A history of the Southwest New Brunswick Aquaculture Environmental Coordinating Committee: the first 25 years, 1989-2014

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TABLE OF CONTENTS

ABSTRACT

Chang, B.D. and Coombs, K.A. 2016. A history of the Southwest New Brunswick Aquaculture Environmental Coordinating Committee: the first 25 years, 1989-2014. Can. Tech. Rep. Fish. Aquat. Sci. 3152: v + 34 p.

The Southwest New Brunswick Aquaculture Environmental Coordinating Committee (AECC) was formed in 1989 to address aquaculture-environmental interaction issues related to finfish farming in the southwestern New Brunswick area of the Bay of Fundy. The committee was established under the Canada–New Brunswick Memorandum of Understanding on Aquaculture Development (MOU). The committee includes representatives from federal and provincial government agencies, and the aquaculture industry. The committee serves as an advisory body to the MOU Management Committee and to the government and industry entities represented on the AECC. The main issues that have been addressed by the committee include: developing an annual environmental monitoring program for the industry; remediating farms showing environmental degradation; determining production levels of farms and holding capacities of bays; developing a performance based management approach to environmental management of finfish farms; reviewing on-going research relevant to the AECC mandate; and determining research priorities.

RÉSUMÉ

Chang, B.D. and Coombs, K.A. 2016. A history of the Southwest New Brunswick Aquaculture Environmental Coordinating Committee: the first 25 years, 1989-2014. Can. Tech. Rep. Fish. Aquat. Sci. 3152: v + 34 p.

Le Comité de coordination sur l’environnement et l’aquaculture du sud-ouest du Nouveau-Brunswick a été mis sur pied en 1989 afin de traiter les enjeux liés aux interactions entre l’aquaculture et l’environnement concernant la pisciculture dans la région de la baie de Fundy, dans le sud-ouest du Nouveau-Brunswick. Le Comité a été établi dans le cadre du Protocole d’entente entre le Canada et le Nouveau-Brunswick sur le développement de l’aquaculture. Il comprend des représentants d’organismes des gouvernements fédéral et provincial ainsi que de l’industrie aquacole. Il fait office d’organisme consultatif pour le Comité de gestion du protocole d’entente de même que les entités du gouvernement et de l’industrie dont des représentants siègent au Comité de coordination sur l’environnement et l’aquaculture du sud-ouest du Nouveau-Brunswick. Les principaux enjeux qui ont été traités par le Comité comprennent les suivants : élaboration d’un programme de contrôles environnementaux annuels pour l’industrie; assainissement des sites d’élevage qui présentent une dégradation environnementale; détermination des niveaux de production des sites d’élevage et des capacités de stabulation des baies; élaboration d’une approche de gestion axée sur le rendement pour la gestion environnementale des fermes piscicoles; examen des recherches en cours liées au mandat du

Comité de coordination sur l'environnement et l'aquaculture du sud-ouest du Nouveau-Brunswick; et détermination des priorités en matière de recherche.

INTRODUCTION

A major issue for the aquaculture industry concerns the interactions between aquaculture and the aquatic environment in which it exists. Aquaculture has an impact on the environment that can be measured, but it is prudent for industry to ensure that environmental conditions remain sustainable for growing the cultured species and, consequently, that they take actions to minimize and mitigate impacts.

The Southwest New Brunswick Aquaculture Environmental Coordinating Committee (AECC) is a joint federal-provincial-industry committee that was established in 1989 to address aquaculture-environmental issues related to finfish aquaculture development in the southwestern New Brunswick (SWNB) area. The committee is a sub-committee of the Canada–New Brunswick Aquaculture Management Committee. The latter committee was established under the Canada–New Brunswick Memorandum of Understanding on Aquaculture Development (MOU), which was signed in April 1989. The AECC serves as an advisory body to the MOU Management Committee and to the government and industry entities represented on the AECC.

TERMS OF REFERENCE

The first terms of reference for the AECC were finalized in 1990. The terms of reference were revised in 1993, and again in 2004. Possible revisions to the terms of reference were discussed in 2005, and again in 2010; however, the 2004 version remains in effect. The three versions are included in Appendix 1.

While there have been some changes to specific items in the terms of reference, the main mandates of the AECC have remained:

- Environmental monitoring of the SWNB finfish aquaculture industry
    - Contribute to the development of a monitoring program
    - Revisions to the monitoring program
    - Review of annual results
    - Environmental management processes and governance
- Information exchange on current research
- Development of research priorities

ORGANIZATIONAL STRUCTURE

The committee has two chairs, one from the federal government (Canada) and one from the provincial government (New Brunswick). The federal co-chair is a representative of Fisheries and Oceans Canada (DFO) while the provincial co-chair was initially from the New Brunswick Department of Fisheries & Aquaculture (NBDFA) and is currently from the New Brunswick Department of Agriculture, Aquaculture & Fisheries (NBDAAF). See Appendix 2 for a list of the co-chairs since the committee's inception in 1989.

Members of the committee represent various government agencies and the aquaculture industry. The federal government has been represented by DFO since the committee's inception. Environment Canada was also represented on the committee until 2012. The New Brunswick government is currently represented by NBDAAF and the New Brunswick Department of Environment & Local Government (NBDELG). Industry representatives include industry associations, individual farming companies, and environmental consultants. Initially, the industry representatives were all marine growout operators, but freshwater hatcheries were also represented starting in 1993. In addition, other research institutes have been represented at times, most notably the Huntsman Marine Science Centre. A list of members is included in Appendix 3. In addition to the members, various guests and observers have been invited to some meetings; these have included scientific researchers, fish farmers, environmental consultants, and other individuals from government and industry.

An organizational meeting for the AECC was held on 31 May 1989. A list of dates of AECC regular meetings held from 1989-2014 is included in Appendix 4. The number of meetings per year has varied considerably, with a high of 9 meetings in 2000. There were no meetings held from August 2007 to March 2010 (primarily due to reorganization of government departments).

In addition to the regular meetings, the AECC has also convened workshops and special meetings on specific topics. A list of workshops and special meetings sponsored by the AECC is included in Appendix 5. This appendix also includes a list of other workshops and meetings which were not sponsored by the AECC, but were highly relevant to the AECC mandate and had strong participation by AECC members.

The AECC reports its activities to the MOU Management Committee. Individual members communicate AECC activities to their respective organizations. To communicate beyond the member organizations, the AECC has given presentations on its activities at stakeholder forums and other relevant meetings.

MAIN ISSUES

Environmental monitoring

A major activity from the beginning of the committee was the development and subsequent revisions of a province-led environmental monitoring program for the SWNB marine finfish cage aquaculture industry. When the committee was formed in 1989, there was no mandatory monitoring of the industry; hence, this was identified as the top priority in the AECC Terms of Reference (see above). David Wildish (the first DFO co-chair of the AECC) developed a proposal for a monitoring program (Wildish et al. 1990). This report, together with discussions held by the AECC, formed the basis for a proposal for the first industry-wide monitoring, concentrating on measuring benthic impacts due to organic enrichment. This proposal was submitted by the New Brunswick Department of Environment (NBDENV) to the Environmental Trust Fund (ETF). The proposal was funded by the ETF for two years, and allowed for

monitoring of all farms in 1991 and 1992 (Thonney & Garnier 1992, 1993). This program included: measurement of water depth; sediment analysis (% silt/clay, % organic matter, redox potential, abundance of *Capitella*); and visual observations by divers (bottom type, % bacterial mat coverage [*Beggiatoa* sp.] of the seafloor under the farm, the presence outgassing, and the abundance and diversity of epibenthic macrofauna). Monitoring was not continued in 1993, due to lack of funding: the ETF would not fund this program on a continuing basis, because it was felt that such monitoring should ultimately be funded by the industry.

In late 1993, NBDFA took over the responsibility (from NBDENV) to ensure that the industry conducts annual monitoring. An annual monitoring program was designed, based on the 1991-1992 program (Washburn & Gillis Associates Ltd. 1995), with input from the AECC. Monitoring was conducted by an environmental consultant on behalf of the farms, starting in 1995; the cost of monitoring was covered by the industry. The program has evolved since then (see Janowicz & Ross 2001; appendix in Chang & Page 2011), with the AECC providing a major advisory role in the revision process.

The initial mandatory annual program (Washburn & Gillis 1995) included: video transects under farms; collection of sediment samples (for analysis of grain size and total organic carbon); measurement of depths; and qualitative assessments based on diver observations (sediment color, consistency, and odor; presence of outgassing; *Beggiatoa* sp. bacterial mat coverage; abundance of predominant fish and macroinvertebrate species; feed and feces distribution; current speed and direction and tidal slack period; and general site aesthetics, including water quality).

The qualitative nature of the site ratings in the early monitoring programs was recognized as a major shortcoming. Subsequent research led to science-based recommendations for a more quantitative approach, based on sediment geochemical parameters (Wildish et al. 1999). Sediment redox potential and sulfide measurements were taken concurrently with the existing parameters during 1998-2000 (Wildish et al. 2001a); however, site ratings during this time continued to be based on the existing rating system and parameters. It was found that ratings using the existing system were comparable to ratings using the geochemical measurements, but the latter were less subjective, as well as being cost-effective; accordingly, a monitoring program based on sediment redox potential and sulfide measurements was recommended (Wildish et al. 2001b).

In 2001-2002 provincial responsibility for the monitoring program was transferred to the New Brunswick Department of Environment & Local Government (NBDELG). This responsibility of NBDELG is under the authority of the Water Quality Regulation – Clean Environment Act. A quantitative environmental rating system was implemented by NBDELG in 2002 (as recommended by Wildish et al. 2001b), with classification of sites based on sediment redox potential and sulfide measurements (NBDELG 2001); standard operating practices for monitoring were also developed (CoastalSmith Inc. 2002). Starting in 2006, sulfide alone was used to classify sites (NBDENV 2006a), because it was found that redox measurements were

sometimes unreliable (Wildish et al. 2004, 2005). However, other parameters and information, such as redox potential and video/visual observations, continued to be included as part of the weight-of-evidence approach for the overall site assessment and classification, as well as to aid in determining cause-effect relationships and appropriate management responses (NBDENV 2006a,b; NBDELG 2012a,b). Research on other potential parameters is on-going, and should lead to the incorporation of new environmental monitoring parameters in the future. The 2006 monitoring program also incorporated a performance based management (PBM) approach to regulating the industry (see below).

The monitoring program and standard operating practices for the annual Tier 1 monitoring and the spatially-intensive Tier 2 monitoring (required at sites showing elevated sulfide concentrations in Tier 1 monitoring) have been revised in recent years (NBDELG 2012a, b), with considerable input from the AECC (including working sub-committees). In addition to discussions during regular AECC meetings, special meetings on the monitoring program were held in April 1999, June 2003, July 2006, and July 2014, and a workshop was held on revisions to the environmental monitoring program in December 2006 (Ross 2007). As part of its review of the SWNB monitoring program, the AECC requested a literature review of environmental monitoring programs for marine finfish aquaculture in other jurisdictions around the world (CoastalSmith Inc. 2006).

AECC members were involved in organizing conference sessions on current aquaculture environmental monitoring research and assessing research needs at the Aquaculture Canada 2012 (Charlottetown, PE) and Aquaculture Canada 2014 (St. Andrews, NB) conferences; several AECC members participated in these sessions. Among the key points raised at these sessions were:

- environmental management objectives must be clearly defined, so that an appropriate monitoring program can be designed;
- regulators need to work toward standardized management objectives, sampling designs, and indicator thresholds (see also Whitehead et al. 2013);
- monitoring tools must be adapted to local habitat conditions (e.g. substrate type and depth);
- monitoring tools must be practical and cost-effective;
- sampling design must account for spatial variability;
- new tools, such as oxygen probes, should be considered; and
- future workshops should be held on a regular basis.

An overview of the Aquaculture Canada 2014 session was published (Whitehead et al. 2015).

In addition to the AECC's role in the development of the monitoring program for marine cage operations in SWNB, the committee reviews the summary of results from each year's program. The intent is to determine if there are any interannual trends which may be due to changes in

farm management practices or monitoring methods, and to provide advice on how to improve the monitoring program. The AECC has also responded to requests from the Province for advice on baseline data requirements for proposed farms (pre-site monitoring).

The AECC has promoted and advised on several research projects addressing issues related to the monitoring of benthic organic enrichment at finfish farms in SWNB. Several AECC members have also participated in the research teams for such projects, including the following:

- Development of geochemical monitoring techniques for salmon farms in SWNB (Wildish et al. 2001a, 2001b, 2004, 2005).
- The spatial distribution of sediment sulfide concentrations under six salmon farms in SWNB (Chang et al. 2011).
- Relationships between sediment sulfide concentrations and selected parameters in Tier 1 environmental monitoring at finfish farms in SWNB (Chang & Page 2011; Chang et al. 2013a).
- Spatial distribution of sediment sulfide concentrations in Tier 2 monitoring of salmon farms in SWNB (Chang et al. 2013b).
- Comparison of results from sediment monitoring at two finfish farms using New Brunswick and Nova Scotia monitoring protocols (Chang et al. 2013c).
- Factors affecting the calibration of electrodes used for monitoring sediment sulfide concentrations at finfish farms (Chang et al. 2014a).
- Research on new monitoring tools, including new potential parameters (such as dissolved oxygen in sediment pore water), new methods for measuring sulfides, and the best methods for collecting sediment samples (on-going research led by DFO).

The AECC also played a key role in the development of NBDELG's environmental management program for land-based finfish aquaculture (primarily freshwater salmon hatcheries) in New Brunswick (NBDELG 2013).

Site remediation

The AECC does not provide advice on remediation of individual sites. The committee has, however, been involved in the general issue of how to remediate impacts on the marine environment due to finfish farming. An AECC working group served as an advisory body in the development of a site remediation guide for the SWNB marine aquaculture industry during 1997-2000. Suggested implementation actions for remediation included:

- Improved husbandry practices (feeding, stocking density, net cleaning)
- Site configuration changes (orientation, cage distribution, cage design)
- Technology
- Fallowing of cage clusters or entire sites
- Year-class separation

- Production decreases
- Assessment of the influence of other sites in the area
- Site abandonment
- Remediation: bacterial or physical
- Physical removal of wastes from under cages

The finalized remediation guide was incorporated into the "Environmental management guidelines for the marine finfish cage aquaculture industry in New Brunswick" (NBDELG 2001).

The AECC served in an advisory capacity for a research project on physical remediation at a salmon farm in SWNB in 2000-2001. This project, which was led by AECC member Roy Parker, found that harrowing using a steel drag was technically feasible and inexpensive, but largely ineffective at improving sediment conditions at a farm with degraded benthic conditions (Parker 2003).

A workshop on physical remediation was held at the St. Andrews Biological Station in September 2001, sponsored by the Gulf of Maine Council on the Marine Environment and Environment Canada. This workshop was co-chaired by AECC Co-chair Marianne Janowicz, and several other AECC members attended. The main conclusions from this workshop were (Clement & Janowicz 2003):

- Front-end planning is the key to preventing environmental degradation;
- Physical remediation is impractical on a large scale at this time (in 2001);
- Approaches to aquaculture development, siting, and management should evolve as new information becomes available;
- Greater transparency is needed in all aspects of aquaculture development and management so that the public is better informed.

Predicting environmental impacts using models

One tool that is considered useful in preventing environmental impacts is the use of models to predict the intensity of impacts at farms. The AECC held a special meeting on the use of models in June 1998; at this meeting, Bill Silvert, a DFO modelling expert at the Bedford Institute of Oceanography (BIO, Dartmouth, NS) gave a presentation on his model for predicting benthic organic deposition rates from fish farms. Some AECC members also attended a workshop on the use of DEPOMOD, a Scottish model for predicting benthic impacts of aquaculture, in July 2005 at the St. Andrews Biological Station (SABS, St. Andrews, NB); the workshop was led by Jon Chamberlain (DFO, Sidney, BC), who was involved in the development and use of DEPOMOD in Scotland and its subsequent use in British Columbia. These models depend on knowledge of site depth, current velocity, and feeding rates to predict the rate of discharge of organic wastes to the seafloor. Although comparisons of DEPOMOD predictions with actual measurements of

sediment impacts in SWNB have produced somewhat inconsistent results, it appears that the model is a useful tool, especially for predicting which sites are likely to produce low impacts (Chang et al. 2012, 2014b). Research is on-going at SABS on the development of the FVCOM (Finite Volume Community Ocean) circulation model for this area; this model should result in improved predictions of the environmental impacts of fish farms in SWNB.

Other waste management issues

The AECC has been asked to provide advice on various waste management issues, including the disposal of mortalities, bloodwater, and other waste materials, and the development of waste management plans for marine finfish aquaculture operations.

AECC members have also been involved in research projects addressing aquaculture waste management issues, including:

- Studies on copper and other metals in sediments under salmon farms in SWNB (Burridge et al. 1999; Parker & Aubé 2002; Parker et al. 2003).
- The environmental fate and impact of chemicals used by salmon farms in SWNB, including those used to treat sea lice (Haya et al. 2001; Page & Burridge 2014; Page et al. 2015).

Production levels and holding capacity

In 1993, the AECC was asked by NBDFA to examine the existing guidelines for the calculation and use of estimated site potentials (ESPs, the maximum potential number of fish which may be permitted on a site at any one time) for marine finfish farms (NBDFA 1993). Shortcomings were identified in the ESP formula, which depended entirely on site area and depth to predict potential capacity. In 1999, an AECC subcommittee was formed to examine the use of ESPs and APLs (allowable production levels), and to be part of the steering committee for a study on tools for determining production levels at farms (Washburn & Gillis Associates Ltd. 1999). Further discussion (including the AECC) eventually led to discontinuing the use of ESPs and APLs, and the introduction of a performance based management approach in 2005 (see below).

The AECC has also been involved in the issue of predicting the holding capacity (for finfish aquaculture) of bays within SWNB. A DFO workshop on the use of models to determine the assimilative capacity of the Letang area for aquaculture was held in St. Andrews, NB in January 1992, with several AECC members participating. The main reason for holding the workshop was concerns due to the large number of farms in the Letang area, which had the highest concentration of farms in SWNB. Although models at that time were unable to predict the holding capacity of the Letang area for aquaculture, they were able to identify some locations of concern.

Holding capacity was a focus of the DFO-led Environmental Studies for Sustainable Aquaculture (ESSA) project, which held workshops in Dartmouth, NS in 2001 and 2002 (Hargrave & Phillips 2001; Hargrave 2002); several AECC members participated in these workshops. This study again noted the high density of farms in the Letang area, indicating the potential for localized dissolved oxygen depletion, and elevated nutrient and carbon discharges in this area. However, it was not possible to produce accurate predictions of the holding capacities of bays within SWNB, largely due to the lack of sufficient data (DFO 2003).

While the results from the annual environmental monitoring at finfish farms in SWNB indicate that there has been habitat degradation immediately under cages at some sites, there is only limited evidence for far-field effects. One study led by the Huntsman Marine Science Centre (HMSC, St. Andrews, NB) found some changes in benthic community structure at locations away from farms within the Letang area, where there is a high density of fish farming (Pohle et al. 2001). A follow-up study is currently underway.

Performance based management

In performance based management (PBM), performance based standards (PBSs) are used to regulate an industry. The PBSs are based on marine environmental quality objectives (MEQOs) which the industry is expected to achieve, without dictating how the industry operates. The PBM approach was discussed at a special AECC meeting on environmental management and regulatory approaches, held in Letang, NB in June 2003. Subsequently, the AECC produced a discussion paper on the use of PBM for marine finfish cage culture in SWNB (AECC 2004), as background information for a workshop convened in Hammond River, NB in November 2004. The workshop's focus was on determining research needs for implementing a PBM approach to environmental management in SWNB (Paynter 2005). Subsequently, the New Brunswick Salmon Growers Association (NBSGA) developed industry codes of practice for PBM. The AECC reviewed these codes, and worked with the NBSGA to refine them.

The workshop and subsequent discussions led to the incorporation of a PBM approach into the revised environmental management program for the marine finfish cage aquaculture in New Brunswick (NBDENV 2006a; NBDELG 2012a). This program uses the sediment sulfide concentration as the PBS, following standard operating practices for monitoring (NBDENV 2006b; NBDELG 2012b). Farms are rated based on the average sediment sulfide concentration measured at two or more locations under the farm during the annual monitoring (Tier 1). Farms showing elevated sulfide concentrations must conduct additional monitoring (Tier 2 and possibly Tier 3) and provide strong justification for maintaining or increasing stocking numbers, while higher sulfide concentrations require stronger mitigation and remediation measures. The AECC has also been involved in subsequent reviews and revisions to the PBM approach, including revisions to the environmental management program and standard operating practices for monitoring (see above).

Federal regulatory issues

While the annual environmental monitoring program is led by the provincial government, farms were also required to comply with habitat provisions within the federal Fisheries Act (until 2012). Consequently, the environmental monitoring program implemented in 2006 (NBDENV 2006a) was linked to the possible need for a Fisheries Act Authorization (FAA), related to the likelihood of causing a harmful alteration, disruption, or destruction (HADD) of fish habitat. This issue was discussed at various AECC meetings, as well as a special meeting held in July 2006, which lead to adjustments to the 2006 monitoring program. As a result of revisions to the Fisheries Act in 2012, the HADD provisions are no longer in force, so the linkages to FAAs were removed from version 3.0 of the environmental monitoring program (NBDELG 2012a).

Related to the revisions of the Fisheries Act is the introduction of new federal Aquaculture Activities Regulations (AARs). The intent of the AARs is to provide national environmental regulations for the aquaculture industry, but allowing for differences in the monitoring protocols in different regions. The currently proposed AARs are based largely on the existing provincial programs, but with some alterations. The AECC was not asked for input during the development of the AARs, although some individual members were consulted. The AARs were implemented in 2015.

Review of on-going research on aquaculture-environment interactions

The committee tries to keep up-to-date on current research relevant to the AECC mandate. In addition to presentations (by members and guest speakers) and discussions during regular meetings, the committee has held workshops and special meetings on specific topics (see Appendix 5).

AECC members have been involved in organizing workshops on aquaculture-environment interactions. These include workshops held in 1990 (Gulf of Maine Working Group 1990) and 1993 (Jones 1993) and a symposium in 1999 (Wildish & Héral 2001), all in St. Andrews, NB (see Appendix 5).

AECC members have also participated in various conferences and workshops where aquaculture-environment research was presented or discussed. The AECC is usually represented at the annual Aquaculture Canada conferences, sponsored by the Aquaculture Association of Canada; these conferences usually include presentations on aquaculture-environment issues. As noted above, several AECC members participated in special sessions on environmental monitoring, including research needs, at Aquaculture Canada 2012 (Charlottetown, PE) and Aquaculture Canada 2014 (St. Andrews, NB). The AECC is also usually represented at the Atlantic Canada Fish Farmers Association (ACFFA) annual technical workshop and research review.

Research priorities

Another major activity has been to determine research priorities, based on input from committee members and others. The intent is to inform management and funding agencies of the research needs in the field of aquaculture-environment interactions pertinent to SWNB.

Although research needs have been a major topic of discussion since the earliest meetings, the first list of AECC environmental research priorities was produced in 1993. A technical session/workshop on aquaculture-environment research priorities was held in St. George, NB in January 1998 (NBDFA & AECC 1998). An outcome of this workshop was an updated list of priority projects. Research priorities have been updated on a regular basis since then. In addition, research priorities were a main topic of discussion at the PBM workshop in 2004 (Paynter 2005).

Lists of research priorities produced by the AECC since 1993 are included in Appendix 6. Two research themes that have been top priorities through most of the AECC's existence are physical oceanography and benthic impacts. Physical oceanography includes collecting data on water circulation, as well as circulation modelling. Understanding of water circulation patterns is needed for predicting environmental impacts, as well as for fish health management. Benthic environmental monitoring has also been a focus of the committee since the beginning. Priorities have included designing and revising the annual monitoring program (see above), as well as more specific topics, including where and how to collect samples, which parameters to measure, and how to analyze samples.

In addition, several other topics have been frequently included in AECC research priorities: far-field effects, water quality monitoring, models for predicting environmental impacts, cumulative impacts, the fate of chemical wastes from fish farms, phytoplankton monitoring, and site remediation.

The topic of aquaculture-fisheries interactions has been raised at several AECC meetings, but it was decided not to pursue this issue at the AECC. Although the committee agreed that this issue was extremely important, it was felt that it was being dealt with by other committees and researchers.

FINAL REMARKS

The AECC has served as a valuable forum for the discussion of aquaculture-environment interactions issues among regulators, researchers, and the SWNB finfish aquaculture industry. It also serves as an example of cooperation among the two levels of government and the industry. As would be expected, some differences of opinion have inevitably arisen over some issues. AECC participants are currently committed to meeting at least three times a year.

A major accomplishment has been the AECC's role in the development and implementation of an annual environmental monitoring program for the industry, including the introduction of a

performance based management approach. The AECC continues to have an important role in reviewing and improving the environmental monitoring program. A shortcoming in the current monitoring program is its heavy reliance on one parameter, sulfides. When Wildish et al. (2004) recommended that the use of redox potential be discontinued as part of the monitoring program, they noted the need for another independent parameter (in addition to sulfides). On-going research projects are looking at some new potential parameters, new methods for measuring sulfides, and the best methods for collecting sediment samples. Research will also be undertaken on parameters that can be used at hard bottom and deep water sites. New models for predicting environmental impacts are being developed; these models will include sediment resuspension. In addition, further research will be conducted on integrated coastal zone management (including aquaculture), using a GIS (geographic information system) approach. The results from these studies, as well as their relevance in SWNB, will be important topics for the AECC in the near future.

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REFERENCES

AECC (Southwest New Brunswick Aquaculture Environmental Coordinating Committee) (2004) Discussion paper: environmental regulation and management related to application of performance based standards for the marine salmon aquaculture industry in New Brunswick. AECC internal report.

Burridge LE, Doe K, Haya K, Jackman PM, Lindsay G, Zitko V (1999) Chemical analyses and toxicity tests on sediments under salmon net pens in the Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci. 2291. Available from: www.dfo-mpo.gc.ca/Library/241588.pdf (accessed December 2015).

Chang BD, Page FH (2011) Analysis of results from the Environmental Management Program Tier 1 monitoring of salmon farms in southwestern New Brunswick, Bay of Fundy: Relationships between sediment sulfide concentration and selected parameters, 2002–2008. Can. Tech. Rep. Fish. Aquat. Sci. 2936. Available from:

www.dfo-mpo.gc.ca/Library/343737.pdf (accessed December 2015).

Chang BD, Page FH, Losier RJ, McCurdy EP, MacKeigan KG (2011) Characterization of the spatial pattern of benthic sulfide concentrations at six salmon farms in southwestern New Brunswick, Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci. 2915. Available from: www.dfo-mpo.gc.ca/Library/342675.pdf (accessed December 2015).

Chang BD, Page FH, Losier RJ, McCurdy EP (2012) Predicting organic enrichment under marine finfish farms in southwestern New Brunswick, Bay of Fundy, Canada: comparisons of model predictions with results from spatially-intensive sediment sulfide sampling. Fisheries and Oceans Canada, Can. Sci. Advisory Secr. Res. Doc. 2012/078. Available from: www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2012/ 2012_078-eng.pdf. (accessed December 2015).

Chang BD, Page FH, Losier RJ (2013a) Variables affecting sediment sulfide concentrations in regulatory monitoring at salmon farms in the Bay of Fundy, Canada. Aquacult. Environ. Interact. 4: 67-79.

Chang BD, Bennett AT, Lyons TA, Parker EV, Page FH (2013b) Analysis of sediment sulfide concentration data from Environmental Management Program Tier 2 monitoring at salmon farms in southwestern New Brunswick, 2007-2011. Can. Tech. Rep. Fish. Aquat. Sci. 3033. Available from: www.dfo-mpo.gc.ca/Library/348097.pdf (accessed December 2015).

Chang BD, Balch T, Bennett AT, Buchan CM, Jacobi CA, Losier RJ, Lyons TA, Page FH, Parker EV, TeKamp CM, Bagnall AG (2013c) Spatially-intensive sediment surveys at two salmon farms in New Brunswick and Nova Scotia in September-October 2011. Can. Tech. Rep. Fish. Aquat. Sci. 3035. Available from: www.dfo-mpo.gc.ca/Library/348136.pdf (accessed December 2015).

Chang BD, Lewis-McCrea LM, Wong DKH, MacKeigan KG, Page FH, Cameron SL, Sweeney RH, Smith AE (2014a) Interlaboratory research on factors affecting the calibration of electrodes used for sediment sulfide analyses at fish farms. Can. Tech. Rep. Fish. Aquat. Sci. 3090. Available from: www.dfo-mpo.gc.ca/Library/352734.pdf (accessed December 2015).

Chang BD, Page FH, Losier RJ, McCurdy EP (2014b) Organic enrichment at salmon farms in the Bay of Fundy, Canada: DEPOMOD predictions versus observed sediment sulfide concentrations. Aquacult. Environ. Interact. 5: 185-208.

Clement J, Janowicz M (eds.) (2003) Aquaculture physical remediation: workshop proceedings (St. Andrews, NB, 20-21 September 2001). Gulf of Maine Council on the Marine Environment. Available from: www.gulfofmaine.org/council/publications/aquacultureworkshopreport.pdf. (accessed December 2015).

CoastalSmith Inc. (2002) Standard operating practices for the monitoring program of the environmental management guidelines for the marine finfish cage aquaculture industry in New Brunswick. Prepared for the New Brunswick Department of Environment & Local Government, Fredericton, NB.

CoastalSmith Inc. (2006) Review of environmental monitoring programs for marine finfish aquaculture. Prepared for Environment Canada, Fredericton, NB.

DFO (Department of Fisheries and Oceans Canada) (2003) Salmon holding capacity in southwestern New Brunswick. Can. Tech. Rep. Fish. Aquat. Sci. 2489. Available from: www.dfo-mpo.gc.ca/Library/275378.pdf (accessed December 2015).

Gulf of Maine Working Group (1990) The environmental impacts of finfish culture: Gulf of Maine Working Group aquaculture workshop (St. Andrews, NB, 1-2 March 1990), summary report. Gulf of Maine Working Group, Augusta, ME and Fredericton, NB.

Hargrave BT (ed.) (2002) Environmental Studies for Sustainable Aquaculture (ESSA): 2002 workshop report. Can. Tech. Rep. Fish. Aquat. Sci. 2411. Available from: www.dfo-mpo.gc.ca/Library/265203.pdf (accessed December 2015).

Hargrave BT, Phillips GA (ed.) (2001) Environmental Studies for Sustainable Aquaculture (ESSA): 2001 workshop report. Can. Tech. Rep. Fish. Aquat. Sci. 2352. Available from: www.dfo-mpo.gc.ca/Library/255687.pdf (accessed December 2015).

Haya K, Burridge LE, Chang BD (2001) Environmental impact of chemical wastes produced by the salmon aquaculture industry. ICES J. Mar. Sci. 58: 492-496.

Janowicz M, Ross J (2001) Monitoring for benthic impacts in the southwest New Brunswick salmon aquaculture industry. ICES J. Mar. Sci. 58: 453-459.

Jones BC (ed.) (1993) Abstract proceedings of the aquaculture-environment interaction workshop (St. Andrews, NB, 24-25 February 1993). Convened by the Gulf of Maine Council on the Marine Environment; sponsored by the New Brunswick Department of Fisheries & Aquaculture (Fredericton, NB).

NBDELG (New Brunswick Department of Environment & Local Government) (2001) Environmental management guidelines for the marine finfish cage aquaculture industry in New Brunswick. NBDELG, Fredericton, NB.

NBDELG (New Brunswick Department of Environment & Local Government) (2012a) The environmental management program for the marine finfish cage aquaculture industry in New Brunswick, version 3.0. NBDELG, Fredericton, NB. Available from: www2.gnb.ca/content/dam/gnb/Departments/env/pdf/MarineAquaculture-AquacoleMarin/EnvironmentalManagementProgramFinfish.pdf (accessed December 2015).

NBDELG (New Brunswick Department of Environment & Local Government) (2012b) Standard operating practices for the environmental monitoring of the marine finfish cage aquaculture industry in New Brunswick, July 2012. NBDELG, Fredericton, NB. Available from: www2.gnb.ca/content/dam/gnb/Departments/env/pdf/MarineAquaculture-AquacoleMarin/StandardOperatingPracticesFinfish.pdf (accessed December 2015).

NBDELG (New Brunswick Department of Environment & Local Government) (2013) Environmental management program for land based finfish aquaculture in New Brunswick, version 1.0. NBDELG, Fredericton, NB. Available from: www2.gnb.ca/content/dam/gnb/Departments/env/pdf/MarineAquaculture-AquacoleMarin/EnvironmentalManagementProgramLandBasedFinfish.pdf (accessed December 2015).

NBDENV (New Brunswick Department of Environment) (2006a) The environmental monitoring program for the marine finfish cage aquaculture industry in New Brunswick, version 2.0. NBDENV, Fredericton, NB.

NBDENV (New Brunswick Department of Environment) (2006b) Standard operating practices for the environmental monitoring of the marine finfish cage aquaculture industry in New Brunswick, July 2006. NBDENV, Fredericton, NB.

NBDFA (New Brunswick Department of Fisheries & Aquaculture) (1993) Guidelines for determining the size and production levels for marine aquaculture sites in the Bay of Fundy. Aquaculture Division, NBDFA, Fredericton, NB.

NBDFA (New Brunswick Department of Fisheries & Aquaculture), AECC (Southwest New Brunswick Aquaculture Environmental Coordinating Committee) (1998) Presentations from the technical session on aquaculture/environment research priorities (St. George, NB, 16 January 1998). NBDFA, Fredericton, NB.

Page FH, Burridge L (2014) Estimates of the effects of sea lice chemical therapeutants on non-target organisms associated with releases of therapeutants from tarped net-pens and well-boat bath treatments: a discussion. Fisheries and Oceans Canada, Can. Sci. Advisory Secr. Res. Doc. 2014/103. Available from: www.dfo-mpo.gc.ca/csas-sccs/publications/resdocs-docrech/2014/ 2014_103-eng.pdf. (accessed December 2015).

Page F, Losier R, Haigh S, Bakker J, Chang BD, McCurdy P, Beattie M, Haughn K, Thorpe B, Fife J, Scouten S, Greenberg D, Ernst T, Wong D, Bartlett G (2015) Transport and dispersal of sea lice bath therapeutants from salmon farm net-pens and well-boats. DFO (Fisheries and Oceans Canada) Can. Sci. Advis. Sec. Res. Doc. 2015/064. Available at: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2015/2015_064-eng.pdf (accessed December 2015).

Parker, R (2003) Physical remediation of sediments at a salmon growing site in Passamaquoddy Bay, New Brunswick. *In:* Clement J, Janowicz M (eds.) Aquaculture physical remediation: workshop proceedings (St. Andrews, NB, 20-21 September 2001). Gulf of Maine Council on the Marine Environment. p. 16. Available from: www.gulfofmaine.org/council/publications/aquacultureworkshopreport.pdf. (accessed December 2015).

Parker WR, Aubé JG (2002) Metal levels in sediment samples collected under salmon aquaculture net pens in the Bay of Fundy, New Brunswick. Environment Canada, Environmental Protection Branch, Atlantic Region, Surveillance Rep. EPS-5-AR-02-01.

Parker WR, Doe KG, Jackman P, Aubé JG (2003) Toxicity of copper-based antifouling coatings to the marine amphipod, *Eohaustorius estuarius.* Environment Canada, Environmental Protection Branch, Atlantic Region, Surveillance Rep. EPS-5-AR-03-01.

Paynter J (2005) Environmental science priorities in support of performance-based management approaches to finfish aquaculture: workshop proceedings (Hammond River, NB, 16-17 November 2004). Prepared for the Southwest New Brunswick Aquaculture Environmental Coordinating Committee. AMEC Earth & Environmental, Fredericton, NB.

Pohle G, Frost B, Findlay R (2001) Assessment of regional benthic impact of salmon mariculture within the Letang Inlet, Bay of Fundy. ICES J. Mar. Sci. 58: 417-426.

Ross JB (2007) Performance based standards workshop for the review and revision of the standard operating practices for the environmental monitoring of the marine finfish cage aquaculture industry in NB: stakeholders' forum record of discussion (St. Andrews, NB,

12-13 December 2006). Hosted by the Southwest New Brunswick Aquaculture Environmental Coordinating Committee (AECC).

Thonney J-P, Garnier E (1992) Bay of Fundy salmon aquaculture monitoring program 1991-1992. New Brunswick Department of the Environment, Fredericton, NB.

Thonney J-P, Garnier E (1993) Bay of Fundy salmon aquaculture monitoring program 1992-1993. New Brunswick Department of the Environment, Fredericton, NB.

Washburn & Gillis Associates Ltd. (1995) Environmental management plan for the marine finfish aquaculture industry in the Bay of Fundy, New Brunswick: final report. Prepared for the New Brunswick Department of Fisheries & Aquaculture, Fredericton, NB.

Washburn & Gillis Associates Ltd. (1999) Evaluation of tools for determining production levels at marine aquaculture sites. Prepared for the New Brunswick Department of Fisheries & Aquaculture, Fredericton, NB.

Whitehead J, Sweeney B, Daggett T, Stagg-Kendall A, Cook D, Smith A, Lewis-McCrea L, Arsenault J (2013) Atlantic Canada's aquaculture environmental assessment and monitoring programs: research requirements to achieve harmonization. Bull. Aquacul. Assoc. Can. 111-1: 42-54. Available at: www.aquacultureassociation.ca/publications/bulletin-of-the-aac/seafood-sustainability-progress-and-challenges-111-1-2013/ (accessed December 2015).

Whitehead J, Chang B, Lewis-McCrea L (2015) Overview of the 2014 Aquaculture Canada environmental monitoring session and facilitated discussion. Bull. Aquacul. Assoc. Can. 2015-1: 26-33. Available at: www.aquacultureassociation.ca/publications/bulletin-of-the-aac/aquaculture-canada-2014-proceedings-of-contributed-papers/ (accessed December 2015).

Wildish DJ, Héral M (eds.) (2001) Environmental effects of mariculture: proceedings of an ICES Symposium (St. Andrews, NB, 13-17 September 1999). ICES J. Mar. Sci. 58: 363-529.

Wildish DJ, Martin JL, Trites RW, Saulnier AM (1990) A proposal for environmental research and monitoring of organic pollution caused by salmonid mariculture in the Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci. 1724. Available from: www.dfo-mpo.gc.ca/Library/114014.pdf (accessed December 2015).

Wildish DJ, Akagi HM, Hamilton N, Hargrave BT (1999) A recommended method for monitoring sediments to detect organic enrichment from mariculture in the Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci. 2286. Available from: www.dfo-mpo.gc.ca/Library/238355.pdf (accessed December 2015).

Wildish DJ, Akagi HM, Garnier E (2001a) Geochemical monitoring of the Bay of Fundy salmon mariculture industry from 1998 to 2000. Can. Tech. Rep. Fish. Aquat. Sci. 2361. Available from: www.dfo-mpo.gc.ca/Library/256310.pdf (accessed December 2015).

Wildish DJ, Hargrave BT, Pohle G (2001b) Cost-effective monitoring of organic enrichment resulting from salmon mariculture. ICES J. Mar. Sci. 58: 469-476.

Wildish DJ, Akagi HM, Hargrave BT, Strain PM (2004) Inter-laboratory calibration of redox potential and total sulfide measurements in interfacial marine sediments and the implications for organic enrichment assessment. Can. Tech. Rep. Fish. Aquat. Sci. 2546. Available from: www.dfo-mpo.gc.ca/Library/284150.pdf (accessed December 2015).

Wildish DJ, Akagi HM, Hamilton N, Hargrave BT (2005) Interfacial geochemistry and macrofauna at a new salmon farm in Passamaquoddy Bay, Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci. 2574. Available from: www.dfo-mpo.gc.ca/Library/287113.pdf (accessed December 2015).

APPENDIX 1: Terms of Reference

Three versions of the AECC terms of reference are included in this Appendix:

1. Original terms of reference: ratified by the AECC in January 1990.

2. Revised terms of reference: accepted by the AECC in July 1993; ratified by the MOU Management Committee in November 1993.

3. Revised terms of reference: January 2004.

APPENDIX 1: Terms of Reference

Terms of Reference (1990)

1. To develop a comprehensive environmental monitoring program to identify the potential impacts of finfish aquaculture on the marine biological, chemical and physical environment in New Brunswick.

2. To coordinate the various Federal-Provincial agency activities in New Brunswick with respect to the assessment of the environmental effects of finfish marine cage culture industry including such topics of developing common data bases, ecosystem modelling, sampling and analysis, hatchery environmental effects, methods of waste disposal for the aquaculture industry, etc.

3. To act as an ongoing technical committee to review and evaluate the information and environmental data from monitoring and scientific research on the impacts of finfish freshwater and marine cage culture operations.

4. To provide advice and make recommendations to government on the impacts of marine sea cage culture on the environment, so that an acceptable level of environmental quality is maintained.

5. To develop and apply criteria for priorizing research on potential impacts of aquaculture and develop rationale for agency participation and cooperation.

6. The Committee will be co-chaired by DFO and DFA and operate under the auspices of the Canada–New Brunswick MOU on Aquaculture Development.*

* DFO = Fisheries and Oceans Canada; DFA = New Brunswick Department of Fisheries & Aquaculture; MOU = memorandum of understanding.

APPENDIX 1: Terms of Reference

Terms of Reference (1993)

The Committee will:

1. Have the responsibility to address all aquaculture-environmental interaction issues in relation to finfish hatcheries and sea cage operations in New Brunswick.

2. Operate under the auspices of the Canada–New Brunswick Memorandum of Understanding (MOU) on Aquaculture Development, and shall report and make recommendations to the MOU Coordinating Committee.

3. Include key government agency representatives, who have a direct interest in aquaculture development/management and/or aquatic environments, and industry associations representing key components of finfish aquaculture.

4. Assess the various Federal-Provincial agency activities with respect to the evaluation of environmental effects arising from or impacting upon the aquaculture industry.

5. Promote the operation of a comprehensive environmental monitoring program so as to allow the identification and mitigation of potential impacts of finfish culture on the biological, chemical and physical environment.

6. Act as an on-going technical advisor to review and evaluate proposals and projects relative to aquaculture-environmental interaction.

7. Provide advice and make recommendations on the interaction of finfish culture and the environment so that an acceptable level of environmental quality can be achieved and maintained.

8. Develop and apply criteria for prioritizing monitoring and research on salmon aquaculture-environmental interactions, and submit a ranked list of such with rationale as recommendations to the MOU Coordinating Committee by March 31st of each year to assist in funding decisions.

9. Be co-chaired by DFO and DFA, with secretariat services to be provided jointly by these departments.*

* DFO = Fisheries and Oceans Canada; DFA = New Brunswick Department of Fisheries & Aquaculture.

APPENDIX 1: Terms of Reference

Terms of Reference (2004)

Purpose:

- To provide a forum for on-going dialogue and exchange of information on aquaculture-environmental interaction issues in relation to marine salmon operations in New Brunswick.
- Act as a technical advisor to research projects, identify research priorities and to develop an annual work plan on issues related to the above.

Operations:

- The Committee will operate under the auspices of the Canada–New Brunswick Memorandum of Understanding (MOU) on Aquaculture Development, and will report and make recommendations to the MOU Coordinating Committee.
- The Committee will be co-chaired by the Canadian Department of Fisheries and Oceans (DFO) and the New Brunswick Department of Agriculture, Fisheries and Aquaculture (DAFA) with secretariat services to be provided jointly by these Departments. Co-chairs will be selected by the responsible Departments.
- The Committee will meet no less than twice yearly.
- An annual work plan with key objectives for the AECC will be developed and presented to the MOU Coordinating Committee on a yearly basis.
- Hold an annual workshop with stakeholders to present on-going research in the area of environmental interactions and initiatives undertaken or supported by this Committee and then to solicit input on the above.

Membership:

In addition to the two co-chairing Departments, the AECC will include:

- Key government agency representatives that have a direct interest in aquaculture development, management, and regulation as it relates to environmental interactions;
- Industry associations representing components of salmon smolt rearing and sea cage operations in New Brunswick; and
- Research groups and other bodies will be invited as deemed appropriate by members as it relates to the Terms of Reference and the annual work plan.
- In addition to the official Committee members, observers will be allowed to attend at the request of a member and with prior approval by the Committee.
- While the representation of the above groups will remain constant, individual Committee membership may change and an updated list will be maintained by the co-chairs and provided to the MOU Committee within regular reporting.

APPENDIX 1: Terms of Reference

Terms of Reference (2004) (continued)

Objectives:

- To identify and prioritize research on aquaculture-environmental interactions.
- To play an active and useful role in assisting the lead agency (New Brunswick Department of Environment & Local Government – NBDELG) in promoting, developing and implementing the N.B. Environmental Management Guide and also any on-going review.
- To present, exchange and discuss activities, observations and results of the various federal and provincial agencies, university research groups, and other stakeholders with respect to the aquaculture-environment interactions as they relate to environmental management, mitigation, remediation, monitoring, and sustainable development of the industry.

APPENDIX 2: AECC co-chairs

The AECC has co-chairs from the provincial and federal governments. This Appendix lists the co-chairs during 1989-2014.

Name	Department	Years
Government of New Brunswick		
Henry, Russell	NBDFA	1989-1990
Jones, Barry	NBDFA	1991-1998
Janowicz, Marianne	NBDFA NBDELG	1998-2000 2000-2002
Coombs, Karen	NBDAFA/NBDAA	2002-2007
no meetings		2008-2009
Lipsett, Kim	NBDAA/NBDAAF	2010-2011
Watson, Kimberly	NBDAAF	2012-present
Government of Canada		
Wildish, David	DFO	1989-1994
Ducharme, André	DFO	1994
Thompson, Brian	DFO	1995-1996
Ross, Jim	DFO	1997-2000
Landsburg, Wade	DFO	2001
Boudreau, Paul	DFO	2002-2005
Crocker, Joe	DFO	2005-2007
no meetings		2008-2009
Cherry, Mike	DFO	2010
McLean, Mark	DFO	2010-present

Acronyms:

DFO: Fisheries and Oceans Canada
NBDAA: New Brunswick Department of Agriculture & Aquaculture
NBDAAF: New Brunswick Department of Agriculture, Aquaculture & Fisheries
NBDAFA: New Brunswick Department of Agriculture, Fisheries & Aquaculture
NBDFA: New Brunswick Department of Fisheries & Aquaculture
NBDELG: New Brunswick Department of Environment & Local Government

APPENDIX 3: AECC membership

The following lists include individuals who attended at least 3 AECC meetings as committee members during 1989-2014. Not included are guests, observers, and substitutes for members.

Name	Years
Government of New Brunswick – Aquaculture*	
Madill, Hugh	1989-2000
Henry, Russell	1989-1993 (co-chair 1989-1990), 2000-2001
Coombs, Karen	1990-1992, 2000-present (co-chair 2002-2007)
Jones, Barry	1991-1998 (co-chair)
Janowicz, Marianne	1997-2000 (co-chair 1998-2000)
McGeachy, Sandi	2003-2006
Brewer, Kathy	2006-2007
Lipsett, Kim	2010-2011 (co-chair)
Watson, Kimberly	2010-present (co-chair 2012-present)
Government of New Brunswick – Environment**	
Shanks, Greg	1989-2000
Thonney, J.-P.	1992-1993
Janowicz, Marianne	2000-2002 (co-chair)
Welles, Darrell	2000-2003
Parker, Ed	2003-2007
Joy, Denise	2003-2006
Corrigan, Sean	2006-2007
Lyons, Troy	2010-present
Bennett, Aaron	2010-2012

* New Brunswick Government Departments − aquaculture:
  1988-2000: Fisheries & Aquaculture
  2000-2006: Agriculture, Fisheries & Aquaculture
  2006-2010: Agriculture & Aquaculture
  2010-present: Agriculture, Aquaculture & Fisheries

** New Brunswick Government Departments − environment:
  1989-2000: Environment
  2000-2006: Environment & Local Government
  2006-2012: Environment
  2012-present: Environment & Local Government

APPENDIX 3: AECC membership

Name	Years
Fisheries and Oceans Canada (DFO)	
Hunter, Rex	1989-1991
Cook, Bob	1989-1992
Wildish, David	1989-1994 (co-chair), 1997-2000
Chang, Blythe*	1989-present
Keizer, Paul	1992-1996
Keating, Brian	1992-1993
Ducharme, André	1994 (co-chair)
Thompson, Brian	1995-1996 (co-chair)
Ross, Jim	1997-2000 (co-chair)
Landsburg, Wade	2000-2001 (co-chair 2001)
Burridge, Les	2000-2004
Hominick, Craig	2001-2002
Boudreau, Paul	2002-2005 (co-chair)
Crocker, Joe	2003-2007 (co-chair 2005-2007)
Rose-Quinn, Tammy	2005-2007
Page, Fred	2005-present
Cline, Gerald	2007-present
Cherry, Mike	2010 (co-chair)
McLean, Mark	2010-present (co-chair)
Parker, Ed	2010-present
Environment Canada	
Aggett, David	1989-1992
Lindsay, George	1993-2001, 2004-2005
Parker, Roy	1999-2004
Dupuis, Hélène	2005-2012
Huntsman Marine Science Centre	
Pohle, Gerhard	1989-1990
Lim, Shirley	1990-1992
Costello, Mark	2000-2002

* served as recording secretary from July 1991 to January 2015.

APPENDIX 3: AECC membership

Last name	Years	Affiliation*
Industry		
Henderson, Gene	1989-1991	NBSGA
Hamilton, Ian	1991-2007	Aqua Fish Farms
Thompson, Bill	1992-1999	NBSGA
Roach-Albert, Shirley	1993-1994	Stolt Sea Farms
Dickie, Mitchell	1993-1998	Scotia Salmon Farms
Guest, Dean	1995-2000	Stolt Sea Farms
Wolf, Skip	1998-2000	Jail Island Salmon/Wolfhead Smokers
Halse, Nell	1999-2004 2005-2007	NBSGA Cooke Aquaculture
Graham, Caroline	1999-2001 2006-2007	Connors Bros. NBSGA
Purdy, Lloyd	1999-2002	Jail Island Aquaculture
Muzzerall, Robin	1999-2000	Connors Bros.
Smith, Jamey	2002-2007	NBSGA
Moran, Hugh	2005-2006	NBSGA
Szemerda, Mike	2007-present	Cooke Aquaculture
Parker, Pam	2010-present	ACFFA
House, Betty	2010-present	ACFFA
Sweeney, Bob	2010-present	Sweeney International Marine Corp.
Smith, Amanda	2012-present	Sweeney International Marine Corp.
Kesselring, Mark	2012-present	Northern Harvest
Griffin, Randy	2014-present	Cooke Aquaculture

* NBSGA (New Brunswick Salmon Growers Association) was superseded by the ACFFA (Atlantic Canada Fish Farmers Association) in 2010. This list does not include a second, short-lived industry association, the Aquaculture Association of New Brunswick, which had representatives at 4 meetings between July 2003 and February 2004.

APPENDIX 4: AECC meetings

The following is a list of dates and locations of AECC regular meetings during 1989-2004

Date	Location
1989-May-31	NBDFA, St. Stephen (organizational meeting)
1989-Jun-12	SABS
1989-Dec-12	SABS
1990-Jan-23	SABS
1990-Oct-16	SABS
1991-May-22	HMSC, St. Andrews
1991-Jul-23	SABS
1991-Nov-26	SABS
1992-Mar-11	SABS
1992-May-20	NBDFA, St. George
1992-Jul-13	NBDFA, St. George
1992-Nov-03	NBDFA, St. George
1993-Apr-01	NBDFA, St. George
1993-Jul-06	NBDFA, St. George
1993-Oct-05	NBDFA, St. George
1993-Dec-02	NBDFA, St. George
1994-Mar-24	NBDFA, St. George
1994-Oct-20	NBDFA, St. George
1995-Mar-29	NBDFA, St. George
1995-Nov-01	NBDFA, St. George
1996-Oct-08	NBDFA, St. George
1997-Oct-15	NBDFA, St. George
1997-Dec-04	NBDFA, St. George
1998-Jan-21	NBDFA, St. George
1998-Apr-22	NBDFA, St. George
1998-May-20	NBDFA, St. George
1998-Jul-17	NBSGA, Letang
1998-Sep-01	NBSGA, Letang
1998-Oct-14	NBSGA, Letang
1998-Nov-24	NBSGA, Letang

Date	Location
1999-Jan-18	NBSGA, Letang
1999-Feb-23	NBSGA, Letang
1999-Apr-21	NBSGA, Letang
1999-Jun-30	NBSGA, Letang
1999-Aug-05	NBSGA, Letang
1999-Sep-13	SABS
1999-Oct-14	NBSGA, Letang
1999-Nov-17	NBSGA, Letang
2000-Jan-06	NBSGA, Letang
2000-Feb-02	NBSGA, Letang
2000-Mar-29	NBSGA, Letang
2000-Apr-26	NBSGA, Letang
2000-May-25	NBSGA, Letang
2000-Aug-08	NBSGA, Letang
2000-Sep-25	NBSGA, Letang
2000-Oct-31	NBSGA, Letang
2000-Dec-08	NBSGA, Letang
2001-Feb-07	NBSGA, Letang
2001-Mar-21	NBSGA, Letang
2001-Jun-06	NBSGA, Letang
2001-Aug-22	NBSGA, Letang
2001-Oct-15	NBSGA, Letang
2001-Dec-11	NBSGA, Letang
2002-Jan-22	NBSGA, Letang
2002-Jul-03	NBSGA, Letang
2003-Mar-21	NBSGA, Letang
2003-May-27	NBSGA, Letang
2003-Dec-10	NBSGA, Letang
2004-Feb-11	NBSGA, Letang
2004-Apr-15	NBSGA, Letang
2004-May-11	minutes missing
2004-Aug-11	NBSGA, Letang
2004-Sep-14	NBSGA, Letang
2004-Nov-02	NBSGA, Letang

APPENDIX 4: AECC meetings

The following is a list of dates and locations of AECC regular meetings during 2005-2014

Date	Location
2005-Jan-25	NBSGA, Letang
2005-May-18	NBSGA, Letang
2005-Sep-07	NBSGA, Letang
2005-Nov-24	NBSGA, Letang
2006-Feb-03	NBSGA, Letang
2006-May-11	NBSGA, Letang
2006-Jun-07	NBSGA, Letang
2006-Jul-25	NBSGA, Letang
2006-Aug-15	NBSGA, Letang
2006-Nov-07	NBDAA, St. George
2007-Mar-22	DFO, St. George
2007-Apr-05	DFO, St. George
2007-May-01	DFO, St. George
2007-May-17	NBDAA, St. George
2007-Jun-11	NBDAA, St. George
2007-Jul-17	NBDAA, St. George

Date	Location
No meetings in 2008 & 2009	
2010-Apr-21	NBDAA, St. George
2010-Jun-15	NBDAA, St. George
2010-Sep-16	NBDAA, St. George
2011-Feb-21	NBDAAF, St. George
2011-Jul-18	NBDAAF, St. George
2012-Mar-01	NBDAAF, St. George
2012-Jun-28	NBDAAF, St. George
2012-Nov-22	NBDAAF, St. George
2013-Jun-25	NBDAAF, St. George
2014-Feb-03	NBDAAF, St. George
2014-Apr-28	NBDAAF, St. George
2014-Jul-21	NBDAAF, St. George

Acronyms:

DFO: Fisheries and Oceans Canada
HMSC: Huntsman Marine Science Centre
NBDAA: New Brunswick Department of Agriculture & Aquaculture
NBDAAF: New Brunswick Department of Agriculture, Aquaculture & Fisheries
NBDFA: New Brunswick Department of Fisheries & Aquaculture
NBSGA: New Brunswick Salmon Growers Association
SABS: St. Andrews Biological Station

APPENDIX 5: Workshops and special meetings

The following is a list of workshops and special meetings sponsored by the AECC

Date	Location	Topic
1998-Jan-16	Masonic Hall, St. George	Technical session: aquaculture/environment research priorities (sponsored by NBDFA and AECC)
1998-Jun-24	NBSGA, Letang	Special meeting on the use of models for aquaculture-environmental issues
1999-Apr-12	NBDFA, Fredericton	Special meeting on the environmental monitoring program
1999-May-11	SABS	Special meeting on current research projects
2003-Jun-26	NBSGA, Letang	Special meeting on environmental management and regulatory approaches
2004-Nov-16/17	Hammond River	Workshop on performance based management
2006-Jul-12/13	SABS	Special meeting on site monitoring in 2006
2006-Jul-24	SABS	Special meeting on the definition of harmful alteration, disruption, or destruction (HADD) of fish habitat
2006-Dec-12/13	SABS	Performance based standards workshop for the review and revision of the standard operating practices for the environmental monitoring of the marine cage aquaculture industry in NB
2014-Jul-29	conference call	Special meeting on revised standard operating practices for 2014

Acronyms:

GMCME: Gulf of Maine Council on the Marine Environment
NBDFA: New Brunswick Department of Fisheries & Aquaculture
NBSGA: New Brunswick Salmon Growers Association
SABS: St. Andrews Biological Station

APPENDIX 5: Workshops and special meetings

The following is a list of other workshops and special meetings with strong AECC participation

Date	Location	Topic
1990-Mar-1/2	St. Andrews	Workshop on the environmental impacts of finfish culture (sponsored by the Gulf of Maine Working Group)
1992-Jan-22	SABS	Workshop on the assimilation capacity of the Letang Inlet for salmonid aquaculture waste (organized by DFO)
1993-Feb-24/25	SABS	Aquaculture-environment interaction workshop (convened by GMCME; sponsored by NBDFA)
1999-Sep-13/17	St. Andrews	ICES Symposium on Environmental Effects of Mariculture
2001-Jan-17/19	BIO	Environmental Studies for Sustainable Aquaculture (ESSA): 2001 workshop
2001-Sep-20/21	SABS	Aquaculture physical remediation workshop (sponsored by the GMCME and Environment Canada)
2002-Jan-16/18	BIO	Environmental Studies for Sustainable Aquaculture (ESSA): 2002 workshop
2005-Jul-26/29	SABS	Workshop on using the DEPOMOD model for predicting benthic effects of fish farms (DFO)
2012-May-29	Charlottetown	Aquaculture environmental monitoring session at Aquaculture Canada 2012 (AAC)
2014-Jun-03/04	St. Andrews	Aquaculture environmental monitoring session at Aquaculture Canada 2014 (AAC)

Acronyms:

AAC: Aquaculture Association of Canada
BIO: Bedford Institute of Oceanography (Dartmouth, NS)
GMCME: Gulf of Maine Council on the Marine Environment
ICES: International Council for the Exploration of the Sea
SABS: St. Andrews Biological Station

APPENDIX 6: Research Priorities

Research priorities were a regular topic of discussion for the AECC. However, specific lists of research priorities were not produced every year.

1993 environmental priorities

The initial AECC research priorities list in 1993 was for general environmental topics (rather than specific projects) related to finfish aquaculture in New Brunswick. The list was in order of priority.

1) Benthic impacts on marine environment, including cumulative effects
2) Impacts of salmon smolt production on freshwater habitat
3) Water column impacts (nutrients, dissolved oxygen, suspended materials, etc.), including cumulative effects
4) Multiple use interactions between municipal sewage and industrial wastes on aquaculture
5) Potential impacts of toxic algae on salmon aquaculture
6) Impact of sea lice on farms (treatment and prevention)
7) Factors influencing spread of disease among farms
8) Impact of aquaculture chemicals on non-target species

1998 research priorities

The AECC, in conjunction with the New Brunswick Department of Fisheries & Aquaculture, held a Technical Session on Aquaculture-Environment Research Priorities in January 1998 (NBDFA & AECC 1998). Invited participants included scientists and consultants involved in environmental monitoring and research for the finfish aquaculture industry in SWNB. An outcome of this workshop was a list of research priorities, including 5 primary research directions, plus 3 other lower priorities.

Primary research directions:

1) Development of a water circulation model for the Bay of Fundy salmon mariculture area
2) Research into environmental and husbandry variables that affect farm production
3) Identify the correlation between environmental variables and disease/parasite epidemics within the Bay of Fundy salmon mariculture industry
4) Test application of the Silvert benthic impact model for carrying capacity and holding capacity in specific geographic areas
5) Identify, undertake, and evaluate site remediation methodology

Additional research items of importance:

- Phytoplankton/eutrophication monitoring
- Interaction of wild vs. cultured salmonid populations
- Impact of activities at cage sites on marine mammals and other marine species

APPENDIX 6: Research Priorities

2000-2001 research priorities

Priorities

- Physical oceanography for sustainable aquaculture development
- Biological oceanographic data required to manage the NB salmon mariculture industry, including benthic-pelagic coupling
- Far-field effects

Other projects

- Physical remediation options
- Effects of chemical wastes on habitat near salmon cage sites and on non-target animals
- Phytoplankton monitoring for predicting impacts on mariculture
- Identify carrying capacity of Passamaquoddy Bay

2001-2002 research priorities

- Physical oceanography for sustainable aquaculture development
- Biological oceanographic data required to manage the NB salmon mariculture industry, including benthic-pelagic coupling
- Far-field effects
- Physical remediation
- Effects of chemical wastes on habitat and non-target organisms
- Water quality monitoring, especially dissolved oxygen
- Aquaculture development and commercial fishing interactions

2002-2003 research priorities

- Physical oceanography for sustainable aquaculture development:
    - Hydrography
    - Water quality monitoring
- Benthic ecology for sustainable aquaculture development:
    - Near and far field effects
    - Applied environmental management for seabed recovery
- Presence, fate, and effects of chemicals of aquaculture origin, including disinfectants, antibiotics, and anti-sea louse therapeutants
- Ecological interactions between farmed fish and wild stocks

APPENDIX 6: Research Priorities

2005 research priorities for performance based management (PBM)

The report on the AECC-sponsored workshop "Environmental science priorities in support of performance-based management approaches to finfish aquaculture" (Paynter 2005) included lists of research priorities in support of a performance based standards (PBS) approach. Research priorities were listed in the following categories.

- Performance based standards
- Benthic conditions: soft bottom and hard bottom
- Interactions between nutrients, water quality, and oceanography
- Species at Risk Act (SARA), fisheries interactions, habitat, and fish health

See Paynter (2005) for specific priorities included within each category.

2011 priority research categories

AECC members were surveyed for input on what they considered to be research priorities for environmental research projects for marine finfish aquaculture. The resulting priorities fell into the following categories:

- Marine benthic quality
- Water quality
- Cumulative effects/carrying capacity – ecosystem based management
- Fish health & chemical use
- Fisheries/wildlife and aquaculture interactions

2011-2012 priority research projects

Priorities

- Comparison of two sampling techniques for collection of benthic sediment samples: diver vs. surface deployed collection
- Application of a predictive model (DEPOMOD) and model validation for organic enrichment
- Resuspension of sediments under fish farms
- Pathways of effects models
- Development of suitable indicators, monitoring tools, and data analysis tools to determine spatial variability of organic enrichment impacts (spatial analysis tools)
- Development of environmental monitoring protocols for integrated multi-trophic aquaculture (IMTA) sites
- Collection of sediment samples to examine copper levels in the environment

APPENDIX 6: Research Priorities

Longer-term projects

- Development of a process to examine video collected during the annual monitoring program
- Establishment of nutrient guidelines around fish farms

2013-2014 priority research projects

On-going and proposed projects were ranked as high, medium, or low priority. Only the high priority projects are listed here.

- Application of a predictive model (DEPOMOD) for organic enrichment (completed)
- Sulfide probe calibration (on-going)
- Identification and evaluation of appropriate environmental indicators and monitoring tools for all substrate types (hard and soft)
- Development of suitable indicators, monitoring tools, and data analysis tools to determine spatial variability of organic enrichment impacts
- Investigation of additional techniques for environmental effects monitoring of soft bottom, shallow water aquaculture sites
- Investigation of techniques for environmental effects monitoring of hard bottom and/or deep water aquaculture sites
- Aquaculture's contribution to cumulative effects in estuarine and marine environments
- Development and evaluation of tools to determine carrying capacity of coastal waters used for aquaculture