Distribution and condition of eelgrass (*Zostera marina*) in the historical goldmining region of Goldboro, Nova Scotia

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TABLE OF CONTENTS

ABSTRACT

Vercaemer, B., O’Brien, J. M., Guijarro-Sabaniel, J. and Wong, M. C. 2022. Distribution and condition of eelgrass (*Zostera marina*) in the historical goldmining region of Goldboro, Nova Scotia. Can. Tech. Rep. Aquat. Sci. 3513: v + 67 p.

Nearshore marine construction activities often involve projects conducted directly in or adjacent to eelgrass beds and can have detrimental effects on eelgrass health, through physical destruction of beds, smothering of plants by sediment, and light reduction from turbidity. A liquefied natural gas (LNG) marine terminal is proposed to be constructed near Goldboro in Isaacs Harbour on the Eastern shore of Nova Scotia in an area where sediments are contaminated with heavy metals from historical goldmining operations. We conducted a pre-impact assessment of the eelgrass beds in Isaacs Harbour and in adjacent contaminated and non-contaminated harbours. We used underwater video to precisely map the eelgrass bed in the direct construction footprint in Isaacs Harbour and to identify eelgrass presence or absence in the nearby region. The overall condition of eelgrass plants in the surveyed area fell within the range of healthy plant characteristics (morphometrics and carbohydrates reserves) seen elsewhere along the Atlantic coast. However, a few stations displayed high arsenic and mercury contamination in sediments, which translated in some cases to high contamination in eelgrass rhizomes and leaves. There would be significant risk of impact on benthic habitat and contamination of marine biota from resuspension of sediments during a construction and operation of a ship terminal in Isaacs Harbour. This pre-impact assessment will allow DFO to assess the LNG terminal construction proposal and develop appropriate mitigation and monitoring procedures. Collected data will also be used for habitat-forming species distribution modeling to inform marine spatial and conservation planning.

RÉSUMÉ

Vercaemer, B., O’Brien, J. M., Guijarro-Sabaniel, J. and Wong, M. C. 2022. Distribution et condition de la Zostère (*Zostera marina*) dans la région minière historique de Goldboro, Nouvelle-Ecosse. Can. Tech. Rep. Aquat. Sci. 3513: v + 67 p.

Les activités de construction côtière marine impliquent souvent des projets menés directement dans, ou à proximité, des herbiers de zostères et peuvent avoir des effets néfastes sur la santé de ces herbiers, par la destruction physique des herbiers, l'étouffement des plantes par les sédiments et la réduction de la lumière par l’augmentation de la turbidité. Il est proposé de construire un terminal maritime de gaz naturel liquéfié (GNL) près de Goldboro à Isaacs Harbour, sur la côte est de la Nouvelle-Écosse, dans une zone où les sédiments sont contaminés par des métaux lourds provenant des opérations historiques d'extraction d'or. Nous avons effectué une évaluation pré-impact des herbiers de zostères dans la baie d’Isaacs Harbour et dans les baies contaminées et non contaminées adjacentes. Nous avons utilisé des vidéos sous-marines pour cartographier avec précision l’herbier de zostères dans l'empreinte de construction directe à Isaacs Harbour et pour identifier la présence ou l'absence de zostères dans les régions voisines. L'état général des plantes de zostères dans la zone étudiée se situait dans la gamme des caractéristiques des plantes saines (morphométrie et réserves de glucides) observées ailleurs le long de la côte atlantique. Cependant, quelques stations ont affiché une forte contamination des sédiments par l'arsenic et le mercure, ce qui s'est traduit dans certains cas par une forte contamination des rhizomes et des feuilles des zostères. Il existerait alors un risque important d'impact sur l'habitat benthique et de contamination du biote marin par la remise en suspension des sédiments lors de la construction et de l'exploitation d'un terminal maritime à Isaacs Harbour. Cette évaluation préalable aux impacts permettra au MPO d'évaluer la proposition de construction du terminal méthanier et d'élaborer des procédures d'atténuation et de surveillance appropriées. Les données recueillies seront également utilisées pour la modélisation de la distribution des espèces formant l'habitat du poisson, utilisée pour la planification de l'espace marin et de sa conservation.

1. INTRODUCTION

Seagrass beds are key coastal habitats that provide many critical ecosystem services, such as fisheries maintenance, shoreline protection, nutrient cycling and storage, and water filtration (Barbier et al. 2011, Fourqurean et al. 2012, Duffy et al. 2015). Nevertheless, these habitats face numerous threats from anthropogenic activities, including impacts from climate change, and consequently global declines in seagrass coverage have been apparent over the last century (Orth et al. 2006; Waycott et al. 2009, Short and Wyllie-Echeverria 2016, Dunic et al. 2021). In the northwest Atlantic region, specifically, the most robust review to date found that rates of change in seagrass area fluctuated from the 1940s to late 1990s, followed by a 40% decline relative to the earliest surveys since the 2000s (Dunic et al. 2021).

Nearshore marine construction is one major human activity that can impact eelgrass beds (Murphy et al. 2022). The dominant species of seagrass in Canada, eelgrass (*Zostera marina*), has been designated an Ecologically Significant Species (ESS) by the Department of Fisheries and Oceans (DFO, 2009) and an environmental sustainability indicator by Environment and Climate Change Canada (ECCC, 2020). Consequently, it is recognized by DFO as important fish habitat and has been prioritized for conservation. Construction projects that are conducted directly in or adjacent to eelgrass beds can have detrimental effects on eelgrass health, through physical destruction of beds, smothering or burial of plants by resuspended sediments, and light reduction from increased water turbidity. Proponents of marine construction are required to obtain authorization under the *Fisheries Act* if eelgrass will be damaged or destroyed within the construction footprint. Impacts to adjacent beds from turbidity plumes and suspended sediments are also likely relevant but are typically not considered. Knowledge of eelgrass distribution and its condition, not only in the direct construction footprint but also in adjacent areas, is thus important to accurately assess impacts and to develop appropriate mitigation procedures.

The presence of contaminants in marine sediments presents an additional layer of risk to eelgrass beds associated with their resuspension by construction activities in the nearshore. A liquified natural gas (LNG) marine terminal has been proposed near Goldboro in Isaacs Harbour on the Eastern shore of Nova Scotia. Marginal wharf construction and associated industrial operations may potentially occur in the short-term. Preliminary information indicates that the proposed project footprint directly overlaps an eelgrass bed with other eelgrass beds occurring in adjacent areas (~2 km radius). Furthermore, sediments in the area are contaminated with heavy metals from historical goldmining tailings deposited near the proposed site (Parsons et al. 2012). Tailings are contaminated with mercury (Hg), which was used in the amalgamation process to recover gold from mined ore, as well as cyanide and arsenic (As), which are naturally present in the auriferous quartz veins. Other potentially toxic elements such as antimony and lead are also present in the tailings (Parsons et al. 2012). These contaminants can accumulate in the marine food chain and have adverse effects on all organisms including submerged plants (Kamal et al. 2004, Lin et al. 2016, Fonseca et al. 2019, Geng at al. 2019, Okereafor et al. 2020). In particular, seagrass leaves and roots provide support for epiphytes and biofilms, which facilitate transport of contaminants from water and sediments to plant tissue through their very thin and porous cuticles (Marín-Guirao et al. 2005, Prasad 2007). Following uptake, metal contaminants generally disrupt the photosynthetic apparatus at the transcriptome level and hinder germination and plant growth rates (Lyngby and Brix 1984, Ralph and Burchett 1998, Nagajyoti et al. 2010). Recently, Qiao et al. (2022) showed that excess heavy metals such as cadmium and copper accumulated in the organelles of eelgrass leaves and roots, causing toxic effects at multiple levels, inhibiting the maximum light quantum yield (Fv/Fm), decreasing most enzyme activity and damaging membrane lipids.

Eelgrass beds proximate to the LNG terminal footprint will potentially face negative impacts related to both the construction process and LNG industrial operations. Sediment resuspension during excavation, dredging, and tanker transport will potentially smother plants and reduce light availability. Heavy metals in the contaminated sediments will be re-suspended and potentially redistributed to previously uncontaminated eelgrass beds. To effectively quantify impacts on eelgrass, extensive pre- and post-impact data are required to detect changes in bed cover and plant condition (e.g., morphology, biomass). Here, we present the results of pre-impact eelgrass surveys intended to provide critical baseline data on eelgrass distribution, abundance, and condition prior to construction along with the distribution of heavy metal concentrations in marine sediments and plant tissues. In addition, we present preliminary results on the distribution and abundance of other sensitive fish habitat such as kelp and other macrophytes.

We used underwater video to map the eelgrass bed in the proposed construction footprint and to identify eelgrass presence or absence in the nearby region. We collected eelgrass plants to assess plant condition using morphological and biomass metrics, and heavy metal contamination in plant tissues. Sediment samples were also collected and analyzed for contaminants. This pre-impact assessment will allow DFO to assess the potential impacts of the LNG terminal construction and develop appropriate mitigation and monitoring procedures.

2. MATERIAL AND METHODS

2.1. Study area and sampling stations

To evaluate the distribution, abundance, and condition of eelgrass and concentrations of contaminants in sediments and eelgrass shoots at the proposed LNG site and surrounding area, we conducted camera surveys and collections of sediments and eelgrass shoots during the summer of 2020. The study area consisted of a ~40 km section (linear distance) of the Eastern Shore of NS, located between Wine Harbour and New Harbour (Figure 1). This area was of particular focus because it includes not only Isaacs Harbour where the LNG site is proposed, but other nearby harbours which have also been affected by historical goldmining operations.

To capture gradients of potential metal contamination, we allocated sampling stations among historical gold mining areas (Isaacs Harbour, Seal Harbour, Wine Harbour and Country Harbour), adjacent areas with no historical mining activity (Coddles Harbour, New Harbour) and areas in between (Port Bickerton area and Harbour and Goose Islands Islands) (Figure 1, Appendix A). Coddles Harbour and New Harbour were considered reference areas in previous studies (Whaley-Martin et al. 2012, Doe et al. 2017). We further subdivided sampling in the Wine Harbour area among the harbour-facing (Wine harbour inside) and open ocean-facing (Wine harbour outside) sides of the highly protected harbour.

Within each area, sampling stations were selected using a stratified random design with survey strata based on substrate type. Depth of sampling was limited to shallower than 10 m as eelgrass is not typically found in deeper water in Atlantic NS (DFO 2009). To generate survey strata boundaries, polygons delineating contiguous areas of predicted substrate classes from a coastline physiographic classification (Greenlaw et al. 2013) were clipped to the 10 m depth contour determined from a digital elevation model (DEM, 35 m resolution) (Greenlaw, unpublished). These clipped polygons included 7 substrate classes across all sampling areas: discontinuous bedrock, gravel, mixed sediment, mud, sand, sand & gravel, and sand & mud. We then randomly selected 20 stations per area, allocating points to each substrate class in proportion to its areal extent. Additional targeted sampling stations were also selected based on the likely presence of eelgrass from satellite imagery. These targeted stations included five locations between Wine Harbour and Country Harbour in the Port Bickerton area (Appendix A) for a total of 169 stations.

A relative wave exposure index (REI) was also calculated for each station, using a modification of the index by Keddy (1982). REI is an index of exposure to wind-driven waves based on fetch. Wind data were obtained from a nearby Environment and Climate Change Canada weather station (Port Hawkesbury Airport, 45.66 N, 61.37 W) from January 2020 to December 2020.

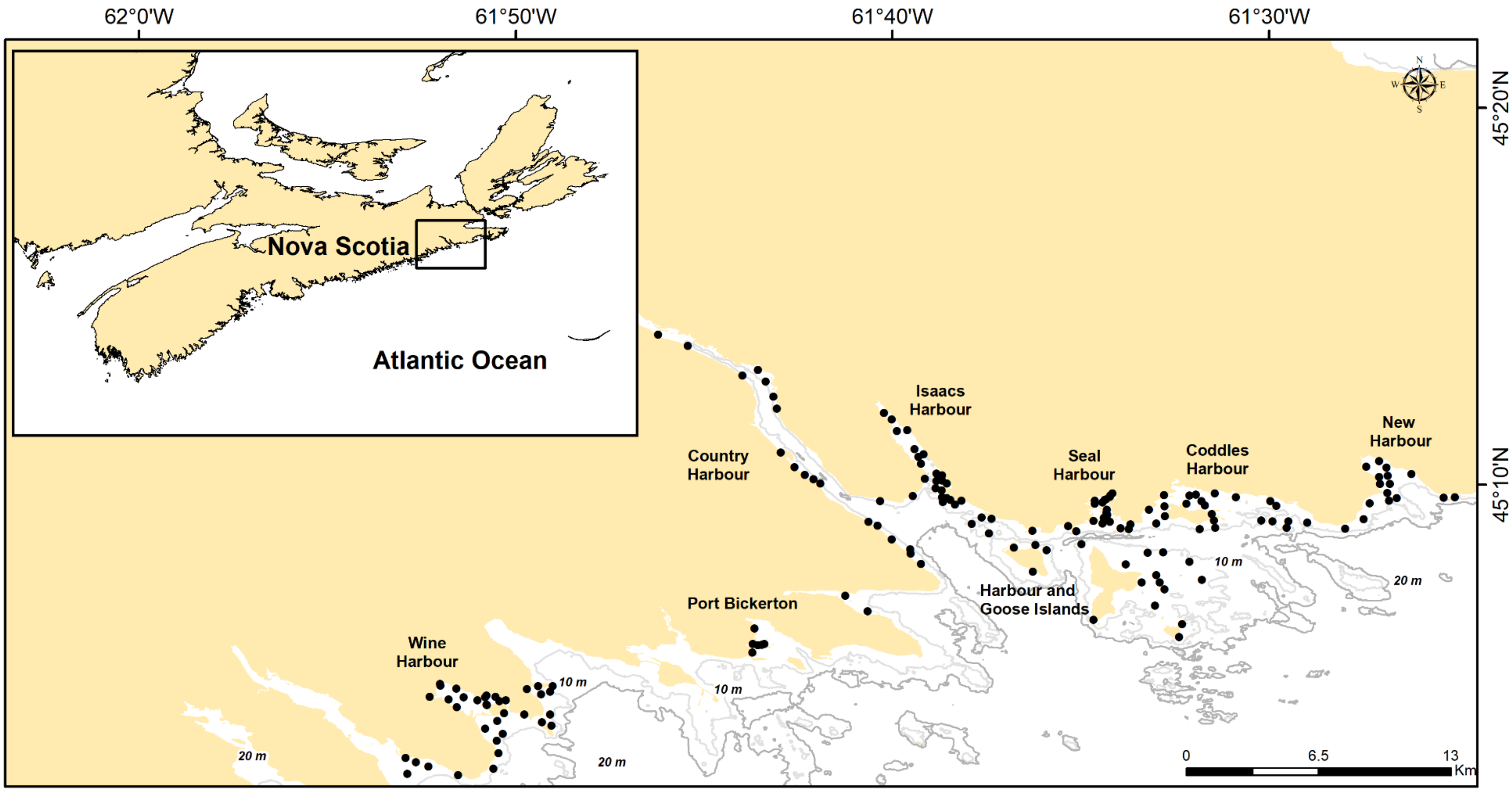

Figure 1. Study area and sampling locations from Wine Harbour to New Harbour, NS.

To document eelgrass presence/absence and percent cover at a finer resolution around the proposed LNG terminal site, and to subsequently create a map of eelgrass cover, we also conducted more extensive camera surveys within a roughly 1.5 km x 2 km area around the site footprint. In this area, 18 longer transects (roughly 500 m - 1.5 km) were identified at the proposed LNG terminal site (Figure 2). These transects ran both perpendicular and parallel to shore and were selected to cover the depth gradient spanned by submerged aquatic vegetation (SAV; i.e., eelgrass, kelp, rockweed) and to coincide with previous camera surveys (Wilson, pers. comm.).

Surveys were conducted from a 23 ft aluminium shore-lander (Pakcat) at all stations between July 21-30, 2020 except in Wine Harbour inside, where a 14 ft aluminium boat (Prince Craft Yukon) was used for ease of access. Due to logistical constraints, the stations within Wine Harbour were sampled on October 21, 2020.

2.2. Video surveys

To obtain information on substrate characteristics and the distribution and abundance of eelgrass and other macrophytes, we conducted short drifts with a downward-facing drop camera at each station. The underwater video system (SPOT X™ Pro Squid) consisted of a watertight housing connected via an umbilical cable to a topside console. A laser bracket holding two lasers 10 cm apart was mounted to the camera housing for image scaling. The live stream capability of this drop camera system allowed the operators to view video feed at the surface captured by a GoPro® HERO7 camera within the watertight housing from a small LCD screen on the topside console and adjust the height of the camera above bottom to ensure the lasers were visible and that the camera remained above any macrophyte canopy. Higher resolution video (2.7k, 16:9 aspect ratio, 23.98 FPS) was recorded directly to the GoPro SD card, while the lower resolution feed (720p), which was relayed to the surface, was stamped with GPS overlay and recorded to a separate SD card in the topside console unit. The GoPro was controlled through voice command and no additional auxiliary light was necessary at the depths sampled.

On station, the camera system was lowered until the bottom and scaling lasers were visible to the camera operators. The actual distance of the camera off bottom varied with visibility, the height of vegetation, and the motion of the boat. The boat was allowed to drift with wind and currents for approximately 2 min while recording benthic habitat. The GoPro running time, depth (m) and GPS position were recorded both at the start and end of the drift (i.e., at the time the camera reached and left bottom, respectively). Running time was noted from the topside video feed. Depth was measured by the boat sounder. GPS waypoints were marked with a handheld unit (Garmin GPSmap 62stc; ~ 3 m accuracy) and the full GPS track was simultaneously

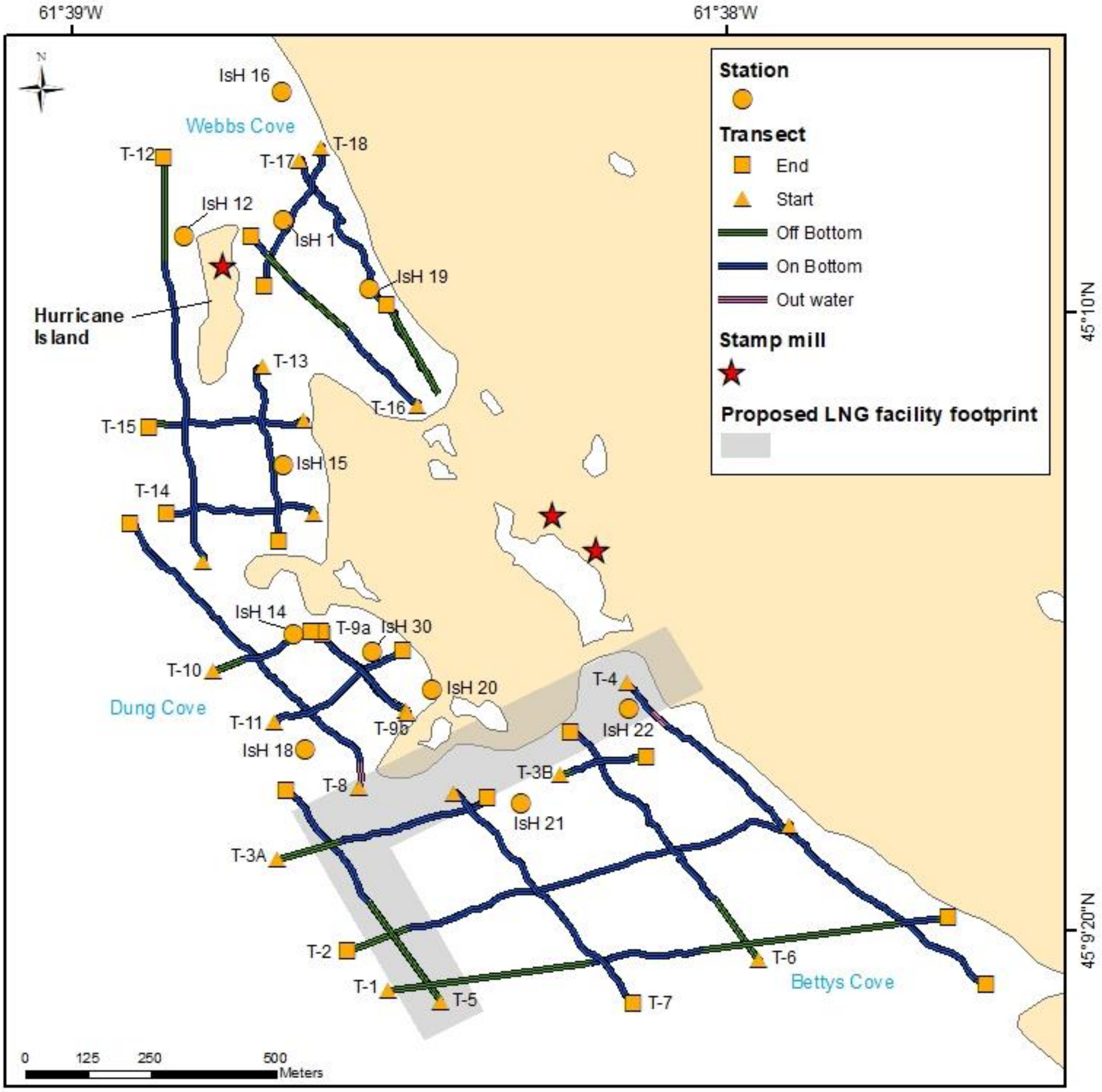

Figure 2. Location of transects (T) and stations (IsH) surveyed near the proposed LNG terminal (grey area), located on the east shore of Isaacs Harbour. Note location of historical stamp mills used in gold mining.

recorded at 1 s intervals. The topside console was used to check video system deployment and record preliminary observations of bottom type and the presence/absence of eelgrass and other macrophytes (e.g., kelps, fucoids). For longer transects around the proposed LNG site, videos were recorded in the same manner but speed was maintained around 1 kn with the survey boat in gear. Transect duration varied from 6.5–17.5 min, and GoPro video resolution was reduced to 1440p (4:3 aspect ratio, 23.98 FPS) due to overheating issues at higher resolutions. Station and transect depths at the time of sampling were corrected to chart datum (lower low water, large tide; LLWLT) according to tidal height predictions from the nearest Canadian Hydrographic Service tidal station (least-cost distance).

2.3. Eelgrass percent cover and mapping

Short transects

To measure percent cover of eelgrass and other macrophytes, for each sampling station, we extracted still frames from the recorded video approximately every 4 m using the open-source software FFmpeg (version 3.3.9). The average length of short drift transects was 44.3 m ± 31.7 m (mean ± SD) and ranged from 12.2 m – 241.3 m. The frame rate to achieve the approximate 4 m spacing between extracted frames was determined from the survey boat speed as calculated from the GPS track length and video duration. Images were scaled using laser points and cropped to a 50 cm x 50 cm area using ImageJ (Schneider et al. 2012). We set a minimum cropped area of 30 cm x 30 cm if the camera field of view did not fit a 50 cm x 50 cm area. Following O'Brien et al. (2022), percent cover of eelgrass and other habitat-forming macrophytes was calculated using a point-count method. In ImageJ a 10 x 10-point grid was overlaid on the cropped image and percent cover for each cover category was determined from the number of grid points intersecting each cover type. Cover categories included eelgrass (*Zostera marina*), kelps (*Saccharina latissima, Laminaria digitata, Agarum clathratum, Alaria esculenta*), and fucoid algae (*Fucus spp., Ascophyllum nodosum*). We extracted a total of 1402 photos from 156 stations where video was recorded, and percent cover values were averaged across frames at each station.

Long transects and mapping around proposed terminal footprint

To quantify eelgrass cover over the length of long video transects conducted around the LNG site footprint, still frames were extracted every 10 s from each video. An evenly spaced grid of 9 x 16 points was overlaid on each frame using ImageJ. An estimation of eelgrass percent cover for each georeferenced frame was obtained by calculating the proportion of the 144 grid points overlying eelgrass shoots. In total, we obtained geo-referenced eelgrass percent cover data from 953 transect frames and an additional 10 "ground truth" stations corresponding to the short drift transects (described above) at sampling stations in the same area (Figure 3).

To create an interpolated eelgrass cover map from geo-referenced eelgrass cover data around the LNG proposal terminal, we used ordinary kriging (OK) as the spatial interpolation method recommended by Li and Heap (2008). This technique is based on a generalized least-square regression that allows for spatial prediction of eelgrass percent cover in unsampled locations by accounting for the spatial dependence between observed data (Goovaerts, 2000). The OK method was initially

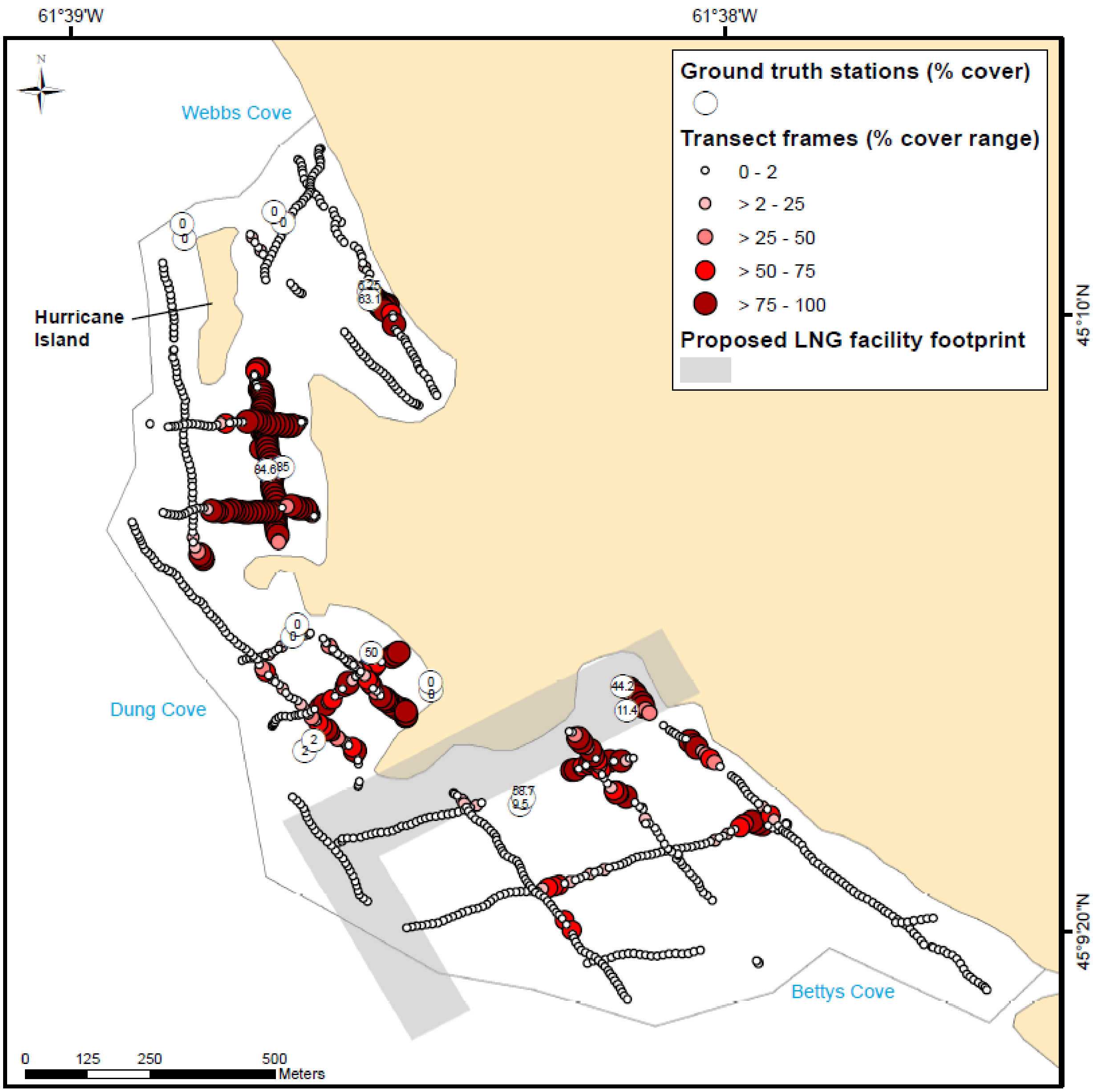

Figure 3. Eelgrass percent cover measured in each extracted long transect frame and drop-camera drift ground truth stations used for interpolation.

performed for the whole study area using ArcMap's Geostatistical Analyst toolbox, ArcMap version 10.7.1 (ESRI, 2011). OK assumes a constant (stationary) mean in space across the study domain (Philip et al. 2012), however the results from the initial interpolation suggested heterogeneous variance across the entire area. In spatially heterogeneous landscapes, non-stationarity is likely to occur and the assessment of the structure of a landscape may change with the extent of the area sampled (Cain et al. 1997, Turner et al. 2001, Wu et al. 2002). To address this issue of non-stationarity, the study area was divided into 3 sub-areas with the most homogenous variance possible using available knowledge of the ecological and physical processes at the site. Preliminary analysis showed that interpolated surfaces of percent cover from these 3 sub-areas had smaller prediction errors than that of the total area.

We also compared interpolation results using OK with results using inverse distance weighting (IDW) by evaluating their overall mean prediction and root-mean-square errors (Gunstra and van Auken, 2007). The model with the minimal error was considered optimal. The smoothness of the resulting prediction surfaces produced by the two interpolation methods was also assessed visually as an indicator of model performance (Appendix B). We found that OK consistently produced errors that were closer to zero compared to those produced by IDW. Visual examination revealed that the surfaces produced using OK were consistently smoother than those produced by IDW (Appendix B). Therefore, we chose OK as the final interpolation method. In the interpretation of interpolated eelgrass maps, we considered 0 % − 2% eelgrass cover as zero cover.

2.4. Sediment collection and analyses

Sediment was collected, when possible, from each station using a Petite Ponar grab (Wildco®). Stations with gravel and cobbles/boulders could not be sampled. A total of 58 sediment samples were collected out of 169 stations. Sediment was scooped from the centre of the grab (5 to 10 cm deep) using a plastic spatula, placed in a labelled plastic bag, kept cool in a Yeti cooler, and then stored for 2 months at -20°C. Sediment samples were thawed and mixed with a plastic spatula and subsampled for the different analyses described below.

Organic matter

Sediment organic matter (OM) was estimated based on weight loss associated with high temperature oxidation of OM. The weight loss (i.e., loss on ignition or LOI) is proportional to the amount of organic carbon. For each station, ~1g of wet sediment was placed in a labelled, ashed, dried, and weighed crucible. 1-2 mL of 10% HCI was added to remove carbonates, with treatment repeated until no longer necessary (i.e., effervescence was absent). The crucibles with the acidified sediments were then dried at 60°C for 24-48 hr. Once fully dried, the crucible and sediment were weighed to obtain the dry weight (DW) and placed into a Vulcan 3-Series Burnout Furnace (Model 3-550) to combust organic material at 500°C for 6 hr. Samples were then cooled overnight, dried for one hour at 60°C, and then weighed to determine the sample ash weight (AW). Percent organic matter was calculated as the ash-free dry weight as:

$$((DW-AW)/DW)*100$$

Grain size

For each station, ~10 g of wet sample was placed into individual labelled aluminum pans and dried for 24-48 hr at 60°C. Once dried, the samples were first passed through a 2 mm sieve and all retained material (> 2mm) was weighed and placed in a pre-weighed and labeled beaker. The remaining sample (< 2 mm) was then passed through a 1 mm sieve, and all retained material (> 1 mm) was weighed and placed in a pre-weighed and labeled beaker. The remaining sediment (< 1 mm) was weighed and also placed in a pre-weighed and labeled beaker. For samples containing sediment < 1 mm, a subsample was taken for further grain size analysis (i.e., 0.1 g for fine sediment (mud and clay) and 0.5 g for coarse sediment (sand)).

For the < 1mm sediment samples, the beakers were placed on a hot plate at 60°C and 1-2 ml of 30% hydrogen peroxide was added to remove organic matter. Treatment was repeated as necessary (i.e., until effervescence was absent). After drying, the beakers were weighed and percent of sediment <1mm, 1-2 mm and > 2 mm was calculated by dividing the dry weight of each portion over the total dry weight summed across each portion.

Milli-Q water was then added to the beakers with < 1mm sediments to remove any sediment from the sides of the beakers. Each beaker was then sonicated for ~15 s before being run through a Beckman Coulter Laser Diffraction Particle Size Analyser (Model LS 13 320). The percent volume of each sediment size category (Table 1) was provided by the Coulter laser. These percent volume categories were multiplied by the < 1mm portion to provide the percent sediment for each category in the total sample. Mean grain size (µm) was also calculated for each sample.

Table 1. Sediment categories based on Udden-Wentworth scale adapted from Wentworth (1922).

Sediment categories	**Grain diameter range (µm)**
Clay	<3.9
Silt	3.9-62
Very Fine Sand	62-125
Fine Sand	125-250
Medium Sand	250-500
Coarse Sand	500-1000
Very Coarse Sand	1000-2000
Fine Gravel	>2000

Metal concentration

For each station ~25 g of sediment was placed in a plastic vial and freeze-dried to ensure that no volatile heavy metals such as mercury were lost. Sediment samples were bulk analyzed at ALS Environmental laboratory (ALS Global, Waterloo, Ont.) using MET-200.2-CCMS-WT/VA and HG-200.2-CVAA-WT/VA protocols which include the reference methods EPA 200.2/6020A (mod) and EPA 200.2/1631E (mod). Metal analysis of 34 metals, from aluminium to zirconium, was performed. Only arsenic and mercury are presented in the main text of this report because of their strong linkage to historical gold mining; however, full metal analysis results are provided in the Appendices. Detection limits were 0.1 ppm for arsenic and 5 ppb for mercury.

Metal concentrations values in sediments were compared against guidelines developed by the Canadian Council of Ministers of the Environment (CCME, 2014): the Interim Sediment Quality Guidelines (ISQG), below which contaminants have limited effect on biota and the Probable Effect Levels (PEL), above which contaminants likely negatively affect biota living in contact with sediments.

2.5. Plant collection and analyses

At each station where eelgrass was present and could be collected, ~40 shoots (~30 for morphometrics and ~10 for metal analysis) with attached rhizomes were randomly uprooted using a grab or a Danforth anchor. Plant samples were rinsed with seawater, placed in labelled Ziploc bags, and kept cool in a Yeti® cooler, then stored at -20°C until further processing.

Plant morphology

For each shoot, the total number of leaves, sheath length, and lengths and widths of the second and third oldest leaves were recorded. Leaf length was measured from the insertion point to the tip of the leaf. Width was measured at a midway point on the leaf blade to the nearest mm. The length (from the insertion point) and width (diameter) of the rhizome were also measured and the number of internodes recorded.

Water soluble carbohydrates

Water soluble carbohydrate (WSC) concentrations were analyzed in 10–16 rhizomes from plants collected at each of four stations in Isaacs Harbour and at one station in each of the two adjacent harbours (Country Harbour and Coddles Harbour). From each plant, a 5–8 cm rhizome section was freeze-dried overnight and then ground using a bead mill homogenizer. Rhizome water-soluble carbohydrates (mono- and oligo-saccharides) were hydrolyzed from duplicate 50 mg DW tissue samples using 80% ethanol and heated to 90°C for 10 min in a closed 2 mL tube and then centrifuged at 13,000×g for 1 min. Supernatants were frozen at -20 °C until further processing. Soluble sugar content in the supernatant was determined using the phenol sulfuric acid method in a microplate assay read at 490 nm (Masuko et al. 2005, Wong et al. 2020). WSC concentrations are reported as µg glucose equivalent per mg of dry weight (µg.mg DW^{-1}).

Metal concentration

For each station, leaves and rhizomes of 10 shoots were pooled per tissue type, freeze-dried and ground in plastic tubes. Between 0.5 and 1 g of dry tissue were bulk analyzed at ALS Environmental laboratory (ALS Global, Waterloo, Ont.) using MET-DRY-MICRO-CCMS-VA and HG-DRY-MICR-CVAA-VA protocols which include reference methods EPA 200.3/6020B and EPA 200.3/245.7. Tissue samples were homogenized and sub-sampled prior to hotblock digestion with nitric and hydrochloric acids, in combination with addition of hydrogen peroxide. Instrumental analysis was done by collision cell inductively coupled plasma - mass spectrometry. Analysis was done for 35 metals (aluminium to zirconium), but in this study we focussed and reported on arsenic and mercury only; however, full metal analysis results are provided in the Appendices. Detection limits were 0.1 ppm for arsenic and 5 ppb for mercury. Concentrations were compared to fish tissue guidelines established by the Canadian Food inspection Agency (CFIA, 2011). These Canadian Guidelines for Chemical Contaminants and Toxins in Fish and Fish Products were used as a substitute in the absence of guidelines for plant tissues.

2.6. Statistical analyses

To visualize relationships among environmental variables, such as depth, REI and sediment characteristics, and eelgrass morphological metrics, we used correlation matrices and scatter plots of matrices (SPLOM; R packages corrgram and psych). The first correlation matrix included all 19 eelgrass morphological and environmental metrics for 25 stations while the second one focussed on rhizome properties with representative leaf and sediment properties. For the second correlation matrix, metrics that were highly correlated with other plant metrics or environmental variables were excluded but all metrics related to rhizomes were retained for a total of 10 variables (i.e., sheath length, rhizome width, internode length, percent OM, grain size, eelgrass percent cover, REI, sediment arsenic and mercury, and WSC concentration in rhizomes). The second correlation analysis differed from the first one in that it included only the 5 stations where both rhizome WSC and sediment metal concentration were measured. We also used a one-way ANOVA and post-hoc Tukey HSD multiple comparisons of means to test for differences in rhizome carbohydrate concentrations among stations. All analyses were performed in R 3.4.4 (R Core Team, 2019).

3. RESULTS

3.1. Eelgrass cover and distribution around the proposed LNG terminal

The interpolated eelgrass map created using OK from eelgrass percent cover data (measured in each extracted frame from long transects and from drop-camera drift ground truth stations) showed four discrete patches of eelgrass in the study area with variable size and eelgrass percent cover (Figure 4). The most extensive patch was located south-west of Hurricane Island (Figure 4). That particular patch was also the most dense with a significant area >75% eelgrass cover and is located ~1.0–1.5 km northwest of the proposed LNG terminal (Figure 4). Patches with lower eelgrass cover occurred in neighbouring Webbs Cove, Dung Cove, and Bettys Cove (Figure 4). Eelgrass in Bettys Cove occurred beneath and adjacent to the proposed LNG terminal footprint in the cover range of 25–75% (Figure 4, Appendix C).

3.2. Eelgrass occurrence and abundance across the study area, depth, and substrate characteristics

Eelgrass was present at 45 stations out of the 169 stations surveyed between Wine Harbour and New Harbour (Figure 5). Percent cover was determined for 160 stations, as the remaining 9 stations had either poor visibility or the video system could not be deployed. Out of the 39 stations where eelgrass was present and percent cover could be determined, cover ranged from 1.33% to 100% (Table 2). Within Isaacs Harbour, the eelgrass beds around the proposed LNG terminal were distinct in that eelgrass was not present at any of the other stations sampled within the harbour (Figure 5). Within the wider study area, eelgrass was particularly extensive and abundant with high cover in Coddles Harbour (Figures 5 and 6). Of the 10 stations with eelgrass cover > 90% (Table 2), all were located in Coddles Harbour. Eelgrass was generally absent or sparse at highly protected sites at the heads of harbours and inlets as well as sites more exposed to wave action around headlands and the Harbour and Goose Islands (Figures 5 and 6).

Stations with eelgrass present ranged from 0–6.5 m in depth (based on LLWLT) (Figure 7), with the exception of one station (HGI5) located north of Goose Island that was 8.5 m deep (Figure 5). Eelgrass was most common between 0–4 m and generally absent both at greater depths and at sites exposed during more extreme low tides (i.e., < 0 m; Figure 7). When eelgrass was present, abundance declined with depth with the highest percent cover values observed between approximately between 0–3 m (Figure 8). Within this depth range, average eelgrass cover frequently exceeded 50% (Figure 8).

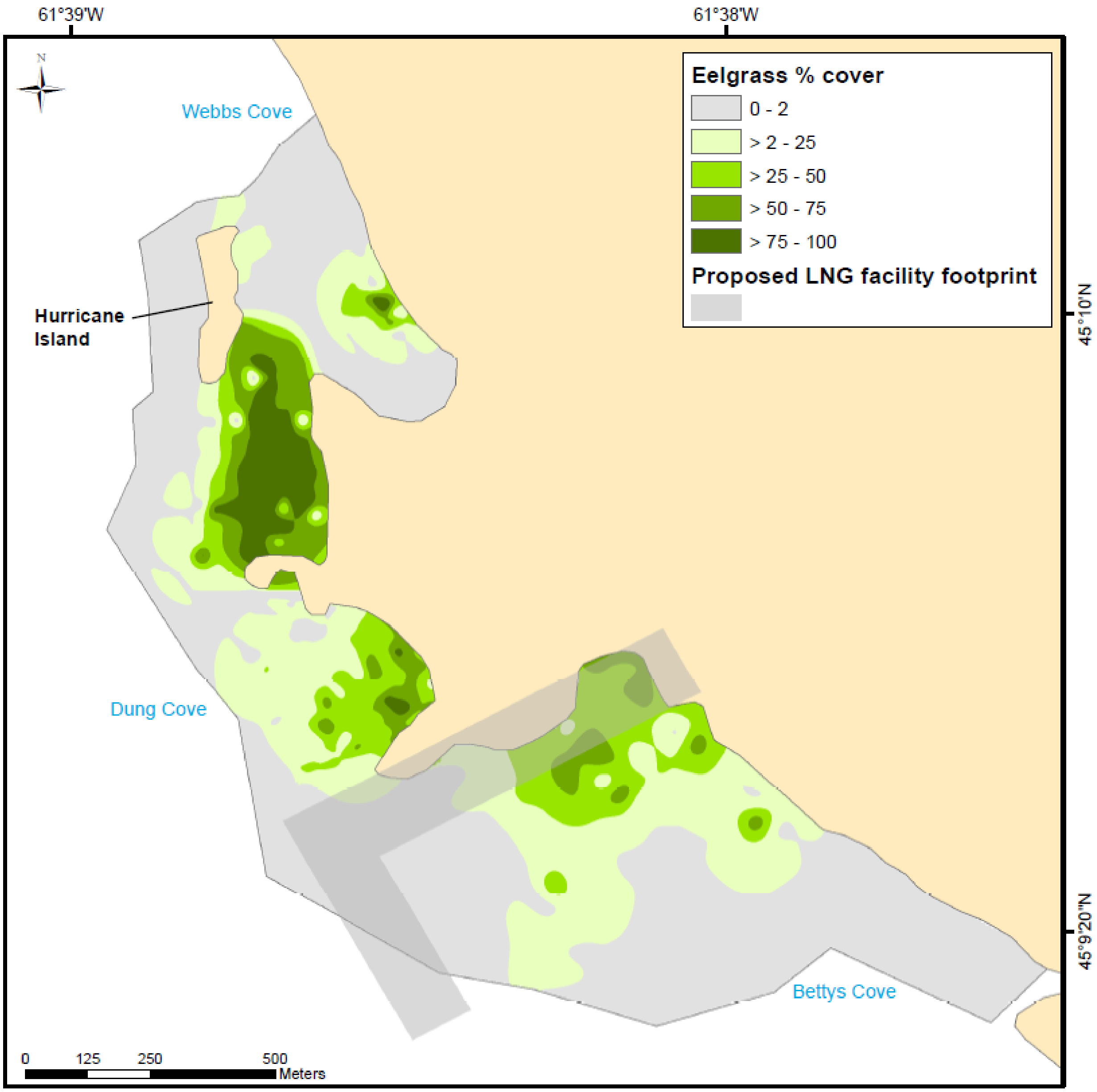

Figure 4. Interpolated eelgrass percent cover beneath and adjacent to the proposed LNG terminal footprint. Eelgrass cover was interpolated using the Ordinary Kriging method. Continuous eelgrass cover is displayed in 5 discrete bins with the 0–2% bin interpreted as zero cover.

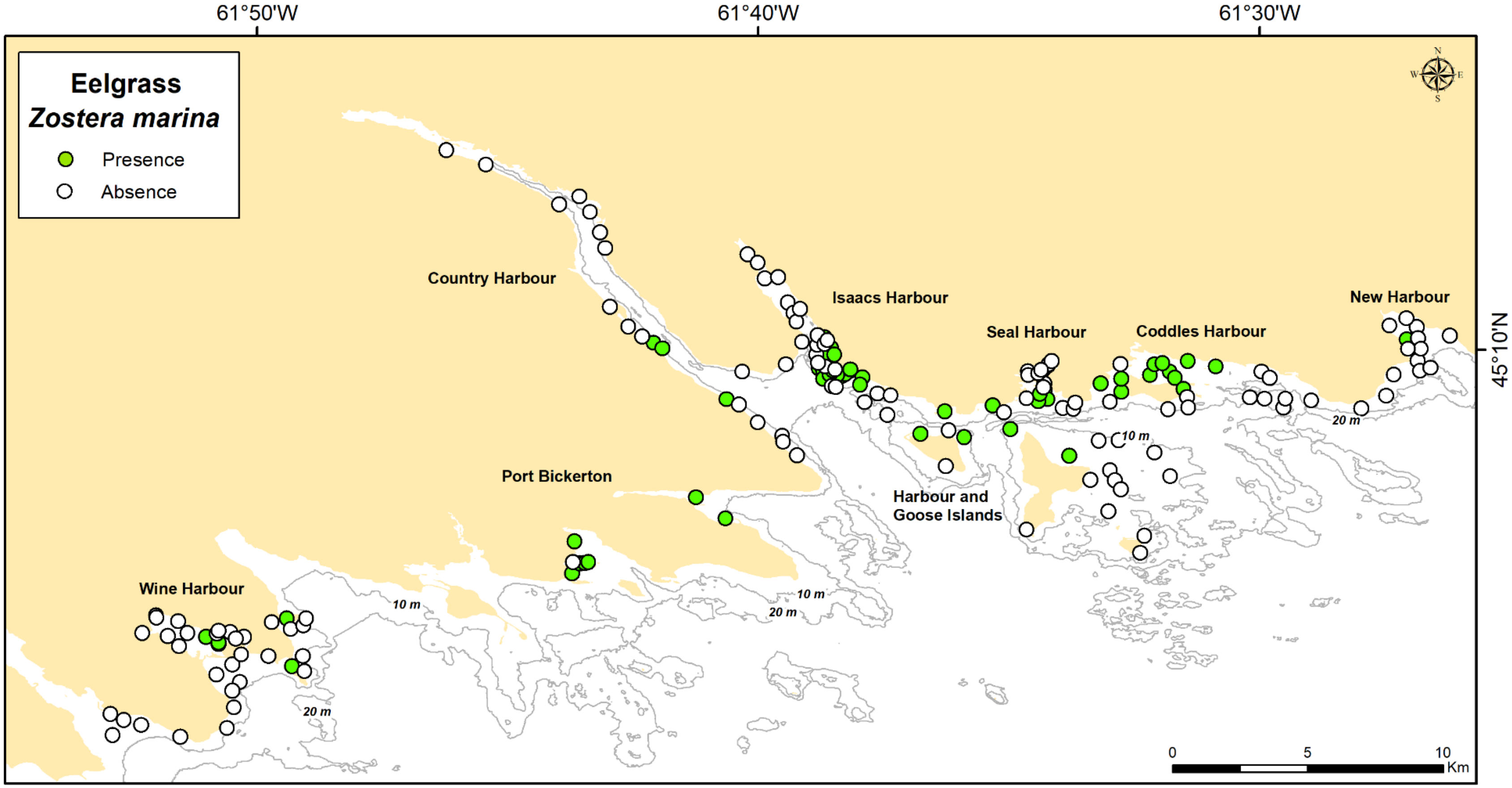

Figure 5. Sampling stations from Wine Harbour to New Harbour where drop camera surveys were conducted (n = 169). Presence or absence of eelgrass *Zostera marina* is indicated by green and white colour, respectively.

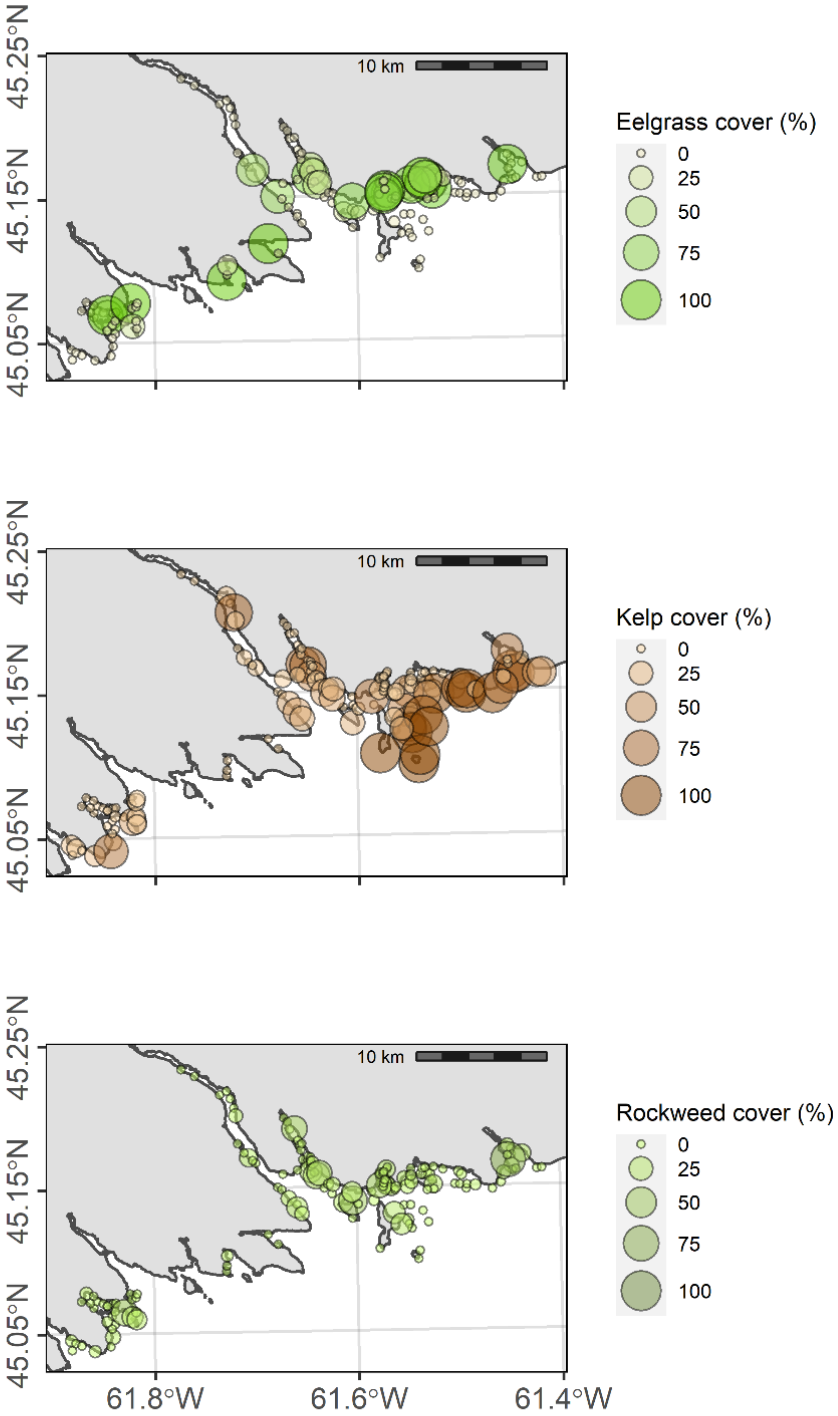

Figure 6. Abundance of habitat-forming macrophytes (eelgrass, kelps, fucoids) at stations sampled with drop-camera surveys between Wine Harbour and New Harbour. Points are the mean percent cover across video frames extracted approximately every 4 m along short drift transects. Higher cover values are indicated by darker hues and larger symbols.

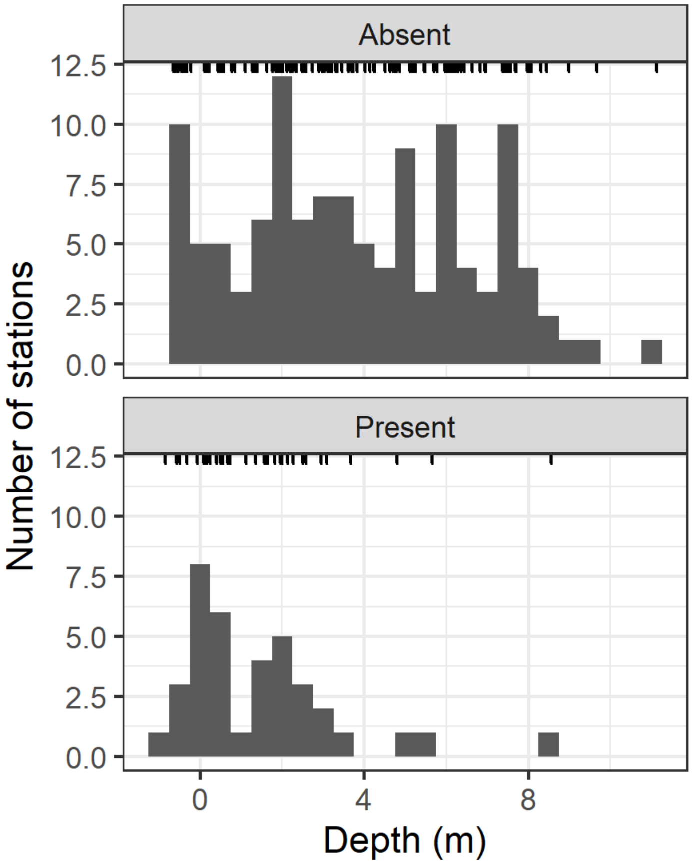

Figure 7. Distribution of drop-camera stations across depth (m with respect to LLWLT) for stations with eelgrass absent and eelgrass present. Bars are counts of stations within a given depth bin. Rug plot at the top of each panel shows observed depth values at individual stations along the continuous depth gradient.

Table 2. Number of drop-camera stations in each of 10 percent cover bins for eelgrass (n = 39).

Eelgrass cover range (%)	Number of stations
0.1-10	6
10.1-20	4
20.1-30	4
30.1-40	5
40.1-50	1
50.1-60	1
60.1-70	4
70.1-80	2
80.1-90	2
90.1-100	10

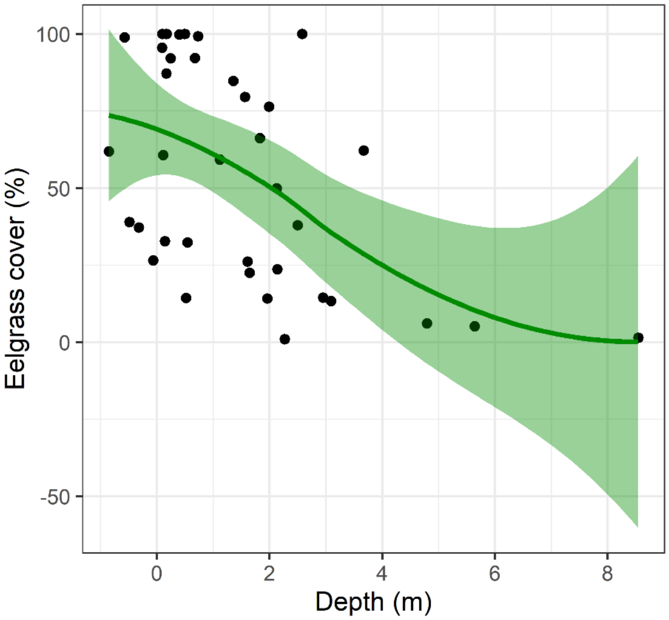

Figure 8. Mean eelgrass percent cover across depths. Points are the average cover at individual sampling stations across video frames extracted approximately every 4 m. The smoothed green line is the fit relationship using a LOESS smoother. Shaded green area is the 95% confidence interval around the smoother.

Regardless of the presence or absence of eelgrass, other macrophytes that provide fish habitat (kelp and other brown macroalgae) usually dominated in stations that were more exposed, with gravel, boulders or other hard substrates present (Figure 6; Appendix D and E). The occurrence of these other habitat-forming species within the study area complimented the distribution of eelgrass. Kelp was particularly abundant in highly exposed environments around Harbour and Goose Islands and the headlands between Coddles Harbour and New Harbour (Figure 6; Appendix E). Subtidal stands of other large brown macroalgae (*Ascophyllum nodosum* and *Fucus* spp.) occurred at a lower abundance throughout the study area, but often co-occurring with either kelp or eelgrass (Figure 6; Appendix D and E). The area of Isaacs Harbour within and adjacent to the proposed LNG terminal represented a particularly unique patchwork of critical fish habitat (eelgrass, kelp, rockweed) due to fine-scale heterogeneity in substrate composition (Figure 6).

From visual classification of seabed characteristics from the video analysis, eelgrass was present on substrate mostly characterized as sand and mud, sand, or sand and gravel, and was only occasionally associated with mud or hard substrate (Table 3). Bare soft sediments (often muddy/silty) largely lacking structure-forming macrophytes were mostly observed at stations more sheltered from wave action (Appendix D and E).

Table 3. Number of stations with absence or presence of eelgrass for each associated sediment type.

		Eelgrass	
Sediment type (visual)	Total number of stations	Absent	Present
Hard Substrate	63	61	2
Sand & Gravel	10	5	5
Sand	27	13	14
Sand & Mud	34	14	20
Mud	35	32	3
Total	169	125	44

3.3. Sediment organic matter and grain size analysis

A more detailed sediment analysis was performed when soft sediment could be collected (59 stations). Organic matter (OM) content varied widely within and between harbours (Figure 9) in relation to wave exposure and grain size. The highest values of OM were found in Country Harbour, a very narrow and long harbour. Conversely, this harbour displayed low mean grain size (Figure 9). High organic matter and low mean grain size were also observed inside the highly protected Wine Harbour (Figure 9).

Eelgrass was more often found growing in sediments composed of fine sand/silt. In contrast, stations with soft sediment that contained a greater fraction of either clay and silt or coarse sand/gravel were mostly associated with the absence of eelgrass (Figure 10). The results of this more detailed sediment analysis corroborated the observed frequency of occurrence of eelgrass across different substrate types as classified from the video analysis (Table 3).

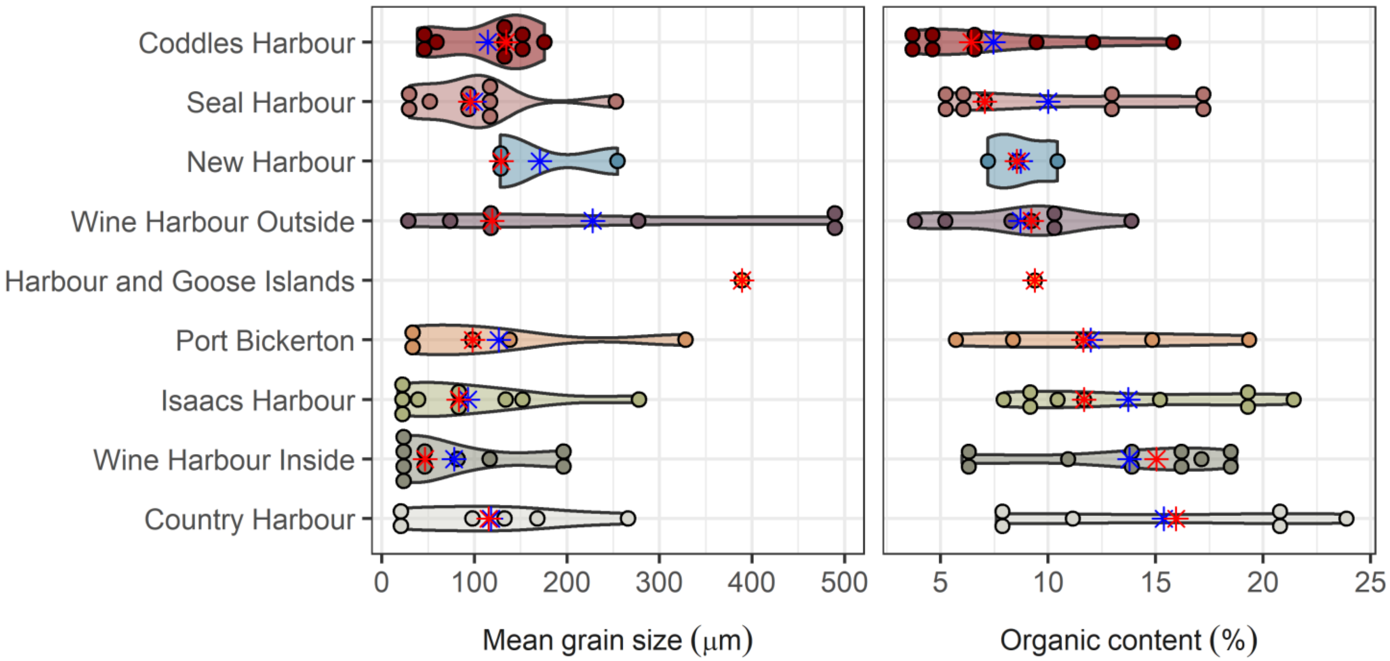

Figure 9. Dotplots illustrating range of sediment characteristics measured at 59 stations across 9 sampling areas in the Goldboro region. Dots are binned values (bin width = 1/30 the range of data) of mean grain size (µm; left panel) and organic content (%; right panel). Shaded areas are the kernel density estimates around values. Blue and red asterisks indicate the mean and median values within a sampling area, respectively. Sampling areas are arranged in order of increasing median organic content.

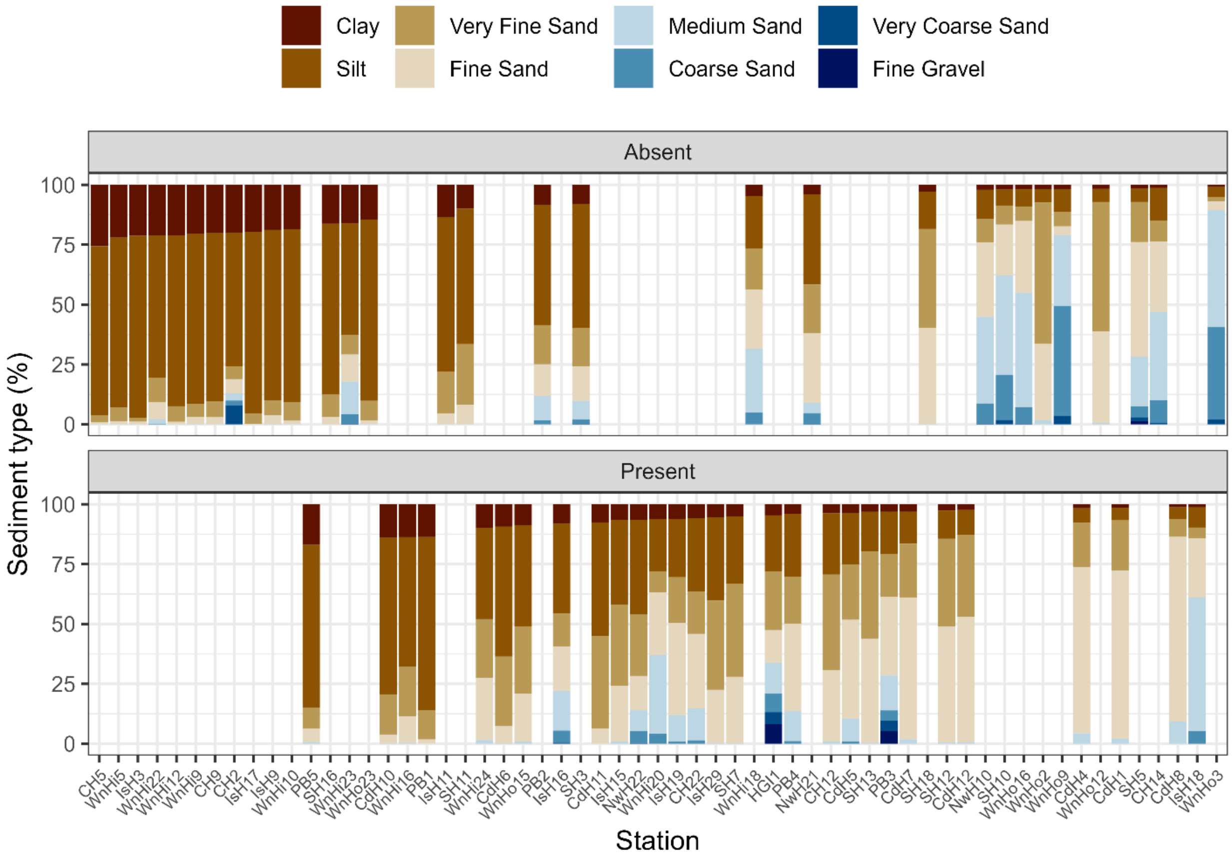

Figure 10. The relative composition of different grain size categories comprising sediments collected from 30 stations with eelgrass absent and 29 stations with eelgrass present from Coddles Harbour to Wine Harbour.

3.4. Plant morphometrics

Plant morphologies varied strongly both within and among the surveyed harbours (Figure 11). However, stations with the greatest sheath length were also the ones with the greatest leaf 3 length, rhizome diameter and internode length (e.g., CdH7, CdH10, IsH29, PB1, PB4, PB5), with some exceptions where internode length was smaller than expected (e.g., Wine Harbour inside) (Figure 11). These relationships are explored with more detail in section 3.8 below. Also, shoots collected at the single station in New Harbour were the longest of all stations but rhizome width and internode length were not particularly high. Certain harbours had plant morphologies that were more consistent across stations (e.g., Seal Harbour), while others (e.g., Coddles Harbour) were more variable (Figure 11). Overall, the morphology metrics of plants collected from Isaacs Harbour fell within the range of values found in the whole area surveyed including the reference areas not impacted by historical goldmining (Figures 11 and 12).

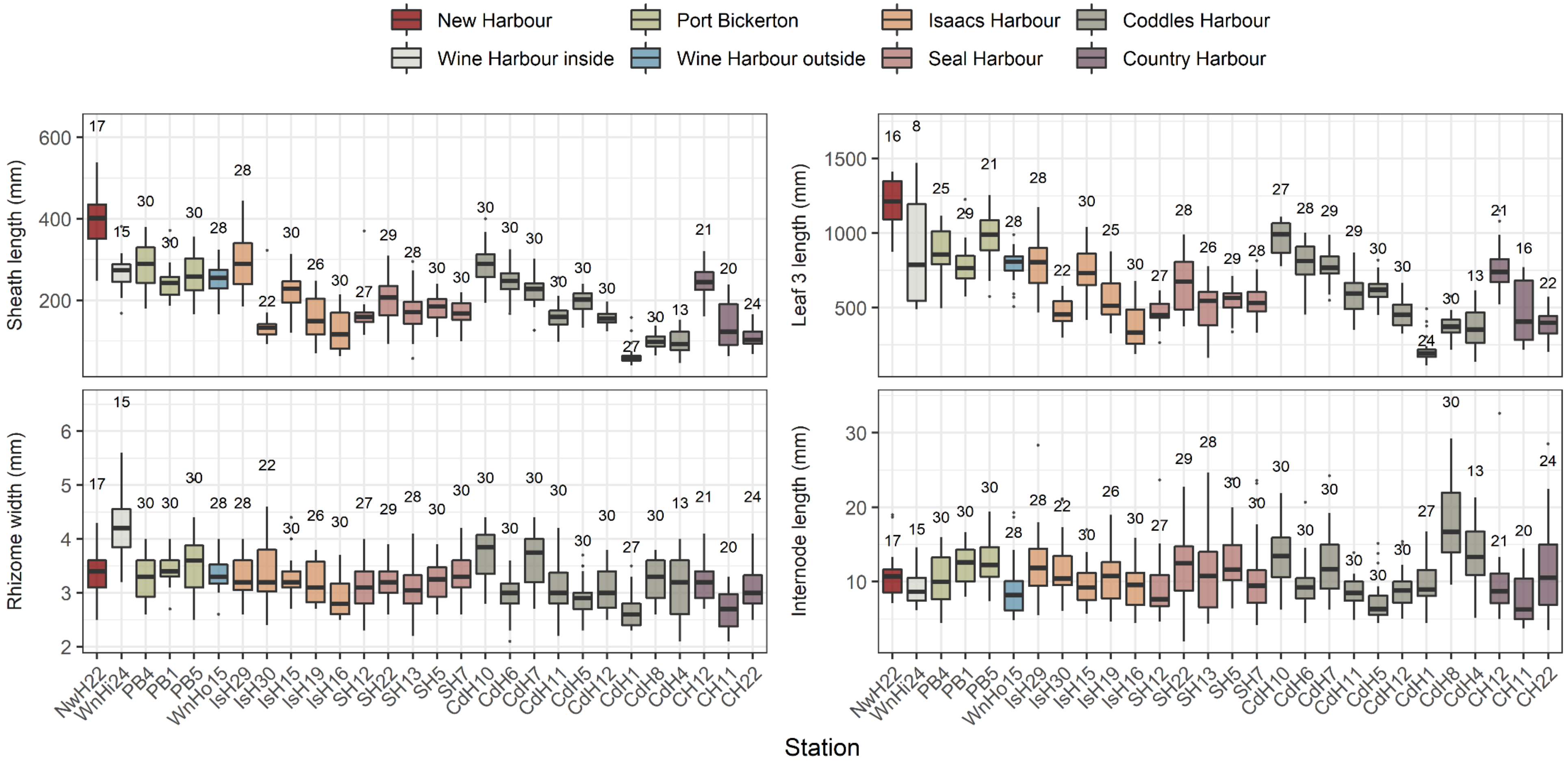

Figure 11. Morphometrics of leaves (sheath length and leaf 3 length) and rhizomes (width and internode length) across stations (mm). Historical gold mining occurred in Isaacs Harbour, Country Harbour, Seal Harbour and Wine Harbour. Numbers above the boxplots indicate number of replicate shoots measured.

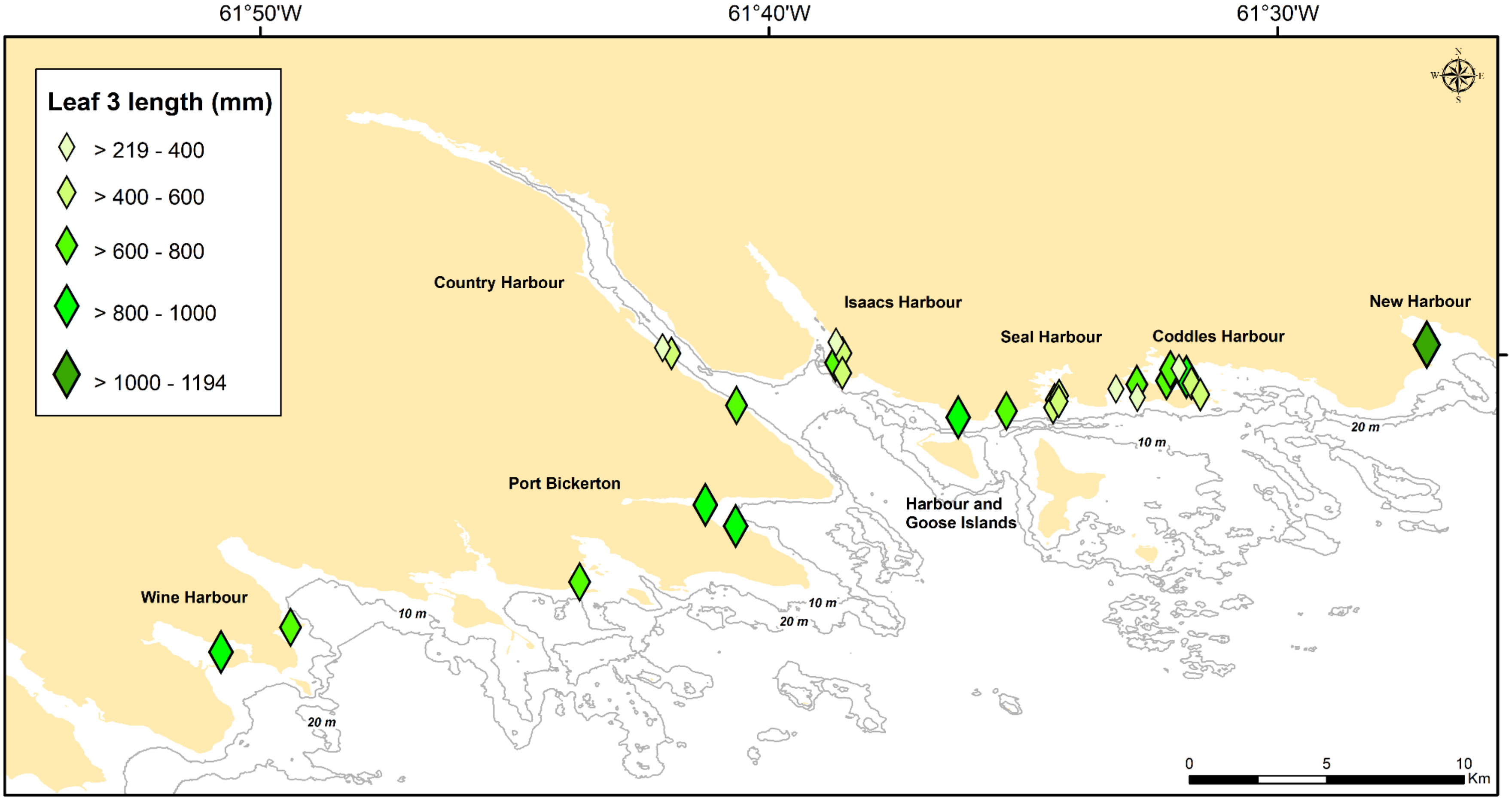

Figure 12. Spatial distribution of one representative metric, mean third leaf (L3) length (mm), across stations, from Wine Harbour to Coddles Harbour. Historical gold mining occurred in Isaacs Harbour, Country Harbour, Seal Harbour and Wine Harbour.

3.5. Rhizome carbohydrates

The mean total soluble carbohydrates concentrations varied from 171–281 µg/mg DW across the 6 stations analyzed (Figure 13). It was significantly lower at a representative site in Coddles Harbour compared to any of the sites analyzed in Isaacs Harbour and CH12 from Country Harbour ($F_{5,78} = 8.826$, $p < 0.001$ and $p < 0.05$ for all Tukey's HSD test multiple comparisons which included CH12). There were no statistically significant differences between any other stations.

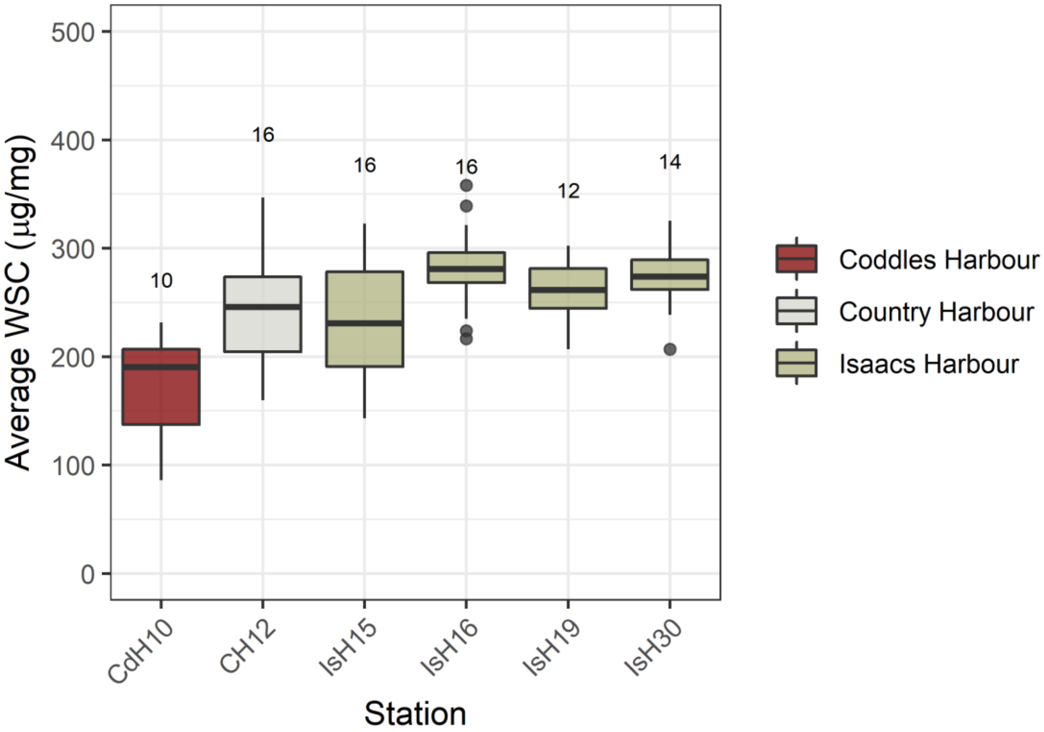

Figure 13. Mean total water-soluble carbohydrates (WSC) in four stations in Isaacs Harbour and two stations in adjacent harbours, Country Harbour where historical gold mining also occurred and Coddles Harbour, considered as a reference non-contaminated harbour. Numbers above the boxplots indicate number of replicates.

3.6. Heavy metal contamination of sediments

Soft sediment grab samples were analyzed for heavy metal concentrations at 58 stations. Here, we are reporting results for arsenic and mercury only, as these are the two main contaminants associated with the historical gold mining that occurred in the area. Arsenic and mercury concentrations in sediments (Appendix F) in the area varied from 0.78–1890 ppm and from 5–3250 ppb, respectively. Harbours with historical gold mining (Wine Harbour, Isaacs Harbour and Seal Harbour) displayed higher levels of arsenic (Figure 14.a) and mercury (Figure 14.b) compared to harbours with lower or no historical gold mining. Sediments in Wine Harbour (inside) were the most highly contaminated followed by Isaacs Harbour (IsH16 and IsH19), for both arsenic and mercury (Figures 14 and 15).

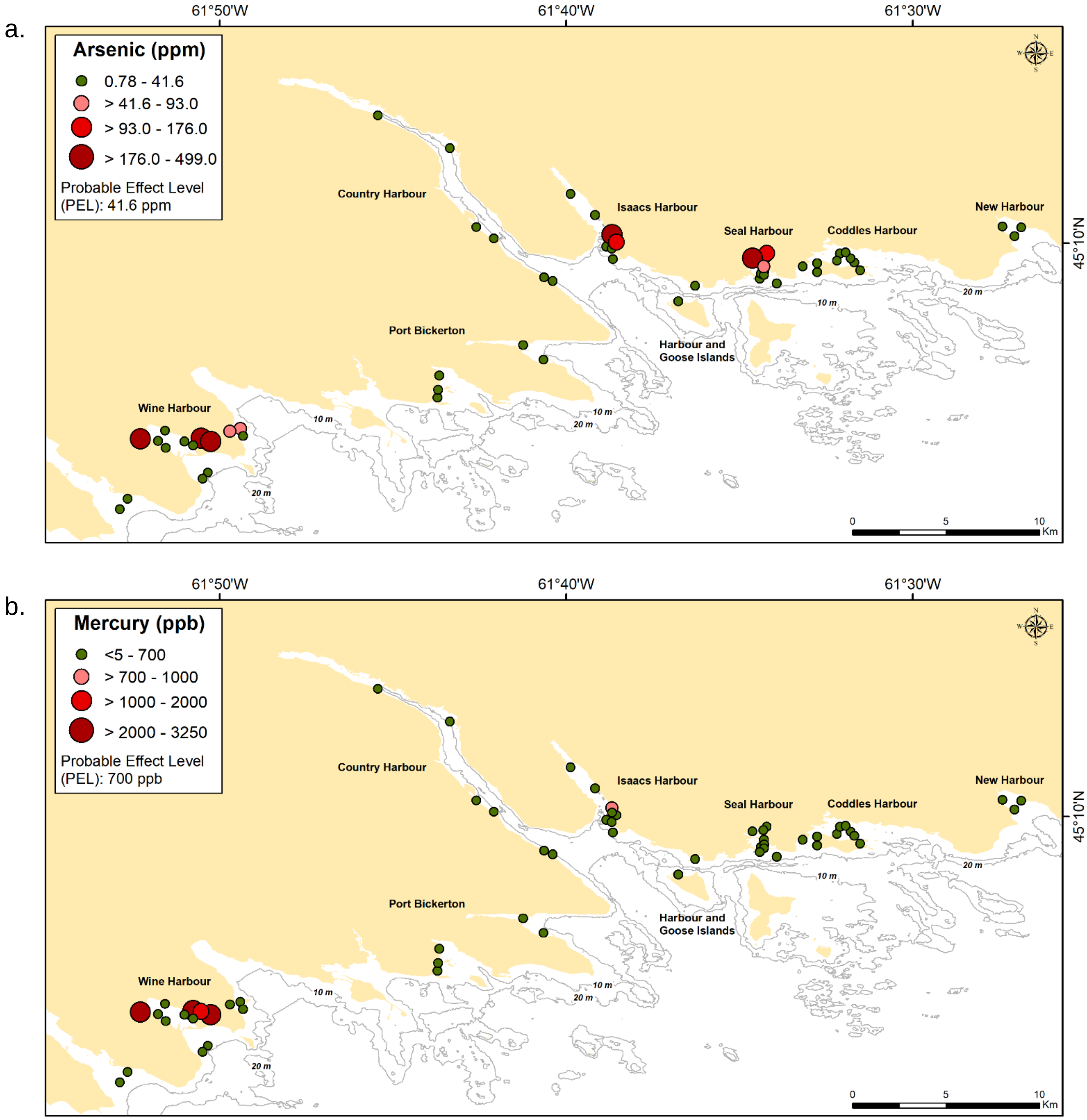

Figure 14. Spatial distribution of arsenic (a.) and mercury (b.) concentrations in sediments of the study area. Probable Effect Levels from CCME are reported in the legend. Historical gold mining occurred in Country Harbour, Isaacs Harbour, Seal Harbour and Wine Harbour.

Conversely, harbours where gold mining did not occur within the watershed, such as Coddles Harbour and New Harbour, as well as areas in Harbour and Goose Islands and around Port Bickerton did not display sediment contamination above the CCME levels. Country Harbour, where gold mining occurred at a lesser intensity, was considered contaminated for arsenic according to the CCME ISQG limit but not for mercury (Figures 15 and 16).

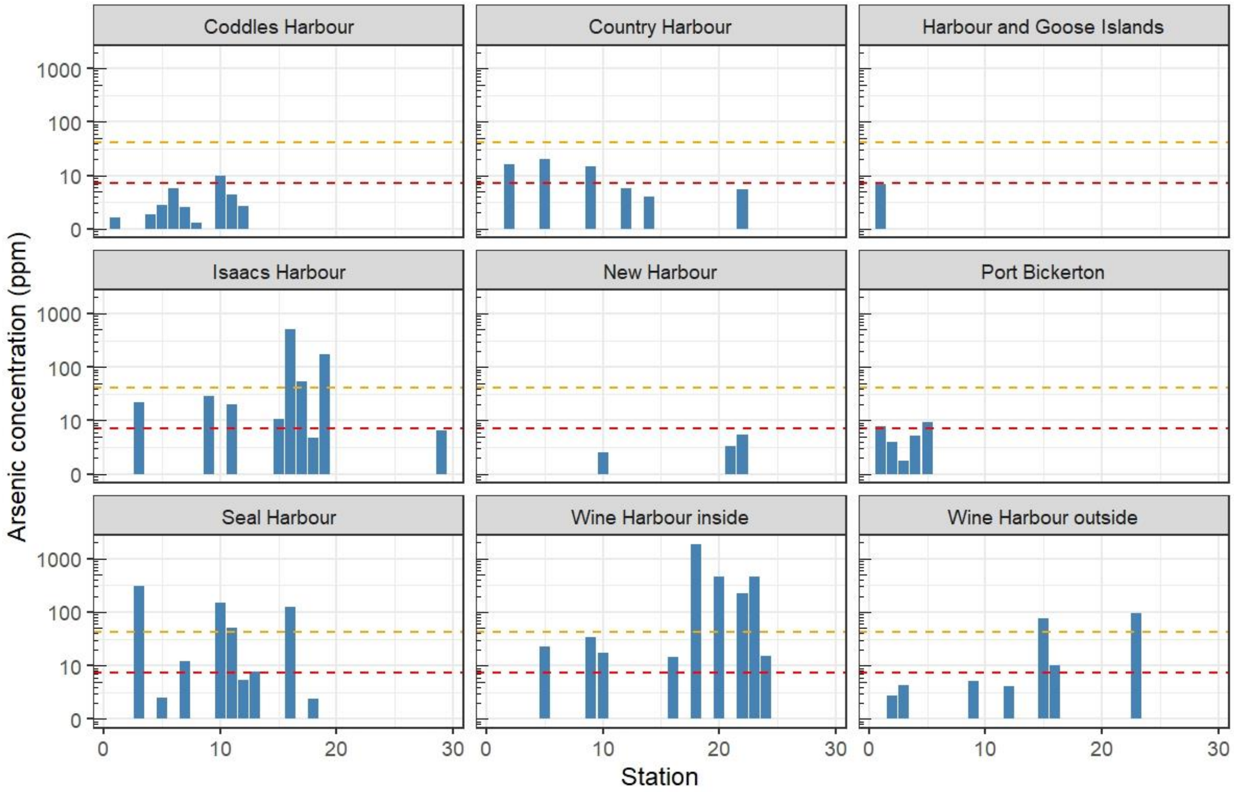

Figure 15. Arsenic concentration (ppm) in sediments collected at 58 stations between Coddles Harbour and Wine Harbour. Historical gold mining occurred in Country Harbour, Isaacs Harbour, Seal Harbour and Wine Harbour. Detection Limit is 0.1 ppm. Absences do not represent 0, rather sediments from those stations were not collected and analysed. The yellow dotted line corresponds to the CCME ISQG threshold (7.24 ppm) and the red dotted line corresponds to the CCME PEL threshold (41.6 ppm). Note logarithmic scale.

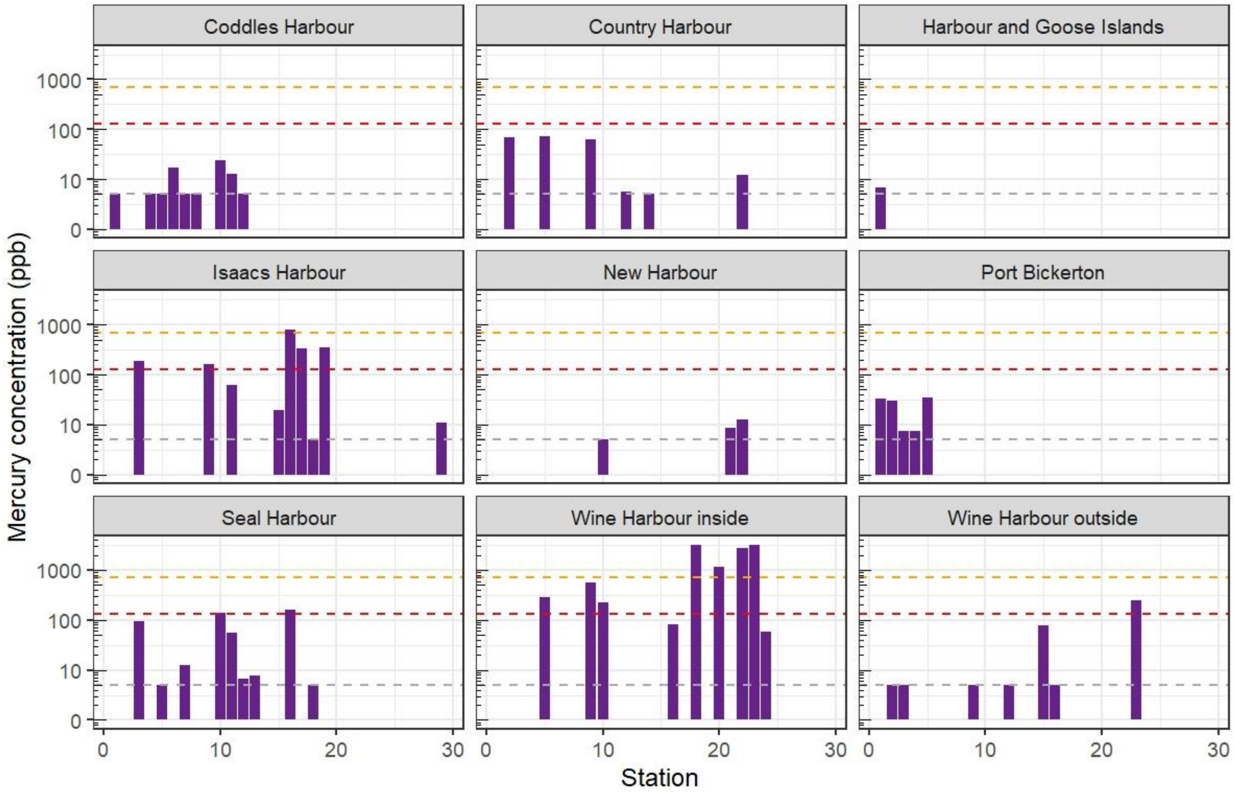

Figure 16. Mercury concentration (ppb) in sediments collected at 58 stations between Coddles Harbour and Wine Harbour. Historical gold mining occurred in Country Harbour, Isaacs Harbour, Seal Harbour and Wine Harbour. Detection Limit is 5 ppb (grey dotted line). Absences do not represent 0, rather sediments from those stations were not collected and analysed. The yellow dotted line corresponds to the CCME ISQG threshold (130 ppb) and the red dotted line corresponds to the CCME PEL threshold (700 ppb). Note logarithmic scale.

3.7. Heavy metal contamination in eelgrass plants

Metal concentrations were also analyzed in eelgrass rhizome and leaf tissues at 28 stations (see Appendices G and H, for the complete analysis of 35 metals in rhizome and leaf tissues, respectively). Eelgrass plants collected at the three stations with the highest levels of arsenic and mercury in sediments showed some level of contamination in both rhizome and leaf tissues, especially in Isaacs Harbour (e.g. IsH16) and at the only station where shoots were collected in Wine Harbour outside (Figures 17 and 18). In Isaacs Harbour, eelgrass collected at both stations IsH16 and 19 showed levels of arsenic in rhizome tissue above the CFIA limit of 3.5 ppm but only shoots collected at IsH16 showed arsenic contamination in leaf tissue (Figure 17.b). In Seal Harbour and Wine harbour, only rhizome tissue showed some level of arsenic contamination (Figure 17.a).

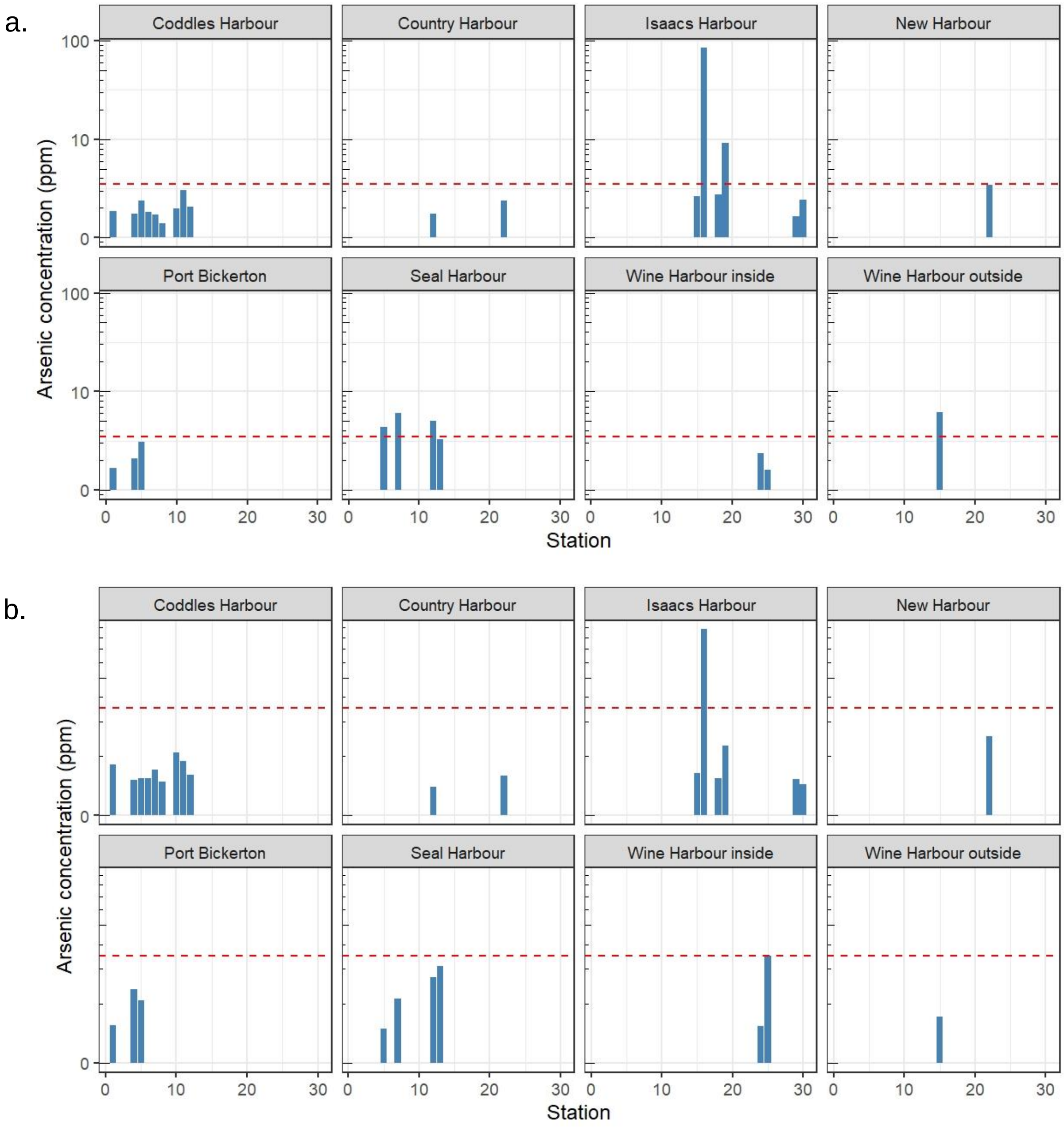

Figure 17. Arsenic concentration (ppm) in rhizomes (a.) and leaves (b.) of plants collected at 28 stations between Coddles Harbour and Wine Harbour. Historical gold mining occurred in Country Harbour, Isaacs Harbour, Seal Harbour and Wine Harbour. Detection Limit is 0.1 ppm. Absences do not represent 0, rather sediments from those stations were not collected and analysed. The red dotted line corresponds to the CFIA threshold of 3.5 ppm. Note logarithmic scale.

Levels of mercury in rhizome and leaf tissues were usually close to the detection limit and much lower than the CFIA limit of 500 ppb at all stations in all harbours,although the level of mercury in rhizome and leaf tissues were moderately high (92 ppb and 24 ppb, respectively) at the IsH16 station (Figures 18 a. and b).

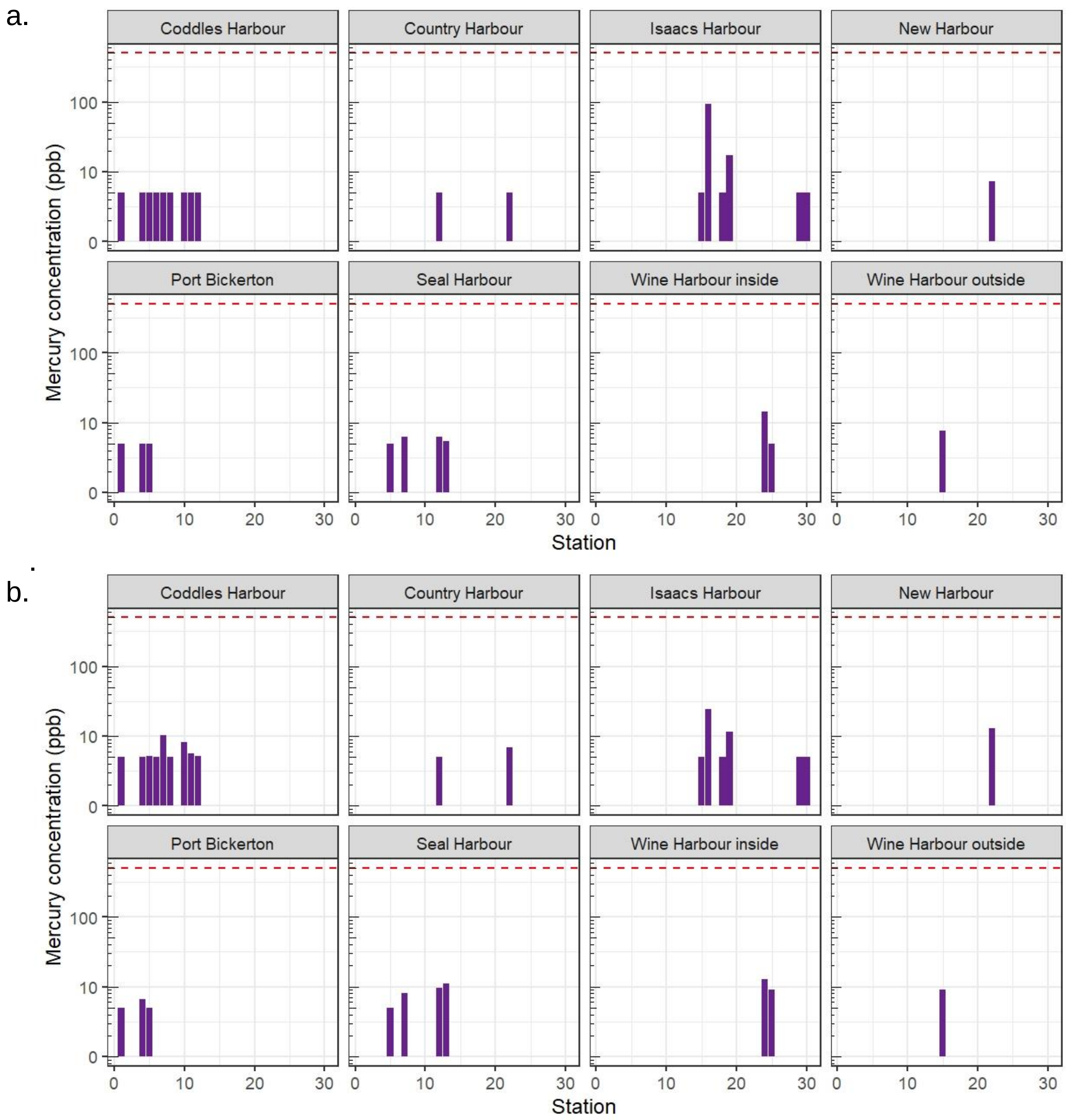

Figure 18. Mercury concentration (ppb) in rhizomes (a.) and leaves (b.) of plants collected at 28 stations between Coddles Harbour and Wine Harbour. Historical gold mining occurred in Country Harbour, Isaacs Harbour, Seal Harbour and Wine Harbour. Detection Limit is 5 ppb. Absences do not represent 0, rather sediments from those stations were not collected and analysed. The red dotted line corresponds to the CFIA threshold of 500 ppb. Note logarithmic scale.

3.8. Relations between eelgrass metrics and environmental variables

All eelgrass morphological metrics (with the exclusion of the number of leaves) were positively correlated with each other (r = 0.62–0.99; Figure 19). Eelgrass percent cover was also positively correlated with each length metric (sheath, second and third leaf). The most dense patches tended to have longer plants, thus high aboveground biomass. Rhizome internode length was positively correlated with rhizome width but negatively correlated with the number of leaves (Figure 19).

Depth was not significantly correlated with any plant metric or other environmental variable. In particular, the sheath and leaf lengths were not significantly correlated with depth, which was unexpected. This may have occured because plants could not be easily collected from the boat at stations where depths were greater than 4 m. This limitation excluded a range of deeper waters where eelgrass shoot length would have likely increased with depth. However, as expected, relative wave exposure index (REI) was positively correlated with grain size (0.57) and negatively correlated with percent organic matter (OM) (-0.52). More exposed stations thus had coarser sediments with lower OM content (note that grain size is also negatively correlated with OM content, -0.66). REI was negatively correlated with leaf width for both second and third leaves, suggesting that eelgrass leaves tended to be narrower when growing in exposed areas. Grain size was negatively correlated with leaf widths and all length measures (-0.44 to -0.54), which meant that shorter plants were growing in coarser sediments. Conversely, longer and wider plants (with thicker rhizomes) were growing in areas with higher OM content (correlation coefficients between 0.44 and 0.65). On the other hand, there was no significant correlation between eelgrass percent cover and OM content, grain size or REI. Similarly, rhizome internode length was not influenced by sediment type or wave exposure in this study.

Pearson’s correlation coefficients also indicated that all arsenic and mercury levels in sediment, rhizomes and leaves were highly correlated with each other, with no significant correlation with eelgrass morphometrics or environmental variables (Figure 19). This lack of relationships implies that contamination was localized, not linked to environmental variables recorded in this study and did not seem to affect aboveground or belowground morphological features of eelgrass plants. A full ecotoxicological study would require additional data and a proper evaluation of physiological effects. A scatter plot matrix showing each correlation plot, data distributions, and associated correlation values without the contamination data is presented in Appendix I.

Carbohydrates concentrations in rhizomes of collected plants were analyzed for a few selected stations and correlations with selected variables were examined (Figure 20). The correlation matrix of 10 variables for 5 stations showed similar correlations

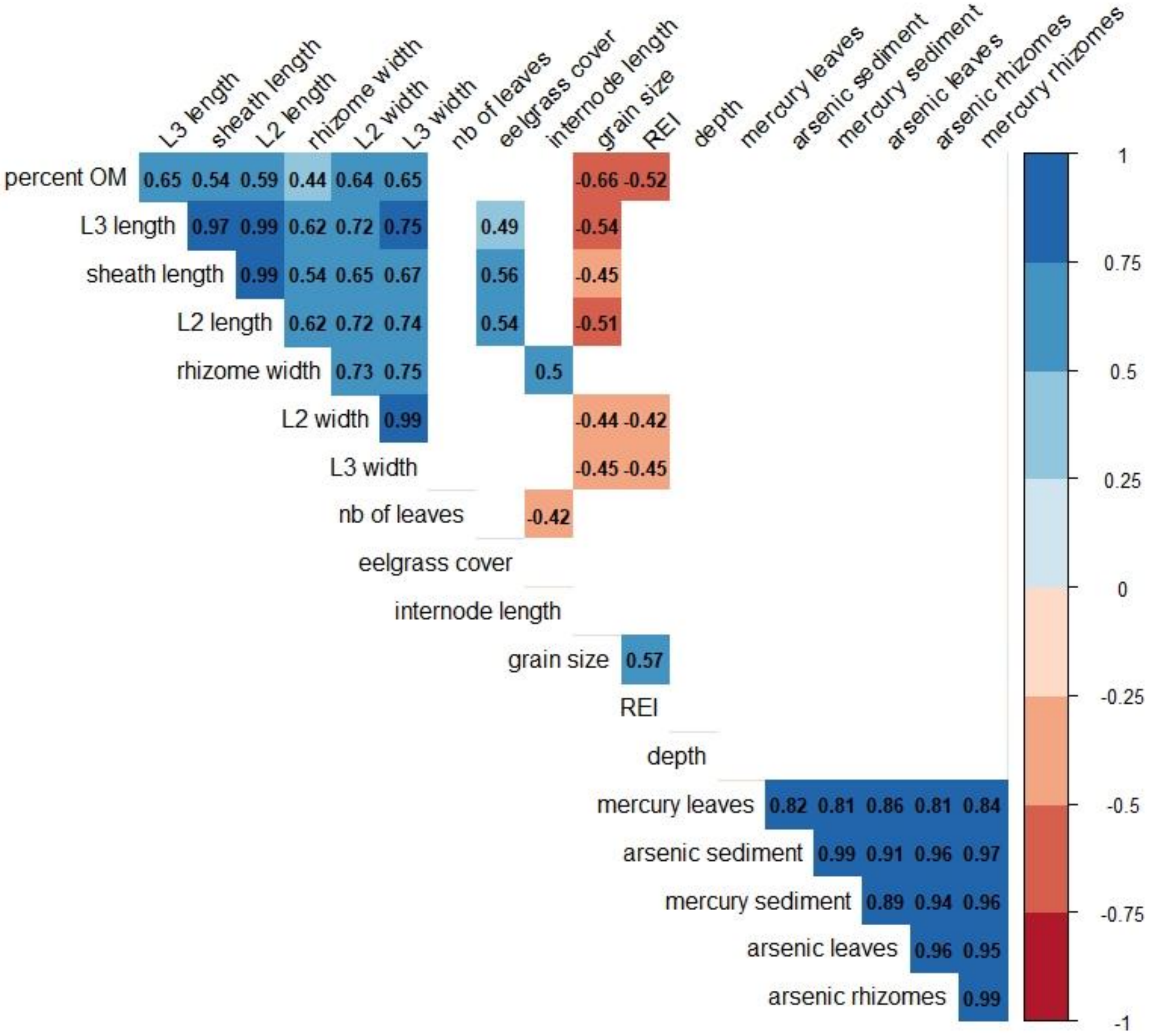

Figure 19: Correlation matrix of all morphological and environmental variables, including arsenic and mercury levels in leaves, rhizomes and sediment (n = 25 stations). Values are Pearson's correlation coefficients with coloured boxes indicating that the p-values are significant at < 0.05. Blank squares represent no significant correlation. OM = organic matter, L2 = second leaf, L3 = third leaf, REI = relative wave exposure index. Color intensity is proportional to the correlation coefficient. Note that the matrix has been reordered according to the correlation coefficients (hierarchical clustering order).

previously observed for the full set of stations (Figure 19). Water soluble carbohydrates (WSC) concentrations were strongly positively correlated with sediment grain size, and strongly negatively correlated with rhizome width, sheath length and eelgrass percent cover (Figure 20). Although REI was not significantly correlated with WSC in this reduced analysis, when combined with previous results (Figure 19), these results suggest that WSC are higher in more exposed areas compared to protected areas (as grain size was positively correlated with REI in the full analysis; Figure 19). However, these relationships would need to be confirmed across a larger number of stations that span a large gradient in environmental conditions.

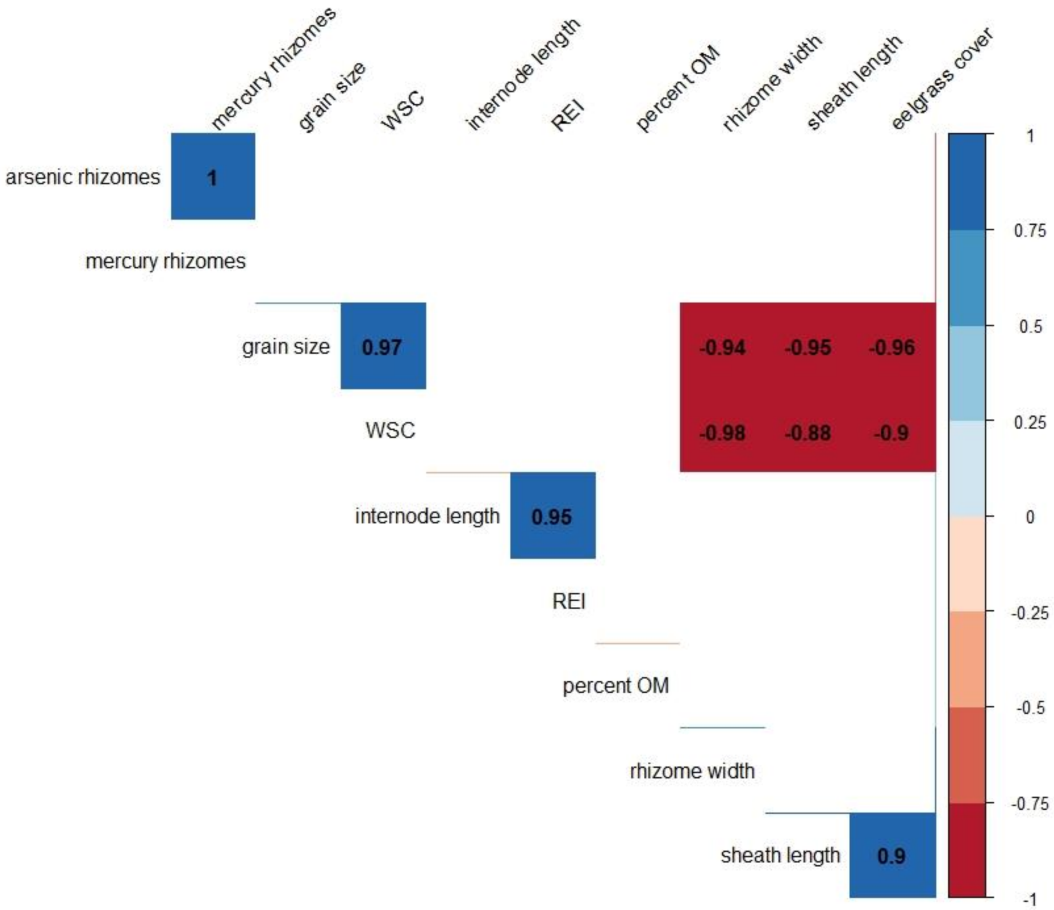

Figure 20: Correlation matrix of selected morphological, physiological and environmental variables (n = 5 stations). Values are Pearson’s correlation coefficients and colors indicate that the p-values are < 0.05 for the corresponding pair test. Blank squares represent no significant correlations. WSC = water soluble carbohydrates, REI = Relative wave Exposure Index, OM = organic matter. Note that the matrix has been reordered according to the correlation coefficients (hierarchical clustering order).

4. DISCUSSION AND CONCLUSIONS

Despite the increasing prevalence of industrial activities in nearshore waters, very few studies of construction impacts, especially pre-impact surveys, are conducted for eelgrass meadows. For the proposed LNG terminal in Goldboro, Isaacs Harbour, we surveyed the benthic environment of the proposed construction footprint, its vicinities, and of adjacent harbours, and collected pre-impact data in the summer. This timing was optimal as the pre-impact survey was aligned with the peak seasonal phenology of eelgrass. This survey allowed for a detailed characterization of the extent and condition of the eelgrass bed around the terminal footprint prior to construction activities, which places this evaluation within a regional context.

First, we reliably delimited the extent of the eelgrass bed around the proposed LNG terminal. This showed that even though the LNG jetty itself will be constructed in waters too deep for eelgrass (> 10 m), the marginal wharf footprint will be constructed directly over eelgrass habitat, which would involve direct destruction of 20–25% of the southern patch of the eelgrass bed. This patch does not have the highest eelgrass cover out of the four areas surveyed within the vicinity of the terminal footprint, but still represents important structural habitat given eelgrass plants provided cover in the range of 25–75% of the bottom.

In addition to direct destruction of the eelgrass habitat within the proposed terminal footprint, adjacent eelgrass patches are at risk of indirect adverse effects of construction activities. Sediments at most stations where eelgrass was present were characterized by mud and sand. These soft sediments, when disturbed during the construction phase or during regular operations, will be easily resuspended and likely increase water turbidity, impacting light availability for all four eelgrass patches in this area. Even the most dense and extensive patch (75–100% cover) located 0.5–1 km north of the planned site could be impacted. The potential level of impact on eelgrass plants will vary depending on the timing of the impact within the seasonal phenology of eelgrass, as well as the intensity and duration of the associated light reduction (Wong et al. 2020, Wong et al. 2021). Furthermore, impacts from light reduction will also depend on wind exposure and tidal current patterns. In order to fully understand the likely impacts of coastal development on fish habitat in this area, hydrodynamic models that include sediment dynamics will be critically important to provide more insight into the resuspension, transport, and settlement of disturbed sediments.

In addition to characterizing the eelgrass beds in the direct vicinity of the proposed LNG facility, we also provided a pre-impact assessment of eelgrass conditions in adjacent areas. We surveyed the presence and percent cover of eelgrass from Wine Harbour to New Harbour and assessed the health condition of the plants as well as their benthic environment. The overall condition of eelgrass plants in the area, including in Isaacs Harbour, fell within the range of healthy plant characteristics (morphometrics and carbohydrates reserves) seen elsewhere along the Atlantic coast (Wong et al. 2013, Krumhansl et al. 2021, Wong, unpublish. data). Stations with longer eelgrass shoots which also had larger rhizomes tended to have higher eelgrass percent cover and percent OM overall. Even though WSC concentrations were significantly higher at Isaacs Harbour stations than at a representative reference station in Coddles harbour, there was no indication that plants were under stress in Isaacs Harbour. This good overall condition of eelgrass plants could be jeopardized by the construction and the operations of the proposed LNG terminal.

Finally, we assessed the heavy metal contamination of sediments and eelgrass tissues to provide insight into relationships with historical goldmining and to highlight potential consequences of sediment disruption. Isaacs Harbour lies in the middle of the Stormont region, which was historically the most productive gold mining area of the 65 historic gold districts in Nova Scotia. Gold was mined in Isaacs Harbour for a century, from 1862–1958 (Bates 1987). Gold (Au) was usually recovered from mined ore using mercury (Hg) amalgamation and an estimated minimum of 10-25% of the Hg used was lost in tailings (EPS 1978). These tailings were typically slurried directly into local water bodies and the ocean. With a conservative estimate of 39,694.3 Troy ounces (or 1234.63 kg) of gold produced in that timeframe in Isaacs Harbour (Bates 1987), and assuming a ratio Hg:Au of 1:1 for amalgamation, up to 308 kg of Hg may have entered the harbour through tailing deposition. Using the same rationale, up to 265 kg, 329 kg and 77 kg of Hg may have been lost in tailings in Lower Seal Harbour, Wine Harbour and Country Harbour gold districts, respectively. Isaacs Harbour is then one of the two most contaminated harbours in the area. We showed that the top layer of sediments in which eelgrass grows is contaminated with mercury and arsenic as of 2020, although peak arsenic and mercury concentrations were likely evident at depths corresponding to periods of mining activities (Little et al. 2015). These contaminated layers were identified from gravity cores at 10-25 cm deep in Isaacs Harbour and 35-45 cm deep in Wine Harbour (M. Parsons, pers. comm.). Little et al. (2015) also noted that some cores showed even higher arsenic and mercury contamination at the sediment-water interface as flocs, consisting of reactive material with high specific surface area, can accumulate and transport contaminants, representing an important pathway for the uptake of contaminants by organisms residing at that interface (Milligan and Law 2013). Any disturbance of these contaminated sediments will re-suspend them into the water column and increase their availability to aquatic organisms, including eelgrass plants. Following high levels of arsenic recorded in soft shelled clams collected from intertidal flats (legacy tailings) in Seal Harbour (Koch et al. 2007), DFO issued a precautionary bivalve shellfish closure for Seal Harbour and Isaacs Harbour in 2005, still in effect to date. To our knowledge, our measurements of heavy metals in eelgrass plants presented here represent the first measurements of heavy metal contamination in eelgrass for Canada.

The most contaminated sediments in Isaacs Harbour were found in Webbs Cove at station IsH16, followed by station IsH19, both located ~100 m away from the stamp mill that was located on Hurricane Island (Figure 2). The levels of arsenic and mercury in sediment at those stations were equivalent to what was found by Parsons (pers. comm.) in the same cove in 2004-2005 (i.e., 107 ppm As and 601 ppb Hg). This result indicates persistent sediment contamination and potential uptake by seagrasses, other submerged aquatic vegetation and benthic fauna. Mercury levels in plants from Isaacs Harbour were below the 500 ppb threshold recommended by CFIA for fish tissue. However plants at both IsH16 and IsH19 stations showed arsenic contamination in rhizome and/or leaf tissue above the threshold. To our knowledge, metal (arsenic) contamination in marine plants was studied only once previously in Nova Scotia. Koch et al. (2007) reported levels of total arsenic in *Fucus spp*. in Seal Harbour in the range of 23-43 ppm (wet weight), 4 times higher than the arsenic concentration of 6-10 ppm in control seaweed from uncontaminated New Harbour. Here we report higher levels of 83 ppm and 7.79 ppm (dry weight) of arsenic in rhizome and leaf tissues, respectively, at IsH16. These levels were 35 and 5 times higher, respectively, than for plants from uncontaminated New Harbour. It should be noted that in contrast to seagrasses, seaweeds grow attached to rocks without rooting in the sediments. Seagrasses thus uptake heavy metals not only from the surrounding waters but also from the sediments.

All metals, whether essential or non-essential (i.e., silver, arsenic, cadmium, mercury and lead) have potentially toxicological and ecotoxicological effects on marine organisms beyond a certain threshold levels. Their behaviour is described in terms of ab(ad)sorption, storage, excretion, and regulation, as well as their route and duration of exposure (Bouchama et al. 2019). Excess metals can bioaccumulate and have acute impacts on marine plants, affecting the photosynthetic apparatus and interfering with mitochondrial activities. This can cause oxidative stress, impede plant metabolism, reduce growth and development, induce leaf chlorosis, and inhibit seed germination (Lewis and Devereaux 2009, Okereafor et al. 2020). Despite these effects, the lack of heavy metal contamination guidelines for both marine plants and invertebrates in Canada is clearly an impediment for impact assessment studies such as this one and, more generally, for the study of potential toxic elements accumulation in marine plants (Geng et al. 2019, LeBlanc et al. 2020).

Although some aquatic plants can employ certain tolerance mechanisms to absorb some contaminants, the uptake ability widely depends on the plant species and the nature of the contaminant (Baker and Walker 1989, Bouchama et al. 2019), highlighting the importance of species- and contaminant-specific ecotoxicological studies. However, very few studies of *Zostera marina* plants and heavy metal contamination are available, especially ecotoxicological studies on mercury or arsenic contamination. Field studies show that eelgrass bioaccumulates arsenic and mercury mostly in belowground tissues (Lin et al. 2016), which is consistent with the higher levels of contaminants in rhizome tissue compared to leaf tissue measured in this study. Existing laboratory studies suggest that eelgrass growth is strongly inhibited by mercury, depending on mercury concentration in surrounding water and exposure time (Lyngby and Brix 1982) and some recent research is exploring the phytoremediation and bioindicator potential of *Zostera marina* transplants in bays polluted by heavy metals, including arsenic and mercury (Lee et a. 2019). However, further research is required to better characterize ecotoxicological effects.

The high levels of heavy metal contaminants measured in Webbs Cove are particularly relevant for assessing the potential impacts of the LNG terminal construction, as this cove is located 2 km north of Bettys Cove, the proposed LNG terminal site. No sediments or eelgrass plants could be collected from the boat platform in Bettys Cove (too many boulders), thus, we were unable to obtain contamination data for sediments or plant tissues at that precise location (Figure 2). However, Bettys Cove is close to two legacy stamp mills located ~200 m north and we would expect similar contamination of sediments and plants as observed in Webbs Cove. A 2008 metal(loid)s study in Isaacs Harbour showed sediment contamination levels of 40 ppm for arsenic and 160 ppb for mercury in Bettys Cove (Walker and Grant 2015). While these levels are lower than those in neighbouring Webbs Cove (stations IsH16 and IsH19) and much lower than station WnHi15 in Wine Harbour, the most contaminated station in our study, they still exceed the CCME ISQG limits for arsenic (7.24 ppm) and mercury (130 ppb). Therefore, there seems to be a significant risk of impact on benthic habitat and contamination of marine biota from resuspension of sediments during a construction and operation of a ship terminal such as the LNG terminal proposed in Bettys Cove, Goldboro. Importantly, any effects of heavy metal contamination would likely overlap with other impacts of the coastal development including increased turbidity/reduced light availability and sediment deposition. As such, an understanding of cumulative and interactive effects of multiple stressors may be critical for determining overall impact on the benthos and coastal food web. The occurrence of healthy eelgrass beds in the vicinity within a patchy mosaic of other critical fish habitats (kelp and fucoids) presents a particular sensitivity as coastal fish utilize these habitats differently throughout different life-history stages (Cote et al. 2004, Schneider et al. 2008).

This pre-impact assessment is useful to inform managers of potential construction impacts on eelgrass functioning, particularly for activities that will disrupt and disturb sediments nearby to or directly in eelgrass beds. The pre-construction plant and sediment data will allow meaningful comparisons with post-construction data and will also potentially provide insight into the impacts of construction activities on eelgrass that are relevant across regions. In addition to environmental impact assessments, the distribution and abundance of eelgrass, kelps and other macroalgae presented here can also support the modelling of the occurrence of critical fish habitat, relevant for management policies related to conservation planning, marine spatial planning, and emergency response (O’Brien et al. 2022).

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Data presented in this report are available from the Government of Canada Open Data portal at https://open.canada.ca/data/en/dataset/ee88aa17-fd30-4d4a-8924-897fd47cf560.

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APPENDICES

Appendix A. Station numbers and locations for each harbour surveyed. Coloured polygons denote the predicted distributions of 7 seabed substrate categories.

Appendix B. (a) Inverse Distance Weighting and (b) Ordinary Kriging visual comparison used to create the interpolated eelgrass map around the proposed LNG site footprint.

Appendix C. Photos extracted from short and long transects in Bettys Cove, Goldboro, NS.

Appendix D. Percent cover of macrophytes and bare substrate at each station where eelgrass was present between Wine Harbour and New Harbour.

Appendix E. Percent cover of macrophytes and bare substrate at each station were eelgrass was absent between Wine Harbour and New Harbour.

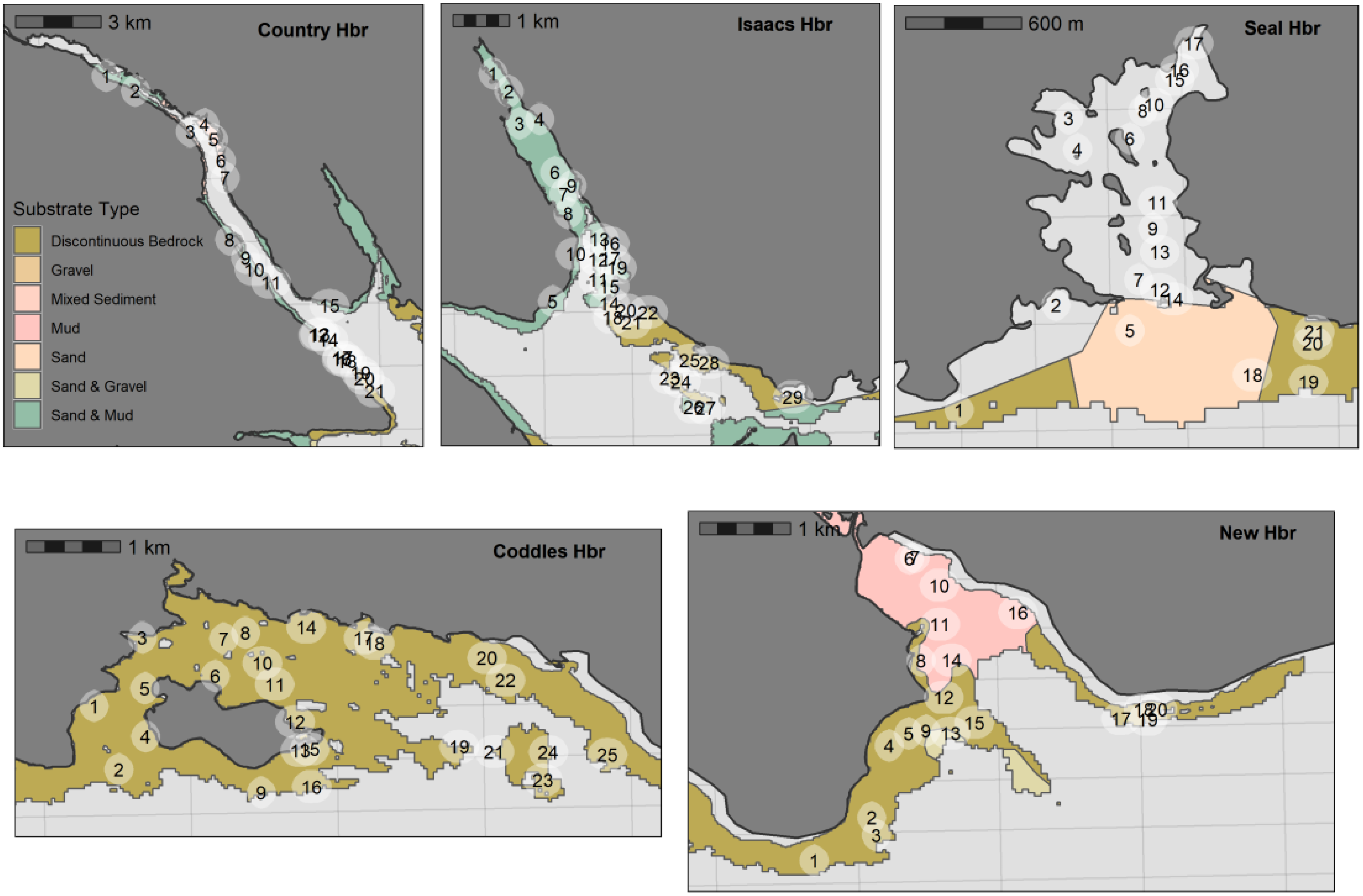
Appendix F. Analysis of 34 metals in sediments from 58 stations between Wine Harbour and New Harbour.

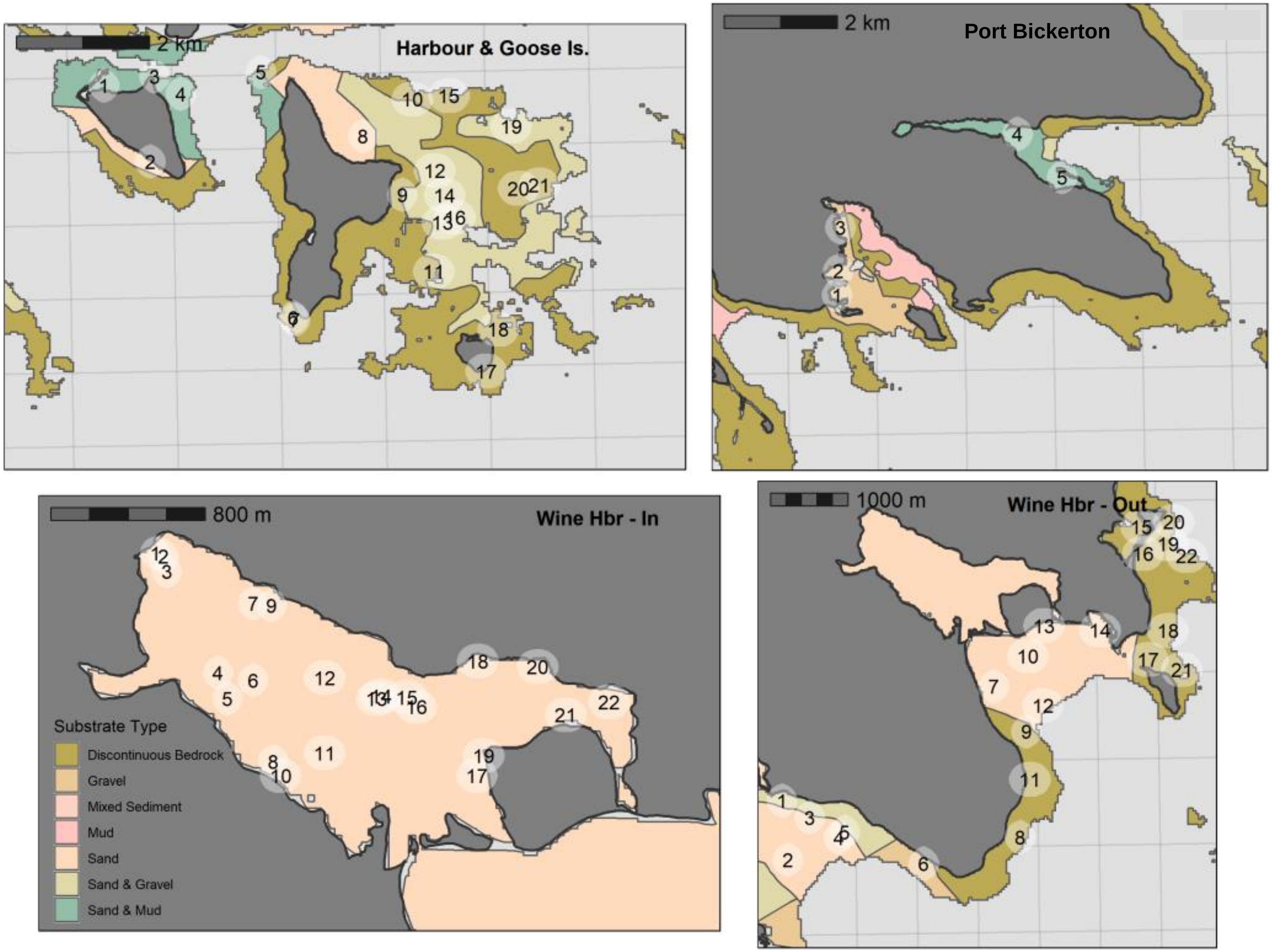
Appendix G. Analysis of 35 metals in dry rhizome tissues collected at 28 stations between Wine Harbour and New Harbour.

Appendix H. Analysis of 35 metals in dry leaf tissue collected at 28 stations between Wine Harbour and New Harbour.

Appendix I. Scatter plot of matrices for selected variables.

Appendix A. Station numbers and locations for each harbour surveyed. Coloured polygons denote the predicted distributions of 7 seabed substrate categories.




2 km
Harbour & Goose Is.
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8
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11
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13
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15
16
17
18
19
20
21
2 km
Port Bickerton
1
2
3
4
5
800 m
Wine Hbr - In
1
2
3
4
5
6
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9
10
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14
15
16
17
18
19
20
21
22
Substrate Type
Discontinuous Bedrock
Gravel
Mixed Sediment
Mud
Sand
Sand & Gravel
Sand & Mud
1000 m
Wine Hbr - Out
1
2
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8
9
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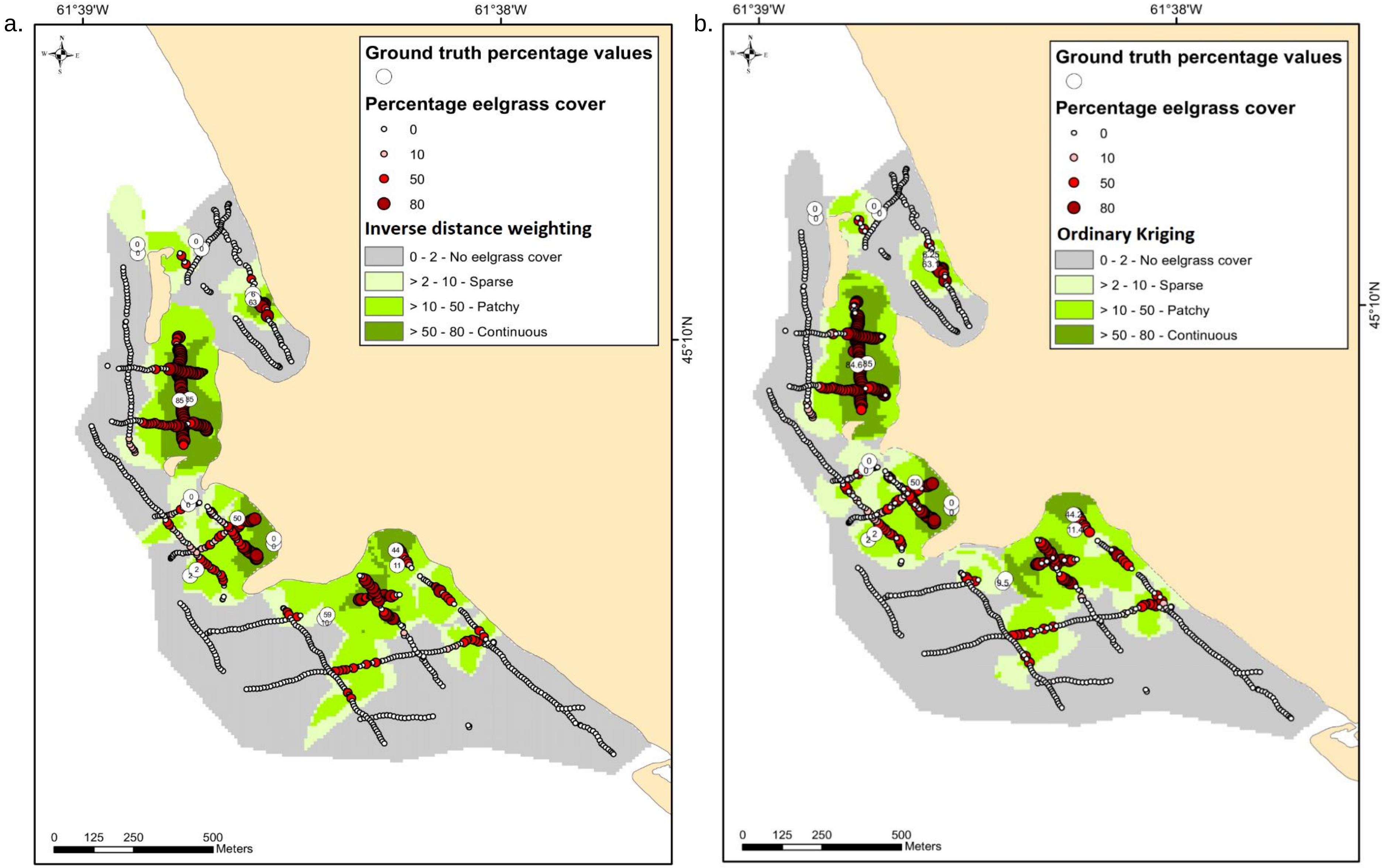
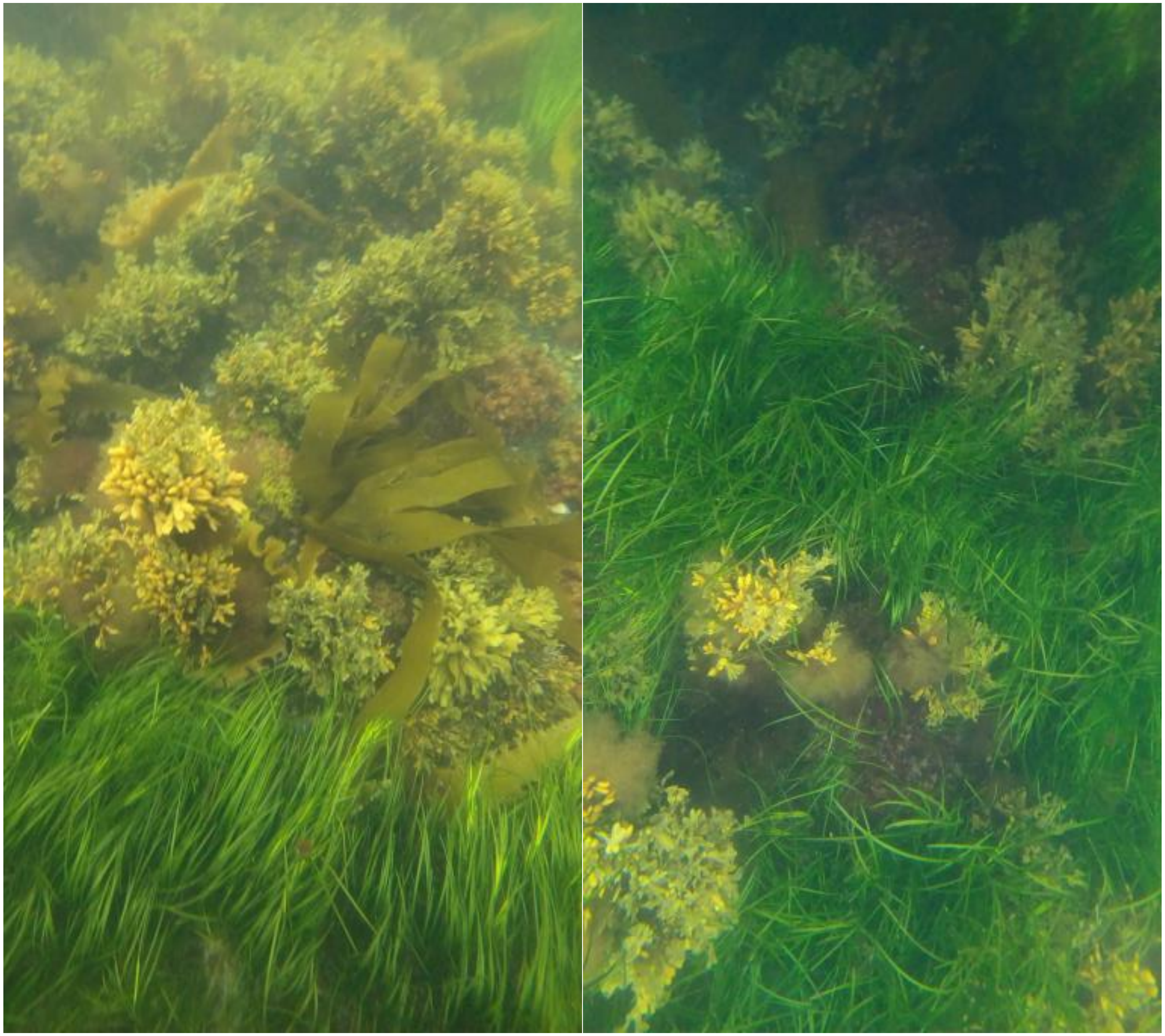
Appendix B. (a) Inverse Distance Weighting and (b) Ordinary Kriging visual comparison used to create the interpolated eelgrass map around the proposed LNG site footprint.

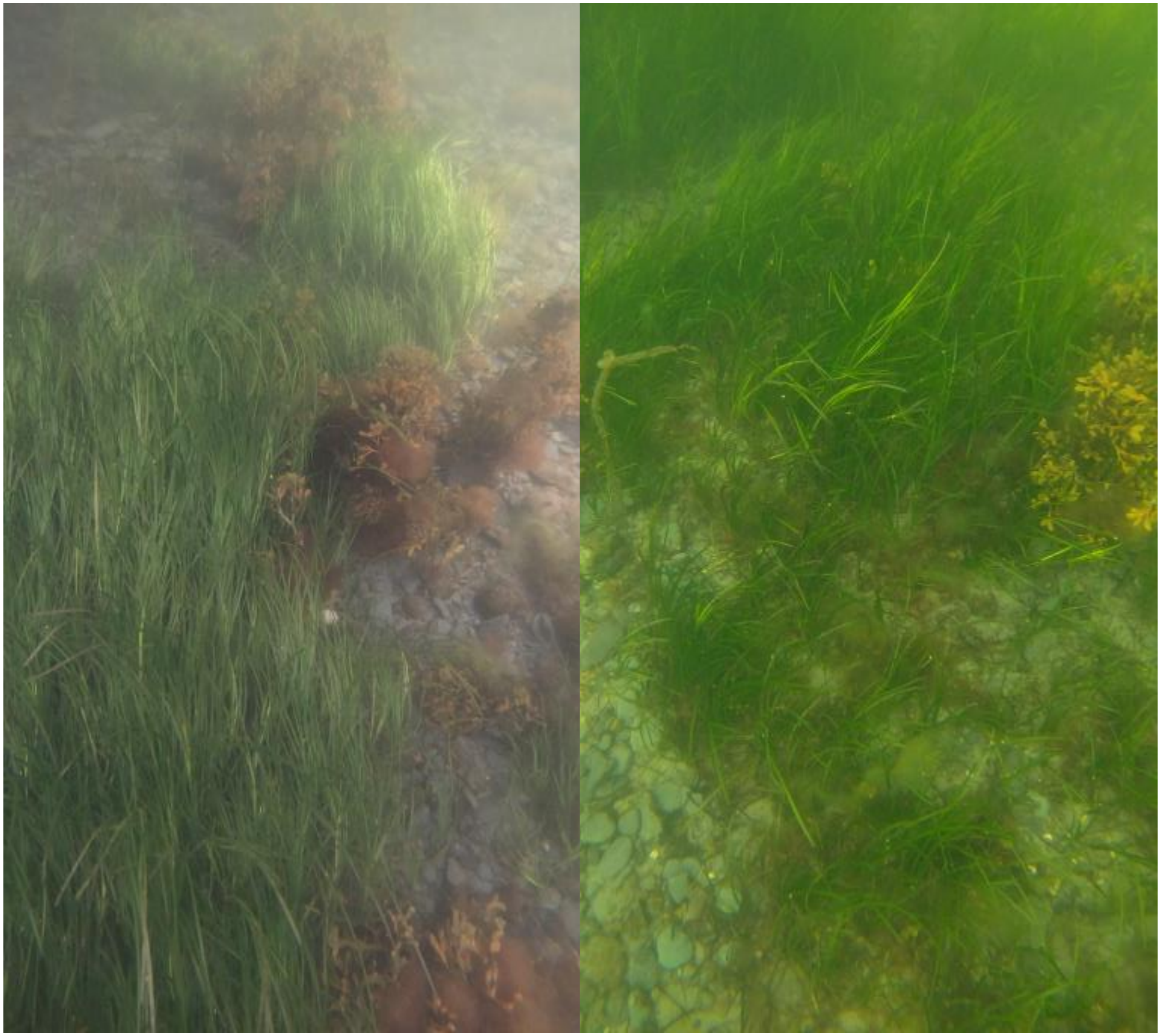


Appendix C. Photos extracted from short (a. IsH21, b. IsH22) and long transects (c.T4) in Bettys Cove, Goldboro, NS.

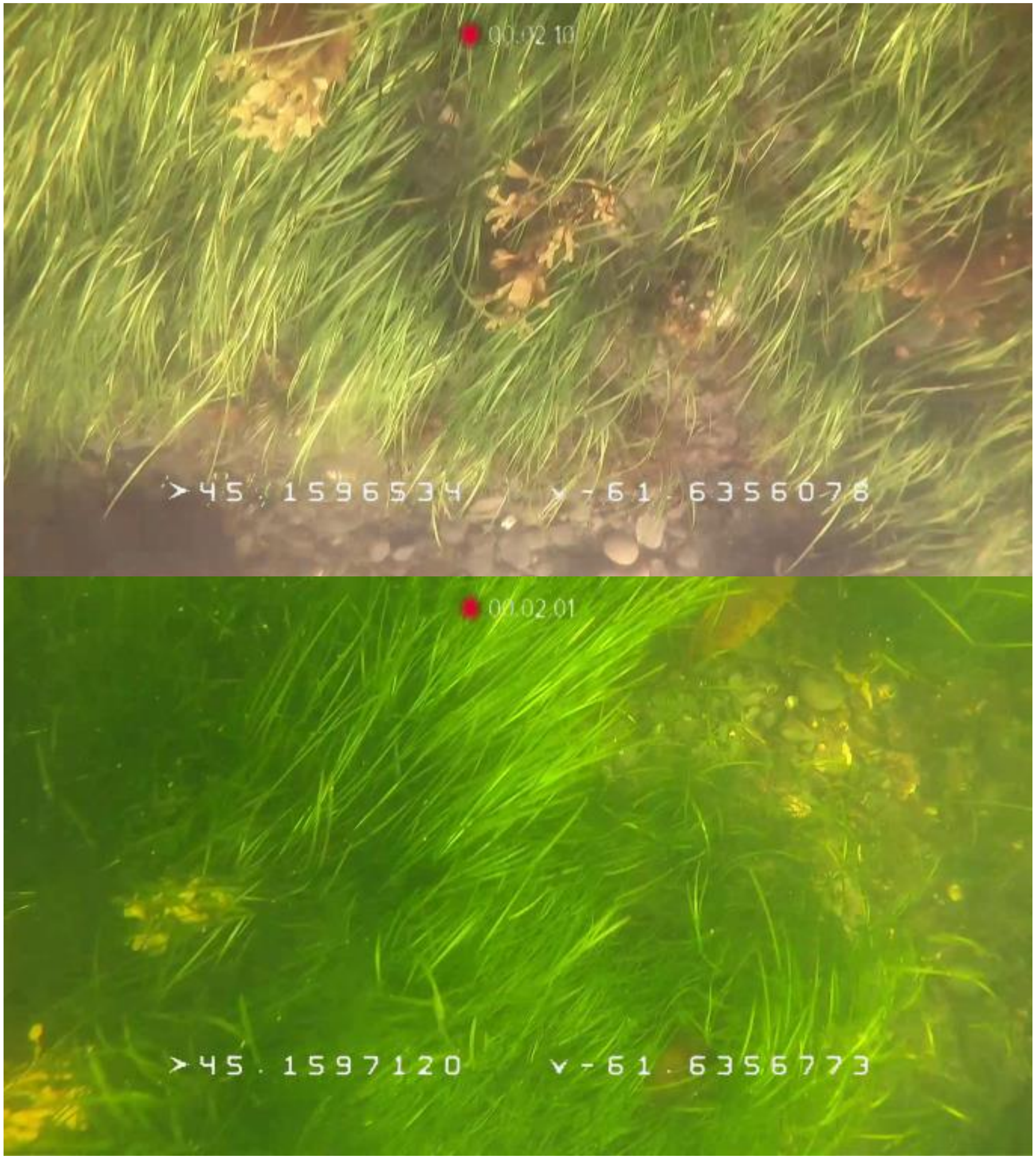
a.



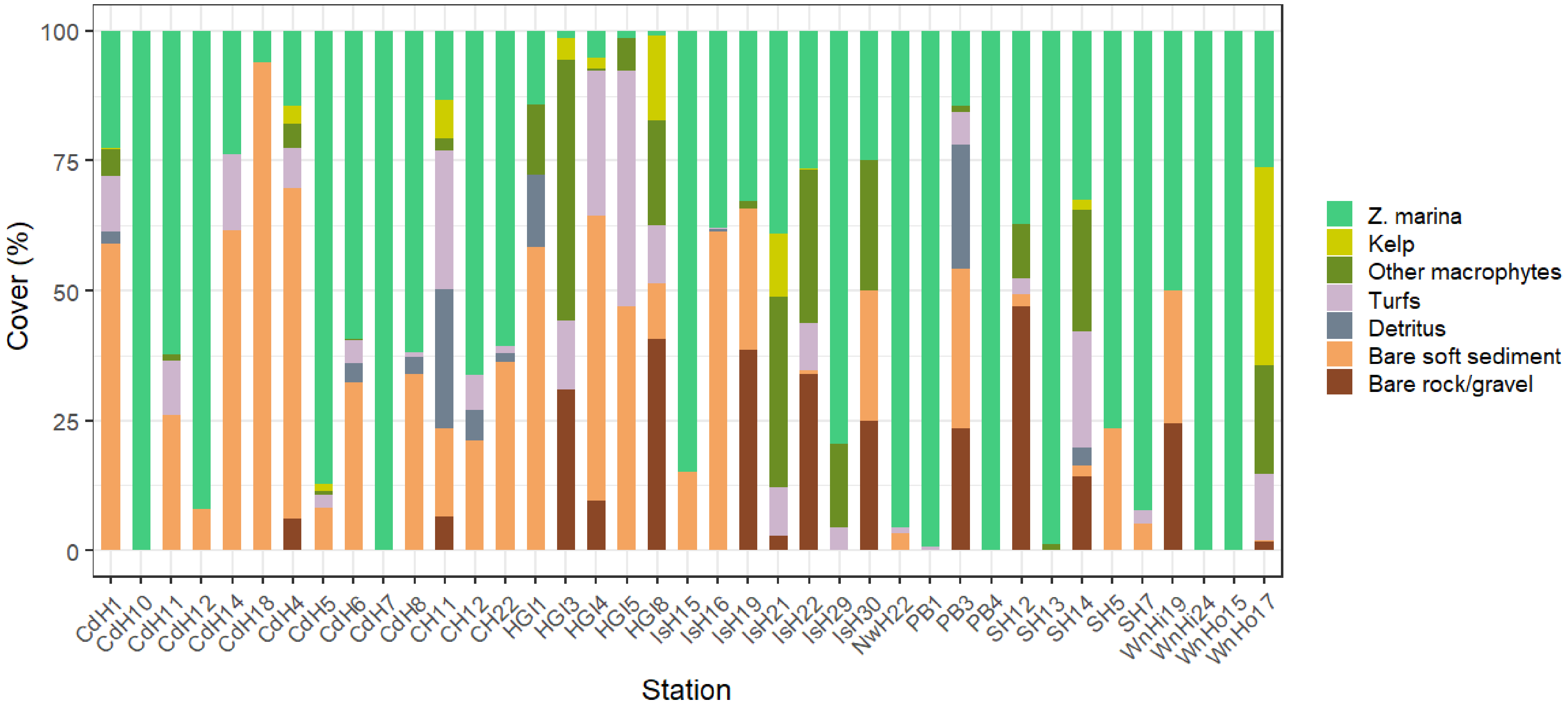
b.



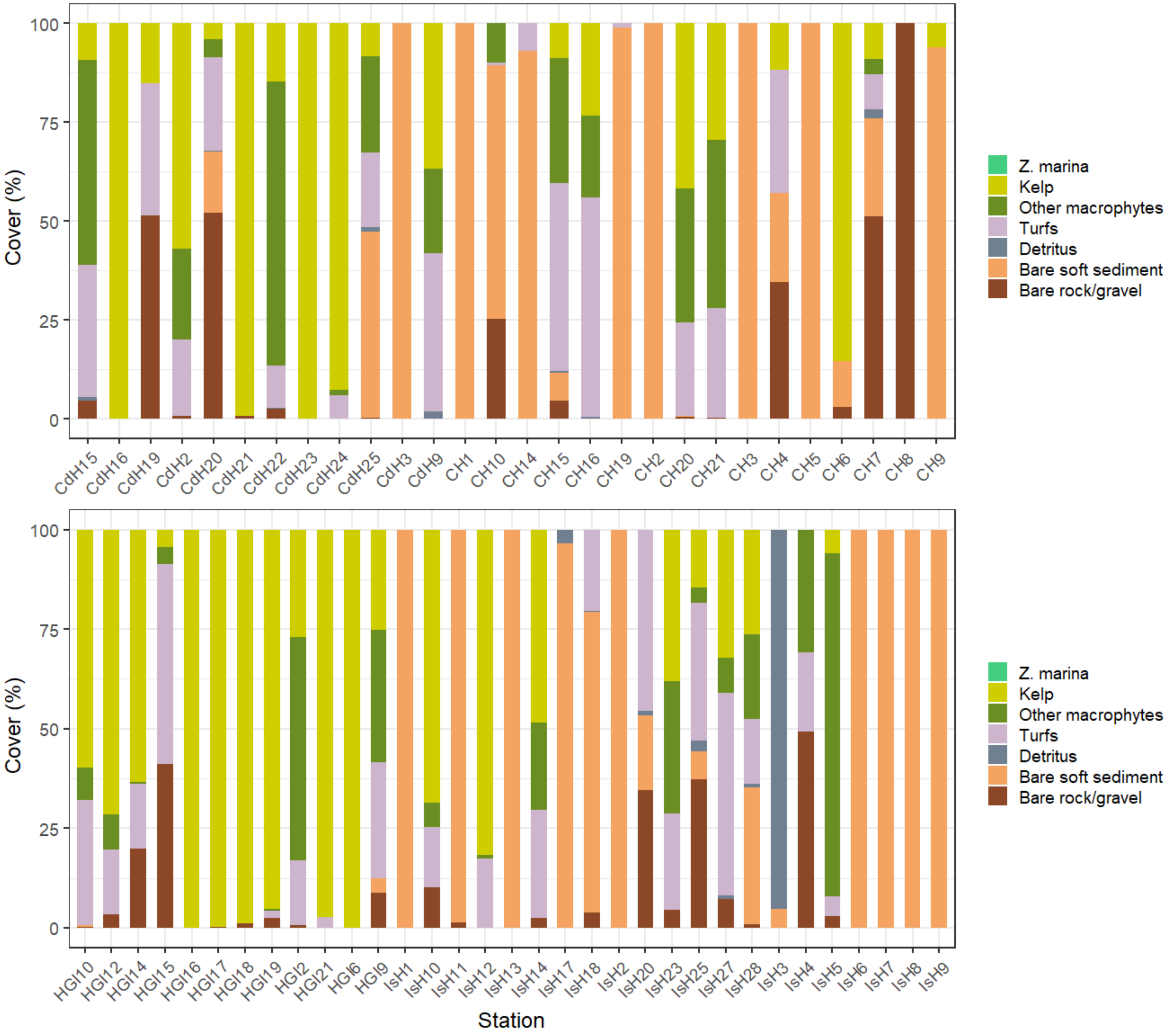
c.


00:02:10
>45.1596534
v-61.6356078
00:02:01
>45.1597120
v-61.6356773

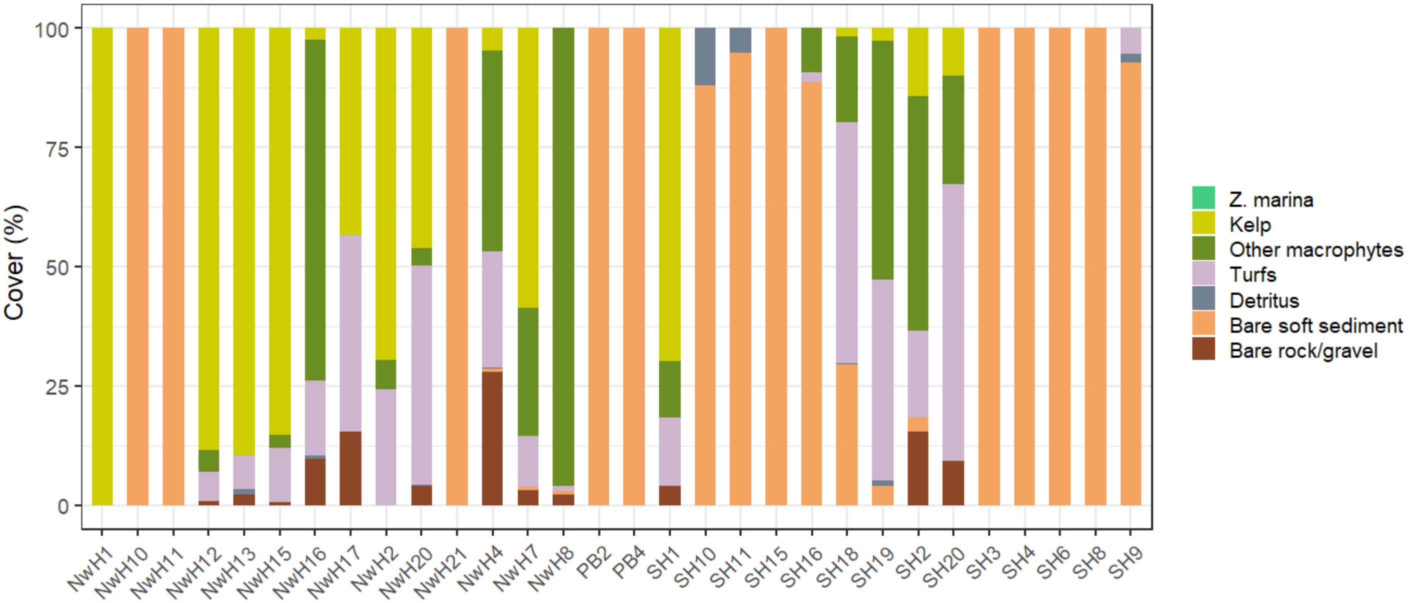
Appendix D. Percent cover of macrophytes and bare substrate at each station where eelgrass was present (n = 39) between Wine Harbour and New Harbour, ordered alphabetically (SH: Seal harbour, NwH: New Harbour, CdH: Coddles Harbour, HGI: Harbour and Goose Islands, PB: Port Bickerton, CH: Country harbour, IsH: Isaacs Harbour, WnHi, Wine Harbour inside, WnHo: Wine Harbour outside).

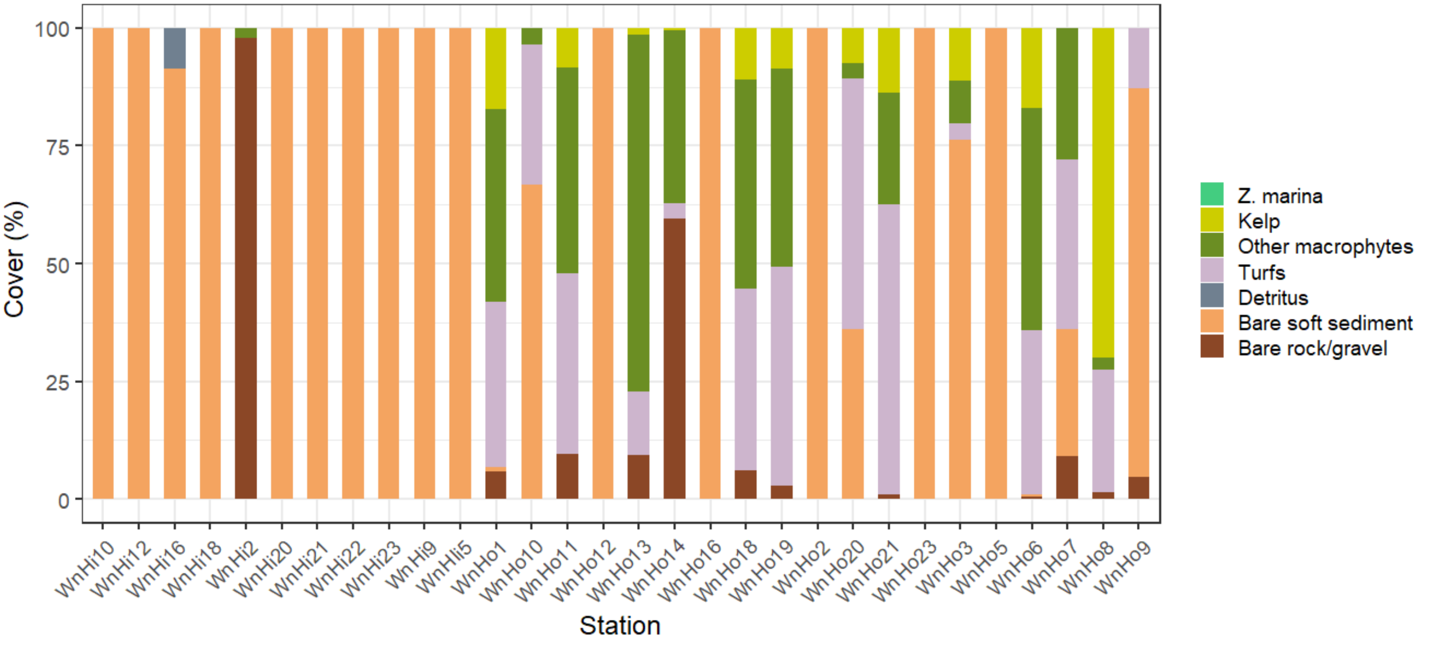


Appendix E. Percent cover of macrophytes and bare substrate at each station were eelgrass was absent (n = 121) between Wine Harbour and New Harbour, ordered alphabetically. Abbreviations are the same as in Appendix D.



Appendix E. Continued.





Appendix F. Analysis of 34 metals in sediments from 58 stations between Wine Harbour and New Harbour (SH: Seal harbour, NwH: New Harbour, CdH: Coddles Harbour, HGI: Harbour and Goose Islands, PB: Port Bickerton, CH: Country harbour, IsH: Isaacs Harbour, WnHi, Wine Harbour inside, WnHo: Wine Harbour outside).

Lab_ID	Station_Code	Station_Number	Latitude	Longitude	Aluminum (Al)	Antimony (Sb)	Arsenic (As)	Barium (Ba)	Beryllium (Be)	Bismuth (Bi)	Boron (B)	Cadmium (Cd)	Calcium (Ca)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Lithium (Li)
	Detection limit				*50*	*0.1*	*0.1*	*0.5*	*0.1*	*0.2*	*5*	*0.02*	*50*	*0.5*	*0.1*	*0.5*	*50*	*0.5*	*2*
	Unit				*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
1	SH18	18	45.14741	-61.5656	3590	<0.10	1.85	8.03	<0.10	<0.20	17.6	0.096	9540	6.58	1.89	1.94	6590	1.90	9.5
2	SH5	5	45.14949	-61.5736	3840	<0.10	1.97	7.12	<0.10	<0.20	8.4	0.048	856	6.74	1.81	1.53	7030	1.56	10.3
3	SH7	7	45.15199	-61.5731	4530	<0.10	11.4	12.3	0.12	<0.20	21.8	0.111	1300	8.43	2.38	3.84	7740	3.96	11.3
4	SH13	13	45.15333	-61.5716	3760	<0.10	7.16	9.17	<0.10	<0.20	21.2	0.073	1090	6.37	1.82	2.66	6520	2.62	9.8
5	SH12	12	45.15149	-61.5717	3540	<0.10	4.91	7.99	<0.10	<0.20	18.5	0.021	1040	5.95	1.75	2.25	5820	2.12	9.6
6	SH10	10	45.16016	-61.572	10600	0.61	149	29.4	0.31	<0.20	60.5	0.645	2880	20.1	5.85	17.3	19900	23.4	21.0
7	SH16	16	45.16182	-61.5703	10700	0.46	124	29.3	0.34	<0.20	61.1	0.707	2800	20.4	5.82	16.2	21100	24.8	21.7
8	SH3	3	45.15958	-61.5772	9490	1.15	307	20.2	0.25	<0.20	31.3	0.312	1980	16.4	4.81	16.7	17700	14.5	18.7
9	SH11	11	45.15554	-61.5717	7440	0.25	49.3	21.6	0.21	<0.20	53.5	0.429	2380	14.6	4.05	10.3	13100	11.5	17.0
10	NwH10	10	45.17434	-61.4479	4650	<0.10	2.05	10.3	0.14	<0.20	<5.0	<0.020	14500	8.28	2.44	2.41	9080	3.08	13.6
11	NwH21	21	45.17468	-61.4568	5360	<0.10	2.82	18.5	0.13	<0.20	9.4	0.126	11900	10.0	3.09	4.03	9920	2.97	14.9
12	NwH22	22	45.17009	-61.4512	6740	0.13	4.92	23.7	0.28	<0.20	21.3	0.202	7250	13.9	3.80	11.2	11800	6.66	18.3
13	CdH7	7	45.16184	-61.5351	4150	<0.10	2.07	11.5	<0.10	<0.20	36.0	0.093	1170	7.51	2.07	2.85	7110	2.42	10.8
14	CdH6	6	45.15825	-61.5364	6070	0.15	5.29	20.4	0.20	<0.20	64.8	0.400	2240	12.4	3.44	8.12	10800	8.12	14.9
15	CdH5	5	45.15707	-61.5461	4650	<0.10	2.34	12.2	<0.10	<0.20	27.6	0.067	1410	8.36	2.34	3.08	8290	2.52	11.4
16	CdH4	4	45.15274	-61.546	4110	<0.10	1.40	8.08	<0.10	<0.20	<5.0	<0.020	1900	7.09	1.98	2.06	7480	1.62	9.9
17	CdH1	1	45.15555	-61.553	3440	<0.10	1.11	6.25	<0.10	<0.20	6.2	<0.020	938	5.48	1.66	1.22	5990	1.29	8.5
18	CdH12	12	45.15373	-61.5254	3770	0.12	2.14	7.86	<0.10	<0.20	16.9	<0.020	1180	6.44	1.89	1.99	6810	1.87	9.4
19	CdH11	11	45.15745	-61.5283	5430	0.11	3.81	17.6	0.14	<0.20	28.0	0.307	2330	10.8	3.09	6.23	9900	5.64	13.6
20	CdH10	10	45.15948	-61.5299	8490	0.27	9.22	30.0	0.27	<0.20	96.6	0.490	2920	18.0	4.69	12.2	14300	10.3	18.9
21	CdH8	8	45.16229	-61.5323	3600	<0.10	0.78	7.07	0.32	<0.20	5.6	<0.020	666	6.01	1.71	0.98	6460	1.15	9.5
22	HGI1	1	45.1389	-61.6129	6180	<0.10	6.30	15.5	0.12	<0.20	22.3	0.146	1420	10.7	2.38	5.28	10800	4.67	19.4

23	PB1	1	45.09238	-61.7287	8390	0.26	7.41	28.5	0.26	<0.20	76.8	0.439	2660	16.8	4.78	13.2	14400	14.4	18.1
24	PB4	4	45.11764	-61.6875	9430	<0.10	4.69	28.1	0.16	<0.20	25.5	0.128	1390	15.9	5.61	8.77	15300	4.28	25.4
25	PB3	3	45.10316	-61.7277	4890	<0.10	1.30	10.4	<0.10	<0.20	8.8	0.049	1010	8.71	3.07	2.31	8280	3.08	13.8
26	PB2	2	45.09628	-61.7284	6200	<0.10	3.50	21.3	0.16	<0.20	20.1	0.177	1660	12.3	3.53	8.23	10400	9.59	15.6
27	PB5	5	45.1107	-61.6776	11500	0.21	8.89	34.8	0.37	<0.20	81.3	0.701	3170	23.4	6.62	20.6	19900	19.2	25.7
28	CH22	22	45.16905	-61.7015	8090	0.10	4.89	32.1	0.21	<0.20	21.7	0.139	1490	15.6	4.35	7.70	12500	6.68	21.6
29	CH12	12	45.15021	-61.6773	6120	<0.10	5.30	26.5	0.17	<0.20	24.2	0.044	2110	11.6	3.43	4.58	9900	3.95	16.7
30	CH2	2	45.22821	-61.7573	12800	0.23	15.9	38.4	0.57	<0.20	52.9	0.955	25200	24.1	6.52	15.6	19800	21.8	30.5
31	CH14	14	45.14851	-61.6732	6360	<0.10	3.47	22.9	0.12	<0.20	5.4	<0.020	5890	12.2	3.63	3.35	11000	2.80	17.2
32	CH5	5	45.21243	-61.7226	16000	0.19	19.6	49.9	0.63	0.26	65.4	0.820	4290	35.0	8.29	22.8	28200	26.9	32.6
33	CH9	9	45.17449	-61.7099	13700	0.19	14.1	48.0	0.54	0.22	61.7	0.604	3870	29.0	7.20	19.9	22200	23.5	29.4
34	WnHo15	15	45.07754	-61.8234	7060	0.20	76.4	17.6	0.20	<0.20	28.4	0.143	1700	11.9	5.23	7.95	13500	6.65	16.2
35	WnHo16	16	45.07389	-61.8222	6260	0.10	9.73	8.35	0.20	<0.20	5.2	0.021	3880	9.40	5.15	5.16	14100	3.75	15.1
36	WnHo12	12	45.05637	-61.839	4120	<0.10	3.55	6.09	0.12	<0.20	<5.0	<0.020	2050	6.68	3.27	1.89	8670	2.20	9.5
37	WnHo9	9	45.05344	-61.8416	7210	<0.10	4.75	11.5	0.18	<0.20	<5.0	<0.020	18600	10.9	5.44	4.46	15900	3.95	17.6
38	WnHo3	3	45.04379	-61.8776	6790	<0.10	3.70	6.92	0.13	<0.20	<5.0	<0.020	10100	10.4	4.75	3.02	13700	3.26	16.0
39	WnHo23	23	45.07627	-61.8284	10400	0.29	93.0	27.4	0.33	<0.20	32.9	0.259	2100	18.4	7.58	12.5	19600	12.2	21.8
40	WnHo2	2	45.03876	-61.8813	3400	<0.10	2.27	4.50	<0.10	<0.20	<5.0	<0.020	2730	5.69	2.29	1.23	6580	1.89	7.7
41	IsH11	11	45.16515	-61.6475	9800	0.17	19.6	30.1	0.29	<0.20	28.2	0.388	2410	19.3	5.24	13.4	16600	13.3	20.3
42	IsH17	17	45.16855	-61.6447	11500	0.29	53.5	34.4	0.42	0.20	58.7	0.699	2990	24.4	6.43	20.6	20200	26.4	24.9
43	IsH3	3	45.19042	-61.6646	14300	0.21	21.7	45.3	0.49	0.20	58.8	0.900	2950	29.3	6.97	21.8	21900	24.8	25.9
44	IsH18	18	45.15904	-61.6444	7020	<0.10	4.28	11.5	0.13	<0.20	<5.0	<0.020	1690	12.3	2.64	3.52	12700	2.09	17.9
45	IsH16	16	45.17087	-61.6447	7510	0.91	499	19.5	0.24	<0.20	19.5	0.265	1340	13.3	3.49	11.9	14100	12.5	15.0
46	IsH15	15	45.16416	-61.6448	6370	0.12	10.2	18.3	0.16	<0.20	25.6	0.069	1500	11.5	2.98	6.42	10400	5.60	15.1
47	IsH19	19	45.16732	-61.6425	9340	0.64	176	16.9	0.26	<0.20	16.2	0.196	1330	14.6	3.45	13.4	17100	14.5	18.5
48	IsH9	9	45.18027	-61.6529	12700	0.21	27.6	42.4	0.47	0.21	49.7	0.680	3500	26.7	6.88	20.7	22700	24.6	26.4
49	IsH29	29	45.14628	-61.6046	4910	<0.10	6.04	16.1	0.11	<0.20	48.8	0.149	1630	10.4	2.47	5.41	8120	4.72	11.0
50	WnHi23	23	45.07271	-61.8715	9360	0.95	450	18.8	0.33	<0.20	32	0.374	5970	14	5.67	9.8	19500	14.6	19.5
51	WnHi9	9	45.07648	-61.8597	13000	0.23	33.4	30.6	0.51	<0.20	105	0.588	3330	23	8.35	16.5	25600	17.2	25.9
52	WnHi20	20	45.07289	-61.8423	5110	1.17	455	8.73	0.11	<0.20	12	0.077	1480	7.97	2.94	6	10600	5.11	8.7
53	WnHi10	10	45.06822	-61.8593	11600	0.18	16.4	26.7	0.44	<0.20	66.4	0.463	2870	20.6	7.71	14.5	23000	13.5	24.5
54	WnHi24	24	45.06947	-61.8462	7070	0.14	14.3	17.9	0.23	<0.20	32.8	0.134	6240	11.3	5.62	7.58	14500	6.27	16.2
55	WnHi18	18	45.0734	-61.8462	4440	4.47	1890	7.74	0.1	<0.20	9.4	0.062	4600	6.56	3.3	5.48	11200	5.95	8.6

56	WnHi22	22	45.07137	-61.8377	10500	0.67	220	24	0.33	<0.20	73.9	0.341	31600	15.6	6.25	12.7	19600	19	18.8
57	WnHi5	5	45.07164	-61.863	15000	0.25	21.9	39.2	0.54	<0.20	48.3	0.423	3830	24.5	9.4	17.7	27000	15.9	26.4
58	WnHi16	16	45.07132	-61.8503	9440	0.17	13.7	24.1	0.35	<0.20	48.5	0.311	2830	15.2	6.49	11.1	16800	9.22	19.4

Appendix F. Continued.

Lab_ID	Station_Code	Magnesium (Mg)	Manganese (Mn)	Mercury (Hg)	Molybdenum (Mo)	Nickel (Ni)	Phosphorus (P)	Potassium (K)	Selenium (Se)	Silver (Ag)	Sodium (Na)	Strontium (Sr)	Sulfur (S)	Thallium (Tl)	Tin (Sn)	Titanium (Ti)	Uranium (U)	Vanadium (V)	Zinc (Zn)	Zirconium (Zr)
	Detection limit	*20*	*1*	*0.005*	*0.1*	*0.5*	*50*	*100*	*0.2*	*0.1*	*50*	*0.5*	*1000*	*0.05*	*2*	*1*	*0.05*	*0.2*	*2*	*1*
	Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
1	SH18	2960	151	<0.0050	1.08	5.99	349	760	<0.20	<0.10	7000	37.5	1400	<0.050	<2.0	161	0.522	6.76	15.3	1.1
2	SH5	2290	148	<0.0050	0.62	6.10	229	570	<0.20	<0.10	1890	9.78	<1000	<0.050	<2.0	193	0.441	6.08	15.0	1.1
3	SH7	3410	158	0.0126	0.83	7.59	393	1000	<0.20	<0.10	7070	15.7	1300	0.053	<2.0	181	0.530	9.11	19.7	1.2
4	SH13	2750	138	0.0078	0.54	5.88	328	910	<0.20	<0.10	5940	13.6	<1000	<0.050	<2.0	174	0.456	6.74	16.8	1.1
5	SH12	2490	145	0.0066	0.36	5.23	299	760	<0.20	<0.10	5060	12.8	<1000	<0.050	<2.0	197	0.415	6.38	14.4	1.1
6	SH10	7790	257	0.140	5.39	18.5	720	2370	0.60	0.12	16900	40.8	10700	0.162	<2.0	326	1.92	23.9	58.8	4.3
7	SH16	6970	270	0.162	5.60	18.2	777	2150	0.66	0.11	12200	39.8	12100	0.183	<2.0	310	2.08	23.7	57.8	3.8
8	SH3	6600	224	0.0956	1.69	16.3	663	1820	0.23	<0.10	9070	23.3	3800	0.107	<2.0	308	0.925	16.3	58.7	5.1
9	SH11	5410	206	0.0565	2.85	13.0	571	1650	0.39	<0.10	10800	30.4	5400	0.129	<2.0	263	1.07	16.6	36.5	2.7
10	NwH10	2810	240	<0.0050	<0.10	7.52	331	1010	<0.20	<0.10	1590	71.3	<1000	0.069	<2.0	291	0.345	7.61	18.9	1.6
11	NwH21	3740	242	0.0087	0.27	8.78	412	1320	<0.20	<0.10	5040	62.6	1200	0.112	<2.0	368	0.469	10.5	22.7	2.1
12	NwH22	5210	235	0.0127	1.57	11.0	517	1800	0.20	<0.10	7000	37.9	1800	0.117	<2.0	418	0.708	15.6	33.2	2.4
13	CdH7	2990	149	<0.0050	0.94	6.63	334	950	<0.20	<0.10	6010	15.6	<1000	0.050	<2.0	208	0.571	7.89	17.5	1.2
14	CdH6	4630	190	0.0173	5.61	11.4	554	1570	0.39	<0.10	11100	30.7	4500	0.107	<2.0	262	1.85	16.1	27.4	2.0
15	CdH5	3230	164	<0.0050	1.71	7.76	313	1010	<0.20	<0.10	5530	16.6	<1000	<0.050	<2.0	266	0.664	8.37	18.3	1.2
16	CdH4	2550	160	<0.0050	0.13	6.67	267	760	<0.20	<0.10	3320	13.9	<1000	<0.050	<2.0	260	0.258	6.16	15.4	1.2
17	CdH1	2260	163	<0.0050	0.21	5.29	233	580	<0.20	<0.10	4350	11.4	<1000	<0.050	<2.0	241	0.314	4.74	12.5	1.5
18	CdH12	3010	148	<0.0050	0.38	5.78	304	770	<0.20	<0.10	6790	15.5	<1000	<0.050	<2.0	207	0.415	6.20	14.8	1.1
19	CdH11	4300	190	0.0127	1.68	10.0	477	1270	0.33	<0.10	9770	25.1	3100	0.094	<2.0	238	0.711	12.7	24.2	1.7
20	CdH10	6630	235	0.0240	3.69	16.0	737	2210	0.70	<0.10	17000	39.3	5700	0.124	<2.0	291	1.33	23.7	39.3	2.3
21	CdH8	2320	148	<0.0050	0.11	5.49	223	680	<0.20	<0.10	3510	8.57	<1000	<0.050	<2.0	174	0.212	5.51	15.4	<1.0
22	HGI1	4070	205	0.0069	1.21	7.71	509	1090	0.22	<0.10	5910	15.6	1700	0.074	<2.0	206	0.656	10.6	25.9	1.5
23	PB1	6020	231	0.0326	4.79	15.7	665	1990	0.59	<0.10	13600	35.1	7200	0.121	<2.0	311	1.84	22.3	42.9	2.4
24	PB4	5570	390	0.0073	1.82	15.2	444	2570	<0.20	<0.10	6580	16.4	1600	0.141	<2.0	442	0.763	17.6	37.4	2.9
25	PB3	3180	151	0.0074	0.55	8.67	305	810	<0.20	<0.10	3430	11.4	<1000	0.057	<2.0	237	0.456	8.45	20.8	1.2

26	PB2	4080	182	0.0299	0.92	10.6	490	1380	<0.20	<0.10	6080	19.7	2100	0.087	<2.0	277	0.631	13.2	30.8	1.6
27	PB5	8190	320	0.0345	7.90	21.6	819	2830	0.86	0.13	16900	46.6	9900	0.247	<2.0	358	2.33	32.8	56.6	3.5
28	CH22	5430	202	0.0122	2.31	13.1	428	2610	0.26	<0.10	8730	18.9	2100	0.119	<2.0	451	0.958	19.7	33.4	1.7
29	CH12	4200	211	0.0056	0.45	10.0	532	2620	<0.20	<0.10	7000	21.4	<1000	0.084	<2.0	438	0.531	14.0	27.9	2.0
30	CH2	7580	314	0.0700	1.76	19.7	759	3160	0.86	0.17	15500	109	8700	0.201	<2.0	254	1.16	37.0	89.9	2.6
31	CH14	4270	204	<0.0050	0.11	10.5	297	1930	<0.20	<0.10	3740	34.1	<1000	0.076	<2.0	438	0.307	13.1	26.4	1.6
32	CH5	11200	353	0.0736	2.67	27.5	1080	4240	1.31	0.20	27000	60.8	17300	0.274	<2.0	328	1.30	46.4	76.1	4.6
33	CH9	9430	319	0.0621	3.13	23.0	1020	3850	1.07	0.16	21200	53.3	11000	0.189	<2.0	382	1.32	40.1	63.2	3.9
34	WnHo15	4470	250	0.0770	2.62	12.9	386	1330	0.23	<0.10	7680	20.0	3500	0.090	<2.0	228	0.874	15.8	31.1	2.0
35	WnHo16	3900	481	<0.0050	0.32	11.7	287	780	<0.20	<0.10	3790	21.1	<1000	<0.050	<2.0	191	0.306	11.2	27.4	3.4
36	WnHo12	2720	336	<0.0050	0.15	7.45	376	470	<0.20	<0.10	3380	14.8	<1000	0.067	<2.0	233	0.321	8.29	17.5	2.0
37	WnHo9	4510	377	<0.0050	0.24	13.3	410	540	<0.20	<0.10	1830	103	<1000	<0.050	<2.0	248	0.366	13.2	31.6	2.3
38	WnHo3	4290	371	<0.0050	0.16	12.1	295	600	<0.20	<0.10	2700	45.5	<1000	<0.050	<2.0	265	0.313	11.7	28.0	2.0
39	WnHo23	6310	311	0.243	1.82	18.3	688	2040	0.33	<0.10	11100	29.5	7600	0.140	<2.0	277	0.822	24.3	47.0	2.4
40	WnHo2	2150	231	<0.0050	0.11	6.00	569	390	<0.20	<0.10	2840	19.8	<1000	0.090	<2.0	287	0.433	6.34	14.2	1.9
41	IsH11	6310	264	0.0624	1.64	17.4	745	2170	0.48	<0.10	11300	29.5	6100	0.138	<2.0	334	0.902	25.0	45.2	2.6
42	IsH17	8160	276	0.338	4.79	21.2	791	2750	0.89	0.15	18100	44.1	10800	0.228	7.4	311	1.90	30.0	57.9	3.1
43	IsH3	9290	311	0.191	4.75	23.5	841	3510	1.00	0.17	21800	44.4	12400	0.236	2.5	424	1.79	35.8	66.5	3.5
44	IsH18	4350	242	<0.0050	0.18	10.7	343	1160	<0.20	<0.10	2660	11.5	<1000	0.071	<2.0	315	0.356	11.3	26.4	2.8
45	IsH16	4640	191	0.796	1.81	12.1	408	1510	0.35	<0.10	5210	16.1	4000	0.095	4.5	242	0.776	15.8	36.9	2.9
46	IsH15	4150	207	0.0194	1.41	10.3	586	1410	0.24	<0.10	5900	16.3	1300	0.073	<2.0	270	0.851	14.5	26.4	1.4
47	IsH19	5860	208	0.347	1.63	13.4	473	1720	0.20	<0.10	4640	16.7	2400	0.094	57.2	270	0.945	15.0	54.1	3.5
48	IsH9	7950	323	0.160	2.25	22.5	853	2960	0.85	0.16	13400	40.3	11000	0.218	2.3	356	1.08	34.4	62.2	3.6
49	IsH29	3740	154	0.0108	1.29	8.79	473	1250	0.22	<0.10	8170	22.4	1500	0.066	<2.0	299	0.577	11.1	22.6	1.8
50	WnHi23	5460	228	3.13	1.56	13.1	731	1740	0.47	<0.10	8800	51.6	9000	0.134	<2.0	247	0.914	25.8	44.7	2.6
51	WnHi9	8680	400	0.553	3.08	22.1	661	2770	0.84	0.11	19500	48.2	14900	0.206	<2.0	371	1.21	32.9	54.3	5.6
52	WnHi20	3340	130	1.15	0.93	7.63	472	640	<0.20	<0.10	3630	18.1	1500	<0.050	<2.0	107	0.622	8.31	27.4	3.7
53	WnHi10	7170	382	0.23	2.33	19.9	596	2410	0.62	<0.10	13300	37.3	11700	0.215	<2.0	313	0.95	27.8	48.2	4.6
54	WnHi24	4620	320	0.0574	1.46	12.9	362	1220	<0.20	<0.10	5770	38.2	2800	0.087	<2.0	215	0.629	16.2	30.9	2.9
55	WnHi18	3260	150	3.25	0.31	8.43	345	540	<0.20	<0.10	3600	34.6	1900	<0.050	<2.0	86.8	0.592	7.11	22.3	3.2
56	WnHi22	6560	272	2.72	4.22	15.4	595	1970	0.58	0.1	12200	112	10100	0.128	<2.0	210	1.53	24.8	44	3.6
57	WnHi5	8310	476	0.287	2.05	24.3	692	3050	0.62	0.11	12900	39.6	11600	0.217	<2.0	445	1.03	36	59.3	5.8
58	WnHi16	5630	330	0.08	2.49	16.7	475	1860	0.39	<0.10	10100	31.3	6100	0.146	<2.0	338	0.942	22.1	38.6	4.4

Appendix G. Analysis of 35 metals in dry rhizome tissues collected at 28 stations between Wine Harbour and New Harbour (see abbreviations, latitude and longitude in Appendix F). Note latitude and longitude for two additional stations, IsH30 (45.160781, -61.64263001) and WnHi25 (45.07253104, -61.84677998).

Lab_ID	**Station_Code**	**Station_Number**	**% Moisture**	**Aluminum (Al)-Total**	**Antimony (Sb)-Total**	**Arsenic (As)-Total**	**Barium (Ba)-Total**	**Beryllium (Be)-Total**	**Bismuth (Bi)-Total**	**Boron (B)-Total**	**Cadmium (Cd)-Total**	**Calcium (Ca)-Total**	**Cesium (Cs)-Total**	**Chromium (Cr)-Total**	**Cobalt (Co)-Total**	**Copper (Cu)-Total**	**Iron (Fe)-Total**	**Lead (Pb)-Total**	**Lithium (Li)-Total**
	Detection limit			*5.0*	*0.010*	*0.030*	*0.050*	*0.010*	*0.010*	*1.0*	*0.010*	*20*	*0.0050*	*0.20*	*0.020*	*0.20*	*5.0*	*0.050*	*0.50*
	Unit			*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
53	CdH1	1	2.5	279	0.033	0.856	2.11	<0.020	<0.020	273	0.578	3610	0.032	0.67	0.174	1.49	458	0.36	1.2
54	CdH10	10	5.6	291	0.073	0.990	2.61	<0.030	<0.030	629	1.06	7460	0.036	0.83	0.256	4.59	511	0.57	1.5
76	CdH11	11	5.7	558	0.063	2.04	3.57	0.021	<0.010	608	0.621	6470	0.0587	1.06	0.301	1.96	1210	0.616	2.12
75	CdH12	12	3.6	526	0.040	1.05	2.36	0.013	<0.010	363	0.529	5030	0.0433	0.88	0.268	1.90	840	0.523	1.79
59	CdH4	4	4.6	194	0.030	0.753	1.19	<0.020	<0.020	314	0.713	4160	0.015	0.47	0.203	2.13	358	0.40	1.0
70	CdH5	5	6.2	526	0.048	1.37	3.25	0.017	<0.010	811	0.503	9330	0.0479	0.97	0.249	2.20	1050	0.632	1.99
51	CdH6	6	3.4	189	0.023	0.804	1.86	<0.020	<0.020	384	0.544	4550	0.021	0.70	0.137	1.32	367	0.32	<1.0
64	CdH7	7	10.0	438	0.018	0.703	1.78	0.013	<0.010	271	0.468	4340	0.0418	1.88	0.223	1.24	570	0.374	1.60
72	CdH8	8	2.2	212	0.029	0.408	1.32	<0.010	<0.010	303	0.586	4330	0.0225	0.50	0.159	1.45	342	0.214	1.14
52	CH22	22	4.2	415	0.039	1.39	4.87	<0.020	<0.020	394	0.377	4860	0.078	0.97	0.292	2.14	764	0.67	1.9
66	CH12	12	3.8	216	0.027	0.752	1.90	<0.010	<0.010	194	0.510	3480	0.0363	0.43	0.157	1.82	306	0.491	1.13
65	IsH30	30	3.9	339	0.062	1.43	2.49	<0.010	<0.010	476	0.652	5850	0.0367	0.64	0.310	2.42	493	2.42	1.39
77	IsH15	15	2.3	257	0.018	1.63	1.70	<0.010	<0.010	346	0.412	3750	0.0271	0.46	0.149	1.43	536	0.362	1.00
74	IsH16	16	2.5	467	0.153	83.0	2.01	0.016	<0.010	313	0.462	4080	0.0469	0.76	0.287	2.53	1040	1.47	1.44
60	IsH18	18	3.9	340	0.057	1.76	4.57	<0.020	<0.020	492	0.830	5960	0.030	0.72	0.346	2.49	977	0.67	2.0
55	IsH19	19	3.6	370	0.035	8.18	1.37	<0.020	<0.020	208	0.271	3420	0.036	0.75	0.208	1.76	757	0.76	1.4
69	IsH29	29	2.7	130	0.019	0.655	1.18	<0.010	<0.010	288	0.327	3780	0.0137	0.29	0.107	1.29	285	0.304	0.88
68	NwH22	22	3.5	835	0.060	2.40	4.94	0.033	<0.010	586	0.341	7380	0.103	3.12	0.441	3.99	1330	1.09	2.92
71	PB1	1	2.9	148	0.015	0.649	1.26	<0.010	<0.010	255	0.338	3740	0.0171	0.43	0.124	1.24	283	0.338	0.72
57	PB4	4	3.2	247	0.036	1.08	1.92	<0.020	<0.020	370	0.352	4630	0.039	0.65	0.174	1.39	448	0.39	1.3
67	PB5	5	3.3	357	0.051	2.06	2.52	0.013	<0.010	383	0.432	4780	0.0482	0.79	0.249	1.48	547	0.608	1.45
50	SH12	12	4.3	585	0.056	4.02	3.53	<0.030	<0.030	556	0.510	6410	0.057	1.44	0.343	2.00	1180	0.91	2.5

56	SH13	13	3.0	337	<0.020	2.30	1.75	<0.020	<0.020	226	0.395	3600	0.031	1.21	0.241	1.92	588	0.55	1.5
63	SH5	5	4.2	1180	0.085	3.38	6.24	0.032	0.011	543	0.735	6190	0.104	1.95	0.597	2.66	2000	1.58	3.85
73	SH7	7	2.3	898	0.046	5.01	4.22	0.026	<0.010	554	0.435	5410	0.0771	2.02	0.420	1.79	1480	1.08	2.62
61	WnHi24	24	8.1	396	0.036	1.36	2.32	<0.020	<0.020	351	0.429	3750	0.041	14.9	0.653	3.70	695	0.46	1.4
58	WnHi25	25	3.5	68	0.029	0.602	1.39	<0.020	<0.020	359	0.550	4360	<0.010	<0.40	0.109	1.56	147	0.37	<1.0
62	WnHo15	15	3.9	258	0.039	5.18	2.13	<0.020	<0.020	398	0.350	4460	0.025	0.53	0.243	1.71	599	0.36	1.3

Appendix G. Continued.

Lab_ID	Station_Code	Magnesium (Mg)-Total	Manganese (Mn)-Total	Mercury (Hg)-Total	Molybdenum (Mo)-Total	Nickel (Ni)-Total	Phosphorus (P)-Total	Potassium (K)-Total	Rubidium (Rb)-Total	Selenium (Se)-Total	Silver (Ag)-Total	Sodium (Na)-Total	Strontium (Sr)-Total	Tellurium (Te)-Total	Thallium (Tl)-Total	Tin (Sn)-Total	Uranium (U)-Total	Vanadium (V)-Total	Zinc (Zn)-Total	Zirconium (Zr)-Total
	Detection limit	*2.0*	*0.050*	*0.0050*	*0.040*	*0.20*	*10*	*20*	*0.050*	*0.10*	*0.0050*	*20*	*0.10*	*0.020*	*0.0020*	*0.10*	*0.0020*	*0.10*	*1.0*	*0.20*
	Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
53	CdH1	6600	16.8	<0.0050	0.600	0.63	4200	32700	9.52	<0.20	0.0336	54300	108	<0.040	0.0050	<0.20	0.0786	0.96	18.6	<0.40
54	CdH10	9860	31.5	<0.0050	3.84	1.30	1040	29200	10.2	<0.30	0.142	45900	205	<0.060	<0.0060	<0.30	1.42	3.55	19.6	<0.60
76	CdH11	9810	24.7	<0.0050	1.67	1.03	2110	50200	13.7	<0.10	0.0419	89700	201	<0.020	0.0105	<0.10	0.326	1.97	12.4	0.40
75	CdH12	6750	21.7	<0.0050	1.85	0.86	698	18500	6.77	<0.10	0.0323	43900	140	<0.020	0.0070	<0.10	0.487	2.48	10.5	0.37
59	CdH4	6520	18.3	<0.0050	0.888	0.66	1580	20300	6.72	<0.20	0.0486	39900	121	<0.040	0.0042	<0.20	0.179	0.74	29.6	<0.40
70	CdH5	10600	21.0	<0.0050	2.38	0.93	1310	28500	8.86	<0.10	0.0350	79100	246	<0.020	0.0087	0.12	0.377	1.92	13.8	0.37
51	CdH6	6010	10.3	<0.0050	1.06	0.50	2300	32500	9.84	<0.20	0.0178	42600	147	<0.040	0.0046	<0.20	0.148	0.84	9.7	<0.40
64	CdH7	7420	20.6	<0.0050	0.915	0.75	3060	30900	8.28	<0.10	0.0172	71700	122	<0.020	0.0065	<0.10	0.149	1.20	15.7	0.49
72	CdH8	7250	18.3	<0.0050	1.25	0.51	879	26700	8.28	<0.10	0.0438	49600	116	<0.020	0.0041	0.16	0.367	1.02	13.7	<0.20
52	CH22	8290	26.7	<0.0050	1.49	1.00	938	22400	8.48	<0.20	0.0274	51500	155	<0.040	0.0066	<0.20	0.292	2.18	19.1	<0.40
66	CH12	7760	13.7	<0.0050	0.692	0.44	4210	30000	9.25	<0.10	0.0533	56100	107	<0.020	0.0045	<0.10	0.0538	0.60	23.6	<0.20
65	IsH30	9010	33.7	<0.0050	1.67	1.24	1310	38800	12.7	<0.10	0.0967	46000	160	<0.020	0.0054	<0.10	0.380	1.75	14.9	0.23
77	IsH15	6860	12.6	<0.0050	1.03	0.49	3010	23200	8.14	<0.10	0.0376	42800	128	<0.020	0.0047	<0.10	0.146	1.13	15.3	<0.20
74	IsH16	7250	20.9	0.0922	1.29	0.83	1740	24400	8.35	<0.10	0.0460	46000	119	<0.020	0.0096	<0.10	0.221	2.40	14.0	0.33
60	IsH18	11700	30.8	<0.0050	1.80	1.12	1100	26000	8.40	<0.20	0.0590	63200	184	<0.040	0.0073	<0.20	0.287	1.47	11.3	<0.40
55	IsH19	6620	15.8	0.0170	0.699	0.61	4350	28000	8.87	<0.20	0.0244	46000	91.8	<0.040	0.0056	1.34	0.0770	1.07	17.2	<0.40
69	IsH29	7330	9.06	<0.0050	0.672	0.33	2680	36100	10.2	<0.10	0.0272	67500	119	<0.020	0.0034	<0.10	0.0700	0.40	12.5	<0.20
68	NwH22	12600	35.6	0.0072	1.93	1.84	5110	35900	11.5	<0.10	0.0399	86500	202	<0.020	0.0121	<0.10	0.356	2.87	34.1	0.48
71	PB1	6400	12.4	<0.0050	0.712	0.39	2870	28100	9.66	<0.10	0.0259	49800	112	<0.020	0.0036	<0.10	0.0731	0.62	10.1	<0.20
57	PB4	8400	21.1	<0.0050	0.896	0.75	5270	38100	10.6	<0.20	0.0390	63200	160	<0.040	0.0054	<0.20	0.113	0.81	15.3	<0.40
67	PB5	8640	10.3	<0.0050	1.15	0.65	1460	48200	13.5	<0.10	0.0171	79700	169	<0.020	0.0065	<0.10	0.231	1.21	10.5	0.22
50	SH12	8620	27.8	0.0063	2.60	1.08	1090	23300	8.22	<0.30	0.0366	53800	186	<0.060	0.0111	<0.30	0.624	2.90	19.0	<0.60
56	SH13	7170	18.5	0.0054	0.923	0.64	1040	24600	8.28	<0.20	0.0290	57500	109	<0.040	0.0058	<0.20	0.133	1.08	15.8	<0.40
63	SH5	9670	60.2	<0.0050	2.93	2.03	1220	22300	7.66	<0.10	0.0677	62500	166	<0.020	0.0132	<0.10	0.700	5.21	39.9	1.24
73	SH7	7790	31.9	0.0062	2.05	1.34	1180	24700	8.62	<0.10	0.0327	58800	148	<0.020	0.0123	<0.10	0.447	3.30	15.3	0.65

61	WnHi24	6380	26.8	0.0143	1.05	6.79	2960	32000	12.3	<0.20	0.0691	30300	109	<0.040	0.0064	<0.20	0.215	1.44	18.4	<0.40
58	WnHi25	7250	22.4	<0.0050	0.706	0.41	2430	37900	11.8	<0.20	0.0282	55300	124	<0.040	<0.0040	<0.20	0.115	0.53	10.0	<0.40
62	WnHo15	7540	22.9	0.0077	0.828	0.60	1770	43000	13.0	<0.20	0.0310	56300	142	<0.040	0.0061	<0.20	0.129	1.09	10.0	<0.40

Appendix H. Analysis of 35 metals in dry leaf tissue collected at 28 stations between Wine Harbour and New Harbour (see abbreviations, latitude and longitude in Appendix F). Note latitude and longitude for two additional stations, IsH30 (45.160781, -61.64263001) and WnHi25 (45.07253104, -61.84677998).

Lab_ID	**Station_Code**	**Station_Number**	**% Moisture**	**Aluminum (Al)-Total**	**Antimony (Sb)-Total**	**Arsenic (As)-Total**	**Barium (Ba)-Total**	**Beryllium (Be)-Total**	**Bismuth (Bi)-Total**	**Boron (B)-Total**	**Cadmium (Cd)-Total**	**Calcium (Ca)-Total**	**Cesium (Cs)-Total**	**Chromium (Cr)-Total**	**Cobalt (Co)-Total**	**Copper (Cu)-Total**	**Iron (Fe)-Total**	**Lead (Pb)-Total**	**Lithium (Li)-Total**
	Detection limit			*50*	*0.1*	*0.1*	*0.5*	*0.1*	*0.2*	*5*	*0.02*	*50*	*0.5*	*0.1*	*0.5*	*50*	*0.5*	*2*	*20*
	Unit			*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
20	CdH1	1	4.7	70.0	0.277	0.813	1.98	<0.010	<0.010	1380	2.01	7720	0.0088	6.64	1.10	5.40	213	0.666	0.60
23	CdH10	10	2.8	115	0.192	1.09	1.88	<0.020	<0.020	1440	1.08	5870	0.016	6.46	0.647	3.38	325	0.74	<1.0
24	CdH11	11	6.8	105	0.177	0.887	1.64	<0.020	<0.020	1110	1.09	5870	0.013	9.38	0.644	3.00	285	0.66	<1.0
27	CdH12	12	4.6	41	0.188	0.603	1.49	<0.020	<0.020	1450	0.839	6710	<0.010	4.55	0.553	2.62	151	0.31	<1.0
8	CdH4	4	7.4	28.1	0.272	0.507	1.72	<0.010	<0.010	1500	2.01	7230	<0.0050	8.45	0.922	4.70	109	0.880	<0.50
6	CdH5	5	6.1	21.7	0.190	0.540	1.21	<0.010	<0.010	1660	0.637	6260	<0.0050	1.77	0.294	1.94	87.5	0.371	<0.50
26	CdH6	6	3.6	20	0.188	0.545	1.15	<0.020	<0.020	1450	1.09	6920	<0.010	2.70	0.594	2.76	105	0.26	<1.0
21	CdH7	7	4.7	89.8	0.212	0.710	1.46	<0.010	<0.010	1640	1.04	6200	0.0096	12.6	0.823	2.71	224	0.416	0.64
29	CdH8	8	4.1	34	0.271	0.490	1.59	<0.020	<0.020	1560	1.43	7440	<0.010	1.52	0.767	3.61	102	0.52	<1.0
9	CH22	22	6.7	49.5	0.215	0.592	1.40	<0.010	<0.010	1750	0.954	5630	0.0053	6.75	0.613	3.58	132	0.629	<0.50
19	CH12	12	<2.0	32.8	0.194	0.396	0.902	<0.010	<0.010	1720	1.22	5690	0.0061	2.67	0.593	2.54	88.2	0.349	0.58
5	IsH30	30	6.5	27.7	0.198	0.444	1.19	<0.010	<0.010	1500	1.49	7020	<0.0050	2.52	0.719	3.41	82.1	0.566	<0.50
22	IsH15	15	3.4	15.8	0.202	0.635	0.984	<0.010	<0.010	1660	1.11	6690	<0.0050	2.72	0.554	2.12	108	0.274	<0.50
25	IsH16	16	4.0	43	0.211	7.79	1.13	<0.020	<0.020	1530	0.883	6650	<0.010	5.05	0.594	3.28	176	0.63	<1.0
11	IsH18	18	14.6	11.0	0.248	0.541	2.07	<0.010	<0.010	1620	1.90	7510	<0.0050	4.84	0.632	4.27	85.5	0.990	0.52
12	IsH19	19	8.0	34.0	0.179	1.26	0.999	<0.010	<0.010	1510	0.870	5780	0.0062	6.08	0.616	2.70	132	0.636	0.53
16	IsH29	29	2.8	25.0	0.188	0.529	0.844	<0.010	<0.010	1520	0.760	5960	<0.0050	2.98	0.461	1.82	106	0.341	0.52
17	NwH22	22	3.8	150	0.211	1.53	2.04	<0.010	<0.010	1520	0.789	6730	0.0276	12.8	0.807	6.98	382	0.899	0.88
13	PB1	1	4.9	33.3	0.179	0.550	1.11	<0.010	<0.010	2150	0.754	6450	0.0055	4.29	0.602	2.38	140	0.343	<0.50
2	PB4	4	7.8	14.9	0.198	1.37	1.05	<0.010	<0.010	1630	0.971	5710	<0.0050	2.10	0.468	2.33	147	0.250	<0.50
4	PB5	5	7.6	75.2	0.149	1.07	1.69	<0.010	<0.010	1340	0.798	5560	0.0102	5.55	0.461	2.40	204	0.406	0.54

18	SH12	12	2.8	148	0.196	1.73	1.74	<0.010	<0.010	1410	0.654	5960	0.0150	24.0	0.798	3.21	366	0.549	0.75
10	SH13	13	7.9	37.5	0.211	2.09	1.26	<0.010	<0.010	1340	0.974	5830	0.0059	6.72	0.802	2.31	146	0.572	0.51
1	SH5	5	7.9	19.9	0.179	0.489	1.11	<0.010	<0.010	1580	1.21	6290	<0.0050	4.77	0.399	3.62	77.0	0.424	<0.50
7	SH7	7	8.8	43.7	0.200	1.12	1.59	<0.010	<0.010	1530	1.02	6180	0.0060	6.31	0.597	2.94	152	0.454	0.52
28	WnHi24	24	4.3	74	0.115	0.540	1.59	<0.020	<0.020	1310	0.847	6240	0.011	3.32	0.722	2.96	142	0.31	<1.0
3	WnHi25	25	9.6	11.5	0.216	2.49	1.07	<0.010	<0.010	1960	0.879	6070	<0.0050	1.19	0.634	2.50	194	0.346	<0.50
14	WnHo15	15	3.6	30.9	0.240	0.717	0.861	<0.010	<0.010	1650	0.730	5060	<0.0050	4.21	0.594	2.53	108	0.278	<0.50

Appendix H. Continued.

Lab_ID	**Station_Code**	**Magnesium (Mg)-Total**	**Manganese (Mn)-Total**	**Mercury (Hg)-Total**	**Molybdenum (Mo)-Total**	**Nickel (Ni)-Total**	**Phosphorus (P)-Total**	**Potassium (K)-Total**	**Rubidium (Rb)-Total**	**Selenium (Se)-Total**	**Silver (Ag)-Total**	**Sodium (Na)-Total**	**Strontium (Sr)-Total**	**Tellurium (Te)-Total**	**Thallium (Tl)-Total**	**Tin (Sn)-Total**	**Uranium (U)-Total**	**Vanadium (V)-Total**	**Zinc (Zn)-Total**	**Zirconium (Zr)-Total**
	Detection limit	*1*	*0.005*	*0.1*	*0.5*	*50*	*100*	*0.2*	*0.1*	*50*	*0.5*	*1000*	*0.05*	*2*	*1*	*0.5*	*0.05*	*0.2*	*2*	*1*
	Unit	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*	*mg/kg*
20	CdH1	9230	196	<0.0050	10.5	3.71	1980	26000	7.19	<0.10	0.0541	33900	204	<0.020	0.0040	<0.10	0.461	1.97	23.7	<0.20
23	CdH10	6610	177	0.0081	6.86	2.94	3470	23800	8.07	<0.20	0.075	31700	135	<0.040	<0.0040	<0.20	0.246	1.93	19.6	<0.40
24	CdH11	6700	108	0.0057	6.64	4.18	3940	21900	6.63	<0.20	0.104	28700	155	<0.040	<0.0040	<0.20	0.295	1.74	17.8	<0.40
27	CdH12	6870	115	0.0052	8.68	2.11	2050	24400	7.90	<0.20	0.053	28000	149	<0.040	<0.0040	<0.20	0.211	1.05	14.4	<0.40
8	CdH4	8140	141	<0.0050	8.45	4.37	2510	21900	6.37	<0.10	0.0758	29300	187	<0.020	0.0061	<0.10	0.261	1.02	41.5	<0.20
6	CdH5	6710	94.8	0.0052	5.65	1.34	3110	24400	7.25	<0.10	0.0674	32800	150	<0.020	0.0044	<0.10	0.177	0.73	14.6	<0.20
26	CdH6	6660	148	<0.0050	8.08	1.55	3360	28500	9.74	<0.20	0.042	29600	152	<0.040	<0.0040	<0.20	0.188	0.80	14.0	<0.40
21	CdH7	7990	114	0.0103	9.14	5.66	3530	26600	8.21	<0.10	0.0462	37900	154	<0.020	0.0044	<0.10	0.494	2.01	16.0	<0.20
29	CdH8	7420	146	<0.0050	8.65	1.39	1630	22100	6.53	<0.20	0.037	28200	181	<0.040	0.0066	<0.20	0.346	0.88	20.3	<0.40
9	CH22	7140	257	0.0068	6.13	3.27	2450	22500	7.21	<0.10	0.0498	34200	137	<0.020	0.0043	<0.10	0.294	2.54	22.7	<0.20
19	CH12	7010	136	<0.0050	6.79	1.58	3580	27600	8.54	<0.10	0.0844	37200	136	<0.020	0.0049	<0.10	0.178	0.64	19.5	<0.20
5	IsH30	7540	158	<0.0050	6.35	2.48	2350	29600	10.0	<0.10	0.134	35900	144	<0.020	0.0057	<0.10	0.253	0.91	19.6	<0.20
22	IsH15	7530	116	<0.0050	8.82	1.35	3320	28200	8.94	<0.10	0.0849	32000	150	<0.020	0.0047	<0.10	0.237	1.00	14.6	<0.20
25	IsH16	6940	144	0.0243	6.75	2.14	2520	23800	7.61	<0.20	0.072	28300	143	<0.040	0.0051	<0.20	0.210	1.09	14.6	<0.40
11	IsH18	9530	181	<0.0050	7.66	2.60	2780	20000	5.98	<0.10	0.144	39600	173	<0.020	0.0051	<0.10	0.254	1.05	17.9	<0.20
12	IsH19	6950	119	0.0114	6.62	2.81	5170	29500	9.79	<0.10	0.0386	36200	139	<0.020	0.0046	0.33	0.177	0.82	17.8	<0.20
16	IsH29	7740	87.5	<0.0050	8.50	1.42	3840	27900	8.46	<0.10	0.0425	37200	137	<0.020	0.0044	<0.10	0.290	0.98	14.5	<0.20
17	NwH22	9980	189	0.0131	9.35	6.21	4610	20700	7.12	<0.10	0.0753	42200	147	<0.020	0.0027	<0.10	0.429	2.46	37.1	<1.6
13	PB1	6990	203	<0.0050	5.57	1.94	4010	26100	8.70	<0.10	0.0511	33100	139	<0.020	0.0056	<0.10	0.128	1.01	15.3	<0.20
2	PB4	7350	151	0.0066	6.45	1.26	3650	26200	7.96	<0.10	0.0472	34500	140	<0.020	0.0032	<0.10	0.242	0.74	13.8	<0.20
4	PB5	7350	70.2	0.0050	6.09	3.26	2930	25900	8.02	<0.10	0.0239	35000	146	<0.020	0.0027	<0.10	0.256	1.30	17.8	<0.20
18	SH12	6630	134	0.0096	5.17	10.0	2700	21900	6.77	<0.10	0.0625	30000	140	<0.020	0.0058	<0.10	0.229	1.39	16.5	<0.20
10	SH13	7890	179	0.0111	8.33	2.98	2560	27400	8.43	<0.10	0.0368	38100	138	<0.020	0.0043	<0.10	0.280	1.13	17.4	<0.20
1	SH5	7320	102	<0.0050	6.49	2.49	3210	26500	7.85	<0.10	0.115	35600	143	<0.020	0.0044	<0.10	0.224	0.71	26.8	<0.20
7	SH7	7960	120	0.0082	7.94	3.03	2820	27600	8.36	<0.10	0.0434	37400	158	<0.020	0.0046	<0.10	0.288	1.33	16.9	<0.20

28	WnHi24	6330	160	0.0128	2.76	4.15	3440	34000	12.8	<0.20	0.125	32700	122	<0.040	<0.0040	<0.20	0.0601	0.64	26.4	<0.40
3	WnHi25	7790	215	0.0091	5.88	1.03	2990	27700	8.98	<0.10	0.0386	35700	143	<0.020	0.0038	<0.10	0.255	0.66	15.7	<0.20
14	WnHo15	7060	242	0.0091	7.36	1.80	2440	26000	8.61	<0.10	0.0417	35600	127	<0.020	0.0067	<0.10	0.226	0.92	12.5	<0.20

Appendix I. Scatter plot of matrices (SPLOM), with bivariate scatter plots below the diagonal, histograms on the diagonal, and the Pearson correlation above the diagonal. OM = organic matter, L2 = second leaf, L3 = third leaf, REI = relative wave exposure index. Lengths and widths are in mm, depth in m and grain size in µm.