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Lithium-Normalized Zinc and Copper Concentrations in Sediments as Measures of Trace Metal Enrichment due to Salmon Aquaculture

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Abstract The results of metal analyses carried out on surficial sediment samples collected in the coastal waters of southwest New Brunswick and the Broughton Archipelago in British Columbia have been used to investigate the use of heavy metals as tracers of salmon farm wastes. New Brunswick in particular has seen rapid expansion of open cage salmon aquaculture in recent years. While techniques have been developed to identify benthic impacts directly beneath the cages, no method has been developed to determine the fate of dispersed wastes. We show that Zn and Cu, two elements associated with aquaculture operations, can be used to identify farm wastes in sediments at some distance from the cage sites. Geochemical normalization for grain size is needed in order to see the small tracer signals. Excess Zn and Cu levels are found in the sediment at varying distances from the salmon cages in depositional areas in southwest New Brunswick and in the Broughton Archipelago. Evidence that links these observations to salmon aquaculture development is described.

Keywords Sediment · Trace metals · Farm waste tracer · Salmon aquaculture · Far-field effects

1 Introduction

Determining where wastes from finfish aquaculture are deposited is an important consideration for the sustainable development of the aquaculture industry. In some cases these wastes can lead to excessive accumulation of organic matter in sediments, increased sediment anoxia and decreased macrofaunal abundance and diversity [1]. While it is simple to see the accumulation of the waste from the farms immediately below the cages in relatively shallow harbours, identification of these wastes in sediments farther away from the farms is more difficult. It is generally difficult to distinguish between the organic wastes from the fish farms and organic matter from other pollution sources or natural organic matter that exists in all sediments. It is thus very difficult to prove that any observed organic matter enrichment originates with farm wastes. A chemical tracer of finfish farm wastes would be a very useful tool for characterizing the deposition of farm wastes in both near- and far-field sediments, and would support environmentally sustainable development of the aquaculture industry.

The purpose of this paper is to investigate the application of Zn and Cu as tracers of wastes from salmon aquaculture operations. Zn's potential as a tracer originates from the fact that Zn is an essential component of the salmon diet [2] that is added to the feed as a supplement. That Zn is highly enriched in the wastes is evident from observations of as much as 400 mg kg^{-1} of Zn in organically-enriched sediments immediately under cages in the Quoddy area of southwestern New Brunswick [3]. Copper is another potential tracer and elevated Cu concentrations have also been observed beneath the Quoddy farm sites, possibly as a result of the use of Cu-based antifoulants by the industry. Zn and Cu can be readily, precisely and inexpensively measured in sediments by inductively coupled plasma mass spectroscopy (ICPMS), which provides simultaneous analysis of Zn, Cu and a number of other metallic elements, making them good candidates for tracer applications. But Zn and Cu are naturally occurring components of all sediments. This makes their use as tracers more difficult because the tracer signal must be distinguished from the natural background. In this paper we will first describe the method we have used to separate natural and tracer Zn and Cu concentrations, and then several of their applications as tracers of farm wastes. Heavy metals are not the only potential tracers of farm wastes; other chemicals added to the environment, such as pigments, pesticides or antibiotics could be potential markers, as could characteristics of the organic matter, such as lipid content or isotope ratios. Metals, however, are appealing as tracers because they are