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Baseline

Metal(loid)s in sediment, lobster and mussel tissues near historical gold mine sites

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ABSTRACT

Previous studies near historical gold mining districts in Nova Scotia have identified significant enrichment of metal(loid)s in coastal marine sediments. Most of this inventory is buried below biologically active zones, although in some areas arsenic has bioaccumulated in marine biota resulting in localised bivalve shellfish closures. Isaacs Harbour is poised for future industrial development, but before potential impacts are predicted, current marine baseline conditions must be determined. To address this gap, this study established a baseline using surface sediments and biota (mussel and lobster tissues), to provide a broader picture of metal(loid)s in the marine environment. Results confirmed previous studies showing that most sediment metal(loid) concentrations still exceeded Canadian Marine Sediment Quality Guidelines, and also provided evidence of Canadian Food Inspection Agency fish tissue exceedances of arsenic in lobster and lead in mussel tissues indicating that some bioaccumulation of legacy contaminants in marine biota continues to the present day.

Historical gold mining in Nova Scotia (between 1860 and 1940) generated more than 3 million tonnes of tailings containing high concentrations of metal(loid)s (mainly As and Hg). Many of the gold districts in Nova Scotia are located along the east coast (Fig. 1). Tailing disposal from these operations caused significant enrichment of metal(loid)s in coastal marine sediments (Little et al., in press; Parsons et al., 2012; Daniels et al., 2012; Milligan and Law, 2013). Sediments in Isaacs Harbour (IH) suffered legacy putative metal(loid) pollution (principally As and Hg) from these tailing wastes (Wong et al., 1999; Parsons et al., 2008; Corriveau et al., 2011). Metal(loid)s in marine sediments, even at low concentrations, can bioaccumulate in marine biota (mussels, crabs and lobster) (Fraser et al., 2011; Walker et al., 2013a,2013b,2013c, 2013d); potentially forming pathways between metal(loid)s in the marine environment and humans (Burger and Gochfeld, 2009). Arsenic derived from historical gold mine tailings in nearby Seal Harbour bioaccumulated in clams, mussels and periwinkles resulting in a bivalve shellfish closure for Seal and Isaacs harbours (Koch et al., 2007; Whaley-Martin et al., 2012, 2013; Doe et al., in press). Most tailing-contaminated sediments were found below the biologically active zone (>15 cm), with As and Hg concentrations ranging from 4 to 568 and <0.05 to 7.4 μg g^{-1}, respectively. Near-surface concentrations still exceeded Canadian Sediment Quality Guidelines (SQGs) in many areas, reflecting continued run-off from on-land tailing deposits and reworking of deeper sediments (Little et al., in press).

Current and proposed future industrial activities in IH include the Sable Offshore Energy Project (SOEI) gas plant (established in 1999) and a liquefied natural gas (LNG) export terminal (expected to be operational by 2018) (Maugeri, 2014). Before potential impacts can be predicted from industrial development, current marine environmental baseline conditions must be determined. Surficial sediments were chosen because they reflect recent inputs of metal(loid)s from both natural and anthropogenic sources (Walker et al., 2013a, 2015a). Lobster and mussels were chosen because they have limited ability to metabolize contaminants in surface sediments, are ubiquitous and widely used as bioindicators (Chou et al., 2003; Garron et al., 2005; Walker, 2014; Walker and MacAskill, 2014).

We compared stations in IH near historical land-based gold mining activities ('exposed'), with stations in adjacent Country Harbour (CH) (perceived as a 'reference' area), although CH was subject to some contamination from gold mining, most of which occurred further up the harbour (Loring et al., 1996). Objectives were to: (1) assess legacy metal(loid) contaminants in wild inter-tidal mussels and surface sediments from IH compared to CH; (2) measure current metal(loid) concentrations in lobster from IH; and (3) compare results to SQGs and fish tissue guidelines established by the Canadian Food Inspection Agency (CFIA, 2011). These data will serve as baseline information, as envisioned by past and present Baseline Editors of this journal (e.g., Hamilton, 1982; Richardson, 2012), against which future monitoring can be compared during construction and operation of nearby industrial facilities.

Stations in IH and CH were sampled in May 2008, with some stations near proposed on-shore industrial development, close to gold mine

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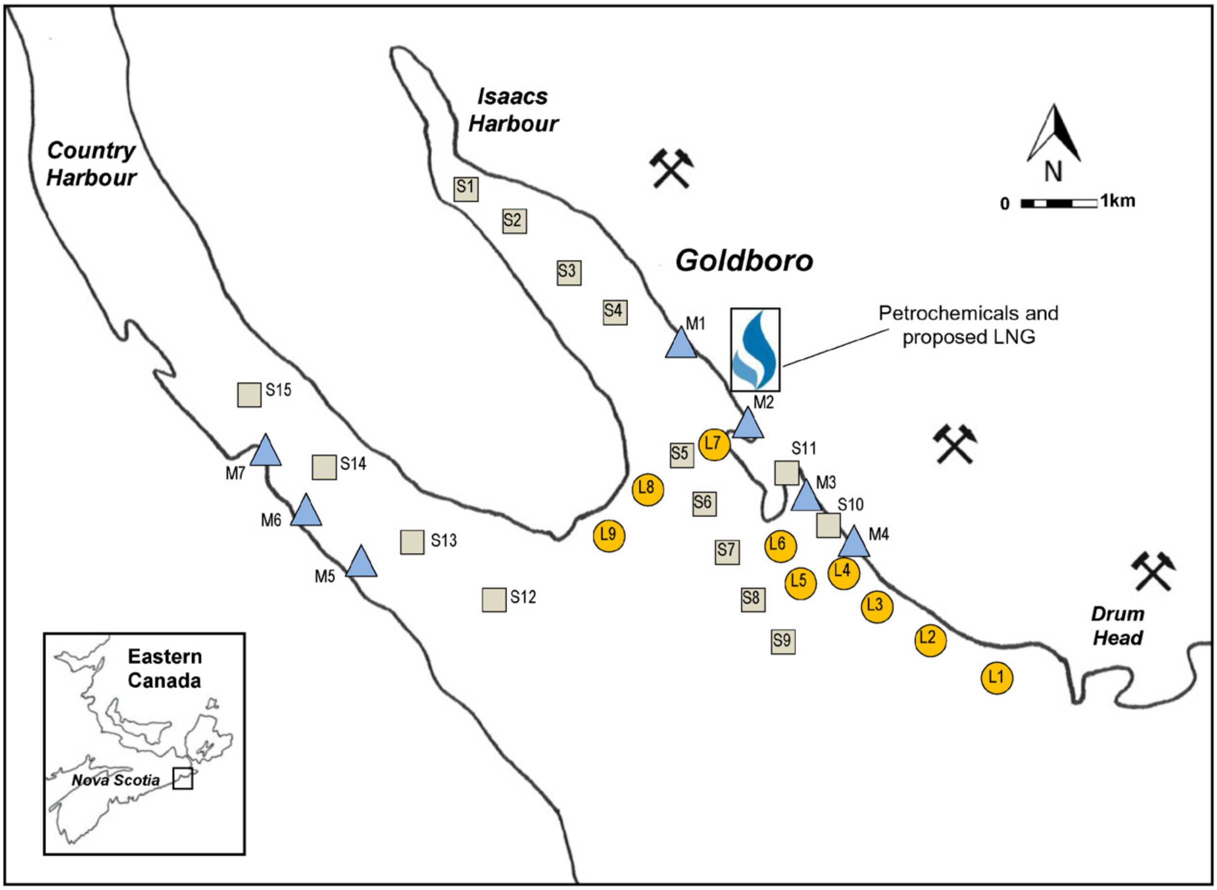

Fig. 1. Sampling stations for sediment (grey squares), wild inter-tidal mussels (blue triangles) and lobster (orange circles) for Country and Isaacs Harbours' relative to historic gold mining areas, current petrochemical and proposed LNG facilities near Goldboro, Nova Scotia.

tailing deposits (Fig. 1). Surface sediments (0–1 cm) were collected using an Ekman grab, taking care to minimise disturbance of sediment before sub-sampling (Walker et al., 2008; Walker and Grant, 2009; Grant et al., 2013). Adult lobsters (*Homarus americanus*) (mean carapace length, 117 mm ± 6.9 SD; mean wet weight [ww], 0.7 kg) were collected from stations in outer IH with abundant hard rocky substrate and transported live on ice in breathable containers to the laboratory (<6 h) for dissection and hepatopancreas tissue analysis. No comparable hard substrates (suitable for lobster) were found in CH. Approximately 40 wild mussels (*Mytilus* spp.) were collected by hand from inter-tidal stations at low tide in IH and CH and kept frozen until analysis.

Sediments and lobster were analysed by AGAT laboratories and mussels were analysed by RPC Environmental Laboratories (both, Standards Council of Canada accredited). Sediments were analysed for grain size by a sieve and a pipette based on the MSAMS-1978 method, total organic carbon (TOC) using a LECO CR-412 Carbon Analyser and metal(loid)s (As, Cd, Cu, Pb, Hg, Zn) using multi-element inductively coupled plasma-mass spectrometry (ICP-MS) based on US-EPA 6020A (US-EPA, 2005). Lobster hepatopancreas tissue and a sub-sample of 20 pooled mussels (enough for 35 g of standardized tissue) were analysed for metal(loid)s (As, Cd, Cu, Pb, Zn) based on US-EPA 6020A and Hg based on US-EPA 245.6 (US-EPA, 2005). Tissue concentrations were expressed as ww. At least one blind field duplicate was included for every ten samples. Detection limits for sediment and tissue samples are shown in Table 1 and differences in all duplicate samples were within acceptable limits (<5%). Significant spatial differences of metal(loid) concentrations ($p < 0.05$) were determined with Student's t-test using Minitab.

Sediments were compared against guidelines developed by Canadian Council of Ministers of the Environment (CCME, 2014). CCME interim sediment quality guidelines (ISQGs) are equivalent to lowest effect level, below which contaminants have little chronic or acute effect on biota, and CCME probable effect levels (PELs) are equivalent to severe effect level, above which biota are very likely to be negatively affected by contaminants (Walker et al., 2015b). Sediment concentrations < ISQGs were considered uncontaminated; concentrations between ISQG and PEL were considered moderately contaminated and values > PEL indicate heavily contaminated. However, naturally occurring (i.e., geogenic) levels of As exceed ISQGs in parts of the study area, so background levels of As based on data in Loring et al. (1996), were substituted for ISQGs.

Sediment TOC based on dry weight was relatively high across all stations (7.5% ± 3.9 SD). Outer IH (S5–S9) sediments were characterized by sand and lower TOC (3.9% ± 1.9 SD), whereas inner IH stations (S1–S4) were comprised of very fine anoxic sand with high TOC (11.0% ± 0.6 SD). Near-shore stations (S10–S11) were characterized by mud and sand (6.1% TOC). Sediments in CH (S12–S15) were characterized by mud and sand with high TOC (9.4% ± 1.1 SD). Sediment metal(loid) concentrations exceeded ISQGs for As, Cd, Cu, Hg and Pb, but were all <PELs (Table 1; Fig. 2). Station S11 had the highest concentrations of As and Hg (40 and 0.16 $\mu g\ g^{-1}$, respectively), which were much lower than the maximum concentrations measured in sediments from Wine Harbour of 568 and 7.4 $\mu g\ g^{-1}$ for As and Hg, respectively by Little et al. (in press). However, concentrations of Cd, Cu, Pb and Zn in surface sediments were comparable to previous surficial sediment concentrations measured by Parsons et al. (2008, 2012), with most below background concentrations for coastal sediments in Nova Scotia