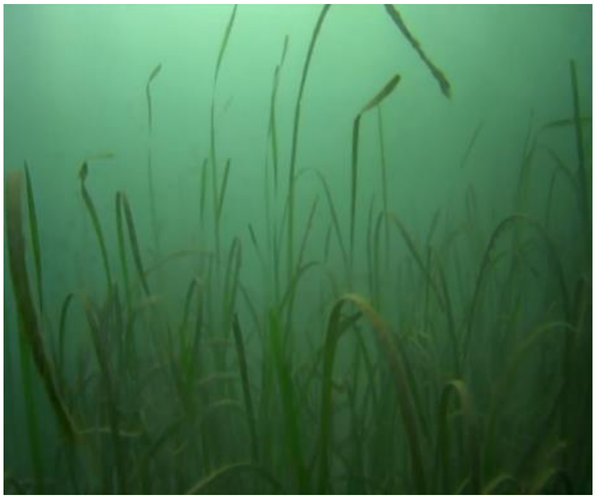
IMPACTS OF HISTORIC LOG STORAGE ON EELGRASS (*ZOSTERA MARINA*) HABITAT IN THE SALISH SEA



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PREFACE

SeaChange Marine Conservation Society, based in the Traditional Territory of the W̱SÁNEĆ First Nations in Brentwood Bay, has been restoring native eelgrass (*Zostera marina*) since 1999 in many nearshore sites of the southern Salish Sea. Often the selected sites for restoration are in decommissioned log boom areas, where woody log debris has altered the chemical, physical and biological health of the sediment over time.

In hopes we could make improved site selections for eelgrass restoration with First Nations and other members of the coastal communities surrounding the Salish Sea, we, in partnership with the Pacific Salmon Foundation supported a student from the BC Institute of Technology (BCIT) to take a deeper dive into the impacts long term log storage might have on eelgrass recovery. The report, authored by Calvin Domarchuk-White follows.

We deeply appreciate the privilege of working for nearshore marine habitat recovery in the territories of Skwxwú7mesh-ulh Temíx̱w (Squamish Nation), Shíshálh (Sechelt Nation), Homalco First Nation, We Wai Kai First Nation, Wei Wai Kum First Nation, K'ómoks First Nation, Hul'qumi'num Treaty Group, Stz'uminus First Nation, Á,LEṈENEȻ ŁTE (W̱SÁNEĆ First Nations), Quw'utsun (Cowichan Tribes). Semiahmoo First Nation and MÁLEXEŁ (Malahat Nation). We consider Calvin's research a step in the direction of healing critical marine species habitat. It is a long journey.

In gratitude,

Sincerely,

SeaChange Executive Director

EXECUTIVE SUMMARY

There is an extensive history of log storage in the Salish Sea. Often logs were stored in the same calm and protected bays that provide ideal conditions for native eelgrass (*Zostera marina*) growth. Eelgrass, which is a habitat-building species, supports biodiversity and provides valuable refugia and forage for Pacific salmon. However, when log booms are in place they block sunlight, which is necessary for eelgrass growth, and slough off organic debris that accumulates on the benthos. Together, these impacts have excluded eelgrass from many nearshore areas. Despite the decommissioning of many log storage areas, eelgrass has not recovered in many cases. Restoration practitioners have been planting eelgrass transplants in former log storage sites in an attempt to increase eelgrass habitat. To date, the outcomes of these efforts have been mixed. Transplant success in these areas is likely hampered by the lasting impacts of log storage on the seafloor and success rates could be improved with a more complete understanding of the legacy of log storage activities.

To gain insights into how a history of log storage affects eelgrass restoration, ten eelgrass transplant sites in the Salish Sea were studied. At each site, the rate of eelgrass transplant success was compared to conditions of interest: total years of log storage use, recovery time (time since last use), pore-water oxygen reduction potential (ORP) (as a proxy measurement for pore-water sulphides), total organic content and benthic invertebrate assemblage. Each site had varying log storage histories, including three 'control' sites with no history of log storage. Historic tenures were identified and mapped. Residual woody debris and sediment pore-water sulphides were identified from the literature as potential environmental stressors to eelgrass in historic wood storage areas. Underwater camera surveys were used to map residual woody debris on the seafloor and divers took subtidal sediment cores to measure pore-water sulphides and total organic content in benthic sediments. Ponar grab samples were taken for benthic invertebrate analysis, and invertebrate assemblage and species indicators were sampled as potential indicators of benthic suitability for restoration.

Analysis of the results did not find a statistically significant relationship between transplant survival and the ORP, sediment organic content, or time since decommissioning of the storage area. However, benthic invertebrate diversity index and total unique taxa were negatively correlated with transplant success and may show a biologically significant relationship.

Overall, conditions across sites were highly variable, for example, underwater camera surveys revealed little residual woody debris cover at many sites, while other sites showed accumulations of woody debris that have persisted for decades after log storage decommission. However, eelgrass was not observed growing on sediments with high woody debris cover. There was no eelgrass living in sediment with organic content >10 mg/g, however, this represents a small proportion of the sediment samples taken overall. More intensive sampling could possibly reveal a relationship between benthic sediment organic content and eelgrass productivity. However, further research would be required to determine the specific concentration of woody debris in benthic sediments that inhibits eelgrass transplant survival.

Field sampling techniques for pore-water oxygen reduction potential and benthic sediment organic content were assessed for practicality and efficacy to meet the needs of restoration practitioners for evaluating sites for restoration. The field sampling for oxygen reduction potential used in this study was deemed to be ineffective as it produced variable and unreliable results; it was also complicated and costly as it required divers for sediment core collection. A simplified method for benthic sediment organic content could be viable for routine assessment. Rather than using divers, as was done during this study, samples could be collected with a Ponar grab. Although a statistically significant relationship was not found between transplant success and benthic sediment organic content, additional sampling that is more location specific may yield more relevant results. Similarly, the viability of benthic invertebrates as indicators was hampered by costly processing which requires technical expertise. However, molecular genetic analysis, such as environmental DNA (eDNA) may offer a simpler, less invasive and more cost-effective method. Future evaluation is required to determine the potential of using eDNA as a method for the identification of potential invertebrate indicators. At the time of this report, eDNA technology is still in development by Biologica Laboratories and the University of Guelph.

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This study took place on the traditional and unceded territories of many Coast Salish Nations. Respectful acknowledgment to the original stewards of these waters are offered to:

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INTRODUCTION

Native eelgrass (*Zostera marina*) habitat is of vital importance to Salish Sea coastal ecosystems. Eelgrass, as an ecosystem engineer, creates habitat that supports incredible biodiversity. Continuous beds of eelgrass have been referred to as 'salmon highways' because they provide habitat for all six species of native anadromous Pacific salmonids at some point in their life histories (Durance 2002). The leaf surfaces of eelgrass host over 350 species of macroalgae and 91 species of epiphytic microalgae, both of which provide the base of the food web of juvenile salmonids in the Pacific Northwest (Phillips 1984). Forage fish, such as Pacific herring (*Clupea pallasii)* a critically important prey for salmonids, also find forage and refuge amongst eelgrass (Southard et al. 2008, Hay 1985).

Despite its important role in Salish Sea coastal ecosystems, the historic range of eelgrass habitat has been decreasing. While there are many factors at play, much of the observed declines in eelgrass extent can be attributed to anthropogenic activities (Nahirnik 2018, Waycott et al. 2009, Simenstad et al. 2000, British Columbia/Washington Marine Science Panel 1994). Since European colonization, population growth and industrial activities have altered and put pressure on the Salish Sea's nearshore environment. Forestry, specifically, has been British Columbia's major industry for most of its colonized history and harvested timber is transported primarily via marine waters, with up to 90% of the annual cut passing through the nearshore environment on its way to be processed (Edgell and Ross 1983). Given the extent, duration and scope of log storage and handling in British Columbia's nearshore environments, it is imperative to investigate the long-term effects of these activities in order to improve critical salmon habitat recovery strategies.

Eelgrass thrives in the sheltered bays and estuaries along the Salish Sea coastline. These calm areas that provide ideal conditions for eelgrass growth, have also been the preferred location of the forestry industry to harbor harvested logs for transport. Logs are stored in rafts or 'booms,' blocking sunlight to eelgrass meadows, which rely on adequate light for photosynthesis and growth While in place, stored logs also shed woody debris and bark that accumulates on the habitat below. This organic debris creates a cap over the benthic sediments, increases the biological oxygen demand, and prohibits pore water exchange at the sediment surface leading to anoxic conditions (Breems and Goodman 2009). Wood waste is then decomposed by sulphate-reducing bacteria that produce hydrogen sulphide in the process (Sutherland et al. 2006, Levings and Northcote 2004, Fenchel 1988, Jorgensen 1982). Hydrogen sulphide build-up in benthic sediment is toxic to eelgrass and can cause sudden die-off (Pedersen et al. 2004), and renders eelgrass seedlings more susceptible to damage and death in anoxic conditions (Dooley et al. 2012).

As many log storage tenures in the shallow nearshore are being decommissioned, these sites now have the potential to be restored. In many former log storage areas restoration practitioners have been replanting with eelgrass transplants. However, the success of eelgrass transplants in decommissioned log tenures has been varied. Transplant site selection is currently hampered by incomplete knowledge of the environmental impacts of log storage on the sea floor, and how these impacts may limit eelgrass transplant establishment and growth (N. Wright, SeaChange Marine Conservation, pers. comm.). While we do not suggest that the potential impacts from log storage are the only variables that affect eelgrass transplant survival in the Salish Sea, very few data exist to assess the scope of impact from log storage to the sea floor.

This study examined the impacts of log storage on eelgrass habitat and restoration success in the Salish Sea nearshore environment. Ten eelgrass transplant sites in the Salish Sea with various log storage histories were evaluated. The overall success of the transplants at each site was compared to several environmental variables relating to historic log storage activities: namely, the total duration of log storage in that area, the time passed since decommission, the oxygen reduction potential in the pore-water of benthic sediments, the concentration of woody debris remaining in the sediment, and the community composition of benthic invertebrates living at these sites.

The goal of this research was to provide data that would contribute to establishing a threshold of impact for eelgrass transplant survival in historic log storage areas and improve site selection for eelgrass habitat restoration in the Salish Sea.

METHODS

Study Sites

Ten eelgrass transplant sites in the Salish Sea were chosen for this study (Figure 1, Table 1). The study sites were limited to those that had received eelgrass transplants in the last five years, had been monitored at least once post-transplant, and were accessible. As such, there are certain variations between sites that could not be controlled for (size, orientation, prevailing currents etc.). However, all sites are relatively sheltered from wind energy and are quiescent enough to allow for fine sediments to settle and provide an ideal rooting matrix for eelgrass plants (see Appendix 8.1 for fetch maps).

Sites represent different regions of the Salish Sea and a range of log use history (Figure 1). For organizational purposes, sites were grouped into three major geographical regions: Howe Sound (Cotton Bay, Halkett Bay, and Tunstall Bay), Sechelt Inlet (Lamb Bay and Porpoise Bay), and East Coast Vancouver Island (Cowichan Bay, Genoa Bay, Mill Bay, and Maple Bay and Royston Wrecks). Seven of these sites have some history of log storage (Cotton Bay, Halkett Bay, Lamb Bay, Cowichan Bay, Genoa Bay, Mill Bay, and Royston Wrecks), and one site from each of the three regions is a 'control' or reference site with no history of log storage (Tunstall Bay, Porpoise Bay, and Maple Bay). All but one site was planted by SeaChange Marine Conservation as part of a coastal restoration initiative. These sites were scheduled for monitoring by SeaChange over the study period, allowing fieldwork to coincide with monitoring efforts. The exception is the Royston Wrecks site, which was transplanted by Project Watershed and monitored by the K'ómoks Watchmen Guardians.

Table 1. Site summary.

SITE	SIZE (HA)	ORIENTATION	LOCATION	HISTORY OF LOG STORAGE	RESTORATION DATE(S)
Cotton Bay	23.2	SW	HS	YES	2019
Halkett Bay	32.2	SW	HS	YES	2016; '18
Tunstall Bay	35.4	SW	HS	NO	2019
Lamb Bay	11.6	SW	SI	YES	2014; '20
Porpoise Bay	92.6	NE	SI	NO	2020
Cowichan Bay	264.1	SE	ECVI	YES	2019
Royston Wrecks	1,006.2	SE	ECVI	YES	2015
Genoa Bay	40.3	S	ECVI	YES	2013; '14; '16; '18
Mill Bay	74.4	SE	ECVI	YES	2014
Maple Bay	62.4	N	ECVI	NO	2014; '15

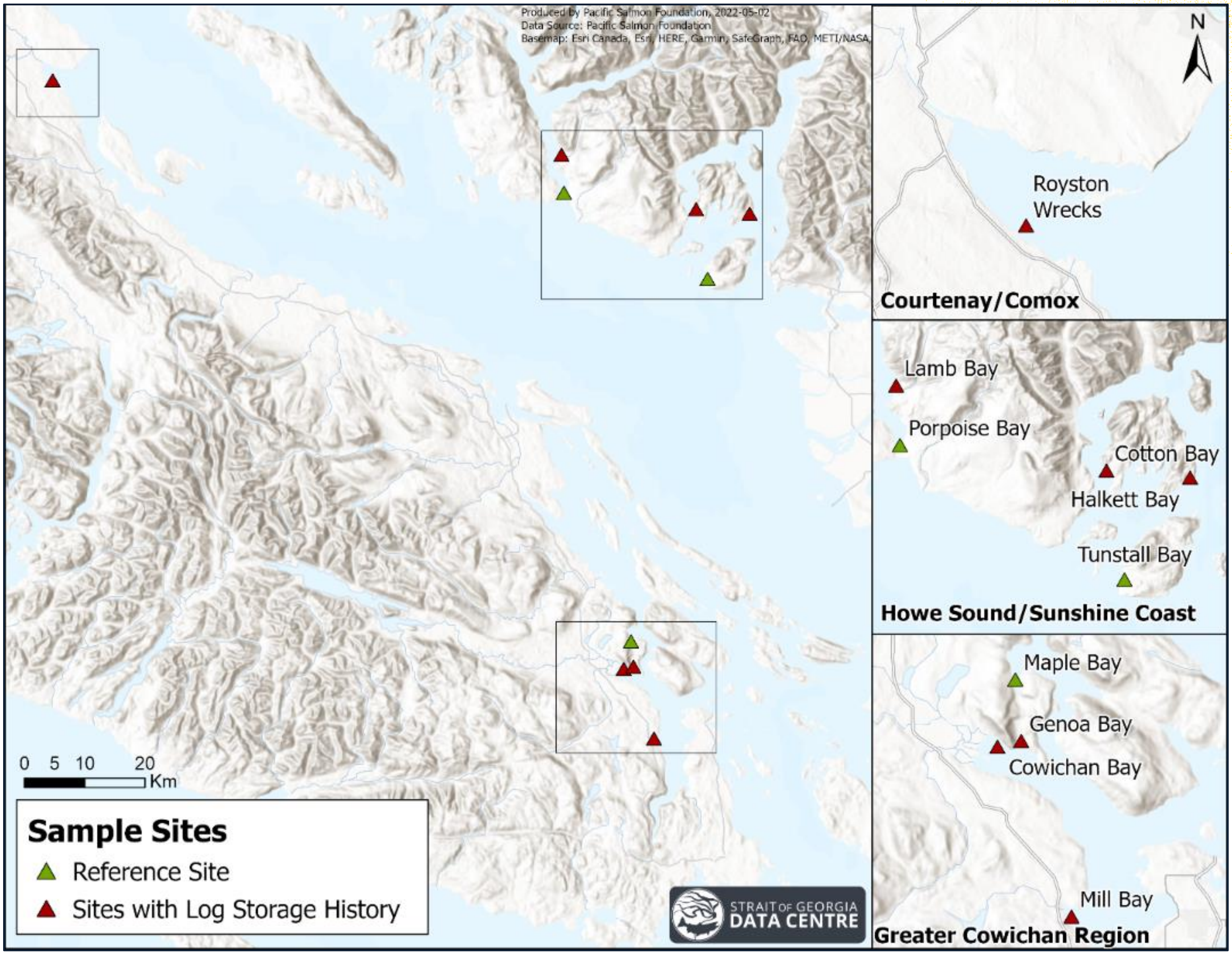

Figure 1. Map of all study sites in the Strait of Georgia portion of the Salish Sea. Sites indicated by red triangles have a history of log storage and sites indicated with green triangles do not have history of log storage Map created by the Strait of Georgia Data Centre, Jake Dingwall. See Appendix B for individual site maps.

Transplant Success

In British Columbia, eelgrass transplants are considered a success when they provide equal productivity (measured in shoot density) to the donor beds, usually after a monitoring period of five years post-transplant (Durance 2001). For the purposes of this study, transplant success was gauged by the working parameters used by SeaChange (Wright 2021). This method measures the success of the transplant at the end of the monitoring period by calculating transplant shoot density as a percentage of the shoot density of the reference donor bed.

These calculations were made from monitoring records provided by SeaChange Marine Conservation (nine sites) and Project Watershed (Royston Wrecks). The SeaChange Marine Conservation sites were planted between 2016 to 2019 and monitored every six months until the end of 2021. Royston Wrecks was planted in 2015 by Project Watershed using the same methods as SeaChange and monitored in 2021 by the K'ómoks Watchmen Guardians.

Log Storage History

Location of Log Storage

The log storage history of each site was first studied using tenure records on file with the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLINRORD). Records were shared as shapefiles containing metadata on the years each tenure was active. These shapefiles were used to map the historic tenure at each site.

Recovery Time and Total Use

Tenure records were cross-referenced with aerial photographs obtained from the University of British Columbia Geographic Information Center to verify recovery time and the total duration of log storage at each study site. The last year of log storage shown in aerial photographs was used to calculate recovery time. In cases where tenures were recorded as 'active' but aerial photos showed no log storage, the last use shown by aerial photography was designated as the last year of use. Exception to this is Mill Bay, which was only used for log storage while the local mill was active from 1859-1878 (M. Alexander, Mill Bay Malahat Historical Society, pers. comm.). No tenure record or relevant aerial photos were available for this site, so log storage duration was estimated based on excerpts and images from "Along Mill Bay Road" (Ellis 1990). For Cotton Bay and Cowichan Bay, which had log tenures at different locations within the sites which were decommissioned at different times, the final log storage year of the tenure closest to the eelgrass transplant was used to determine the last year of use. If both provincial tenure records and aerial photos did not go back far enough to capture when a site was first used for log storage, then the logging tenures directly upland of the study site was used to estimate total years of use. For Halkett Bay, the first year of use was determined using a technical report on file with the federal government (McDaniel 1973).

Pore-water Oxygen Reduction Potential

Oxygen reduction potential (ORP) was measured as a proxy for pore-water sulphides, as hydrogen sulphides has been shown to be toxic to eelgrass (Pedersen et al. 2004). ORP can be measured directly in the field, potentially making this technique easily replicable by community restoration practitioners.

Sample collection

The sediment core samplers were constructed from 1 metre lengths of 4" acrylic tubing, with a beveled lower edge to facilitate insertion into the sediment. Handlebars, aluminum pipe wrapped in a thin layer of rubber, were added through the tubing at approximately ¾ of the total length. Electrical tape was applied for reinforcement where the handlebar was attached. Two 4" adjustable rubber caps were used to seal the ends of the sampler. For pore-water sampling, holes were drilled into the tube every 10 cm to allow for measurements at eelgrass rooting-depth without disturbing the sample. These holes were taped over when not in use.

Sediment cores were collected by a diver. The diver descended with the tube uncapped and pushed the sampler into the sediment using the handlebars. In some cases, a trowel was also necessary to excavate around the sampler. The top of the tube was capped to create suction. Then, the sampler was carefully tilted to one side until the bottom end could also be capped and the sample could be transported to the surface (Figure 2). Sediment core sample design was based on the design used by the Pacific Salmon Lab (UBC).

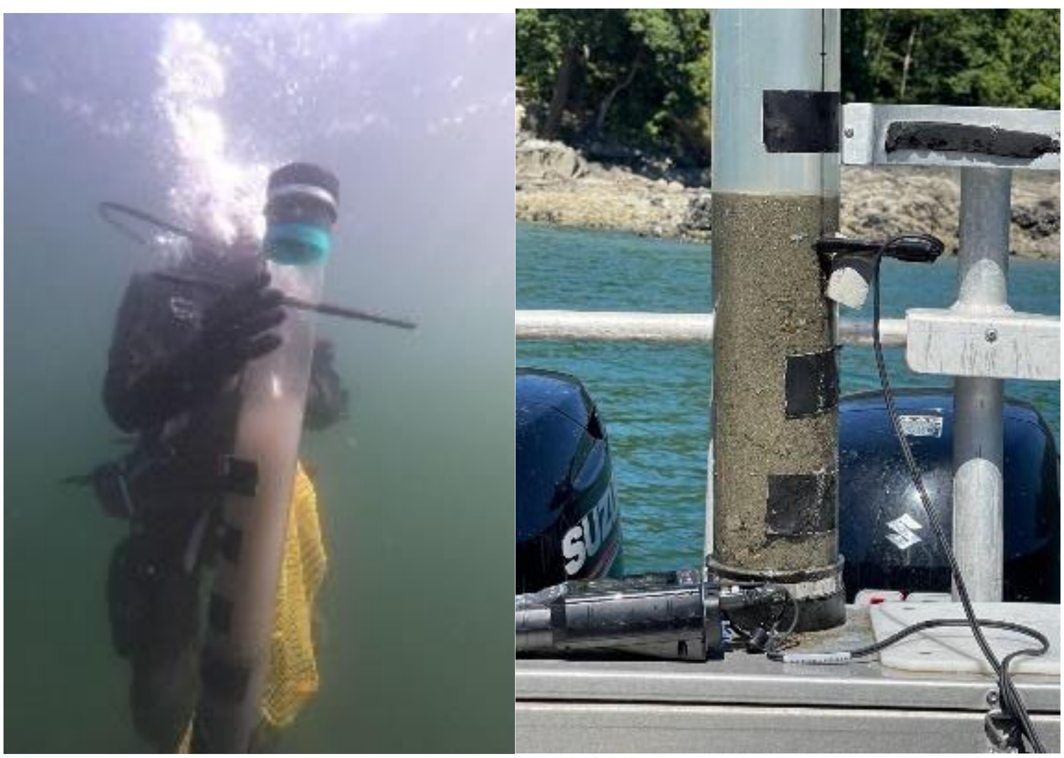

Figure 2. Left: a sediment core sample being transported to the surface by Dustin Price of A-Tlegay Fisheries Society. Picture taken by Zach Everson of A-Tlegay Fisheries and used with permission. Right: a sediment core sample with an Orion Star portable meter inserted into the upper 10 cm of sediment to measure pore-water oxygen reduction potential.

The amount of sediment sampled at each site varied due to differences in sediment grain size, compaction, and the presence of large-shelled fauna or bedrock affecting how deep a sampler could be pushed into the sediment. A tight seal was difficult to obtain in sediments with larger grain sizes, causing some sediment to fall out of the bottom of the sampler during extraction. Most of the sediment core samples were taken to approximately 30 cm of depth; however, sample depths ranged from 15 cm to 40 cm.

Three replicate sediment core samples were taken at the transplant location at each site. Sites with a history of log storage (i.e. not reference sites) were also sampled across the subtidal area of the entire site up to a total of eight samples per site at representative locations of potential subtidal eelgrass habitat (e.g. < 30 ft at low tide). Intertidal areas were not sampled as they are subject to a wider range of stressors that are beyond the scope of this study. The locations of the additional samples taken outside of the transplant area were determined by dividing the area of interest into three or four equal-sized sections (depending on the overall size of the site) and throwing a marked weight from the boat at random while crossing each section. The dive team then sampled as close to that weight as possible. The sampling locations were recorded using a handheld Garmin GPSMAP 64x and mapped using ArcMap software. Samples were taken between August and December of 2021. See Appendix B for sediment core sample regime maps.

Sample analysis

Sediment pore-water ORP was measured using an Orion Star A320 Series Portable Meter (Figure 2) in each of the subtidal sediment cores brought to the surface. This study was concerned only with the ORP in the pore-water within the rooting depth of eelgrass (top 10 cm). With drilled holes located at 10 cm intervals, the OPR probe was inserted into the corresponding hole that was less than 10 cm from the sediment-water interface and measurements logged.

Benthic Woody Debris – Sediment Total Organic Content

From the transplant location at each site, one randomly selected replicate sediment core was retained for gravimetric woody debris analysis from the transplant locations. From sites with a log storage history, two or three cores collected outside the transplant locations were also retained for analysis to gain better understanding of the distribution of woody debris at these sites (see Appendix B for sediment core sample regime maps).

Samples were not obtained from the Tunstall Bay transplant site, so there are no samples from that site, and one of the samples from Mill Bay was lost due to technical issues in the field and laboratory.

Each sample was sieved through a 9 mm, 4.75 mm, 2.36 mm mesh sieve, and any material finer was retained in a 'pan' (Figure 3) to aid in the drying and sorting processes. The sample portions were placed into aluminum baking tins and dried at 90°C in an oven for twenty-four hours to remove all moisture. The total dry weight of each grain size from each sample was noted.

Figure 3. Left: samples were sorted through 9.5 mm, 4.75 mm, and 2.36 sieves to separate samples into four grain sizes. The finest grain sizes were washed through and collected in a pan. Right: the 9.5 mm and 4.75 mm grain sizes were hand-sorted into wood and bark, other organics, sediments, and shell components.

The dry materials retained in the 9 mm and 4.75 mm sieves were hand-sorted into wood and bark, mineral, and biologic components (shell, vegetation, etc.) (Figure 3). The mass of wood and bark was calculated as a percent of the total dry mass, and then converted to mg/g. Whenever possible, wood and bark from each sample was then separated and calculated individually for further analysis.

The material from the 2.36 mm and 'pan' were too fine to separate by hand. Instead, a 'mass-lost-on-ignition' technique (Wang et al. 2010) was used to obtain the organic proportion of the samples. These sediments and materials were individually bagged and homogenized using a kneading action. A three-gram subsample was taken at random from each 2.36 mm and 'pan' portion and burned at 550°C for twelve hours in a Fisher Scientific Isotemp Conventional Oven. This technique burns all organic material in marine sediment samples, leaving shell and inorganic material (Wang et al. 2010). The mass of organic carbon lost from each sample was calculated as a percent of the total dry mass and then converted to mg/g. This measurement was then reduced by a third to account for over-estimation in the 'mass-lost-on-ignition' techniques (Wang et al. 2010). This adjusted measurement was then used as a proxy for wood and bark content for the 2.36 mm and 'pan' grain sizes.

Total wood and bark content from each of the four grain sizes in each sample was then combined, calculated as a percent of the total sample dry mass, and converted to mg/g.

Woody Debris and Vegetation Cover – Underwater Towed Camera Surveys

Underwater video footage of the seafloor was taken using a Delta Vision HD Splashcam towed underwater camera. Dependent on the total area of the site, study sites were divided into four to seven approximately equidistant transects, and the camera was towed along each transect by boat. Transects commenced on the seaward side of the study sites and travelled towards shore at a maximum speed two knots, in order to keep the camera steady. A handheld Garmin GPSMAP 64x was used to record our location every four seconds, which is the recommended timeframe for video analysis (N. Nahirnik, Ecofish, pers. comm.). The exact time of day that each video recording began was used to match the video frames with time-stamped GPS coordinates. The footage was then reviewed, and the frame occurring at each four second interval was given a cover class rating from 0-5 (Table 2) for both woody debris and vegetation (eelgrass and algae) based on visual assessment (Figure 4). The corresponding location of eacht frame was used to map these values. Residual woody debris and vegetation cover were mapped using ArcMap.

Video surveys were done between September and December of 2021. Due to inclement weather conditions, Tunstall Bay could not be filmed.

Table 2. Cover class ratings used in the underwater towed camera survey.

RATING	COVER
0	none
1	1-5%
2	5-25%
3	25-50%
4	50-75%
5	75-100%

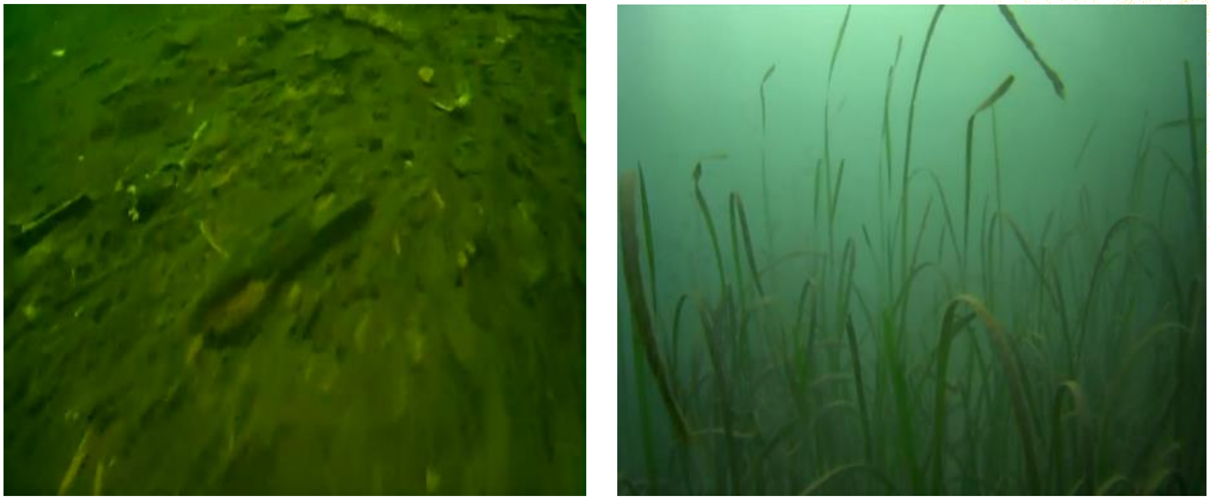

Figure 4. Still frames from underwater towed camera footage. The left image depicts residual woody debris on the seafloor of Lamb Bay and the right image depicts eelgrass (*Zostera marina*) in Cowichan Bay. Footage collected and edited by Calvin Domarchuk-White.

Benthic Invertebrate Species Composition

Benthic invertebrate samples were collected using a standard 9 x 9" Ponar grab sampler. One sample was taken at the transplant location at each study site along the seaward edge of the transplanted area, as close to the transplant as possible without damaging any eelgrass. A sample was retained if the Ponar returned more than half full of sediment. Each Ponar sample was then sieved through a 0.5 mm screen. The remaining sediment was funneled into collection jars and preserved with ethanol. Samples were then transported to Biologica Laboratories in Victoria, B.C. for analysis.

All benthic invertebrate samples were sorted using a dissecting microscope at 10–40x magnification by trained technicians. To minimize sorter bias, samples were distributed among technicians such that no one person sorted every replicate of a given sample. Due to large debris volumes, samples were subsampled using a Caton tray. A minimum 1/4 split is the recommended acceptable split for marine seafloor samples (Environment Canada 2002, 2010, 2012). Six of the samples were subsampled to a 1/4 split. Prior to subsampling with a Caton tray, whole samples were examined for large, unique and rare organisms (>1.0 cm), which were then removed from the debris. These organisms were identified and enumerated separately. This procedure is meant to improve the detection of rare taxa and capture the abundance of large organisms accurately. Following the preliminary whole sort, all sample debris was spread evenly over a Caton grid, and 1/4 of the sample was randomly selected and removed for microscopic sorting.

To identify the organisms, the laboratory used a combination of dissecting (10–40x) and compound (100–1000x) microscopes and standard taxonomic keys to a species level whenever possible, and to the lowest practicable level otherwise. Unique taxa from each sample were referenced individually to be utilized for DNA analysis. All specimens have been archived in air-tight glass vials with 95% ethanol and stored in a freezer until DNA analysis can be completed. Taxonomic data were recorded in Biologica's custom database (see Appendix 8.7 for benthic invertebrate raw data). Benthic invertebrate communities were analyzed for species richness using the Margalef Index ((S - 1) / ln N) which corrects for variable sample sizes between sites. Communities were also analyzed for species evenness using Pielou's Evenness Index (H'/ln(S) where H = Shannon Weiner Diversity Index). Invertebrates that could not accurately be identified were not included in the final analyses.

Statistics

A One-Way ANOVA was used to examine for differences in the sediment habitat indicators (ORP, sediment organic content, and invertebrate assemblage measures, namely: species diversity derived from a Margalef Index analysis, number of unique taxa, and total number of invertebrates) between sites with a history of log storage and sites with no history using Microsoft Excel. Fitted line plot regression analysis was used to investigate for relationships between transplant success and sediment habitat indicators as well as the amount of time passed since the decommission of log storage to see if any of these could be used as a predictor of transplant success using Microsoft Excel. P values of less than 0.05 were considered significant. Invertebrate assemblage data were explored with an nMDS in Primer v6, to look for patterns worth further investigation with ANOSIM. The assemblage data were standardized and square root transformed prior to a creating a Bray Curtis similarity resemblance matrix for the nMDS and subsequent ANOSIM analysis.

RESULTS

Study Site Transplant Success

The success of transplants varied across the sites, ranging from 0 at Royston Wrecks, meaning no transplants remained, to over 100 at Halkett Bay and Maple Bay, indicating the transplant sites had a higher density of shoots than the donor beds (Figure 5). On average, the transplants in the Howe Sound region fared the best (mean 91.0, Stdev 19.5), followed by the transplants on the East Coast of Vancouver Island (mean 72.0, Stdev 50.9), and transplants in Sechelt Inlet fared the worst (mean 38.0, Stdev 14.1). However, eelgrass transplants in reference sites did not reliably fare better than transplants in historic log storage sites. The mean transplant index score for sites with no log storage history was higher at 84.0 (Stdev 44.0) than the mean of the sites with a log storage history at 65.3 (Stdev 41.0), but this was

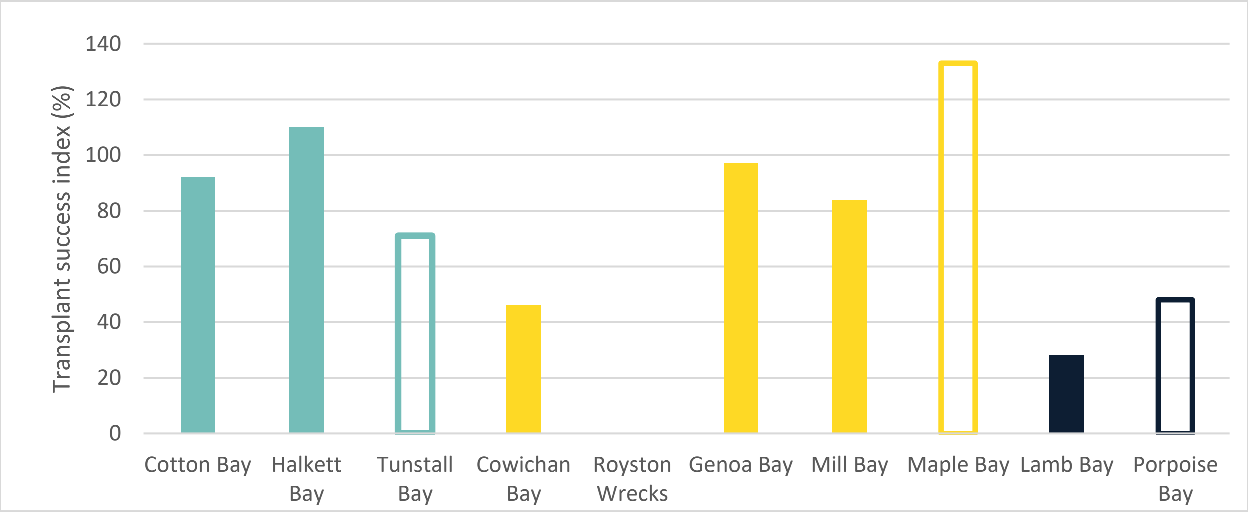

Figure 5. The relative success of each site's eelgrass transplant, calculated as the shoot density of the transplant as a percent of the shoot density of its reference bed by the end of the monitoring period. The three hollow bars represent the three reference sites with no history of log storage. Howe Sound sites have teal bars, East Coast Vancouver Island sites have yellow bars and Sechelt Inlet sites have dark blue bars.

not statistically significant.

Log Storage History

The study sites represent a spectrum of log storage use histories (Table 3). Provincial tenure records were sparse and did not accurately portray the full log storage history for any of the sites. In most cases, only the most recent tenures are on file with the province. Neither Halkett Bay nor Genoa Bay had any tenures on file, even though historical aerial photos show logs stored at these sites. The earliest tenure record on file for any of the sites was from 1997. Aerial photos proved to be a better resource for determining the log storage history of each site. But, in most cases, the photo records did not go back far enough to determine when a site was first used. Records for historical logging tenures were more complete than log storage tenures. In lieu of any direct evidence, the first recorded instance of upland logging was used to estimate when a site was first used for log storage (see Appendix B for log storage tenures maps).

Table 3. Log storage use history of each study site. Use was verified using aerial photos; however, the photo recordrarely dated back far enough to determine when a site was first used. Therefore, the first recorded occurrence of logging upland of each site was also determined. These logs were likely to have been stored in the adjacent nearshore and may represent the first time a site was used for storage; therefore, the first year of logging was used to calculate the estimated total years of use.

SITE	LAST LOG STORAGE YEAR	RECOVERY TIME	VERIFIED TOTAL YEARS OF USE	FIRST LOGGING UPLAND	ESTIMATED TOTAL YEARS OF USE
Cotton Bay	2012	10	48	1953	59
Cowichan Bay	2012	10	45	1931	81
Royston Wrecks	2004	18	40	1961	43
Lamb Bay	1997	25	21	1947	50
Genoa Bay	1988	34	21	1931	57
Halkett Bay	1984	38	34	unknown	34
Mill Bay	1878	144	19	1859	19

Regression analysis comparing the transplant success to the total years in use (R^2=0.0671) and years since decommission (R^2=0.0722) did not find a significant relationship (Figure 6 and Figure 7).

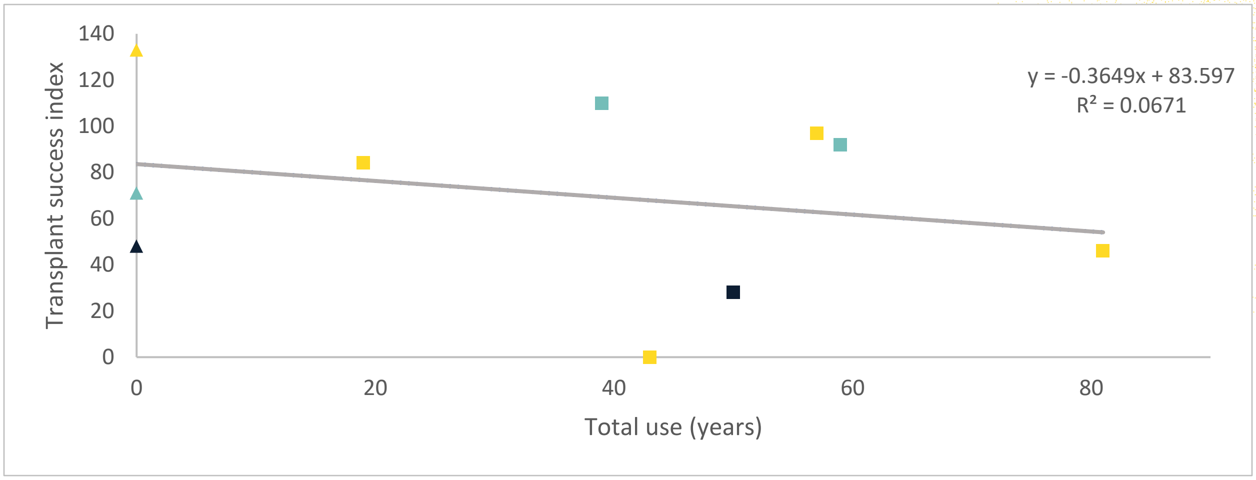

Figure 6. Eelgrass transplant success in comparison to total use as a log storage site in years. Transplant success is calculated as the shoot density of the transplant as a % of the shoot density of the reference bed. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols.

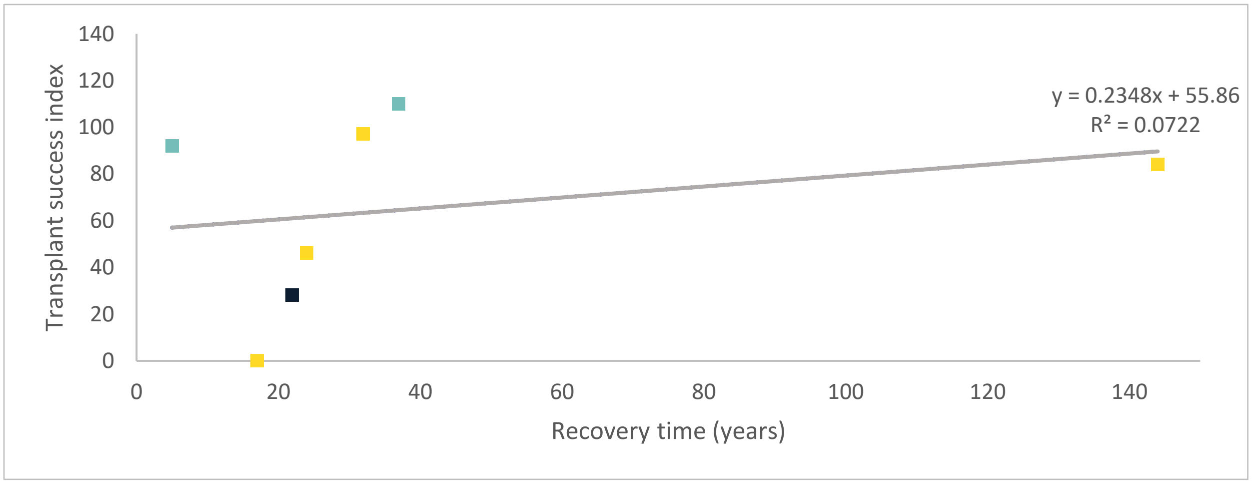

Figure 7. Eelgrass transplant success in comparison to recovery time since last use as a storage site in years. Transplant success is calculated as the shoot density of the transplant as a percentage of the shoot density of the reference bed. Only sites with log storage histories are depicted in this figure. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols.

Pore-water Oxygen Reduction Potential

Pore-water oxygen reduction potential (ORP) in marine sediments typically ranges from +500 mV in oxic sediments to -200 mV in anoxic sediments. Negative oxygen reduction potential indicates reduction and may result in the production of sulphides (Sutherland et al. 2006, Schulz 2000). Field measurements of ORP were indicative of anoxic conditions at several of the study sites. The average ORP at each site ranged from -72.4 mV at Genoa Bay to 621.2 mV at Tunstall Bay. The mean ORP of the sites with a logging history (n=7) was lower at 40.8 mV (Stdev 119.3) compared with the sites with no logging history (n=3) at 233.0 mV (Stdev 341). However, measurements were highly variable between sites and across each site individually (Figure 8) and the ANOVA did not find a statistically significant difference. Regression analysis did not find a significant relationship between ORP and transplant success (R^2=0.014) (Figure 9). Further analysis of the data revealed a seasonal influence to the readings, likely confounding the results. See Appendix D for pore-water reduction potential data.

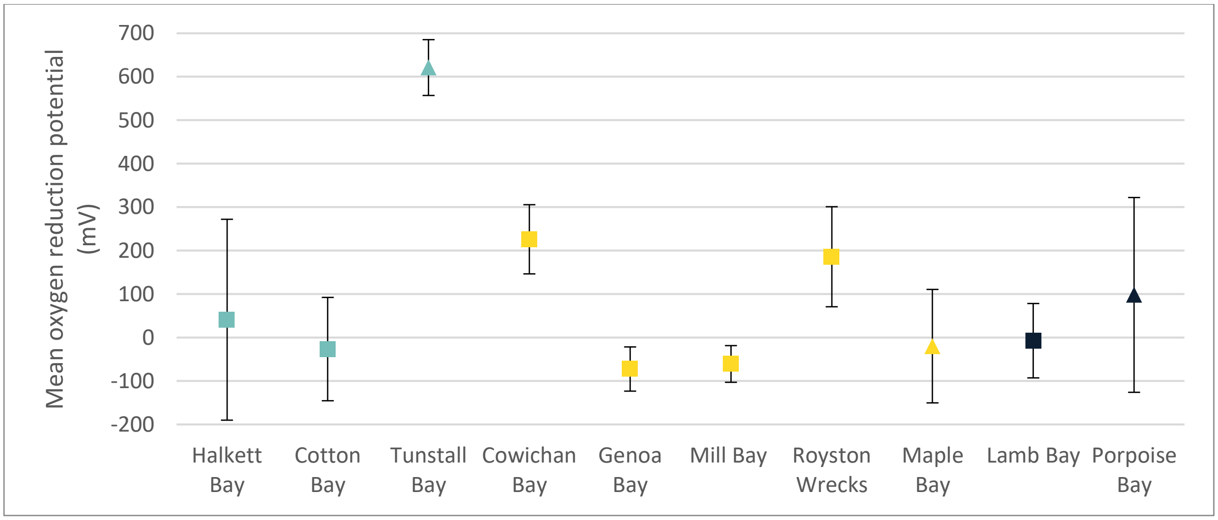

Figure 8. Average oxygen reduction potential by study sites. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols. Halkett Bay n=7, Cotton Bay n=8, Tunstall Bay n=3, Cowichan Bay n=7, Genoa Bay n=7, Mill Bay n=7, Royston Wrecks n=6, Maple Bay n=3, Lamb Bay n=8, Porpoise Bay n=3.

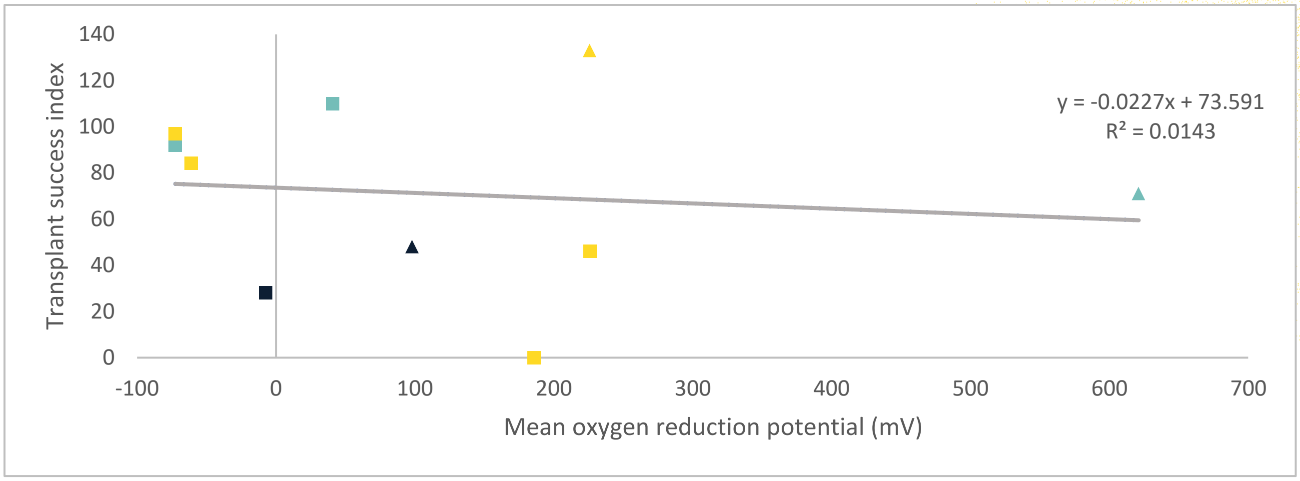

Figure 9. Eelgrass transplant success in comparison to mean oxygen reduction potential (mV). Transplant success is calculated as the shoot density of the transplant as a percentage of the shoot density of the reference bed. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols.

Benthic Woody Debris – Sediment Total Organic Content

The mean sediment total organic content was greater at the sites with a logging history (n=6) at 13.5 mg/g (Stdev 25.6) than at the sites with no logging history (n=2) at 2.49 mg/g (Stdev 2.58). Again, sites were highly variable and there was a small sample size for the control sites, as such the ANOVA did not find a statistical difference between historic log storage and control sites. Regression analysis did not reveal any significant relationship between organic content and transplant success (R^2=0.1398) (Figure 10).

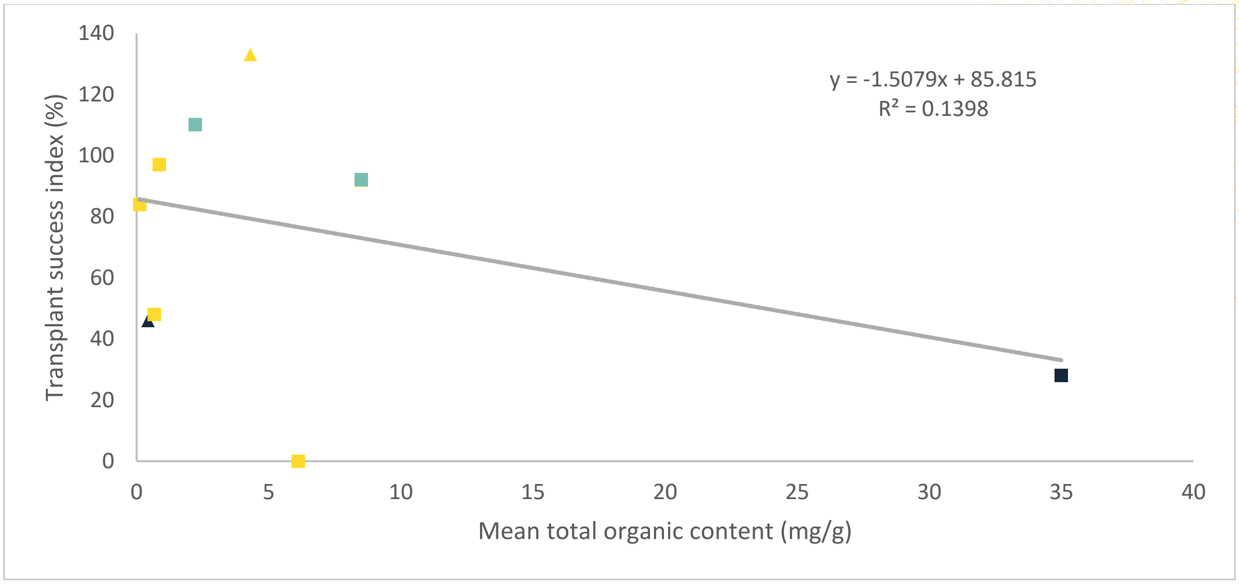

Figure 10. Eelgrass transplant success in comparison to mean total organic content (mg/g). Transplant success is calculated as the shoot density of the transplant as a percentage of the shoot density of the reference bed. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols. The Tunstall Bay site sample was lost due to technical difficulties in the field. See Appendix E for sediment total organic composition data.

On average, samples taken inside historic log storage tenures contained 12.8 mg/g more organic content than samples taken outside tenures, however values were variable and this difference was not statistically significant. Sediment samples taken where eelgrass lived contained very little organic content, less than 2 mg/g (Figure 11).

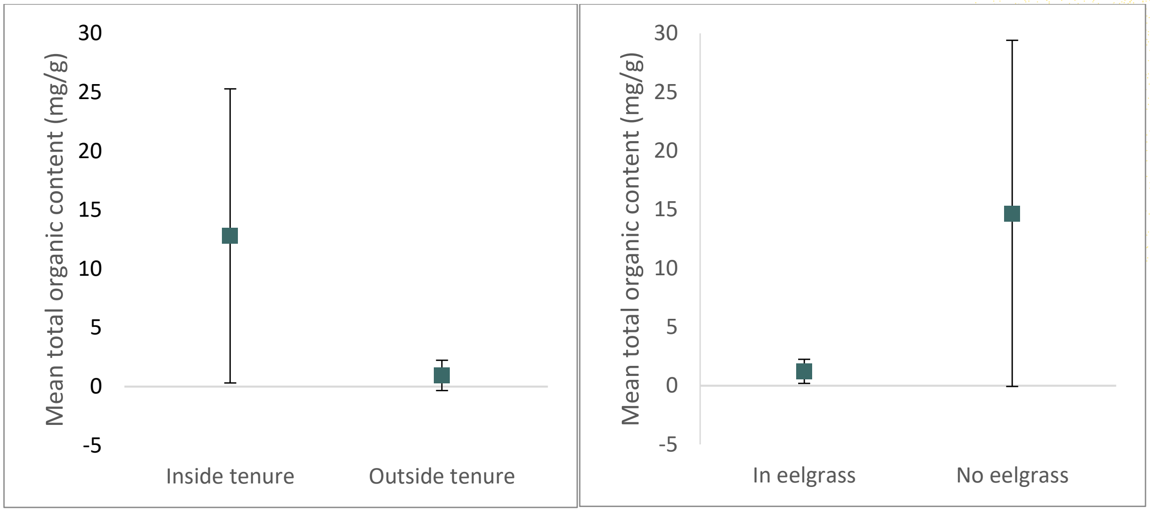

Figure 11. Average total organic content of sediment samples (mg/g) taken across all study sites. The graph on the left compares average total organic content from sediment samples taken from inside a historic log storage tenure (n = 15) to that of sediment samples taken where no tenure existed (n = 8). The graph on the right compares the average total organic content of sediment samples taken within or just beside eelgrass beds (n = 10) to that of sediment samples taken in areas with no eelgrass (n = 13).

Woody Debris and Vegetation Cover – Underwater Towed Camera Surveys

Woody debris cover and vegetation cover were mapped across transects for each site (Figure 12 - Figure 16). See Appendix F for underwater towed camera data.

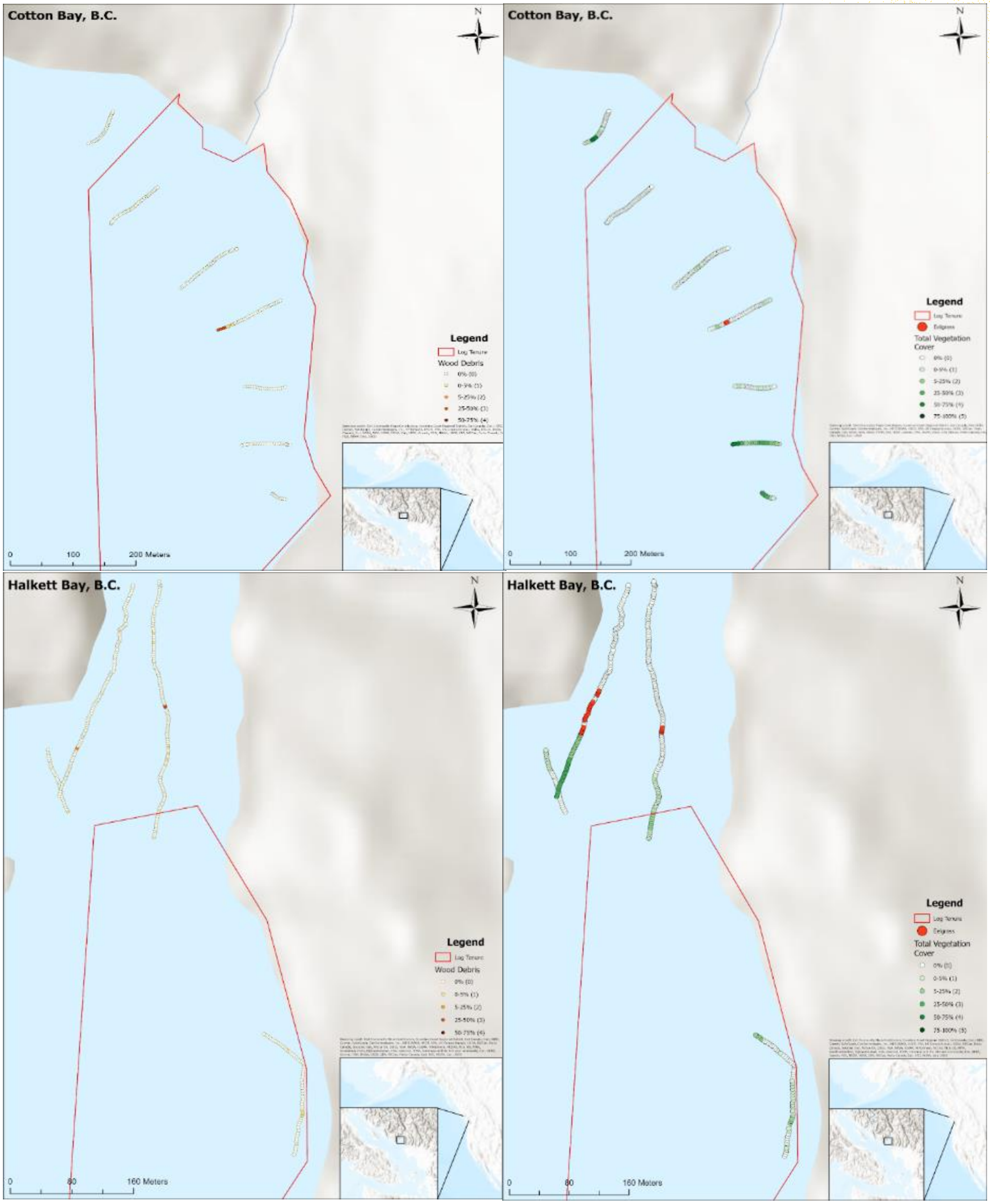

Figure 12. Woody debris cover (left) and total vegetation cover (right) in Cotton Bay (upper) and Halkett Bay (lower), Howe Sound. Cover data was obtained using underwater towed video transects and indicated by coloured dots along transect. Red outlines indicate historic tenure areas for log storage. Frames of transect points were assigned a cover class based on relative abundance. Maps created by Jake Dingwall using ArcMap.

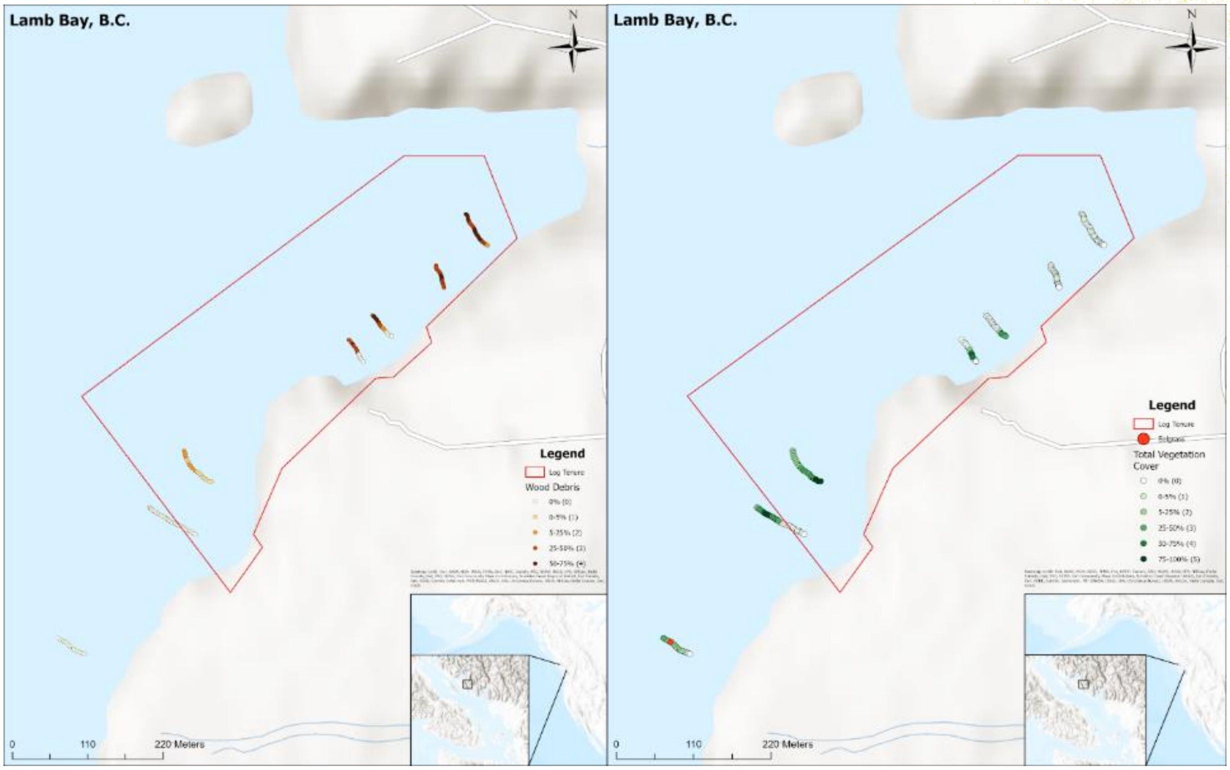

Figure 13. Woody debris cover (left) and total vegetation cover (right) in Lamb Bay, Sechelt Inlet. Cover data was obtained using underwater towed video transects and indicated by coloured dots along transect. Red outlines indicate historic tenure areas for log storage. Frames of transect points were assigned a cover class based on relative abundance. Maps created by Jake Dingwall using ArcMap.

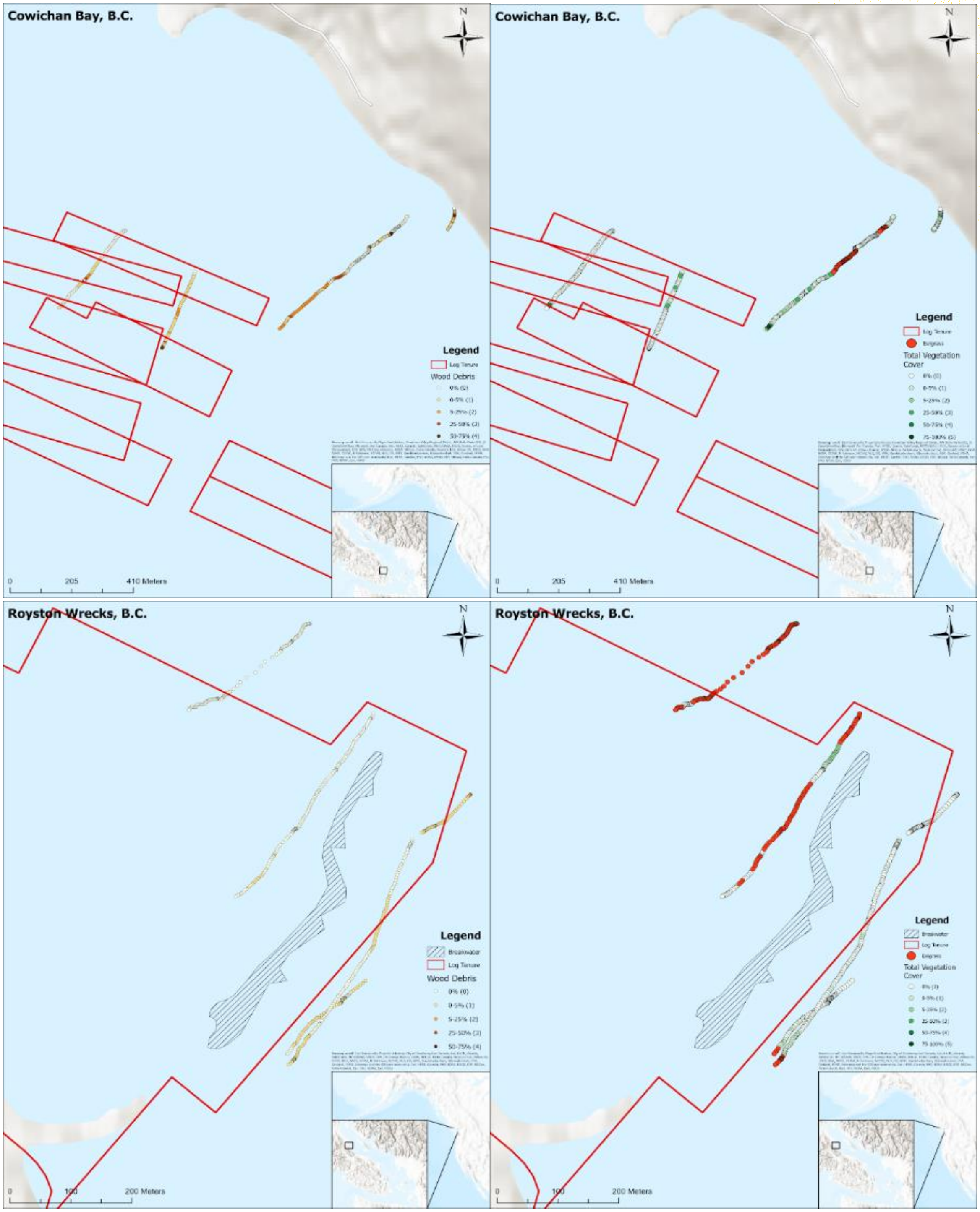

Figure 14. Woody debris cover (left) and total vegetation cover (right) at Cowichan Bay (upper) and Royston Wrecks (lower), East Coast Vancouver Island. Cover data was obtained using underwater towed video transects and indicated by coloured dots along transect. Red outlines indicate historic tenure areas for log storage. Frames of transect points were assigned a cover class based on relative abundance. Maps created by Jake Dingwall using ArcMap.

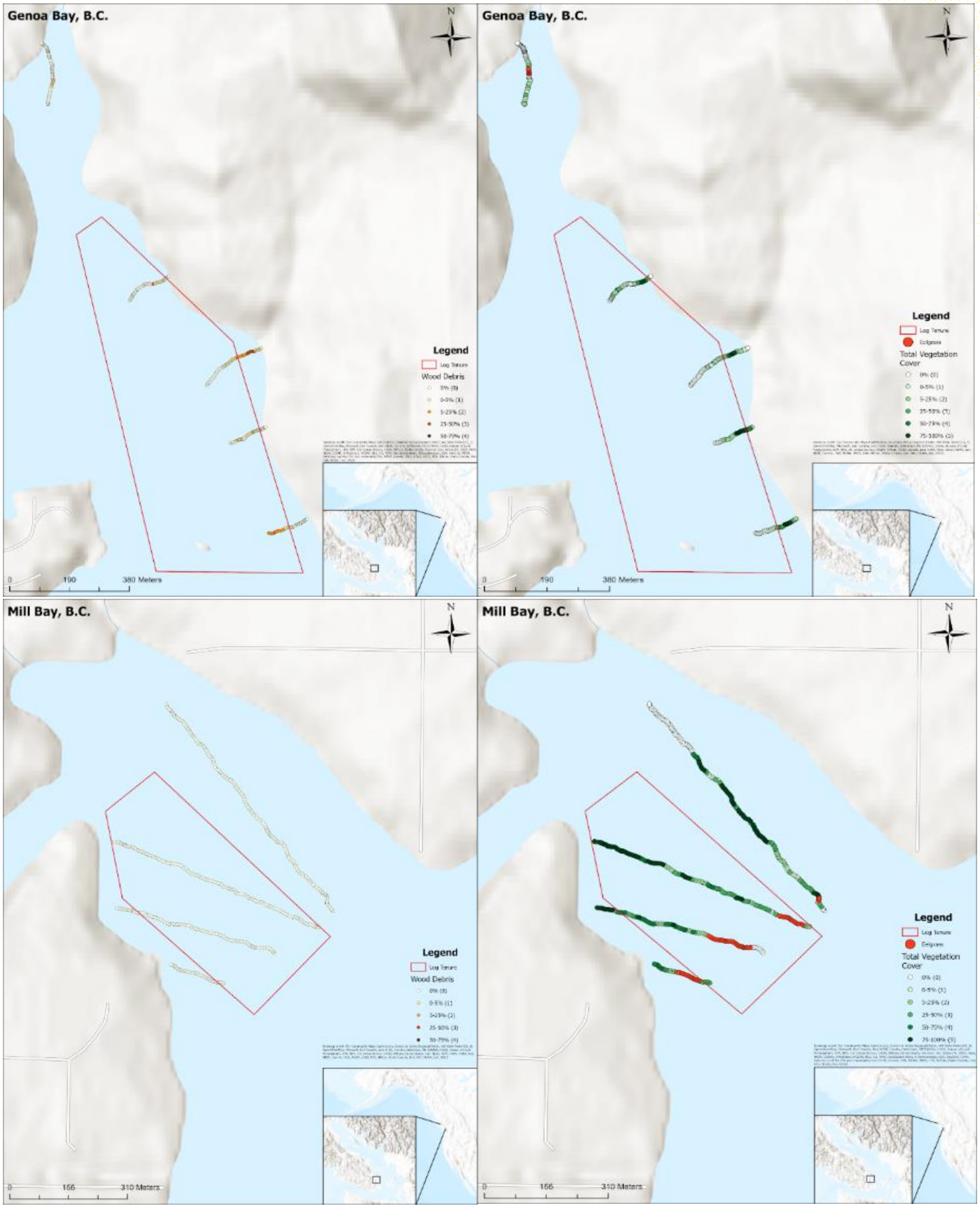

Figure 15. Woody debris cover (left) and total vegetation cover (right) in Genoa Bay (upper) and Mill Bay (lower), East Coast Vancouver Island. Cover data was obtained using underwater towed video transects and indicated by coloured dots along transect. Red outlines indicate historic tenure areas for log storage. Frames of transect points were assigned a cover class based on relative abundance. Maps created by Jake Dingwall using ArcMap.

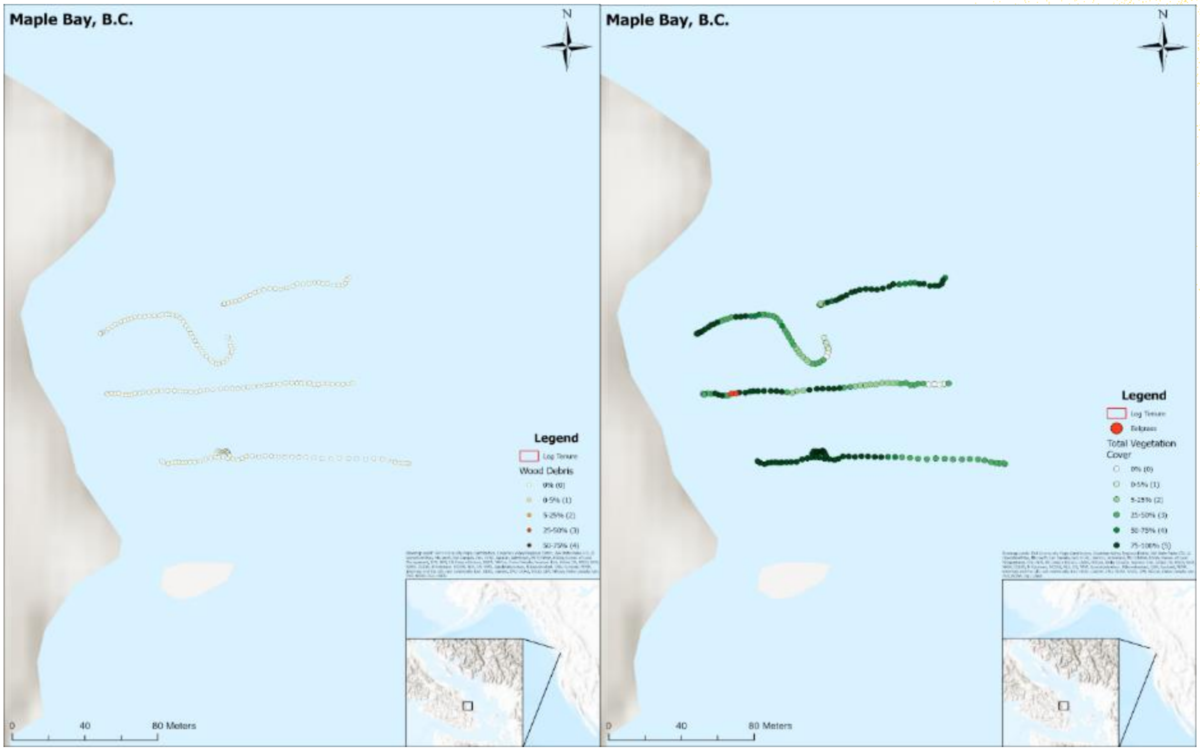

Figure 16. Woody debris cover (left) and total vegetation cover (right) in Mill Bay, East Coast Vancouver Island. Cover data was obtained using underwater towed video transects and indicated by coloured dots along transect. Red outlines indicate historic tenure areas for log storage. Frames of transect points were assigned a cover class based on relative abundance. Maps created by Jake Dingwall using ArcMap.

Benthic Invertebrate Species Composition

The benthic invertebrate analyses revealed a range of species across the study sites (see Appendix G for benthic invertebrate data). The samples contained between 121 and 1,376 individual invertebrates, and between nine and 41 distinct taxa (Table 4). Similar Margalef Index results (index of species richness) were found at sites with a history of logging (n=7, mean 3.923, Stdev 1.486) and the control sites (n=3, mean 3.520, Stdev 1.137). Total abundance of benthic invertebrates was greater in the sites with log storage history with a mean of 562 species present (Stdev 416), compared to a mean of 197.3 (Stdev 90.1), however, the results varied greatly by site and the difference was not statistically significant.

Table 4. The total abundance, total taxa, Margalef Index of species richness and Pielou's EvennessIndex of benthic invertebrates found at each site.

SITE	TOTAL ABUNDANCE	TOTAL TAXA	MARGALEF INDEX	PIELOU'S EVENNESS INDEX
		Howe Sound		
Halkett Bay	651	26	3.1	0.74
Cotton Bay	381	21	3.4	0.66
Tunstall Bay	265	27	4.7	0.81
		Sechelt Inlet		
Lamb Bay	1376	41	5.5	0.65
Porpoise Bay	95	17	3.5	0.7
		East Coast Vancouver Island		
Cowichan Bay	313	23	3.8	0.57
Royston Wrecks	741	41	6.1	0.79
Genoa Bay	350	24	3.9	0.66
Mill Bay	121	9	1.7	0.77
Maple Bay	232	14	2.4	0.75

Regression analysis did not reveal a significant relationship between the total number of species or Pielou's evenness index and transplant success (Figure 17 and Figure 20). However, there was a significant negative relationship between transplant success and Margalef index (R^2=0.601, p<0.01) (Figure 18). Related, the total unique taxa also showed a negative relationship (R^2=0.455, p=0.01) with transplant success (Figure 19).

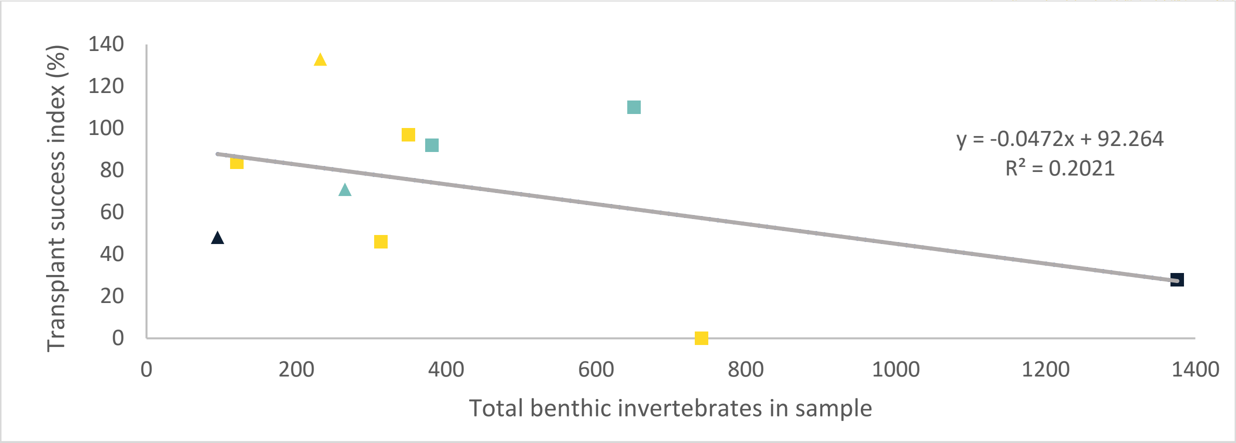

Figure 17. Eelgrass transplant success compared with the total benthic invertebrates identified from the Ponar grab sample collected adjacent to transplants. Transplant success is calculated as the shoot density of the transplant as a percentage of the shoot density of the reference bed. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols.

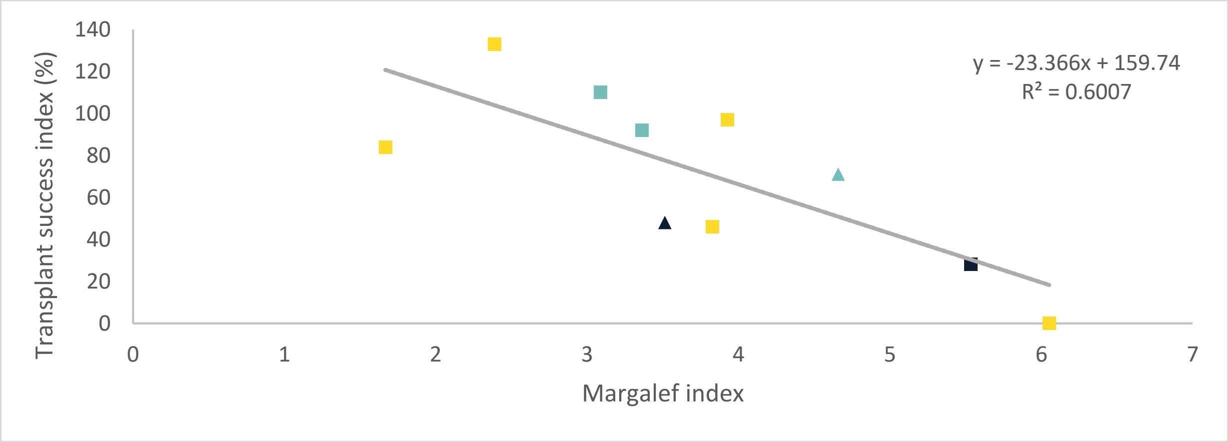

Figure 18. Eelgrass transplant success compared with the total benthic Margalef index from the Ponar grab sample collected adjacent to transplants. Transplant success is calculated as the shoot density of the transplant as a percentage of the shoot density of the reference bed. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols.

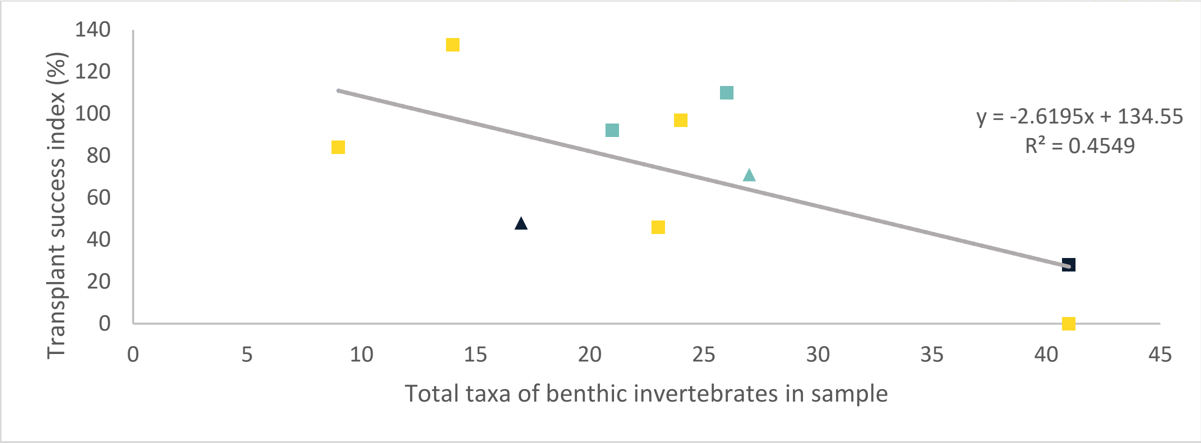

Figure 19. Eelgrass transplant success compared with the total benthic invertebrate taxa identified from the Ponar grab sample collected adjacent to transplants. Transplant success is calculated as the shoot density of the transplant as a percentage of the shoot density of the reference bed. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols.

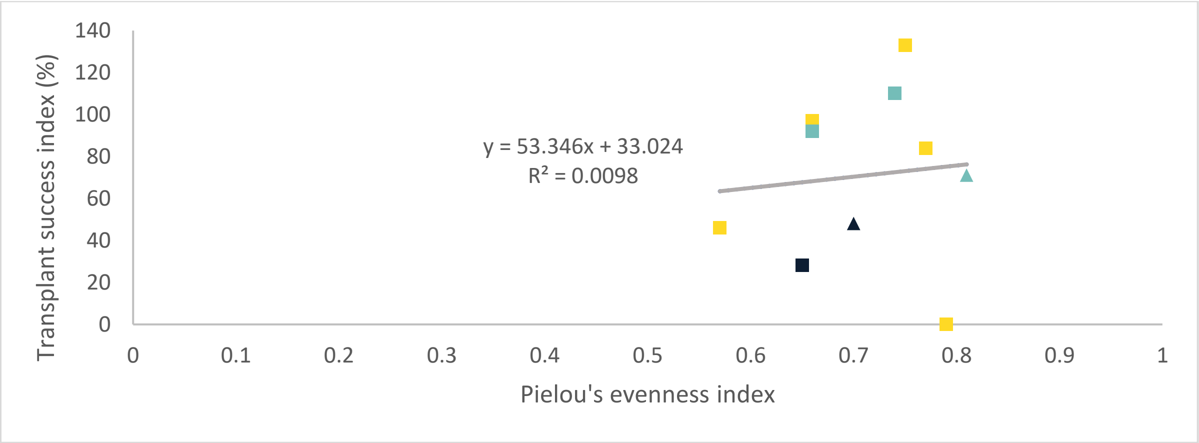

Figure 20. Eelgrass transplant success compared with the Pielou's evenness index from the Ponar grab sample collected adjacent to transplants. Transplant success is calculated as the shoot density of the transplant as a percentage of the shoot density of the reference bed. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols

The community composition by phyla in each sample also varied between sites (

Figure 21 – Figure 22). In general, annelids were the most common phyla with arthropods and mollusks making up the majority of the remaining phyla present in the samples.

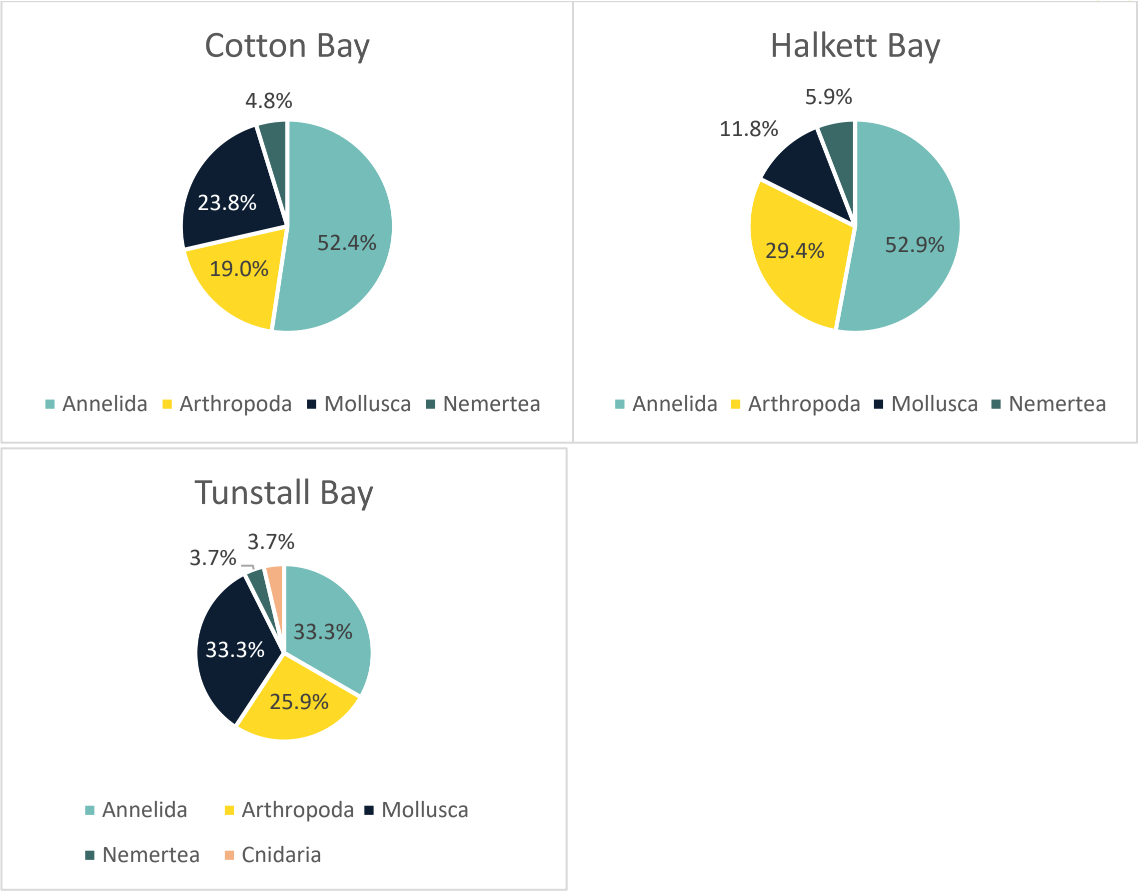

Figure 21. Invertebrate community composition by phyla for the Ponar grab samples from the Howe Sound sites.

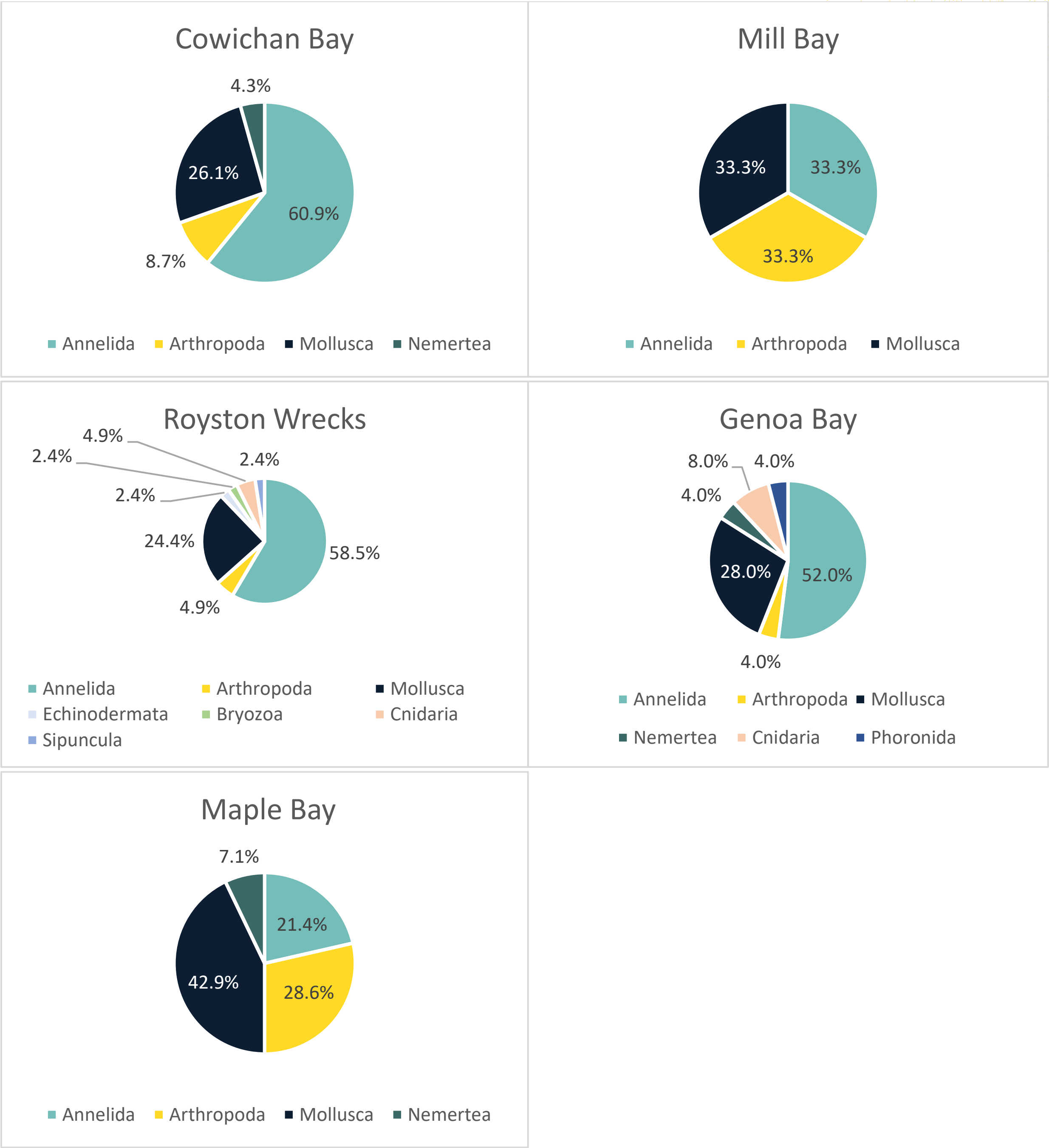

Figure 22. Invertebrate community composition by phyla for the Ponar grab samples from the East Coast of Vancouver Island sites.

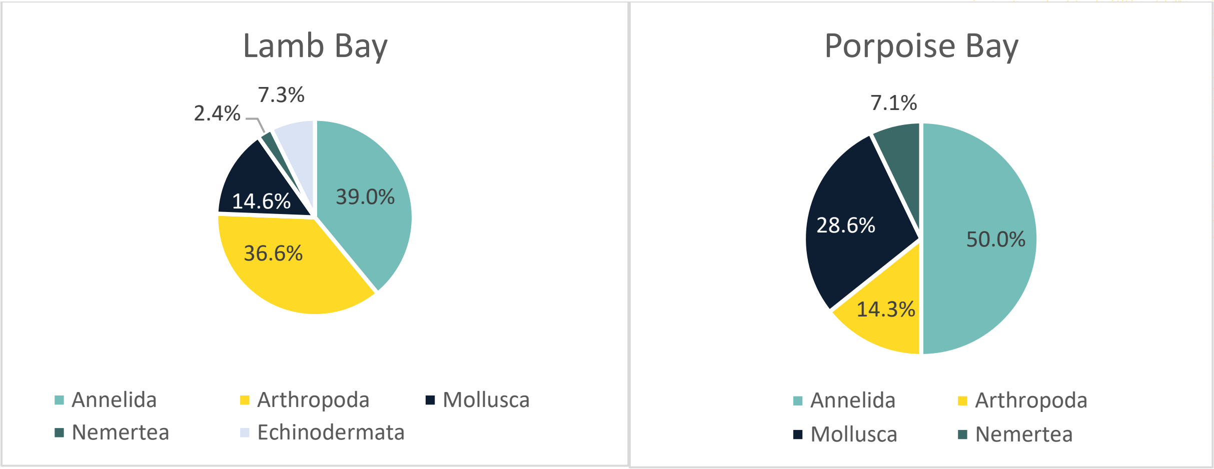

Figure 23. Invertebrate community composition by phyla for the Ponar grab samples from the Sechelt Inlet sites.

An obvious indicator species, suite of indicator species, or community assemblage linked to transplant success was not found. The two sites with the highest concentrations of residual woody debris (Lamb Bay and Royston Wrecks) were also the sites with the highest number of taxa and greatest species richness. As such, there were species present that were unique to each of these sites which may indicate high levels of organic pollution (Table 5). However, none of these species were found at both Lamb Bay and Royston Wrecks. Although not the same species, these two sites did have the presence of juvenile echinoderms. Plotting the overall assemblage by non-metric multidimensional scaling (nMDS) showed weak groupings by site location (Figure 24), and not by log storage history or transplant success. Sampling for benthic invertebrates was limited to only one sample taken per site, and a greater sampling effort may yield more refined results that consider the relative abundance of different suites of species.

Table 5. Unique species found at study sites with high concentrations of residual woody debris (>35 mg/g).

LAMB BAY		ROYSTON WRECKS	
Phyla	Species	Phyla	Species
Annelida	*Ampharete sp.*	Annelida	*Eteone sp.*
Annelida	*Axiothella rubrocincta*	Annelida	*Magelona longicornis*
Annelida	*Exogone dwisula*	Annelida	*Melinna elisabethae*
Annelida	*Malmgreniella berkeleyorum*	Annelida	*Oxydromus pugettensis*
Annelida	*Nereis procera*	Annelida	*Prionospio jubata*
Mollusca	*Turbonilla sp.*	Annelida	*Scoletoma tetraura*
Echinoderm	*Chiridota sp.*	Annelida	*Spiochaetopterus costarum*
Echinoderm	*Pentamera sp.*	Annelida	*Spiophanes berkeleyorum*
		Arthropoda	*Leucon sp.*
		Bryozoa	*Alderina sp.*
		Cnidaria	*Rhizorhagium formosum*
		Mollusca	*Axinopsida serricata*
		Mollusca	*Leukoma staminea*
		Mollusca	*Parvilucina tenuisculpta*
		Echinoderm	*Amphiodia urtica*

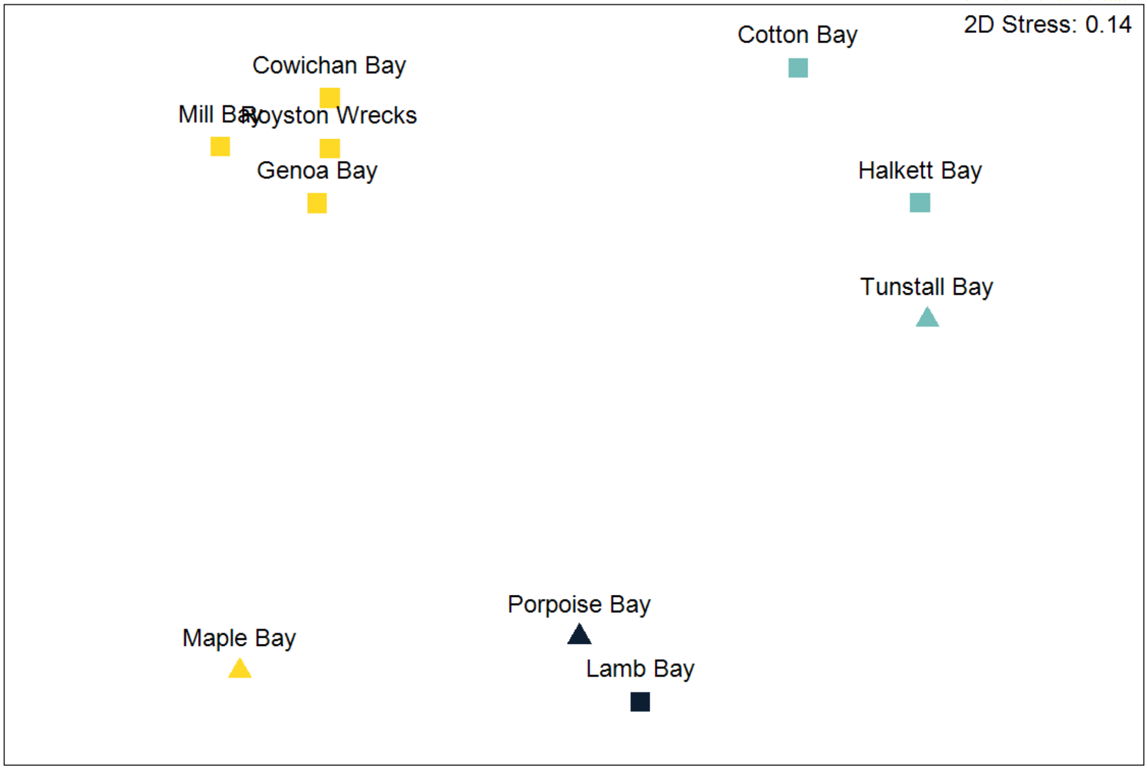

Figure 24. nMDS plot showing invertebrate community assemblage by site. Sites with log storage histories are represented by square symbols and triangles are reference sites with no history of log storage. Howe Sound sites have teal symbols, East Coast Vancouver Island sites have yellow symbols and Sechelt Inlet sites have dark blue symbols.

DISCUSSION

Eelgrass is widely recognized for the habitat values it provides and there has been an impetus to increase the total area of eelgrass in the Salish Sea. In particular, there is interest in restoration of eelgrass in those areas where it has been locally expatriated such as beneath decommissioned log storage tenures. SeaChange Marine Conservation Society has been undertaking eelgrass restoration with transplants at a number of sites in the Canadian Salish Sea in recent years, however, the success of these restoration efforts has been mixed. Since the act of restoring eelgrass requires considerable resources, including extracting transplants from local donor beds of eelgrass, identifiable environmental or biological indicators to assess if restoration is likely to be successful would be highly valuable. This study served as an initial investigation of the lasting ecosystem impacts associated with the common forestry practice of storing logs in sheltered bays and estuaries and the implications for eelgrass restoration. The goal was to improve site selection for eelgrass habitat restoration in historic log storage areas by establishing thresholds of impact for eelgrass transplant survival and identifying indicators that could be used to assess a site's potential for successful restoration. A concurrent aim was to evaluate the practicality and efficacy of field sampling techniques for restoration practitioners to assess site suitability.

Overall, conditions across sites were variable and we were not able to find a definitive indicator for restoration success from this pilot study. As is the case in all natural environments, there are many external factors and conditions that may contribute to the success of eelgrass establishment that cannot be controlled for or measured due to being beyond the scope of the study. However, there are notable results and observations relating to benthic woody debris and invertebrates suggesting that they may prove useful indicators with further investigation. The results suggest eelgrass can not establish where there are high concentrations of woody debris. The invertebrate assemblage diversity index or particular phyla groups may be indicative of adverse eelgrass growing conditions. Additional studies would be useful to better understand thresholds of woody debris concentrations and the relationship between benthic invertebrates, environmental conditions, and eelgrass transplant success. In the following sections, we comment on each measure as far as its potential as a useful indicator and practicality of application by restoration practitioners.

Benthic Woody Debris

The amount of residual woody debris on the seafloor may be a promising indicator of a historic log storage site's suitability for eelgrass transplants. Although the regression analysis did not show a statistically significant relationship between eelgrass transplant success and average sediment woody debris concentration at the study sites, a more localized approach may be more relevant than considering a site-wide average. From the mapping of woody debris and vegetation cover, we could see that eelgrass did not grow directly in sediment with visibly high concentrations of woody debris. Only in Cotton Bay did eelgrass grow relatively close to sediment with high woody debris cover, but this cover was an intact sunken log perched on the benthic sediment rather than characteristic bark debris material in direct contact and capping the sediment. No eelgrass was recorded in sampled areas where woody debris concentration exceeded 10 mg/g, however, we cannot definitely identify this as a threshold, because few samples contained more than this concentration. More detailed sampling across a range of woody debris concentrations would be needed to establish a meaningful and accurate threshold.

Woody debris sediment organic content sampling methods could be simplified to be more feasible for restoration practitioners. Rather than diver-collected cores, which were used in this study to simultaneously collect samples for ORP measurements, sediment could be obtained using a Ponar grab sampler. This would reduce the cost and increase the accessibility of sampling for residual woody debris. It should be noted that neither sediment core samplers nor Ponar grab samples may be able to account for residual woody debris buried deep in areas of high sedimentation, and a different method that can sample deeper into the sediment may be required in these areas. More research is recommended to further understand the relationship between residual woody debris in the benthic environment and eelgrass habitat productivity. The sample processing methods for sediment organic debris could also be simplified. In all samples in which the total organic content exceeded 10 mg/g, grain sizes of organic matter smaller than 4.75 mm contributed to less than 2% of the total organic content in a sample. This suggests that drying and hand-sorting the larger grain sizes of a sample (greater than or equal to 4.75 mm) may be sufficient in estimating the total residual woody debris in former log storage areas. This negates the need for a muffle furnace, making this analysis faster and more cost-effective.

Benthic Invertebrates

Benthic invertebrates live in close contact to or are immersed within benthic sediment. They tend to be sedentary and, as such, they cannot avoid exposure to contaminants and other stressors present in their habitat. Therefore, invertebrates can act as biological indicators of pollution in marine sediments (Duterte et al. 2013, Hyland et al. 2005, Muxica et al. 2005, Eaton 2001, Smith et al. 2001). While benthic invertebrate species richness has been reported to be somewhat reduced by sediment organic content greater than 10 mg/g and greatly reduced at sediment organic content levels greater than 35 mg/g (Hyland et al. 2005), we did not find the same relationship. Lamb Bay, the site with the highest organic content, and Royston Wrecks, the third highest, had the greatest number of taxa present at 41 species at each. A negative relationship was found between eelgrass transplant success and total taxa and Margalef species richness index suggesting that the invertebrate community may be a useful indicator. In B.C., Picard et al. (2003) found benthic invertebrates were more reliable than pore-water oxygen reduction potential at indicating elevated levels of woody debris accumulation. We did not find a single stand-out species or a 'fingerprint' of a community that seemed to be indicative of eelgrass success or failure from the samples analyzed. It is worth noting that the two sites with the poorest eelgrass survival (Royston Wrecks and Lamb Bay) were the only sites that had juvenile echinoderms present in the sample. Again, as this was a pilot study with only a single sample representing a site, greater sampling may be able to find an indicator species or a useful benthic invertebrate measure.

With echinoderms only present at sites with high levels of organic carbon in the benthic sediments and poorest survival rates, they could potentially serve as an indicator. Only juvenile echinoderms were found in the samples, however, which would be difficult for the average restoration practitioner to differentiate in the field (T. MacDonald, Biologica Laboratories, pers. comm.). Perhaps, the presence of adult echinoderms at a site could indicate high levels of organic enrichment, and could be used to help preclude areas from eelgrass transplant site selection. However, further study would be required to distinguish which species of echinoderm and at what abundance.

Benthic invertebrate sampling with a Ponar grab is simple and accessible for practitioners, however, the sample processing and species identification requires specialists and is time-consuming and costly. There may be potential to minimize costs by shifting to an environmental DNA (eDNA) approach over specialist sorting and identification. As part of this study, Biologica Laboratories in Victoria, B.C., who analyzed the samples, also had the DNA sequenced with Canadian Centre for DNA barcoding. These data will be used to explore eDNA as a cost-effective means of analyzing benthic communities that is more accessible and less disruptive to the environment.

Log Storage History

From what could be inferred from tenure records, log storage history did not show a strong relationship with transplant success. Neither the time since last use nor total use seemed to indicate whether a site would have successful transplants. However, it is difficult to draw conclusions as Provincial log storage tenure records for the study sites are sparse and did not represent the total log storage history for any of the tenured sites. The earliest tenure record for any site dated from 1997. Land use tenures have been collected by the Province since the 1850s and were originally stored in hand-written registers (Gov't of B.C.). These records were digitized in the 1980s and subsequently made web-accessible in 1999. It is possible that some records were lost before or during the digitizing process. Aerial photos are a better resource, but they often do not date back far enough to determine when a site was first used for log storage. A more-in depth review that includes local knowledge would be useful in accurately determining the historical scope and potential impact of log storage in the Salish Sea.

Pore-water Oxygen Reduction Potential

The pore-water OPR was measured as a proxy for pore-water anoxia and indicator hydrogen sulfide, which has been shown to inhibit eelgrass growth. Unfortunately, we faced several challenges with pore-water ORP. The meter readings fluctuated and were slow to stabilize even within sites from samples in close proximity. We also found the results were highly variable and did not appear to be influenced by the woody debris content of the sample. Upon reviewing the data, which was collected over several months, the greatest signal seems to be the month that the sampling was done. Furthermore, the method was not practical. Taking measurements in the field required divers to excavate a core and return it to the surface intact making the method costly, difficult, and unreliable. If this method were to be tested further, the importance of sampling at a similar time of year, increased replication, and using a standardized depth within the sediment column would be recommended.

In sum

The scope of the project was related to assessing benthic factors related to log storage, however, there are numerous environmental influences that may affect the success of eelgrass transplants. Anthropogenic factors such as land use within the associated watershed, housing density of the adjacent foreshore, and the prevalence of marine structures (docks, buoys, etc.) have also been shown to negatively impact eelgrass habitat over time, and likely played a role in the success of eelgrass transplants at the study sites (Nahirnik 2018). There are also factors such as sedimentation and wave energy which would vary across microhabitats and may play a role in transplant establishment. Standardized methods and controlled experiments are needed to tease apart the conditions associated with log storage activities to fully grasp their implications and larger-scale models which consider multiple environmental factors are needed to assist practitioners in decisions for where to invest efforts into restoration.

RECOMMENDATIONS

First, it would be valuable to conduct an in-depth review of the history of log storage throughout the Salish Sea. This would establish the first known log storage use of individual sites, and help to track how log storage activities may have altered sites from their original state. This work could include community mapping events, Traditional Ecological Knowledge, interviews with community elders, and gathering of historical primary documents. This work would help establish the pre-impact ecological conditions of sites and trace the flow of timber through the waterways of the Salish Sea over its colonized history.

Also, further sampling of residual woody debris content at other former log storage sites throughout the Salish Sea would be valuable in creating a robust dataset to examine how woody debris either accumulates or is dispersed from a site and, therefore, how quickly sites are able to reach pre-impact benthic conditions. This sampling may also be used to estimate the amount of organic carbon that log storage has added to the Salish Sea overall. The field work done in this study has helped to design sampling techniques which would be much simpler and cost-effective to accomplish in future work. Sampling for woody debris can be done using a Ponar grab sampler, without the use of divers. It is also possible, if further research produces similar results, that woody debris samples need only be dried and hand-sorted to establish residual woody debris content.

Finally, restoration efforts are most effective when based on sound baseline data. Data collected today can be used to help restoration practitioners of the future. Currently, there exists very little data on the benthic conditions in the Salish Sea overall. Any further work which provides environmental data for baseline conditions, whether through underwater mapping, sediment organic content measurements, or benthic invertebrate sampling, will provide valuable information to help guide the efforts of restoration practitioners in the future.

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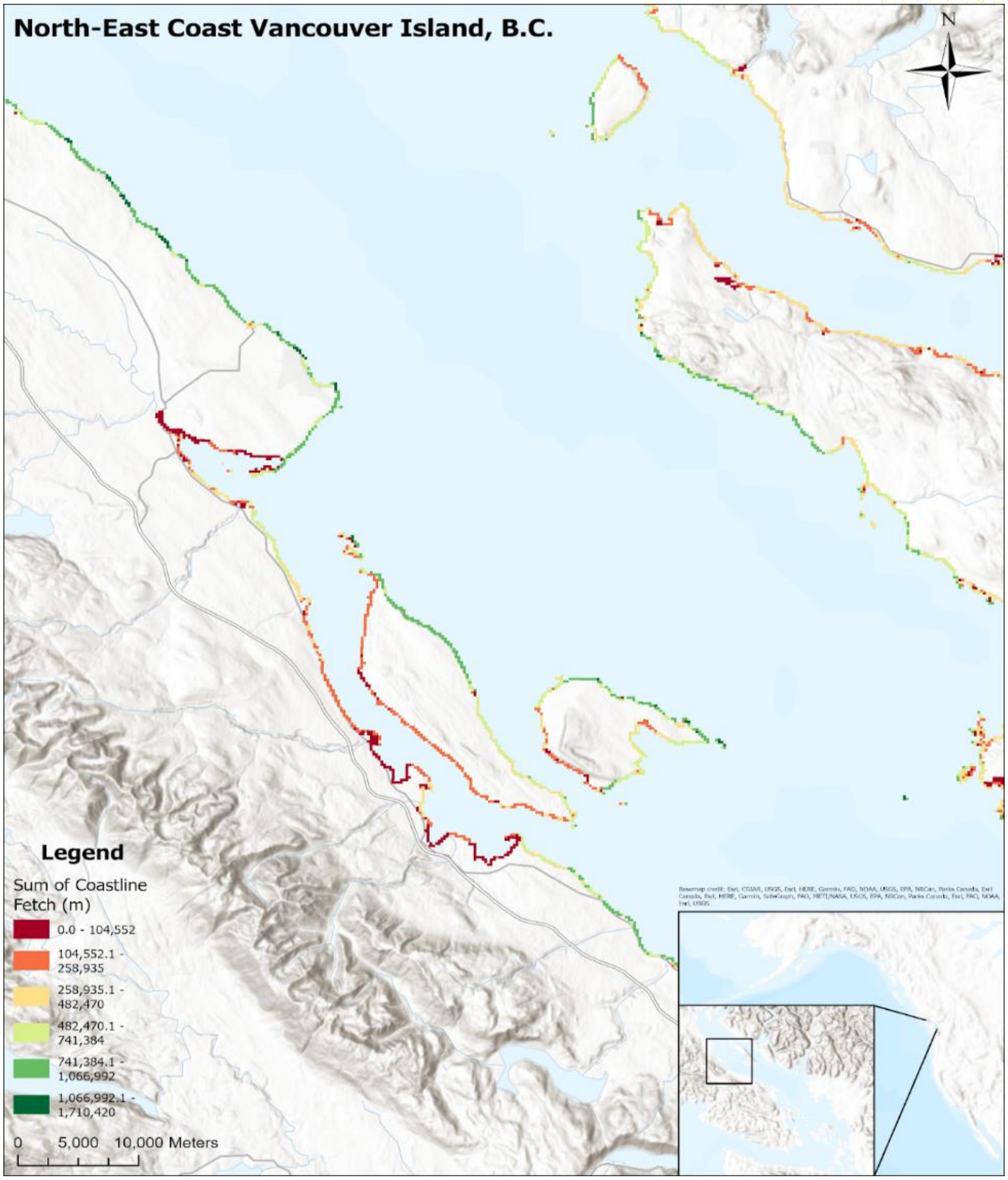
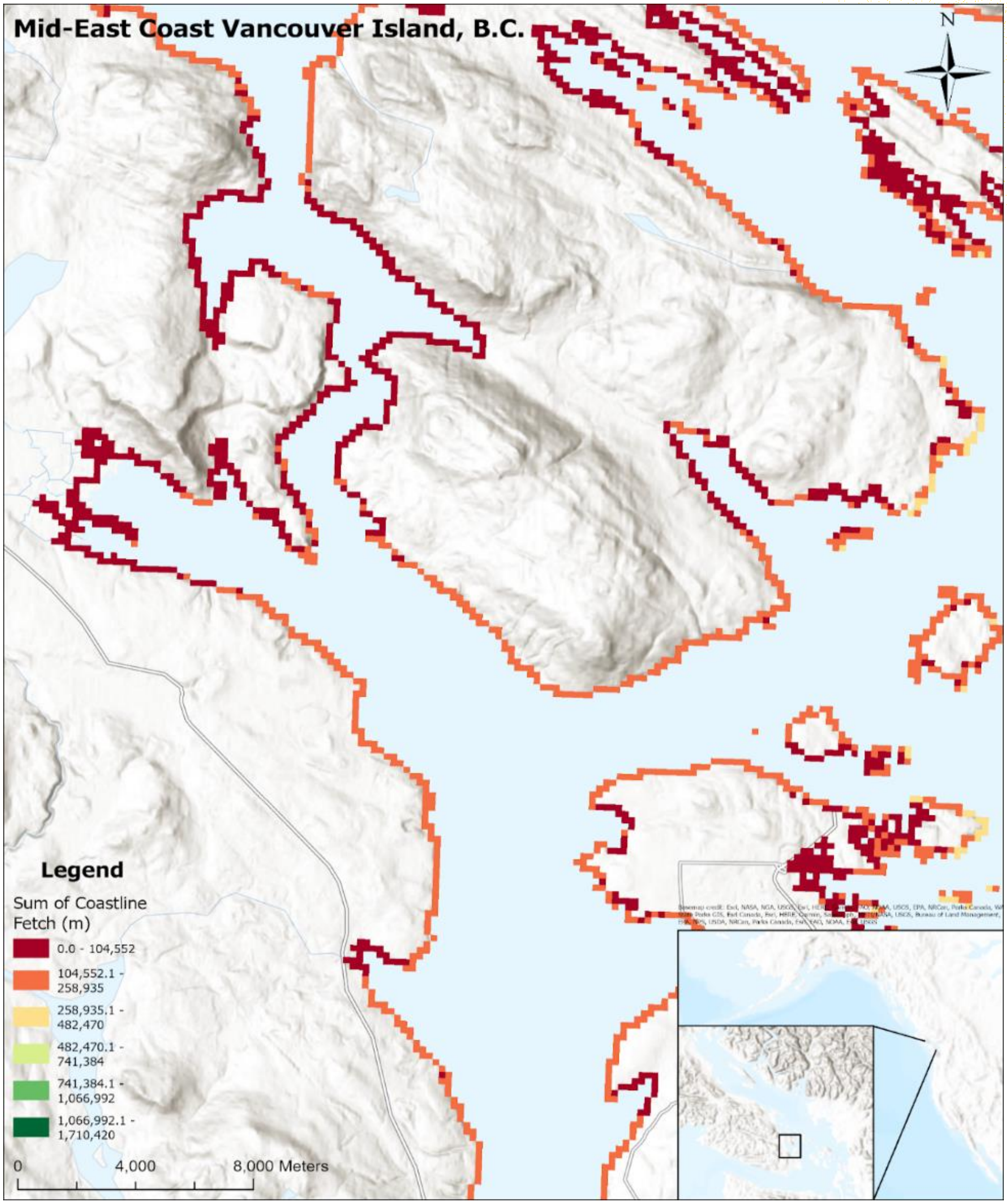
APPENDICES

A. Fetch Maps

The following maps show the potential coastline fetch for the regions with samples sites. Fetch is calculated by the sum of the total distance, in meters, from a site to its nearest shore in every direction (360°). Fetch data layer created by Dr. Alejandra Mora Soto and maps created by Jake Dingwall using ArcMap.

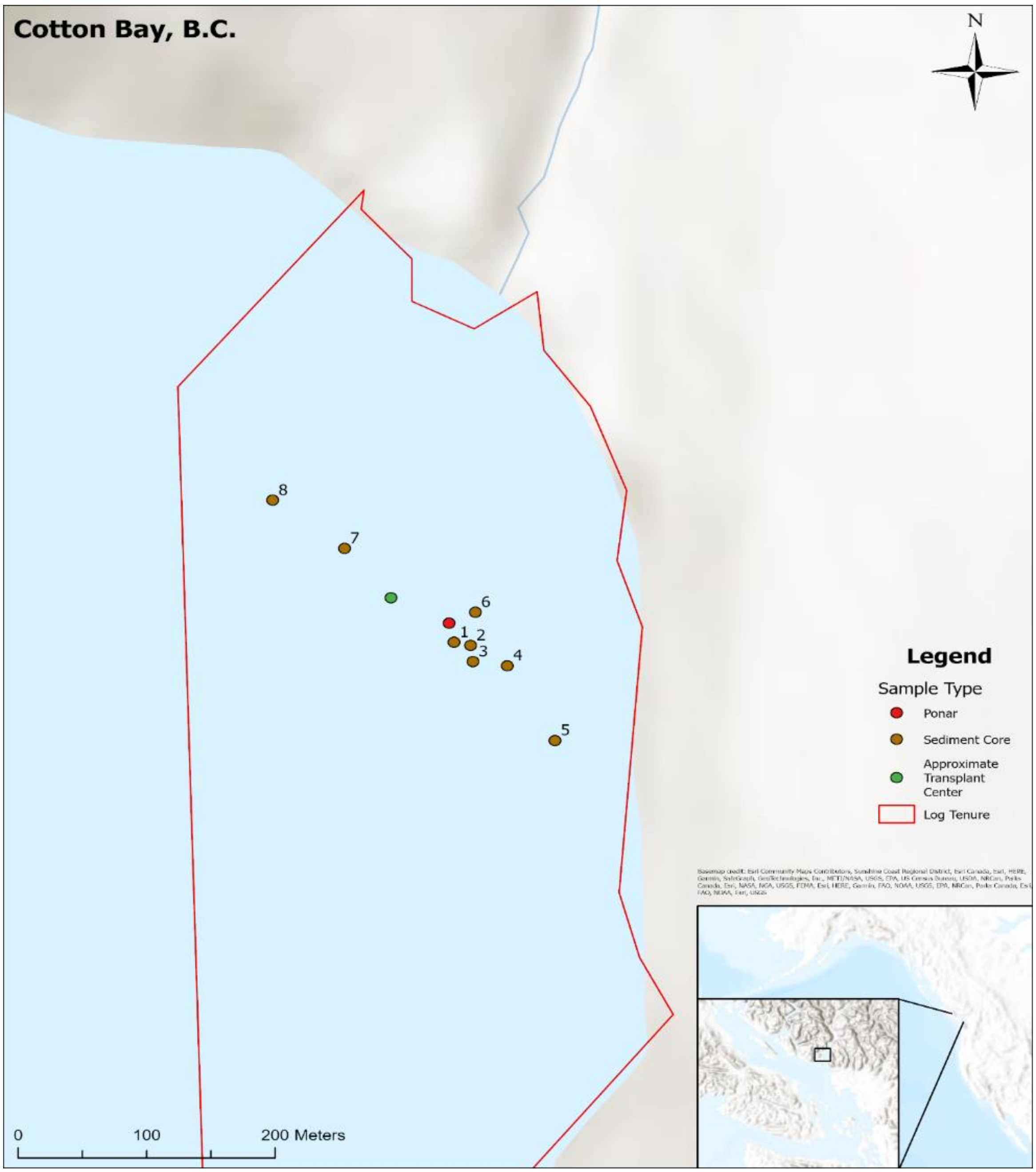

North-East Coast Vancouver Island, B.C.
N
Legend
Sum of Coastline Fetch (m)
0.0 - 104,552
104,552.1 - 258,935
258,935.1 - 482,470
482,470.1 - 741,384
741,384.1 - 1,066,992
1,066,992.1 - 1,710,420
0 5,000 10,000 Meters

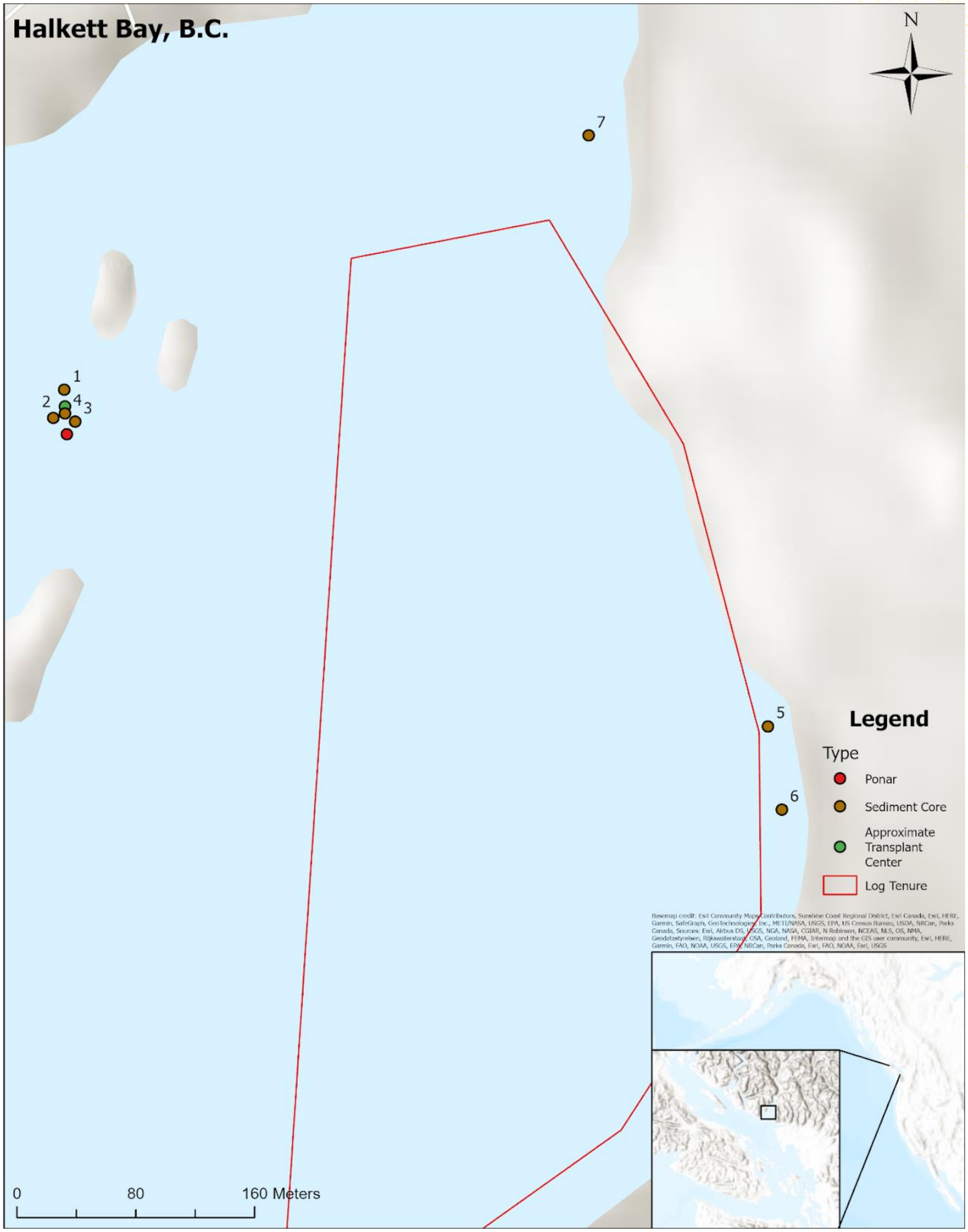

Mid-East Coast Vancouver Island, B.C.
N
Legend
Sum of Coastline Fetch (m)
0.0 - 104,552
104,552.1 - 258,935
258,935.1 - 482,470
482,470.1 - 741,384
741,384.1 - 1,066,992
1,066,992.1 - 1,710,420
0
4,000
8,000 Meters

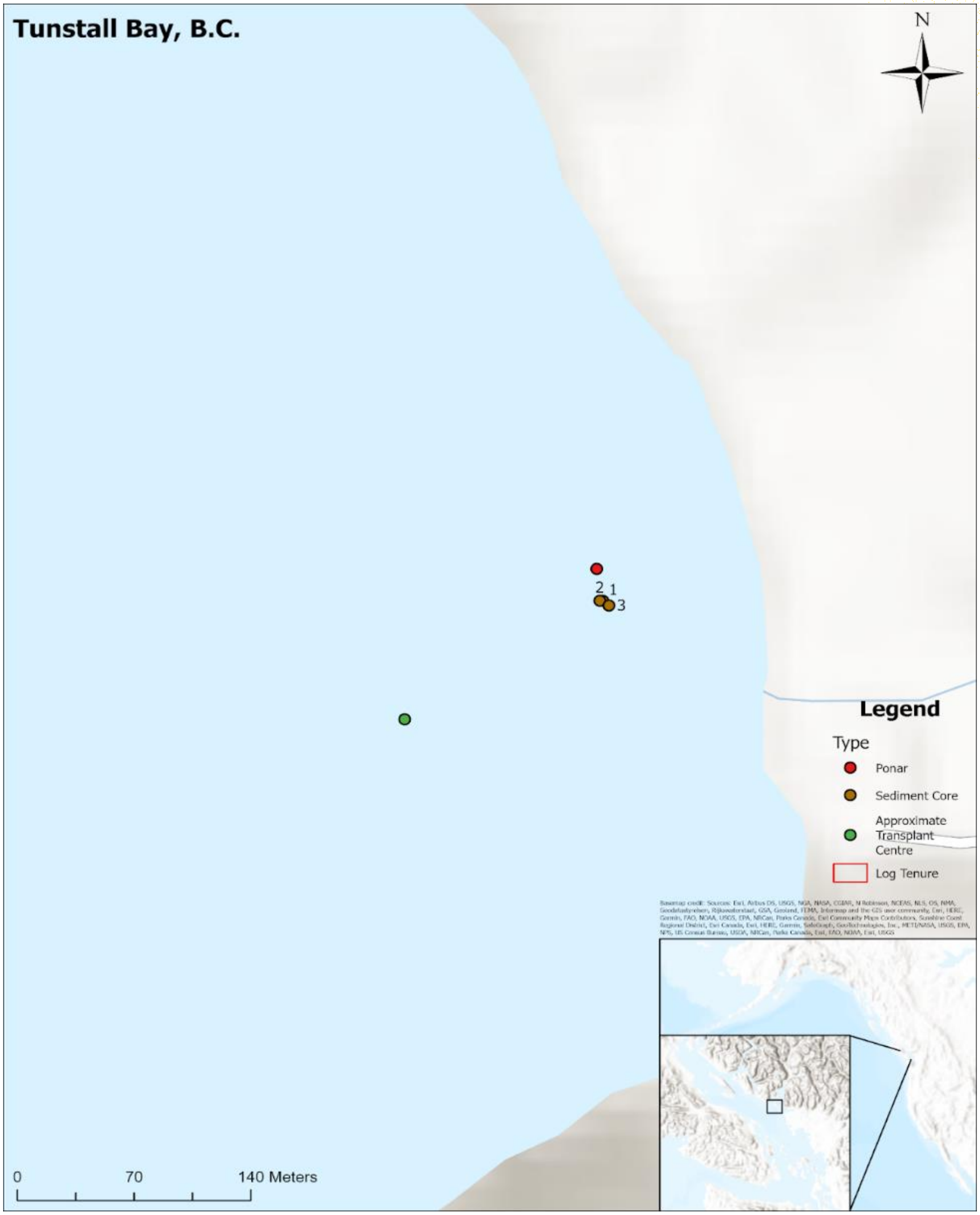
B. Study Site Sample Location Maps

The following maps show the study sites with historic log tenure outlined in red where applicable, eelgrass transplant location, and Ponar grab sample location. Also depicted are individually labelled sediment core sample locations. Map created using ArcMap by Jake Dingwall.

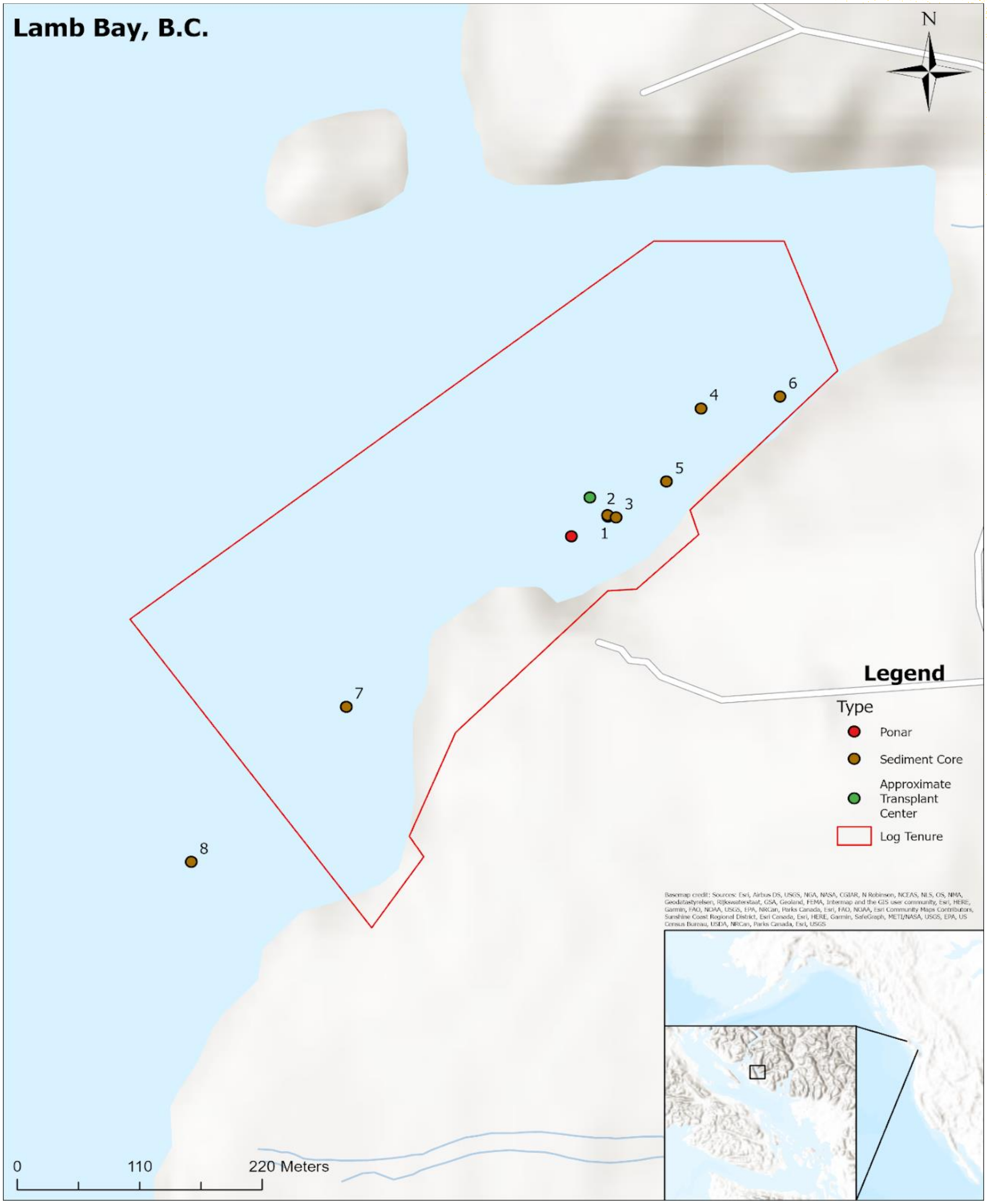
Howe Sound

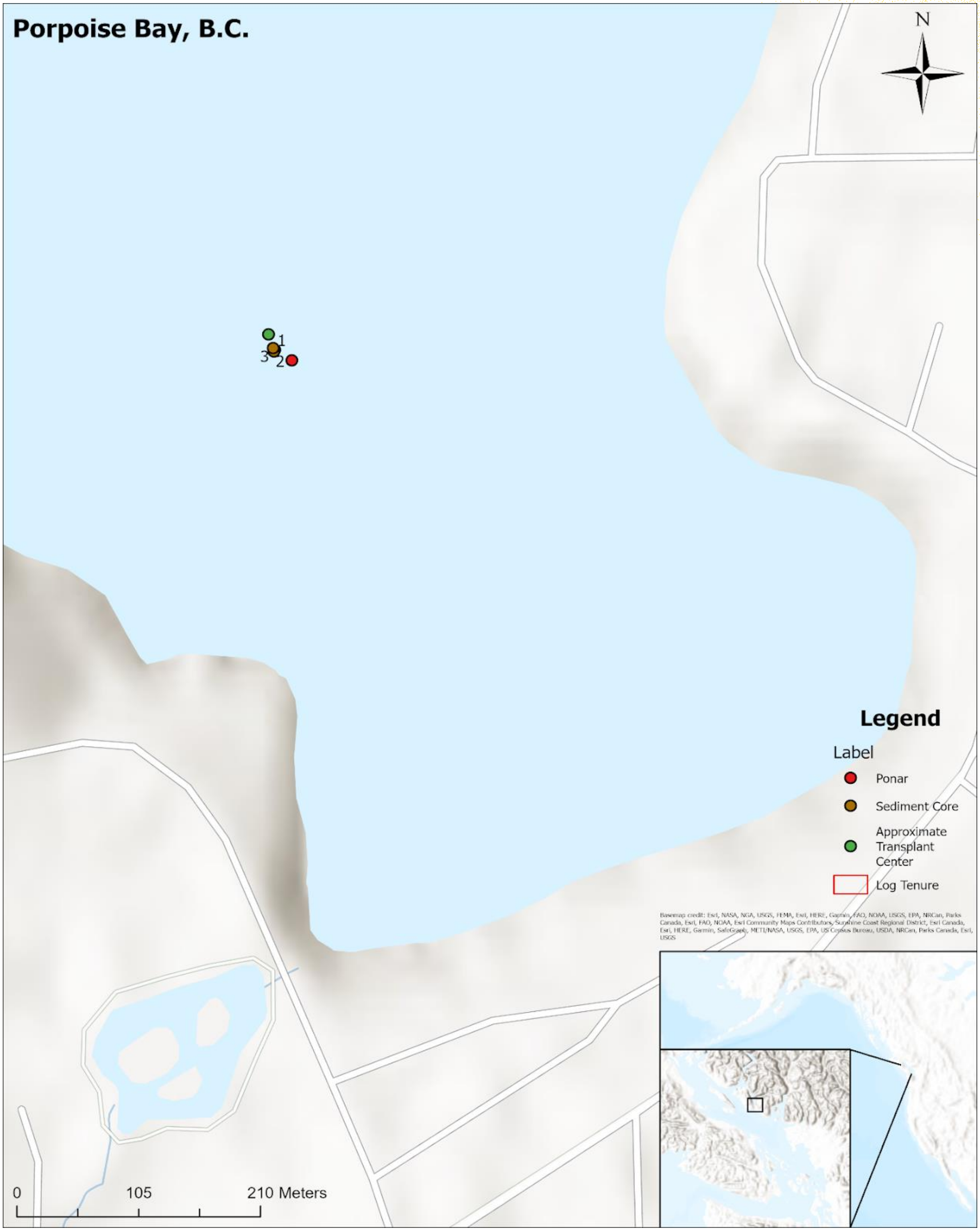



Halkett Bay, B.C.
N
7
1
2
4
3
5
6
Legend
Type
Ponar
Sediment Core
Approximate Transplant Center
Log Tenure
0
80
160 Meters

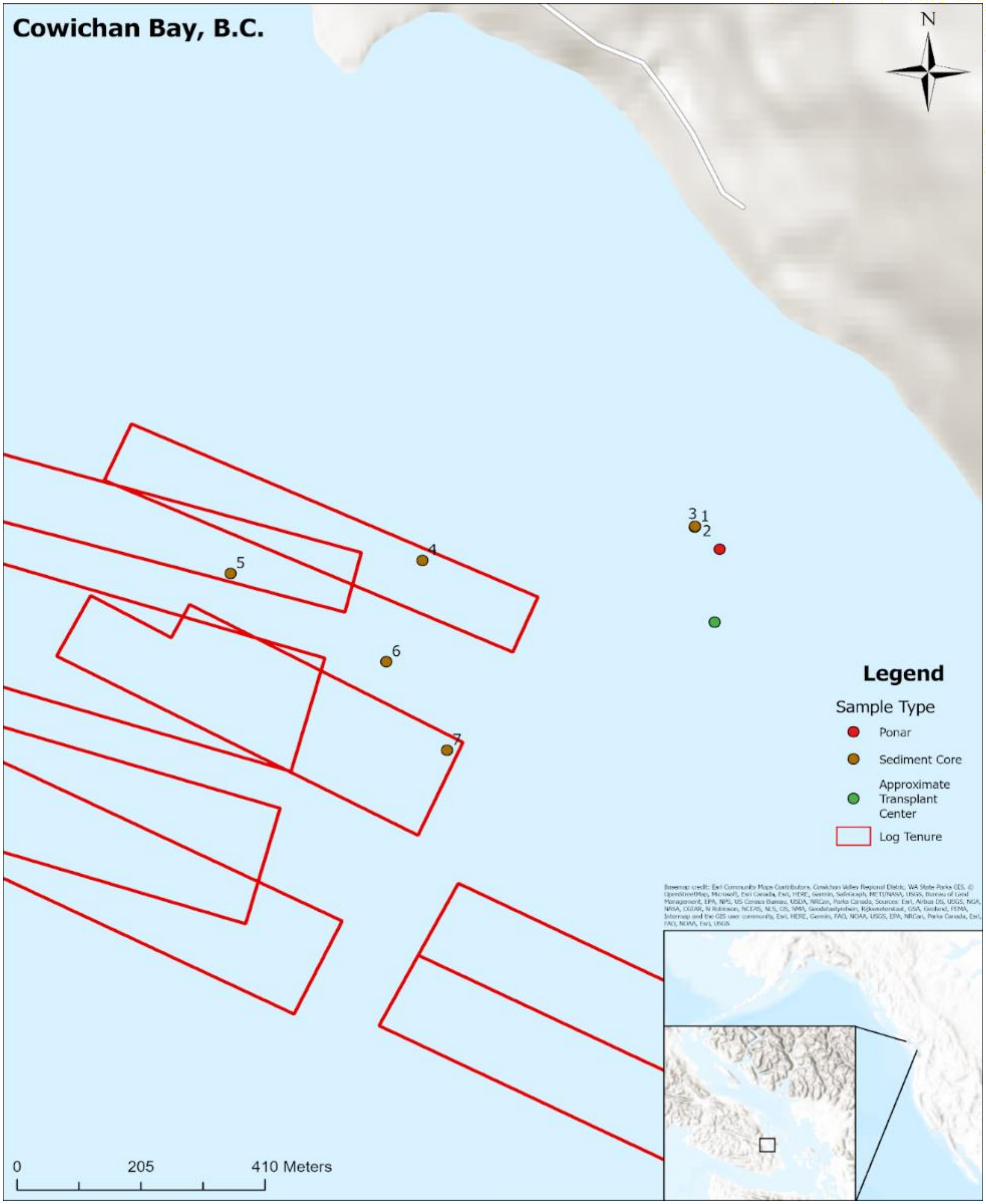

Tunstall Bay, B.C.
N
2
1
3
Legend
Type
Ponar
Sediment Core
Approximate Transplant Centre
Log Tenure
0
70
140 Meters

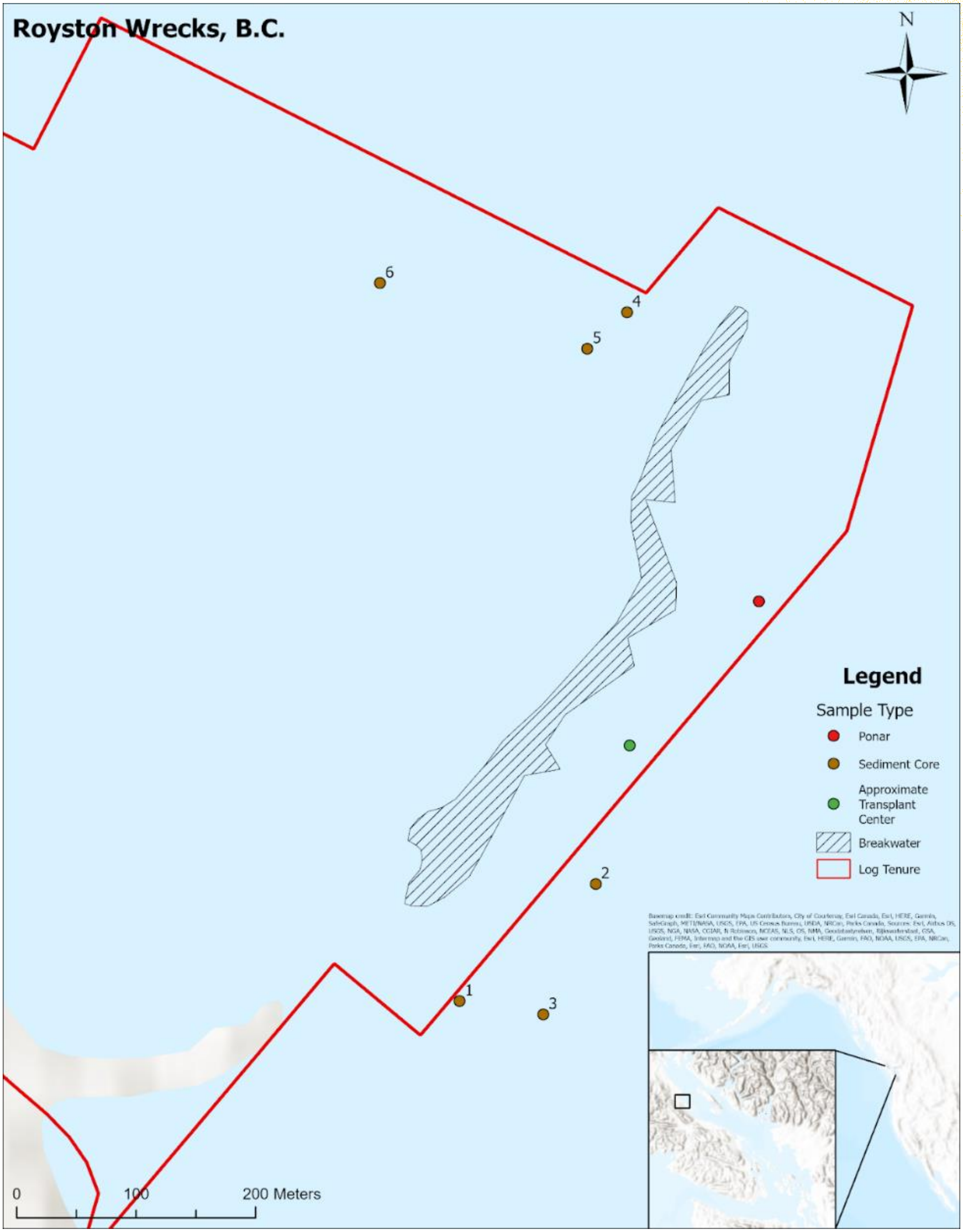
Sechelt Inlet

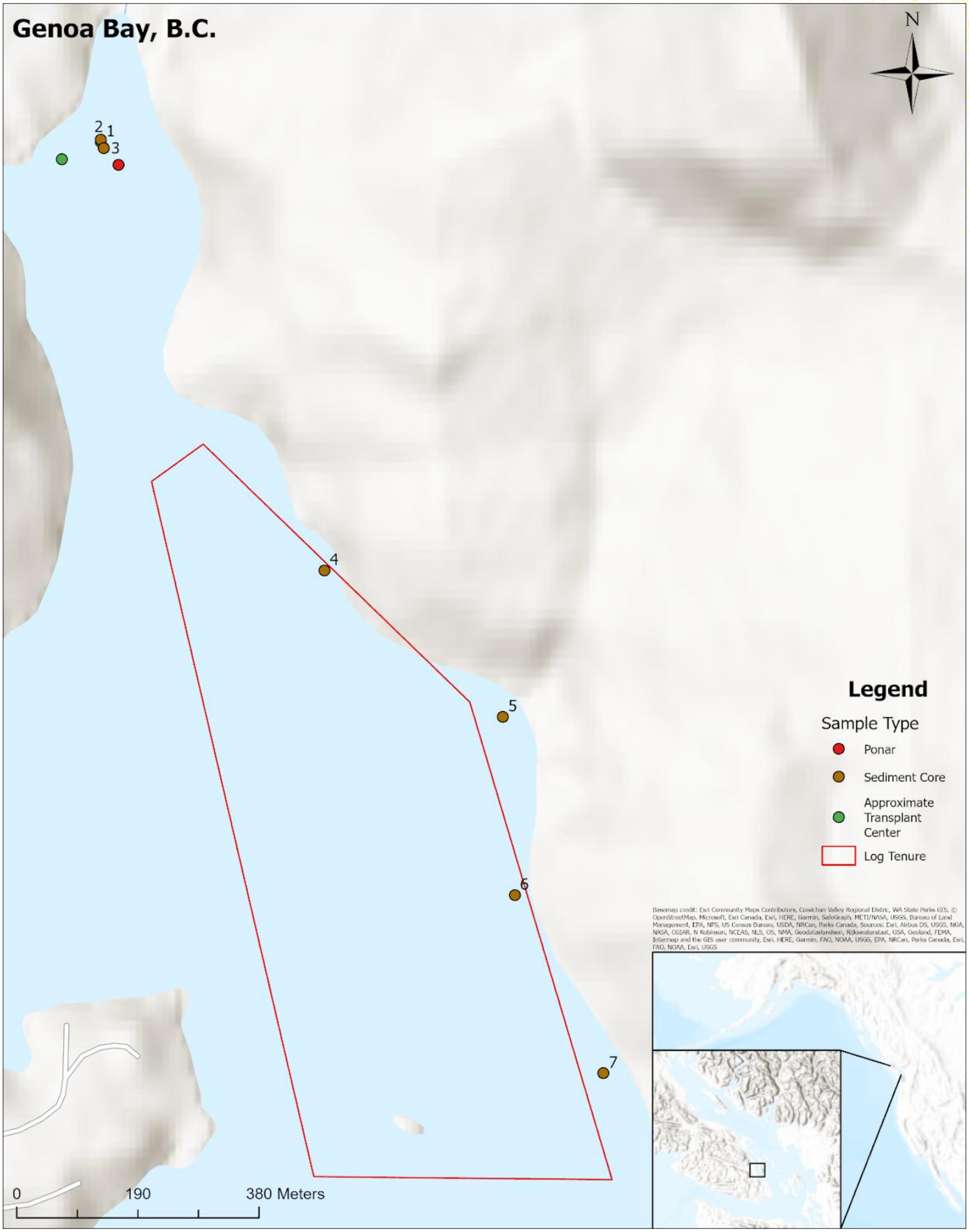



Porpoise Bay, B.C.
N
1
2
3
Legend
Label
Ponar
Sediment Core
Approximate Transplant Center
Log Tenure
0
105
210 Meters

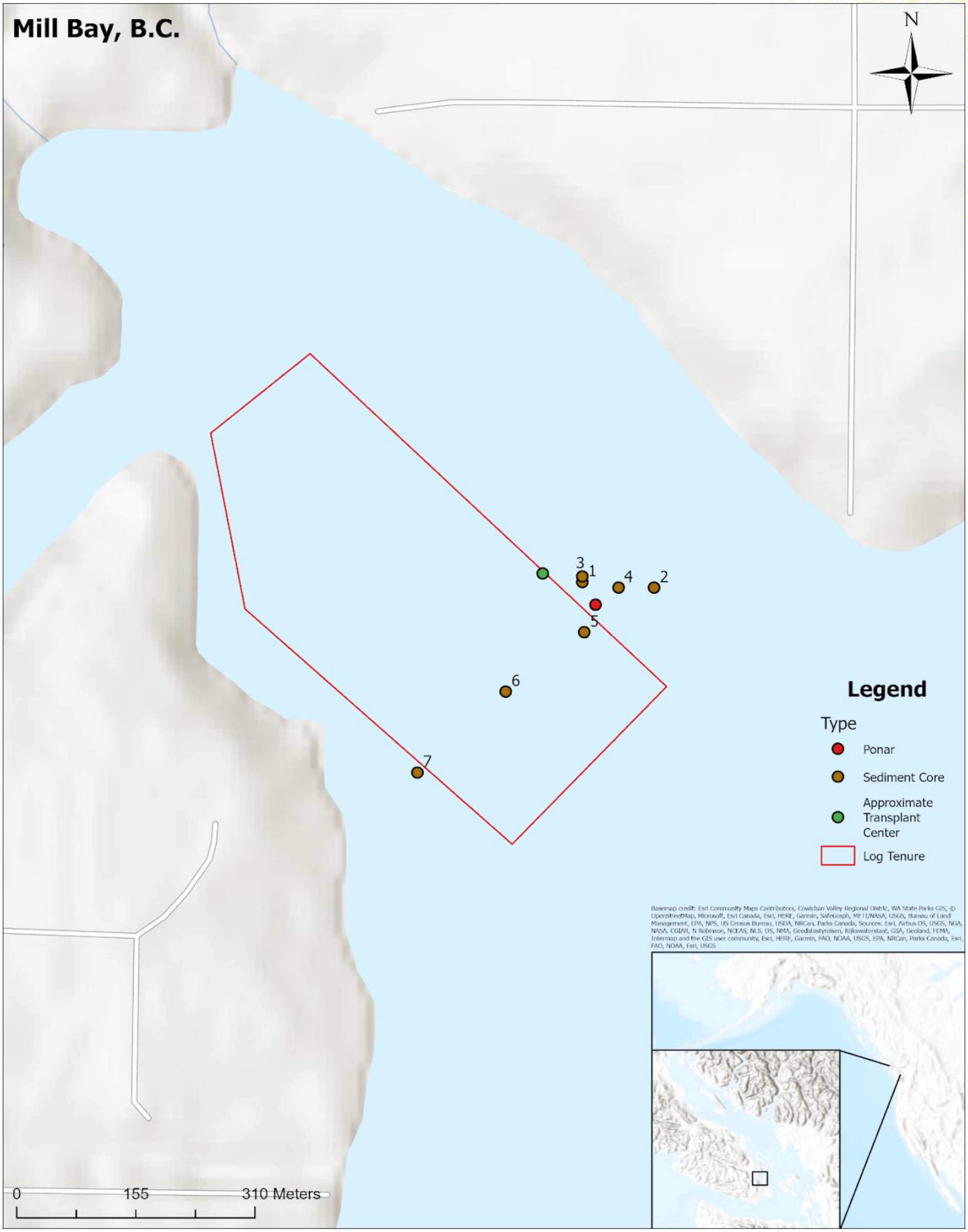
East Coast Vancouver Island

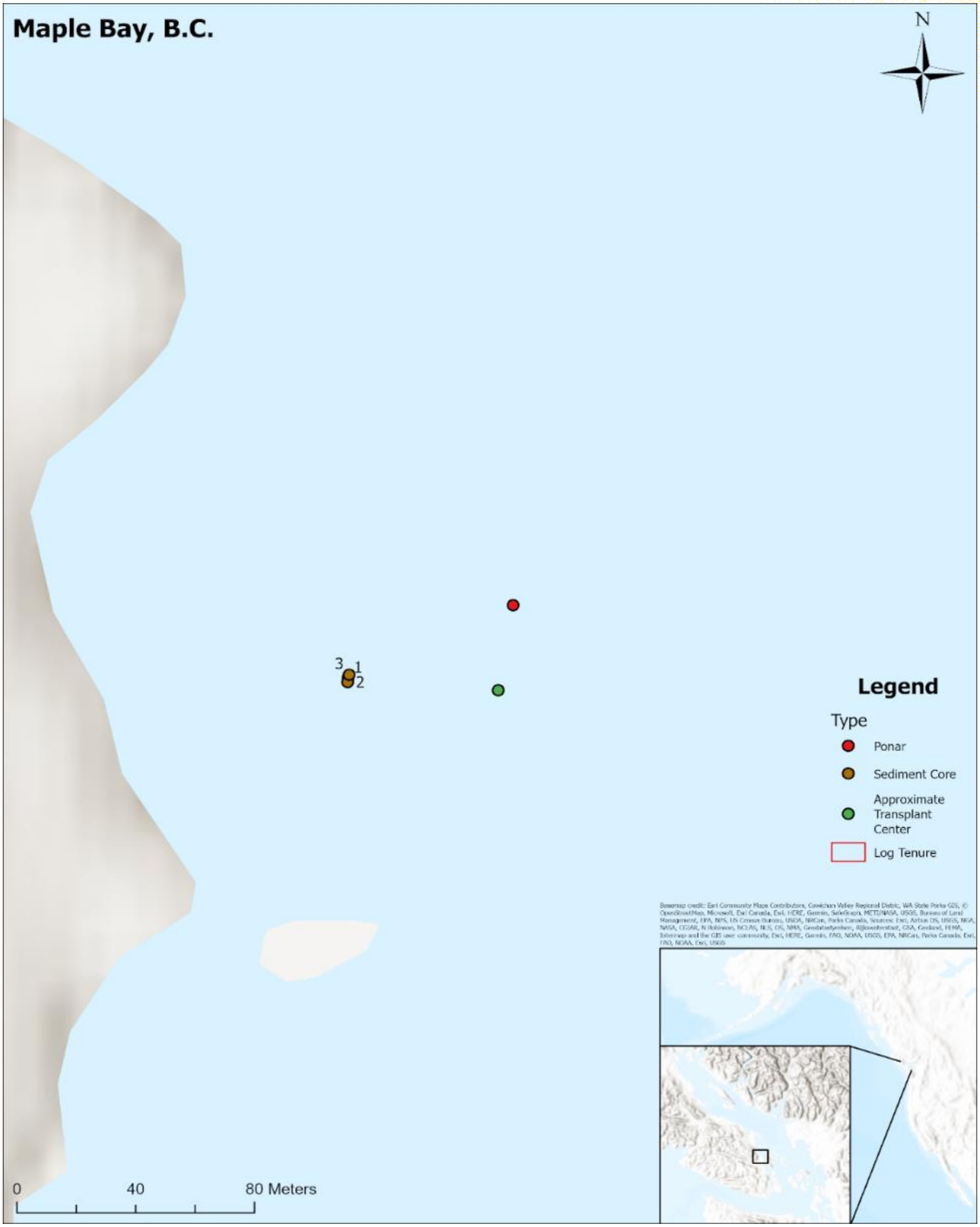



Royston Wrecks, B.C.
N
6
4
5
2
1
3
Legend
Sample Type
Ponar
Sediment Core
Approximate Transplant Center
Breakwater
Log Tenure
0
100
200 Meters



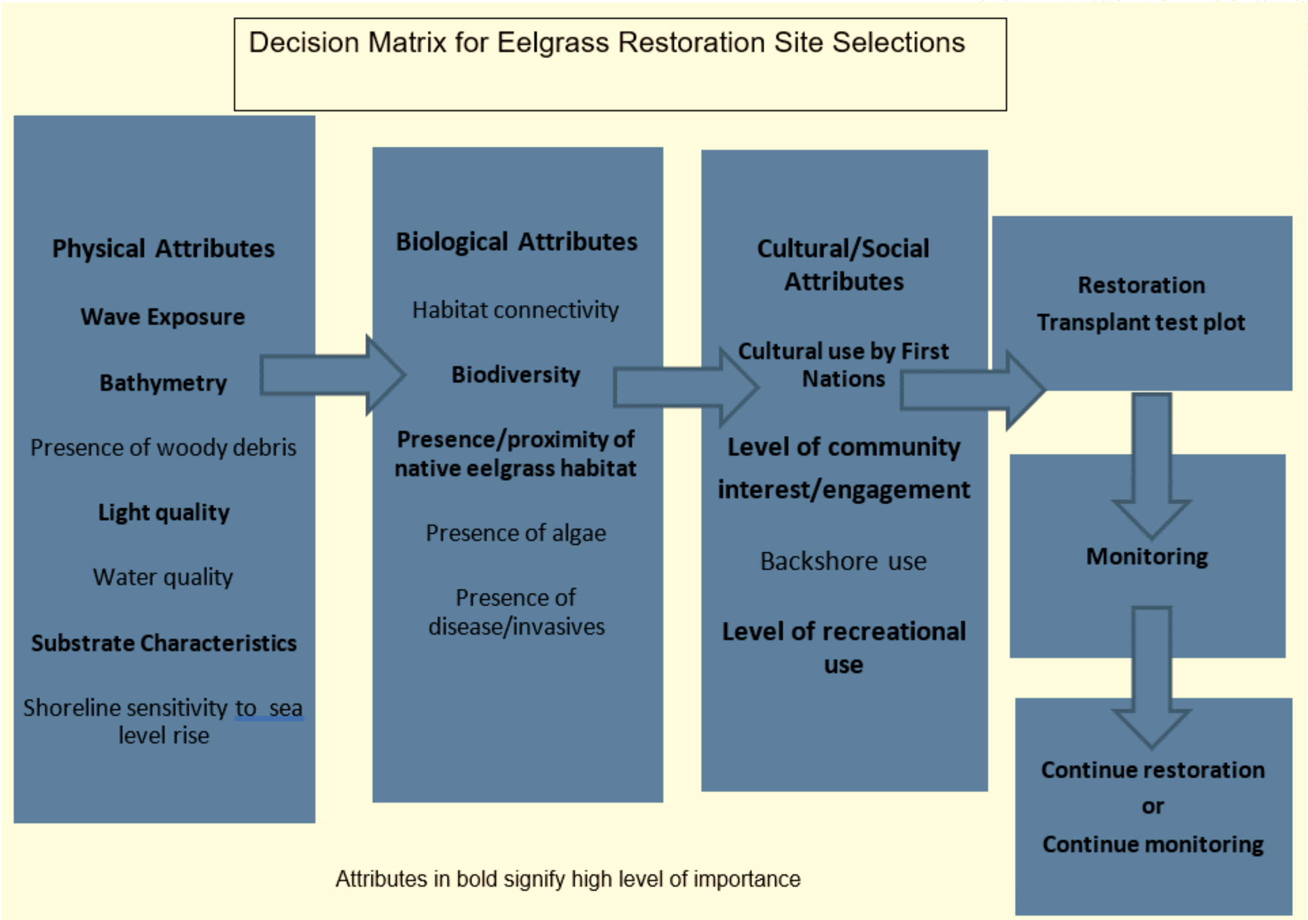
Genoa Bay, B.C.
N
2
1
3
4
5
6
7
Legend
Sample Type
Ponar
Sediment Core
Approximate Transplant Center
Log Tenure
Basemap credit: Esri Community Maps Contributors, Cowichan Valley Regional Distric, WA State Parks GIS, © OpenStreetMap, Microsoft, Esri Canada, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, NRCan, Parks Canada, Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada, Esri, FAO, NOAA, Esri, USGS
0
190
380 Meters


Mill Bay, B.C.
N
3
1
4
2
5
6
7
Legend
Type
Ponar
Sediment Core
Approximate Transplant Center
Log Tenure
Basemap credit: Esri Community Maps Contributors, Cowichan Valley Regional Distric, WA State Parks GIS, © OpenStreetMap, Microsoft, Esri Canada, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, US Census Bureau, USDA, NRCan, Parks Canada, Sources: Esri, Airbus DS, USGS, NGA, NASA, CGIAR, N Robinson, NCEAS, NLS, OS, NMA, Geodatastyrelsen, Rijkswaterstaat, GSA, Geoland, FEMA, Intermap and the GIS user community, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NRCan, Parks Canada, Esri, FAO, NOAA, Esri, USGS
0
155
310 Meters



Maple Bay, B.C.
N
3
1
2
Legend
Type
Ponar
Sediment Core
Approximate Transplant Center
Log Tenure
0
40
80 Meters

C. Eelgrass Transplant Selection Decision Matrix



Eelgrass transplant site selection matrix used by SeaChange Marine Conservation, reproduced with permission.

D. Pore-water Oxygen Reduction Potential Data

Pore-water oxygen reduction potential raw data from all sites.

SAMPLE	OXYGEN REDUCTION POTENTIAL (MV)	MONTH SAMPLED
Halkett Bay 1	367.6	August
Halkett Bay 2	263.8	August
Halkett Bay 3	286.5	August
Halkett Bay 4	-150.1	December
Halkett Bay 5	-159.7	December
Halkett Bay 6	-161.1	December
Halkett Bay 7	-160	December
Cotton Bay 1	162.1	August
Cotton Bay 2	111.2	August
Cotton Bay 3	128.8	August
Cotton Bay 4	-157.8	December
Cotton Bay 5	-154.1	December
Cotton Bay 6	-146.7	December
Cotton Bay 7	-147.6	December
Cotton Bay 8	-8.3	December
Tunstall Bay 1	616.8	August
Tunstall Bay 2	626.7	August
Tunstall Bay 3	620.1	August
Royston 1	97.1	October
Royston 2	143.7	October
Royston 3	73.9	October
Royston 4	241.7	October
Royston 5	186.5	October
Royston 6	372.4	October
Maple Bay 1	40.5	October
Maple Bay 2	-44	October
Maple Bay 3	-55.9	October
Cowichan 1	154.1	October

Cowichan 2	159.3	October
Cowichan 3	318.9	October
Cowichan 4	140.2	October
Cowichan 5	223.4	October
Cowichan 6	363	October
Cowichan 7	223.4	October
Mill 1	194.1.	October
Mill 2	-92.1	October
Mill 3	-49.4	October
Mill 4	23.9	October
Mill 5	-102	October
Mill 6	-64.2	October
Mill 7	-80.9	October
Genoa 1	-83.9	October
Genoa 2	-59.2	October
Genoa 3	-37.5	October
Genoa 4	-76.2	October
Genoa 5	10.6	October
Genoa 6	-91.9	October
Genoa 7	-169	October
Lamb 1	140.5	December
Lamb 2	53.2	December
Lamb 3	-150.5	December
Lamb 4	46.6	December
Lamb 5	-154.1	December
Lamb 6	-28.1	December
Lamb 7	-7.5	December
Lamb 8	41.6	December
Porpoise 1	198.8	December
Porpoise 2	24.7	December
Porpoise 3	70.8	December

E. Sediment Total Organic Content Data

Sieve Contents

Sieved contents at the 9.5 mm grain size of sediment core samples from each site.

SIEVE SIZE: 9.5 MM						
SAMPLE	TOTAL DRY MASS (G)	WOOD (G)	BARK (G)	BARK & WOOD (G)	INORGANIC (G)	BIOLOGIC (G)
Maple	230.4	5.474	2.01	7.484	87.6	123.3
Porpoise	2.3	0.129	0.502	0.631	0.63	0.774
Halkett 1	69	0	0	0	67.44	3.19
Halkett 2	108.1	0.21	1.936	2.146	79.6	24.7
Halkett 4	49.5	0.48	1.78	2.26	32.197	13.644
Royston 1	43.3	0.749	19.853	20.602	0	24.964
Royston 4	12.4	0.174	0.749	0.923	5.168	5.261
Royston 6	9.9	0.756	2.043	2.799	0.289	5.754
Lamb 2	11.4	0.4	7.2	7.6	3.6	0.5
Lamb 4	41.9	14.7	21.9	36.6	1.8	0
Lamb 7	106.227	0	0	0	89.232	16.917
Lamb 8	188.8	0	0	0	180.5	7.9
Cotton 1	18.9	0	0	0	17.71	1.13
Cotton 3	3.9	0	0.22	0.22	2.39	0.89
Cotton 5	334	1.6	9.6	11.2	319.1	0
Cowichan 1	86.3	0	0	0	74.653	11.286
Cowichan 5	840.6	0	0	0	836.1	2.596
Cowichan 7	139.1	0.131	2.554	2.685	128.581	8.019
Mill 2	84.8	0	0	0	82.3	2.8
Mill 7	3.2	0	0	0	0	2.891
Genoa 2	24.6	0.894	0.476	1.37	17.197	5.431
Genoa 5	215.5	0	0	0	200.243	15.201
Genoa 7	82.2	0.023	0.026	0.049	65.238	16.139

Sieved contents at the 4.75 mm grain of sediment core samples from each site. CND stands for 'could not determine,' meaning the particles could not be accurately differentiated between wood and bark. These particles were not included in equations pertaining to the overall percentages of wood and bark in samples. The Halkett 4 sample was too fine to be differentiated overall and was analyzed completely via the muffle furnace.

SIEVE SIZE: 4.75 MM						
SAMPLE	TOTAL DRY MASS (G)	WOOD (G)	BARK (G)	BARK & WOOD (G)	INORGANIC (G)	BIOLOGIC (G)
Maple	374.1	CND	CND	3.699	140.8	84.3
Porpoise	8.5	0.481	0.387	0.868	0	1.007
Halkett 1	424.8	0	0	0	421.6	0.1
Halkett 2	217.2	CND	CND	8.246	164.6	42.5
Halkett 4	Too fine – muffle furnace					
Royston 1	6.5	1.409	1.619	3.028	0	3.387
Royston 4	41.2	0.483	2.629	3.112	24.547	10.162
Royston 6	29.9	0.159	0.595	0.754	20.324	8.151
Lamb 2	18.5	0.612	12.7	13.312	4.771	0.487
Lamb 4	41.98	1.1	41.2	42.3	1.8	0
Lamb 7	333.512	0	0.332	0.332	323.633	8.234
Lamb 8	269.8	0.2	0	0.2	262.3	6.4
Cotton 1	29.7	0	0.13	0.13	28.17	1.2
Cotton 3	14.1	0.15	0.26	0.41	12.22	1.1
Cotton 5	134.4	CND	CND	21	112.4	0.5
Cowichan 1	143.9	0	0.254	0.254	137.778	5.07
Cowichan 5	246.3	0.001	0	0.001	244.2	1.463
Cowichan 7	207.2	0.172	0.403	0.575	204.983	1.546
Mill 2	202.5	0.2	0	0.2	201.3	1.2
Mill 7	2.5	0	0	0	0.495	1.624
Genoa 2	26.6	0.862	2.074	2.936	18.297	4.386
Genoa 5	361.6	CND	CND	0.009	349.013	13.517
Genoa 7	79.3	0.104	0	0.104	44.209	34.749

Mass-lost-on-ignition

Sieved contents of sediment core samples which were too fine to be hand separated, and were analyzed using mass-lost-on-ignition in a muffle furnace. Samples are broken down by site and size (2.36 mm and the finest particles that washed through than all sieves and were collected in the 'pan'). Three of the sediment core samples were sub-sampled three times to help track overall variability in the 'mass-lost-on-ignition' method.

SAMPLE	SIZE	CRUCIBLE WEIGHT (G)	SAMPLE BEFORE (G)	SAMPLE AFTER (G)	MASS-LOST-ON-IGNITION (G)	TOTAL ORGANIC CONTENT (MG/G)
Cotton 1	2.36	17.661	3.009	2.949	0.06	0.20
Cotton 1	pan	14.732	3.028	2.969	0.059	0.19
Cotton 3	2.36	16.87	2.894	2.768	0.126	0.44
Cotton 3	pan	15.404	3.062	3.016	0.046	0.15
Cotton 5 (1)	2.36	16.876	2.991	2.531	0.46	1.54
Cotton 5 (1)	pan	15.503	3.031	2.906	0.125	0.41
Cotton 5 (2)	2.36	14.734	3.007	2.6	0.407	1.35
Cotton 5 (2)	pan	18.098	3.0	2.888	0.112	0.37
Cotton 5 (3)	2.36	15.4	3.036	2.529	0.507	1.67
Cotton 5 (3)	pan	16.507	2.996	2.884	0.112	0.37
Cowichan 1	2.36	15.504	3.036	2.99	0.046	0.15
Cowichan 1	pan	16.872	3.014	2.977	0.037	0.12
Cowichan 5	2.36	16.881	2.968	2.93	0.038	0.13
Cowichan 5	pan	16.508	3.018	2.972	0.046	0.15
Cowichan 7	2.36	16.505	3.0	2.96	0.04	0.13
Cowichan 7	pan	18.099	2.961	2.911	0.05	0.17
Genoa 2	2.36	17.659	2.987	2.602	0.385	1.29
Genoa 2	pan	16.869	2.98	2.968	0.012	0.04
Genoa 5	2.36	15.402	3.004	2.953	0.051	0.17
Genoa 5	pan	14.734	3.048	3.0	0.048	0.16
Genoa 7	2.36	16.873	2.98	2.898	0.082	0.28
Genoa 7	pan	14.734	3.032	2.897	0.135	0.45

Halkett 1	2.36	17.66	2.995	2.964	0.031	0.10
Halkett 1	pan	15.4	3.044	3.006	0.038	0.12
Halkett 2 (1)	2.36	15.338	2.99	2.905	0.085	0.28
Halkett 2 (1)	pan	15.4	3.048	2.954	0.094	0.31
Halkett 2 (2)	2.36	16.87	2.991	2.904	0.087	0.29
Halkett 2 (2)	pan	16.504	3.002	2.93	0.072	0.24
Halkett 2 (3)	2.36	17.659	3.01	2.941	0.069	0.23
Halkett 2 (3)	pan	15.504	3.013	2.945	0.068	0.23
Halkett 4	4.75	15.504	3.016	2.927	0.089	0.30
Halkett 4	2.36	16.504	3.036	2.929	0.107	0.35
Halkett 4	pan	15.4	3.0	2.855	0.145	0.48
Lamb 2	2.36	15.5	3.057	2.5	0.557	1.82
Lamb 2	pan	14.5	2.974	2.318	0.656	2.21
Lamb 4	2.36	18.1	3.045	3.0	0.045	0.15
Lamb 4	pan	14.7	3.028	1.41	1.618	5.34
Lamb 7	2.36	17.7	2.978	2.958	0.02	0.07
Lamb 7	pan	15.5	3.039	1.5	1.539	5.06
Lamb 8	2.36	14.47	3.02	2.995	0.025	0.08
Lamb 8	pan	18.18	3.001	2.963	0.038	0.13
Maple	2.36	16.87	2.97	2.871	0.10	0.33
Maple	pan	17.666	2.967	2.883	0.084	0.28
Mill 2	2.36	18.1	3.02	2.986	0.034	0.11
Mill 2	pan	16.5	3.061	3.019	0.042	0.14
Mill 7	2.36	14.74	3.025	2.739	0.286	0.95
Mill 7	pan	17.661	3.007	2.964	0.043	0.14
Porpoise	2.36	15.4	3.004	2.62	0.384	1.28
Porpoise	pan	14.734	2.977	2.952	0.025	0.08
Royston 1	2.36	15.4	3.0	2.417	0.583	1.94
Royston 1	pan	17.661	2.963	2.847	0.116	0.39
Royston 2	2.36	15.339	3.007	2.91	0.097	0.32

Royston 2	pan	18.098	2.958	2.89	0.068	0.23
Royston 3 (1)	2.36	15.502	3.045	2.968	0.077	0.25
Royston 3 (1)	pan	18.096	2.969	2.933	0.036	0.12
Royston 3 (2)	2.36	16.504	3.018	2.959	0.059	0.20
Royston 3 (2)	pan	17.659	3.013	2.974	0.039	0.13
Royston 3 (3)	2.36	17.233	3.015	2.967	0.048	0.16
Royston 3 (3)	pan	15.34	2.965	2.924	0.041	0.14

F. Underwater Towed Camera Categorized Footage Data

The spreadsheets categorizing underwater camera footage from this study are too large to be included in this report. Each row in a spreadsheet represents four seconds of filming, and spreadsheets are therefore hundreds of rows long for each site. The Strait of Georgia Data Centre has published all maps created for this study, and a digital cope of categorized video data from each site is available at sogdatacentre.ca

G. Benthic Invertebrate Raw Data

SAMPLE ID	PHYLUM	CLASS	ORDER	FAMILY	TAXON	COUNT
Halkett Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde picta	1
Halkett Bay	Annelida	Polychaeta	Phyllodocida	Hesionidae	Microphthalmus sp.	1
Halkett Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys caeca	5
Halkett Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys sp.	2
Halkett Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys sp.	4
Halkett Bay	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe minuta	2
Halkett Bay	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe sp.	56
Halkett Bay	Annelida	Polychaeta	Terebellida	Pectinariidae	Cistenides granulata	8
Halkett Bay	Annelida	Polychaeta		Opheliidae	Armandia brevis	10
Halkett Bay	Annelida	Polychaeta		Orbiniidae	Scoloplos armiger	2
Halkett Bay	Annelida	Polychaeta		Orbiniidae	Scoloplos armiger	5
Halkett Bay	Annelida	Polychaeta		Orbiniidae	Scoloplos sp.	3
Halkett Bay	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella japonica	1
Halkett Bay	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium sp.	6
Halkett Bay	Arthropoda	Malacostraca	Cumacea	Nannastacidae	Cumella vulgaris	21
Halkett Bay	Arthropoda	Malacostraca	Decapoda	Crangonidae	Crangon sp.	1
Halkett Bay	Arthropoda	Malacostraca	Decapoda	Pinnotheridae	Scleroplax granulata	1
Halkett Bay	Mollusca	Bivalvia	Cardiida	Cardiidae	Clinocardium nuttallii	4

Halkett Bay	Mollusca	Bivalvia	Myida	Myidae	Mya sp.	6
Halkett Bay	Mollusca	Bivalvia	Venerida	Veneridae	Nutricola sp.	8
Halkett Bay	Mollusca	Gastropoda	Littorinimorpha	Caecidae	Caecum dextroversum	1
Halkett Bay	Mollusca	Gastropoda		Pyramidellidae	Odostomia sp.	1
Cotton Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde picta	7
Cotton Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde sp.	6
Cotton Bay	Annelida	Polychaeta	Phyllodocida	Hesionidae	Microphthalmus sp.	7
Cotton Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys caeca	2
Cotton Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys sp.	6
Cotton Bay	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe sp.	26
Cotton Bay	Annelida	Polychaeta	Spionida	Spionidae	Pseudopolydora sp.	1
Cotton Bay	Annelida	Polychaeta	Terebellida	Pectinariidae	Cistenides granulata	4
Cotton Bay	Annelida	Polychaeta		Capitellidae	Mediomastus sp.	2
Cotton Bay	Annelida	Polychaeta		Opheliidae	Armandia brevis	3
Cotton Bay	Annelida	Polychaeta		Orbiniidae	Scoloplos armiger	20
Cotton Bay	Annelida	Polychaeta		Orbiniidae	Scoloplos sp.	2
Cotton Bay	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella japonica	13
Cotton Bay	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium acherusicum	1
Cotton Bay	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium insidiosum	1
Cotton Bay	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium sp.	6
Cotton Bay	Arthropoda	Malacostraca	Cumacea	Nannastacidae	Cumella vulgaris	5
Cotton Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Macoma balthica	4
Cotton Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Tellina modesta	1
Cotton Bay	Mollusca	Bivalvia	Myida	Myidae	Mya arenaria	2
Cotton Bay	Mollusca	Bivalvia	Myida	Myidae	Mya sp.	30
Cotton Bay	Mollusca	Gastropoda	Cephalaspidea	Aglajidae	Melanochlamys diomedea	1
Tunstall Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys sp.	13

Tunstall Bay	Annelida	Polychaeta	Phyllodocida	Nereididae	Platynereis bicanaliculata	1
Tunstall Bay	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe sp.	11
Tunstall Bay	Annelida	Polychaeta	Spionida	Spionidae	Prionospio sp.	2
Tunstall Bay	Annelida	Polychaeta	Spionida	Spionidae	Rhynchospio glutaea	2
Tunstall Bay	Annelida	Polychaeta		Opheliidae	Armandia brevis	6
Tunstall Bay	Annelida	Polychaeta		Opheliidae	Ophelia limacina	1
Tunstall Bay	Annelida	Polychaeta		Orbiniidae	Scoloplos armiger	8
Tunstall Bay	Annelida	Polychaeta		Orbiniidae	Scoloplos sp.	30
Tunstall Bay	Annelida	Polychaeta		Paraonidae	Aricidea (Aricidea) minuta	1
Tunstall Bay	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium sp.	1
Tunstall Bay	Arthropoda	Malacostraca	Amphipoda	Photidae	Photis sp.	3
Tunstall Bay	Arthropoda	Malacostraca	Cumacea	Lampropidae	Hemilamprops sp.	5
Tunstall Bay	Arthropoda	Malacostraca	Cumacea	Nannastacidae	Cumella sp.	14
Tunstall Bay	Cnidaria	Hydrozoa	Leptothecata	Campanulariidae	Campanularia sp.	12
Tunstall Bay	Mollusca	Bivalvia	Cardiida	Cardiidae	Clinocardium nuttallii	31
Tunstall Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Macominae indet.	18
Tunstall Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Tellina modesta	8
Tunstall Bay	Mollusca	Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	4
Tunstall Bay	Mollusca	Bivalvia	Myida	Myidae	Cryptomya californica	2
Tunstall Bay	Mollusca	Bivalvia	Myida	Myidae	Mya sp.	2

Tunstall Bay	Mollusca	Bivalvia	Venerida	Mactridae	Simomactra falcata	1
Tunstall Bay	Mollusca	Bivalvia	Venerida	Veneridae	Nutricola sp.	45
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Chrysopetalidae	Paleanotus bellis	3
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde picta	1
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Hesionidae	Podarkeopsis sp.	1
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Hesionidae	Micropodarke dubia	1
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Micronephthys cornuta	1
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Nereididae	Nereis procera	1
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Nereididae	Platynereis bicanaliculata	23
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Nereididae	Platynereis bicanaliculata	1
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe minuta	10
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe minuta	1
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe sp.	56
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Polynoidae	Malmgreniella berkeleyorum	1
Lamb Bay	Annelida	Polychaeta	Phyllodocida	Syllidae	Exogone dwisula	6
Lamb Bay	Annelida	Polychaeta	Spionida	Spionidae	Paraprionospio alata	1
Lamb Bay	Annelida	Polychaeta	Spionida	Spionidae	Prionospio lighti	2
Lamb Bay	Annelida	Polychaeta	Spionida	Spionidae	Prionospio sp.	2
Lamb Bay	Annelida	Polychaeta	Terebellida	Ampharetidae	Ampharete sp.	1
Lamb Bay	Annelida	Polychaeta	Terebellida	Pectinariidae	Cistenides granulata	1
Lamb Bay	Annelida	Polychaeta		Maldanidae	Axiothella rubrocincta	1
Lamb Bay	Arthropoda	Malacostraca	Amphipoda	Ampithoidae	Ampithoe lacertosa	1
Lamb Bay	Arthropoda	Malacostraca	Amphipoda	Aoridae	Aoroides sp.	5
Lamb Bay	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium acherusicum	1
Lamb Bay	Arthropoda	Malacostraca	Amphipoda	Corophiidae	Monocorophium sp.	1
Lamb Bay	Arthropoda	Malacostraca	Amphipoda	Oedicerotidae	Americhelidium sp.	1
Lamb Bay	Arthropoda	Malacostraca	Amphipoda	Photidae	Photis sp.	2
Lamb Bay	Arthropoda	Thecostraca	Balanomorpha	Balanidae	Balanus crenatus	6

Lamb Bay	Arthropoda	Malacostraca	Decapoda	Panopeidae	Lophopanopeus bellus	1
Lamb Bay	Arthropoda	Malacostraca	Decapoda	Pinnotheridae	Pinnixa schmitti	2
Lamb Bay	Arthropoda	Malacostraca	Isopoda	Munnidae	Munna sp.	2
Lamb Bay	Arthropoda	Malacostraca	Isopoda	Paramunnidae	Munnogonium tillerae	1
Lamb Bay	Arthropoda	Malacostraca	Tanaidacea	Leptocheliidae	Leptochelia dubia complex	11
Lamb Bay	Echinodermata	Holothuroidea	Apodida	Chiridotidae	Chiridota sp.	12
Lamb Bay	Echinodermata	Holothuroidea	Dendrochirotida	Phyllophoridae	Pentamera sp.	1
Lamb Bay	Mollusca	Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	27
Lamb Bay	Mollusca	Gastropoda	Littorinimorpha	Rissoidae	Alvania compacta	110
Lamb Bay	Mollusca	Gastropoda	Neogastropoda	Columbellidae	Mitrella gausapata	21
Lamb Bay	Mollusca	Gastropoda	Neogastropoda	Mangeliidae	Kurtziella plumbea	1
Lamb Bay	Mollusca	Gastropoda	Neogastropoda	Nassariidae	Nassarius mendicus	6
Lamb Bay	Mollusca	Gastropoda		Pyramidellidae	Turbonilla sp.	1
Porpoise Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde picta	4
Porpoise Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde sp.	4
Porpoise Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Micronephthys cornuta	7
Porpoise Bay	Annelida	Polychaeta	Phyllodocida	Nereididae	Platynereis bicanaliculata	1
Porpoise Bay	Annelida	Polychaeta	Phyllodocida	Polynoidae	Tenonia priops	2
Porpoise Bay	Annelida	Polychaeta	Sabellida	Oweniidae	Owenia sp.	1
Porpoise Bay	Arthropoda	Malacostraca	Cumacea	Lampropidae	Hemilamprops sp.	2
Porpoise Bay	Arthropoda	Malacostraca	Tanaidacea	Leptocheliidae	Leptochelia dubia complex	4
Porpoise Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Tellina modesta	4
Porpoise Bay	Mollusca	Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	2
Porpoise Bay	Mollusca	Gastropoda	Littorinimorpha	Rissoidae	Alvania compacta	45

Porpoise Bay	Mollusca	Gastropoda	Neogastropoda	Columbellidae	Mitrella gausapata	1
Porpoise Bay	Mollusca	Gastropoda	Neogastropoda	Mangeliidae	Kurtziella plumbea	1
Porpoise Bay	Mollusca	Gastropoda	Neogastropoda	Nassariidae	Nassarius mendicus	4
Royston Wrecks	Annelida	Clitellata	Haplotaxida	Naididae	Tectidrilus sp.	66
Royston Wrecks	Annelida	Polychaeta	Eunicida	Lumbrineridae	Lumbrineris sp.	3
Royston Wrecks	Annelida	Polychaeta	Eunicida	Lumbrineridae	Scoletoma sp.	4
Royston Wrecks	Annelida	Polychaeta	Eunicida	Lumbrineridae	Scoletoma tetraura complex	2
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Glyceridae	Glycera sp.	1
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde picta	13
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde sp.	11
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Hesionidae	Oxydromus pugettensis	1
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Micronephthys cornuta	10
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys ferruginea	1
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys sp.	1
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Nereididae	Platynereis bicanaliculata	1
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe minuta	10
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Pholoidae	Pholoe sp.	12
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Phyllodocidae	Eteone sp.	1
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Pilargidae	Pilargis berkeleyae	3
Royston Wrecks	Annelida	Polychaeta	Phyllodocida	Polynoidae	Tenonia priops	1

Royston Wrecks	Annelida	Polychaeta	Spionida	Spionidae	Paraprionospio alata	1
Royston Wrecks	Annelida	Polychaeta	Spionida	Spionidae	Prionospio jubata	5
Royston Wrecks	Annelida	Polychaeta	Spionida	Spionidae	Prionospio lighti	31
Royston Wrecks	Annelida	Polychaeta	Spionida	Spionidae	Prionospio sp.	42
Royston Wrecks	Annelida	Polychaeta	Spionida	Spionidae	Prionospio steenstrupi	2
Royston Wrecks	Annelida	Polychaeta	Spionida	Spionidae	Pseudopolydora paucibranchiata	1
Royston Wrecks	Annelida	Polychaeta	Spionida	Spionidae	Spiophanes berkeleyorum	4
Royston Wrecks	Annelida	Polychaeta	Terebellida	Ampharetidae	Melinna elisabethae	1
Royston Wrecks	Annelida	Polychaeta		Capitellidae	Mediomastus sp.	10
Royston Wrecks	Annelida	Polychaeta		Chaetopteridae	Spiochaetopterus costarum complex	1
Royston Wrecks	Annelida	Polychaeta		Magelonidae	Magelona longicornis	3
Royston Wrecks	Annelida	Polychaeta		Magelonidae	Magelona sp.	2
Royston Wrecks	Arthropoda	Malacostraca	Cumacea	Leuconidae	Leucon sp.	1
Royston Wrecks	Arthropoda	Malacostraca	Decapoda	Pinnotheridae	Pinnixa sp.	16
Royston Wrecks	Echinodermata	Ophiuroidea	Amphilepidida	Amphiuridae	Amphiodia sp.	5
Royston Wrecks	Echinodermata	Ophiuroidea	Amphilepidida	Amphiuridae	Amphiodia urtica	17
Royston Wrecks	Bryozoa	Gymnolaemata	Cheilostomatida	Calloporidae	Alderina sp.	16
Royston Wrecks	Cnidaria	Hydrozoa	Anthoathecata	Bougainvilliidae	Rhizorhagium formosum	2
Royston Wrecks	Mollusca	Bivalvia	Cardiida	Tellinidae	Macoma nasuta	1
Royston Wrecks	Mollusca	Bivalvia	Cardiida	Tellinidae	Tellina modesta	34

Royston Wrecks	Mollusca	Bivalvia	Cardiida	Tellinidae	Tellina sp.	3
Royston Wrecks	Mollusca	Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	115
Royston Wrecks	Mollusca	Bivalvia	Lucinida	Lucinidae	Parvilucina tenuisculpta	23
Royston Wrecks	Mollusca	Bivalvia	Lucinida	Thyasiridae	Axinopsida serricata	17
Royston Wrecks	Mollusca	Bivalvia	Venerida	Veneridae	Leukoma staminea	9
Royston Wrecks	Mollusca	Gastropoda	Neogastropoda	Columbellidae	Mitrella gausapata	19
Royston Wrecks	Mollusca	Gastropoda	Neogastropoda	Nassariidae	Nassarius mendicus	1
Royston Wrecks	Mollusca	Gastropoda		Pyramidellidae	Odostomia sp.	4
Maple Bay	Annelida	Polychaeta	Phyllodocida	Hesionidae	Micropodarke dubia	1
Maple Bay	Annelida	Polychaeta	Phyllodocida	Nereididae	Platynereis bicanaliculata	21
Maple Bay	Annelida	Polychaeta	Phyllodocida	Nereididae	Nereididae indet.	2
Maple Bay	Annelida	Polychaeta		Opheliidae	Armandia brevis	10
Maple Bay	Arthropoda	Malacostraca	Decapoda	Thoridae	Heptacarpus sp.	1
Maple Bay	Arthropoda	Malacostraca	Isopoda	Munnidae	Munna sp.	1
Maple Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Tellina sp.	6
Maple Bay	Mollusca	Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	1
Maple Bay	Mollusca	Gastropoda	Littorinimorpha	Rissoidae	Alvania compacta	1
Maple Bay	Mollusca	Gastropoda	Neogastropoda	Columbellidae	Mitrella sp.	1
Maple Bay	Mollusca	Gastropoda	Neogastropoda	Columbellidae	Mitrella tuberosa	1
Mill Bay	Annelida	Clitellata	Haplotaxida	Naididae	Tectidrilus sp.	12
Mill Bay	Arthropoda	Malacostraca	Amphipoda	Photidae	Photis sp.	1
Mill Bay	Arthropoda	Malacostraca	Decapoda	Pinnotheridae	Pinnixa sp.	2
Mill Bay	Arthropoda	Malacostraca	Nebaliacea	Nebaliidae	Nebalia pugettensis complex	4
Mill Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Macoma nasuta	1
Mill Bay	Mollusca	Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	4
Mill Bay	Mollusca	Gastropoda	Neogastropoda	Columbellidae	Mitrella gausapata	1
Genoa Bay	Annelida	Clitellata	Haplotaxida	Naididae	Tectidrilus sp.	101

Genoa Bay	Annelida	Polychaeta	Phyllodocida	Glyceridae	Glycera americana	1
Genoa Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde picta	10
Genoa Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde sp.	4
Genoa Bay	Annelida	Polychaeta	Phyllodocida	Hesionidae	Podarkeopsis glabrus	1
Genoa Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys caecoides	1
Genoa Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys sp.	1
Genoa Bay	Annelida	Polychaeta	Phyllodocida	Phyllodocidae	Eteone sp.	1
Genoa Bay	Annelida	Polychaeta	Phyllodocida	Polynoidae	Tenonia priops	1
Genoa Bay	Annelida	Polychaeta	Sabellida	Oweniidae	Owenia johnsoni	8
Genoa Bay	Annelida	Polychaeta	Spionida	Spionidae	Prionospio steenstrupi	1
Genoa Bay	Annelida	Polychaeta		Capitellidae	Capitella capitata complex	2
Genoa Bay	Annelida	Polychaeta		Orbiniidae	Leitoscoloplos pugettensis	5
Genoa Bay	Annelida	Polychaeta		Orbiniidae	Scoloplos sp.	1
Genoa Bay	Arthropoda	Malacostraca	Cumacea	Nannastacidae	Cumella vulgaris	1
Genoa Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Tellina sp.	18
Genoa Bay	Mollusca	Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	23
Genoa Bay	Mollusca	Bivalvia	Myida	Myidae	Mya sp.	10
Genoa Bay	Mollusca	Gastropoda	Littorinimorpha	Rissoidae	Alvania compacta	4
Genoa Bay	Mollusca	Gastropoda	Neogastropoda	Nassariidae	Nassarius mendicus	2
Cowichan Bay	Annelida	Clitellata	Haplotaxida	Naididae	Limnodriloides victoriensis	1
Cowichan Bay	Annelida	Clitellata	Haplotaxida	Naididae	Tectidrilus sp.	151
Cowichan Bay	Annelida	Polychaeta	Phyllodocida	Glyceridae	Glycera sp.	1
Cowichan Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde picta	12
Cowichan Bay	Annelida	Polychaeta	Phyllodocida	Goniadidae	Glycinde sp.	2
Cowichan Bay	Annelida	Polychaeta	Phyllodocida	Hesionidae	Podarkeopsis glabrus	1
Cowichan Bay	Annelida	Polychaeta	Phyllodocida	Nephtyidae	Nephtys sp.	1

Cowichan Bay	Annelida	Polychaeta	Sabellida	Oweniidae	Owenia johnsoni	3
Cowichan Bay	Annelida	Polychaeta	Spionida	Spionidae	Prionospio sp.	1
Cowichan Bay	Annelida	Polychaeta	Terebellida	Pectinariidae	Cistenides granulata	3
Cowichan Bay	Annelida	Polychaeta		Capitellidae	Capitella capitata complex	3
Cowichan Bay	Annelida	Polychaeta		Capitellidae	Mediomastus sp.	1
Cowichan Bay	Annelida	Polychaeta		Magelonidae	Magelona sp.	1
Cowichan Bay	Annelida	Polychaeta		Orbiniidae	Leitoscoloplos pugettensis	3
Cowichan Bay	Arthropoda	Malacostraca	Amphipoda	Aoridae	Grandidierella japonica	1
Cowichan Bay	Arthropoda	Thecostraca	Balanomorpha	Balanidae	Balanus sp.	1
Cowichan Bay	Mollusca	Bivalvia	Cardiida	Cardiidae	Clinocardium nuttallii	5
Cowichan Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Macoma nasuta	3
Cowichan Bay	Mollusca	Bivalvia	Cardiida	Tellinidae	Tellina modesta	25
Cowichan Bay	Mollusca	Bivalvia	Galeommatida	Lasaeidae	Kurtiella tumida	8
Cowichan Bay	Mollusca	Gastropoda	Neogastropoda	Nassariidae	Nassarius mendicus	1

H. Author's Notes on Study Limitation and Method Recommendations

This study was a pilot study combining many different techniques to explore the connections between wood waste deposition and eelgrass survival. Lessons learned by the author are listed to inform future restoration practitioners that may want to build off of this work.

For a scientific study, more comparable sites may improve the chances of more conclusive findings. Standardized methods (sample collection and processing) increased replication, as well as consideration for the timing (i.e. sampling within the same season) would also be needed.

This study used sample cores made from acrylic plastic, which proved to be prone to breaking, particularly with holes drilled in the sides. In the future, it would be better to make the samplers from Pyrex plastic (J. Smith, pers. comm.) without holes and insert the probe to a standard depth from the top of the core.

The method of sediment sampling used was also difficult to standardize, it is recommended testing methods for ones that will work across sites and sediment types. For processing the samples, completely homogenizing the samples and taking standardized subsamples, and drying each subsample as a complete unit would provide more accurate results.

The aluminum baking tins used to pour sediment samples into for drying were easily damaged, more robust containers are recommended.

The underwater towed camera "fishtailed" very easily while being pulled along the transects, providing shaky footage which was sometimes unusable. This was remedied using the addition of several weights to steady the passage of the camera. The above-water components of the SplashCam camera did not perform when wet, therefore should be protected from rain.

Underwater towed camera footage was assessed using visual percent cover estimation, however a software may provide more accurate and faster percent cover analysis.