioner as a partner in 5-person Dairy Practice, in Wisconsin from that time until 1986 when he became a partner in a 10-person Mixed Practice until 2006. He then joined Merck Animal Health as Senior Technical Services Specialist, receiving a M.Sc. degree in Epidemiology, from Michigan State University, 2009 during his tenure. His specialities are vaccinology, immunology and animal welfare initiatives - developing materials for employee training for animal care and handling.

Kasha Cox

Kasha Cox is the North America aquaculture business director for Merck Animal Health. In this position, Kasha is responsible for coordinating Merck's North American aquaculture strategy, continued growth and technical support for the business. Kasha first joined Merck Animal Health in 2005 and was instrumental in the successful launch of Aquaflor® (florfenicol) and the start-up of Merck's U.S. aquatic business. Kasha has 30 years of experience in the U.S. aquaculture industry where she was owner and president of Aqua Health Laboratories, a fish health consulting firm, and co-founder of the catfish industry's leading aquaculture supply distributor.

ASSESSING THE EFFECTS OF HIGH OXYGEN FRESHWATER SATURATION ON ATLANTIC SALMON (SALMO SALAR) GROWTH, AND OVERALL HEALTH WITHIN A SIMULATED COMMERCIAL HATCHERY SETTING

-presented by Michael Beattie, GIS Gas Infusion Systems

The basics of fish gill function, and countercurrent flow exchange of dissolved oxygen in water to blood was reviewed. Other facts regarding fish gill exchange were presented including the distance between lamellar surfaces < 10 microns and that non-soluble oxygen micro-bubbles can collapse gill lamellae and block the passage of water therefore

reducing oxygen uptake. Increases to total gas pressure can lead to mortality from what is called Gas Bubble Disease (GBD). Originally thought to be caused by dissolved nitrogen, it has now been shown that super saturation is a function of all total dissolved gas pressures which includes any increase of the oxygen partial pressure. Injection of oxygen alone can induce both chronic and acute GBD.

GIS proprietary Gas Infusion Modules extract nitrogen from water and infuse dissolved oxygen in a 1-for-1 molecular exchange via a polymer coated micro-porous fiber material. The infused oxygen is bubble-less and extremely stable, with a half-life of over 150 hours. The reaction efficiency is independent of water temperature and does not increase total gas pressure. These modules range from small cigar size units up to large stainless-steel units, engineer certified to be placed on barges/well boats or in a building. During testing at Dalhousie Univ. Aquatron facility, the dissolved oxygen (DO) level was raised up to 437% DO in 17 C sea water with no change in total gas pressure, therefore no potential issues with GBD. A photo was provided of fish in a tank at 200% DO illustrating the absence of any bubbles. The units are also extremely efficient, infusing 300g O2/min with water flow rates up to 8000 l/min.

Fish research data presented was based on trials at Huntsman Marine Science Centre over the past 14 months. The first phase of work was to evaluate fish health, survival, growth and hematocrit levels in freshwater at an ambient (control) level of 100% DO, compared to 150% and 200% DO. The experimental design and methods were discussed in which a generic early rearing production plan was followed to simulate commercial hatchery activities and handling for various early life stages to smoltification. Fish start weights were as low as 0.2g (first feeding salmon) and up to 146g in pre-smolt fish.

Mortality in GIS groups were significantly lower than the ambient group (90% lower), and it was noted that most mortalities in the ambient group occurred around handling events. The salmon in the 150% GIS and 200% GIS groups were significantly larger (49% larger) than ambient groups when assessed during the second density reduction activity as shown using GLM analysis. The GIS groups had lower hematocrit levels as suspected because less red blood cells are needed in high dissolved oxygen environments. The GIS fish groups were tested to evaluate survival post immediate transfer to ambient freshwater and seawater from there respective high dissolved oxygen levels. There was 100 % survival 60 days post transfer to both ambient freshwater and saltwater. Necropsies were conducted routinely with no notable lesions or tissue abnormalities recorded. There was also no difference in the number of precocious fish between groups.

Future research directions may include work to evaluate vaccine efficacy, response to disease challenges in freshwater and in saltwater (post-smolting), and identification of genetic markers for immune upregulation.

A GIS container unit has been in use at a hydroelectric facility as part of the fish ladder operation. The GIS unit has reduced the environmental footprint, eliminated the need for an 18" "attraction flow" and increased the dissolved oxygen levels from 98% to 126%. This year double the number of fish successfully passed up the ladder, with decreased mortalities and turn-arounds. Previously NBPC experienced 100 moralities for every 3000 fish using the ladder, while after the addition of the GIS unit there were a maximum of 12 mortalities for every 3000 fish.

See Attached Presentation

<u>Michael Beattie</u>

Dr. Mike Beattie is the President of Gas Infusion Systems but previously served 14 years as the Chief Veterinarian Aquaculture for the Province of New Brunswick and is an adjunct professor at the Atlantic Veterinary College. He holds multiple degrees in marine biology (BSc Honors, MSc), international marketing (Norwegian School of Business) and Veterinary Medicine, AVC (1994). He was accepted as a member of the Royal College of Veterinary Surgeons in 1997 (UK). Mike is an active reviewer for NSERC and ACRDP national projects and has participated on the Canadian

Science Advisory Secretariat regarding aquaculture issues. In the past, Mike spent 10 years with Nutreco N.V. (one of the largest Aquaculture/Agriculture companies in the world) and served in the capacity of Product Manager/Research & Development Manager - North America. Mike was a co- lead researcher for a multi-disciplinary team awarded the Federal "Award of Merit" for oceanic research involving sea lice management and de-naturing of toxic pesticides in 2011. The team was the first group to utilize hydrographic models and flouricine dye, to predict the dispersal/dilution of disease, pesticides and drug residues.

VETERINARY OVERSIGHT OF MEDICALLY IMPORTANT ANTIMICROBIALS
-presented by Jean Szkotnicki, Canadian Animal Health Institute

Health Canada has prepared a list of medically important antimicrobials (MIA) used in veterinary medicine that can be found in the following link https://www.canada.ca/en/public-health/services/antibiotic-antimicrobial-resistance/animals/veterinary-antimicrobial-sales-reporting/list-a.html. MIA are considered to be important in human medicine. The MIA are further divided into Categories I, II and III antimicrobials based on their importance in human medicine, whether it is a preferred drug for treatment of serious infections and whether there are alternatives to treat a disease. Category IV are antimicrobials not important in human medicine and not associated with antimicrobial resistance (AMR) e.g., ionophores.

For the agriculture sector, several regulations are now changing the requirements for reporting and the process for using MIAs in food production and companion animals. By end of March 31st veterinary MIA's sales volumes by species must now be reported annually for the previous calendar year. Product labels of all in-feed and in-water MIA's must now have prudent use statements, and growth promotion claims / non-therapeutic purposes were phased out in Dec. 2018. There has been a 17% decrease in volume use of antimicrobials over the last two years. The market branding of "raised without antibiotics" is associated with the unintended consequences impacting animal welfare. This includes higher mortality rates in some poultry flocks e.g. 21 % in some untreated flocks versus 1 -2 % when raised using antimicrobials.
New for agriculture, there will be increased veterinary oversight as all MIAs will now have prescription status requiring oversight by licensed veterinarians. This is an important part of antimicrobial stewardship. Approximately 340 veterinarian drugs will move from over the counter (OTC) designation to veterinarian prescription only. A valid Veterinary, Client, Patient Relationship (VCPR) will have to be in place for a veterinarian to be able to prescribe product.

The following link illustrates the list of the antimicrobials that now have prescription status as of December 1, 2018; https://www.cahi-icsa.ca/uploads/userfiles/files/CAHI_MIA_Poster_Feb27_2018_website%20ENG(2).pdf.

The Canadian Health Institute (CHI) has provided the kg of active ingredients to the Public Health Agency of Canada over the last decade by family of drugs, province sold to, companion or production animal. This information can be found in the Canadian Integrated Programme for Antimicrobial Resistance (CIPARS) report. CAHI is also working with groups like the Veterinary Drug Directorate (VDD) and the Canadian food Inspection Agency (CFIA) to move forward on alternatives to antimicrobials such as gut modifiers as they are neither designated as a food, nor a drug, and therefore are not covered in current regulation.

A new program to oversee the importation and sale of Veterinary Health Products (VHPs) in Canada was implemented November 13, 2017. VHPs are low risk drugs in dosage form used to maintain or promote the health and welfare of companion and food-producing animals. They are not for use to treat, prevent, or cure disease and would include items such as vitamins, minerals and traditional medicines.

Is the future antibiotic free? Prevention and good biosecurity are not enough to eliminate diseases entirely in animals, so antimicrobials need to continue to play a part in an integrated management system.

See Attached Presentation

Jean Szkotnicki

Jean Szkotnicki is President of the Canadian Animal Health Institute (CAHI), a trade association representing companies that develop and manufacture pharmaceuticals, biologicals, feed additives and pesticides used to support the health and well-being of our companion and food animals. In her capacity as President, Jean works with CAHI members to develop Institute policy and strategic directions. Liaison and communication activities with regulatory authorities, producer groups, veterinary associations, research institutions and the media are also important in her role. Jean has both BSc (Agr) and MSc degrees from the University of Guelph, Guelph, Ontario. She was inducted into the Canadian Agricultural Hall of Fame in 2017.

SEA LICE DATA MONITORING AND CONTROL IN ATLANTIC CANADA

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

The salmon aquaculture industry is a decade into the sea lice management issue. It was 2008-2009 when sea lice began to show tolerance to the in-feed product SLICE and late 2009 when the industry started to collect data in what would become the FishiTrends database. The first complete year of data for New Brunswick was 2010, which was a bad year for industry, with Newfoundland and Nova Scotia joining the program in 2014 and 2015 respectively. The industry experienced a similarly difficult year in 2019 likely related to available treatment resources. Data was presented showing that each BMA is tracked over time regarding lice abundance and water temperatures, and every year these factors fluctuate. Lice abundance in 2018 was similar to 2017 which was higher than most other years except 2010. Water temperatures on average have been the highest in 2010, 2012, 2016, and 2018, going above 14°C in the summer (as an average for entire industry) and having warm winter temperatures in the year previous.

Graphical summaries showed the total number of bath treatments that have occurred each year since 2009 and the breakdown of the products used each year, including mechanical treatments using warm water and water pressure starting in 2017 and 2018 respectively. Response to the two bath treatment products available has been part of the monitoring completed using the supplied data. Response to treatments with hydrogen peroxide have shown a lot of variation in lice reductions, but the reason is unclear. If we consider lice reduction is successful when 95% or more of lice have been removed following treatment, then less than 10% of treatment events were successful last year. Restrictions on the amount of treatment chemical used per day often resulted in sites completing a single treatment of each pen but spread over a longer period. Over the years, fewer than 20% of treatments have been successful (i.e. at 95% or greater removal) for mobiles removal every year. Data presented on a limited number of warm water treatments showed very good lice reduction, but the process still takes time to go through the entire site.

Data on in-feed treatments since 2009 was also presented showing the use of two primary products with the annual breakdowns. All marine chemical treatments (both in-feed and bath) are occurring with reduced frequency compared to early years. Use of new in-feed sea lice products in hatcheries may be contributing to reduced marine treatments.

See Attached Presentation

Larry Hammell

As an aquatic veterinary epidemiologist, Dr. Larry Hammell has been the lead proponent on many large, clinical research projects and partnerships with industry and government agencies. Dr. Hammell's research focuses on aquatic

food animal health studies including disease detection and surveillance, health management through identification of risk factors and disease prevention and biosecurity studies, and clinical trials for improved responses to disease treatment and prevention. Currently the Dean (Interim) of the UPEI Faculty of Graduate Studies, he is also Professor and Associate Dean (Graduate Studies & Research) at the Atlantic Veterinary College, University of Prince Edward Island, and Co-Director of the Collaborating Centre for Epidemiology and Risk Assessment of Aquatic Animal Diseases (ERAAAD) for the World Organisation for Animal Health (OIE).

"GREENING" FISH HEALTH TREATMENT: ALTERNATIVES AND INNOVATIONS
-presented by Joel Halse, Cooke Aquaculture

In 2013, all sea lice treatments were completed using chemicals, either topical or in-feed products and the need for innovation was recognised. Hydrogen peroxide had shown decreased efficacy, there was no effective in feed treatment, and there were no other options in use commercially at that time. In 2016, 99% of sea lice treatments involved either a hydrogen peroxide product or Salmosan. Innovation was required.

The first rough schematic detailing the idea of a shower using warm water was drawn in early 2013 and a list of success criteria for any green technology was developed that included avoiding the use of chemicals, minimizing the impact on fish and removing the sea lice from the fish and environment. The capacity to treat large volumes of fish every day would also be added to this initial list. Five years after this first drawing (presented) which included multiple prototypes and significant research and development, the Cooke R is now operating in Maine as a commercial unit.

Other green sea lice technologies such as the Snorkel, lice skirts and cleaner fish are being used in Newfoundland operations, but the focus of sea lice removal in the Bay of Fundy has been on the mechanical options using with warm water or water pressure. All these systems work on basically the same process of crowding and pumping the fish aboard the vessel, remove the lice and capture them as the water passes through a filter on the way out of the treatment unit.

The warm water systems expose the fish to 32°-36°C water for approximately 25 seconds via either a bath or shower. The lice seem to become "unconscious" and let go of fish so that as the clean fish are released into a pen, the lice and water go through a filter where the lice are captured. With the water pressure unit (hydrolicer), the water pressure comes from behind the fish and lice such that the lice cannot hold on to the fish. Data on mechanical treatment efficiency indicates that the warm water systems provide 95-96% sea lice removal and the water pressure system provides 80-90% sea lice removal, possibly due to "shadowing" by lice allowing some to remain.

Cooke has three units in operation and one unit in production. The Sea Flow technology (hydrolicer), the Steinsvik warm water bath (thermolicer) and the Cooke R warm water shower (Cooke IP) are all in use while a new vessel with 2.5 times the capacity of the Cooke R (approximately 200t salmon per hour) is in development. NRC-IRAP and ACRDP funding has been provided to aid the research and technology testing required to enable these treatment vessels to be developed and evaluated, along with collaboration with the scientific community.

Through the use of these 'Green Technologies', the 2018 sea lice treatment season (at time of presentation) saw 81% of treatments occurring without the use of chemicals and with sea lice captured post treatment.

What else is possible in the next 5 year is still a question. "Self serve" sea lice removal systems have been theorized and prototypes are being developed. Options to eliminate crowding and pumping the fish would also be an improvement to the treatment process.

Joel Halse

Joel is the Corporate Engineer for Cooke Aquaculture Inc., where he oversees a team of engineers and project managers that create and implement new technologies for Cooke operations around the world. Joel joined Cooke in 2009 and has been involved with several cross-departmental innovation projects and initiatives. He has imported technologies from other countries and industries and is listed as the inventor on two of Cooke's patents to date: a constant diameter pumping system, and a warm water shower slide for salmon. He previously served as an Aerospace Engineering Officer in the Canadian Air Force.

FISH FARM HEALTH ISSUES: PERSPECTIVES, POLITICS, AND THE PRECAUTIONARY PRINCIPLE
-presented by Hugh Mitchell, AquaTactics Fish Health

The history of salmon farming in Maine and New Brunswick was reviewed highlighting the development of freshwater hatcheries, marine farms, fish heath issues, and the associated activities. The review also included the development of early fish health regulations, their implications for farmers and the politics that began to surround the industry. Examples of some key "junk" science papers against aquaculture that have been published over the past twenty years were discussed with concerns identified, and a list of ten red flags for bad science presented.

Since 2017, Washington State has become one of the most anti-salmon farming places in the world and a review of the reasons for the recent legislative changes highlighted why this happened and lessons learned for Canada. Atlantic Salmon farming in WA State, banned in 2018 for reasons including, it is competition for commercial and Tribal fishermen, it is a good revenue-generating cause for NGO's and researchers, and because the potential hazards of the industry were overstated. Scientifically defined or managed risk was not a part of the discussion.

A similar situation is seen in British Columbia as anti-salmon farming activists are using the fear of disease to restrict and remove the industry from the marine environment (pathogen=disease & "amplification"), without any epidemiological evidence. This approach has been used before with Infectious Hematopoietic Necrosis Virus (IHN) which has been proven to be endemic in Pacific Northwest, and Infectious Salmon Anemia (ISA) which, after more than $400K spent on testing, has failed to prove the virus is on the west coast. Piscine orthoreovirus (PRV) is the latest virus to be used in this campaign. Viruses are the most abundant and genetically diverse life forms in the ocean with approximately 150 billion viruses found in just one teaspoon of sea water. Viruses are arguably the fastest-evolving biological entity on this planet, so if you transport fish between any bodies of water these "exotic" viruses will also be transported with the fish. The question is which viruses we should be concerned about, if any.

In reviewing the criteria for determining if there is evidence supporting association and causation relationship between PRV from farmed fish affecting wild fish, evidence was presented to show how each factor was not supported. There is no consistency; meaning there is no relation between PRV load in farmed salmon versus wild salmon in Norway, or specificity in where PRV is found – close to or far away from salmon farms. There is evidence to show that PRV was detected in salmon in the Pacific Northwest before net pen farming of Atlantic salmon occurred in the region. There is low association strength since lab and field studies have shown that fish can have high PRV loads with no disease, and PRV may be associated with HSMI in Norway but there is no data that PRV causes mortalities in wild Pacific salmon. There is other information that indicates that the hazard is negligible. Although classification via only the first segment has been deemed inadequate by Norwegian researchers vs. whole genome sequence comparison, using the S1-only segment classification, the worst strain of PRV 1 (1b) does not kill on its own and requires poor husbandry or

other diseases to be present, and in lab trials in Norway it does not cause mortality or morbidity. On the west coast of the US, there has been no HSMI seen in any samples (heart or muscle), taken for other reasons and submitted to Washington Animal Disease Diagnostic Lab at Washington State University (WSU-WADDL), for past 4 years. The virus can't be grown in the lab for challenges, and fish with HSMI can't be found to use blood filtrate.

Anti fish farming activists play up the environmental, food safety, and disease hazards of the industry equating risk with hazard, while in reality any risk is a combination of the potential hazard and potential exposure to the hazard. The example of stairs as a hazard was provided to show that stairs are not eliminated when viewed as a risk, the risk is managed in several ways. The precautionary approach garners greater public support but creates biases and several problems including that fact that the absence of an effect can never be proved. It is not a risk management tool. There is a need to convey the hazards of not having a strong north American aquaculture sector within the seafood supply chain and aquatic ecosystems.

See Attached Presentation

<u>High Mitchell</u>
Dr. Hugh Mitchell received his Bachelor of Science in Marine Biology from the University of Guelph; a Master of Science in Aquatic Ecology from the University of Toronto; and a Doctor of Veterinary Medicine from U. of Guelph's Ontario Veterinary College in 1989. He then immigrated to the US and took up the position of Fish Health Manager for Ocean Products, a salmon farm based in Eastport, Maine, USA. The farm was purchased by Connors Brothers (later "Heritage Salmon"), and he became the Veterinarian / Production Analyst for its East Coast operations. While in Maine, he helped develop fish vaccines, and pioneered mass injection vaccination in salmon in North America. This led to positions as Clinical Trials / Veterinary Services Manager; Manager of Development; and later: Technical Support Manager for Biomed. After 5 years, he formed his own consultant company servicing global aquaculture operations. In 2000, he accepted the position of Manager, Professional Services USA with Novartis Animal Health's new Aqua Business unit and managed the North American Aqua Business. In January 2009, he then accepted the position of VP, International Marketing and Technical Development for Aquatic Life Veterinary Services of Western Chemical and Syndel Labs. In 2011, he purchased the veterinary clinic with his colleague, Dr. Tom Goodrich, the fish vaccine pioneer, and changed its name to AquaTactics Fish Health.

WHY ARE AUTOGENOUS BIOLOGICS NEEDED?
-presented by Kalena Statutiak, Gallant Custom Laboratories Inc

Gallant Custom Laboratories Inc. is a CFIA licensed, autogenous biologics manufacturing facility in Cambridge, ON, supplying vaccines for agriculture and aquaculture specializing in pathogen isolation.

Microorganisms (virus and bacteria) are continuously evolving producing new variants and new emerging pathogens. These developments and changes in farming practices can reduce the efficacy of treatments or vaccines, if they are available. New commercial products may take up to five years to be licenced and enter market. Since autogenous biologics can be produced in 6-12 weeks, as well as help with antibiotic reduction initiatives, this option in required to work with, or as an alternative to, commercial vaccines.

A biologic or biopharmaceutical, is any medicinal product manufactured in, or extracted from, a biological source such as an inactivated bacteria (bacterin), a live attenuated or killed viral product (vaccine) or a product that contains neutralized toxins (toxoid). These are prescription-based products only and are derived from pathogens isolated from the target farm and / or production system that has epidemiologically linked units. This type of vaccine can be used

when commercial products are not available, or they are no longer effective, and must be manufactured in a licensed facility.

There is a requirement for good diagnostics to understand what is (are) the relevant pathogen(s), if there are multiple pathogens and is there any variation within pathogen(s). Some inhouse diagnostics for isolations can be provided but generally regional labs are used for isolates. Isolates are stored at -80°C but their use is restricted to two years from date of isolation.

Organisms isolated from many fish such as Atlantic cod, lumpfish and tilapia have been used to create an autogenous vaccine, and for salmon, isolates of Tenacibaculum spp. and Vibrio spp. are available. Autogenous vaccine can also be customized based several factors including the type of adjuvant and the potential use of multiple antigens in one vaccine. Autogenous biologics are a customizable tool that can be used as a rapid and targeted approach to manage pathogens in aquaculture, with the product created for the farm of origin having a shelf life of one year.

Kalena Statutiak

Kalena first joined Gallant Custom Laboratories Inc. in 2009, where her laboratory management skills were put to the test in supporting autogenous bacterin and vaccine manufacturing, project management and developing site operational requirements, such as the expansion of company policies and procedures. During her tenure as General Manager, she was responsible for the development and implementation of an electronic documentation system for the eventual move to paperless company records and for inventory efficiency management. Kalena now takes on the role of President and brings with her in depth experience as a consultant in large scale initiatives in the areas of human and animal health. Gallant Custom Laboratories Inc. was first founded in 1994 by Jackie Gallant, and was acquired by IDT in 2015. Kalena now leads growth of Gallant Custom Laboratories Inc. under the IDT Biologika umbrella by contributing to the Canadian and global capabilities of the Autogenous Veterinary Biologics division and is dedicated to the expansion of products and services.

DECODING IMPORTANT REGULATORS OF SEA LICE PHYSIOLOGY USING GENE SILENCING

-presented by Laura Braden, Senrio Research Scientist, AquaBounty Canada, Adjunct Faculty, Department of Veterinary Medicine, Atlantic Veterinary College

Mitigating the salmon louse problem in the salmon farming industry requires a multi-pronged approach which currently includes tools in categories including chemical, non-chemical, mechanical and pen structure additions. Sea lice are highly adaptive organisms that become tolerant and or resistant to new situations and treatment products very quickly. The silencing of genes using RNA interference (RNAi) has been successfully applied to the salmon louse physiology in the areas of host recognition and reproduction. The mechanism of RNA interference (RNAi) was explained with the process ending in the targeted messenger RNA (mRNA) cleaved and degraded so there is no functional protein created. This gene knockdown effect has lasted 2-3 weeks in *Lepeophtheirus salmonis*.

Using this method, the focus of the work presented was directed toward the process of chitin synthesis, important in the moulting process in sea lice and critical for survival. Several key enzymes in the chitin synthesis pathway were targeted as potential critical process points using RNAi in the nauplii life stage and evaluated though the copepodid stage. Some copepodids from the various treatments were then used to evaluate fish infection capability. All six treatments resulted in a reduction in the number of chalimus observed after 1 week, however, this was only significant in two of the treatments trialed. Of these two treatment groups, one group of copeopidids were effectively unable to attach to the host fish, and there were no lice observed on these fish at seven days post infection. These copeopodids showed an altered phenotype with appendages grossly enlarged, thickened, and malformed compared to the other treatments. They were unable to distribute throughout water column and there were many nauplii II “stuck” in molting

process. So, the RNAi was successful at the knockdown of genes involved in chitin synthesis in *L. salmonis* larvae but there are obvious compensatory mechanisms present so this must be assessed further.

The use of RNAi was also evaluated with regard to putative sea lice virulence factors. There are approximately 60 proteins in the secretions of L. salmonis that help the parasite feed and stay attached to their host, similar to ticks. Coho salmon infected with Atlantic L. salmonis respond like Atlantic salmon infected with west coast L. salmonis as they are "non-native hosts" for the parasite. There appears to be higher abundance of proteins in the gut of Atlantic sea lice after feeding on Atlantic salmon, so these proteins are a potential target for RNAi. Pre-adult lice were injected with five different RNAi fragments and returned to" incubator" fish for seven days. The sea lice were then removed from incubator fish and transferred to naïve fish for 48 hours post infection after which the fish were sampled using qPCR. There was a significant effect of the knockdown of some of these targets both in the parasite (appeared to effect blood feeding), as well as the host (dysregulation of immune function in the skin). There are more trials planned to assess this relationship further.

RNAi is a valuable tool for various health and production challenges in livestock currently with increasing use in the salmon farming industry. Precision gene editing will play a large part in future solutions to today's issues.

Laura Braden

Dr. Laura Braden originally hails from British Columbia, where she obtained her doctorate in Molecular Immunology from the University of Victoria, investigating mechanisms of resistance to L. salmonis among different salmonid species. Shortly after her PhD in 2015, she moved to the east coast to work with Dr. Mark Fast at the Atlantic Veterinary College using different "OMICs" techniques to investigate host-parasite interactions, aquatic animal health and mechanisms of resistance against disease. Last fall she accepted a position with AquaBounty Canada as a research scientist where she plans to leverage the latest advances in biotechnology to tackle common problems in aquaculture. As an adjunct professor at UPEI, Dr. Braden intends to integrate academic research with industry to drive development of novel management strategies for issues that plague the sector. She has over a decade of experience in aquatic animal health and has presented her work at international conferences in Europe, South and North America.

FISH MICROBIOME AND eDNA: SETTING THE SCENE FOR THE AQUACULTURE INDUSTRY
-presented by Julie LaRoche - Dalhousie University

The morphological traits of fish tell us something about their role or status in the ecosystem, but bacteria don't have a lot of observable characteristics, so within a drop of water there is no visible way to tell different types of bacteria apart or which may be a pathogen. Bacteria are everywhere including volcanos, glaciers and deserts and within all the microbial habitats they are found, often in symbiotic relationships with other organisms, like cows and humans. The human microbiome is composed of approximately 10 to the 14 (10^{14}) cells, at least 10 times more than the number of human cells in our body. Human health is greatly influenced by our microbiome.

Shellfish and fish like all other animals are colonized by microbes that form their microbiomes. Even more important for marine or aquatic species, the animals are drinking the water directly and are taking into their GI track the bacteria that are prevalent in the environment.

Diet and environment will affect a microbiome composition, and in times of global warming, ocean acidification and increased eutrophication it is important to know the composition of the healthy microbiome of fish and shellfish, and know their metabolic potential, i.e. what type of enzymes they have, and which are beneficial to the nutrition and survival of the economically important shellfish.

Illumina next generation DNA sequencing of a marker gene (usually a variable region of the 16S ribosomal RNA gene) can be used to produce a microbiome signature and thereby identify the bacteria in plankton, sediments, fecal or tissue samples. The sequences obtained from a sample are classified taxonomically by comparing them one by one to very large and comprehensive "libraries" or databases of known sequences that have a taxonomic classification since if a matching barcode is not in database, the bacteria cannot be identified. Usually, we find a match but, in a sequencing, run there are usually some new sequences that are too distant to be classified, and can be registered as "novel" operational taxonomic units (or OTUs).

NGS amplicon tag sequencing results are compositional because there are only a fixed number of sequences that can be gained per sample. Therefore, when the relative abundance of one type of bacteria goes down another one must go up within a given sample. The relative abundance of each bacterial type within a sample does not tell us anything about what the absolute abundance is. However, the sequencing tells us about the composition of the microbial community in a given environment and that could also provide some very important clues about the functioning of the bacterial community or its metabolic activity. Total bacterial load of each bacteria type will affect things like recycling in RAS biofilm and in the sediments of coastal aquaculture farms.

Lateral gene transfer can occur between environmental bacteria and gut bacteria of an organism via food items allowing novel function to develop in the gut bacteria. A good example of the acquisition of a new function in gut bacteria is seen in the gut microbiome of some Japanese costal communities. For thousands of years the Japanese people in these communities were eating seaweeds that they harvested directly along the beaches and this led to transfer of genes from the bacteria associated with the seaweed to the bacteria in the human gut. These genes were encoding special enzymes that allowed the member of the coastal communities to more efficiently digest the seaweeds (Heheman et al. 2010) These new genes in the gut bacteria help degrade the seaweed and provides a more complete assimilation of the nutrients available. In research trials, salmon gastrointestinal track microbiome was evaluated over time as fish were fed two different diets. Bacterial DNA was extracted from fish feces and showed that by week two a difference could be observed in the microbial community between the feed types. We have seen before that the diet influences the microbiome composition in trout (Michl et al. 2017) and there is some interest to characterize the healthy gut microbiome of farmed salmon.

There are a variety of ways in which microbiome research could benefit the aquaculture industry. For fish health the benefits could include rapid identification of bacteria involved in secondary infections, development of fish probiotics, and the ability to assess recovery from treatment. On the farm site, this type of work could help evaluate the fallowing process and benthic monitoring, as well as provide the capability for the rapid detection of toxic alga in the environment. Environmental genomic sensing is a way to use the eDNA found in a water sample to detect the presence of larger organism like sharks and endangered species in the ocean in real time.

Heheman, Jan-Hendrik, Gaelle Correc, Tristan Barbeyron, William Helbert, Mirjam Czjzek, Jan-hendrik Hehemann, and Gurvan Michel. 2010. "Transfer of Carbohydrate-Active Enzymes from Marine Bacteria to Japanese Gut Microbiota." *Nature* 464 (April). doi:10.1038/nature08937.

Michl, Stéphanie Céline, Jenni-Marie Ratten, Matt Beyer, Mario Hasler, Julie LaRoche, and Carsten Schulz. 2017. "The Malleable Gut Microbiome of Juvenile Rainbow Trout (Oncorhynchus Mykiss): Diet-Dependent Shifts of Bacterial Community Structures." *PloS One* 12 (5). Public Library of Science: e0177735.

See Attached Presentation

Julie LaRoche

After obtaining my PhD in biology from Dalhousie University in Nova Scotia, Canada, Julie LaRoche worked in New York and Germany before returning to Dalhousie two years ago to occupy the Canada Research Chair in marine biogeochemistry and microbial genomics in the Department of Biology. Building the lab from scratch, Julie is developing and applying approaches to study how marine microbes and biochemical processes are affected by global climate change.

USING MICROBIAL EDNA TO ASSESS ORGANIC LOADING IMPACTS TO BENTHIC HABITAT IN THE VICINITY OF SALMON AQUACULTURE IN THE BAY OF FUNDY
-presented by Shawn Robinson, DFO-SABS

The work presented was founded on the idea that impacts to an ecosystem can be detected at different size scales (from bacteria to fish) and that the ease and cost of sampling can differ significantly among the different size categories. Due to the slow accumulation of sediment on the ocean bottom, the benthic sediment surface represents current activity as opposed to further down in the sediment that could represent decades in the past. The objective of the study was to evaluate the variability in surficial bacterial populations based on distance from the farm, season and depth in the sediment. Two farm sites were used in the study, one with a very soft bottom and one with a harder bottom. Replicate samples were taken at pen edge, 50m from pen edge and 200m from pen edge. Samples of 200 to 400 mg of sediment taken with a syringe sampler. DNA was extracted from the samples, and the ribosomal RNA gene was sequenced using the V4 region for species discrimination. Multidimensional scaling (MDS) plots were presented showing significant differences in the bacterial taxonomic groups based on distance from the farm and between surface samples versus those further down in a core sample. Significant differences were also noted in the classes of bacteria based on time of year, and different bottom types. The ratios of anaerobic to aerobic bacteria differed in proximity to the site and may be a useful tool for assessing benthic organic impacts and recovery in the future. This approach of using bacterial eDNA to assess impacts indicates this is an easy and cost-effective tool.

As with the human microbiome (the suite of bacteria found within an organism), understanding the microbiome of the various invertebrates found around the farm as well as the salmon could provide information on what a healthy population and therefore a healthy environment looks like. Data from eDNA profiling was provided to show the top ten bacterial classes for sea scallops, sea urchins and sea cucumbers. The microbiome in salmon mucus is especially important in fish health. Data provided showed the top twenty genera identified. There were a large number of bacteria found in the mucus samples, although for many of these, their ecological role is unknown. One genus identified, *Pseudoalteromonas*, is known to produce an array compounds with antimicrobial, antifouling, algicidal and antibiotic activities. There is a good possibility that this genus might be participating in the immune system of the fish.

Going forward, the eDNA environmental monitoring project will continue to sample different sites during different seasons, identify key indicator groups, and determine what taxonomic level should be used for potential monitoring. The salmon/invertebrate microbiome work will continue with samples from different sites and seasons within the North American and European farming regions. One goal will be to attempt to standardize the location on the animal and number of samples required for accurate and representative samples.

See Attached Presentation

Shawn Robinson
Dr. Shawn Robinson has been working as a research scientist since 1988 with the Dept. Fisheries and Oceans at the Biological Station in St. Andrews, New Brunswick. He is also currently an adjunct professor at the University of New Brunswick and works closely with several other international colleagues. He is actively engaged in applied ecological research on a wide range of marine invertebrate species such as blue mussels, sea scallops, sea urchins, sea cucumbers, soft-shell clams, worms, sea lice and marine bacteria. His research team is studying the natural ecological processes by

which these animals interact and utilise their environment so that better and more sustainable culture techniques can be developed; such as the concept of integrated multi-trophic aquaculture or IMTA for example.

THE USE OF METAGENOMICS IN FISH HEALTH

-presented by Tony Manning, RPC

Like genomics, metagenomics is both a set of research techniques and a research field which hopes to provide a way to deal with current challenges in clinical and environmental microbiology. Metagenomics is made possible by next-generation sequencing (NGS) or high-throughput sequencing and can be applied to fish health in many ways, including the identification of new or emerging disease agents, in cases where the pathogen responsible is unknown or when the disease agent is non-culturable. In these types of scenarios, metagenomics can be used to provide information such as the diversity of the microbial community and relative abundance per sample, as well as track changes in microbial taxa over time. The technical approach to determine the diversity of microorganisms within the community of interest is referred to as "marker gene amplification metagenomics". This process uses polymerase chain reaction (PCR) amplification of regions of ribosomal RNA genes to identify bacteria, fungi and parasitic protozoa. This type of metagenomics can be used to help identify pathogens and describe microbial community changes associated with disease state.

Beyond determining microbial diversity, a metagenomic approach can be used to determine the genes present in the microbial community under examination; this can be used to evaluate the community impacts on the health of their hosts. Whole metagenome shotgun sequencing, which takes the "What genes are there?" approach to the sample, captures the collective microbial genomes contained in a sample, but will also sequence any host DNA present. The host DNA from tissue samples will dominate the sequence information obtained and can reduce the ability to detect rare microbial genes or taxa. High capacity sequencers can ensure sufficient sequencing depth for detection of microbial genes among host samples. Examples of findings using this approach include the detection of antimicrobial resistance genes, which has implications on treatment, or the discovery of metabolic pathways for nutrient utilization which could lead to the development of novel culturing techniques for certain microbes. Viruses with DNA genomes can be detected through whole metagenome shotgun sequencing, while the study of viruses with RNA genomes require either special approaches or the use of RNASeq.

Interpretation of sequencing results can be complicated, and accuracy can be affected by factors such as experimental design, reference database, analysis platform, and experience. For a metagenomic study the sampling regimes must include suitable reference samples, healthy fish from within and outside the test population, and healthy tissue from infected individuals (e.g., skin infections). Background information on microbial assemblages found over time is required to identify causative agents associated with infected samples. Options for sample preservation and storage must also be considered depending on the study.

See Attached Presentation

<u>Tony Manning</u>

Dr. Tony Manning works as a Senior Scientist at RPC in the Food, Fisheries and Aquaculture Dept where he has collaborated with industry and research organizations on projects with ISAV, BKD, sea lice, and bacterial ulcer diseases in relation to disease resistance and vaccine and treatment efficacy. He also has worked on fish reproduction, salmon responses to light/photoperiod manipulation in sea cages, and gene expression studies. He will give a presentation on the use of metagenomics in the study of fish health issues, highlighting its application in examining bacterial assemblages in hosts.

MODERNIZING POPULATION AND COMMUNITY MONITORING WITH eDNA
-presented by Anaïs Lacoursière-Roussel, DFO-SABS

No area of the world is not impacted by human activity whether it is by resource exploitation, urbanization or climate change. Coastal biodiversity reflects those human impacts in the marine environment and the potential cumulative impacts from various sources. eDNA work can be applied to the aquaculture sector to look at questions around the magnitude and scope of impact on non-target organisms, such as lobster, that would result from the use of pest control products or differentiate cumulative large-scale ecosystem impacts.

Using the ecosystem-wide monitoring approach, eDNA has been used to look for the presence of lobster and their prey over time. Post larval and young-of-year lobster numbers are significantly correlated with the abundance of copepods. Data presented from 1989 to 2015 shows that recent widespread declines in post larval lobster may be linked to changes in the zooplankton assemblage at the base of the pelagic food web.

Monitoring biological data to understand responses of biodiversity to multiple stressors requires substantial and consistent funding. This will allow us to ensure the correct methodology is used to encompass factors such as long-time series data, for both pelagic and benthic organisms, multiple samplings per year include sensitive stages of organisms involved, and standardized method in heterogeneous coastal ecosystems (i.e., gravel, sand, etc) is developed. eDNA is a cost-effective promising approach to develop a large-scale dataset to better understand the responses of biodiversity to multiple stressors. A very small amount of water contains DNA from many organisms and DNA metabarcoding can provide biodiversity information and quantitative PCR (qPCR) can provide species specific and abundance information.

The overall goal of the research planned is to develop an ecosystem-wide approach using eDNA that can be deployed several times a year for an extensive number of years to better understand biodiversity changes by achieving several smaller goals, for which data was presented. Data presented showed there is huge biodiversity found across all phylum detected with less than 15L of water and there is confidence that eDNA metabarcoding will help detect species loss and introduction of exotic species. eDNA sampling may be able to provide life stage history information such as the reproductive period for various species. Ecosystem stability may be informed by data collected throughout the seasons to assess significant monthly variation of the community structure and the community structure during the transition from summer to winter. There is natural background variation and the annual community structure cycle can, over time, inform what is normal versus large-scale impacts and can show the recovery period related to the timing of the stressors. Population distribution and abundance data may be obtained through eDNA monitoring to help fill gaps in regional species distribution data for such species as Atlantic salmon. Work with wild salmon in the Bay of Fundy has started and will continue for next three years.

<u>Anaïs Lacoursière-Roussel</u>
Anaïs Lacoursière-Roussel is a new research scientist working for Fisheries and Oceans Canada (DFO) in St Andrews. She is the scientific leader of the Aquaculture Monitoring Program (AMP), which aims to encompass finfish and shellfish growing areas on both coasts. The objective of this new national program is to provide information at an appropriate time and spatial scale to support aquaculture policy and regulatory decision-making. Her career goal is to improve coastal management decisions by integrating the latest innovative tools into large-scale monitoring surveys. She studied Marine Sciences at the Université du Québec à Rimouski. To obtain a strong expertise in sustainable development, she pursued at the Université de Lausanne in Switzerland in Environmental Sciences. She did her graduate studies on the relationship between anthropogenic activities and invasion success. She found that molecular markers could be used to detect the human vectors associated with the spread of exotic species and demonstrated that these new molecular methods are more effective than classical methods such as surveys. She collaborated with the most advance theoretical ecologists at McGill University, whereas she learned to develop effective large-scale sampling methods and management strategies complying with Canadian laws, standards and regulations with DFO scientists. In addition, she worked for DFO on various projects such as the reproduction of shrimps, Snow crabs, American lobsters and for the development of mussel aquaculture. She also acquired knowledge on population genetic at Windsor University (Ontario) and learned on the

most advanced marine biosecurity modeling techniques at Cawthron Institute in New-Zeeland. As postdoctoral fellow, from 2013 to 2017, her role was to evaluate the potential of the environmental DNA (eDNA) to contribute to the sustainable maintenance and the long-term economic viability of aquatic species in complementary domains of activity, such as: recreational fisheries, the conservation of biodiversity and the Northern economic development. Her international project unites world leaders in the development of the eDNA methods in relation to aquaculture, fisheries, global shipping, climate, navigation infrastructure, global trade, and policy.

A PILOT STUDY TO INVESTIGATE THE MIGRATION OF JUVENILE SALMON AND THEIR INTERACTIONS WITH AQUACULTURE IN PASSAMAQUODDY BAY

-presented by Marc Trudel, DFO-SABS

Migration is part of the life history of many species within the animal kingdom and has documented ecological consequences whether though the transport of nutrients and energy between locations or through the levels of the food chain. The life cycle of Atlantic salmon involves an example of one of these migrations, though in contrast to those of other animals, little is really known about the details of the estuarine and coastal migration of Atlantic salmon. The project data presented was obtained during a pilot project in 2018 designed to follow tagged salmon smolt on the initial part of their migration route.

The methods follow those of past projects conducted in 1995 and 1996 by LaCroix (2004). This work showed an overall smolt survival rate of 71% and 82% respectively leaving Passamaquoddy Bay. Hatchery smolt were migrating mostly through the western passage in 1995 and wild smolt were migrating primarily through the Letete Passage in 1996 with the migration of post smolts seeming to track surface currents during spring and summer. Residence time was about the same for both wild and hatchery smolts, on average about 5 days from release to exit of the Bay.

The current study objectives were to determine the migration route and residence time of juvenile Atlantic salmon in Passamaquoddy Bay, estimate stage-specific survival rates from the estuary to the open ocean and determine the extent of the interactions of juvenile salmon with marine salmon aquaculture sites. The 2018 study design included 29 DFO receivers located within and outside the Magaguadavic Basin estuary, at the exit points of Passamaquoddy Bay and on salmon farms. Two other receivers operated by the Ocean Tracking Network could follow the smolts after they left the Bay on their migration route around Nova Scotia and Newfoundland. Two groups of thirty smolt were used in this project, all originating from the St John River stock, and reared in substrate ponds at the Mactaquac Biodiversity Facility. The smolt groups were released on May 25 and on June 6 below the Magaguadavic dam and at the same time drifters were released in order to assess surface currents.

The nets from the Gaspareau fishery and the obvious predator gauntlet at the release point was a concern but preliminary data suggests estuary survival was, at a minimum, 86.7% and 90% for the respective release dates as the smolt moved out at night on the ebb tide. After the first release approximately 95.5% of the smolt left Passamaquoddy Bay by the Western Passage, while after the second release only about 82.6% of the smolt left via this route. Of the smolt that left the estuary from the first release, approximately 84.6% of the smolt survived to the point where they left Passamaquoddy Bay. For the second release the survival rate is approximately 85.1%. The smolt stayed within the Bay for an average of approximately 4.5 days and 3.6 days respectively.

While in the Bay, 23 of the 52 fish that reached the inner arrays were detected within the 500m tag range of the receivers at aquaculture sites. Average residence time at individual aquaculture sites was approximately 16 minutes (range 30 sec to 77 min). Only 9 out of the 23 salmon visited two or more sites.

The plans for 2019 include the use of new tags that will have temperature and pressure sensors to determine the nature of the predation observed and adding more receivers and releasing smolt over three time periods. Smolts will also be released above and below the Magaguadavic dam to evaluate mortality through this barrier.

See Attached Presentation

Marc Trudel

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

Plenary Discussion - What are the R&D Priorities?

Before off-shore systems can be contemplated for the Bay of Fundy, forecasting tools need to improve and there is a need for real time and accurate data. Most of the data available is not for the areas of farming interest. For RAS systems, there is a need to better understand biofilms throughout the system and how factors such as feed and feces impact system efficiencies.

Additional research is needed on all fronts within the fish health theme. The multi-faceted challenges of sea lice remain a research priority, as well as the need for more and / or new tools and products. Gene silencing in sea lice and the work to produce vaccines using the targets identified is of great interest to the industry and needs to be pursued.

eDNA research work appears to be a valuable tool on many fronts in environmental monitoring though validation for the information obtained is required before this can be interpreted and potentially used for management decisions.

Research that provides greater understanding of wild salmon and interactions near aquaculture sites can contribute to productive discussions and interactions with traditional marine users. Wild salmon smolt migration routes within Passamaquoddy Bay and potential interactions with salmon farms will continue and hopefully expand to provide clear beneficial information.

Forum Wrap-up

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

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

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

Participants

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