acffa Atlantic Canada Fish Farmers Association

ACFFA Annual Technical Workshop
And
Research Review 2014

FINAL REPORT

November 5 and 6, 2014

Huntsman Marine Science Center

St. Andrews, NB

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Acknowledgements

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Thanks also to ACRDP for collaboration on this workshop.

The ACFFA also gratefully acknowledges and thanks all the speakers and presenters for their participation.

Introduction

The Atlantic Canada Fish Farmers Association hosted its annual technical workshop and research review on November 5 and 6, 2014 at the Huntsman Marine Science Centre in St. Andrews, New Brunswick. This annual workshop is designed to support the review and discussion of R&D results, profile new technologies, enable communication on various projects and activities being undertaken by industry members and other stakeholders and discuss new research direction or ongoing knowledge gaps.

Presentations in 2014 provided knowledge on various aspects of climate change. Topics discussed in this area focused on current and potential impact in our region from changing climate, monitoring environmental impacts from climate change and on emerging projects to help mitigate potential impacts.

The new six year inner Bay of Fundy Atlantic salmon recovery project between ACFFA, Fort Folly First Nation and Fundy National Park was discussed as were broodstock selection programs and a project to evaluate the potential of ensiling mortalities.

Enhanced farm management practices and fish health continue to be a primary focus of research discussion for the salmon aquaculture industry in Atlantic Canada. Presentations in this area included information on diagnostic tools, ulcer disease, melanisation, treating large populations, and the potential of "good" bacteria. Sea lice presentations covered topics of modelling, monitoring, resistance, new treatment technology and wild reservoirs.

Over 120 individuals attended the technical workshop and included representatives from the aquaculture industry from across Canada, local, national and international researchers, pharmaceutical companies, federal and provincial regulators and other community stakeholders including fishery and conservation interests.

Agenda

acffa Atlantic Canada Fish Farmers Association

Annual Workshop and Research Review 2014

November 5 and 6, 2014
Huntsman Fundy Discovery Aquarium, St. Andrews, NB

TUESDAY, NOVEMBER 4, 2014

7:00 pm Welcome Reception at the Algonquin

WEDNESDAY, NOVEMBER 5, 2014

8:00 **Registration and Coffee / Muffins**

8:30 Welcome and Introduction – Pamela Parker, ACFFA
8:45 Social Licence and the Aquaculture Industry in Canada - Ruth Salmon, CAIA
9:10 Ocean Acidification in the Atlantic Canada - Kumiko Azetsu-Scott, Bedford Institute of Oceanography
9:35 Project Summary of the Charlotte County Community Vulnerability Assessment 2013-2014; Community Recognition of Projected Climate-Related Impacts - Kim Reeder

10:00 **Refreshment Break**

10:30 Life-long effects of early experience in iBoF Atlantic salmon – Corey Clarke, Fundy National Park
11:00 Individual & family selection - maintaining genetic diversity in the breeding nucleus – Amber Garber, HMSC
11:30 NAIA Ensiling Project: ensiling and utilization of salmonid mortalities in NL – Darrell Green, RDC NAIA

12:00 **Lunch**

1:00 Hydrodynamic investigation of scale model fish cage-arrays: implications for IMTA and related research - Adam Turner, UNB
1:30 Net Alternatives – an ever changing industry - Ted Weaire, GMG
2:00 Melanization - a problem on the rise? – Nils Steine, PHARMAQ

2:30 **Refreshment Break**

3:00 Sea lice trends 2014 - Larry Hammell, AVC
3:30 Models and observations of sea lice: what about the larval stages? – Jon Grant, Dalhousie
4:00 Can the bacteria that live on salmon be involved in sea louse resistance? An initial study – Steve Leadbeater, DFO-SABS

4:30 Wrap up / Adjournment

THURSDAY, NOVEMBER 6, 2014

8:00 **Coffee and Muffins**

8:30 Welcome and Introduction
8:45 Clams on acid: Experimental effects of sediment acidification on juvenile soft-shell clams and implications for northwest Atlantic shellfisheries - Jeff Clements, UNBSJ
9:10 Using video monitoring to monitor benthic changes due to aquaculture: visual indicators and challenges – Dounia Hamoutene, DFO NL
9:35 Moving away from local effects and toward ecosystem-based management of fish farming - Jon Grant, Dalhousie

10:00 **Refreshment Break**

10:30 Novartis Aqua PEI – capabilities, commitment and innovation - Spencer Russell, Novartis Animal Health
11:00 MALDI-TOF Mass spectrometry for rapid identification of aquatic bacterial pathogens – Jan Giles, AVC
11:30 Bacterial kidney disease diagnostics: tools of the trade - Ben Forward, RPC

12:00 **Lunch**

1:00 What are the "good" bacteria doing around aquaculture sites in the Bay of Fundy and why should we care? - Shawn Robinson, DFO-SABS
1:30 An update on ulcer disease in Atlantic salmon salt water aquaculture – Sophie St. Hilaire, AVC
2:00 Antibiotic treatment of bacterial diseases in large salmon populations - Derek Price, AVC

2:30 **Refreshment Break**

3:00 Where are all the sea lice in Cobscook Bay? – Mike Pietrak, U Maine
3:30 Latest technology on tarpaulin treatments in Norway - Julie Bugge, Aqua Pharma
4:00 SLICE – Feed and the SLICE Sustainability Project - Dafydd Morris, Merck Animal Health

4:30 Adjournment

Thanks to our sponsors!!

Many thanks to our collaborator on this project: ACRDP

Presentation Synopses and Speaker Biographies

The following synopses were completed by the speakers or prepared by ACFFA and approved by the speakers.

Wednesday, November 5, 2014

SOCIAL LICENCE AND THE AQUACULTURE INDUSTRY IN CANADA

- presented by Ruth Salmon, Canadian Aquaculture Industry Alliance

The fundamental inconsistency with the existing federal regulatory framework and the resulting consequences for aquaculture operations is the basis for CAIA's work to develop a national strategy for the Canadian aquaculture industry. The need for a strong development strategy was demonstrated via graphs showing that despite enormous competitive advantages, Canada's production has flat-lined and our market share has fallen by 40% during the past decade - while our competitors' production has increased significantly. The Canadian aquaculture industry is also losing investment to other countries at a time when it should be growing to economic development challenges in rural coastal communities and to meet the rising global demand for farmed seafood.

The Fisheries and Ocean's Minister has requested that CAIA move forward with background development work on a Canadian Aquaculture Act and CAIA has a proposal going forward for a five-year aquatic Minor Use Minor Species (MUMS) program which would support access to increased feed and fish health products. CAIA's technical documents assessing the regulatory roadblocks to growth and missed economic and social opportunities are resonating within DFO, Provincial Ministers of Agriculture as well as within the Senate and Standing committees. Some of these documents include:

- Overview/Broad Elements of a new Aquaculture Act (March 2013) and Legal Elements of an Aquaculture Act (May 2013)
- Policy and Program Reform (February 2014)
- Building an Effective BRM Model for Canadian Aquaculture Based on Worldwide Best Practices
- Social Licence and the Aquaculture Industry in Canada (Feb 2014)

The purpose of the discussion paper *Social Licence and the Aquaculture Industry in Canada* was:

- To define social licence
- To explain the key characteristics and measures of "social licence" or "social licence to operate" (SLO)
- To describe social licence activities by the Canadian aquaculture sector
- To stimulate informed discussion on social licence for both the aquaculture sector and government

Through multiple examples, the challenges of finding a clear, attainable definition with measurable indicators and understanding of how to "obtain" a social licence became obvious. Social license is dynamic; it changes with new information, new people and new circumstances. The challenge for the aquaculture sector is how to overcome the message that the industry "does not have social licence" simply because some do not agree with the development of the industry, when the reality is the Canadian aquaculture sector has built and

maintained businesses for decades through partnerships with local communities and with First Nations and that they are partners in working waterfronts throughout Canada.

The role of government in enabling industry to obtain and maintain social licence was identified and explained. This includes the mandate for government to establish sound, risk-based management systems, endorse systems of standards and publicly recognize best practices, and assist companies to engage communities through research, resources, training programs, employment incentives.

In the theory of how to obtain a social licence to operate (SLO) three boundaries for companies / industries to overcome were presented, moving from legitimacy, through credibility to trust. Indicators of SLO in the aquaculture industry were identified at the various levels which provided evidence that aquaculture companies in Canada have achieved, and continue to maintain, high levels of social license with their communities.

See Attached Presentation

Ruth Salmon

Ruth Salmon brings more than a decade of aquaculture experience to the Canadian Aquaculture Industry Alliance, having served five years as Executive Director of the BC Shellfish Growers Association and seven years as a private consultant. She has held senior positions with the Canadian agri-food industry – as General Manager of the Alberta Milk Producers Association and Advertising Manager with the Dairy Bureau of Canada. Having worked at both the provincial and national levels, Ruth takes a special interest in the promotion and expansion of the aquaculture industry across Canada.

OCEAN ACIDIFCATION IN ATLANTIC CANADA

– presented by Kumiko Azetsu-Scott, Bedford Institute of Oceanography

About one quarter of the carbon dioxide (CO_2) released into the atmosphere since the 1800's through human activity (anthropogenic carbon), has been taken up by the oceans. As a result of this seawater uptake of CO_2, the pH of the ocean is decreasing from its pre-industrial level, meaning the ocean is becoming more acidic and its chemistry is changing rapidly. The rate of change is now one hundred times faster than at any time in the last 25 million years.

Many life processes are sensitive to CO_2 and pH. The most direct impact would be to organisms such as sea urchins, sea stars, shellfish and corals that form calcium carbonate ($CaCO_3$) shells and skeletons because acidity increases the solubility of $CaCO_3$. Indirect impacts through food chains would be to fish such as herring, salmon and cod. Carbon dioxide is more soluble in cold water than in warm water, so colder waters tend to be more acidic. Organisms at higher latitudes and inhabiting deeper, colder waters are; therefore, potentially have greater negative impacts than organisms living in the tropical seas.

Different response of organisms to elevated CO_2, therefore higher acidic, conditions may result in competitive advantages that could drive the re-organization of many ecosystems, which in turn, could have significant ecological and biogeochemical implications.

The literature on the effect of ocean acidification on fish is limited and more study is needed due to variation within and between species in response to changes in pH. Work to date has shown that ocean acidification causes sensory and behavioural impairment in fish and some invertebrates, also the impact on immune responses to diseases is an emerging field.

Other consequences of ocean acidification include changes in nutrient chemistry, availability and toxicity of metals to organisms, decreased absorption of low frequency ocean sound (noisier ocean at low pH), and a decrease in ocean's ability to sequester atmospheric CO_2.

The methods and new technologies available to monitor ocean acidification were discussed and results from the Labrador Sea, Shediac, Hudson Bay and the Scotian Shelf were presented. Monitoring is being done in the Scoitan Shelf, Gulf of St. Lawrence, Newfoundland Shelf and Labrador Shelf in 2014. Data shows that the coastal environments are more variable in pH than those in offshore.

Severe damages due to ocean acidification are imminent which will have socio-economic impacts if we cannot stabilize CO_2 levels in the atmosphere.

See Attached Presentation

Kumiko Azetsu-Scott
Dr. Kumiko Azetsu-Scott is a research scientist, leading a carbon and tracer group at Bedford Institute of Oceanography, and an adjunct professor at Department of Oceanography, Dalhousie University. Her research interest includes climate change and carbon cycles in the ocean, ocean acidification, tracer studies for ocean processes and the interaction between the Arctic and the Northwest Atlantic. She has coordinated several ocean acidification programs in Department of Fisheries and Oceans, Canada. She serves as a Canadian representative for Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP), a member of Global Ocean Acidification Observing Network (GOA-ON) and a lead author of Arctic Monitoring Assessment Programme Report for ocean acidification in the Arctic.

COMMUNITY VULNERABILITY ASSESSMENT OF CLIMATE CHANGE AND VARIABILITY IMPACTS IN CHARLOTTE COUNTY, NEW BRUNSWICK

- presented by Kim Reeder, Consultant

In recent years, Charlotte Country has experienced multiple and significant climatic events such as floods, blizzards, and ice storms. These events have impacted the communities to varying degrees but overall have resulted in human health impacts, physical and infrastructure damage, loss of household savings, temporary loss of services resulting in economic disruption, and environmental damage. With proactive initiatives to address future hazards lacking, Reeder initiated and organized the St Stephen and St Andrews Community Vulnerability Assessments (CCCVA) during 2013 with the support of the St Croix Estuary Project. Eastern Charlotte Waterways Inc. (ECW) also became a partner organization and encouraged further community participation to support a county–wide Community Vulnerability Assessment. The group hired climatology experts, engaged academia and shared down-scaled information on topics such as socio-economic systems, sea-level rise, and inland flooding.

There has been an increase in the number of rain events resulting in over 58mm of rainfall since 1993. A slide, indicating 3 different time periods from 2011 to 2100, shows the number of days per year with a daily maximum temperature exceeding 25 degrees C is predicted to increase in all areas of the province. The increase in frequency of days above 30 degrees C is especially dramatic and will result in and increased demand for effective air conditioning in buildings, shade areas and drinking water. Species are already moving north and soft shell issues are being seen with lobster.

LiDAR (**Li**ght **D**etection **A**nd **R**anging) an optical technology to map physical features with very high resolution was used to create projections of local sea-level rise for coastal Charlotte County. Estimates of the anticipated changes in total sea-levels for 2010, 2025, 2055, 2085

and 2100 time frames represent the worst case flooding scenario resulting from the simultaneous occurrence of a significant storm surge event for the respective return-periods AND a high astronomical tide (HHWLT) at a given location. The worst case emissions scenario from the IPCC report completed seven years ago has already been surpassed so 2013 data was be used in the our projects. With an estimated local sea-level increase of 0.88 – 0.94m by 2100, the report indicates that the 1 in 100 year flooding scenario (4.94m) becomes a one in 25 year event by 2025 and an annual event by 2055. Projections show Blacks Harbour and Grand Manan are subsiding by four and six centimeters (cm) per century respectively (Daigle 2014). These projections also indicate the mean Higher High Water Large Tide for St Andrews is 7.88m (Chart Datum) in the current 19 year cycle. This level was surpassed on several occasions in 2013 and 2014. The highest annual maximum tides are projected for 2016 at over 8m.

Future work within this project includes a series of consultations with industry and government stakeholders. During these consultations, Eastern Charlotte Waterways will communicate anticipated climate risks, recommendations and proposed actions to industry. Industry feedback will help facilitators understand the adaptation goals of industry along with capacity and likelihood for participation in adaptive and mitigation actions. Facilitators will then partner with local government to develop adaptation strategies for each municipality.

See Attached Presentation

Kim Reeder
Kim Reeder is a "from away" who chose to make Bocabec, Charlotte County her home over 20 years ago. Though Ms. Reeder's education is forestry based, she has worked in the environmental field for the past 15 years focusing primarily on community concerns regarding the land water interface throughout the St Croix watershed. Most recently Kim has been consulting for local municipalities and ENGOs.

CASCADING LIFE-LONG EFFECTS OF EARLY EXPERIENCE IN ATLANTIC SALMON

- presented by Corey Clarke, Fundy National Park

The history of the inner Bay of Fundy Atlantic salmon population was presented and details of the Live Gene Program (LGB) in response to listing the salmon as endangered under the Species at Risk Act (SARA). Poor marine survival is considered to be most limiting factor in population recovery.

Since 2006 the recovery strategy for the Upper Salmon River (USR) was to release fry and parr into the river each year. Monitoring data showed fry releases were producing a larger smolt that would leave the river in their second year, while the parr would leave the river at 1 year. However, since neither group were returning to the river after their marine phase a project was initiated with the Atlantic Canada Fish Farmers Association (ACFFA) to assess if holding fish in marine pens for one year would have a positive effect to the marine phase of the life cycle.

In 2010, USR smolts of fry and parr release origin were transported to a marine farm site for a grow-out period of about eighteen months. From this group, 344 fry and parr-origin grilse were released to the IBoF near Fundy National Park to monitor homing ability back to the USR. In addition, 100 fry and 100 parr-origin grilse were used in spawning experiments to monitor egg viability.

Egg viability experiments, showed significantly higher survival for offspring of parents released into the river as fry. 2011 adult releases returned well in 2012 to mark 20-year

highs on both park rivers. Sampling these returns showed that fry release-origin and marine reared adults returned in greater numbers than those released as parr or reared in the hatchery. Smolts from releases of marine reared adults will migrate in spring of 2014 and 2015.

The results from these studies led to several conclusions:

- Early-stage exposure may shape especially life-long fitness
- Managers should prefer wild environments shaping these stages when wild fitness is goal (i.e. survival in bay, progeny)
- Adult releases produce 100% captive-free smolts
- Marine cage rearing offers a powerful potential for adult production for recovery considering historic wild numbers

Moving forward, a new six year project with new partners was initiated. Cooke Aquaculture was engaged through ACFFA as the primary industry partner with Fundy National Park and Fort Folly First Nation with support from DFO to help the recovery on their respective rivers. In collaboration with NB DAAF, Fundy Park and Petitcodiac smolt were transported to the Huntsman Marine Science Centre and held for several months to complete fish health testing requirements to meet the regulatory requirements for introduction to a salmon farm site. The smolt have now been transferred to a marine farm on Grand Manan and will remain there until the fall of 2015 when they will be returned to their natal river.

The long-term goals of five to six year project include:

- Adults releases to rivers near historic numbers from 2015-19.
- Captive-free smolt migrations 2018-'22.
- Natural returns 2019-23
- Novel accomplishments in conservation strategy

Challenges to be addressed over the course of the project include optimizing the diet to maximize the maturation / grilsing rate of the salmon, which is the opposite of what commercial farmers want to achieve, and determining if there are methods which will maximize spawning activity after release and enable the monitoring fitness and the long-term effects on ecosystem.

See Attached Presentation

Corey Clarke

Corey Clarke leads Fundy National Park's salmon recovery program and has worked on IBoF Salmon recovery for Parks Canada in Fundy for 15 years. He has completed a MSc at MUN which developed an award winning partnership project with Parks Canada and the Aquaculture Industry. The project grew wild Fundy National Park smolts to maturity in sea pens which later contributed to 20 year-high salmon observations in Fundy National Park rivers.

INDIVIDUAL AND FAMILY SELECTION: MAINTAINING GENETIC DIVERSITY IN THE BREEDING NUCLEUS

- presented by Amber Garber, Huntsman Marine Science Centre

A broodstock program is required for livestock whether for enhancement or commercial production. Breeding programs are built to retain genetic diversity (retain rare alleles), prevent inbreeding, and improve traits to reduce cost of production including increasing animal health and faster growth/time to harvest. An increase in survival and growth by 1% and 5% would result in (increase per generation with selection likely up to 10%):

- Direct cost savings of $0.03/kilo at 1% = +$300,000 profit for every 10,000 tonnes of production
- Direct cost savings of $0.07/kilo at 5% = +$700,000 profit for every 10,000 tonnes of production

Several key steps must be taken to establish a broodstock program to meet the needs of a client:

1. define the goals of the potential program,
2. evaluate existing programs that may meet those goals (purchase stock) or if a new program must be developed,
3. identify a founder stock and appropriate individuals chosen to begin the process.

Performance of selected traits must be evaluated after a program is initiated to ensure that the goals are achieved within the families chosen. Tradeoffs occur as a broodstock program is developed and implemented with every choice having its share of advantages and disadvantages. There are two options for family production: communal tanks and individual family rearing tanks. Each of these options has advantages and disadvantages that are further refined based on when either of these strategies is implemented. In creating progeny and ensuing production, there are several options for breeding methodology to make family crosses, assessment of progeny (e.g., when and what to measure) and data analysis (e.g., statistical models, random and fixed effects). To select the best performers from those progeny, there are also options for types of selection, such as family selection or combined selection (individual and family), and use of a total merit index involving all traits of interest.

The program developed by the Huntsman Marine Science Centre was explained with examples of family evaluations for growth, BKD and sea lice resistance, and reduced incidence of deformities. These traits were discussed, in part, to discuss the difficulty in developing a Total Merit Index (TMI) to be used for selection as it is sometimes difficult and/or impossible to improve multiple traits simultaneously and improving all traits simultaneously results in smaller overall improvements compared with selection for a single trait. Additionally, the importance of a secure method of data storage and comprehensive statistical analysis (relational database management program) was mentioned.

See Attached Presentation

Amber Garber

Dr. Amber Garber has been involved in aquaculture and wild fisheries studies since 1998. Her primary topics of research include breeding and broodstock development, development of molecular markers for aquaculture and wild fisheries, population genetics studies, and stock enhancement. She has applied her expertise to commercial production and stock enhancement broodstock programs to varying degrees for red snapper, hybrid striped bass, Atlantic cod, rainbow trout, brook trout and Atlantic salmon. Amber has also been involved with and led experiments in fish physiology, disease challenges, sea lice management and proprietary research. Amber moved from North Carolina State University (Raleigh, North Carolina, USA) to the Huntsman Marine Science Centre (St. Andrews, New Brunswick, Canada) in 2006 where she is a Research Scientist in Aquatic Services.

THE NAIA ENSILING DEMONSTRATION PROJECT (SALMON KEEPING COWS WARM AT NIGHT)

- presented by Darrell Green, Newfoundland Aquaculture Industry Association

Fish material management in Newfoundland is a challenge for the seafood industry. Data was provided covering the years from 2011 to 2013 and projected to 2020 on the amount of farmed salmon harvested, the resulting offal produced and moralities that are part of the

waste stream. Options to manage these waste streams are limited and where facilities exist they are often located far from the salmon aquaculture operations making them costly. In an effort to address the mortality waste stream in a cost-effective manner ensiling of mortalities and consolidated local handling (e.g. transfer station?) are being considered by the Newfoundland industry.

Research work on ensiling fish was previously conducted at the Marine Institute but fish used were from the capture fisheries, and because ocean dumping of wild fish is allowed, is easier and less expensive, there was no pressure by the wild fishery to invest in the required technology. More recently (2011-2013) research scale work was completed by Gray Aqua Group and the agriculture sector is experimenting with the use of silage from mortalities as liquid fertilizer.

Based on some of this work and knowledge that silage is being used by companies in other jurisdictions, NAIA is pursuing an Ensiling Demo Project. The project began when NAIA led a trip to Norway and Scotland for representatives of four salmonid aquaculture companies and two processing companies to further investigate industry practices and connect with supply companies. The trip included visits to farm sites collecting mortalities for ensiling, providers of ensilage equipment and systems, a silage and mort handling equipment manufacturer, and ensilage handling companies. The tour also included presentations from silage processors and equipment companies of salmon processing and high-end uses of offal for animal and near future human nutrition.

Since the group's return equipment needs and specifications, costing and budget and proposal preparation activities have been completed with submission to funding agencies to support the demo project. The intent is to have the equipment arrive in February / March 2015 so companies can evaluate the equipment for six months. NAIA will report on the project including experience, costs and options for management of mortalities in NL. The end use for the silage will also be evaluated. Work to develop a liquid fertilizer will continue with the NL Federation of Agriculture. A dairy farm will also evaluate the use of the silage in their anaerobic digester to create power for the farm, bedding for the cows, compost and liquid fertilizer for their fields.

See Attached Presentation

Darrell Green

Darrell Green is the Research and Development Coordinator (RDC) for the Newfoundland Aquaculture Industry Association (NAIA), and one of four members of the Atlantic Canada Aquaculture Industry Research and Development Network (ACAIRDN). Darrell has a B.Sc. in Biology from Memorial University and a Graduate Diploma in Aquaculture from the Fisheries and Marine Institute of Memorial University. Since 1997 he has worked in the aquaculture industry, starting off with short contracts at NAIA and the Canadian Centre for Fisheries Innovation (CCFI) and then as a tilapia farm manager in Ontario, Canada. He then spent seven years at the Ocean Sciences Centre working on aquaculture research projects involving cod, halibut and blue mussels, before joining the team at NAIA in 2007. In his current capacity as R&D Coordinator he helps to initiate and coordinate aquaculture R&D in Newfoundland while acting to maintain communication of aquaculture R&D issues between industry, government and academic researchers throughout Atlantic Canada

HYDRODYNAMIC INVESTIGATION OF SCALE MODEL FISH CAGE ARRAYS: IMPLICATIONS FOR IMTA AND RELATED RESEARCH

- presented by Adam Turner, University of New Brunswick

The project was designed to determine hydrodynamic wake properties, cage interactions and drag forces around marine aquaculture arrays, comparing east coast and west coast cage site designs. The east coast of Canada uses plastic, circular cages moored with a grid system while the west coast industry mainly uses steel, square systems which have implications on cage spacing and current velocity between and around the units. The project goal is to improve integrated multi-trophic aquaculture (IMTA) performance overall, with specific objectives to determine patterns of nutrient plumes, best placement of extractive species, cage deformation and oxygen concentrations.

Previous work guided the current project. Other work showed that the more sinker weight attached to the cage less cage deformation occurred from current forces. DFO completed experimental investigations on a single scale model fish cage to determine flow patterns and therapeutant dispersion determining therapeutants are expected to dilute rapidly from a cage site and show very little impact at short distances from the cages. The DFO work also showed cage deformations under different current loads. Work completed on flow within stocked cages showed fish swimming in a circular pattern cause outflow at swimming depth, thus restricting inflow and causing flow recirculation at other depths. Flow evaluation with respect to net porosity found flow blockage and recirculation in cases with low porosity netting (bio fouling).

During project work at the Marine Institute Flume Tank Facility, six model velocities were chosen to reflect full scale velocities ranging from 0.08m/s to 0.28m/s for the square model, and between 0.05 and 0.175m/s for circular model. Cage deformation tracking was completed at all specified current velocities, but only data for square cages was collected because the depth of circular cages was not sufficient for tracking deformations. First cage deformation was significantly larger than others; second and third cage deformations in the square model were very similar.

While recording wake velocity measurements flow was too slow in wake of cages to activate the Swoffer current meters, and increasing free stream velocity caused unrealistic net deformations. The meters propeller will be retrofitted for the second trials.

Experiments to determine drag on a two by three cage array showed that for square cages, drag on row 2 is approximately half of row 1 and though an equal percentage drop was expected for row 3 it was not observed. The drag measurements for row 3 were similar to row 2, which is consistent with cage deformation observations. For the circular cage array, the drag on row 3 is higher than row 2 for most flow speeds. The simultaneous dye release work showed that the speed between the first and second cages is three times slower than the incidental velocity. Estimates of dye clearance time from the cages indicated down-current cage clear at 2.07 ± 0.06 times slower than the up-current cage, regardless of incidental speed. Current speed within and outside of sequential cages in the array demonstrated with drogue-balls also showed the flow reduced in second and third cage of array.

All of this work will be repeated in a second experimental trial within the next few weeks.

See Attached Presentation

Adam Turner

Adam Turner is a graduate student at the University of New Brunswick, studying Mechanical Engineering. He received his bachelor's degree from UNB in Mechanical Engineering in 2013. Adam is currently working on his master's thesis under Dr. Tiger Jeans and Dr. Gregor Reid, experimentally investigating hydrodynamic properties of fish cage arrays. Adam's interests are in the fields of aerodynamics and hydrodynamics.

NET ALTERNATIVES - AN EVER CHANGING INDUSTRY

- presented by Ted Weaire, GMG Fish Services

Nylon netting has been used in the aquaculture industry since 1985 but the company has been searching for new products to improve net performance. Challenges with nylon netting include lack of consistency with supply and net itself with stress over time, low resistance to abrasion from washing or chaffing on-site, cost for re-working the net and continual install / removal operations, and the cost of applying anti-foulant. Nylon is also not as effective in preventing predator attacks as desired, so the evaluation and testing of polyethylene (PE) netting began in 2011. Innovations in the industry are changing the way materials are used to farm. New materials must be resilient, resistant, flexible and consistent.

Data on breaking strengths of various nylon and PE nets showed the much higher values for PE and that breaking strength for nylon decreases over time which is not the case for PE.

Two products that have been under evaluation were highlighted, one main net and two predator nets, to provide a performance comparison with the typical nylon netting. The product being used for the main net is specifically designed for in-situ cleaning, is hydrophobic so does not absorb water and loose strength like nylon, has a waxy smooth yarn surface reducing bio-fouling on the net and is durable, hard wearing withstanding abrasion during net cleaning. An evaluation of the net strength shows negligible reduction observed after almost three years of operation. The thinner twine used in these nets and therefore smaller joints help the net hang true in the water and allows better water oxygen flow. PE netting eliminates the need for anti-foulants.

One predator net under evaluation has a stainless steel wire core which provides four times the bite resistance of normal PE netting. This net has the highest stiffness rating over all synthetic nets to ensure shape is maintained and along with its high abrasion resistance offers an excellent surface for cleaning with in-situ net washers. This netting also prevents mud ingress to minimize algae formation; therefore, no anti-foulant is required. Cage specific data was presented showing improved resistance to predation.

A second predator net being evaluated has a specially developed mix of various fibers and resins to duplicate the properties of the other net. This net does not have the stainless steel wires but added higher abrasion properties without compromising on stiffness. The in-situ machine cleaning is very efficient due to high stiffness and excellent abrasion resistance especially when wet and it has 2.5 times the cut resistance of standard PE braided netting.

Each product has successfully met the challenges identified earlier – improved water and oxygen flow, reduced operational expenses, improved quality control and net performance, and an environmentally friendly product. Work will continue to assess the value of new net fibers as they become available

Ted Weaire

Ted Weaire has been the General Manager of Cooke Aqua Service Operations for the last 6 years. Previous to this he was a Management Consultant to Cooke Aqua.

MELANIZATION - A PROBLEM ON THE RISE?

- presented by Nils Steine, PHARMAQ

Melanin is deposited anywhere in a salmon where there has been an inflammation and connective tissue (scar tissue) develops. It is tasteless and not in any way harmful, but causes downgrading when the salmon is processed. This downgrading may bcost the aquaculture industry over $10 million dollars globally. For a period, a lot of attention was paid to melanization linked to vaccine side-effects. Although these have been greatly reduced over the last 10-15 years, problems with melanin (black-spots) have not been eliminated and in many places are on the increase.

The research institute Nofima is leading a project to evaluate the problem. In Norway, the further north a site is located, the lower the percentage of melanisation is observed. Data presented indicating the percentage of black spots observed from 2011 to 2014 in Norway overall and by region. Age and size also seem to influence the amount of black spots seen in processed salmon. Data from the 2012 year class of major northern Norwegian producers indicates that melanization is one of the leading cause of downgrades.

A cooperative project between PHARMAQ AS and Marine Harvest to evaluate existing and new vaccines administered intraperitoneally and in dorsal median sinus (DMS) was discussed.
Twelve trial groups were established to evaluate eight vaccines and the two injections sites, with one group receiving saline injection and another untreated to act as controls. At slaughter all fish were evaluated and the percent downgrading due to melanin spots in fillet recorded. Overall the melanin spots were present in fillets from all groups, including high numbers in the PBS-control group and the untreated control group; oil adjuvanted vaccines or the vaccination procedure does not seem to be the cause. It was suggested that melanin spots are most probably caused by healing of bruises and may be caused by jumping activity in the net pen and does not necessarily have to be a result of a broken rib bone (oedema).

Information presented from a 2013 PhD thesis analysed similar spots in vaccinated and unvaccinated fish and there were as many pigmented fish in the unvaccinated as in the vaccinated groups. Findings may indicate that a congregation of cells containing melanin is created as a support function to defense and repair mechanisms during chronic inflammation, which causes the black discolouration.

What causes the melanin is still unknown and more work is needed. The melanin deposits come in a number of distinct forms, with the assumption that causes vary and different solutions are probably necessary dependent on cause.

Some other findings and conclusions from work completed included:

- S0s worse than S1s.
- Padding of cages (trauma): No difference
- High/low density: no difference
- Higher water temperature seems to cause higher levels
- The majority of black spots seem to come late in the seawater phase
- High EPA+DEA vs normal diet: No difference

There are discussions to evaluate the fall combination of high temps, low DO, high energy feed and burst swimming (lactic acid build –up). A number of other studies are ongoing and Nofima is looking for more industry data.

See Attached Presentation

Nils Steine

Nils Steine completed a MSc in aquaculture / fish health and so in Norway is called an Authorized Fish Health Biologist. Nils worked in a fish health service company in Northern Norway in the 90's and as the Fish Health Manager for the production company, Atlantic Salmon of Maine from 2000-2004. From 2005-2008 he worked as a fish health consultant in BC, with emphasis on physiology /smolting, vaccines and fish health services. He then moved with the family to Stavanger, Norway and has worked with PHARMAQ since that time, serving as a technical and sales representative for Canada and parts of Norway.

SEA LICE 2014 UPDATE – NEW BRUNSWICK INDUSTRY TRENDS

- *presented by Larry Hammell, Atlantic Veterinary College*

As resistance to Emamectin Benzoate emerged in New Brunswick salmon farms starting in 2009, industry, government, and AVC combined their efforts to collaboratively create a comprehensive response to monitoring sea lice trends and control options. This included formalizing the requirement for weekly sea lice counts on 30+ fish per site, having experienced counters (from AVC) act as a 3rd party verification and to provide site training, bioassays on sea lice collected from sites, and applying clinical trial methods to assess treatment responses at farms. The massive level of new data being generated was used in a web-based data management program, called Fish-iTrends or FiT, designed by AVC to provide immediate visualization of lice patterns and treatment responses over time and location.

Widespread use of FiT began in early 2010 and now has virtually all NB sites reporting lice counts and treatment events at least weekly. FiT was used to generate graphs and tables presented at the meeting. Audits of site counting (sponsored by NBDAAF in 2014) showed consistent under-counting of chalimus stages and generally consistent on the other stages (although when there was disagreement, sites under-counted compared to 3rd party). Each week varies so it is difficult to clearly conclude an overall trend, but it appeared that 2014 was slightly lower than 2012 and 2013 for many of the weeks (2011 remains the lowest lice year). Treatments have been progressively applied to lower and lower AF lice levels indicating more aggressive control actions generally. Salmosan tarp treatments were modified by industry in 2013 and 2014 (compared to 2010) to enable longer duration exposure to Salmosan. The greatest response to Salmosan was seen in 2013 when there was 80% removal (compared to 65% in 2014 and only 40% in 2010) for AF and 92% removal of PAAM stages (compared to 83% in 2014 and 69% in 2010). Paramove well boat treatments had a median removal of 85% AF and 80% PAAM in 2014.

See Attached Presentation

Larry Hammell

Larry Hammell is an aquatic epidemiologist. He has been the lead proponent on many large, clinical research projects and partnerships with industry and government agencies. In collaboration with the National Veterinary Institute of Norway, he was the founding Director of the Collaborating Centre for Epidemiology and Risk Assessment of Aquatic Animal Diseases (ERAAAD) for the World Organization for Animal Health (OIE). He is currently Professor in the Department of Health Management, Director of the Healthy Fish Healthy Environment Healthy Food project working on clinical aquatic health projects, and holds the Innovation PEI Research Chair in Epidemiology for Aquatic Food Production, at the Atlantic Veterinary College, University of Prince Edward Island, Canada

MODELS AND OBSERVATIONS OF SEA LICE: WHAT ABOUT THE LARVAL STAGES?

- presented by Jon Grant, Dalhousie University

Water-borne diseases are difficult to predict and manage because of the fluid ocean environment. In the case of sea lice, the early stages are free living. Nauplii live off energy stores until they moult to copepodid stage and find a host to complete the cycle. The free swimming stages allow the movement of the sea lice between farms with the tide; therefore, any attempt to model sea lice movement must incorporate farm scale and bay scale transport. Diagrams presented show how the Susceptible-Exposed-Infectious-Recovered (SEIR) disease model and Simile models (system dynamics) attempt to address this. Underlying this system is a numerical circulation model of tides. Combining these approaches may be most accurate – one program uses data for the adults in a farm-based model which will predict egg production, subsequently those data are used in a spatial plankton model to follow the distribution of the eggs through hatching and early life stages.

Sea lice behaviour and dispersion will change in response to environmental conditions. Sea lice need a certain water temperatures at each life stage for metamorphosis and numbers at each stage change over time due to lice hatching, mortality, advective loss or metamorphosis to the next stage, so modelling and groundtruthing all these parameter is difficult. An egg distribution model with subsequent life history has been created for Shelburne Harbour NS. While sea lice are not problematic for NS fish farming, creation of disease models is an important predictive capability, and applicable to all fish farm sites. Research on groundtruthing the distribution of planktonic stages through in-situ microscopy continues.

See Attached Presentation

Jon Grant

Jon Grant is the NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture, a multi-year partnership with Cooke Aquaculture and Dalhousie University. He is a Professor of Oceanography at Dalhousie. Trained as a benthic ecologist, he holds a BSc from Duke University and PhD from the University of South Carolina. Jon has worked in aquaculture-environment interactions for more than 25 years and authored well over 120 scientific papers. Working with both the shellfish and finfish farming industry, Jon has pioneered concepts and tools for assessing carrying capacity in field culture. Ecosystem models have been developed for coastal bays including explicit criteria for sustainability. This work has led to rigorous application of ecosystem-based management and marine spatial planning to aquaculture, including incorporation of remote sensing and GIS. With extensive experience in oceanographic instrumentation and environmental assessment, Jon has conducted aquaculture research worldwide. His work with the salmon farming industry involves an intensive field and modelling program as well as collaborations with DFO, provincial governments, AVC, and international partners.

CAN THE BACTERIA THAT LIVE ON SALMON BE INVOLVED IN SEA LOUSE RESISTANCE? AN INITIAL STUDY

- presented by Steve Leadbeater, St. Andrews Biological Station

At the Saint Andrews Biological Station (Department of Fisheries and Oceans Canada) collaborative research activities have been undertaken to better understand sea lice (*Lepeophtheirus salmonis*) biology, their relationship to their environment and host, the treatments and methods used to reduce their abundance near or at aquaculture rearing sites. Of these, improving our understanding of inherent family related differences in resistance to sea lice holds promise to reduce treatment frequency and improve fish health.

A research project with Cooke Aquaculture Inc. and Laval University has been developed. This work is focused on understanding the role of salmon skin and gut microbiological ecology in protection against parasites and pathogens in conjunction with family related differences of the host. The microbiota is the sum of all microbiological organisms living on a host as well as in the digestive system and is involved in a wide range of host functions including immune defense.

Six hundred pit tagged salmon whose pedigree had been determined and representing 50 families were screened for resistance to louse infestation. Water flow was stopped just prior to addition of copepodid lice and oxygen was added to maintain saturation. The copepodid stage is able to find hosts within a short time and soon after, the exposure water flow was resumed and fish were not handled until the required sampling time points. At 48 hours prior to infection, 48 hours post exposure (PE), 14 days PE and 30 days PE, 25 fish from each of six tanks were randomly removed for sampling. In addition to weight and length data, fish mucus was collected by sterile swab while feces were sampled by hand stripping. Lice counts were performed on days 14 and 30. At day 30 all remaining fish were sampled for lice load, weight, length and sex was recorded. Microbial DNA is waiting sequencing and sorting against DNA libraries. Variation in lice infection count data seems promising, with lice load levels ranging between less than ten to more than 60 per individual.

The next steps will be to compare the differences in microbial community response to lice infestation and plan projects to move towards manipulation of the community structure to enhance host resistance to sea lice.

This work was done with financial support from Fisheries and Oceans Canada's Aquaculture Collaborative Research and Development Program (ACRDP), NSERC-engage grant to Laval University and Cooke Aquaculture Inc. Support from the Huntsman Marine Sciences Center, Saint Andrews Biological Station and Carlos Rangel has been essential to the work.

Steve Leadbeater

Steve Leadbeater received his Bachelor's degree from University of New Brunswick in Saint John in 1995 and began working in the field of marine species aquaculture development. He was involved in the development of haddock as an aquacultures species, working with Heritage Salmon and the National Research Council of Canada (NRC-IMB). In 2008 Steve completed a Master's degree in Biology and in 2007 began work at the Saint Andrews Biological Station on aquatic animal health and salmon biology projects. He operates and oversees activities in the bio-containment lab designed for the study of diseases impacting salmonids, as well as other fish and invertebrate species. Current studies involve many partners from industry, academia, non-government and government groups working on projects such as ISAv susceptibility, Bacterial Kidney Disease and sea lice resistance. It is Steve's responsibility to collaborate with research teams to help design and execute live animal trials to answer aquatic animal health research questions, while complying with the Canadian Food Inspection Agency (CFIA) requirements for holding laboratory certification.

Thursday, November 6, 2014

CLAMS ON ACID: EXPERIMENTAL EFFECTS OF SEDIMENT ACIDIFICATION ON BURROWING & DISPERSAL OF JUVENILE SOFT-SHELL CLAMS

- presented by Jeff Clements, University of New Brunswick

In setting the stage for discussion about the project and results, the process of ocean acidification was presented. Carbon dioxide mixes with seawater and creates a weak acid – carbonic acid – which releases hydrogen (H+) ions into the marine environment. The number of H+ ions increase, resulting in a drop in pH (10fold increase in H+ ions=drop of 1 pH unit). Acidic waters become corrosive to organisms with calcium carbonate shells, particularly in early life stages. This doesn't just affect overlying water, but can enter sediments and further affect pore water, which is already much more acidic than overlying water. The effect is even more pronounced in estuaries due to anthropogenic input of acidifying chemicals such as nitrogen, sulfur, and carbon. This lead to the question: Can current levels of sediment acidification affect juvenile soft-shell clam burrowing, dispersal, and recruitment in the Bay of Fundy? It is known that larvae and juvenile clams "test" the sediment prior to settling/burrowing and so it was hypothesized that the more acidified the sediment the less likely juvenile clams will burrow.

This project began in the lab using aragonite saturation state as a measure of acidity in the sediment, with low aragonite equating to more acidic conditions, and measuring the percentage of juveniles that burrowed or dispersed under various sediment conditions. In the lab experiments, regardless of size class of juveniles, the more acidic the sediment the fewer clams burrowed and the more clams dispersed away from the more acidic area. In the next phase of the project, sediment from Bay of Fundy mud flats was used in the lab to examine natural acidification levels and juvenile clam behaviour. The clams didn't burrow if the sediment was acidic and if current was provided the clams dispersed away from the more acidic conditions.

Experiments then evaluated the effect of buffering the sediment with either gelatin (stabilize pH) or shell hash (stabilize and raise pH) on juvenile clam distribution as compared to a control. In general, more juveniles were found in buffered sediments (regardless of buffer type) than in non-buffered sediments, suggesting that simply stabilizing pH and not necessarily raising it could alleviate the effects of sediment acidification. Further work was done to assess juvenile mortality at pH levels of 7.3, 7 and 6.8 over seven day and fourteen day time periods. Observed mortality was highest with the fourteen day exposure time regardless of pH treatment. Mortality increased as the pH decreased but was most significant between the 7.3 and 7 pH groups. If the pH was changed slightly over the seven and fourteen days, as it might happen in the marine environment, the mortality level was lower than those groups kept constantly at 7 and 6.8. The loss of oysters and scallops from hatcheries on the West coast presented draw the conclusion that acidified sediment and seawater may lead to a loss of larval and juvenile shellfish production on the Atlantic coast if proper measures are not implemented before acidification becomes a major problem.

Graphs of pH measurements in the local areas of Red Head Road, Pocologan and Trynor's Cove over several time periods in 2012 show that pH is variable on the temporal scale of days to months, ranging from 7.5 to 6.4. This indicates that the Bay of Fundy sediment is already acidic and could be affecting larval and juvenile shellfish production on clam flats. The sediment environment is variable within and among mud flats, but pH is an environmental parameter that should be monitored as there is the potential to impact other organisms as well.

See Attached Presentation

Jeff Clements
Jeff Clements is a Ph.D. candidate at the University of New Brunswick, Saint John. Academically, he is interested in the ecology of bottom-dwelling animals (primarily shellfish) in coastal waters and understanding the environmental factors that impact their populations, communities, and ecosystems. His Ph.D. research focuses on the impacts of sediment acidification on the behaviour, physiology, and recruitment of juvenile clams in the Bay of Fundy.

USING VIDEO MONITORING TO MONITOR BENTHIC CHANGES DUE TO AQUACULTURE: VISIBLE INDICATORS AND CHALLENGES

- presented by Dounia Hamoutene, NL Department of Fisheries and Oceans

Approximately 90% of the aquaculture sites in Newfoundland have hard bottom substrates and are located in areas with depths of between 30m and 100m presenting challenges for industry and regulators in conducting benthic monitoring for potential impacts. The standard monitoring parameters of sulphide and redox potential are difficult to apply because they require sediment grabs/samples and chances of obtaining a usable grab, have been identified as less than 40 per cent. Other tools are needed in Newfoundland and the use of video to identify / quantify the presence of species of *Beggiatoa* bacteria and Opportunistic Polychaete Complex (OPC) as candidates of indicator species of impact has been evaluated. The genus *Beggiatoa* consists of sulfide-oxidizing bacteria commonly found at oxygen/sulfide interfaces. OPCs are found on enriched substrates and have been associated with high sulphide conditions.

Standard operating procedures have been established to describe video monitoring protocols to be applied to the NL context. Video collected at sampling stations are viewed and a representative picture selected with image capture. Substrate types are identified and percent coverage determined from the picture using imaging software such as Image J. The percent coverage of indicator species is recorded along with species identification and abundance counts. In good visibility conditions, it was determined that species must be larger be larger than 1cmx1cm to be correctly identified. Our data analyses suggest minimal observer variability. A detailed instructional manual for observers is provided and can be used by environmental companies when conducting assessments.

Work conducted to review required baseline and pre / post production benthic monitoring data suggests that *Beggiatoa* and OPC were only found on aquaculture sites and are visual indicators of aquaculture effect on the benthos observed on different substrate types. *Beggiatoa* and OPC were found correlated with known indicators of aquaculture activities such as flocculent presence, off-gassing and sulfides (up to a certain concentration), but results also suggest that benthic hypoxic conditions may exist in some sites prior to aquaculture activities. OPC and *Beggiatoa* presence is associated with lower benthic biodiversity and abundances. However, correlations of abundances and richness with distance from cage were weak, and stations close to cages were not always statistically different from stations further away or at the non-production site. Work was also conducted to determine if candidate indicators would provide information on impact gradation; data presented showed that indicators decreased with distance from cage but exhibited patchy distributions. More work is required to evaluate how indicators as well as abundances/richness values collected by video monitoring can be used to determine lower levels of disturbance.

The dominant polychaete in the OPC was identified as a new species *Ophryotrocha cyclops* and appears to consume *Beggiatoa,* be involved in sulfur cycling and fish pellet degradation. *Beggiatoa* coverage did not always increase with higher sulphide levels. The absence of

Beggiatoa (or lack of visibility) can also be the result of oxygen depletion and/or a lack of sulphide flux not always indicating an absence of aquaculture impact. Information on *Beggiatoa* coverage should be considered in the light of other evidence gathered through video imaging, such as benthic richness and diversity, as well as the presence of other indicators (polychaetes, flocculent, offgasing, etc.) especially if sulphide and redox values are not available.

Work to date confirms that video-based assessments can detect major aquaculture related changes in benthic communities, but cannot at present identify lower levels of disturbance. References provided within the presentation and below provide more details on the points discussed in this synopsis.

Department of Fisheries and Oceans (DFO) 2014. Potential impacts of finfish aquaculture on hard bottom substrates and development of a standardized monitoring protocol. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/017.

Hamoutene, D., Sheppard, L., Mersereau, J., Oldford, V., Bungay, T., Salvo, F., Dufour, S. and Mabrouk, G. 2014. Applicability of the use of visual indicators [presence of Beggiatoa and/or Opportunistic Polychaete Complexes (OPC)] to identify benthic changes due to aquaculture on various substrates. DFO Can. Sci. Advis. Sec. Res. Doc. 2014/063. v + 17 p.

See Attached Presentation

Dounia Hamoutene
Dr. Dounia Hamoutene is a research scientist and acting section head of the DFO Newfoundland Region Aquaculture section. She is DFO's regional expert in finfish aquaculture on issues related to the environmental monitoring of aquaculture operations on hard-bottom and salmon farmed-wild interactions.

MOVING AWAY FROM LOCAL EFFECTS AND TOWRDS ECOSYSTEM BASED MANAGEMENT OF FISH FARMING

- presented by Jon Grant, Dalhousie University

For benthic impacts in aquaculture, the management questions are generally: what are the environmental quality objectives (EQO) and how can ecosystem goods and services be preserved. This often concerns assessment of oxic status. Regulatory questions follow; what do we measure, on what scale is this to be measured and what are the appropriate thresholds.

Choosing an appropriate farm site will help avoid impacts to ecosystem goods and services and conflicts with other users, and will establish a baseline from which to regularly assess the site's ability to maintain oxic conditions. Sulphide readings are used as a proxy for oxygen in near-field benthic monitoring but are known to have large fluctuations both temporally and spatially. It is unclear if other sources of variation are methodological or analytical.

Impact on the local scale (near-field) does not have implications for the wider scale / ecosystem impact. Quotes provided from Price and Morris (2013; NOAA Technical Memorandum NOS NCCOS 164) and from Brager, et al. 2015 (Aquacult. Env. Interact. 6: 135-149) suggest that farm-induced effects on the surrounding site are localized and episodic. Near field regulatory standards vary according to province. New Brunswick and Nova Scotia apply the standard at 0 metres, while British Columbia applies the regulatory standard at 30m from cage edge. Internationally, many jurisdictions establish an Allowable Zone of Effect (AZE) in benthic monitoring and recognize that impact is expected within the allowable zone

while monitoring is focused beyond this zone – on the far field impacts. A definition of AZE and statements describing how it can or should be implemented were presented. One such statement indicated that for better integration of multiple uses in coastal zones Marine Spatial Planning (MSP) should be used. An example was presented to show how MSP could be used by establishing a zone of influence around a farm and other resource activities / habitats, evaluating their extent of overlap and interaction intensity, and whether that interaction is positive, negative or neutral.

See Attached Presentation

Jon Grant
Jon Grant is the NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture, a multi-year partnership with Cooke Aquaculture and Dalhousie University. He is a Professor of Oceanography at Dalhousie. Trained as a benthic ecologist, he holds a BSc from Duke University and PhD from the University of South Carolina. Jon has worked in aquaculture-environment interactions for more than 25 years and authored well over 120 scientific papers. Working with both the shellfish and finfish farming industry, Jon has pioneered concepts and tools for assessing carrying capacity in field culture. Ecosystem models have been developed for coastal bays including explicit criteria for sustainability. This work has led to rigorous application of ecosystem-based management and marine spatial planning to aquaculture, including incorporation of remote sensing and GIS. With extensive experience in oceanographic instrumentation and environmental assessment, Jon has conducted aquaculture research worldwide. His work with the salmon farming industry involves an intensive field and modelling program as well as collaborations with DFO, provincial governments, AVC, and international partners.

MALDI-TOF MASS SPECTROMETRY FOR RAPID IDENTIFICATION OF AQUATIC BACTERIAL PATHOGENS

- presented by Jan Giles, University of Prince Edward Island

The work discussed is collaboration between Jan S. Giles, P. Jeffrey Lewis, Beatrice M. Despres, Charlotte A. Ramey, C. Anne Muckle and David B. Groman

The bacteriology lab set-up was described with explanation of traditional methods of the "classical" Bact-T identification process. This process was then compared with the Matrix Assisted Laser Desorption Ionization-Time Of Flight or MALDI-TOF mass spectrometry process. The short blast laser allows the ribosomal proteins to be released from the isolate and ionized. The raw spectral data is then used to identify the isolate. This process can evaluate 96 isolates in one run, returning identifications for each and score between 0 (not reliable identification) and 3 (highly probable species identification).

A comparative case study of both methods was presented using the bacterial disease agent of Enteric Red Mouth, *Yersinia ruckeri.* With the traditional method the bacteria has to be grown on a special medium (streaked), then samples taken to gram stain and conduct several biochemical and serological test. Presumptive identification would take a minimum of 24-48 hours with additional time needed for confirmed identification. With the MALDI-TOF MS the confirmed identification would take 30 to 60 minutes. The visual presumptive identification of *Yersinia ruckeri* within a mixed culture of certain other bacteria was shown to be difficult and the traditional method would have to be completed for several bacterial colonies to ensure proper identification, but could be completed within the 60 minute time frame of the MALDI-TOF MS. This is possible due to a commercial Main SPectrum (MSP) database comprised of over 5,000 thousand genus and species of bacteria and fungi, including 26 isolates of *Yersinia* species.

Addition and validation of user-generated MSPs can enhance classification efficiency substantially. For *Yersinia* this was completed through the collection of diagnostic samples isolated in the Atlantic salmon kidney from both freshwater and saltwater aquaculture sites in eastern Canada and then identified by biochemical testing, serology and confirmed by 16s ribosomal DNA sequencing. User-generated MSPs have been completed for *Flavobacterium columnare, Flavobacterium psychrophilum* and for typical and atypical *Aeromonas salmonicida while work continues for Renibacterium salmoninarum and Streptococcus iniae.* Future goals include work with several other species of interest to the aquaculture industry including *Vibrio salmonicida* and *Moritella viscosa.*

Giles requested diagnostic samples from the industry to assist with this work.

See Attached Presentation

Jan Giles
Jan Giles attended the Nova Scotia Agricultural College, completing the Biology Lab Technology program. She obtained her BSc in Microbiology from the University of Guelph in 1988 then worked for a year in the Ontario Ministry of Natural Resources Fish Health Lab (U of Guelph. Jan moved to PEI in 1989 to start a MSc at the Atlantic Veterinary College on the minimum inhibitory concentrations of several antibiotics on aquatic bacterial pathogens and plasma levels of two quinolones in Atlantic salmon plasma. She returned to UPEI and completed a Bachelors of Education in 2005 and joined the AVC Diagnostic Services Bacteriology lab in 2006, where she is currently the Head Technologist and Lab Supervisor.

BACTERIAL KIDNEY DISEASE (BKD) DIAGNOSTICS: TOOLS OF THE TRADE

- presented by Ben Forward, New Brunswick Research & Productivity Council

Prior to discussing the tests used to diagnose Bacterial Kidney Disease (BKD) in Atlantic salmon, the causative agent- the bacteria *Renibacterium salmoninarum* was described. The diagnosis of BKD through culturing of live cells of *R. salmoninarum* is not ideal in that six to eight weeks are required before cells will grow and enable the routine identification process. If the sample contains other bacteria capable of growing on the selective media, the *R. salmoninarum* may be out competed by these other species and be hard to detect. Direct and Indirect Fluorescent Antibody Tests (DFAT / IFAT) detect both live and dead cells. They are rapid and inexpensive but tend to lack the sensitivity of other methods; the IFAT test is more sensitive than the DFAT test. Low level infections could be missed and sample processing is important to obtain accurate results. Polymerase Chain Reaction (PCR) is a DNA / RNA-based detection of living and dead cells and is among the most sensitive methods. This process also has the advantage of needing small amounts of tissue and lends itself to high sample throughput. There are various types of PCR including RT-PCR, nPCR, qPCR, and qRT-PCR. The process of qPCR was described which has higher specificity than PCR and can provide quantitative information on bacterial load. The ELISA or enzyme-linked immunosorbent assay is a protein based detection system which uses antibody mediated detection of antigen. It is a high throughput process which provides qualitative and semi quantitative results, but there are some reports of cross-reactivity and result interpretation is highly dependant on a negative population background.

There are numerous publications comparing the different diagnostic tools but not all studies were in agreement as to the best BKD diagnostic tool. Papers from 2006-2013 were referenced showing the authors diagnostic comparison rankings. While the majority of papers identify qPCR as the best tool, different types of qPRC assays are specified. There are many reasons why the papers come to differing conclusions and drawing a clear conclusion as to the best diagnostic can be challenging. The studies differ in the study design, the level of

infection, the sampling strategy (often poorly defined), the extraction methodology used, and assay methodologies differ (often poorly described). In the RPC experience qPCR is the better tool but the lab uses both ELISA and qPCR in combination to help diagnose an infection in progress.

Regardless of test, the protocol details, ability for quality assurance / quality control and regular equipment calibration are very important for assay performance.

See Attached Presentation

Ben Forward
Dr. Forward is Head of the Food, Fisheries, & Aquaculture department at the New Brunswick Research & Productivity Council (RPC), in Fredericton, NB, Canada. He holds a PhD in Biochemistry from the University of Victoria and a BSc with honors in Biology from the University of New Brunswick. As Department Head he oversees three divisions providing R&D and diagnostic services in the areas of Fish Health, Microbiology, and Forensic Biology and has served as project lead on numerous applied molecular and microbiological R&D projects. He is an adjunct professor at UNBSJ, member of the Canadian Society of Forensic Science, Society for Wildlife Forensic Science, and Aquaculture Association of Canada.

WHAT ARE THE "GOOD BACTERIA DOING AROUND AQUACULTURE SITES IN BAY OF FUDNAY AND WHY SHOULD WE CARE?

- presented by Shawn Robinson and Hannah Bradford, St. Andrews Biological Station

Marine bacteria could be compared to the dark matter of the universe. They are almost impossible to see, but their influence is felt everywhere in the system. Bacteria and other microbes are key players in the energy flow within all environments, so the scale of their roles must be understood in ecosystem based approaches such as Integrated Multi-Trophic Aquaculture (IMTA). Bacteria are a widely diversified group of organisms that live in all habitats in the ocean, oxic and anoxic. They interact intimately with other species and the vast majority are non-pathogenic. Many specialize on the breakdown of organic carbon. This is relevant to aquaculture since the feeding process of salmon produces faeces that are enhanced in their carbon content due to selective retention of lipids and proteins by the fish. We estimate that 36% of the waste produced is organic and available to the microbes.

Benthic and pelagic field sampling and organic analyses were completed at several salmon farms in the Quoddy region to investigate the organic carbon available to the microbes. Samples of food, faeces, particles in the water and benthic sediment were taken to estimate the organic content. While organic loading rates can be reasonably high around aquaculture sites compared to reference sites, the pattern is not clear-cut and results can be variable. Fish food and faeces have high organic content (~90 and 80% respectively) while the material in sediment traps is low in organics (25%) and the sediment around sites is very low (5-10%) in organics. With no larger organisms observed, bacteria and other micro-organisms appear responsible for this breakdown. Protocols used to enumerate bacteria from the water column were described and seasonal abundance data presented, along with the respective carbon conversion rates of the bacteria collected.

Our results suggest that bacteria and other microbes appear to be rapidly converting solid waste organic nutrients into soluble inorganic forms such as carbon dioxide and ammonia that can be recycled into the surrounding ecosystem and taken up by seaweeds in an IMTA system and the natural ecosystem. Interestingly, considering how ubiquitous and abundant bacteria are and their affinity for organic carbon, they may also turn out to be significant competitors for larger IMTA species that could also consume some of the larger particles. The information

being obtained from this project will be used to make IMTA systems more efficient in the future.

See Attached Presentation

Shawn Robinson
Dr. Shawn Robinson has been working for the past 18 years as a research scientist with Fisheries and Oceans at the St. Andrews Biological Station in New Brunswick. He is also an adjunct professor at the University of New Brunswick and the Nova Scotia Agricultural College. He is also actively engaged in applied ecological research on marine shellfish species such as blue mussels, sea scallops, sea urchins and soft-shell clams. His research team is studying the natural processes by which these animals interact and utilise their environment so that better and more sustainable culture techniques can be developed. One example of this research is the study of integrated multi-trophic aquaculture (IMTA), sometimes known as polyculture,) where shellfish are grown in conjunction with other species to produce a more sustainable and productive system. Much of this work involves collaborative projects with industry and academic partners and takes a more holistic view of the aquaculture system combining biology, physics, economics, sociology, and government policy.

UPDATE ON (WINTER?) ULCER DISEASE

- presented by Sophie St-Hilaire, Atlantic Veterinary College

The Norwegian experience with ulcer disease provided background for work being conducted in Canada, where researchers found mixed pathogens associated with ulcer disease but have primarily identified *Moritella viscose* as the causative agent. Norwegian studies suggest the bacteria *M. viscosa* produces extracellular products which act on the fish in a number of ways including creating a biofilm that permits evasion of immune system and increases bacterial attachment. Gross lesions are found on the fish and systemic infections resulting in acute mortality in the lab within one week after exposure. On Norwegian farms, ulcer disease is seen at cold water temperatures less than 8° to 10° Celsius with farm mortality of approximately 10%. There is a poor response to antibiotics as the fish are off feed when they die.

In Canada ulcer disease occurs at various temperatures including at temperatures greater than 10° Celsius. The fish do go off feed before the ulcer is severe. We examined fish with early lesions and they were already "off-feed", suggesting it might be difficult to treat affected fish with in-feed antibiotics once ulcers are present. . The mortality rate ranges between farms and within pens on farms. Cumulative mortality data was presented for ulcer disease for 7 farms showing high between cage variation as well as a large variation between sites.

Some preliminary results from bacterial culture indicate all skin lesions with a moderate to heavy mixed growth of bacteria while no significant pathogens could be detected in the kidney of affected fish. Of the fish we evaluated *M. Viscosa* was not detected in the skin cultures and the causative agent could not be identified. It is interesting to note that most of the fish with advanced lesions did not have systemic infection. Blood chemistry data suggests that fish mortality is from osmoregulatory problems.

Several research questions can be identified from work completed to date. A transmission study or 16S analysis should be initiated to confirm whether *M. Viscosa* and/or other pathogens are involved in cases of ulcer disease in Canada. In an attempt to improve treatment efficacy evaluations of probiotics, the role of early treatment, and ability of various antibiotics / dosage to effectively reach the skin should be pursued. Also risk factors that predispose or increase mortality associated with ulcer disease likely exist given the wide range of mortality associated with this disease even between pens within farms and should be

investigated. To prevent the disease through vaccine development, the causative agent(s) needs to be confirmed and the appropriate area of the immune system targeted. The apparent temperature dependence of the disease could also be researched to determine if fish exposure at non-virulent temperatures could induce protection.

See Attached Presentation

Sophie St-Hilaire

Sophie St-Hilaire is the Canadian Research Chair and an Associate Professor at the Atlantic Veterinary College in PEI, Canada. Dr. St-Hilaire received her veterinary degree from the University of Prince Edward Island in 1994. She then completed her MSc and PhD in veterinary epidemiology at the University of Saskatchewan and the University of Guelph, respectively. She has worked in the field of aquatic animal health for over 20 years. Prior to accepting her position at the AVC in August 2011 she worked for a number of government agencies including: the Department of Fisheries and Oceans in Canada, University of Guelph, the Centre for Environment, Fisheries & Aquaculture Science in the UK, and Idaho State University in the U.S. Since her appointment at the AVC she has worked on several bivalve and invasive species projects for PEI, as well as continuing with projects on salmonid disease control in Chile and British Columbia. She recently started a project on ulcer disease on the West and East Coast of Canada.

ANTIBIOTIC TREATMENT OF BACTERIAL DISEASES IN LARGE SALMON POPULATIONS

- *presented by Derek Price, Atlantic Veterinary College*

Bacterial diseases may result in significant losses to fish farmers due to the complexity of fish health management and the reality that although these diseases may be treated with antibiotics, drug options are limited. Several factors may play a role in treatment failure including inaccurate diagnosis, the use of an inappropriate drug and / or dosage, or the pathogen resistance. The dynamics of a large population is another potential factor in antibiotic treatment success, which was evaluated in Chile using farmed Atlantic salmon with Salmon Rickettsial Syndrome (SRS).

The bacterium which causes SRS, *Piscirickettsia salmonis,* is persistent in the marine environment, with many strains and with virulence differences. It is a chronic disease affecting all salmonids and is primarily horizontal transmitted between fish resulting in a mortality rate between 5 and 30 per cent. It is the most common infectious disease in salt water in Chile with an approximate 60 per cent farm prevalence. Various prevention and control methods are being employed including vaccination, site placement, biomass control and antibiotics, although antibiotic treatments are reportedly not as effective as desired.

The SRS study objective was to determine what factors affected the probability of mortality returning to a normal weekly level (<0.1%) after an antibiotic treatment. Data from over 100 farms was used in a logistic model which included information collected on fish weight, water temperature, level of mortality prior to treatment, and antibiotic used. Three different antibiotics were assessed.

The main conclusion was the probability of treatment failure was different for each product and depended on the mortality before treatment and the weight of fish. Not treating early enough in the infection process increased the probability of treatment failure no matter what antibiotic was used, and the effect of the product also depended on the fish weight. The effect of weight on treatment failure and the observed difference between products may be due to feeding frequency and pharmacokinetics. Florfenicol treatments at high temperature had a higher probability of failure, especially when fish are above 2kg.

Future research includes evaluation of different feeding strategies to improve treatment response and dose and duration of treatments required for treatment success. With dose / duration evaluations the appropriate withdrawal periods and resistance issues must also be considered.

Derek Price
Derek is a PhD student at the AVC. He received his DVM in Chile and worked for several years as a veterinarian before returning to graduate school.

WHERE ARE ALL THE SEA LICE? SEARCHING COBSCOOK BAY

- presented by Mike Pietrak, University of Maine

Two labs within the University of Maine are collaborating on sea lice research using a two pronged approach – wild fish sampling and monitoring sea lice through the use of sentinel cages. The collaboration began in year two of a three year Cobscook Bay survey of wild fish which included day and night sampling between May and November using benthic and pelagic trawls and intertidal seining. From this work all fish caught were identified, weight and length information collected and the fish were examined for sea lice.

In this first year over six thousand fish from thirty-four species were examined. The majority of fish caught were the three-spine stickleback, but black spotted stickleback, winter flounder, mummichog and Atlantic herring were also caught in relatively high numbers. Sea lice were only found on ten of the species collected and all were *Caligus elongatus* (Genotype 1) no *Lepeophtheirus salmonis* were found. The examination of the three-spine stickleback showed a *C. elongatus* prevalence of 12% in 2012 and 17% in 2013. Monthly prevalence data for 2012 and 2013 indicates that *Caligus* are most prevalent on three-spine stickleback in spring and late fall. Prevalence data presented for June, August and September of 2013 between the inner, central and inner bays indicated that distribution can vary. No wild reservoirs for *L. salmonis* have yet to be found in Cobscook Bay.

To collect sea lice field data using sentinel cages, each month sixty-seven fish per cage were deployed at four locations for one week before being removed and examined for sea lice. A graph was presented showing the number of infected fish found monthly at each site from June 2013 to July 2104. The major period of infection is the fall with all sites reaching a prevalence of 100% by September – October. All sites had fewer infected fish by December with no observed infection by January – February 2014. The sentinel fish were infected earlier in the second year with 100% prevalence at one site by May / June. A graph showing the infectious pressure of sea lice in Cobscook Bay with average weekly temperatures for each site across the same time frame showed similar results. The majority of sea lice identified at each location were at the copepodid or chalimus stage.

Data was also presented showing the number of sea lice per gram of fish examined for each site over time. Horizontal lines at 0.1 and 0.8 indicate the three threshold values identified in literature. Values below 0.1 are considered to be sub-clinical with no physiological impacts, values between 0.1 and 0.8 are fish with sub-clinical infections that have been impacted physiologically, and values above 0.8 are fish that would be classified as clinically infected (Wagner et al. 2008). Overall, infection levels are low enough that no physiological impacts should be expected in migrating wild smolts infected with sea lice.

Field and lab work is continuing for the larger project which will include Agent Based Modeling and CART analysis. This third aspect to the current work will be to integrate modeling into the process to try and understand the results seen in the field.

See Attached Presentation

Mike Pietrak
Mike became interested in aquaculture while still an undergraduate student at Ithaca College. After working at several marine labs and on a schooner for 3 years after graduation he attended the University of Maine and obtained a Master's of Science in Marine Biology. Mike then went to work for the Maine Aquaculture Association (MAA) as the Project Manager and Biologist. Eventually returning to the University of Maine for a PhD, where he began looking at the role of mussels co-cultured with either cod or salmon in spreading or removing fish pathogens from the water. Interests and previous work include: public education about aquaculture, bringing current scientific knowledge and understanding to growers, and conducting applied on farm research. In all activities the focus has been on developing and implementing new husbandry techniques to improve the economic and environmental sustainability of cold water marine and freshwater aquaculture.

LATEST TECHNOLOGY ON TARPAULIN TREATMENTS IN NORWAY

- presented by Julie Bugge, Aqua Pharma

Norway has a large capacity to perform sea lice bath treatments on Atlantic salmon. The industry can treat three to four 157m cages per day (2.5-3.5 hrs/cage) or four to five 120m cages per day, totaling 500 – 2800 tons of salmon per day (depending on fish size). These treatments are completed with a variety service and support vessels. The small treatment vessels are approximately 36m long and can hold two to five ISO containers for Interox Paramove. The larger vessels are approximately 58m long and can hold 16 ISO containers. Barges and work vessels from the site with the appropriately sized cranes and personnel are also required to assist. A series of videos were presented representing the complete bath treatment process.

The fish should be starved for 50 degree days prior to initiating a bath treatment and environmental conditions prior to and on the day, such as algae counts, should be evaluated. Once the treatment activity is approved the main net is brought up to the appropriate depth and the oxygen hoses are deployed across the cage to start oxygen delivery. Crew members on the various boats around the cage should have optical oxygen meters and monitoring of the dissolved oxygen level should begin as soon as the oxygen system is started and continue until one half an hour post treatment.

Next the dosing hoses are deployed which go across the cage and hang down into the cage and have holes along its length for the release of product throughout the cage area. The tarp is deployed against the current so the required vessel must be positioned at the appropriate side of the cage and the tarp is pulled with the cranes below and around the cage circumference. Once the tarp is in place and the dosing hoses are connected, all personnel should return to their respective boats for the treatment to start.

Before the treatment dose is applied, and dose of 200ppm Interox is added to confirm the correct cage volume and dose to be used. The fish behaviour should be monitored all through the process and adjustments made to the cage net depth, oxygen level etc as needed. After treatment is concluded, the tarp can be removed and the main net lowered slowly to prevent the fish from rushing down into the cage too quickly.

See Attached Presentation

Julie Bugge
Julie is a Marine Biologist for Aqua Pharma responsible for research and development. She has a Master of Marine Biology from the Norwegian College of Fisheries and Science, University of Tromsø (2009).

Workshop Conclusions and Research Issues

Research continued to provide the salmon farming industry and stakeholders with large amounts of information on a range of topics important to fish health, operational best practices and environmental management, knowledge gaps and questions remain and therefore research must continue. In 2014 we saw an increased focus on climate change. The aquaculture industry understands that aspects of climate change such as storm strength / frequency and sea level rise will impact infrastructure, but components like ocean acidification and sediment pH changes are less understood and more challenging to address. The potential effect on fish in relation to complicated process such as immune responses to diseases, changes in nutrient chemistry and availability and toxicity of metals are areas requiring large monitoring and research efforts.

Environmental management programs focused on benthic monitoring are important to farm management. Sites or regions with hard bottoms need alternative tools to the current sediment analysis for sulphide and these tools must be validated to ensure identification and quantification of indicators chosen. If candidate indicator species are used they must be identified, understood and evaluated for their ability to indicate what if any benthic disturbance.

In the area of fish health research work is required to correctly identify the causative agent for diseases or other fish health concerns. In the case of ulcer disease work can be completed on risk factors and prevention options like vaccines, probiotics and broodstock resistance. Having quick, accurate methods of detection are needed for diseases like BKD to provide veterinarians with the ability to properly diagnose and treat fish. The efficacy of available treatment products and delivery methods requires continuous evaluation especially with recent work indicating fish weight, feeding frequency and the product itself may be factors that determine treatment success or failure. The limited number of vaccines and treatment products available to veterinarians is always a concern for farmers and work to develop and test new products and/or improve existing medicines warrant support.

Sea lice prevention and management is a priority for the salmon farming industry and one that is multi-faceted. Research should continue to better understand sea lice behaviour, dispersion and sources especially in the face of varied and changing environmental conditions. In the face of these changing environmental conditions, ensuring that accurate data is ground-truthed before being used in the development of on and off farm models is critical. The role of factors like salmon skin and gut microbiological ecology in protection against parasites needs further investigation to determine if manipulation of the community structure can enhance host resistance to sea lice. Pharmaceutical preventative and control options for sea lice are needed along with on farm management options for prevention and control and green technology is also necessary.

Work needed to improve efficiency and performance of integrated multi-trophic aquaculture (IMTA) sites was presented during the workshop, as well as other operational needs to identify and test options for mortalities management as well as new net fibers.

The ACFFA once again appreciates the continued contribution of the public and private research community in supporting our annual technical workshop and we will continue to work on behalf of the salmon farming industry in identifying industry research priorities and collaborative research activities. As of this report, a working group has been formed to pursue a stand-alone workshop that will focus on climate change; what we know and what we need to address to ensure the long-term sustainability of the salmon farming industry in Atlantic Canada.

Participants

First Name	Last Name	Company
Bev	Bacon	RDI Strategies
Jane	Beckerton	Northeast Nutrition
Tillman	Benfey	University of New Brunswick
Jessica	Binney	Kelly Cove Salmon
Clarence	Blanchard	Future Nets & Supplies
Annette	Boerlage	UPEI-Atlantic Veterinary College
Helen	Bouchard	NB Agriculture, Aquaculture & Fisheries
Christy	Bourque	Mitchell McConnell Insurance
Ian	Bricknell	UMaine Aquaculture Research Institute
Chris	Bridger	Huntsman Marine Science Center
Chuck	Brown	Cooke Aquaculture
Julie	Bugge	AquaPharma
Rod	Carney	NB Community College
Erin	Carpenter	Kelly Cove Salmon
Jon	Carr	Atlantic Salmon Federation
Blythe	Chang	Dept. of Fisheries & Oceans
Thierry	Chopin	University of New Brunswick
Julie	Cissell	Solvay Chemical
Corey	Clark	Parks Canada
Kathy	Cleghorn	NB Agriculture, Aquaculture & Fisheries
Jeff	Clements	University of New Brunswick
Jeff	Cline	Dept. of Fisheries & Oceans
Devon	Cobham	NBCC Student
Sarah	Cook	Skretting
Mike	Cooke	Cooke Aquaculture
Karen	Coombs	NB Agriculture, Aquaculture & Fisheries
Lara	Cooper	Dept. of Fisheries & Oceans
Jack	Corey	NBCC Student
Kasha	Cox	Merck Animal Health
Aaron	Craig	Northern Harvest Sea Farms
Alan	Donkin	Northeast Nutrition
Kevin	Dow	NBCC Student
Terry	Drost	Four Links Marketing

Joe	English	NBCC Student
Ramon	Filgueira	Dalhousie University
Ben	Forward	NB Research and Productivity Council
Joshua	Francis	Kelly Cove Salmon
Evie	Gagne	Kelly Cove Salmon
Jonathan	Gagne	Enterprises Shippegan Ltd.
Amber	Garber	Huntsman Marine Science Center
Sheldon	George	Cooke Aquaculture
Jan	Giles	Atlantic Veterinary College Diagnostic Services
Danielle	Goodfellow	Aquaculture Assoc of Nova Scotia
Caroline	Graham	NB Community College
Jon	Grant	Dalhousie University
Darrell	Green	Newfoundland Aquaculture Industry Assoc.
Randy	Griffin	Kelly Cove Salmon
Nell	Halse	Cooke Aquaculture
Larry	Hammell	UPEI Atlantic Veterinary College
Dr. Dounia	Hamoutene	Dept. of Fisheries & Oceans
Samantha	Hartley	NBCC Student
Braden	Hatt	EWOS
Murray	Hill	Atlantic Canada Fish Farmers Assoc.
Jason	Holmes	Northeast Nutrition
Betty	House	Atlantic Canada Fish Farmers Assoc.
Larry	Ingalls	Northern Harvest Sea Farms
Tim	Jackson	NRC-IRAP
Kathy	Kaufied	Atlantic Canada Fish Farmers Assoc.
Bill	Keleher	Kennebec River Biosciences
Ivan	Kerfont	NBCC Student
Mark	Kesselring	Northern Harvest Sea Farms
Greg	Lambert	Cooke Aquaculture
Steven	Leadbeater	Dept. of Fisheries & Oceans Biological Station
Jonathan	Lovett	NBCC Student
Jennifer	Lovett	NBCC Student
Joe	Lund	University of PEI
Troy	Lyons	NB Dept. of Environment & Local Gov't.
Monica	Lyons	Dept. of Fisheries & Oceans
Holly	MacIsaac	NBCC Student
Ken	MacKeigan	Dept. of Fisheries & Oceans

Tony	Manning	NB Research and Productivity Council
Andrew	McCool	Syndel Laboratories Ltd.
Tom	McEachrean	NB Agriculture, Aquaculture & Fisheries
Sandi	McGeachy	NB Agriculture, Aquaculture & Fisheries
Jason	McGrattan	Novartis Animal Health
Alastair	McNeillie	Solvay Chemicals
Vicky	Merritt-Carr	Dept. of Fisheries & Oceans
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Christine	Moore	Intrinsik Environmental Sciences Inc.
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Landon	Norton	Syndel Laboratories Ltd.
Thomas	Ogilvie	NB Agriculture, Aquaculture & Fisheries
John	O'Halloran	Aqua Vet Services
Rodney	O'Neil	Cooke Aquaculture
Pamela	Parker	Atlantic Canada Fish Farmers Assoc
Keng	Pee Ang	Cooke Aquaculture
Mike	Pietrak	UMaine Aquaculture Research Institute
Al	Pineau	Northern Harvest Sea Farms
Derek	Price	University of PEI
Gordon	Quaiattini	Maple Leaf Strategies
Dr. Don	Rainnie	Private Consultant
Kim	Reeder	Private Consultant
Gregor	Reid	CIMTAN
Shawn	Robinson	Dept. of Fisheries & Oceans
Tammy	Rose-Quinn	Dept. of Fisheries & Oceans
Spencer	Russell	Novartis Animal Health
Ruth	Salmon	Canadian Aquaculture Industry Alliance
Steve	Smith	Kelly Cove Salmon
Jamey	Smith	Huntsman Marine Science Center
Arianna	Smith	Kelly Cove Salmon
Sophie	St. Hilaire	University of PEI
Trevor	Stanley	Skretting
Nils	Steine	Pharmaq

Bob	Sweeney	Sweeney International Marine Corp.
Mike	Szemerda	Cooke Aquaculture
Gary	Taylor	Skretting
Tom	Taylor	Northeast Nutrition
Bruce	Thorpe	NB Agriculture, Aquaculture & Fisheries
Adam	Turner	University of New Brunswick
Raphael	Vanderstichel	UPEI Atlantic Veterinary College
Shawna	Wallace	Atlantic Salmon Federation
Peter	Warris	PEI Aquaculture Alliance
Ted	Weaire	GMG Services
Daryl	Whelan	NL Dept. of Fisheries & Aquaculture
Jennifer	Wiper	Cooke Aquaculture
David	Wong	Dept. of Fisheries & Oceans
Roger	Wysocki	Dept. of Fisheries & Oceans
Daniel	Zapata	NBCC Student

CANADIAN AQUACULTURE INDUSTRY ALLIANCE | ALLIANCE DE L'INDUSTRIE CANADIENNE DE L'AQUACULTURE

Farming Canadian Waters with Care

Social Licence and Aquaculture

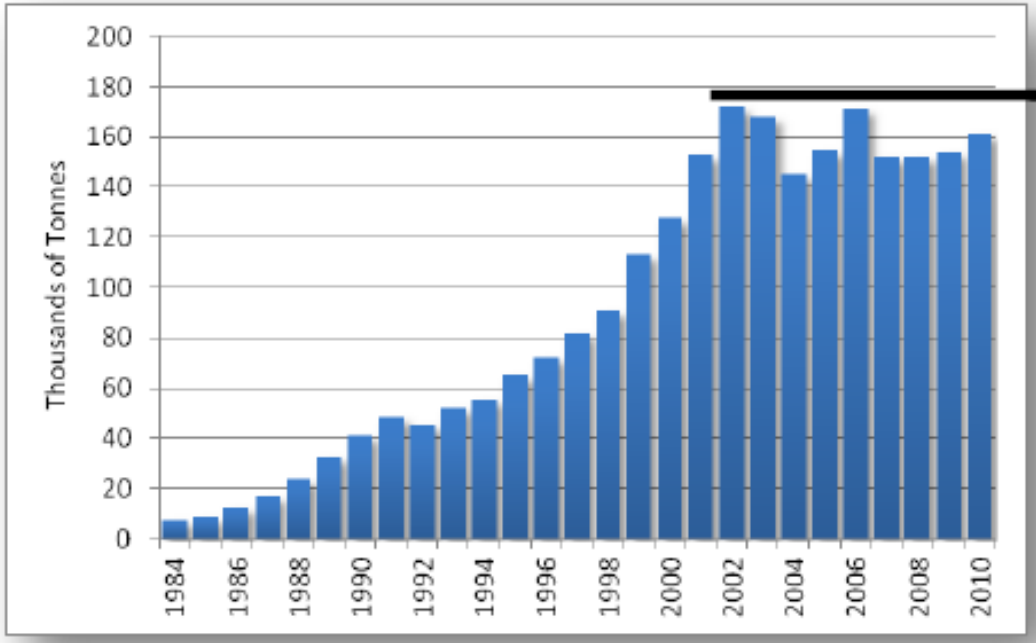
ACFFA Annual Fall Workshop
November 5, 2014

Agenda

- The National Strategy for Aquaculture Development
- The issue, challenges and barriers
- Roadmap & Update
- Social License to Operate – CAIA Discussion Document

13 years of stagnated growth

Aquaculture Production in Canada (1984 to 2010)

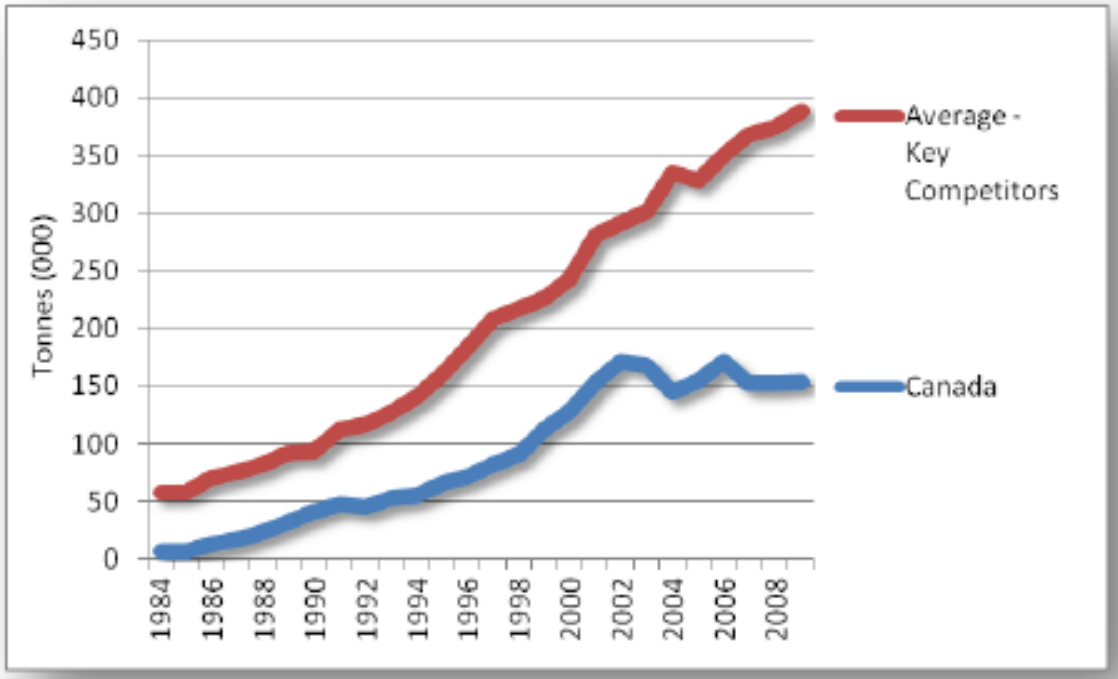


Aquaculture production has stagnated over the past 13 years

Source: FAO Statistics

Context: Falling behind key competitors

Aquaculture Production – Canada vs. Key Competitors (1984-2009)



Canada has experienced a 47% loss in global market share since 2002

Source: FAO Statistics

Key competitors = U.S., Australia, Norway, Chile, New Zealand, Scotland, Ireland

Summary of Challenges and Barriers

Despite all Canada's natural advantages for aquaculture:

- Industry has seen over 13 years of stagnated growth
- We are losing market share & falling behind key competitors
- Canada is losing investment to other countries

30 years of studies/experts/committees have called for fundamental change in legislation, regulations and policies:

- Regulatory system is complex, uncertain and confusing
- Federal & provincial overlap and duplication
- Patchwork quilt of statutes created decades ago to guide a wild fishery; Fisheries Act does not even mention aquaculture

What is the Roadmap for Implementation of the National Strategy for Aquaculture Development?

- CAIA is working with the federal government to build the foundation for policy, regulatory and legislative reform for Canadian aquaculture

- CAIA also proactively engaging Provincial Governments to ensure they are party of national development strategy agenda

Update on National Strategy

- Our case for the creation of a Canadian Aquaculture Act is being embraced - Minister's office requested that CAIA move forward with background development work on Aquaculture Act
- The federal government wants to deliver on the employment and wealth generation that is possible with modest sustainable growth.
- Proposal going forward for a 5 year aquatic MUMS program resulting in increased feed and fish health products
- CAIA's documents assessing the regulatory roadblocks to growth and missed economic and social opportunities are resonating with the Ministers of Fisheries and Agriculture as well as within the Senate and Standing committees

Evidence-Based Discussion Documents

- **From the priority issues identified, CAIA has prepared evidence-based documents to facilitate discussion, recommendations and actions**

- ✓ Regulatory Cost, Economic Impacts and Overall Social Welfare Benefits of the Aquaculture Sector in Canada (May 2013)
- ✓ Predictable Tenure/Lease/License Framework (Mar 2013)
- ✓ Overview/Broad Elements of a new Aquaculture Act (Mar 2013) and Legal Elements of an Aquaculture Act (May 2013)
- ✓ Improved Access to Feed & Fish Health Products (May 2013)
- ✓ Farmed Seafood and Canadian Health ("Seafood Saves Lives") (Nov 2013)
- ✓ Regulatory Reform (Nov 2013)
- ✓ **Social Licence and the Aquaculture Industry in Canada (Feb 2014)**
- ✓ Growth and Footprint in the Canadian Aquaculture Industry
- ✓ Framework for MUMS Program for aquaculture

Brian Lee Crowley & Social License

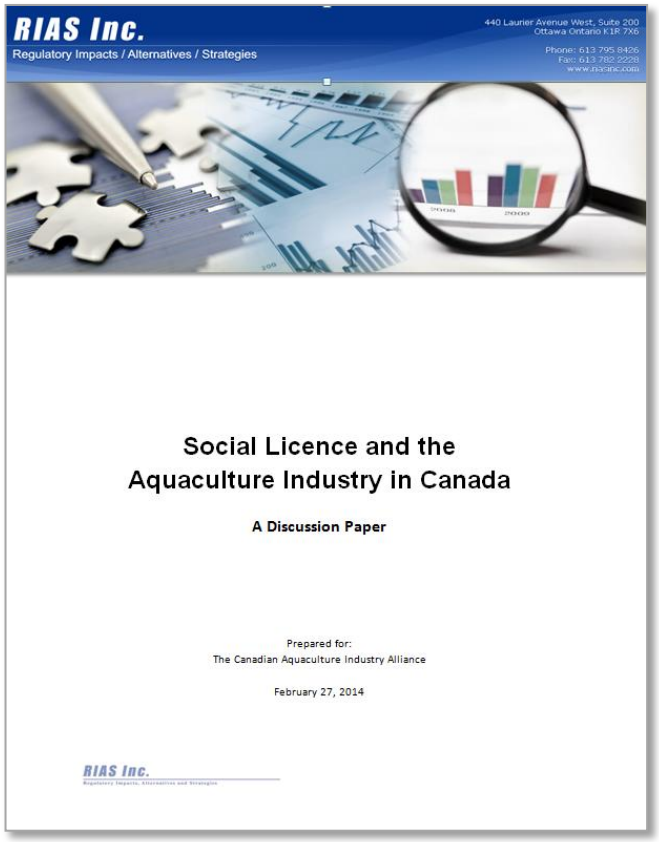
Managing Director – Macdonald Laurier Institute

- "Those who oppose certain developments, such as pipelines, are exploiting the concept of social license to get their way"
- "The problem, is that social license is not a common set of rules for establishing that a given project has received the approval of society in general"
- "Instead it's become a catch-all concept that opponents can wield against those with whom they disagree"
- "Because they're opponents of the project, they can say you don't have social license because we don't agree with you", he says

Social License and the Aquaculture Industry in Canada

Purpose of the Discussion Paper

- To define social licence
- To explain the key characteristics and measures of “social licence” or “social licence to operate” (SLO)
- To describe social licence activities of the Canadian aquaculture sector
- To stimulate informed discussion on social licence for both the aquaculture sector and government



Defining Social Licence

Social License "is not obtained in a courthouse. It is earned from the people of a community, the stakeholders of the project. It is not written on paper, but you can see it in people's faces when they talk about the development. It is about ***mutual respect, shared benefits, common trust****."* Patrick James (2000)

"Defining social licence is, at least in part, an exercise in subjectivity. It reaches beyond regulatory approval to the domain of public opinion, public perception and, inevitably, public relations…. Ultimately, social licence is about building consensus, not agreement. There will always be groups and individuals who take a hardline position and will not accept any decision other than one that reflects their views. ***But legitimacy is still attainable if those who offer policy advice make their best efforts to more fully engage in a dialogue with stakeholders****."* Dale Eisler, Policy Options, January 2014

Defining Social Licence

Social License "is defined by the people, and when we talk about community, community is not necessarily a homogeneous being. We look for a consensus position and what is driving that. ... ***So a social licence is based on people's perceptions, it's impermanent, it's unwritten, it's subject to change.***" *Ian Thomson, CBC Radio,* April 17, 2014

"It's not new, but over the last couple of years the idea that corporations need to obtain a "social licence to operate" has rocketed to the top of ideological hit parade… Apparently it's not enough that business operates in a free-market economy governed by property rights, regulation, the rule of law and the market. Now business needs something more, some kind of project-by-project public consent … or face constant war with NGOs and an endless parade of people with social, political and ideological grievances." Terence Corcoran, National Post, April 22, 2014.

The Challenges

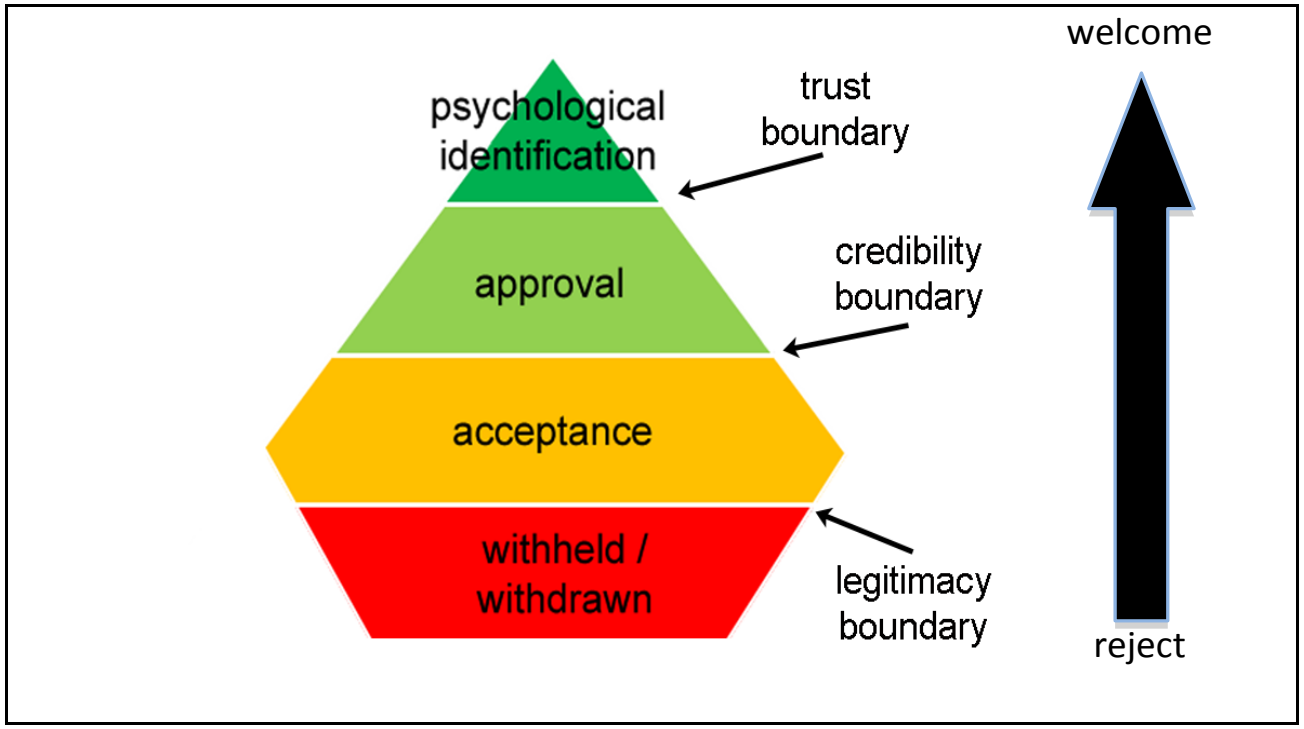
- Broad challenges
  - Defining social licence so that it is understandable, attainable
  - Clarifying who "grants" social licence – (hint: no "one")
  - Measuring social licence in a meaningful way

- Challenge for aquaculture – reality vs. perception
  - **Reality** - aquaculture has built and maintained the business for decades in Canada through partnerships with local communities and with First Nations
  - **Perception** – a common refrain by some is that the industry "does not have social licence"
  - This perception appears to be based on efforts of a very small but vocal group of anti-aquaculture activists, yet the assertions of this small group have been disproven/debunked, many times

Old arguments, old consequences…but the debate is changing

The same old arguments continue . . .	*The same old consequences continue . . .*	*But…the social license debate is changing . . .*
• Sea lice • Escapes • View shed • Not "natural" • Running out of feed • Feeding fish to fish • Competition for wild fisheries • Corporate! • Foreign! • Profit-seeking! • Toxic, unsafe to eat	• Regulatory indifference & hostility • Slow, stalled decision making processes • Lack of sites • Political and economic risk • Lack of growth, lack of investment • Lack of economies of scale • Higher costs • Slower technological chain • Loss of market share	• Farmed fish are everywhere • Farmed salmon are everywhere • Consumers like farmed salmon • Buyers want farmed salmon • Food supply issues are becoming more recognized

The Theory - What SLO Involves



What SLO does not involve

1. Is not granted by courts or governments
2. Is not absolute; may change over time
3. Is not necessarily all-encompassing; usually a site by site basis
4. Is not likely or expected to represent a 100% consensus

Important Roles of Government

1. Mandate – to establish sound, risk-based management systems

2. Facilitate - assist companies to engage communities through research, resources, training programs, employment incentives. Can help company demonstrate legitimacy.

3. Partner - work with stakeholders and companies to bring complementary skills and inputs together (on complex social & environmental problems)

4. Endorse - systems of standards and publicly recognize best practices

Delivering on these roles is critical, but government often falls short

Indicators of SLO in the Aquaculture Industry
1 - Economic Interaction/Legitimacy

- Research and evidence that companies play an important role in ensuring local communities directly benefit from their financial investment in the community

- Local employment is a key factor - providing options for rural families and keeping families in small communities across Canada, providing a range of employment options

- As local employment has stabilized, the supply and service industries supporting the sector also grow (processing plants, net-washing facilities, catering and grocery outlets, barges and haulers, expanded grocery and hardware stores in small communities)

- Industry investment is often matched by investments by provincial and local governments to further leverage the investment to benefit the communities

Indicators of SLO in the Aquaculture Industry
2a - Socio-Economic Legitimacy

- Significant socio-economic effect in local communities across Canada with increases in full-time year-round employment

- Communities (e.g. Mayor of Blacks Harbour) note an improvement in the social health of the community as a result of the employment e.g. reduced incidence of family violence, teen pregnancy stats have all improved due to the work force stabilization.

- Enhancing community assets - schools, daycares , hospitals and nursing homes have improved in coastal, rural and FN communities

Indicators of SLO in the Aquaculture Industry
2b - Interactional Legitimacy

- Companies have worked to establish opportunities for input and dialogue where concerns can be raised in a fair and respectful way
  - NL - annual community open houses and workshops fill information gaps
  - NS – establishment of Community Liaison Committees, encouraging open communication
  - NB – Joint research partnerships have benefited companies, communities and researchers

- Range of financial support by aquaculture companies across Canada to school lunch programs, classroom activities in small rural schools, support to local food banks, etc.

- Significant volunteer efforts by employees - contributing to the well being of their communities by providing volunteer hours and financial contributions to a wide range of community activities and efforts.

Indicators of SLO in the Aquaculture Industry
3 - Psychological Identification/ Institutional Trust

- Institutional Trust = enduring regard for each other's interests
- BC - major focus on building First Nations agreements that benefit both the companies involved and the local First Nations community
- NL - formal agreement between the aquaculture industry (NAIA) and wild fishing industry union (FFAW) through the Fisheries and Aquaculture Committee for Transparency and Sustainability (FACTS).
- Atlantic Canada – a commitment to hire local people where possible

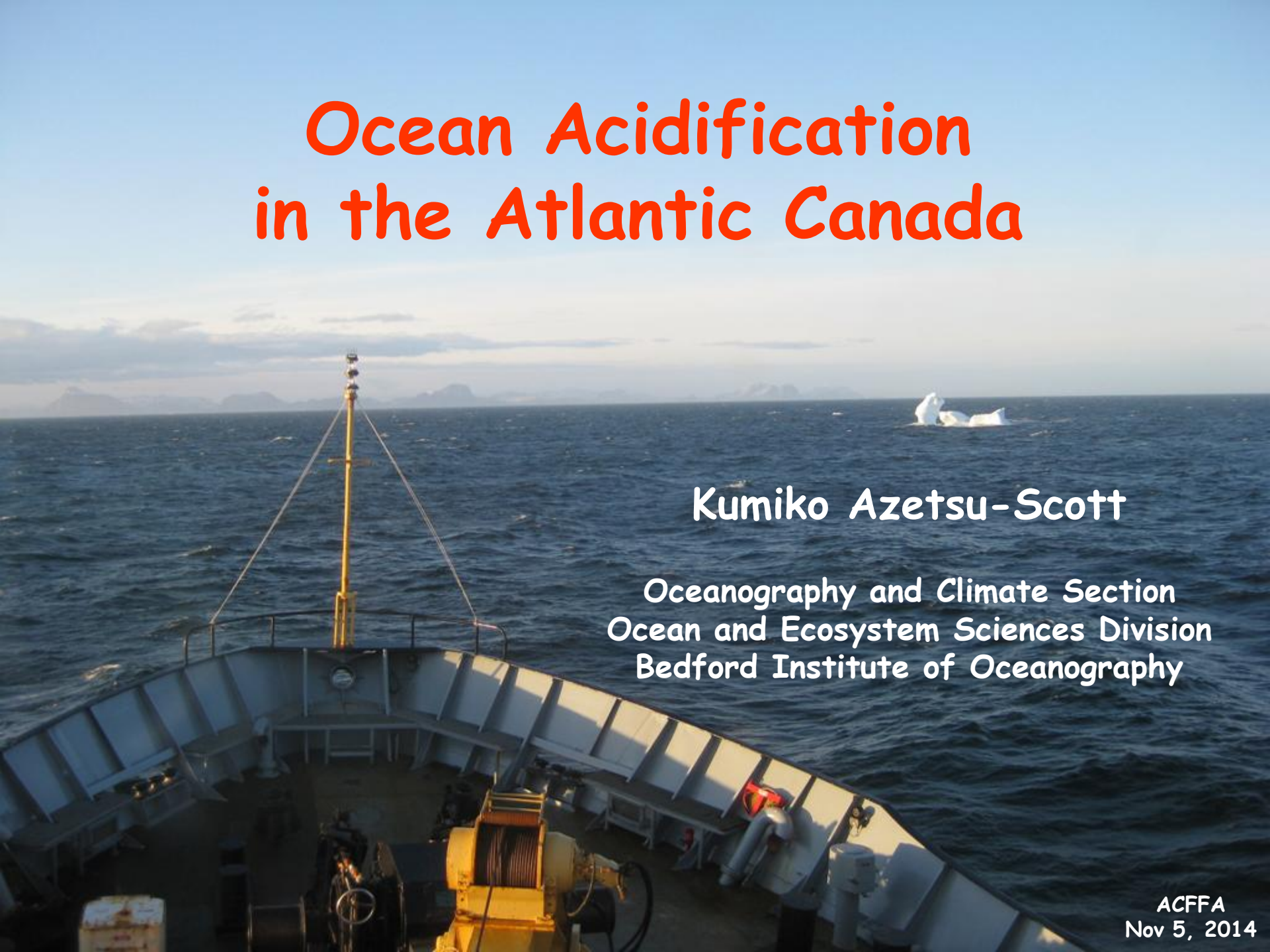
Public acceptance - polling

- Polls and studies of the level of public acceptance by Canadians of the industry are positive (nationally, NB, NS, BC etc.)
- Evidence suggests that the industry reaches an “approval” level regionally and nation-wide
- But what weight does this carry in the discussion of social license?

Summary

- SLO is not absolute, no clear set of rules. It is not clearly defined and very often misunderstood.
- For an aquaculture site, social license to operate is rooted in the beliefs, perceptions and opinions held by the local population.
- Social license is dynamic; it changes with new information, new people and new circumstances. Social license needs to be earned and then maintained by companies at the community level.
- The evidence in this paper suggests that even in the face of a very small but vocal group of activists, aquaculture companies in Canada have achieved, and continue to maintain, high levels of social license with their communities.

Ocean Acidification in the Atlantic Canada

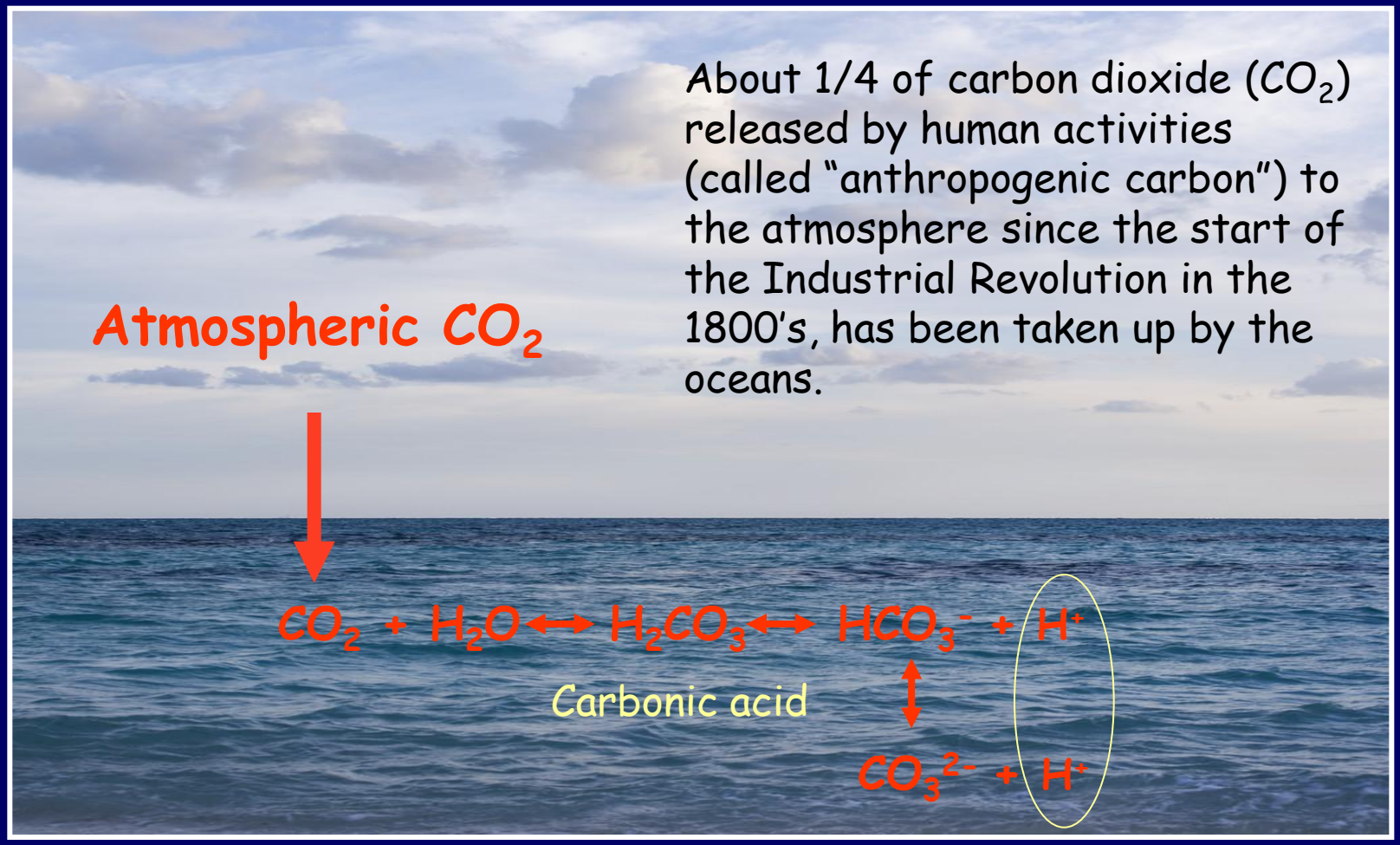


Kumiko Azetsu-Scott

Oceanography and Climate Section
Ocean and Ecosystem Sciences Division
Bedford Institute of Oceanography

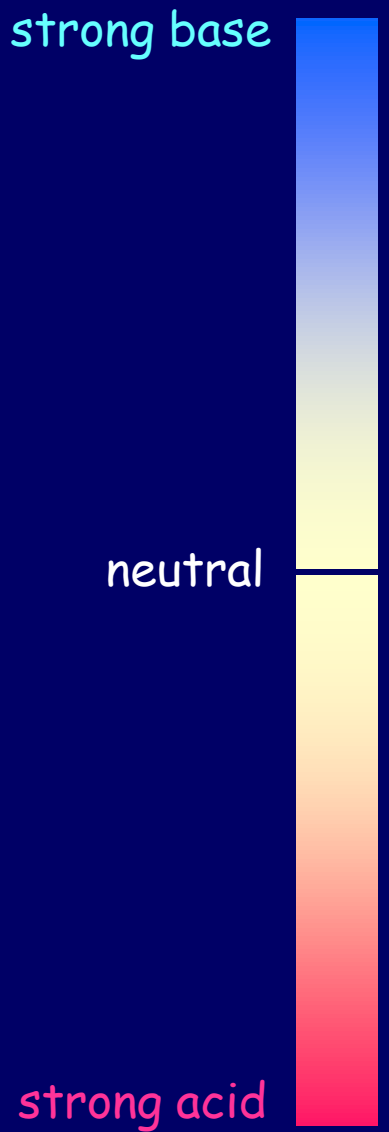
ACFFA
Nov 5, 2014

What is Ocean Acidification?



pH is a measure of acidity

$$pH = -\log_{10}[H^+]$$

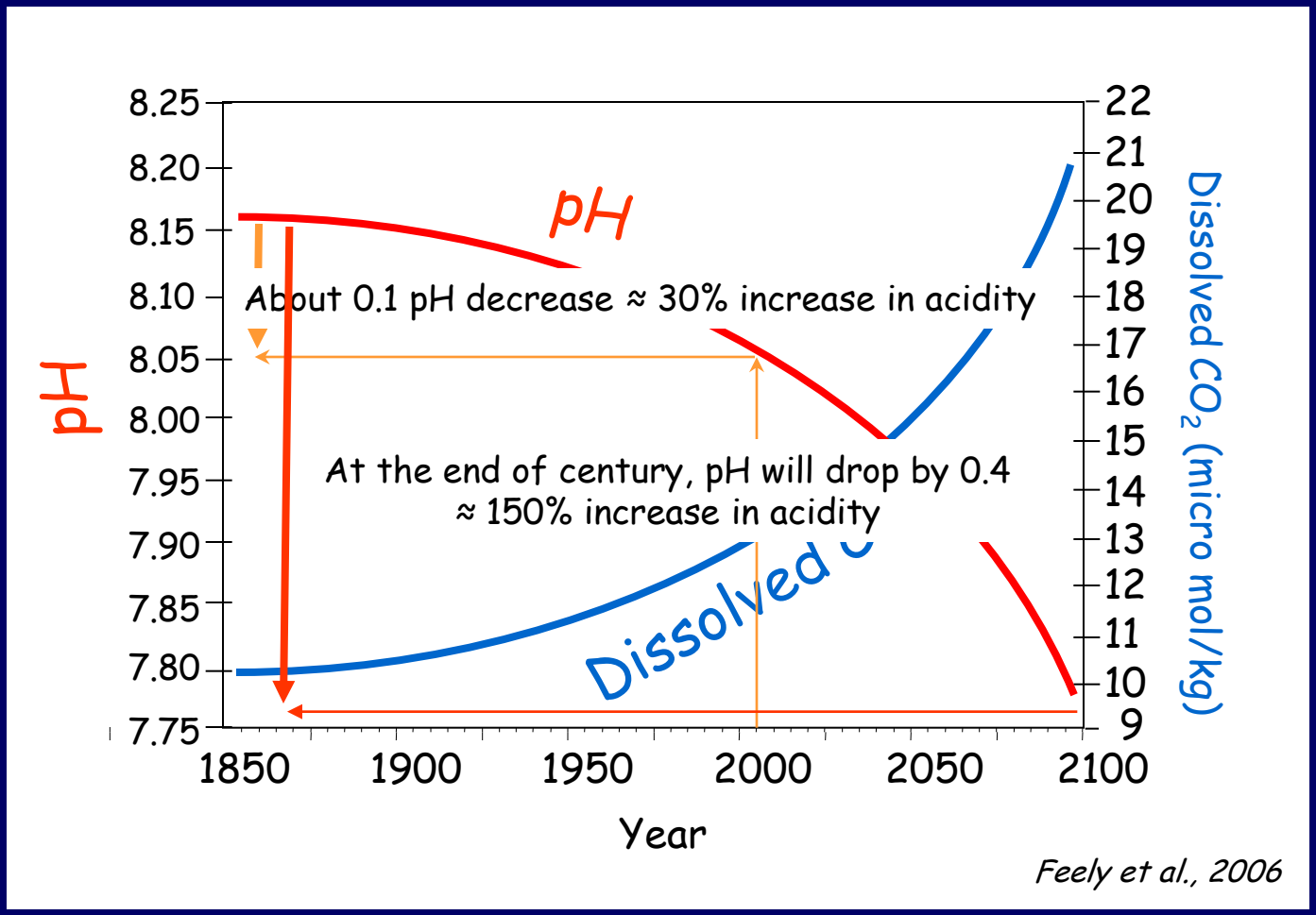


14	Household lye
13	Oven cleaner
12	Household bleach
11	Household ammonia
10	Hand soap
9	Baking soda
8	Sea Water (8.16, pre-industrial)
7	Blood
6	Milk
5	Coffee
4	Wine
3	Vinegar, Carbonated beverages, Beer
2	Lemon juice
1	Gastric acid
0	Battery acid

↓ Decreasing pH
Increasing acidify

Ocean Acidification

Historical and Projected pH and Dissolved CO_2 in the Ocean



Feely et al., 2006

396.90ppm Nov 1, 2014

May 10, 2013, *daily averages temporarily reached 400 ppm*

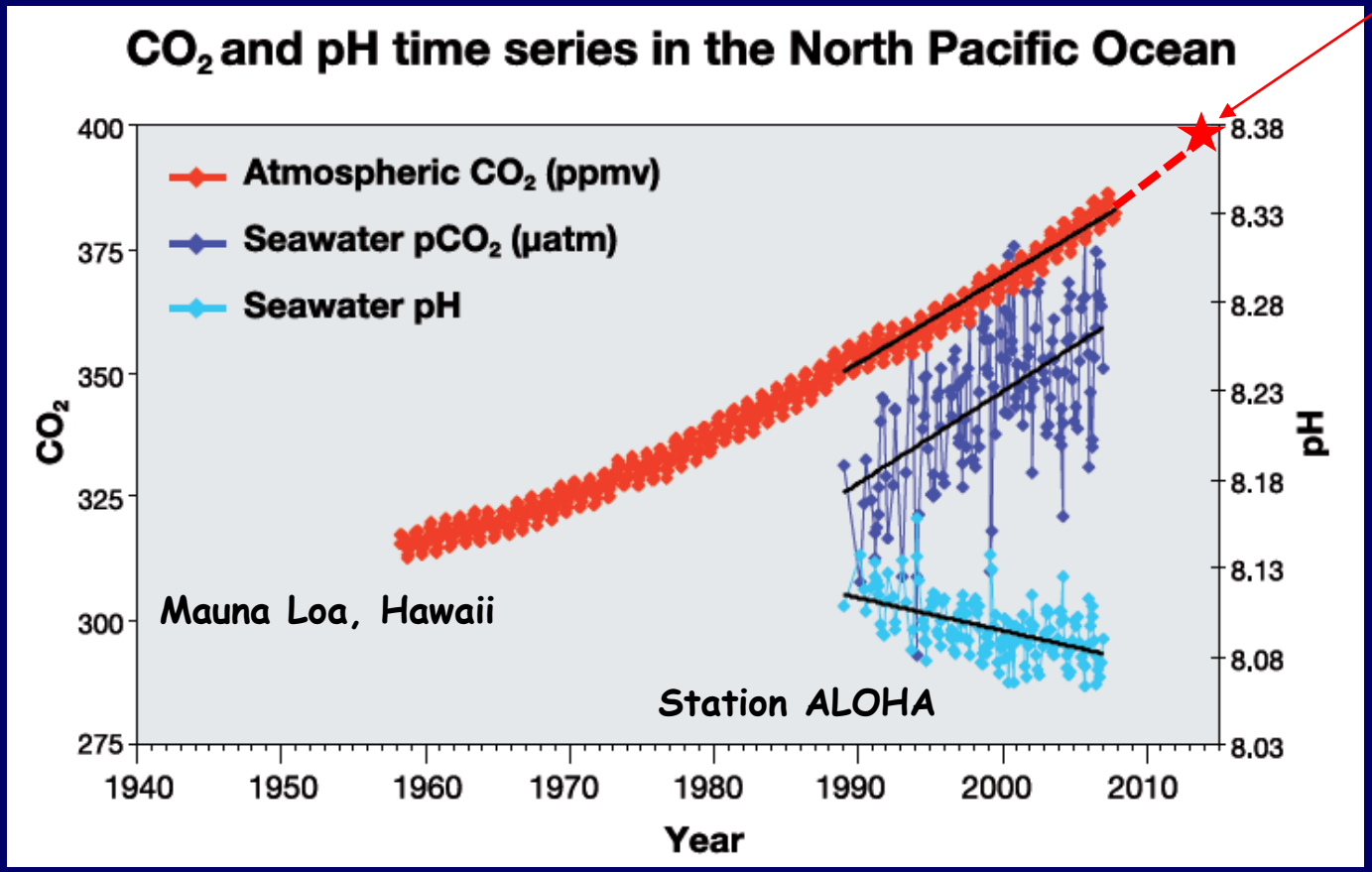
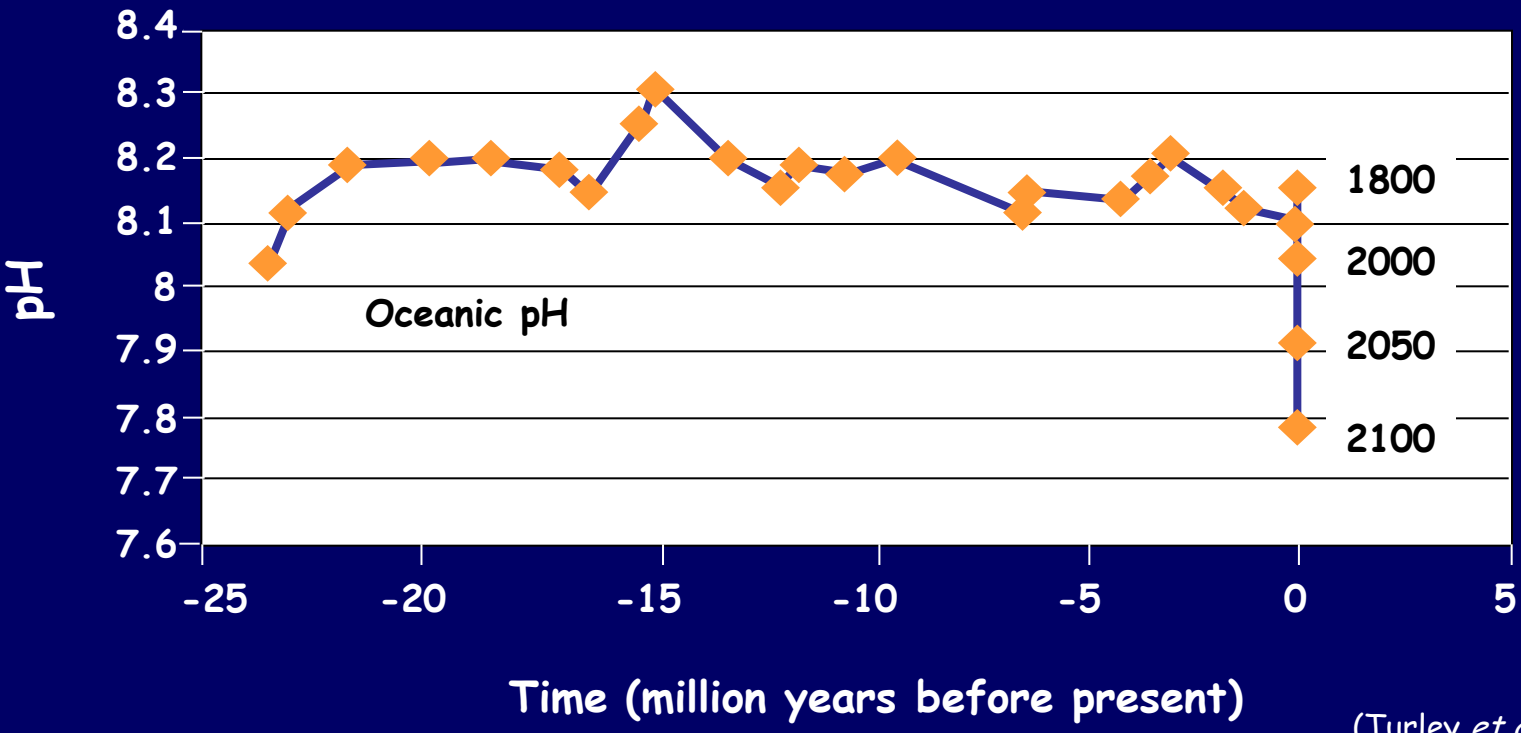


Figure credit: Richard A. Feely, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, USA, with atmospheric data from Pieter Tans and seawater data from David Karl. Adapted from Feely (2008) in Levinson and Lawrimore (eds), *Bull. Am. Meteorol. Soc*, 89(7): S58.

From "A summary for Policymakers from the Second Symposium on the Ocean in a High-CO_2 World"

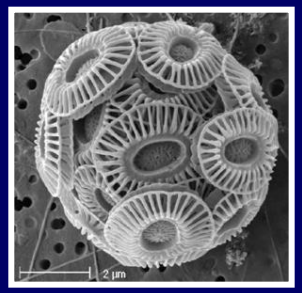
Past and Contemporary pH



(Turley *et al*, 2006)

Can organisms adapt to this rate of change ?
How do ecosystems respond to this change?

Many life processes are sensitive to carbon dioxide and pH;
The most direct impact would be to organisms that form calcium carbonate ($CaCO_3$) shells and skeletons because acidity increases the solubility of $CaCO_3$



Phytoplankton
Coccolithophore

Zooplankton
Pteropod
(sea butterfly)

Zooplankton
Foraminifera

Echinoderm
Sea urchin

Crustacean
Lobster

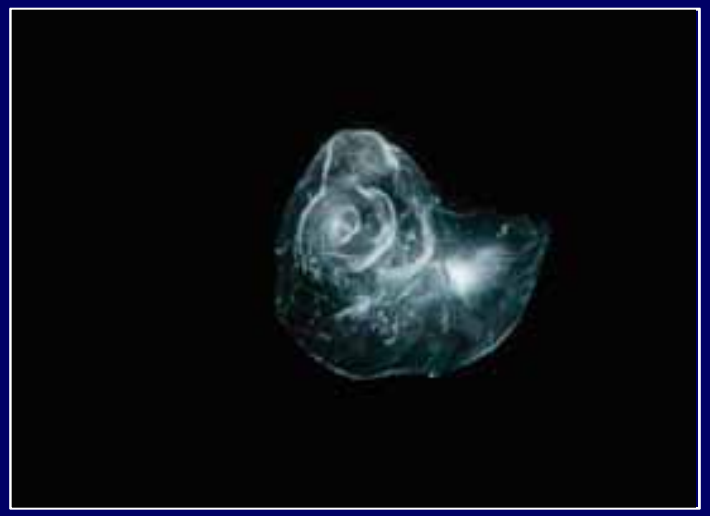
Echinoderm
Brittle star

Deep-sea coral

Mollusc
Scallop
Oyster
mussel

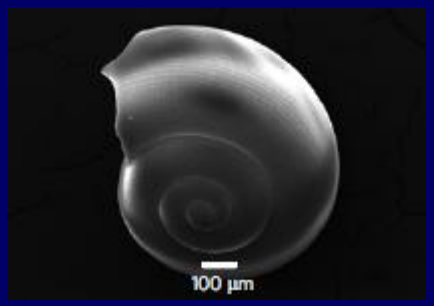
Pteropod (sea butterfly) is an important food source in northern waters for fish such as herring, salmon and cod

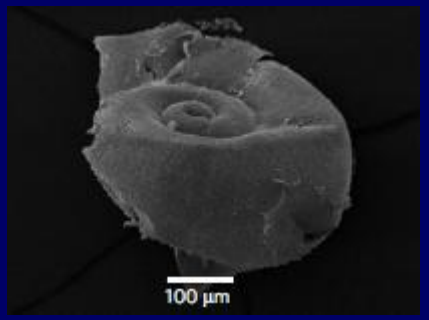
placed pteropods in seawater at the pH projected for the Southern Ocean by 2100.



Fabry, 2012

Within 48 hours, the pteropod shell began to dissolve

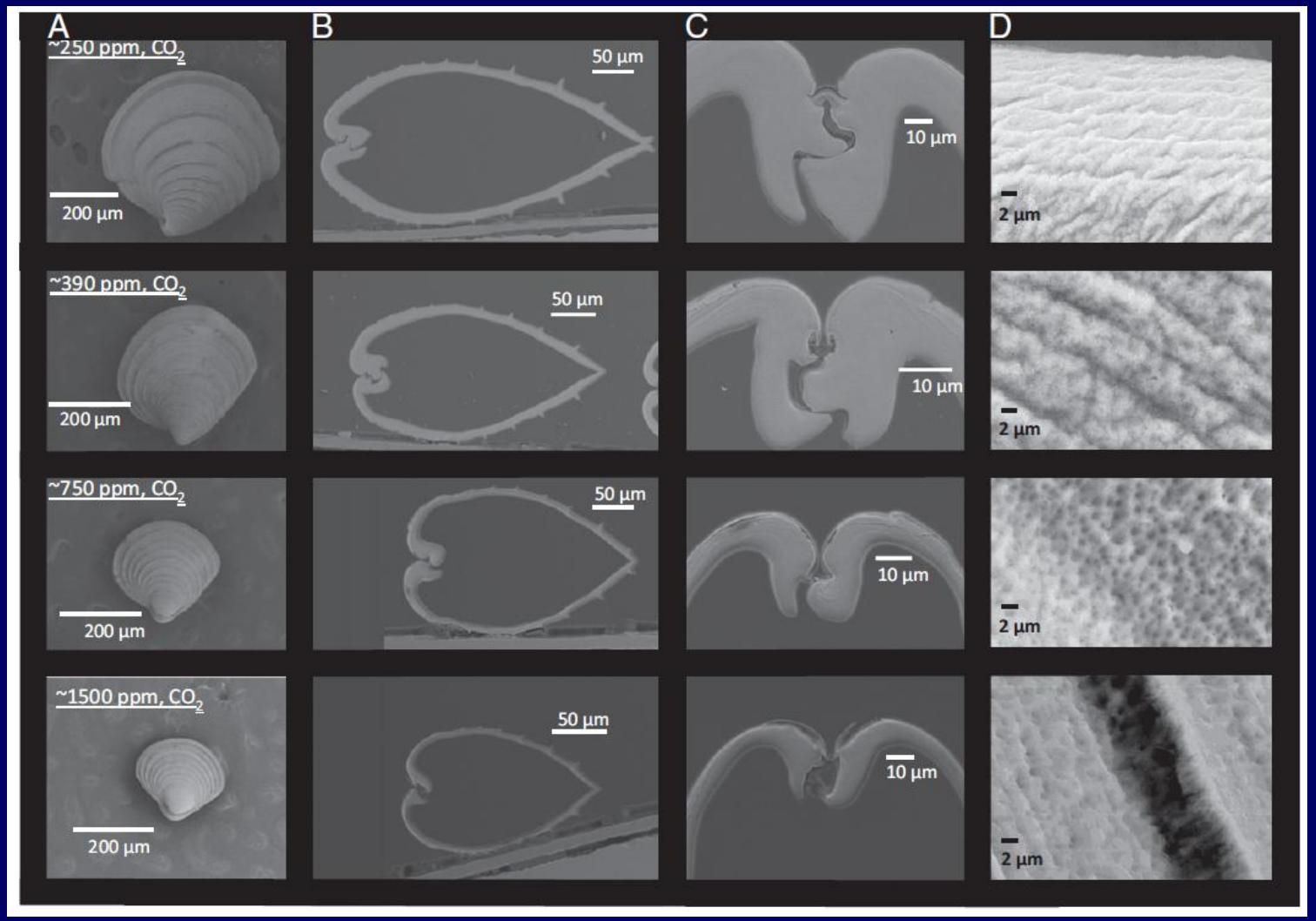




Extensive dissolution of live pteropods in the Southern Ocean, Bednaršek et al., 2012

SEM images of M. mercenaria (quahog or hard clam) larvae (baby) grown under a range of CO_2 concentrations (36-day old)

Lower pCO2
higher pH



higher pCO2
lower pH
More acidic

(Talmage and Gobler, 2010)

In recent years, natural and hatchery larval production have been severely depressed in the Pacific Northwest, and a lack of sufficient "seed" has threatened an industry with a total economic value estimated US$278 million as of 2009 (Pacific Coast Growers Association, 2010)

Ocean Acidification Linked with Larval Oyster Failure in Hatcheries (NSF, press release April, 12, 2012) - Increase in ocean acidification led to collapse of oyster seed production at Oregon hatchery

Ocean Acidification Can Mess with a Fish's Mind ?

In more acidic waters clown fish wander too far from safety, sea snails fail to avoid prey

A reef fish was exposed to high CO2, which interfered with their sense of smell.

ocean acidification could cause sensory and behavioral problems for many sea creatures if global CO2 levels continue to rise

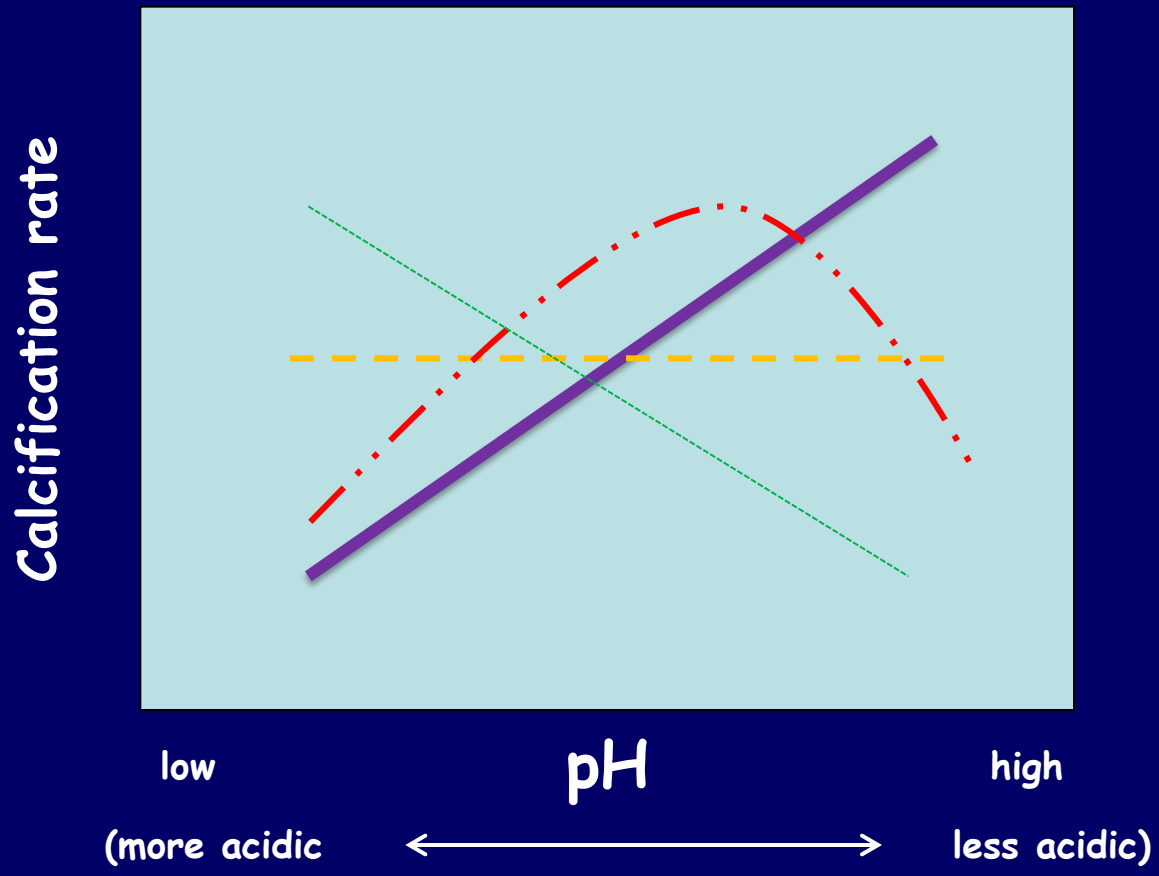
Yes, Nemo

(Fischetti, 2012, Scientific American)

Ocean Acidification on Fish

- Fish are generally considered to be more resilient to direct effects of OA
- acid-base balance in high CO2 environment necessitate additional energy cost
- OA causes sensory and behavioural impairment in fish and some invertebrates
- Juvenile life stages appear more susceptible to future OA, but the sensitivity is highly variable
- Impact of OA on immune responses and disease is an emerging field
- "bottom-up" changes in the food web

More you study, you realized how complex biological responses to ocean acidification are….



Winners and Losers

Different response of calcifiers to elevated CO_2 conditions may result in competitive advantages that could drive the re-organization of many ecosystems, which in turn, could have significant ecological and biogeochemical implications.

Studies for Ecosystem Responses

Naturally high CO_2 environment (under-sea volcanoes)

Long-term ecosystem response
- Shift in the benthic community composition (pH 7.4 – 8.2)
- No indication of adaptation
- Winners (sea grasses, brown algae) and losers (calcareous group)

Hall-Spencer et al., 2008

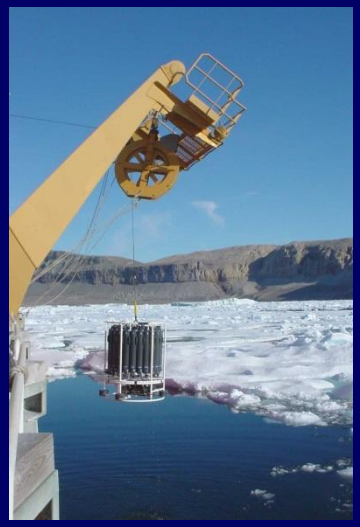
Other Consequences of Ocean Acidification

- Nutrient chemistry (different nutrient forms)
- Availability and toxicity of metals to organisms
- Decrease in absorption of low frequency ocean sound (noisier ocean at low pH)
- Decrease of ocean's ability to sequester atmospheric CO_2

How to monitor Ocean Acidification ?

sail to the study area

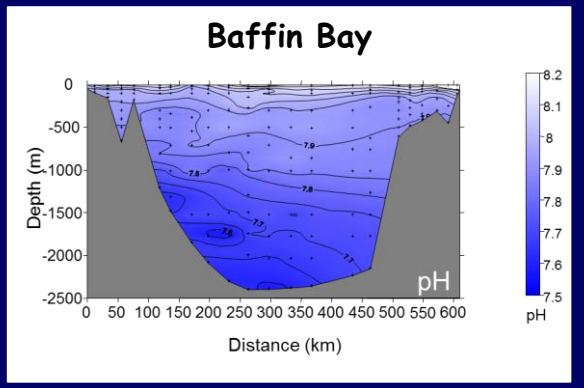
collect water samples from the ship



Preserve samples to bring back

Analyze them in our laboratory

Analyze them on the ship



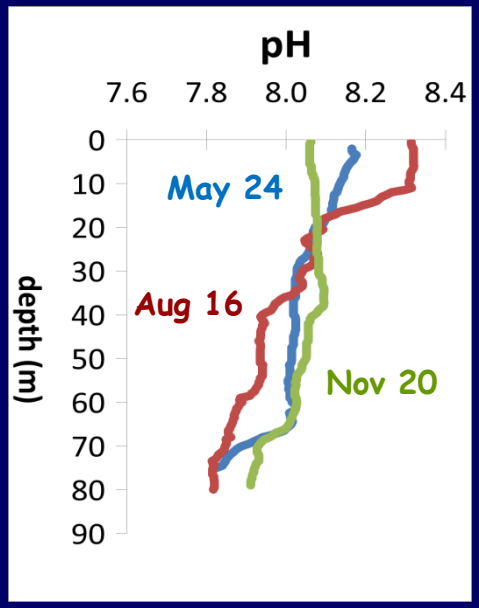
Azetsu-Scott *et al.*, 2010

New technologies

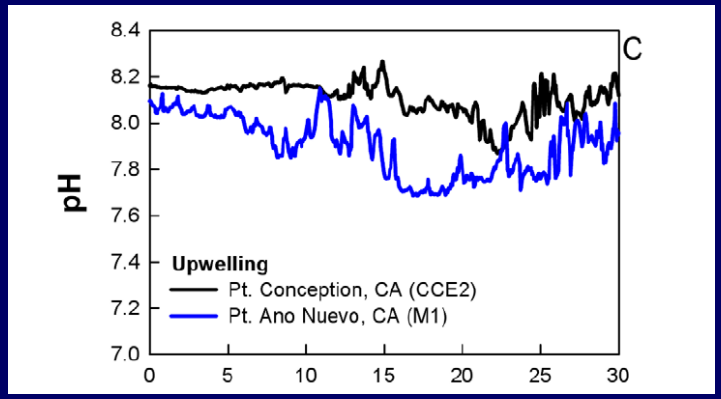
High vertical resolution sensor for profiling

+

pH sensor



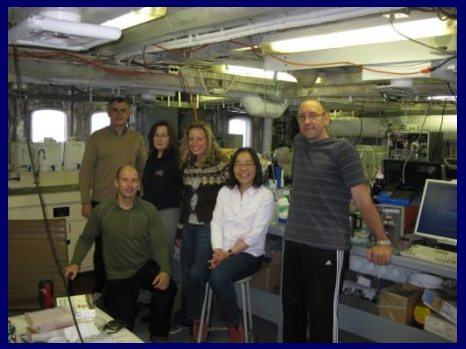
High temporal resolution sensor for buoy



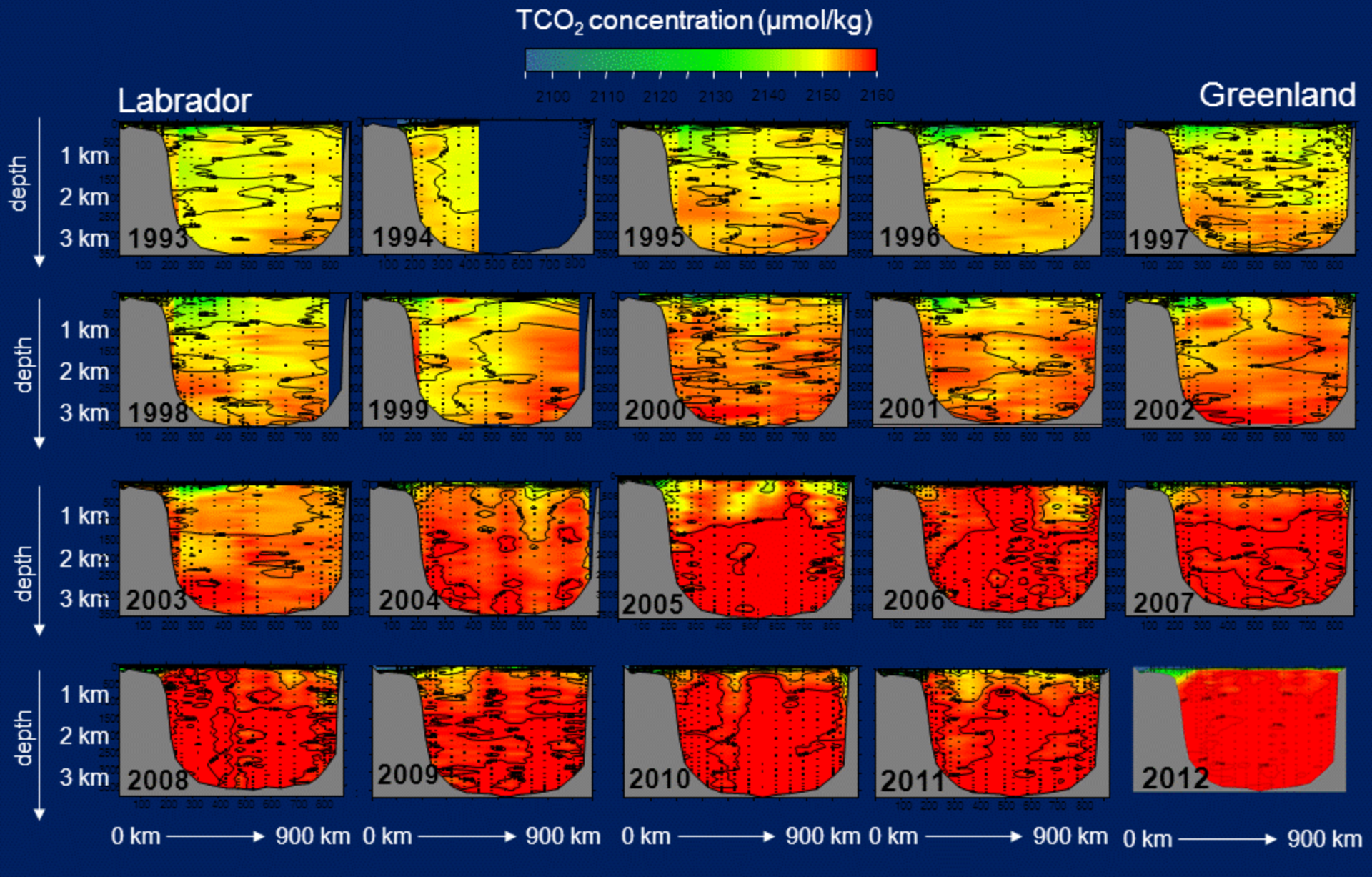
Hofmann et al., 2011

The Labrador Sea

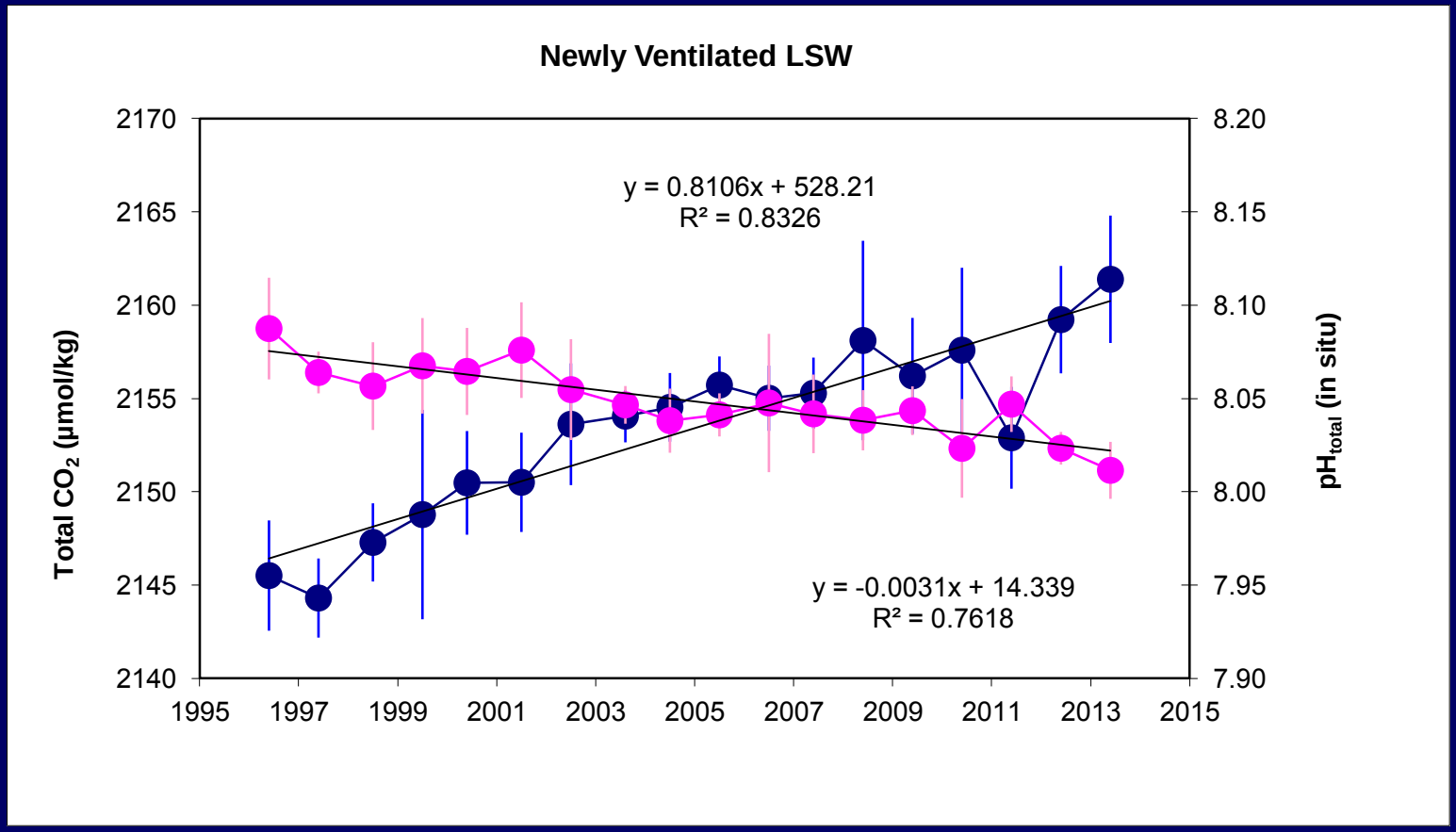
the lung and heart in the earth system

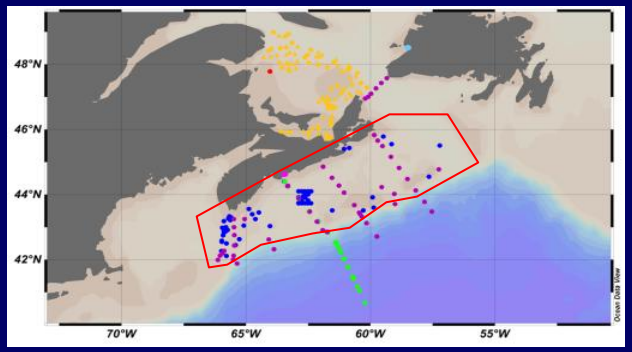


the relentless increase of total CO_2 in the Labrador Sea AR7W section from 1993 (mostly green and yellow) to 2012 (mostly red)

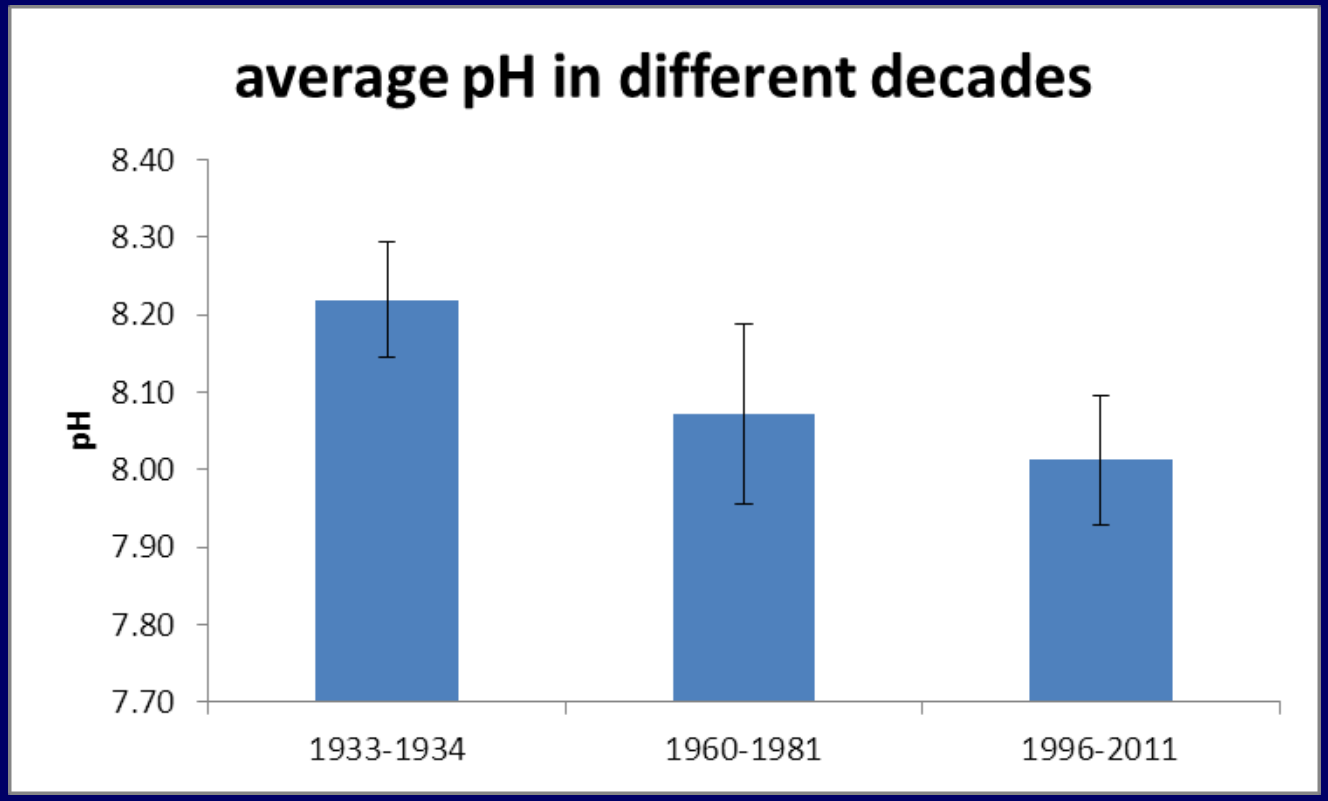


Total CO_2 concentration and calculated pH in the newly ventilated Labrador Sea Water (100m-500m)

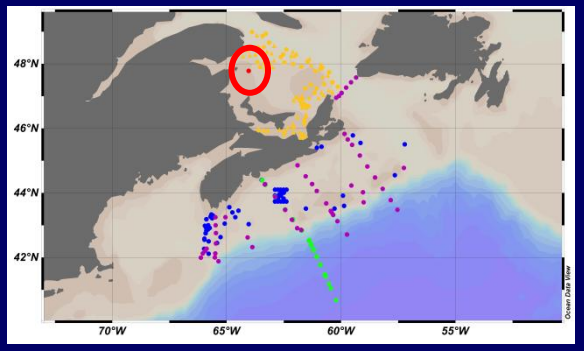




pH change on the Scotian Shelf

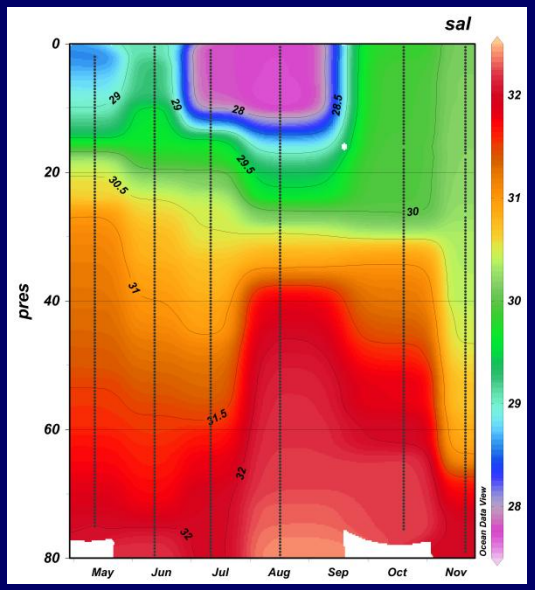


Decrease rate 0.003/year, global average=0.002/yr, Iceland shelf = 0.0024/yr



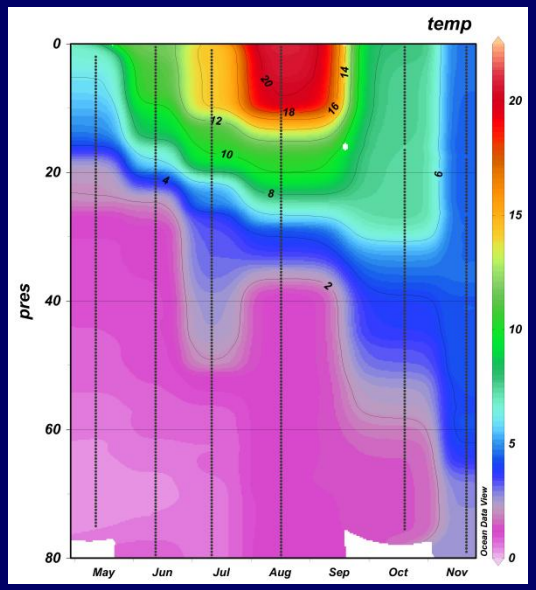
Shediac time series Station (May – November 2012)

salinity



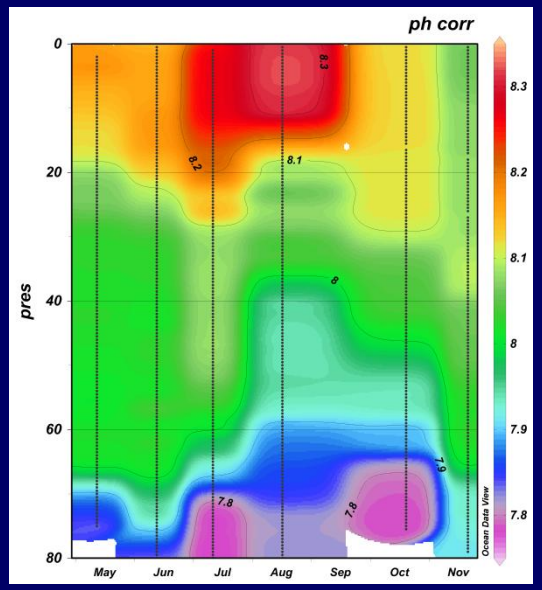
May **Aug** **Nov**

temperature



May **Aug** **Nov**

pH(total)



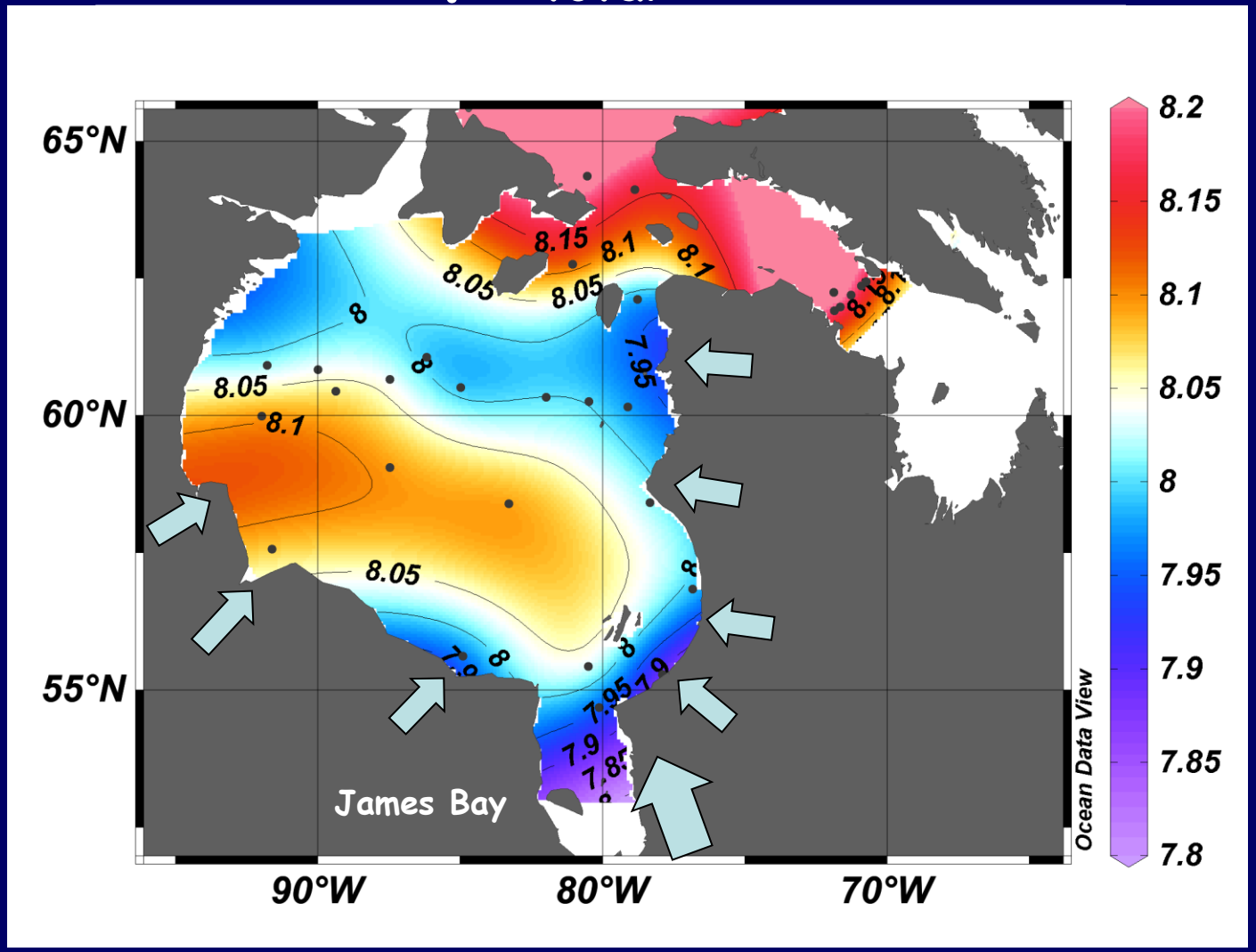
May **Aug** **Nov**

pH varied from 8.07-8.39 at surface (<10m) and from 7.73-7.88 at the bottom

Acidification in coastal area can be enhanced by;

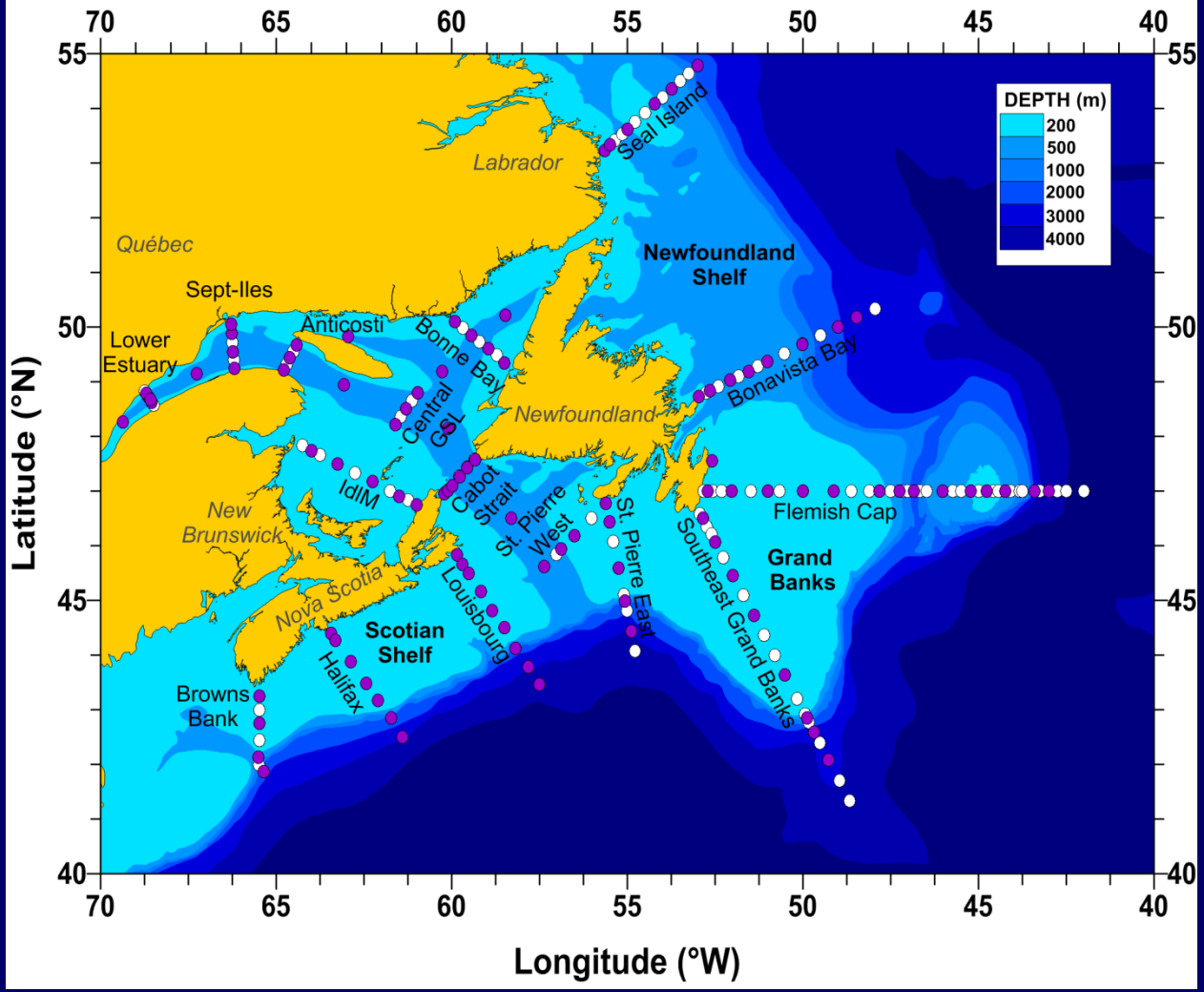
- River runoff is naturally more acidic
- Runoff of nutrients from land-based activity can cause a local biological activity enhancement, then decay of organic matter (lowered oxygen and increase of CO_2)
- Emissions of other acidifying gasses, such as nitrogen oxides (Nox) and sulfur oxides (Sox)

Hudson Bay System Surface pH_{total} distribution



Azetsu-Scott et al., 2014

Atlantic Zone Monitoring Program



Human beings are now carrying out a large scale geophysical experiment of a kind that could not have happened in the past nor be reproduced in the future (Revelle and Suess, 1957)

Ocean Acidification is:

- underway
- already detectable
- accelerating (but recovery will be slow)
- severe damages are imminent
- will have socioeconomic impacts
- can be controlled only by limiting future atmospheric CO_2 levels

(Monaco Declaration, 2009)

Thank you

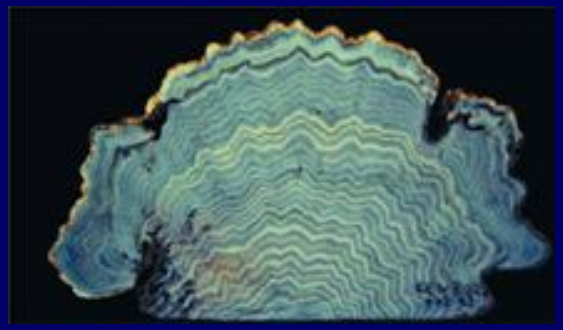
Acknowledgement

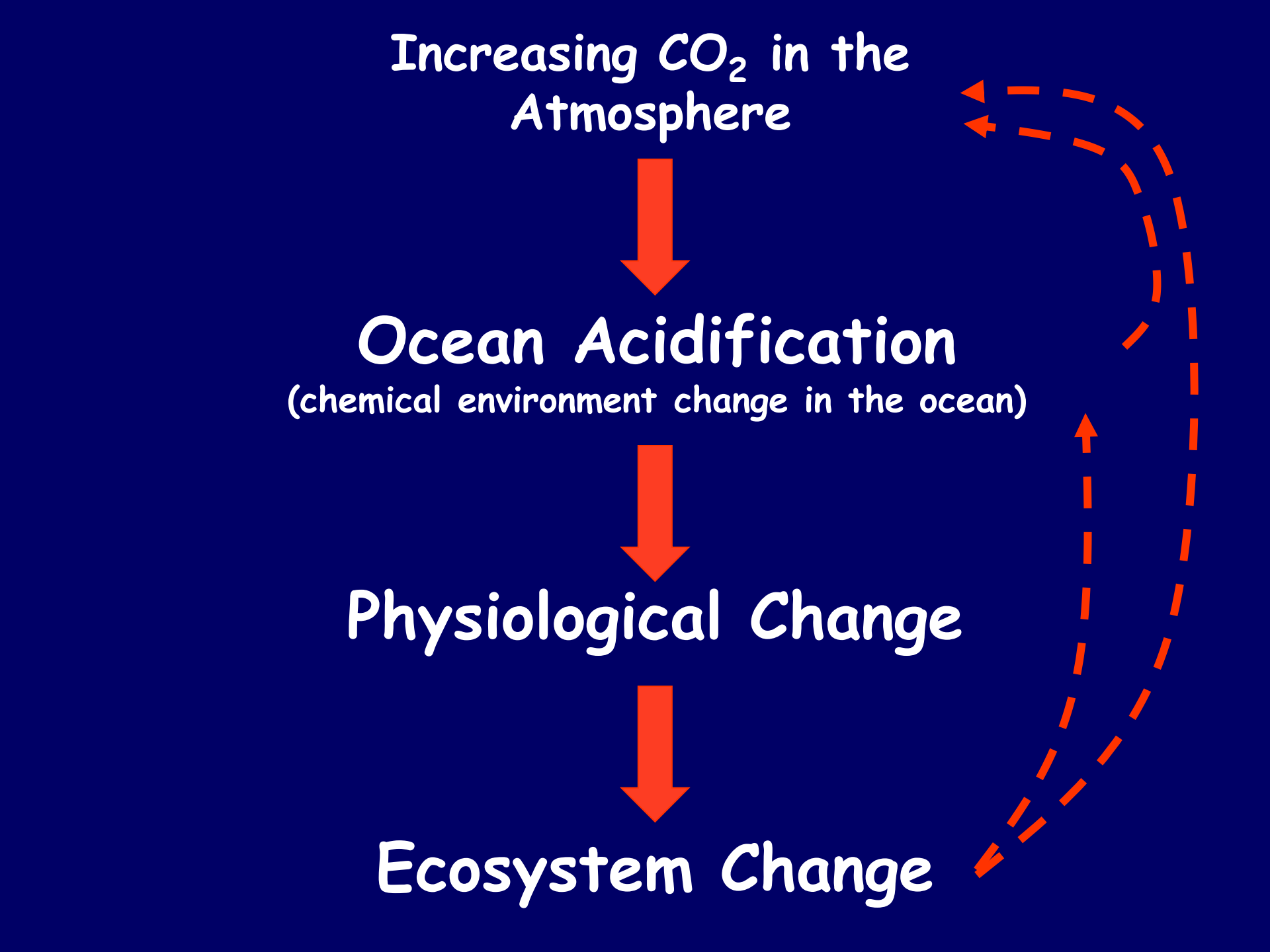
Stephen Punshon,Sally Walker, Lorenza Raimondi, Kayla Corey-Menu, Darlene Childs

Funding support: DFO (IGS, ACCASP, CCSI, AZOMP, AZMP), NSERC, NSF, Homarus Inc.

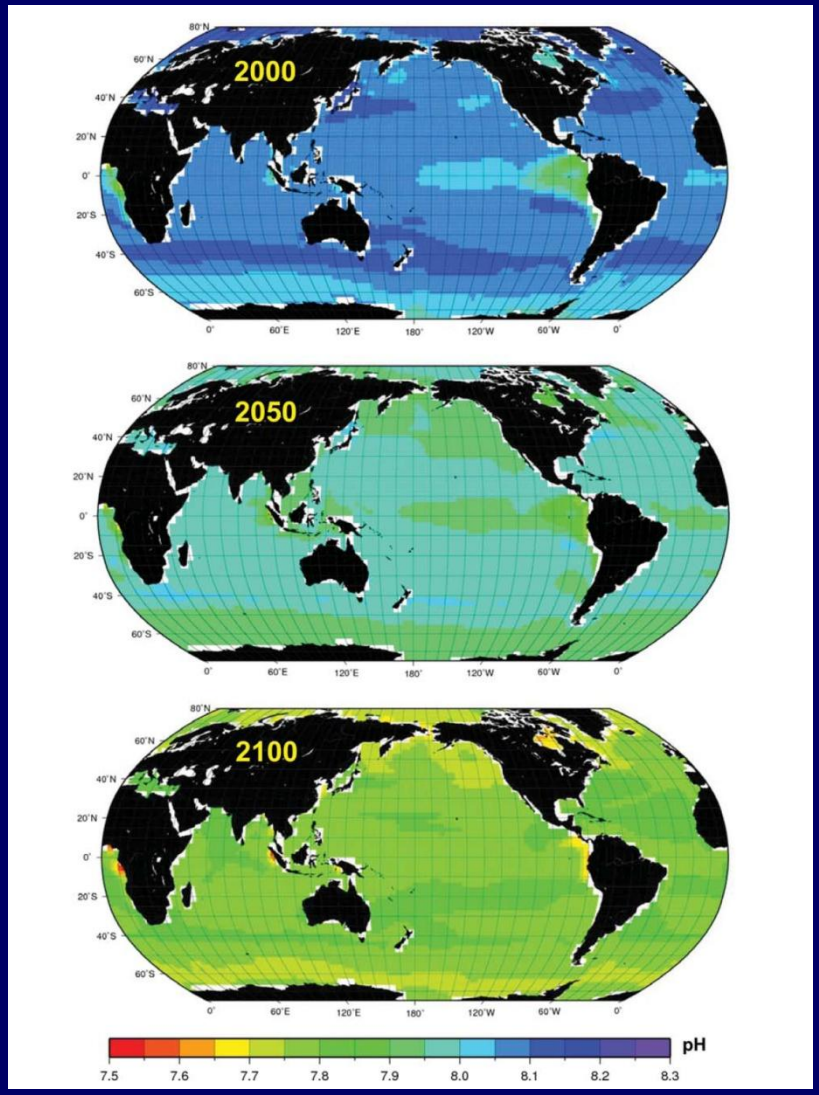
Possible Biological Effects

- Calcification decrease
- Growth/development
- Reproduction/physiology
- Metabolic rate
- Depression of immune system
- Behaviour
- Survival




Increasing CO_2 in the Atmosphere
Ocean Acidification
(chemical environment change in the ocean)
Physiological Change
Ecosystem Change

Model projections of global patterns in decreasing surface pH for historical fossil fuel emissions to 2000 and SRES A2 emissions From the Canadian Earth System Model CanESM-1.0 (Christian et al., 2010).

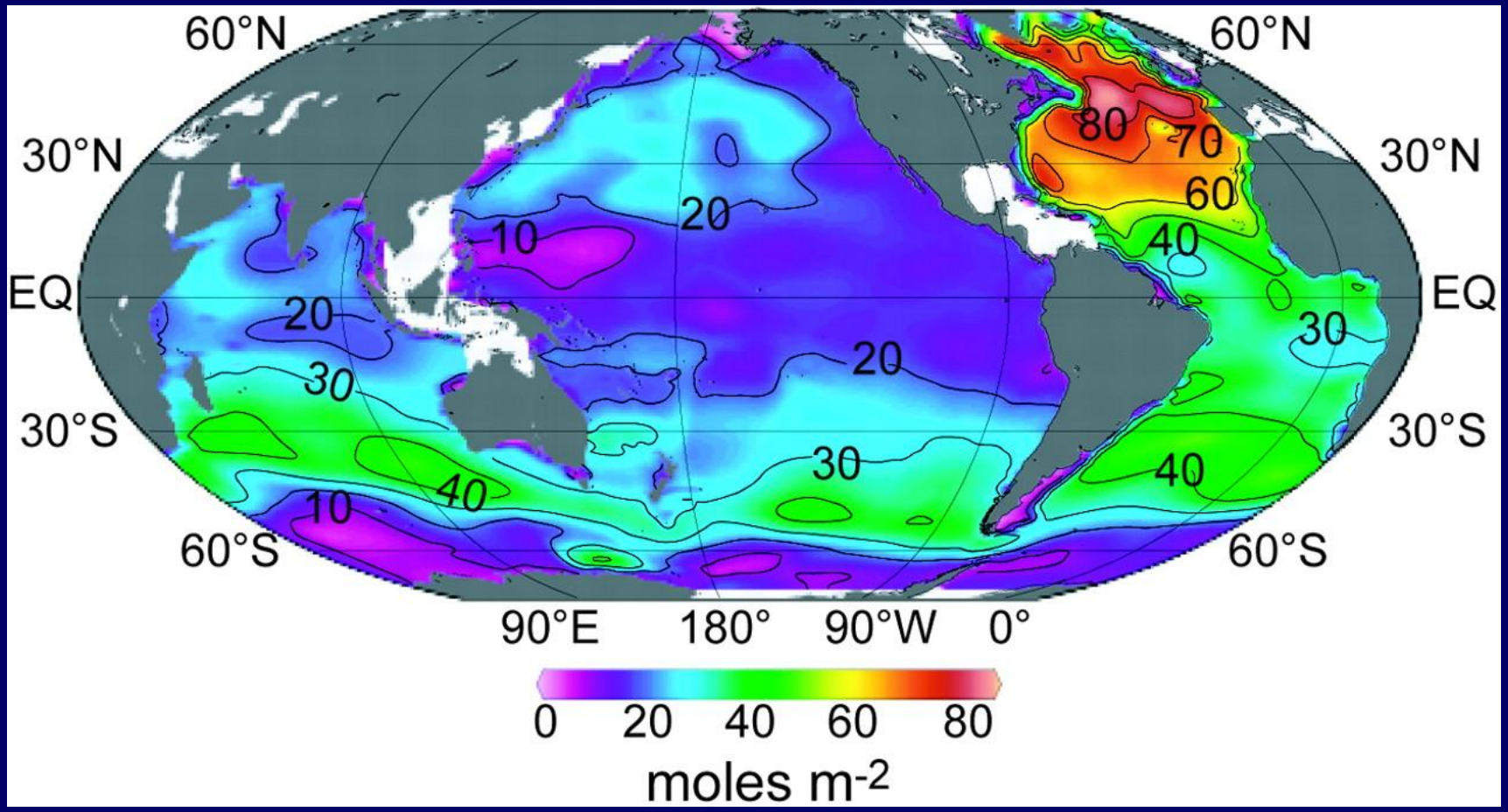


Denman et al., 2011

- **Cold water takes up more CO_2 from the atmosphere**
- **$CaCO_3$ (shells and skeletons) more soluble in cold water**

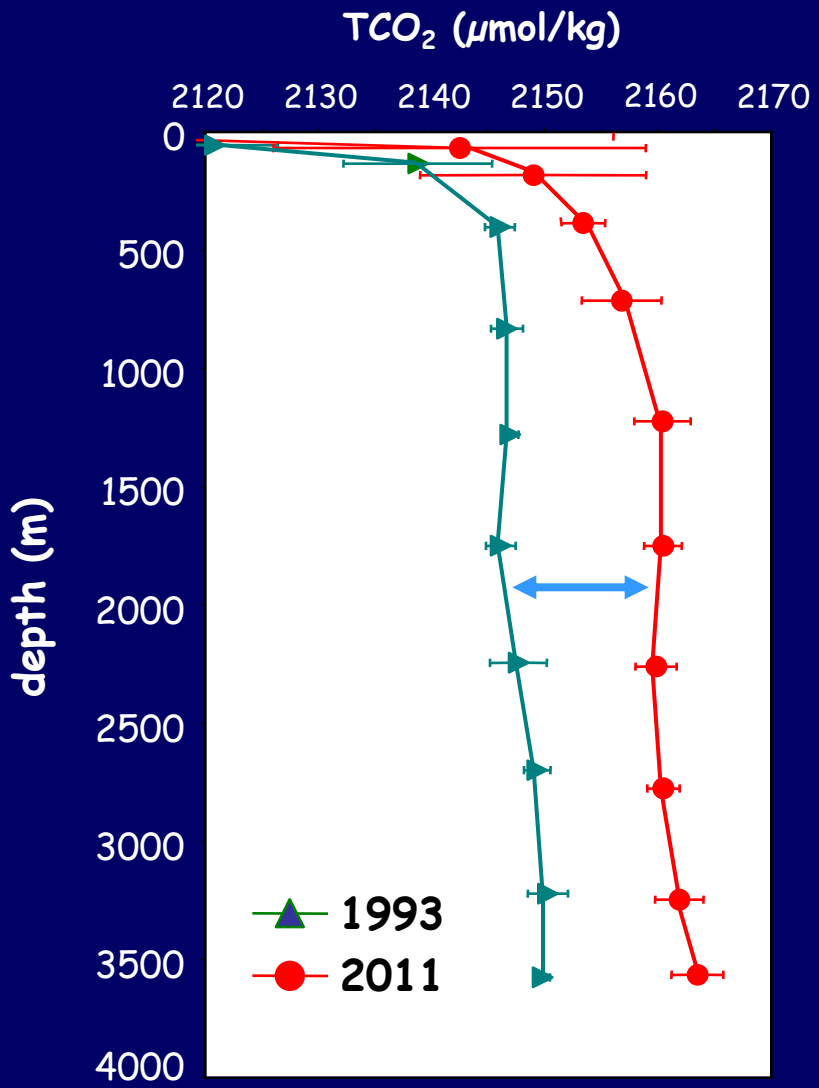
High-latitude surface waters are predicted to experience detrimental effects earliest, likely within decades

Where is anthropogenic CO_2 in the Ocean?



(Sabine et al., 2004)

Total CO_2 concentration profiles in the central Labrador Sea in 1993 and 2011 (averages of 10 stations)

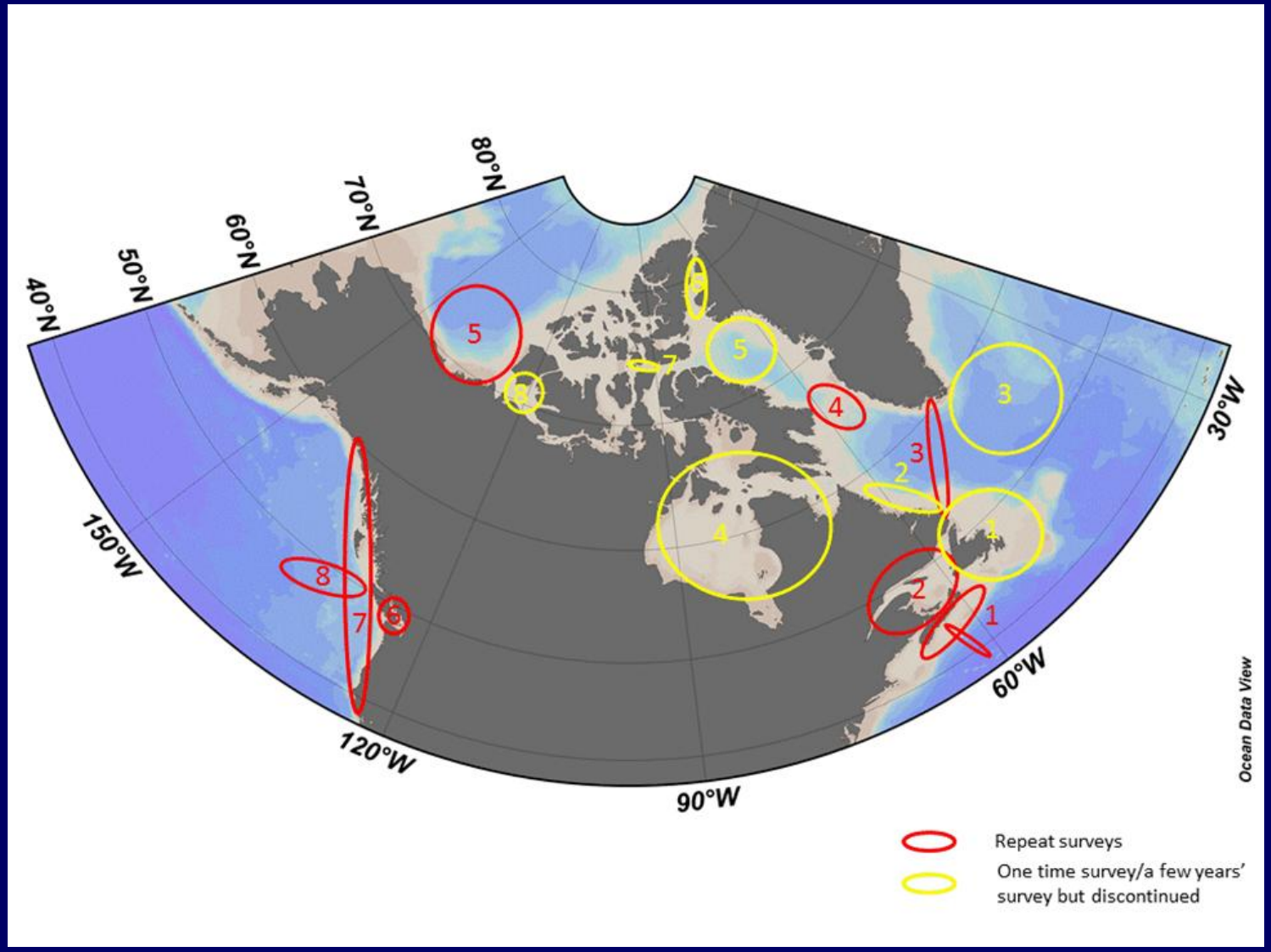


carbon inventory in the Labrador Sea has increased by 7.2 X 10^8 ton from 1993 to 2011

- equivalent of about 240,000,000 Hummers

- 30% of entire fossil fuel emission during the same period by Canada

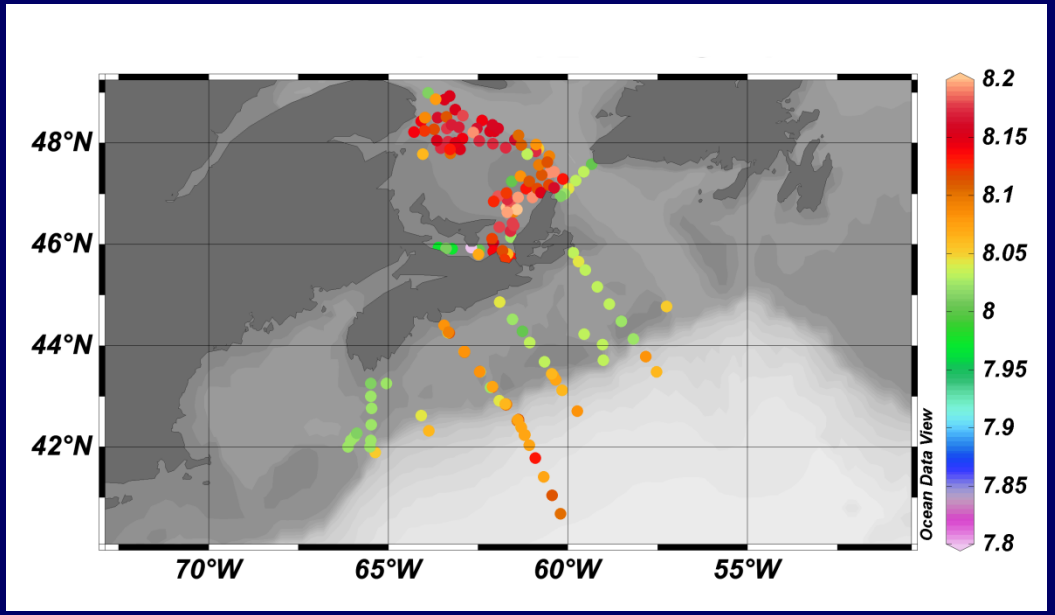
A map of study sites in Canadian Waters



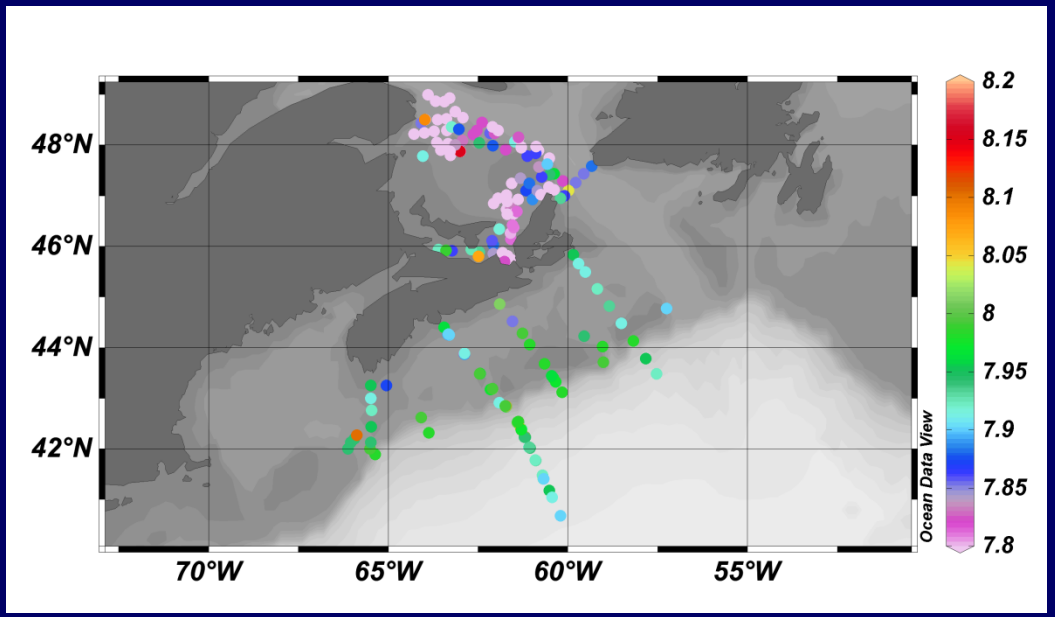
Azetsu-Scott et al., 2014

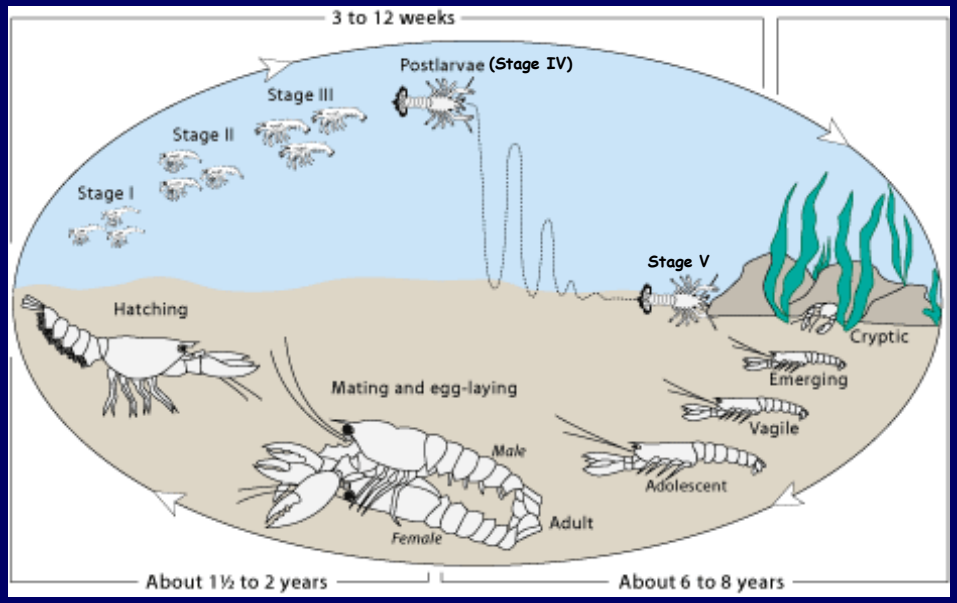
pH(total) distribution at surface and bottom water (data collected after 2006)

Surface (<10m)

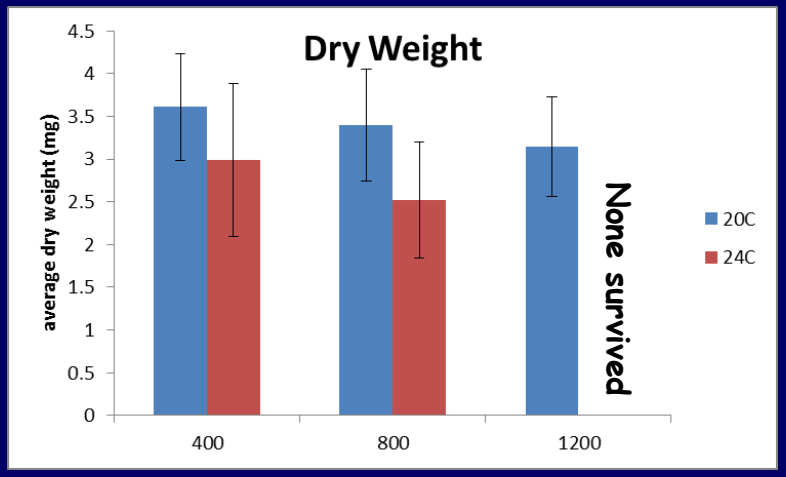


bottom

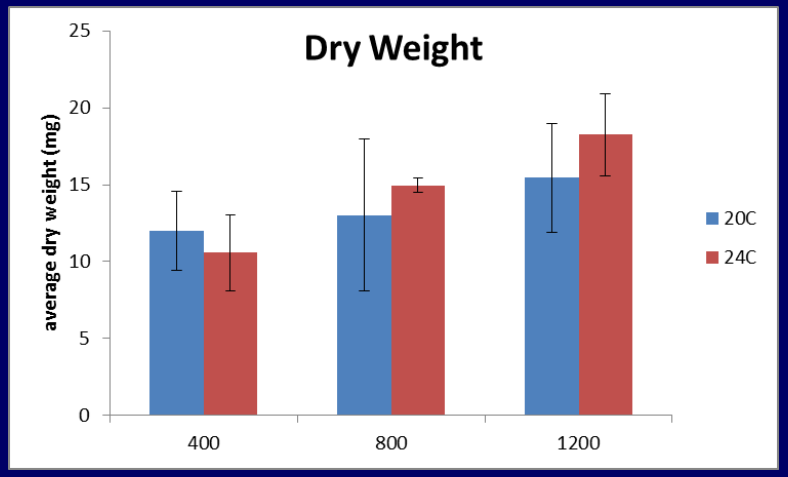




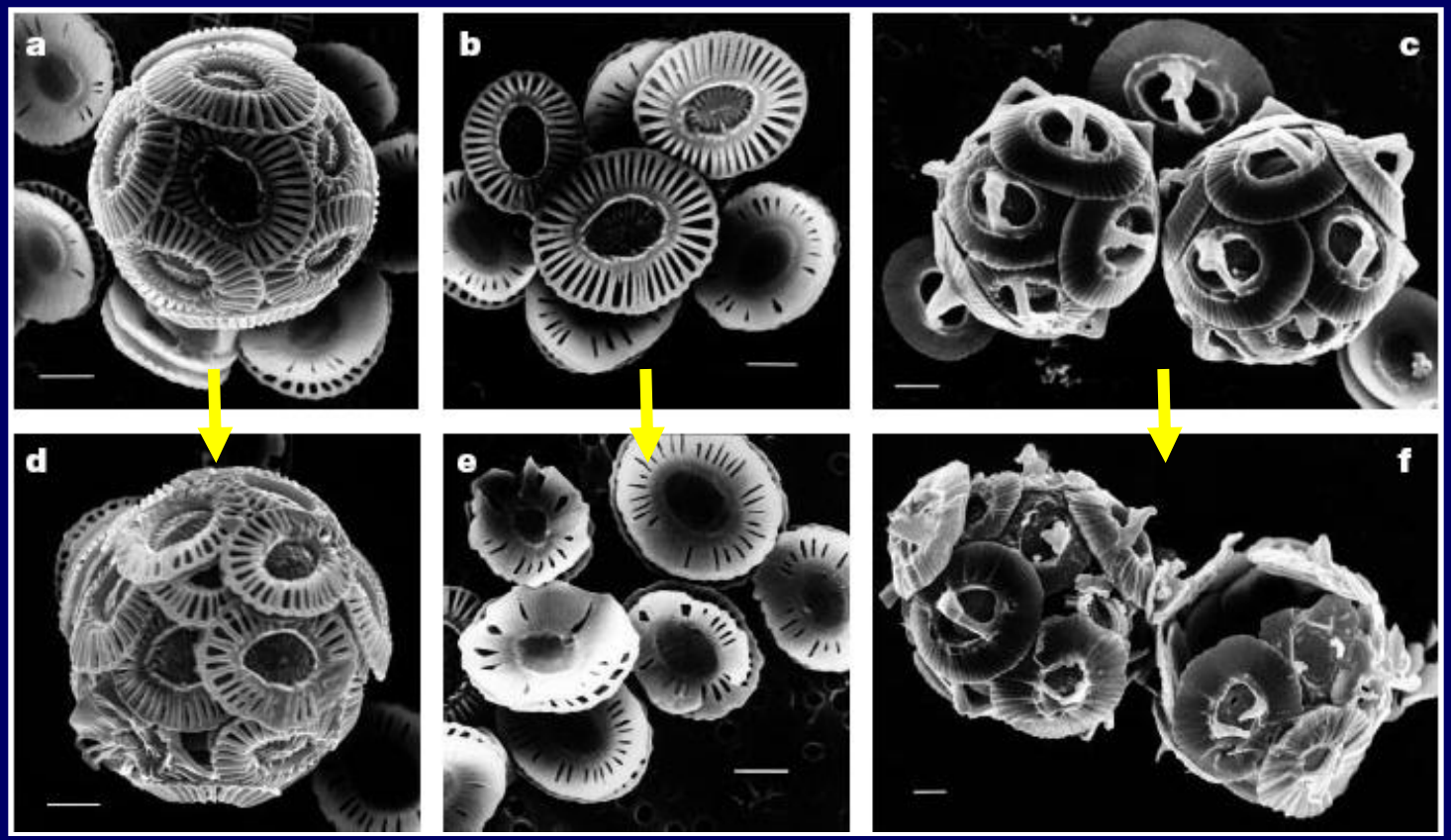
stage IV



stage V



Coccolithophore, *Emiliania huxleyi*, was exposed to high pCO_2 = low pH water



pCO_2=300 ppm (~pre-industrial level)
pH~8.1

pCO_2=780~850 ppm (2~3 times of pre-industrial level)
pH~7.8

Decrease in formation and malformation of shell

Riebesell et al., 2000

Socio-Economic Impact

- Total value of commercial sea fishery landings in Atlantic Canada is $1.83 billion in 2012
- over 85% of it is from shellfish
- Among shellfish, $664 million was from the lobsters, $435 million from crabs and $334 from shrimp
- Aquaculture production of bivalves (Clams/Quahaug, Oyster, Scallop and Mussel) produces over $158 million in the Atlantic Canada
- post-catch processing and shipping etc. contribute more to Nova Scotia's Gross Domestic Product and support regional household incomes
- Ocean acidification, therefore, imposes the real and urgent threat to the Atlantic Canada's livelihood.

Community Vulnerability Assessment of Climate Change and Variability Impacts in Charlotte County, New Brunswick

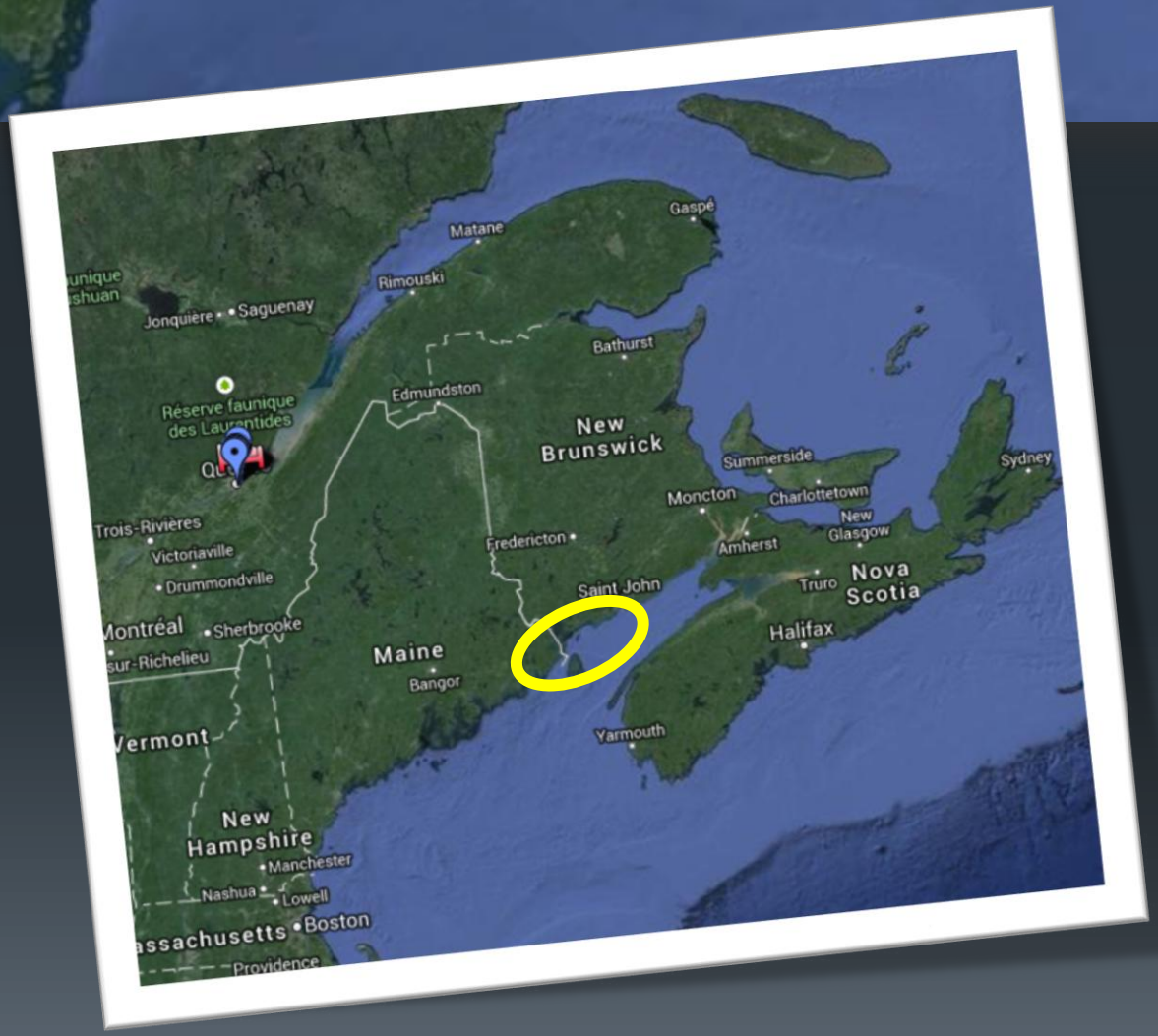
Presented by:

Kim Reeder,
Consultant

Environment Canada

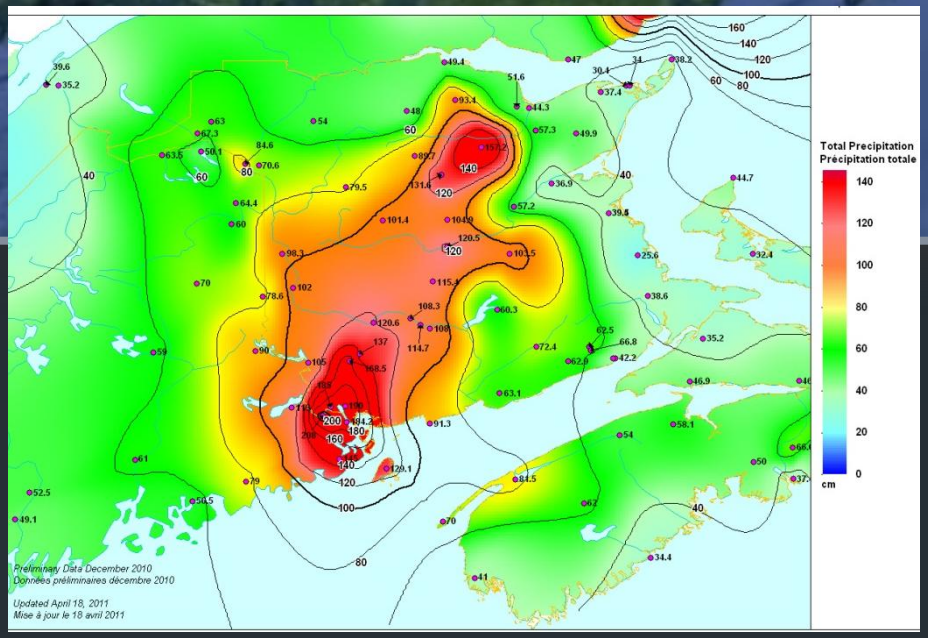
intact INSURANCE

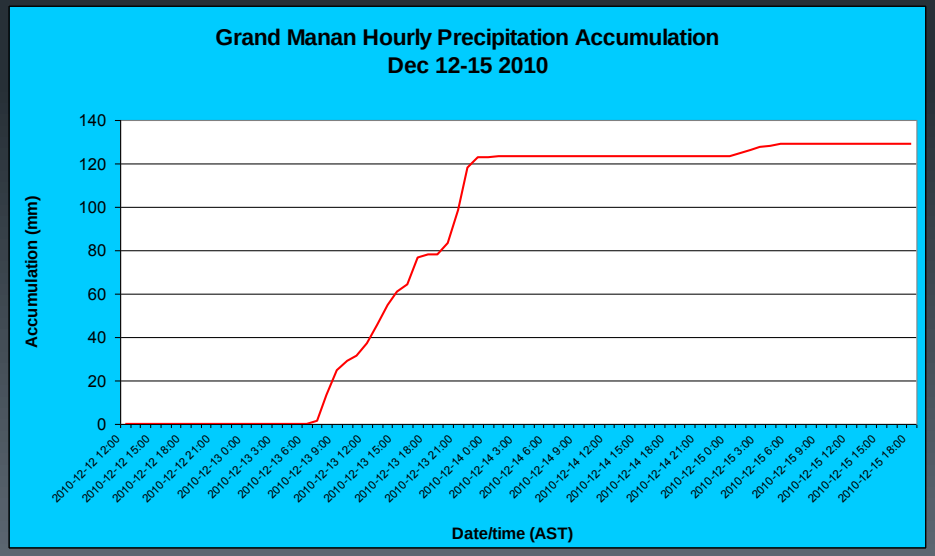
New Nouveau Brunswick



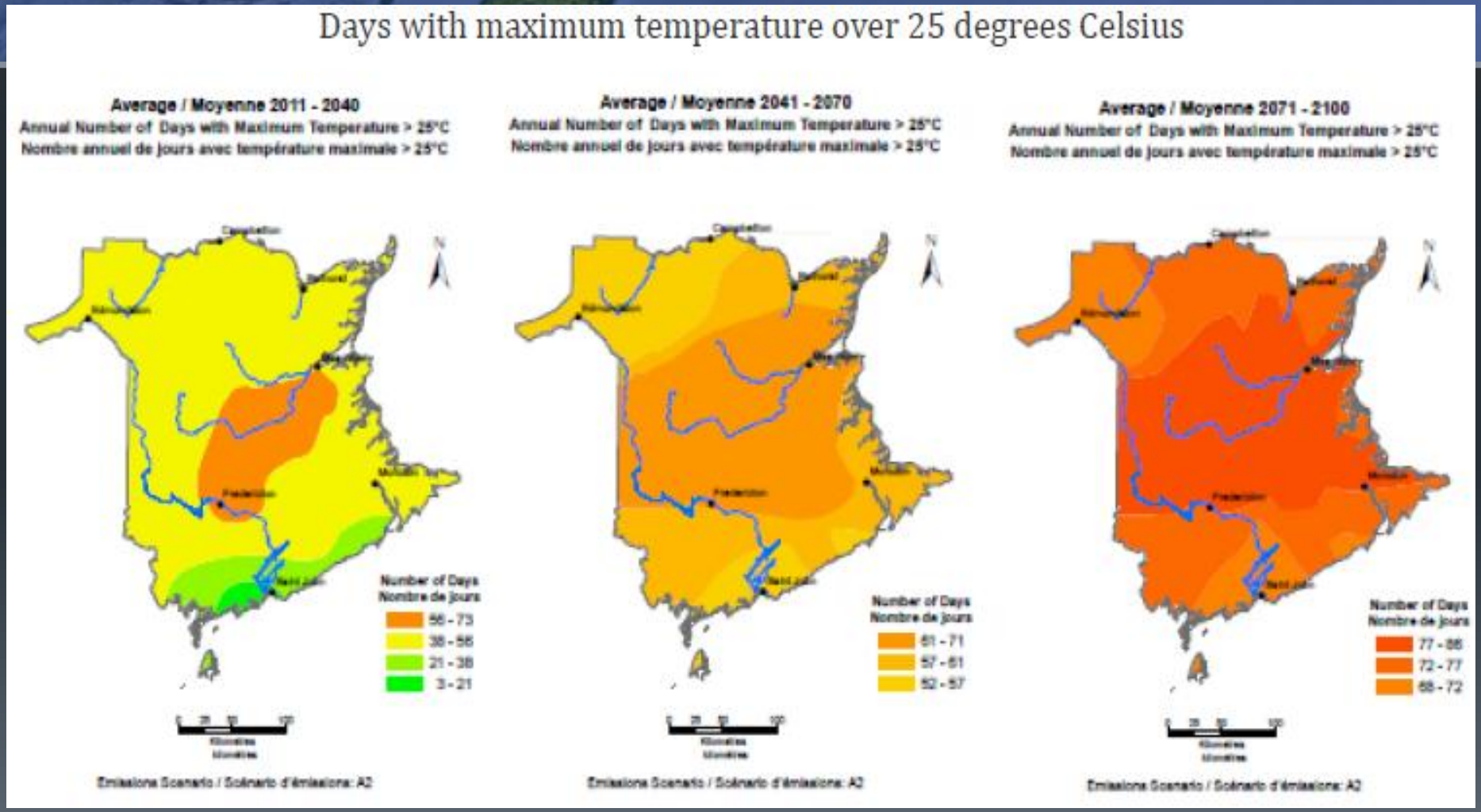
Community Meetings

Hyper Local Weather Information

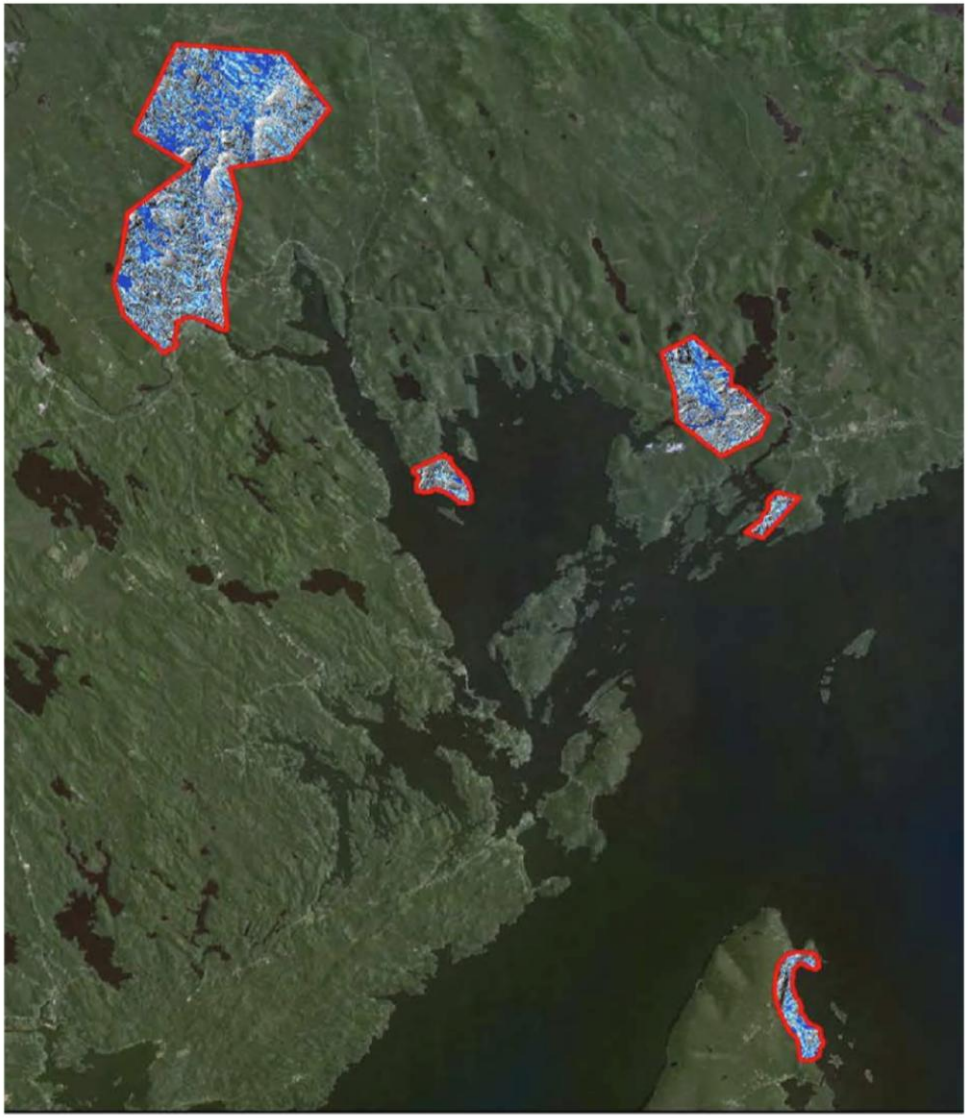


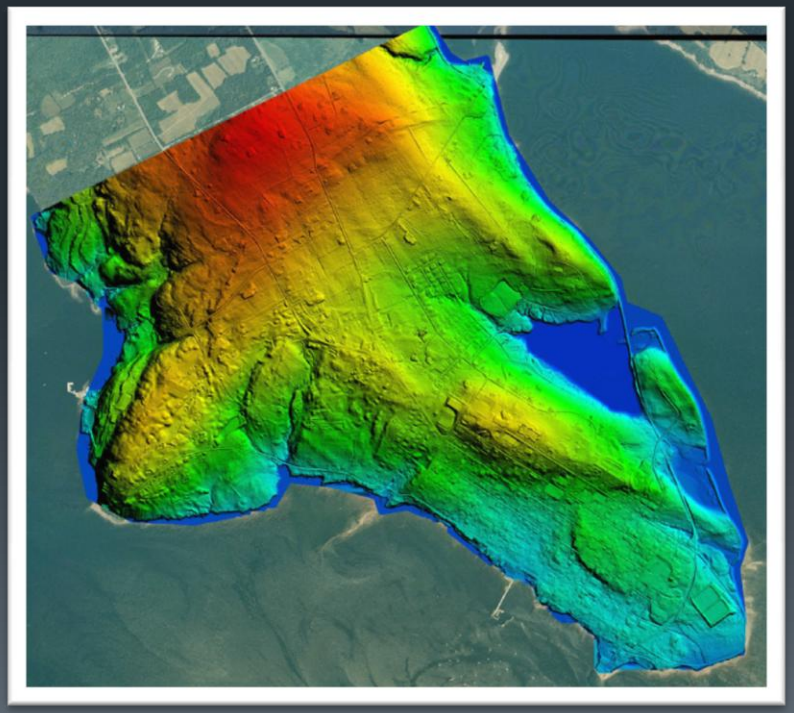


Regional Information

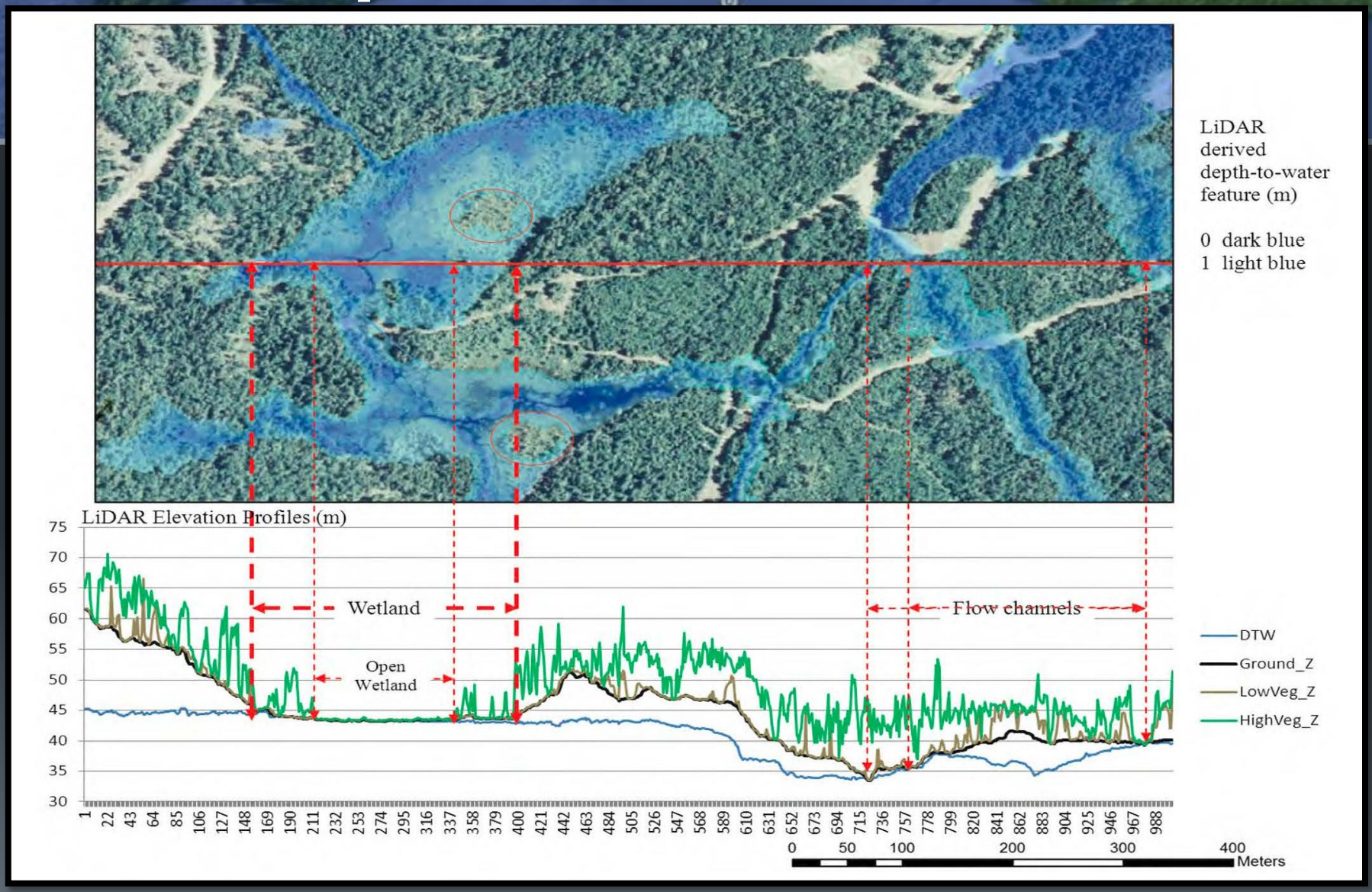


LiDAR Applications

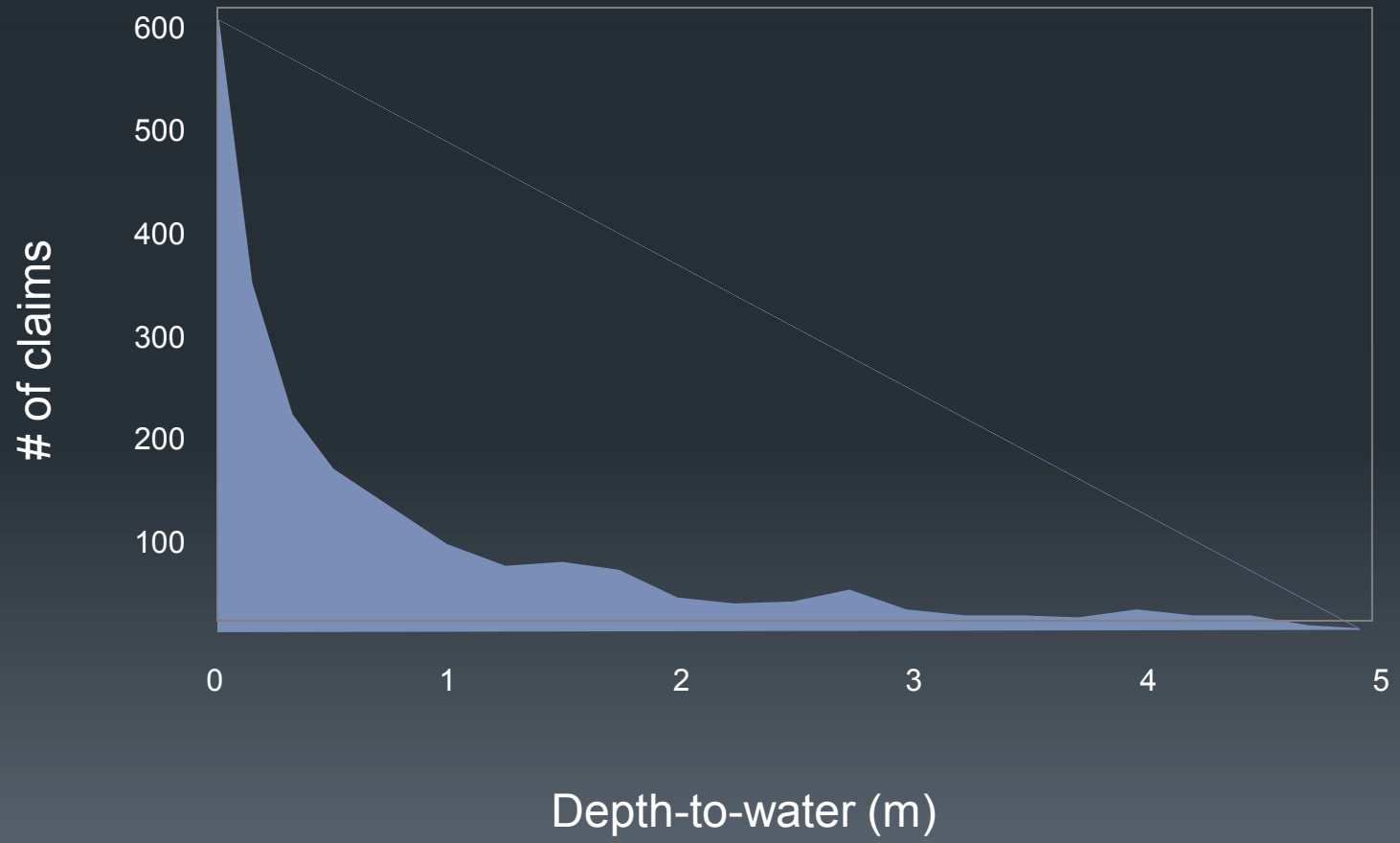




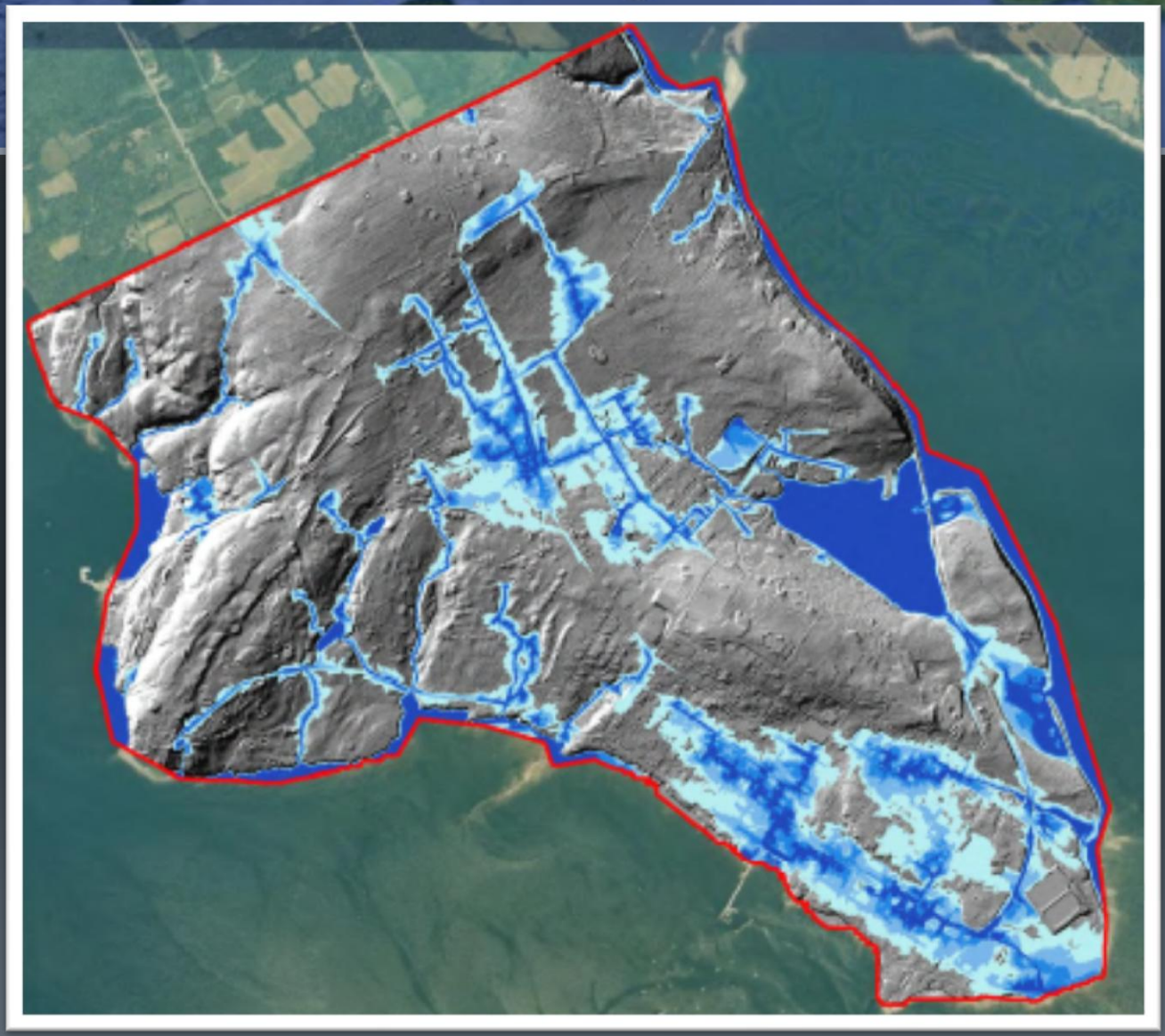
LiDAR Applied Depth to Water Index



Frequency of NB flood claims, December 2010



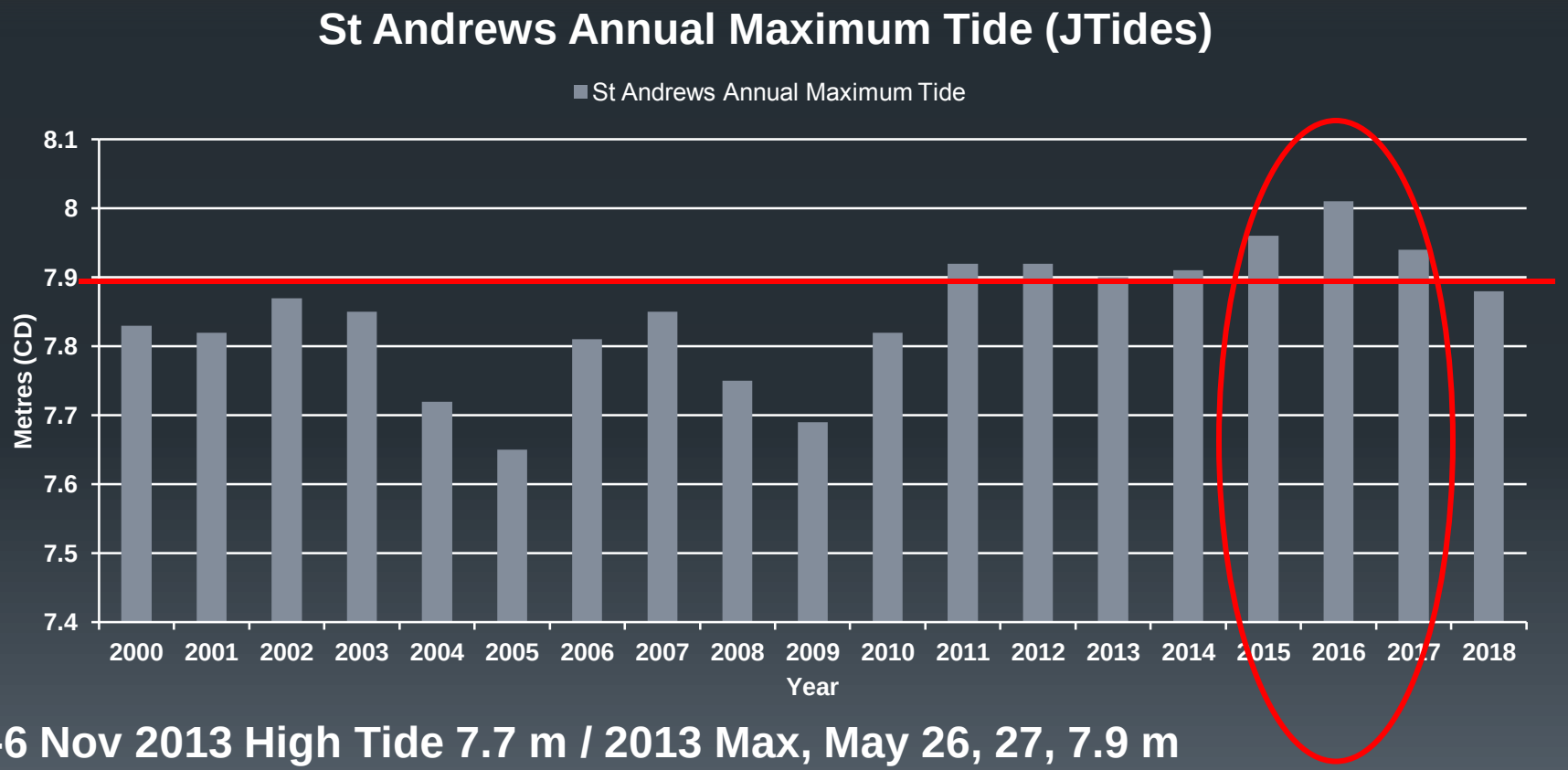
LiDAR Applied for Inland Flooding Scenarios



LiDAR & IPCC for projected sea-level rise contours

HHWLT Baseline – St Andrews

HHWLT 7.88 m CD/ 4.03 m CGVD28 (CHS)



4-6 Nov 2013 High Tide 7.7 m / 2013 Max, May 26, 27, 7.9 m

Source: R.J. Daigle Enviro

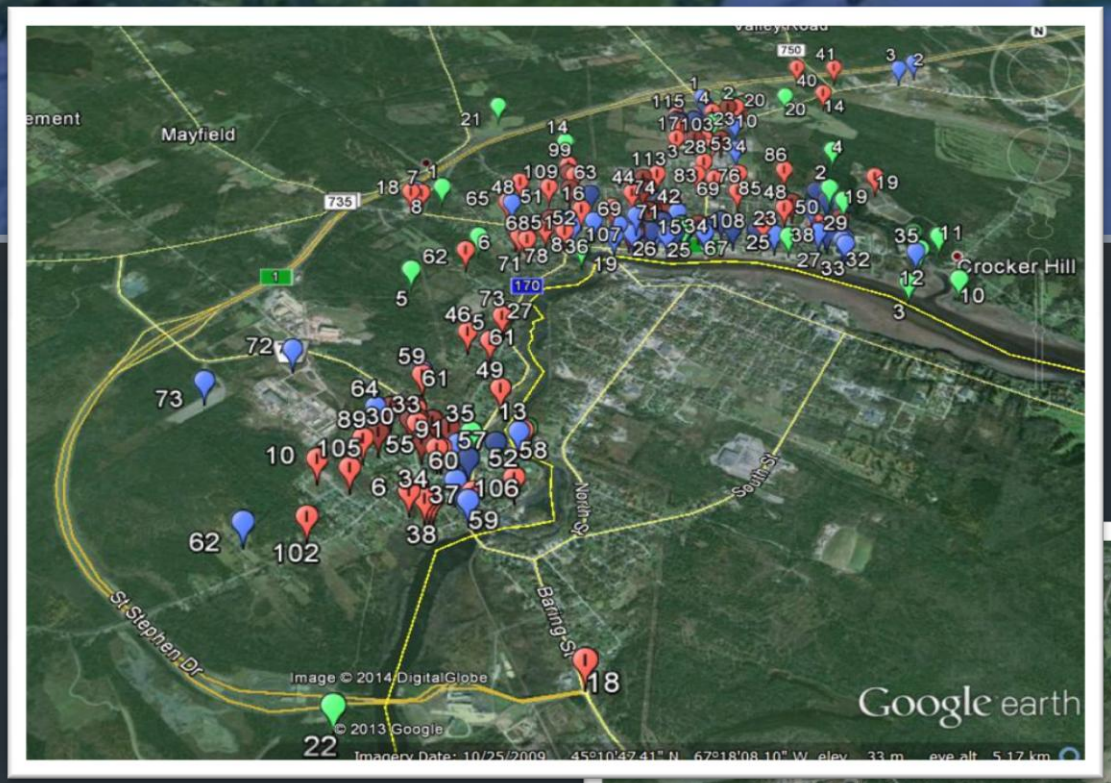
Flooding Scenarios – Saint Andrews

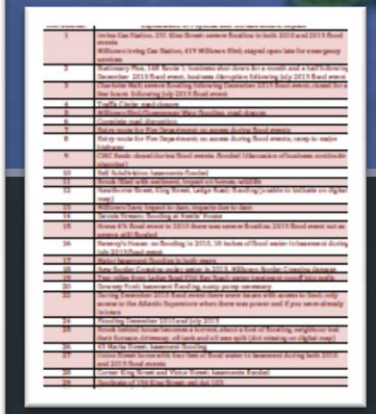
Flooding Levels (metres CGVD28) – Saint Andrews

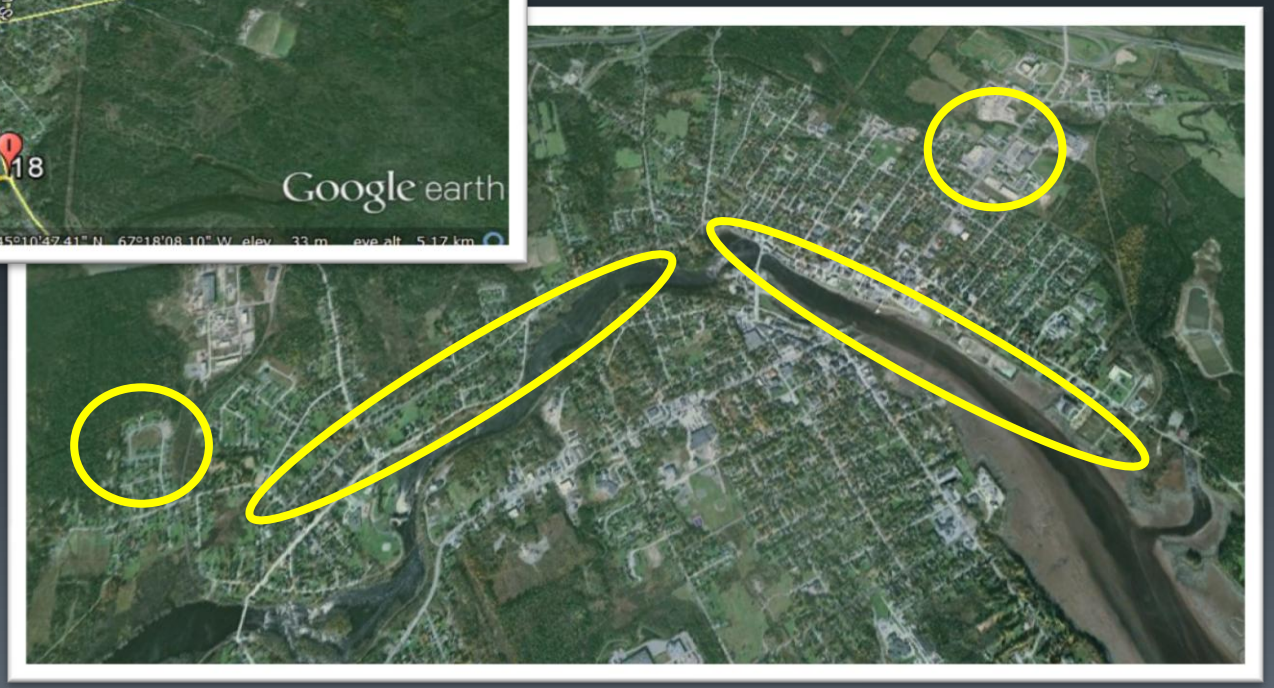
Period	Residual	Level 2000	Level 2025	Level 2055	Level 2085	Level 2100
1-Year	0.47 ± 0.20	4.47 ± 0.20	4.60 ± 0.23	4.82 ± 0.31	5.15 ± 0.41	5.35 ± 0.49
2-Year	0.54 ± 0.20	4.54 ± 0.20	4.67 ± 0.23	4.89 ± 0.31	5.22 ± 0.41	5.42 ± 0.49
5-Year	0.64 ± 0.20	4.64 ± 0.20	4.77 ± 0.23	4.99 ± 0.31	5.32 ± 0.41	5.52 ± 0.49
10-Year	0.71 ± 0.20	4.71 ± 0.20	4.84 ± 0.23	5.08 ± 0.31	5.41 ± 0.41	5.61 ± 0.49
25-Year	0.80 ± 0.20	4.80 ± 0.20	4.93 ± 0.23	5.15 ± 0.31	5.48 ± 0.41	5.68 ± 0.49
50-Year	0.87 ± 0.20	4.87 ± 0.20	5.00 ± 0.23	5.22 ± 0.31	5.55 ± 0.41	5.75 ± 0.49
100-Year	0.94 ± 0.20	4.94 ± 0.20	5.07± 0.23	5.29 ± 0.31	5.62 ± 0.41	5.82 ± 0.49

Source: R.J. Daigle Enviro

Community Identified Vulnerabilities



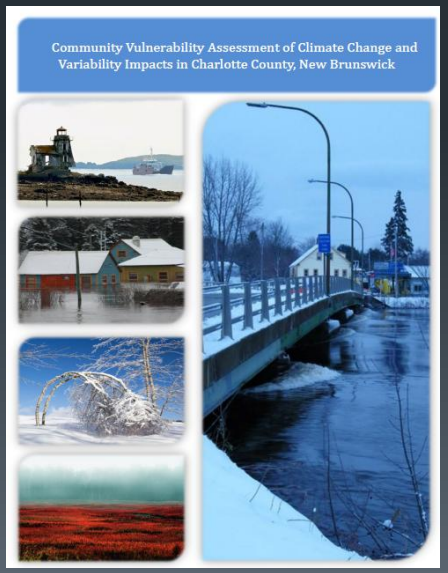




Community Recommendations

3.4.5 Recommendations

it was evident that there may be a need to explore economic diversification within the Blacks Harbour area in order to safeguard the community's economic wellbeing against the changing ocean conditions and resultant economic impacts to the local fisheries.



3.5.6 Recommendations

The main recommendation of the working group on Grand Manan was developing a plan for economic diversification. This was specifically related to the shift from a local to a regional species advisory board by DFO. It is now more difficult to adapt fisheries policies for predators and invasive species and, the diversification of species harvesting. The species advisory board used to be based in St. George and is now in Dartmouth, Nova Scotia, and, as such, it has become difficult for Grand Manan as the policies are regionally based as opposed to local. Additionally, the DFO has examined climate change impacts on the Atlantic wide fisheries, but has not addressed issues specifically related to Grand Manan. It was suggested by the working group that further study regarding the impact of climate change on the species upon which their main industry depends is necessary.

Next Steps

www.ecwinc.org

And Event

www.stateofthestcroix.org

parkscanada.gc.ca

CASCADING LIFE-LONG EFFECTS OF EARLY EXPERIENCE IN ATLANTIC SALMON.

ACFFA workshop 2014

Clarke, C.N., [1] Fraser D.J.[2] Purchase C.F. [3]

[1] Lead, Salmon Recovery Program, Parks Canada, Fundy National Park, Alma NB

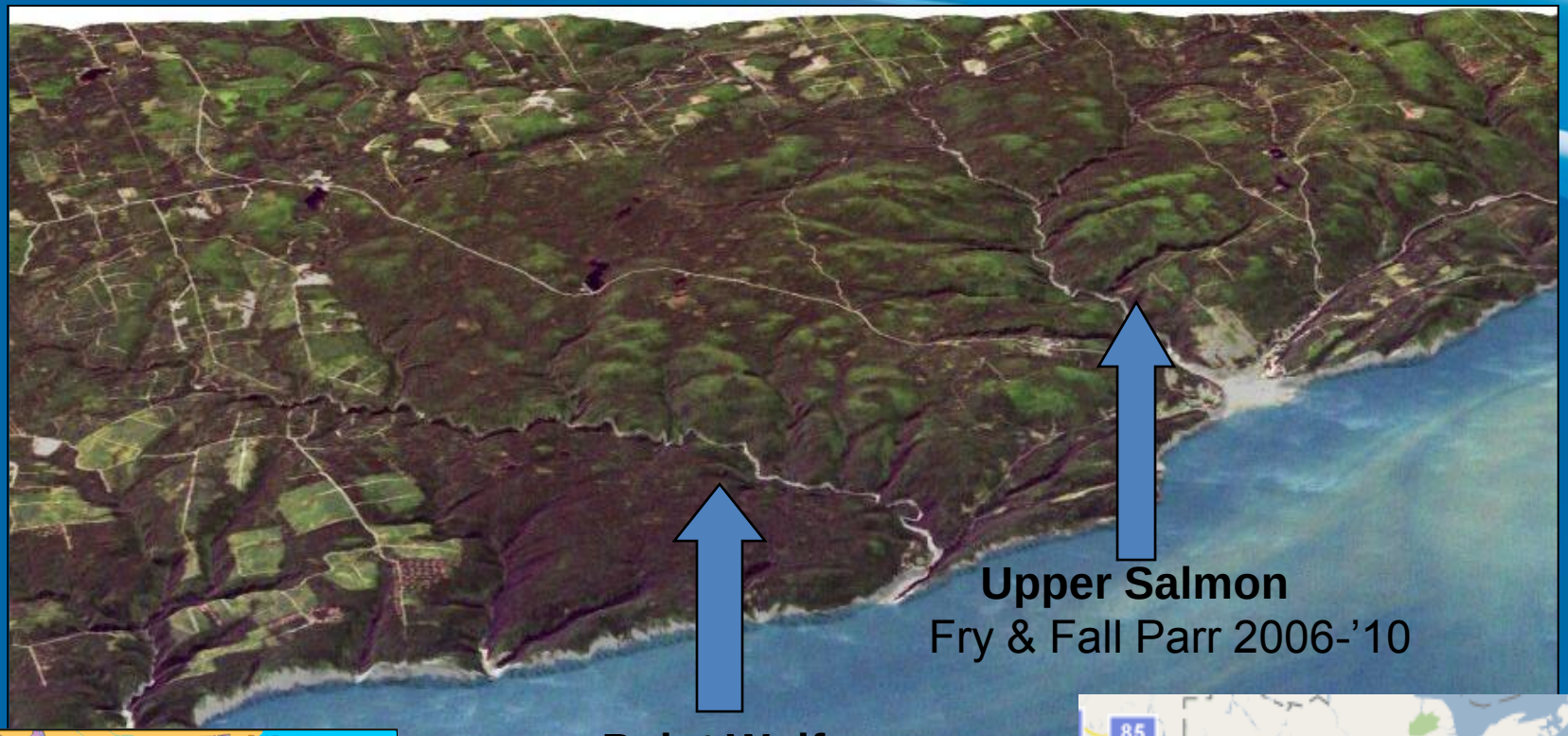
[2] Department of Biology, Concordia University, Montreal PQ

[3] Department of Biology, Memorial University of Newfoundland, St. John's NL

Parks Canada Parcs Canada

Canada

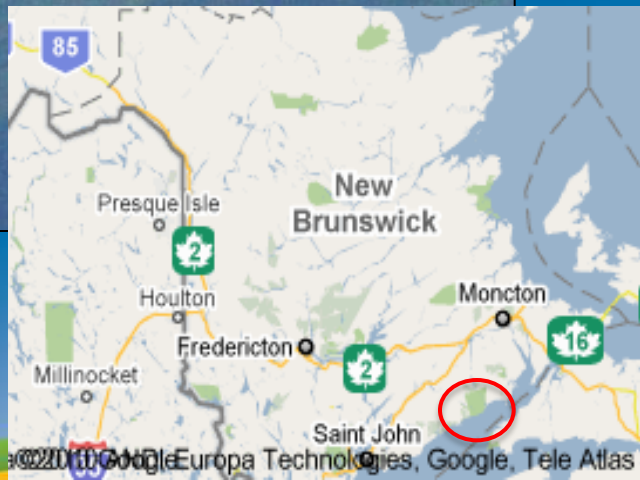
Atl. Canada – NB - FNP Rivers



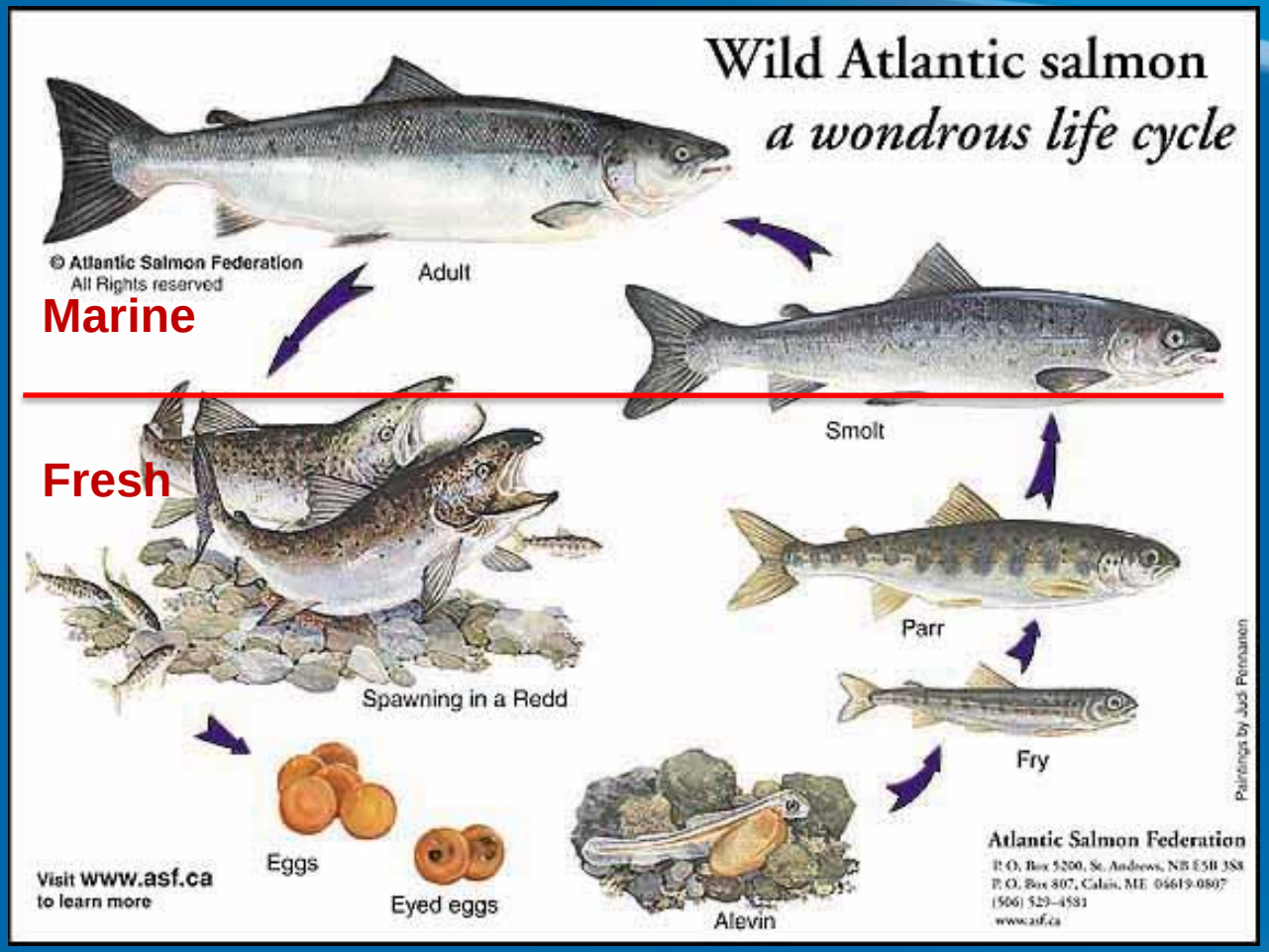
Upper Salmon
Fry & Fall Parr 2006-’10

Point Wolfe
Adult only 2003-’10

Bringing you Canada's natural and historic treasures



Why are IboF Salmon Endangered?



- Historic returns of more than 40,000 have been reduced to as few as 250

Marine survival considered to be most limiting recovery.

Assessed as Endangered by COSEWIC in 2001

2001- 2003 assessment of FNP stocks

Conclusions from '01-'03 Assessment of FNP rivers:

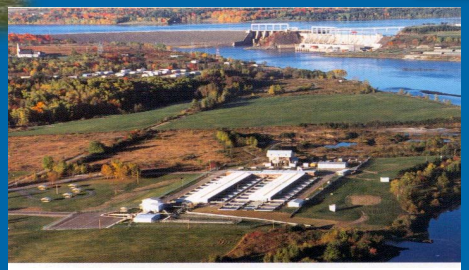
- Juv. density declining
- Insufficient returns to recover
- Genetic diversity concern

ACTION:
Capture remnant families, Live Gene Bank (LGB), release @ various stages

DFO MACTAQUAC "LGB"

By 2006, families captured in LGB... no improvements in returns

Collect As Smolt



DFO LGB

Captive Rear

Adult or Juvenile Releases

But which strategy produced better lifetime fitness ?
We investigated Fry vs Parr

4yr overview (1 generation)

- **Phase I: Release-smolt (2008-2012)**
- **Phase II: Smolt-adult (2010-2011)**
- **Phase III: Spawning-eyed egg (2011-2012)**
- ***2SW returns (2012)**

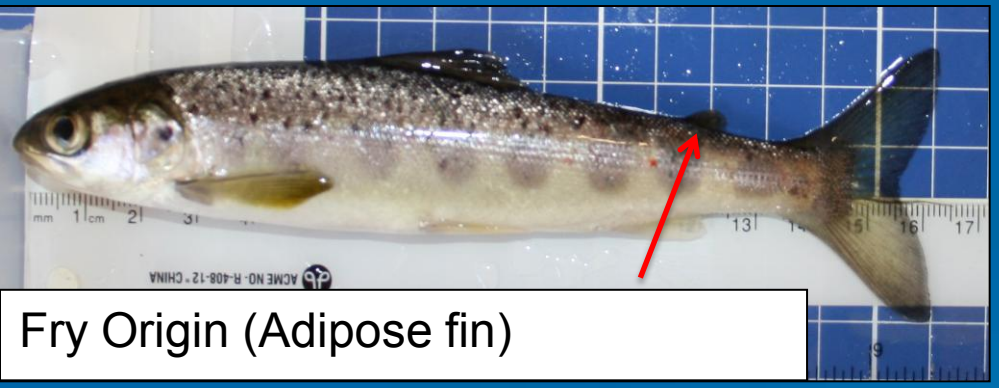
  ***Unpublished**

Phase I
Release of 450k fry and 55k Parr in ‘08-’09

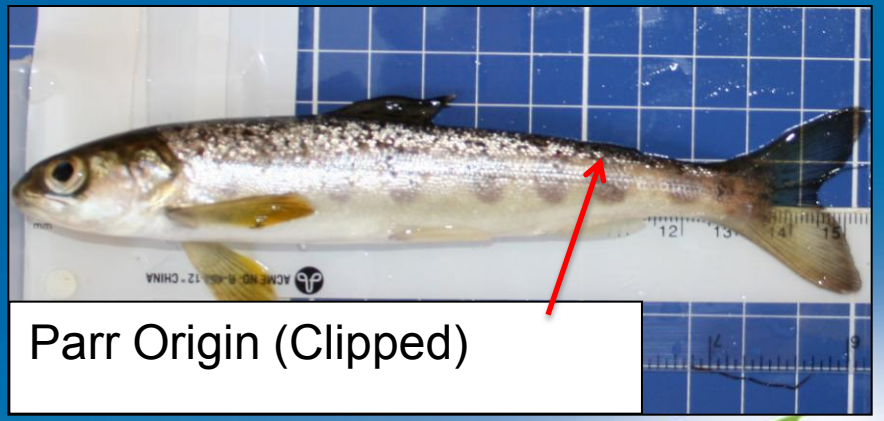
- FRY = Post hatch, unfed
- PARR = 5 mos. feeding post hatch

Phase I - Design

- Collection as smolt (RST) 2009-2012 (age 1+ - 3+)



Fry Origin (Adipose fin)

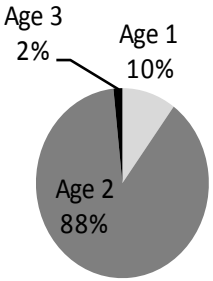


Parr Origin (Clipped)

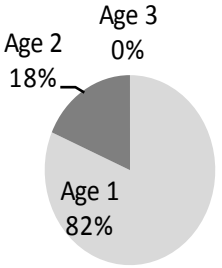
Phase I -Results

- Fry produced fewer, larger, older, smolts migrating at the same time.

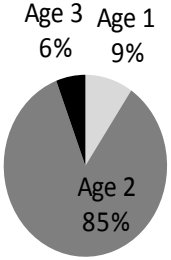
Trait	Fry	Parr
Surv. to smt.	2%	**23%**
Weight	**34g**	21g
Age	**2**	1
Run Time	insig	insig



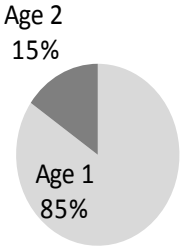
2008 Release: Fry Origin (n=832)



2008 Release: Parr Origin (n=368)

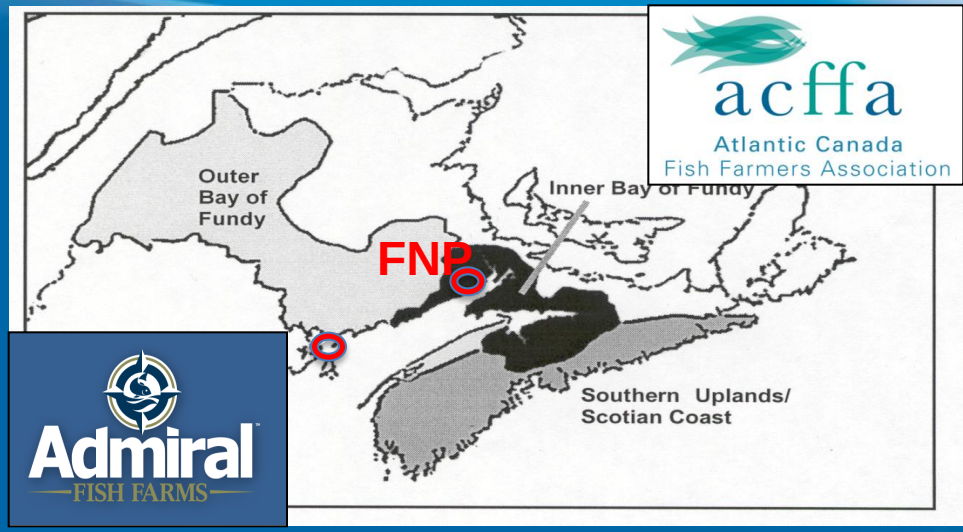


2009 Release: Fry Origin (n=327)



2009 Release: Parr Origin (n=1051)

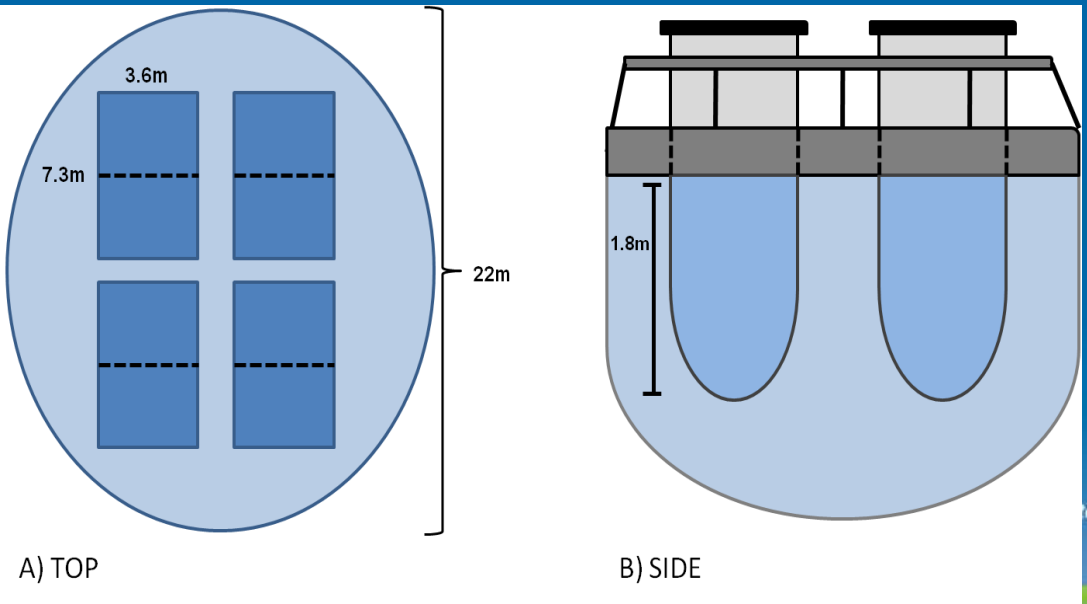
Phase II



-With current low marine survival, a proxy marine environment was used.
- 2010 USR smolts were reared in BoF sea cages during marine life phase.

Phase II - Design

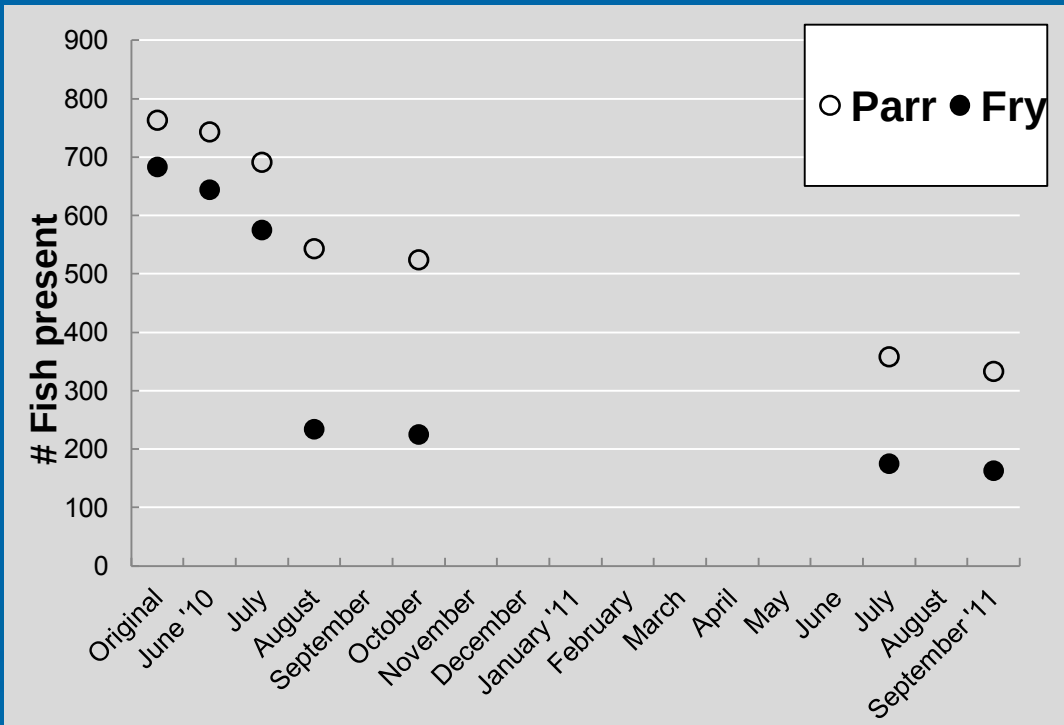
- Regular inventory of cage blocks tracked survival
- 2 growing season-ending inventories to measure size.



Phase II - Results

- Fry produced fewer, bigger, slower growing but same amount of mature adults

Trait	Fry	Parr
Survival	24%	**44%**
Weight Gain	**1202g**	970g
Growth Rate	36 g/g	52 g/g
Maturation Rate	44%	44%



Survival throughout marine rearing phase

Phase III

- 100 fry and 100 parr retained for spawning to monitor egg viability

- 319 were tagged and released to IBoF to monitor homing ability

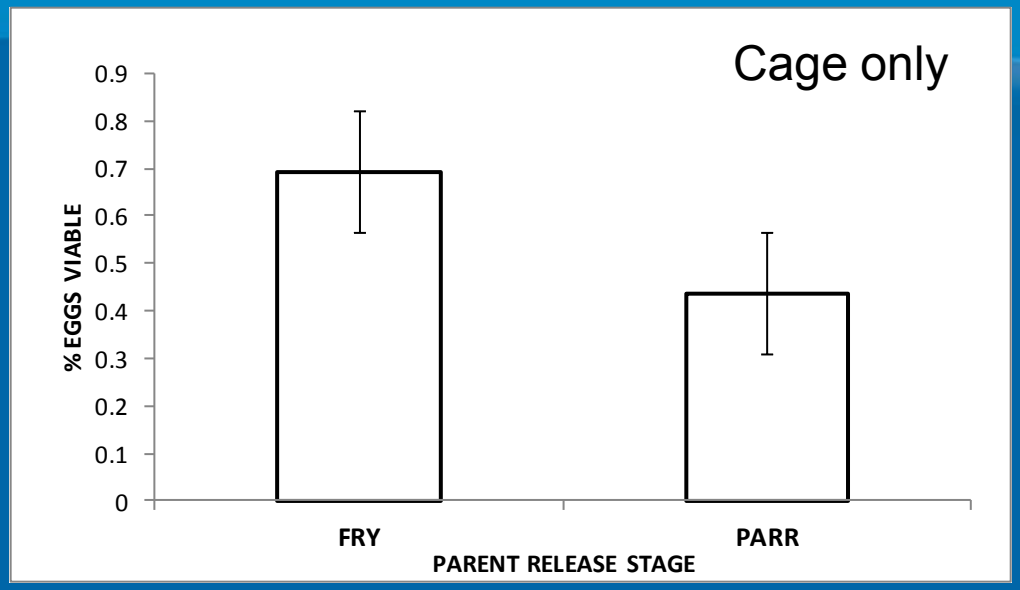
Phase III – Design

Spawning Fry & Parr release-origin parents

14 crosses of Fry parents
9 crosses of Parr parents

Viability recorded weekly for 5 months

Phase III - Results



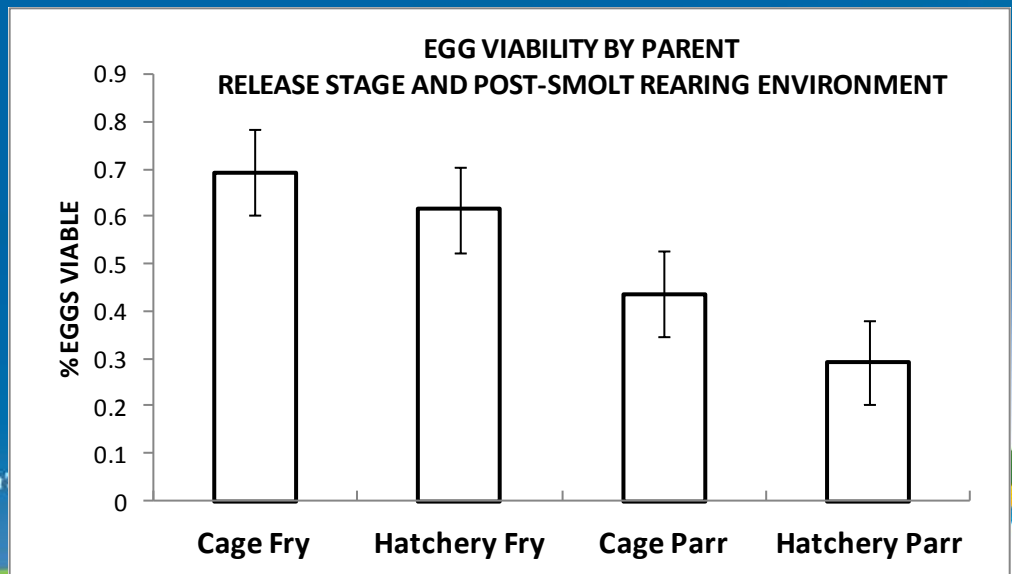
Fry-release parents
reared from smolt in sea cage
produced more viable offspring

Trait	Fry	Parr
Egg viability	**69%**	44%
Egg size	**7.8mm**	7.1mm
Fecundity	1950	1980

Fry-release parents
produced more viable offspring than parr
regardless of post smolt environment

-Later-life exposure mattered but less than early exposure

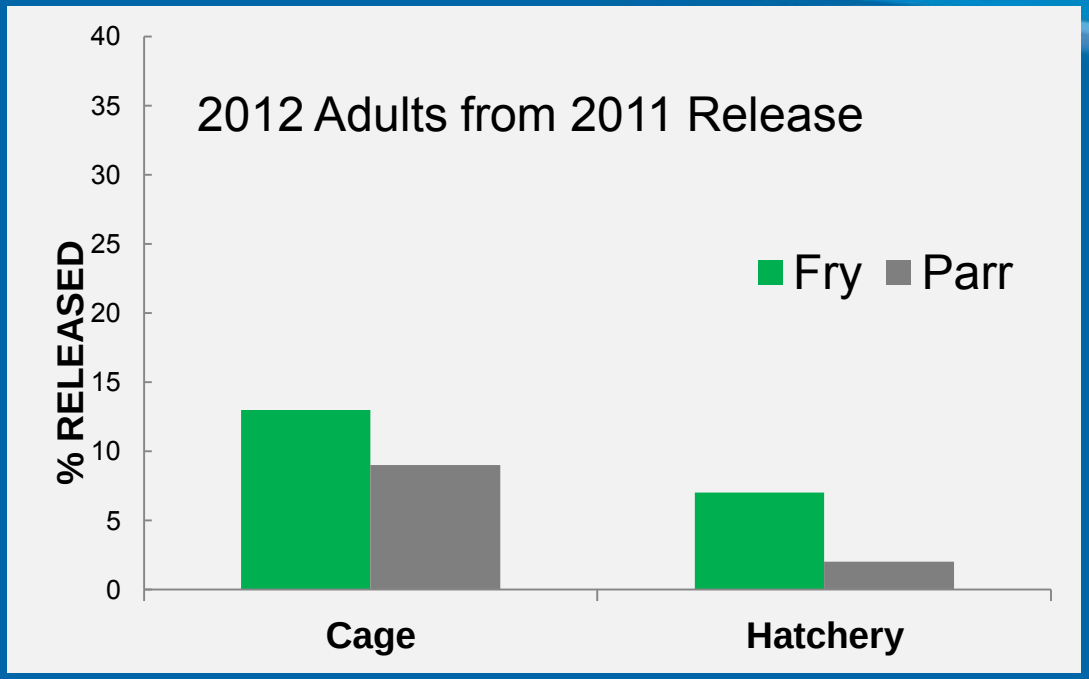
-Fish later released back to FNP



2012 USR Adults, a >20yr high!

42 Observed Adults

2012 USR Adults



Of 188 Cage- and 70 Hatchery-reared 2011 adults:

-11% of Cage returned (13% of Fry, 9% of Parr)

-4% of Hatchery returned (7% of Fry, 2% of Parr)

Results summary

		FRY	PARR
Phase I	**Smolt Size**	LARGER	SMALLER
	Smolt Age	OLDER	YOUNGER
	Smolt Run Time	SAME	SAME
	Release-Smolt Survival	2%	23%
Phase II	**Growth**	SLOWER	FASTER
	Adult Weight	HEAVIER	LIGHTER
	Smolt-Grilse Survival	24%	44%
	Maturation rate	SAME	SAME
Phase III	**Egg Size**	LARGER	SMALLER
	Fecundity	SAME	SAME
	Egg viability	69%	44%
*Untested	***2SW Returns**	13%	9%

Conclusions

- Early-stage exposure may especially shape life-long fitness
- Managers should prefer wild environments shaping these stages when wild fitness is goal (ie survival in bay, progeny)
- Adult releases produce 100% captive-free smolts
- Cage rearing offers powerful potential for adult production for recovery considering historic wild numbers

parkscanada.gc.ca

Partners were key to progress

Inner Bay of Fundy Atlantic Salmon Habitat Recovery

Admiral FISH FARMS

MEMORIAL UNIVERSITY

UNIVERSITÉ Concordia UNIVERSITY

OCEAN TRACKING NETWORK
Headquartered at Dalhousie University, Canada

Atlantic Salmon Federation
Fédération du Saumon Atlantique

acffa
Atlantic Canada Fish Farmers Association

Fisheries and Oceans Canada | Pêches et Océans Canada

New Nouveau Brunswick CANADA

Cooke AQUACULTURE Inc.

Parks Canada | Parcs Canada

Canada

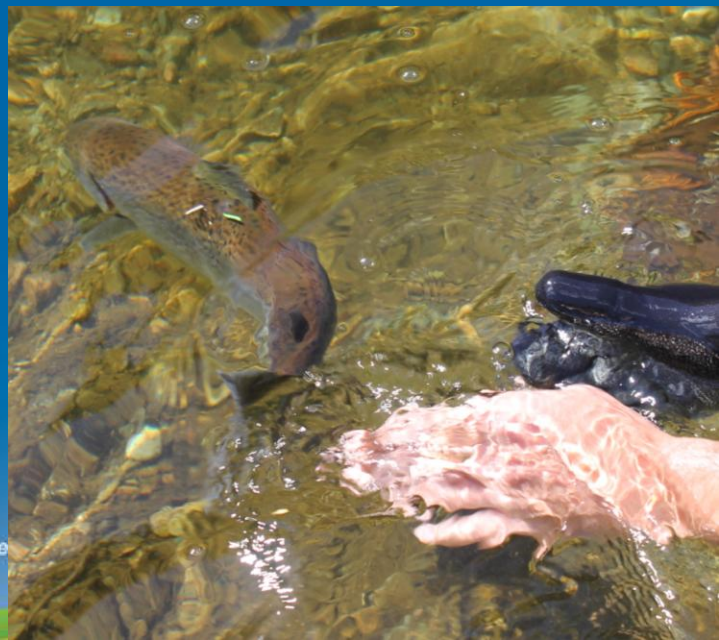
Moving Forward:

New project, new partners, new potential

- Cooke Aqua engaged through ACFFA as primary industry partner
- Fort Folly First Nation engaged with support from DFO for Petitcodiac
- Through collaboration with NBDAAF, FNP and Petitcodiac smolt held at Huntsman and transferred to Grand Manan upon health clearance.

Anticipated outcomes

- Adults releases to rivers near historic #’s 2014-’18.
- Captive-free smolt migrations 2018-’22.
- Natural returns 2019-’23
- Novel accomplishments in conservation strategy

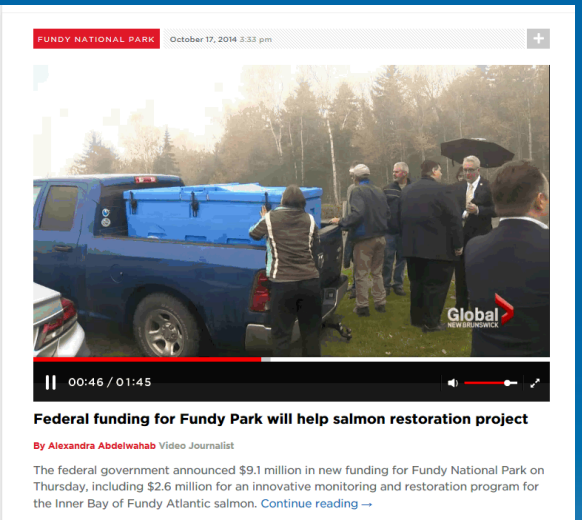


Challenges to address

- Cage design for growing small #’s efficiently
- Optimizing diet for wild-type development
- Maximizing maturation/grilsing
- Maximizing spawning activity after release
- Monitoring fitness and effects on ecosystem

Early Success

- Minster Moore announces collaboration
- Feature in National TV Documentary
- Several partner interviews in media



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Partners will continue = progress

Cooke AQUACULTURE Inc.

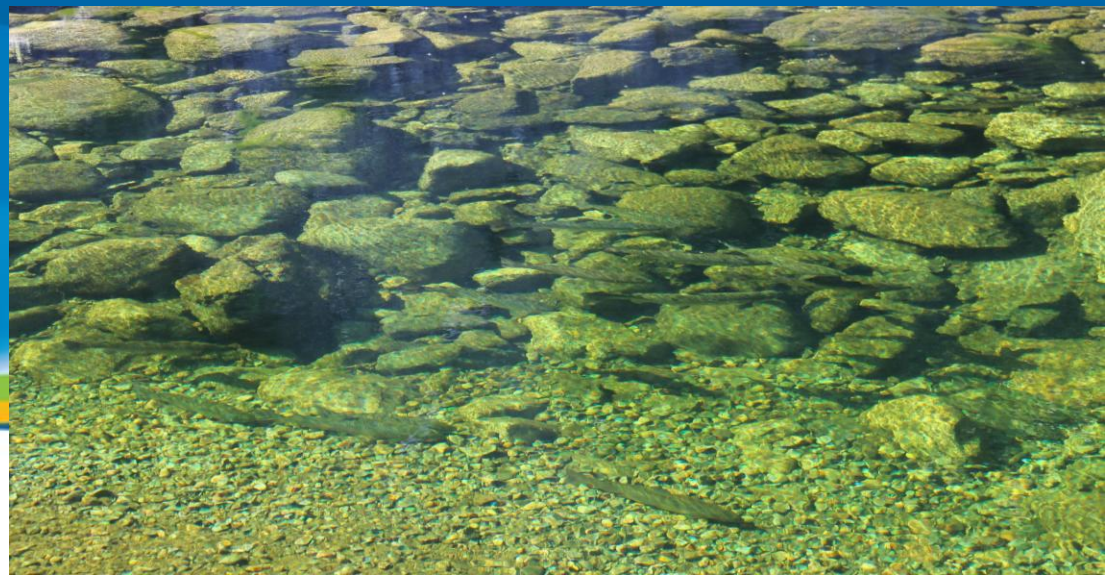
acffa
Atlantic Canada Fish Farmers Association

Inner Bay of Fundy Atlantic Salmon Habitat Recovery

New Nouveau Brunswick CANADA

Fisheries and Oceans Canada | Pêches et Océans Canada

HUNTSMAN
Ocean Sciences Océaniques



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Huntsman Marine Science Centre St. Andrews, NB

Individual and Family Selection: Maintaining Genetic Diversity in the Breeding Nucleus

Amber Garber

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Overview

- ✓ **Everyone needs a broodstock program...**
  - **What is a broodstock program?**
  - **Overview**
  - **Breeding nucleus versus production**

Images from: www.northernharvestseafarm.com

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What is the purpose?

- Retain genetic diversity
  - For stock enhancement retain rare alleles
- Prevent inbreeding
- Improve traits to reduce cost of production, increase health of animal, faster time to harvest
- Increase in survival and growth by 1% and 5%
  - Direct cost savings of $0.03/kilo at 1% = +$300,000 profit for every 10,000 tonnes of production
  - Direct cost savings of $0.07/kilo at 5% = +$700,000 profit for every 10,000 tonnes of production

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Step 1 – Define Goals

- Goals – What industry would like to accomplish?
  - Improved growth, disease resistance
- Are breeding programs already in place?
  - Does this program have goals that are appropriate for present culture conditions?
  - If yes, then purchase stocks for culture
- If selection goals and/or stocks are not appropriate for current culture system and broodstock not suitable or available
  - Establish new broodstock development program
- Steps 2 and 3 – Founder stock to be used and collecting appropriate individuals

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Traits Considering

- ✓ Growth
- ✓ Resistance to Bacterial Kidney Disease (*Renibacterium salmoninarum*)
- ✓ Resistance to Sea Lice (*Lepeophtheirus salmonis*)
- ✓ Survival
- ✓ Incidence of deformities
- ✓ Fillet yield
- ✓ Fillet quality
- ✓ Sexual maturation

Images from: www.northernharvestseafarm.com

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Initiation of a Broodstock Program

Step 4 – Establish Program/Evaluate Performance

Family Production

- ✓ Communal rearing
- ✓ Individual family tanks

Images from: www.northernharvestseafarm.com

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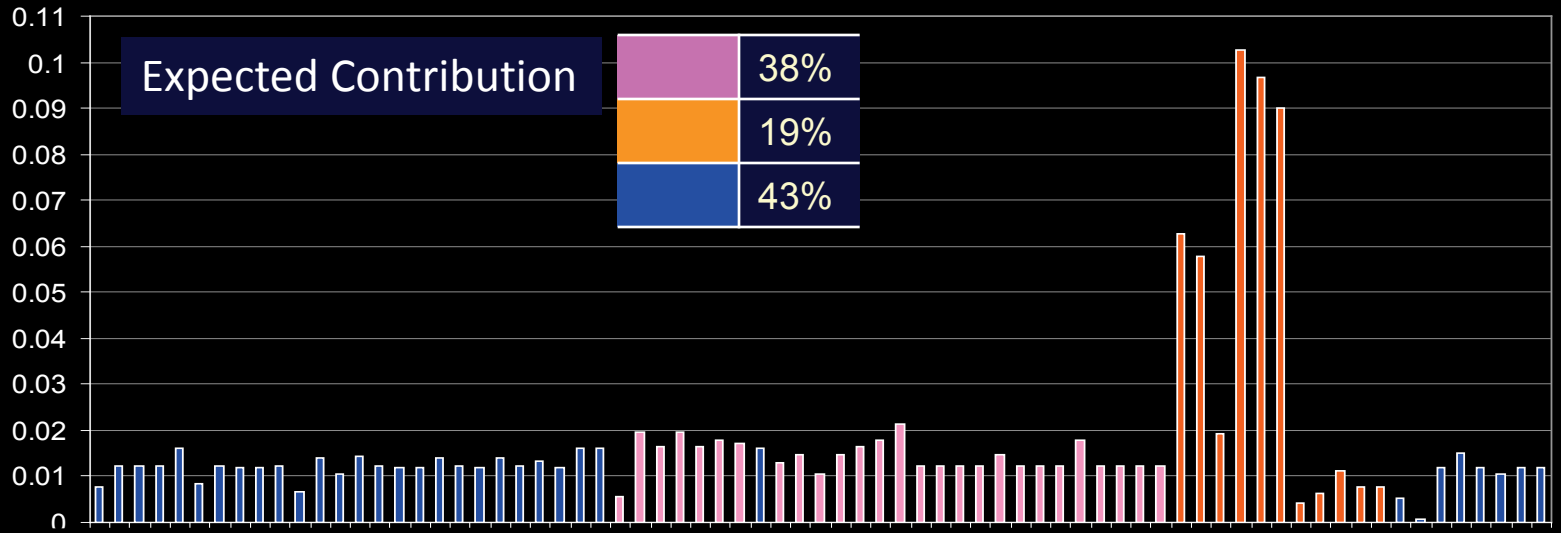
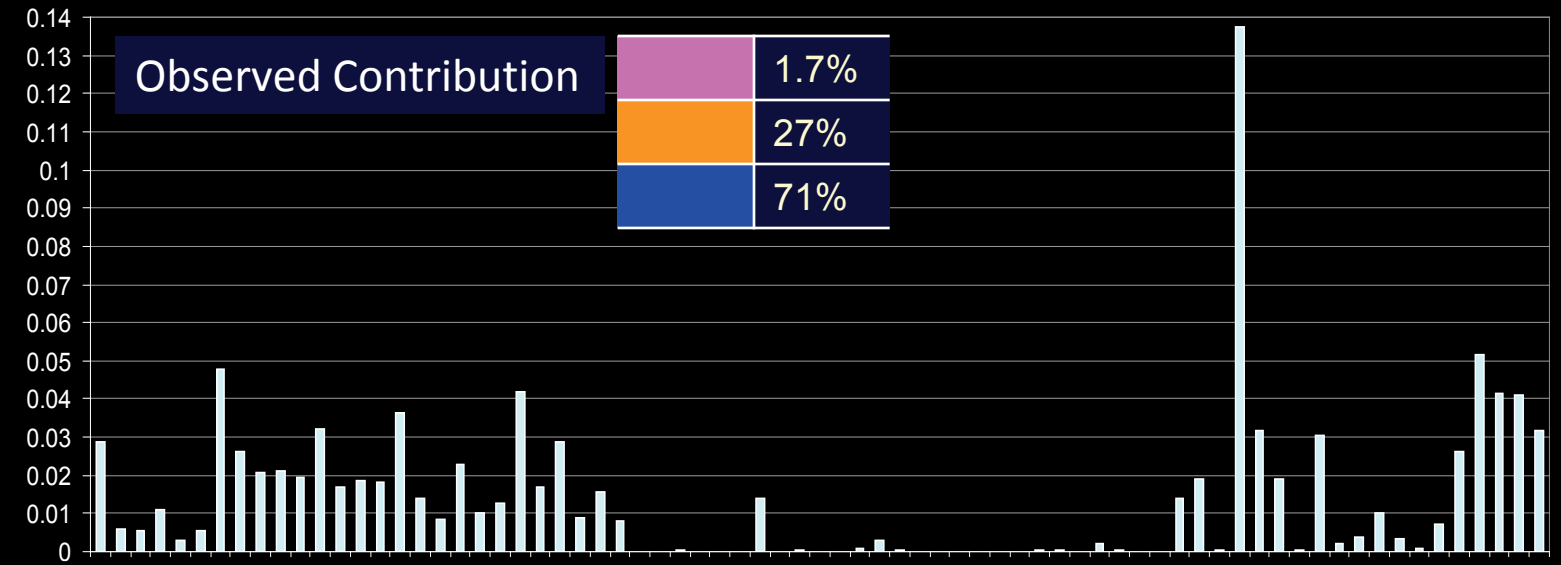
Communal Rearing

Example of progeny from individual families mixed when they were too small to be physically tagged





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Family Production

- **Communal tank(s)**
  - Potential issue – differential mortality
    - Try to mix equal numbers of individuals from each family at an early stage but when initial mortality has subsided to some extent
  - Less tanks to maintain (if multiple tanks can introduce environmental variation here as well)
  - Individual identification by fin clipping and genotyping a requirement when PIT tagging
  - May lose some family data (e.g., genotyping after removing slinks and vaccination to reduce costs)
- **Individual family tanks**
  - Potential issue – environmental variation
    - Try to minimize any environmental variation between tanks – stocking density similar, water quality, feeding, etc.
  - Many small tanks to maintain
  - May choose not to genotype (one tank = one family)
  - Ability to obtain data from entire family

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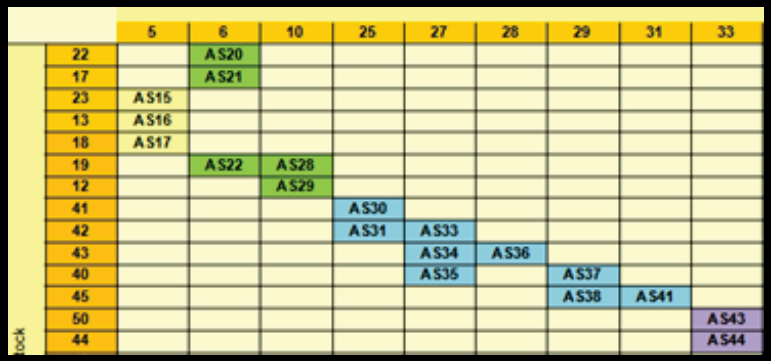
Steps to Production

- Broodstock acquisition and spawning
- Breeding methodology
  - Full factorial
  - Partial factorial
- Assessments
  - When to measure fish – PIT tagging, pre-smolt, post-smolt, pre-spawn, spawn, challenge testing
- Data Analysis
  - Type of statistical model (e.g., animal model)
  - Type of analysis – univariate, multivariate
  - Random effects – Fish and Fish&Family
    - Fish – All relationships/relatedness (FS, HS)
    - Fish&Family – Adds non-heritable effects result of specific sire and dam
  - Fixed effects – vary with analysis – tank, year class, system, etc



	5	6	10	25	27	28	29	31	33
22		AS20							
17		AS21							
23	AS15								
13	AS16								
18	AS17								
19		AS22	AS28						
12			AS29						
41				AS30					
42				AS31	AS33				
43					AS34	AS36			
40					AS35		AS37		
45							AS38	AS41	
50									AS43
44									AS44

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Heritability

h^2 = Additive Variance/Phenotypic Variance

- ✓ **Resemblance between relatives**
  - **How similar are you to your mother and father?**
  - **How similar are you to a first cousin or other close relative?**
- ✓ **When selective pressure is exerted to improve a trait, response of the trait is directly related to the narrow-sense heritability (h^2)**

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Initiation of a Broodstock Program

Step 4 – Establish Program/Evaluate Performance

- ✓ There is more than one way to skin a fillet…
  - Family Selection – ranking of family groups according to the mean performance of each family and families are retained or discarded from breeding program
  - Combined Selection (Individual and Family)
    - ✓ Estimate breeding value of individual - data on individual, information on full and half sibs, pedigree
    - ✓ Typically most efficient type of selection
    - ✓ Used in livestock breeding

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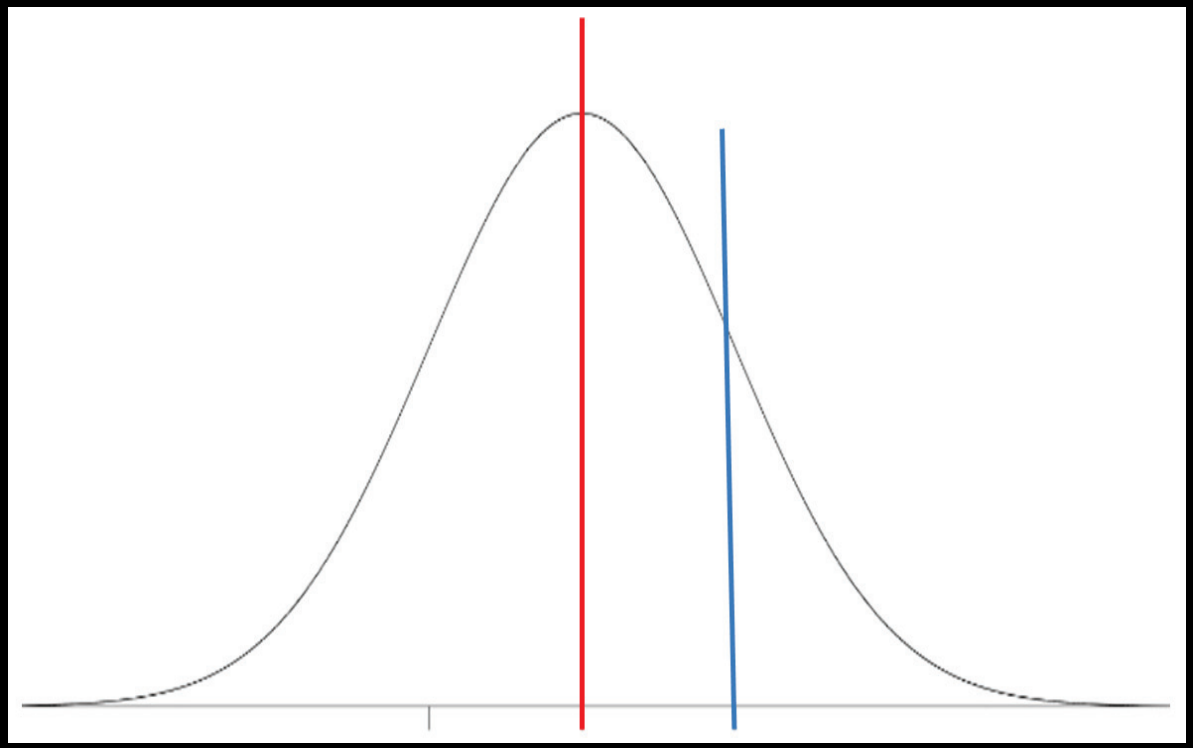
Continuous Normal Distribution



Individuals are selected based on their breeding value which likely means that genetics from a larger number of families are retained

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Step 4 – Establish Program/Evaluate Performance

- Method of selection ultimately based on:
  - Facilities and financial resources available
  - Heritability of the targeted trait
  - Nature of the trait (e.g., normally distributed; whether records can be obtained on live individuals, etc.)
  - Reproductive capacity of the species

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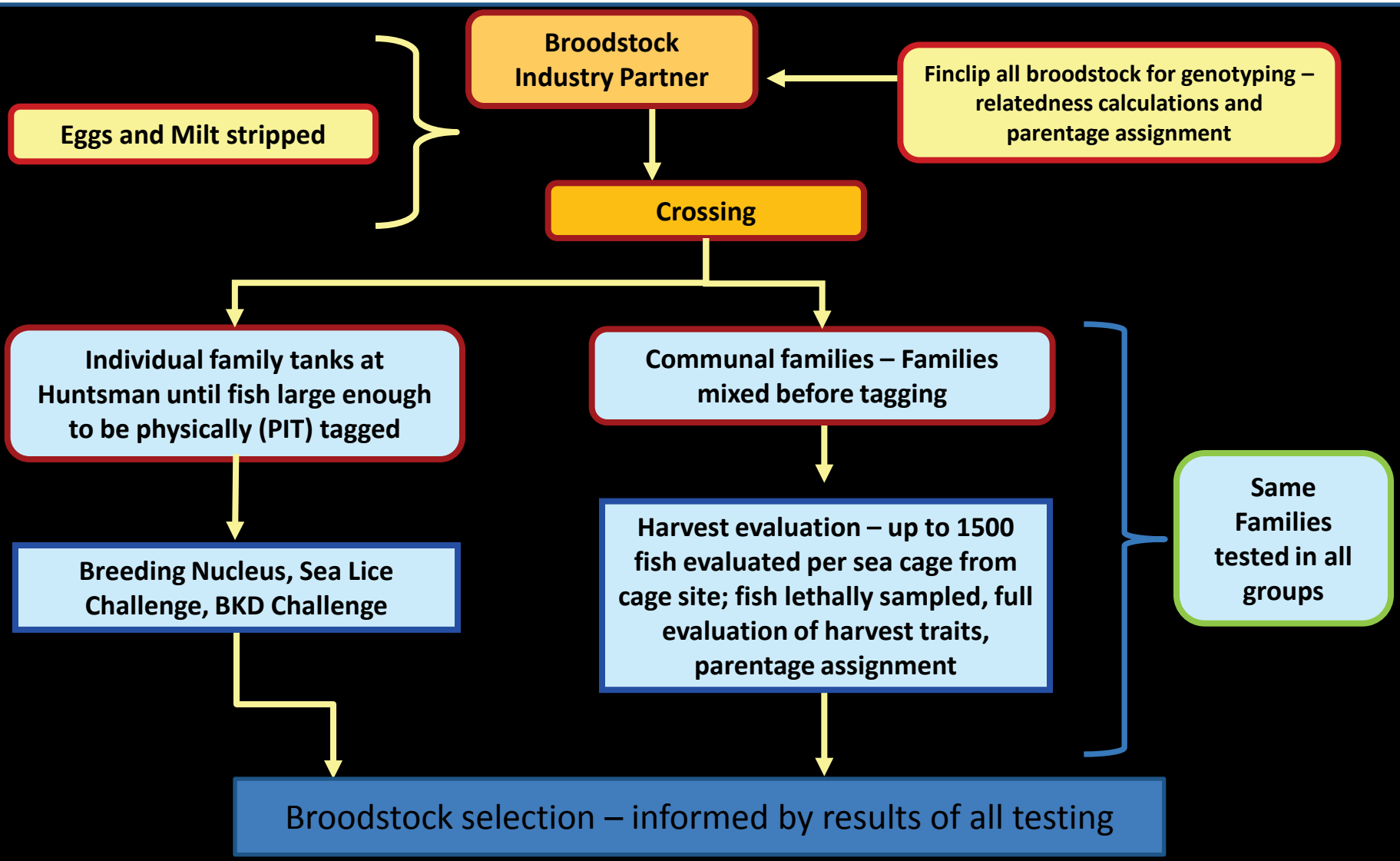
HMSC Program



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Traits Considering

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- ✓ Sexual maturation

Images from: www.northernharvestseafarm.com

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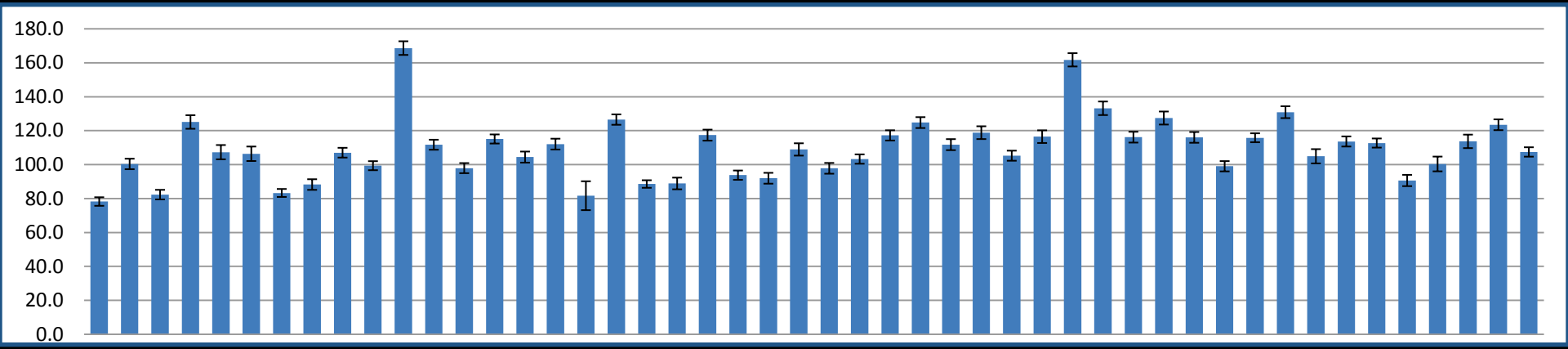
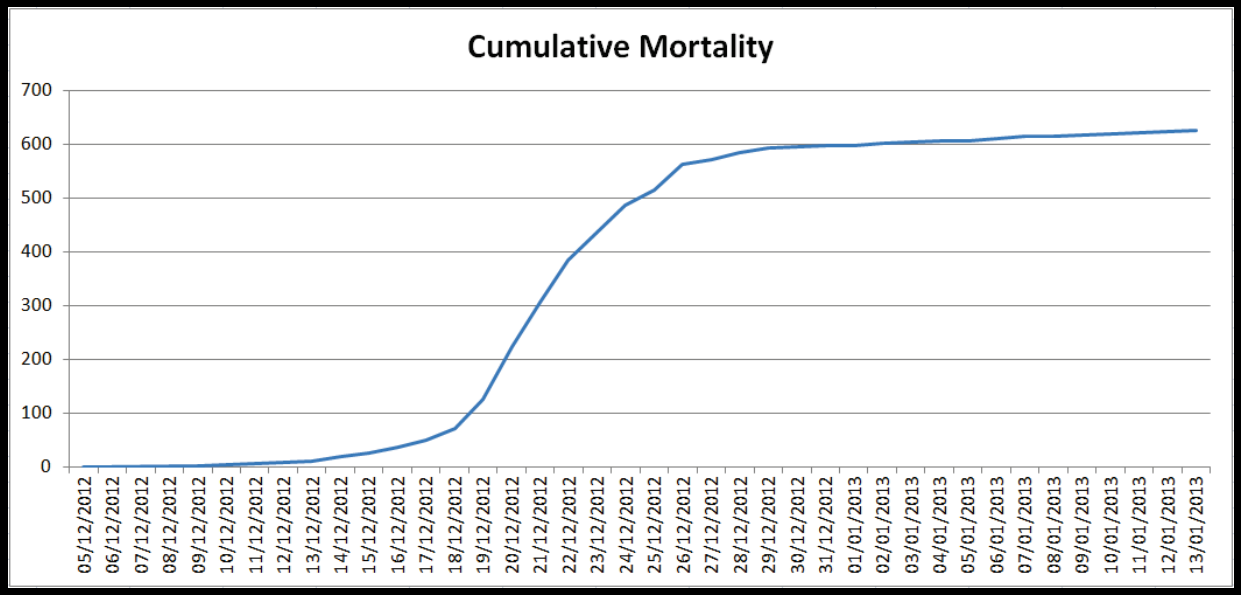
Individual and Family Variation in Growth



- $h^2 = 0.35 \pm 0.10$, up to 10% gains each generation (Norwegian BP)
- 0.2-0.3 other studies for Norwegian Atl salmon of 2-3 yrs
- Quinton et al. (2005), St. John River stock, 0.1-0.2 in 2-3 yrs (univariate, multiple sites analyzed together)
- ✓ 41918 fish, 132 families, 67 sires, 77 dams

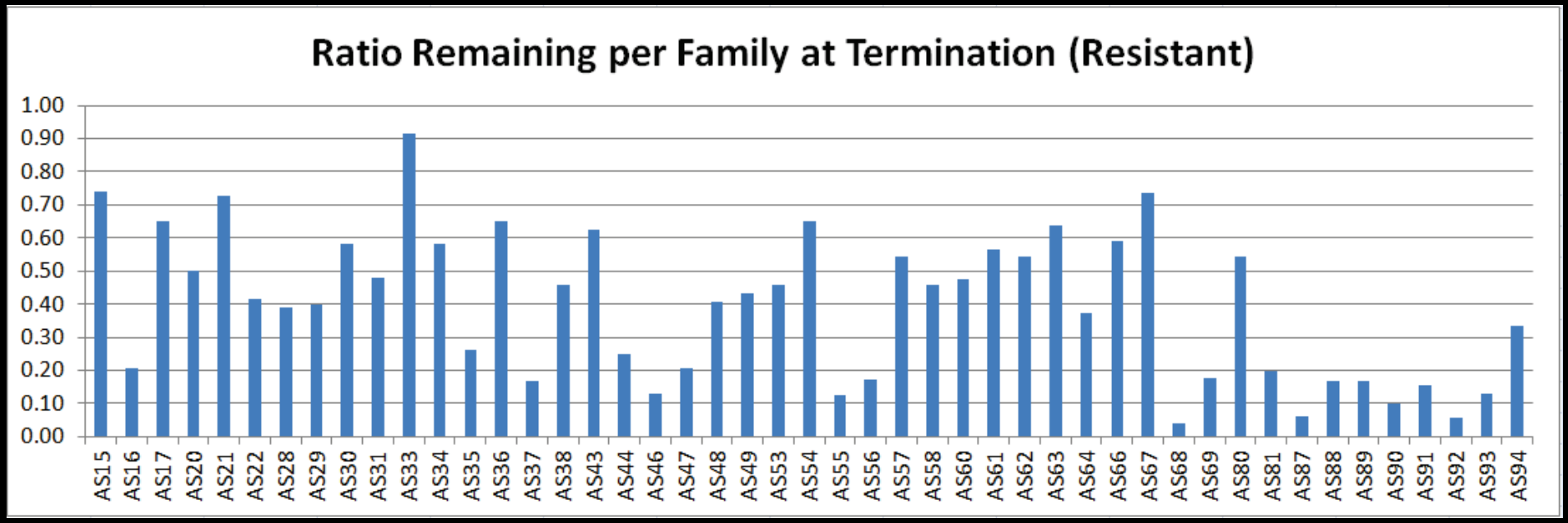
✓ **0.27±0.06 at ~2.5 yrs**

Individual and Family Variation in BKD Resistance



- ✓ Challenge ran from 5 December 2012 to 13 Jan 2013
- ✓ Each salmon ip injected
- ✓ 48 families, 1037 salmon challenged
- ✓ Challenge terminated when mortality had subsided
  - Remaining salmon processed day 40-41
    - Ext/int appearance, measurements, samples collected

Individual and Family Variation in BKD Resistance



- ○ Not studied as often, $h^2 = 0.23$ (Gjedrem & Gjoen 1995)
- ✓ Preliminary estimate of $h^2 = 0.28 \pm 0.15$ bivariate (wt, days to succumb), random fish & family, fixed tank

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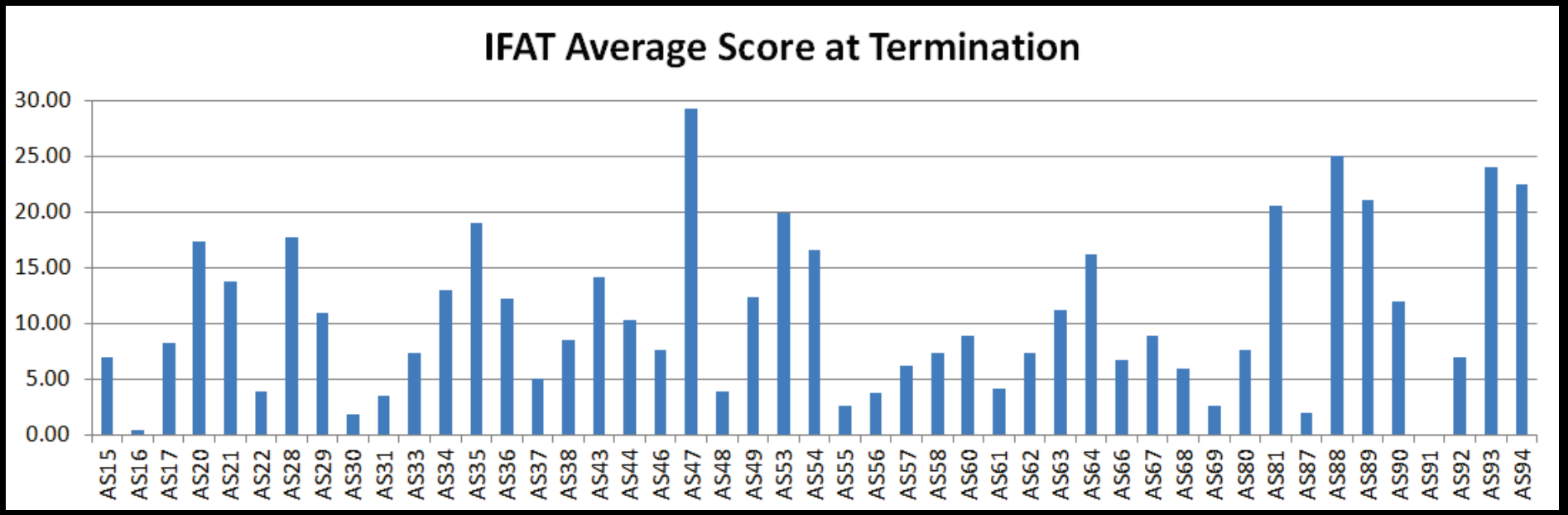
Individual and Family Variation in BKD Resistance



- ✓ **148 of the 421 salmon at termination had IFAT scores of 0 (35%)**

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Broodstock Program Sea Lice Challenge

2010YC – challenged in 2012

- 48 families tested
- 31 sires, 24 dams
- every family represented in each tank
- 12-33 fish per family
- 1102 total fish across all tanks & families

2011YC – challenged in 2013

- 83 families tested
- 36 sires, 53 dams
- each family in 3 tanks
- 10-21 fish per family
- 1329 total fish across all tanks & families

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Heritability

- ✓ Bivariate analysis with weight
  - ✓ Random fish model; year class and tank fixed
    - ✓ $h^2 = 0.33 \pm 0.05$
  - ✓ Random fish & family model; year class and tank fixed
    - ✓ $h^2 = 0.20 \pm 0.07$

Images from: www.northernharvestseafarm.com

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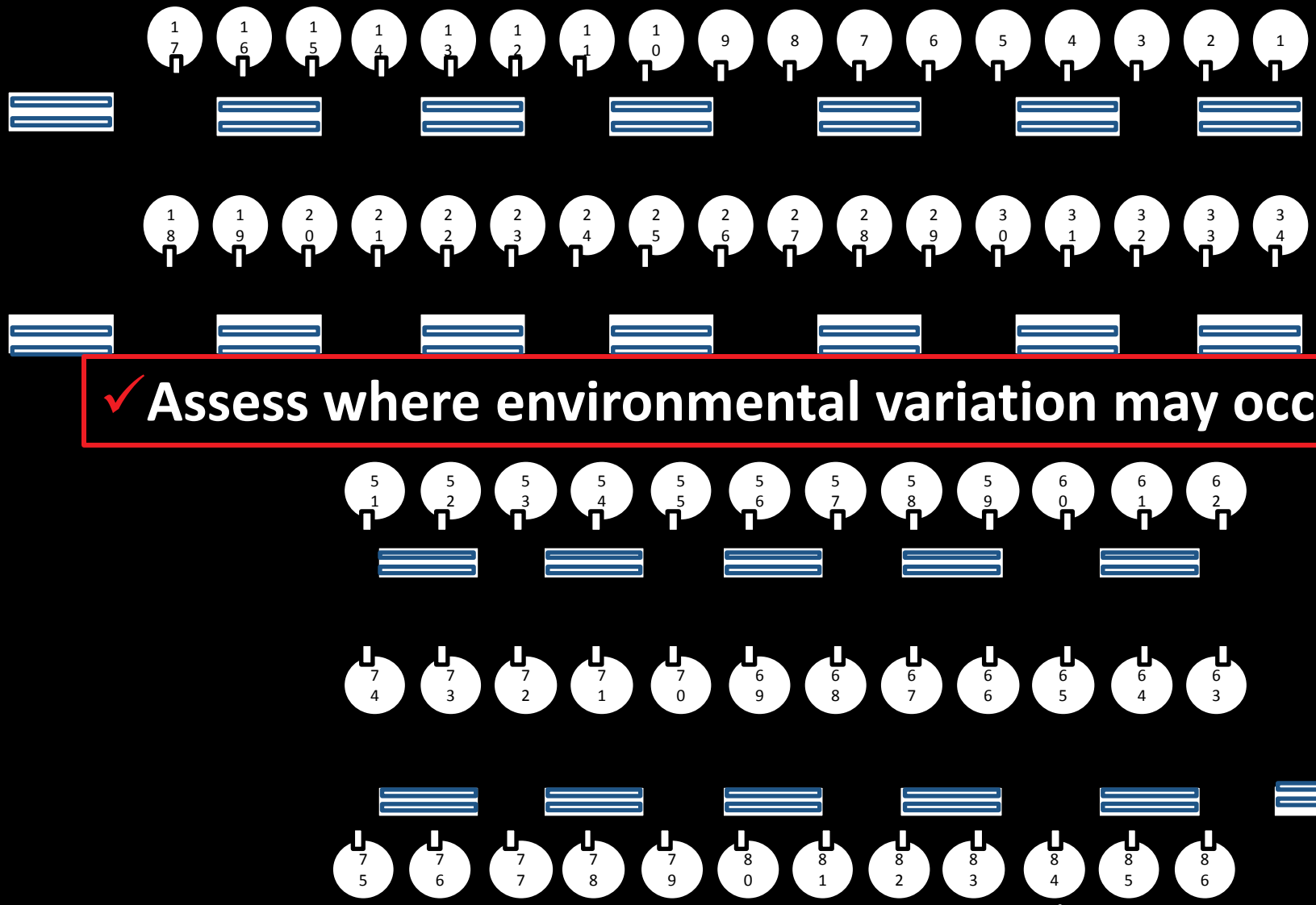
Assessing Cause of Deformities

Families Located in Individual Family Tanks



✓ Assess where environmental variation may occur

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Families Located in Individual Family Tanks

✓Assess where environmental variation may occur

- ✓Year class
  - 2010, 2011, 2012
- ✓Tanks
  - 86 tanks
- ✓Row
  - Six rows
- ✓System
  - Two systems
- ✓Flow
  - Water enters tanks on right or left

Fixed Effects

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Environmental Variation in Prevalence of Deformities

- ✓ Significance of Fixed Effects
  - ✓ Using SAS, mixed procedure, REML
  - ✓ Random family
  - ✓ Trait absence/presence (1,2) deformity
  - ✓ 57663 Fish, 214 Families, 133 Sires, 132 Dams
    - Year Class $P<0.0001$
    - Tank $P=0.7283$
    - Row $P=0.4051$
    - System $P=0.3743$
    - Flow $P=0.1643$

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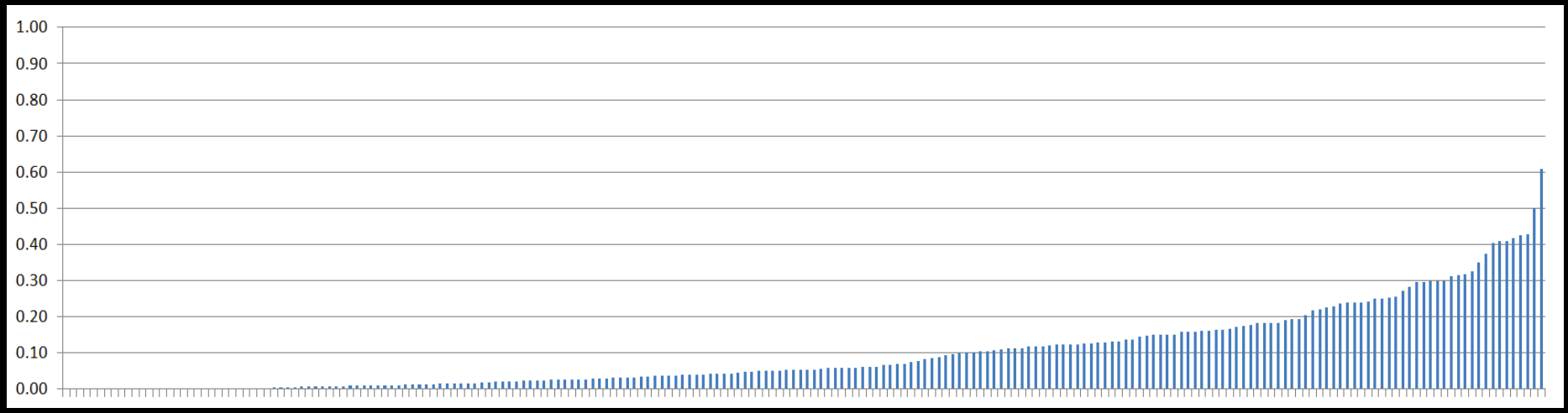
Genetic Variation in Prevalence of Deformities



- ✓ 57663 individuals, 214 families, 133 sires, 132 dams
- ✓ 90% of the salmon have no deformities
- ✓ 10% displayed deformities
  - 68% were slight and would likely not be caught by industry
- ✓ 8% opercula, <2% jaw/head, <0.5% spinal

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Developing a TMI

- ✓ Too Much Information!! or Total Merit Index
- ✓ How will each trait play with another?
  - Strong positive genetic correlation – YEAH!?! = ease in improving both traits simultaneously
    - Positive can be bad if one trait going up while the other goes up is a bad thing (e.g., fast growth and early sexual maturation)
  - Strong negative genetic correlation – YEAH!?! = ease in improving both traits simultaneously
    - Negative can be good if one trait going up while the other goes down is a good thing (e.g., fast growth and reduced number of sea lice/body weight)
  - No real genetic correlation – Ut-Oh!! = Unable to improve both traits simultaneously
    - Find another way to improve a trait

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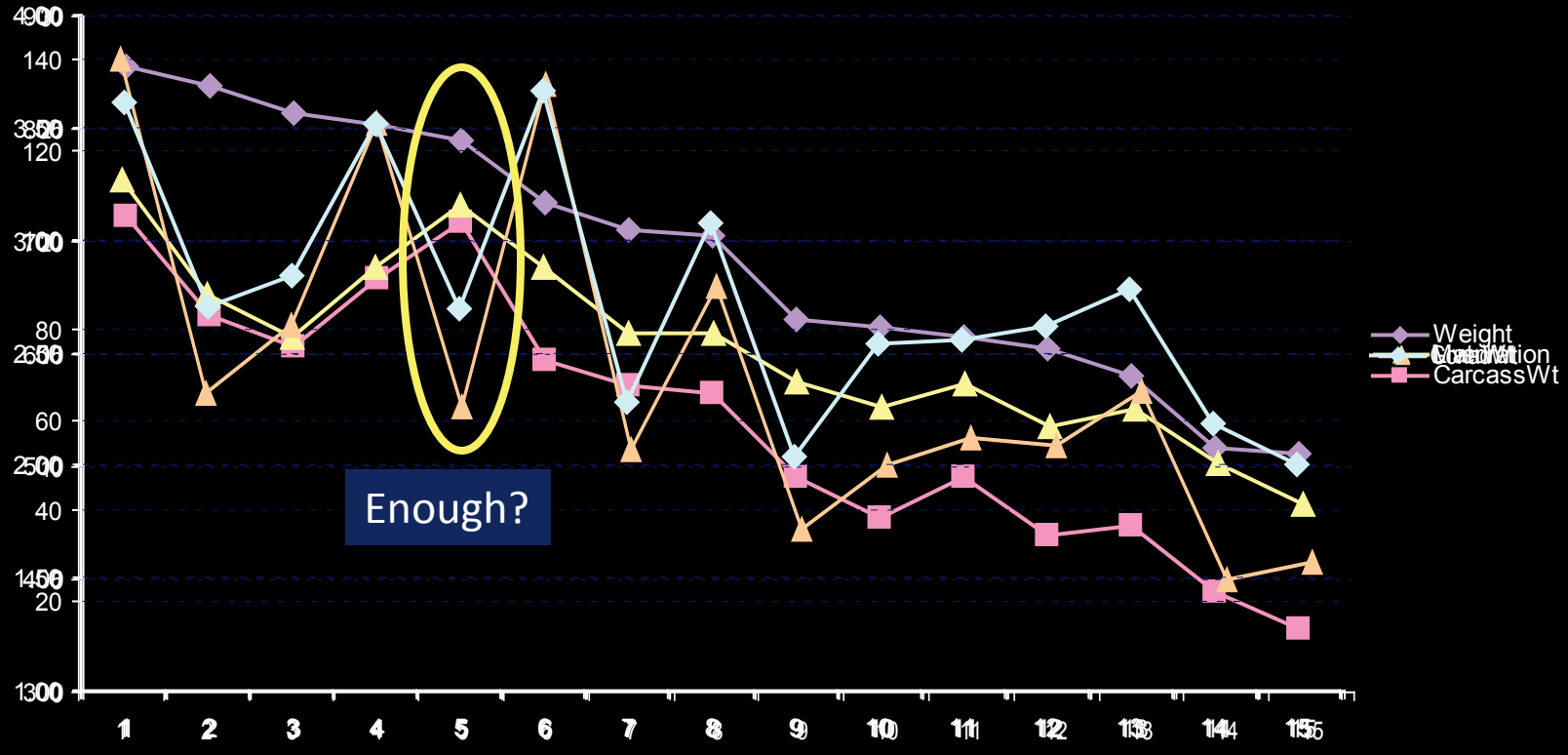
Developing a TMI



- ✓ Variation of Means for 15 Families Shown
  - ✓ Total Weight (512-855g)
  - ✓ Carcass Wt (355-722g)
  - ✓ Liver Wt (41-113g)
  - ✓ Gonad Wt (6-28g)
  - ✓ Maturation (2.0-3.7)

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Developing a TMI

Family	FR wt2	FR wt4	FR BKD	FR Sea Lice	FR Deformity	FR Smt Mortality	FR ESM
1001063	2	4	4	2	1	3	30
1001020	4	5	22	3	1	8	33
1001055	18	6	39	23	14	32	23
1001038	20	7	16	7	19	16	32
1001067	25	8	12	17	18	39	10
1001016	9	9	47	19	1	6	28
1001047	8	10	38	6	24	17	21
1001037	16	11	37	28	28	25	24

FR = Family Rank based on estimated breeding value for a family

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Relational Database Management Program – All Data from Egg to Plate!!

Tag reader selected to scan tag numbers directly into worksheet.

'Excel' button opens and exports data to Excel.

CERES

File Edit Help Username Password Logout

Login Notes Connect Data Entry DataSets External tabPage1 tabPage5

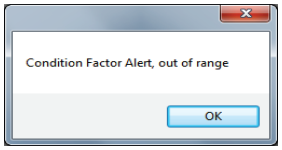
Active Forms T4S2000 (direct) Save Excel Stats

Total Weight (g)	Standard Length (cm)	Condition Factor (SL)	Deformity Numerical Score	Deformities Letter Code	Comments	PIT Tag Number	New Tank ID	Tank A2	Tank A4	n (Tank A1)	Total	Family ID	Old Tank Id	Individual Fish Number	Group	Date	Time
7.6	7.8	1.6	0000			945000000267857	a2	8	8	3	19	1001015	24	100100001	Breeding N		3:05 PM
4.8	7.7	1.05	0000			945000000770777	a2	8	8	3	19	1001015	24	100100002			
4.6	6.7	1.53	0000			945000000199928	a2	8	8	3	19	1001015	24	100100003			
7.0	7.7	1.53	0000			945000000576823	a4	8	8	3	19	1001015	24	100100005			
6.4	7.5	1.52	0000			945000000366936	a2	8	8	3	19	1001015	24	100100004	Bre		PM
4.4	6.6	1.53	0000			945000000188680	a4	8	8	3	19	1001015	24	100100006	Challenge Experiments	6/20/2012	3:12 PM
5.2	7.1	1.45	0000			945000000157184	a4	8	8	3	19	1001015	24	100100007	Challenge Experiments	6/20/2012	3:14 PM
5.0	6.8	1.59	0020	scf			n	8	8	3	19	1001015	24	100100008	Surplus	6/20/2012	3:15 PM
6.6	7.5	1.56	0000			945000000798535	a2	8	8	3	19	1001015	24	100100009	Breeding Nucleus	6/20/2012	3:18 PM
5.3	7.1	1.48	0000			945000000884231	a2	8	8	3	19	1001015	24	100100011	Breeding Nucleus	6/20/2012	3:20 PM
4.1	6.6	1.43	0020	edf	eroded dorsal fin		n	8	8	3	19	1001015	24	100100010	Surplus	6/20/2012	3:20 PM
			0000			945000000776191	a4	8	8	3	19	1001015	24	100100012	Challenge Experiments	6/20/2012	3:21 PM
						945000000363134	a4	8	8	3	19	1001015	24	100100013	Challenge Experiments	6/20/2012	3:22 PM
			0000			945000000354253	a2	8	8	3	19	1001015	24	100100014	Breeding Nucleus	6/20/2012	3:28 PM
5.0	6.9	1.52	0020	scf			n	8	8	3	19	1001015	24	100100015	Surplus	6/20/2012	3:29 PM
7.1	7.2	1.9	0000			939000001194992	a4	8	8	3	19	1001015	24	100100017	Challenge Experiments	6/20/2012	3:30 PM
6.0	7.4	1.48	0000			945000000175250	a4	8	8	3	19	1001015	24	100100018			3:30 PM
7.0	7.5	1.66	0000			939000001178214	a							100			M
7.2	7.7	1.58	0000			939000001231456	a							100			PM
5.5	6.6	1.91												100100020			3:40 PM

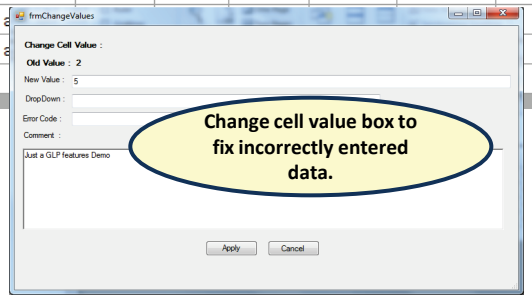
Counts can be completed on any column (e.g., count number of fish per treatment/tank).

Calculations made as data is entered.

Right click in a cell to set autoincrement, repeating values, etc. in real time.



Alerts set to indicate when data or calculation out of specified range.



Change cell value box to fix incorrectly entered data.

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Program Development Support Provided By:

Atlantic Canada Opportunities Agency
Agence de promotion économique du Canada atlantique
Canada

FI NB IF
INNOVATION

Northern Harvest Sea Farms

Images from: www.northernharvestseafarm.com

The NAIA Ensiling Demonstration Project (Salmon keeping cows warm at night).

Darrell Green
Research and Development Coordinator

Overview

- The Challenge
  - Fish material management in NL
  - Infrastructure and options (lack thereof)
- The Solution
  - Why silage may work in NL
- The Approach
  - Project Goals and Objectives
  - Project overview

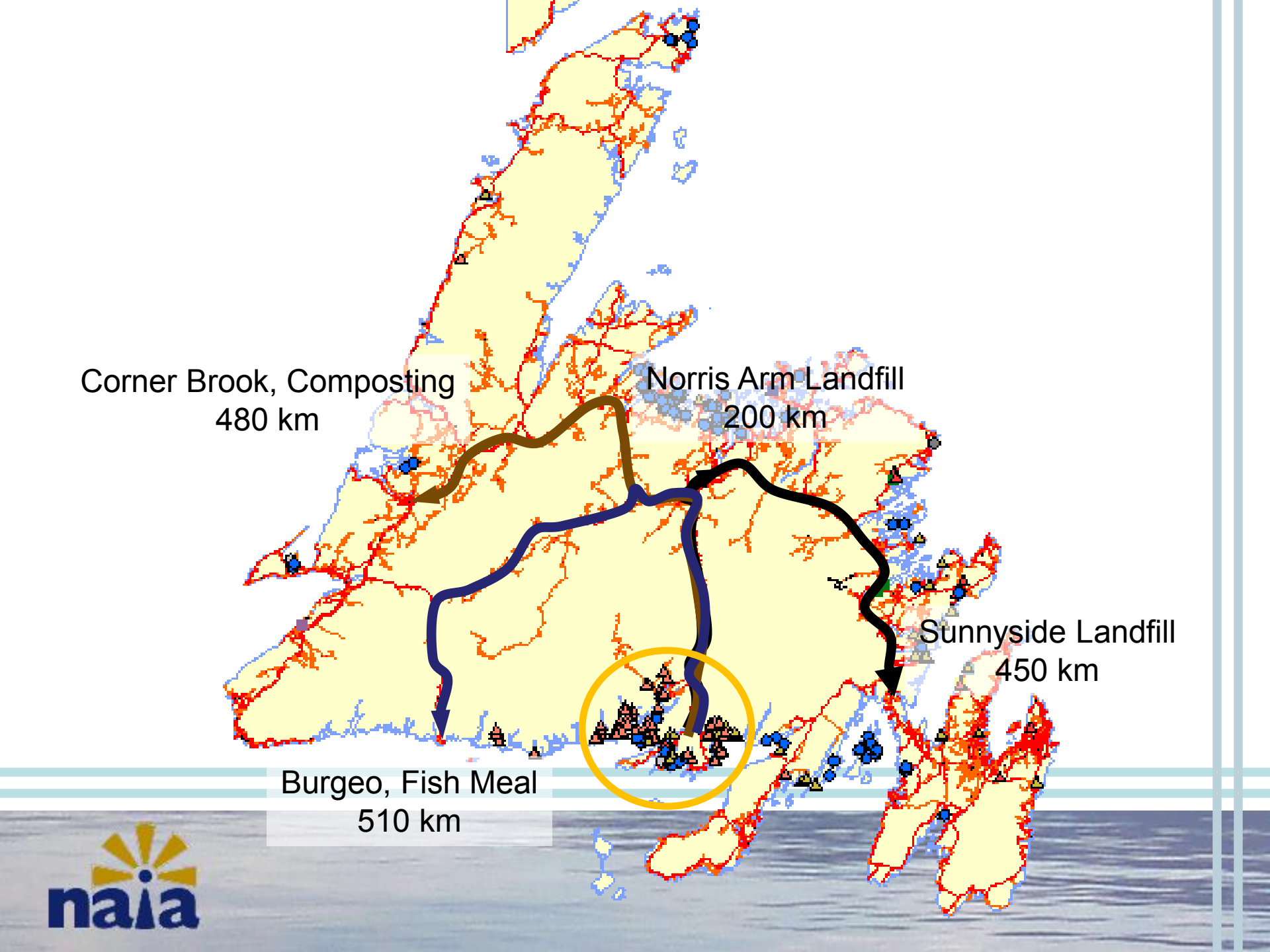
Management of By-products – Newfoundland and Labrador

Project Focus

Year	Harvest (MT)	Mortalities (MT)	Offal (MT)	Total (MT)
2011	15,338	1,841	3,068	4,908
2012	19,126	2,295	3,825	6,120
2013	22,200	2,945	3,807	6,752
2020	45,000	8,300	11,900	14,000

Limited / Changing Options in NL

- Composting infrastructure not well established
  - 1 commercial company – not currently in operation
  - Municipal composting programs non-existent
- Landfills
  - Small local landfills set up for residential only
  - Norris Arm Regional Waste Mangmt Facility – 200 KMs
  - Norris Arm - Organic facility not available
- Rendering
  - 1 commercial company
  - Far from farming area and expensive


Corner Brook, Composting
480 km
Norris Arm Landfill
200 km
Sunnyside Landfill
450 km
Burgeo, Fish Meal
510 km

Management of mortalities

- Summary: Why silage may be a good option
  - All options are costly (but silage has costs too)
  - Current option = 450 km = $$$
  - Available options change – up to 2 years ago; composting - up to 1 year ago; Norris Arm WMF
  - High level of uncertainty in disposal options
  - Changes add costs (employees' time, logistics) and are challenging
  - Consolidation of efforts (e.g. transfer station?) for silage handling may reduce overall costs ???

Ensiling of fish wastes

- History
  - Marine Institute of Memorial University
    - Experimental projects for almost 20 years.
    - Capture fisheries. No pressure to invest – ocean dumping allowed - easier / cheaper.
  - Gray Aqua Group – experiments - silage for fertilizer
    - Silage from morts – liquid fertilizer.
    - NSAC and NL Fed. Agriculture
    - Trials on crops - 2011, 2012, 2013.
    - Research scale.

The NAIA Ensiling Demo Project

- Goal
  1. Promote the use of silage for mort handling
  2. Show benefits
     A. biosecure practice - inactivates pathogenic organisms on site
     B. stabilizes organic constituents of fish mortalities for further use, thus reducing reliance on landfilling
  3. Encourage the development of silage utilization in NL
     - Open other options for disposal / use

The NAIA Ensiling Demo Project

- Objectives

  Part 1 – trip to investigate industry practices in Scotland / Norway – connect with supply companies

The NAIA Ensiling Demo Project

Attended by:

Salmonid farming companies:

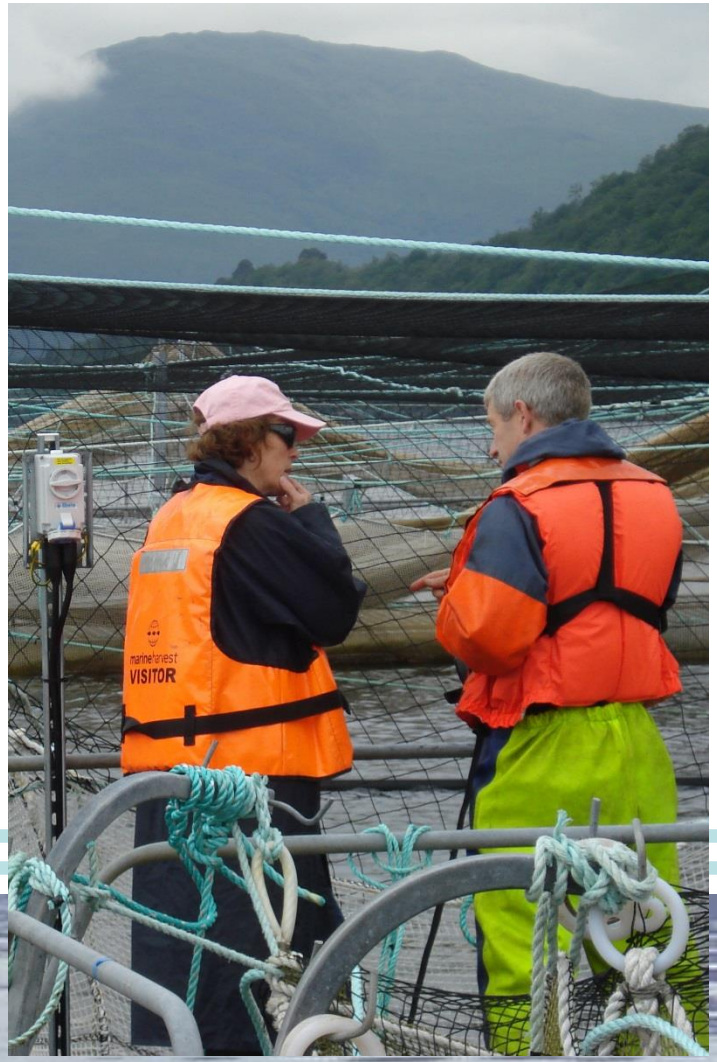
- Northern Harvest Sea Farms NL
- Cold Ocean Salmon
- Nova Fish Farms
- Gray Aqua Group Ltd.

Processing companies:

- Barry Group
- Shell Ex

The NAIA Ensiling Demo Project

- Farm visits



The NAIA Ensiling Demo Project

- Ensiling systems and equipment

The NAIA Ensiling Demo Project

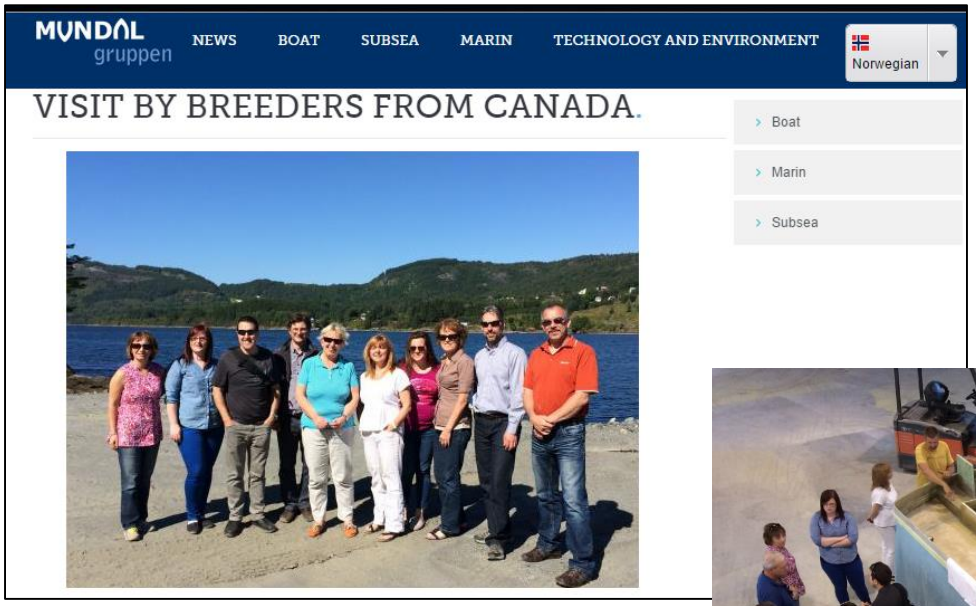
- Silage handling company

The NAIA Ensiling Demo Project

- Presentations from silage processors and equipment companies

The NAIA Ensiling Demo Project

- Silage and mort handling equipment manufacturer



The NAIA Ensiling Demo Project

- Salmon processing and high-end uses of offal for animal and human nutrition (near future)

The NAIA Ensiling Demo Project

- Objectives
  - Part 2 – Purchase, operation and evaluation of ensiling equipment in NL operational environment
  - Equipment
    - Ensilers
    - Generators
    - Bulk storage
    - Transport tanks

The NAIA Ensiling Demo Project

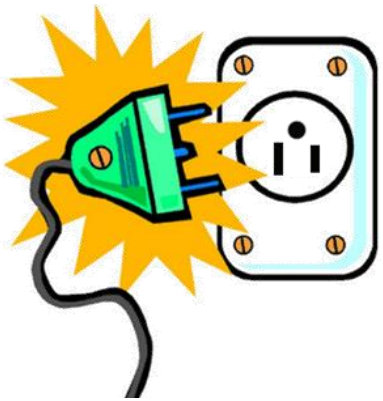
- Current activity
  - Company equipment needs and equipment specifications
  - Equipment costing and budget preparation
  - Proposal preparation
  - Now ready to submit to funding agencies
- Timeline for Demo
  - Equipment arrival: February or March
  - Demo the equipment for 6 months
  - Create a report which outlines the experience, costs and options for management of morts in NL

End use of the silage

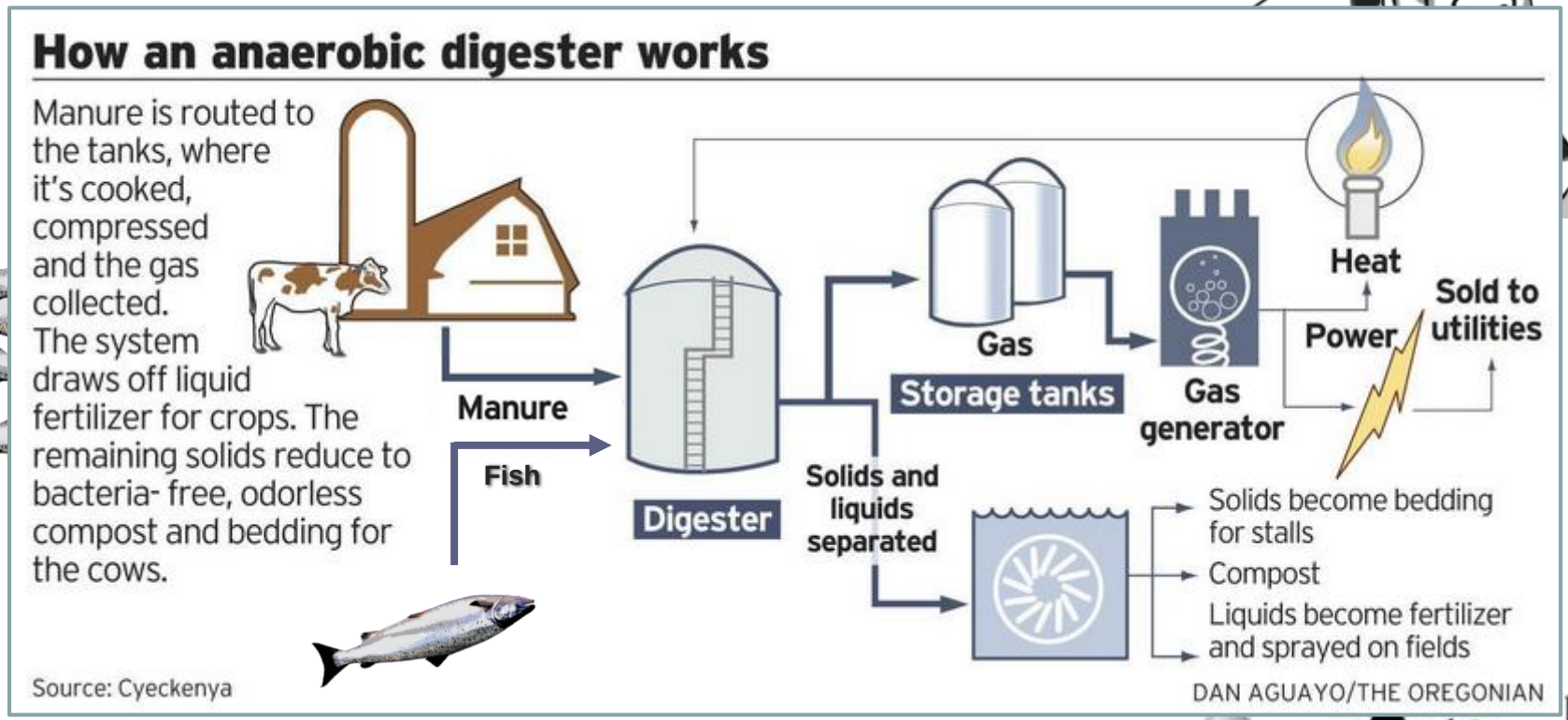
NL Federation of Agriculture

End use of the silage

?



End use of the silage



NAIA Demo Project Partners

- Cold Ocean Salmon
- Northern Harvest Sea Farms NL
- Gray Aqua Group
- Nova Fish Farms

- New World Dairy


Thank you
www.naia.ca
dgreen@naia.ca

Hydrodynamic Investigation of Scale Model Fish Cage Arrays: Implications for IMTA and Related Research

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November 5th, 2014

Co-Authors:
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NSERC Canadian Integrated Multi-Trophic Aquaculture Network
Réseau canadien d'aquaculture multitrophique intégrée du CRSNG

Integrated Multi-Trophic Aquaculture

Fed Aquaculture + Suspension Extractive Aquaculture

Finfish

Organic
Shellfish

Inorganic
Seaweeds

Project Scope

- Determine hydrodynamic wake properties, cage interactions and drag forces
  - East coast (circular) vs. West coast (square) open water aquaculture arrays
    - Cage spacing
    - Current velocity
- Project goals:
  - Improve IMTA performance
  - Determine patterns of nutrient plumes
  - Placement of extractive species
  - Cage Deformation
  - Oxygen concentrations
  - Ventilation

East Coast Cage Array

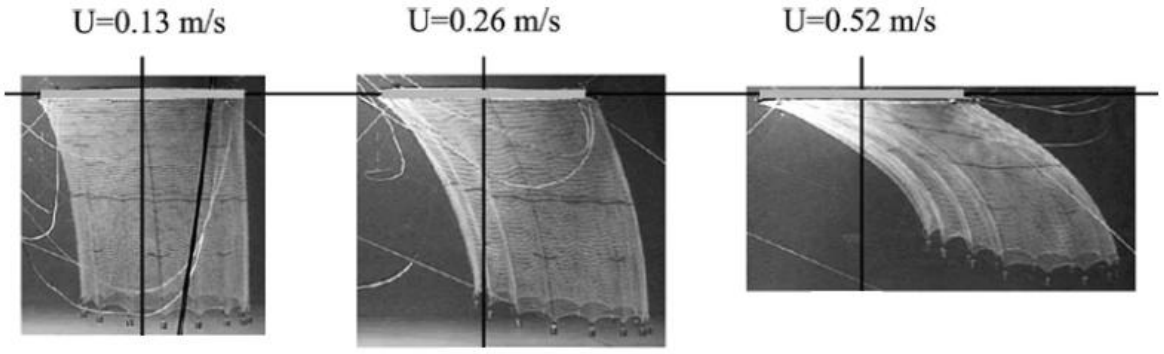
Photos courtesy of: Andrew Cooper, Gregor Reid

West Coast Cage Array

Photo courtesy of: Marine Harvest Canada

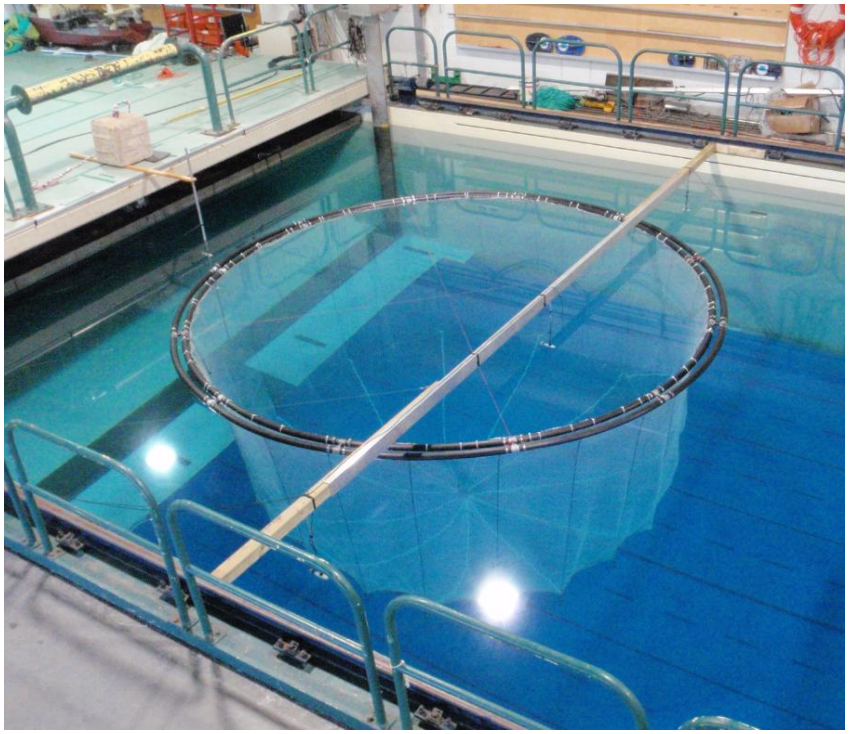
Previous Experiments on Fish Cages

- Lader and Enerhaug (2005) [1]
  - Performed an experiment to determine cage deformations with respect to bottom weighting and current velocity.
  - Found that current forces and cage deformation are highly dependent. More sinker weight attached to the cage means less cage deformation.



Previous Experiments on Fish Cages

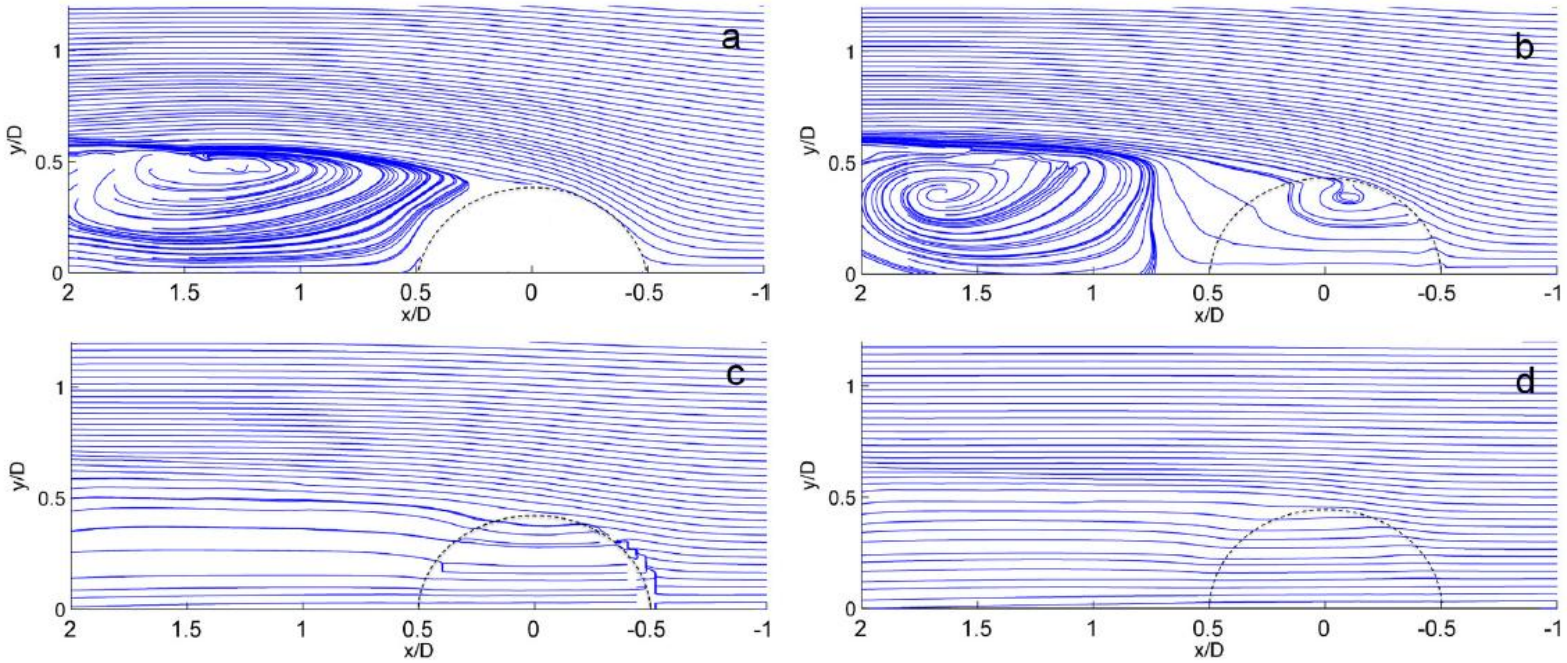
- Department of Fisheries and Oceans Canada (2010) [2]
  - Performed an experimental investigation on a single scale model fish cage to determine flow patterns and therapeutant dispersion.
  - Found that therapeutants are expected to dilute rapidly from a cage site and show very little impact at short distances from the cages.
  - Showed cage deformations under different current loads.



Previous Experiments on Fish Cages

- Gansel et al.
  - (2011) Performed a study to determine flow field inside stocked fish pens [3].
    - Single point velocity measurements and dye visualization.
    - Fish swim in circular pattern, causing outflow at swimming depth, thus restricting inflow. Caused flow recirculation at other depths.
  - (2012) Performed two studies(Tow tank [4] and flume tank [5]) to determine the flow field around a fish cage with respect to net porosity.
    - PIV measurements.
    - Found flow blockage and recirculation in cases with low porosity netting (bio fouling)

Previous Experiments on Fish Cages

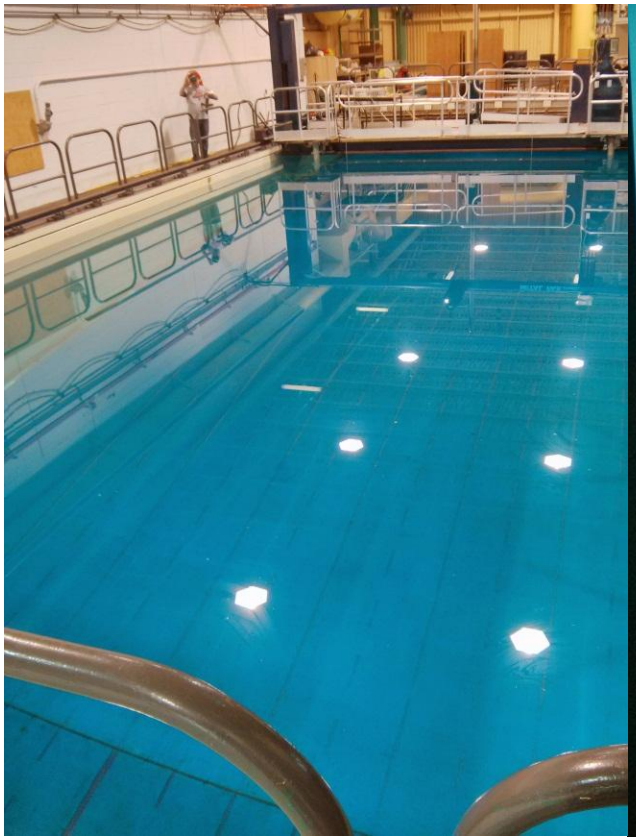


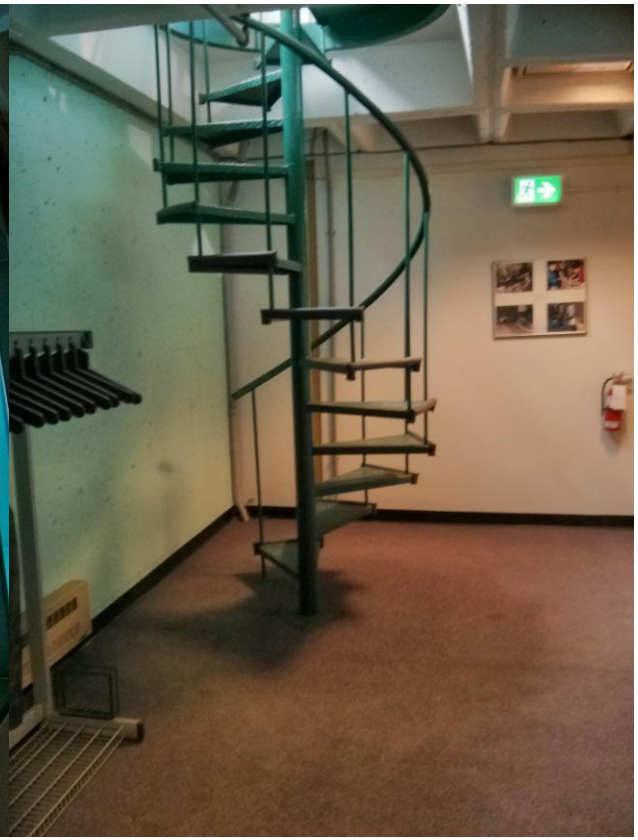
Streamlines of water flow in and around a single fish cage. (a), (b), (c), and (d) show cage porosities of 0%, 30%, 60%, and 75% respectively.[8]

Marine Institute Flume Tank Facility

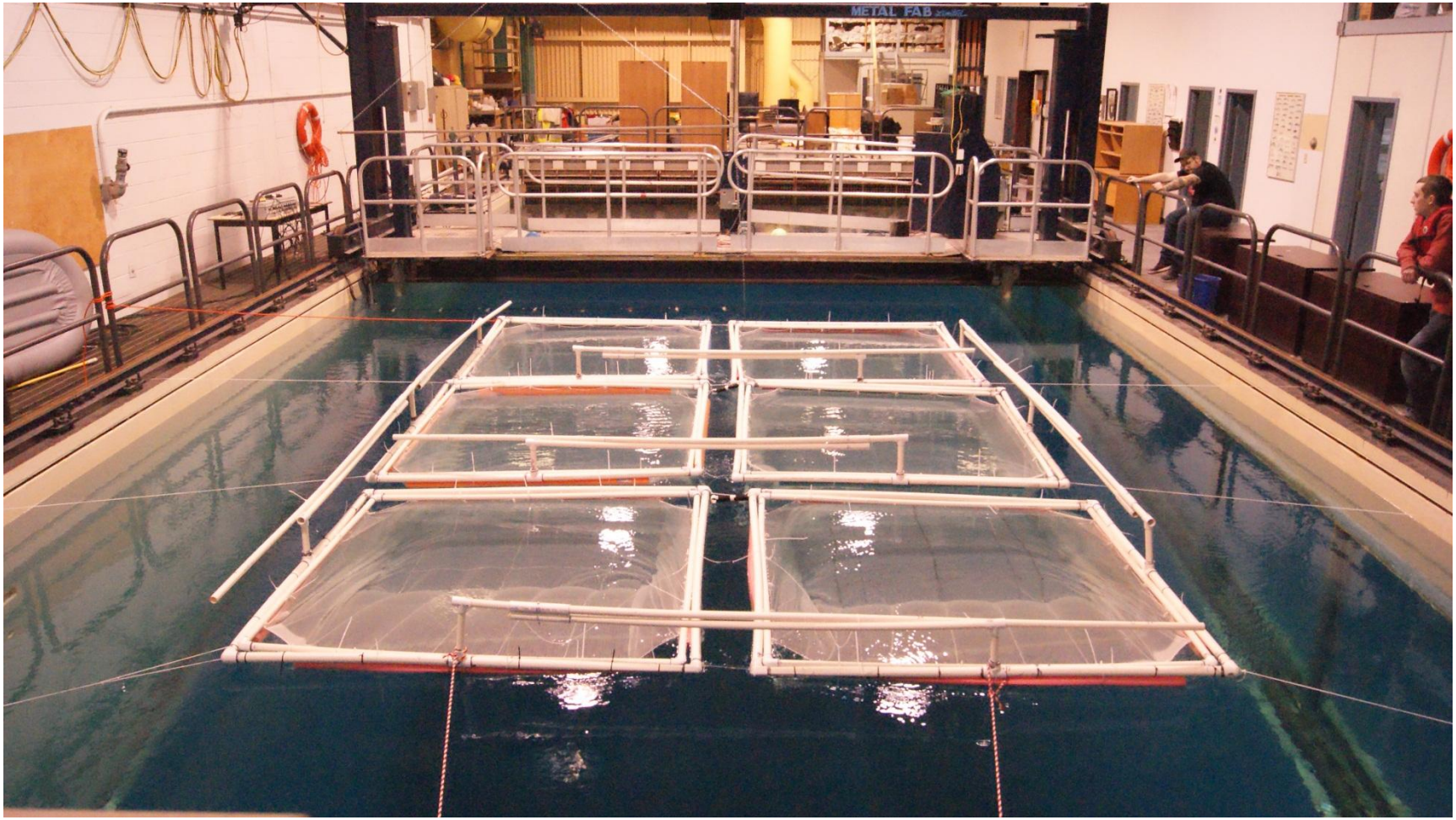
- Marine Institute of Memorial University of St. Johns, Newfoundland
- Largest recirculating flume tank in the world
- Dimensions: 8m wide, 4m deep, 22.25 m length
- Side glass display panel
- Flow speeds (~0.05-1.0 m/s)
- Overhead crane
- Movable over-water tram
- Moving ground plane

Marine Institute Flume Tank Facility





Marine Institute Flume Tank Facility



Experimental Objectives

1. Measure drag forces
   - Realistic inputs for computational models
2. Measure wake velocity
   - Swoffer current meters
3. Dye release for flow visualization
4. Measure cage deformations

Variables:

- Flow Velocity (<1m/s)
- Cage Spacing ($0.27d_c$, $0.91d_c$)

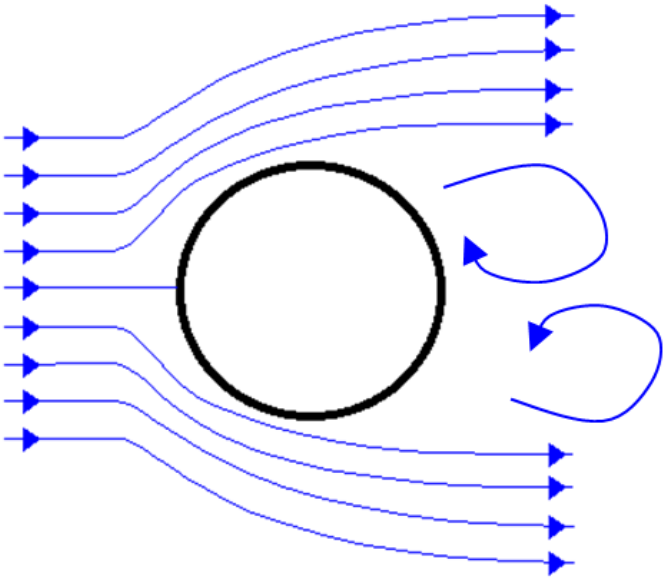
Model Net Scaling

- Geometric Similarity:
  - Shape of the structure is matched.
  - Ratio of horizontal to vertical forces acting on the netting.
- Dynamic Similarity [6]:
  - Froude Scaling: $Fn = \frac{U}{\sqrt{gl}}$
  - Ratio of inertia forces to gravity forces.
  - Reynolds Scaling: $Re = \frac{lU}{\nu}$
  - Ratio of inertia forces to viscous forces.
  - Ensures fluid forces are correctly scaled.

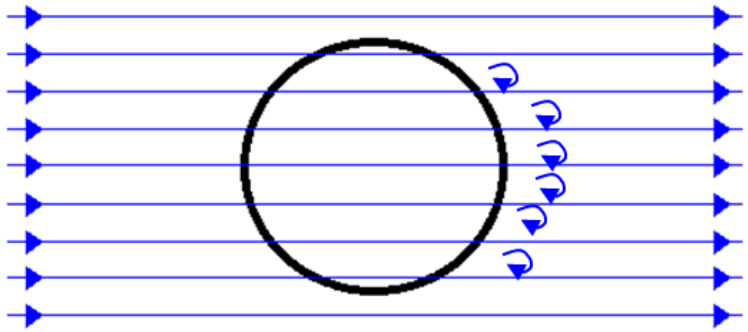
Model Net Scaling

- Two length scales to consider when scaling for dynamic similarity

Cage diameter (d_c)

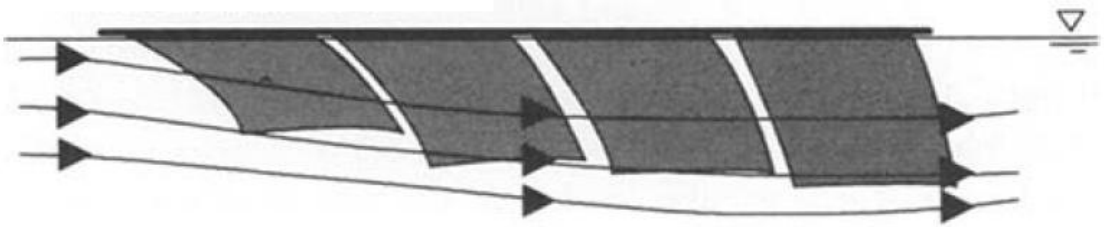


Twine diameter (d_t)



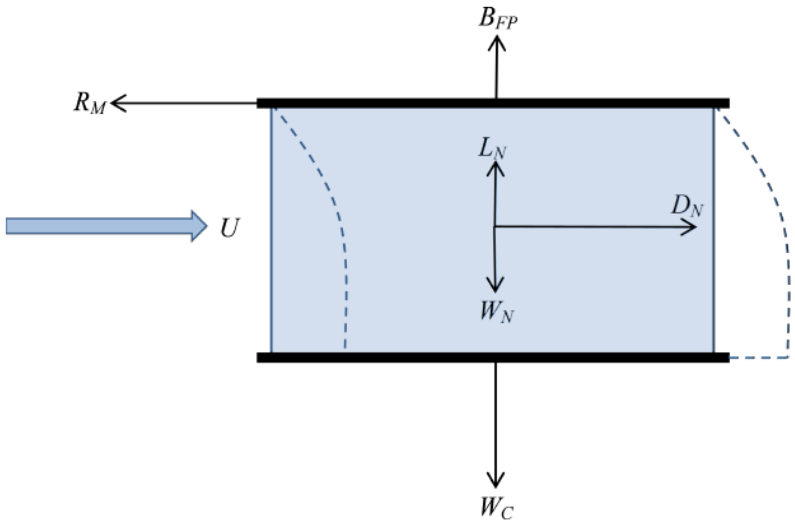
Model Net Scaling

- Both Reynolds scaling and Froude scaling cannot be achieved by using the same fluid (Model Testers Dilemma) [7]
- Length parameters were scaled by different scaling ratios
- Cage Diameter reduced by 15 times, twine diameter only reduced by 3 times
- Dynamic similarity cannot be achieved for all major length scales in flow
- Flow field is highly dependent on cage shape:



Loland, 1993 [8]

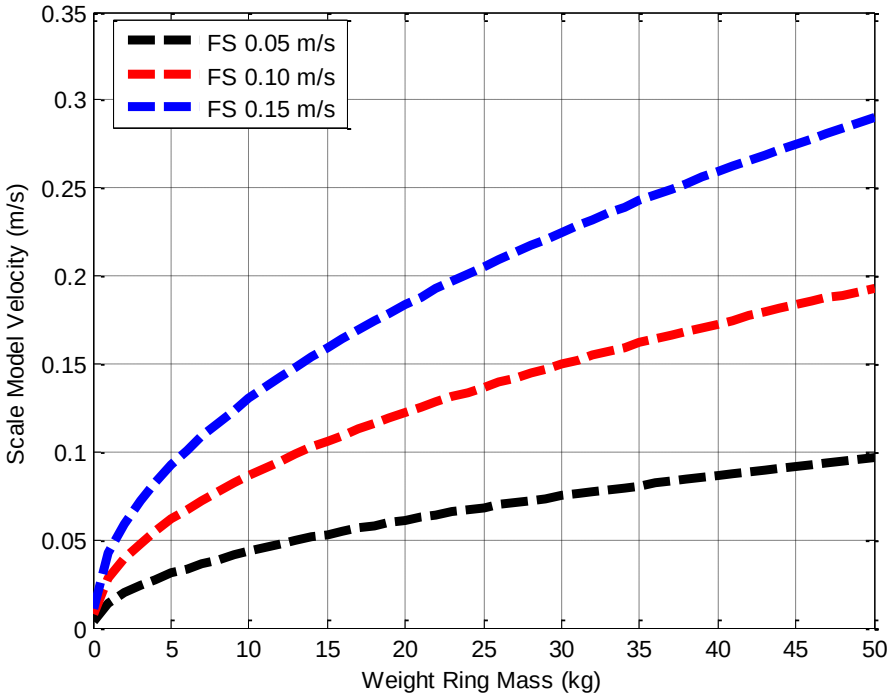
Model Net Scaling

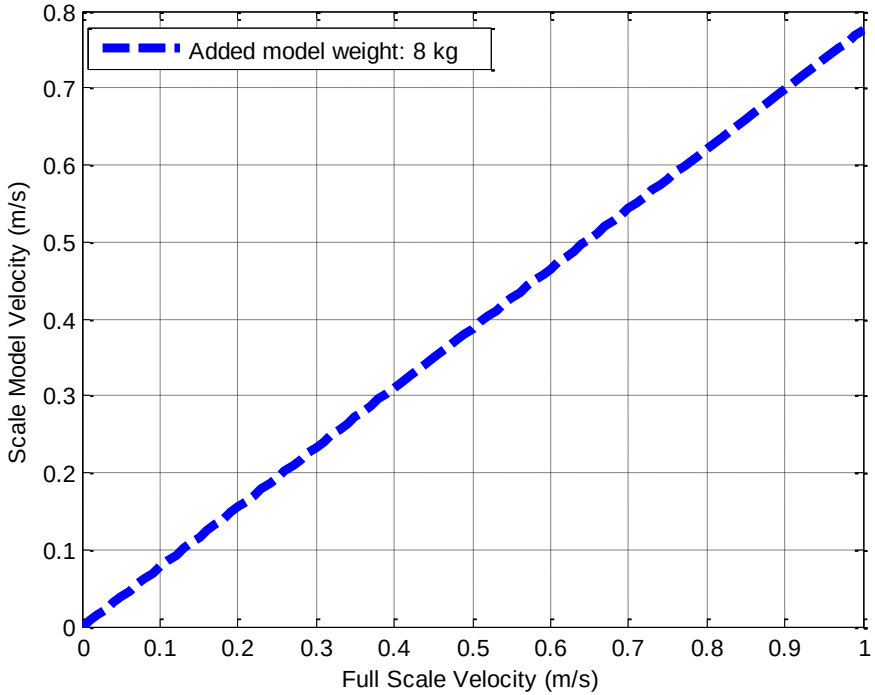


- Force Ratio Scaling to ensure proper net shape
- Considers different properties of full scale and model netting
- Similar netting porosity

$$\frac{\rho_{FS}U_{FS}{}^2 D_{FS} l_{FS} C_{D,FS}}{W_{C,FS} - 0.5\rho_{FS}U_{FS}{}^2 D_{FS} l_{FS} C_{L,FS} - 0.785(\rho_{FS} - \rho_{net})\pi D_{FS} l_{FS} d_{FS} g(1-P)} = \frac{\rho_M U_M{}^2 D_M l_M C_{d,M}}{W_{C,M} - 0.5\rho_M U_M{}^2 D_M l_M C_{L,M} - 0.785(\rho_M - \rho_{net})\pi D_M l_M d_M g(1-P)}$$

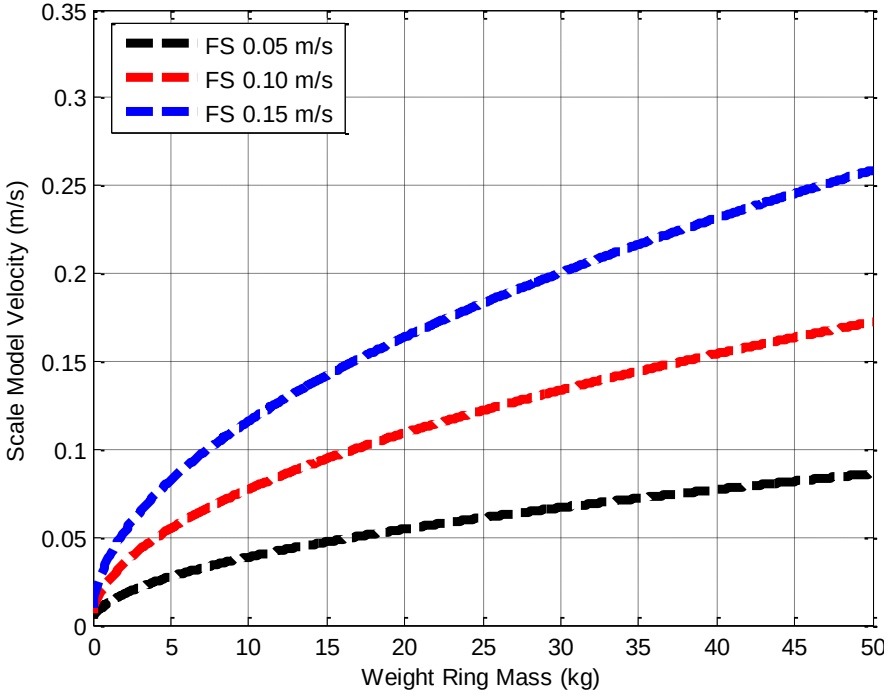
Model Net Scaling

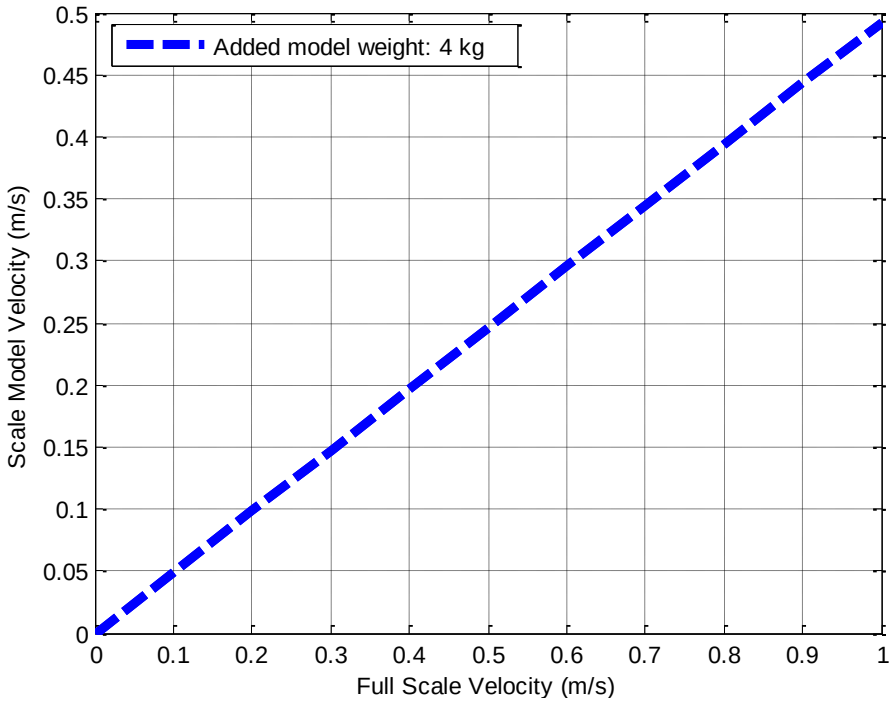




Square cages: Force scaling

Model Net Scaling



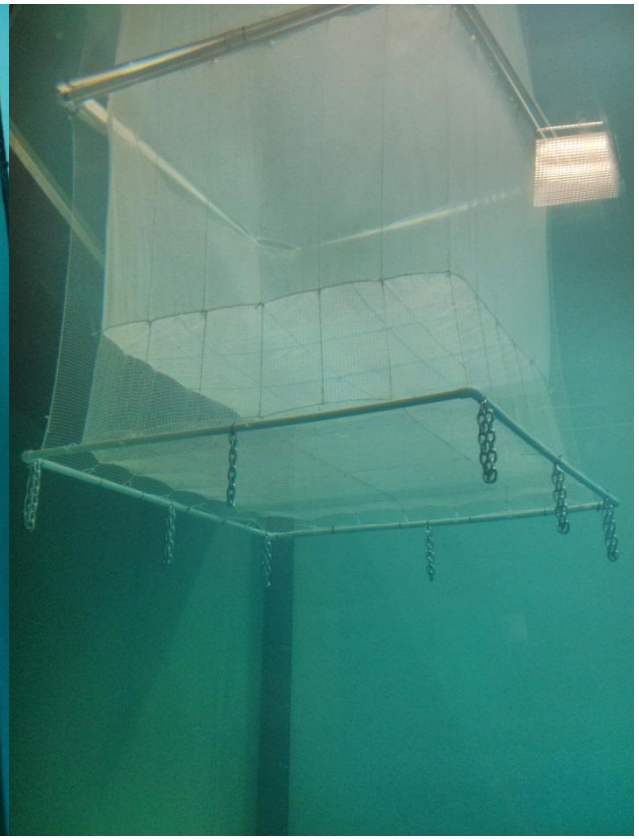


Circular cages: Force scaling

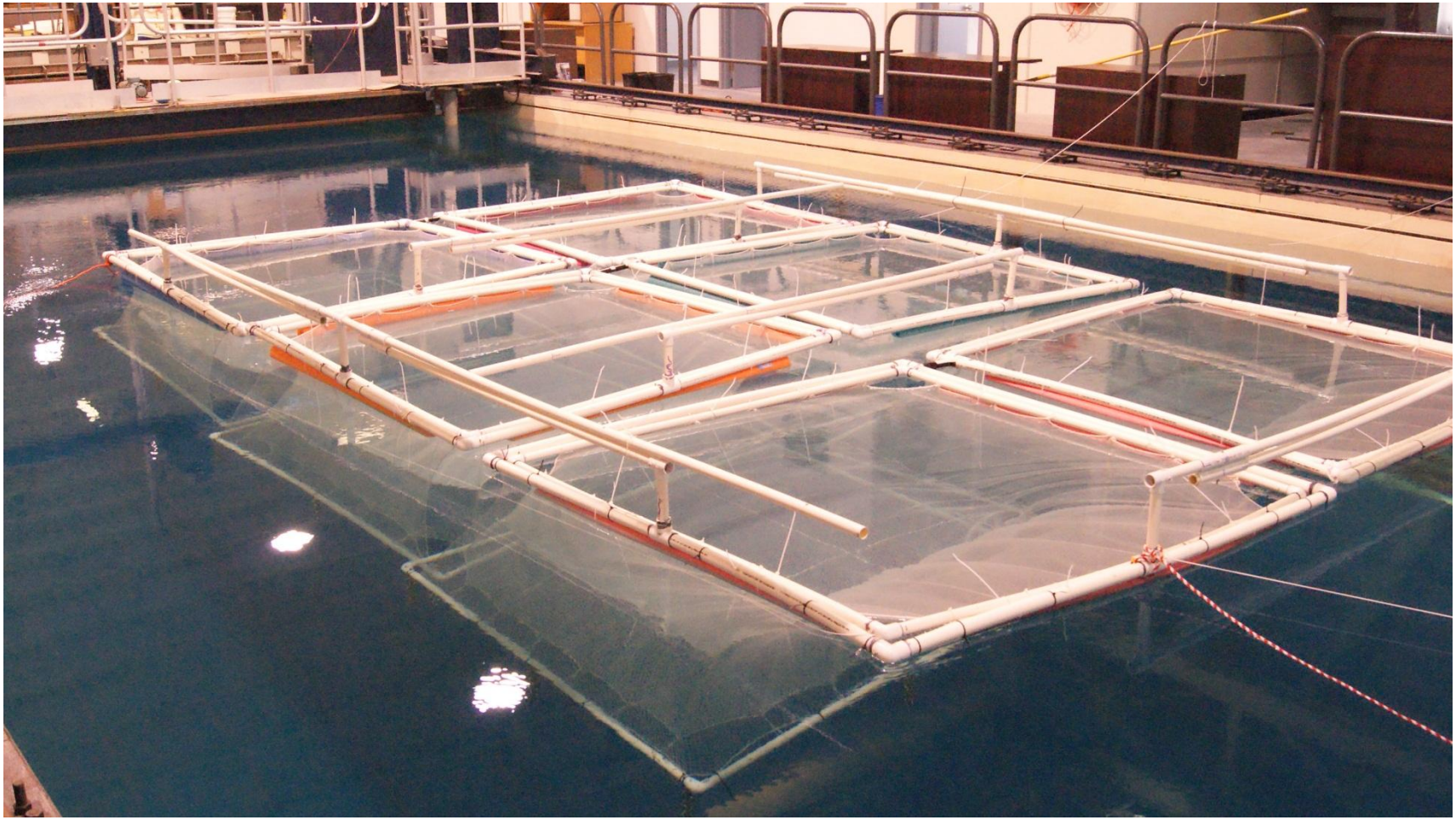
Experimental Current Velocities

- Choose circular and square model velocities to reflect full scale velocities based on force ratio scaling method
- Full scale velocities: 0.10, 0.15, 0.20, 0.25, 0.30, 0.35 (m/s)
- Square model velocities: 0.08, 0.12, 0.16, 0.20, 0.24, 0.28 (m/s)
- Circular model velocities: 0.05, 0.075, 0.10, 0.125, 0.15, 0.175 (m/s)

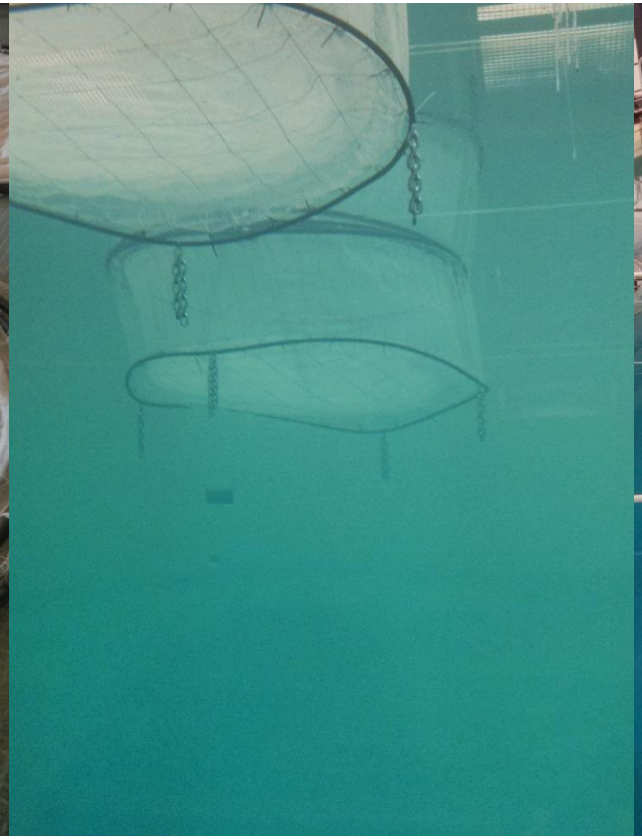
Model Cage Designs



Model Cage Designs



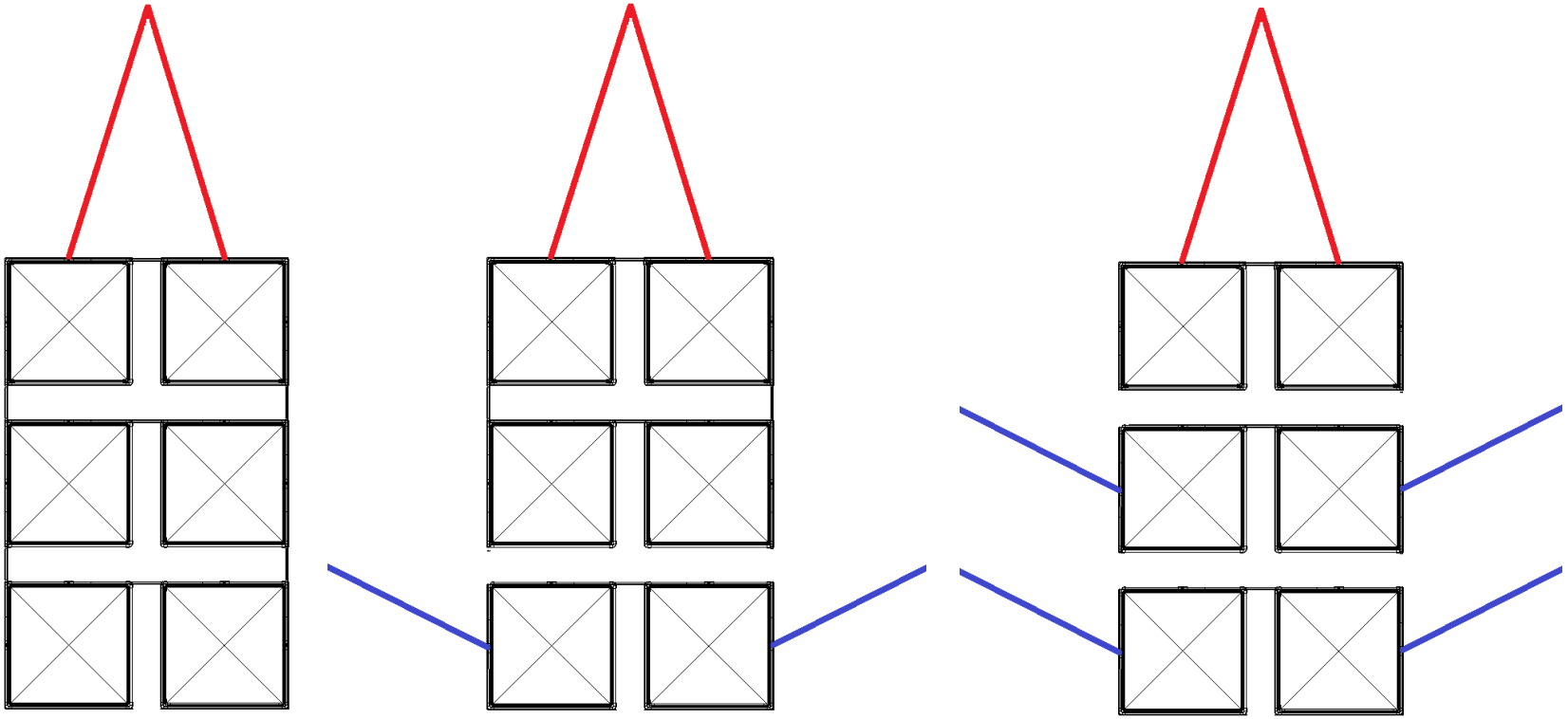
Model Cage Designs



Model Cage Designs

Experimental Methodology

- Drag measurements at all specified current velocities.



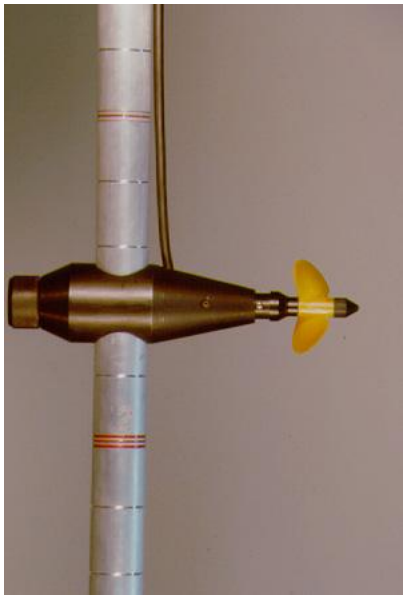
All 6 cages

Front 4 cages

Front 2 cages

Experimental Methodology

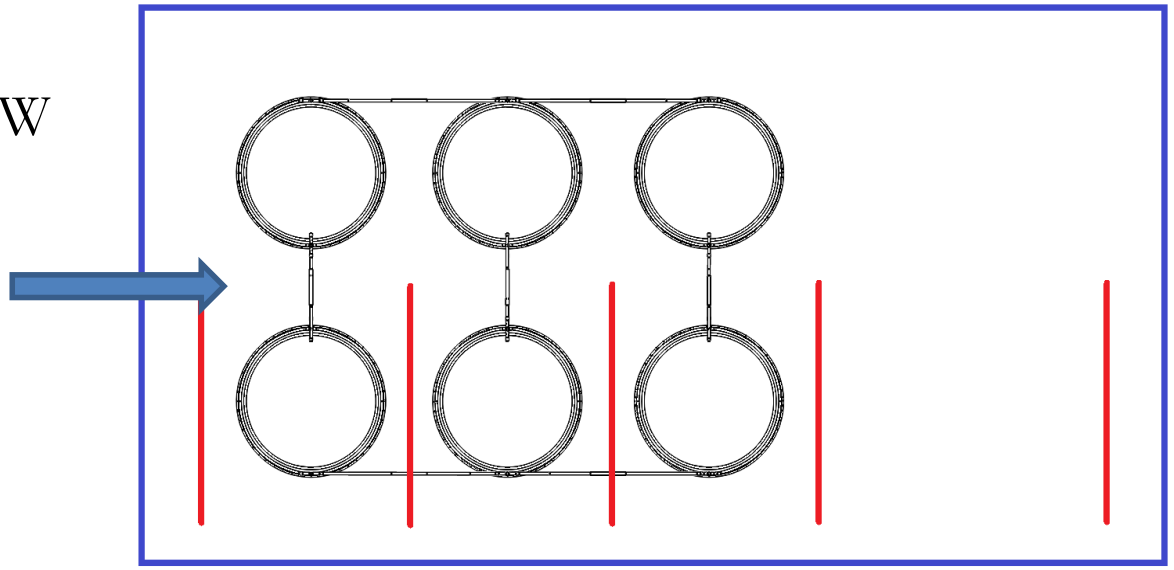
- Wake velocity study
- Swoffer propeller current meters
- 8 swoffer meters mounted to a bar, used to measure wake velocities across flume tank
- Lowered and raised bar with the overhead crane



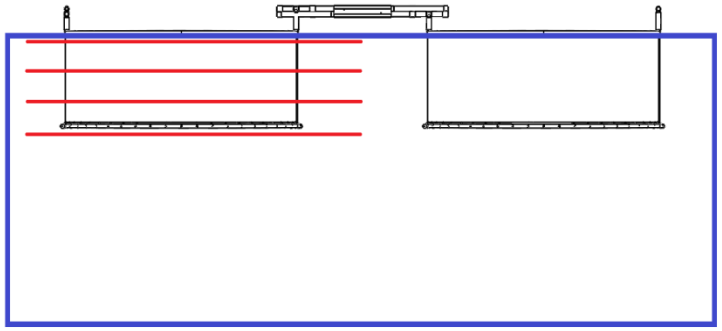
Experimental Methodology

- Drag measurements at all specified current velocities.

TOP VIEW

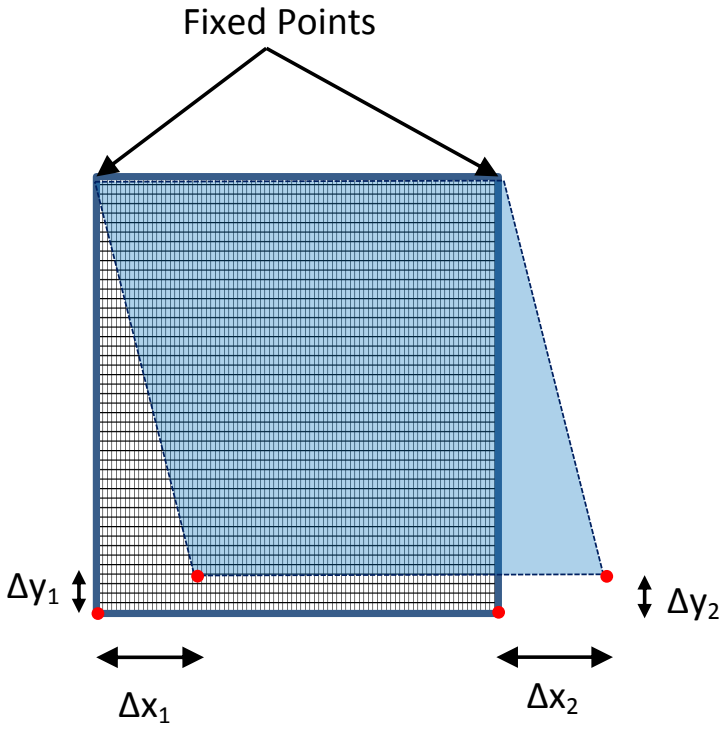


FRONT VIEW

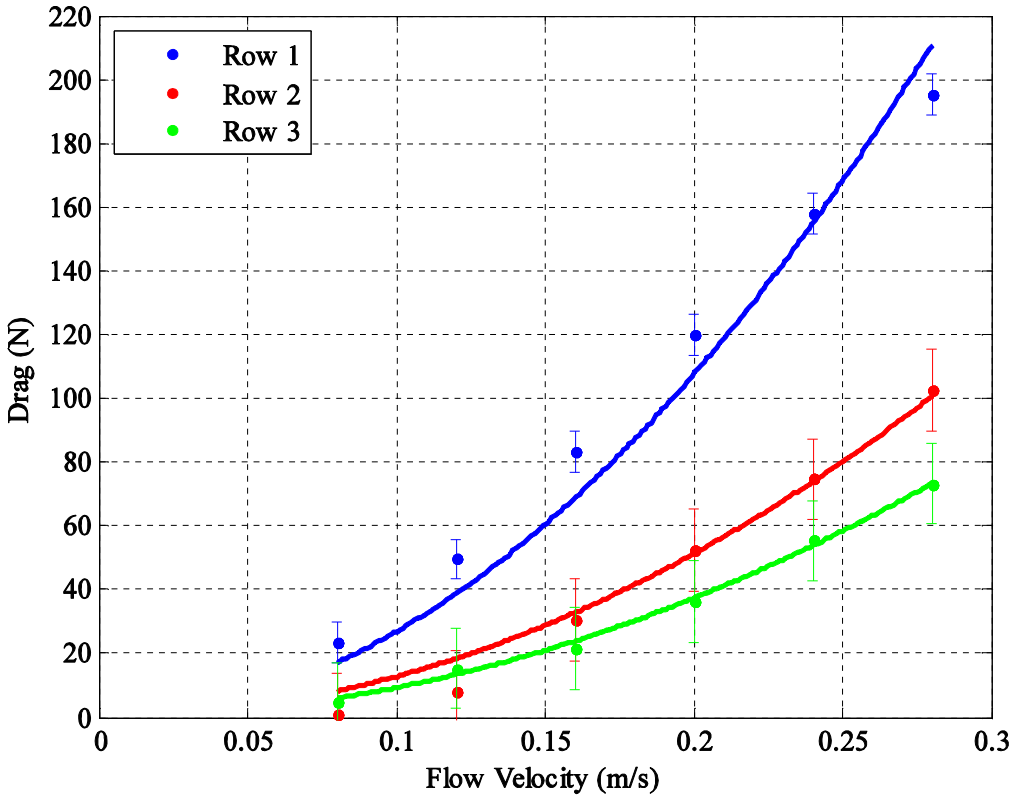


Experimental Methodology

- Cage deformation tracking at all specified current velocities
- Square cages only, depth of circular cages isn't sufficient for tracking deformations

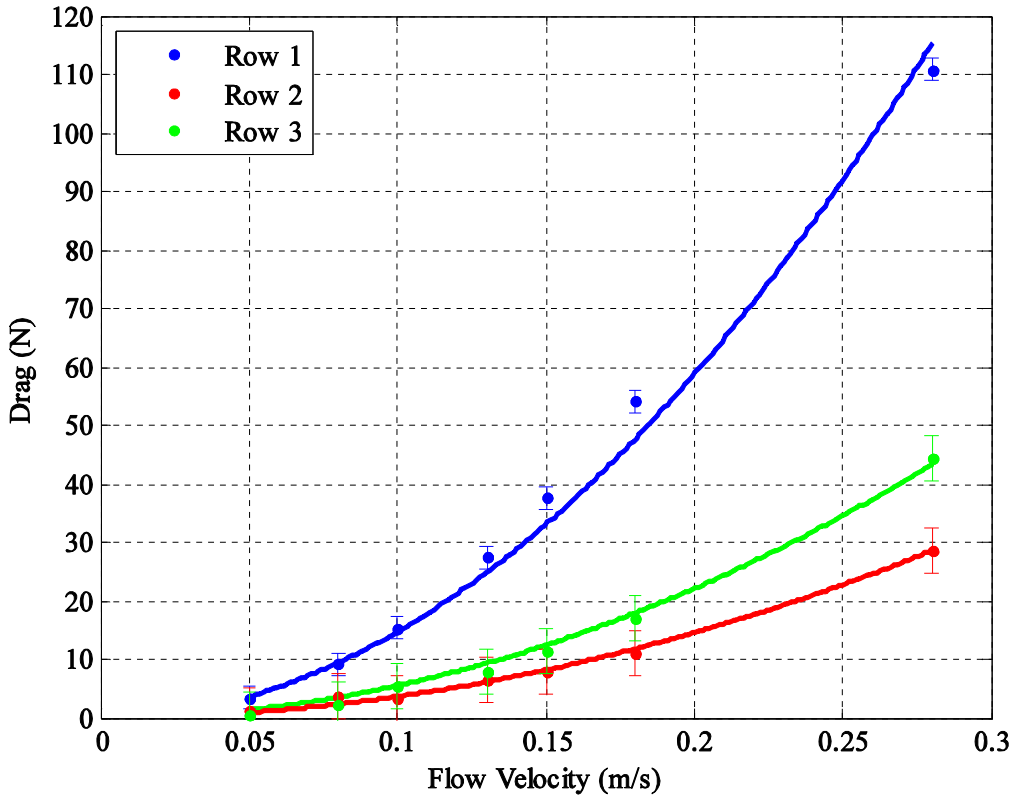


Results: Drag Measurements



- Row 2 ≈ 0.5Row 1
- Row 3 ≈ 0.75Row 2

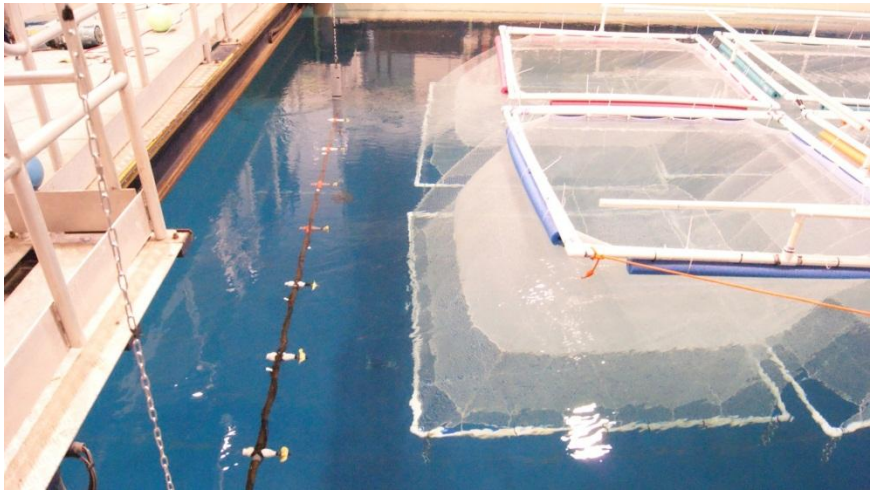
Results: Drag Measurements



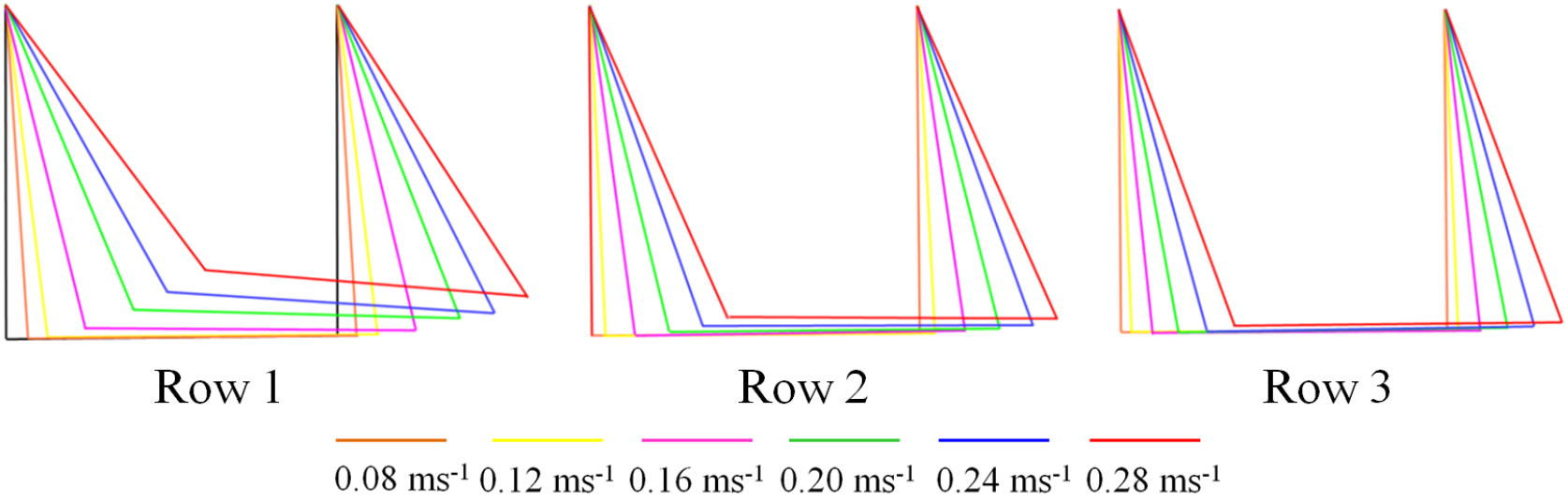
- Row 3 has higher drag than Row 2
- Row 3 experiencing higher velocities than Row 2

Results: Wake Velocity Measurements

- Swoffer meter threshold 0.12-0.15 m/s
- Flow too slow in wake of cages to activate current meters
- Increasing free stream velocity caused unrealistic net deformations
- Max 0.5 m/s without activating current meters
- Cage frames began to bend significantly



Results: Cage Deformation



- Square cage net deformation
- Second and third cage deformations are very similar
- First cage deformation greatly larger than others

Results: Cage Deformation

Link

Conclusions (To Date)

- Cage drag is proportional to U^2, as expected.
- For square cages, drag on row 2 is approximately half of row 1.
- An equal percentage drop is expected for row 3, but is not seen.
- Drag on row 2 and 3 are similar, which is consistent with cage deformation observations.
- For circular cages, drag on row 3 is higher than row 2 for most flow speeds.
- Flow velocities exiting cages are very slow and not possible to measure with existing measurement devices.

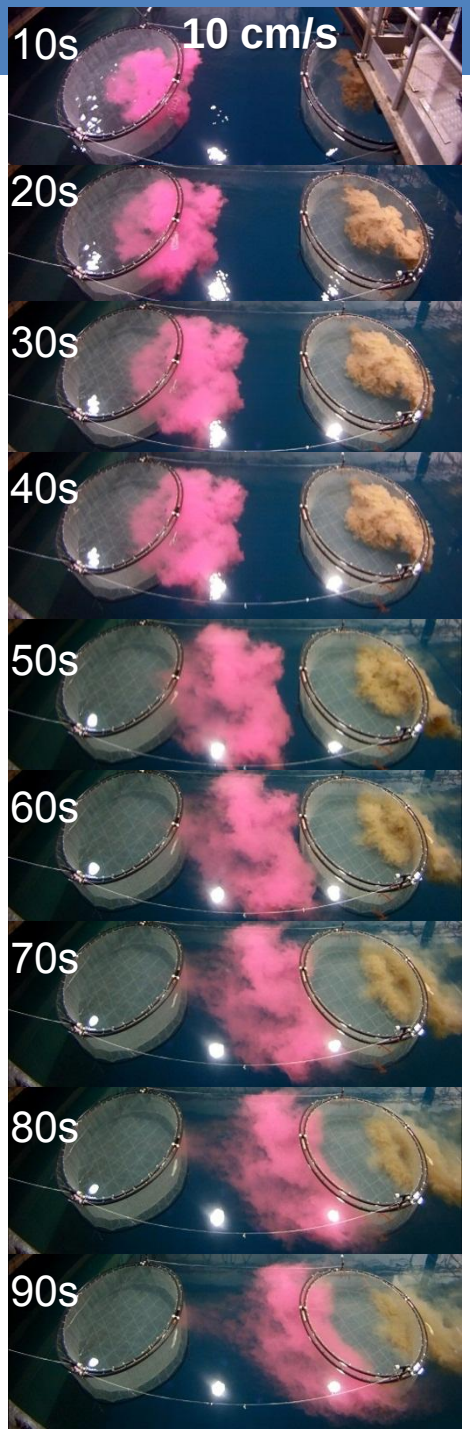
HQP Flume Tank Workshop

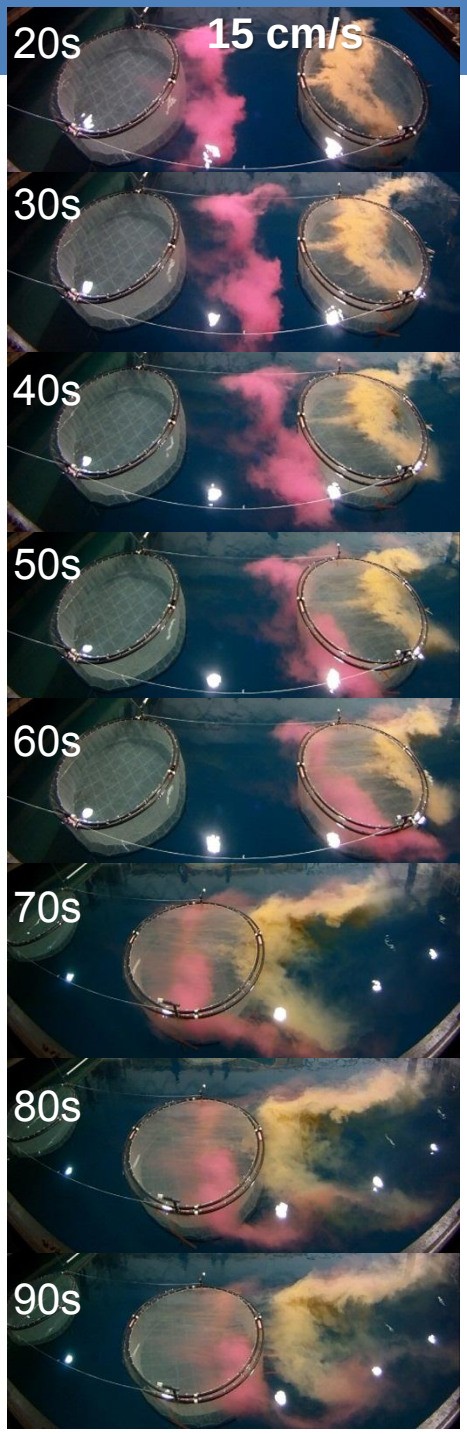
Training objective

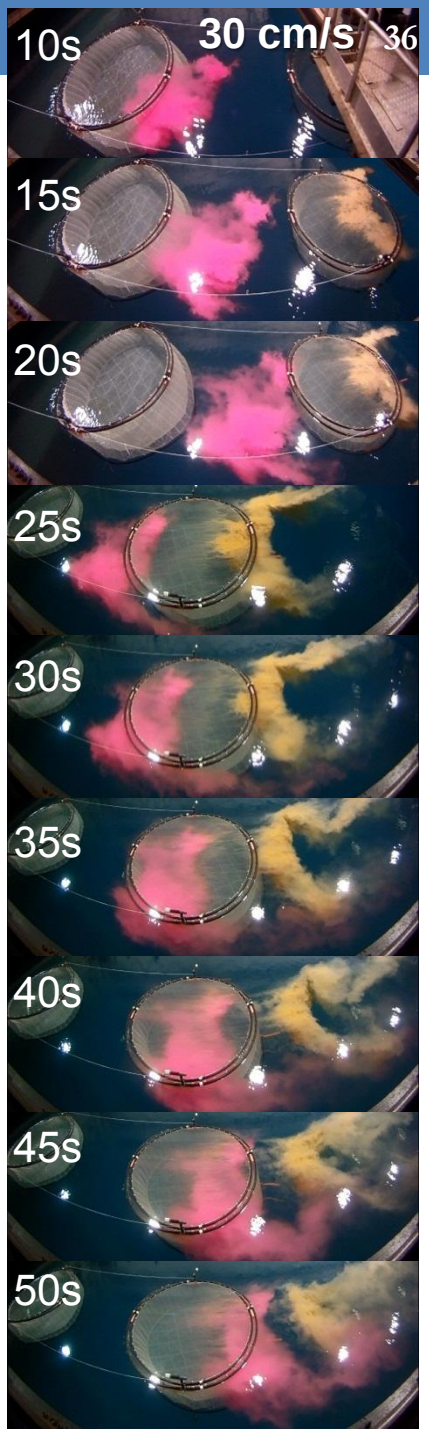
- Apply a team-based research approach to a complex problem, under conditions of time and resource limitations, with the goal of producing a publishable research document.

Scientific objective

- Document mixing behavior and wake morphology of current flow passing through a model cage array, to guide in the optimal placement of co-culture species at IMTA fish farms.

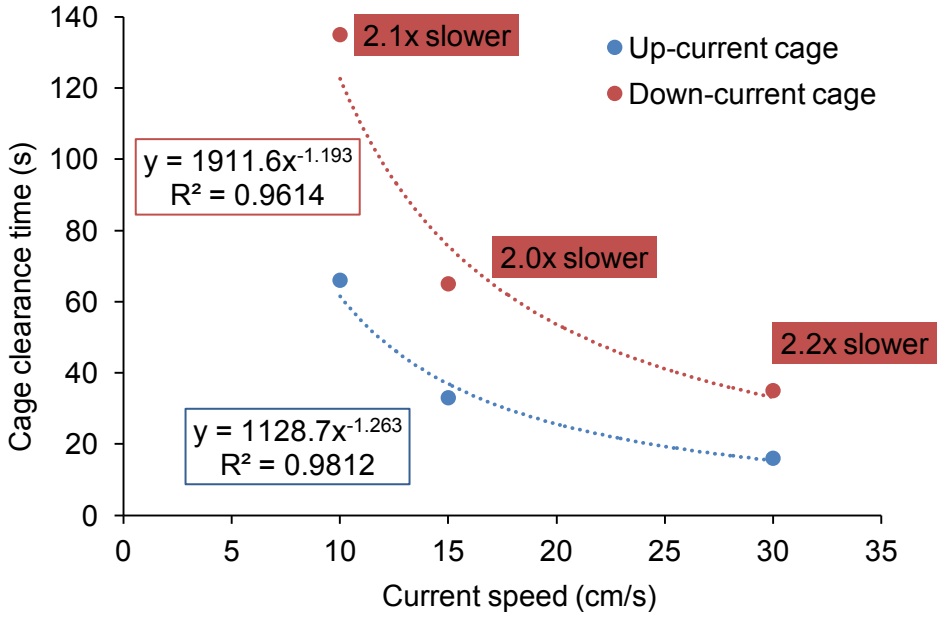

10 cm/s
10s
20s
30s
40s
50s
60s
70s
80s
90s


15 cm/s
20s
30s
40s
50s
60s
70s
80s
90s


30 cm/s
10s
15s
20s
25s
30s
35s
40s
45s
50s

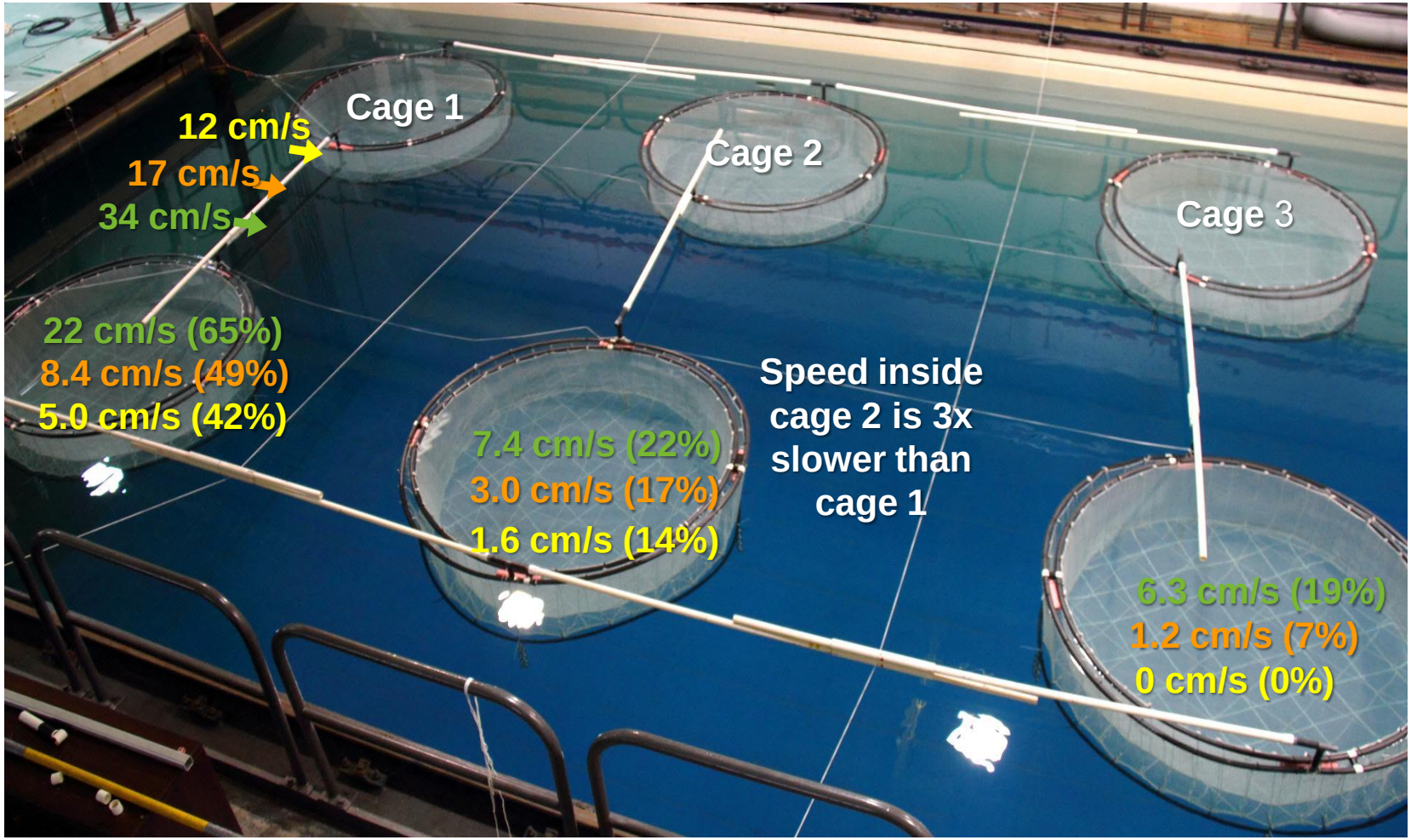
Simultaneous Dye Release

- Speed between 1st & 2nd cages is 3x slower than incidental
- Estimate of dye clearance time from the cages indicated down-current cage clears at 2.07 0.06 times slower from the up-current cage, regardless of incidental speed



Drogue Ball Release

Current speed inside sequential cages & relative to outside speed



Future Work

- Second Experimental Trial (Nov 19-27)
- Swoffer meter propeller retrofitting
- Wake velocity study
  - Cage Array
  - Single Cage
- Update drag data for circular cages
- Dye Release for both circular and square cages

References

[1] Lader, P. Enerhaug, B., 2005. "*Experimental Investigation of Forces and Geometry of a Net Cage in Uniform Flow*". IEEE Journal of Oceanic Engineering, Vol. 30, No. 1.

[2] Parsons, J et al., 2010. "*Construction and Evaluation of a Scale Model of a Finfish Cage Under Different Flow Regimes Simulating Bath Therapeutant Exposure*". Department of Fisheries and Oceans Canada.

[3] Gansel, L et al., 2011. "*Flow Fields Inside Stocked Fish Cages and the Near Environment*". ASME J. Offshore Mech. Arct. Eng., 2011.

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Acknowledgements

NSERC Canadian Integrated
Multi-Trophic Aquaculture Network

Réseau canadien d'aquaculture
multitrophique intégrée du CRSNG

Melanization, a problem on the rise?

PHARMAQ

We make aquaculture progress

Thanks to:

- Much of the documentation in this presentation is from the Phd desertation

Studies of extracutaneous pathological pigmentation
- black spots –
in Atlantic salmon

By Hilde Anette Søiland Fagerland





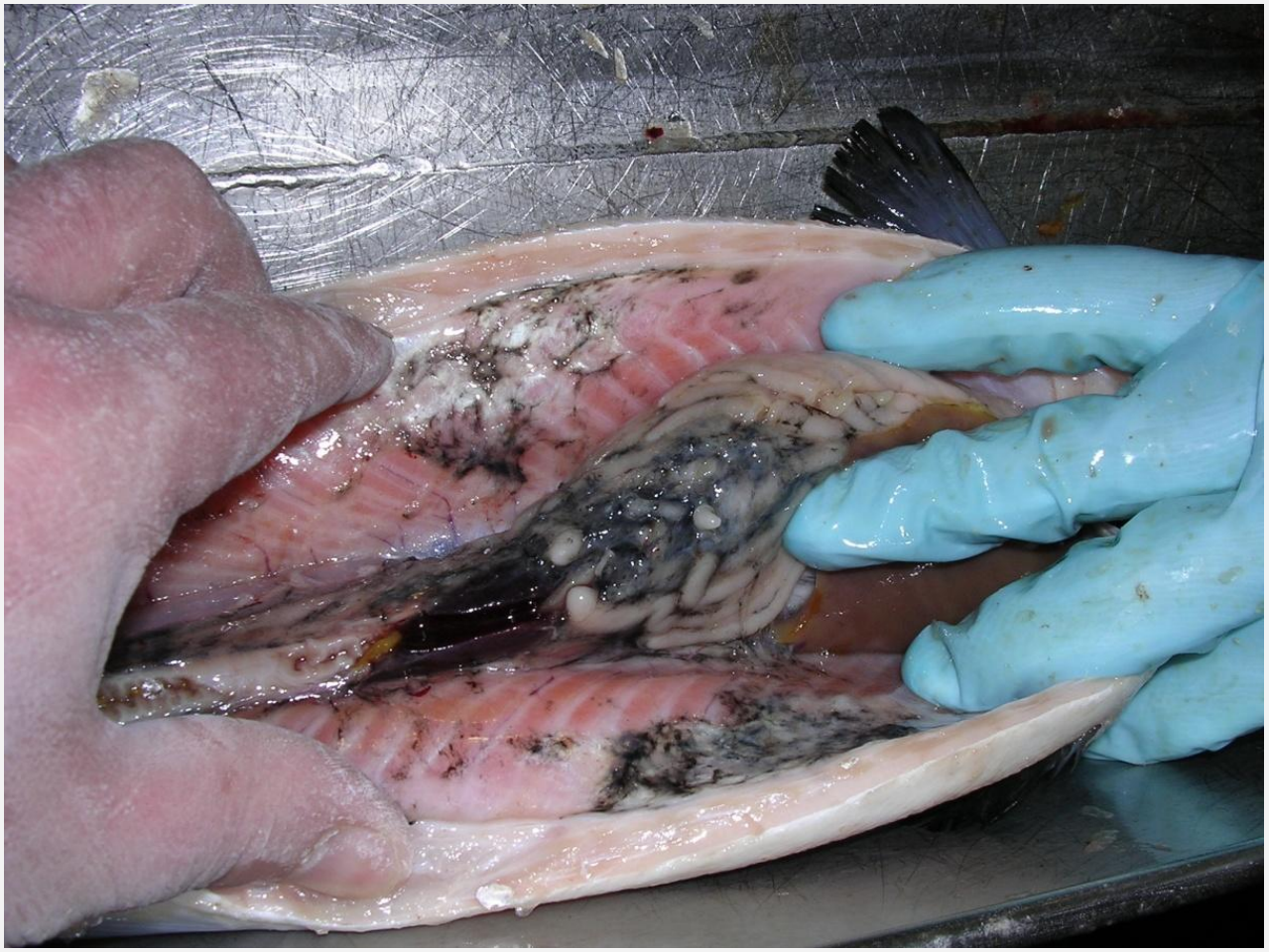



Photos available on www

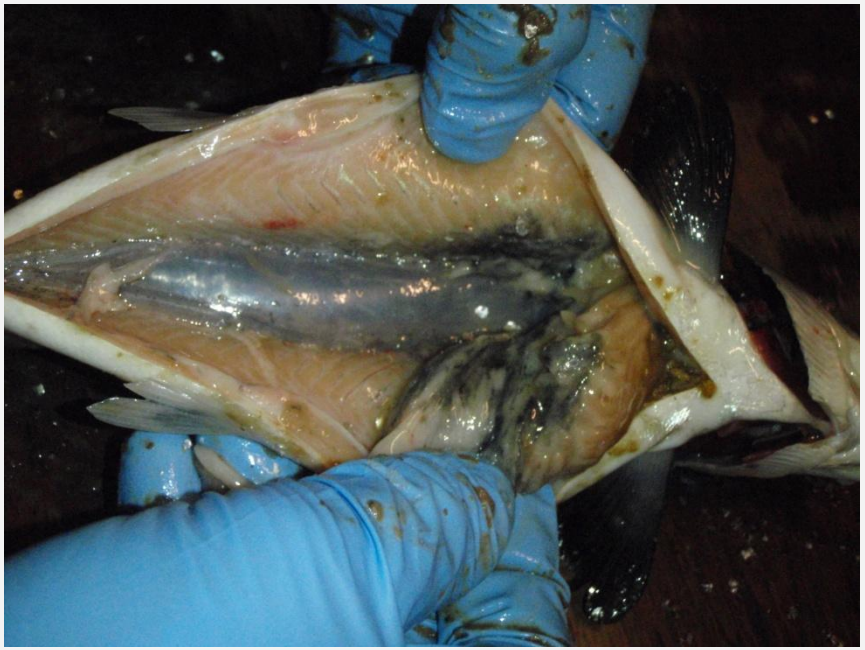

Melanin in salmon

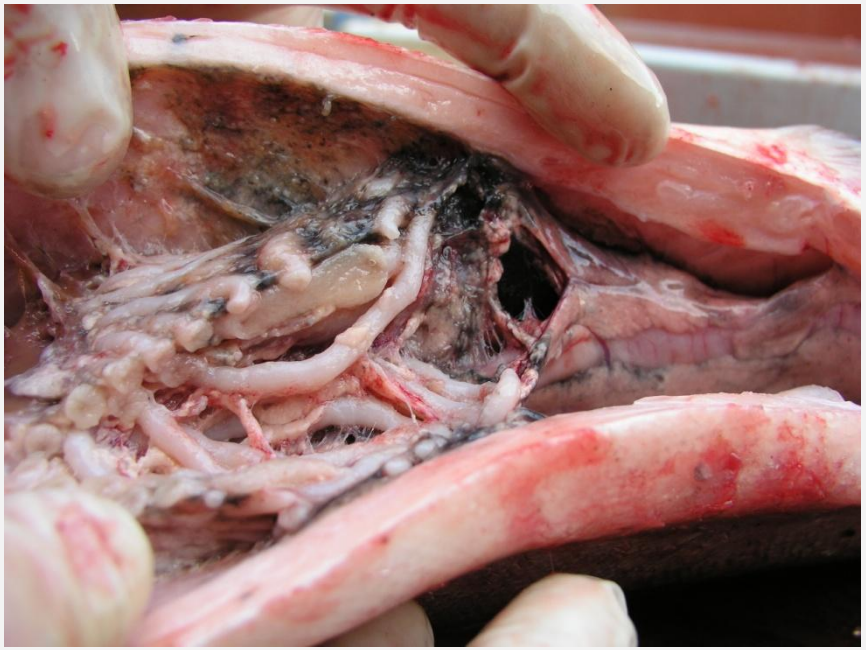
- Melanin is deposited anywhere in a salmon where there has been an inflammation and connective tissue (scar tissue) develops.
- Melanin is tasteless and not in any way harmful, but causes downgrading.

Melanin and vaccination

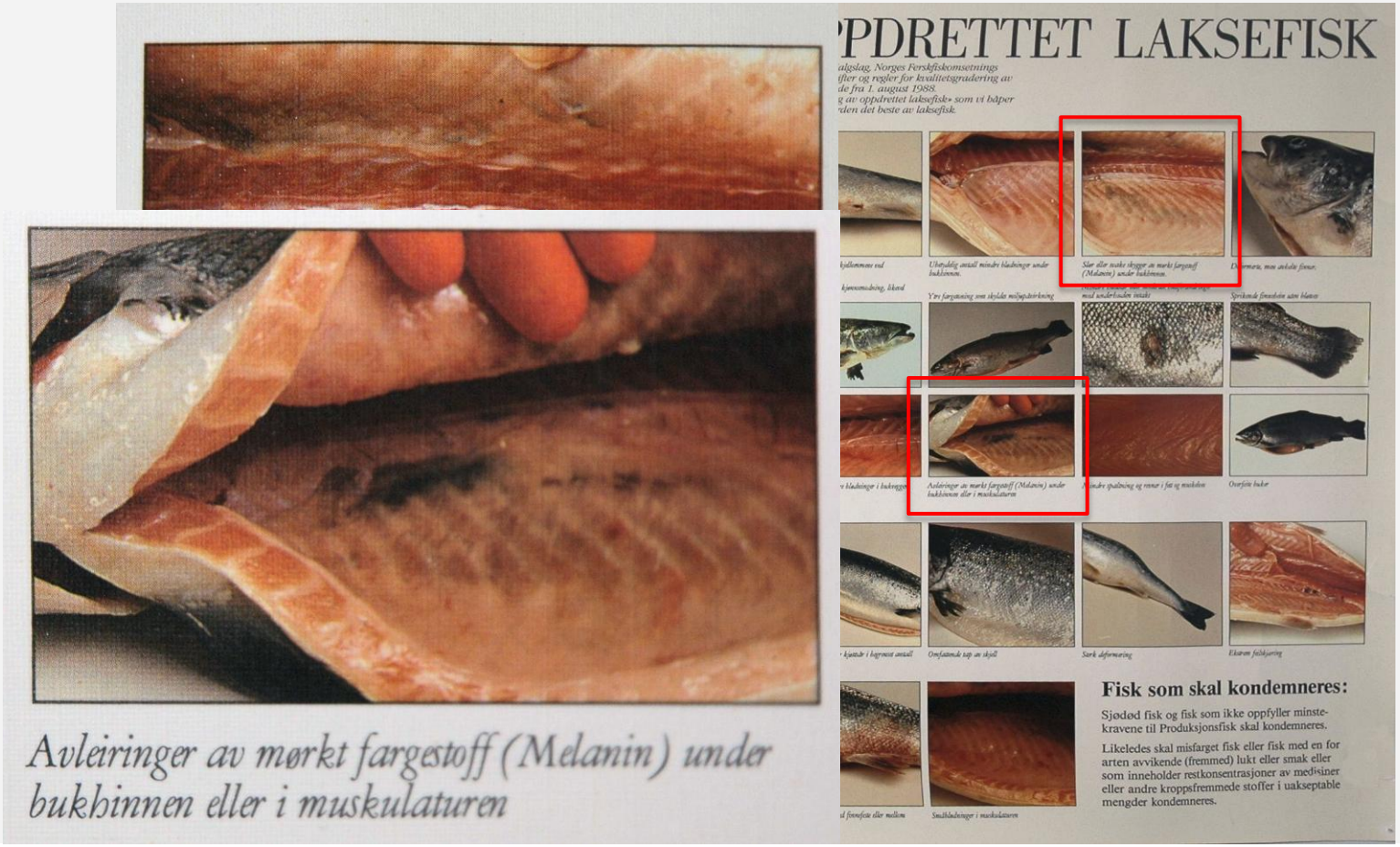


More horrible fish





So are vaccines the main cause of melanin?



Melanin in Norway

- Problems with serious vaccine side-effects have been greatly reduced over the last 10-15 years.
- Problems with melanin and «black-spots» have not been reduced, and in many places are on the increase.
- Melanin is the main reason for downgrading for many producers.
- Melanization takes many different forms

Melanin

Southern Norway summer 2013

Newfoundland summer 2013

Maine USA , May 2001

Chile August 2013

70% is this

Mørke flekker i laksefilet

-Årsaker til forekomst og forebyggende tiltak

2012-2015

Prosjektbeskrivelse

Sammendrag:	*Går til:*
Det overordnede målet er å forhindre dannelse av mørke flekker i laksefilet. I dette ligger en søken etter årsaker til at flekkene oppstår for at kunne anbefale tiltak som kan bidra til å løse problemet. Aktivitetene i prosjektet er delt i fire arbeidspakker (AP): [1]Kartlegging, [2]Vaksine og helse, [3]Fôr og [4]Sortering og skade. Det vil være et nært samarbeid mellom AP1-4, som vil gå parallelt i perioden 2012 og ut 2014.	Fiskeri og havbruksnæringens forskningsfond

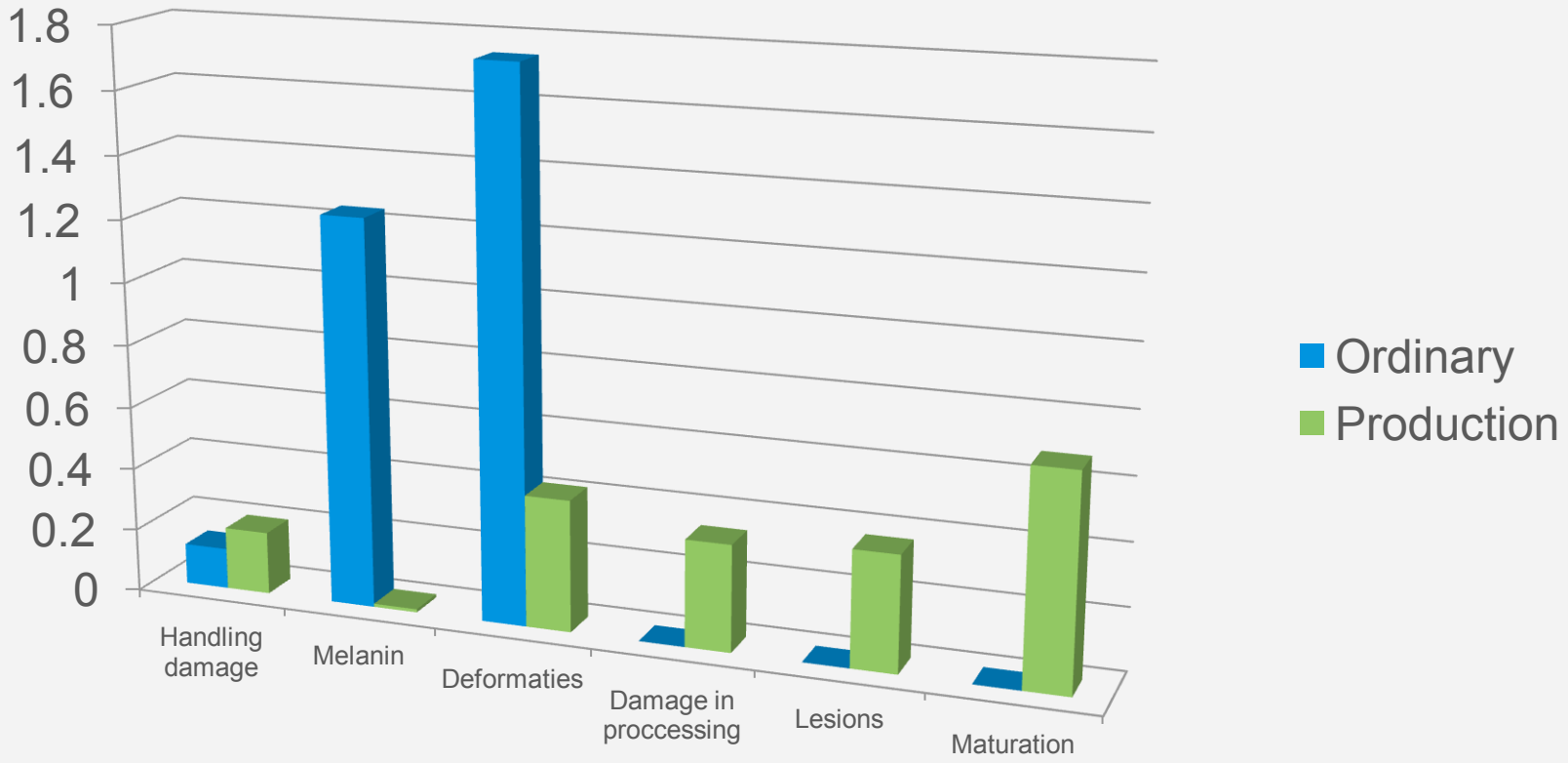
Rutinemessig kartlegging av forekomst av mørke filetflekker utføres av kvalitetskontrollører ved filetanlegg med geografisk spredning. Registreringene danner grunnlag for etterrettelig statistikk samt dybdeanalyse for å avdekke årsakssammenhenger. To basispopulasjoner med PIT-tag merket uvaksinert og vaksinert (ulike regimer) laks produseres: mullårssmolt (**BP0+**) og ettårssmolt (**BP1+**). Etter vaksinering undersøkes laksen jevnlig for mørke filetpigmenter frem til slakt. Produksjonsparametere, morfometri og blod analyses også. Mørke filetflekker undersøkes ved avbildende spektroskopi, foto, histologi, sammensetning og genuttrykk. Øvrige kvalitetsegenskaper undersøkes av utvalgt fisk. **BP0+** vil i en 3 måneders periode før slakt få et sluttfôr med og uten forhøyet sink, vitamin E eller fôrtoksiner (ulike vaksineregimer blandet i merder). **BP1+** vil undersøkes mht effekt av lavt sinknivå frem til vaksinering samt fra sjøutsett til slakt. I

Dark spots in Norway salmon

Year	Norway %	Mid %	North %	Dorsal %
2011	13	16	11	0,8
2012	16	18	15	0,9
2013	18	20	13	1,6
2014	19	24	13	1,3

Causes of downgrading

Major North Norwegian producer, 2012 generation



Project 11.05 FT

Evaluation of safety and efficacy for commercially available and new test vaccines in Atlantic salmon (*Salmo salar*), following administration intraperitoneally and in Dorsal Median Sinus (DMS).

Cooperation between PHARMAQ AS and Marine Harvest

Svein Alexandersen, Øyvind Oaland and Olav Breck

Background

	Down grading	Causes of downgrading (%)					
		Melanin	Blood spots	Color	Short tail	Lesions	Other
February	17.9%	10.3	2.6	1.8	0.0	0.1	0.4
March	13.0%	8.2	2.9	0.8	0.2	0.8	0.4
April	13.8%	8.6	3.1	0.5	0.0	2.3	0.4
May	13.5%	8.1	2.1	1.0	0.1	0.7	1.0
June	12.3%	8.0	1.8	1.4	0.0	0.5	1.2
July	10.1%	6.9	1.3	0.4	0.1	0.0	1.1
August	12.1%,	7.3	1.7	2.2	0.0	0.0	0.9
September	11.7%	8.1	1.6	1.0	0.0	0.0	0.3
October	13.0%	10.0	1		0.0	0.0	0.4
November	16.1%	13.1	1		0.0	0.0	0.6
December	16.3%	13.3	1.8	3.1	0.1	0.1	0.2
YTD	**14.2 %**	**10.3**	**2.2**	**1.6**	**0.1**	**0.4**	**0.7**

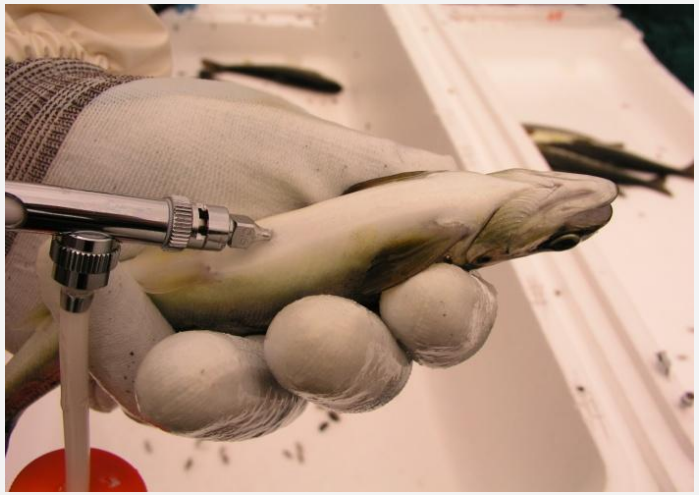
12.5%

Trial groups

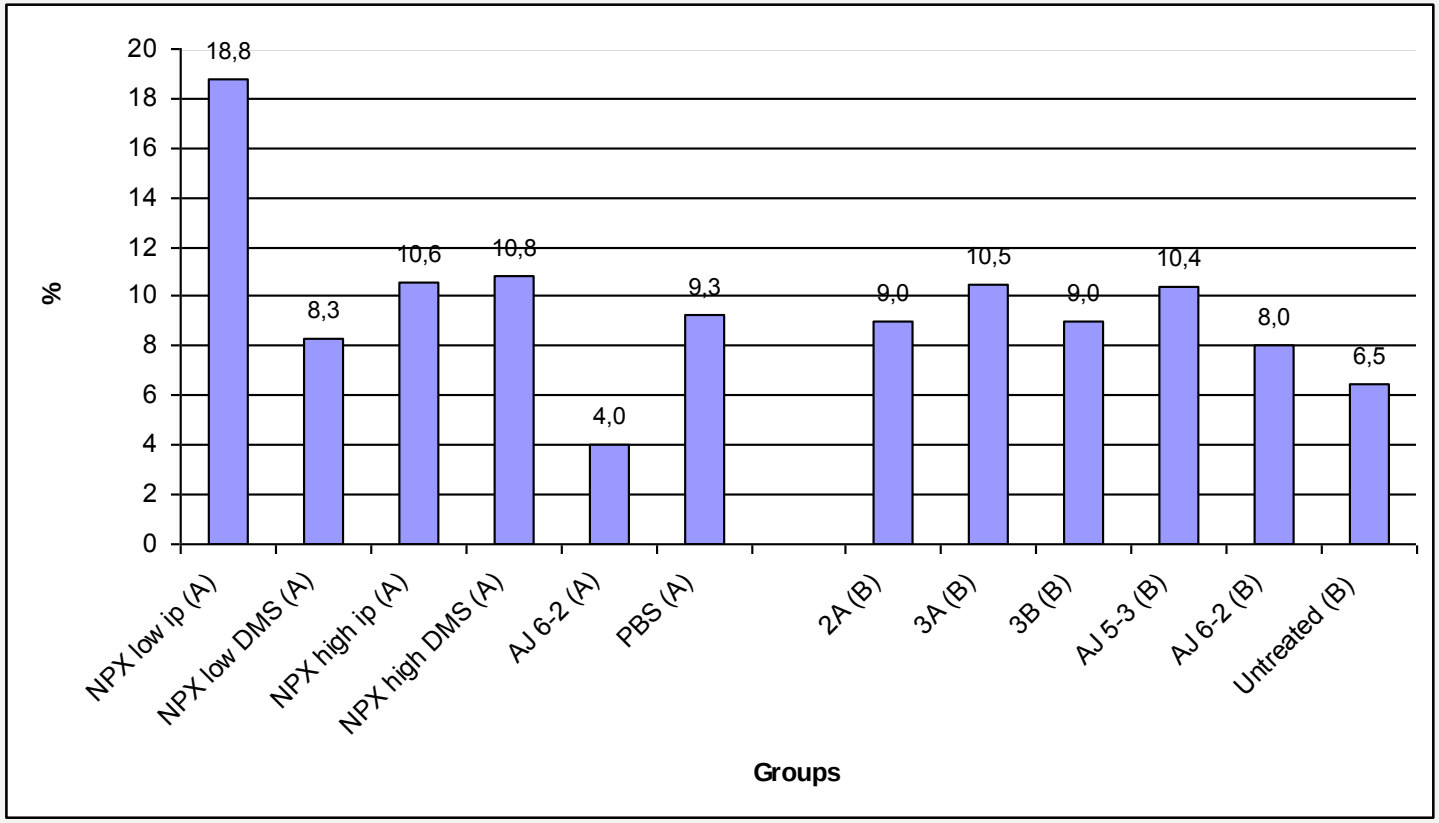
Group no.	Fish no.	Tank/Cage	Vaccine	Dose ml	Inj. Site	Tagging
1	200	A	AJ 6-2	0.1	i.p.	Ad
2	300	A	NPX low	0.05	i.p.	RM
3	250	A	NPX low	0.05	DMS	LM
4	300	A	NPX high	0.05	i.p.	Ad + RM
5	250	A	NPX high	0.05	DMS	Ad + LM
6	200	A	PBS	Control	i.p.	Non
7	200	B	AJ 6-2	0.1	i.p.	Ad
8	200	B	2A	0.1	i.p.	RM
9	200	B	3A	0.1	i.p.	LM
10	200	B	3B	0.1	i.p.	Ad + RM
11	200	B	AJ 5-3	0.1	i.p.	Ad + LM
12	200	B	Untreated			Non

DMS-injection technique

- Socorex self-refilling syringe
- Improved oil adjuvanted vaccine administered in dose 0.05 ml
- 4 x 0.6 mm needle
- 3 to 4 fish per minute (relatively slow compared to ip vaccination)



Slaughter control
% downgrading due to melanin spots in fillet



5. Conclusions

- Different from Føniks 06.02 ES this trial showed insignificant difference in growth between DMS and ip vaccinated groups
- There was no significant differences in weights between groups vaccinated with the NPX vaccine (0.05 ml) and ALPHA JECT 6-2
- Using the DMS technique will not reduce the downgrading of fillets due to melanin spots in the fillet
- Melanin spots in fillet is present in all groups, including high numbers in the PBS- control group and the untreated control group and does not seem to be caused by oil adjuvanted vaccines or the vaccination procedure.
- All groups showed similar frequencies of melanin and bruises as registered in MHN region South regular quality controls.
- Melanin spots are most probably caused by healing of bruises and may be caused by jumping activity in the net pen and does not necessarily has to be a result of a broken rib bone (oedema).
- Standard grade fillets due to adverse reactions in the DMS-region could all be upgraded to Premium D-trim fillets in the NPX low-group and 90% could be up-graded to D-trim fillets in the NPX high-group.
- Fish vaccinated with the NPX vaccines revealed low adverse reactions

Blackspot on unvaccinated fish

18 months post transfer

Melanine

Sep 2013, PhD thesis, Hilde Fagerland, Norw. Vet College

- **Black marks been linked to the use of oil adjuvanted vaccines.**
- **This study shows similar characteristics also in unvaccinated fish.**
- **At harvest as many as 10-30% of salmon may show signs of black spots in the fillets. This is caused by**
  - **Chronic inflammation sites in the muscle, with a congregation of cells containing melanine, causing the black mis –coloration.**

- **By using knowledge from vaccinated fish, similar spots in unvaccinated could be analysed.**
  - The structural build-up of the spots in unvaccinated fish were similar to the ones found in vaccinated fish
  - There were as many pigmented fish in the unvaccinated as in the vaccinated groups

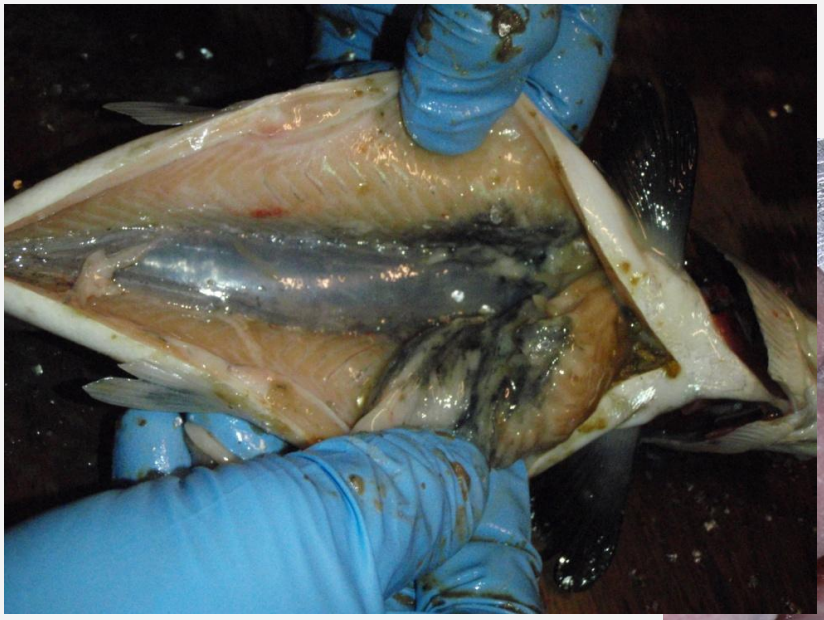
In summary our findings may indicate that the melanine is created as a support function to defense and repair mechanisms during chronic inflammation.

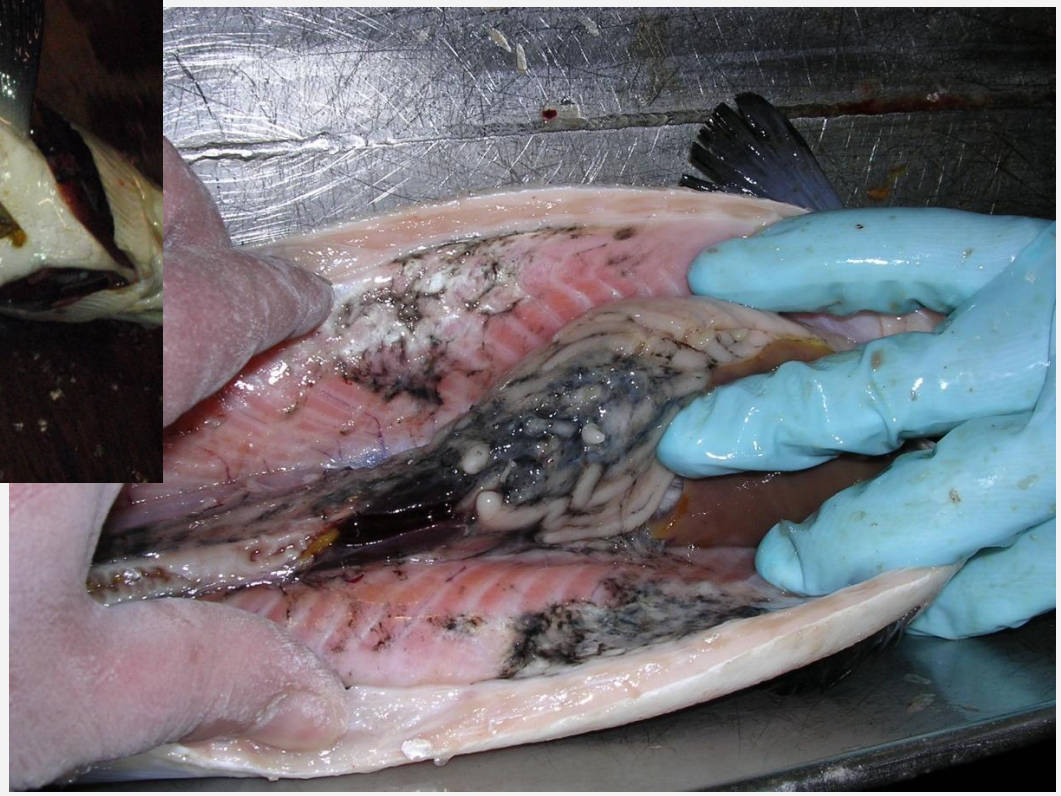
So what causes melanin?

- Basically: We don’t know.
- Melanin deposits come in a number of distinct forms, and we must assume that causes vary.
- More work is needed, and different solutions are probably necessary dependent on cause.

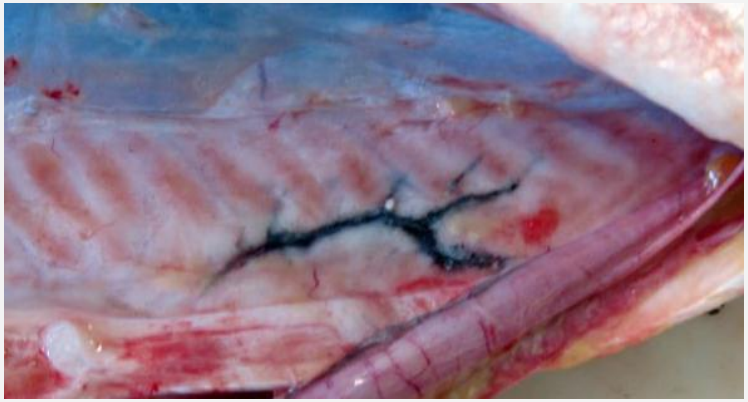
- Some examples:

Vaccine and vaccination



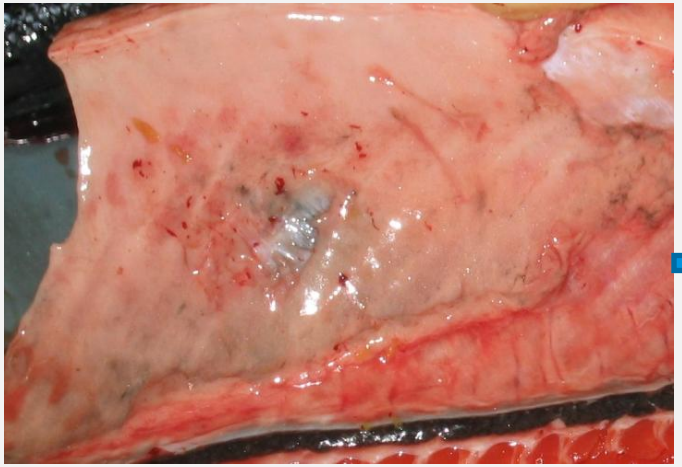


Deposit of vaccine i muscle

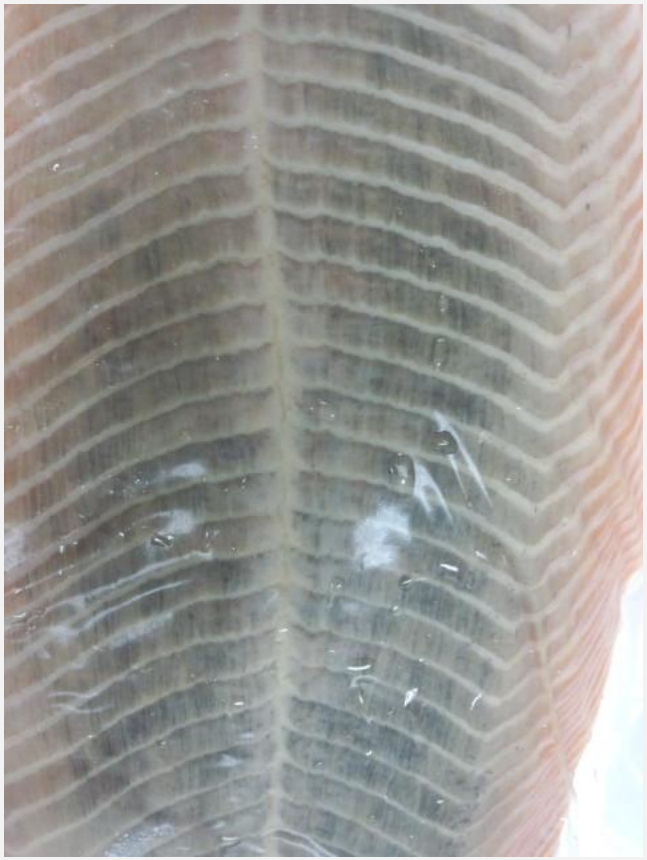


Black spots and blood spots.

Blackspot og vaccine relatet melanin?



Chronic inflammation in red muscle?



Findings and Activities

(production companies evaluations)

- S0s worse than S1s.
- Some sites/producers repeatedly have high levels of melanin, while others repeatedly have low levels.
- Padding of cages (trauma): No difference
- High/low density: no difference
- Higher water temperature seems to cause higher levels
- The majority of blackspots seem to come late in the seawater phase.

Findings and activities contd.

(production companies evaluations)

- Increasing number of Sea lice treatments: Increases melanine (but no the basic)
- Genetics: Larger variation within families than between families
- High EPA+DEA vs normal diet: No difference
- Looking at Zn, P, Fe, antioxidants
- Fractured pin bones and rib bones may cause melanizaton
- Single cell necrosis in white muscle:
  - Poorly vascularized

Findings and activities contd.

(production companies evaluations)

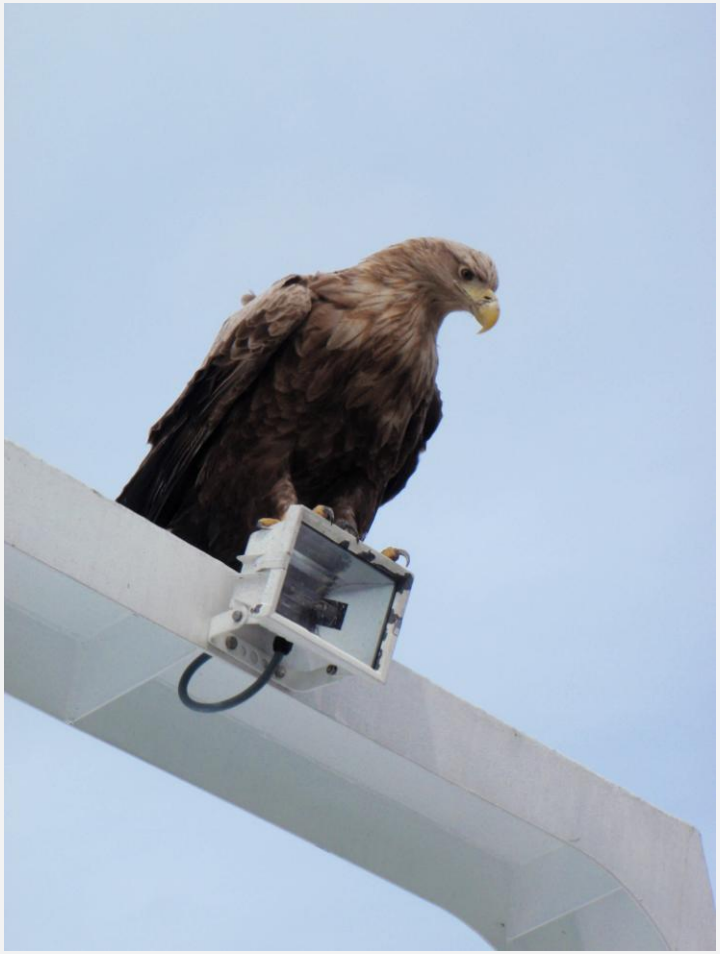
Discussion: Fall-Combination of

- high temps,
- low DO,
- high energy feed and
- burst swimming (lactic acid build –up)?

Probably also:

- And almost certainly a thing or two we haven't yet thought about.
- And we find it everywhere there is salmon farming

Increased focus on melanin



Increased focus on melanin

- A number of studies ongoing.
- Some preliminary findings/assumptions:

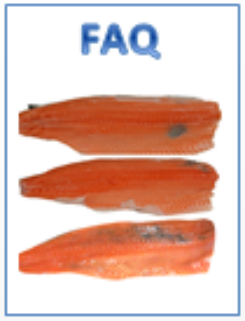
Melanine

Updated December 2013

MELANIN DEPOSITION IN SALMON FILLETS

Frequently asked questions

Dark discoloration of salmon fillets is mainly due to the deposition of melanin pigments. The discoloration may have different manifestations, from localized spots to more diffuse and widespread melanisation on the fillet side or under the skin/subcutaneously. Dark stained fillets cannot be sold as high quality products and therefore represent a significant economic problem for the salmon farming and processing industry



What is melanin?

- Melanin is a group of natural pigments found in most plants and animals
- Melanin is a powerful natural antioxidant
- In humans, melanin (eumelanin) is the primary determinant of skin colour

What causes melanin deposition in salmon fillets?

- Melanin pigments are deposited as a response to tissue damage or local inflammatory conditions
- Melanin deposition is a natural part of a fish's immune system
- Dark discoloration of salmon fillets is mainly due to melanin deposition, but dark spots can also contain blood pigments and scar tissue or a combination of melanin, blood and scar tissue.
- The causality is complex, and not related to one single cause.

Is it safe to consume fillets with melanin deposits

- Melanin is a safe and natural antioxidant
- Melanin can be used as a natural antioxidant in the food, cosmetic and pharmaceutical industries
- Dark pigments in various foods, such as caviar, are delicious

The information given in the FAQ is derived by the partners in the FHF project "Dark spots in salmon fillets. Causes and preventive measures"
For further information, please contact
Turid Mørkøre e-mail turid.morkore@nofima.no or Kristin Espe e-mail kristin.espe@fhf.no

Updated December 2013

Occurrence of melanin spots in salmon fillets

- Approximately 12% of Norwegian salmon fillets have lightly stained spots smaller than 3cm in diameter and 2% of the fillets have darker spots larger than 3cm on average.
- Most spots (70%) are located in the front part of the abdomen
- Dark spots are also observed in wild living salmon, hence it is not likely that the phenomenon will disappear completely

What is being done to reduce the presence of dark fillet spots

- The Norwegian Seafood Research Fund (FHF), on behalf of the farming industry, has supported research on dark fillet spots since 2008 to reveal causes, provide reliable statistics and to define measures to reduce the problem. The research within this area was intensified in 2012, involving several industrial stakeholders and research communities.
- Reliable statistics require good, consistent, continuous and comprehensive recording of dark fillet spots. Therefore unified registrations at filleting plants along the Norwegian coast have been developed and implemented. Registrations of frequency and severity together with background data (genetics, vaccines/fish health, feed, rearing, harvesting etc.) is collected in a database to provide reliable and updated statistics. Information on fish origin is used to search for causes to the problem. However, such an epidemiological approach requires patience as the results evolve on a long-term basis. Updated statistics on the frequency of dark spots are published continuously.
- Specific ongoing research projects (apart from the registrations/ epidemiological study)
  - Vaccine and vaccination
  - Feed composition
  - Environmental rearing conditions
  - The importance of physical trauma and stress
  - In depth characterisation of fillets with dark pigmentation to improve our ability to define causes

The information given in the FAQ is derived by the partners in the FHF project "Dark spots in salmon fillets. Causes and preventive measures"
For further information, please contact
Turid Mørkøre e-mail turid.morkore@nofima.no or Kristin Espe e-mail kristin.espe@fhf.no

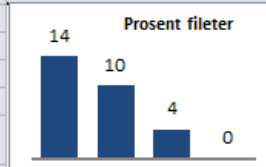
MELANINREGISTRERING revidert 062014.xlsx - Microsoft Excel

Fil | Hjem | Sett inn | Sideoppsett | Formler | Data | Se gjennom | Visning | Acrobat

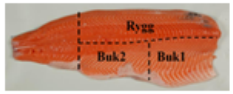
Hent eksterne data: Fra Access | Fra webområde | Fra tekst | Fra andre kilder | Eksisterende tilkoblinger
Tilkoblinger: Oppdater alt | Tilkoblinger | Egenskaper | Rediger koblinger
Sorter og filtrer: Sorter | Filtrer | Fjern | Bruk på nytt | Avansert
Dataverktøy: Tekst til kolonner | Fjern duplikater | Datavalidering | Konsolider | Hva-skjer-hvis-analyse
Grupper | Del opp gruppe

M101

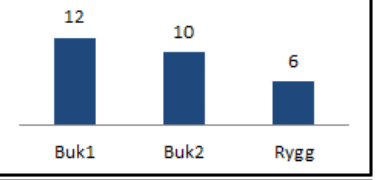
FLEKKER (poeng)			
Ingen misfarging	0	Flekk 3 - 6cm	4
Diffus flekk, alle størrelser	1	Område større enn 6cm	8
Flekk mindre enn 3cm	2	*Gjennomsnitt*	*0.50*



Antall (%) fileter med flekk(er)
25



FLEKK (poeng)	1	2	4	8	Totalt %
Buk1	5	4	3	0	12
Buk2	6	4	0	0	10
Rygg	3	2	1	0	6
Total	*14*	*10*	*4*	*0*	



skjema sendes til thomas.larsson@nofima.no

Frivillige registreringer
Utført: JA / NEI

Kommentarer

F. eks. om det er fisk med flere flekker innenfor samme område eller avvik for partiet (bløt filet, brusk, deformiteter e.l.)

	FLEKKER I FILET (poeng) flere flekker i samme område summeres			Blek, 0/1 (se fanen "Forklaring")	Gaping, 0/1 (se fanen "Forklaring")
Filet	Total poeng	Buk 1	Buk 2	Rygg	
1	1	1	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	1	1	0	0	0	0
5	0	0	0	0	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0
8	1	1	0	0	0	0
9	0	0	0	0	0	0
10	1	0	1	0	0	0
11	0	0	0	0	0	0
12	1	1	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0

SPØRSMÅL SOM BESVARES FOR HVER GRUPPE FISK SOM BEDØMMES
Sett gjerne ? der informasjon mangler

Prosessanlegg navn/nr:					
Navn på bedømmer:					
Lokalitetsnr (navn):				Kvalitetsklasse:	
Dato ved slakt:		Sjøtemp:		Superior	
Dato ved måling:		Merd nr:		Ordinær	
Vektklasse:		Lot nr:		Produksjon	

TILLEGGSINFORMASJON

Smolt					
Leverandør:					
Utsett *måned:*		*år:*		Stamme:	

Forklaring | Registreringsskjema

Klar

Nofima contact

Turid Mørkøre

Turid.morkore@nofima.no


Thank you for your attention!
Questions or comments?

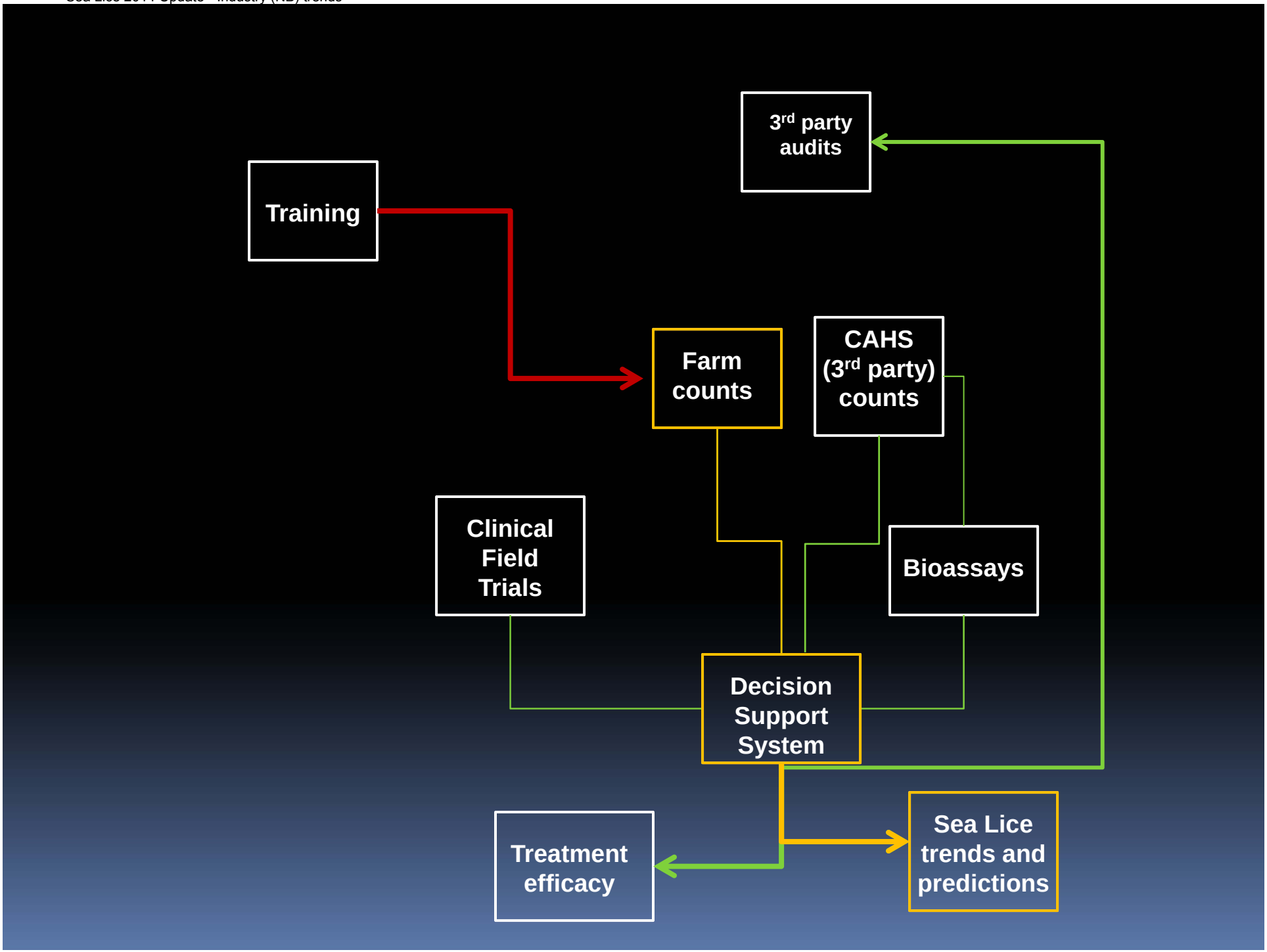
Sea Lice 2014 update

industry (NB) trends

Larry Hammell
Professor, Dept of Health Management
Director, AVC Centre for Aquatic Health Sciences
Innovation (PEI) Research Chair, Aquatic Epidemiology

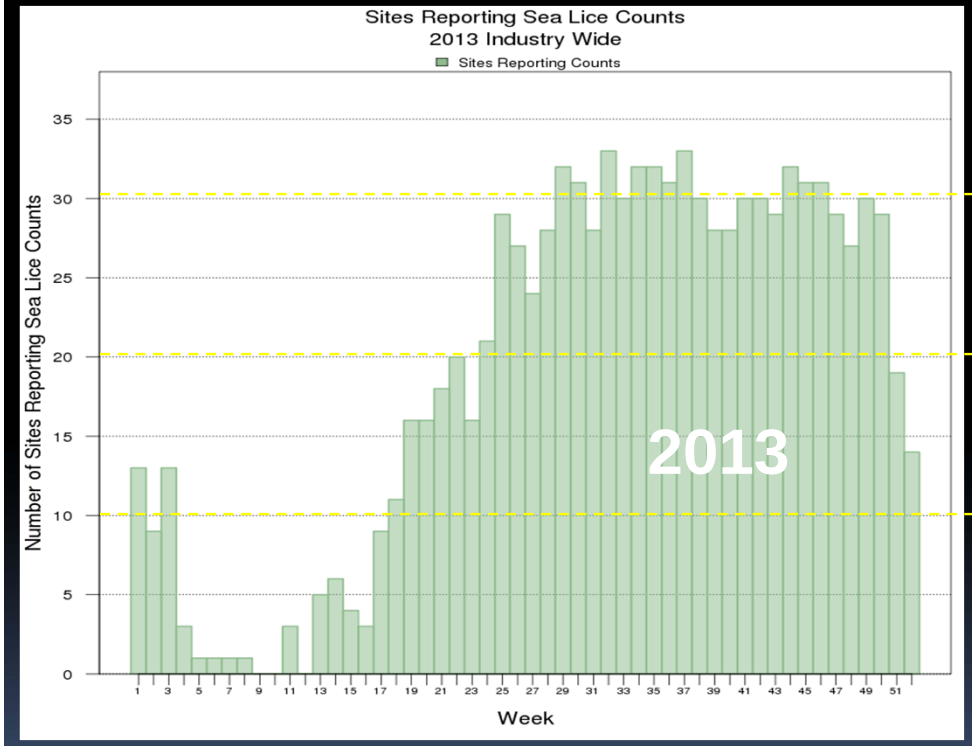
outline

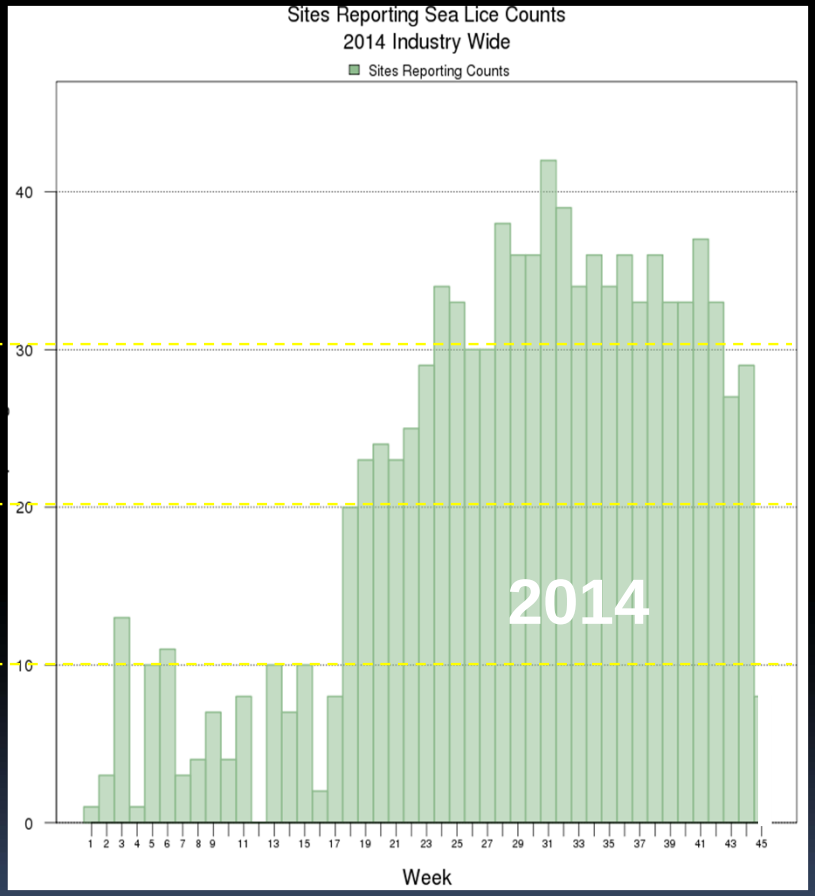
- Fish-iTrends (FiT) data input by industry (and AVC)
- Sea lice trends industry-wide and some more detailed examples
- Sea lice treatment monitoring (focus on market year fish)
- Concluding remarks about industry lice patterns and treatments

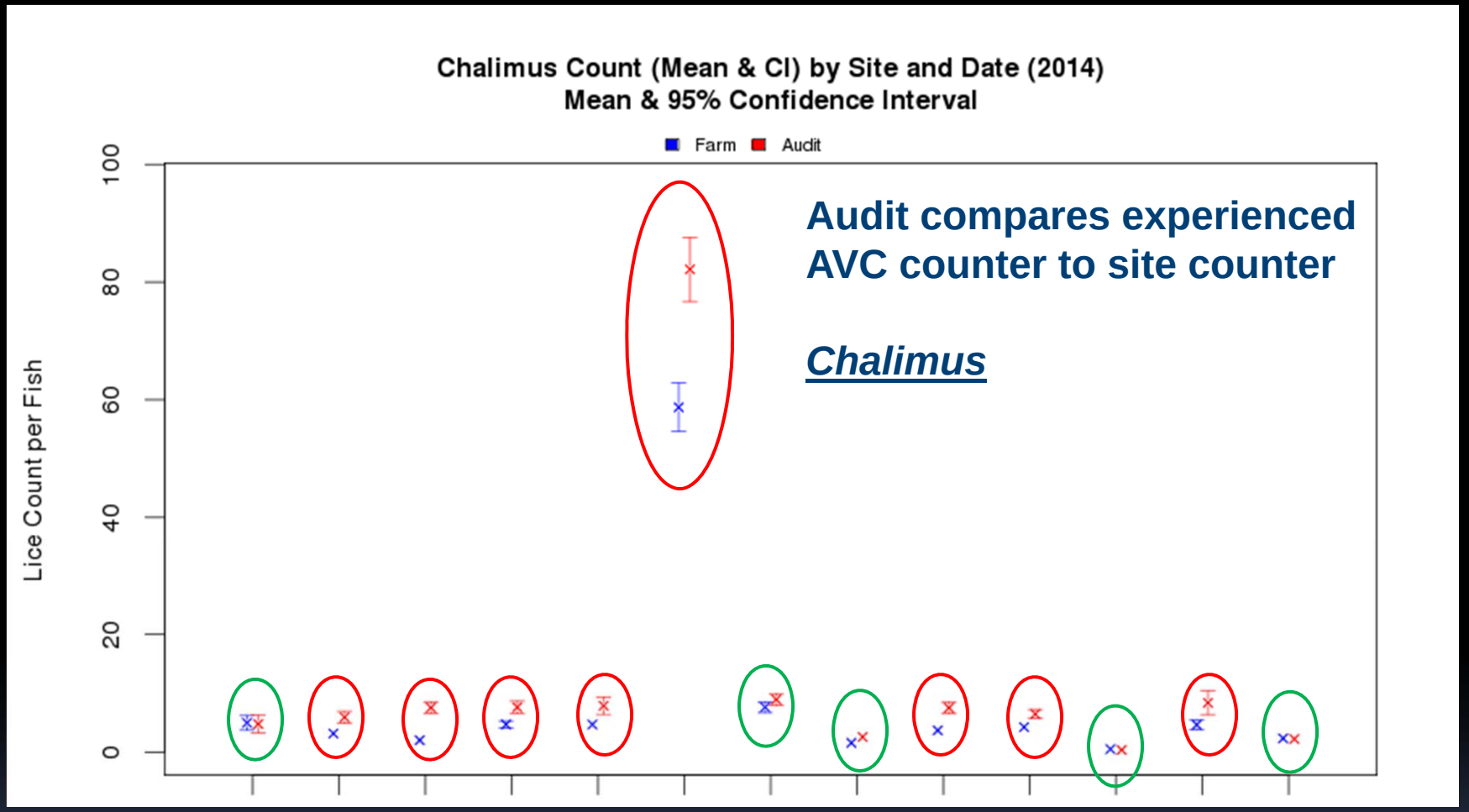

3rd party audits
Training
Farm counts
CAHS (3rd party) counts
Clinical Field Trials
Bioassays
Decision Support System
Treatment efficacy
Sea Lice trends and predictions

Sites using FiT

(NB only
NL, NS starting to enter data)

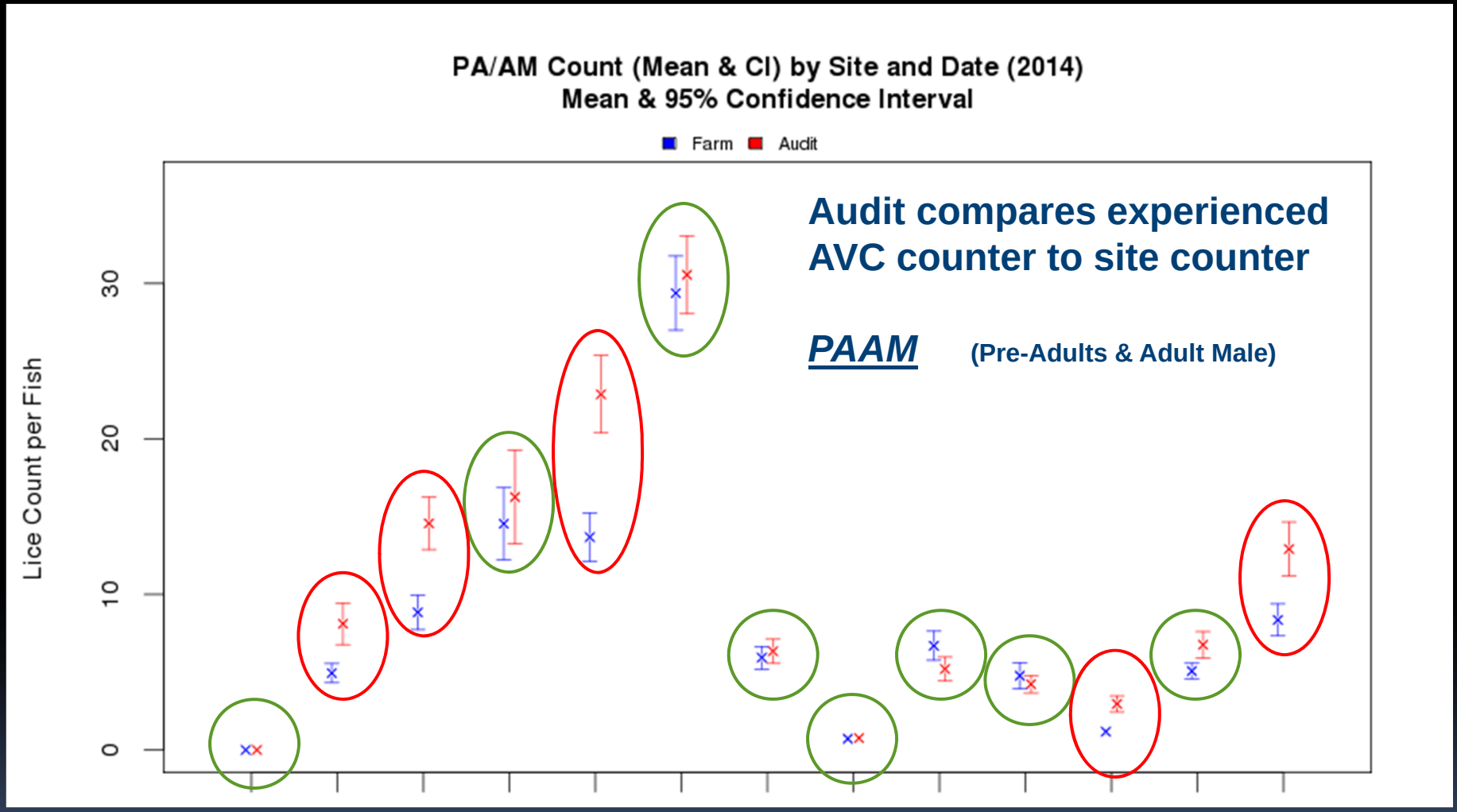






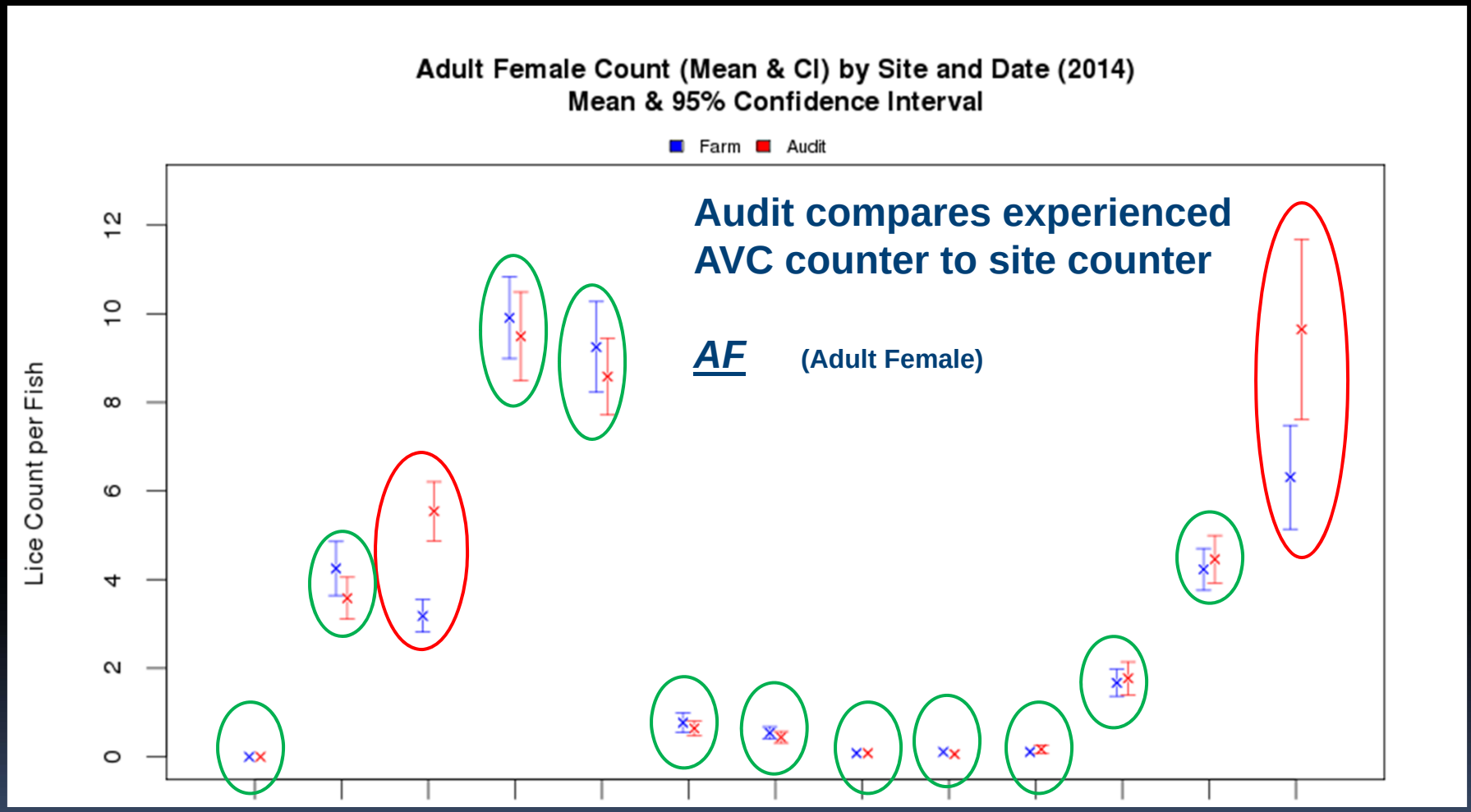
Chalimus counting: **5 / 13 sites agree**
8 / 13 sites disagree

(under-count consistently but not dramatically different)



PAAM counting: **8 / 13 sites agree**
5 / 13 sites disagree

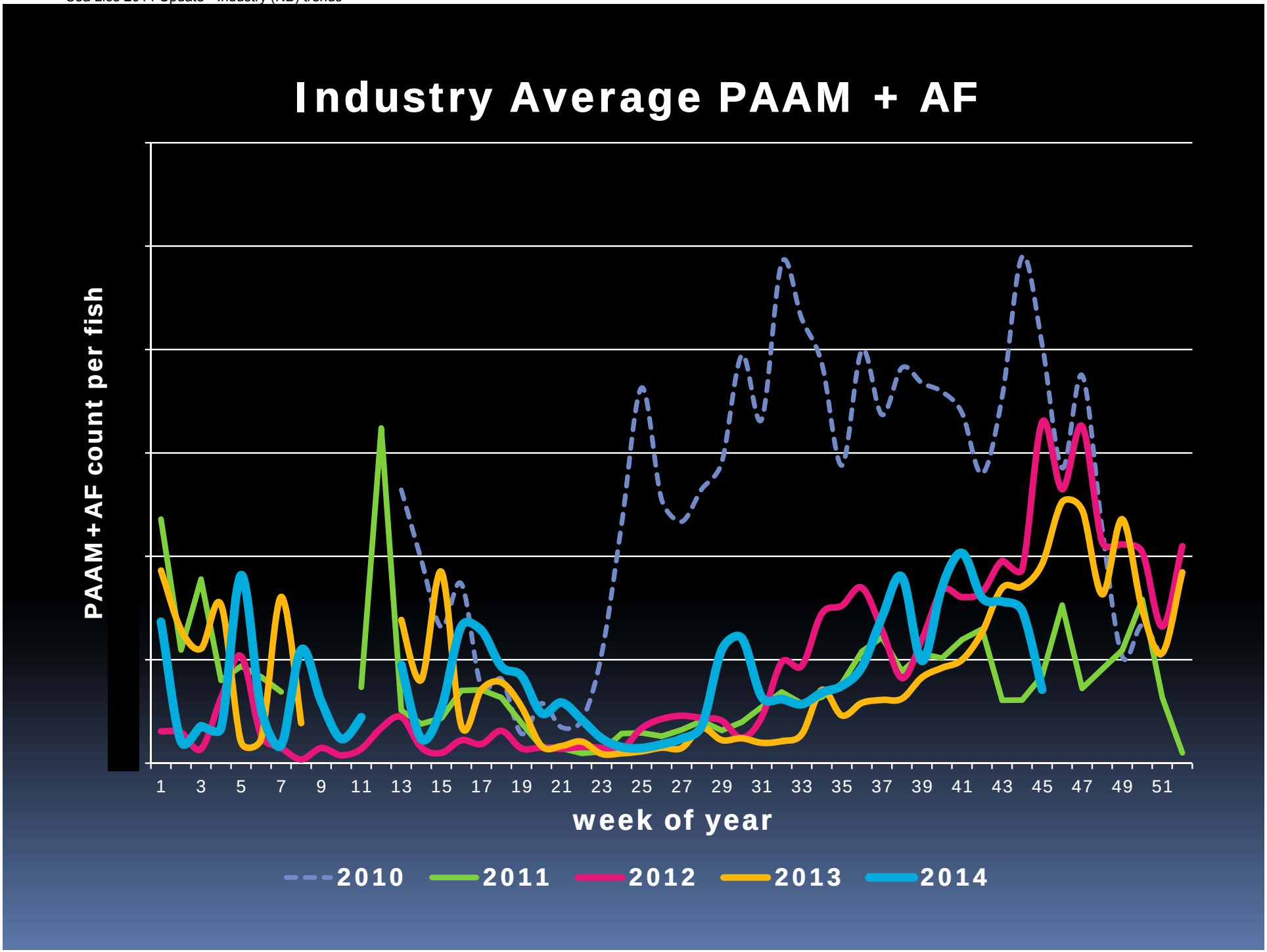
(when disagree, site under-counts PAAM)

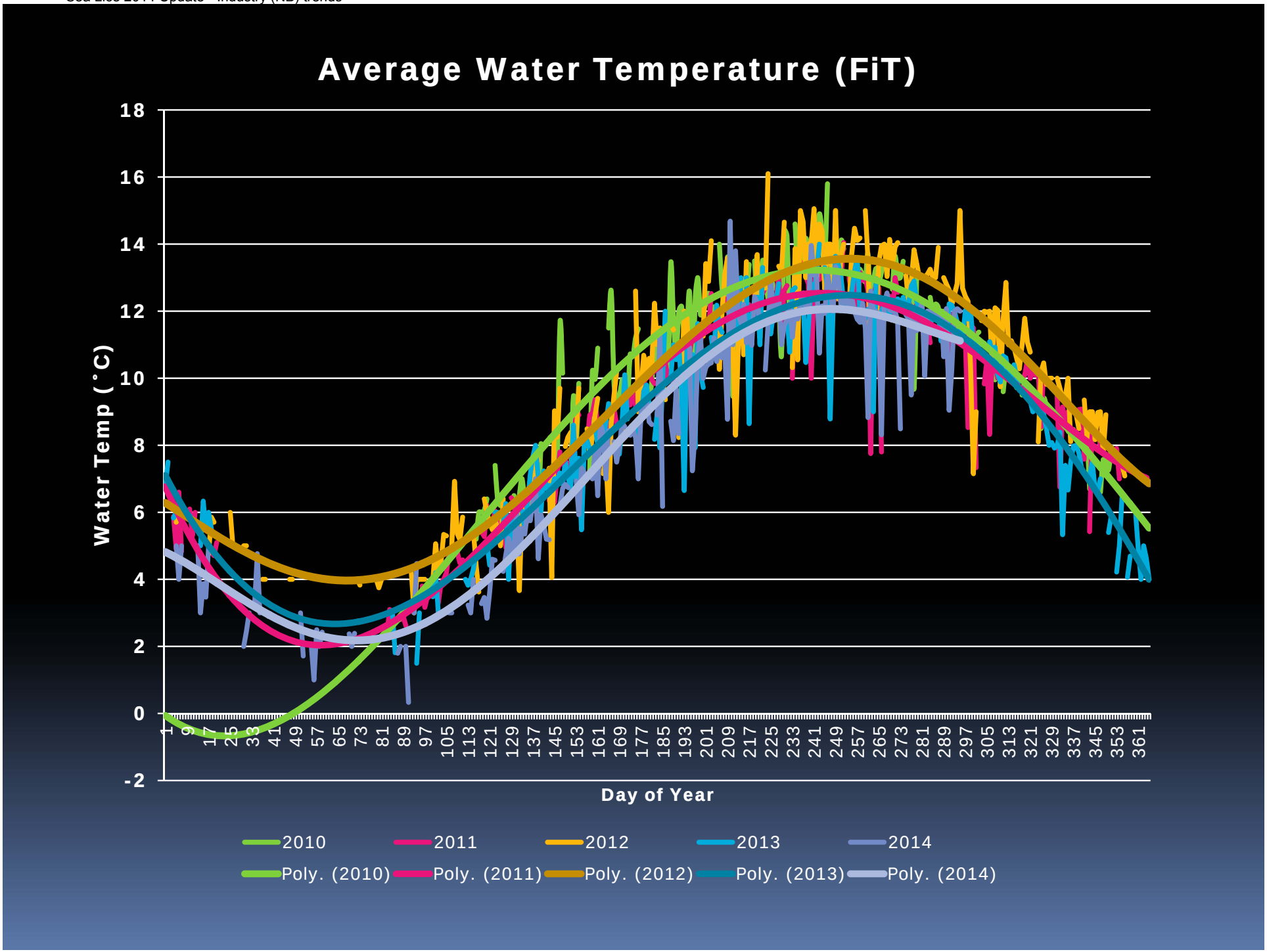


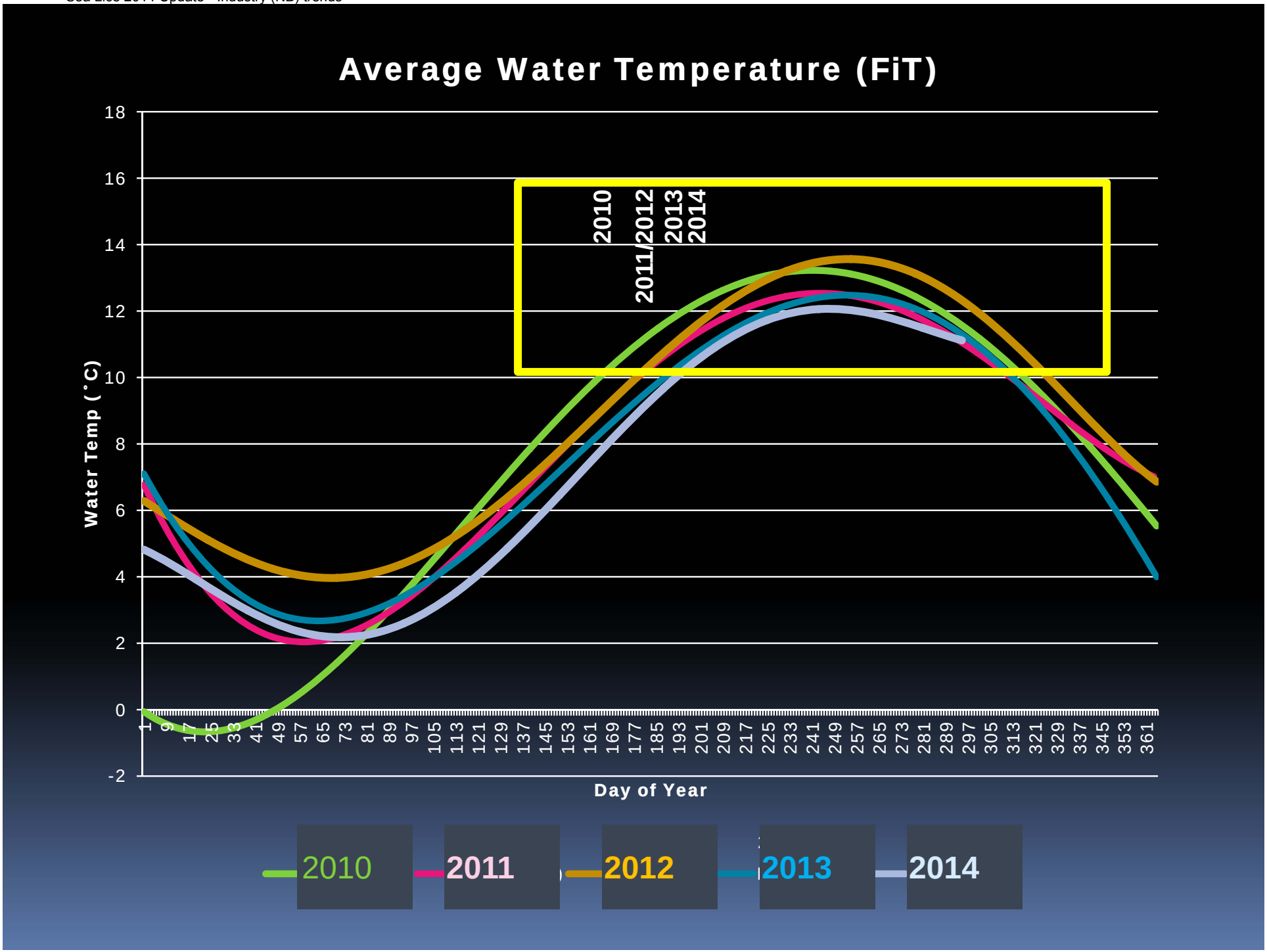
AF counting: 11 / 13 sites agree
2 / 13 sites disagree

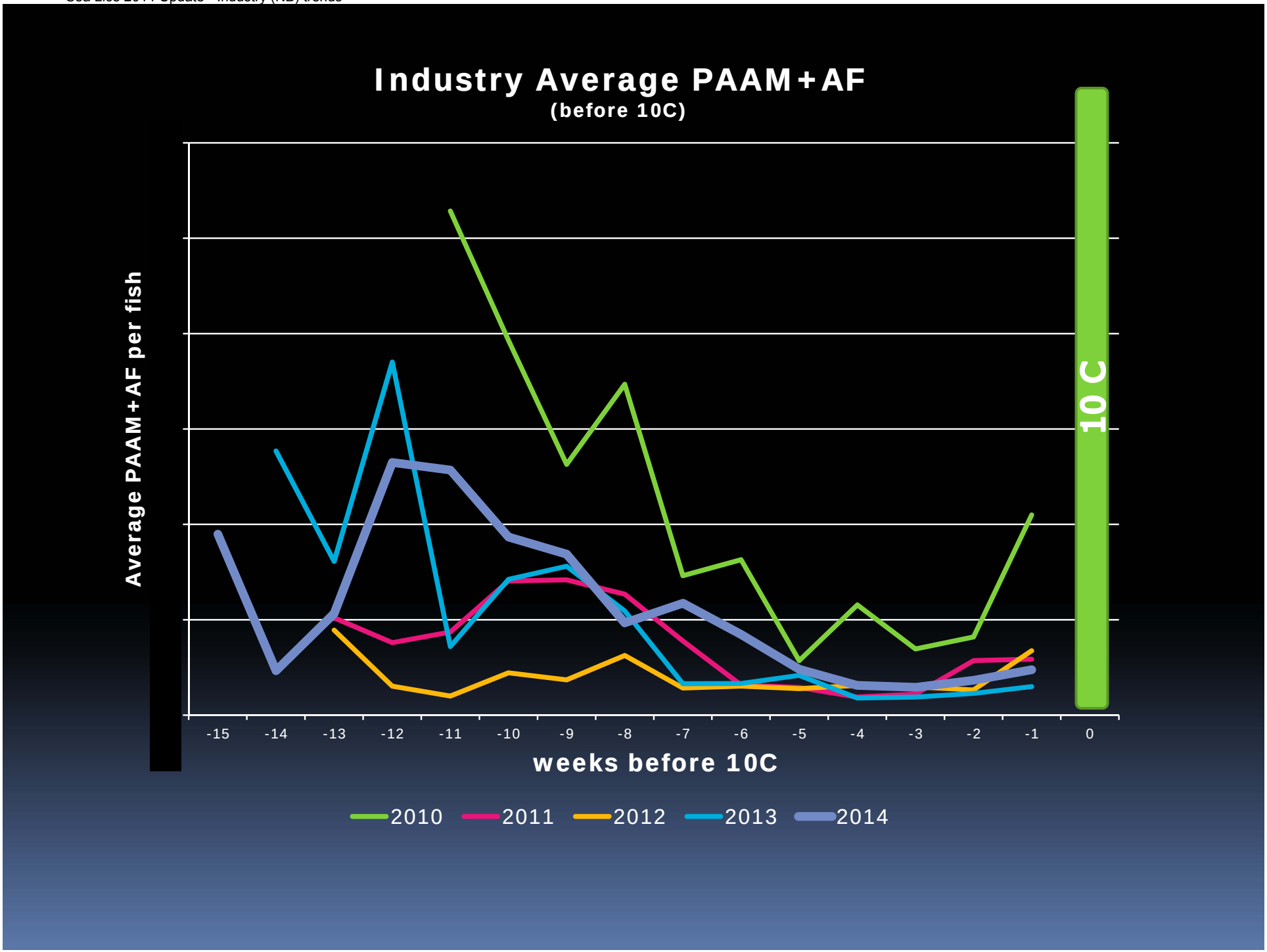
(AF are counted consistently compared to experienced counter)

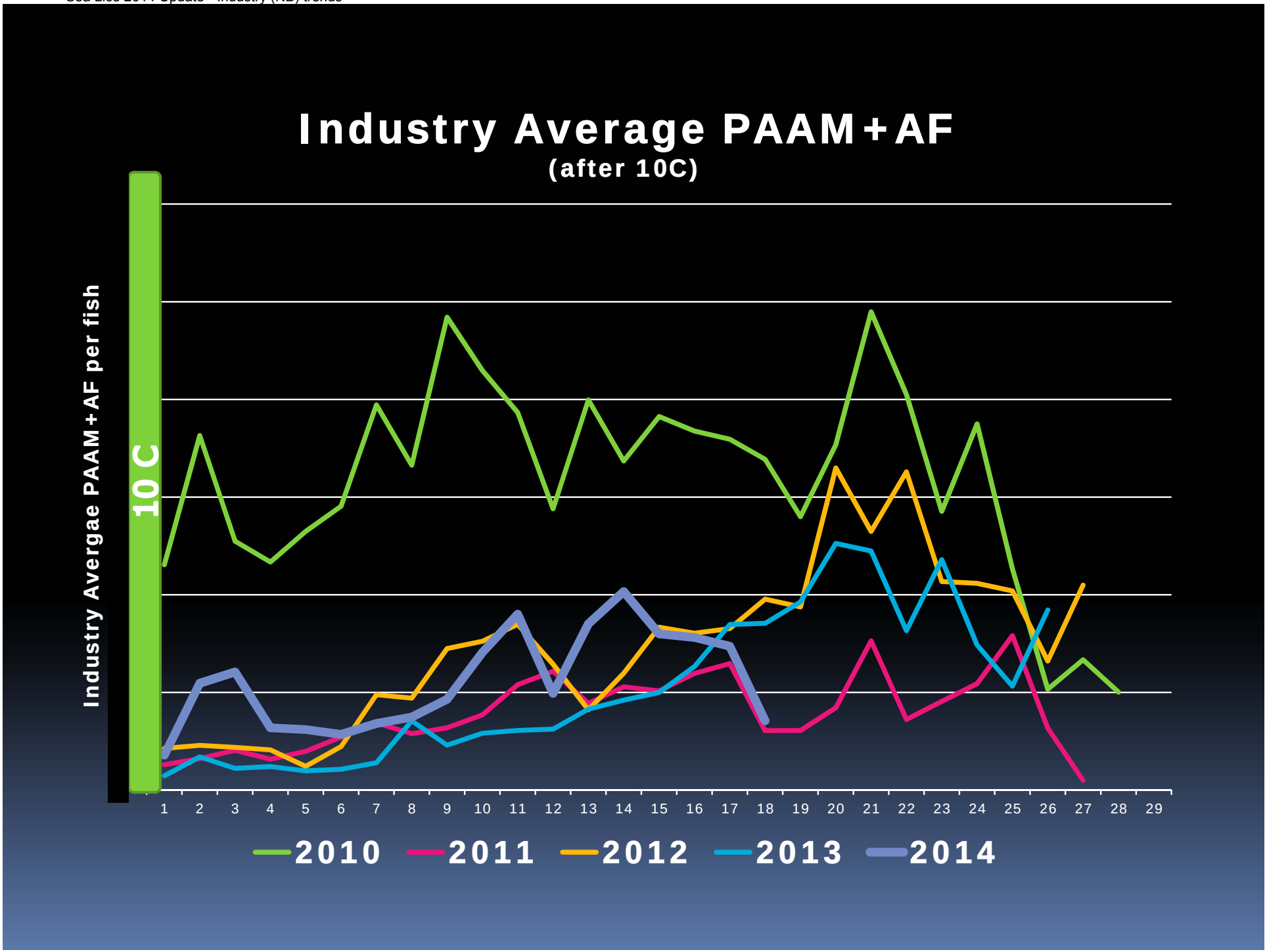
SEA LICE TRENDS

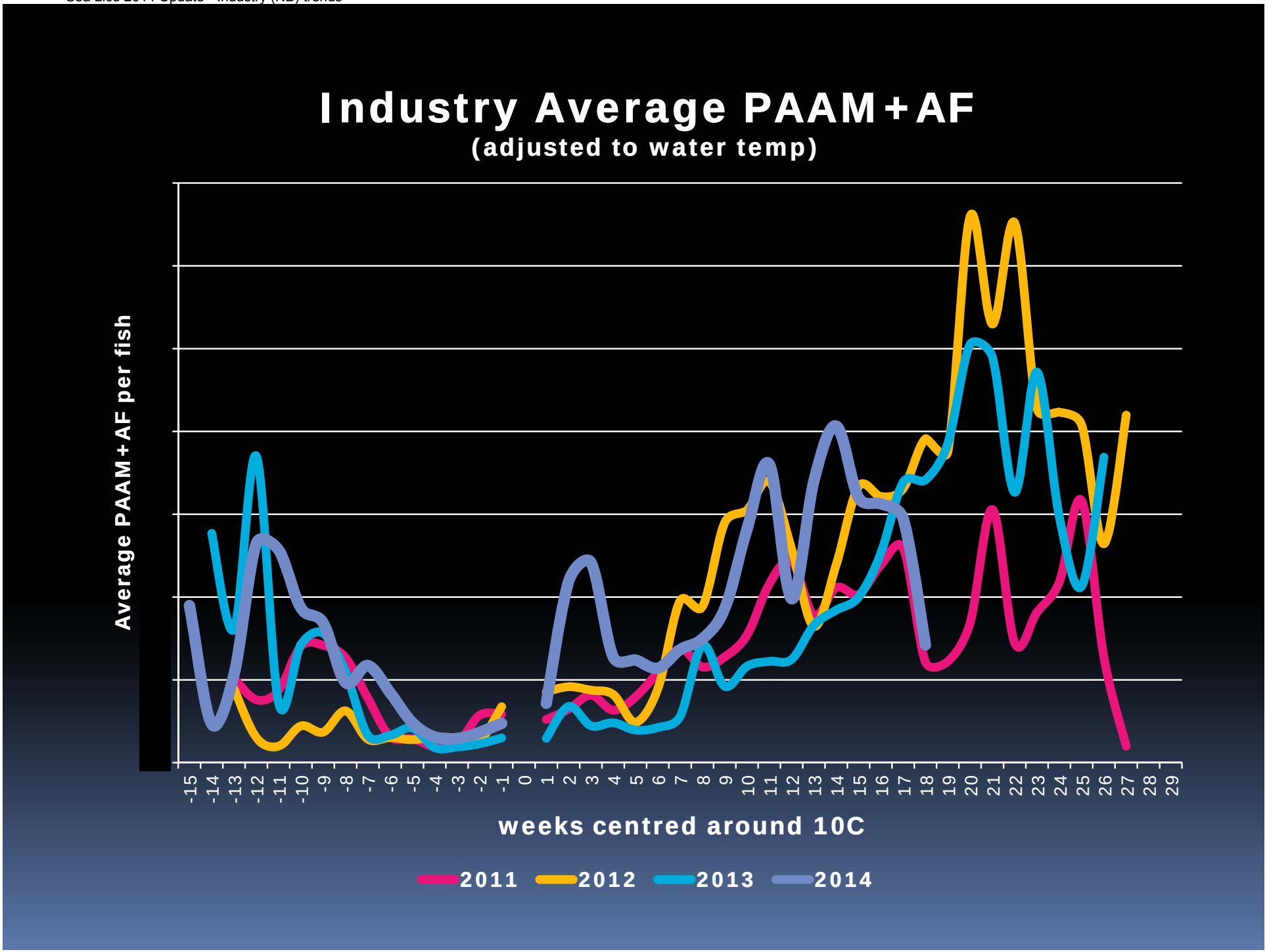

Industry Average PAAM + AF
PAAM+AF count per fish
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51
week of year
2010
2011
2012
2013
2014

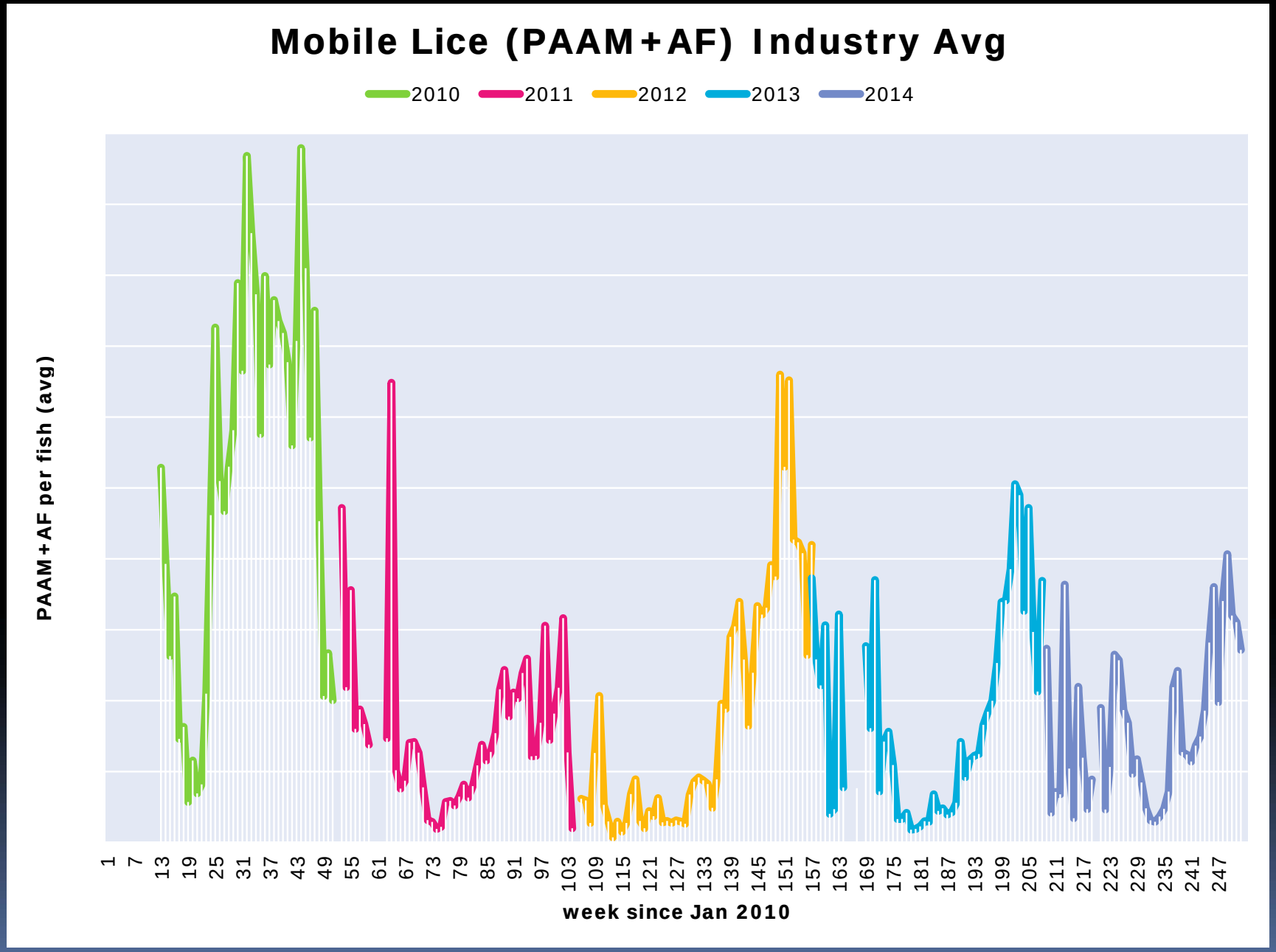

Average Water Temperature (FiT)
Water Temp (°C)
18
16
14
12
10
8
6
4
2
0
-2
1 9 17 25 33 41 49 57 65 73 81 89 97 105 113 121 129 137 145 153 161 169 177 185 193 201 209 217 225 233 241 249 257 265 273 281 289 297 305 313 321 329 337 345 353 361
Day of Year
2010
2011
2012
2013
2014
Poly. (2010)
Poly. (2011)
Poly. (2012)
Poly. (2013)
Poly. (2014)

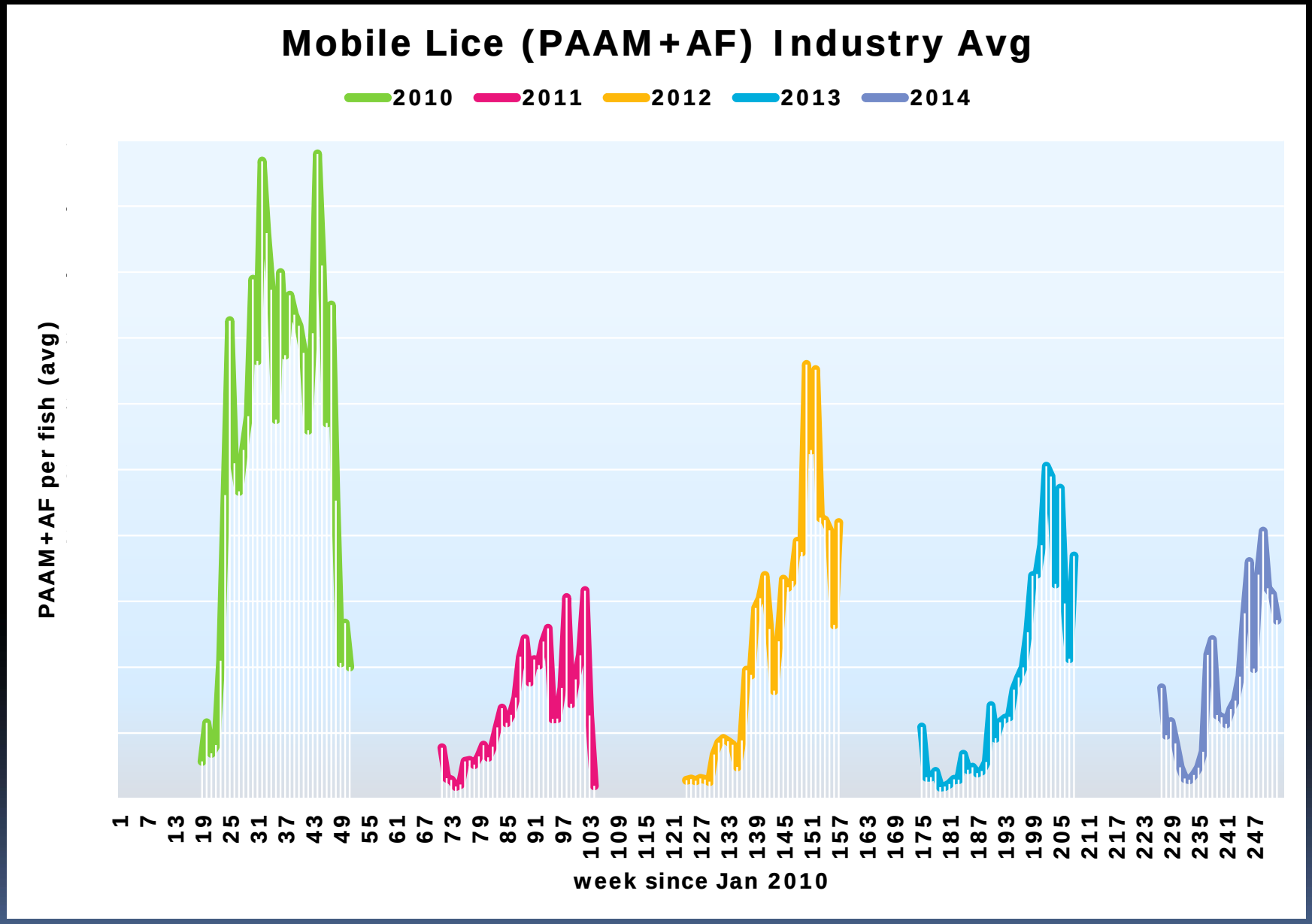

Average Water Temperature (FiT)
Water Temp (˚C)
18
16
14
12
10
8
6
4
2
0
-2
1
9
17
25
33
41
49
57
65
73
81
89
97
105
113
121
129
137
145
153
161
169
177
185
193
201
209
217
225
233
241
249
257
265
273
281
289
297
305
313
321
329
337
345
353
361
Day of Year
2010
2011
2012
2013
2014
2010
2011/2012
2013
2014

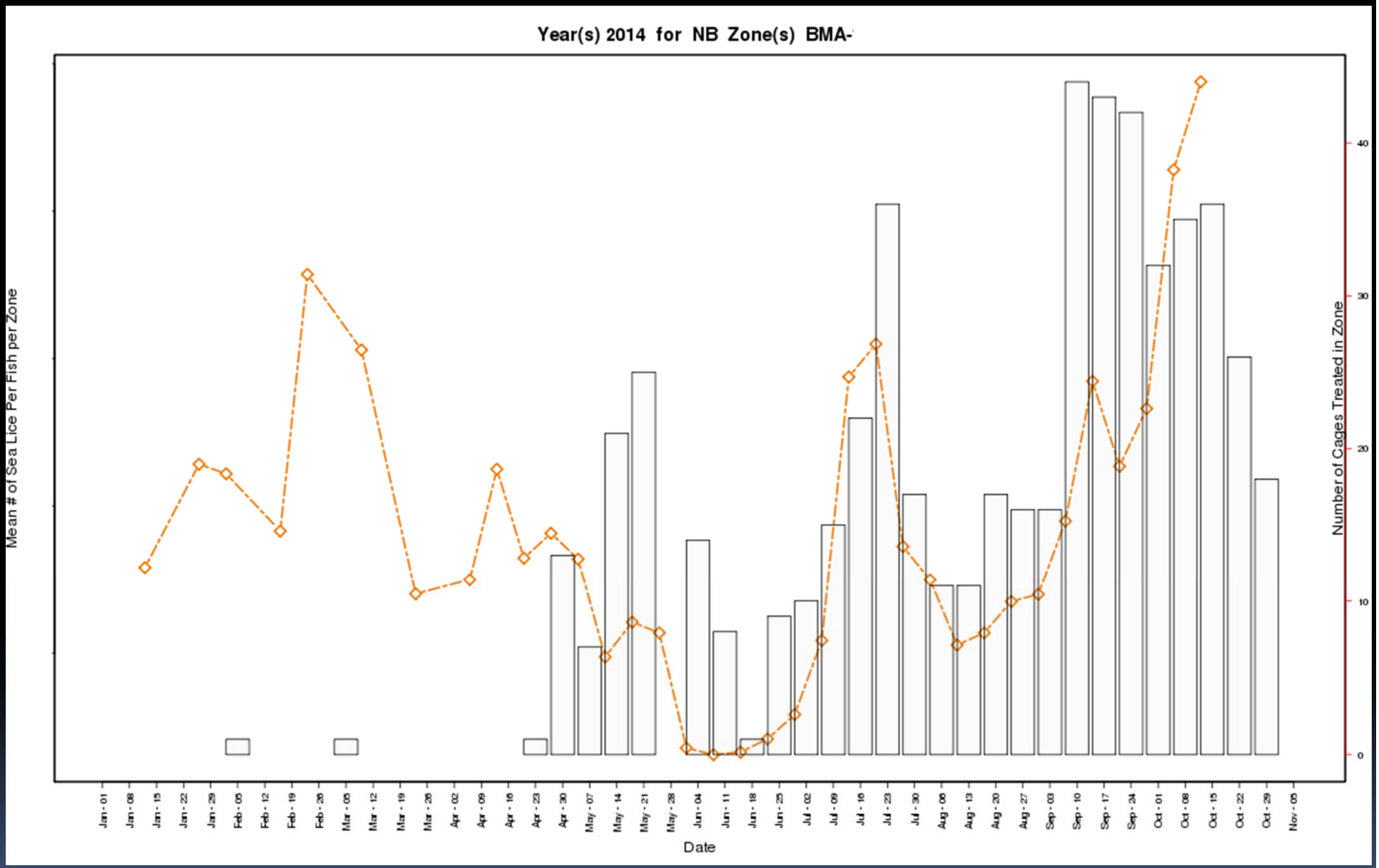

Industry Average PAAM+AF
(before 10C)
Average PAAM+AF per fish
10 C
-15
-14
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
weeks before 10C
2010
2011
2012
2013
2014

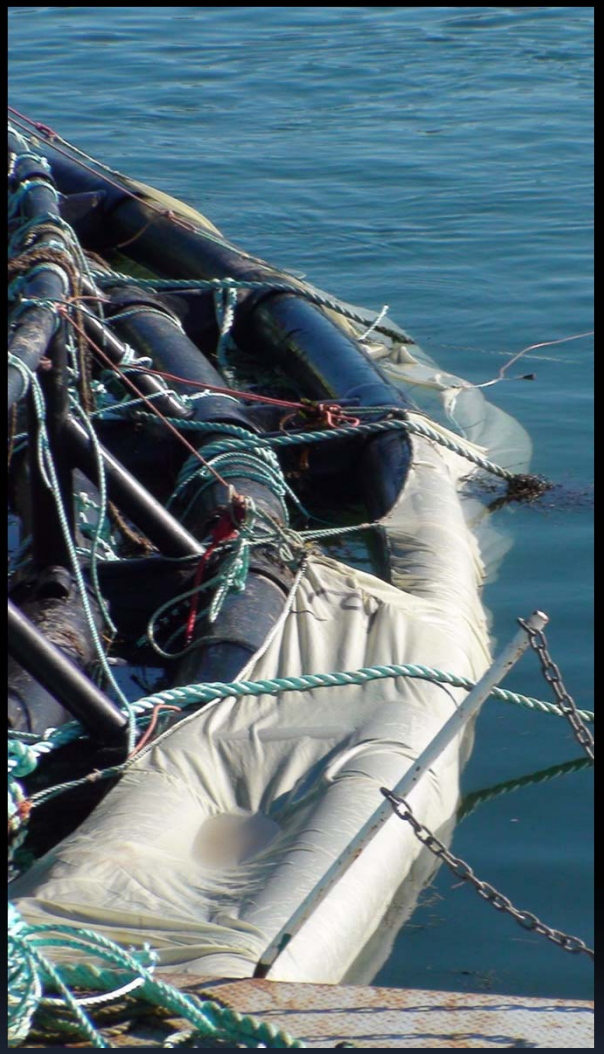

Industry Average PAAM+AF
(after 10C)
Industry Avergae PAAM+AF per fish
10 C
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
2010
2011
2012
2013
2014


Industry Average PAAM+AF
(adjusted to water temp)
Average PAAM+AF per fish
-15 -14 -13 -12 -11 -10 -9 -8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
weeks centred around 10C
2011
2012
2013
2014

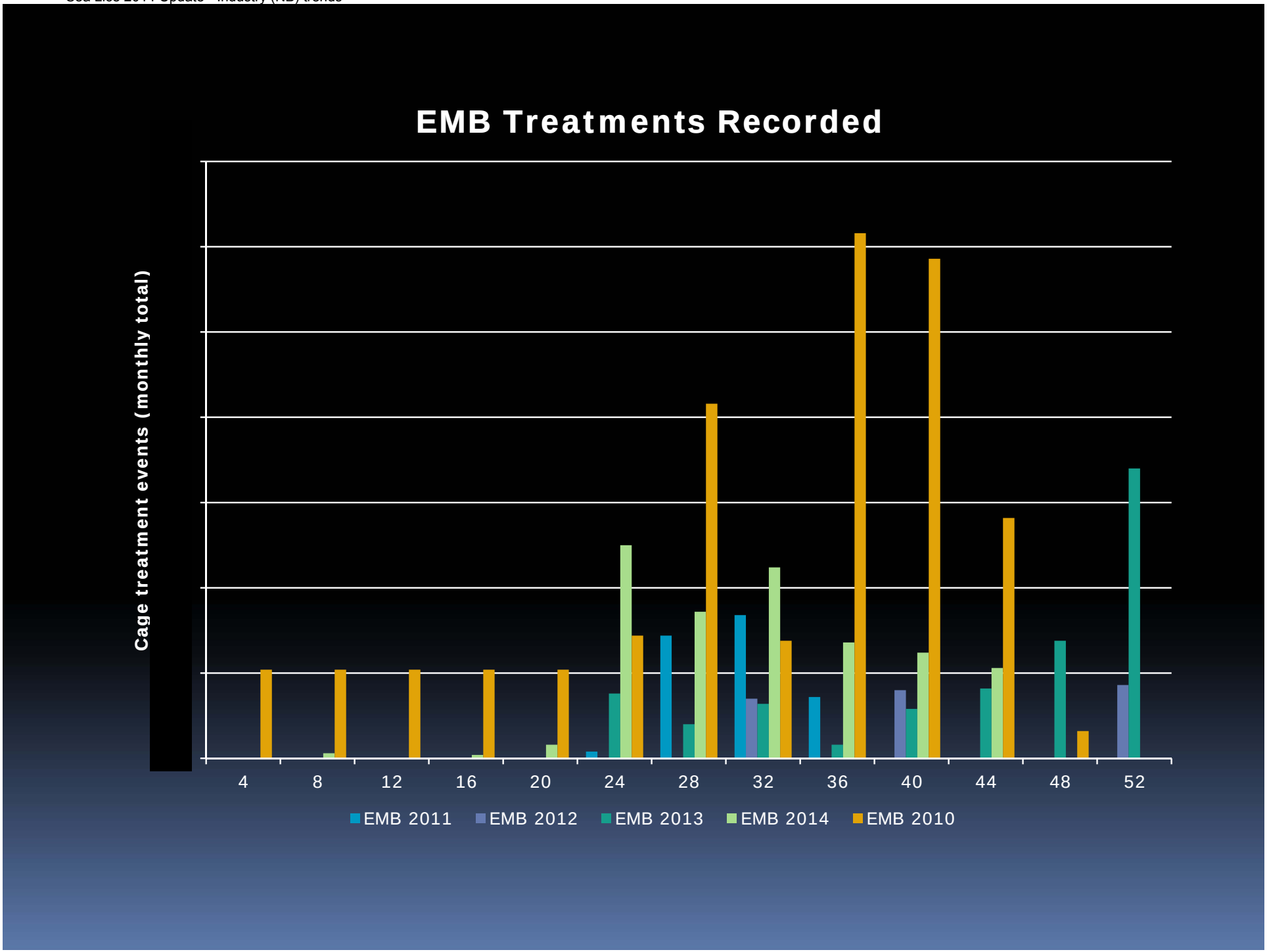

Mobile Lice (PAAM+AF) Industry Avg
2010
2011
2012
2013
2014
PAAM+AF per fish (avg)
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
109
115
121
127
133
139
145
151
157
163
169
175
181
187
193
199
205
211
217
223
229
235
241
247
week since Jan 2010


Mobile Lice (PAAM+AF) Industry Avg
2010
2011
2012
2013
2014
PAAM+AF per fish (avg)
1
7
13
19
25
31
37
43
49
55
61
67
73
79
85
91
97
103
109
115
121
127
133
139
145
151
157
163
169
175
181
187
193
199
205
211
217
223
229
235
241
247
week since Jan 2010

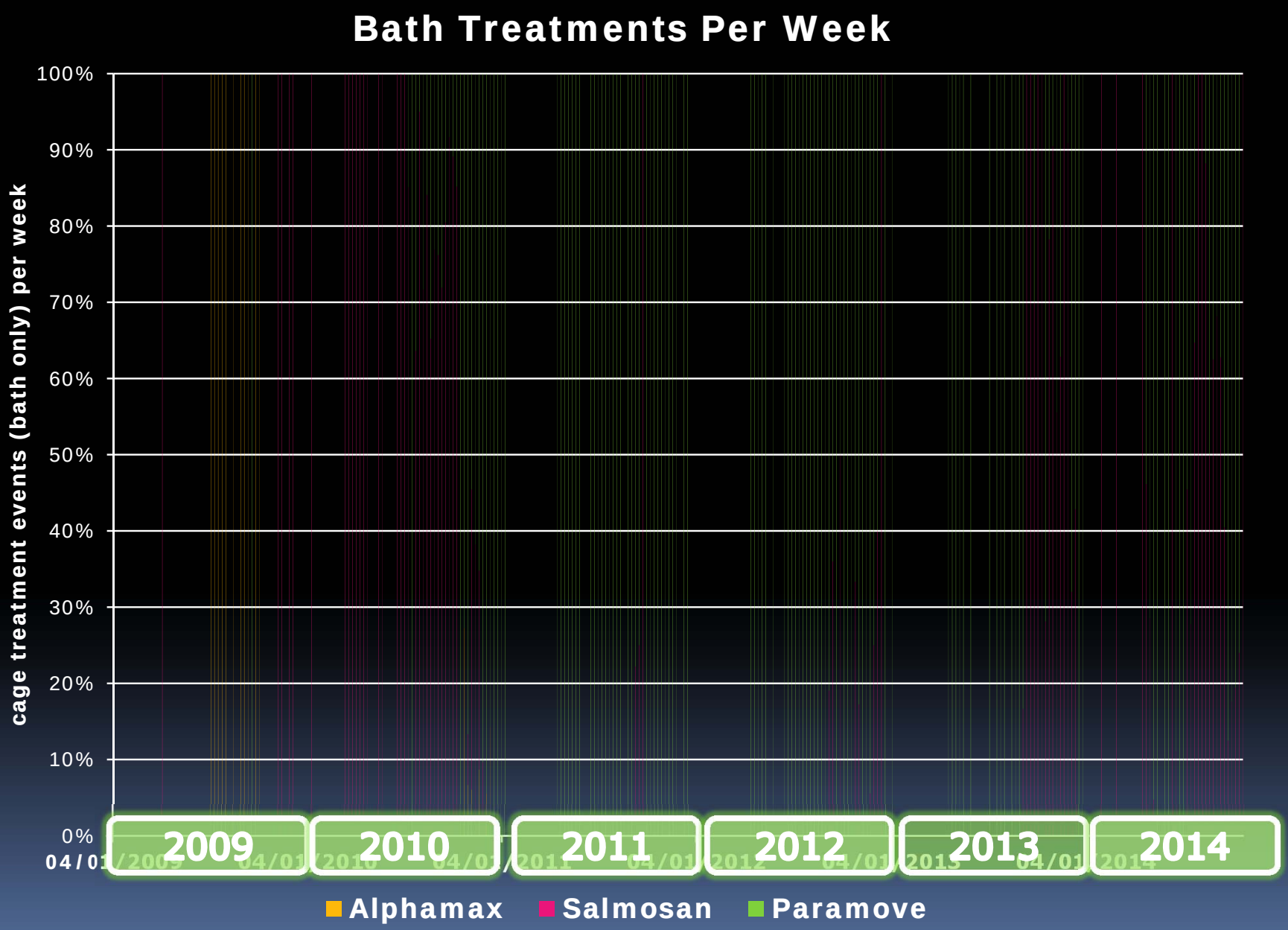

Year(s) 2014 for NB Zone(s) BMA-
Mean # of Sea Lice Per Fish per Zone
Number of Cages Treated in Zone
Date
Jan - 01
Jan - 08
Jan - 15
Jan - 22
Jan - 29
Feb - 05
Feb - 12
Feb - 19
Feb - 26
Mar - 05
Mar - 12
Mar - 19
Mar - 26
Apr - 02
Apr - 09
Apr - 16
Apr - 23
Apr - 30
May - 07
May - 14
May - 21
May - 28
Jun - 04
Jun - 11
Jun - 18
Jun - 25
Jul - 02
Jul - 09
Jul - 16
Jul - 23
Jul - 30
Aug - 06
Aug - 13
Aug - 20
Aug - 27
Sep - 03
Sep - 10
Sep - 17
Sep - 24
Oct - 01
Oct - 08
Oct - 15
Oct - 22
Oct - 29
Nov - 05
0
10
20
30
40

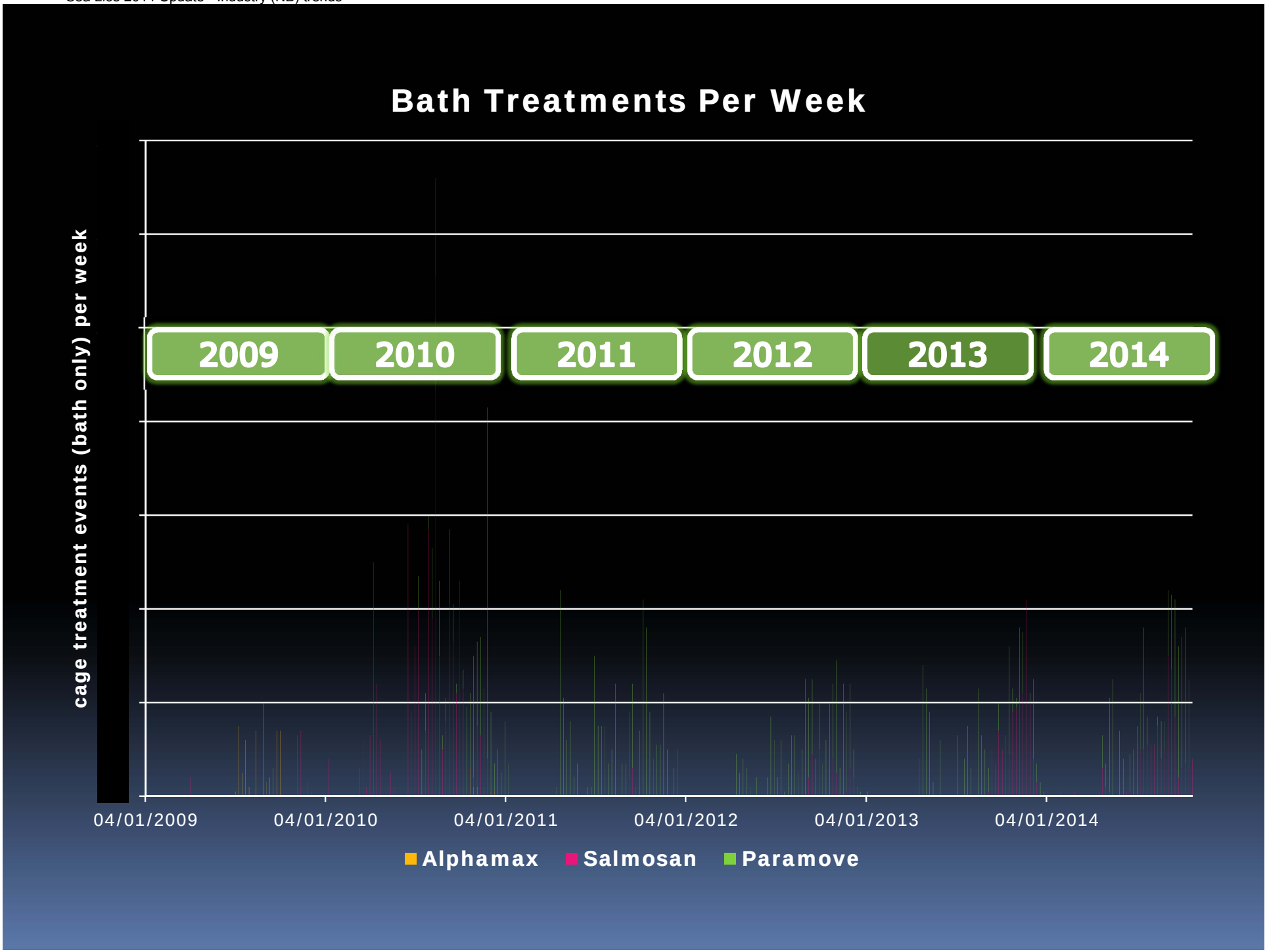


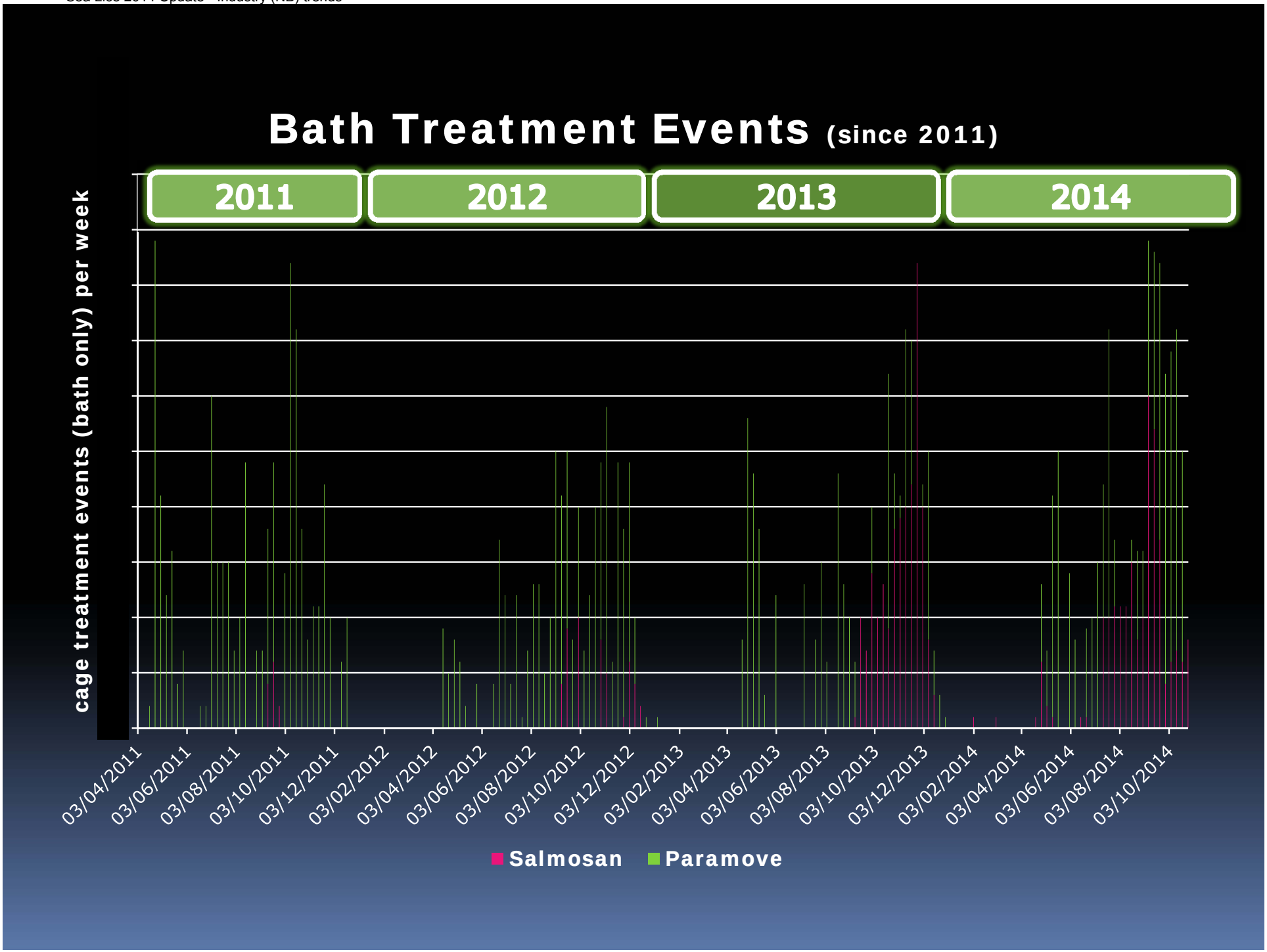
BATH TREATMENTS


EMB Treatments Recorded
Cage treatment events (monthly total)
4
8
12
16
20
24
28
32
36
40
44
48
52
EMB 2011
EMB 2012
EMB 2013
EMB 2014
EMB 2010

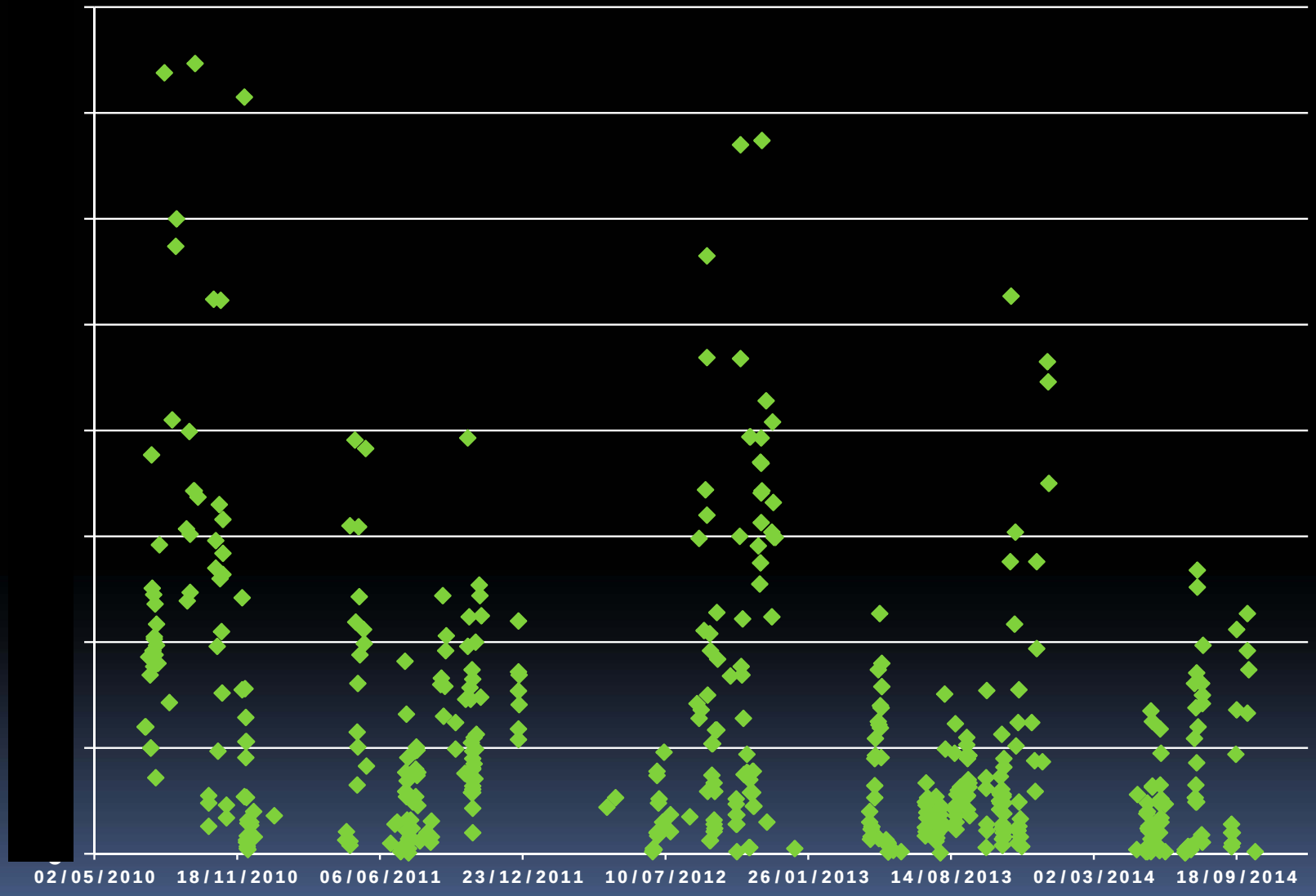
Proportion Use (% of weekly treatments for each bath)

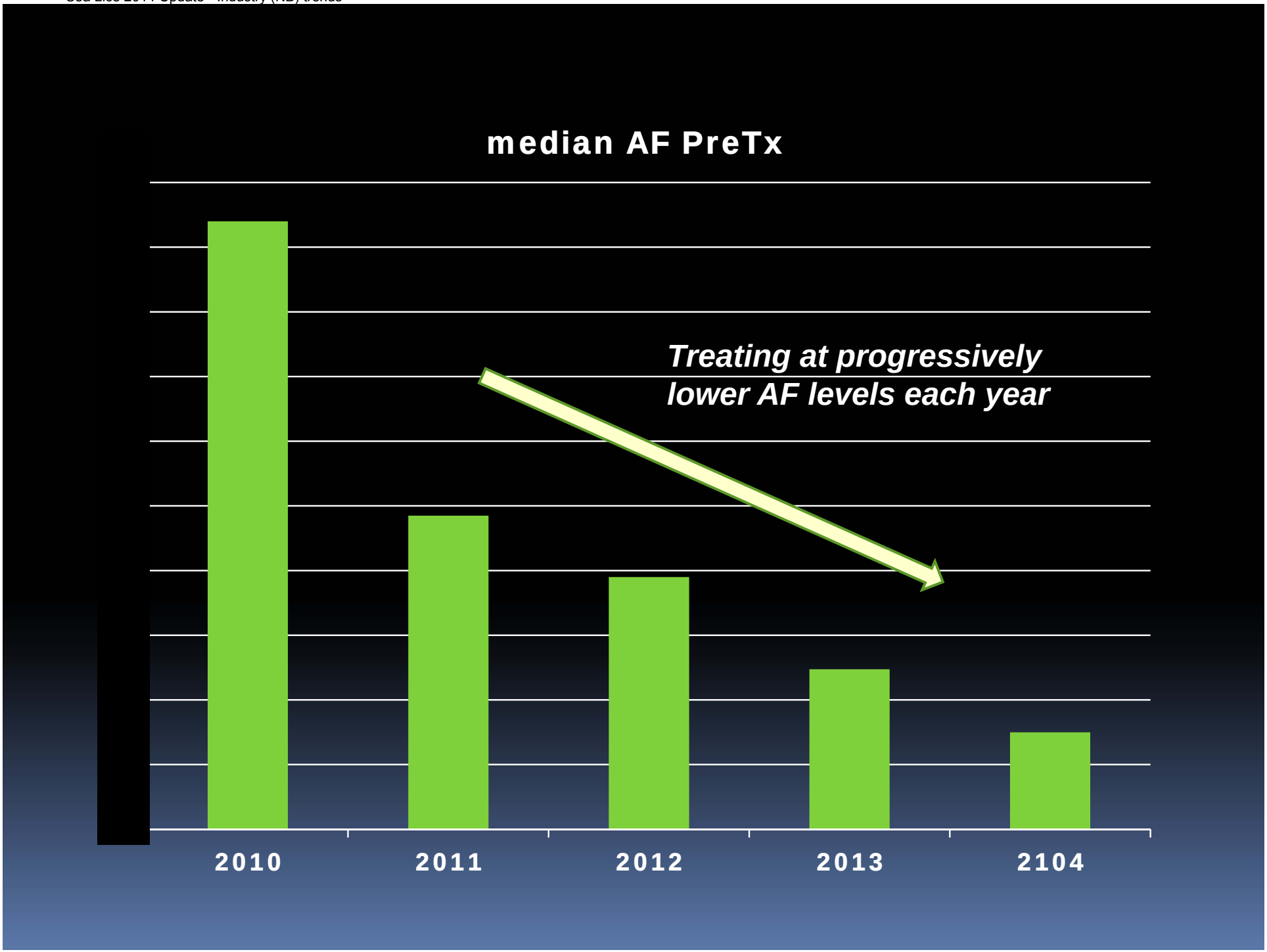



Bath Treatments Per Week
cage treatment events (bath only) per week
2009
2010
2011
2012
2013
2014
04/01/2009
04/01/2010
04/01/2011
04/01/2012
04/01/2013
04/01/2014
Alphamax
Salmosan
Paramove

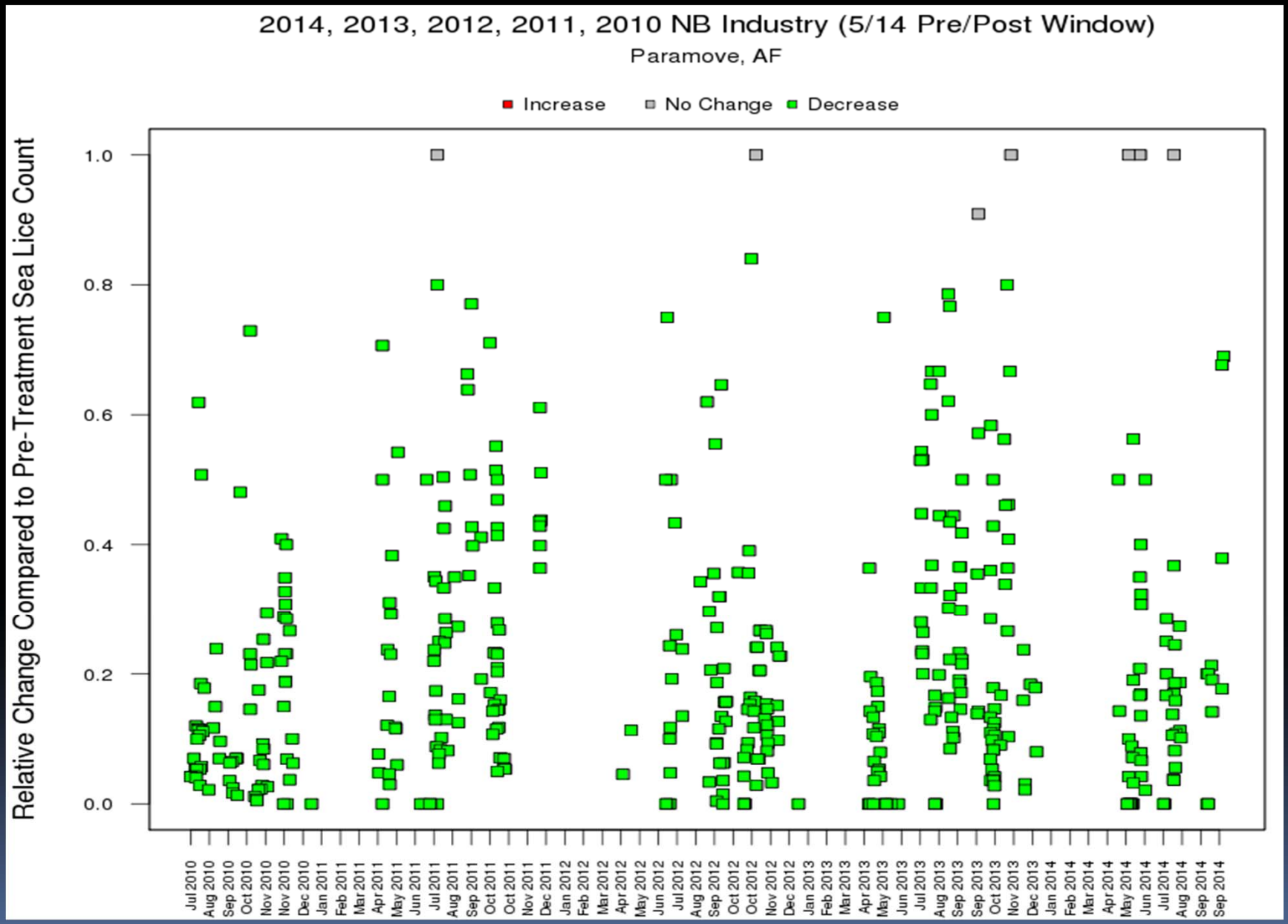

Bath Treatment Events (since 2011)
2011
2012
2013
2014
cage treatment events (bath only) per week
03/04/2011
03/06/2011
03/08/2011
03/10/2011
03/12/2011
03/02/2012
03/04/2012
03/06/2012
03/08/2012
03/10/2012
03/12/2012
03/02/2013
03/04/2013
03/06/2013
03/08/2013
03/10/2013
03/12/2013
03/02/2014
03/04/2014
03/06/2014
03/08/2014
03/10/2014
Salmosan
Paramove

Pre Treatment AF

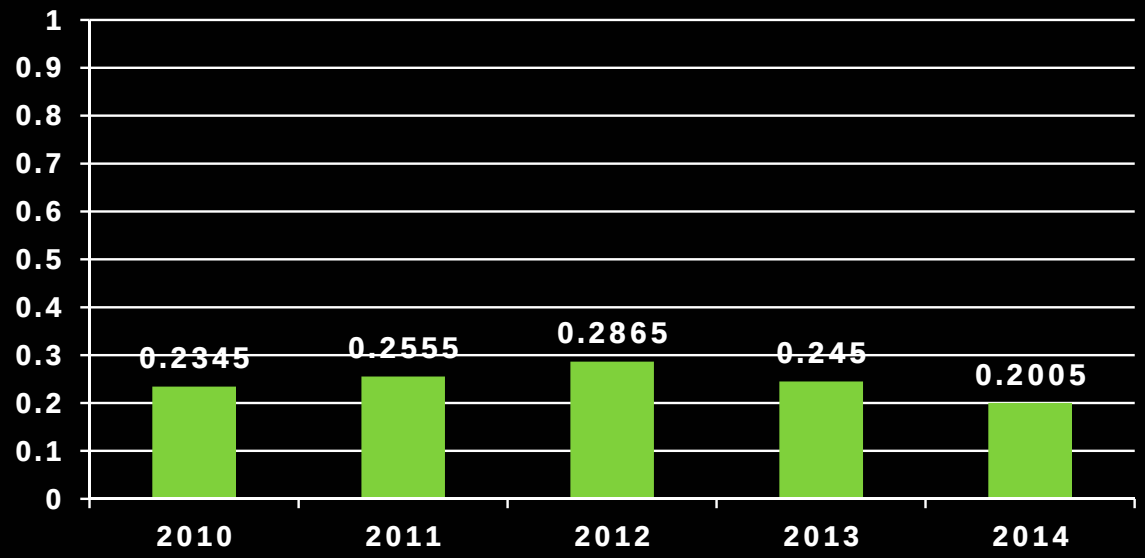


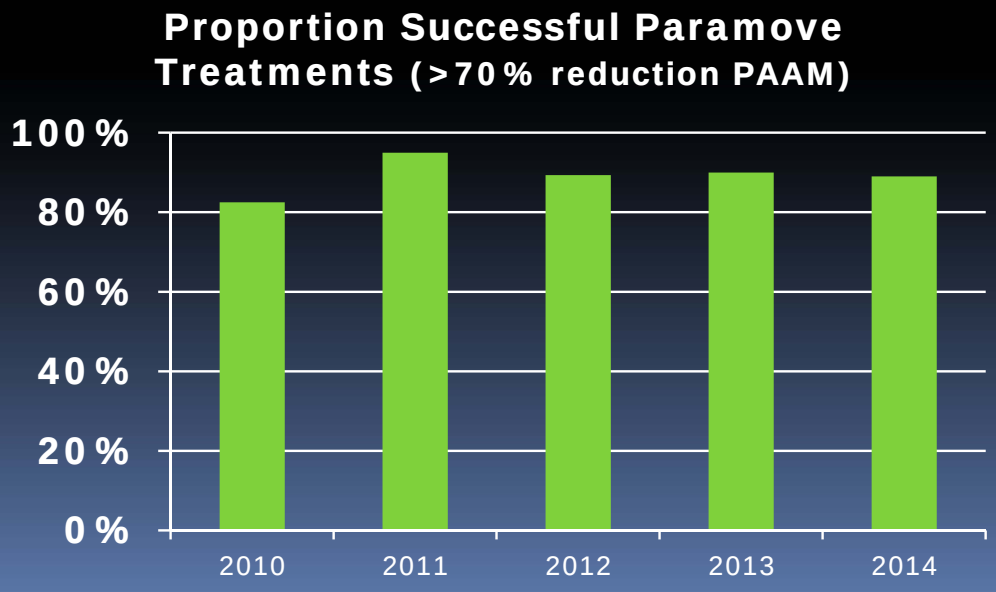

median AF PreTx
Treating at progressively lower AF levels each year
2010
2011
2012
2013
2104

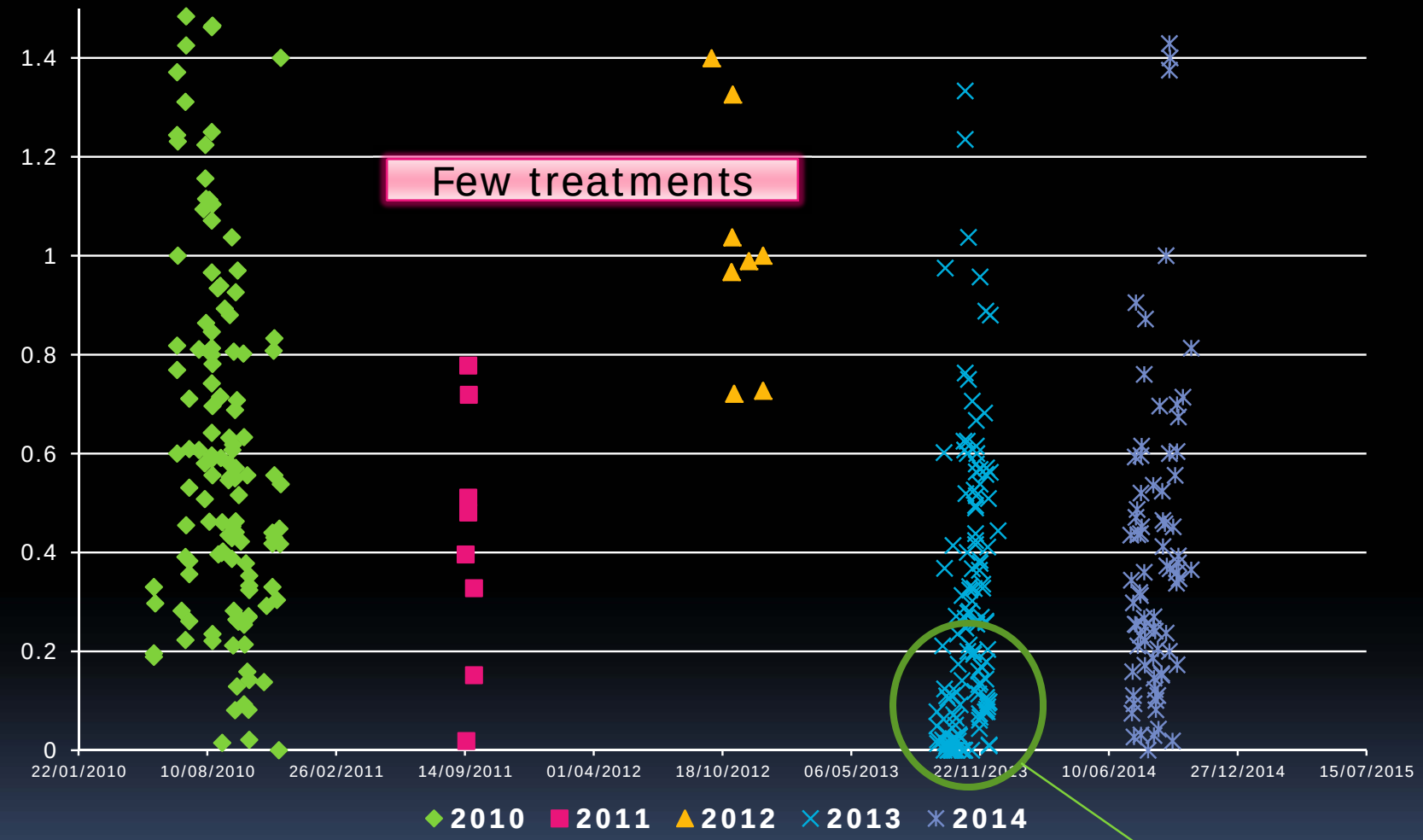
Relative Change = 0 means all lice removed after treatment



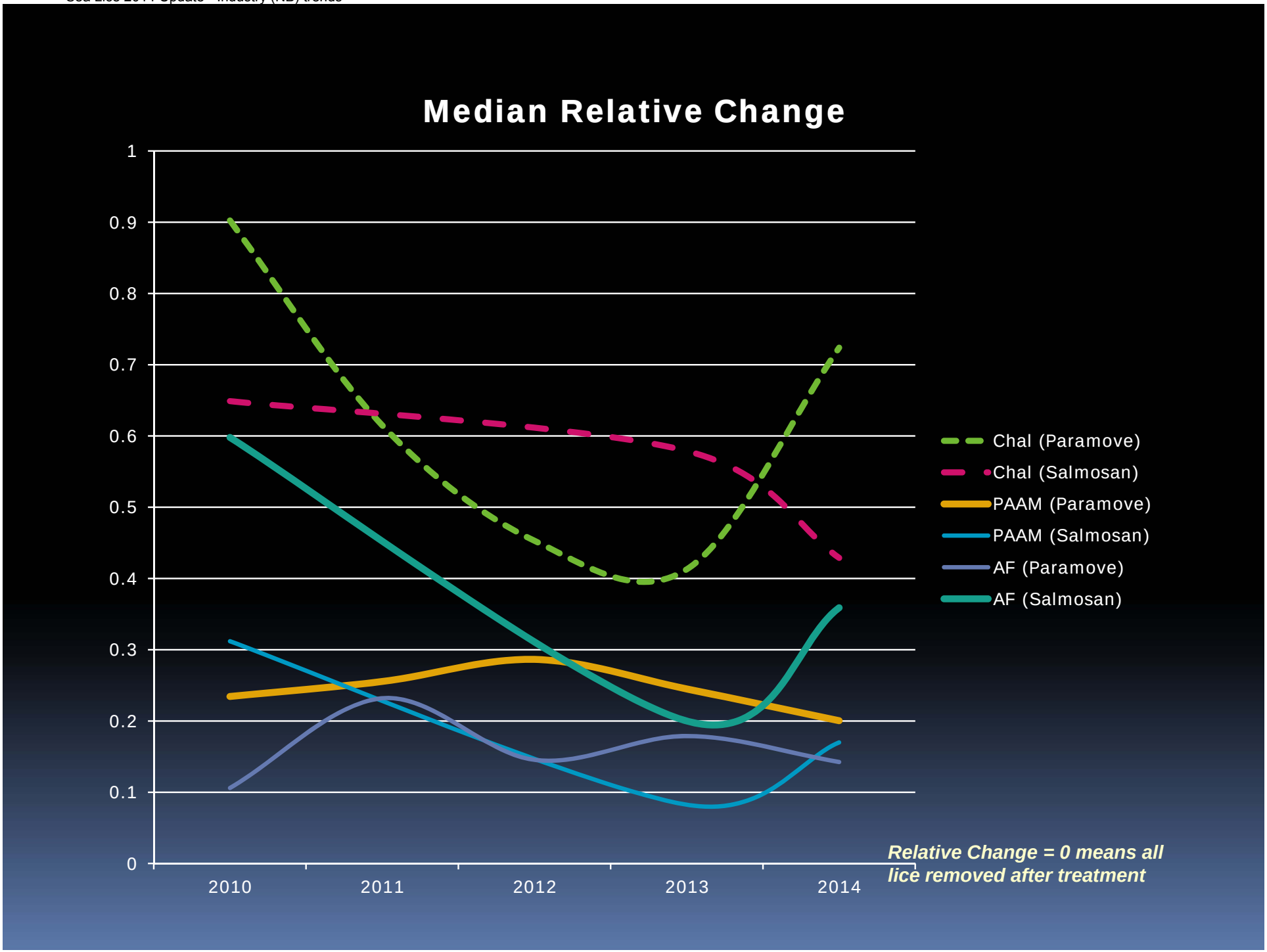
Relative Change = 0 means all lice removed after treatment







Relative Change = 0 means all lice removed after treatment


Median Relative Change
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2010
2011
2012
2013
2014
Chal (Paramove)
Chal (Salmosan)
PAAM (Paramove)
PAAM (Salmosan)
AF (Paramove)
AF (Salmosan)
Relative Change = 0 means all lice removed after treatment

Concluding Remarks - records

- Excellent participation by NB industry in Fish-iTrends
  - NL, NS starting
- Audits show some discrepancy in Chalimus, PAAM (when different, site counts lower)
  - May affect measures of treatment response

Concluding Remarks – sea lice patterns

- 2014 appears to be 2nd lowest lice year
  - not as low as 2011 for mobiles
  - slightly lower than 2012 and 2013
  - Recent decreases bring levels close to 2011 for same week of year

Concluding Remarks – sea lice treatments

- Industry more aggressive at treating
  - Median AF counts are lower at time of treatment
  - Trend has improved each year since 2010

Concluding Remarks – sea lice treatments

- Salmosan tarping success improved starting in 2013
  - 2013 and 2014 much better than 2010
    - too few treatments in 2011 & 2012 to assess
  - Attributed to longer duration exposure in tarps
- AF removal
  - Paramove well boat greatest success in 2014
    - Median 82-85% removal
  - Salmosan tarp best in 2013
    - Median 80% removal in 2013 vs 65% in 2014 vs 40% in 2010
    - Less variation in response compared to 2010
- PAAM removal
  - Salmosan tarp best in 2013; similar to Paramove well boat in 2014
    - Salmosan: median 92% removal in 2013 vs 83% in 2014 vs 69% in 2010
    - Paramove: median 75% removal in 2013 vs 80% in 2014 vs 77% in 2010

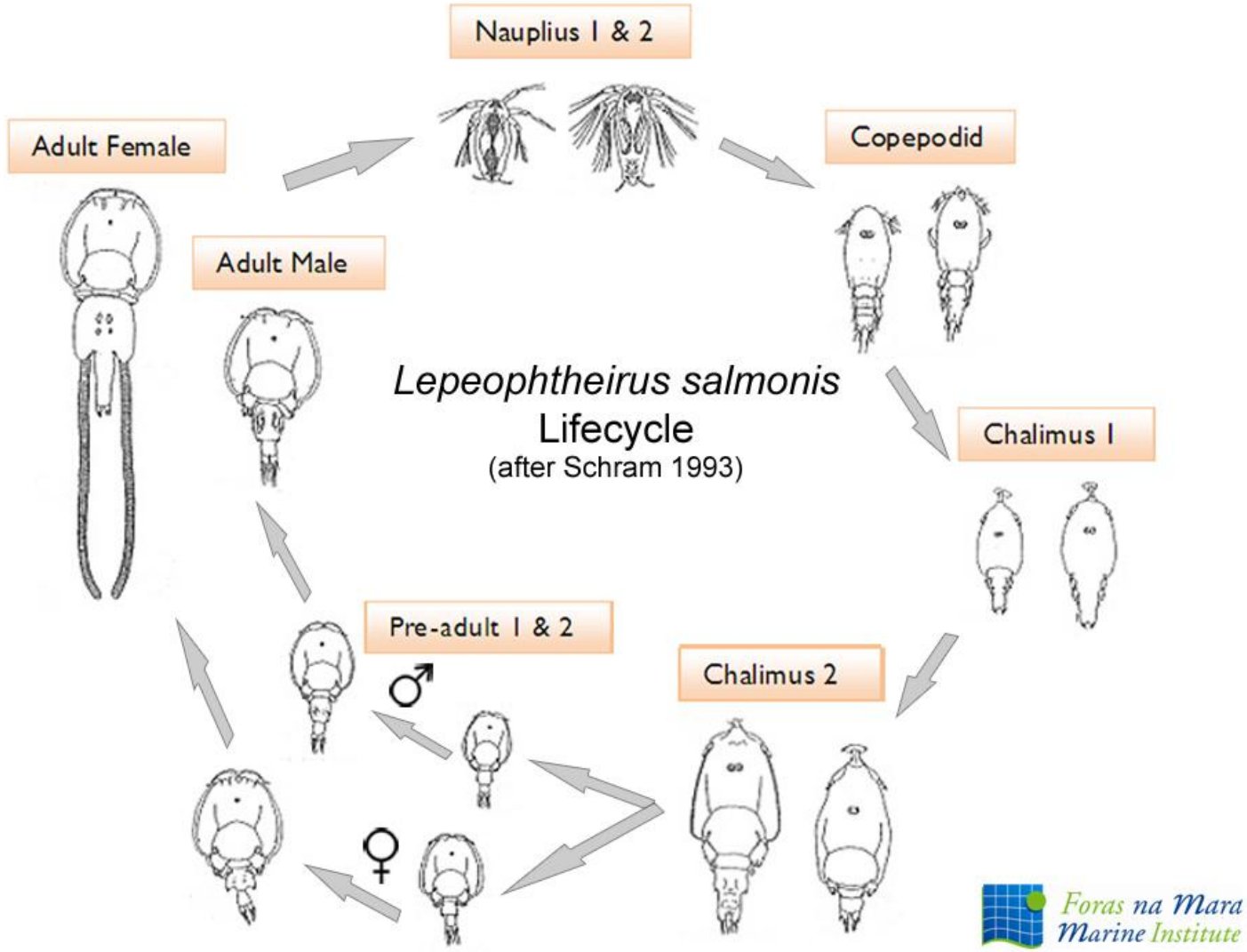
acknowledgements

- ACFFA / NAIA – support for sea lice monitoring and research program and on-going FiT support
- NBDAAF – 5 yr support for AIF + additional support for sea lice monitoring / research program
- NLDFA, PEI Innovation, PEI FARD, NSDFA – 5 yr support for AIF
- ACOA / AIF – *Healthy Fish Healthy Food Healthy Environment* Project

Models and observations of sea lice: what about the larval stages?

Jon Grant
NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture

Ramon Filgueira
Dalhousie University and
NSERC Visiting Postdoc, DFO Moncton



Foras na Mara
Marine Institute

Journal of Fish Diseases 2005, 28, 603–613

A mathematical model of the growth of sea lice, *Lepeophtheirus salmonis*, populations on farmed Atlantic salmon, *Salmo salar* L., in Scotland and its use in the assessment of treatment strategies

C W Revie[1], C Robbins[2], G Gettinby[3], L Kelly[3] and J W Treasurer[4]

1 Department of Computer and Information Sciences, University of Strathclyde, Glasgow, UK
2 Grallator, Hayfield, High Peak, Derbyshire, UK
3 Department of Statistics and Modelling Science, University of Strathclyde, Glasgow, UK
4 Scottish Association for Marine Science, Ardtoe, Acharacle, Argyll, UK

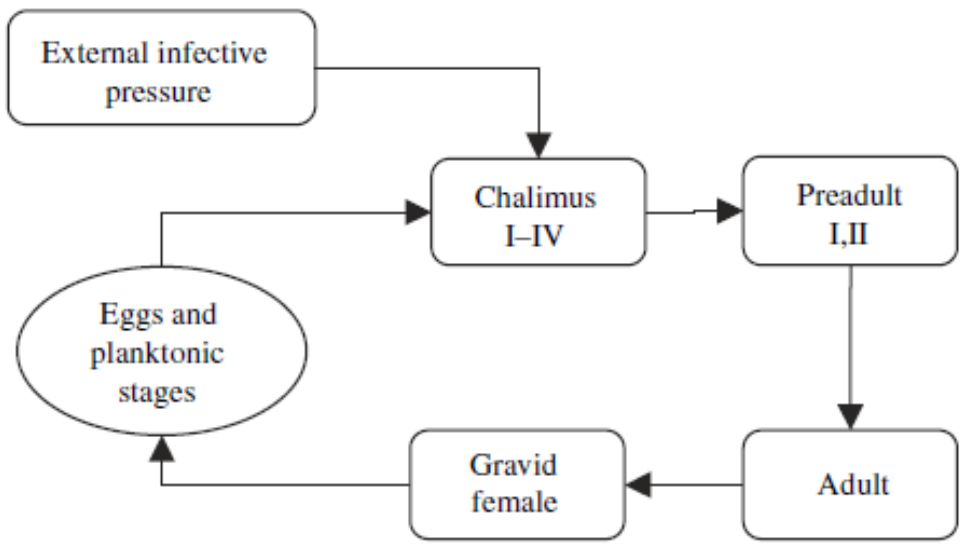


Figure 1 Flow chart of the key stages of the *Lepeophtheirus salmonis* life cycle associated with infection of farmed salmon populations.

Preventive Veterinary Medicine 108 (2013) 285–293

Contents lists available at SciVerse ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

A comparison of modelling approaches to assess the transmission of pathogens between Scottish fish farms: The role of hydrodynamics and site biomass

Nabeil K.G. Salama*, Alexander G. Murray

Marine Scotland Science, Marine Laboratory, 375 Victoria Road, Aberdeen, AB11 9DB, UK

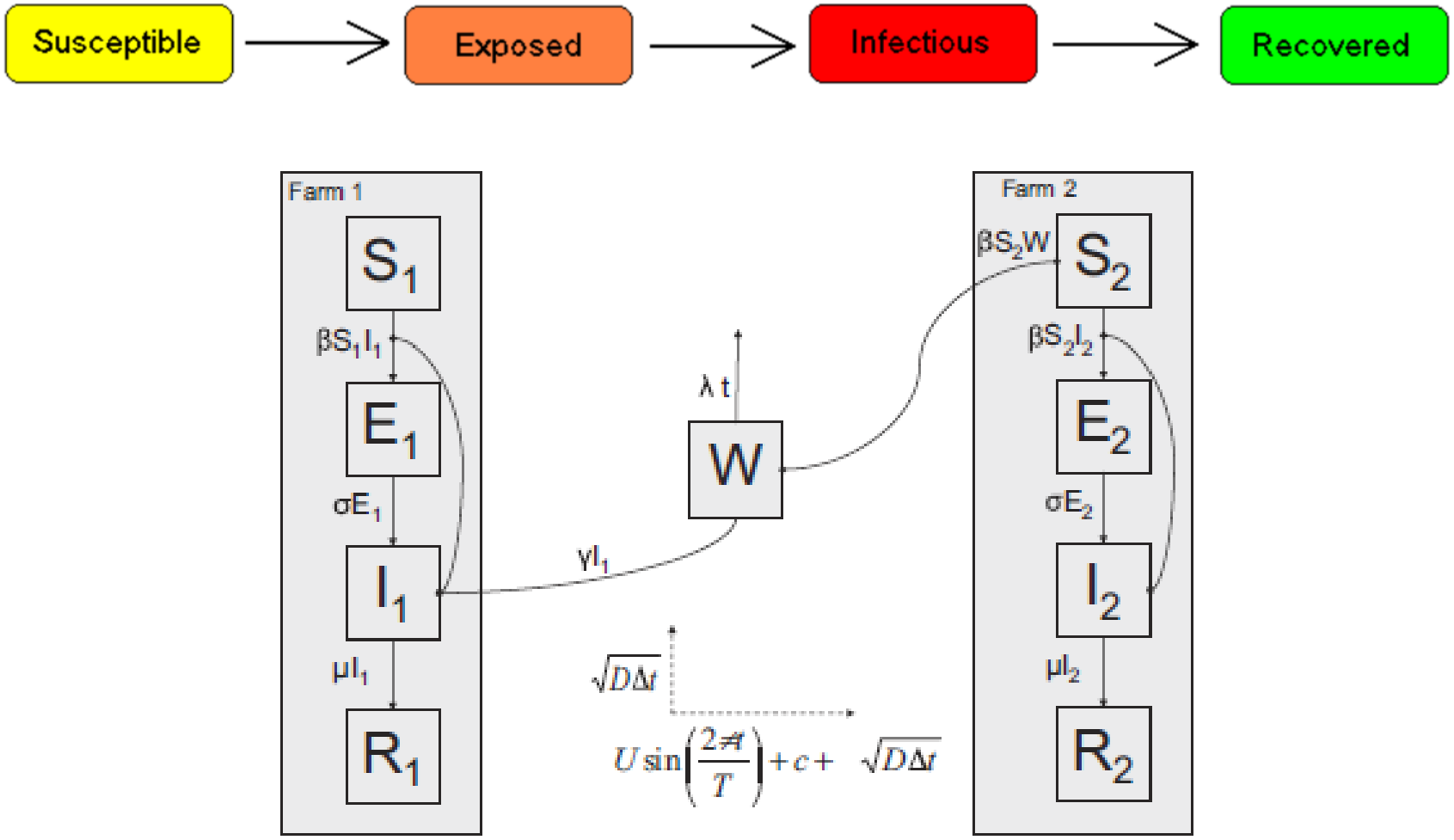
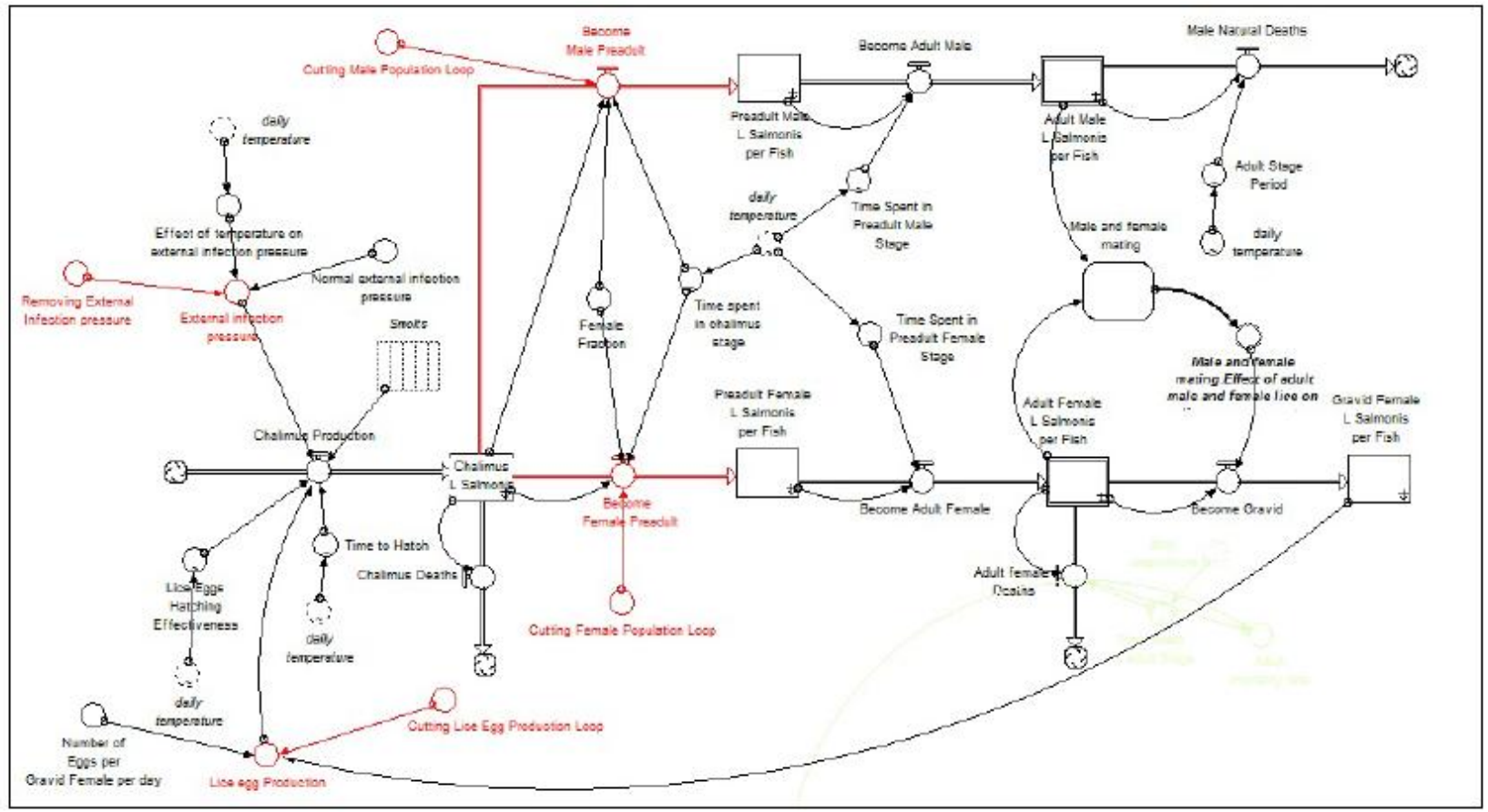
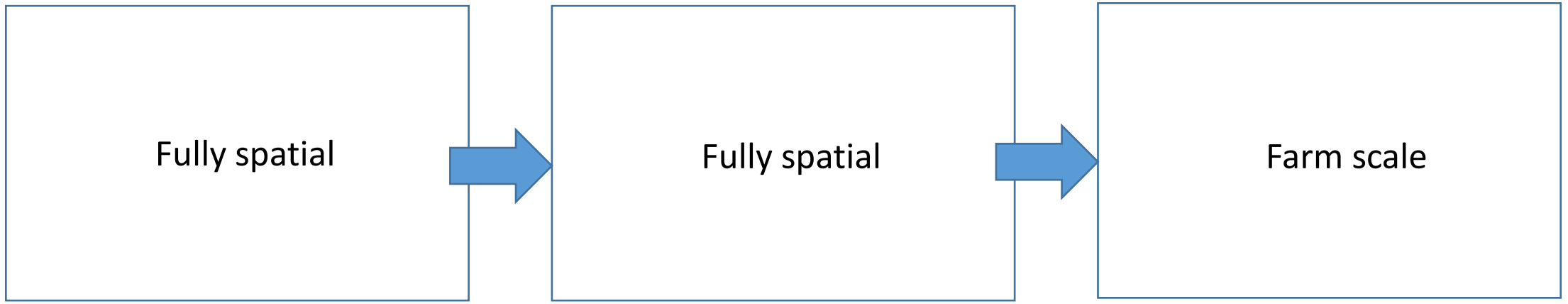


Fig. 1. A schematic representation of the compartmentalised *SEIR* farm models connected by a waterborne phase that transports the shed pathogen particles in a 2D dimensional plane. (See Table 1 for parameters.)

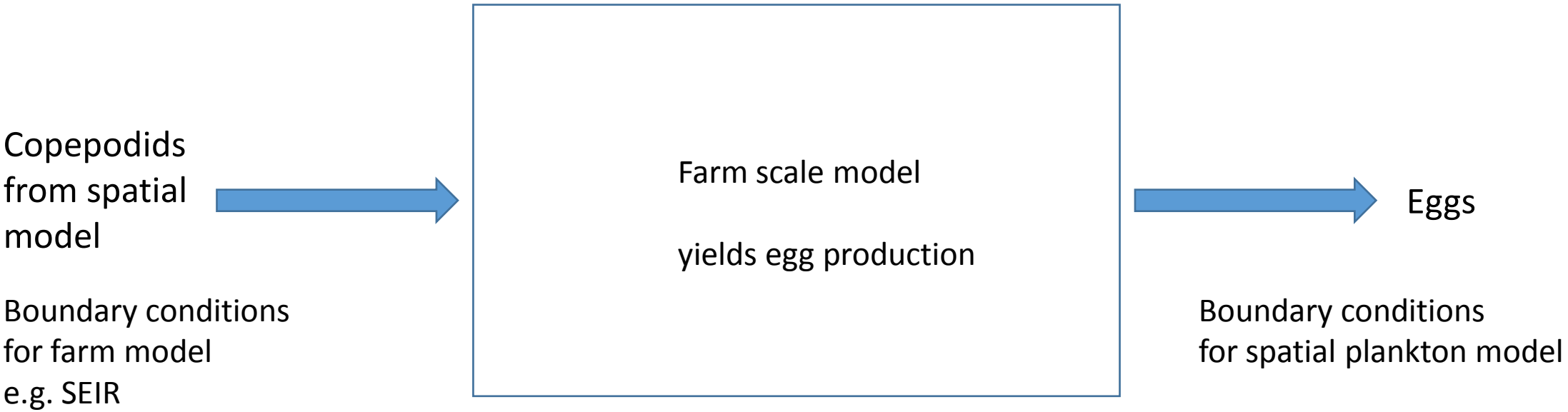
The role of system dynamics approaches in aquatic disease management: an application to sea lice control in Norway (Hamza MSc.) – Stella model

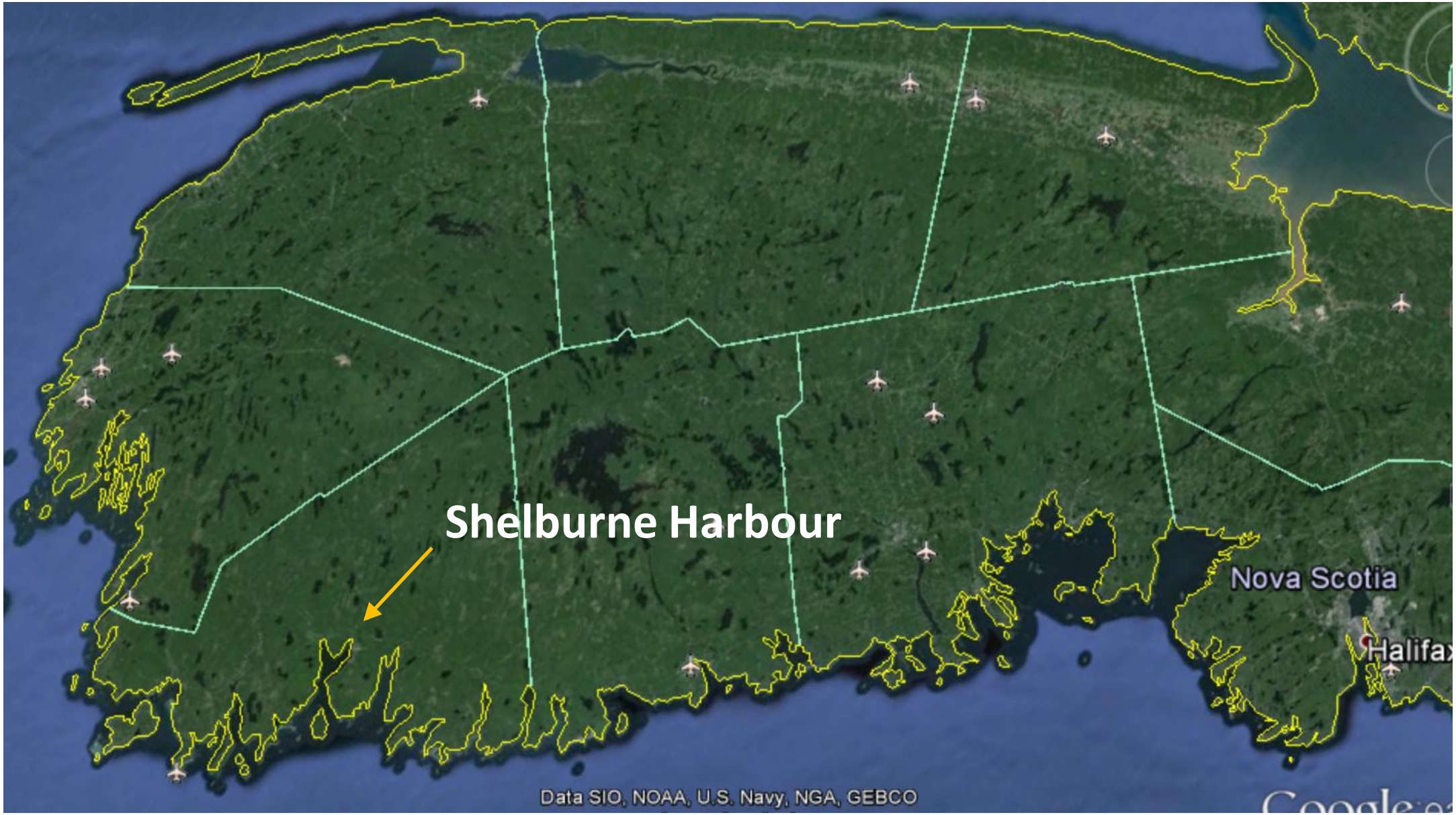


Model components

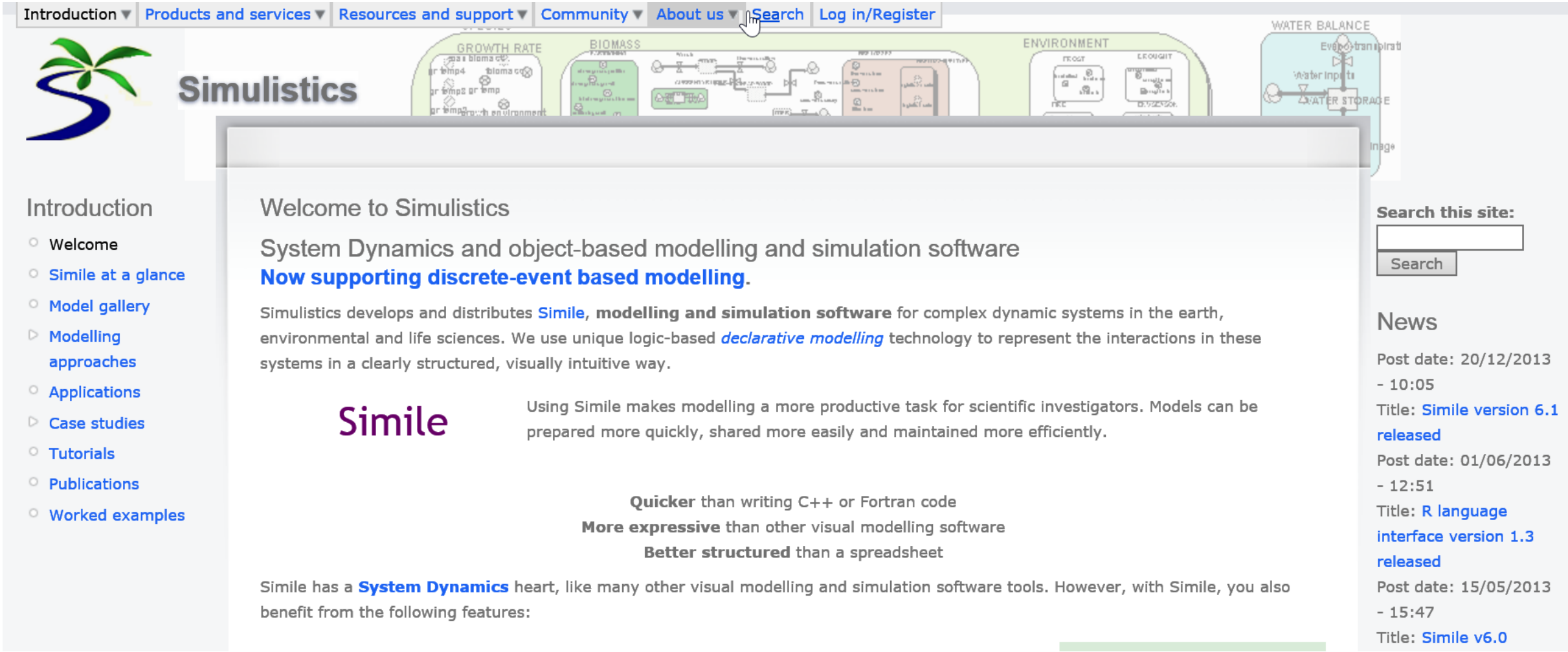


Coupled models

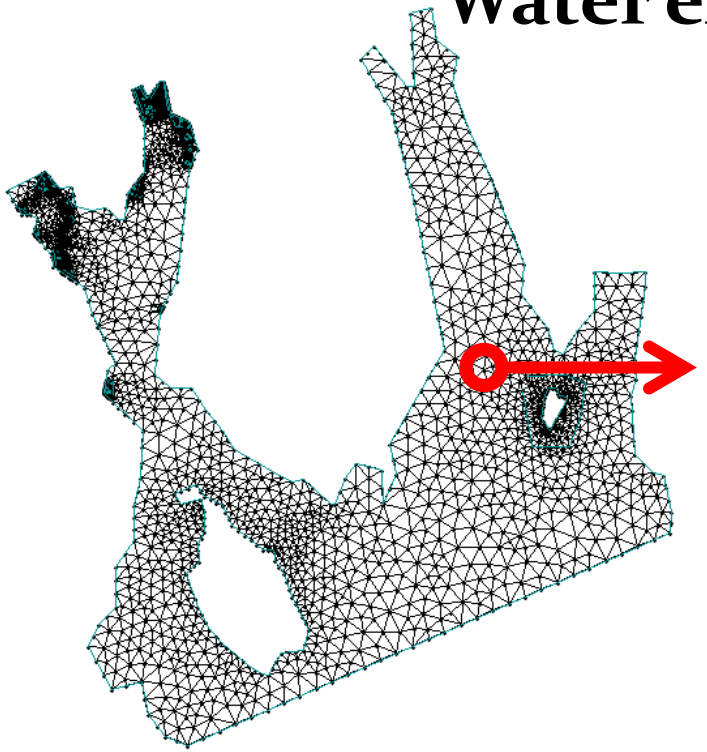



Shelburne Harbour
Nova Scotia
Halifax
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

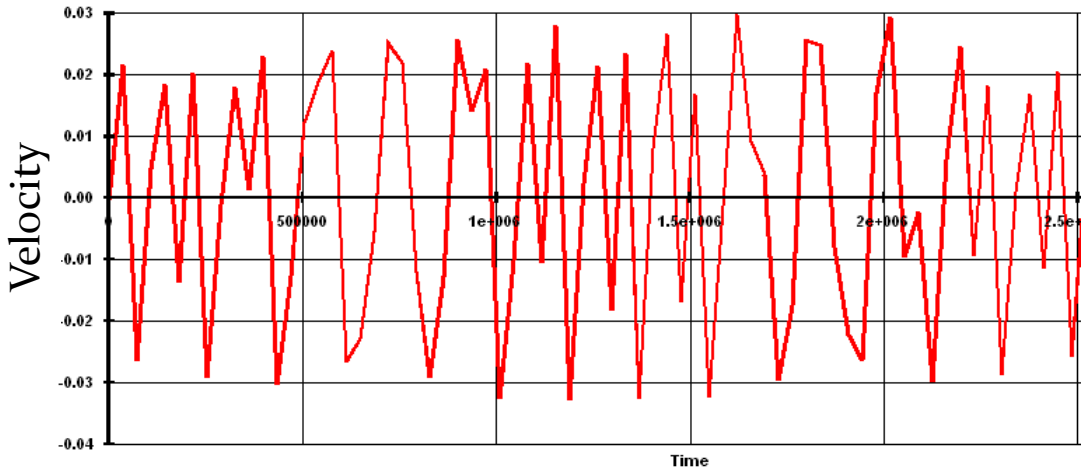
simulistics.com



Water exchange calculations

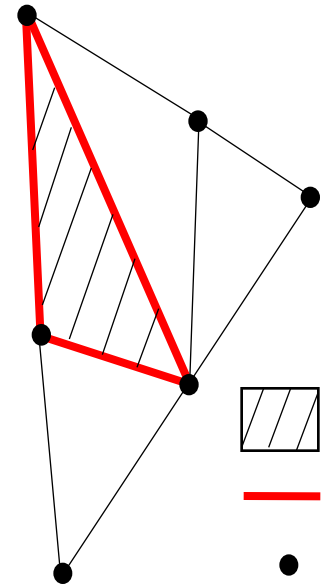


Finite-element grid



Averaged St. Venant equations

	A	B	C	D
1	Entry-Box	Exit-Box	Exchange-Entry	Exchange-Exit
2	5	1	85.188	5.9355
3	7	1	135.97	5.4523
4	102	2	5.834	100.79
5	139	2	1.1102	74.693
6	517	2	5.4049	81.089
7	121	3	6.0446	42.681
8				
9				
10				



Water Flow in each link

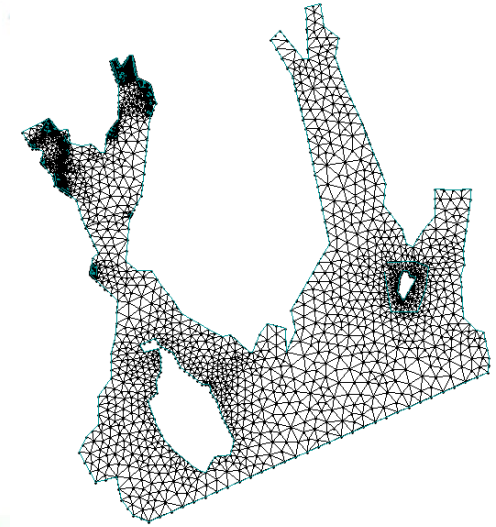
Element

Link

Node

Coupling AquaDyn with Simile

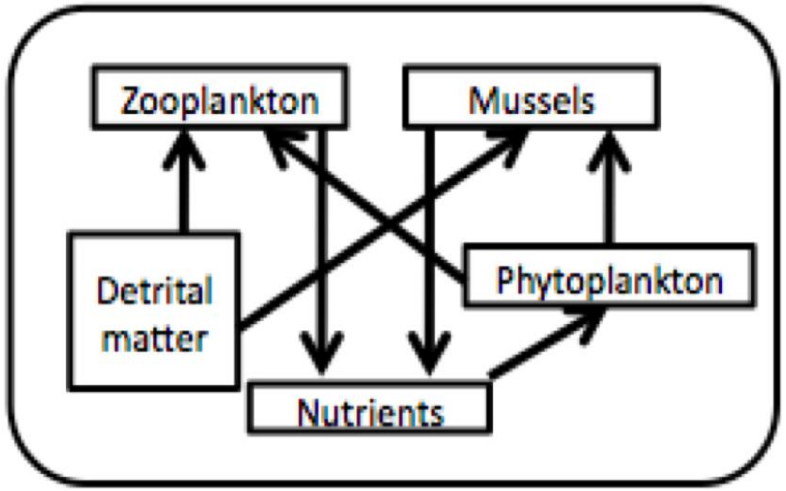
Aquadyn



Matlab

	A	B	C	D
1	Entry-Box	Exit-Box	Exchange-Entry	Exchange-Exit
2	5	1	85.188	5.9355
3	7	1	135.97	5.4523
4	102	2	5.834	100.79
5	139	2	1.1102	74.693
6	517	2	5.4049	81.089
7	121	3	6.0446	42.681
8				
9				
10				

Simile

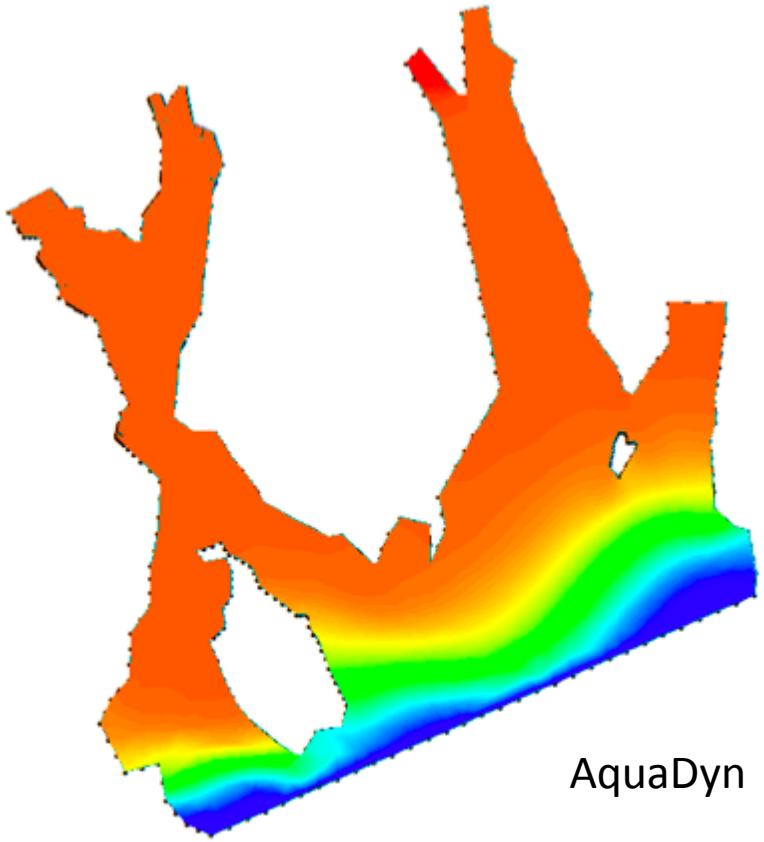


Inflow submodel

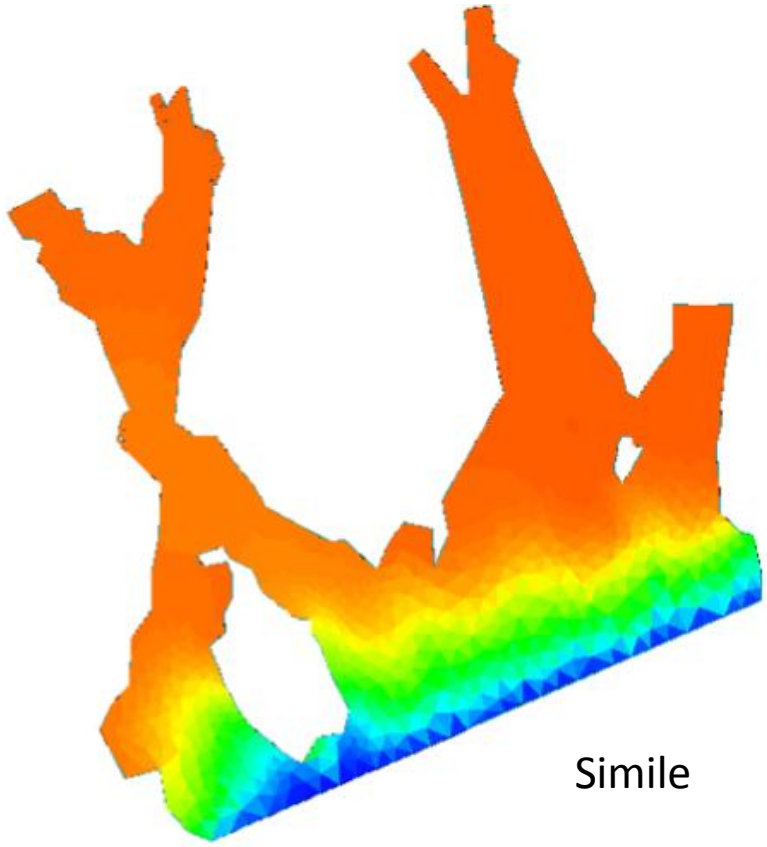
Outflow submodel

Connections submodel

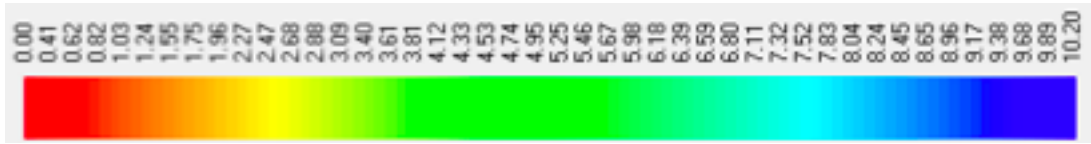
Coupling validation



AquaDyn



Simile



Conservative Tracer Concentration

Vol. 5: 127–141, 2014
doi: 10.3354/aei00098

AQUACULTURE ENVIRONMENT INTERACTIONS
Aquacult Environ Interact

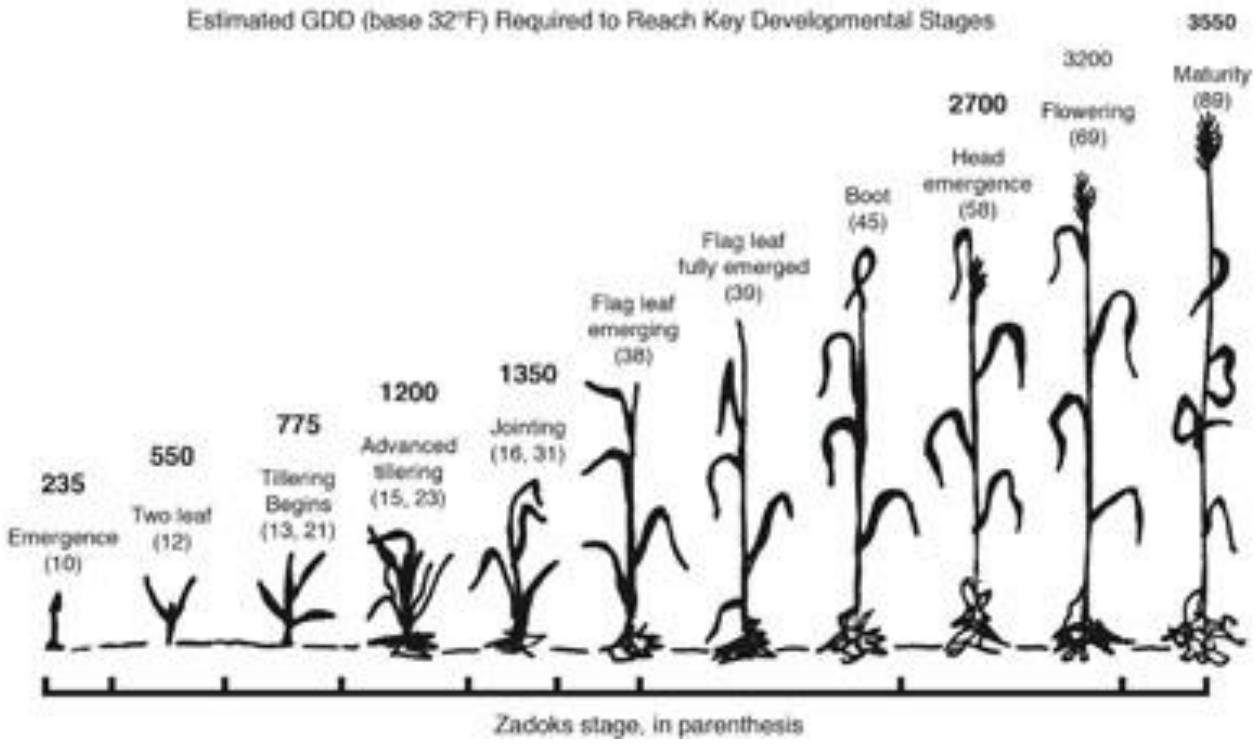
Published online June 4

Vertical salmon lice behaviour as a response to environmental conditions and its influence on regional dispersion in a fjord system

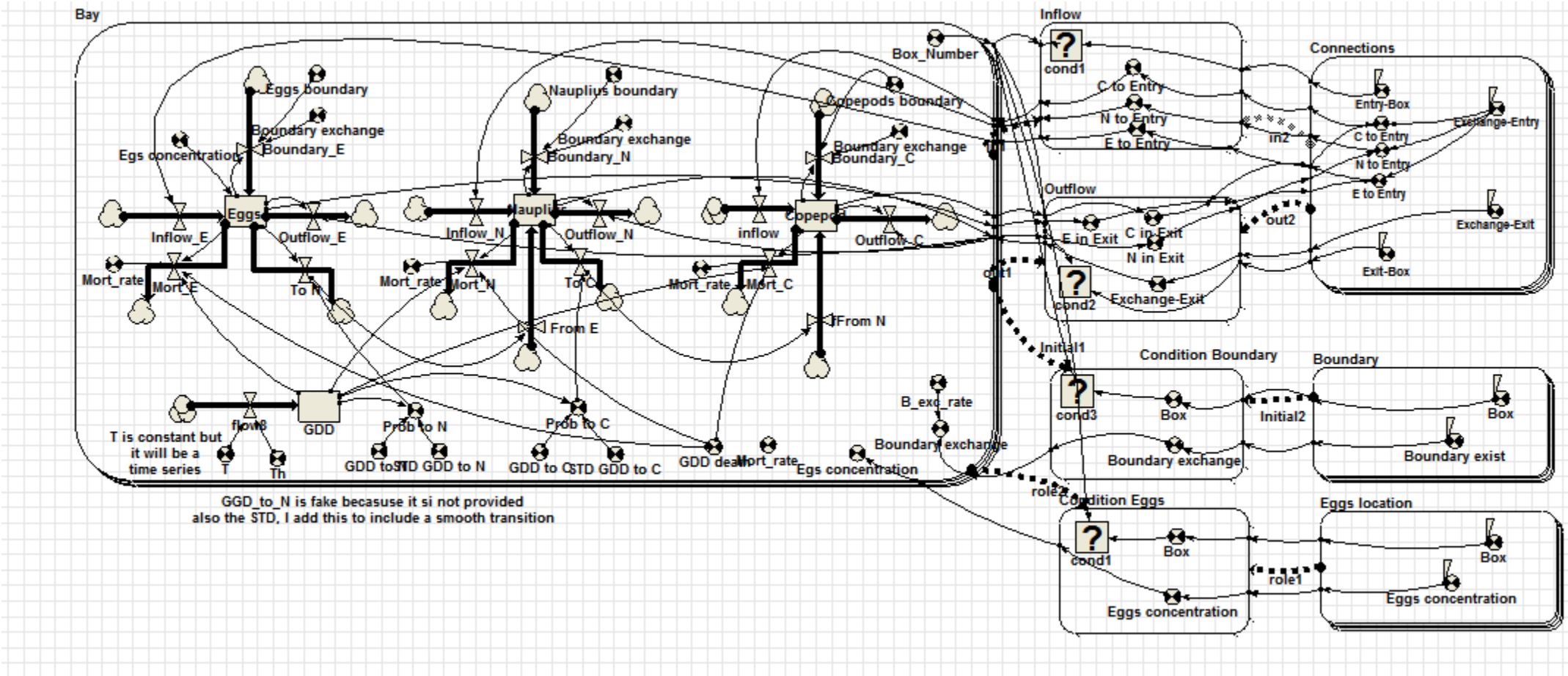
Ingrid A. Johnsen[1,*], Øyvind Fiksen[2,3], Anne D. Sandvik[1], Lars Asplin[1]

[1]Institute of Marine Research, PO Box 1870 Nordnes, 5817 Bergen, Norway
[2]Department of Biology, University of Bergen and Hjort Centre for Marine Ecosystem Dynamics, Box 7803, 5020 Bergen, Norway

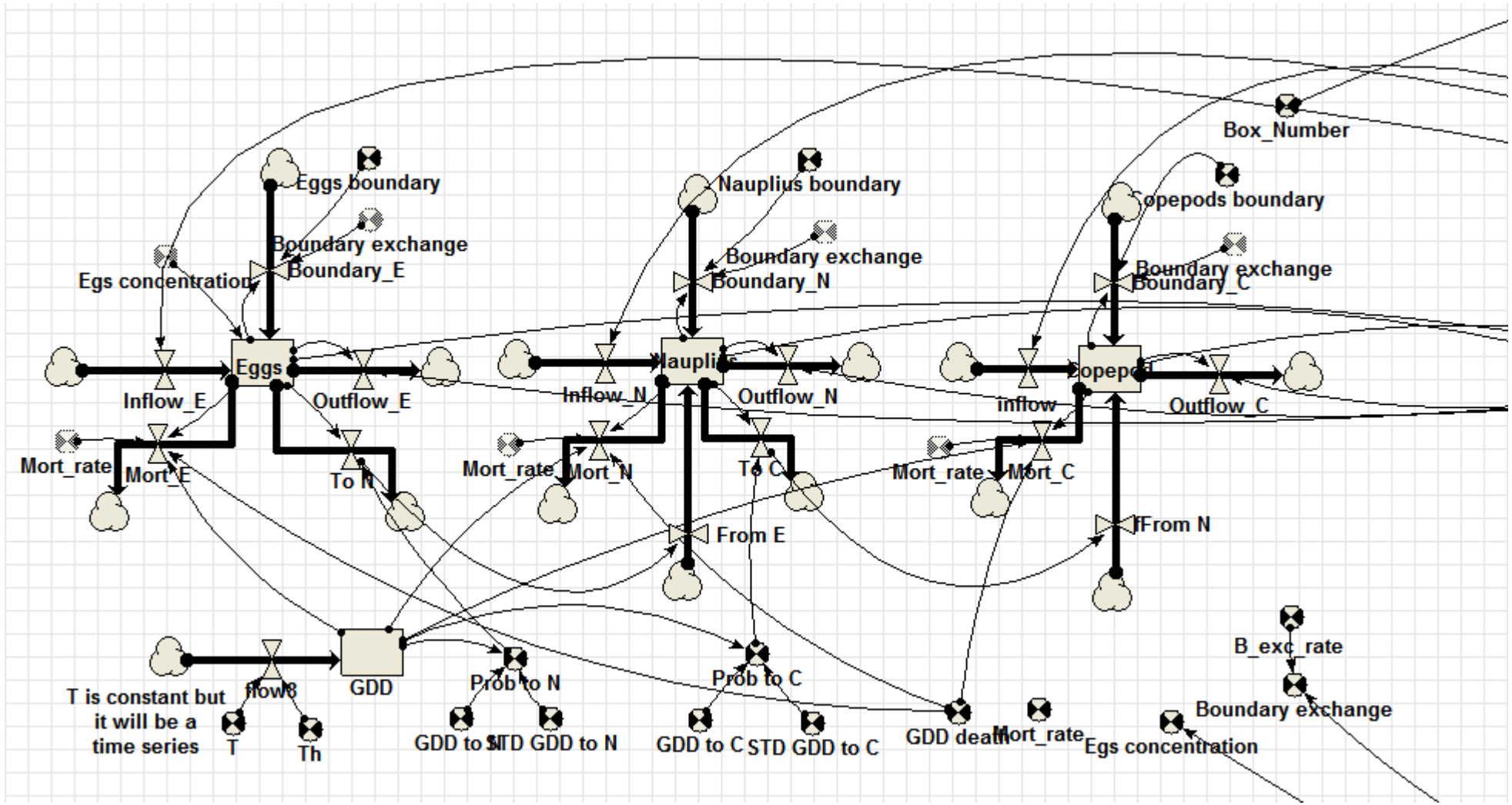
Growing degree days (GDD)
‘temperature time’



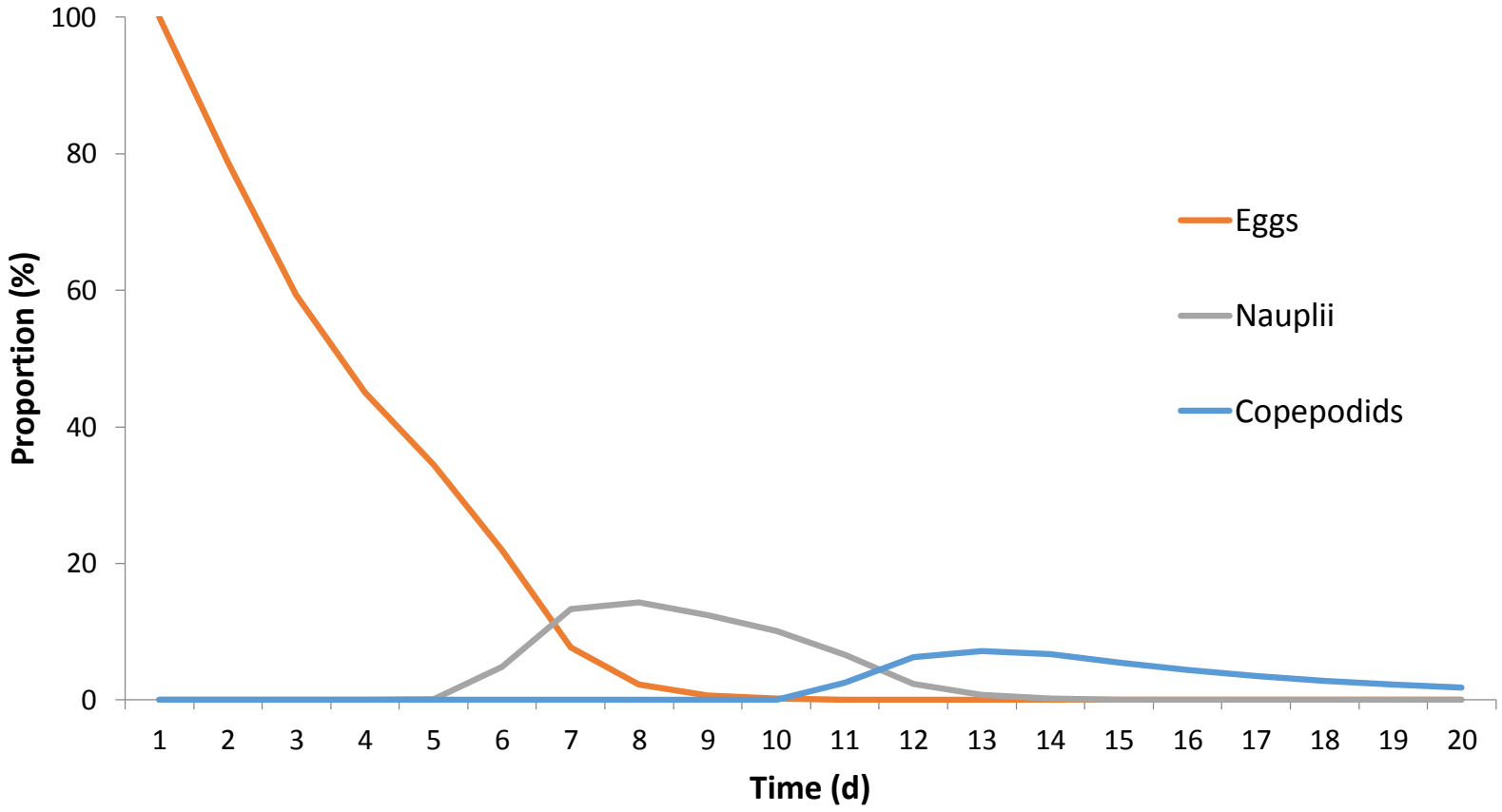
Fully spatial plankton model



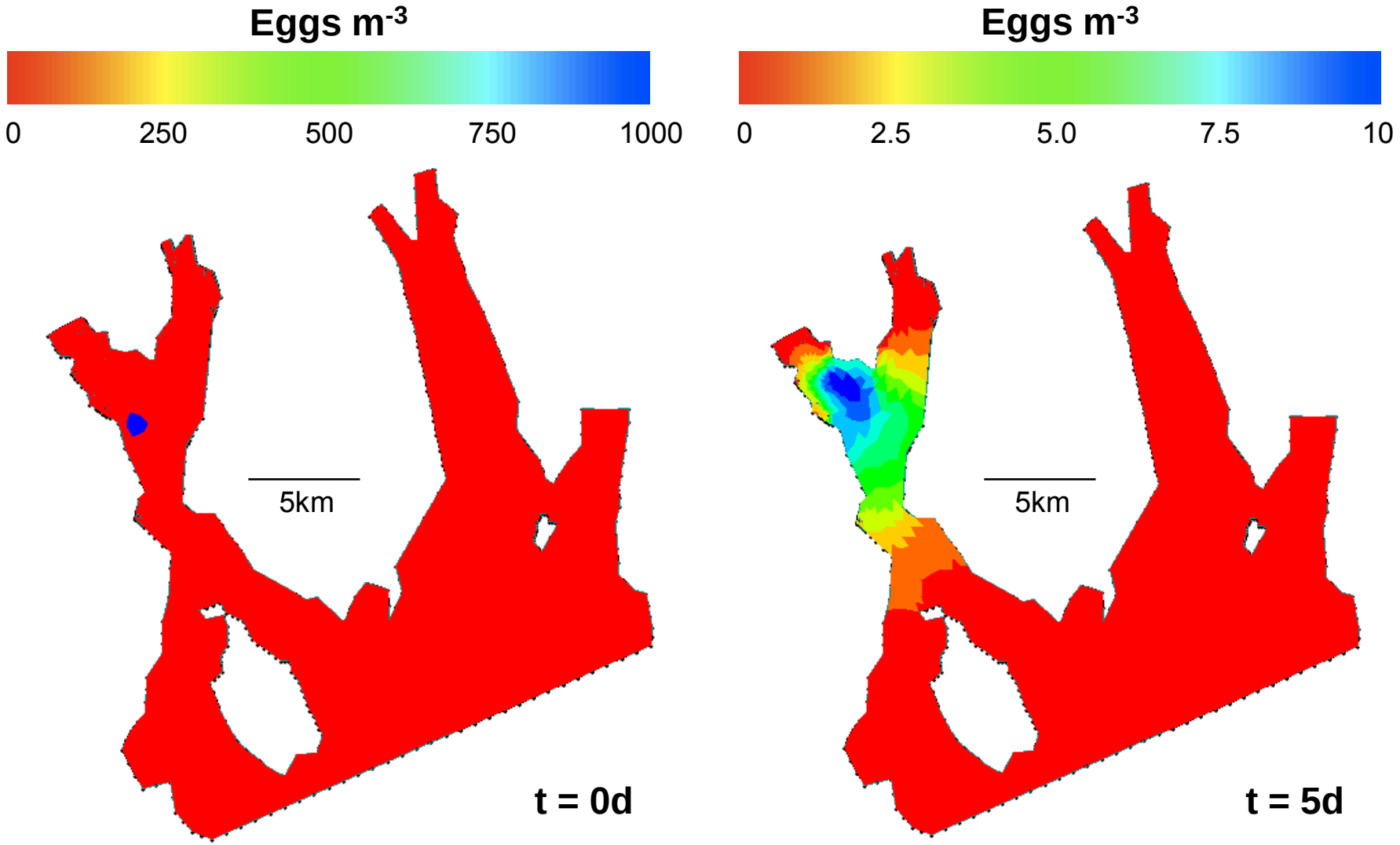
Planktonic stages



GDD Model results



Eggs distribution



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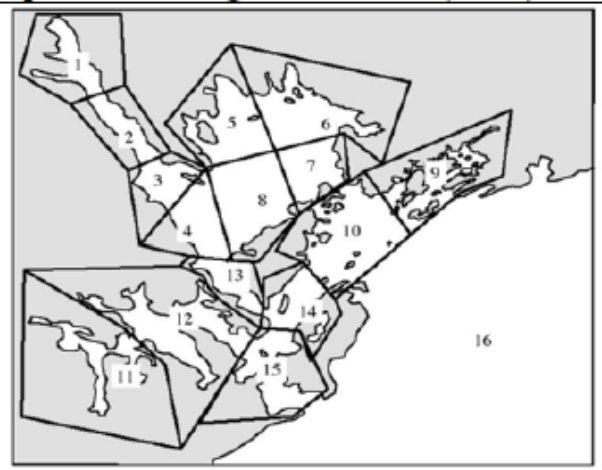
Ecological Modelling 193 (2006) 295–314
ECOLOGICAL MODELLING
www.elsevier.com/locate/ecolmodel

A probabilistic approach of flow-balanced network based on Markov chains

Delphine Leguerrier[a,b], Cédric Bacher[c,*], Eric Benoît[d], Nathalie Niquil[a]

Passamaquody bay

The following example corresponds to Passamaquoddy bay (bay of Fundy) for which Thompson et al. (2002) provided the quantitative information used to compute residence time as explained in Leguerrier et al. (2006).



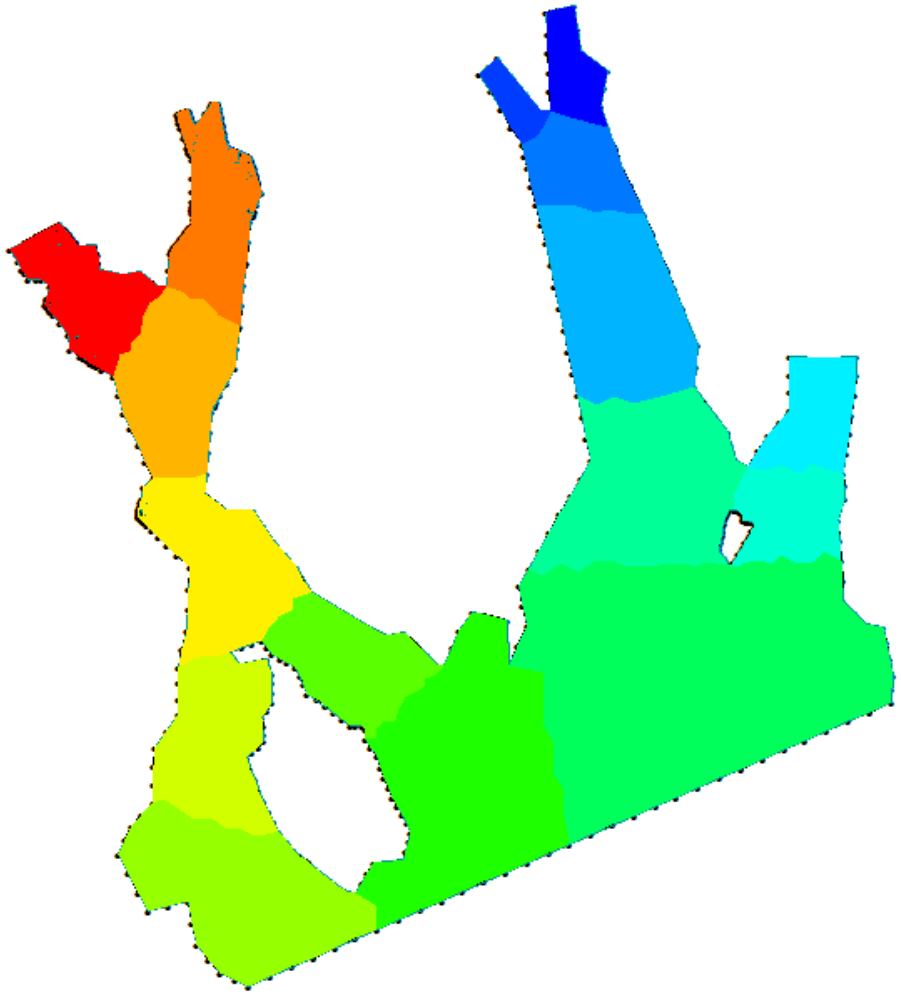
Passamaquoddy bay system (Thompson et al., 2002), composed of 15 inner boxes and one ocean boundary defined as an additional box (number 16). Flows are computed by using a hydrodynamical and transport model. Simulations of a tracer are run for one tidal cycle and several scenarios of initial concentration. Transition probabilities are computed from the numbers of particles found in each box.
Below is the probability matrix. Diagonal terms refer to the probability to stay in one box, whereas other terms refer to the probability to pass from one box to another during one time unit (here one day)

P matrix for Passamaquoddy Bay system (from Thompson et al., 2002)

P	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	99	1														
2	1	96	3													
3		3	91	3				1								
4			6	89				5					3			
5					96	2	2									
6						97	3									
7						1	70	5	2	10						
8				4	4		9	82		1			2			
9									93							
10							9	5	3	78			3	12	1	
11											99	1				
12											1	96		1	6	
13				4									75	13		
14										3			17	72	4	
15												3		2	80	
16							7	2	2	8					9	100

P_{ij} gives, in percentage, the probability that a particle in j at t arrives in i at $t+\Delta t$, Δt being 1 day (the arrow indicates the source and target compartments). The 16th compartment is the exterior of the system.

Conservative tracer experiments

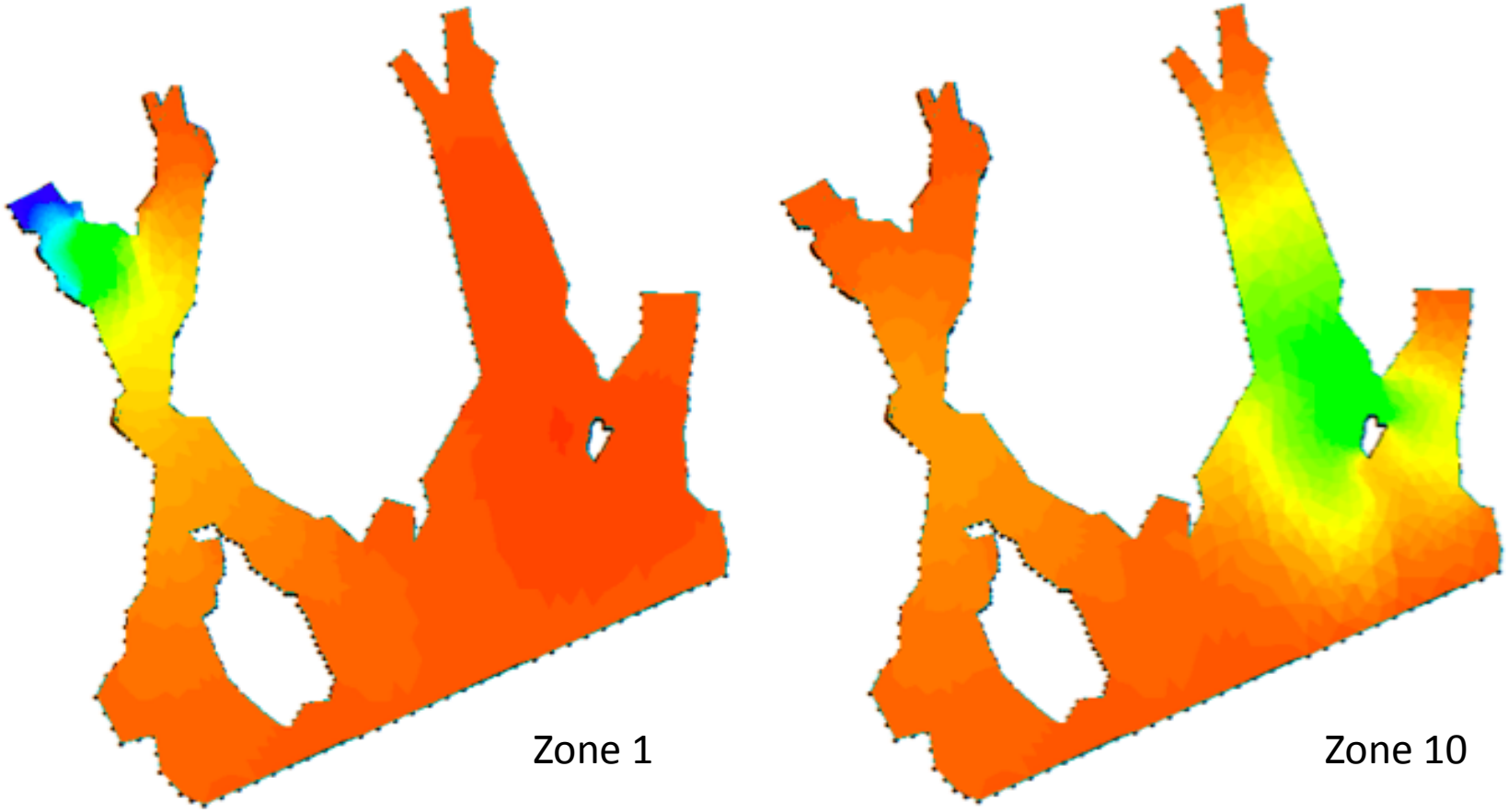


Group the 9773 elements in the model domain in 16 Boxes. For each Box:

- Fill Box with a 10 units of tracer per m^3.
- Set tracer level all other boxes to 1 units per m^3.
- Run the simulation for 10 days.
- Record the mean concentration in all 16 boxes at 12 hourly intervals.

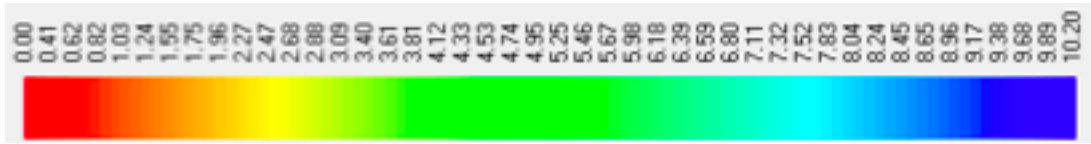
Although the area was divided in 16 Boxes, the model was run considering 9773 elements in order to have a finer description of the hydrodynamics

Conservative tracer results



Zone 1

Zone 10



Conservative Tracer Concentration

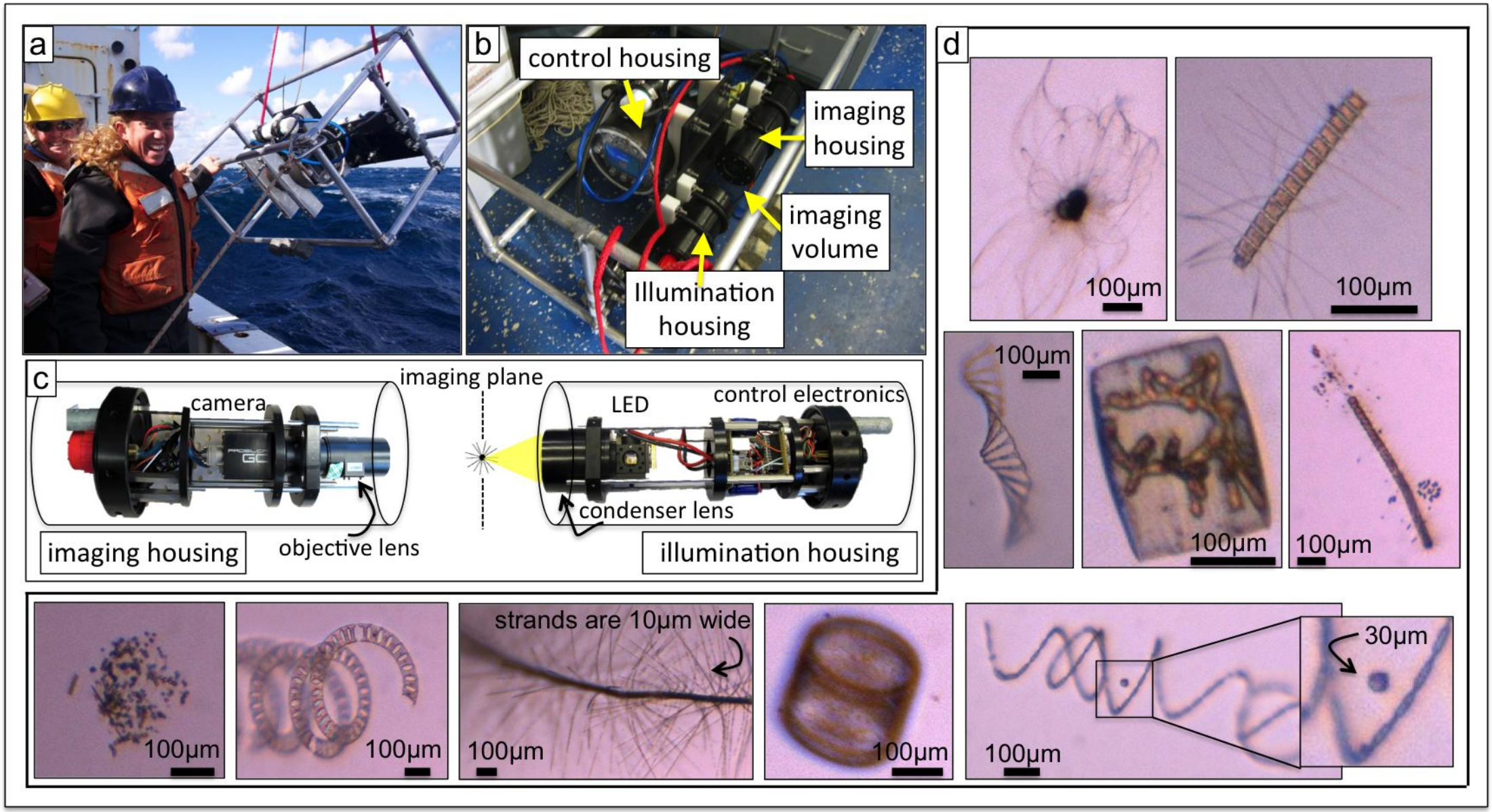
source/target	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	73	2	23	2	0	0	0	0	0	0	0	0	0	0	0	0	0
2	2	79	18	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	15	12	60	10	1	0	1	0	0	0	0	0	0	0	0	0	0
4	1	1	14	55	15	4	9	0	0	0	0	0	0	0	0	0	0
5	0	0	1	6	60	30	0	0	0	0	0	0	0	0	0	0	3
6	0	0	0	2	39	45	0	1	0	0	0	0	0	0	0	0	13
7	0	0	4	40	5	1	46	4	0	0	0	0	0	0	0	0	1
8	0	0	1	10	1	0	29	40	1	0	0	0	0	0	0	0	18
9	0	0	0	0	0	0	1	4	39	12	14	5	2	0	0	0	22
10	0	0	0	0	0	0	0	0	4	55	12	4	21	3	0	0	1
11	0	0	0	0	0	0	0	0	4	0	48	47	0	0	0	0	1
12	0	0	0	0	0	0	0	0	1	0	20	79	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	9	1	0	61	22	4	4	0
14	0	0	0	0	0	0	0	0	0	0	0	0	7	49	23	21	0
15	0	0	0	0	0	0	0	0	0	0	0	0	2	32	61	5	0
16	0	0	0	0	0	0	0	0	0	0	0	0	2	28	5	65	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100

Transition probability matrix for 5 days.

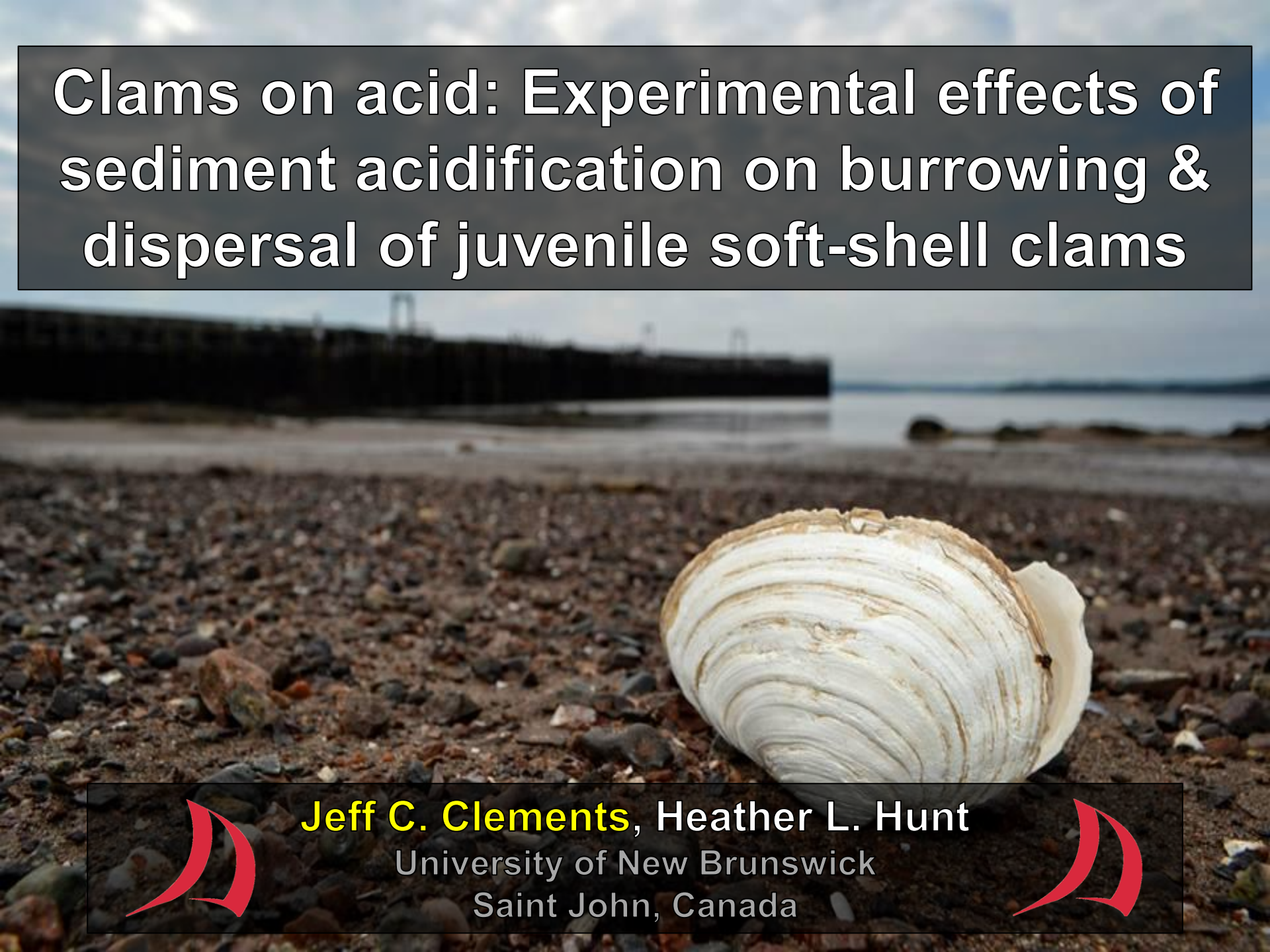
source/target	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	31	16	32	10	5	2	2	0	0	0	0	0	0	0	0	0	1
2	16	36	30	9	4	2	2	0	0	0	0	0	0	0	0	0	1
3	22	20	29	12	8	4	3	0	0	0	0	0	0	0	0	0	2
4	9	9	16	16	21	13	5	1	0	0	0	0	0	0	0	0	10
5	2	1	4	9	32	21	2	1	0	0	0	0	0	0	0	0	28
6	1	1	3	7	28	19	2	1	0	0	0	0	0	0	0	0	38
7	8	7	16	20	20	12	7	1	0	0	0	0	0	0	0	0	9
8	4	4	10	17	13	7	7	1	0	0	0	1	0	0	0	0	35
9	0	0	1	2	1	1	1	0	2	3	11	25	4	4	2	2	40
10	0	0	0	0	0	0	0	0	2	7	13	26	13	15	9	9	6
11	0	0	0	0	0	0	0	0	2	1	26	63	1	0	0	0	5
12	0	0	0	0	0	0	0	0	2	1	27	66	0	0	0	0	3
13	0	0	0	0	0	0	0	0	1	5	4	6	15	29	20	19	1
14	0	0	0	0	0	0	0	0	0	2	1	1	9	35	26	26	0
15	0	0	0	0	0	0	0	0	0	2	0	0	9	35	28	25	0
16	0	0	0	0	0	0	0	0	0	2	0	0	9	35	25	29	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100

Transition probability matrix for 30 days.

Groundtruthing planktonic stages: in situ microscopy Tali Treibitz, Univ. Haifa

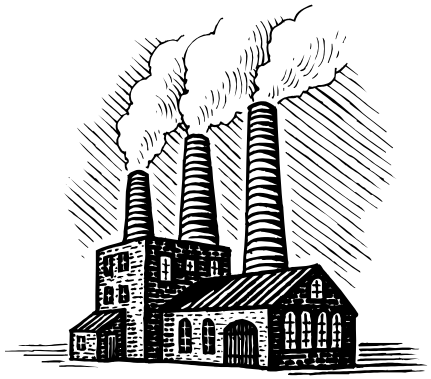


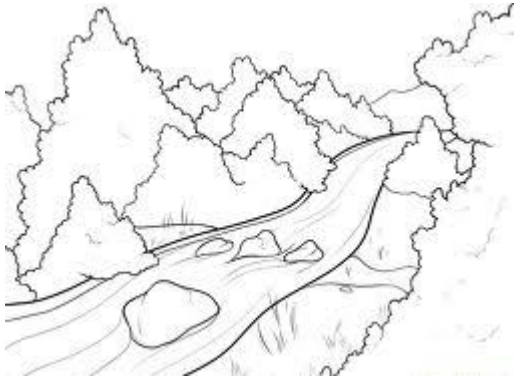
Clams on acid: Experimental effects of sediment acidification on burrowing & dispersal of juvenile soft-shell clams



Jeff C. Clements, Heather L. Hunt
University of New Brunswick
Saint John, Canada

Coastal Acidification





CO_2
Atmospheric

CO_2 + H_2O → H_2CO_3
Dissolved — Carbonic acid

H^+
Hydrogen ions

HCO_3^{-1} → CO_3^{-2}
Bicarbonate ions — Carbonate ions

Clams on acid

0 days **4 days** **7 days**

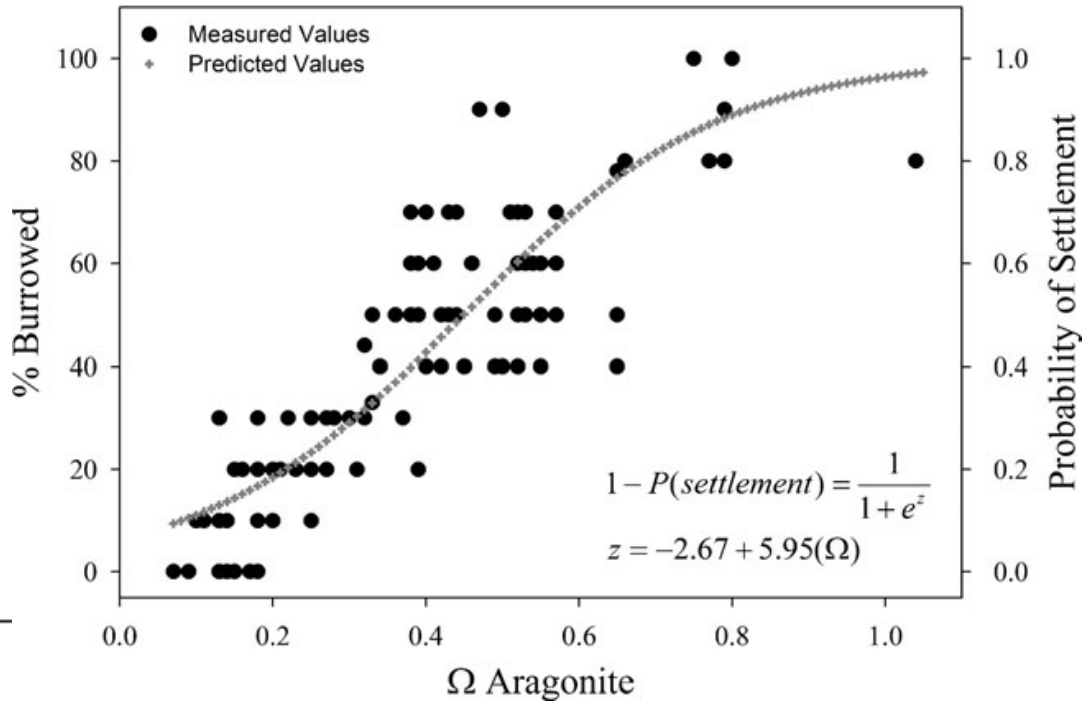
Green et al. (2009) *Limnol. Oceanogr.* **54:** 1037-1047.

0.2 mm clams

M. mercenaria

Implications

M. mercenaria



Estuaries and Coasts
DOI 10.1007/s12237-012-9549-0

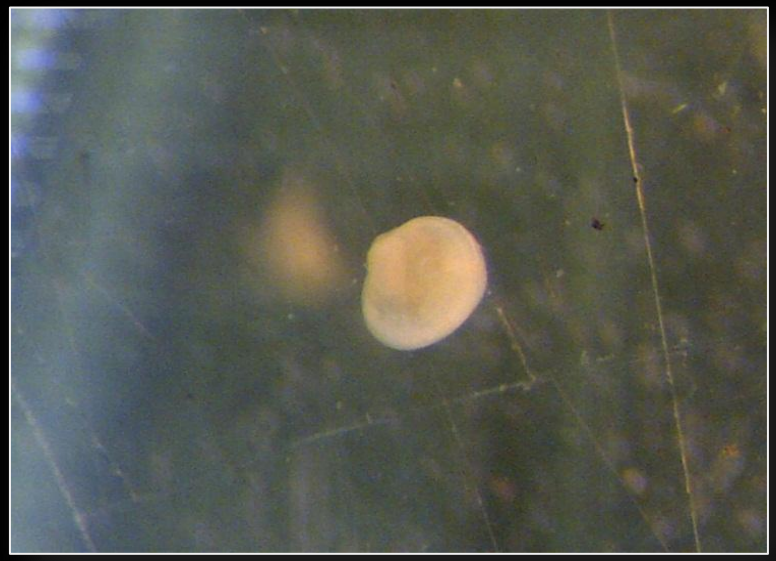
Carbonate Mineral Saturation State as the Recruitment Cue for Settling Bivalves in Marine Muds

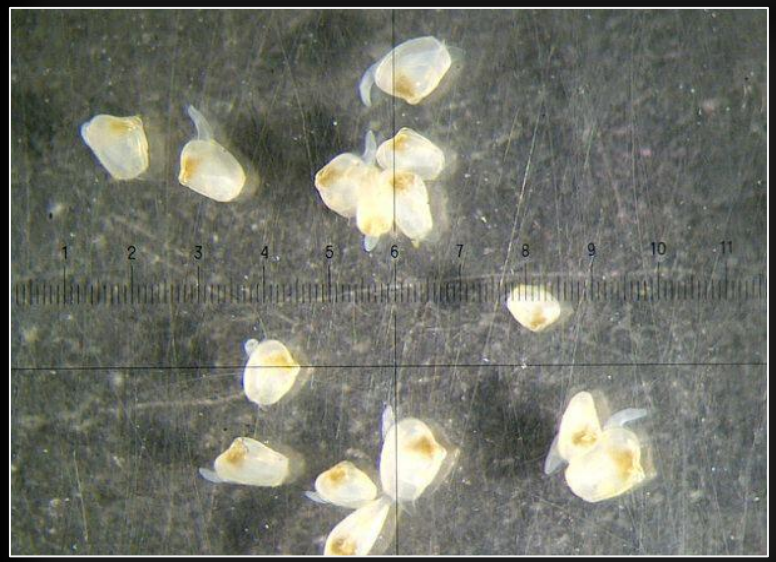
Mark A. Green · George G. Waldbusser · Lane Hubaze · Eric Cathcart · Joshua Hall

Primary question

Can sediment acidification affect juvenile soft-shell clam burrowing, dispersal, and recruitment?

Soft-shell clam





Infaunal

Tolerant

Fishery

Maine: $13mil USD

Aragonitic shell

Soluble

Burrowing & dispersal

Geochemistry

Experiment 1.0

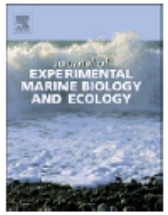
Can sediment acidification affect juvenile soft-shell clam burrowing and dispersal in the lab?

Journal of Experimental Marine Biology and Ecology 453 (2014) 62–69

Contents lists available at ScienceDirect

Journal of Experimental Marine Biology and Ecology

journal homepage: www.elsevier.com/locate/jembe



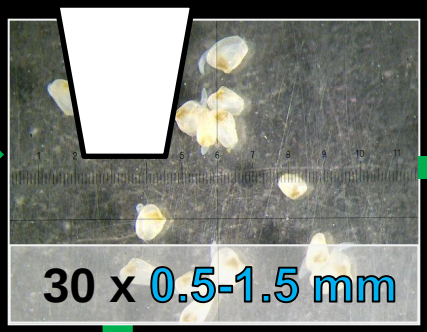
Influence of sediment acidification and water flow on sediment acceptance and dispersal of juvenile soft-shell clams (*Mya arenaria* L.)

Jeff C. Clements *, Heather L. Hunt

University of New Brunswick Saint John Campus, Department of Biology, 100 Tucker Park Road, Saint John, NB E2L 4L5, Canada

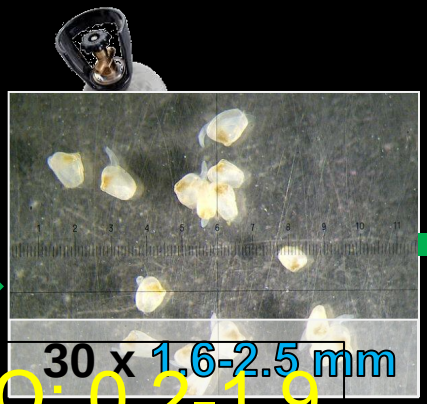
Flume

BURROWING **DISPERSAL**



11 cm s^{-1}

23 cm s^{-1}

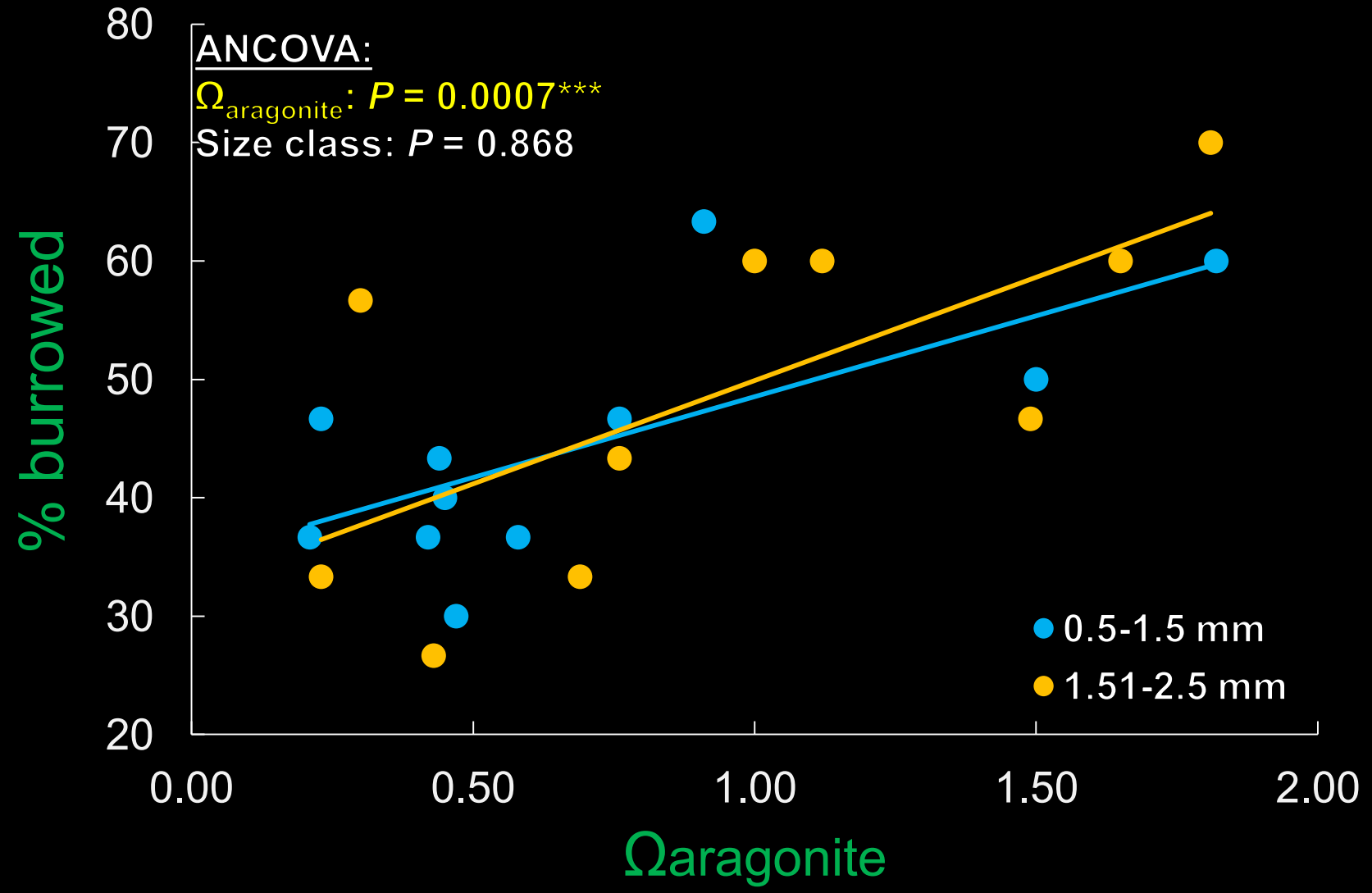


11 cm s^{-1}

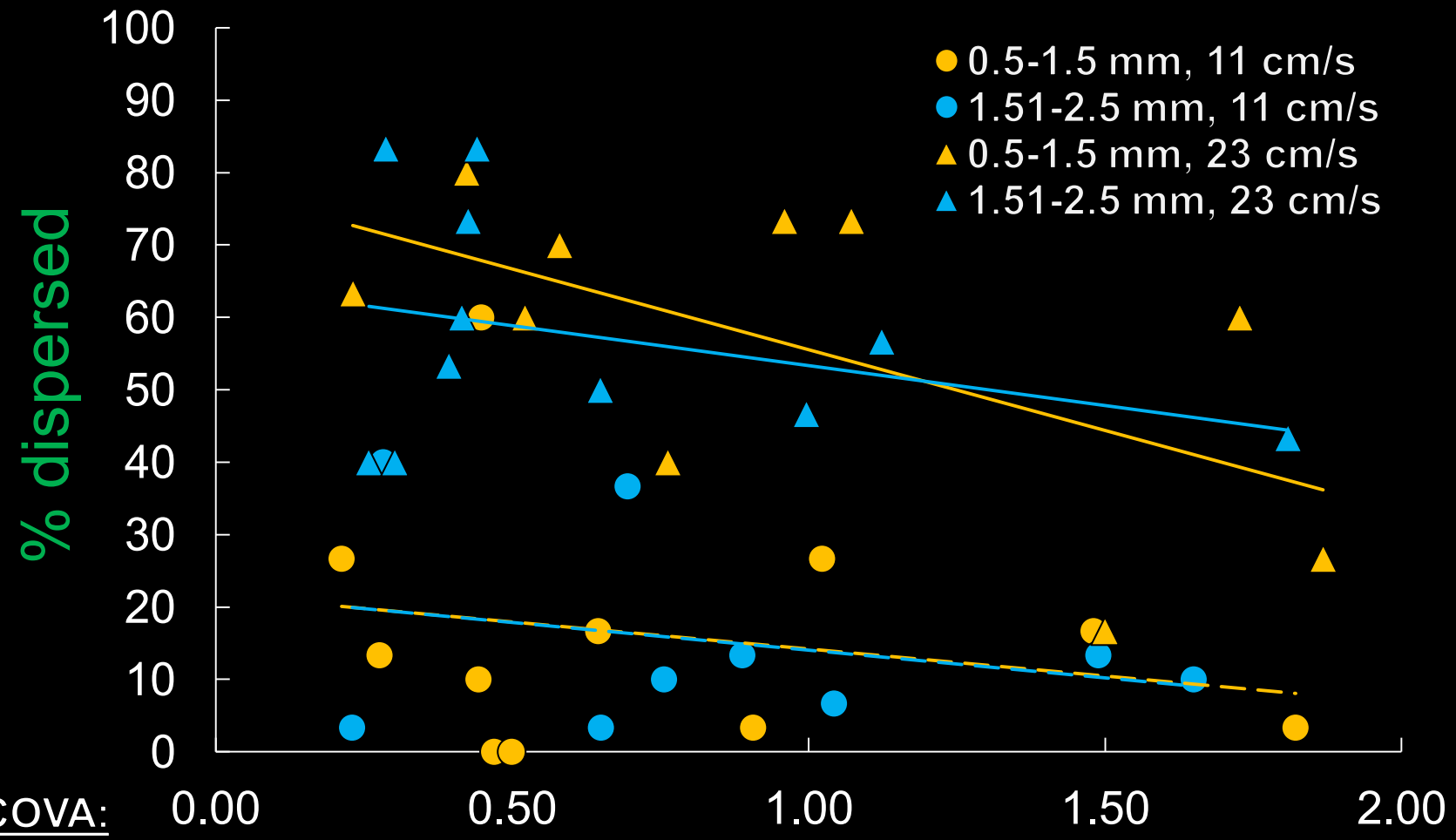
23 cm s^{-1}

Ω: 0.2-1.9

Rejection!


ANCOVA:
$\Omega_{aragonite}$: P = 0.0007***
Size class: P = 0.868
% burrowed
80
70
60
50
40
30
20
0.00
0.50
1.00
1.50
2.00
Ωaragonite
0.5-1.5 mm
1.51-2.5 mm

Get me outta' here!



ANCOVA:

$\Omega_{aragonite}$: $P = 0.0206^{*}$

Flow speed: $P = 0.0001^{***}$

Size class: $P = 0.5490$

Size class × Flow: $P = 0.7330$

Experiment 2.0

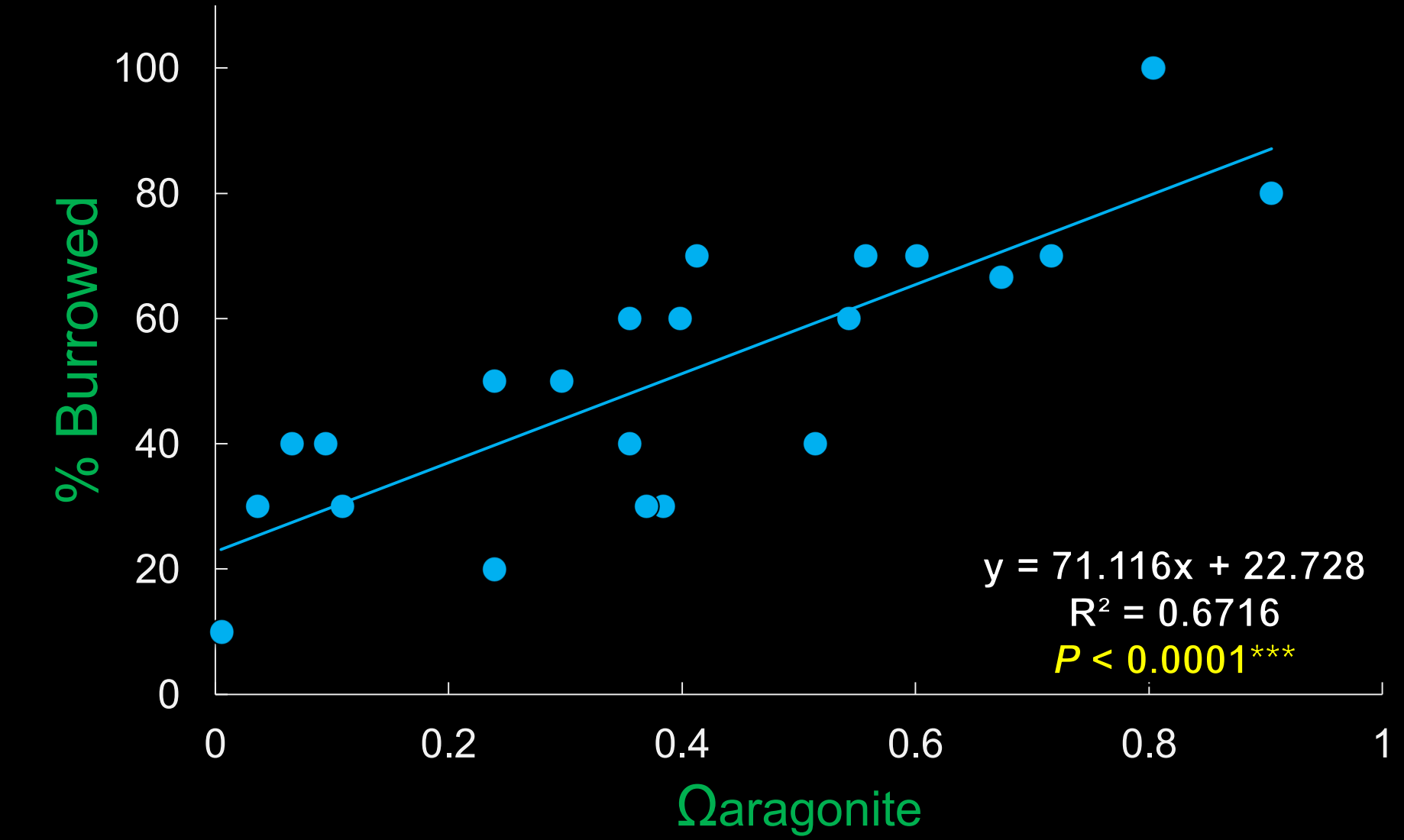
Can natural sediment acidification affect juvenile soft-shell clam burrowing in the lab?

Experiment 2.0

22 cores

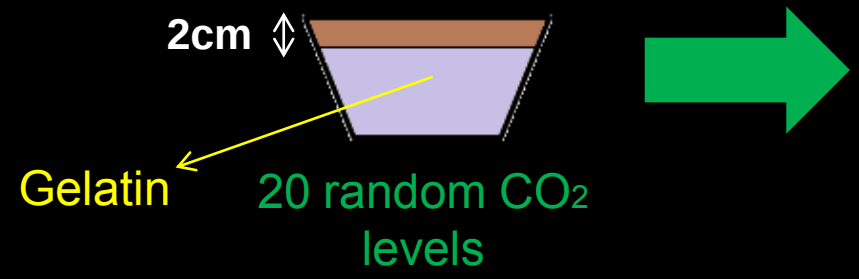
10 clams 2-5 mm

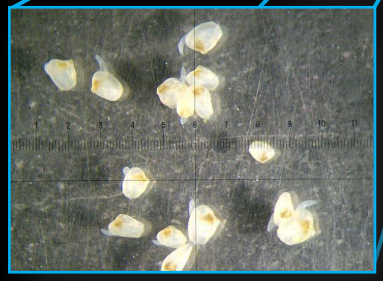
Rejection!


% Burrowed
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
Ωaragonite
y = 71.116x + 22.728
R² = 0.6716
P < 0.0001***

Playing in the mud

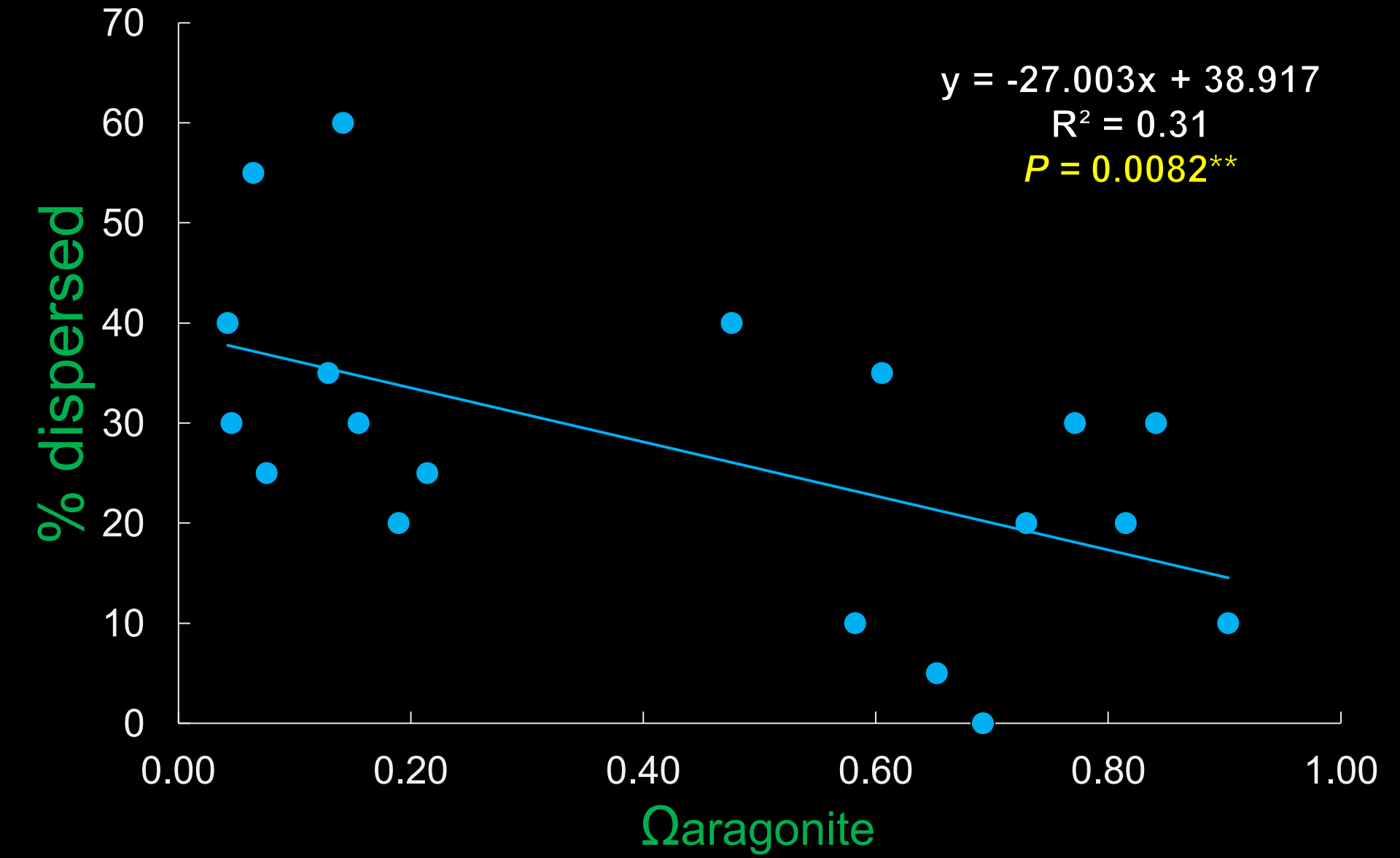
EXPERIMENT A



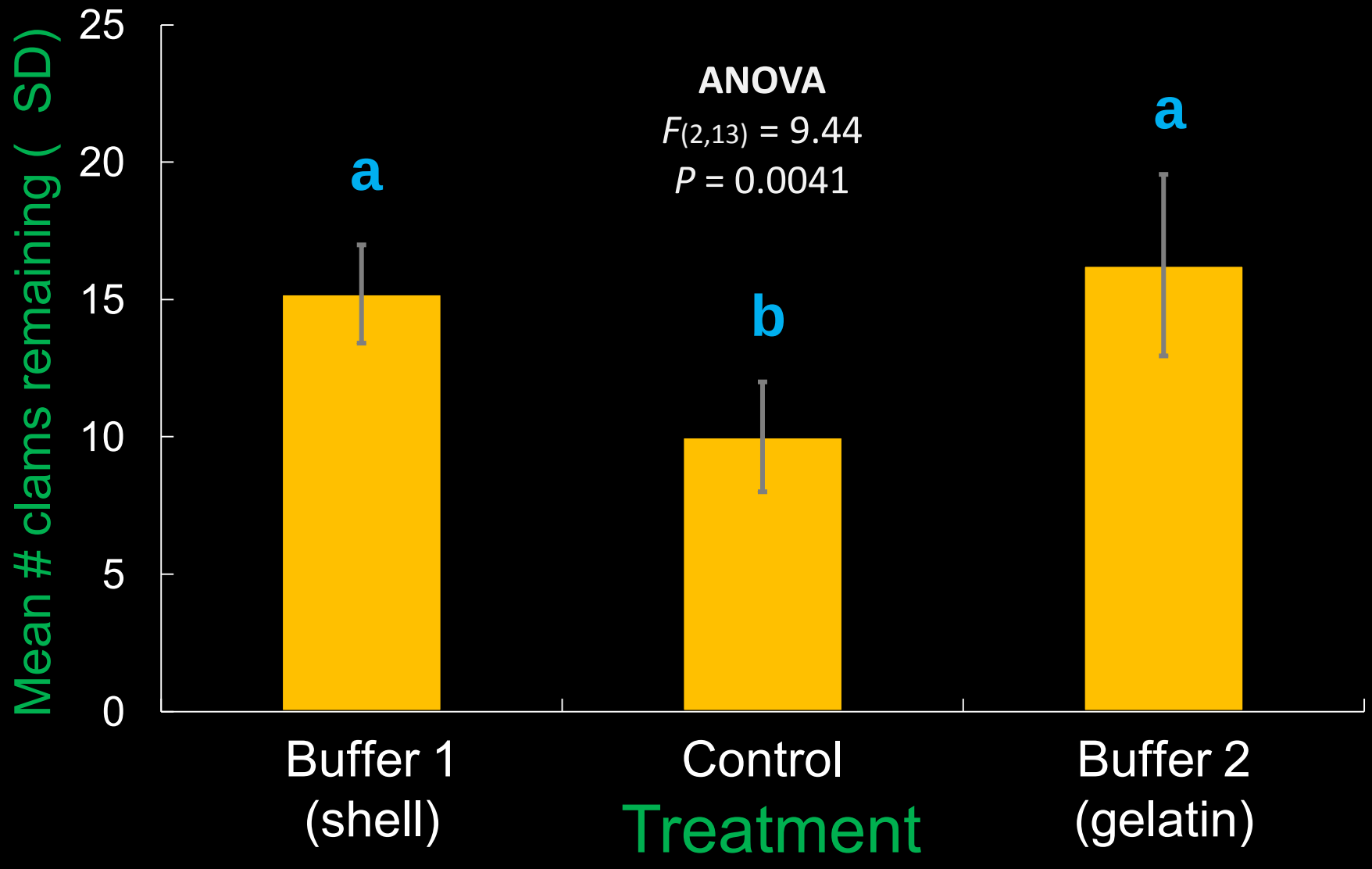


20 clams < 2 mm

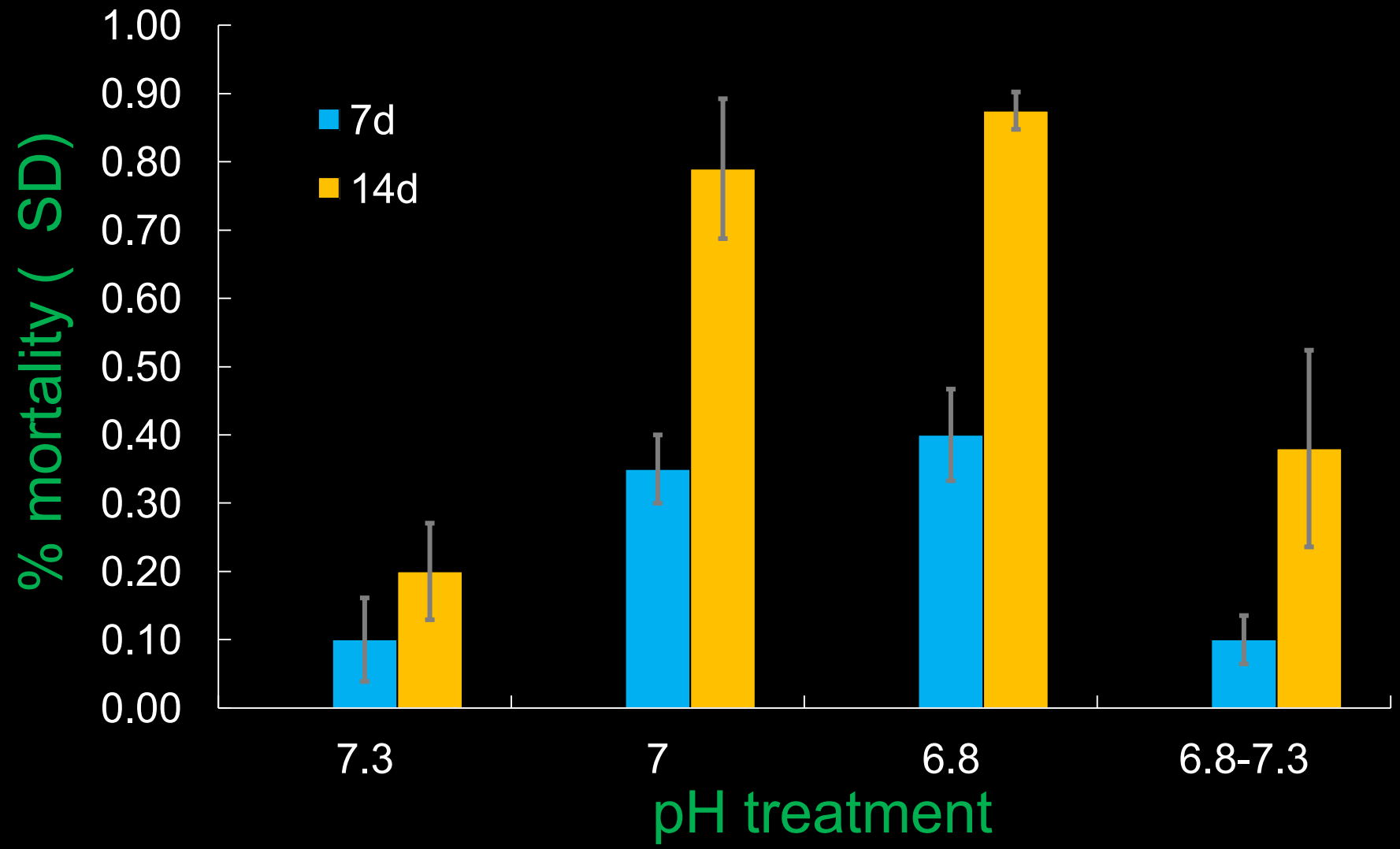
Get me outta' here!



Buffering…


Mean # clams remaining (SD)
25
20
15
10
5
0
ANOVA
$F_{(2,13)} = 9.44$
$P = 0.0041$
a
b
a
Buffer 1 (shell)
Control
Buffer 2 (gelatin)
Treatment

Why?


1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
% mortality (SD)
7d
14d
7.3
7
6.8
6.8-7.3
pH treatment

Aquaculture

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FISHERIES

An acidic ocean threatens shellfish farms

BRENNAN CLARKE

VICTORIA — Special to The Globe and Mail

Published Sunday, Oct. 30 2011, 9:08 PM EDT

Last updated Thursday, Sep. 06 2012, 10:30 AM EDT

0 comments 39 38 1 0 0 AA

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For more than two decades, Rob Saunders grew his shellfish larvae in ordinary seawater drawn from the pristine natural environment of Baynes Sound, one of the most productive shellfish farming areas on B.C.'s West Coast.

Now the water in Baynes Sound is so acidic, Mr. Saunders' fragile seed stock will die unless he artificially adjusts the PH level in his hatchery tanks.

"Because of ocean acidification the only way we can grow any larvae – oysters, clams, mussels, geoducks, you name it – is to take the CO2 out of the seawater," said Mr. Saunders, CEO of Island Scallops, the largest producer of shellfish seed stock on province's West Coast.

"We would have been out of business this year if we didn't figure out how to solve the problem."

Ocean acidification, a worldwide phenomenon linked to global warming, was identified as a serious threat to the shellfish industry in Oregon and

Originally published June 21, 2012 at 9:24 PM | Page modified June 22, 2012 at 1:34 PM

Willapa Bay oyster grower sounds alarm, starts hatchery in Hawaii

A Willapa Bay shellfish company is shifting some of its business to Hawaii because of ocean acidification that scientists believe is killing tiny oyster larvae in shellfish farms along Washington's coast.

By Craig Welch

Seattle Times environment reporter

After 34 years rearing shellfish in Willapa Bay, Dave Nisbet was in a bind: Nature had stopped providing.

Oysters were no longer reproducing naturally on the Washington Coast. Oyster larvae were even dying in nearby hatcheries, which use seawater to raise baby shellfish that get sold as starter seed to companies like Nisbet's Goose Point Oysters.

But when, in 2009, Nisbet heard oceanographers identify the likely culprit — increasingly corrosive ocean water, a byproduct of the same greenhouse gases that contribute to global warming — the oysterman did the unthinkable.

Nisbet took out a loan and spent three years testing and building a new hatchery that opened recently. In Hawaii.

BRIAN J. C

The owners of Goose Point C in Willapa Bay since the mid-1 hatchery in Hawaii because o to raise oysters in the Northw

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Acidic water blamed for West Coast scallop die-off

Nanaimo-based Island Scallops has shut down its processing plant and laid off a third of its workforce

BY RANDY SHORE, VANCOUVER SUN FEBRUARY 25, 2014

Recommend 1.1k Tweet 81 +1 31 Pin it 1 Comment 55 ShareThis

STORY | PHOTOS (1)

High acidity is being blamed for a mass die-off of B.C. scallops.

Ten million scallops that have died in the waters near Qualicum Beach due to rising ocean acidity are the latest victims in a series of marine die-offs that have plagued the West Coast for a decade.

MORE ON THIS STORY

- B.C.'s iconic fish species being displaced by warming oceans: UBC study
- Fragile glass sponges lead Sun reporter to bottom of Howe Sound (with Video)

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The great oyster crash

By OnEarth

18 Aug 2011 6:12 PM 81 comments 18 shares SHARE

This OnEarth column was written by Eric Scigliano.

In the summer of 2007, something strange and troubling happened at the Whiskey Creek Shellfish Hatchery on Netarts Bay in Oregon, which raises oyster larvae for shellfish growers from

21 NOV 2011: REPORT

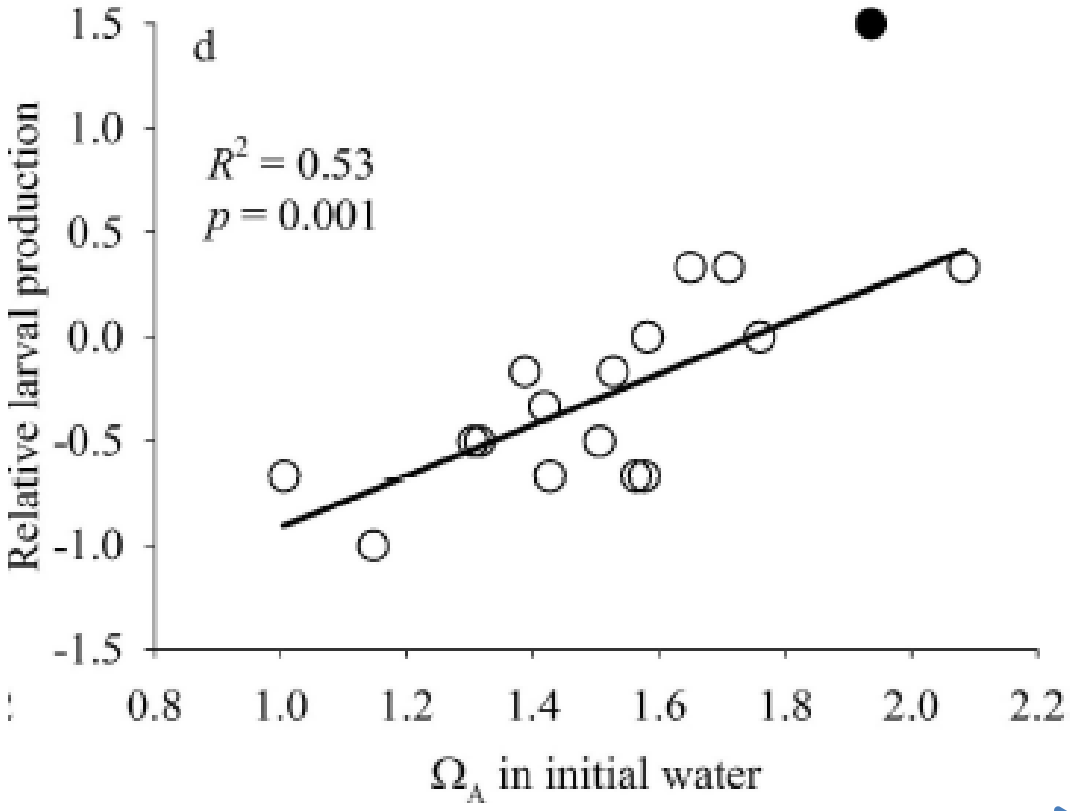
Northwest Oyster Die-offs Show Ocean Acidification Has Arrived

The acidification of the world's oceans from an excess of CO_2 has already begun, as evidenced recently by the widespread mortality of oyster larvae in the Pacific Northwest. Scientists say this is just a harbinger of things to come if greenhouse gas emissions continue to soar.

BY ELIZABETH GROSSMAN

Aquaculture

Acidified conditions = no larval production



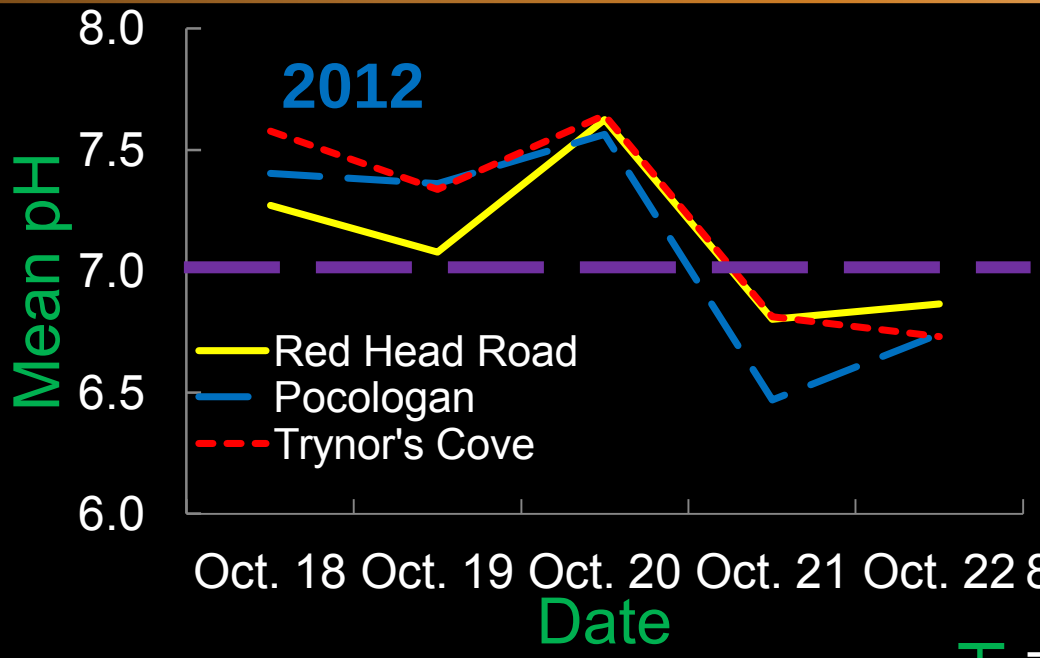
DECREASING ACIDIFICATION

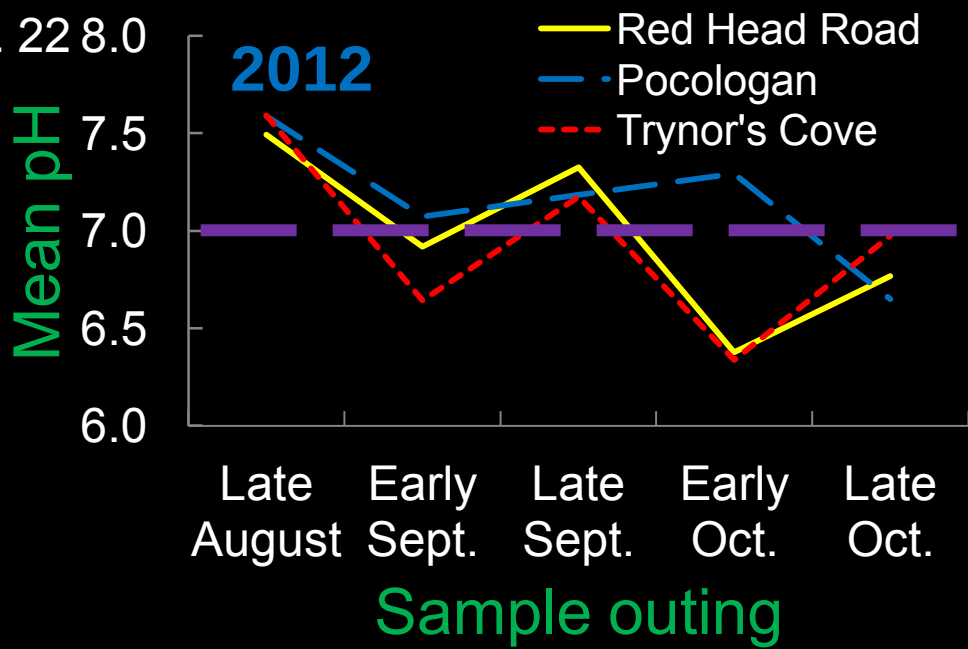
Crassostrea gigas

No larvae = no fishery/aquaculture!

Barton et al. (2012)

What we know


8.0
7.5
7.0
6.5
6.0
Mean pH
2012
Red Head Road
Pocologan
Trynor's Cove
Oct. 18
Oct. 19
Oct. 20
Oct. 21
Oct. 22
Date


8.0
7.5
7.0
6.5
6.0
Mean pH
2012
Red Head Road
Pocologan
Trynor's Cove
Late August
Early Sept.
Late Sept.
Early Oct.
Late Oct.
Sample outing

Acknowledgements

A. Downie, K. Woodard, B. Irish, M. Dejardins, A. Castillejos, J. Boddy, P. Vazquez, M. Arellano

M. Green, SJC Maine

MJ Maltais, A. McAslan, D. Scott, K. Cummings

G. Protopopescu/ Downeast Institute

NSERC
CRSNG

Thank you!

j.clements@unb.ca
Twitter: @biolumiJEFFence

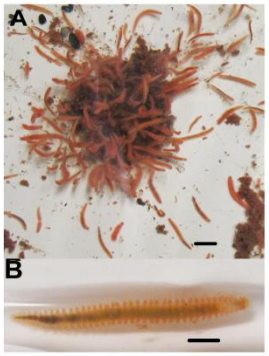
Questions?

- Approximately 90% of the aquaculture sites have hard substrates (a lot of them are very patchy) at depths between 30 to more than 100m in accordance with DFO siting criteria (>30m depth; deep subtidal zone).
- Quantitative standards (sulphide, redox potential) are difficult to apply universally over a broad range of habitat types as they require sediment grabs/samples.

Candidate indicators

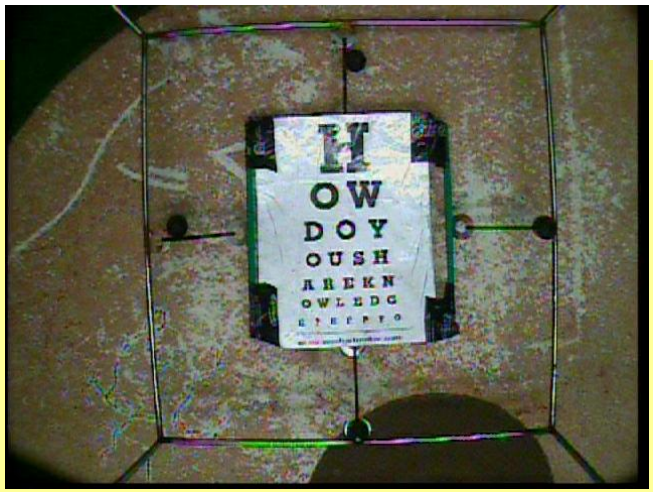
The genus *Beggiatoa* consists of Gram negative, filamentous, sulfide-oxidizing, gliding bacteria commonly found at oxygen/sulfide interfaces such as those present in sediments, hot spring outflows, hydrothermal vents, and hypersaline ponds.

On soft substrates near finfish cages, OPC is often associated with low oxygen and high sulphide levels (Wildish and Pohlem 2005). These conditions are thought to represent low habitat quality.



The Video Analysis Process

- View all videos collected at a station
- Selection a representative picture with image capture
- Identification of substrate types and determination of % coverage (freeware like “image J” can accomplish this) (50cm x 50cm)
- Record indicators (#’s, and % coverage)
- Identify species and count abundances
- Comment anything notable
- It was determined that under normal conditions visibility can be as good as 1cmx1cm

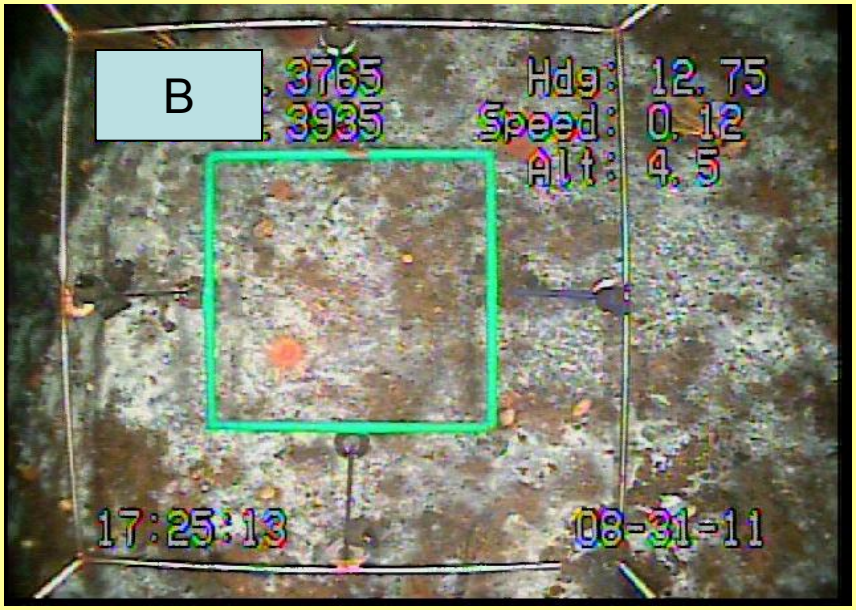


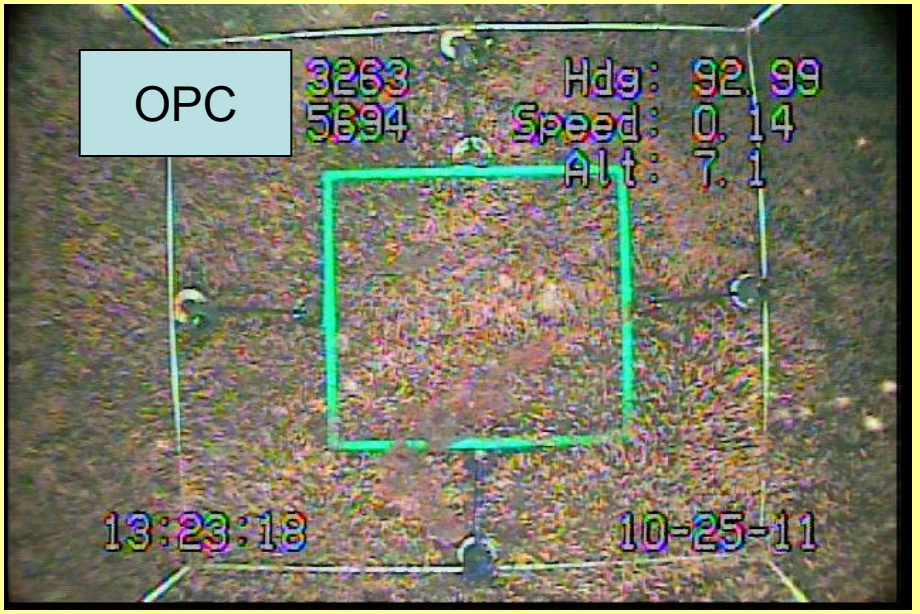
- Our results suggest that there is minimal observer variability and therefore we recommend providing a detailed instructional manual and adequate training to observers to reduce the margin of error.

- A standard of practice for use of camera was developed as well as a photographic guide to benthic species of hard bottom communities on the south coast of Newfoundland has also been developed. Both can be used by environmental companies when conducting their assessments.

DFO. 2012. Standard operating procedures (SOP) for underwater video camera system. Newfoundland, Canada. www.dfo-mpo.gc.ca/library/347683.pdf
DFO. 2012. A photographic guide to benthic species of hard-bottom communities in Southwest Newfoundland. www.dfo-mpo.gc.ca/library/347684.pdf

Mabrouk G. Bungay T., Drover D., and Hamoutene D. 2014. Use of remote video survey methodology in monitoring benthic impacts from finfish aquaculture on the south coast of Newfoundland (Canada). DFO Canadian Science Advisory Research Document 2014/039. v+15p.


B
Hdg: 12.75
Speed: 0.12
Alt: 4.5
17:25:13
08-31-11


OPC
3263
5694
Hdg: 92.99
Speed: 0.14
Alt: 7.1
13:23:18
10-25-11

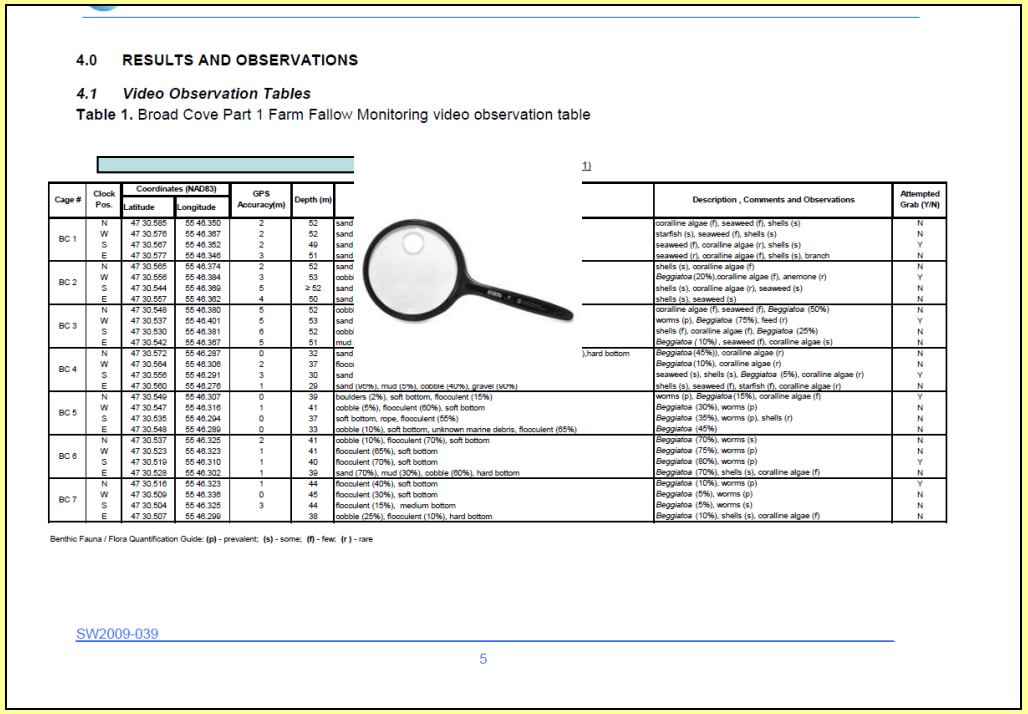

B & OPC
Hdg: 226.4
Speed: 0.34
Alt: 9.2
19:18:19
06-16-12


B & OPC
Hdg: 215.5
Speed: 0.33
Alt: 9.8
18:38:58
07-26-11

Monitoring reports

- BASELINE (Before aquaculture activities)
- PART I (After harvest- end of production)
- PART II (After fallow- most cases 1 year fallow)

- DATA OF ALL SAMPLING STATIONS ARE SUMMARIZED (% presence/absence or means)



4.0 RESULTS AND OBSERVATIONS

4.1 Video Observation Tables

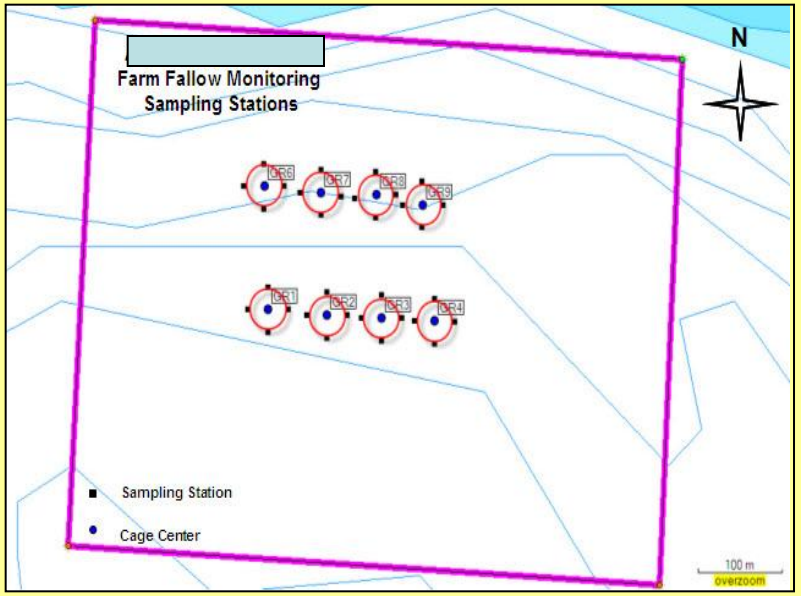
Table 1. Broad Cove Part 1 Farm Fallow Monitoring video observation table

Cage #	Clock Pos.	Coordinates (NAD83) Latitude	Longitude	GPS Accuracy(m)	Depth (m)		Description , Comments and Observations	Attempted Grab (Y/N)
BC 1	N	47 30.585	55 46.350	2	52	sand	coralline algae (f), seaweed (f), shells (s)	N
	W	47 30.576	55 46.367	2	52	sand	starfish (s), seaweed (f), shells (s)	N
	S	47 30.567	55 46.352	2	49	sand	seaweed (f), coralline algae (r), shells (s)	Y
	E	47 30.577	55 46.346	3	51	sand	seaweed (r), coralline algae (f), shells (s), branch	N
BC 2	N	47 30.565	55 46.374	2	52	sand	shells (s), coralline algae (f)	N
	W	47 30.558	55 46.384	3	53	cobbl	*Beggiatoa* (20%),coralline algae (f), anemone (r)	Y
	S	47 30.544	55 46.369	5	≥ 52	sand	shells (s), coralline algae (r), seaweed (s)	N
	E	47 30.557	55 46.362	4	50	sand	shells (s), seaweed (s)	N
BC 3	N	47 30.548	55 46.380	5	52	cobbl	coralline algae (f), seaweed (f), *Beggiatoa* (50%)	N
	W	47 30.537	55 46.401	5	53	sand	worms (p), *Beggiatoa* (75%), feed (r)	Y
	S	47 30.530	55 46.381	6	52	cobbl	shells (f), coralline algae (f), *Beggiatoa* (25%)	N
	E	47 30.542	55 46.367	5	51	mud	*Beggiatoa* (10%) , seaweed (f), coralline algae (s)	N
BC 4	N	47 30.572	55 46.287	0	32	sand	*Beggiatoa* (45%), coralline algae (r)	N
	W	47 30.564	55 46.306	2	37	flocc	*Beggiatoa* (10%), coralline algae (r)	N
	S	47 30.556	55 46.291	3	30	sand	seaweed (s), shells (s), *Beggiatoa* (5%), coralline algae (r)	Y
	E	47 30.560	55 46.276	1	29	sand (30%), mud (5%), cobble (40%), gravel (5%)	shells (s), seaweed (f), starfish (f), coralline algae (r)	N
BC 5	N	47 30.549	55 46.307	0	39	boulders (2%), soft bottom, flocculent (15%)	worms (p), *Beggiatoa* (15%), coralline algae (f)	Y
	W	47 30.547	55 46.316	1	41	cobble (5%), flocculent (60%), soft bottom	*Beggiatoa* (30%), worms (p)	N
	S	47 30.535	55 46.294	0	37	soft bottom, rope, flocculent (55%)	*Beggiatoa* (35%), worms (p), shells (r)	N
	E	47 30.548	55 46.289	0	33	cobble (10%), soft bottom, unknown marine debris, flocculent (85%)	*Beggiatoa* (45%)	N
BC 6	N	47 30.537	55 46.326	2	41	cobble (10%), flocculent (70%), soft bottom	*Beggiatoa* (70%), worms (s)	N
	W	47 30.523	55 46.323	1	41	flocculent (65%), soft bottom	*Beggiatoa* (75%), worms (p)	N
	S	47 30.519	55 46.310	1	40	flocculent (70%), soft bottom	*Beggiatoa* (80%), worms (p)	Y
	E	47 30.528	55 46.302	1	39	sand (70%), mud (30%), cobble (60%), hard bottom	*Beggiatoa* (70%), shells (s), coralline algae (f)	N
BC 7	N	47 30.516	55 46.323	1	44	flocculent (40%), soft bottom	*Beggiatoa* (10%), worms (p)	Y
	W	47 30.509	55 46.336	0	45	flocculent (30%), soft bottom	*Beggiatoa* (5%), worms (p)	N
	S	47 30.504	55 46.325	3	44	flocculent (15%), medium bottom	*Beggiatoa* (5%), worms (s)	N
	E	47 30.507	55 46.299		38	cobble (25%), flocculent (10%), hard bottom	*Beggiatoa* (10%), shells (s), coralline algae (f)	N

Benthic Fauna / Flora Quantification Guide: **(p)** - prevalent; **(s)** - some; **(f)** - few; **(r)** - rare

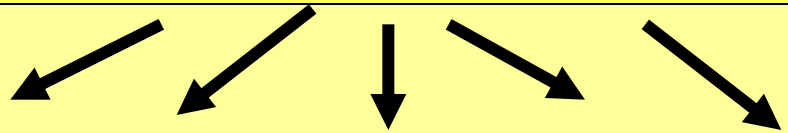
SW2009-039

5



Using Decision Tree Analyses

THE PREDICTORS= AQUACULTURE STAGE, LENGTH OF PRODUCTION/FALLOW, DEPTH, SUBSTRATE



THE VARIABLE = THE PARAMETER MEASURED (REDOX (mean values), SULFIDES (mean values), OPC (%presence sampling points), BEGGIATOA (%presence sampling points), OFFGASING (%presence sampling points), FLORA (%presence sampling points), FAUNA (%presence sampling points)

THE QUESTION: WILL THE PREDICTORS INFLUENCE THE PARAMETER RESPONSES AND IN WHAT ORDER?

Main predictors and PRE values for decision trees generated for Fauna, Flora, Beggiatoa, OPC, Redox, Sulfides, Flocculent, and Offgasing. Predictors include: substrate type, depth, and report type.

Parameter	First Predictor	Second predictors	PRE
Fauna (n=57)	Substrate	Substrate	50.8%
Flora (n=57)	Type of reports (Baseline < Part1 and 2)	Substrate	34.4%
***Beggiatoa* (n=57)**	**Aquaculture stage (Baseline < Part1 and 2)**	**Aquaculture stage (Part2 < Part1)**	**75.4%**
OPC (n=57)	**Aquaculture stage (Baseline < Part1 and 2)**	**Depth**	**69.3%**
Redox (n=32)	**Aquaculture stage** (Baseline > Part1 and 2)	Substrate	40.8%
Sulfides (n=32)	**Aquaculture stage** (Part1 > Baseline and Part2)	Substrate	74.0%
Flocculent (n=57)	**Aquaculture stage** (Baseline < Part1 and 2)	Substrate	87.7%
Offgasing (n=56)	**Aquaculture stage** (Part1 > Baseline and Part2)	Type of reports (Baseline < Part2) and Substrate	58.8%

Correlation coefficients between parameters as explored using Pearson Product Moment correlation (after Bonferroni adjustment, significance is at $P < 0.002$).

	Flora	Flocculent	Offgasing	Redox	Sulfides	Beggiatoa	OPC
Fauna	0.179	-0.073	-0.077	-0.031	-0.322	-0.016	0.047
Flora		0.219	0.102	-0.170	0.079	0.389	-0.005
Flocculent			**0.679**	- 0.462	**0.832**	**0.894**	**0.740**
Offgasing				-0.481	**0.625**	**0.538**	**0.416**
Redox					- 0.436	-0.430	-0.188
Sulfides						**0.747**	**0.632**
Beggiatoa							**0.606**

Beggiatoa and OPC (n=24)→ 2894.7 1813.8 µM (749 to 7016 µM) (**oxic B to anoxic**)
Beggiatoa and OPC (n=8)→ -258.4 ± 159.4 mV (-407 to 412 mV) (**oxic A to anoxic**)

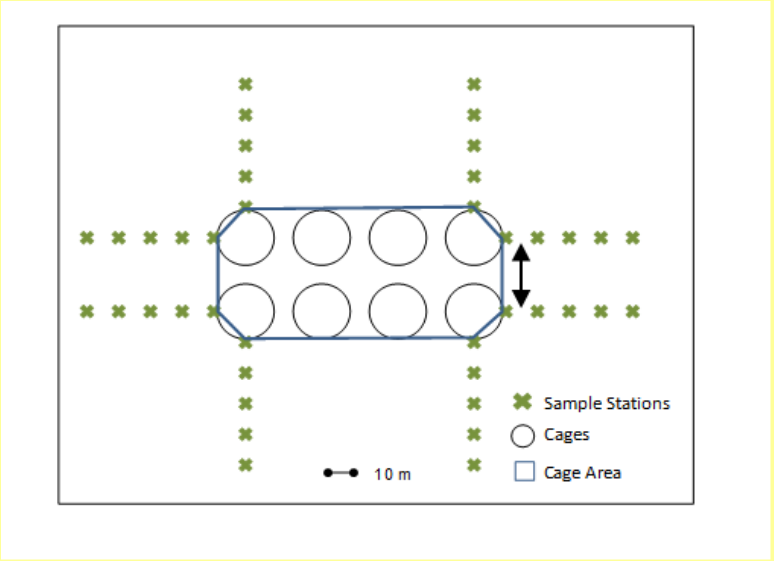
Beggiatoa and OPC were not found in reference sites and are visual indicators of aquaculture effect on the benthos observed on different substrate types.

They correlate well with known indicators of aquaculture activities such as flocculent presence, offgasing and sulfides.

Our results suggest that benthic hypoxic conditions may exist in some sites prior to aquaculture activities. This report highlights the importance of collecting counts/abundance of fauna and flora in order to better evaluate epibiotic richness.

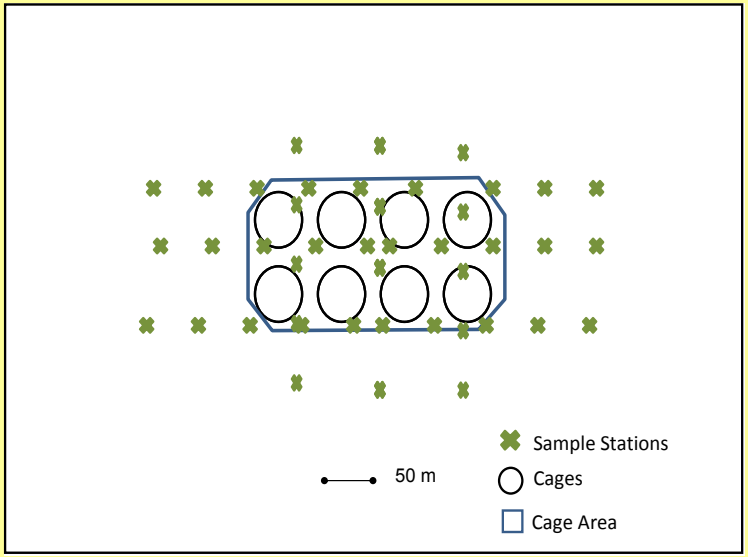
Hamoutene D., Mabrouk G., Sheppard L., MacSween C., Coughlan E., and Grant C. 2013. Validating the use of *Beggiatoa* sp. and opportunistic polychaete worm complex (OPC) as indicators of benthic habitat condition at finfish aquaculture sites in Newfoundland. Canadian Technical Report of Fisheries and Aquatic Sciences. 3028 : vii + 18 p.

Correlation coefficients and associated probabilities (Spearman rank order) between distance and percent coverage (first line) or presence/absence (values between brackets) of *Beggiatoa*, OPC, and flocculent. For Part 1 monitoring reports, n = 307 stations.



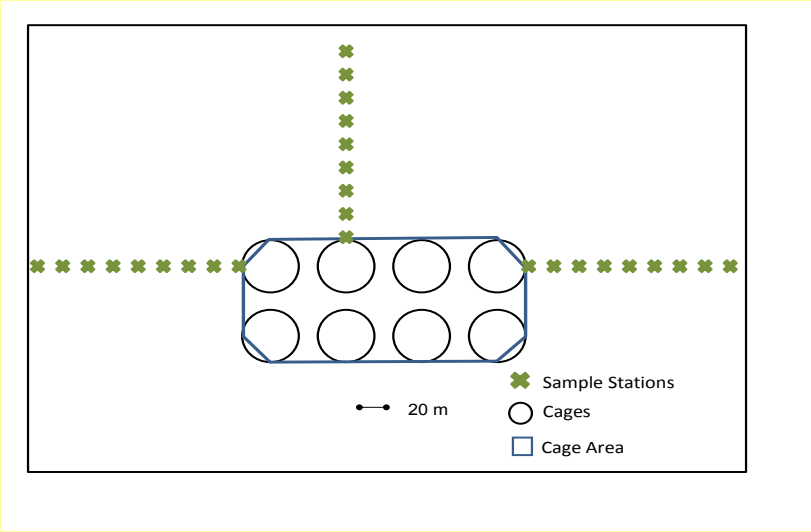
Correlation	Floc. Part 1	Beg. Part 1	OPC Part 1
Distance	-0.095, P=0.097 (-0.104), P=0.070	**-0.189, P<0.001 (-0.187), P<0.001**	0.031, P=0.589 (0.039), P=0.496
Floc. Part 1		**0.355, P<0.001 (0.324), P<0.001**	**0.587, P<0.001 (0.575), P<0.001**
Beg. Part 1			0.074, P=0.198 (0.088), P=0.123

Correlation coefficients and associated probabilities (Spearman rank order) between distance and percent coverage (first line) or presence/absence (values between brackets) of *Beggiatoa*, and OPC. For sampled sites in 2010, n =182 stations.

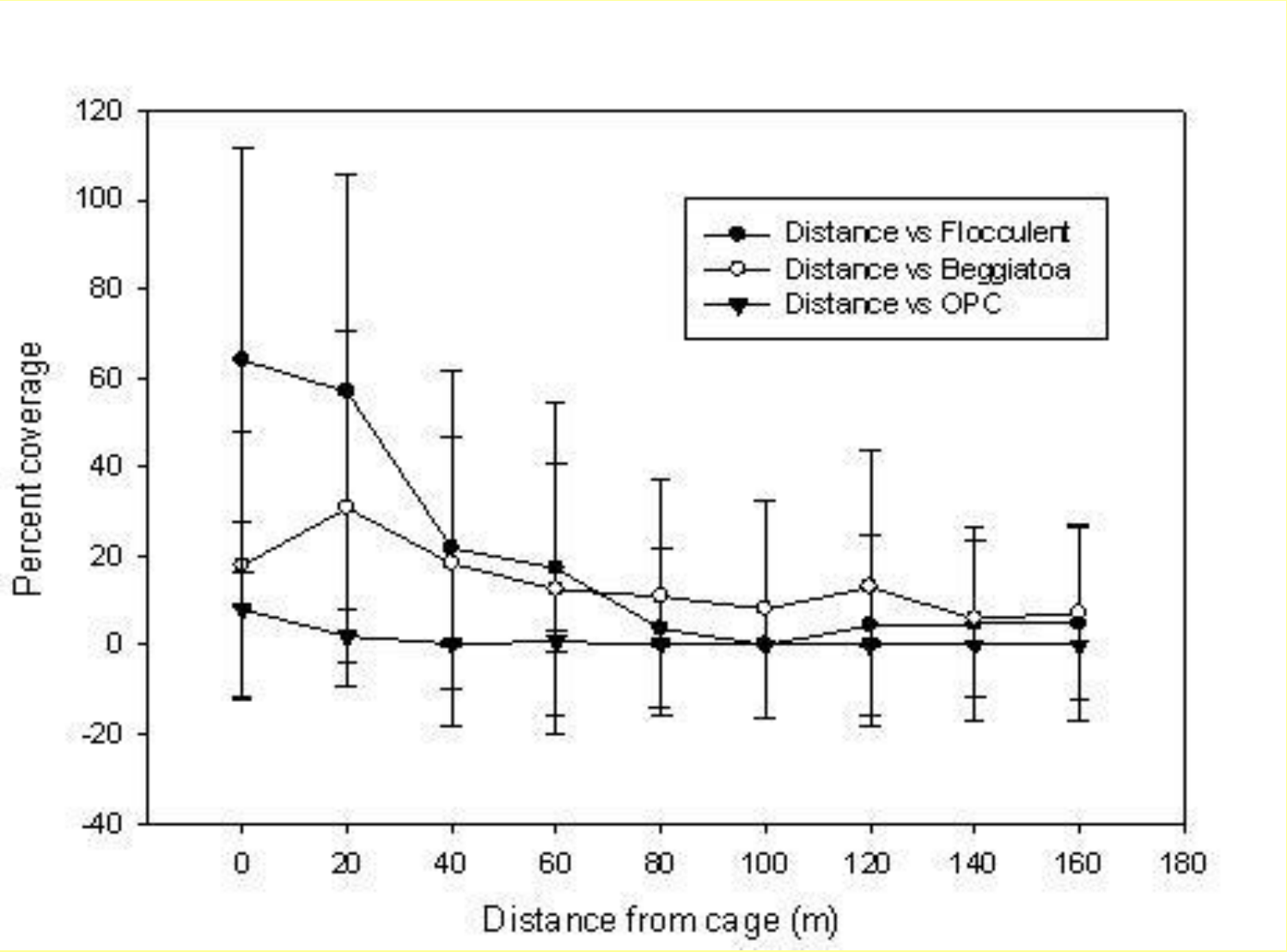


Correlation	Beg. Sampled 10	OPC Sampled 10
Distance	-0.254, P<0.001 (-0.254), P<0.001	**-0.290, P<0.001** **(-0.292), P<0.001**
Beg. Sampled 10		**-0.020, P=0.790** **(0.210), P<0.05**

Correlation coefficients and associated probabilities (Spearman rank order) between distance and percent coverage (first line) or presence/absence (values between brackets) of *Beggiatoa*, OPC, and flocculent. For sampled sites in 2011-12, n = 235 stations.



Correlation	Floc. Sampled 11-12	Beg. Sampled 11-12	OPC Sampled 11-12
Distance	**-0.528, P<0.001** **(-0.523), P<0.001**	**-0.331, P<0.001** **(-0.349), P<0.001**	**-0.347, P<0.001** **(-0.346), P<0.001**
Floc. Sampled 11-12		**0.531, P<0.001** **(0.530), P<0.001**	**0.571, P<0.001** **(0.587), P<0.001**
Beg. Sampled 11-12			**0.395, P<0.001** **(0.399), P<0.001**



Mean percent cover of *Beggiatoa*, OPC, and flocculent material with distance from cages (m) using data extracted from eight Newfoundland aquaculture sites (after one year production in 2011 and 2012). N varies from 21 to 27 stations for every distance from cage.

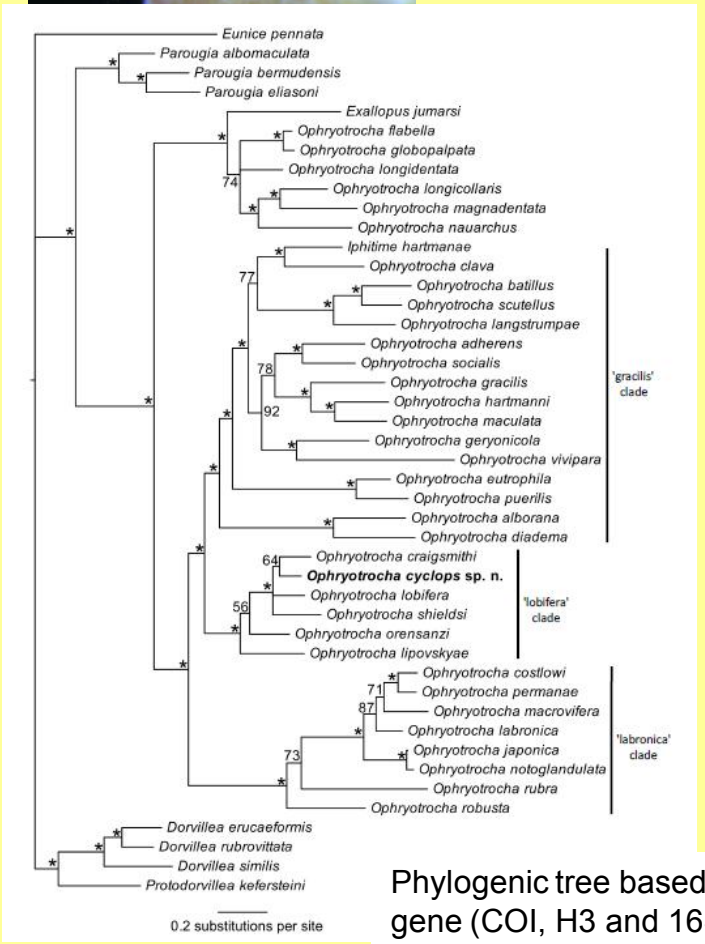
- *Beggiatoa* and OPC were not present in reference sites and found to be linked with aquaculture activities independently of depth and substrate type. Their presence is associated with lower benthic biodiversity and abundances.

- *Beggiatoa* and OPC correlate well with known indicators of aquaculture activities such as flocculent presence, offgasing and sulphides (up to a certain concentration).

- Indicators were found to decrease with distance from cage though exhibiting patchy distributions. Despite this patchiness, average differences in indicators coverage between stations along transects in the same direction were inferior to 10%.

WE NEED TO KNOW MORE ABOUT THESE INDICATORS

Identification OPC



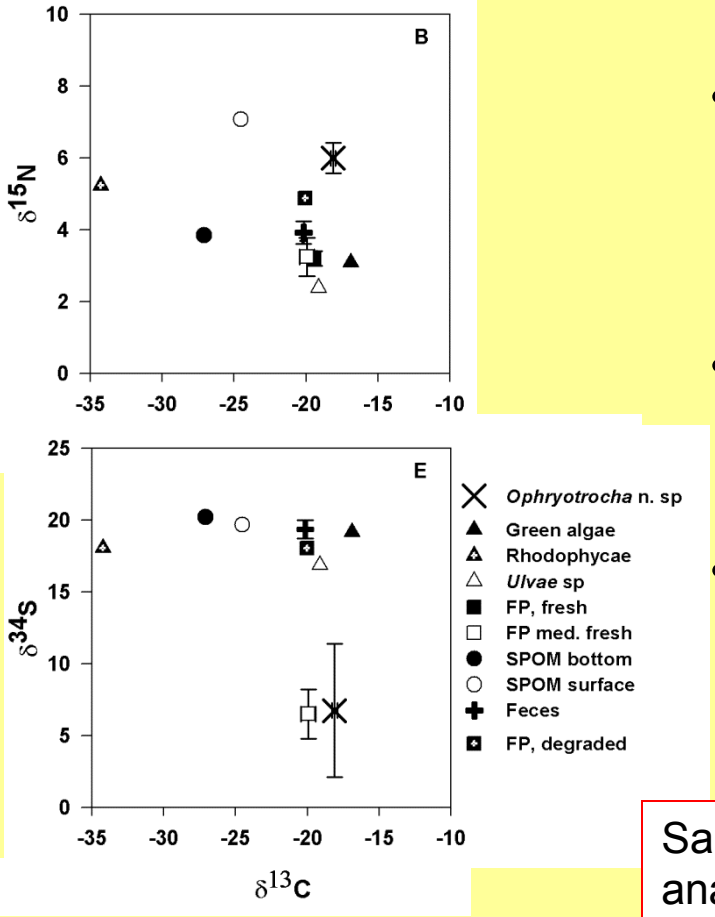
Phylogenic tree based on three gene (COI, H3 and 16S)

- Dorvilleidae have a high sulfidic tolerance and species composition may change according to ecological niches (specialisations in terms of diet)
- Dominated by a single species
- New species of Dorvilleidae: *Ophryotrocha cyclops* (dorsal single eye)
- Found in Greenland at 120 m depth on whale bones
- Presence in extreme habitats with sporadic overload of organic matter (methane seep, hydrothermal vent, aquaculture, forest litter)
- Presence of jaws so not a suspension feeder

SALVO F., WIKLUND H., DUFOUR S.C., HAMOUTENE D., POHLE G.and WORSAAE K. (2014). A new annelid species from whalebones in Greenland and aquaculture sites in Newfoundland: *Ophryotrocha cyclops*, sp. nov. (Eunicida: Dorvilleidae). Zootaxa, in press.

Trophic source OPC (1)

Production site

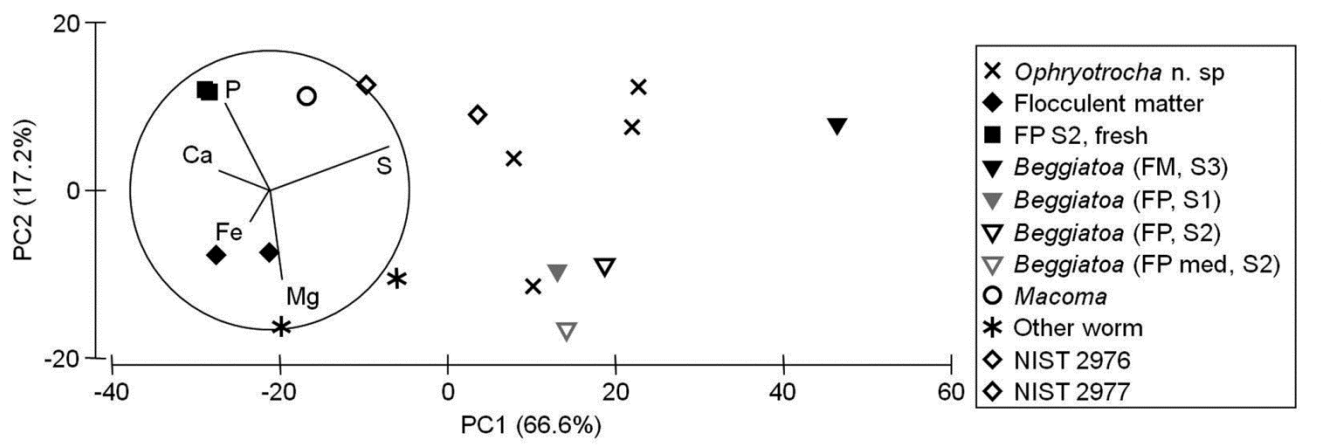


Stable isotope analysis ($\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$) of different sources of OM at the seafloor underneath aquaculture sites

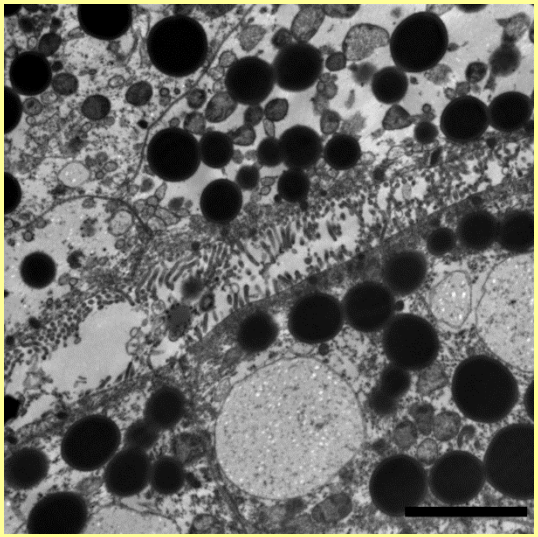
- Not a suspension feeder
- Stable isotope analysis of $\delta^{13}C$, $\delta^{15}N$ and $\delta^{34}S$ + Trace element analysis
- Collection fresh Fish Pellets+ SPOM + OM in nets (flocculent matter, macroalgae, FP degraded and worms) + we grew bacterial mats on flocculent
- Study of 3 sites, differences between sites: differences in food sources in terms of degradation level of OM
- Discrimination of food sources: mostly fish pellets and bacteria according to their isotopic signal

Salvo F., Hamoutene D., and Dufour S.C. 2014. Trophic analyses of opportunistic polychaete (Ophryotrocha n. sp.) at salmonid aquaculture sites. Journal of the Marine Biological Association of the UK., in press.

Trophic source OPC (2)



PCA on trace element analyses of different sources of OM at the seafloor underneath aquaculture sites



TEM of gut cells of *Ophryotrocha cyclops*

- High concentration of lipid droplets in the gut cells (fish pellets? Role?)
- Low accumulation of Cu and Zn in flocculent matter and low proportion in fish pellets
- High concentration of Fe in flocculent matter
- High S in bacteria as well as in polychaetes → bacteria as a food source?
- ***O. cyclops* involved in sulfur cycling and fish pellet degradation**

Conclusions

1) trophic linkages between *Ophryotrocha cyclops* and degrading fish pellets (reflected in lipid accumulation in gut epithelial cells);

2) polychaetes also likely consume *Beggiatoa* spp.

Fatty acid analyses will help us investigate the relative importance of bacteria and fish pellets to the diet of OPC

Potential functional roles

1. accelerate the remineralization of excess organic matter and aid in the recovery of benthic habitats
2. selective feeding on bacteria: might stimulate microbial productivity and accelerate nutrient cycling at the seafloor (S)
3. Influence remineralization via increase of oxygen fluxes within sediments

Redox potential and sulfide values corresponding to *Beggiatoa* coverage at baseline, P1, and P2 stations.

Beggiatoa	**Baseline**		**P1**		**P2**	
(%)	Redox (mV)	Sulfides (μM)	Redox (mV)	Sulfides (μM)	Redox (mV)	Sulfides (μM)
0	-126.1 (n=213)	804.3 (n=213)	-344.0 [a] (n=41)	3830.0 [a] (n=41)	-371.0 [a] (n=63)	796.5 [a] (n=63)
1-29	NA	NA	-341.0 (n=53)	3740.0 (n=53)	-302.0 [a, c] (n=60)	1065.0 [b] (n=60)
30-59	NA	NA	-319.0 (n=28)	3331.5 (n=28)	-330.0 [b] (n=8)	2670.0 [b] (n=8)
≥60%	NA	NA	-304.0 [b] (n=11)	2220.0 [b] (n=11)	-338.0 (n=3)	2270.0 (n=3)

Hamoutene D., 2013. Sediment sulfides and redox potential associated with spatial coverage of *Beggiatoa* sp.at finfish aquaculture sites in Newfoundland, Canada. ICES Journal of Marine Sciences. doi: 10.1093/icesjms/fst223

Statistically significant differences were observed between the absence and presence of *Beggiatoa*, rather than between different levels of coverage.

The largest % coverage of *Beggiatoa* was associated with sulfide values between ~300 to 5000 µM. No *Beggiatoa* was found at P1 stations with a median value exceeding 3000 µM (75% percentile of 5500 µM). This may suggest the existence of an upper limit in sulfide concentrations where conditions are no longer suitable for *Beggiatoa* development (anoxic conditions in the overlying water).

Surprisingly, in both P2 and baseline stations *Beggiatoa* was not visible at concentrations similar to some P1 stations (~ 800 µM) and described in the literature as coinciding with *Beggiatoa* development:

- Mussmann et al. (2003) describes *Beggiatoa* occurrence in large numbers in some coastal seabeds without forming visible mats on the sediment surface (bacteria are present deeper in the sediment).
- Nelson et al. (1986) and Kamp et al. (2008) conclude that the linear increase of *Beggiatoa* biomass has to be accompanied by a constant sulfide flux (both fallowed and reference stations have not “received” recent organic deposition)

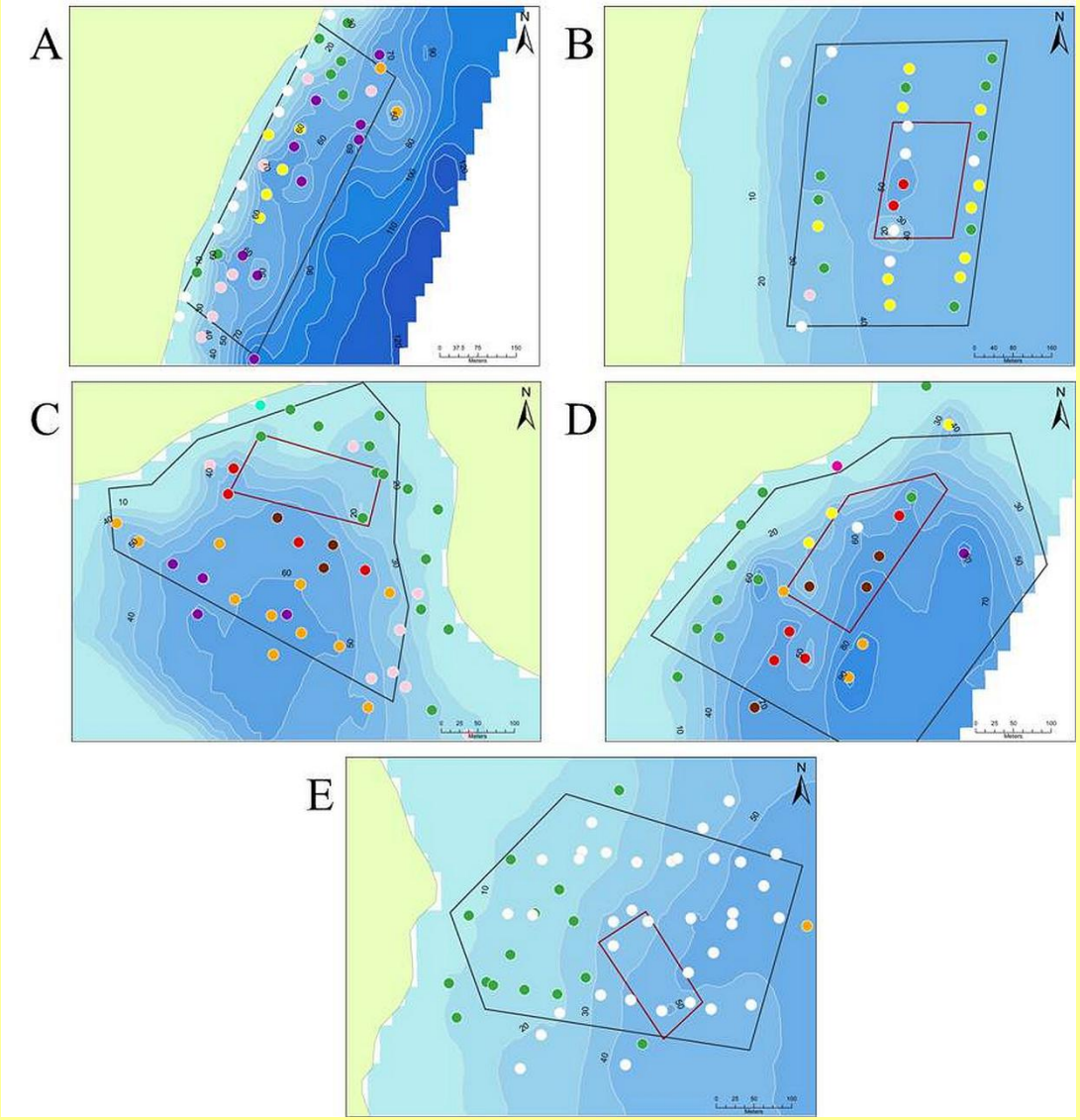
What are the effects of aquaculture on benthic assemblages (abundances and composition)? Can we characterize the changes using video analyses?

In this study, we use video surveys to characterize benthic assemblages at sites with no aquaculture, with varying amounts of finfish production, and undergoing fallowing periods. Video analyses revealed a patchy distribution of benthic organisms (identifiable at a high taxonomic level), characterized by low natural abundances and richness.

Hamoutene D., Salvo F., Bungay T., Mabrouk G., Couturier C., Ratsimandresy R., Dufour S.C. (2014) Assessment of finfish aquaculture effect on Newfoundland epibenthic communities through video monitoring. North American Journal of Aquaculture, in press

Main assemblages at 4 sites (1NON, 3PR, 1F)

#	Dominant taxa	Contribution (%)	Similarity (%)	Median depth and range (m)	Sites where present (n of stations)
1	Anemones	52.5	76.1	60 (43 – 99)	NON (10), PR2 (5), PR3(1)
	Sea stars	43.9			
2	Anemones	96.7	80.2	55 (41 – 93)	NON (2), PR2 (11), PR3 (3), FAL (1)
3	*Lithothamnium* sp.	51.6	73.7	46 (20 –85)	NON (9), PR21(1), PR2 (8)
	Anemones	35.1			
	Sea stars	10.5			
4	Sea stars	97.0	83.5	48 (38 – 67)	NON (7), PR1 (10), PR3 (3)
5	*Lithothamnium* sp.	96.2	85.9	24 (6 – 80)	NON (7), PR1 (11), PR2 (14), PR3 (10), F (15)
6	*Beggiatoa* sp.	96.9	82.3	54 (43 – 68)	PR1 (2), PR2 (5), PR3 (4)
7	OPC	98.7	88.8	59 (30 – 78)	PR2 (3), PR3 (4)



Distribution of benthic assemblages on bathymetric maps of study sites: (A) NON (no production), (B) PR1, (C) PR2, (D) PR3 and (E) FAL. Black lines indicate lease boundaries and red lines show the location of fish cages when present. Each circle represents a sampled station (not to scale), and numbers indicate the assemblage found at a given station. 1 = purple, 2 = orange, 3 = light pink, 4 = yellow, 5 = green, 6 = red, 7 = brown, No visible organisms = white. Two stations with different assemblages are in cyan and fuchsia.

- Aquaculture activities appeared to have led to an overall decrease in total abundance and taxon richness as highlighted by the comparison of stations grouped in three categories: non-production, in production, or fallow.
- We note that overall abundance and taxon richness showed a slight increase with distance from cage as highlighted by Kruskal-Wallis comparisons and correlation

- Despite the decrease in abundance and taxon richness revealed by ANOVAs, comparative ANOSIM analyses do not reveal important effects of aquaculture on the composition and structuring of these assemblages.
- We found no indication that particular benthic organisms (besides OPC and *Beggiatoa* sp.) were more abundant at production or fallow sites compared to the reference site. Instead, we found lower abundances of sponges at production sites compared to the non-production site.

Video analyses revealed a patchy distribution of benthic organisms (identifiable at a high taxonomic level), characterized by low natural abundances and richness.

Benthic communities at aquaculture sites showed evidence of organic matter enrichment through the presence of *Beggiatoa* sp. and/or opportunistic polychaete-dominated assemblages, bare stations, flocculent matter, and lower abundances and richness near aquaculture cages.

Maps of sites in production showed that the area of aquaculture impact was influenced by bathymetry, located underneath cages and in some instances up to 145 m away from net pens, and often directed away from the coastline.

At the fallow site, a large percentage (~70%) of stations was barren, suggesting potentially hypoxic/anoxic conditions and warranting further investigations of fallow periods. Our analysis confirms that video-based assessments can detect major aquaculture related changes in benthic communities, but cannot at present identify lower levels of disturbance.

CONCLUSIONS- THE TOOLS

- We have established minimum requirements needed for achieving good quality videos suitable for analysis. Factors such as added lighting and camera angle resulted in creating high quality images.

- Consistency in areas covered by video imaging was achieved by using quadrants.

- No differences between observers were found when evaluating the presence of indicators of benthic change (i.e. *Beggiatoa* or OPC) therefore ensuring consistency in data to be used for regulatory assessments.

CONCLUSIONS- THE NL ENVIRONMENT

- The benthic assemblages identified across the study sites show a patchy distribution (including patchy substrates), with some relationships with depth, substrate type, and the proximity of finfish cages. Some of them were bare or had very little fauna/flora presence.

- Our results also suggest that benthic hypoxic conditions may exist in some sites (baseline reports) prior to aquaculture site set-up.

CONCLUSIONS- THE MONITORING - SPATIAL EXTENT – LINK WITH BIODIVERSITY/RICHNESS

- When transforming percent coverage values in dummy variables (absence/presence) we found the same trends suggesting that presence/absence of indicators could also be used as an adequate trigger to inform of waste deposition at finfish sites.

- The spatial extent of indicators highlights the necessity of extending sampling transects ~ 100m (to properly delineate areas of deposition). Number of stations can be reduced though by increasing distance separating them to 20-30m.

- Our studies confirm that video-based assessments can detect major aquaculture related changes in benthic communities, but cannot at present identify lower levels of disturbance

- After the fallow period, our results suggest a reduction of the spatial extent of indicators to the area below cages. Bare habitats and persistence of hypoxic conditions on some sites require further research regarding the fallow period and its role especially in the light of regulatory regime changes.

Moving away from local effects and toward ecosystem-based management of fish farming

Jon Grant
NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture

Management and Regulations

- Roles and responsibilities
- Laws, regulations and policies
- Aquaculture Regulatory Reform
- Land and water use
- Environmental management

Proposed Aquaculture Activities Regulations

When finalized, the proposed *Aquaculture Activities Regulations* would resolve uncertainties in the application of various federal acts, eliminate overlap and duplication issues, and reflect the unique circumstances of aquaculture.

The proposed Regulations will clarify conditions under which aquaculture operators may treat their fish for disease and parasites, as well as deposit organic matter, under sections 35 and 36 of the *Fisheries Act*. As in the past, the Regulations would require that only products regulated by Health Canada under the *Pest Control Products Act* or the *Food and Drugs Act* may be used. The proposed Regulations will also impose greater public reporting from the aquaculture industry, as well as specific environmental monitoring and sampling requirements.

- The Proposed Monitoring Standard outlines the level of monitoring detail that would be required from aquaculture operators to ensure consistent, high-quality data – Published in August 2014

Management and regulatory targets for fish farming

Benthic impacts

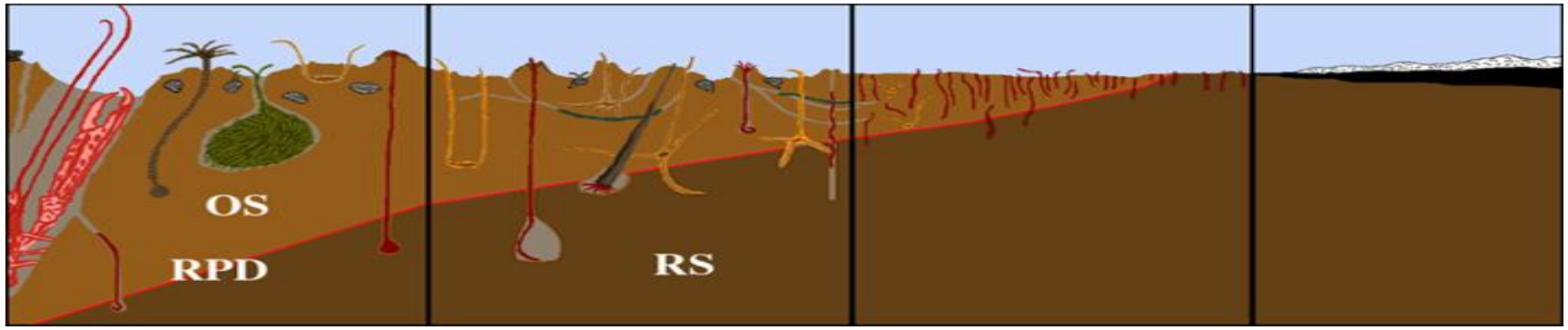
Disease

Nutrification (ammonia)

Contaminants

Habitat alteration or overlap with fisheries etc.

DEFINITIVE: Pearson-Rosenberg model of benthic disturbance & succession



Organic input stimulates oxygen consumption, exceeding oxygen renewal, leading to anoxic conditions

<u>4 Effects:</u>
Different fauna
Elevated sulfides
Reducing sediments (black color)
White sulfur bacteria

Aquaculture and organic loading

We know the effects, but questions remain:

What should be measured?

What scale should be used?

What should the threshold be?

What are our environmental quality objectives (EQO)?

Preserve ecosystem goods and services

What are we trying to assess?

A measure of departure from hypoxia

Why?

Answer 1: Because we will harm the ecosystem

Answer 2: Because we will harm a small area of bottom

Siting is different from ongoing monitoring

Siting:

Avoid impacts to ecosystem goods and services

Avoid conflicts with other users

Establish baseline

Monitoring of ongoing farm sites:

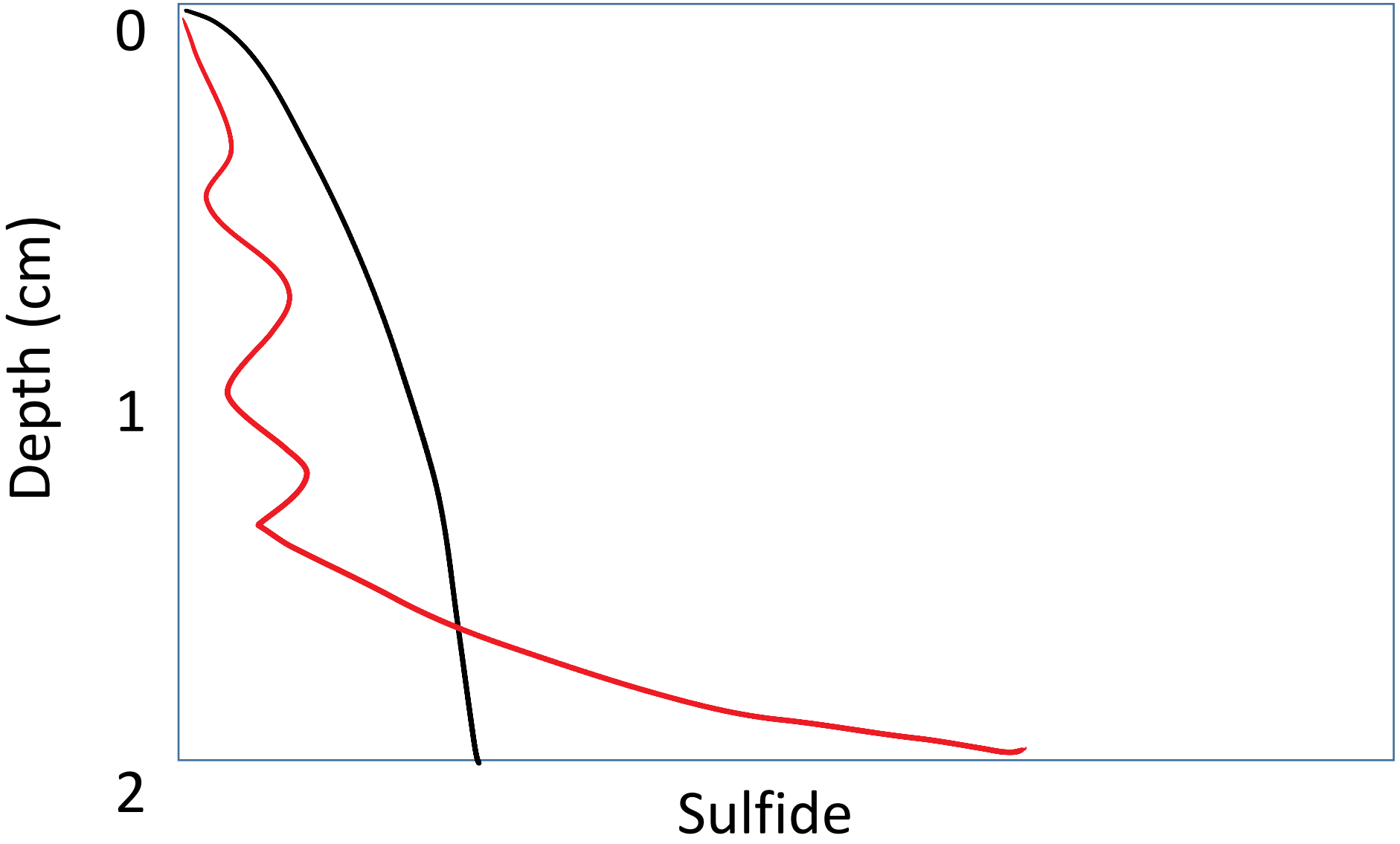
Continue to assess oxic state

What about near-field sulfides?

Are the sources of variation methodological and analytical?

Will finer resolution of existing methods change the outcomes of EMP decisions?

The problem with a 2cm blended sediment sample



Sediment profile imaging: benthic community assessment

15 cm

Monterey Bay Aquarium Seafood Watch®

Atlantic salmon

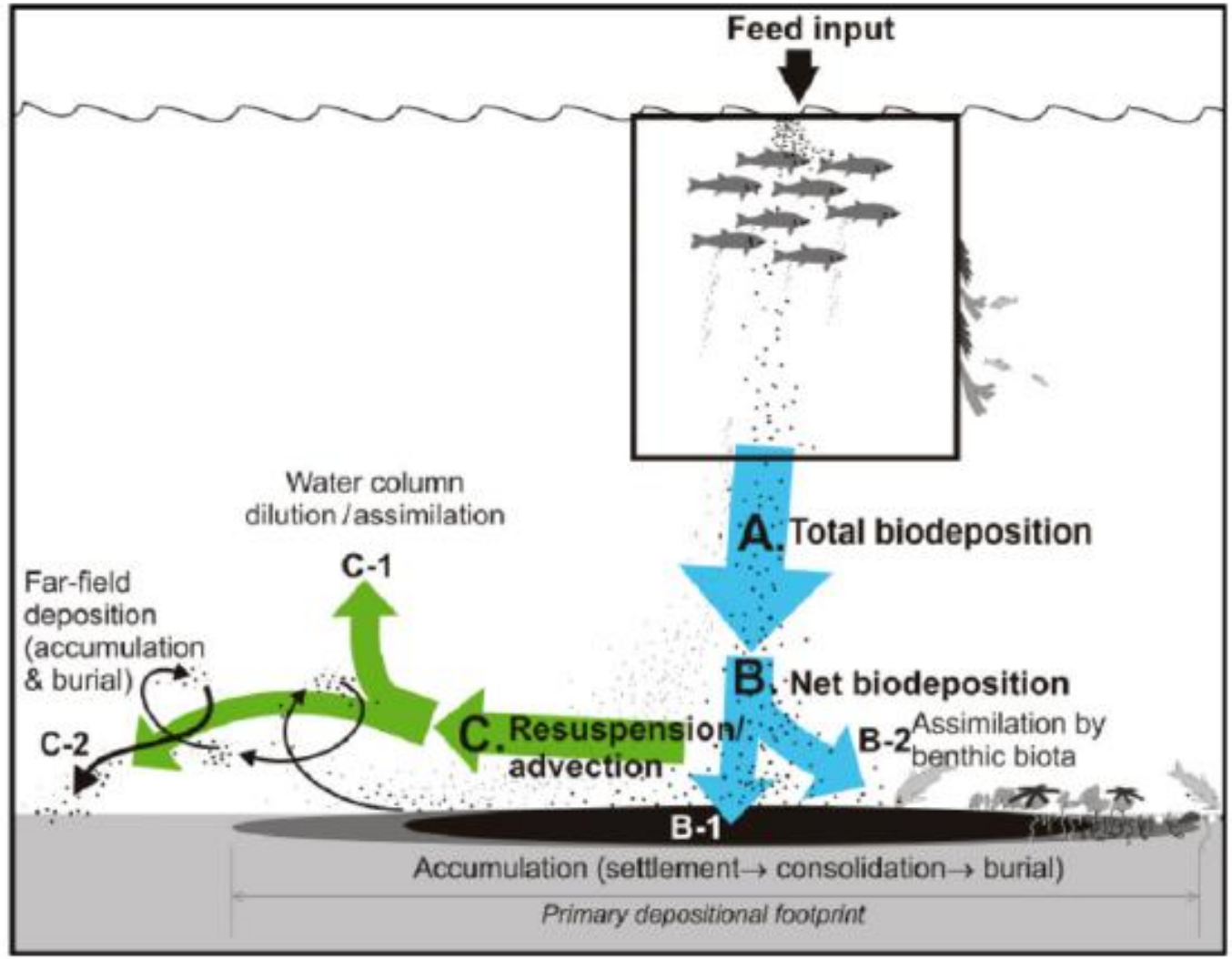
Salmo salar

British Columbia, Canada

Net Pens

March 31, 2014

Peter Bridson – Seafood Watch


Feed input
Water column
dilution /assimilation
C-1
Far-field
deposition
(accumulation
& burial)
C-2
A. Total biodeposition
B. Net biodeposition
C. Resuspension/
advection
B-2
Assimilation by
benthic biota
B-1
Accumulation (settlement→ consolidation→ burial)
Primary depositional footprint

Lack of far-field effects

Monterey Bay report:

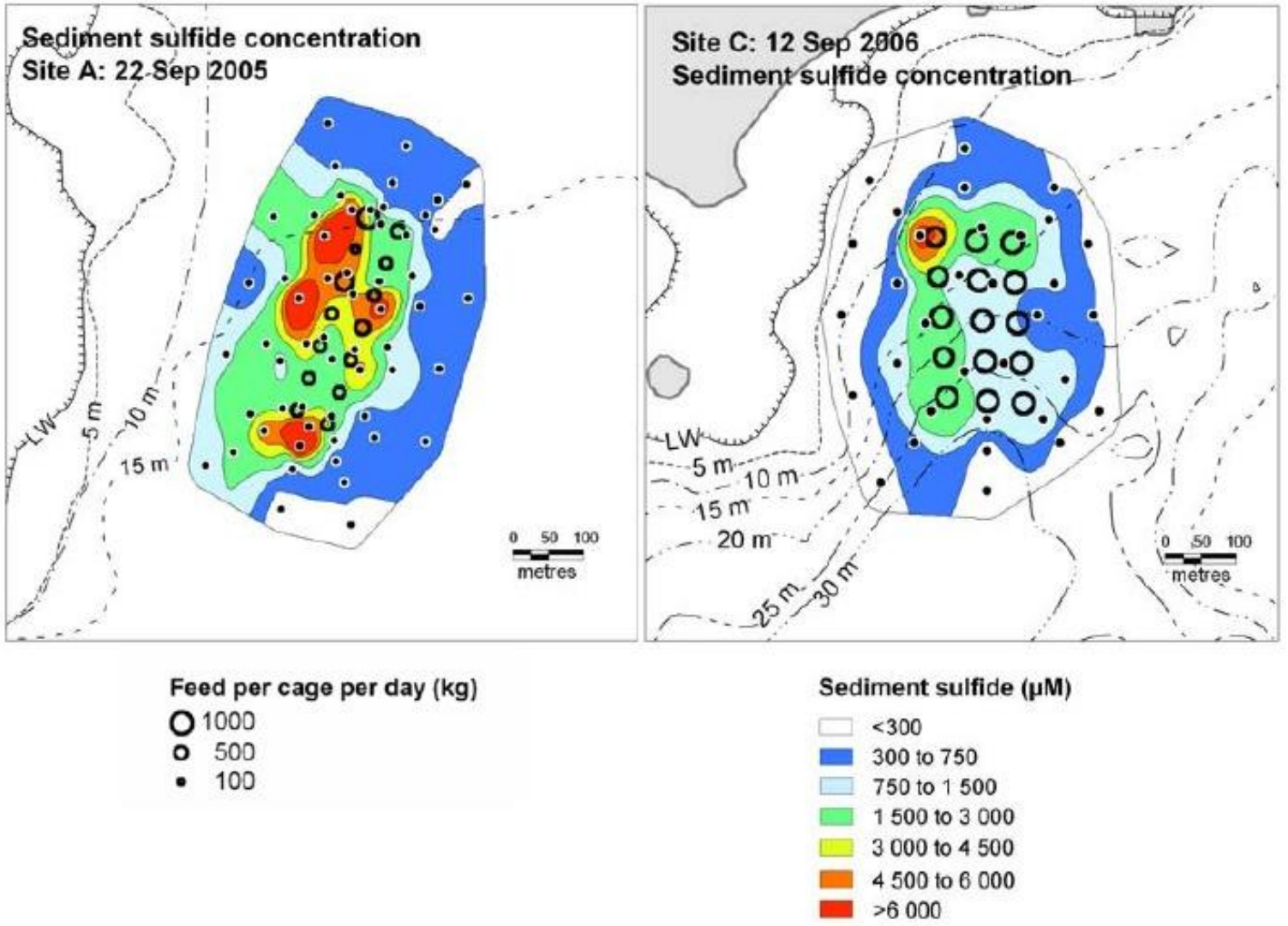
"Roberts et al. (2010)… confirmed that salmon farms are a source of trace elements in the marine environment. However…salmon farms did not appear to be elevating concentrations in nearby clam tissue and sediments"

"…with the exception of a few shallow poorly flushed embayments, the potential for net pen enhancement of phytoplankton populations is remote or non-existent."

"The release of wastes cannot be systematically equated to deleterious environmental changes as it is frequently assumed in much of the literature or popular press."

Brager, Cranford, Grant, Robinson, in press:

"The results suggest that any farm-induced effect on the surrounding particle field at the study sites would be highly localized and episodic."



Sulfide can't travel

Figure 4. Contour plots of sediment sulfide concentrations on the seafloor under 2 salmon aquaculture sites (A and C). Black circles represent cages, with circle sizes representing the feed rate.

DFO CSAS Rep. 2012/042

Near-field standards

British Columbia:
Threshold applied at 30m

Nova Scotia and New Brunswick:
Threshold applied at 0m

At 30m in Nova Scotia, most sites would be oxic

GENERAL FISHERIES COMMISSION FOR THE MEDITERRANEAN

COMMISSION GÉNÉRALE DES PÊCHES POUR LA MÉDITERRANÉE

Palazzo Blumensthil, Via Vittoria Colonna 1, 00193 Rome, Italy. Tel: + 390657055730 - www.gfcm.org

COMMITTEE ON AQUACULTURE

WORKING GROUP ON SITE SELECTION AND CARRYING CAPACITY (WGSC)

WGSC – SHoCMed Workshop on the definition and environmental monitoring within Allowable Zone of Effect (AZE) of aquaculture activities within the Mediterranean countries

Malaga, Spain 16-18 November 2011

AZE = Allowable Zone of Effect

"the area of sea-bed or volume of the receiving water body in which competent authority allow the use of specific EQSs for aquaculture, without irreversibly compromising the basic environmental services provided by the ecosystem"

"within the AZE (i.e. in the immediate vicinity of the farm) **some deviation from national and international standards is expected** but not beyond a point (threshold) where critical goods and services provided by the marine ecosystem are irreversibly compromised"

AZE = Allowable Zone of Effect

“Establishing AZE requires spatial accuracy for the mooring of fish farms and the shape of AZE could follow a mix of **administrative process and dispersion model**. The use of mathematical models to incorporate AZE-EQS should be considered”

“Once AZE is defined, environmental quality objectives should be identified, and the use of several reference/control sites is needed”

“Marine Spatial Planning as a tool for a better integration of multiple uses in coastal zoneshould be employed”

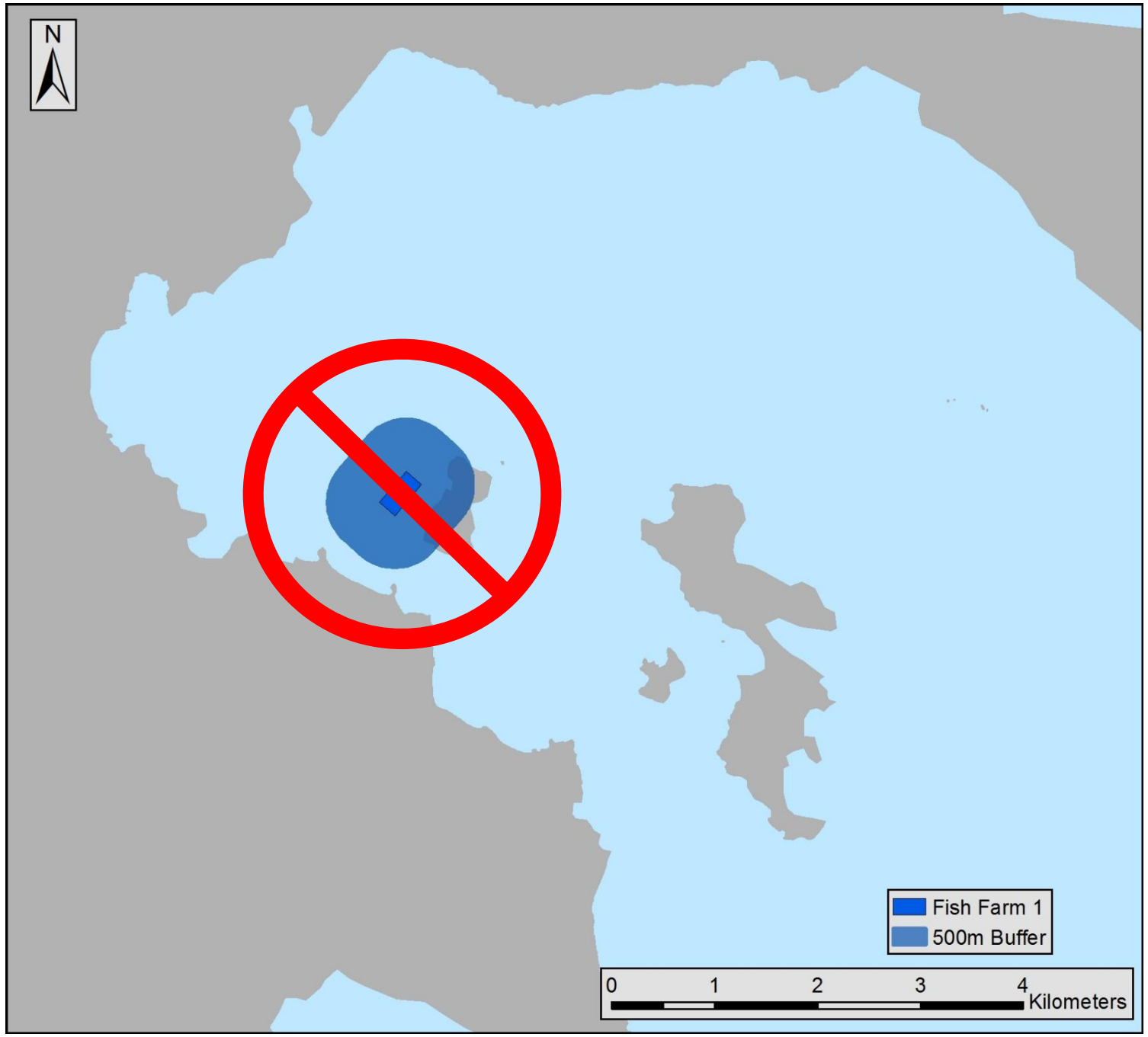
Scenario 1

Zone of Influence (ZOI): 500 meter buffer

- Not representative of reality

ZOI defined by:

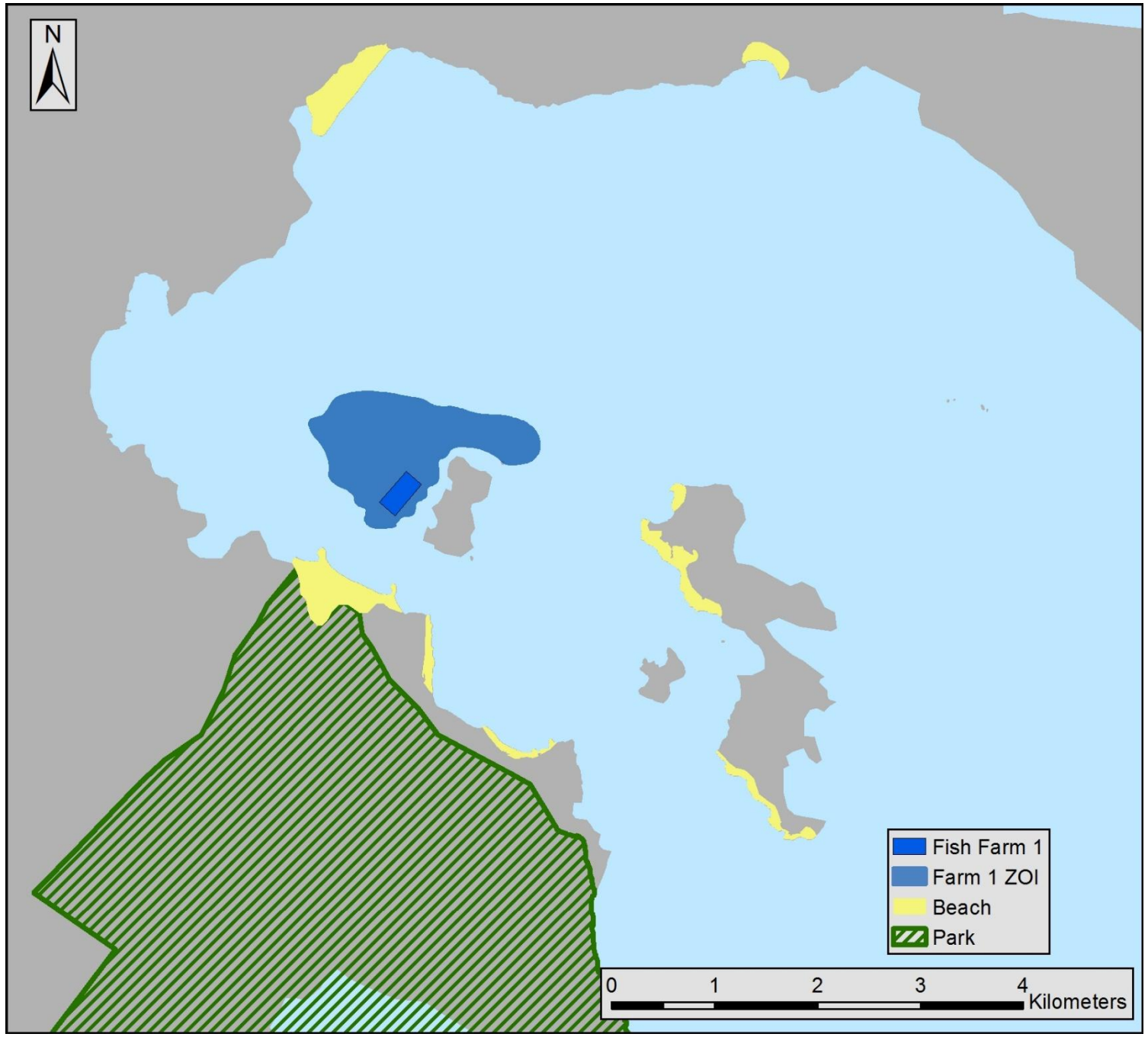
- Spatial extent and intensity of activity
- Oceanographic models (i.e., currents)
- Ecosystem models (i.e., nutrients)



Scenario 1

Recreation & tourism ($$$):

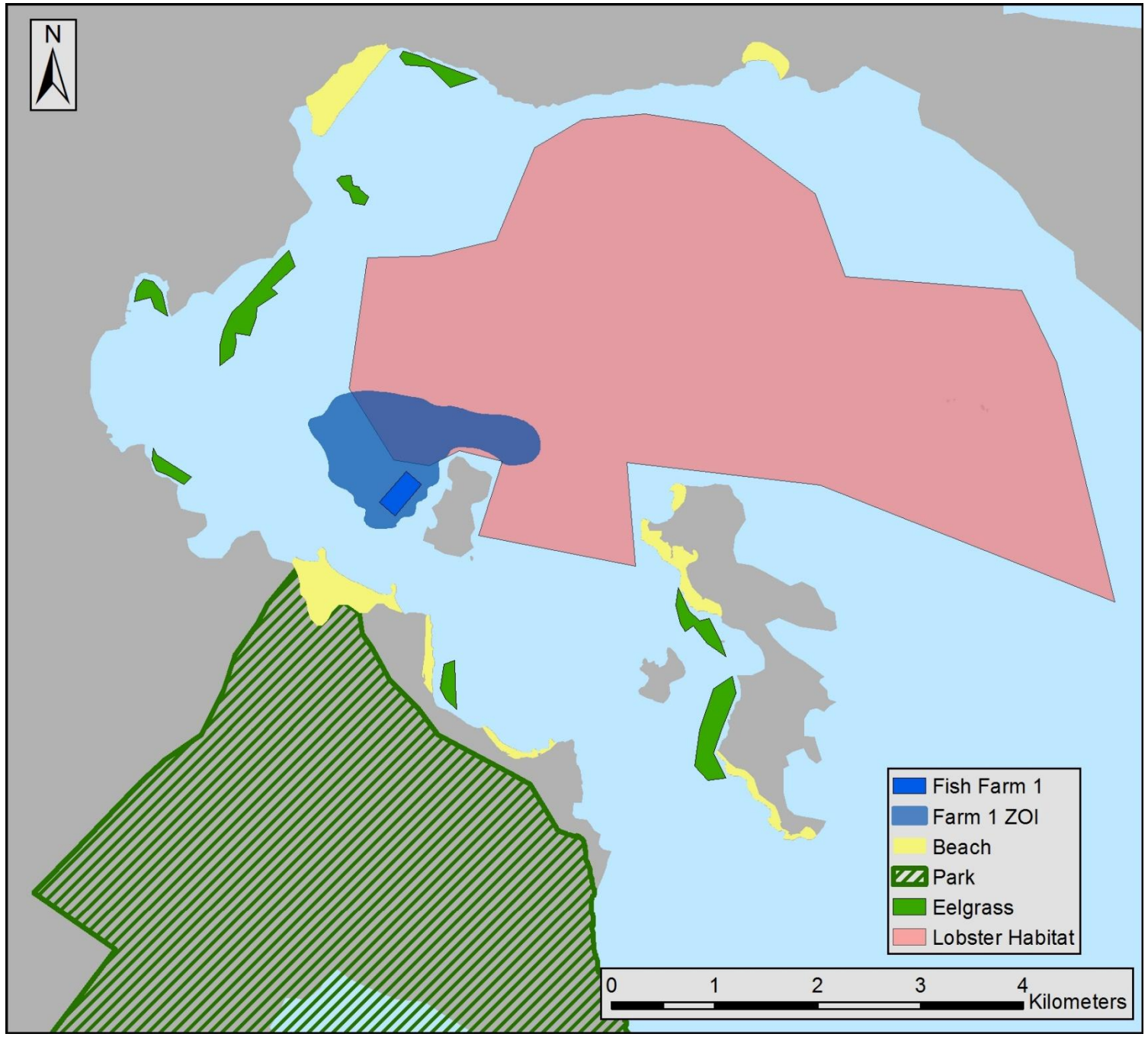
- Beaches
- Parks



Scenario 1

Habitats:

- Eelgrass
  - Ecological resource (biomass)
  - Ecosystem services ($$$)
- Lobster
  - Fishery resource (biomass)
  - Activity ($$$)



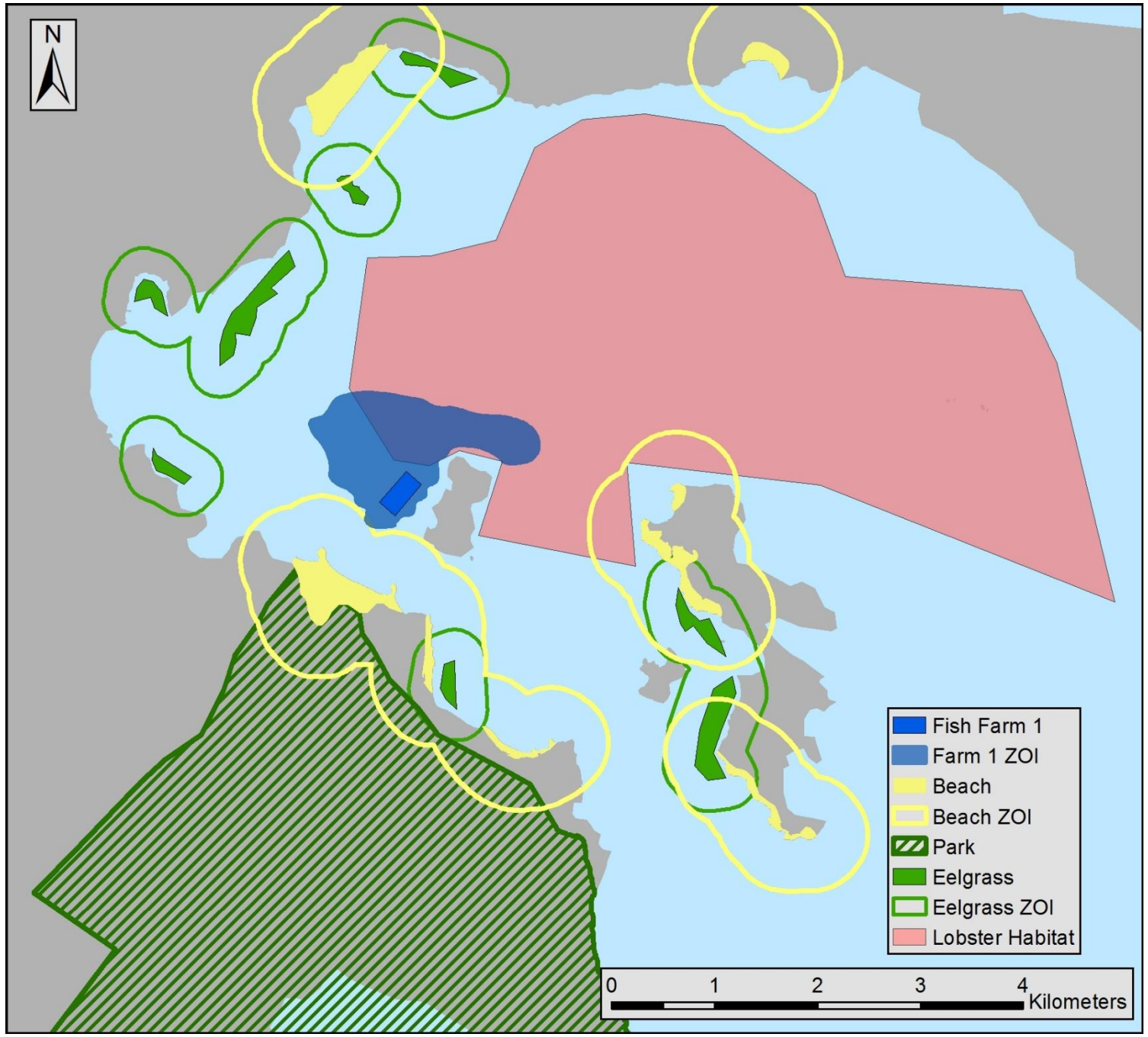
Scenario 1

Apply ZOIs, identify overlap

Interaction intensity is variable, and can go both ways

No overlap (or no effect):

- Beach/eelgrass
- Beach/lobster
- Lobster/eelgrass



Scenario 1

Farm/Lobster: **75 hectares**

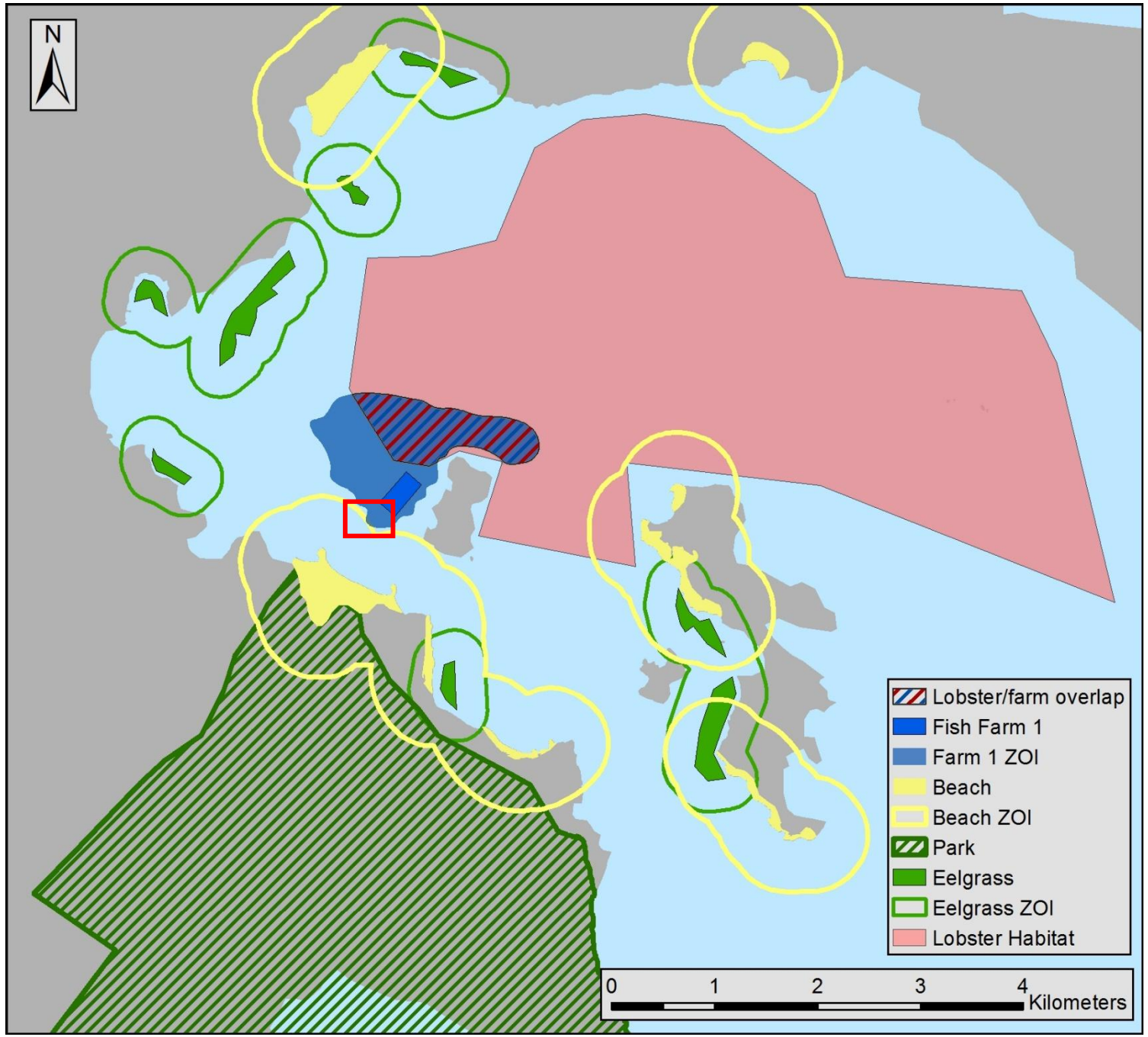
Lobster -> Farm: neutral

Farm -> Lobster: **negative???;** affecting 3.75% of the resource/habitat

Farm/beach: **<0.1 hectares**

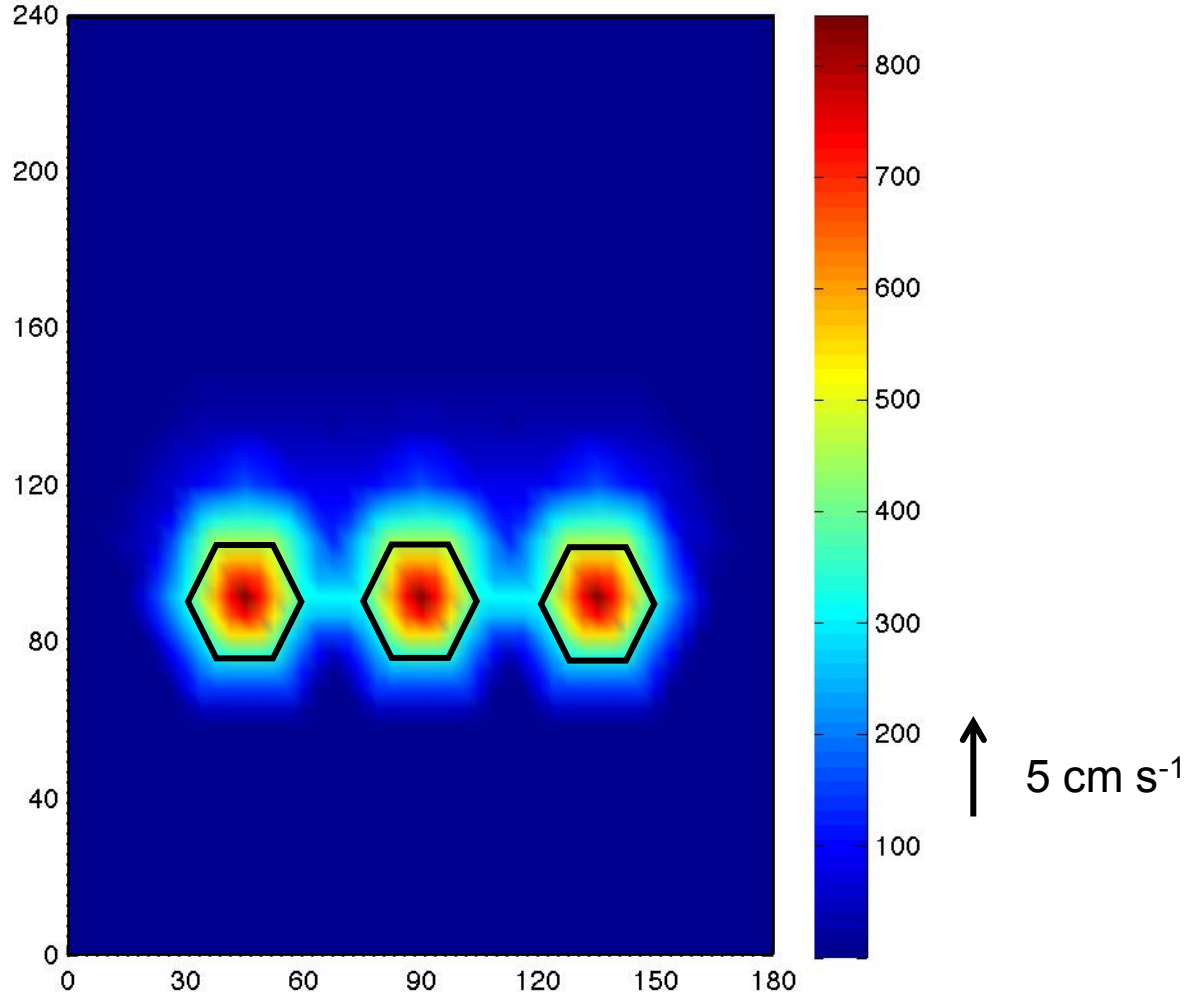
Beach -> Farm: neutral

Farm -> Beach: **negative???;** negligible effects



Fish faeces (mgC m^{-3})

Fish cages



Conclusions:

Adopt an approach to AZE for eastern Canada – models or prescriptive buffer

Sample sulfide at 0m, AZE boundary, and reference

Measure sulfide and redox in the grab on the vessel (?)

Set decision thresholds for AZE boundary

Keep 0m values above anoxic

Consider alternative variables to sulfide in the medium-term

Adopt MSP for site planning/management

MALDI-TOF Mass Spectrometry for Rapid Identification of Aquatic Bacterial Pathogens

[1]**Jan S. Giles,** [2]P. Jeffrey Lewis, [2]Beatrice M. Despres, [2]Charlotte A. Ramey, [2]C. Anne Muckle and [1]David B. Groman

[1]Aquatic Diagnostic Services, University of Prince Edward Island, 550 University Ave., Charlottetown, PEI, Canada, C1A4P3;

[2]Department of Pathology and Microbiology, University of Prince Edward Island, 550 University Ave., Charlottetown, PEI, Canada, C1A 4P3

Outline

Introduction to the Bacteriology Lab

Introduction to the MALDI-TOF MS

Identification of *Yersinia ruckeri*: Traditional methods & by MALDI-TOF MS

Validation of the MALDI-TOF MS

Work in progress and future research

Questions

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The Bacteriology Lab: Setting up the Samples

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The Bacteriology Lab: Obtaining Isolated Colonies

"Streaking"

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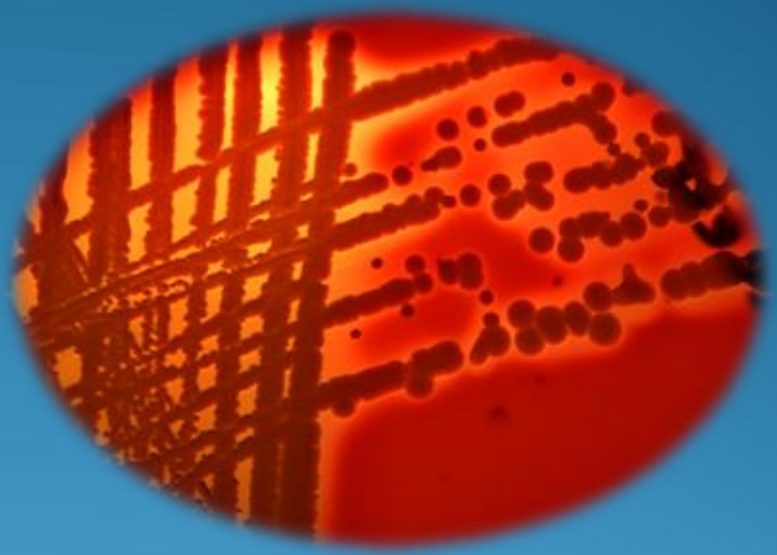
The Bacteriology Lab: Culture Media

Blood Agar

Non-hemolytic colonies



Hemolytic colonies

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The Bacteriology Lab: Identification of Bacteria

Traditional Methods
"Classical" BacT

Versus

MALDI-TOF
Mass Spectrometry

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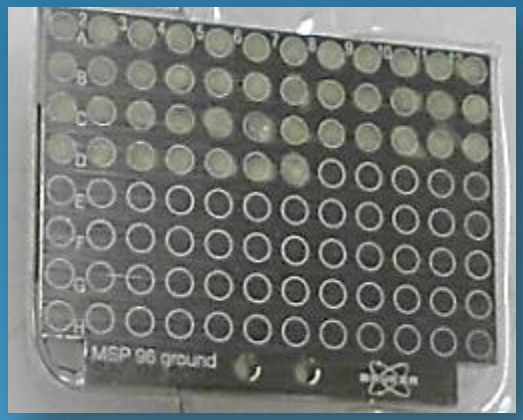
Introduction to the MALDI-TOF MS

Matrix
Assisted
Laser
Desorption
Ionization-
Time
Of
Flight

Microflex LT
Nitrogen laser (UV)
FlexControl 3.3
BioTyper RTC 3.0

Introduction to the MALDI-TOF MS

Isolated colony is “smeared” onto the surface stainless steel target



Target = 96 different isolates

Introduction to the **MA**LDI-TOF MS

Isolated colony is smeared onto the 96 well stainless steel target

Add 1uL of **Matrix** (HCCA) & let dry

Breaks open the cell wall

Protein-matrix complex dries on the surface of the target

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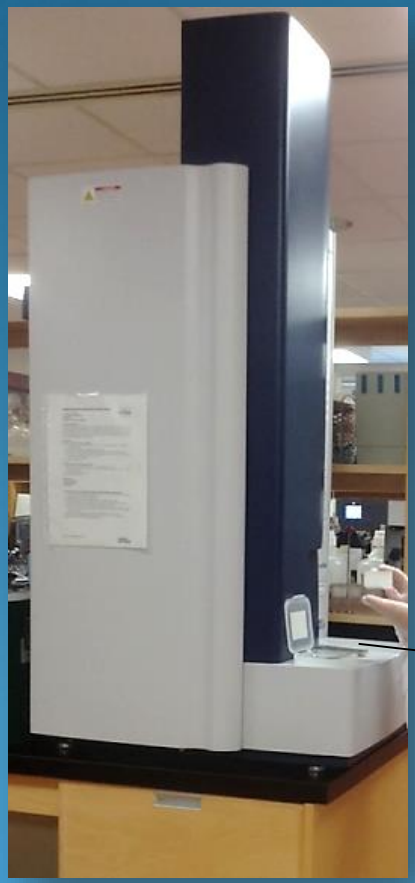
Introduction to the MALDI-TOF MS

Isolated colony is smeared onto the 96 well stainless steel target

Add 1uL of Matrix (HCCA) & let dry



Insert target into the MALDI-TOF MS

Enter isolate information into the Biotyper RTC software program

Introduction to the MA**LD**I-TOF MS

Isolated colony is smeared onto the 96 well stainless steel target

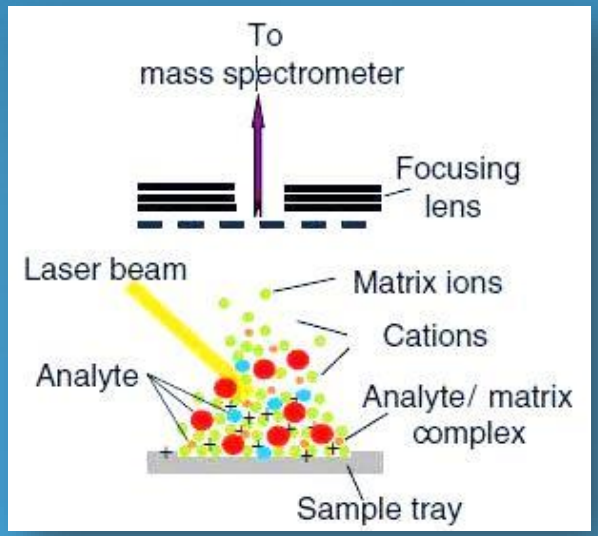
Add 1uL of Matrix (HCCA) & let dry

Insert target into the MALDI-TOF MS

Laser (30-50% intensity): short blasts

Thermal **desorption** of the proteins (ie: vaporizes the matrix & "releases" the proteins within the matrix)

Ribosomal proteins are readily **ionized**



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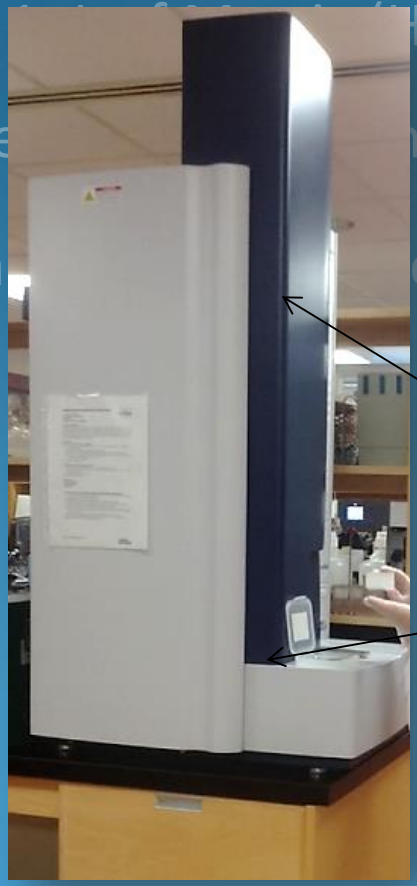
Introduction to the MALDI-TOF MS

Isolated colony is smeared onto the 96 well stainless steel target

Add [illegible]HCCA) & let dry

Inse[illegible]e MALDI-TOF MS

La[illegible]esorption of the proteins



Electric field accelerates the **ionized proteins** into the vacuum tube

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Introduction to the MALDI-**TOF** MS

Isolated colony is smeared onto the 96 well stainless steel target

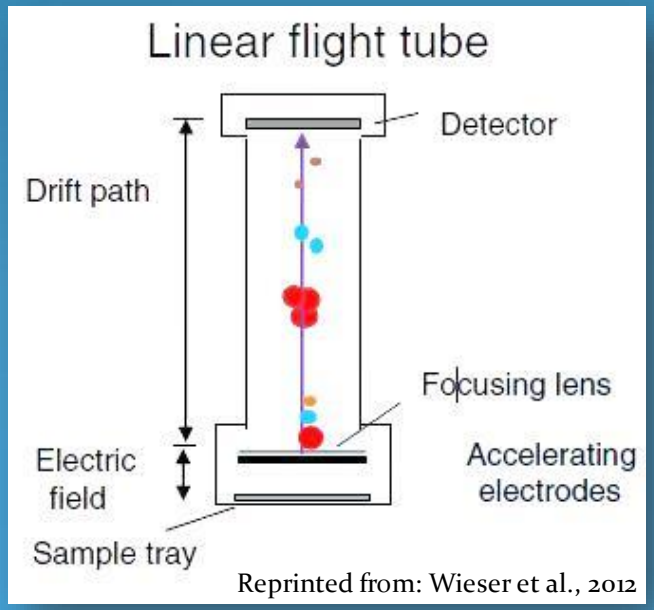
Add 1uL of Matrix (HCCA) & let dry

Insert target into the MALDI-TOF MS

Laser = Thermal desorption of the proteins

Electric field accelerates the ionized proteins

Time of Flight (TOF) measured based on mass & degree of ionization



Reprinted from: Wieser et al., 2012

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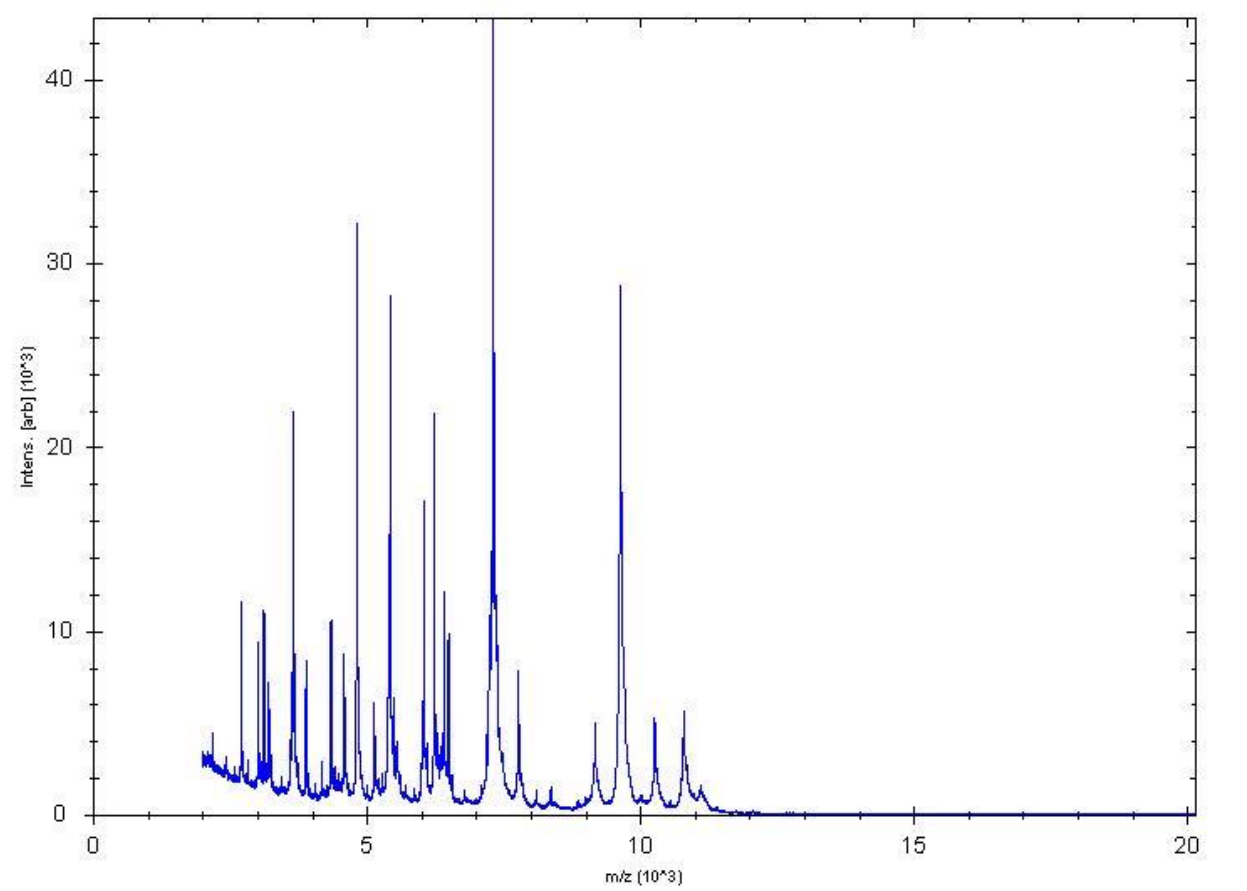
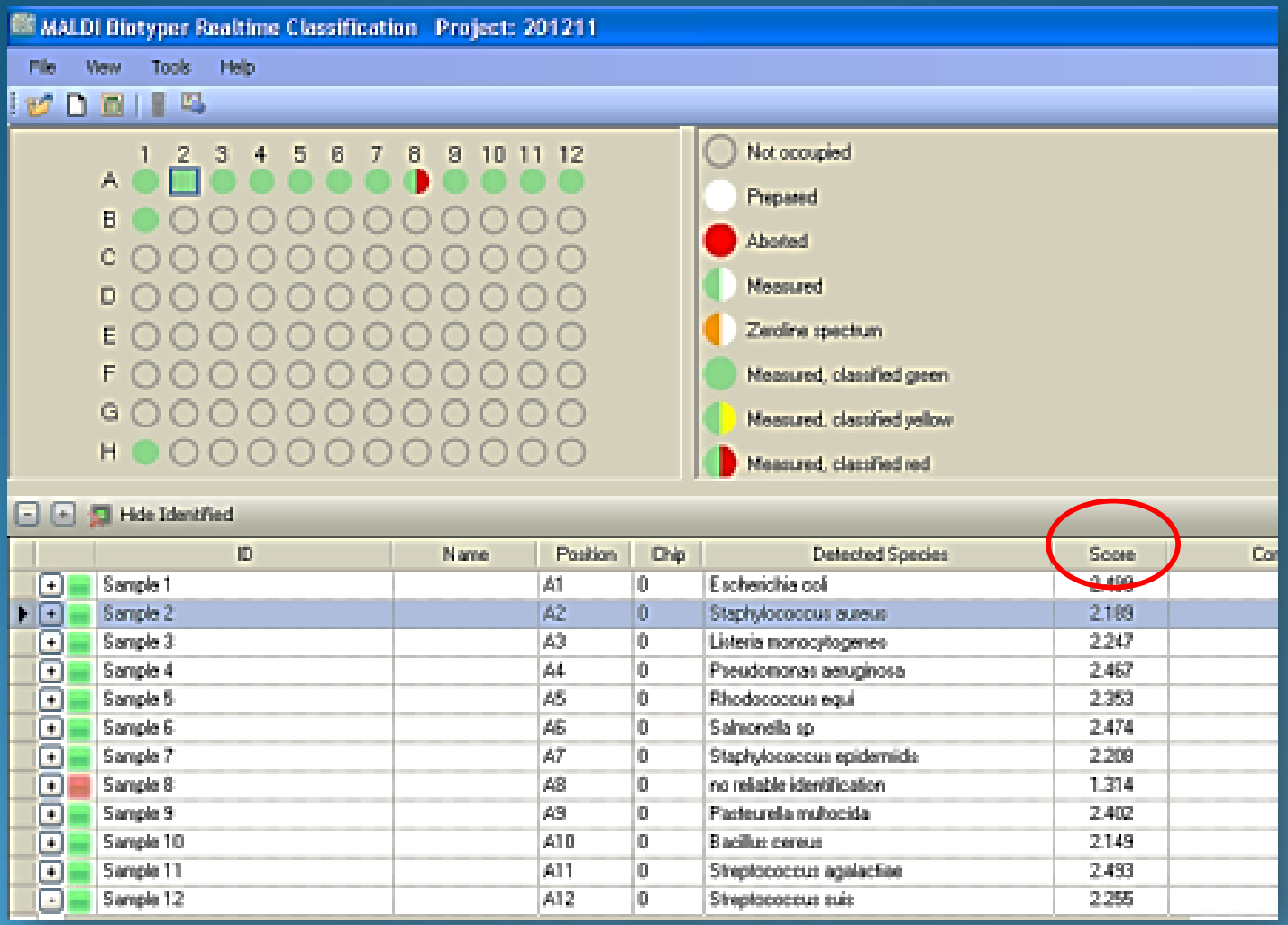


Figure 7. Raw spectra acquired from *Yersinia ruckeri* isolate U20839-05. Mass-to-charge ratio (m/z) (10^3) on the x-axis, intensity (arbitrary units) (10^3) on the y-axis.

Slide courtesy of C. Ramey, AVC

Introduction to the MALDI-TOF MS



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Introduction to the MALDI-TOF MS

Meaning of Score Values

Range	Description
2.300 ... 3.000	highly probable species identification
2.000 ... 2.299	secure genus identification, probable species identification
1.700 ... 1.999	probable genus identification
0.000 ... 1.699	not reliable identification

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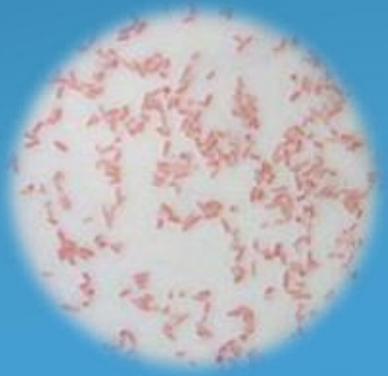
Identification of *Yersinia ruckeri* (Enteric Red Mouth):

Traditional Methods:

Non-hemolytic, white colony that grows at 35°C

Gram negative bacilli



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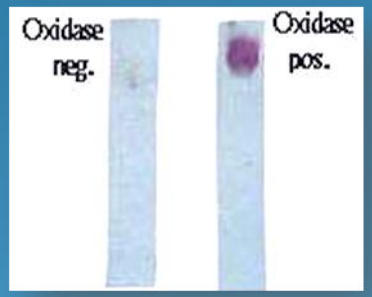
Identification of *Yersinia ruckeri* (Enteric Red Mouth):

Traditional Methods:

cytochrome-oxidase negative



TSI (Triple Sugar Iron)

K/A = alkaline/acid

= Glucose fermenter

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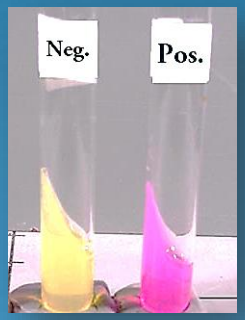
Identification of *Yersinia ruckeri*: Traditional vs MS

Traditional Methods:

Non-hemolytic, white colony that grows at 35°C

Gram negative bacilli, cytochrome-oxidase negative

Biochemical "tube" tests



API 20E

ATLANTIC VETERINARY COLLEGE · UNIVERSITY OF PRINCE EDWARD ISLAND · A C

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Identification of *Yersinia ruckeri*: Traditional vs MS

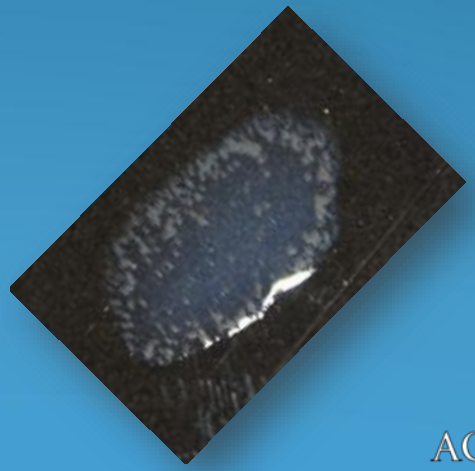
Traditional Methods:

Non-hemolytic, white colony that grows at 35°C

Gram negative bacilli, cytochrome-oxidase negative

Biochemical tests, API 20E

Serology: slide agglutination
Serotypes I & II



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Identification of *Yersinia ruckeri*: traditional vs MS

Traditional Methods:

Presumptive ID: minimum of 24-48 hours

Confirmed ID: 48 hours plus

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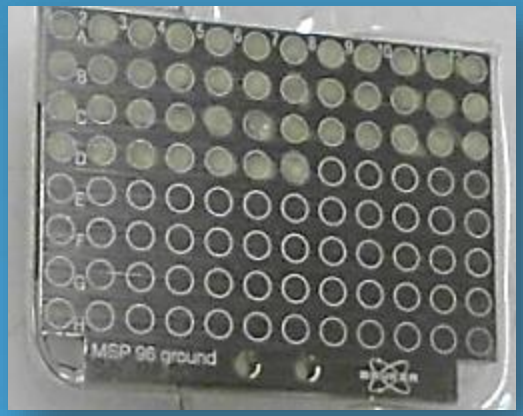
Identification of *Yersinia ruckeri*: traditional vs MS

MALDI-TOF MS:

Confirmed ID: 30 – 60 minutes

Note: Advantage of rapid ID of multiple samples (96 sample target finished in ~1 hour)



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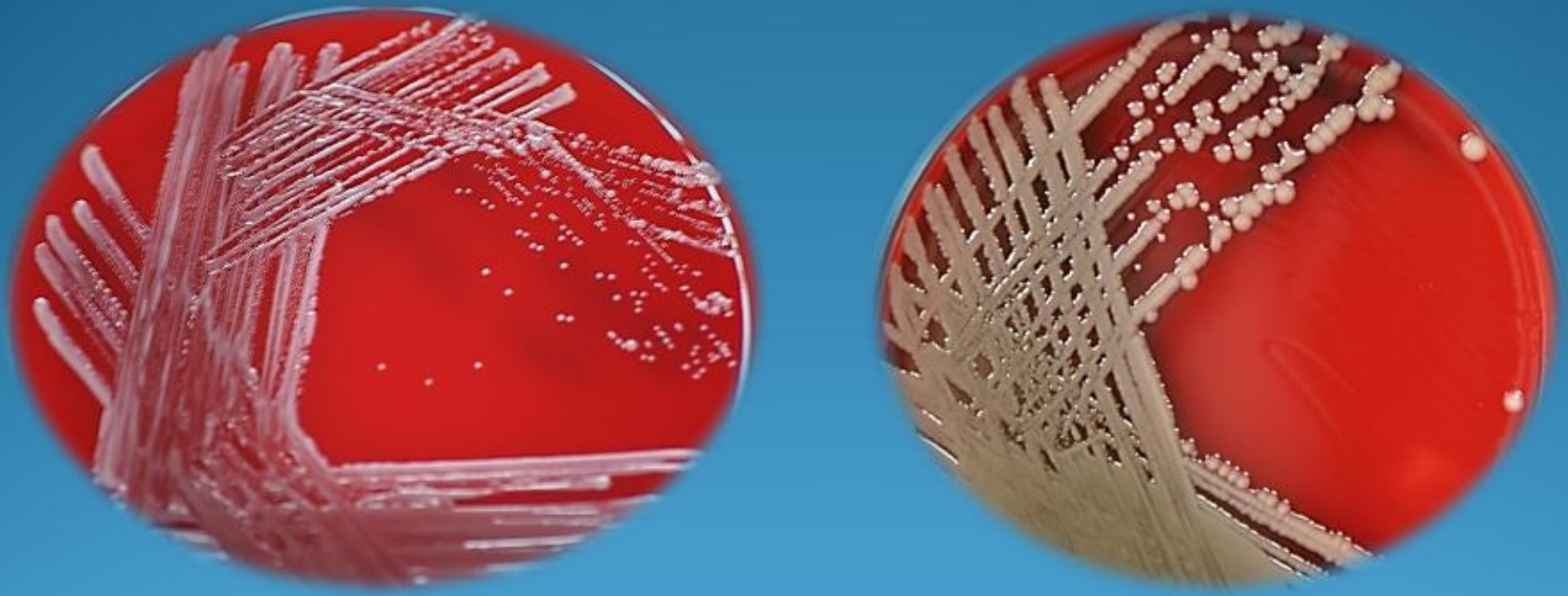
Identification of *Yersinia ruckeri* in a mixed culture



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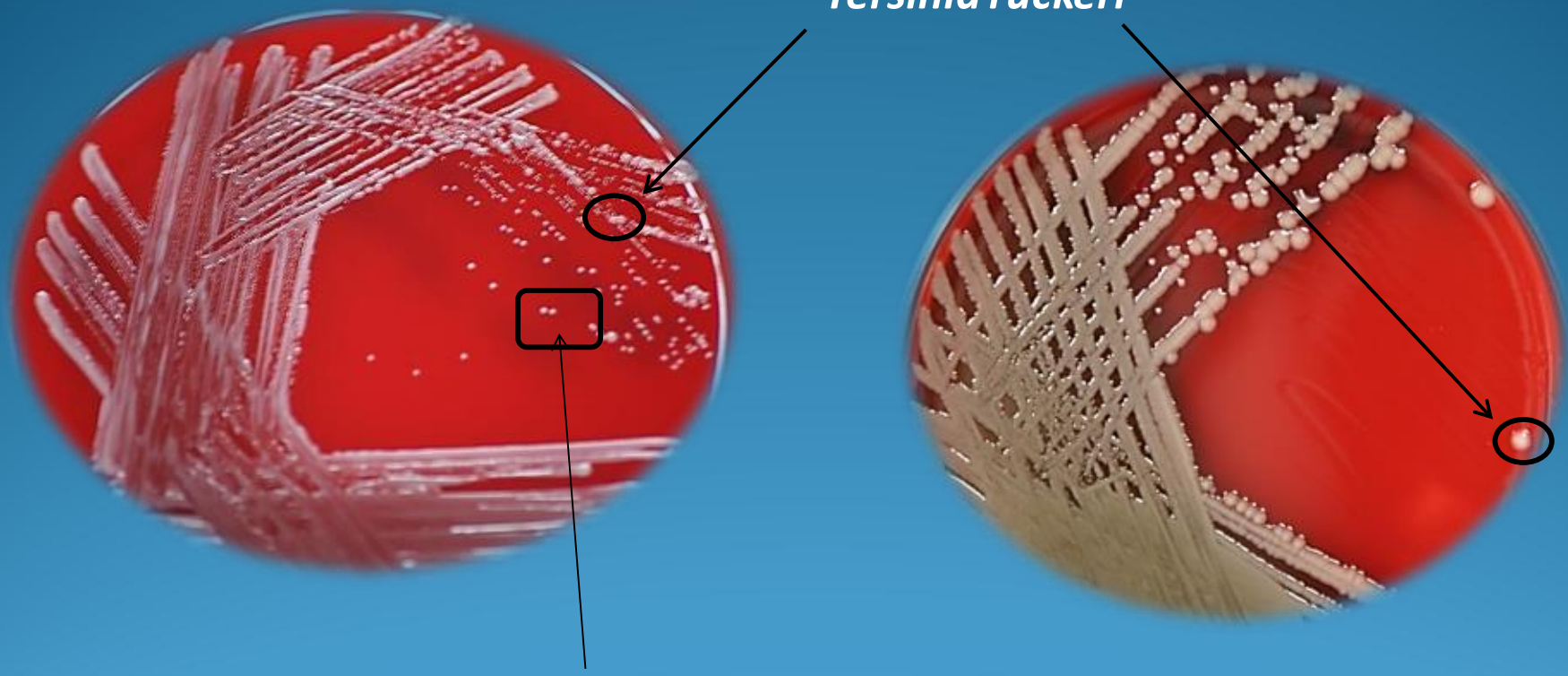
Identification of *Yersinia ruckeri* in a mixed culture



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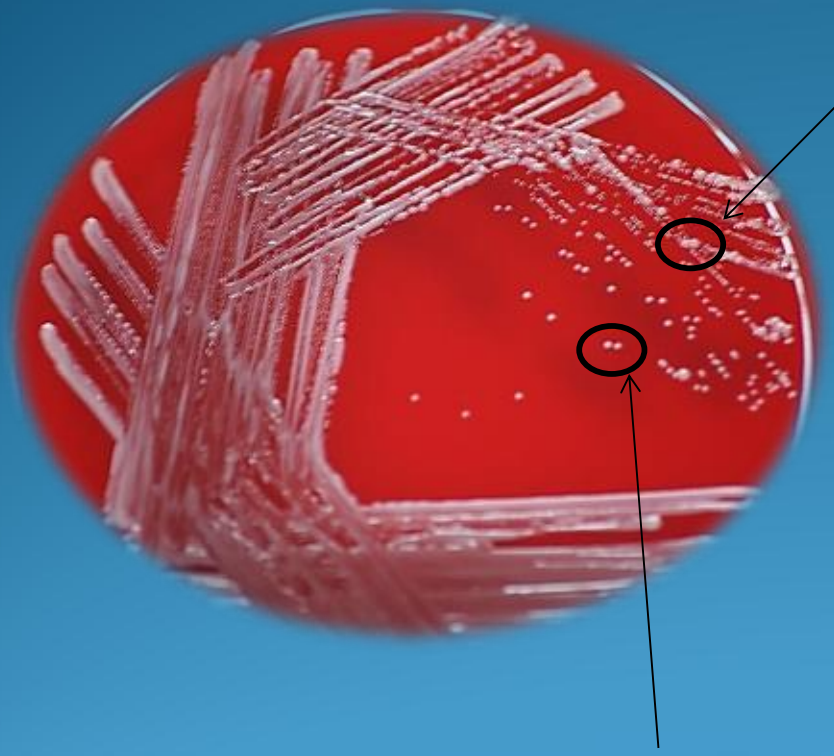
Identification of *Yersinia ruckeri* in a mixed culture



Both are white, non-hemolytic colonies that grow at 35°C and are Oxidase negative

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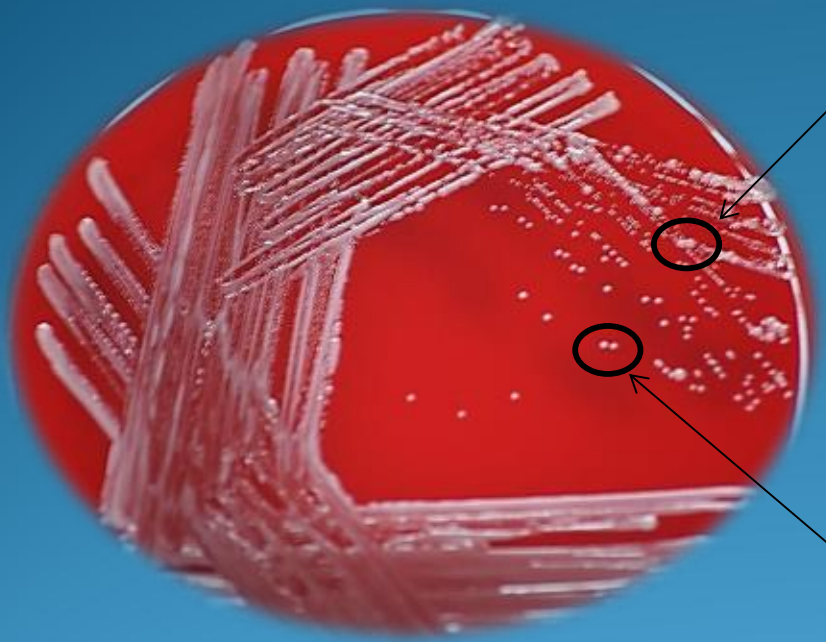
Identification of *Yersinia ruckeri* in a mixed culture



Yersinia ruckeri

= gram negative bacilli

Lactobacillus sp.

= gram positive bacilli

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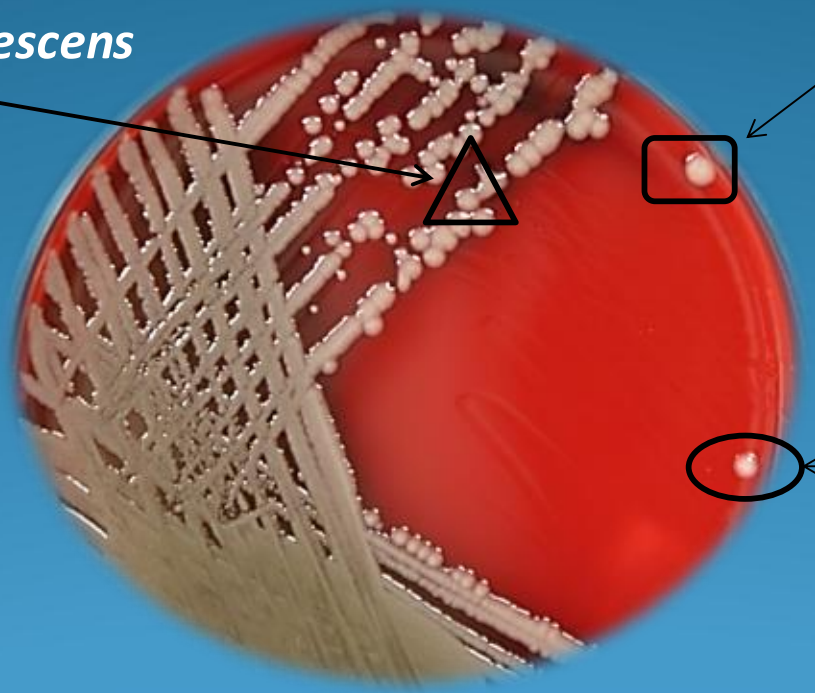
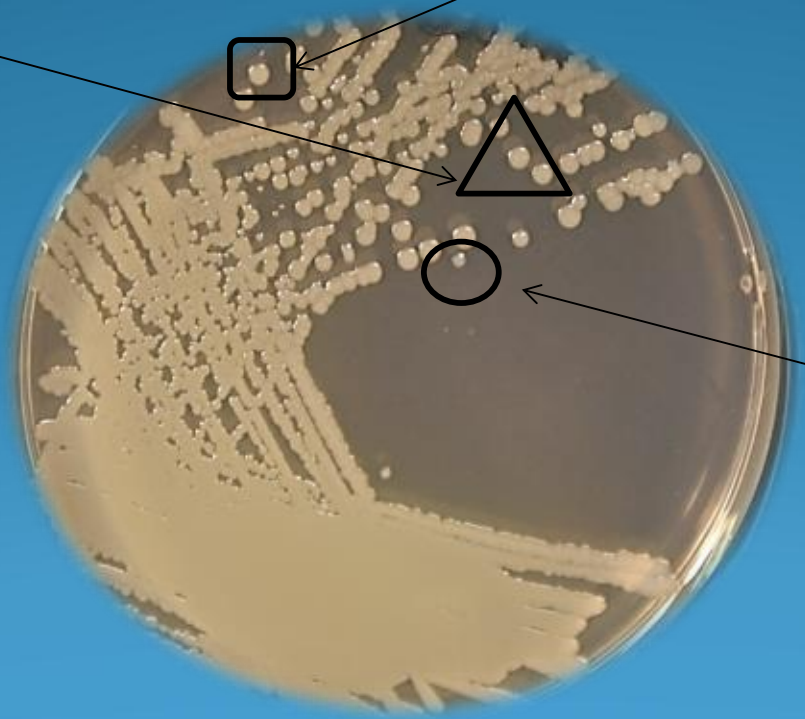
Identification of *Yersinia ruckeri* in a mixed culture
(Blood agar)



Identification of *Yersinia ruckeri* in a mixed culture

(Brain Heart Infusion Agar)



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Screening for *Yersinia ruckeri* in a mixed culture

Traditional Methods:

Presumptive ID: minimum of 24-48 hours

Confirmation: 48 hours plus

MALDI-TOF MS:

Confirmed ID: 30 – 60 minutes

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Validation of the MALDI-TOF MS

WHY?

Commercial **M**ain **SP**ectrum (MSP) database contained:

1 isolate of *Yersinia ruckeri*

11 isolates of *Y. enterocolitica*

14 isolates of other *Yersinia* spp.

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Validation of the MALDI-TOF MS

BEFORE validation and addition to database:

Analyte ID	Organism (best match)	Score Value	Organism (second best match)	Score Value
U17472-05-4	Yersinia ruckeri	2.186	Yersinia enterocolitica	1.987
U28080-06-FSK	Yersinia ruckeri	2.207	Yersinia enterocolitica	1.994
U20839-05	Yersinia enterocolitica	2.02	Yersinia ruckeri	2.014
U18707-08-F1	Yersinia ruckeri	2.15	Yersinia enterocolitica	2.017
U19630-04-A	Yersinia enterocolitica	2.16	Yersinia ruckeri	2.112

Meaning of Score Values

Range	Description
2.300 ... 3.000	highly probable species identification
2.000 ... 2.299	secure genus identification, probable species identification
1.700 ... 1.999	probable genus identification
0.000 ... 1.699	not reliable identification

Validation of the MALDI-TOF MS

11 isolates of *Yersinia ruckeri* 01

Diagnostic samples isolated Atlantic salmon kidney
both freshwater and saltwater aquaculture sites in Atlantic Canada

Identified by biochemical testing, serology
and confirmed by 16s ribosomal DNA sequencing

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Validation of the MALDI-TOF MS

Isolate	ID/Score Before Validation	ID/Score After Validation*
U20839-05	*Y. enterocolitica* 2.02 *Y. ruckeri* 2.014	*Y. ruckeri* 2.578 - 2.644
U19630-04-A	*Y. enterocolitica* 2.16 *Y. ruckeri* 2.112	*Y. ruckeri* 2.637 – 2.687
U17472-05-4	*Y. ruckeri* 2.186 *Y. enterocolitica* 1.987	*Y. ruckeri* 2.601 – 2.645

*Isolates were tested after growth for 48 h on blood agar at 22°C & 35°C, Tryptic soy agar at 22°C & Brain heart infusion agar at 22°C

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Validation completed for:

Flavobacterium columnare

Flavobacterium psychrophilum

Renibacterium salmoninarum

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Work in Progress

Aeromonas salmonicida subspecies *salmonicida* (typical)

Aeromonas salmonicida subspecies *nova* (atypical)

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Future Goals:

Vibrionaceae family:

- *Listonella anguillarum*
- *Vibrio ordalii*
- *Vibrio salmonicida*
- *Moritella viscosa*

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Acknowledgments

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MERIAL Veterinary Scholars Program

Dr. Thomas Loch, Dept. Pathobiology & Diagnostic Investigation, College of Veterinary Medicine, Michigan State University

Dr. P. Jeffrey Lewis and Béatrice Després,
AVC MALDI-TOF Mass Spectrometry Classification Research & Development Unit

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Questions? jgiles@upei.ca

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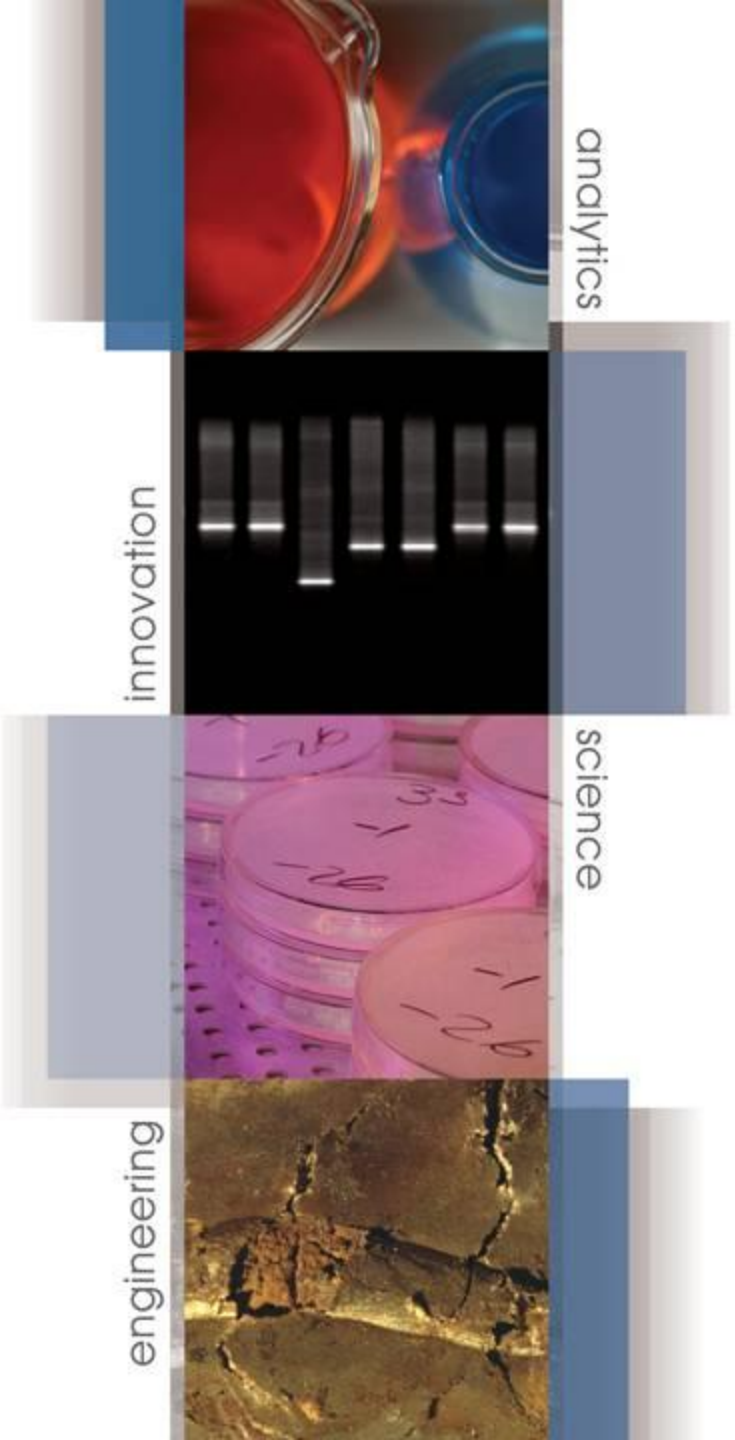
rpc
SCIENCE & ENGINEERING

BKD Diagnostics: Tools of the Trade

Benjamin S. Forward, PhD



Topics

- *R. salmoninarum* basics
- Diagnostic tests
- Test comparisons from the literature
- Lab experience
- Interpreting confounding results - a model?

Renibacterium salmoninarum

- Causative agent of BKD
- Gram-positive bacterium
- Vertically and horizontally transmitted
- Intra and extracellular
- MSA (p57) major virulence factor
  - 2 and 3 gene copy variants
  - Quantitative, more copies, more virulent
  - Target for diagnostics
  - Autolytic protease, cellular adhesion

rpc

Renibacterium salmoninarum

- Genome sequenced
- Other putative virulence factors identified
  - Capsular polysaccharides
  - Heme sequestration
  - Hemolysins
  - Multiple putative antibiotic resistance genes
    - macrolide resistance genes (Erythromycin)
    - up-regulated in response to Eryth & Azith (unpublished)

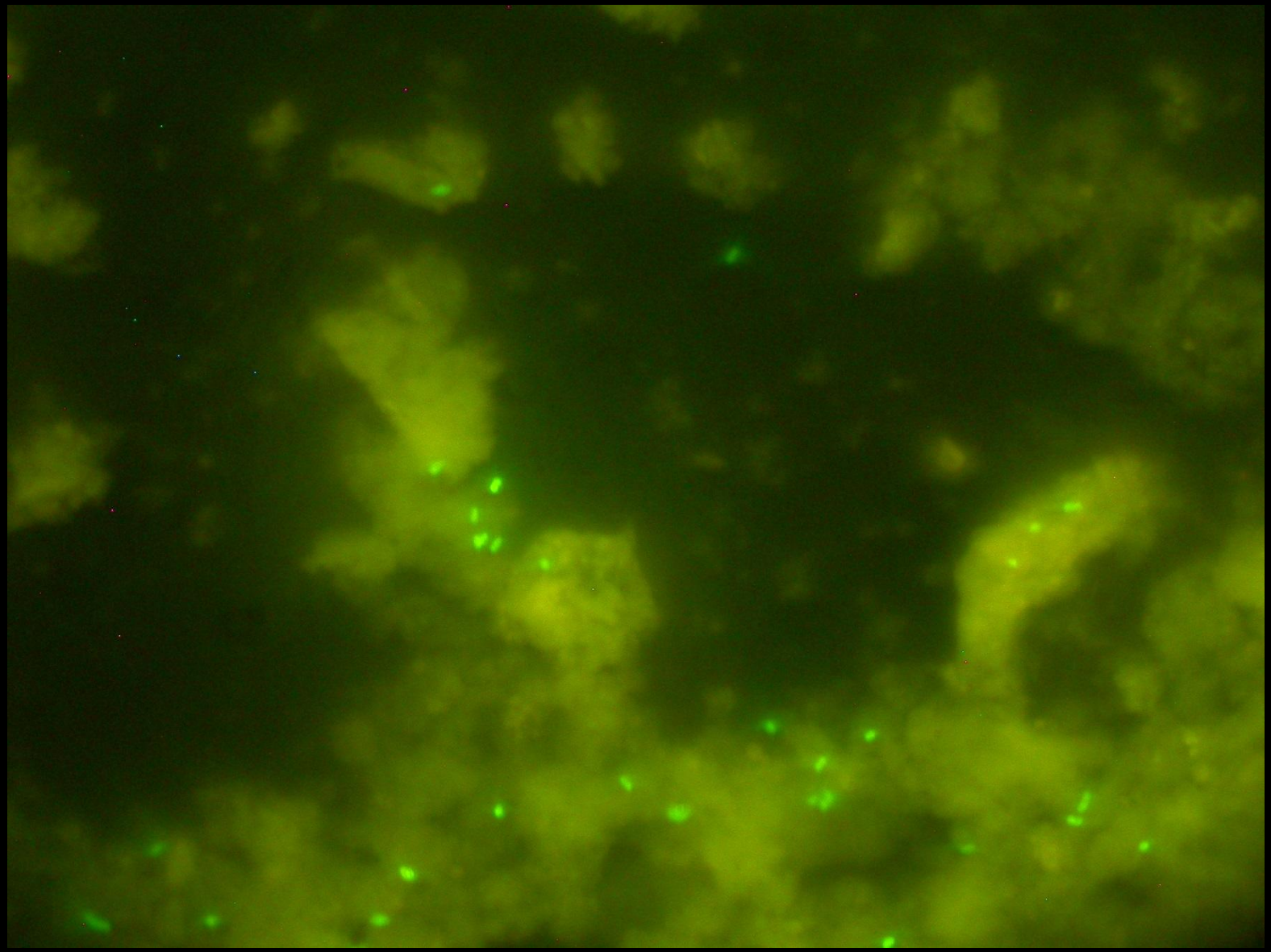
rpc

Diagnostic Assay - Culture

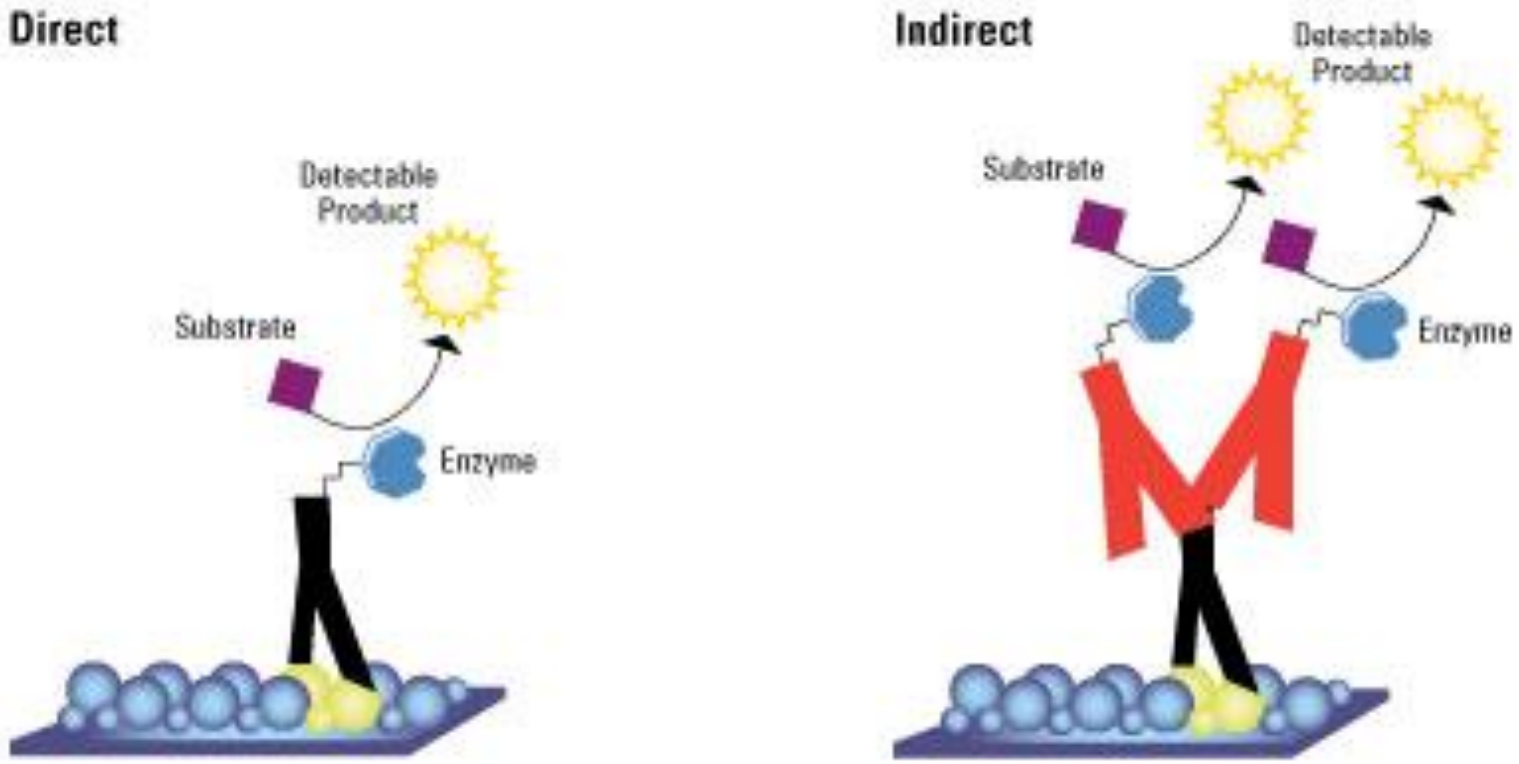
Assay Tools - Culture

- Detects living cells
- Drawback is that 6-8 weeks of culture required for growth (19 weeks)
- Modifications can decrease time but standardization and identification of critical factors are required for routine use
- Competing growth may limit detection at low levels

Assay Tools - DFAT / IFAT



DFAT / IFAT



www.piercenet.com

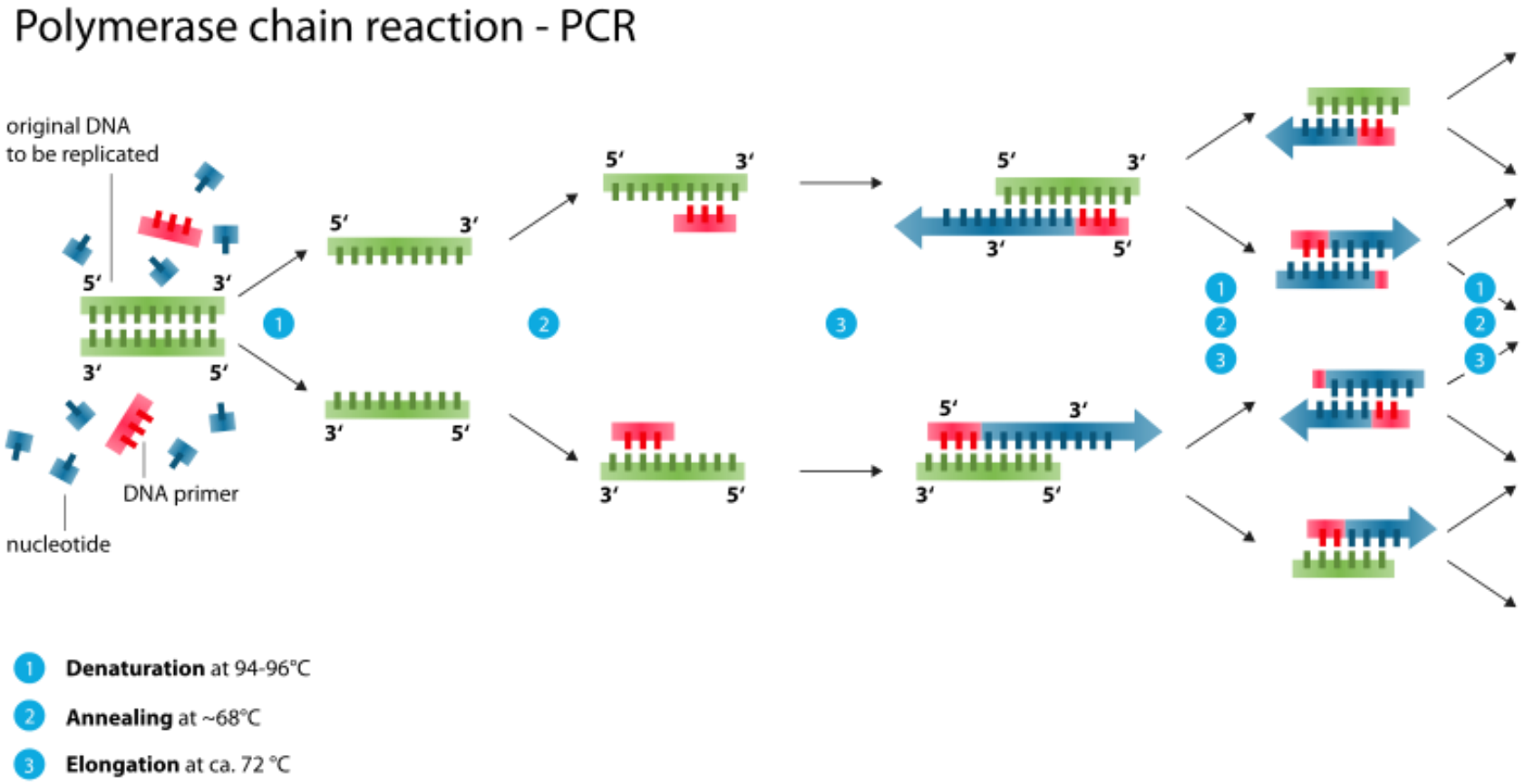
Assay Tools - DFAT / IFAT

- Detects living and dead cells
- Rapid and inexpensive
- Tends to lacks sensitivity of other methods
- Low level infections could be missed depending on fields scanned and sample area collected from
- Sample processing important – homogenate vs tissue imprint

Assay Tools - “PCR”

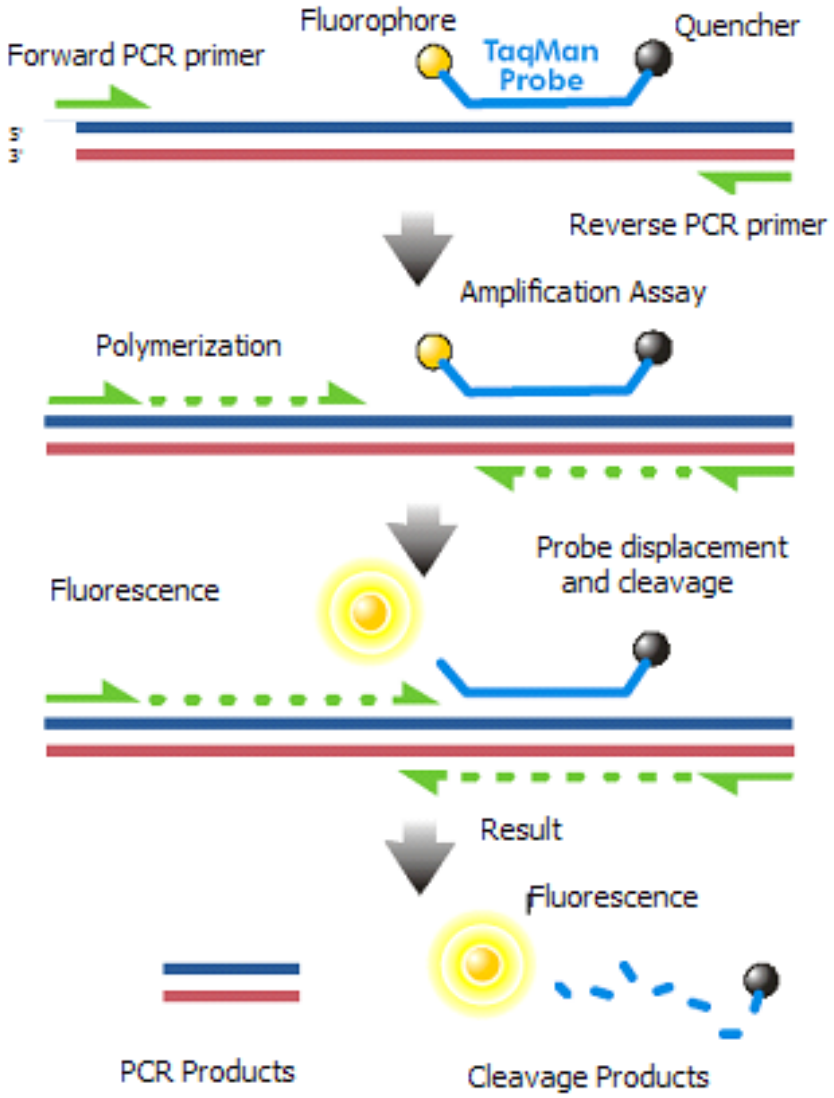
- DNA/RNA-based detection of living and dead cells
- Among the most sensitive methods
- PCR, RT-PCR, nPCR, qPCR, qRT-PCR
- Utilizes small amount of tissue
- Lends to high throughput
- Can be subject to PCR inhibition but is controllable

PCR



en.wikipedia.org

qPCR - TaqMan

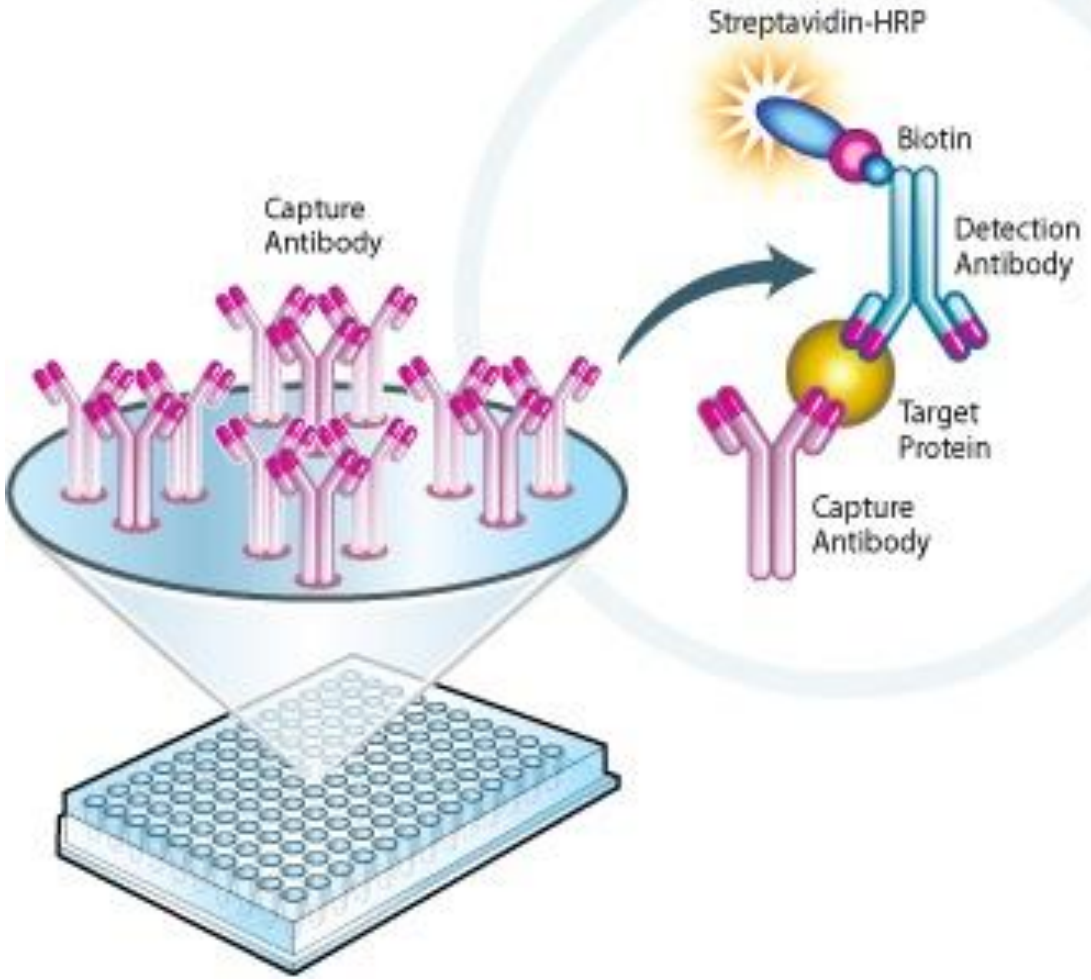


en.wikipedia.org

Assay Tools - qPCR

- Increased specificity vs PCR due to addition of probe (MSA2 gene)
- Subject to less opportunity for contamination due to lower sample handling (vs nPCR)
- No gel electrophoresis
- High throughput
- Can be quantitative – bacterial load

ELISA

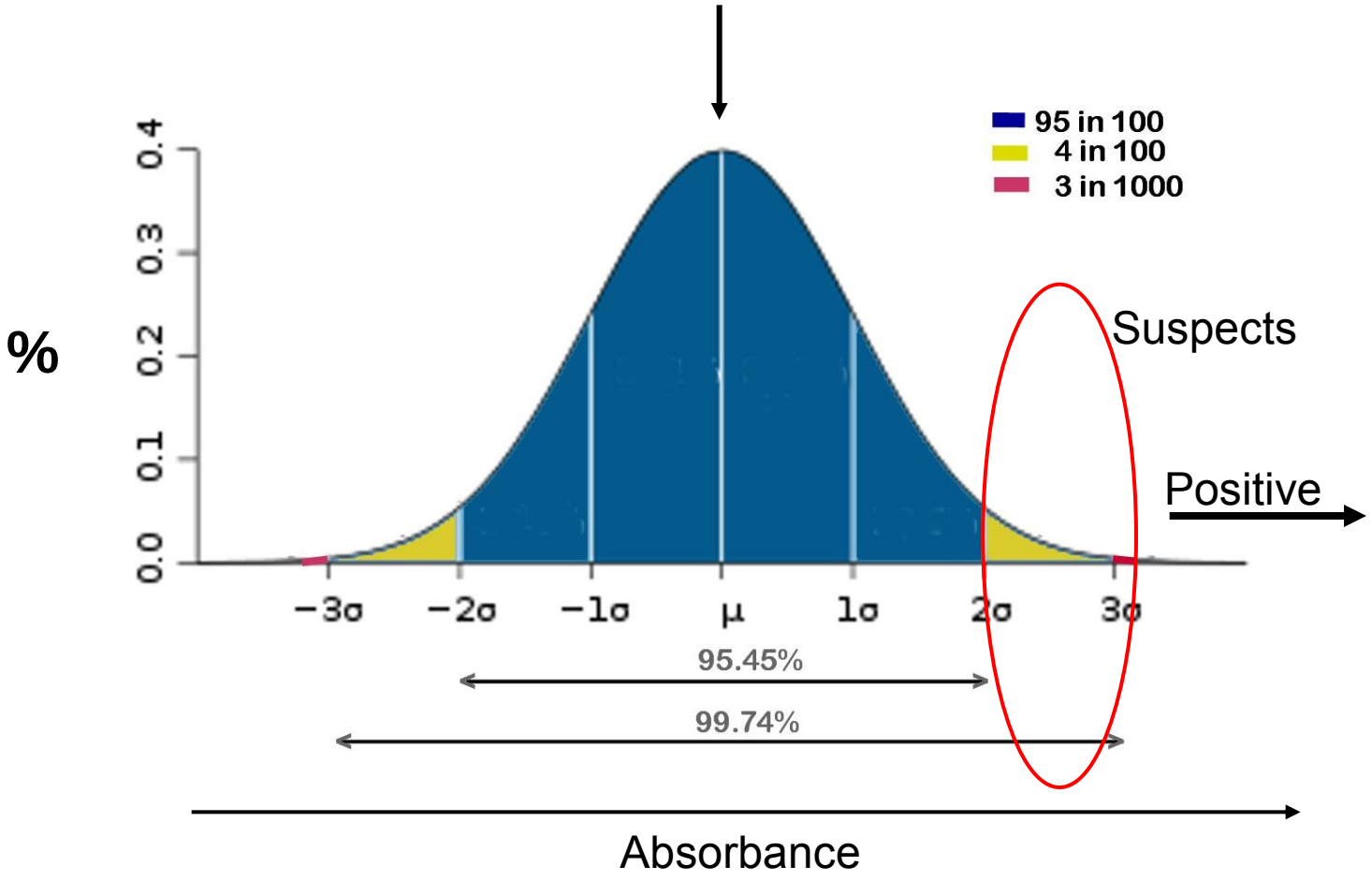


www.abcam.com

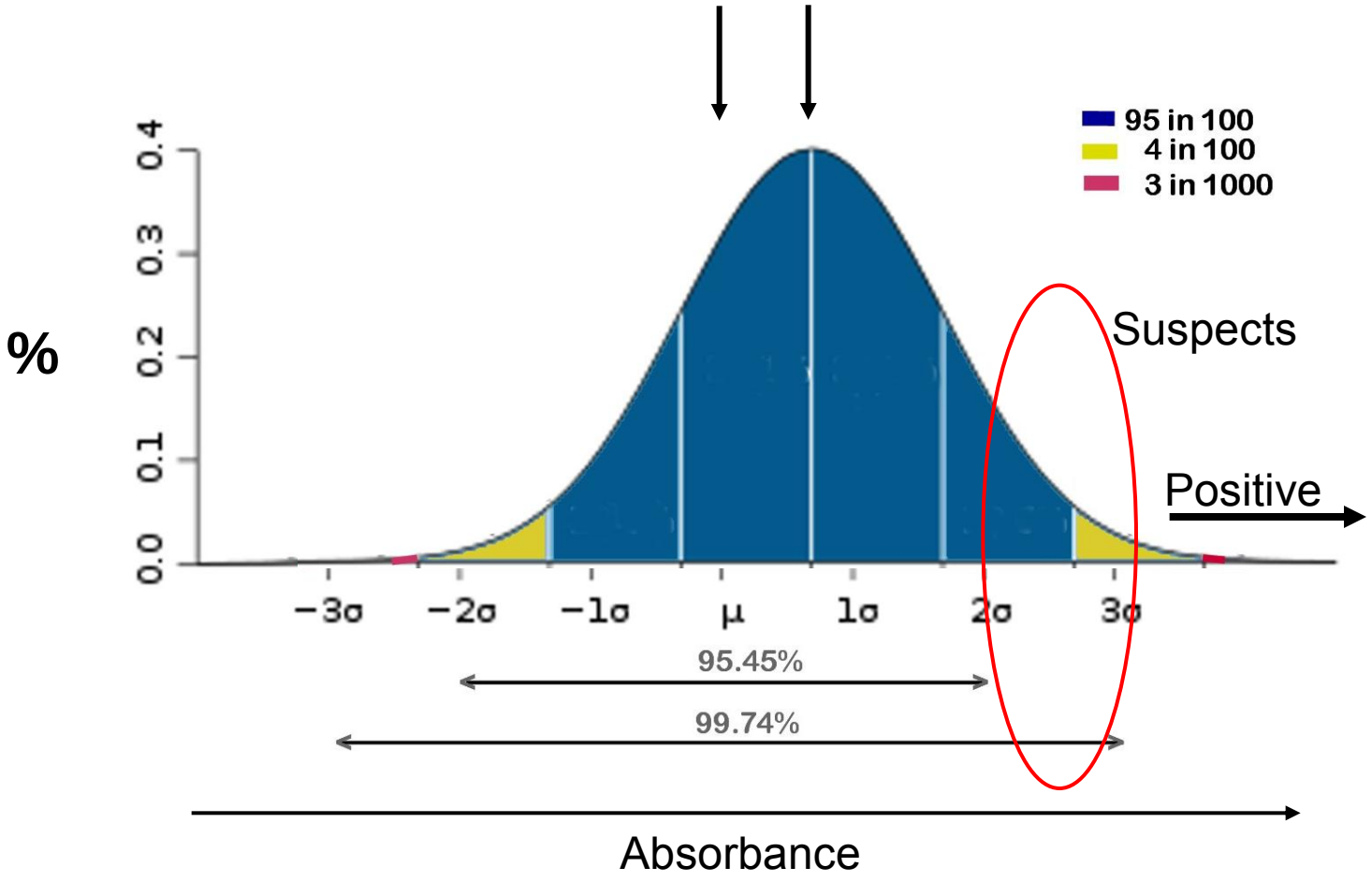
ELISA

- Protein Based
- Antibody mediated detection of antigen
- Qualitative +/- - semi quantitative
- High throughput
- Polyclonal vs monoclonal antisera
- Some reports of cross-reactivity
- Lot to lot variation in antibody titres
- Negative population dependent cut-offs

Background – Negative Pop



Background – Negative Pop



Test Comparisons from the literature

- Numerous publications exist comparing different diagnostic tools
- Not all studies agree


FRUSTRATION
AHEAD
!

Diagnostic Comparisons

- Chase et al, 2006 – qPCR (MSA) = ELISA > nPCR
- Bruno et al, 2007 – qPCR (blood) > culture = ELISA > IFAT = gram stain
- Suzuki and Sakai, 2007 – qPCR > qRT-PCR
- Okuda et al, 2008 – PCR = IFAT
- Jansson et al, 2008 – qPCR (MSA) > qPCR (16S) > ELISA

Diagnostic Comparisons

- Faisal and Eissa, 2009 – nPCR > Culture > ELISA
- Sandell and Jacobson, 2011 – qPCR (MSA) > qPCR (ABC)
- Elliott et al, 2013
  - Culture > MF-FAT > nPCR > qPCR (MSA=ABC) > ELISA
  - ELISA > FAT > Culture > qPCR > nPCR

Why is this?

- High vs low level of infection
  - High = agree; Low = disagreement
- Study designs include tests on culture, spiked matrices, IP injected populations and naturally infected populations
  - results differ across test population

Why is this?

- Sampling strategy (often poorly defined)
- Extraction methodology
- Analytical quantity – each test is different
- Assay methodologies differ (often poorly described)
- Low level infection – non uniform pathogen distribution and developmental phase effecting target abundance
- Matrix effects

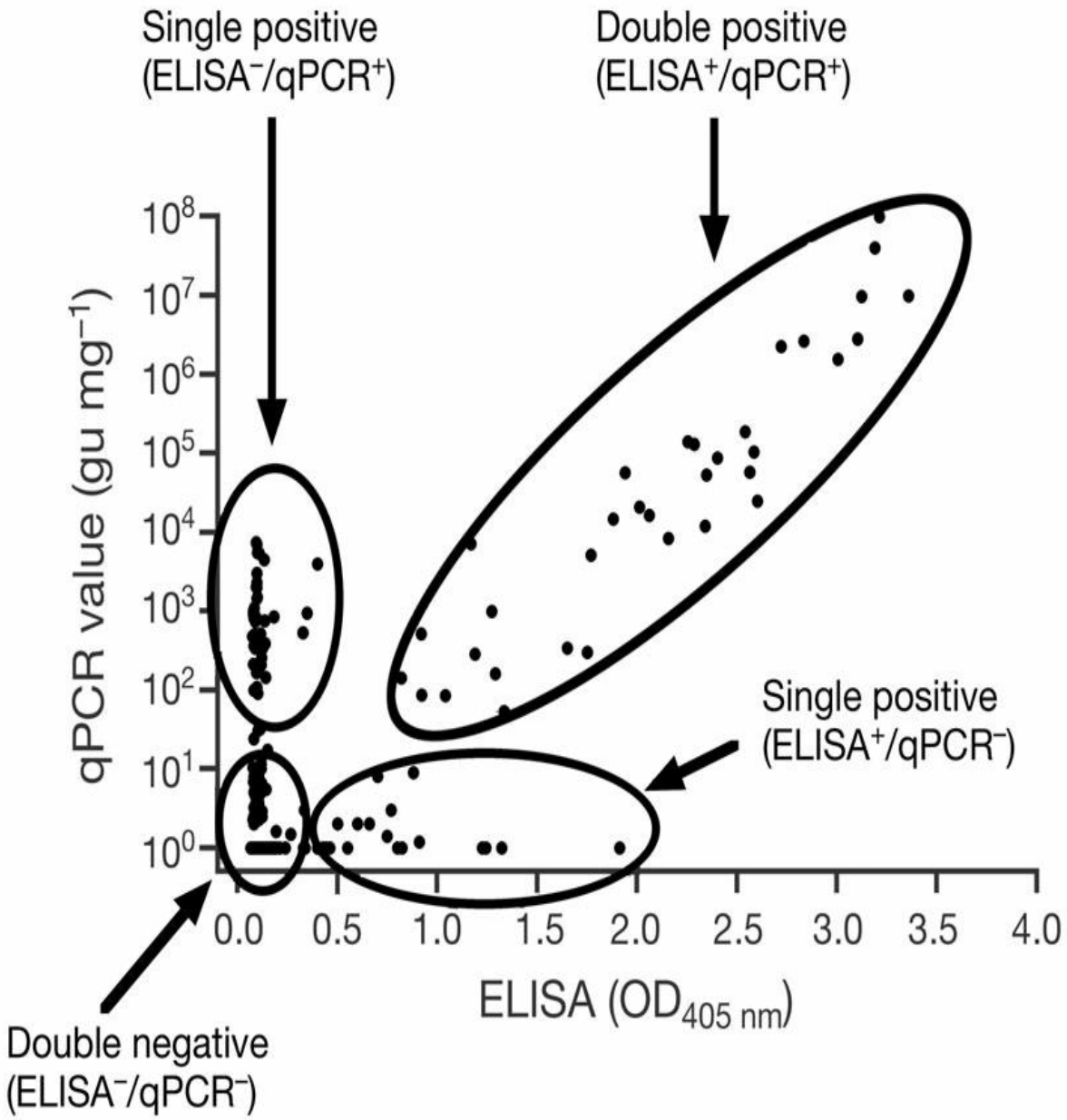
rpc

In General

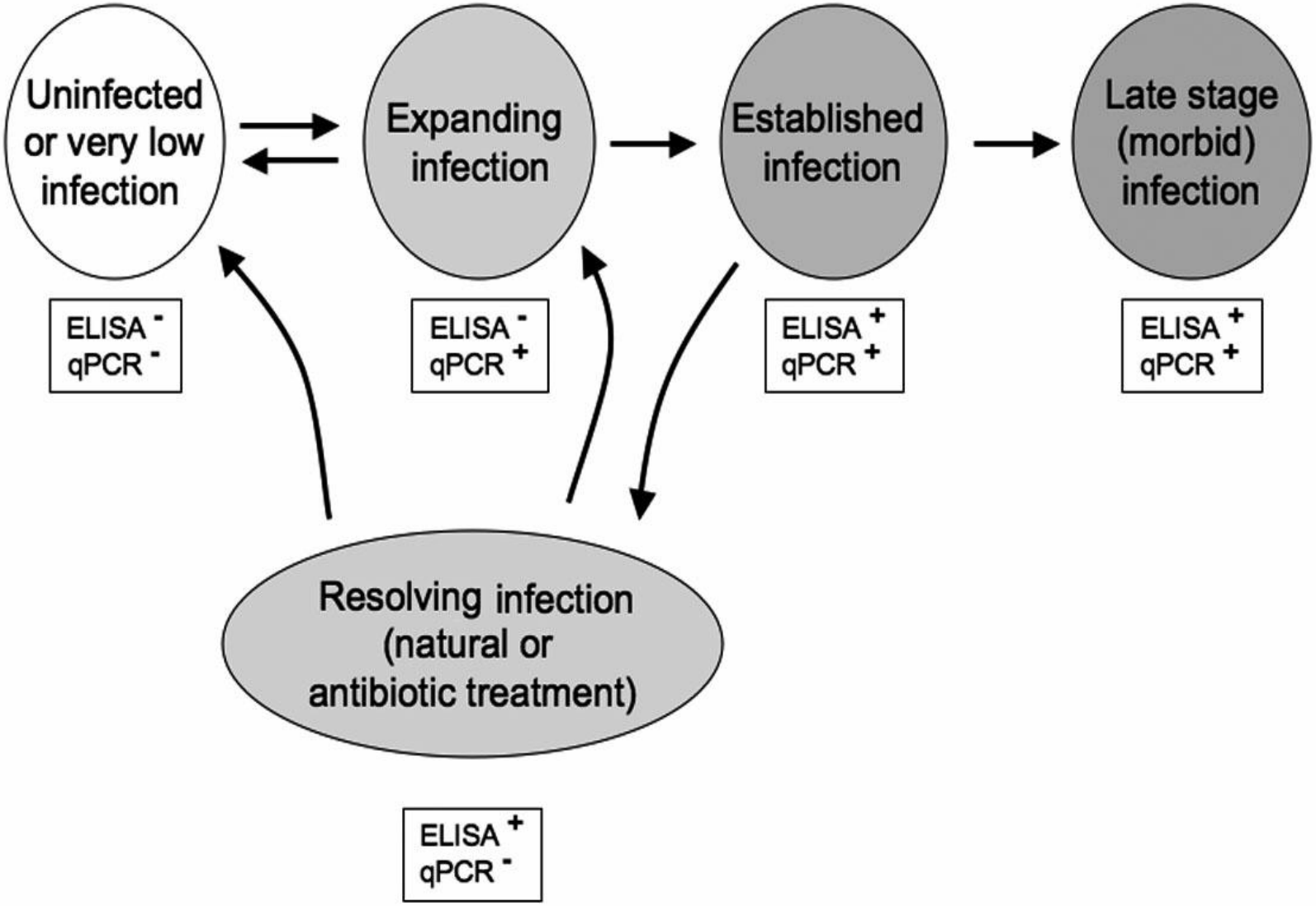
- qPCR methods are more sensitive in natural populations (not all are equal)
- ELISA is comparable but somewhat less sensitive
- Desirable as very amenable to screening large numbers of samples

RPC Experience

- IFAT + culture still useful tools
- In our experience: qPCR >~ ELISA > others
- Sensitive, specific, high throughput for screening, quantitative
- Concordance <100% as with many others
- Why?



Nance et al. 2010, Diseases of Aquatic Organisms **91:**113-119.



Nance et al. 2010, Diseases of Aquatic Organisms **91:**113-119.

Final Diagnostic Points

- For DNA based, extraction protocol is important – i.e. lysozyme employed?
- What PCR protocol is used?
- Based on what publication (MSA, ABC, 16S targets)?
- Internal controls for PCR inhibition?
- ELISA and IFAT, monoclonal or polyclonal antisera – is it QA/QC'd from manufact.?
- Regular equipment calibration?

rpc

Thank You!

What are the “good” bacteria doing around aquaculture sites in the Bay of Fundy and why should we care?

Shawn Robinson, Hannah Bradford, David Thumbi, Bruce MacDonald, Ben Forward, Gregor Reid, Taryn Minch, Mathew Liutkus, Thierry Chopin

Outline

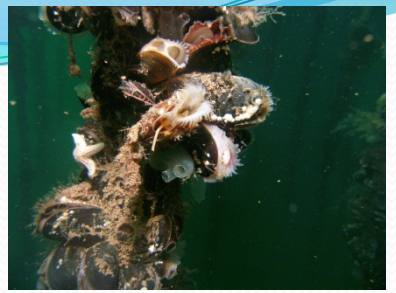
- Brief introduction to marine bacterial ecology
- Questions resulting from their ecological role
- Results from some of our IMTA-based projects
- Implications of the findings for the future

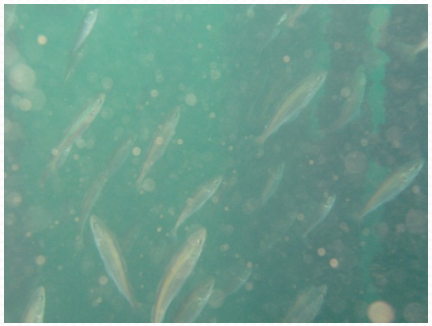
Bacterial Statistics

(from C.B. Munn 2005 and Whitman et al 1998)

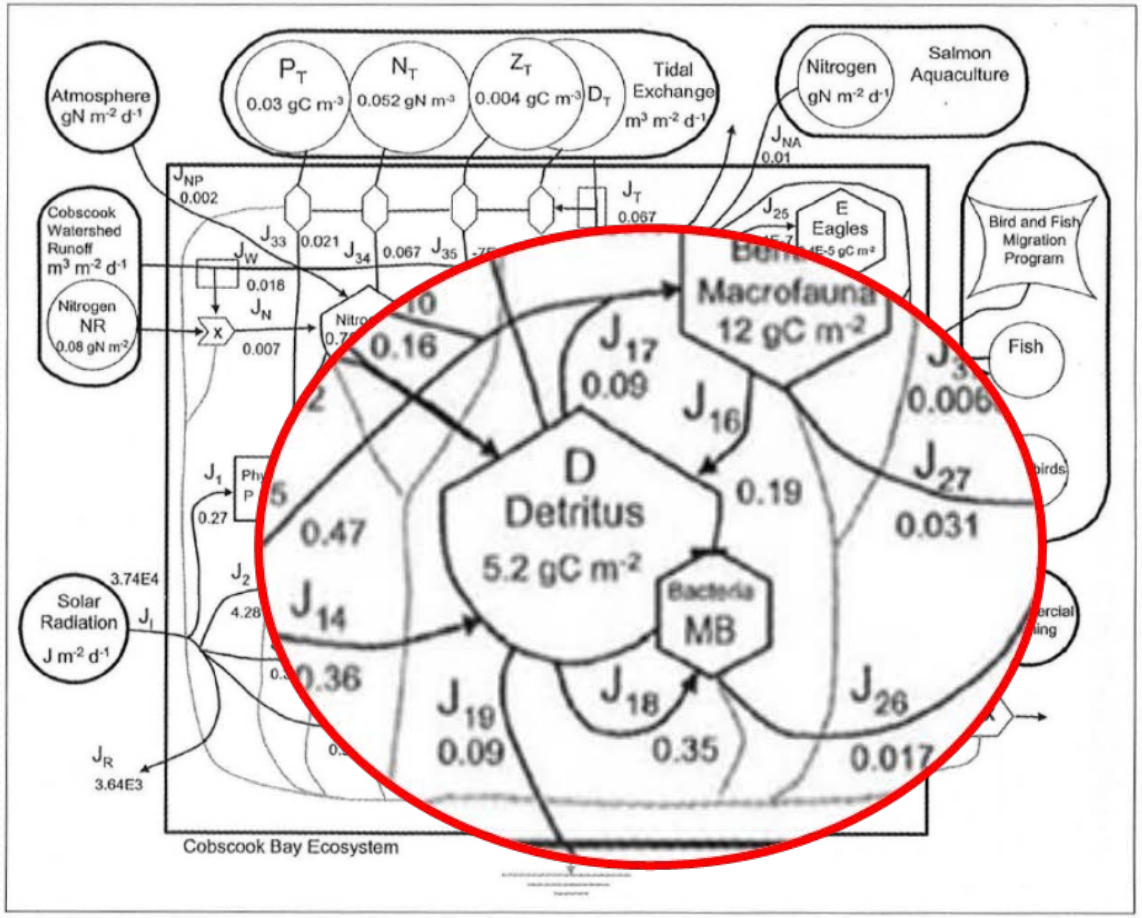
- Not really understood until end of 20th century
  - Genetic based techniques
  - New field of study (new species, new compounds, new uses)
- Abundance
  - In top 150m represent 90% of all cells (from the Pacific)
  - Decrease with depth
  - Oceans – 1.18 x 10^{28} prokaryotes (99% estimated viable but not culturable)
  - Many are smaller than 0.6 µm
  - About 50% of the biomass of all other life forms
- Responsible for the production of biofilms
  - Fouling
  - Spat settlement
- Fixes carbon in the environment
  - Comprises a large fraction of fossil fuels
  - Active in the carbon and nitrogen cycle
- Types
  - Aerobic vs anaerobic
  - Heterotrophs vs chemoautotrophs
  - Pathogenic vs non-pathogenic

Habitats

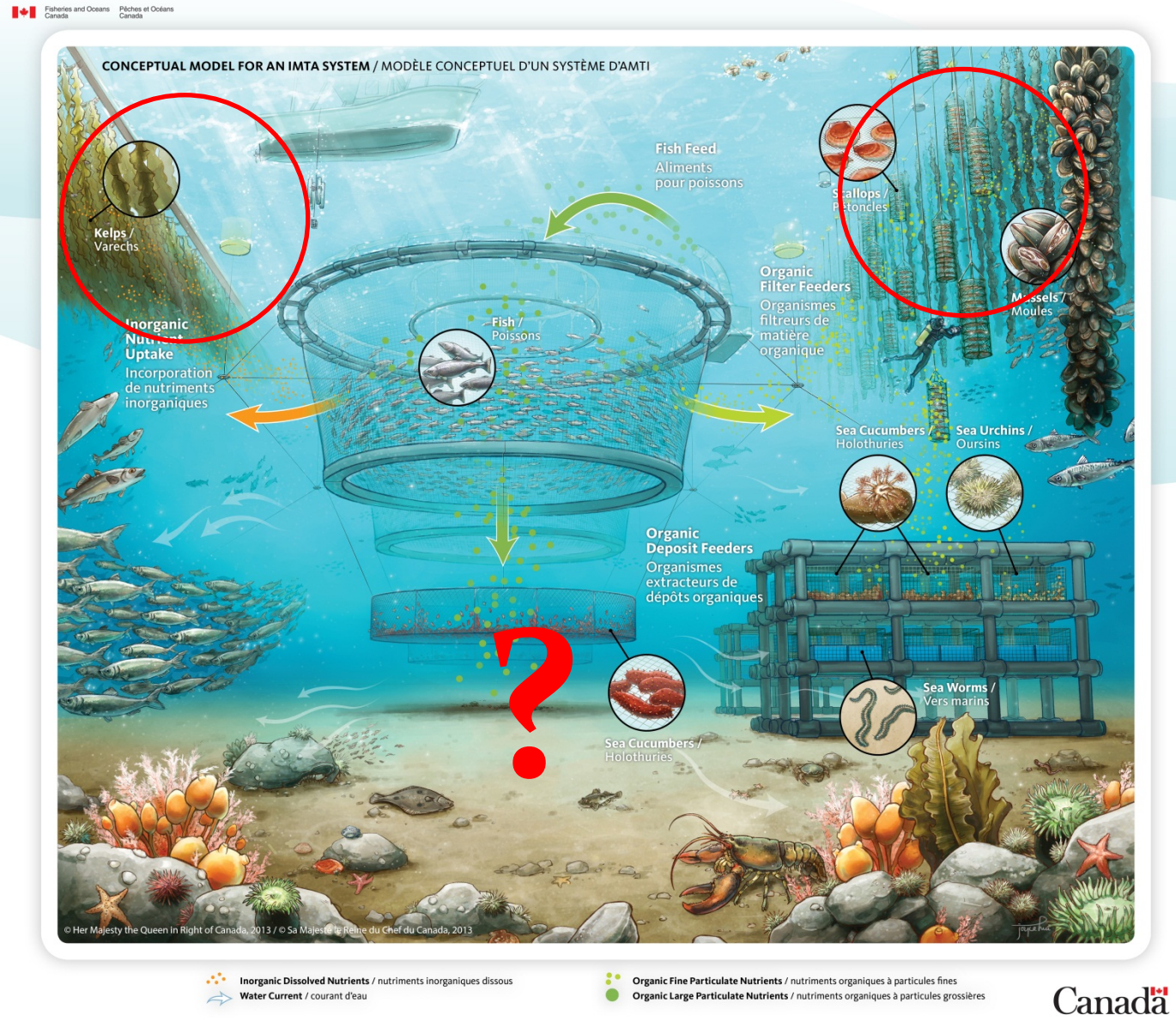




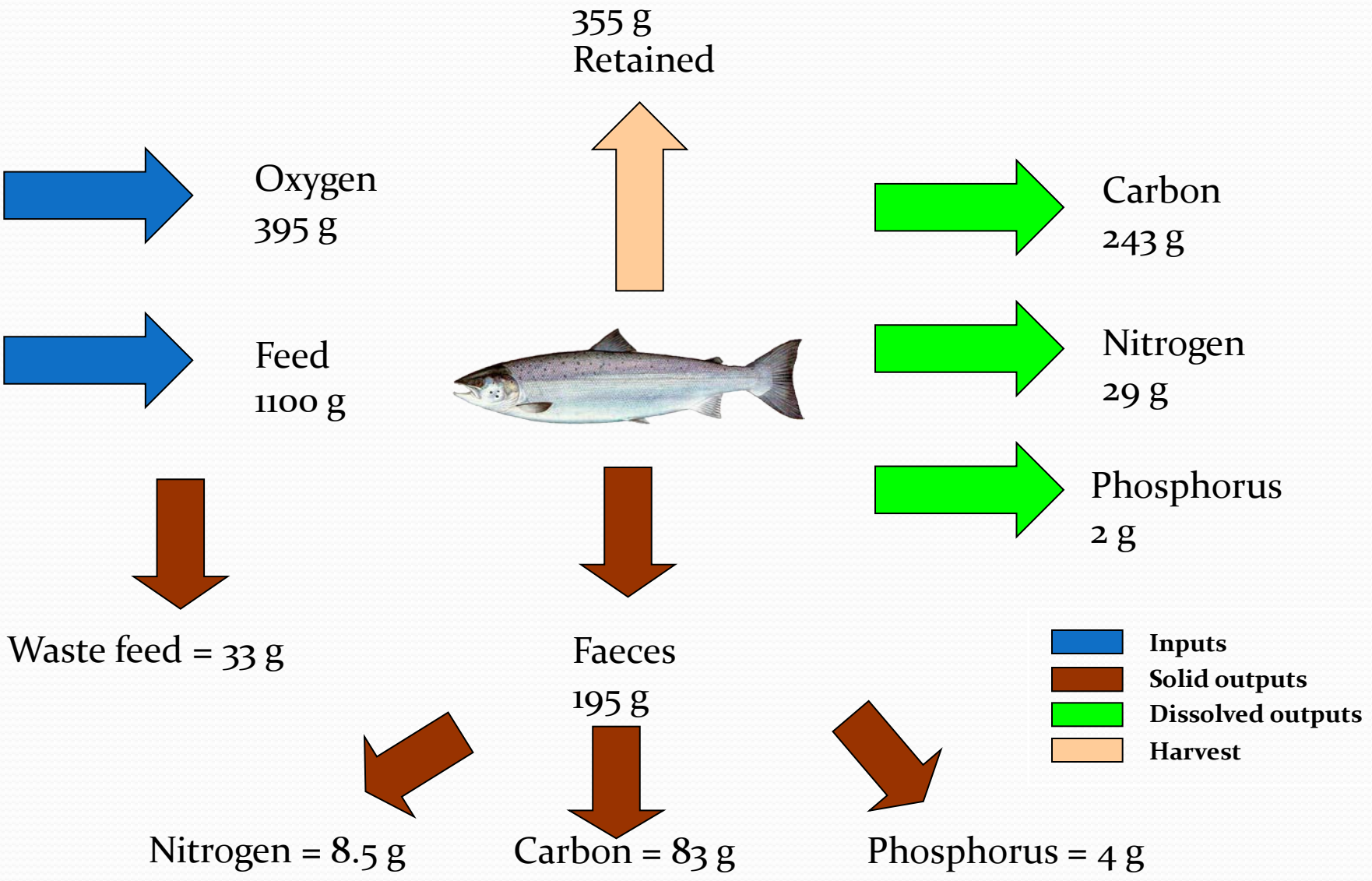
Cobscook Bay Energy Flow



IMTA as a Holistic System



Inputs and outputs for 1 kg growth of salmon as the fed trophic level



What organic material is actually being loaded?

Estimation of faecal composition and the amount produced from the consumption of a typical Atlantic salmon feed for grow out sized (>2000g) fish

	Proximate composition of salmon feed (%)	Digestibility (%)	Amount Digested (%)	Amount in faeces (%)
Protein (min)	39	90	35.1	3.9
Fat (min)	33	95	31.4	1.7
NFE (max)	10	60	6.0	4.0
Fibre (max)	1.5	10	0.15	1.35
Phosphorus (approx.)	1.2	50	0.6	0.6
Minerals (max)	6.8	50	3.4	3.4
Moisture (max)	8.5			
Total	100			14.9

36%

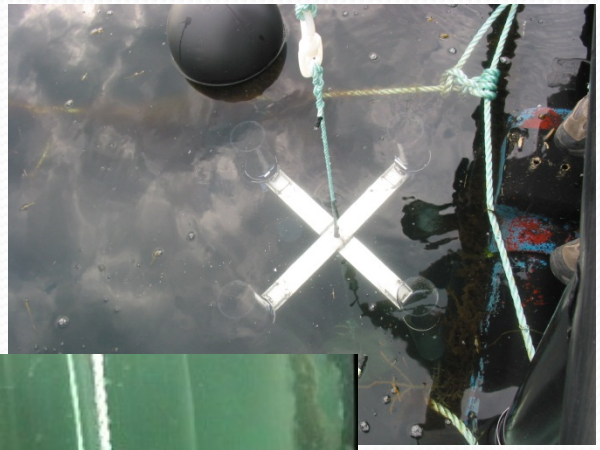
Organic component
(1/2 of phosphorus)

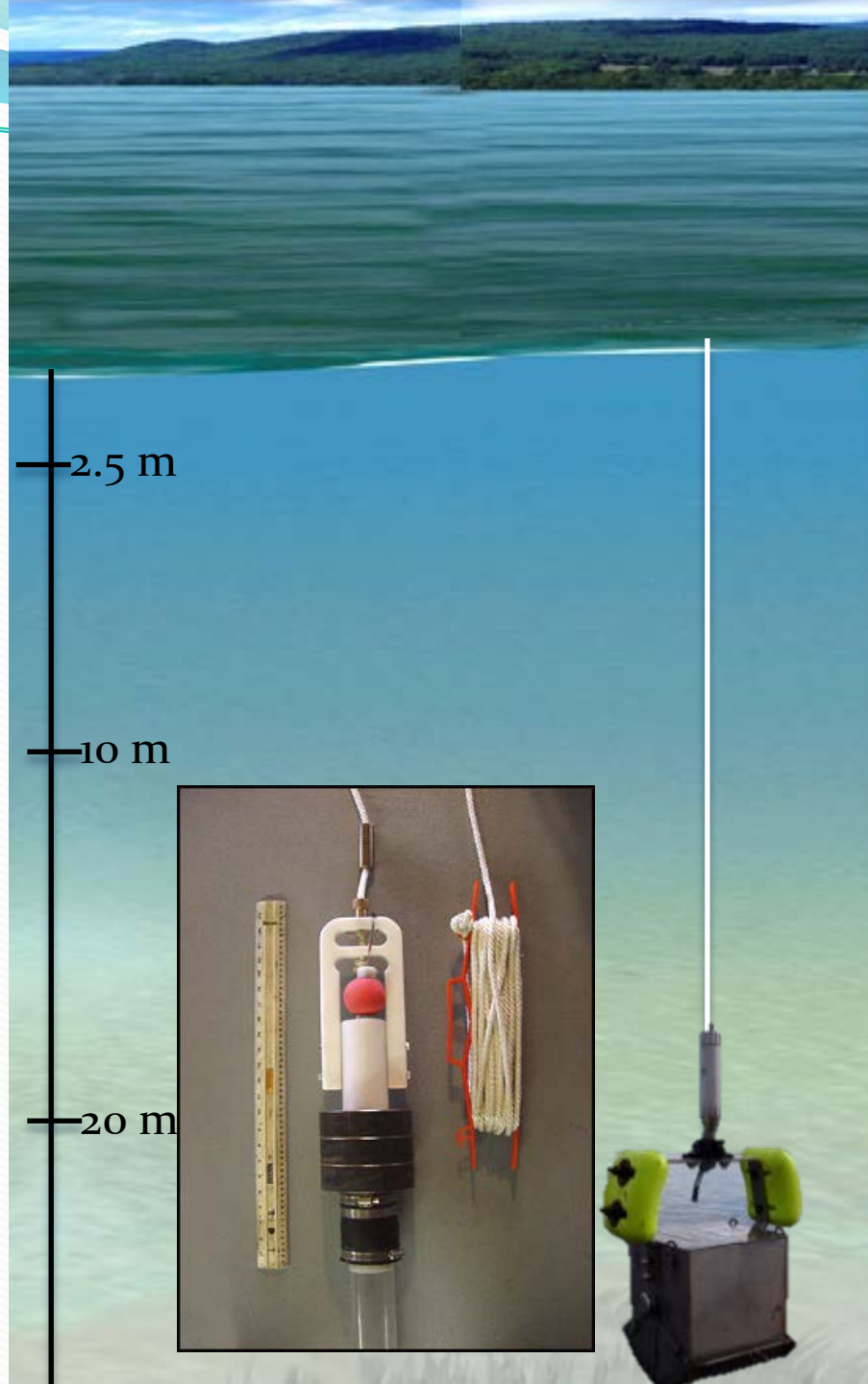
Questions

- How much material do we have to work with and do bacteria (and other micro-organisms) make a noticeable difference?
- Are there any patterns of distribution?
- Can we predict their effects?
- Is it possible to use bacteria in aquaculture?

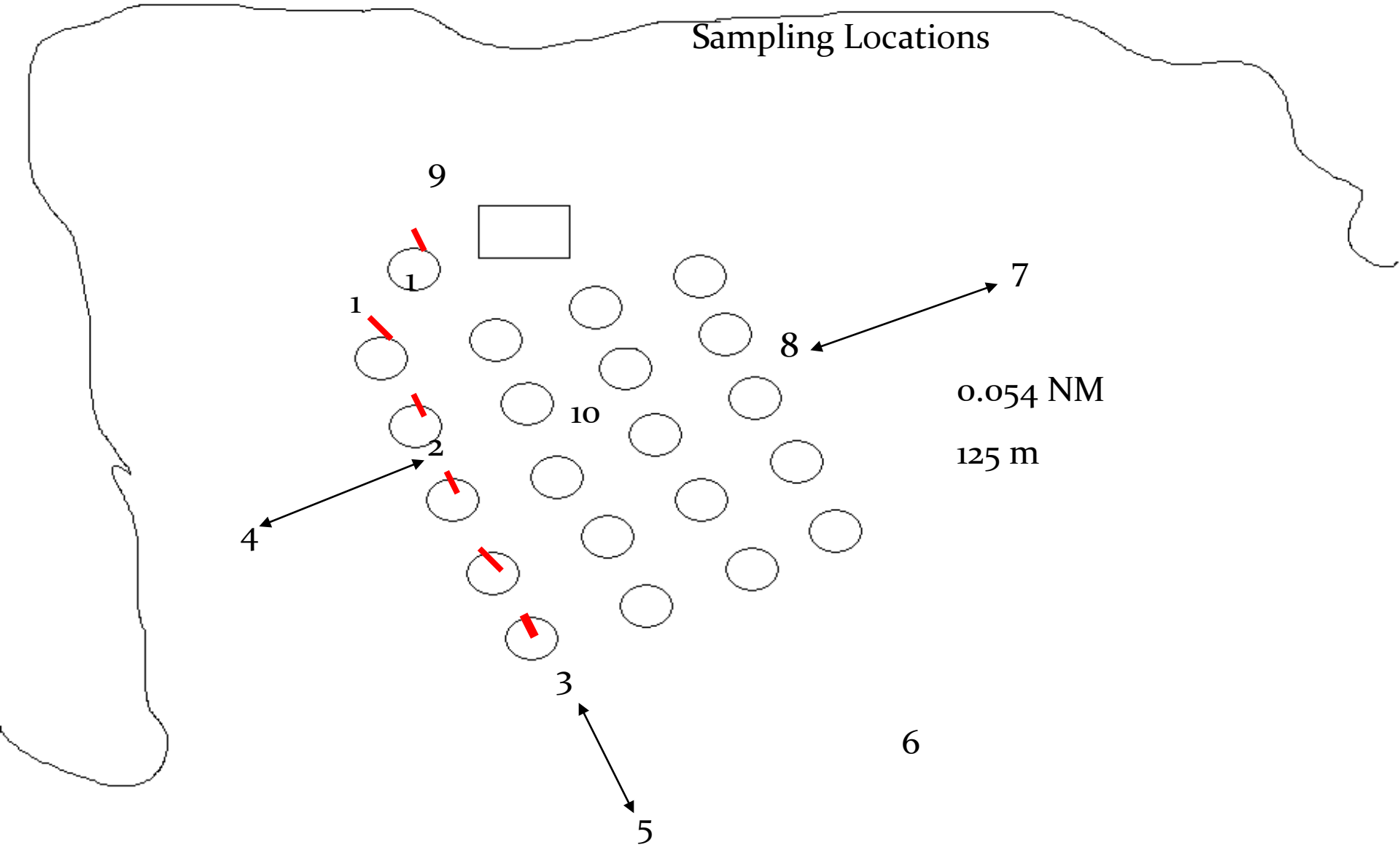
Sample Collection

- Triplicates
- Pelagic samples collected via pump or Niskin bottle
- Benthic samples collected via benthic grab sampled
- Sediment traps
- Corer



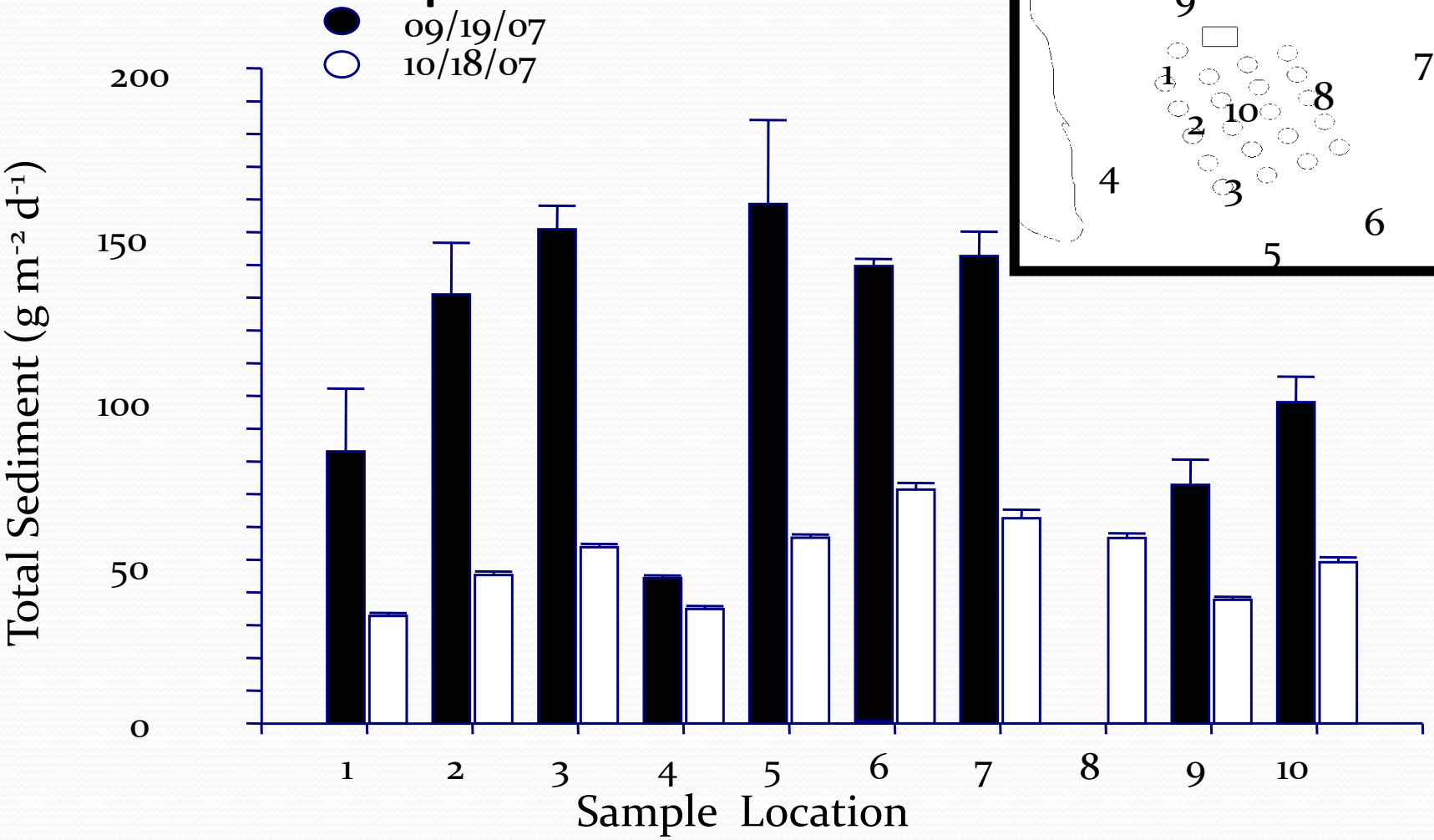


Crow Island



Total Sediment (g m^{-2} d^{-1})

at each sample location



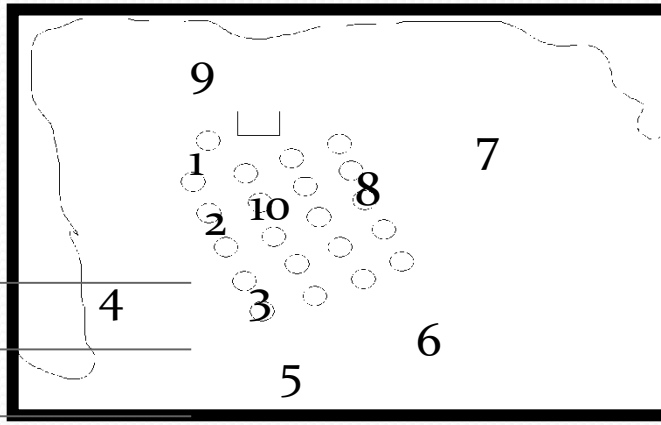
Organic Analysis

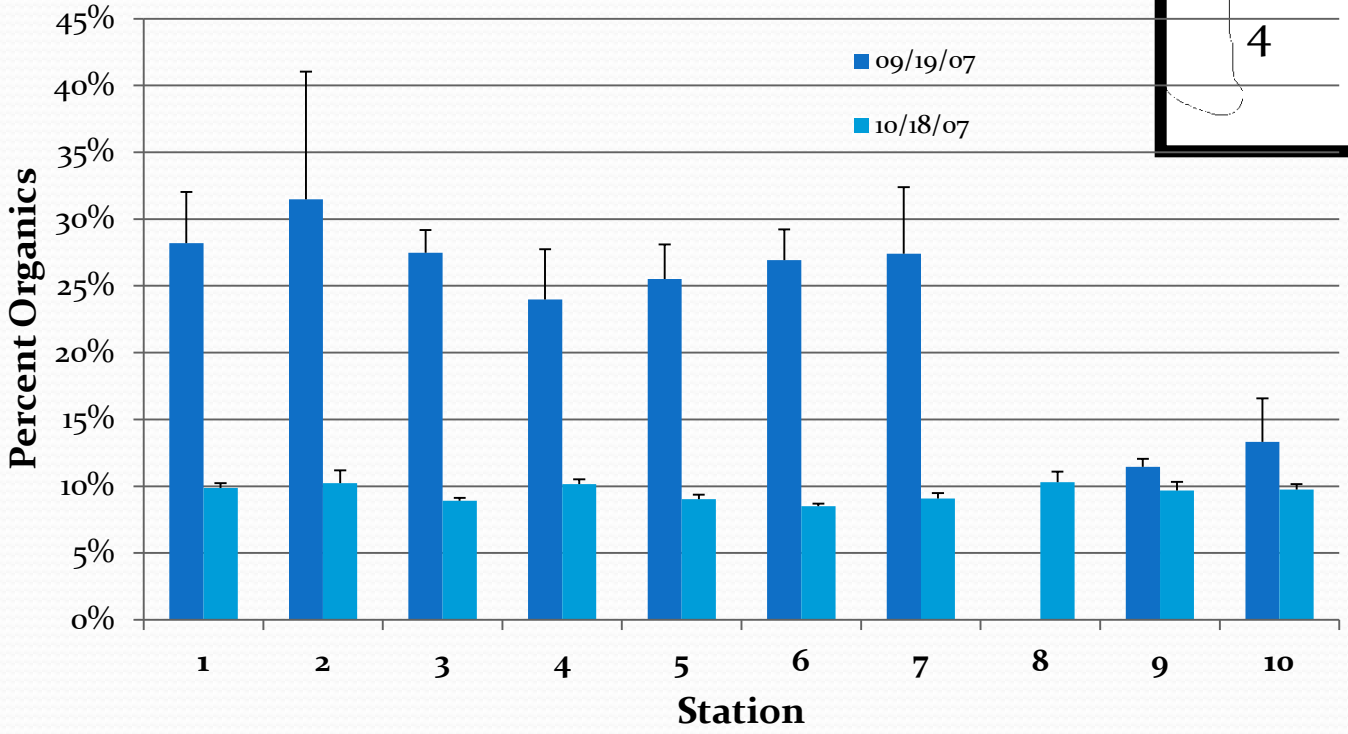
- Loss on Ignition (**LOI**)
  - **Dry weight** ➔ Drying oven (80°C) for 5 hr
  - **Ashed weight** ➔ Muffle Furnace (475°C for 5 hr)
- **Calculate:**

% organics and pore water loss

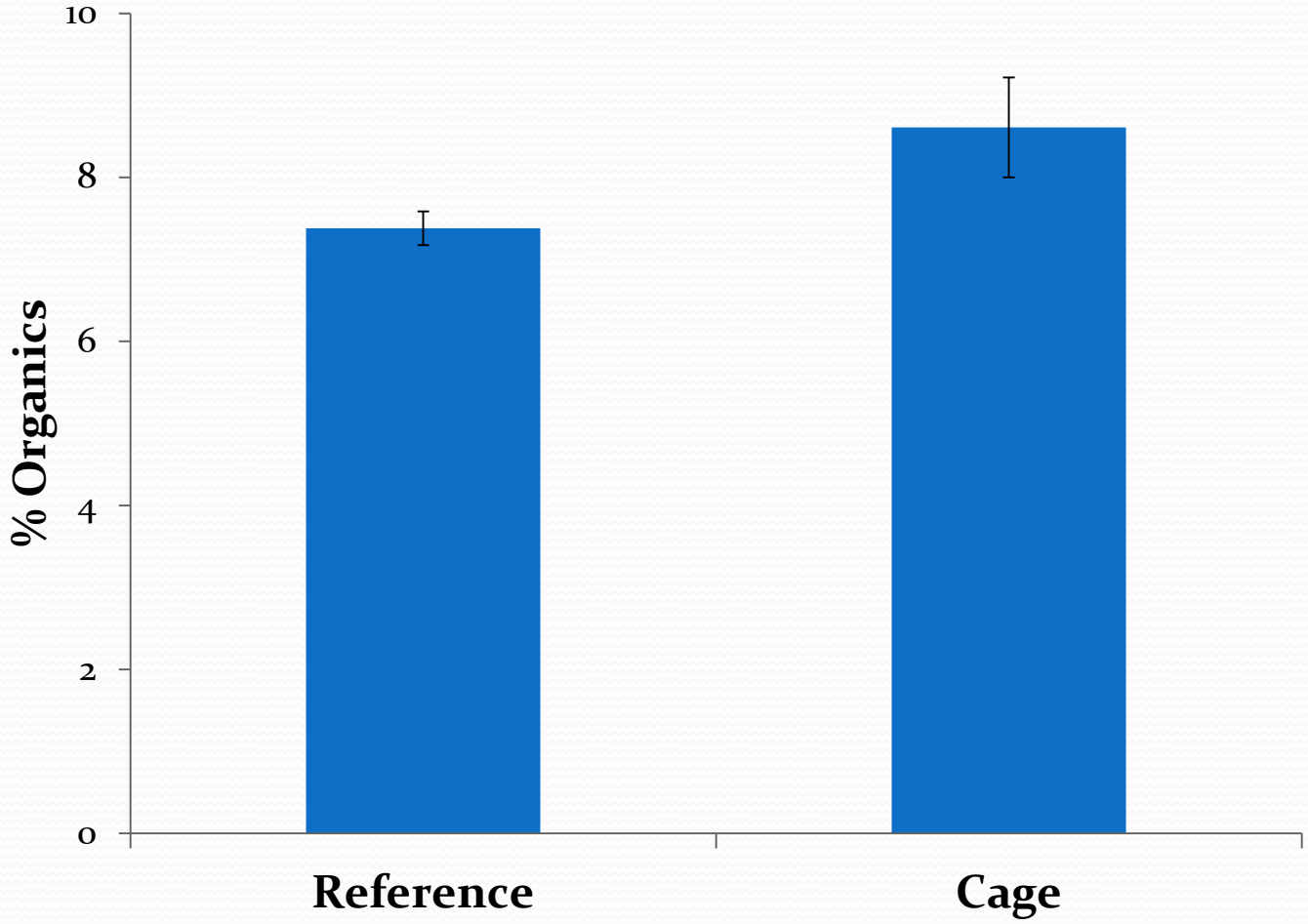
  - 45-55% C

Percent (%) Organic Matter

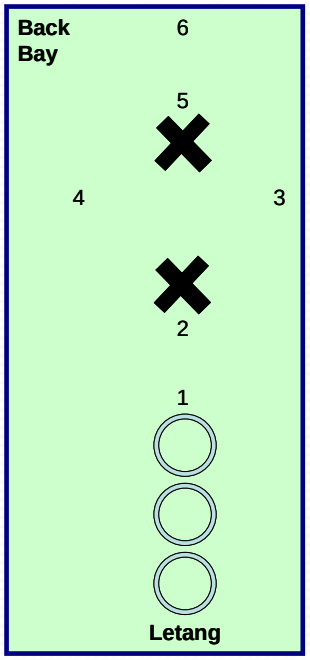


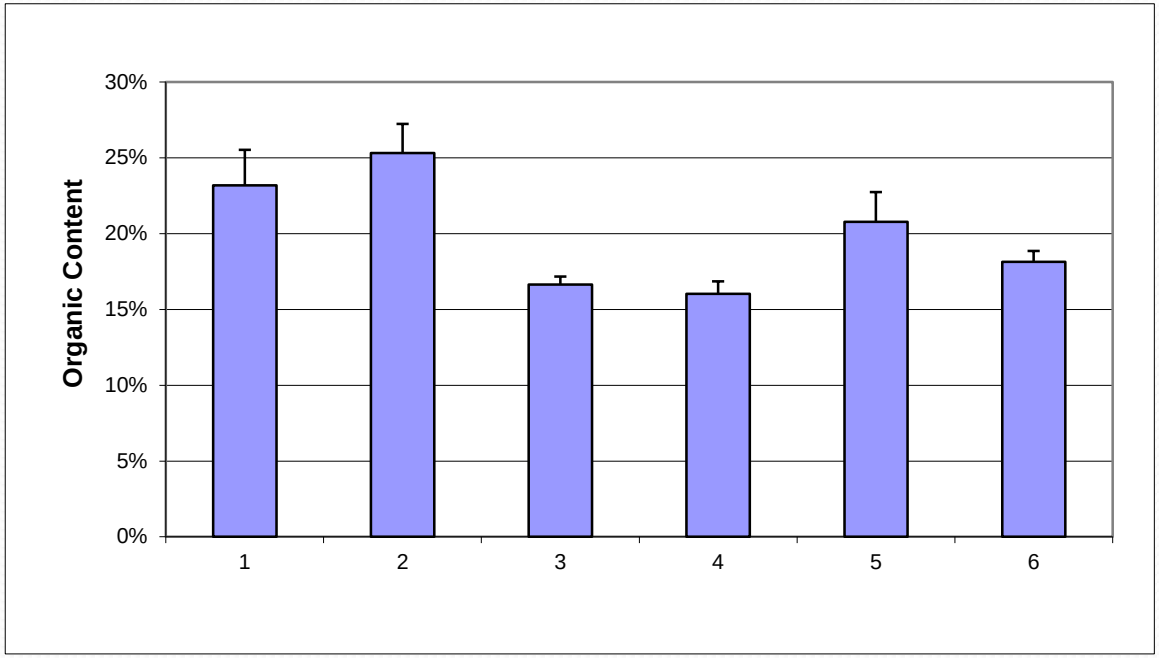


September 2014

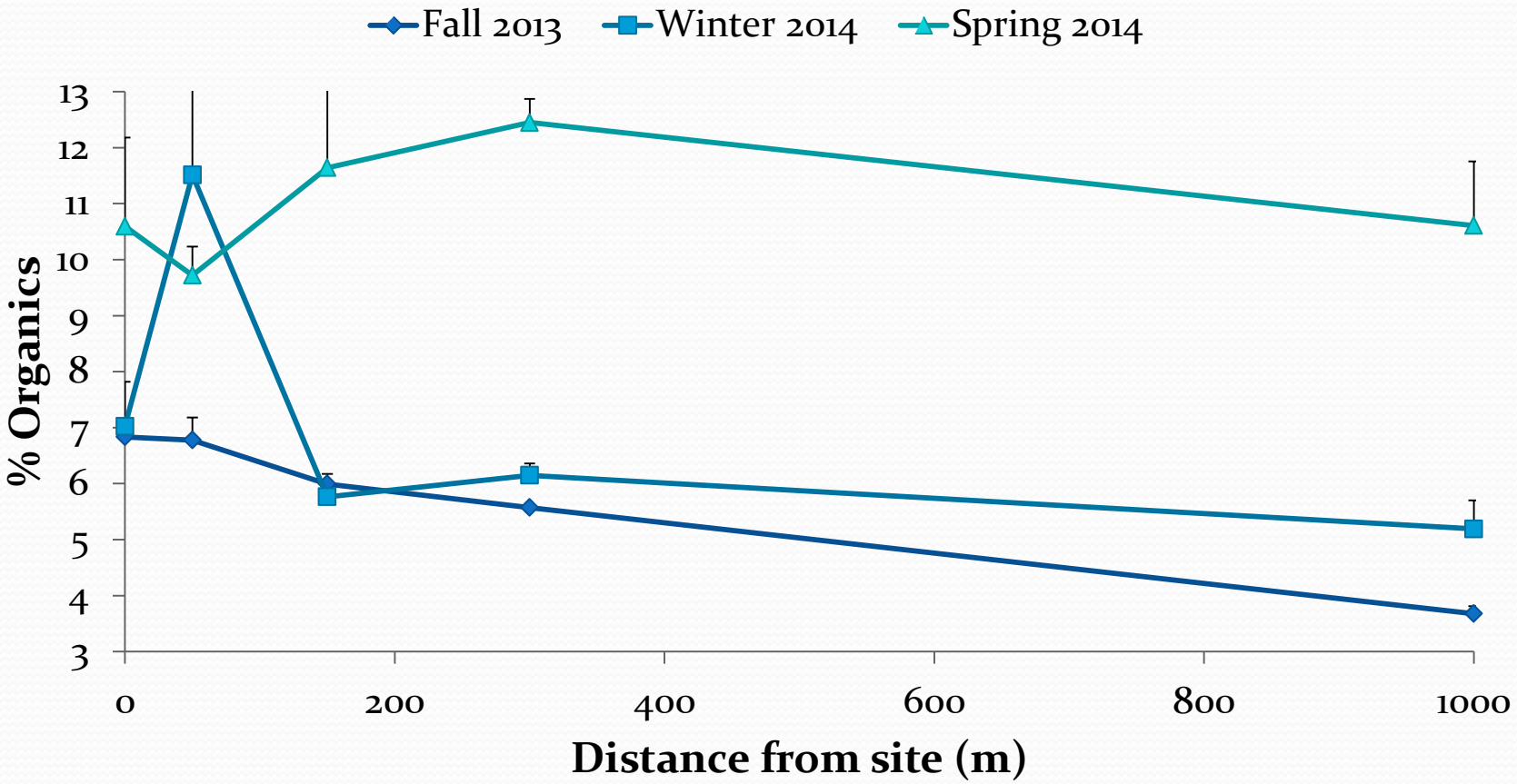


July 2011 - ICage





Passamaquoddy Bay



Passamaquoddy Bay – Cores July 2014

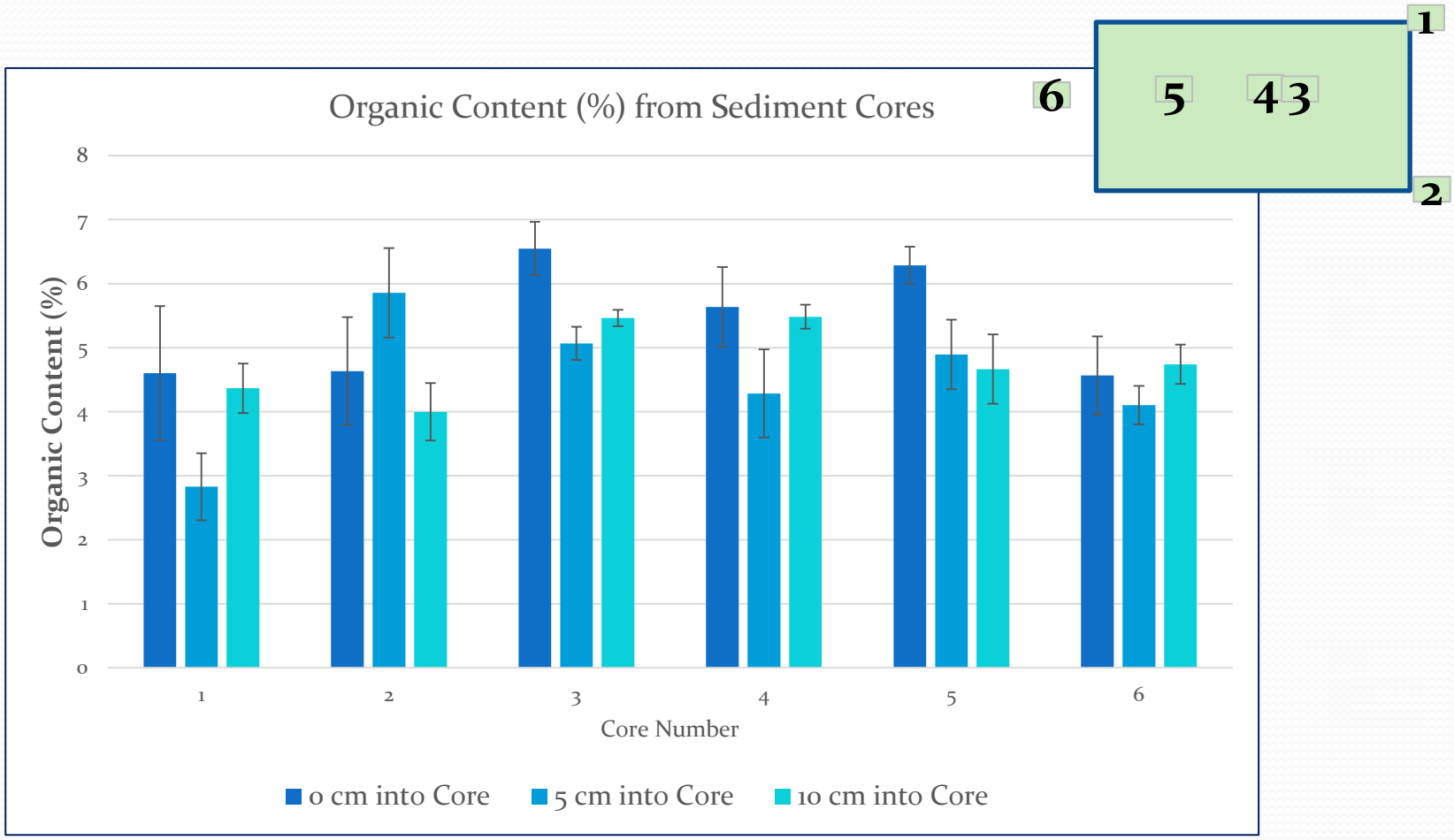


Table 2

Table 2. Absorption efficiency (AE) of organic content of diet to biodeposit produced by four experimental diets; shellfish starter, diatom, salmon faeces and fines from salmon feed.

***Origin;* Diet** **Organic Content (%) of**	***Algal*** Mixed algal	***Algal*** Diatom	***Salmon farm*** Salmon Feed	***Salmon farm*** Salmon Faeces
Biodeposit	**29.4 (± 1.1)**	**25.7 (± 1.0)**	**59.4 (± 1.3)**	**32.4 (± 0.7)**
Diet	**76.9 (± 0.4)**	**65.9 (± 0.8)**	**93.1 (± 0.3)**	**77.1 (± 2.2)**
Absorption efficiency (AE)	**87**	**81**	**90**	**86**

Note: Presented data are the combination of all three size classes, and are the means (± Standard error) of the grouped data set. Organic content was derived from the weight loss after combustion. Absorption efficiency is the efficiency with which organic material is absorbed from ingested food material, derived from (Conover, 1966).

Conclusions on loading

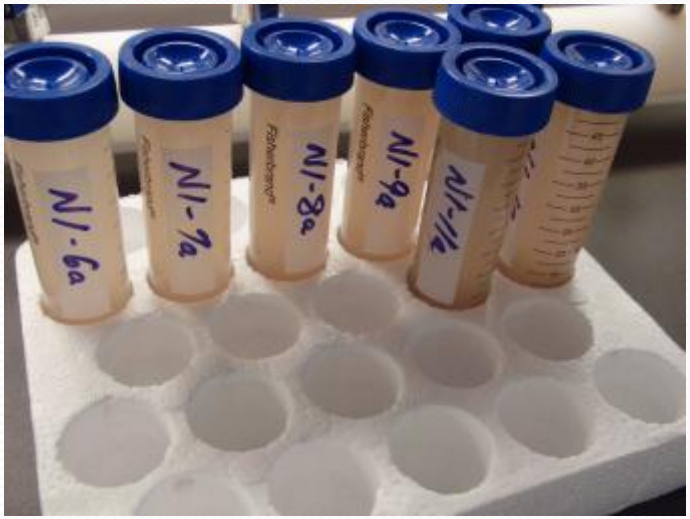
- Loading rates can be reasonably high around aquaculture sites compared to natural conditions, but the pattern is not clear-cut (variable)
- Organic content of food and faeces is high (~90 and 80% respectively). Natural seston is medium (40%)
- Material in sediment traps is low (25%)
- Sediment around sites is very low (5-10%)
- Conversion occurs in 24 hr in many cases
- Bacteria and other micro-organisms look responsible (guilty?) No observable larger organisms.

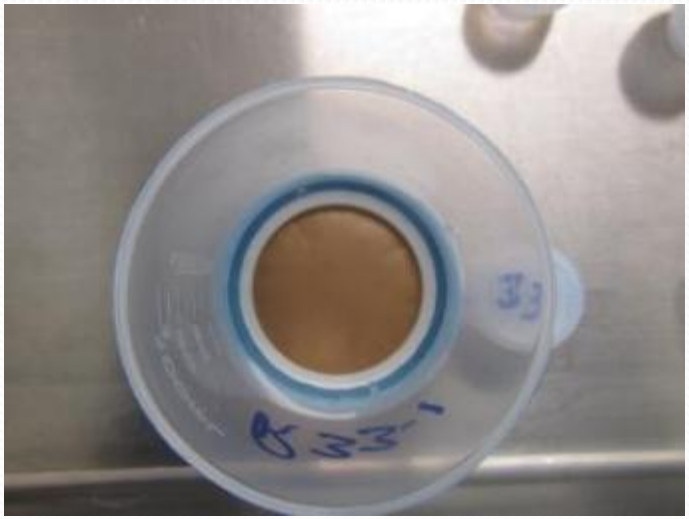
Questions

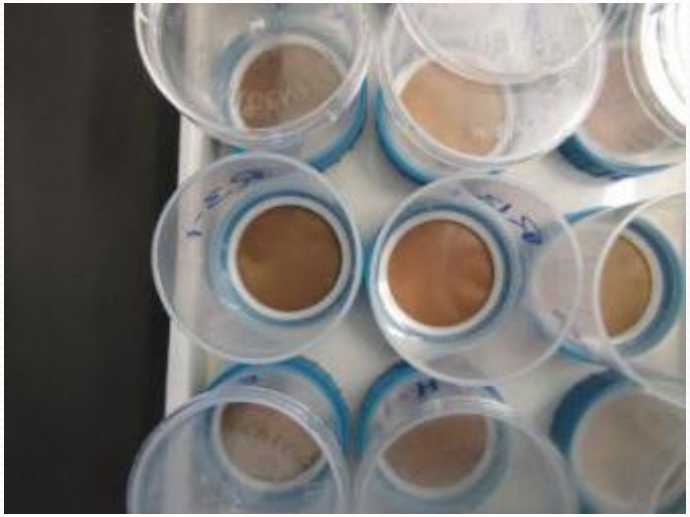
- How much material do we have to work with?
- Do bacteria (and other micro-organisms) make a noticeable difference?
- Are there any patterns of distribution?
- Can we predict their effects?
- Is it possible to use bacteria in aquaculture?

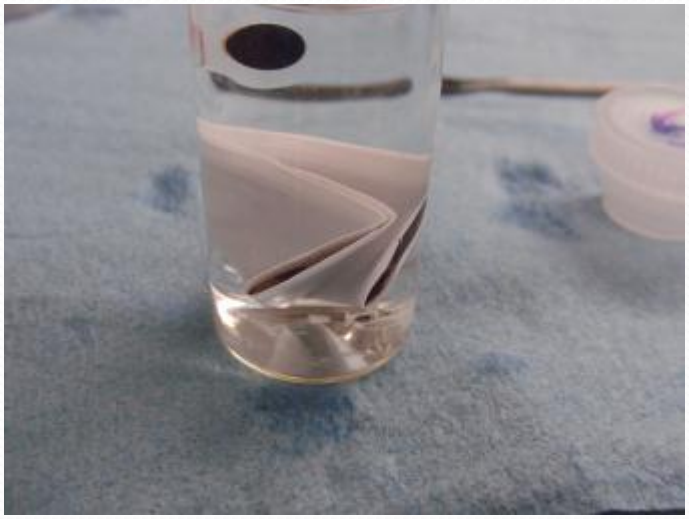
Water sampling

Sample extractions









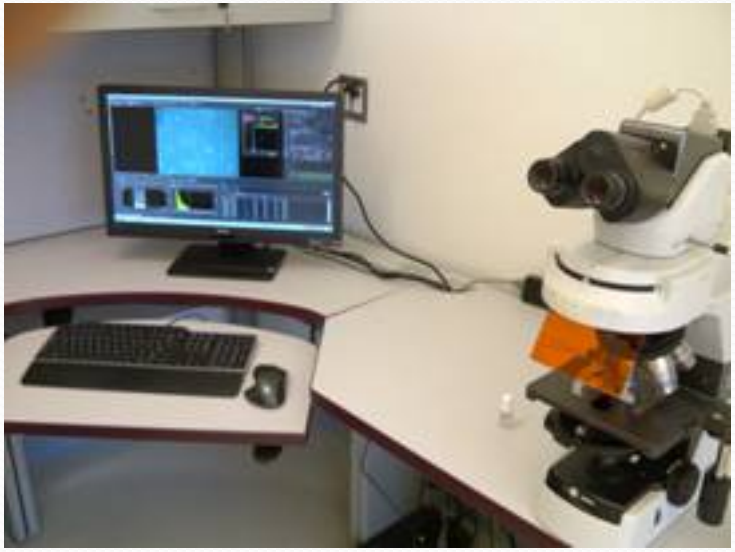
Bacterial Enumeration

Protocols To-date

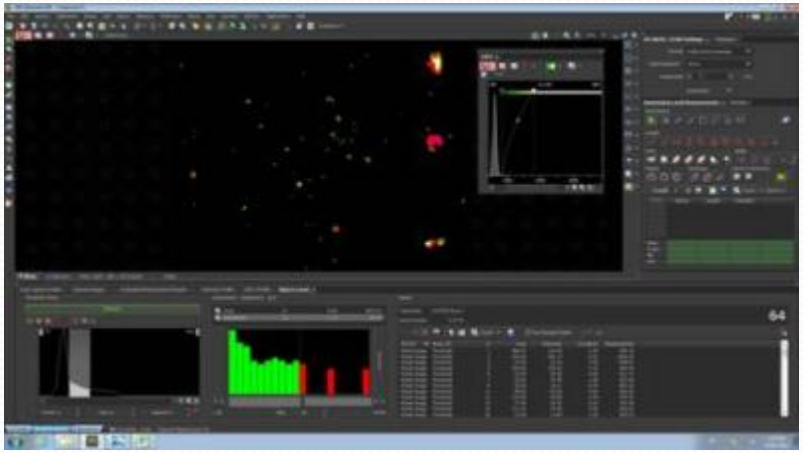
- 1500 ml of water sampled with Niskin bottles at aquaculture sites along a transect (3 replicates)
- Samples placed on ice and transported back to SABS
- 50 ml of sample filtered onto 0.2 µm filter after 20 µm pre-filter to remove larger seston
- Stained with DAPI stain directly in the filter tower for 10 min and then rinsed with 30 ml phosphate buffered saline
- Filter removed and placed on a microscope slide with a cover slip

Bacterial Enumeration

Protocols To-date

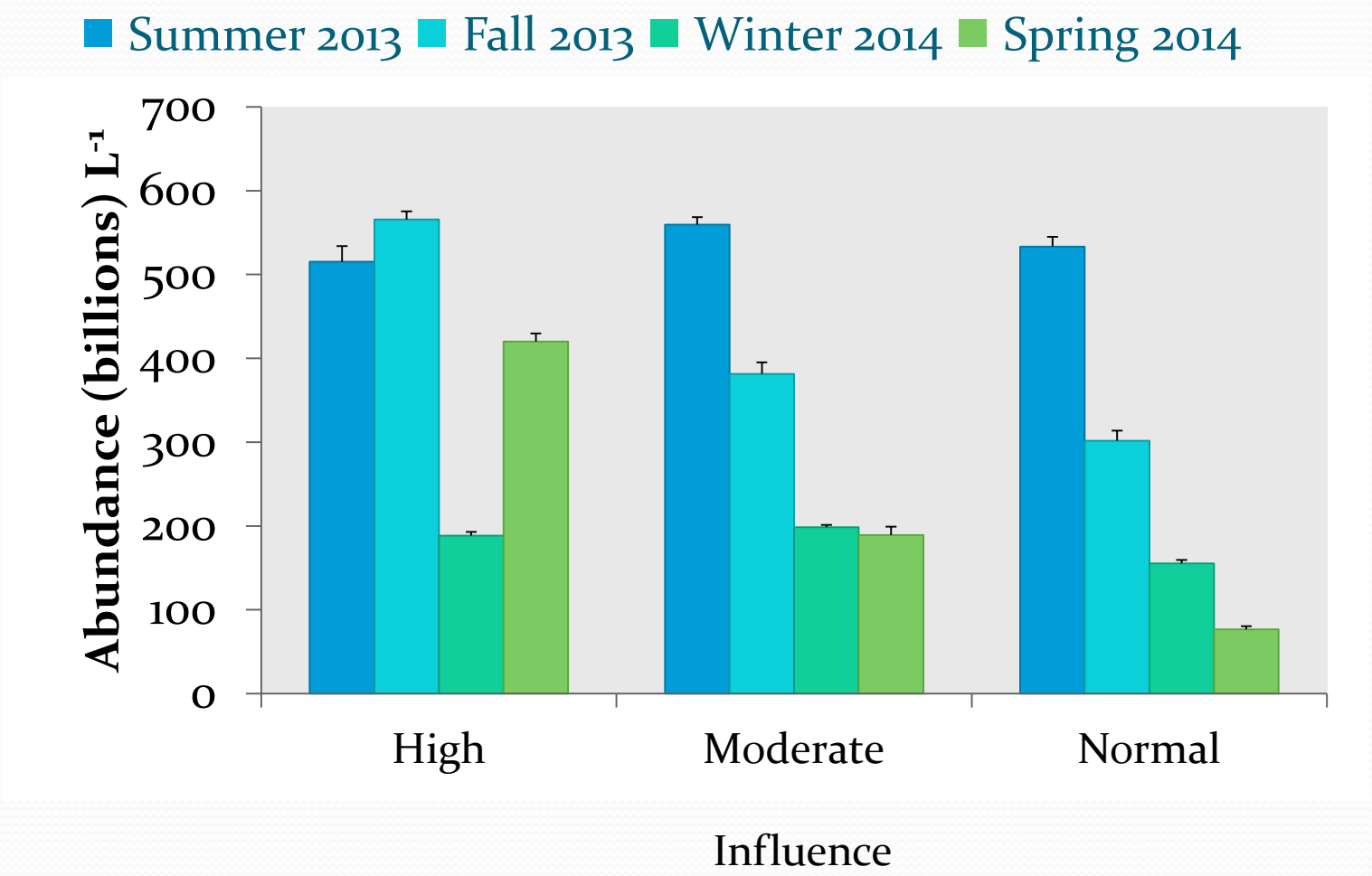


- Slides kept in dark container
- Placed on epifluorescent microscope with DAPI filter set and analysed with NIS Elements software
- Bacteria counted based on fluorescence and size
- Images “grabbed” quickly and saved before fluorescence faded
- Multiple fields imaged on each slide and exported to Excel



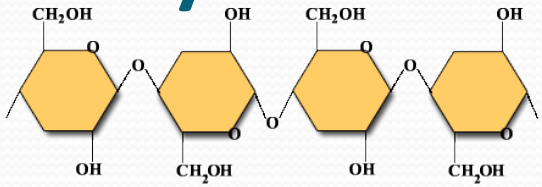
Bacterial Abundance

Pelagic

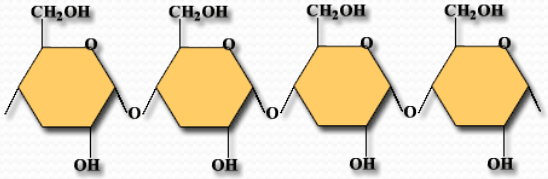


Digestibility of Carbon Sources

Cellulose

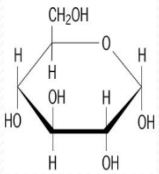


Starch



From: http://web.visionlearning.com/custom/chemistry/custom/

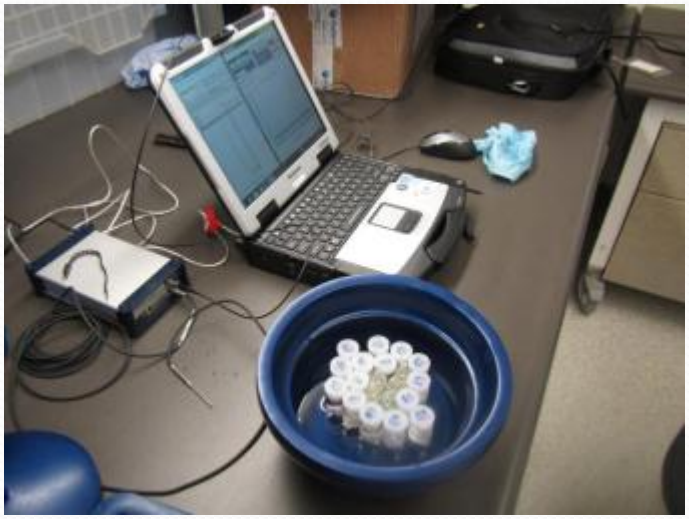
Glucose

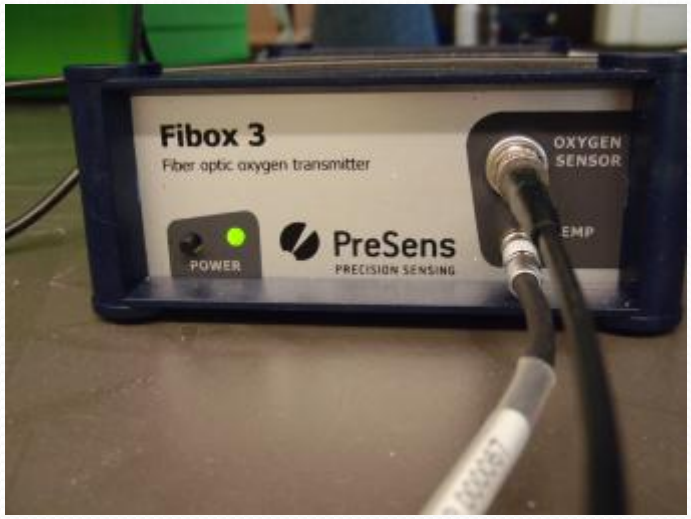


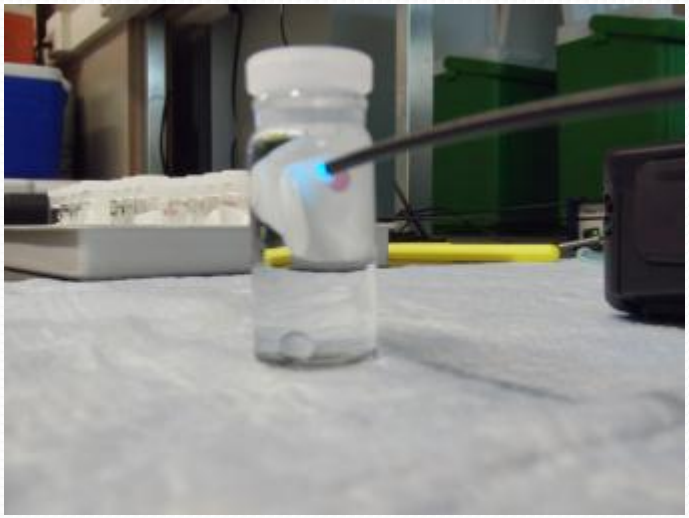
Carbon conversion factor

- $C_6H_{12}O_6\ (s) + 6\ O_2\ (g) \rightarrow 6\ CO_2\ (g) + 6\ H_2O\ (l) + \text{heat}$

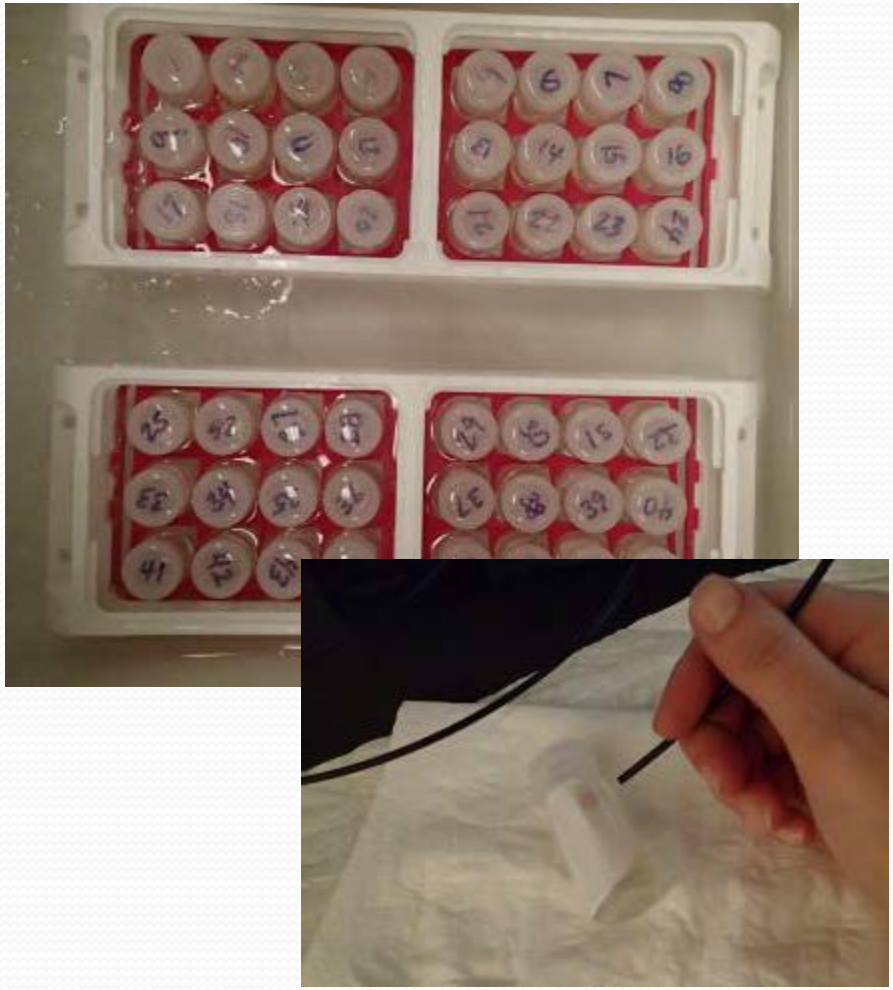
Oxygen measurements



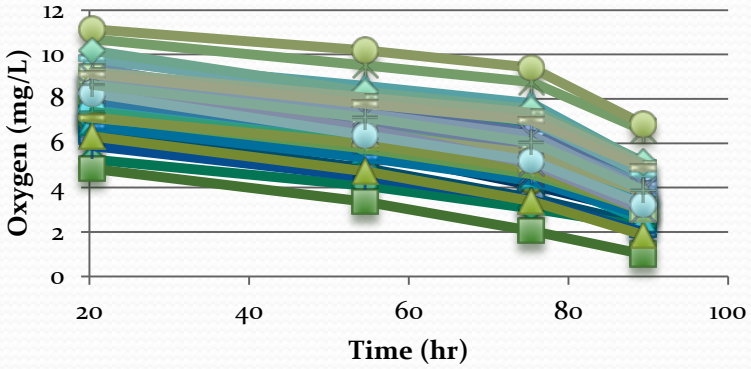




Microbial Community Respiration

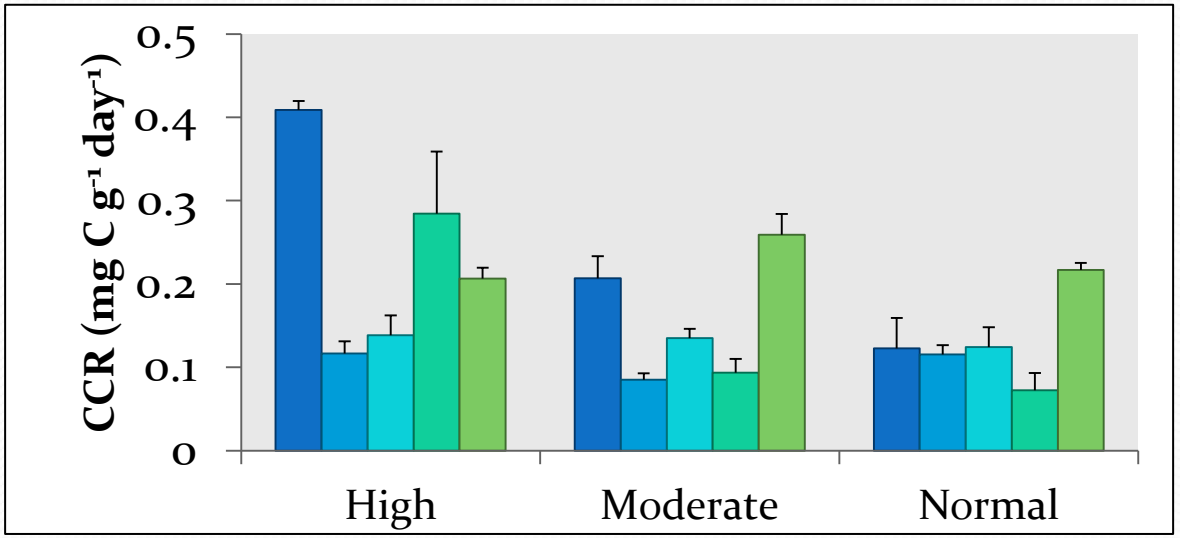


- **Filter** 800 mL through 0.2 µm filter funnel or ~1.7g of sediment.
- **Measure** the rate of oxygen consumption (mg/L/hr)
  - oxygen optodes attached to incubation bottles
  - Presens oxygen sensor (Fibox 3 ©)

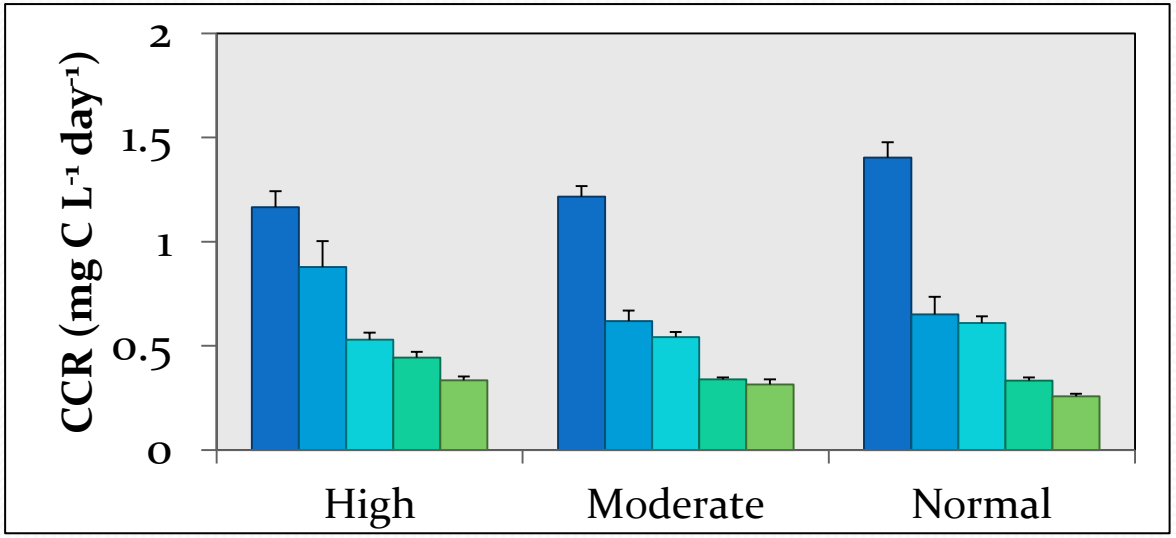


Spring 2013 Summer 2013 Fall 2013 Winter 2014 Spring 2014

Benthic

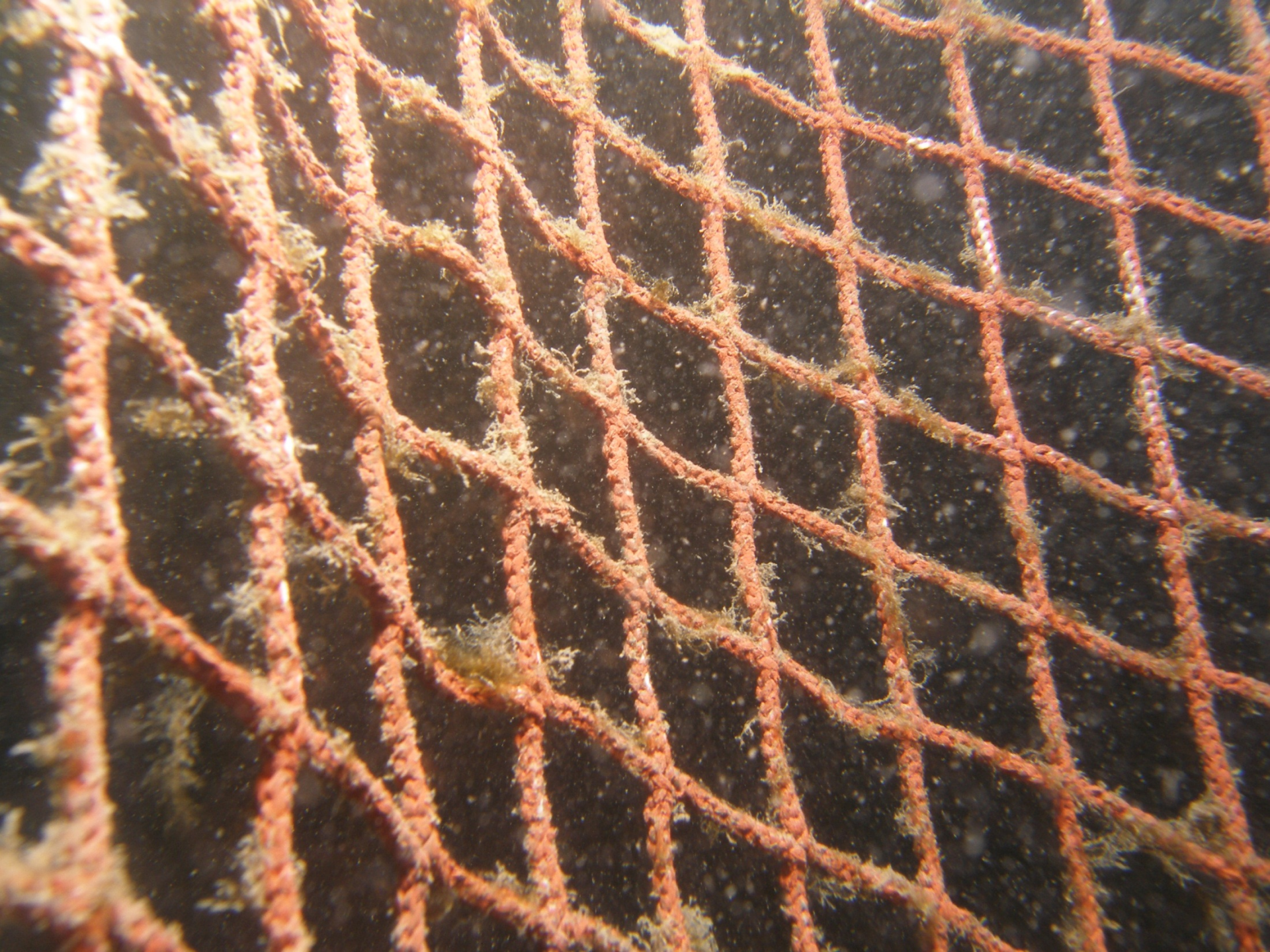


Pelagic



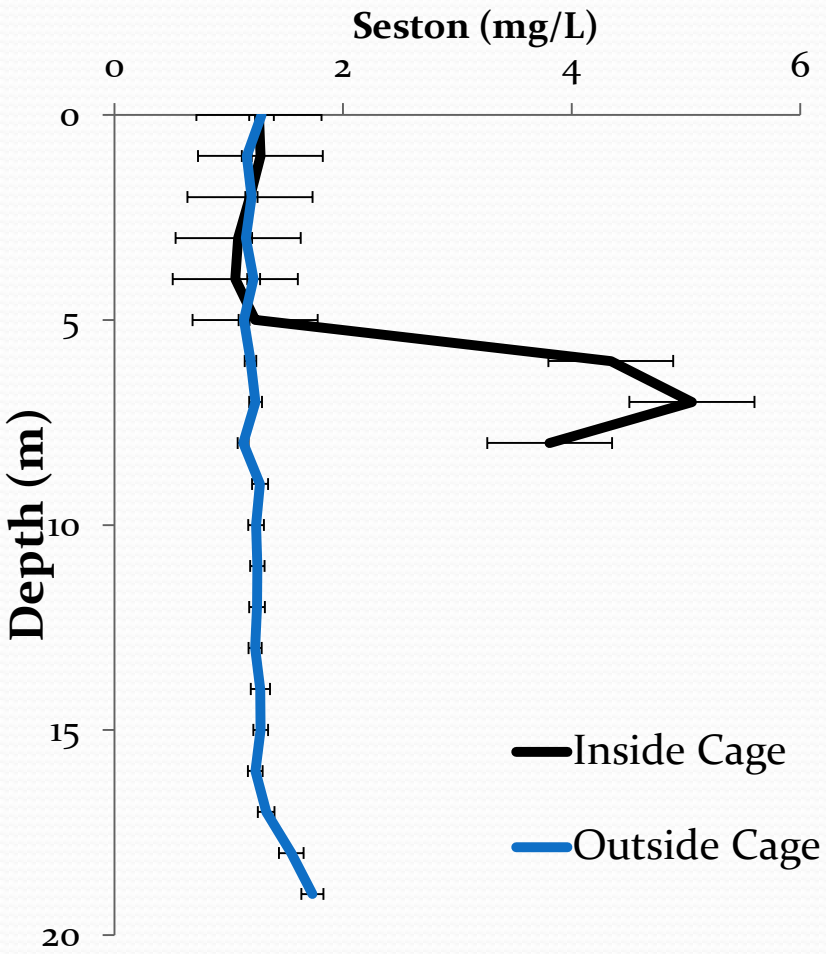
Questions

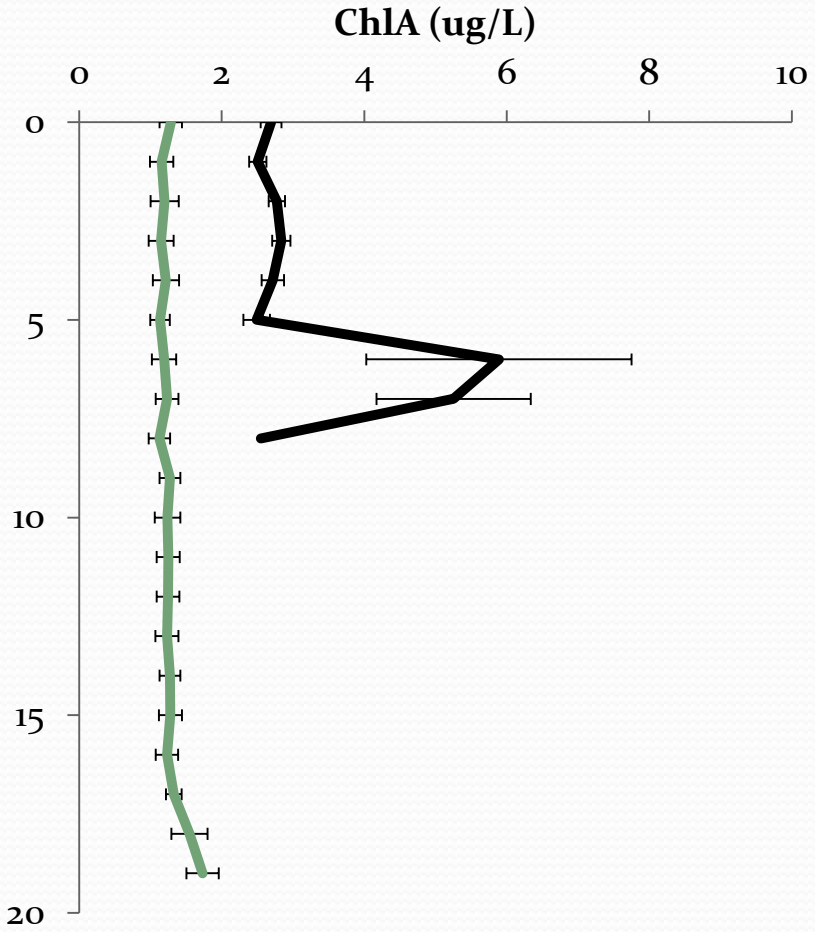
- How much material do we have to work with?
- Do bacteria (and other micro-organisms) make a noticeable difference?
- Are there any patterns of distribution?
- Can we predict their effects?
- Is it possible to use bacteria in aquaculture?

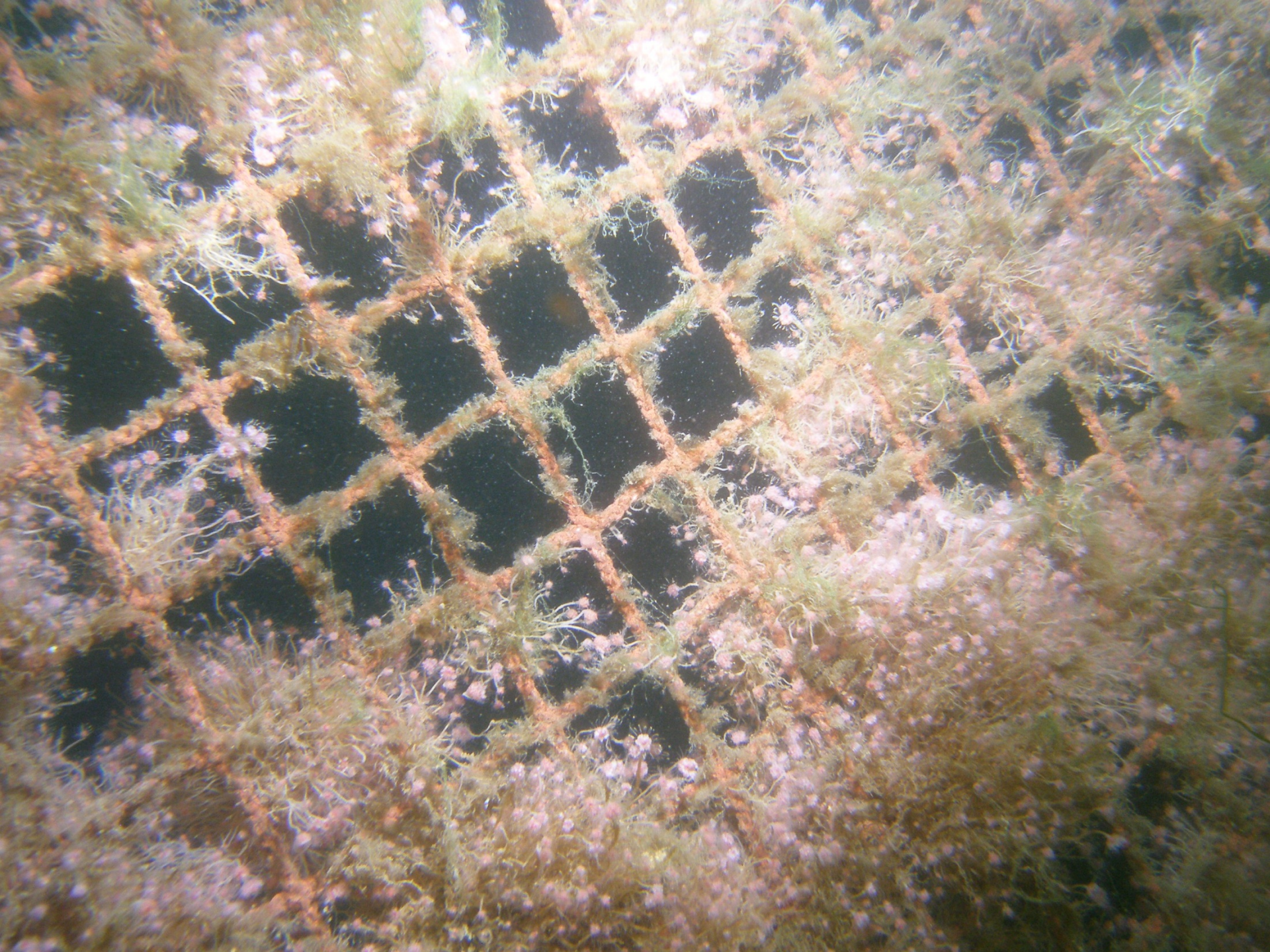


Measuring Seston and Chlorophyll

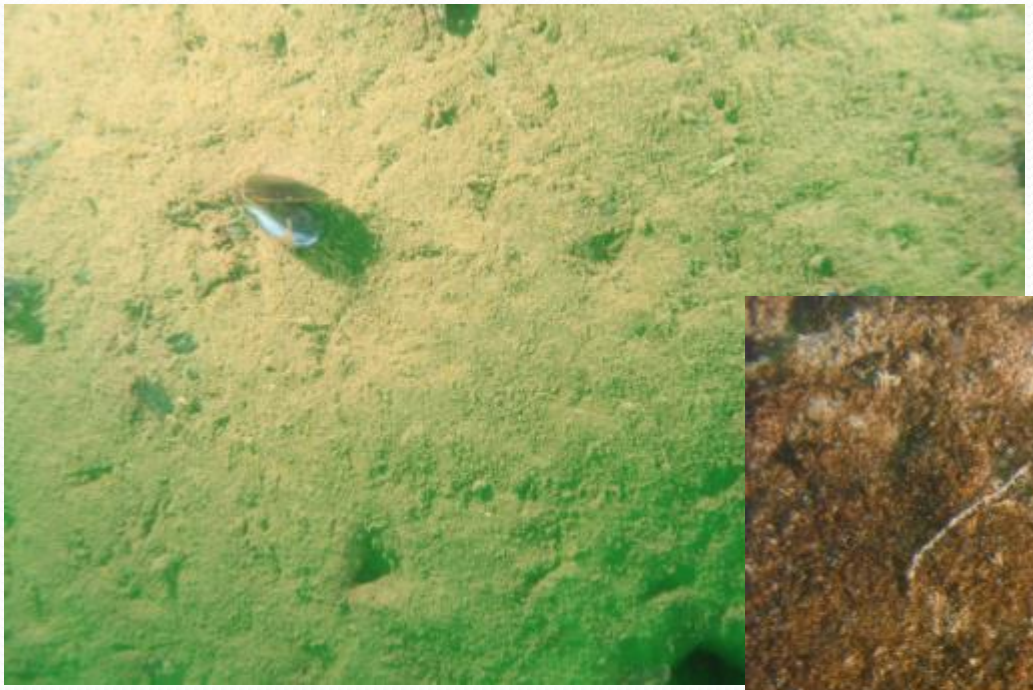
September 2014







Microscale environments



Potential directions

Increasing microbial surfaces

Summary

- Bacteria and other micro-organisms are an important constituent of aquaculture sites
- Only a small number are pathogenic and problematic to the farm. Most are doing something beneficial, that we do not know about.
- They appear to be rapidly converting the waste organic nutrients into organic forms that can be recycled into the surrounding ecosystem and taken up by seaweeds and algae. They may be significant competitors for IMTA species.
- They will contribute to the food web in the local area.
- The site can be looked at as a super-organism in the flow of energy that could be made more efficient in the future.

Acknowledgements

- This work was supported by the Natural Sciences and Engineering Research Council of Canada (NSERC) strategic Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN) in collaboration with its partners
  - Fisheries and Oceans Canada
  - The University of New Brunswick
  - Cooke Aquaculture Inc.
- The Atlantic Canada Opportunities Agency – Atlantic Innovation Fund
- Thanks to the captain and crew of the Canadian Coast Guard Viola M. Davidson for all their help

Update on (Winter?) Ulcer disease

Derek Price, Dave Groman, Jan Giles, and Sophie St-Hilaire

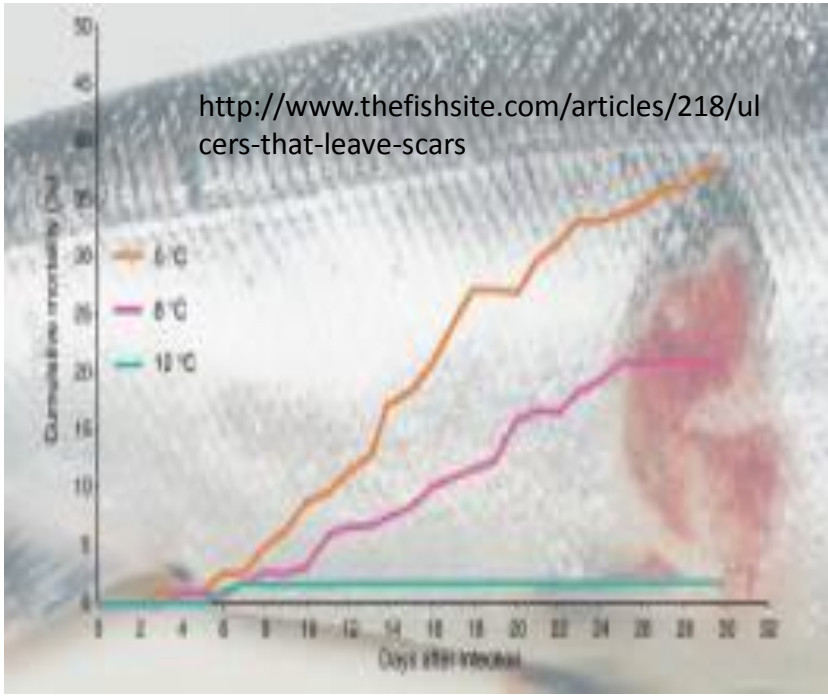
Norwegian experience

- Mixed pathogens but primarily
  - ***Moritella viscosa***
  - *Vibrio wodanis* +/-
  - *Tenacibaculum* sp. +/-
- Damage to skin increases risk of infection with *M. viscosa*

  but not necessary
- *M. viscosa* produces extracellular products: lipooliosaccharide & proteases
  - Cytotoxic effect and hemolysis
  - Biofilm that permits evasion of immune system
  - Increases mobility
  - Obstructs keratocyte re-epithelialization
  - Increases bacterial attachment

Norwegian experience

- Gross lesions consistent with cytotoxic effect
  - Fish die acutely
    - Within one week after lab exposure
  - Petechial hemorrhage in visceral organs
- Systemic infections
- Cold temperature <8 -10 ^{0}C
  - Farm mortality ~10%
  - Extracellular products temperature dependent
  - Commensal bacteria reduced at cold temperatures?
  - Fish immunity reduced at cold temperatures?
- Poor response to antibiotics
  - Fish off feed when they die

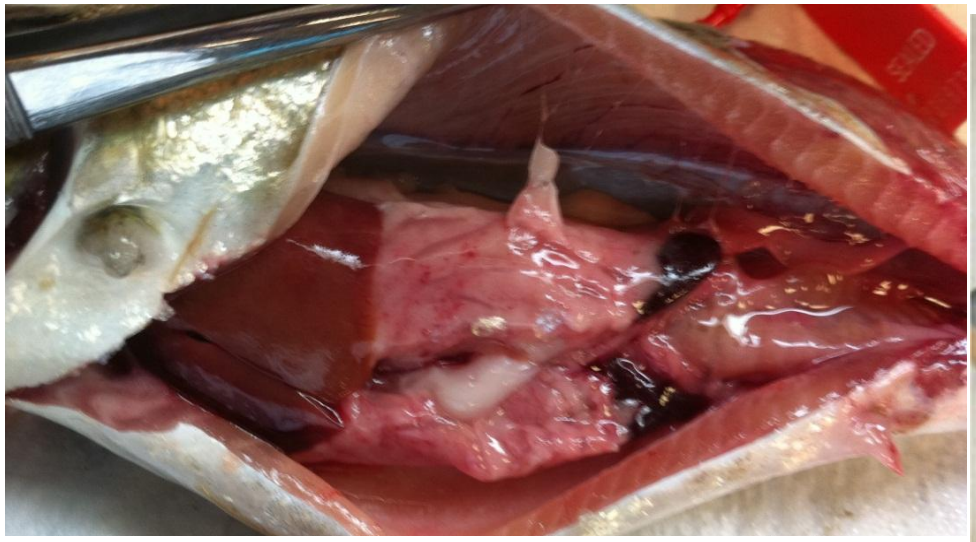


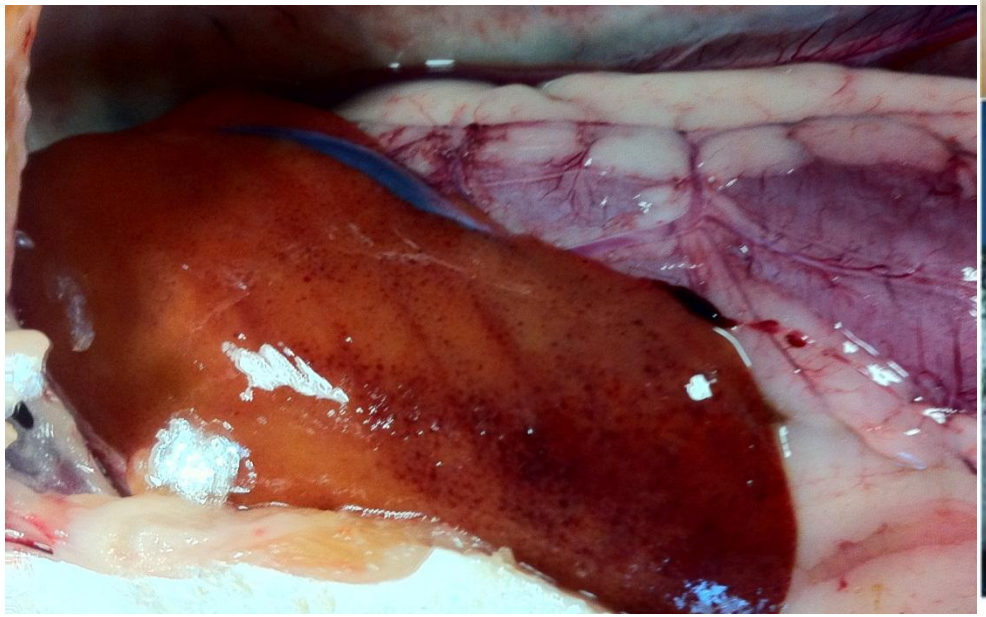
Ulcer disease in Canada

Norway Ulcer disease associated with *M. viscosa*

Gross clinical signs

Canada





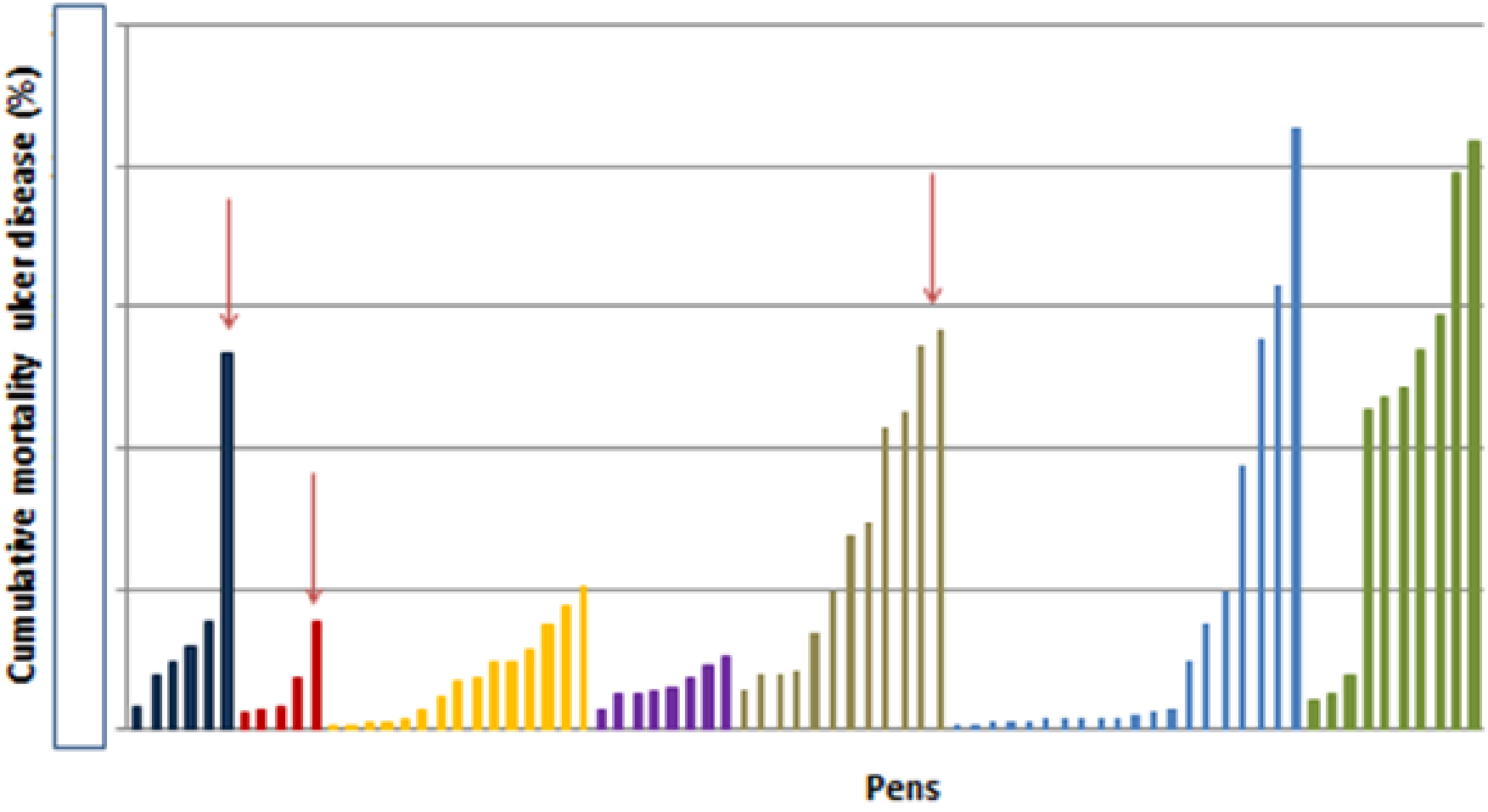
Norway

http://www.fom-as.no/no/nyheter/32/

Canadian experience

- Ulcer disease occurs at various temperatures incl. >10 ^{o}C
- Fish go off feed before the ulcer is advanced
  - Fish with early signs had food in lower intestine
  - Consistent with cytotoxins and hemolysin?
- Mortality rate ranges between farms and within pens on farms

Cumulative mortality for ulcer disease for 7 farms



Range of mortality within pens and between farms

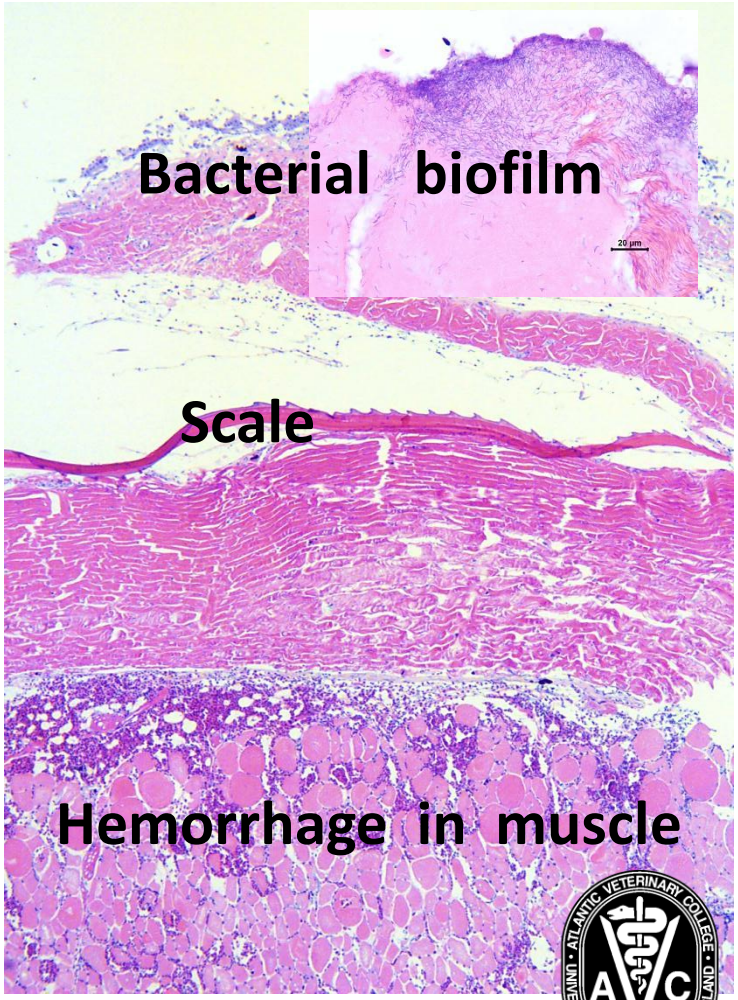
Preliminary Culture Results

- Skin cultures (n= 7)
  - All fish had moderate to heavy mixed growth
    - Unable to tell what was primary cause of lesion.
    - *M. viscosa* not detected
      - Norwegian study only detected *M. viscosa* 39% of cases by culture but 88% by PCR
- Kidney cultures (n=12)
  - Early lesions had no growth (n=3)
  - Advanced lesions had mixed growth (5/9)
    - Many not infected systemically

http://www.thefishsite.com/fishnews/11002/norwegian-researcher-sheds-light-on-winter-ulcer

Imprint and Histological findings

- Imprints of kidneys
  - Negative (n=6)
- Histology (n=6)
  - Ulceration of skin with necrosis of skeletal muscle
  - Evidence of colonization with mixed bacterial populations
  - Kidney, gill, pyloric caeca, pancreas, spleen
    - No significant morphological changes or evidence of bacteria
- Suggests no systemic infections



Research Questions

Prevention

- Vaccination
  - What organism(s) do we vaccinate against ?
    - Examine more cases and determine primary pathogen(s)
      - Make sure we have the appropriate organism before we engage in experiments
  - Should we be targeting mucosal antibodies if we are trying to prevent ulcer formation?

Blood chemistry suggests mortality is from osmoregulatory problems

	Sodium (nmol/L)	Chloride (nmol/L)	Potassium (nmol/L)
Normal range	150 -180	127 -136	0.6-2.9
Fish with early lesions (n=2)	168	132	3.4
Fish with advanced lesions (n=6)	203	164	7.3

Treatment of ulcer disease

- Need to prevent ulcers
- Bacterial disease (antibiotics)
- Two Problems
  - Need to get antibiotics in the skin
  - Fish go off feed shortly after they develop skin lesion
    - Treated very early in the disease process

Research Questions

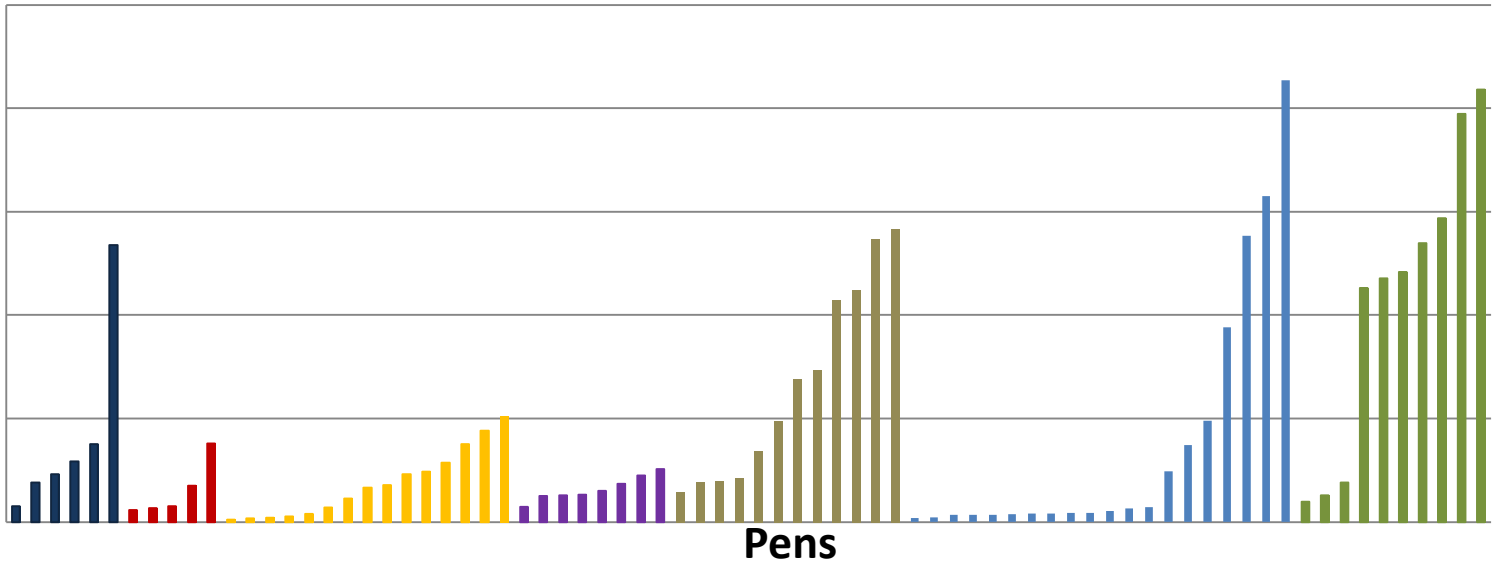
Control

- How do we improve treatment efficacy?
  - Evaluate different dosages of different products for their concentration in the **skin**
  - Can we improve efficacy by starting treatment earlier in the disease process ?
  - Would probiotics help?

http://www.marvesa.com/site/products/feed_fish_oils.html

Research Questions

- Are there risk factors that predispose or increase mortality associated with ulcer disease?
  - Why do we see such a wide range of mortality within a farm with this disease?
    - Data on pen level mortality, treatments, and events surrounding outbreaks



Research Questions

http://www.vetcare.gr/ARTPRES/Fish_Vaccination_Strategies.htm

- Is the cytotoxic effect of the bacteria temperature dependent ?
  - Can exposure at non-virulent temperatures induce protection against this organism?
    - What is the primary organism(s)!

Acknowledgements

- CERC for funding
- East and West Coast fish farmers and divers for samples and data

Contact information to participate in our ulcer disease project 2014/2015

- Derek Price (dprice@upei.ca) &
- Sophie St-Hilaire (ssthilaire@upei.ca)
  902- 620-5190

Where are all the sea lice? Searching Cobscook Bay

M. Pietrak, C. Frederick, A. Jensen, S. Barker, G. Zydlewski, D. Brady and I. Bricknell

1865 THE UNIVERSITY OF MAINE
AQUACULTURE Research Institute

1865 THE UNIVERSITY OF MAINE
School of MARINE SCIENCES

Joining of Two Labs

The Larger Project

Farmed Fish

Sea Lice

Local Ecosystem

Sea Lice

2- Pronged Approach

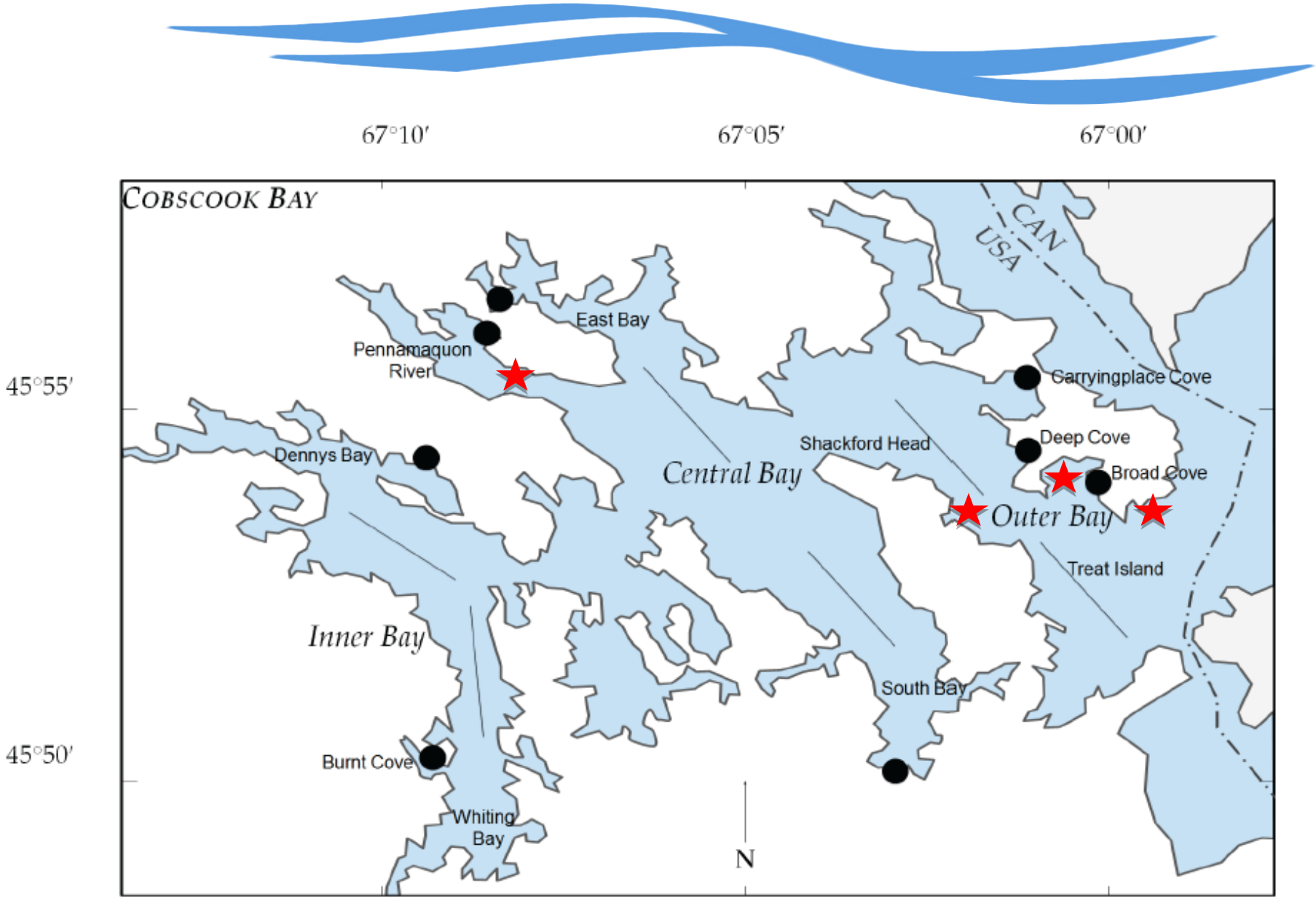
Wild Fish Sampling

Sentinel Cages

Wild Fish Sampling

- Joined years 2 & 3 of Cobscook Bay survey
- Benthic & Pelagic Trawls
- Intertidal Seining
- Day & Night samples
- May - November

Cobscook Bay

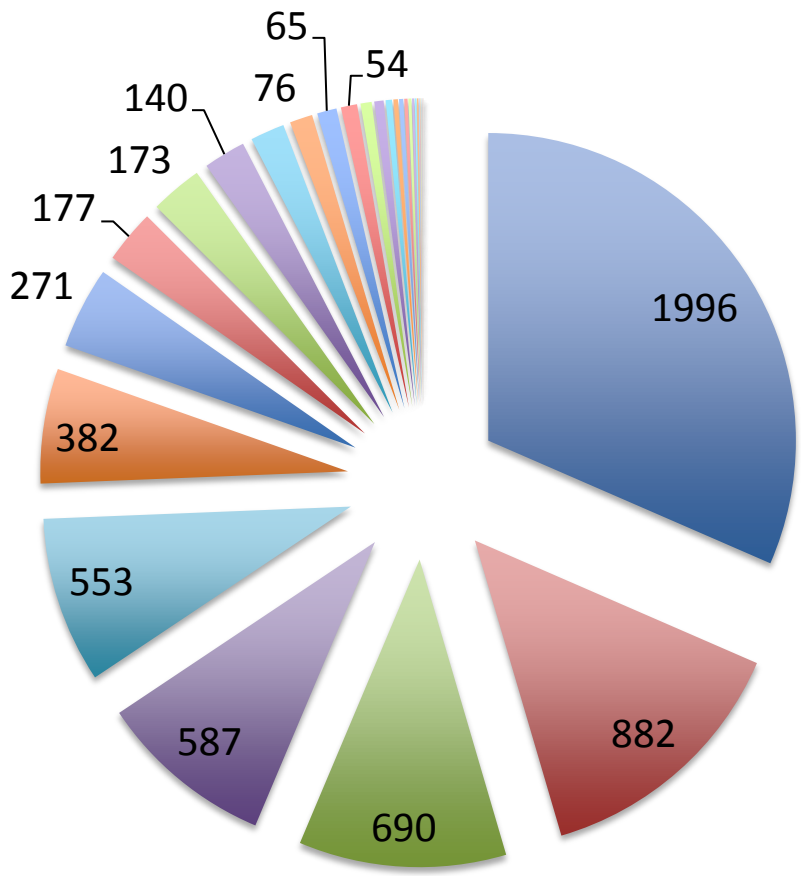


Fish Processing

- Fish were ID'd weighed & lengthed
- Examined all fish for lice

- Keep fish with lice
- Subset of sticklebacks

Composition of Fish Caught – Yr 1



Threespine stickleback

Blackspotted stickleback

Winter flounder

Mummichog

Atlantic herring

Atlantic silverside

Alewife

Longhorn sculpin

6,329 Total Fish – 34 Species

Vieser, J. 2014 MSc Thesis

Sea Lice on Wild Fish

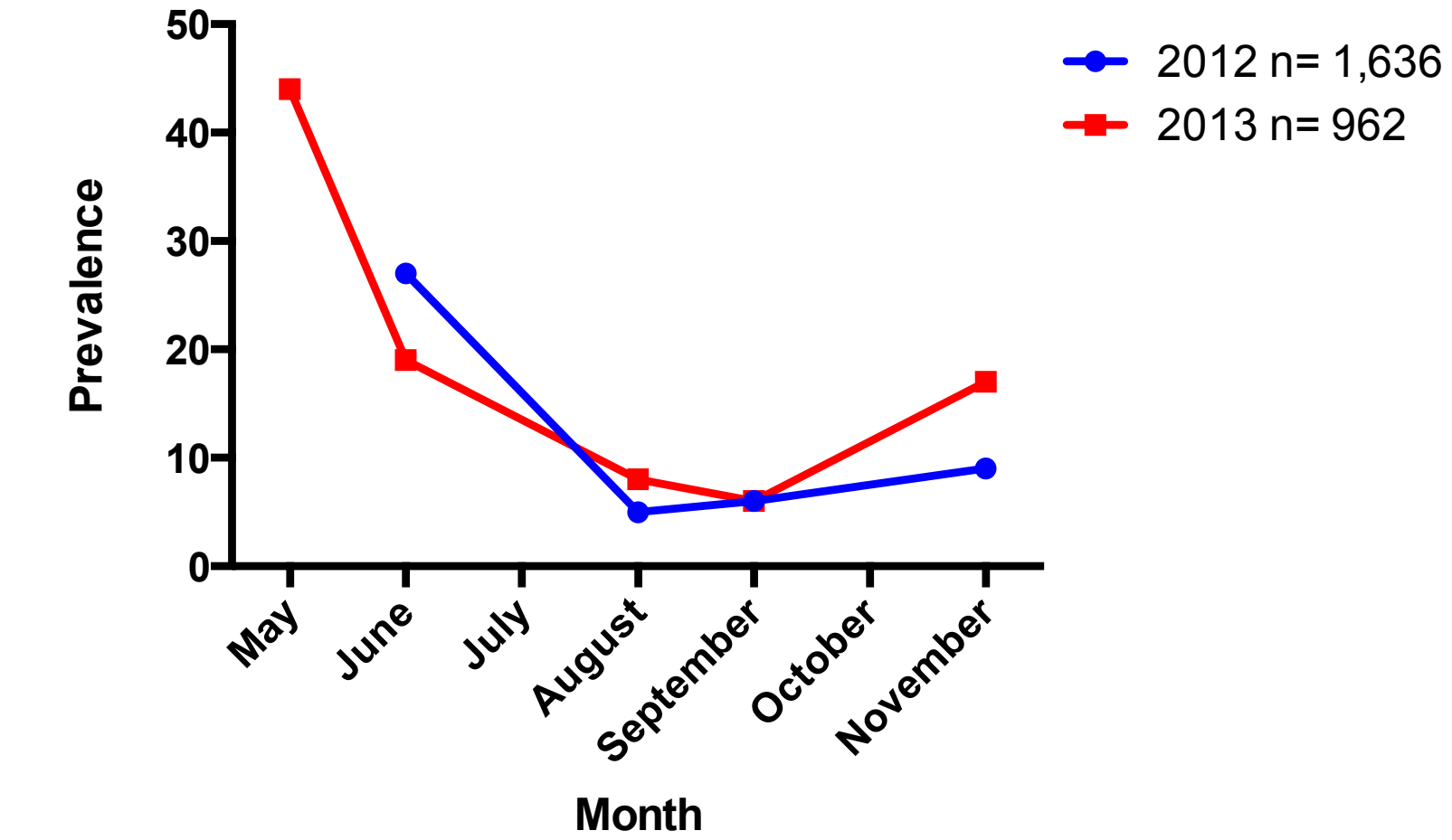
All lice were *Caligus elongatus* Genotype 1

Found lice on 10 species

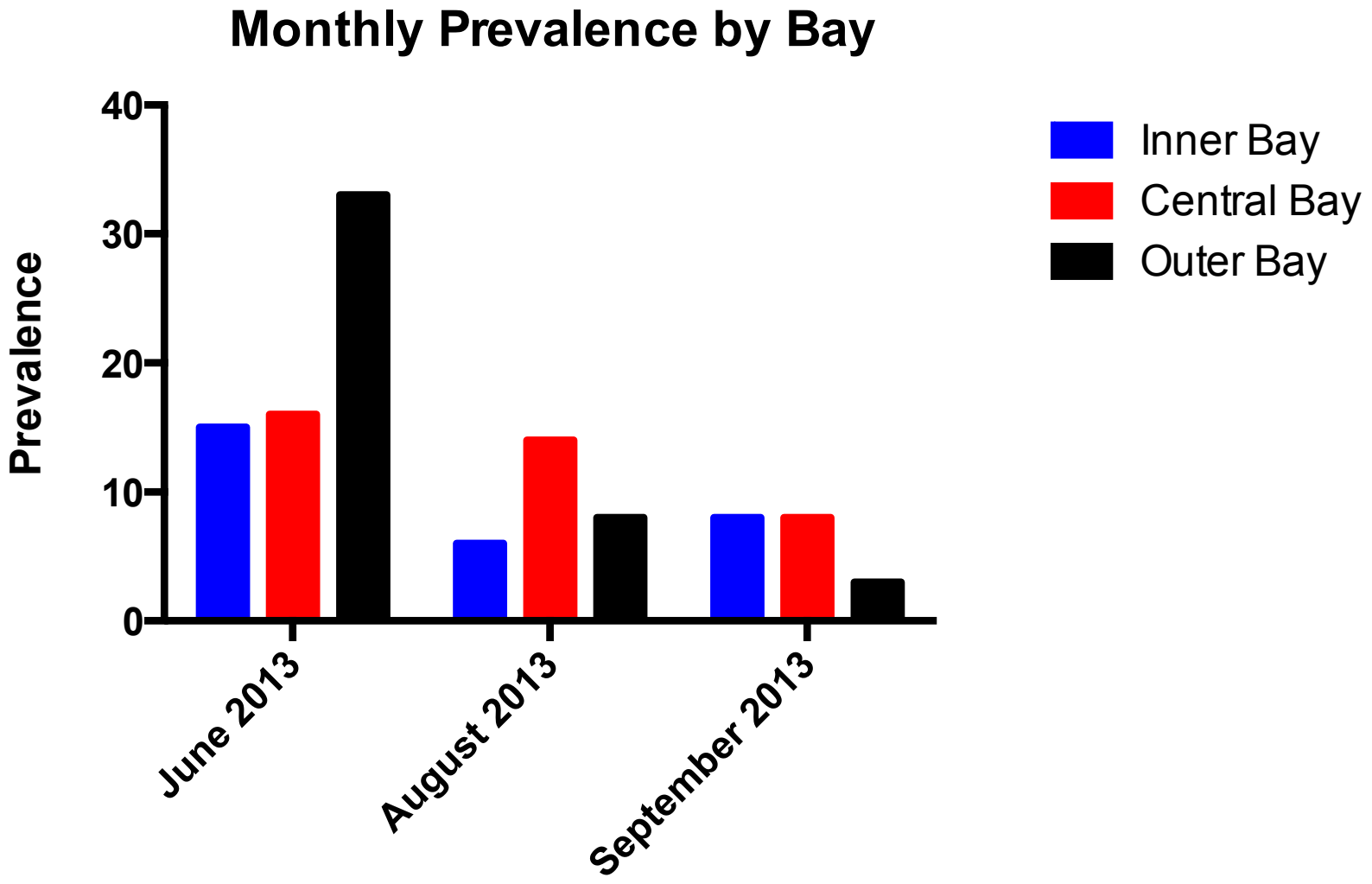
Prevalence on Threespine Stickleback

2012	12%
2013	17%

Monthly Prevalence



Differences Between Bays



Conclusions – Wild Fish

Caligus elongatus is most prevalent in spring and late fall

Distribution can vary in between bays

2- Pronged Approach

Wild Fish Sampling

Sentinel Cages

Collecting Sea Lice Data from the Field

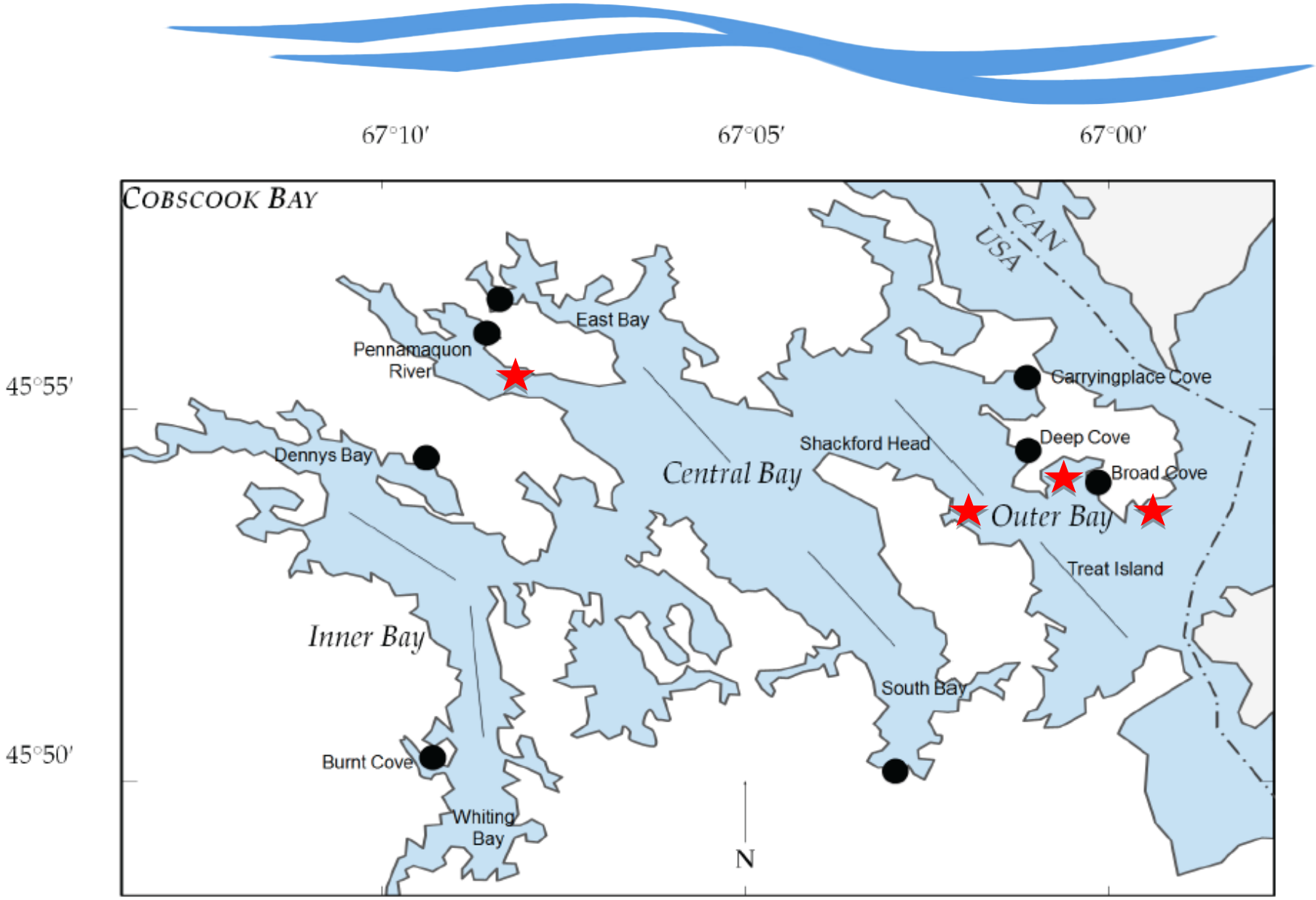
Fish Deployment

Fish Examination

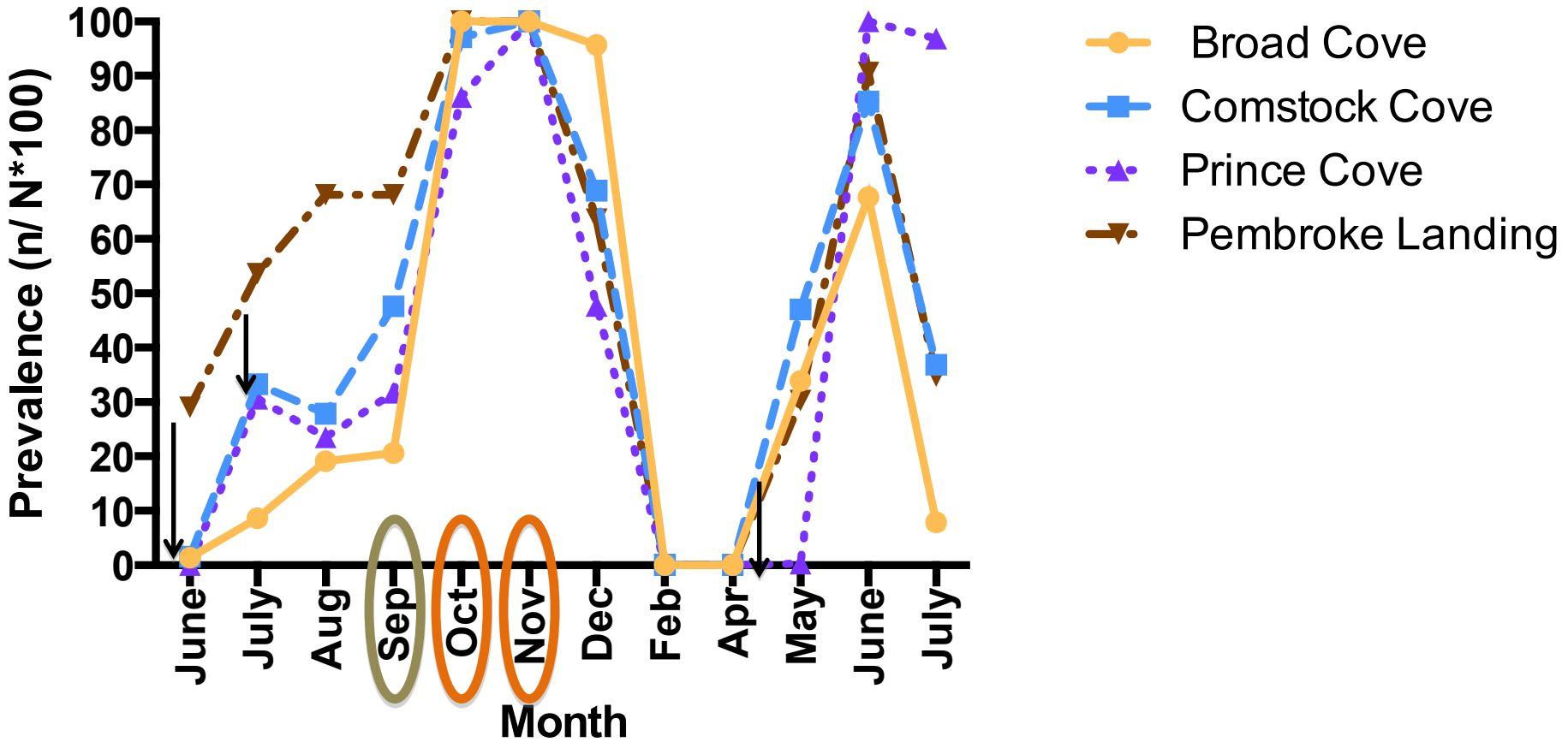
Fish Retrieval

Sentinel Cages

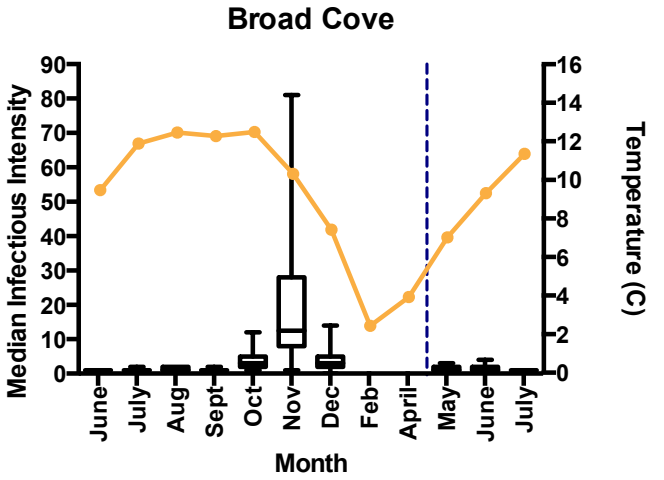
Cobscook Bay

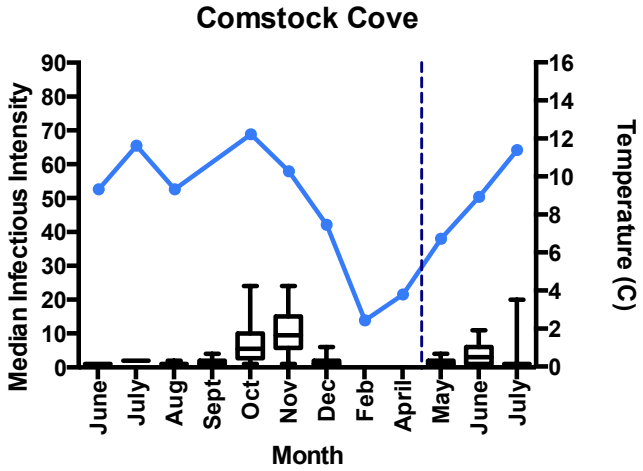


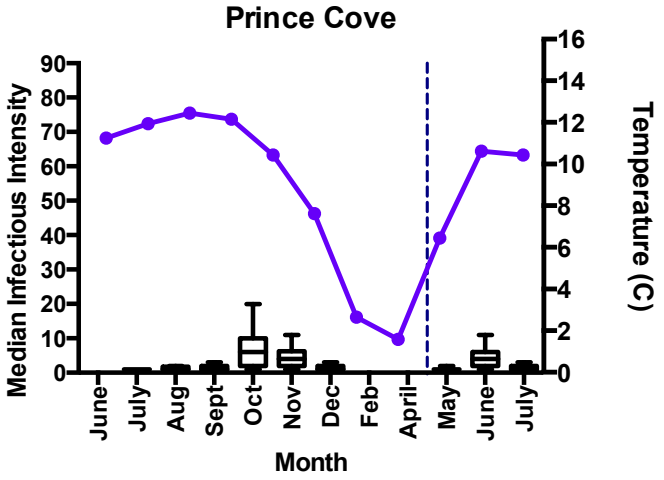
Prevalence of Sea Lice Infection in Cobscook Bay

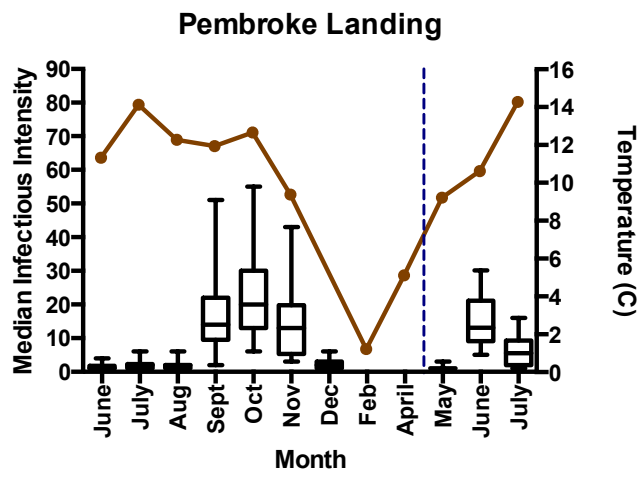


Infectious Pressure of Sea Lice in Cobscook Bay



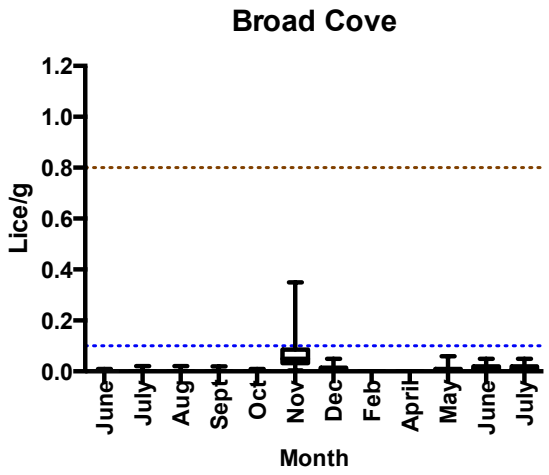


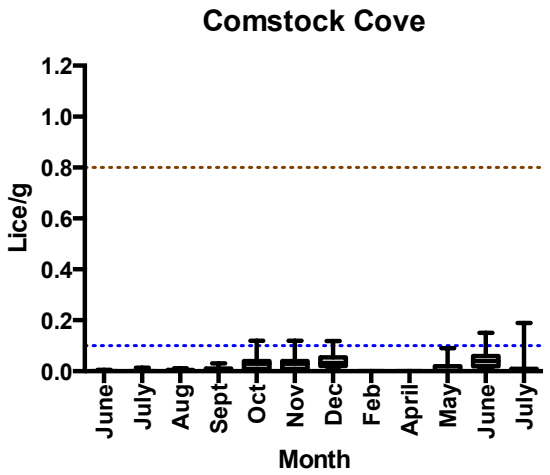


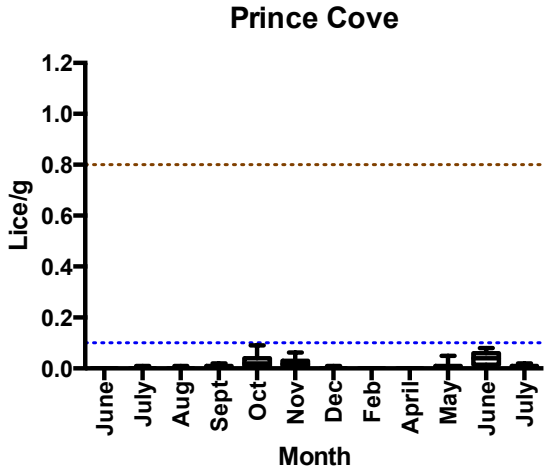


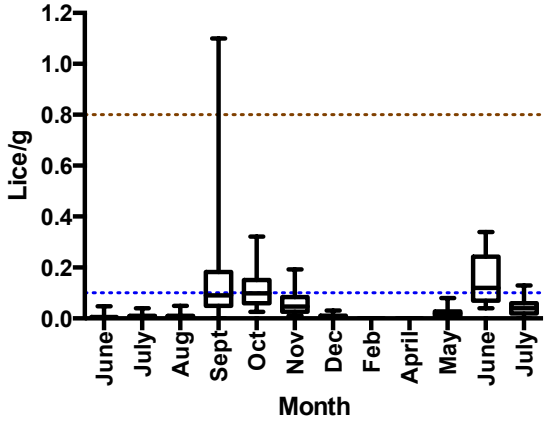
Observed Infection Levels in Cobscook Bay

Wagner et al. 2008 taken from Grimnes and Jakobsen 1996









Conclusions

Peak infectious pressure from September-November, with 0% infectious pressure over the winter

Low infectious pressure between March-June, when wild smolts are migrating

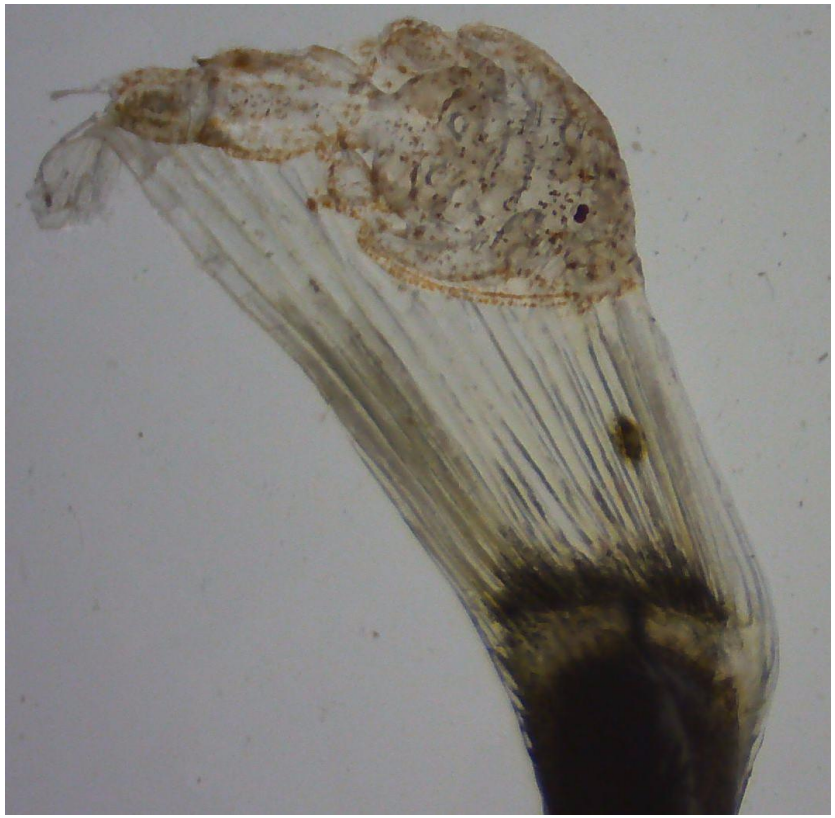
The infectious pressure in Cobscook Bay for caged fish rarely exceeds levels impacting physiological health

Implications

Wild reservoirs for *L. salmonis* remain to be found in Cobscook Bay

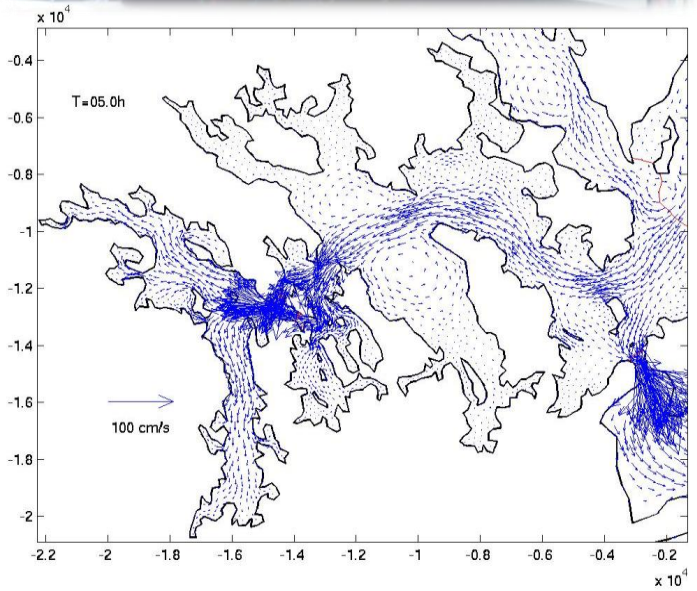
Fallowing should be an effective management strategy for controlling L. salmonis on farms

Infectious pressure is low during the outmigration window for wild smolts



Longer-Term Project

- Continuing Field Work
- Species Differentiation
- In-lab experimentation
- Agent Based Modeling and CART analysis



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Sea Grant Maine

Sea Grant National Sea Grant College Program

TARPAULIN TREATMENTS 2014

Julie Bugge

Norway

Aqua Pharma

Capacity bath treatments (All medicines)

- 3-4 x 157 m cages pr. day (2,5-3,5 hrs/cage)
- 4-5 x 120 m cages pr day

- 500 – 2800 tons of salmon pr day (depending on fish size)

Aqua Pharma

”Large and smaller vessels”

Aqua Pharma

”Large and smaller vessels”

Aqua Pharma

Work vessels

Aqua Pharma

Water quality

- Visibility min 6 m in Norway (Algea)
- Visibility min 4 m in Norway (humus/freshwater)

- Take algea samples (start sampling 4 days before treatment and do it daily)

Aqua Pharma

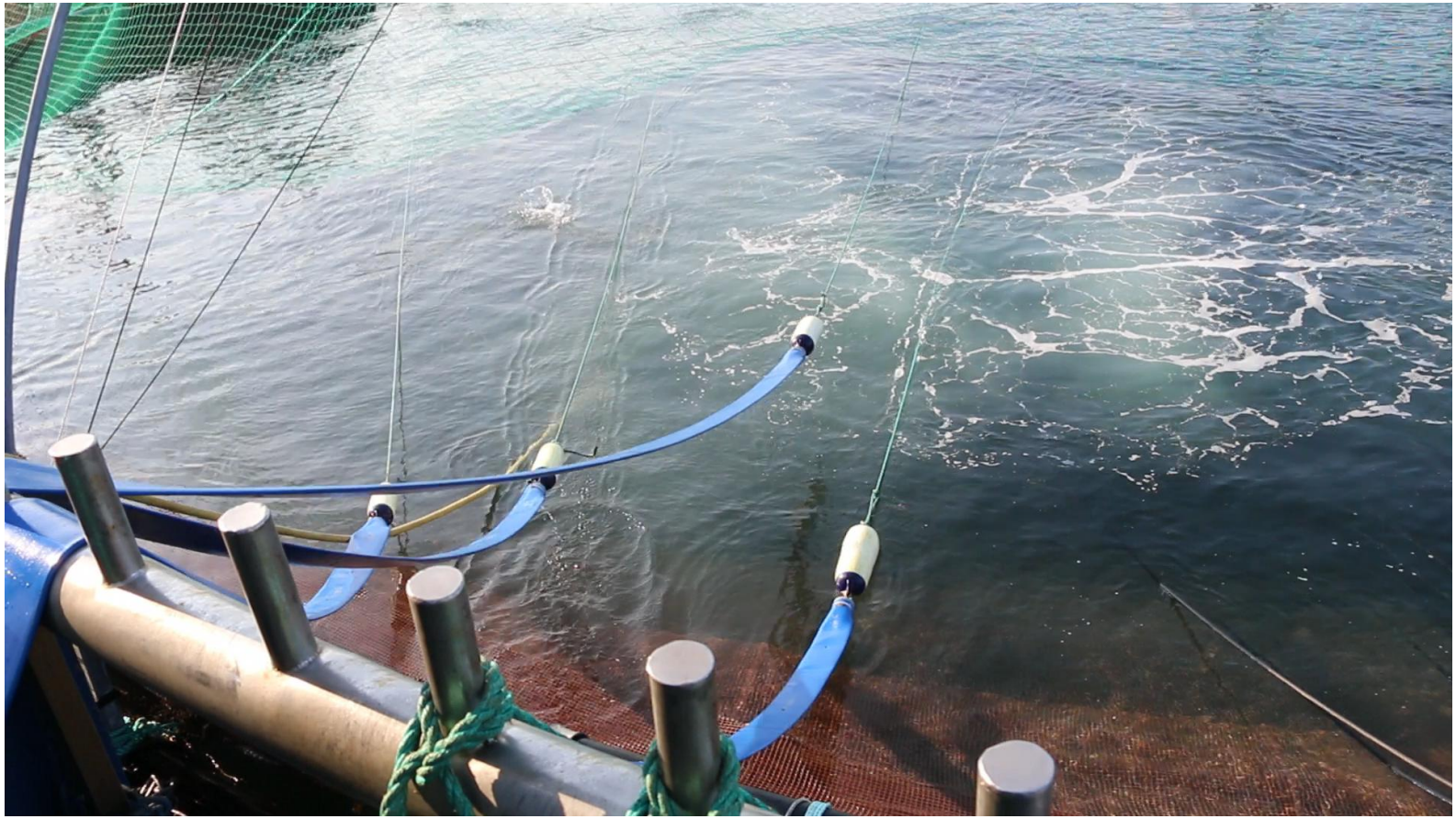
Arrival in the morning

Aqua Pharma

Oxygen Hoses

Aqua Pharma

Dosing Hoses



Aqua Pharma

Connecting hoses

Aqua Pharma

Tarpaulin / Triplex

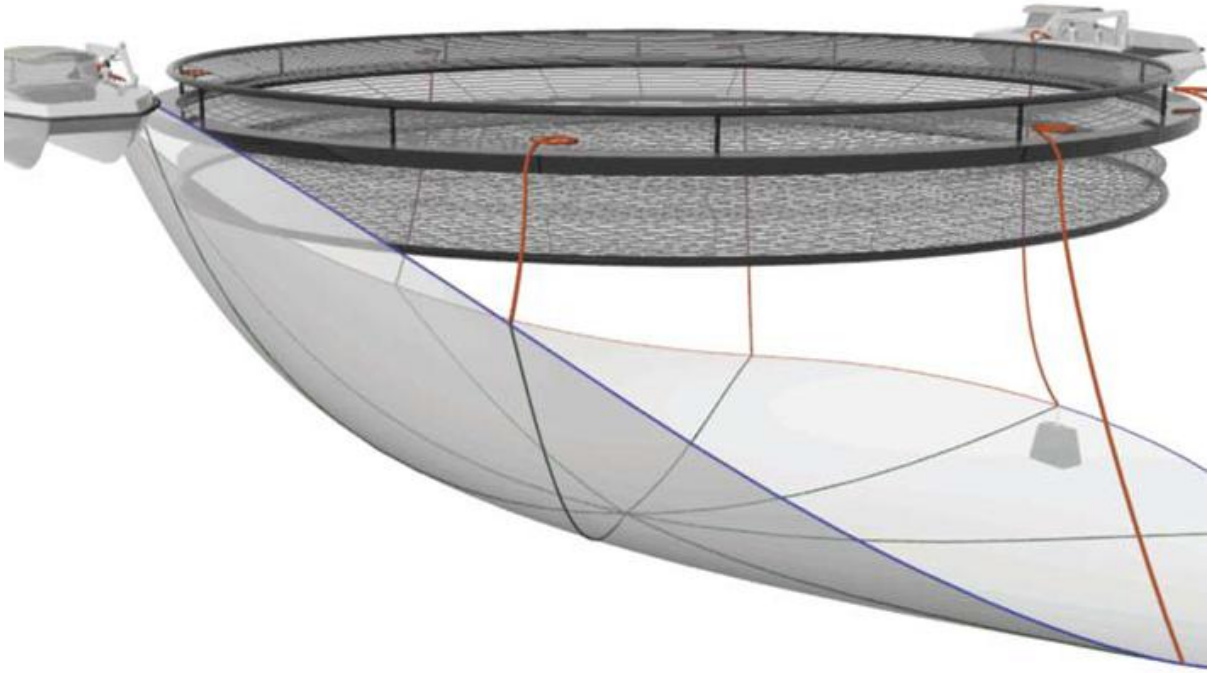
Aqua Pharma

Tarpaulin

Aqua Pharma

Tarpaulin types

- Flat, china hat and muffin



Aqua Pharma

Connecting Tarpaulin

Aqua Pharma

Dosing unit

Aqua Pharma

Dosing

Aqua Pharma

Holding time

Aqua Pharma

Fish during treatment

Aqua Pharma

Fish during treatment

Ending treatment

Aqua Pharma

Tarpaulin intake + Bottom ring

Aqua Pharma

Effect and success factores

- Effect similar to wellboat treatment

- Important parameters
  - Kg/m3 (60-65 kg/m3)
  - Stabile O2-values

Aqua Pharma

End…

Aqua Pharma