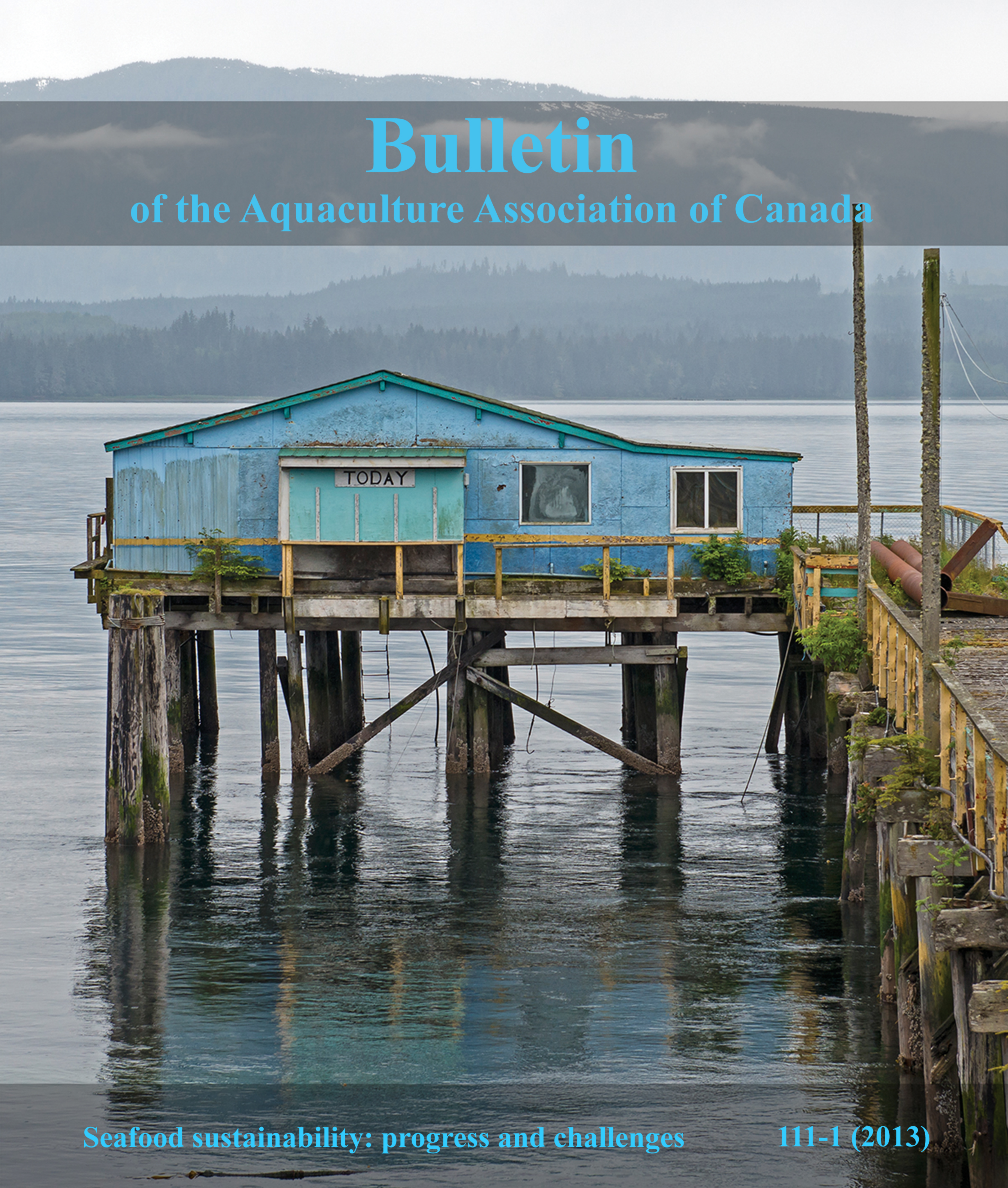
Bulletin

of the Aquaculture Association of Canada



Seafood sustainability: progress and challenges

111-1 (2013)

Bulletin

de l'Association aquacole du Canada

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of the Aquaculture Association of Canada

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Seafood sustainability: progress and challenges

Shelley King

Introduction from the President

I'd like to welcome you to the latest issue of the AAC Bulletin, "Seafood sustainability: progress and challenges". This timely issue covers a diverse range of topics from improved methods of scallop culture, to the environmental regulatory challenges of monitoring salmon farms in Atlantic Canada. However, sustainability here is not just restricted to aquaculture proper. Modern aquaculture now accounts for more than half the global seafood consumption. Given this new reality and the inexorable link between aquaculture and fisheries, sustainability of both seafood sources should be considered in consort. Articles in this issue pursue this theme. Perspectives on seafood sustainability certification programs and the merits of eco-labelling are reviewed in a discussion forum, by grocers, scientists, marketers, fishermen, government and a professional chef; the Benthic Ecology Workshop celebrates 30 year of promoting fisheries and aquaculture research in the wider ecosystem; and a mass mortality of stocked tilapia is documented along with the lessons learned. While the AAC is a Canadian organization, its members and colleagues have a global interest in sustainability and this is reflected in the enclosed articles. Perspectives from the USA, Europe and Africa are also represented. We are not facing these issues in isolation. I therefore invite you to peruse this issue and share with us, some of the advancements and trials in seafood sustainability.

Shelley King
President of the Aquaculture Association of Canada

Mot de la Présidente

Je tiens à vous présenter la dernière édition du Bulletin de l'AAC, "Durabilité des produits aquatiques marins: progrès et défis". Cette question d'actualité couvre un large éventail de sujets allant de l'amélioration des méthodes de culture du pétoncle, aux défis que posent la réglementation environnementale et les programmes de surveillance des élevages de saumon au Canada atlantique. Cependant, la durabilité ici ne se limite pas à l'aquaculture comme telle. L'aquaculture moderne fournit désormais plus de la moitié de la consommation de fruits de mer mondiale. Compte tenu de cette nouvelle réalité et du lien inexorable entre l'aquaculture et les pêches, la durabilité de ces deux sources d'approvisionnement doit être considérée globalement. Les arrticles dans ce numéro abordent cette thématique. Les programmes de certification de la durabilité des produits de la mer et les mérites de l'éco-certification sont discutées par des détaillants, des scientifiques, des professionnels de la mise en marché, des pêcheurs, des représentants gouvernementaux et un chef professionnel ; l'atelier d'écologie benthique célèbre 30 années de promotion de la recherche halieutique et aquacole dans une perspective écosystémique; et une mortalité massive de tilapias et les leçons apprises sont documentées. Bien que l'AAC soit un organisme canadien, ses membres et collègues ont un intérêt beaucoup plus large en termes de durabilité, intérêt qui se reflète dans les articles ci-joints. Des perspectives en provenance des États-Unis, de l'Europe et de l'Afrique sont également présentées. Nous ne sommes pas les seuls à être confrontés à ces problèmes. Je vous invite donc à prendre connaissance de ce numéro et à partager avec nous vos progrès et travaux visant la durabilité de l'approvisionnement en fruits de mer.

Shelley King
Présidente, Association aquacole du Canada

How the Aquaculture and Innovation Market Access Program (AIMAP) helps foster aquaculture sustainability: A case study with scallop culture in the Bay of Fundy

G.M. Falk, S. Backman and J. Gallie

Gloria Falk

The Department of Fisheries and Oceans Canada (DFO) through its Aquaculture and Innovation Market Access Program (AIMAP), aims to help the Canadian aquaculture industry enhance its sustainable performance by refining management techniques and technologies. From 2008-2013, AIMAP funding was provided to innovative aquaculture projects that contributed to sustainable production (e.g. increased productivity or reduced production costs), increased species diversification, enhanced environmental performance, or market access. A good example of an AIMAP project is that of the scallop producer, Magellan Aqua Farms. Existing salmon cage technology was modified into more effective, environmentally friendly scallop rearing units, while an Integrated Multi-Trophic Aquaculture approach with sea urchins, successfully controlled cage fouling.

Introduction

Magellan Aqua Farms is a family owned artisan shellfish aquaculture operation with a scallop farm in Passamaquoddy Bay (Bay of Fundy, NB) producing premium farmed scallops for the local white tablecloth market. The company continually seeks innovative, sustainable ways to improve their scallop culture efficiencies, and AIMAP provided an excellent opportunity to improve the effectiveness of their scallop culture operation.

The standard practice for suspended scallop culture utilizes lantern nets, originally developed for suspended oyster culture. Lantern nets have long been used because their design enables access to food sources and protection from predators. The disadvantage however, is the high operation and maintenance cost relative to their rearing capacity. As part of the company's ongoing efforts to increase sustainable production, Magellan Aqua Farms investigated innovative methods to improve grow-out efficiencies, by combining modified salmon cage technologies with traditional lantern culture methods for cultured scallops and other symbiotic co-cultured species.

"Lantern nets have long been used because their design enables access to food sources and protection from predators. The disadvantage however, is the high operation and maintenance cost relative to their rearing capacity."

The objectives of the project were to:

1. Design and build a prototype cage for improved husbandry
2. Develop the operational needs of the prototype cage
3. Assess the performance of the prototype cage with sea urchins to reduce bio-fouling. and manual cleaning

Methods

Prototype cage

The innovative prototype design used the standard salmon farm "bird-net" support stand reinforced with a honeycomb shaped hub to both provide rigidity and to ensure uniform distribution of scallops. The cage was sized to enable significant production increase compared to traditional lantern nets. Typical salmon cage bird-net support stands are constructed of HDPE welded pipe and can vary in size but are frequently 20m in circumference x 2.2 m high, a surface area of 29 m^2. In consultation with Dr. Shawn Robinson (DFO) and Darren Cheney, Marine Systems International Inc. (MSI), a modified design was developed and produced by MSI. This modification reduced the height of the cage to 1.5 meters and added a center hub with radiant spokes (Fig. 1). A custom built containment net was designed to encircle the scallop cage, for initial stocking as well as routine husbandry. The net was constructed from a combination of both Aquagrid™ and traditional knotted polyester mesh, reinforced with 3/8" Polysteel™ rope in vertical and horizontal planes as well as the upper and lower circumference. A zipper was placed in the top panel to allow diver access. The containment net was secured to the cage using 3/8" Polysteel™ rope. Several scallop cages with containment nets were constructed for deployment.

Figure 1: Completed prototype cage with added hub and spokes.

In preparation for deployment, a modified submerged long line system was placed on site with yellow buoys at the surface connecting to the anchor (Figure 2). These cages were transported to the site and moored at the surface for stocking and then submerged. Unfortunately, during the temporarily mooring a hurricane passed through the area and all but two cages remained.

Stocking and sampling

In June of 2011, yearling scallops were harvested from traditional lantern nets. Subsamples were measured for shell diameter and height. The animals were then divided and stocked at a density of 30 scallops/m^2, in 5 clean lantern nets (10 levels), and the two remaining test cages. A population of 150 green sea urchins (between 20-40mm), were placed in each cage. The lantern nets were secured adjacent to the cages. The trial duration was approximately 5 months. The intended one month sampling schedule was impeded due to a diver access issue (see Results section), and consequently it was only practical to sample at the study's beginning and end. The level of bio-fouling was to be determined by the level of *Polydora* (sp.), on scallops. *Polydora* is a tube dwelling polychaete that is typically removed by hand with a scrub, from the scallops during harvest.

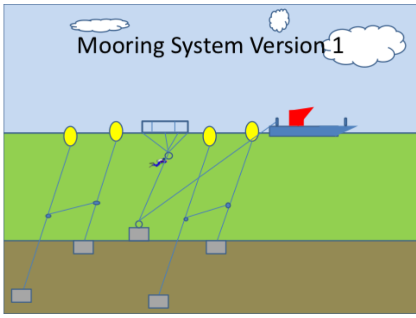

Figure 2a: A diver attached a line to the bottom harness on the cage after passing the line through a pulley on a mooring block positioned midway between the submerged longlines.

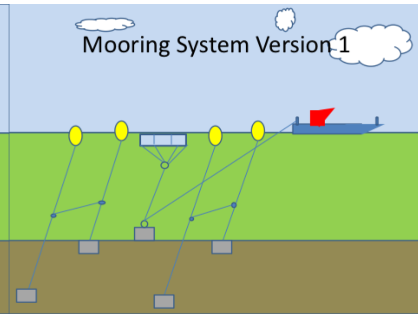

Figure 2b: The site vessel tugged on the anchor line to submerge cage.

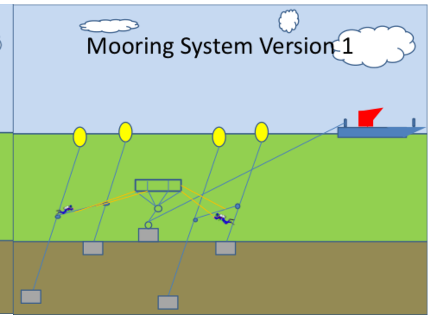

Figure 2c: The cage was fully submerged, divers secured cage to longlines using 4 lateral lines extending from the lower ring, equally distant apart. The pulley line was then tied to the surface buoy for future use.

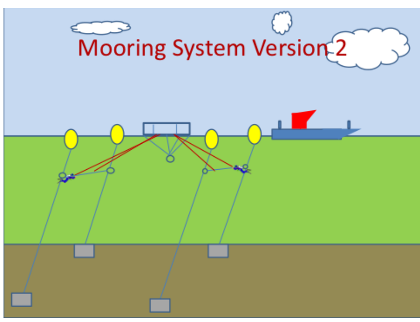

Figure 3a: A diver attached the lateral mooring lines from the cage to the lantern net longlines while the cage remained at the surface.

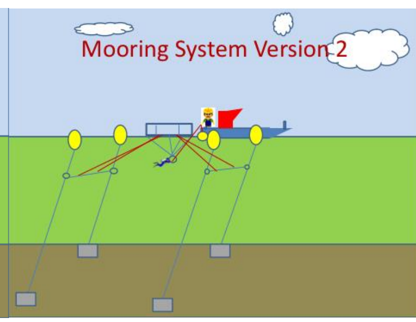

Figure 3b: The weight balls remained on the deck of the barge, until ready. Once the diver tied the 3-4 lines and was safely out of the water. The weights were "kicked over" the side and pulled the cage to depth.

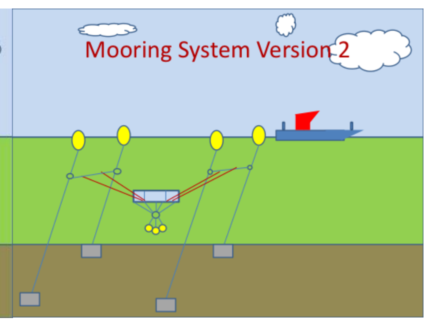

Figure 3c: The final configuration of the modified submerged cage, moored to the longlines of lantern nets. Additional weight balls below the containment net remained in situ, until the cage become slightly negatively buoyant and remained submerged.

Results

Cage Mechanics

The physical structure of the cage system provided a rigid sturdy and robust platform for which to attach the containment net. The containment net was attached and readied for deployment in 25 minutes, significantly faster than the anticipated 2 hour preparation time. The scallops were stocked by pouring them through the opened zipper of the partially submerged cage. After the initial stocking scallops distributed themselves within the cage floor and began exhibiting feeding behaviour within a very short time.

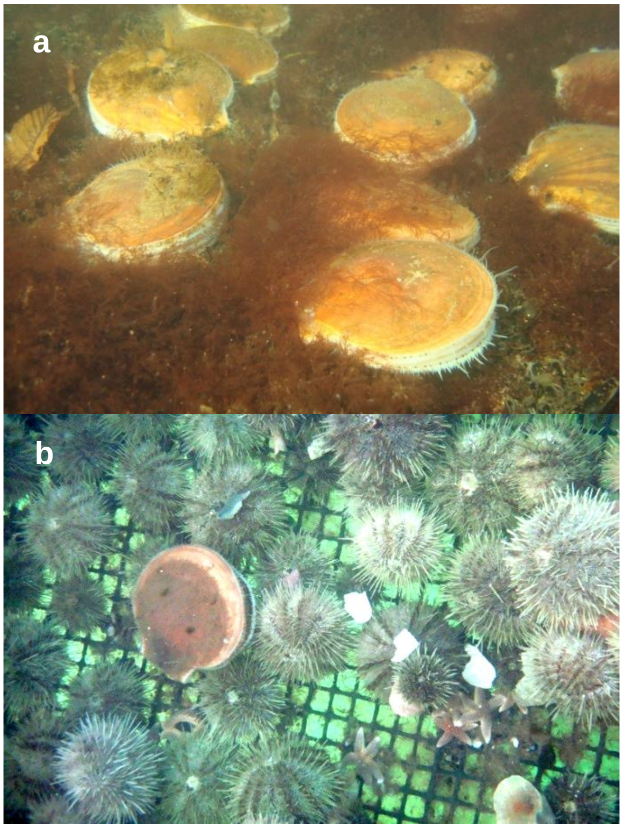

Figure 4: a) Scallops feeding on the bottom of the newly designed scallop cage. b) Sea urchins on bottom of newly designed scallop cage.

There were a number of challenges with stability during the cage deployment phase. While on the surface and partially submerged, the cage was very stable and easy to work around. However, the intrinsic buoyancy of the cage prevented easy sinking. Consequently, 6 – 60 lb weight balls were tied to the top rail around the circumference and holes were drilled in the lower ring enabling water entry to the structure to reduce overall buoyancy. The addition of the weight to the top rail made the structure very unstable. Currents forced the cage into a ferris wheel orientation in the water column, and it was very difficult to right the cage from this position. Silt was also stirred up by these activities, reducing diver visibility, causing great difficulty finding mooring lines and anchors. It took multiple attempts over several days with additional contract divers in order to fully submerge the cage.

The lessons learned from the initial cage deployment resulted in a vastly improved mooring mechanism (Fig. 3a, b, c). The improved mooring system has the advantage of using the existing longlines for lantern net suspension. The lateral lines for the new cages can be tied between existing lanterns and therefore do not reduce the usable space on the longline, eliminating the cost of a separate mooring grid. With this system, the 4 mooring lines for the new cage are attached to the longline while the cage is floating on the surface, and where the diver is in shallow water with good visibility. The 4-point harness which originally pulled the cage down via a mooring block and pulley system can be used to tie several weight balls, until the cage becomes slightly negatively buoyant. All downward forces are evenly applied and balanced against the upward tension in the lateral lines.

The cages were finally moored with no further structural stability issues during the 5 month deployment period. There were however, problems with diver access through the containment net. During stocking, it became apparent that the zipper installed for diver access was too short and would not provide sufficient access to allow a fully equipped diver to safely enter the cage without risk of entanglement. Consequently, sample collection was achieved using long handled dip net passed through the zipper. A much longer zipper will be installed for future cage iterations.

The Aquagrid™ proved superior to the traditional mesh in that much of the light fouling could easily be wiped off and other sessile organisms found it less appealing. The traditional mesh with its many crevices and higher relative surface area provided a surface more prone to bio-fouling.

Scallop Culture Performance

The biological performance data indicated a slight improvement in growth performance within the cages, likely due to the larger mesh and reduction in fouling which improved water flow (Table 1). There was also lower mortality associated with starfish predation despite a higher density of starfish in the test cage (see below). No mortalities were observed in the test cages, however 5 dead scallops were found in one lantern net which appeared to be the result of starfish predation, 3 large sea stars were also recovered from the lantern net.

"The biological performance data indicated a slight improvement in growth performance within the cages, likely due to the larger mesh and reduction in fouling which improved water flow."

Upon examination, the scallop cages with urchins were significantly cleaner than the lantern nets (Fig. 4). Observations within the cages indicated that the environment closely resembled the typical benthic habitat for scallops. Figure 4a shows the cage floor and scallops exhibiting active feeding behavior. Figure 4b shows the anti-bio-fouling effect of the urchins. While the effect of urchins on some fouling organisms in general, could be assessed, no polydora was present on the scallops in the lantern nets or the cages. Therefore urchin effectiveness against this particular bio-fouling organism could not be assessed.

Table 1: Summary of cage scallop production

Unit	Average shell diameter (mm)	Average shell height (mm)	Average meat weight (g)	Average meat weight (g)	Mortality (individuals)	Average gain in shell diameter (mm)	Average gain in shell height (mm)
Lantern net	97	27	18.7	18.7	4	14	6
Scallop cage 1	99	25	18.95	19.97*	0	17	4
Scallop cage 2	101	25	21		0	17	4

*Average of both cages

There were numerous sea stars observed within the test cages, however they seemed to be more focused on incidental mussels that were present on the mesh. In this respect, the sea stars acted as a biological anti-foulant. Due to the large volume of the cage, it appears the scallops were able to move away from the advancing sea stars. This is not possible in the lantern nets where the confined space allowed the sea stars to develop an ingenious method for attacking the scallops. The sea stars were observed hanging down from the arms on the top of the scallop. The scallop was not aware of the attack until the sea star had a firm grip. This was not a viable option in the scallop cages due to the high ceiling and large volume. There were however, several sea urchin remains in the scallop cages likely the result of sea star predation. There is a concern that once the sea stars consume all of the mussels and reach a larger size that the scallops will be at risk. This situation will be monitored.

Discussion

"Due to the large volume of the cage, it appears the scallops were able to move away from the advancing sea stars. This is not possible in the lantern nets where the confined space allowed the sea stars to develop an ingenious method for attacking the scallops."

The first objective, to design and build a prototype cage, was highly successful. The bird stand design currently used by salmon farms required only slight modification with the addition of a hub and spoke reinforcement to the top and bottom. This resulted in a structure which was strong, resilient, manageable in size, and an excellent platform for the scallop containment.

The second objective, access and develop the operational needs of the prototype cage, was successful in the sense that a number of unanticipated buoyancy control and stability issues were identified during this project phase. Through trial and error, slight modifications to the cages were made and more significant alterations applied to the mooring system, resulting in a simpler, less costly, user friendly design.

The third objective, to assess the bio-fouling clearing capacity of urchins, was also successful. The overall design performed well with lower mortality in the scallop cages relative to the lantern nets. The large open cage area allowed the scallops an opportunity to escape from the inevitable predation by sea stars. Subjective assessment of net material suggested the Aquagrid™ was easier to clean, less affected by fouling and provided a more stable substrate for the scallops.

The ultimate goal for switching the gear types and operational systems was to be able to lower the overall cost of production. Based on the improved mooring system, which eliminated the costs associated of a separate mooring system and a greatly simplified method for deployment; a stocking density of 44 scallops/m^2 resulted in a reduced cost of production as compared to traditional lantern nets.

This AIMAP project has helped Magellan Aqua Farms to continue to grow as the premium high quality sustainable scallop producer in southern New Brunswick. The company plans to continue to utilize Integrated Multi-trophic Aquaculture principles and refine the mechanics of the modified salmon cage technology and eventually replace existing lantern nets with updated versions of the prototype for scallop grow-out.

Acknowledgements

Special thanks to Carla Dale, Craig Reynolds, Cindy Webster of the DFO Maritimes Region; Dr. Shawn Robinson, St. Andrews Biological Station; Chris Saulnier, Aqua Fish Farms Ltd.; Clarence Blanchard, Future Nets Inc.; Darren Cheney, MSI; Admiral Fish Farms; and Jeremy Rattray and Amy Robinson who volunteered countless hours in order to make this project successful.

Authors

Gloria Falk is a manager at Fisheries and Oceans Canada, National Capital Region, Steve Backman is President of Magellan Aqua Farms and Jenna Gallies is a junior communications officer at Fisheries and Oceans Canada Maritimes Region.

The Benthic Ecology Workshop in St. Andrews: thirty years presenting research on ecology, fisheries and aquaculture

Gregor K. Reid

The Benthic Ecology Workshop

The Benthic Ecology Workshop (BEW) provides researchers and stakeholders in areas related to benthic ecology, an opportunity to share their latest findings in a relaxed and informal atmosphere. The workshop is held every two years at the St. Andrews Biological Station (SABS) of Fisheries and Oceans Canada (DFO). All facets of benthic and marine ecology are eligible for discussion and attendees can expect a diversity of research exposure at any given BEW. The inexorable link between fisheries, aquaculture and the benthic environment, ensure these areas figure prominently. The fisheries research presented often relates to spawning, nursery and foraging habitat of the benthos. The aquaculture component commonly focuses on the potential for benthic alteration due to aquaculture activities and new approaches in the field. These themes are evident in presentations from the most recent BEW (see Table).

"One of the largest benefactors of the workshop's accessibility and proximity, are of course, students… It is not unusual for a supervisor to bring their entire body of graduate students to the workshop."

The latest BEW occurred this past year from November 7-9th, 2012. There were over 40 in attendance (Fig. 1) and 20 presentations were given. There was also a day-long seminar on Dynamic Energy Budget (DEB) modelling, given by Jaap van der Meer (Fig. 2) from the Royal Netherlands Institute for Sea Research. DEB theory partitions energy of cold-blooded animals into a structural body and reserve pool[(1)]. This method quantifies energy flow through organisms, from assimilation to allocation, growth, reproduction, and maintenance, using a mechanistic modelling approach[(2)]. DEB is often used for research on carrying capacity.

Legacy of the Benthic Ecology Workshop

The BEW has always been designed as a low-cost affair to foster accessibility for as many participants as possible. Unlike many workshops and conferences, there is no registration fee. This is possible in part, because the St. Andrews Biological Station has generously provided use of its Conference Centre. While attendees are welcome to source their own accommodations, reasonable lodging and meals are always made available at the residences of the neighbouring Huntsman Marine Science Centre. The workshop is conveniently held in St. Andrews, within practical driving distance from much of New England, Quebec, and the Maritime Provinces. As such, the workshop has become a popular liaison opportunity for researchers from French and English speaking Canada. One of the largest benefactors of the workshop's accessibility and proximity, are of course, students. The reasonable cost, car-pooling options and student friendly format, make it a

Figure 1: The Benthic Ecology Workshop 2012

Left to right

Front row
Rachelle Porter, Marie-Josee Abgrall, Amanda Smith, Dounia Hamoutene, Gehan Mabrouk, Jessica Whitehead. Karen Coombs, Steve Backman, Shawn Robinson, Jeff Barrell, Francisco Bravo, Chantal Coomber, Angéline LeBlanc, Isabelle Tremblay, Angelina Kraft, Peter Cranford, Kristen Legault, Vanessa Zions

Back row
Aaron Bennett, Brent Law, Marc Ouellette, Kevin Ma, Gregor Reid, Tara Daggett, Barry Hill, Michelle Simone, Andrew Cooper, Marc Blanchard, David Wildish, Thomas Guyondet, Michael Brown, Jon Grant, Jaap van der Meer, Heather Hunt, Ramón Filgueira, Cédric Bacher, Nicole Leavitt, Louis Ferguson, Marcel Fréchette, Brent Wilson, Kurt Simmons, Jack Fife, Blythe Chang

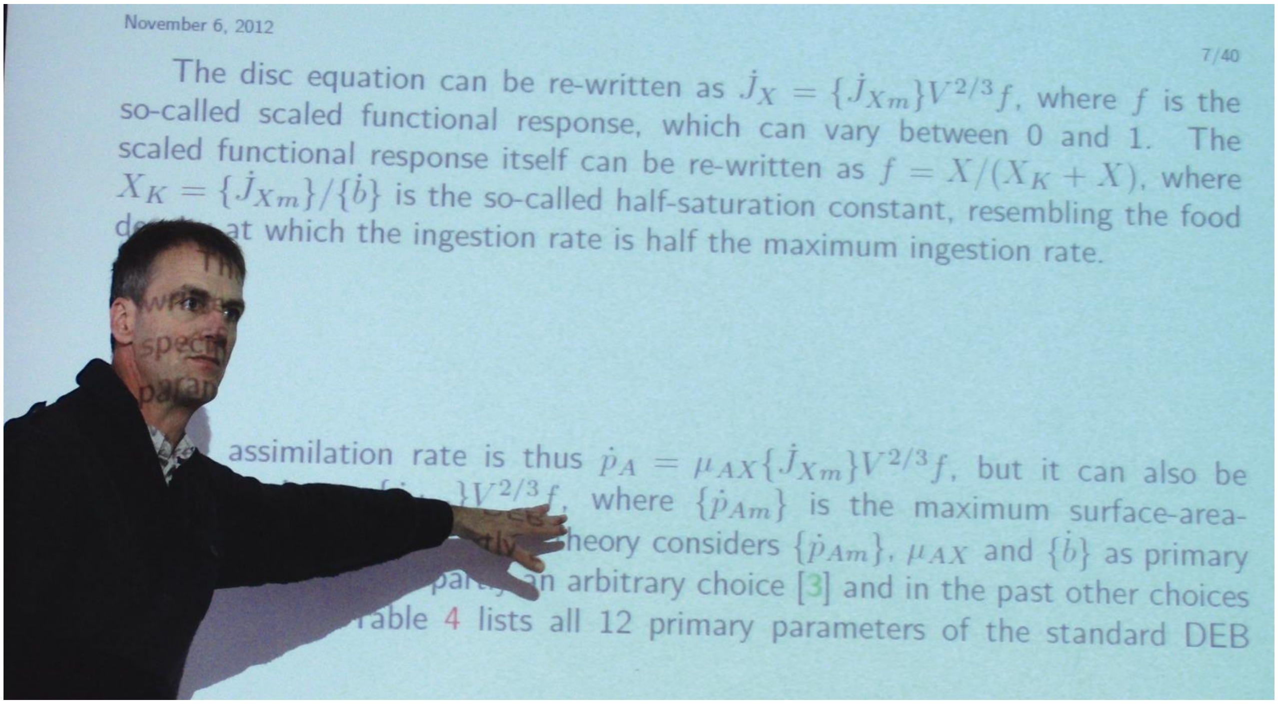

Figure 2: Jaap van der Meer from the Royal Netherlands Institute for Sea Research describes the finer points of Dynamic Energy Budget (DEB) modelling at the 15th biannual, Benthic Ecology Workshop in St. Andrews, New Brunswick.

Figure 3: Workshop co-founder David Wildish at the 2012 Benthic Ecology Workshop

favourite for many a graduate student and supervisor. It is not unusual for a supervisor to bring their entire body of graduate students to the workshop.

This past year, the BEW celebrated its 15th workshop, near 30 years since the first workshop in 1983. The workshop was originally initiated by SABS research scientist Dr. David Wildish (Fig. 3) in collaboration with Dr. Jon Grant (Dalhousie University) and DFO research scientist Dr. Barry Hargrave from the Bedford Institute of Oceanography (BIO). Dr. Wildish retired in 2005 and Dr. Hargrave in 2007; while Dr. Jon Grant has continued his role as a workshop organizer these past 3 decades. Drs. Shawn Robinson (SABS) and Peter Cranford (BIO) joined as organizing leads in 1989 and 2005, respectively. Presenters from the first BEW(3) are shown in Fig. 4. A photograph of all first BEW participants could not be found. However, a photograph of participants in the following 1985 BEW(4) (Fig. 5), is shown below.

The longevity and success of this workshop is evidence of the dedication and enthusiasm of researchers in their field. The BEW demonstrates that successful workshops can occur without the need for undue cost and complex sponsorship; perhaps more relevant now than ever given the present era of fiscal restraint.

Benthic Ecology Workshop 2012 Presenters

Title and presenting author[1]	Authors	Summary
 Welcome and Introduction to the 15th Biennial Benthic Ecology Workshop	Shawn Robinson St. Andrews Biological Station, Fisheries and Oceans Canada	This workshop has been going for the past 30 years and has brought a core group of researchers together to discuss their ongoing research. Very impressive.
 A test of a model of internal state regulation of clearance rate in mussels	Marcel Fréchette[1], José Urquiza[2], Gaétan Daigle[2], Dominic Rioux-Gagnon[2] [1] Institut Maurice-Lamontagne, Pêches et Océans Canada [2] Université Laval	Reported results of field trials assessing internal state filtration for modelling clearance rate in mussels
 Dynamic Energy Budget, population growth rates and habitat mapping	Cédric Bacher, Candice Sénéchal Institut français de recherche pour l'exploitation de la mer (IFREMER)	Exploration of methods to predict growth, reproduction, response to environment change and habitat assessment
 Aquaculture impacts on the surrounding sediment	Michelle Simone Department of Oceanography, Dalhousie University	Discussed upcoming research on benthic health quality index and sediment profiles to assess aquaculture impacts
 Effects of habitat heterogeneity on denitrification and carbon oxidation rates in coastal sedimentary environments exposed to shellfish aquaculture	Francisco Bravo Department of Oceanography, Dalhousie University	Backgrounder on sediment chemistry in support of a research proposal to quantify and qualify benthic environments and potential effects of shellfish aquaculture
 Changes in coastal geomorphology control estuarine secondary productivity	Ramón Filgueira[1,2], Thomas Guyondet[1], Luc André Comeau[1], Jon Grant[2] [1]Aquaculture and Coastal Ecosystems, DFO Gulf, Moncton [2]Department of Oceanography, Dalhousie University, Halifax	Examples of climate change induced shoreline breaching and how this effect on water flow, effects to primary production and shellfish aquaculture sustainability
 Soft shell clam populations: does organic matter really matter?	Marie-Josée Abgrall, Department of Biology, University of New Brunswick (SJ)	Role of benthic organic matter on metals and hydrogen sulfides, and consequent effects to clam populations

 The use of bacterial mats (*Beggiatoa* spp.) and opportunistic polychaete complex (OPC) as potential indicators of habitat alteration around finfish aquaculture sites over hard bottom substrates in NL, Canada	Dounia Hamoutene [1]; Lee Sheppard[1], Dwight Drover[1], Vanessa Oldford[1], Joe Mersereau[1], Elizabeth Coughlan[2], Gehan Mabrouk [1], Carol Grant [2] [1] Aquaculture, Biotechnology and Aquatic Animal Health Section, Fisheries and Oceans Canada [2] Habitat Division, Fisheries and Oceans Canada	Explored the reliability of using *Beggiatoa* mats and polychaete complexes to monitor aquaculture impacts in Newfoundland
 Novel methods for quantifying the structure of coastal landscapes using local spatial statistics	Jeff Barrell Department of Oceanography, Dalhousie University	Outlined a method for mapping the spatial structure of seagrass habitat using the Getis-Ord Gi* local spatial statistic
 Mathematical and stochastic modelling of blue mussel organic deposition potential in IMTA systems	Gregor K. Reid University of New Brunswick/ St. Andrews Biological Station, Fisheries and Oceans Canada	Presented a model to determine the amount of salmon culture organics in the diet of co-cultured blue mussels to reduce net organic load at an IMTA site
 Influence of surface sediment pH and carbonate saturation state on soft-shell clam (*Mya arenaria*) recruitment in the Bay of Fundy, New Brunswick, Canada	Jeff C. Clements, Heather Hunt* Department of Biology, University of New Brunswick	Detailed ongoing trials investigating pH and carbonate saturation effect on soft shelled clam dispersal, recruitment and juvenile morphometrics
 Extractive mussel aquaculture: the acrobatics and balancing act of sustainability science	Peter Cranford Bedford Institute of Oceanography , Fisheries and Oceans Canada	Explored mussel aquaculture influences on phytoplankton, nutrient dynamics and extraction efficiency of particles in IMTA
 Amphipods in sediment trap samples: investigations at a deep-sea, long-term observatory in the Arctic Ocean	Angelina Kraft, Eduard Bauerfeind, Eva-Maria Nöthig, Ulrich V. Bathmann Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany	Examples of climate change induced shifts in amphipod communities in the European Arctic and their contribution to "atlantification"
 A model of clearance rate regulation in mussels	Marcel Fréchette Institut Maurice-Lamontagne, Pêches et Océans Canada	Reviewed different feeding modules (within larger models such a DEB) and advocated the need for new module developments

 Representative planning: Achieving representation at different scales and data availabilities using ecological classifications	Michelle Greenlaw, St. Andrews Biological Station, Fisheries and Oceans Canada	Review of habitat mapping and advancements in coastal ecological classification in the Maritimes Region
 General discussion on trends in benthic ecology and upcoming issues	Jon Grant Department of Oceanography, Dalhousie University	The myriad of problems facing the biosphere including marine systems calls for an even greater role of benthic ecology in providing solutions to monitoring and management.
 A standardized geodatabase to describe and classify marine habitats, in the estuary and Gulf of St. Lawrence, and its use for identifying essential habitats of species at risk	Marc Ouellette[1], Jean-Denis Dutil[2] [1]Gulf Fisheries Centre, Moncton, Fisheries and Oceans Canada [2]Maurice-Lamontagne Institute, Fisheries and Oceans Canada	Progress on species at risk spatial mapping and its role in decision support
 On a driftwood log and a prayer: the long distance dispersal of Talitrids	Dave Wildish St. Andrews Biological Station (*emeritus*), Fisheries and Oceans Canada	Presented a new theory about the dispersal and evolution of Talitrids (see *J.Nat. Hist.* 46:2329-2348)
 Biodiversity of the shallow rocky sub-tidal in the Quoddy Region, Bay of Fundy**:** Investigation of spatial patterns and taxonomic sufficiency using cobble-filled larval collectors	Brent Wilson, Rémy Rochette, Heather Hunt Department of Biology, University of New Brunswick	Spatial assessment of biodiversity in the Quoddy Region (Bay of Fundy), with emphasis on taxonomic resolution
 Impacts of wind-generated submerged bubble layers on optical measurements of calcium carbonate in the southern ocean	Michael Scott Brown[1], Susanne Craig[1], Bryan Franz[2], Jeremy Werdell[2], Xiaodon Zhang[3], Jon Grant[1], Marlon Lewis[1], William Balch[4] [1]Department of Oceanography, Dalhousie University [2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA [3]Department of Earth System Science and Policy, University of North Dakota [4]Bigelow Laboratory for Ocean Sciences, East Boothbay, ME	A thesis aiming to improve remote sensing of calcium carbonate particles (i.e. coccolithophores in the Great Calicite belt) by teasing out optical interference of wind driven bubble formation

[1] Presenting author is the lead author unless indicated by an astrick (*)

Figure 4: Presenters from the first annual Benthic Ecology Workshop in 1983

Left to right: John Roff, Don Rhoads, Roger Newell, Kee Muschenheim, David WIdish. Jon Grant, David Kristmanson, Ulrich Lobsiger

The 1983 Benthic Ecology Workshop corresponded with the 75th Anniversary of St. Andrews Biological Station

Figure 5: Participants of the second annual Benthic Ecology Workshop

From left to right

Front row: Decoste, Brock, Butman, Kranck, Boudreau, Baretta, Pett, Fréchette, Walting, Peer
Second row: Martin, Frost, Baily, Grant, Newell, Harding, Wilson, Waiwright, Mayer
Steps: Lobsiger, Keizer, Scoditti, Schwinghamer, Bourget, Muschenheim, Wildish

Jon Grant, Marcel Fréchette and David Wildish, in the photograph above, were also in attendance at the 15th Benthic Ecology Workshop in 2012.

Perhaps one of the greatest testaments to success of the workshop is the repeat attendance of long time participants, some of whom who have retired (Fig. 4). A number of the 2012 BEW attendees can also be seen in the 1985 workshop photograph. The styles may have changed but the commitment endures.

If you are interested in participating in a future BEW, please contact lead organizer Shawn Robinson at Shawn.Robinson@dfo-mpo.gc.ca.

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Author

Gregor Reid works for the Natural Sciences and Engineering Research Council of Canada (NSERC) Strategic Network, the Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN), through the University of New Brunswick (UNB). He is located at the St. Andrews Biological Station (SABS) of Fisheries and Oceans Canada (DFO).

Perspectives on sustainable seafood: report of the 2012 St. Andrews Seafood Forum

Robert L. Stephenson

Introduction

Sustainability is a topic of critical importance to both aquaculture and fisheries. Increasingly these industries are being asked to demonstrate to retailers and the public that their activities are sustainable. At the same time, the landscape of sustainability is changing as management moves towards ecosystem-based and integrated management approaches. Sustainability, therefore, is also a critical issue for coastal communities and seafood producing areas. It represents a common challenge for aquaculture, fisheries, and other coastal activities, and it is worthy of strategic discussion.

The 2012 St. Andrews Seafood Forum intended to explore the diverse nature of sustainability, and to encourage discussion about the evolving concept of sustainable seafood[1]. The forum included two panels with a total of seven perspective presentations and discussion sessions following each panel. There were approximately 100 audience participants.

"Sustainability is a topic of critical importance to both aquaculture and fisheries. Increasingly these industries are being asked to demonstrate to retailers and the public that their activities are sustainable."

The panellists brought diverse expertise and experience related to the concept, application and study of sustainable seafood. Johan Verreth, a professor at Wageningen University and advisor to the sustainable seafood program of a major Dutch retailer, described results of a comparative study of seafood sustainability programs. Steve Lutz, executive vice president of Neilsen Perishables Group, a Chicago-based marketing and consulting firm, summarized results of a major marketing study related to sustainable seafood. Lauren Lavigne, Aquaculture Management Directorate at Fisheries and Oceans Canada (DFO) provided an overview of Canada's new Aquaculture Sustainability Reporting Initiative. David Smith, VP Sustainability for Sobeys Inc, spoke of the approach of a major Canadian retailer to sustainable seafood. Jean Guy d'Entremont, President of Scotia Harvest Group, offered the perspective of the commercial fishery including an account of the development of approaches to implement sustainability in regional fisheries and in his family fishing business. Chris Aerni, Rossmount Inn, discussed sustainability from the perspective of a chef and owner/operator of a restaurant and inn. Rob Stephenson, of DFO's St. Andrews Biological Station

[1] The Bay of Fundy is a 'seafood region'. The Seafood Forum (http://www.standrewsseafoodforum.com/index.html), held as part of the 2012 St. Andrews Seafood Festival (http://www.standrewsseafoodfestival.ca/), was an event aimed at celebrating what has been accomplished and discussing what must be done going forward. It was intended to provide interesting and novel programming that would a) link the diverse experience and interests of the area (including explicitly fisheries, aquaculture, and science), b) provide an opportunity to explore areas of communal interest, and c) showcase the region as one of innovation, leadership and productivity. The Forum was held at the Huntsman Marine Science Centre, June 6-7, 2012.

and the Canadian Fisheries Research Network based at University of New Brunswick, offered the perspective of a fisheries scientist who has been working on the concepts of sustainability, and acted as moderator for the panels.

This paper attempts to synthesize the perspectives from panel presentations and major aspects of the discussion. Further information, including panel presentations, is available at the St. Andrews Seafood Forum website: http://bayoffundyseafoodweek.com/theseafoodforum.html.

Diverse perspectives on sustainable seafood

Stephenson discussed the move to consideration of a broader perspective of sustainability in fisheries represented by the Bay of Fundy herring fishery, in coastal marine planning (citing the case of the SWNB Marine Resource Planning initiative) and among the scientific community as exemplified by the 2009 Gulf of Maine Symposium and recent research in a project of the Canadian Fisheries Research Network. There is an international move towards sustainability through management of coastal activities using a larger set of criteria and higher standards associated with the 'ecosystem-approach', 'marine spatial planning' and 'integrated management'. Recent legislative changes in both Canada and the USA encourage a more comprehensive view of sustainability that includes ecological, economic, social and institutional considerations. While there has been progress towards achieving sustainability, it is not clear what the end point should be. He posed the questions: How would we know when we have achieved sustainability? What are the minimum criteria? Does it have to be the same in all areas.

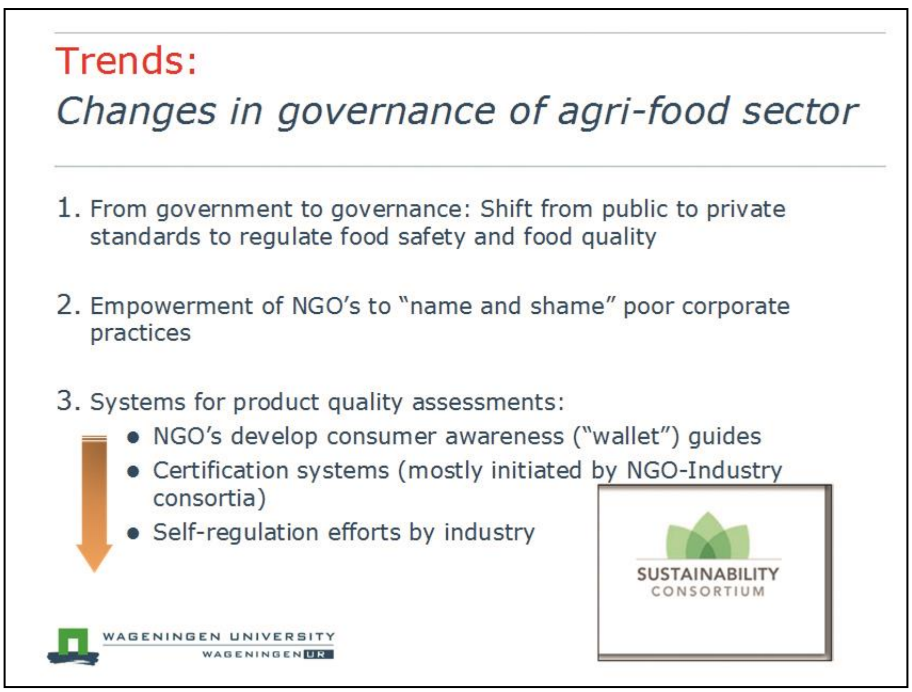

Figure 1: (J. Verreth)

Verreth discussed the trends in the agri-food sector 'from government to governance' with a shift from public to private standards to regulate food quality (Fig 1). This, combined with increased empowerment of NGO's to 'name and shame' poor corporate practices, has led to a variety of systems for product quality assessment.

There are three types of certification:

1st party (self declared), 2nd party (relationship between buyer and seller), and 3rd party (independent party sets standards and does evaluation). Credibility of certification systems is critical. In general 3rd party schemes are most credible. Governmental institutions have a critical role in developing standards and guidelines. Comparison of eco-labelling schemes in a benchmarking study suggests that most overlook socio-economic aspects and bio-physical aspects of sustainability. Further, the impact of certification schemes (on encouraging/ improving sustainability) is not well documented yet. Verreth suggested that seafood sustainability should be a non-competitive issue, like food safety, and that the application of 'life cycle' (e.g. cradle2grave) analyses (Fig 2) will become the reference method for evaluation of sustainability in seafood.

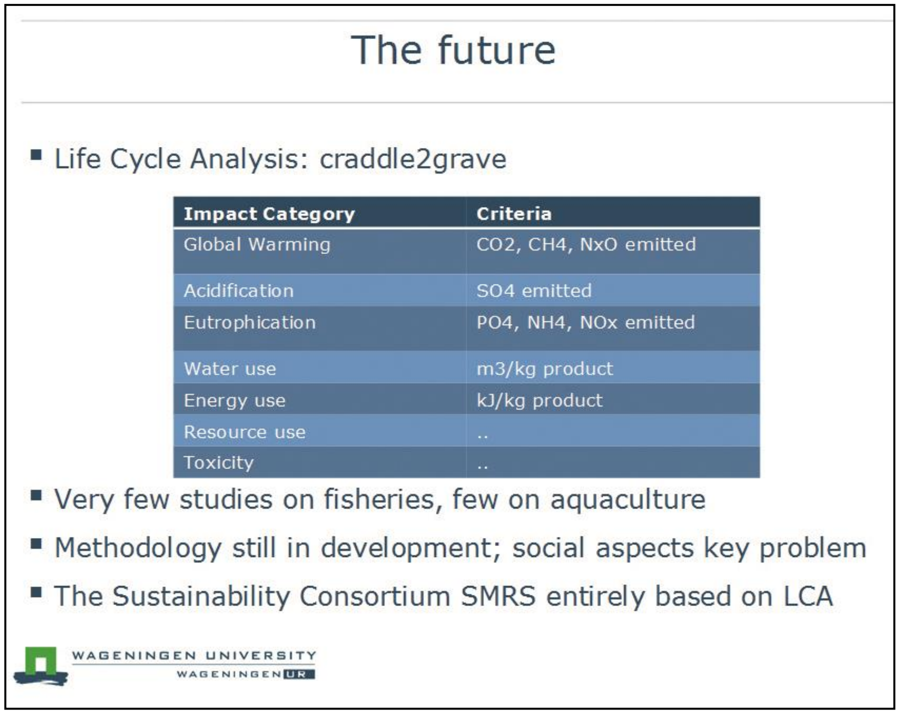

Figure 2: (J. Verreth)

Jean Guy d'Entremont described how sustainability issues had influenced development of his fishing company in recent years. His family has been involved in the fishery for generations and would like to ensure that the fishery resources remain healthy for generations to come. He and his company have been involved in several developments in recent years related to sustainability, including development of Canada's code of conduct for responsible fishing operations (1998), and are committed to principles of responsible fishing and long-term sustainability of resources. Sustainability is specified in the company vision ('…remaining on the leading edge in involvement in resource management and scientific data and taking a proactive approach in ensuring sustainability of the Canadian fisheries'). The company has replaced vessels and equipment and made changes in aspects of fishing, processing, company management and marketing to ensure high quality, sustainable, products.

Chris Aerni described sustainability as one element of a food concept for his restaurant and inn that includes 'local, fresh, seasonal, organic, wild, regional, honest and sustainable' (Fig. 3). He made the point that 8 years ago he didn't

Figure 3. (C. Aerni)

use the word sustainable, but that a supply of high quality sustainable food has long been critical to his restaurant business. He described increasing client interest in the source and sustainability of seafood, noting that he has seen a change from people looking for a room first, to looking for food first ('a restaurant with rooms'). He stated that sourcing high quality food items is second only to cooking in time and effort spent in his business, and that he is always considering 'Where do I get my seafood from tomorrow?' Aerni noted a substantial change in recent years (for example at the International Boston Seafood Show over the past three years) from a few claiming to be 'sustainable' to virtually all claiming 'sustainability' – and asked if sustainability had become just a marketing word? He posed the questions: Who defines sustainability in our industry? Are we to leave it to others (certification bodies) or should we do it our own way (in a regional, local approach)? He stated that the Chef's dream would be that those living around the Bay of Fundy and Gulf of Maine would combine their know-how (industry, science, politics) to go hand in hand to a local/regional solution of more sustainable seafood.

Lauren Lavigne described the background and recent developments in Canada's Aquaculture Sustainability Reporting Initiative (first report issued May 2012). She emphasized the importance of economic, environmental and social elements which can be quantified (benchmarked or tracked) to demonstrate progress and improvement. She described the increasing need to demonstrate sustainability as critical to market access and social license.

Lavigne discussed aspects of third party certification related to animal health and welfare considerations, food safety, environmental and social considerations and of organic and other international standards. She emphasized the practical aspects of implementation, and the roles of various parties, including industry, non-governmental organisations, certifying agencies and government in contributing to management for sustainability.

David Smith discussed the importance of documenting the origin/sources of seafood. In the past 4 years Sobeys has made the origin of products from 220 seafood sources 'visible' to the buying public. This has allowed implementation of a rating system for all products using credible, independent, science-based metrics. Smith suggested that certification to date has largely been applied to making reasonably sustainable sources better (those classified as yellow to green), but that there was a need to go 'beyond certification' and eco-labels to 'fix the worst first' (Fig. 4).

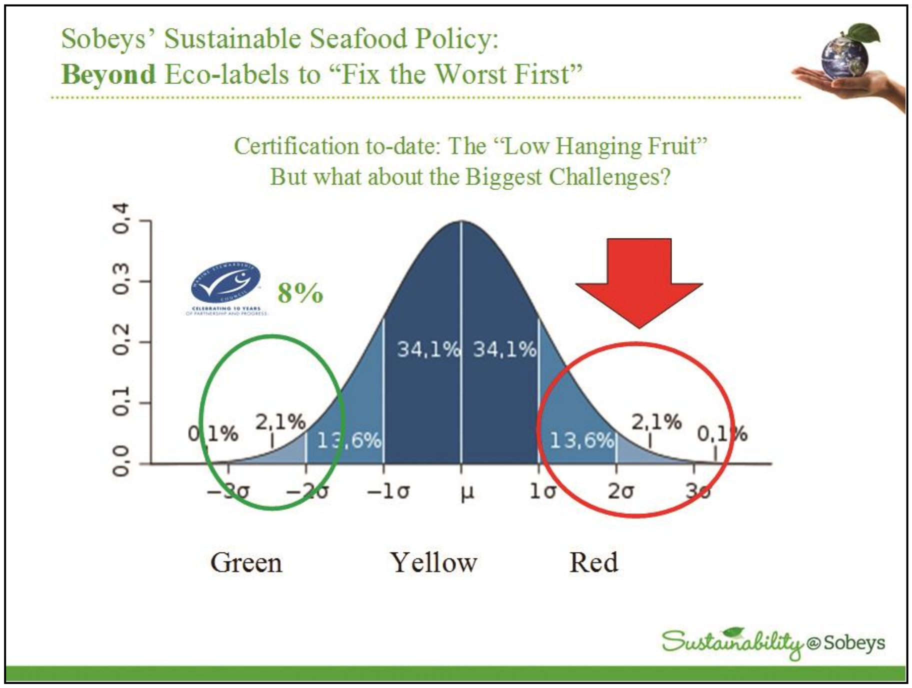

Figure 4: (D. Smith)

Smith referred to the Global Seafood Sustainability benchmarking initiative which is driving improvements. Consumers are increasingly aware of, and concerned about sustainability but want it as a 'given' with the price very near the same. Customers want to take action and to make appropriate choices but are overwhelmed and confused by labels (the 'seafood certification jungle') and not able to act (Fig. 5). Smith suggested that knowing the source of a product (such as demonstrated with the 'this fish' traceability initiative) is more interesting and useful to consumers. He suggested that 'sustainability' is not a user-friendly word, but that the concept of 'responsible' rather than 'sustainable' would be more useful.

Steve Lutz presented the results of a 2010 study of what consumers know and think about sustainable seafood. Although consumers are generally aware of sustainability-related issues, their purchase decisions in both supermarkets and restaurants are based more on other aspects, especially food safety, type of fish, and price. 'Sustainability' is most easily linked to long term species viability. Self-described 'knowledgeable' buyers and consumers under the age of 35 are much more likely to be aware of sustainability, use available seafood guides and note signage/menu information. The heavier (more frequent) seafood consumers rank sustainability higher. Awareness of, and regard for, eco-labels is relatively low. Seafood sustainability has yet to gain 'certified organic' levels of consumer recognition. 'Certified organic' is a relatively clear and well understood label for which people are willing to pay.

People are not yet willing to pay for certified seafood. For seafood certification to matter, it has to be as simple and powerful as 'certified organic'

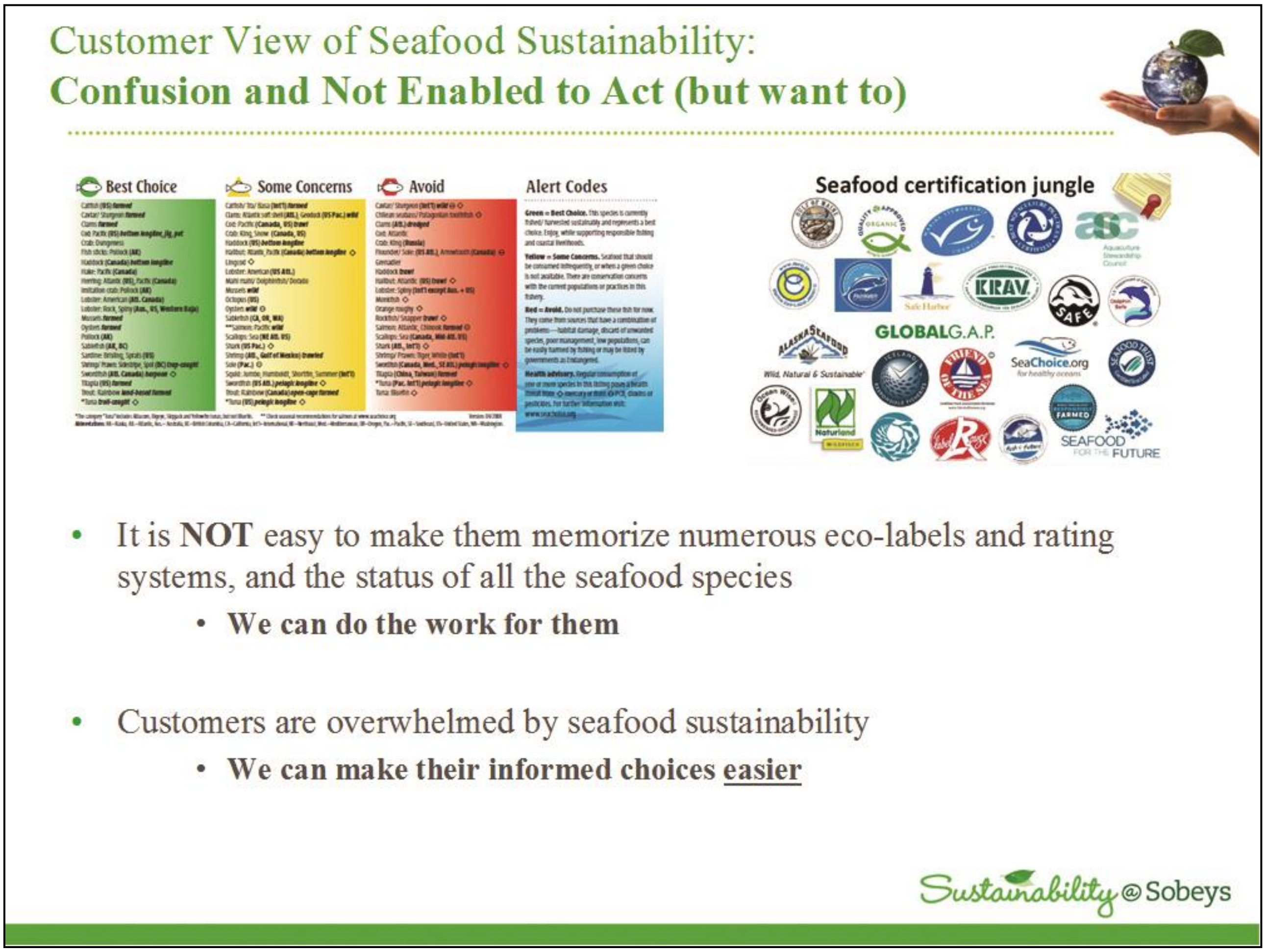

Figure 5: (D. Smith)

Seafood sustainability as a strategic issue for fisheries and aquaculture

Importance

Seafood sustainability is increasingly in the news. When negative aspects related to sustainability become a news issue, they can become very large issues very quickly - and there can be a lot of (negative) impact.

Pressure to demonstrate sustainability

The pressure to be sustainable and to prove sustainability is increasing. The international context has changed in recent years (including the introduction of the ecosystem approach, agreements such as the Convention on

Biodiversity, development of the code of conduct for responsible fishing) and much of that context is now engrained in national policies. In addition there has been major realization regarding climate change and the need for stewardship in the face of change. There is increased public pressure to obtain and maintain sustainability as a condition of 'social license'.

Coastal marine and resource management has been evolving toward sustainability. Fisheries, aquaculture and other activities are increasingly being evaluated (audited) for sustainability through:

1) More rigorous/comprehensive management plans
2) Marketplace certification
3) Emerging evaluations of cumulative performance in ecosystem assessments

Defining sustainable seafood

Problem of scope and definition

Although the concept of sustainability is very old, it has recently become a topic of new/renewed interest and importance. Verreth (Fig. 6) cited a forestry example from 1693, in which Von Carlowitz wrote: 'We should organize our economy in a way that we will not suffer scarcity of timber, and where it is lumbered we should strive for young growth at its place'. Modern applications commonly refer to the Brundtland Commission (1987) definition: 'Sustainable development meets the needs of the present generation without compromising the ability of future generations to meet their needs'.

Sustainability is a broad term and contains diverse aspects. While it is commonly recognized as having four elements, or pillars (conservation, social, economic and governance (or 'institutional'), Fig. 7), the definition and use are dynamic and relative.

Stephenson (Fig. 8) referred to a working definition being studied in a project of the Canadian Fisheries

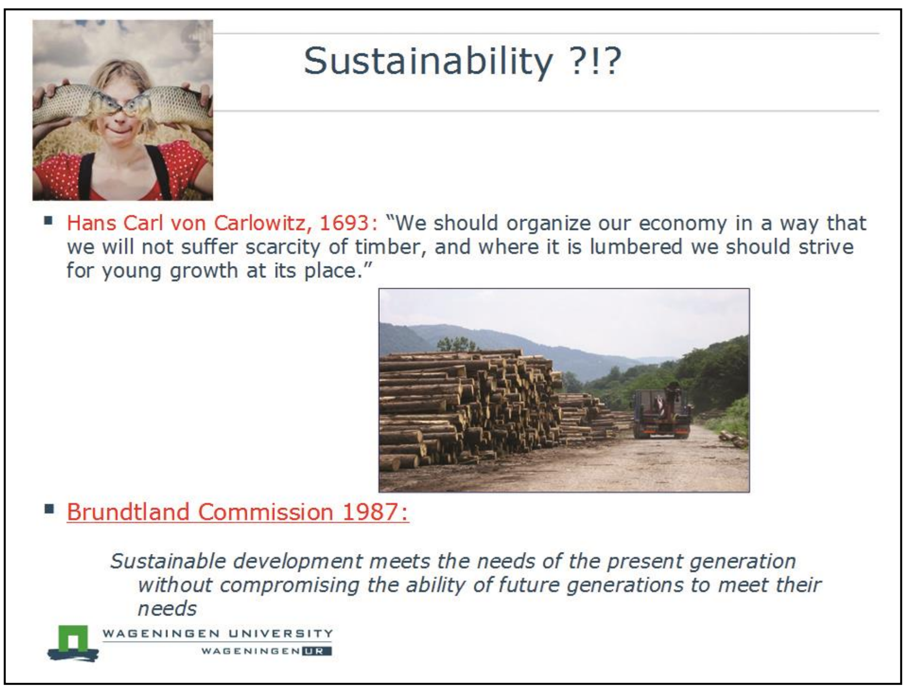

Figure 6: (J. Verreth)

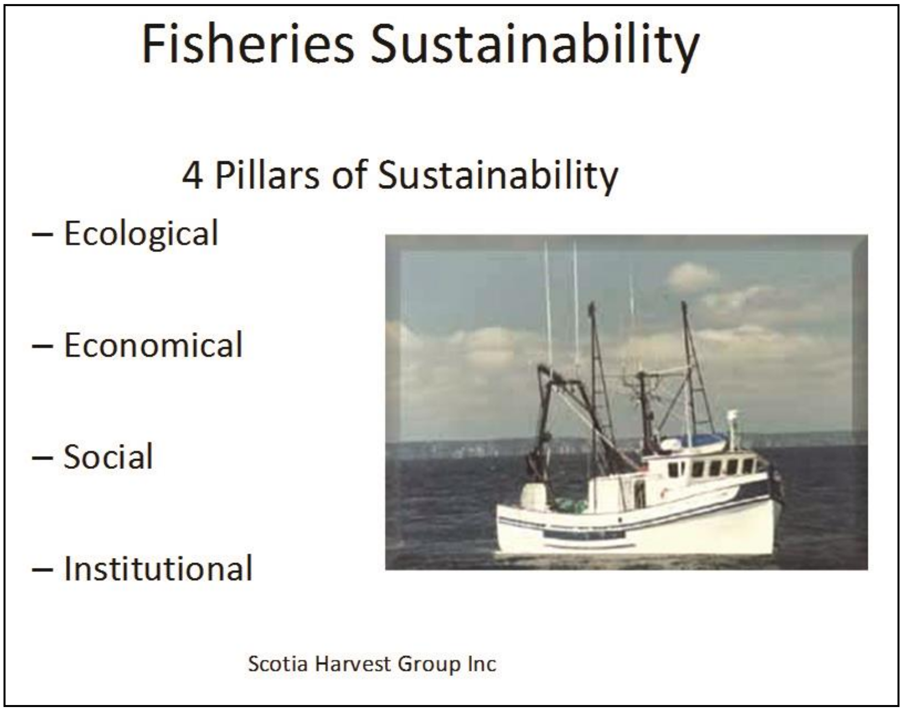

Figure 7: (J.G. d'Entremont)

Research Network and a diverse set of elements that includes ecosystem health and productivity, ethical and equitable fisheries, viable communities, health and wellbeing of participants, and responsible participatory governance.

Both Lutz and Smith referred to the complexity of a definition of sustainability and the confusion that surrounds the concept in the minds of seafood purchasers. While there are internationally accepted standards/guidelines (e.g. FAO code of conduct; FAO guidelines for certification), these are general/broad. They require more specific definition and a robust regulatory and governance framework for successful implementation.

Implementing Sustainability

Stephenson suggested that the major challenges to implementing sustainability include insufficient consideration of cumulative effects, lack of definition and insufficient integration of the full suite of conservation, economic, social and institutional goals of sustainability. Sustainability is usually seen as requiring a participatory process for definition and an ongoing process of improvement as new information becomes available. The specific definition and development of criteria (objectives) have been a challenge. While some general objectives are generally recognized (environmentally sustainable, socially acceptable, economically viable, administratively effective, transparent process), the problem has been in defining specific objectives with performance indicators and other metrics that would allow practical implementation in diverse situations. Societal views regarding sustainability can be expected to evolve over time. Lavigne suggested that while sustainability is the ultimate goal, it is perhaps more productive to consider 'pathways to sustainability'- how fisheries or aquaculture can operate responsibly in the marine environment, using best practices and adapting those practices in light of new knowledge to achieve continuous improvement.

Trade-offs among diverse objectives

The multidimensional nature of sustainability demands consideration of tradeoffs among objectives. d'Entremont discussed the need for 'a delicate balance among 4 pillars', and stated that the balance of pillars is a societal choice. Stephenson pointed to the need for research on decision support tools that would help articulate and compare management scenarios/options.

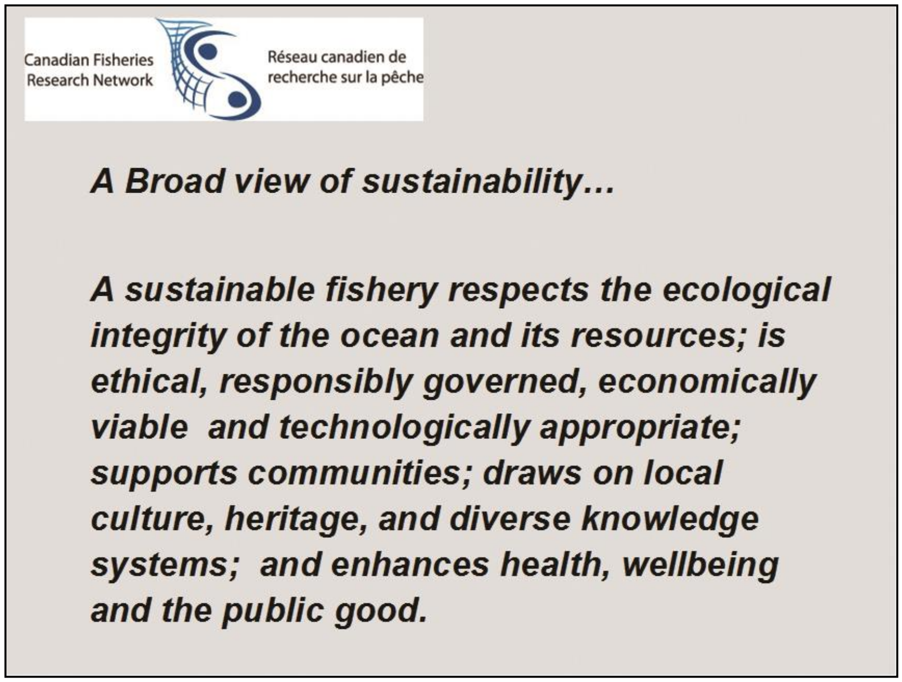

Figure 8: (R. Stpehenson)

Branding

Several panellists addressed the current problem of labelling/branding related to sustainability. There are presently a multitude of schemes related to branding aspects of sustainability. Both Smith and Lutz emphasized that the buying public are confused by the 'jungle of brands' (Fig. 5).

Lutz summarized survey results indicating that most do not consider sustainability branding when choosing seafood, pointing out that people make choices quickly, and choose based on other criteria (safety, price and type). Market research indicates that although people may want to consider sustainability issues, the current labelling is ineffective for most consumers. Because of the confusion about brands people are, essentially, trusting the store ('whatever he puts on the shelf I will buy').

Lutz pointed to a subset of self-described 'knowledgeable' buyers and consumers who are much more likely to be aware of sustainability and to use seafood guides and signage, and d'Entremont described the success of extracting best value by branding haddock.

In addition to the problem of the number of brands and certification schemes, there is a wide range in criteria used to refer to sustainability. The rapid increase in claims of sustainability has led to a perception of 'green washing' and a reduction of standards. Several panellists pointed to the importance of clear, verifiable standards and to the importance of third party certification.

Lutz suggested the need for a simpler system of branding. He suggested that either sustainability branding needs to be valued (so that people will pay more), or even better, it should be accepted as a 'given' so that it is a non-competitive item (like food safety). Smith pointed to the marketing dilemma of allowing choice among a range of products and working towards an informed consumer who will choose for sustainability ('choice influencing') versus offering a smaller set of sustainable products ('choice editing').

Discussions and issues to explore further

- Sustainability remains a strategic issue for aquaculture, fisheries and other coastal activities.

- There is need for continued development of the concept (practical definition) of sustainability and especially for implementation. What does sustainability mean in practical terms? What are the minimum criteria? How would we know when we have achieved sustainability? The concept of sustainability will continue to evolve, so this needs to be an ongoing discussion.

"In addition to the problem of the number of brands and certification schemes, there is a wide range in criteria used to refer to sustainability. The rapid increase in claims of sustainability has led to a perception of 'green washing' and a reduction of standards".

- There is considerable interest in seafood and food security, both in terms of ensuring healthy seafood products and of the role of seafood in relation to healthy diets and human health ('food as the next health care').

- There is obvious need for further consideration of seafood branding and certification. Where should seafood branding go? Is there a way of overcoming the apparent problems of the 'jungle of brands'?

- From a regional branding perspective, there is an interesting issue of what makes this area unique? Aerni asked if there is the possibility of a Fundy Brand (like the *appellation d'origine contrôlée* (AOC)?). D'Entremont mentioned the challenge going from boutique level to world stage. He suggested the need for top quality, year round supply (continuity of supply), connection/association with the resource.

- There appears to be need for discussion and education around the appreciation of local seafood. Much of the fish being used in restaurants today is frozen and imported. Seafood is seasonal, so there is a need for honesty and education resources. If people are to appreciate local seafood there needs to be education and encouragement.

- Stephenson suggested that the implementation of an integrated approach to the management of multiple human activities for sustainability requires further discussion, research and development in several areas:

1) Articulation of the specific criteria for sustainability (with performance indicators, reference points and relevant data series)
2) Methods for evaluating/quantifying sustainability in management (including life cycle analyses and management strategy evaluation)
3) Methods for evaluating cumulative impacts of multiple activities in an area
4) Decision support tools that would enable scenario development and comparison.

Panel members of the 2012 St. Andrews Seafood Forum: Perspectives on Sustainability

Chris Aerni
Chef, Owner/Operator, Rossmount Inn, St. Andrews

After a traditional chef's training in Switzerland and extended education in business studies 30 years ago, Chris Aerni travelled and worked in various restaurants and hotels gaining experience in the different kitchen ranks and corporate managerial positions from Australia to Toronto. In 2001 he and his wife purchased the Rossmount Inn in New Brunswick, an 87 acre estate, set between the forest and the sea including an 18 room country Inn with a fully licensed bar and restaurant. The restaurant at the Rossmount Inn has gained a wonderful reputation throughout the Maritimes for its creative, market fresh cuisine honoring local ingredients and the people who produce them.

Robert Stephenson
Research Scientist, St. Andrews Biological Station and University of New Brunswick

Dr. Rob Stephenson is a research scientist with the Canadian Department of Fisheries and Oceans (DFO) St. Andrews Biological Station, and Visiting Research Professor at the University of New Brunswick. He is currently Principal Investigator of the Canadian Fisheries Research Network – an NSERC-funded network that is linking academics, industry and government in collaborative fisheries research across Canada. Stephenson has worked extensively on the ecology, assessment, and management of Atlantic herring, and more broadly on issues related to fisheries resource evaluation and Fisheries Management Science. Current research interests include fisheries ecology and management, development of integrated coastal zone management, implementation of the ecosystem approach (particularly in fisheries and aquaculture), and development of policies and strategies for sustainability of marine activities. Dr. Stephenson holds a B.Sc. from Trent University (Peterborough, Ont.), and a Ph.D. from the University of Canterbury (Christchurch, N.Z.). From 2005-2009 he was Director of the St. Andrews Biological Station (St. Andrews, New Brunswick). Dr. Stephenson has been an active contributor to fisheries science internationally, including roles as chair of Resource Management and Pelagic Fish Committees of the International Council for Exploration of the Sea (ICES). He has been an Honorary Research Associate of the Dept of Oceanography, Dalhousie University, and in 1999-2000 was visiting Research Professor and the Finnish Game and Fisheries Research Institute (Helsinki, Finland).

Jean Guy d'Entremont
President, Scotia Harvest Seafoods, and Marro Management Inc.

Jean Guy d'Entremont was born in Yarmouth, Nova Scotia. He currently resides in West Pubnico with his wife, Marlene. Jean Guy graduated from St. Anne du Ruisseau High School in 1979 and joined his father, uncle, and three cousins in the fish business in 1980. At age 23, Jean Guy skippered an inshore dragger and fished extensively in the Bay of Fundy, Scotian Shelf, and out around Sable Island. He successfully completed his Fishing Masters Class 4 course in 1987. After seven years as skipper, he regained a position on shore to help coordinate the fleet of 5 vessels once the groundfish quota system was put in place. In 1994, Jean Guy initiated the work to develop the Joint Industry/DFO ITQ groundfish survey that has been ongoing since 1995. Jean Guy was one of the original six fishermen that first sat down to develop a Canadian Code of Conduct for Responsible Fishing Operations in which the consensus code was adopted in 1998. In 1998, he was appointed to the Fisheries Resource Conservation Council by the Federal Minister of Fisheries. In 2002, the Minister appointed Jean Guy vice-Chair of the Council and as Chairman from November 2003 to September 2010.

In 2000, Jean Guy's peers appointed him Co-Chair of the North Atlantic Responsible Fishing Council Steering Committee. His duties have been co-chairing the 2nd and 3rd North Atlantic Responsible Fishing Conferences; in St. John's, Newfoundland, in November of 2000, and on June 9-11, 2003 in Yarmouth, Nova Scotia. The North Atlantic Responsible Fishing Council Steering Committee has the duty to promote responsible fishing practices across the North Atlantic.

In 2006, he went out on his own and started two fish harvesting companies, Scotia Harvest Seafoods Inc. and Marro Management Inc., which Jean Guy is currently President and sole owner of Scotia Harvest Seafoods Inc. as well as President and co-owner of Marro Management Inc. Jean Guy is a former member of the Nova Scotia Fisheries Sector Council, and currently participates as industry co-chair of the national Seafood Value Chain Roundtable. Jean Guy feels his greatest accomplishment was to be able to provide a good career opportunity to his 3 sons, Alain, Gilles and Raymond, in the global seafood business of the future.

Lauren Lavigne

Team Lead of the Aquaculture Sustainability Reporting Initiative within the Aquaculture Management Directorate at Fisheries and Oceans Canada

Lauren Lavigne is currently the Team Lead of the Aquaculture Sustainability Reporting Initiative within the Aquaculture Management Directorate at Fisheries and Oceans Canada. The Aquaculture Sustainability Reporting Initiative is a collaborative effort between federal and provincial governments, the aquaculture industry and other stakeholders to *provide fact-based, credible information to document conditions and demonstrate the sustainability of aquaculture in Canada.* Prior to this role she was Senior Aquaculture Certification Analyst responsible for developing and managing DFO's Aquaculture Sustainability Outreach Program and improving industry's capacity to achieve third party certification. Lauren has spent most of her career involved in international market development and trade for Canadian food and beverage products. She previously worked at Agriculture and Agri-Food Canada as a Senior International Market Development Officer for seafood, as well as the Japan Desk Officer. She also completed a temporary assignment at the Consulate General of Canada in New York City as the Agri-Food and Beverage Trade Commissioner for the Tri-State area. Lauren holds a Bachelors degree in Business Administration from the University of Western Ontario in London, Ontario and has recently completed the LEAD (Leadership in Environment and Development) Fellowship Training Program. She currently lives in Vancouver, BC where she is an active sailor, skier and windsurfer.

Steve Lutz

VP Neilson Parishables Group: steve@perishablesgroup.com

Steve Lutz is executive vice president of Neilsen Perishables Group, a Chicago-based marketing and consulting firm. His primary work involves helping organizations understand and merge consumer information and supermarket sales data to develop innovative growth strategies. He has worked for more than 30 years in various areas of marketing and management. As respected industry leader, Steve has been a top-rated speaker at the Food Marketing Institute, Produce Marketing Association, Canadian Produce Marketing Association, Boston International Seafood Show and other meetings throughout the world. Prior to co-founding the Perishables

Group in June, 2000, Steve served as president and CEO of the Washington Apple Commission. His previous marketing experience includes Nutri-System as well as The Olgilvy Group. He was primarily responsible for the development of marketing and advertising programs, leading several national accounts including Westin Hotels of Mexico, K2 Ski Company, Helly Hansen and Chateau Ste. Michelle Winery. His work also involved the brand development and launch of the Columbia Crest winery, now one of the 10 largest wineries in the United States. Steve holds an MBA from City University in Seattle and a bachelor's degree in communications/advertising from Washington State University. He also completed the marketing management program in the graduate school of business at Stanford University. He is a past member of the board of directors for the Produce Marketing Association and currently serves on the Retail/Foodservice Board of United Fresh. Steve is an avid skier, triathlete and runner and has competed in the Boston Marathon three times. He has been married for 30 years and has three sons.

David Smith
Vice President of Sustainability, Sobeys, Inc.

Founded over 100 years ago, Sobeys Inc. is a Canadian supermarket company with about 1400 stores across the country and $16 billion in annual revenue. David leads Sobeys sustainability direction, covering direct operations (retails stores, fleets, warehouses) and product sourcing (including sustainable seafood, agriculture, packaging, social compliance, animal welfare). He also participates in numerous Canadian, North American, and global sustainability committees, including with The Consumer Goods Forum and the Global Social Compliance Program. In his previous position with Sobeys, David was General Manager of its new small urban store concept. Prior to Sobeys, David was National VP of Marketing for Whole Foods Market, Austin, Texas, during which time he was on the Organic Trade Association marketing committee, was on the inaugural Wi-Fi industry marketing committee while with a California-based wireless networking start-up, was with McDonald’s Restaurants of Canada, and was with a developing country master franchisee for Pizza Hut and KFC. David has an undergraduate degree in environmental science and a MBA.

Johan Verreth, PhD
Professor, Chair Aquaculture and Fisheries Group, Department of Animal Sciences, and Director Graduate School Wageningen Institute of Animal Sciences, Wageningen University, The Netherlands.

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An unprecedented incidence of tilapia mass mortality due to *streptococcus iniae* infection in the White Nile, at Jebel Aulia dam reservoir, Khartoum, Sudan

Thomas George

Abstract

Mass mortality of only Tilapia species (25-700 g) occurred in the reservoir and beyond the Jebel Aulia Dam for 40 km. This happened one week after 60,000 live tilapia fingerlings, crowded in fiberglass water tanks, were transported and released at the Jebel Aulia Dam Reservoir on the White Nile during June 2010, without following the procedures of transporting live fish. Laboratory water analysis and examination of infected fish showed no harmful effects due to pesticides or heavy metals but, high levels of bacteria. This paper reports the details of this unfortunate incidence and recommendations to avoid such ecological catastrophes in the future.

Introduction

"…mass mortality of only tilapia species caused confusion and terribly affected the Khartoum fish market as consumers abstained from buying fish for several weeks. This paper … suggests what should be undertaken to avoid such ecological catastrophe in the future.

The White Nile is a river in Africa that rises in the Great Lakes of Central Africa as far as Southern Rawanda, flowing north through Tanzania, Lake Victoria, Uganda and enters Southern Sudan at Nimule. The White Nile (Fig.1) then flows further north and joins the Blue Nile at Khartoum, the capital of Sudan, to form the Nile proper (the longest river in the world). It flows 7,088 km (4,405 miles), with a 1-2 km wide bed, before pouring its waters into the Mediterranean Sea after passing through Egypt. North of the Egyptian capital, Cairo, the Nile proper splits into two branches, the Rosetta Branch to the west and the Damietta Branch to the east to form a large delta that empties into the Mediterranean Sea.[1,2]

In 1937 the White Nile was impounded for flood control, water storage, and irrigation purposes (recently for electricity generation), creating the Jebel Aulia reservoir, 40 km south of Khartoum. The dam (Fig. 2) was constructed 377 m above sea level, with a total length of 5 km and 22 m in height. The reservoir surface area ranges from 600 to 1500 km². The maximum depth is 12 m with a mean from 2.2 to 6 m, and a volume of 3.5 cubic meters. The lake's length is 500 km with a maximum width in the vicinity of the dam between 6 and 7 km. The reservoir's level starts to drop in February and continues until the end of May. It reaches its maximum level in September after the flooding season is over. Fish in the reservoir was reported in 1985 by Asma to consist of 54 species, 27 genera belonging to 13 families; the catch is predominantly tilapia spp.[3]

In aquaculture ponds and natural water streams pathogens including bacteria, fungi, and parasites are always present, but the immune system of healthy fish prevents them from becoming a problem. However, stress weakens fishes' immune systems and this may lead to infection by bacteria, etc.(4) This is in fact what happened during the 16-18 of June, 2010, one week after 60,000 live tilapia fingerlings (2-3 g) were released into the White Nile at Jebel Aulia Dam Reservoir. The release followed a lengthy transport in crowded fiberglass tanks, without following the technological and acclimatization procedures of transporting live fish. About five tons of only tilapia species (25-700 g) died along a water stretch of about 40 km downstream, north of the dam reservoir. This mass mortality of only tilapia species (Fig. 3) caused confusion and terribly affected the Khartoum fish market as consumers abstained from buying fish for several weeks. This paper reports the details of this unprecedented incidence of mass mortality of only tilapia species in the White Nile and suggests what should be undertaken to avoid such ecological catastrophe in the future.

Figure 1: Map of the Nile River

Figure 2: Jebel Aulia Dam

Figure 3: Tilapia mass mortality

Figure 4: Clinical signs

Necropsy and laboratory analysis

Laboratory analysis and examination of infected fish showed no harmful effects due to pesticides or heavy metals but, high levels of bacteria (Tables 1, 2). Clinical signs (symptoms) of generalized hemorrhagic septicemia in affected fish included, anoxia, lethargy, skin melanosis, hyperemia and pectoral hemorrhages in the anal region and over the fins, hemorrhagic and necrotic lesions (including the skin), exophthalmia (protruding eyes) with preoccular heamorhages, corneal opacity in one or both eyes, erratic swimming motion and a curved body with abdominal distension. At autopsy, the spleen was typically enlarged while both the liver and kidney were pale. The abdominal cavity was distended and contained bloody exudates. The gill filaments were decayed due to mass hemorrhage and had a bad smell (Fig.4).

Table 1. Chemical analysis results of heavy metals in the waters of the White Nile on July 14, 2010 according to the Sudanese Standard & Metrology Org. (SSMO).

Pb concentration	N.D. (<0.0005 mg/L)	Maximum acceptable 0.0070 mg/L
Cd concentration	N.D. (<0.0005 mg/L)	Maximum acceptable 0.0030 mg/L
Cr concentration	N.D (<0.0005 mg/L)	Maximum acceptable 0.0400 mg/L

Table 2. Microbiological laboratory analysis of dead infected fish on July 14, 2010, according to the Sudanese Standard & Metrology Organization (SSMO)

TEST	STANDARDS (SDS 2039) Limit per g						RESULTS Limit per g	COMPLIANCE
	n	c	m	M	n	c		
APC	5	3	$5x10^3$	10^6	4	4	Uncountable	Non compilant
Escherichia coli	5	3	10	$5x10^2$	4	4	+ve	Non compilant
Coagulase +ve staph	5	2	10^3	10^4	4	0	Nil	Compilant
Vibrio parahaemolyticus	5	2	10^2	10^3	4	4	-ve	Compilant

While *Streptococcus* bacteria was identified, the analytical capacity was unavailable to positively identify *Streptococcus iniae* to the species level.

Discussion

On several occasions, before and after the incidence of tilapia mass mortality, I had published articles in the Bulletin of AAC, Northern Aquaculture and local Canadian/ Sudanese Newspapers on the effects of *S. iniae* on tilapia fish and humans.[5,6,7,8] *S. iniae* is actually present in the water and becomes active only when the fish are crowded/stressed and that is why fish farmers should be enlightened on how to handle live fish to avoid *S. iniae* infections. As a matter of fact, the dam reservoir provided an ideal environment for *S. iniae* to multiply i.e. warmth (above 25 ˚C), low water level and breeding season of tilapia with nests built in shallow waters along the banks of the White Nile (Fig.5). The resulting mass mortality of tilapia caused confusion and terribly affected the Khartoum fish market because consumers abstained from buying fish for several weeks. However, when the people read the newspaper and knew the cause of mortality and that eating cooked fish poses no risk, market condition returned to normal.[9]

Besides the signs described earlier, a characteristic sign of *S. iniae* is the presence of erratic, disoriented swimming movements, mainly in moribund fish, which has led to the term "mad tilapia disease". As a matter of fact, this abnormal swimming behavior is caused by meningoencephalitis resulting from streptococcal invasion and infection of the brain and meninges.[5] Also, it is to be noted that *S. iniae* is not restricted only to tilapia species. Worldwide streptococcal infections have been reported in about 22 fish species, and the so-called "mad fish disease" is unlike "mad cow disease" or BSE (bovine spongiform encephalopathy), which is caused by a prion (infectious protein particle), not a bacterium. Furthermore, in a

Figure 5: **Tilapia breeding nests**

press release, the American Tilapia Association[10] stated that "the report of "mad fish disease" is inaccurate, highly inflammatory and must be withdrawn; streptococcus makes neither humans nor fish mad"!

Aquaculture has been growing more rapidly than any other food-producing sector in the world and recent increases in per capita food fish supply has been obtained from aquaculture.[11] However, fish farmers should note that the impact of streptococcal infections, especially in commercial aquaculture operations, occurs more frequently than in natural waters. Annual worldwide loss estimates caused by *S. iniae* in tilapia species exceed US $150 million. In the United States, tilapia farmers lost more than US $10 million when *S. iniae* caused mortalities of 30 to 50% in fish cultured in ponds and 75% in fish reared in closed systems.[5] Now, as aquaculture in Sudan is progressing by leaps and bounds and tilapia, *Oreochromis niloticus*, is the main species cultured, there is great potentials for serious strep outbreaks to occur in future as tilapia fish are held in confinement. This is mainly because *O. niloticus* is a prolific breeder and stocking densities in ponds are soon upset, resulting in crowded conditions, stresses and ultimately streptococcal infections. Therefore, it is high time to avoid this problem in Sudan by culturing all male tilapia through sex reversal by using the hormone 17 alpha-methyltestosterone (MT) or through hybridization technique or introduce monosex male tilapia known as GMT or Genetically Male Tilapia.[12]

"Annual worldwide loss estimates caused by S. iniae in tilapia species exceed US $150 million. In the United States, tilapia farmers lost more than US $10 million when it caused mortalities of 30 to 50% in fish cultured in ponds and 75% in fish reared in closed systems."

To use sex reversal technique, the local authorities in Sudan have to approve the process due to withdrawal times. Guererro[13] and Macintoch[14] ascertained that after five days from withdrawal of hormone-feed, the levels of the male sex hormone in the tested fish return to normal indicating that no residues are present. With several months from the time of withdrawal of hormone-feed to the time of consumption of treated fish, consumers are assured that the fish are absolutely safe for eating. Therefore, the use of this technique in Sudan should be approved and initially, be restricted to recognized hatcheries that provide tilapia fingerlings to the fish farmers in order to ensure its proper handling and use. With respect to the application of hybridization technique or the use of GMT, it is necessary to introduce exotic tilapia species which is not recommended for Sudan as it has three indigenous tilapia species and protection of their biodiversity is extremely important.

Conclusion and recommendations

1) The dam reservoir provided an ideal environment for the bacteria Streptococcus, introduced by the release of stressed infected tilapia fingerlings, to multiply – warmth (above 25°C), low water level and nutrient-rich, lots of places to hide, and plenty of fish especially, tilapia which builds its breeding nests in shallow waters along the river bank (Fig. 3). Therefore, it is strongly recommended that fish farmers abide with the technological and acclimatization procedures of transporting live fish as illustrated in (Fig. 6) in

order to avoid similar future ecological catastrophes of Streptococcus infections.

2) Although tilapia species. are well known to tolerate adverse water quality and other stressors better than most other fish species, only tilapia from 100 g to market size are typically susceptible to *S. iniae*. Why? It is unknown and research is needed on this aspect. Cooperation between scientists in Canadian and Sudanese institutions is recommended.

3) It is extremely necessary in tilapia culture to raise all-male stock to avoid altering the stocking densities. Consequently, in order to boost commercial production it is high time local Authorities in Sudan to approve the use of sex reversal hormone MT; as it has been proved to have no health side effects on consumers when used properly.

4) Hybridization techniques and the use of Genetically Male Tilapia (GMT) necessitate the introduction of exotic tilapia species and this is not recommended for Sudan but rather for other countries which do not have indigenous tilapia species.

5) Fish farmers are advised to practice "preventive medicine" as part of any management procedure as this is the best and least expensive

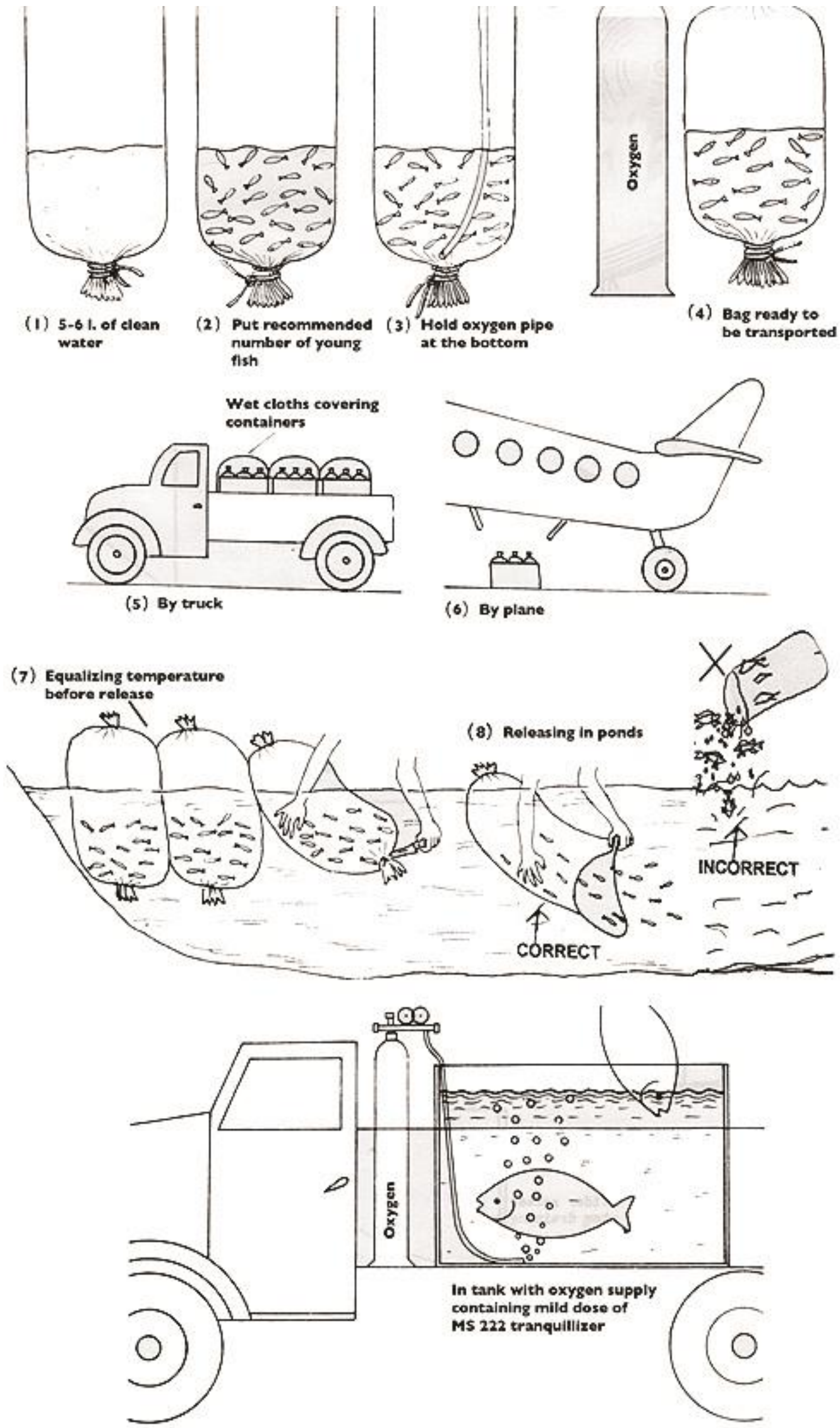

Figure 6: FAO Diagram of live fish transport[15]

method of disease control and hence, secure more profit for the fish farmer. This is because once the disease enters a tilapia farm/production centre, it becomes extremely difficult to eradicate.

6) *S. iniae* may be easily misidentified by conventional automated microbiology systems. Therefore, for correct identification, molecular genetic methods, such as DNA sequencing and DNA-DNA hybridization, are recommended.[16]

7) State laboratories in Sudan should be well equipped to analyze the presence of *Streptococcus* in specimens of infected dead fish, develop techniques to detect streptococcal disease at an early stage and also, develop vaccines for humans and tilapias against *S. iniae*. Cooperation between Canadian and Sudanese scientists is strongly recommended.

8) The National media (TV and Radio) in Sudan and other African countries should include programs to enlighten citizens, in particular fish farmers, about the different aspects of aquaculture in order to boost tilapia production safely.

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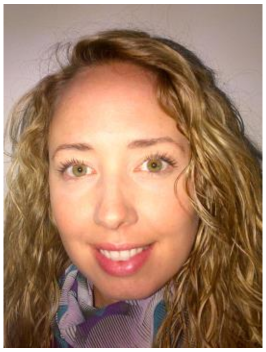

Jessica Whitehead

Atlantic Canada's aquaculture environmental assessment and monitoring programs: research requirements to achieve harmonization

Jessica Whitehead, Bob Sweeney, Tara Daggett, Allison Stagg-Kendall, Dave Cook, Amanda Smith, Leah Lewis-McCrea and Janelle Arsenault

"…lack of harmonization results in different provincial regulatory objectives, resulting in inconsistencies in how the marine-finfish, cage-aquaculture, environmental monitoring is conducted in the region."

Abstract

An *Atlantic Provinces' Memorandum of Understanding for the Development of the Aquaculture Sector* has indicated support for increased cooperation amongst the Atlantic provinces, partnering on mutually beneficial initiatives promoting sustainable aquaculture development in Atlantic Canada. Environmental monitoring was one of the agreed initiatives. However the regulations and policies governing aquaculture environmental monitoring in the Atlantic provinces are different for each province and have yet to be harmonized. This lack of harmonization results in different provincial regulatory objectives, resulting in inconsistencies in how the marine-finfish, cage-aquaculture, environmental monitoring is conducted in the region. Another issue is existing monitoring programs currently focus on "threshold monitoring", and thus identify problems that have already occurred, rather than focusing on preventative monitoring. This article describes various environmental assessment and monitoring programs in New Brunswick, Nova Scotia and Newfoundland and will look at some of the research needed to bring both industry and the regulatory agencies to a mutually agreed upon level of harmonization in Atlantic Canada.

Introduction

Sweeney International Marine Corp. (SIMCorp) was established in January 2002 and has been conducting marine baseline assessments and environmental monitoring for the finfish aquaculture sectors in NB, NS and NL for the past ten years and as such, has acquired a great deal of experience across the Atlantic region. Aquaculture environmental assessments and monitoring are practices which assess the relationship between aquaculture and the marine environment, with the purpose of ensuring the environmental sustainability of the marine-finfish, cage-aquaculture industry.[1,2,3]. These environmental assessments and monitoring programs are implemented under the authority of provincial acts (New Brunswick: *Water Quality Regulation – Clean Environment Act*;[4] Nova Scotia: *Fisheries and Coastal Resources Act;*[5] Newfoundland: *Aquaculture Act*)[6] and the federal *Fisheries Act* (DFO).[7] On January 18, 2008, the Atlantic provinces signed a Memorandum of Understanding (MOU) for the Development of the Aquaculture Sector; section 2.1 states:

"The Parties agree to work towards a harmonized regulatory and policy environment, to the extent that this is possible, in areas such as leasing and licensing programs, environmental monitoring, introductions and transfers, aquaculture statistics, and aquatic animal health." (8)

To date, the Atlantic provinces have not harmonized these regulations and policies for environmental monitoring. As a result, each Atlantic province has a different regulatory framework, and growers communicate with different governing bodies, depending on the province and type of environmental monitoring conducted (Fig.1). Even when the same level of environmental monitoring is considered, standard operating procedures (SOPs) outlining monitoring methodologies are inconsistent between the provinces. The differences between provincial monitoring programs are detailed below as a means to identify research required to achieve harmonization.

In NB, NS and NL, there are two classes of environmental monitoring regulations: baseline assessments and threshold monitoring. Baseline assessments are conducted either when applying for a new aquaculture lease or to amend approved lease boundaries.(2,9) Baseline assessments provide preliminary information on environmental conditions at a proposed site prior to the initiation of finfish farming. The assessment evaluates the proposed site

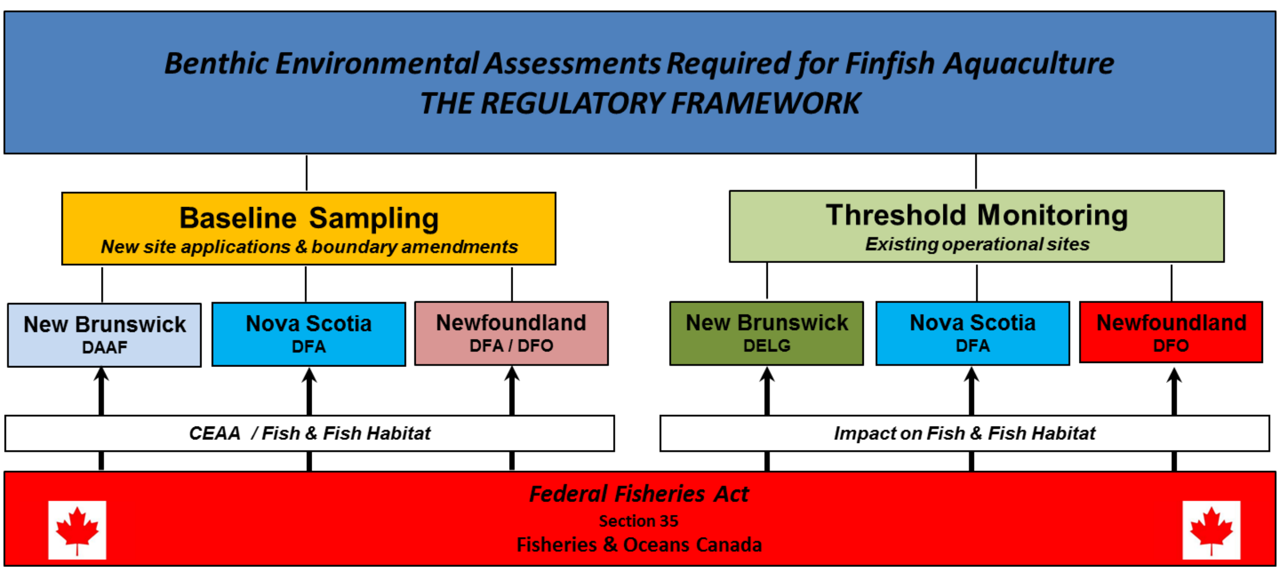

Figure 1: The Atlantic provinces' regulatory framework for finfish aquaculture benthic environmental assessments. Following the introduction of Bill C-38, environmental assessments (EA) are no longer required for aquaculture. That being said, a newly developed environmental effects determination (EED) process under CEAA 2012 may be required by Transport Canada for aquaculture projects occurring on federal lands with the potential of posing environmental risks. The completion of an EA to fulfill the requirements of provincial regulators will still be necessary for new site applications and boundary amendments.

for the development of sustainable aquaculture.[2,9] Threshold monitoring is conducted to evaluate the health of the benthic environment within aquaculture lease areas during the course of the marine finfish grow-out phase. This is achieved by measuring environmental impact indicators. Quantifiable indicators with predefined value ranges are used to classify the level of impact. Should particular thresholds be exceeded, enhanced monitoring and mitigative measures are typically required.[1,2] Comparisons between baseline and threshold monitoring data are used to identify changes in the benthic environment originating from finfish production.

Baseline Assessments

Baseline assessment sampling requirements vary according to each of the Atlantic provinces (Table 1, Fig. 2). NB, NS and NL are consistent in sampling each lease corner and stations within the lease boundaries of a proposed aquaculture site,[9,10,11] albeit with varying sampling configurations (Fig. 2). In NS, baseline assessment sampling configurations are not the same for all sites, as sampling locations are defined using anticipated production levels and cage configurations.[11]

Table 1. Differences in provincial baseline environmental sampling requirements for finfish aquaculture.

	BASELINE ASSESSMENTS		
Requirements	**New Brunswick**	**Nova Scotia**	**Newfoundland**
Sampling stations			
Lease corners	x	x	x
Within lease	x	x	x
Reference		x	
Video monitoring			
Transects	x		
Drops	x	x	x
Sediment sampling			
Sulphide (µM)	x	x	x
Redox (mV_{NHE})	x	x	x
Organic content (%)	x	x	
Porosity (%)	x	x	
Grain size (mm)	x	x	
Current meter	x	x	
Depth profile	x		

Underwater video footage is collected during baseline assessments in all three Atlantic provinces and this is used as a tool to visually identify the condition of the benthic environment of an aquaculture lease.[9,10,11] The differences in video collection methodologies between NB, NS and NL are the number and configuration of video stations with respect to the aquaculture lease, and whether video footage is collected along a transect or from stationary drops. In NL, aquaculture sites with five proposed finfish cages or less are required to produce video recordings from each proposed cage location. For aquaculture sites with more than five cages, the entire lease is divided into 100 x 100-m grids and video footage is collected from each grid node.[10] Both NS and NL perform stationary drops for video collection at all sampling locations.[10,11] NB conducts stationary drops at each lease corner; however a 150-m video transect is surveyed through the center of the lease along with a 50-m video transect extending away from the lease boundary in the direction of the prevailing current (Fig. 2).[9]

Sediment samples are collected at sampling stations remotely with surface-deployed sediment grabs and in some occasions where water depth is less than 30 m, by divers using sediment core tubes.[9,10,11] NS and NL are required to collect three sediment replicates per station.[10,11] Sediment collection is not mandatory in NL if video footage does not reveal soft sediments.[10] NB collects four sediment samples in the center of the proposed lease and 2 replicates from each of the lease corners and at the end of the 50-m transect.[9] All provinces collect one sediment sub-sample per grab for analysis.[9,10,11] Table 1 lists the required analysis each province performs on the sediment sub-samples.

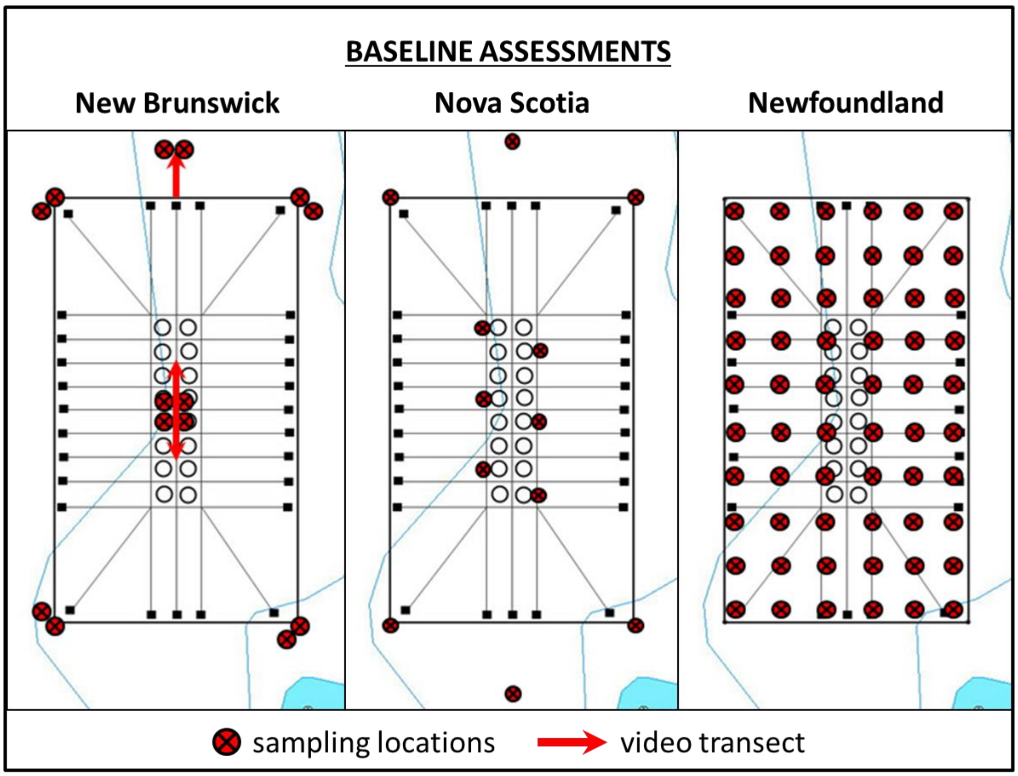

Figure 2. Differences in provincial baseline environmental sampling configurations for finfish aquaculture.

Current meter deployments are required for NB and NS baseline assessments and must be conducted near the center of the proposed site, with speed and directional measures (1-m sampling bins for a 5-min averaging period) required every 15 minutes, over a minimum duration of 35 days.[9,11] Depth profile imaging is required only for NB baselines to illustrate bathymetry contours throughout the lease.[9]

Threshold Monitoring

The threshold-monitoring programs in each of the Atlantic provinces operate from different regulatory frameworks and as a result the SOPs differ

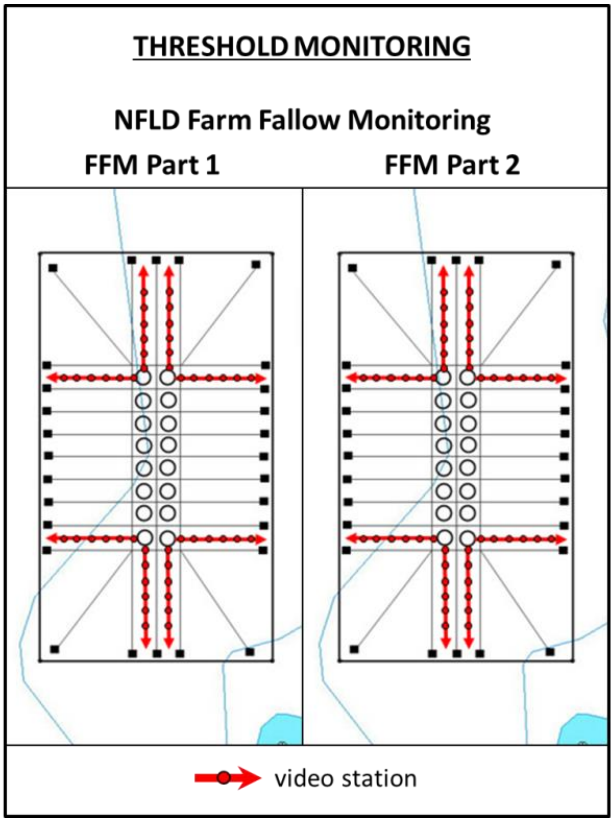

Figure 3: Configuration of sampling stations for NL FFM Part I and II.

dramatically. Thresholds are used as a decision support tool to indicate whether marine finfish operations are compliant with the environmental quality objectives (EQO) for each province. For NB and NS, the EQO is to maintain oxic sediment conditions.[1,2]

Waste production and organic loading can have adverse impacts to marine benthic habitats by increasing oxygen consumption rates, which may result in hypoxic or anoxic sediment conditions.

The NL marine-finfish, cage-aquaculture, threshold-monitoring program is termed Farm Fallow Monitoring (FFM) and is currently at an interim stage with research being carried out to define an EQO. Presently, FFM is conducted in two parts. Part I occurs two weeks before to two weeks after a fallow period begins and is used to assess the benthic conditions beneath an aquaculture lease in relation to maximum biomass. Part I sampling requires the collection of video recordings of the benthos by stationary drops of an underwater camera at 10-m intervals along two perpendicular transects at each corner of the cage array. Transects begin at cage edge (*i.e.* 0 m) and extend up to a maximum distance of 50 m (Fig. 3). Additional transects are compulsory for sites with more than nine cages in a row. If the video footage reveals an absence of organic accumulation after 30 m, video recordings can be discontinued. If organic accumulation is identified, FFM Part II is required, which repeats the sampling conducted in Part I. Part II must be completed four to eight weeks before a fallow period ends and compares FFM Part I results to pre-stocking benthic conditions to determine the efficacy of the fallow period. Sediment collection and analysis are not components of the current FFM program; although sediment is collected on occasion to aid in verifying sediment consistency.[3]

NB and NS each implement a distinct environmental monitoring program (EMP) to regulate the marine-finfish, cage-aquaculture industry. Annual monitoring of finfish aquaculture farms in NB and NS occurs when feeding and waste production is typically highest.[1,2] The NS Level I EMP is carried out once, between the beginning of June to the end of September,[2] while NB Tier 1 EMP is performed once between the beginning of August and the end of October (Table 2).[1] The basis for determining the number of sampling stations differs among these provinces. NS Department of Fisheries and Aquaculture (DFA) uses the number of fish stocked during each production cycle to define the number of required sampling stations,[2] while NB bases the number of stations on the number of fish on site at the time of monitoring (Table 3)[1], except when harvesting has commenced or is completed. In these cases, the number of stations reverts back to the number and location of stations during the most recent Tier 1 or 3 EMP.

Table 2. Annual sampling schedules for NB and NS EMP

		J	F	M	A	M	J	J	A	S	O	N	D
NB	Tier 1								■	■	■		
NB	Tier 2									■	■	■	
NB	Tier 3			■	■	■							
NS	Level I						■	■	■	■			
NS	Level II							■	■	■	■		
NS	Level III			■	■	■							

Moreover, the criterion for determining the sampling locations is dissimilar. NB EMP sampling stations are located along the outside perimeter of the cage layout, at cages with the highest biomass. The specific configuration of the sampling stations depends on the prevailing water current patterns at each farm, for which there are two defined current patterns (*i.e.* linear and curving) that determine station positioning.[12] Sampling station locations for NS EMP are either designated or approved by DFA and are based on cage layouts and on regions of a site with the highest production cages. Sampling stations are located outside of or within the cage array at equal intervals on either side of a longitudinal axis that extends through the site's center, beginning with a station at either end of the axis. The sampling stations can remain in the same location in NS throughout a production cycle (18-24 months) so long as the stock is not rotated within the site and the stocking number and cage configuration remains unchanged. Unlike NB, NS requires that two alongshore reference stations be sampled, per lease, during Level I and Level III monitoring. One station is located upstream and the other downstream, 100 – 300 m away from the site in areas of similar depth and sediment consistency. Sampling stations that are associated with historically high sulphide values (*i.e.* $\geq$ 3000 µM) from previous sampling years continue to be sampled during subsequent Level I monitoring until these stations return to oxic conditions.[11]

Further differences exist between NB and NS EMP video recording methodologies. NB utilizes 50-m transects at each sampling location, which extend away from cage edge in a straight line. The video camera is lowered every 10 m along the transect line to capture approximately 1-min, video recordings of benthic conditions, or divers video the entire length of the transect line (Fig. 4a).[12] NS does not employ the use of transects and requires

Table 3. The basis of the number of sampling station for NS and NB EMP's.

NOVA SCOTIA

Maximum number of fish during production cycle	Number of sampling stations (not including reference stations)	Number of sediment samples
0 - 450,000	3	9
450,001 - 600,000	4	12
600,001 - 750,000	5	15
750,001 - 900,000	6	18
900,001 - 1,050,000	7	21
1,050,001 - 1,200,000	8	24

NEW BRUNSWICK

Number of fish onsite at the time of monitoring	Number of transects	Number of sediment samples
0	0	6
1 - 200,000	2	6
200,001 - 300,000	3	9
300,001 - 400,000	4	12
400,001 - 500,000	5	15
500,001 - 600,000	6	18
600,001 - 700,000	7	21
700,001 - 800,000	8	24
800,001 - 900,000	9	27
900,001 - 1,000,000	10	30

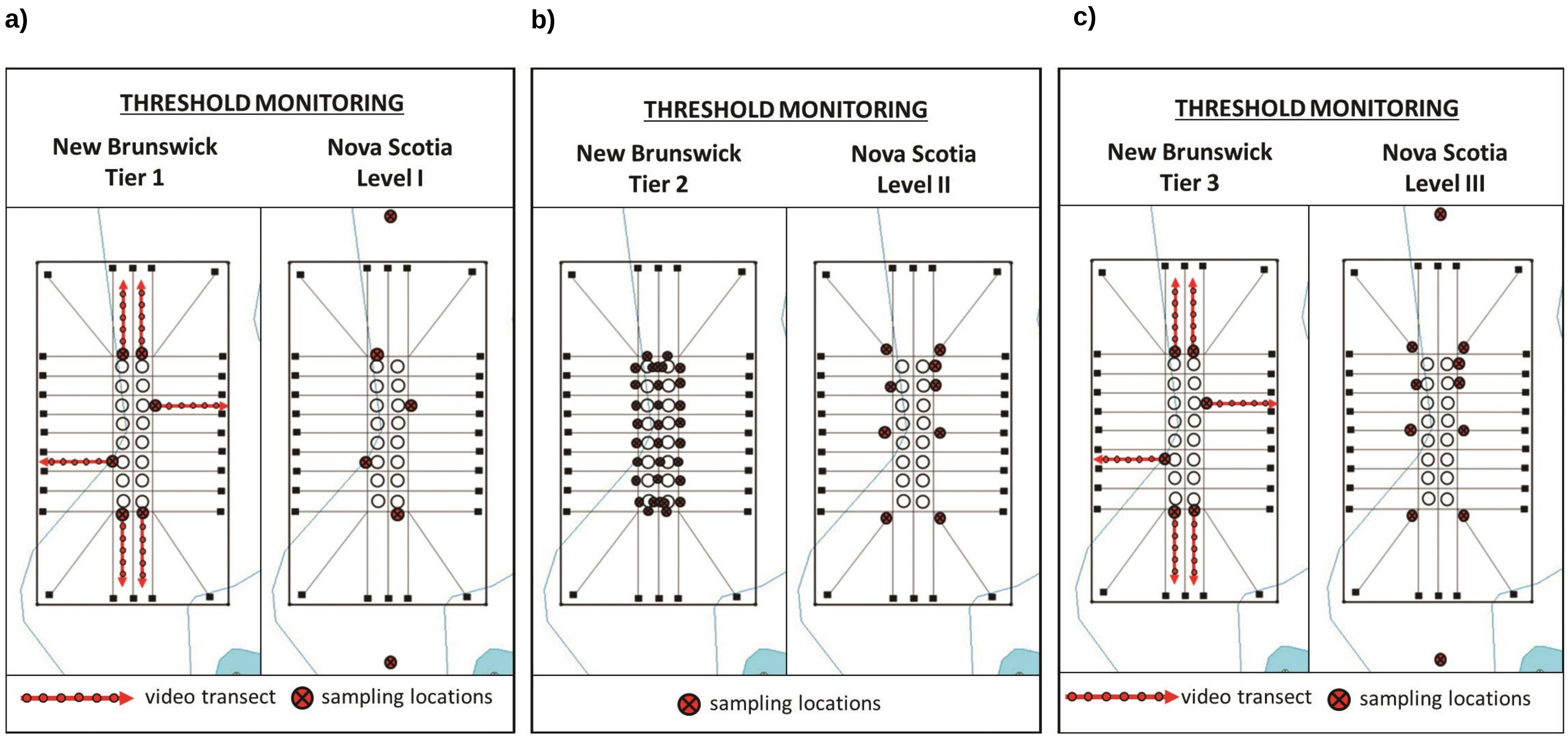

Figure 4: Schematics showing the station configuration for the NB and NS, **a)** annual monitoring event, **b**) second annual monitoring event **c)** third annual monitoring event

the collection of video footage for a minimum period of 2 minutes over 5 m^2 to capture the conditions of the benthic environment. Spatial coverage is achieved by vessel drift, towing the camera along the length of the vessel deck, or by diver.[11] Sediment samples are collected in both provinces at the cage edge by either a surface-deployed sediment grab or diver-deployed core tubes.[11,12] NB requires that three sediment sub-samples be extracted from at least one grab per station,[12] while NS stipulates that three separate grab deployments be performed and one sub-sample be extracted from each.[11] With respect to sediment analysis requirements, sulphide concentrations are the primary indicator of habitat degradation due to organic loading in both provinces.[11,12] NS also requires the collection of sediment organic content and porosity data (Table 4).[11]

Table 4. Differences in NB and NS EMP sampling requirements for finfish aquaculture.

	EMP	
Requirements	**New Brunswick**	**Nova Scotia**
Sampling stations		
Within lease	x	x
Reference		x
Video monitoring		
Transects	x	
Drops	x	x
Sediment sampling		
Sulphide (µM)	x	x
Redox (mV_{NHE})	x	x
Organic content (%)		x
Porosity (%)		x

Environmental monitoring of the marine finfish aquaculture industries in NB, NS and BC rely on the measurement of sulphide concentrations in sediment within farm leases as the fundamental indicator of adverse environmental impacts from finfish farming. The measured sulphide values determine each site's environmental rating (*i.e.* site classification) and play an important role in decisions regarding future production levels.[1,2,13] There has been significant discussion regarding the reliability of sulphide concentration as an indicator of benthic health due to the observed variability in sulphide-probe calibration protocols (Table 5), the spatial distribution of sulphide in marine sediments and temporal concentration fluctuations. In NB, the environmental performance ratings for marine-finfish, cage-aquaculture farms are determined by calculating the entire site's mean sulphide value and assigning a corresponding classification (Table 6).[1] NS thresholds are not based on a site mean; sulphide

Table 5. Differences in sulphide probe calibration specifications between NB, NS and BC.

	NEW BRUNSWICK[12]	NOVA SCOTIA[11]	BRITISH COLUMBIA[13]
Calibration standards	100, 1000 and 10000 µM	100, 500, 1000, 5000 and 10000 µM	10, 100 and 1000 µM OR 100, 1000 and 10000 µM
Use after calibration	< 72 hours post calibration	< 3 hours post calibration	< 3-4 hours post calibration
Frequency of calibration	Maximum use of 3 hours	Maximum use of 3 hours	Change between sampling sessions OR < 3-4 hours
Sample storage	< 72 hours	< 72 hours	< 60 minutes

means are calculated for each station and site classifications are determined based on the percentage of station means that fall within a certain classification range (Table 7).[2]

Table 6. Site mean sulphide values used to determine site classification and level of monitoring in NB.

Site Classification		NEW BRUNSWICK	
		Sulphide Value (µM)	Required Monitoring
Oxic	A	< 750	Tier 1
	B	750 - 1499	Tier 1
Hypoxic	A	1500 - 2999	Tier 1
	B	3000 - 4499	Tier 1, 2
	C	4500 - 5999	Tier 1, 2, 3
Anoxic	Anoxic	> 6000	Tier 1, 2, 3

*Note: Tier 1 sampling is performed during the regular monitoring season only.

In NB and NS, enhanced monitoring is required when sediment sulphide means are ≥ 3000 µM.[1,2] This monitoring must be performed within 20 days after Tier 1 monitoring in NB[1] and 35 days following Level I monitoring for NS (Table 2).[2] For NB Tier 2, sediment samples are collected on four opposite sides of each corner cage, from cage edges along the perimeter of the site and in between each cage (Fig. 4b). Three sediment sub-samples are required per station and can be collected from a single grab deployment. Video monitoring is only required if a sufficient quantity of sediment cannot be collected at a station. This is done to verify the sediment type and benthic conditions in the absence of a sample. Redox analysis is completed for one sub-sample per station, while sulphide analysis is conducted on all samples collected.[12] The site classification is re-evaluated based on the mean sulphide value for the entire site following Tier 2.[1] NS samples the outer edge of cages adjacent to the stations from Level I with elevated sulphide values (*i.e.* ≥ 3000 µM), the grid corner compensator buoys and perimeter buoys at no more than 200-m spacing (Fig. 4b). Three grab deployments are required per station with one sub-sample extraction per grab. Video monitoring is required at all stations according to the methods described for Level I. Sediment analysis includes redox and sulphide measurements for all samples collected; porosity and organic matter analyses are not required for Level II

Table 7. Proportion of station mean sulphide values used to determine site classification and level of monitoring in NS.

Site Classification		NOVA SCOTIA		
		Sulphide Value (µM)	Proportion of Stations Within Each Sulphide Value Range to Designate Site Classification (%)	Required Monitoring
Oxic	A	< 750	≥ 51	Level I
	B	750 - 1500		Level I
Hypoxic	A	1500 - 3000	≥ 50	Level I
	B	3000 - 6000	≥ 50	Level I, II
Anoxic	Anoxic	> 6000	≥ 70	Level I, II, III

*Note: Level I sampling is performed during the regular monitoring season only.

monitoring. The Level II sulphide results do not supersede the site classification derived from Level I sampling.[2]

Tier 3 monitoring is triggered in NB when Tier 1 or Tier 2 site mean sulphide values are ≥ 4500 µM (Table 6) and must be conducted between March 1 and May 31 (Table 2).[1] NB Tier 3 follows the sampling and analysis regime conducted during the most recent Tier 1 monitoring event (Fig. 4c).[12] Additional Tier 2 monitoring is compulsory if the site sulphide mean from the Tier 3 assessment is ≥ 3000 µM.[1] NS Level III monitoring is required when ≥ 70% of station sulphide means are 6000 µM or higher (Table 7).[2] Level III station locations are based on a variation of the Level II sampling configuration and aims to determine seasonal variation of the benthic conditions by performing sampling in the winter or early spring. Video, sediment collection and subsequent analyses are carried out as described for Level II monitoring.[11] In NB and NS, additional sampling and analysis can aid in confirming and identifying the issues responsible for surpassing environmental thresholds. Best management practices (BMP) are implemented to prevent negative impacts to the environment where aquaculture is conducted. Such practices include waste management, record keeping and reporting, equipment cleaning and disinfection, and feed handling and storage. Additional BMPs are required when sites are classified beyond the oxic sediment condition, with the implementation of additional BMPs intensifying as the sulphide concentrations indicate that oxygen availability is decreasing.[1,2]

"A single set of environmental management guidelines (EMGs) or SOPs cannot apply to all substrates."

Research

While the present article examines the Atlantic region's aquaculture environmental monitoring programs, it is appropriate to incorporate BC's methodologies here as they further illustrate the inconsistencies between provincial SOPs in regards to sulphide probe calibrations and analysis (Table 5). SOP comparisons between NB, NS and BC indicate significant variations in sulphide probe calibrations. Eliminating these differences would help to:

1) Produce undisputed sulphide measurements
2) Compare results between environmental monitoring companies
3) Compare sediment sulphide concentrations from year to year at a particular site
4) Compare results obtained by government audits.

To ensure the use of sulphide probes in environmental monitoring for the finfish aquaculture industry in Canada is as consistent, reliable and accurate as possible, it is essential to standardize procedures.

The environmental monitoring program in NL provides alternatives for assessing the health of marine benthic substrates when sediment collection is not possible. This is largely due to the hard bottom nature of the seafloor in NL. NB and NS also encounter hard bottom substrates during monitoring events; however, SOPs do not outline alternatives for determining benthic health in the absence of sediment collection. A single set of environmental management guidelines (EMGs) or SOPs cannot apply to all substrates. The finfish aquaculture sector requires separate EMGs and SOPs for a range of parameters such as: soft bottom low energy sites, hard bottom high energy sites, shallow water sites and deep water sites. Research priority must be given to video and visual imaging protocols and to the interpretation of video and images to aid in the assessment of environmental performance and sustainability when sediment collection is not feasible.

"Research priority must be given to video and visual imaging protocols and to the interpretation of video and images to aid in the assessment of environmental performance and sustainability when sediment collection is not feasible."

Positioning strategies require some attention, particularly due to the different sampling configurations employed by the Atlantic provinces for environmental monitoring (Fig. 2). This will be illustrated for baseline sampling using a hypothetical aquaculture site (Fig. 2) with 900,000 fish evenly distributed throughout 16 cages, in a 2 x 8 grid, within an 900 x 500-m lease. Baseline sampling in NL is rigorous and would divide a site as described above, into 100 x 100-m grids with sampling occurring at each grid node.[10] This approach would create 60 sampling stations. Video is collected once per station, while sediment is collected, when possible, from triplicate grabs per station (180 potential sediment samples). NB and NS baseline sampling occurs at each lease corner, at stations inside the lease (at a much reduced intensity level compared with NL) and outside the lease.[2,9] In NB, the hypothetical site would yield 6 baseline video sampling locations (each lease corner, along a 150-m transect and 50-m transect), 14 sediment stations (two stations per lease corner, four stations in the center of the lease and two stations at the end of a 50-m transect) and 14 sediment samples (1 grab per station and 1 sub-sample per grab).[9] NS baseline sampling locations are prescribed on a site-by-site basis considering cage configuration and proposed stocking. The hypothetical site in NS would result in 12 video sampling locations (each lease corner, 6 stations within the lease and 2 reference stations) and 36 sediment samples, assuming triplicate grab attempts per station.[2] Research could examine the effectiveness of each positioning strategy in capturing 'baseline' benthic conditions by performing each baseline assessment sampling regime at a variety of locations (controls, active sites, non-operational sites, variety of substrates and in each province). Similarly, each provincial threshold-monitoring positioning-strategy could be conducted in the same vicinity and results compared to determine if and how conclusions differ regarding the health of the seafloor. Additionally, new sampling configurations and tools should be examined, which may provide a more thorough representation of benthic health.

Conclusion

The aforementioned monitoring inconsistencies between provinces give cause for concern. Baseline-sampling-station density differs dramatically between the Atlantic provinces with NL employing the most rigorous sampling configuration but requiring minimal sediment analysis. Post-stocking, monitoring programs do not focus on prevention of environmental damage but instead focus on threshold monitoring consisting of single, annual, monitoring events and only require additional monitoring after the benthos is suspected to be impacted. This approach is reactive rather than proactive. NB and NS threshold monitoring programs are focused on sampling during the period of highest biomass and intensive growth, when the risk of environmental impacts from aquaculture production is highest.[(1,2)] NS does conduct repetitive sampling of historical high stations to ensure recovery to oxic conditions and samples reference stations to ensure that the depositional-erosional characteristics are comparable at the farm.[(2)] NL FFM samples at the end of one production cycle and at the beginning of the next to assess the assimilative capacity of the benthos and determine efficacy of the fallow period, relying solely on visual indicators of benthic health.[(10)]

The reliance on sulphide level as the sole, benthic-health indicator and for site classification purposes is concerning due to the variability of specific sulphide probe calibration protocols, the spatial distribution of sulphide in marine sediments and the temporal fluctuations in sulphide concentrations. As in NL, the inability to collect sediments from hard-packed bottoms must be acknowledged by aquaculture environmental regulators, and appropriate protocols must be made available to determine site classifications in the absence of sediment analysis. Sulphide probe calibration protocols should be described in detail and adopted across the country and new visual imaging tools for interpreting environmental performance could greatly improve the aquaculture environmental assessment and monitoring programs.

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