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Sediment Geochronologies for Fish Farm Contaminants in Lime Kiln Bay, Bay of Fundy

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Abstract Sedimentation rates were measured on gravity cores collected near finfish cages in Lime Kiln Bay, N.B. in the Western Bay of Fundy using the radionuclide tracers ^{210}Pb and ^{137}Cs. Sediment cores collected close to aquaculture sites that have undergone extensive salmon fish farm activity over the past 20 years exhibit elevated levels of Zn and Cu in the upper 50 cm of the cores. Sediment geochronologies indicate that the threshold horizons for elevated Zn and Cu levels conform to the initial introduction of fish farms into Lime Kiln Bay in 1981. The source of the Zn is the fish feed while Cu is associated with chemical agents used to reduce fouling of the cages by marine biota. The highest contaminant levels for Zn ($> 250\ \mu g\ g^{-1}$) and Cu ($> 70\ \mu g\ g^{-1}$) were measured in sediment cores collected within the "footprint" of previously abandoned sites. The contaminant signals decrease with increasing distance away from the cages to values approaching background levels at distances greater than 200 m from the original cage locations. Zn and Cu concentrations have remained elevated in sediments for the five-year period between the removal of the cages and the date of core collection, suggesting that remobilization of these metals from sediments following the termination of aquaculture operations may be minimal. P is present at elevated levels in sediments close to aquaculture sites because it is an important constituent of marine organic material associated with fish feed pellets and fish farm wastes. Elevated Cd, Mo and U levels were also observed in sediments deposited under salmon cages during past periods of aquaculture operations. These elements are soluble in seawater, but can be authigenically precipitated in sediments under reducing conditions. In the present study they have been used as indirect tracers of fish farm activities owing to their transfer from seawater to sediments under the anoxic sed-

iment conditions generated by the high sediment flux of reactive organic material from aquaculture operations.

Keywords Aquaculture wastes · Copper · Sedimentation rates · Radionuclide and trace metals · Zinc

1 Introduction

Commercial finfish aquaculture operations can impose significant stresses on environments in which large quantities of fish are confined to relatively small volumes of seawater. Much of the environmental impact of fish farms is local, and may include oxygen depletion of the water column and enhanced organic and nutrient loadings in underlying sediments that may, in turn, result in anoxia and depauperation of the benthos. However, fish farms are also capable of generating long-lived, persistent contaminants that may have far-field environmental effects. Although the discharge of these types of contaminants from aquaculture sites is an environmental concern, it may also represent an opportunity to trace the far-field influence of aquaculture using these contaminants as tracers, and may thereby provide a new tool for quantifying industry impacts.

One method for studying discharges of particle-reactive contaminants from industrial sources and their dissemination in the environment involves the analysis of contaminant uptake in sediments. For example, Yeats et al. [1] have observed high levels of Zn and Cu in surface sediments in the Letang region of the Western Bay of Fundy, which they ascribe to releases from proximal salmon aquaculture sites. Their conclusions are based partly on the fact that equally high levels of Cu and Zn are absent from similar sediment regimes that are more remote from aquaculture sites. Further, sediments under salmon aquaculture cages in New Brunswick have been shown by Chou et al. [2] to be enriched in Zn and Cu. Similar results have been reported both in sediments under salmon aquaculture cages in British Columbia [3] and in sediment traps adjacent to salmon net pens [4]. Recent measurements of elevated levels of Zn in salmon food pellets [2, 4] support the widely held belief that the source of the Zn in the sediments is the salmon feed. Although Cu is added to salmon feed as a micronutrient at quite low levels [5], the most likely source of the Cu in sediments underlying aquaculture sites is the antifouling agents used to reduce fouling of the nets by marine biota [6].

In an effort to further characterise the discharge of Zn and Cu from finfish aquaculture sites, a series of sediment cores was collected from the Letang region and analysed for metals and radionuclides. ^{210}Pb and ^{137}Cs distributions were used to determine sedimentation rates for each core and these were then used to determine contaminant geochronologies. However, in addition to known fish farm contaminants, other inorganic contaminants were