Trace Metals in Sediments of Port Mouton Bay - 2009-2011

Summary

A study of sediments in Port Mouton Bay began in October 2009 and was repeated in October 2010 and 2011. Trace metals have been used as tracers of salmon farm waste in the sediments of coastal waters of southwest New Brunswick and the Broughton Archipelago of British Columbia to qualitatively predict where farm wastes have been deposited in the sediments and the relative depositions at different sites in the same area (Yeats et al., 2005).

In October 2009, 3 months after cessation of fish feeding at the Spectacle Island farm site and after a previous year (June 2008 to June 2009) of stocking at reduced capacity, levels of copper and zinc were highest in sediments within the farm lease site (and exceeding the CCME Sediment Quality Guideline for copper) and elevated at distances 400-2000 m from the farm site relative to levels at a more distant point near Port Mouton Island.

In October 2010 and 2011 after 15 and 27 months of fallowing at the farm site, this pattern continues. Levels of copper in sediments were very similar to levels detected in 2009 except for higher levels at some stations within the farm lease site and at one of the far-field stations. Generally higher lithium values suggest migration of finer sediments to the far-field.

A far-field footprint of trace metal enrichment from the salmon farm is indicated in the lithium-normalized copper and zinc data. Based on these results and on accumulation of copper in the sea surface microlayer, further releases of copper in Port Mouton Bay are unacceptable.

Introduction

A collaborative study of sediments in Port Mouton Bay was begun in October 2009 by a team led by Dr. Jon Grant of Dalhousie University's Department of Oceanography. Friends of Port Mouton Bay (FPMB) Science Team facilitated the field surveys with the cooperation of Cooke Aquaculture. The study was continued in October 2010 and 2011.

Methodology

A grid of 40 stations (Figure 1) encompassed sand, gravel and mud bottom and included the site of a salmon farm near Spectacle Island which had operated continuously for 15 years. The farm site was operating at reduced capacity during 2009 and feeding of fish stopped on July 20, 2009.

Grab samples of sediment were taken at 29 stations on October 7, 2009, and at a further 11 stations on November 7-8, 2009 (Figure 1) 23 stations were re-visited on October 14, 2010 and

on October 18, 2011. FPMB submitted for trace metal analysis samples of sediment from a subset of 10 stations selected to include locations of fine sediment mud and elevated levels of organic matter (Figure 1). Two stations, 28 and 43, most distant from the farm site, exhibited low levels of organic matter (2%) in 2009 and are comparable to baseline levels of organic matter sampled at predominantly mud stations in the outer harbor near Port Mouton Island (Dominator Marine Services, 2007). Stations 20, 21 and 23 were within the farm lease site. Station 14 is ~400 m N of the farm site. Station 24 is ~ 500 m SSW of the farm site, Station 44 is near Carter's Beach ~ 500m SW of the farm site, and Station 34 is ~2000 m SSE of the farm site. Trace metal analysis was repeated in 2010 and 2011 for 9 stations. Station 44 was omitted.

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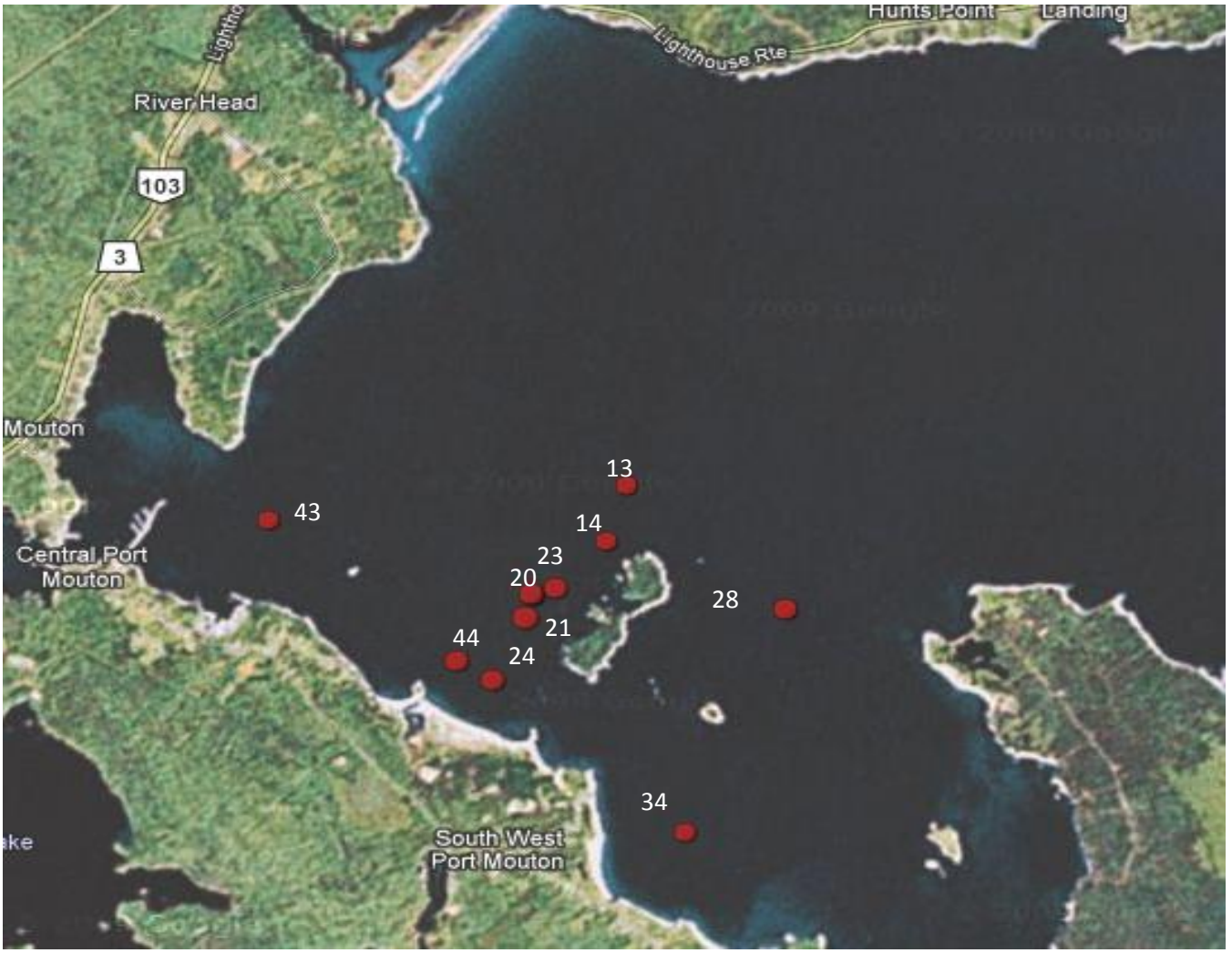


Figure 1. Chart showing the stations analyzed for trace metals and lithium concentrations centred around Spectacle Island.

The top 2 cm of the grab samples were analyzed for copper (Cu), zinc (Zn), lithium (Li), and tin (Sn) in 2009 and for Cu and Li in 2010 and 2011 at the Resource Productivity Council laboratory

in Fredericton, New Brunswick. Samples were air-dried and sieved at 2 mm, portions were digested with nitric and hydrofluoric acids and the resulting solutions were analyzed for trace elements by ICP-MS.

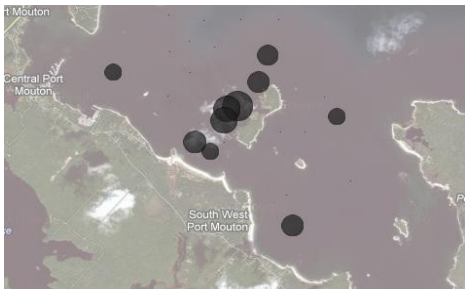
Results

The results are shown in Table 1 below and in Figure 2.

Table 1. Concentration of zinc, copper, lithium and tin (mg/kg) sampled in Port Mouton Bay sediments (October, 2009) and concentration of copper and lithium (October 2010, 2011)

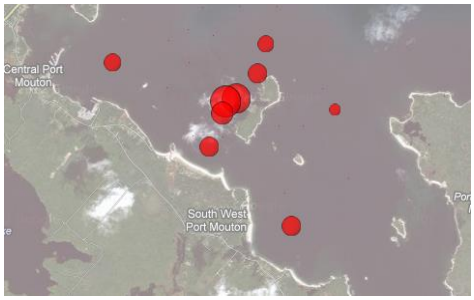
Station #	Copper (mg/kg)			Zinc (mg/kg)	Lithium (mg/kg)			Tin (mg/kg)
	2009	2010	2011	2009	2009	2010	2011	2009
13	12	12	11	39	18.7	30.0	28.8	1.8
13 (Lab Duplicate)	12	12	11	39	19.0	30.0	28.3	1.8
14	15	16	14	44	19.4	34.6	31.1	2.1
20	26	38	42	64	24.4	36.0	35.3	2.1
21	28	20	29	64	24.6	36.9	36.1	2.5
23	32	35	29	82	23.7	35.7	33.8	2.3
24	17	16	16	48	23.2	39.1	35.7	2.4
28	7	6	6	27	20.9	25.1	22.9	1.4
34	15	15	11	45	20.4	37.2	32.1	2.3
43	8	13	11	28	19.8	31.9	28.0	1.3
44	16	-		48	23.8	-	-	2.4
	-							

2009 copper data are contrasted with 2010 and 2011 data in Figures 2 and 3.

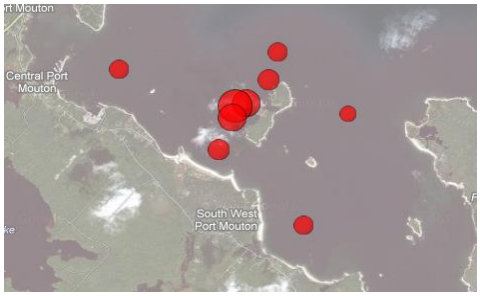


Zn 2009 (27-82 mg/kg)

Cu 2009 (7-32 mg/kg)



Cu 2010 (6-35 mg/kg)



Cu 2011 (6-42 mg/kg)

Figure 2. Chart showing the stations analyzed for copper and zinc with relative concentrations from Table 1.

The natural variability of Cu and Zn concentrations in sediments is largely related to grain size and mineralogy of the sediments (Yeats et al. 2005). Li data were used in this study to provide normalization for grain size and mineralogical differences in Port Mouton Bay sediments.

Results for Cu in Table 1 show:

- Lowest levels of 7-8 mg/kg in 2009 for the two stations most distant from the farm site; 6 mg/kg in 2010 at the most distant station near Port Mouton Island and an increase to 13 mg/kg in 2010 and to 11 mg/kg in 2011 at the other distant station in the inner harbour.
- Highest levels of 26-32 mg/kg in 2009, 20-38 mg/kg in 2010 and 29-42 mg/kg in 2011 were on the farm lease site;
- Elevated levels of 12-17 mg/kg at points 400 – 2000m distant from the farm site in both 2009 and 2010 and slightly lower at 11-16 mg/kg in 2011.

Results for Zn in Table 1 in 2009 show:

- Lowest levels of 27-28 mg/kg at most distant stations;
- Highest levels of 64-82 mg/kg on the farm lease site
- Elevated levels of 39-48 mg/kg at points 400 – 2000 m distant from the farm site (except the most distant station #28 near Port Mouton Island). Zn and Sn were not measured in 2010 and 2011.

Li levels are higher than 2009 levels by 50-80% in 2010 and by 40-60% in 2011 at all stations.

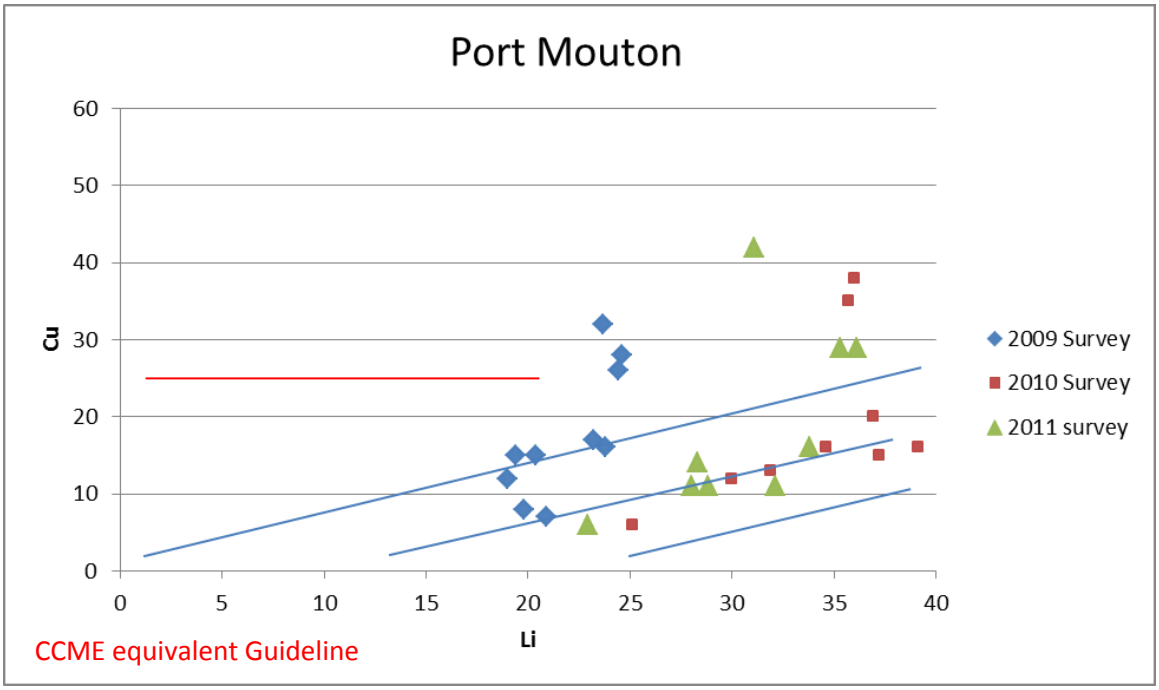
The Canadian Council of Ministers of the Environment (CCME) Interim Sediment Quality Guideline (ISQG) for Cu in marine environments is 18.7 mg/kg. The CCME Interim Sediment Quality Guideline (ISQG) for Zn in marine environments is 124 mg/kg. These guidelines are based on a less rigorous laboratory digestion for sediments using only nitric acid which generally produces results about 75% as large as the hydrofluoric and nitric acid digestion in Maritime sediments (P.Yeats, personal communication). Allowing for the difference in laboratory methodology, the levels of Cu on the lease site are above the Threshold of Effects Level (TEL) in marine environments provided by the CCME Sediment Quality Guideline in 2009, in two of three stations on the lease site in 2010, and in the three stations in 2011. Figure 3 shows the equivalent CCME Guideline corrected for differences in laboratory procedures. None of the Cu and Zn data reach the toxic effect levels of CCME's Probability of Effects Level (PEL) Guideline.

Discussion

Historical industrial activity in Port Mouton Bay was limited to the traditional fishery and fish processing before finfish aquaculture began in 1992. The sample grid in the 2009-10 Port Mouton Bay sediments study was designed to avoid potential nearshore influences of sewage sources.

A comparison of Port Mouton Bay 2009 data with harbours from the Atlantic south shore not affected by anthropogenic inputs or odd mineralogy (courtesy of Phil Yeats from data published in Loring et al. 1996) is shown in Figures 4, 5, 6 and 7. These figures show Cu and Zn plotted vs. Li. The plots include lines that represent background conditions (the central line is the metal vs Li best-fit relationship for the data from south shore harbours not affected by anthropogenic inputs or odd mineralogy, and the two outer lines are 95% confidence bands). The Port Mouton Bay Cu and Zn data which show levels above the background conditions from reference harbours as represented by the Cu or Zn vs. Li regression line are indicated.

The higher Li levels in 2010 and 2011 at all stations except the most distant station (#28) near Port Mouton Island in Figure 3 suggest that finer sediments have migrated from the farm site.



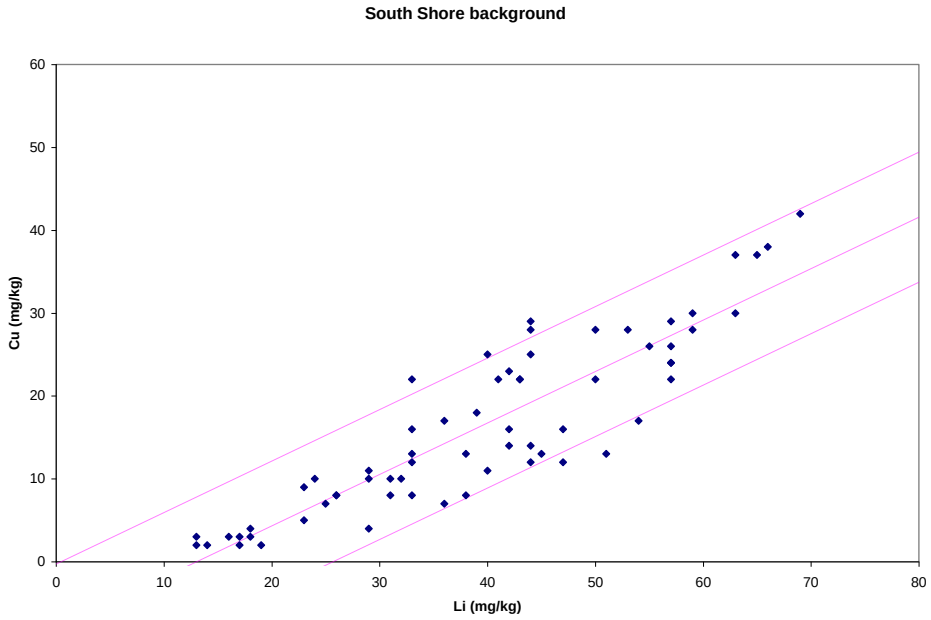
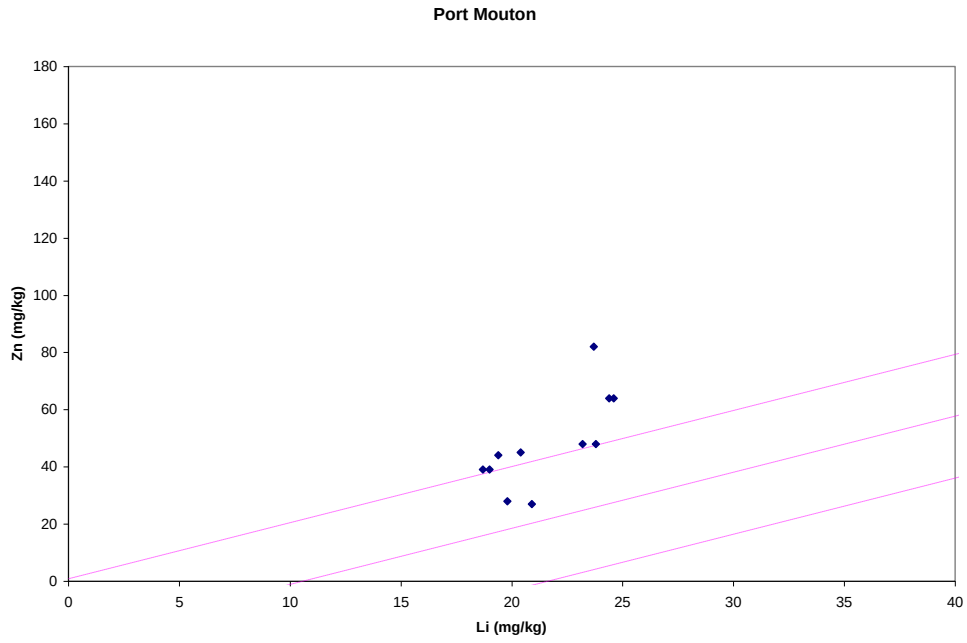


Figure 3 (top) shows Port Mouton Bay levels of Cu, 2009, 2010 and 2011, normalized for Li in sediments contrasted with typical South Shore Nova Scotia coastal background levels of Cu not affected by anthropocentric inputs in Figure 4 (bottom).



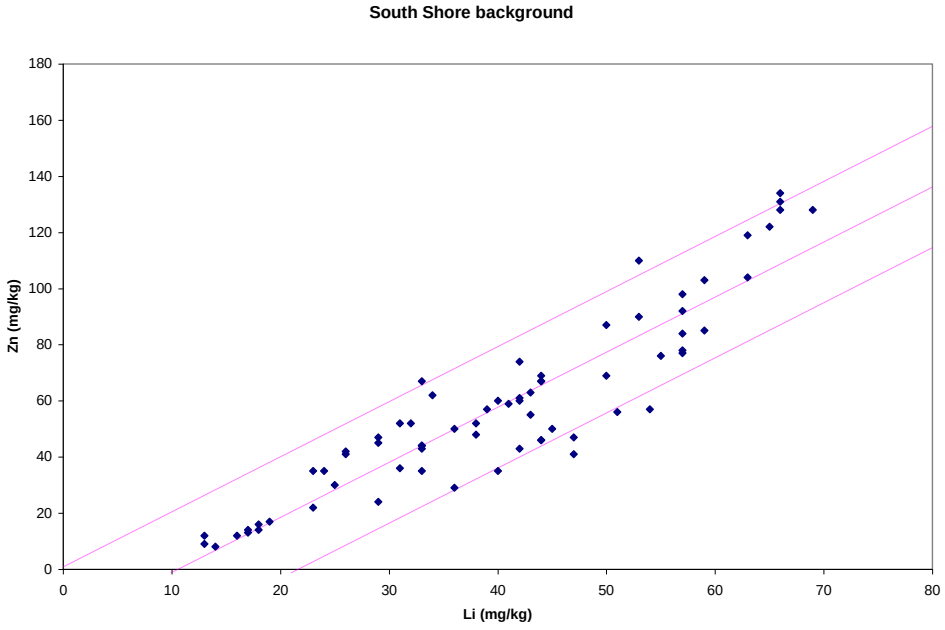


Figure 5 (top) shows Port Mouton Bay levels of Zn, 2009 normalized for Li in sediments contrasted with typical South Shore Nova Scotia coastal background levels of Zn not affected by anthropocentric inputs in Figure 6 (bottom).

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Copper sulphate and zinc sulphate are ingredients in fish feed and copper is the active ingredient in antifoulants that are routinely applied to nets used in finfish aquaculture. Copper and zinc are present in waste feed and fish feces; Cu leaches from treated nets and both Cu and Zn are bound in sediments. Lethal and sub-lethal effects of sediment copper on marine organisms have been established. Effects of copper and zinc in sediments at aquaculture sites are dependent on bioavailability and exposure. (Pathways of Effects for Finfish and Shellfish Aquaculture, Canadian Scientific Advisory Secretariat Scientific Advisory Report 2009/071, DFO, http://www.dfo-mpo.gc.ca/CSAS/Csas/Publications/SAR-AS/2009/2009_071_e.htm). Factors such as recovering oxic conditions can increase bioavailability to marine organisms.

Heavy metals have been used as tracers of salmon farm waste in the coastal waters of southwest New Brunswick and the Broughton Archipelago of British Columbia to qualitatively predict where farm wastes have been deposited in the sediments and the relative depositions at different sites in the same area (Yeats et al., 2005).

Figures 7 and 8 show the relationship between concentrations of Cu and Zn and % organic matter in Port Mouton Bay. Highest concentrations of Cu and Zn generally occurred where organic matter content was highest. (In 2010 the concentration of Cu for one of the stations on the farm site was very high (35 mg/kg) but the corresponding % organic matter analysis was lost in the laboratory procedure.)

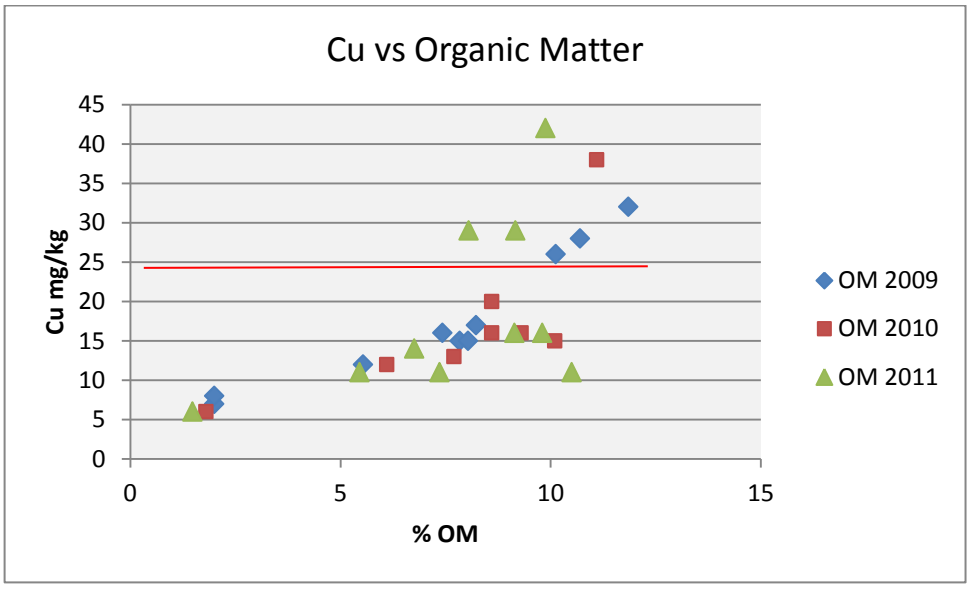

Figure 7. Copper levels in relation to % Organic Matter in Port Mouton Bay, 2009, 2010, 2011. CCME equivalent Guideline

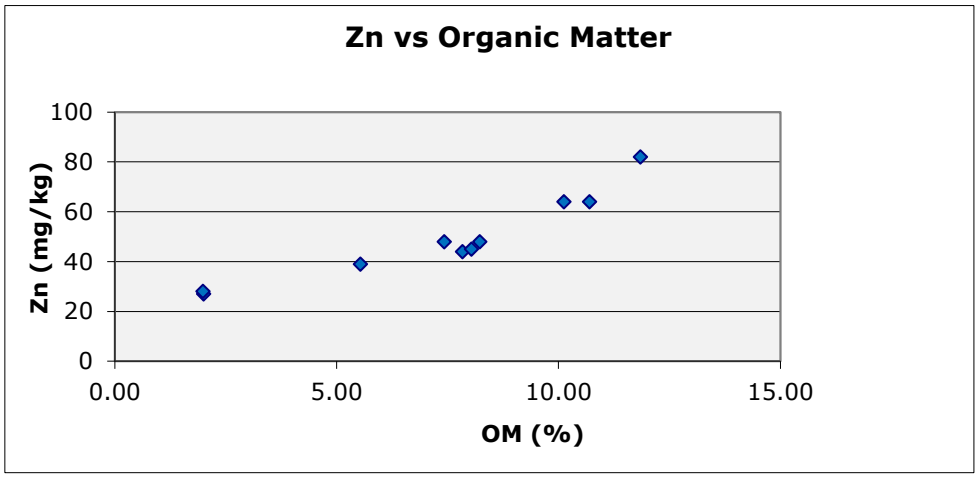

Figure 8. Zinc levels in relation to % Organic Matter in Port Mouton Bay, 2009

Smith et al. (2005) measured decreasing Cu and Zn signals in sediments with increasing distance away from abandoned cages at distances greater than 200 m in Lime Kiln Bay, Bay of Fundy, New Brunswick where concentrations remained elevated over a period of five years suggesting minimal remobilization of these metals from sediments after abandonment of farming activities. The persistence of the metal concentrations in sediments shown by Smith et al (2005) in the Bay of Fundy and in this study in Port Mouton Bay demonstrates a low energy and less dynamic hydrodynamic (physical) environment where waste material can remain even when farms are fallowed.

In this report we have focused on metals and organic matter which sink and accumulate in the sediments. Metal molecules, complexed with organic molecules, also accumulate in the sea surface microlayer, often at concentrations higher than in the water column, likely due to fish-oil droplet and gas-bubble scavenging. Buoyant fish eggs and crustacean larvae such as lobster and crab can also be found in this microlayer. This pathway has been studied in the vicinity of the farm site in Port Mouton Bay and described in a research paper published in the Marine Pollution Journal Bulletin (Loucks et al., 2012).

http://www.sciencedirect.com/science/article/pii/S0025326X12002457

http://www.friendsofportmoutonbay.ca/news.html, June 12, 2012

The study concluded that:

> Elevated and enriched concentrations in the sea surface microlayer over distance from the farm site led, as a result of wind-drift, to an enlarged farm footprint. The levels of copper in both sediments and sea surface microlayer exceeded guidelines for protection of marine life.

Conclusions

Concentrations of Cu and Zn are highest in 2009 within the lease site and are elevated at distances of 400 m to 2000 m from the site. A far-field footprint of trace metal enrichment from the salmon farm is indicated in these Li-normalized Cu and Zn data.

In 2010 and 2011 this pattern continues. Levels of Cu in sediments were very similar to levels detected in 2009 except for higher levels at some stations within the farm lease site and one of the far-field stations. Higher Li values in 2010 and 2011 suggest migration of finer sediments to the far-field. The persistence of Cu in the sediments demonstrates the low energy hydrodynamic environment in Port Mouton Bay.

Based on these results, exceeding CCME guidelines as they do, further accumulation of copper in Port Mouton Bay is unacceptable.

References

Dominator Marine Services Ltd. 2007. Baseline Survey, Site #1251, Port Mouton , Nova Scotia, submitted to Aqua Fish Farms

Loring, D.H., Rantala, R.T.T., Milligan, T.G. (1996). Metallic Contaminants in the Sediments of Coastal Embayments in Nova Scotia , Canadian Technical Report Fisheries and Aquaculture Science 2111.

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

Smith, J.N., P.A. Yeats and T.G. Milligan.2005. Sediment Geochronologies for Fish Farm Contaminants in Lime Kiln Bay, Bay of Fundy *in* Barry Hargrave (ed) Environmental Effects of Marine Finfish Aquaculture, The Handbook of Environmental Chemistry, Vol.5 M, Springer, pp.221-236.

Yeats, P.A., T.G. Milligan, T.F. Sutherland, S.M.C. Robinson., J.A. Smith, P. Lawton and C.D. Levings. 2005 . Lithium–Normalized Zinc and Copper Concentrations in Sediments as Measures of Trace Metal Enrichment due to Salmon Aquaculture Fundy *in* Barry Hargrave (ed) Environmental Effects of Marine Finfish Aquaculture, The Handbook of Environmental Chemistry, Vol.5, Water Pollution, Part M. Springer.