Nova Scotia Environmental Monitoring Program for Finfish Aquaculture

An Update (2006-2011)

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Atlantic Coalition for Aquaculture Reform

Summary

In 2006, the Nova Scotia Department of Fisheries and Aquaculture (NS DFA) reported on the results of their Environmental Monitoring Program (EMP) for the marine aquaculture industry from 2003 to 2005. For regulatory purposes, total dissolved sulphide levels in sediments are the main parameter used to determine direct impact of an aquaculture operation. Monitoring results (2003-2005) indicated that only a few finfish monitoring stations reported sulphide levels in the B - hypoxic (polluted) category and one station reported sulphides in the C - anoxic (grossly polluted) range. Virtually all of the shellfish sites reported sulphides in the A - oxic (normal) range. An update on sulphide monitoring results for finfish aquacultures sites from 2006 to 2011 indicated a significant increase in the number of finfish monitoring stations reporting B - hypoxic (or polluted) and C - hypoxic (or grossly polluted) conditions compared to the 2003-2005 monitoring period. The results also indicated that overall environmental quality associated with finfish sites had decreased since the 2003-2005 reporting period. The effectiveness of NS DFA's new 2011 Environmental Monitoring Program Framework to ensure aquaculture sites maintain oxic levels has yet to be demonstrated or evaluated.

Background

In 2006, the Nova Scotia Department of Fisheries and Aquaculture (NS DFA) issued a report on the results of their Environmental Monitoring Program (EMP) for the marine aquaculture industry in Nova Scotia from 2003 to 2005. The department established the EMP program in 2003.

For regulatory purposes, the NS DFA's EMP focused on sediment geochemistry. Operators of aquaculture sites were required to measure marine sediments for sulphide, redox, organic content and porosity. While a suite of parameters were measured, total dissolved sulphide levels were the main parameter used to determine direct impact of an aquaculture operation. Sulphides are an indicator of habitat degradation due to organic waste loading. NS DFA established Environmental Quality Definitions (EQDs) and operations with sulphide levels below 1300 µM of sulphide were given an A or normal-oxic designation. Operations with sulphide levels between 1300 µM and 6000 µM were given a B or sub-oxic designation and sites with sulphide levels above 6000 µM were given a C or anoxic designation (**Appendix A**).

A change in sediment sulphide, oxygen, organic content and porosity is accompanied by a change in the biological community in the sediments. The biological implications of changes in sediment sulphide levels are described and illustrated in an expert opinion document prepared for DFO (Hargrave 2006) and published in the peer-reviewed literature in 2008 (Hargrave et al.

2008). Based on expert opinion, sediments with sulphide levels between1500 µM and 6000 µM are classified as polluted and the biological diversity of the organisms living in the sediments, measured by various indices, is described as reduced. When sulphide levels are over 6000 µM, the sediments are classified as grossly polluted and the biological diversity is very low (**Appendix B**). While NS DFA measured and evaluated environmental quality at aquaculture sites in geochemical terms, changes in the biological community were not monitored.

At the end of 2005, the province reported that there were 36 finfish sites (which included salmon and steelhead trout open pen sites, land-based farm sites and hatcheries) and 123 shellfish sites (mostly mussels). The report did not indicate how many of the 36 finfish sites were active sites or salmon open pen sites. Production of salmon/steelhead trout in marine open pens in 2003 was 5210 mt, 2049 mt in 2004 and 5703 mt in 2005 (https://gov.ns.ca/fish/aquaculture/stats/). Based on these production figures and an average production per site of 500 - 750 mt, it is estimated that there were between 5 and 7 marine open pen finfish sites in operation.

The 2006 DFA EMP report summarized the mean sulphide concentrations for all stations sampled from 2003 to 2005 in relation to the province's Environmental Quality Definitions (EQDs) **(Figure 1)**. The report concluded that a few finfish monitoring stations reported sulphides in the B - hypoxic category and one station reported sulphides in the C - anoxic range. Virtually all of the shellfish sites reported sulphides in the A - oxic range. The report concluded that "overall findings from this baseline sampling revealed that the majority of sites showed no significant impact".

Since the publication of the 2006 DFA report, there has been no further reporting on the results from the province's Environmental Monitoring Program (EMP) for marine aquaculture operations. Environmental monitoring data for aquaculture sites are not publicly available in Nova Scotia, unlike in New Brunswick where this information is posted each year on the New Brunswick Department of Environment and Local Government website (http://www2.gnb.ca/content/gnb/en/departments/elg/environment/content/water/content/marine_aquaculture.html).

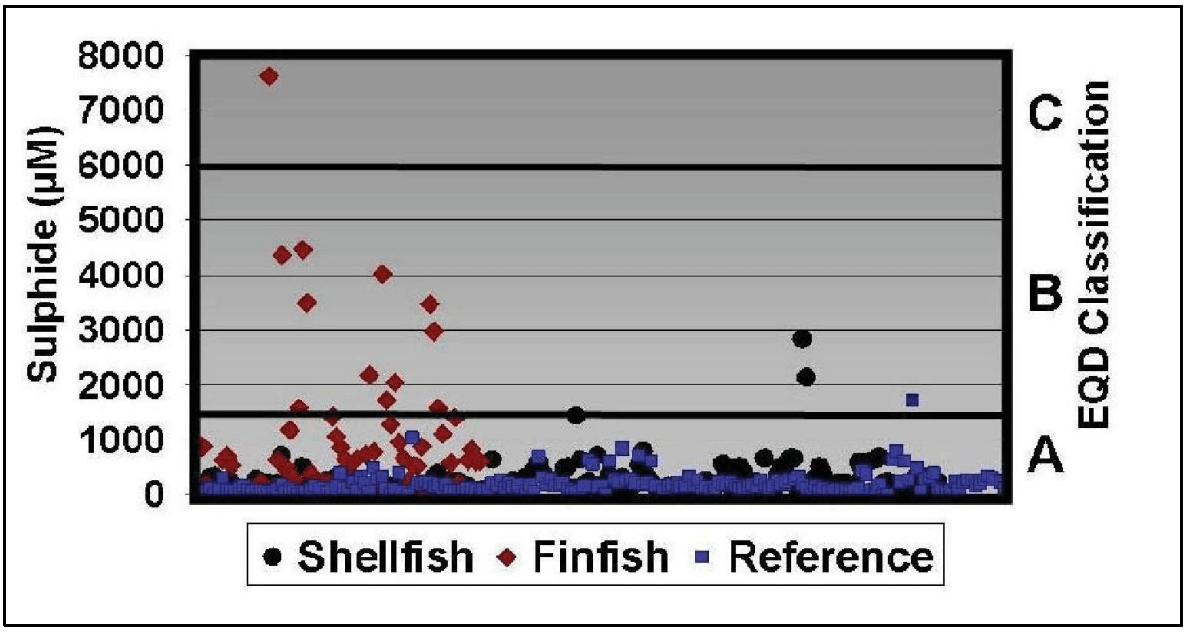


Figure 1. Mean Sulphide by Sampling Station - 2003 to 2005
The 2006 NS DFA report does not indicate how many finfish farms were in production for the time period covered by the graph. Based on production figures, the number of sites is estimated to be between five and seven sites. NS DFA did not plot monitoring data by year making it impossible to detect any trends in sulphide levels at farm sites over time. Source: Reproduced from the NS DFA's 2006 EMP Report, page 5.

In March 2011, the NS DFA released a new Environmental Monitoring Program Framework for Marine Aquaculture and Standard Operating Procedures for the Environmental Monitoring of Marine Aquaculture. The Environmental Monitoring Program (EMP) Framework set out new Environmental Quality Definitions which raised the level of sulphide considered oxic from 1300 µM to 1500 µM and prescribed the appropriate number and location of monitoring stations based on production levels. The EMP also states that the "marine Environmental Quality Objective (EQO) is to maintain oxic conditions". If oxic conditions are not met, sites must inform NS DFA of the efforts taken to improve site conditions.

2006-2011 Update

In the fall of 2012 and in response to requests by individuals and community groups, the NS DFA began releasing historic and current environmental monitoring data on open pen finfish operations. In addition to the monitoring data, maps identifying sampling locations were also released. Data for 11 of 16 finfish leases were released. Data for the McNutts Island (Outer Shelburne Harbour) and the Coffin Island (Liverpool) sites were requested but not received as of the publication of this report.

From 2006 to 2011 sulphide monitoring results for finfish aquaculture sites indicate that there has been a significant increase in the number of finfish monitoring stations reporting B - hypoxic (or polluted) and C - anoxic (or grossly polluted) conditions compared to the 2003-2005 monitoring period (**Figure 2**). The results also indicate that overall environmental quality associated with finfish sites has been decreasing since the 2003-2005 reporting period.

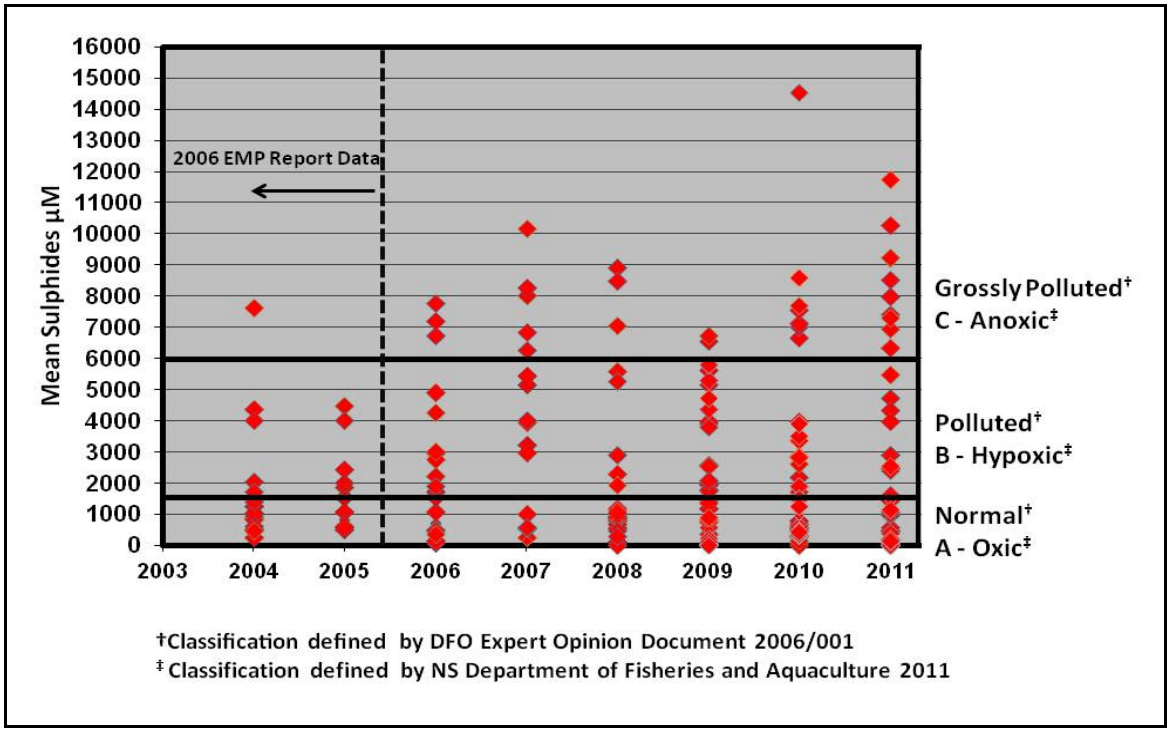


Figure 2. Mean Sulphides for Open Pen Finfish Sites - 2003 to 2011
This graph represents the results of environmental monitoring for sulphides at 11 of 16 open pen finfish leases. The graph does not include reference sites. Not all finfish leases were in production between 2003-2011. Data Source: NS DFA 2012

The NS DFA's environmental quality objective to maintain oxic conditions on lease sites did not come into effect until 2011. Prior to the implementation of this new policy, the majority of finfish leases operating between 2006-2010 failed to maintain A - oxic (normal) conditions (**Appendix A**). Except for two leases (Sandy Point which was surrendered in 2011 and lease #1039 in the Annapolis Basin), the majority of finfish lease sites reported oxic conditions on their leases in 2011. However, these results are misleading for several reasons:

- three of the 16 leases (Boston Rock, Hartz Point and Shelburne Trout) were surrendered by the site owners and no monitoring took place on these sites in 2011;
- one lease (Spectacle Island) was in the third year of fallowing;

- sampling stations with high sulphides on two leases (Owls Head, lease #1039 Annapolis Basin) were not resampled in 2011 or 2012;
- two of 16 leases (Grand Passage, Freeport) were new leases which began production in 2011 and therefore all monitoring data collected in 2011 would reflect baseline, pre-production conditions;
- two of 16 leases (Long Beach, lease #1040 Annapolis Basin) were brought back into production after several years of inactivity; and
- there were no data available on the remaining four leases.

The new 2011 EMP framework outlined a suite of measures aquaculture sites were required to take in order to meet the NS DFA's Environmental Quality Objective (EQO) of oxic sediment conditions. For example, if 70% of the sampling stations on a site have sulphide levels over 6000 µM, the site would be classified as anoxic and would be in non-compliance with the NSDFA license approval and the federal *Fisheries Act*. The site operator would be required to work closely with government agencies and follow any specific directions given by the agencies which could include an expedited harvest program, fallowing, consultation prior to restocking (if applicable), increased monitoring and limitations to future operations (production levels, site layouts, equipment and staff requirements, etc.).

Whether these new measures are effective in maintaining sulphides at oxic levels has yet to be evaluated. However, the past histories of several finfish sites that have implemented some of these measures (e.g., fallowing, moving pens within a lease, reducing production) demonstrate that these measures result in only a temporary reduction in sulphides (**Appendix A**). Once fish production resumes, sulphide levels often rise above 1500 µM and serial fallowing can result in sulphide levels rising to even higher levels that those measured previous to the fallowing period. The monitoring results for the Sandy Point lease in Shelburne Harbour illustrate this point (**Appendix A**). Prior to a fallow period of 3 months, sulphide levels at the site had reached 9000 µM. After the fallow period, sulphides dropped to 2000 µM. Once production resumed, sulphide climbed to almost 12,000 µM in 2011.

The 2006 NS DFA EMP report suggested that organic waste is biodegradable and the effects "can quickly be reversed." Monitoring data from 2006 to 2011 illustrates that it can take some time for sulphide levels to drop. For example, sulphide levels at the Spectacle Island lease remained high (4000 µM) after 15 months of fallowing (Appendix A).

Future Considerations

The NS DFA's 2006 EMP report concluded by stating that the data collected would "go a long way to ensure that aquaculture in Nova Scotia remains environmentally sustainable" and that the department would use the data collected between 2003-2005 to "assess risk between variables (e.g. finfish vs shellfish, bay vs site, active site vs non-active site)". No risk assessment reports have been published by NS DFA.

The focus of NS DFA's 2011 EMP for aquaculture operations is on sediment geochemistry but it is well documented that it takes longer for the biological community to recover from the impacts of waste loading than the geochemistry of the sediments (Lin and Bailey-Brock 2008, Brooks et al 2004, McLeod et al, 2004, Pereria et al 2004, Pohle et al 2001). There are no requirements in the NS EMP to monitor the biological community during production or fallowing.

In addition, the build-up of copper in sediments from open pen fish farms is an emerging regulatory and environmental issue. High concentrations of copper and zinc in sediments have been reported in several studies examining the impacts of open net pen salmon farms on the benthic environment (Loucks et al. 2012, Milewski 2012 unpublished data, Sutherland et al. 2007, Yeats et al. 2005, Smith et al. 2005, Brooks et al. 2003, Chou et al. 2002).

The Canadian Council of Ministers for the Environment (CCME) has established interim sediment quality guidelines (ISQGs) and probable effect levels (PELS) for copper and zinc (CCME 1999). Copper is known to be toxic to aquatic organisms at elevated concentrations and the CCME PEL guidelines refer to levels of copper or zinc in sediments at which adverse biological effects are likely to occur (CCME 2002).

High concentrations of copper around fish farms have been linked to several pathways: (1) excretion of more concentrated Cu in the fish feces; (2) the use of antifoulants on nets; and (3) accumulation and breakdown of the feed that loses organic material without dispersing metals into the water column (Chou et al. 2002). Unlike sulphide levels which can decrease over time, copper does not remobilize and therefore does not appear to be decrease over time (Smith et al. 2005).

Two studies have recently reported copper levels above CCME guidelines for the protection of marine life under fish farms in Nova Scotia (Loucks et al.2012, Milewski 2012, unpublished data). Copper levels at the former Sandy Point lease in Shelburne Harbour were at toxic levels (Milewski 2012, unpublished data). There are no requirements in the NS EMP to monitor or limit copper or zinc at aquaculture sites.

References

Brooks, K.M., Stierns, A.R., Backman, C. 2004. Seven year remediation study at the Carrie Bay Atlantic salmon (Salmo salar) farm in the Broughton Archipelago, British Columbia, Canada. Aquaculture 239:81-123.

Brooks, K. M., Stierns, A.R., Mahnken, C.V.W., Blackburn, D.B., 2003. Chemical and biological remediation of the benthos near Atlantic salmon farms. Aquaculture 219:355–377.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian sediment quality guidelines for the protection of aquatic life: Copper. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment (CCME). 1999. Canadian sediment quality guidelines for the protection of aquatic life: Zinc. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (CCME), 2002. <http://www.ccme.ca/assets/pdf/sedqg_summary_table.pdf> (accessed 28.12.12).

Chou, C.L., Haya, K., Paon, L.A., Burridge, L., Moffatt, J.D. 2002. Aquaculture-related trace metals in sediments and lobsters and relevance to environmental monitoring program ratings for near-field effects. Marine Pollution Bulletin 44:1259-1268.

Hargrave, B.T., Holmer, M., Newcombe, C.P., 2008. Towards a classification of organic enrichment in marine sediments based on biogeochemical indicators. Marine Pollution Bulletin 56:810-824.

Lin, D.T., Bailey-Brock, J.H. 2008. Partial recovery of infaunal communities during a fallow period at an open-ocean aquaculture. Marine Ecology Progress Series 371:65-72.

Loucks, R.H., Smith, R.E. , Fisher, C.V., Fisher, E.B. 2012. Copper in the sediment and sea surface microlayer near a fallowed, open-net fish farm. Marine Pollution 64:1970-1973.

Macleod C.K., Crawford, C.M., Moltschaniwskyj, N.A. 2004. Assessment of long term change in sediment condition after organic enrichment: defining recovery. Marine Pollution Bulletin 49(1-2):79-88.

Milewski, I. 2012. Unpublished data collected October 2012 at a former fish farm in Shelburne Harbour, Nova Scotia.

Pereira, P.M.F., Black, K.D., McLusky, D.S., Nickel, T.D. 2004. Recovery of sediments after cessation of marine fish farm production. Aquaculture 235:315-330.

Pohle, G., Frost, B., Findlay, R. 2001. Assessment of regional benthic impact of salmon mariculture within the Letang Inlet, Bay of Fundy. ICES Journal of Marine Science 58:417-426.

Nova Scotia Department of Fisheries and Aquaculture. 2011. Environmental Monitoring Program Framework for Marine Aquaculture in Nova Scotia.

Nova Scotia Department of Fisheries and Aquaculture. 2011. Standard Operating Procedures for the Environmental Monitoring of Marine Aquaculture in Nova Scotia.

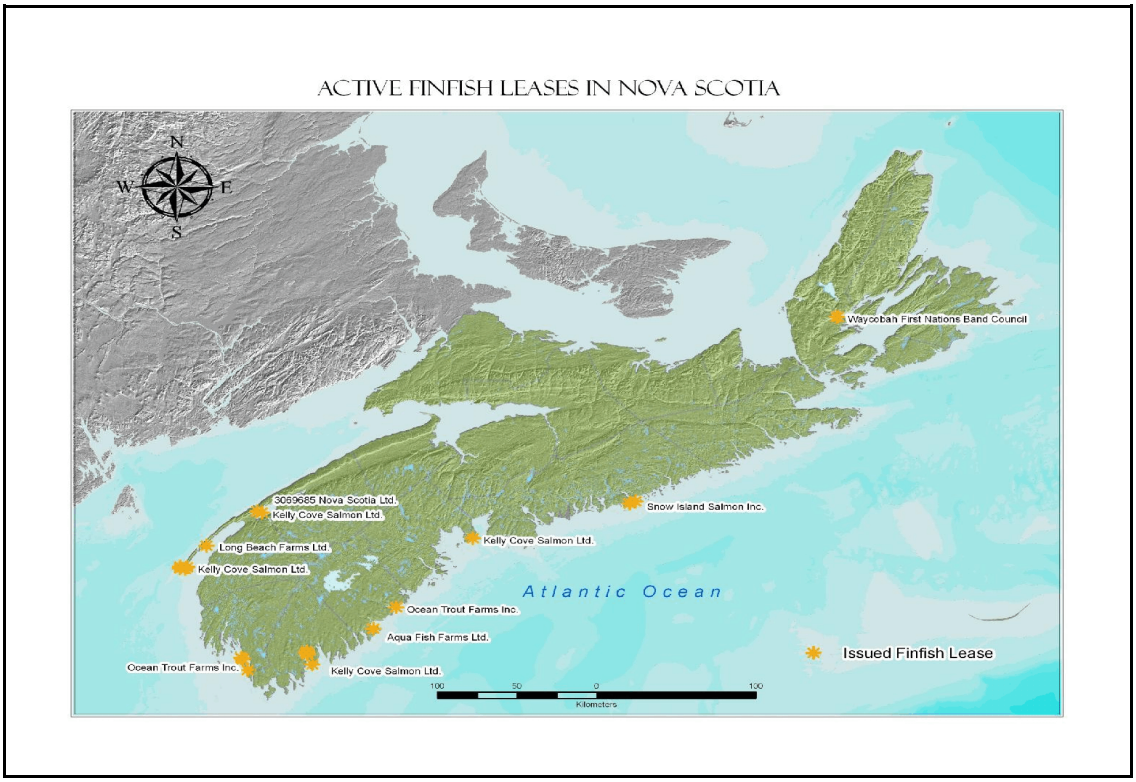
Smith, J.N., Yeats, P.A., Milligan, T.G., 2005. Sediment geochronologies for fish farm contaminants in Lime Kiln Bay, Bay of Fundy. In: Hargrave, Barry (Ed.), Environmental Effects of Marine Finfish Aquaculture, The Handbook ofEnvironmental Chemistry, 5 M. Springer, pp. 221–236.

Sutherland, T.F., Petersen, S.A., Levings, C.D., Martin, A.J., 2007. Distinguishing between natural and aquaculture-derived sediment concentrations of heavy metals in the Broughton Archipelago, British Columbia. Marine Pollution Bulletin 54:1451–1460.

Yeats, P.A., Milligan, T.G., Sutherland,T.F., Robinson, S.M.C.,Smith, J.N., Lawton, P., Levings, C.D. 2005. Lithium-normalized zinc and copper concentrations in sediments as measures of trace metal enrichment due to salmon aquaculture. In: Hargrave, Barry (Ed.), Environmental Effects of Marine Finfish Aquaculture, The Handbook of Environmental Chemistry, 5 M. Springer, pp. 207–220.

Appendix A - Environmental Monitoring Results for Individual Finfish Lease Sites in Nova Scotia

There were approximately 16 finfish (salmon and trout) leases in 2011; 12 of the 16 leases were salmon open pen farms and the remaining leases were trout farms. Not all leases were in operation in 2011. An outbreak of the infectious salmon anemia (ISA) virus on the McNutt Island salmon farm in Outer Shelburne Harbour in early 2012 resulted in fish being removed from all farm sites in inner and outer Shelburne Harbour. Restocking of farm sites in Shelburne Harbour is expected to occur in 2013.



Source: NS Department of Fisheries and Aquaculture 2012

The 2011 NS DFA Environmental Monitoring Program (EMP) laid out the criteria that determined the level of monitoring and mitigation for each aquaculture site. The thresholds and any follow-up actions set out in the EMP are intended to "to ensure the sustainability of the aquaculture industry." (NS DFA EMP Framework, page 3)

The NS DFA EMP states that sites with sulphide levels over 1500 µM must do more monitoring and "the site operator must adjust appropriate BMP's [Best Management Practices] to improve environmental performance." (NS DFA EMP Framework, page 9).

The classification of aquaculture sites as oxic/normal, hypoxic/polluted and anoxic/grossly polluted are based on the Nova Scotia Department of Fisheries and Aquaculture Environmental Quality Definitions 2011 (below) and DFO expert opinion document 001/06 (**Appendix B**).

	Sediment Classification		
Measurement	**Oxic**	**Hypoxic**	**Anoxic**
Sediment colour	Tan to depth > 0.5 cm	Tan to < 0.5 cm with some black sediments at surface	Surface sediments black
Microbial presence	No sulphur bacteria present	Patchy sulphur bacteria	Widespread bacterial mats
Macrofaunal Assemblage	Wide array of infauna and epifauna	Mixed group of mostly small infauna	Small infauna only
Sulfide, µM	**< 750 (A) 750 to 1500 (B)**	**1500 to 3000 (A) 3000 to 6000 (B)**	**> 6000**
Redox (Eh), mV	>100 (A) 100 to -50 (B)	-50 to -100 (A) -100 to -150 (B)	< -150
Organic matter, %	<= reference*	1.5 to 2X ref.	> 2X reference
Porosity, %	<= reference*	1 to 10X ref.	> 10X reference

Environmental Quality Definitions for the Nova Scotia Marine Aquaculture Industry.
Source: NS Department of Fisheries and Aquaculture 2011 EMP Framework, page 5.

The following histories and environmental monitoring results for 11 of 16 open pen finfish sites have been compiled with data provided by the NS Department of Fisheries and Aquaculture in 2012. Data for the McNutts Island site (Outer Shelburne Harbour) and the Coffin Island site (Liverpool), were requested but not made available by NS DFA. Both sites reported the ISA virus onsite in 2012. Data for sites in Pubnico Point and Wycocomagh Bay were not available.

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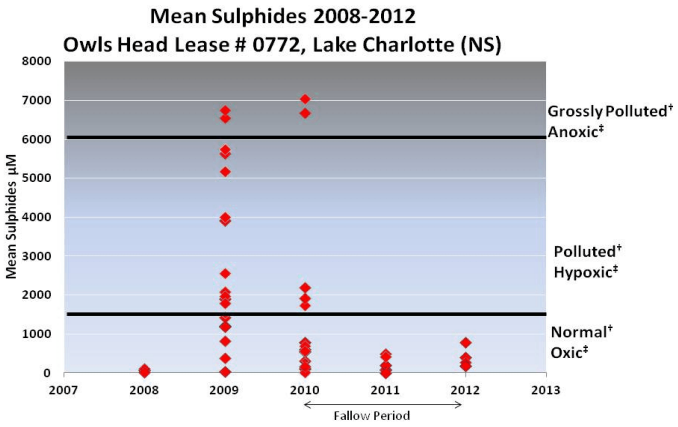
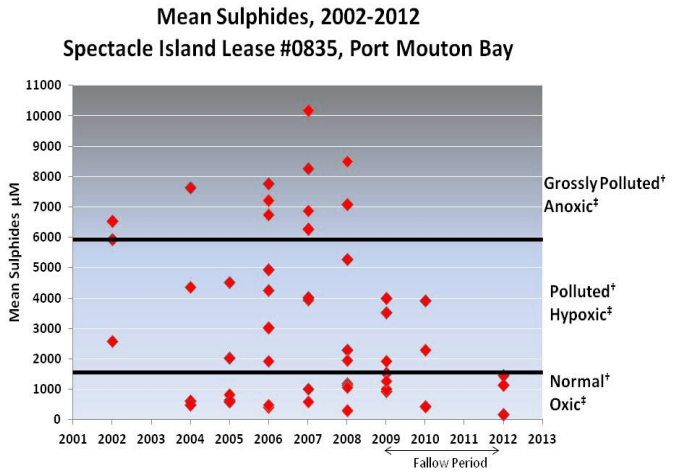
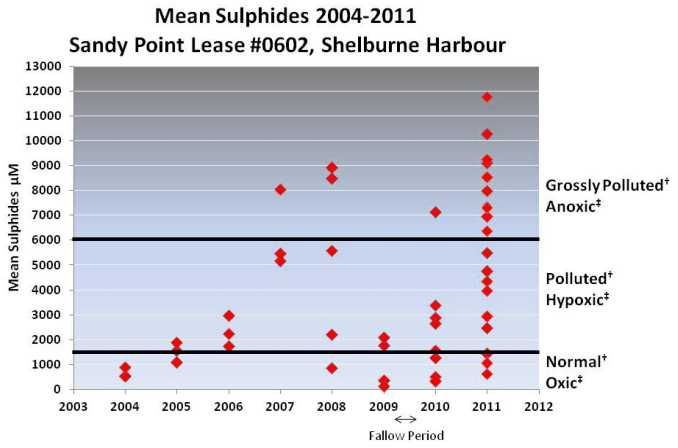
HISTORY



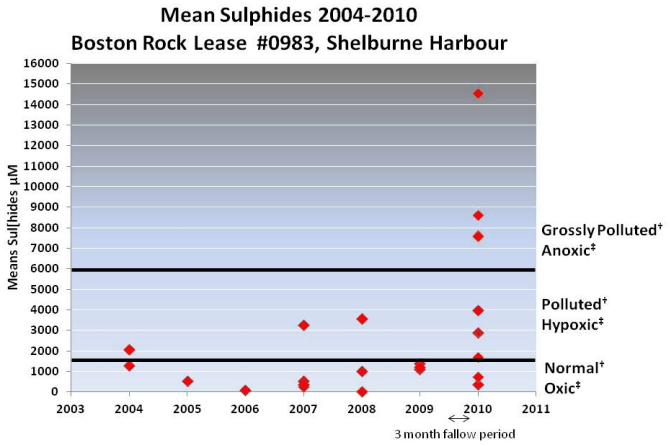
- operated by Snow Island Salmon
- located near Sheet Harbour
- fallowed for two years after sulphides reached 7,000 µM in 2010
- farm area with high sulphides not re-sampled in 2011 or 2012
- re-stocked in 2012
- new monitoring stations located 50-100 meters from area of high sulphides



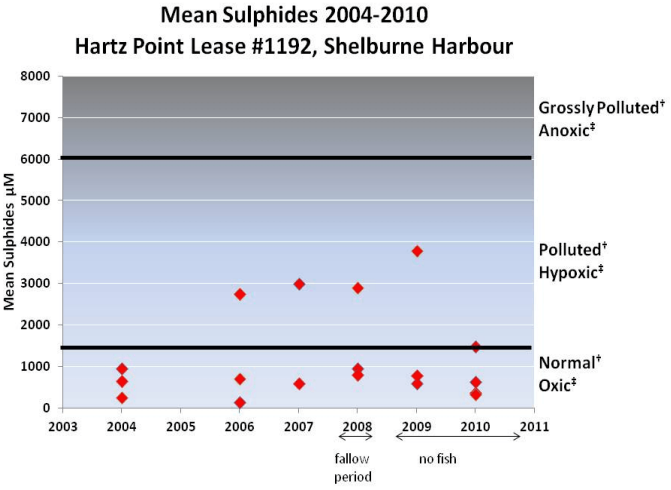
- operated by Aqua Fish Farms until 2009
- ownership transferred to Ocean Trout Farms Inc in 2012
- fallowed for three years after sulphides reached over 10,000 µM in 2007 and over 8,000 µM in 2008
- re-stocked with trout in 2012
- a study found higher levels of copper in sediments and on the sea surface in the vicinity of the salmon farm than guidelines for the protection of marine life (Loucks et al. 2012)



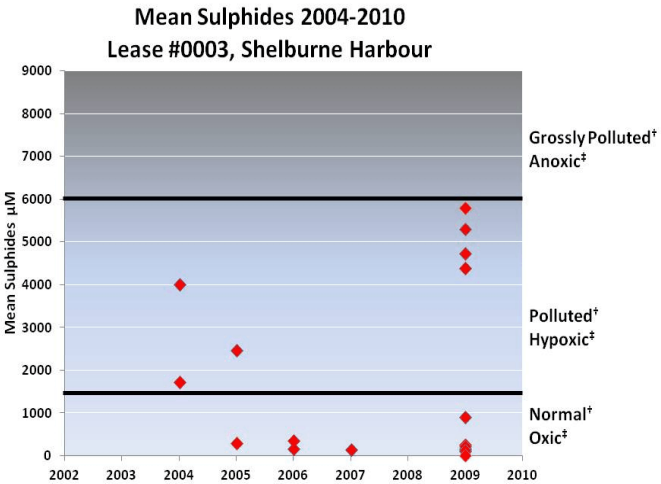
- 2005 acquired by Kelly Cove Salmon
- farm fallowed for 3 months in 2009
- re-stocked in July 2009
- sulphides climbed to 7000 µM in 2010 and over 11,000 µM in 2011
- lease surrendered October 2011
- new lease 100 meters north of old lease
- study shows sea bottom at old site remains devoid of marine life and copper and zinc are at toxic levels after one year with no fish
- no stocking in 2012 due to ISA outbreak on McNutts Island site



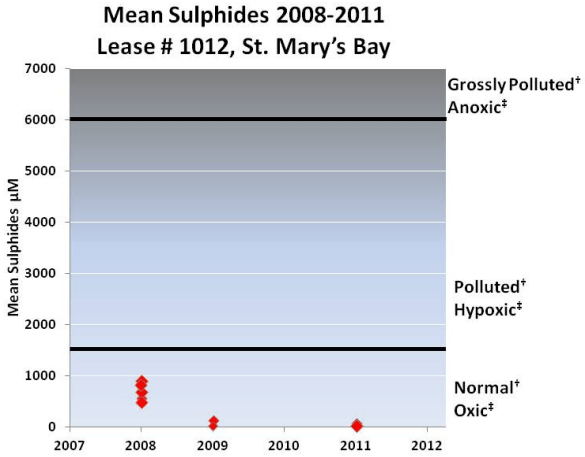
- 2005 acquired by Kelly Cove Salmon
- farm stocked April 2007
- fish harvested mid-2009
- fallowed for 3 months in 2009
- restocked with trout October 2009
- lease surrendered in 2011 after sulphides reach almost 15,000 µM
- new lease 100 meters east of old lease
- no stocking at new site in 2012 due to ISA outbreak on McNutts Island (Outer Shelburne Harbour) farm



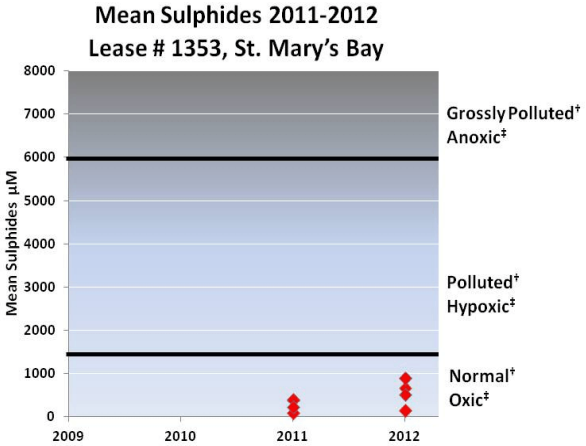
- 2005 acquired by Kelly Cove Salmon
- site stocked May 2006
- fish transferred off site May 2007
- site receives 157,000 fish May 2007
- fish harvested Aug 2007
- site fallowed for 9 months
- restocked May 2008
- all fish transferred Sept. 2008 to McNutt Island site
- 2011 lease surrendered; new lease 100 meters east of old lease
- no stocking at new site in 2012 due to ISA outbreak on McNutts Island (Outer Shelburne Harbour) farm



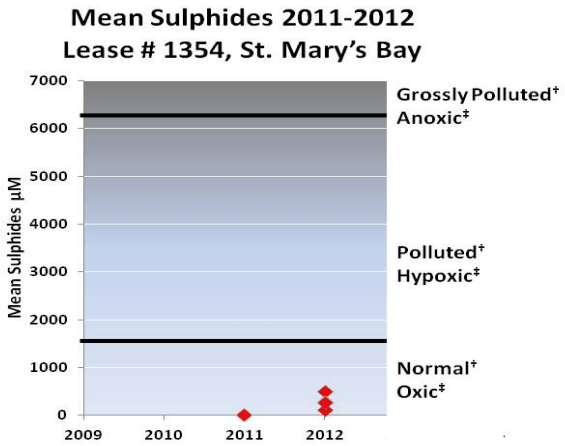
- owned by Cooke Aquaculture
- referred to as Shelburne Trout site
- located 250 meters north of Boston Rock lease #0983
- site history incomplete
- stocked with trout Dec. 2008
- sulphides reach almost 6,000 µM in 2009
- fish harvested Feb. 2010
- lease surrendered in 2011



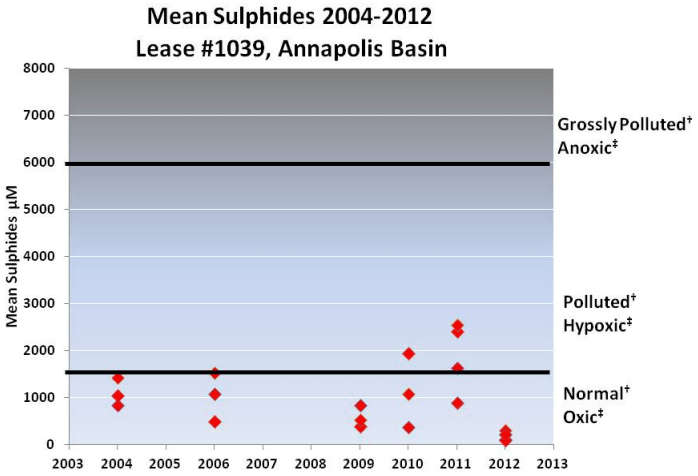
- owned by Long Beach Farm Ltd
- located off Long Beach, inner St. Mary's Bay
- originally stocked with trout
- site stocking history unknown
- no fish on site for at least a year



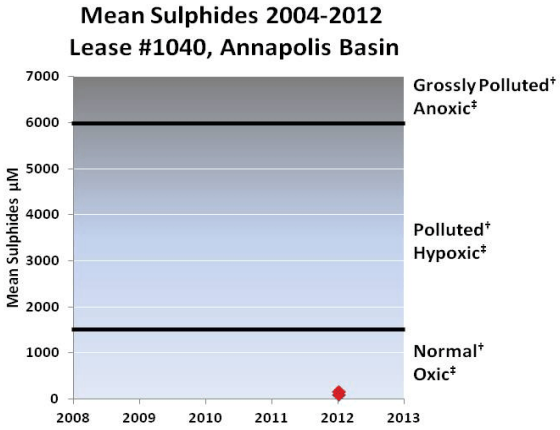
- owned by Kelly Cove Salmon
- referred to as the Grand Passage site
- licensed to grow 1,000,000 fish
- stocked in 2011; number of fish unknown
- after one year sediment sulphide levels rise despite deep waters (50 metres)



- owned by Kelly Cove Salmon
- referred to as the Freeport site
- licensed to grow 1,000,000 fish
- stocked in 2011; number of fish unknown
- after one year sediment sulphide levels rise despite deep waters (40-50 metres)



- operated by Kelly Cove Salmon
- located near Digby
- stocking history unknown
- stations with high sulphides not resampled in 2012
- Oct/Nov 2012 number of net pens increased from 11 to 16



- lease transferred to Kelly Cove Salmon in 2011
- lease located near Port Wade
- a farm previously on the site destroyed by ice
- no fish on the site since 2004
- stocked with salmon in June 2012

Appendix B - A Benthic Enrichment Nomogram illustrating the relationship between changes in sediment geochemistry cause by organic loading and the response of the biological community.

Source: Hargrave BT, Homer M and Newcombe CP. 2008. Towards a classification of organic enrichment in marine sediments based on biogeochemical indicators. *Marine Pollution Bulletin* 56: page 820.