Eelgrass Restoration on Galiano:

A *Zostera Marina* Restoration Project Design in Whaler Bay, Galiano Island, B.C.

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Executive Summary

Eelgrass is a fundamental part of the Salish Sea Marine habitat, providing ecosystem services ranging from: nearshore habitat for vulnerable marine life, shore and sediment stabilization, filtering sediment and increasing seawater visibility and light penetration, food provisioning, to incredibly efficient carbon sequestration. Despite the established status of eelgrass as a critical component of a healthy marine ecosystem, eelgrass health has been at a steady decline globally (Wright, Boyer, & Erikson, 2014). However, not all hope is lost: eelgrass restoration projects are increasingly prevalent in coastal communities. In the Salish Sea alone, over 30 eelgrass restoration projects have taken place since 2016 (SeaChange Society, 2016).

The purpose of this report is to provide the Galiano Conservancy Association (GCA) and public community of Galiano Island with an outline of necessary steps and considerations for the restoration of eelgrass meadows in the Gulf Islands region. The two potential restoration sites in Whaler Bay, located on southern Galiano Island, have a variety of attributes that increase the likelihood of successful eelgrass restoration. These attributes include: ideal substrate composition (mud and sand), historical records of eelgrass presence, low wave energy, weak currents, the presence of an infeeding freshwater creek, and the interest of the local community. That said, there are other characteristics of the Bay that reduce the overall health of the marine ecosystem and pose a risk to the potential success of eelgrass restoration. The presence of the old log handling and storage lease; various commercial and residential dock leases and permissions; dock construction, anchorage and moorage; heavy recreational and commercial use of the Bay; marine debris; nutrient and chemical pollution from industry and agriculture; raw sewage and septic systems from surrounding residences and vessels; grey water; and the abundant presence of migratory birds, are the core concerns we address throughout the report. Our study presents a set of recommendations to allow for a better understanding of the health of the Whaler Bay marine ecosystem, increase likelihood of successful eelgrass restoration, and engagement and education for the public to help heal this nearshore environment. Specifically, we recommend:

- The GCA contact Galiano Timber Limited to ensure that no more activity will be taking place on the log handling and storage lease before its expiration date on June 25th, 2022.

- The logging and marine debris be cleaned up from Whaler Bay, and the substrate and seawater be tested for forest industry contaminants from fertilizers, pesticides, and nutrient loading.
- The community be provided with educational sessions on sustainable boating practices, control of invasive species, and conservation anchorage and moorage.
- Test and record the wave energy, current, and tides in Whaler Bay at potential donor sites, and ensure the conditions match closely with the priority restoration sites.
- Analyze the riparian vegetation of infeeding streams and the shoreline for health, ability to stabilize the shoreline and sediment, and ability to filter runoff. If the riparian zone is in need of restoration, we suggest planting native vegetation that are known for their ability to absorb heavy metals from road runoff and stabilize banks.
- Concentrate eelgrass restoration in subtidal zones, in part to mitigate damage from grazers – namely Canada Geese.
- A planned and maintained monitoring program (i.e., every 6 months for 5 years; volunteer-driven) should be established to track the progress of the transplanted eelgrass and assess potential risks, such as seasonal algae blooms.
- For volunteer-recruitment and engagement opportunities, network with the Gulf Islands School District (SD64) and provide local youth with valuable hands-on restoration experience and education.
- Use interpretive 'Voluntary Eelgrass Protection Zone' signage in the Whaler Bay area to decrease the likelihood of recreational activities dislodging the restored eelgrass shoots.
- Follow careful protocol for harvesting eelgrass shoots from donor sites, in order to increase genetic diversity and avoid transmitting risks, such as eelgrass wasting disease and invasive species.

1.0 Introduction

Our project is focused on the restoration of eelgrass at two designated priority sites on Galiano Island. The non-profit organization SeaChange Marine Conservation Society and the Galiano Conservancy Association (GCA) are looking to implement an eelgrass restoration project on Galiano Island; thus, we are uniquely situated to provide these organizations with relevant information on eelgrass and best practices for restoration. The species of eelgrass native to the area *(Z. marina*) is a type of submerged aquatic vegetation (SAV) that, while providing significant benefits to marine ecosystems and coastal communities, has been declining globally primarily due to anthropogenic activity. The aim of our report is to provide SeaChange and the GCA with a comprehensive, site-specific restoration and monitoring strategy for eelgrass recovery in Whaler Bay, located on southern Galiano Island. We provide detailed information on the two designated transplant sites, and discuss recommendations for donor site selection based on physical observations and data provided by the 2013 Islands Trust Eelgrass Inventory. While assessing the viability of Whaler Bay for eelgrass restoration is one of our primary goals, this project necessarily involves community engagement and education on multiple levels. We recommend educating the community on topics ranging from less destructive dock construction to the threat of marine invasive species, and mobilizing community as participants and organizers throughout all stages of the project.

2.0 Goals

Our goals in this report are to:

1. Evaluate the viability of Whaler Bay as a potential site for eelgrass (*Z. marina)* restoration through physical observation and research.
2. Synthesize the available data and relevant academic literature on best practices for eelgrass restoration for the future use of the GCA.
3. Provide recommendations on community engagement, education, and consultation regarding eelgrass, in order to ensure the long-term success of restoration efforts.
4. Facilitate the future ecological health and connectivity of marine riparian and subtidal ecosystems in, and around, Whaler Bay.

3.0 Eelgrass

3.1 Range

Z. marina is the subspecies of eelgrass that is native to British Columbia. It is an aquatic flowering seagrass that is commonly found in intertidal and subtidal zones throughout the coastlines of the northern hemisphere (Phillips et al., 1983). Specifically, on the west coast of North America, eelgrass can be found from the Gulf of California all the way up to the Bering Sea (Phillips et al., 1983).

3.2 Habitat and Identification

Z. marina is the most common of the 65 eelgrass species and subspecies presently known (Thom et al., 2008). It grows in dense patches and its leaves are generally an inch wide and can grow up to three feet in length (Phillips et al., 1983). *Z. marina* is found in areas with minimal wave action and a lack of strong currents; it attaches itself to the seafloor via its rhizomes, which take hold of sediments that make up substrates, such as sand or mud.

3.3 Reproduction

Z. marina can reproduce via seed germination or vegetatively; in the Salish Sea, *Z. marina* propagates from vegetative shoots by perennial rhizomes from early spring until mid-summer (Phillips et al., 1983). In Puget Sound, *Z. marina's* flowering shoots appear in late spring and reach the highest abundance in mid-late summer, before releasing its seeds in the fall (Phillips et al., 1983). Due to its proximity to Galiano Island, Puget Sound is well suited as a reference for eelgrass restoration. Restoration efforts on the West Coast of North America have been successful only via physically transplanting *Z. marina* and allowing it to grow via vegetative shoots, as opposed to the original method of eelgrass restoration via seed germination (Thom *et al.*, 2008). However, it is important to note that more experimentation will be required to find out whether seed germination could be an additional method for the restoration of eelgrass ecosystems in coastal British Columbia waters.

3.4 Importance

Eelgrass provides a plethora of valuable ecosystem services to human and nonhuman beings. Eelgrass is understood as having a higher global value, in terms of ecosystem services, than coral reefs, and only slightly less global value than that of tropical forests (Costanza *et al*, 2014). Eelgrass creates environmental conditions that are more habitable for many other aquatic species in intertidal and subtidal zones: it pumps oxygen into sediment and manages dissolved oxygen levels, and reduces suspended substrate, sediment, chlorophyll and other nutrients in the water column (Short & Neckles, 1998). The filtering and cleaning of the water by eelgrass allows for sunlight to penetrate further into the sea and for more plant species to photosynthesize and live in the area, supporting increased biodiversity and resiliency. Eelgrass ecosystems have also been credited as being highly efficient carbon sinks (Thom et al., 2008). Although eelgrass only takes up a small portion of the marine landscape, it accounts for up to 20% of the total global carbon sequestration in marine sediments and is also responsible for significant nutrient cycling to deeper oceanic zones (Hejnowicz et al., 2015). Additionally, eelgrass beds serve as important nearshore habitat, acting as nurseries for juvenile salmon and feeding habitats for migratory waterfowl (Short & Neckles, 1998). Although no notable fish nurseries have been noted in Whaler Bay, possibly due to degradation from past lumber operations, eelgrass restoration would, at the very least, provide habitat for infaunal and epifaunal species, such as butter clam *(Saxidomus giganteus)* and Northern kelp crab (*Pugettia producta*).

4.0 Initial Site Assessment

4.1 Priority Site Area

Islands Trust and the GCA carried out eelgrass and substrate mapping on the Gulf Islands and, due to ideal substrate composition (mud and sand) and the historical presence of eelgrass, Whaler Bay was highlighted as a priority site for *Z. marina* restoration. Figure 2 displays a full map of Galiano with the two priority restoration sites in Whaler Bay, circled in red. Figure 3 displays a close up map of Whaler Bay, with the two green circles representing the priority sites highlighted by the GCA.

Our preliminary site assessment suggests that Whaler Bay is an ideal *Z. marina* restoration site. The two priority sites have evidence of waning patchy subtidal *Z. marina* beds with 25% coverage or less (Figure 4), which is indicative of healthy, high coverage beds in the past. As one local observer described: “When Islanders think about the south arm of Whaler Bay, what comes to mind? The log dump, the government dock, a muddy polluted bottom, fouled water, bad smells on Sturdies Bay Road?” (Ages, 2010, para. 1). Whaler Bay is a complicated site. According to Ages (2010), it is in one of the most developed areas on Galiano Island, and is well known with locals for the visible pollution and putrid stench at low tide. The muddy substrate in the southern arm of Whaler Bay is devoid of vegetation and littered with marine debris, and the lifeless mudflats of low tide sits where a vibrant intertidal ecosystem belongs. During the presentation of this design project at the GCA's Millard Learning Centre, community members expressed discontent with the polluted Whaler Bay area, and stated that restoration would be greatly appreciated (C. Power, personal communication, June 30, 2019). Benefits of restoration to the community include: ridding the area of the low tide stench, increasing visibility in the water, improving the health of the marine ecosystem, the possible return of forage fish, and returning the natural beauty of the bay.

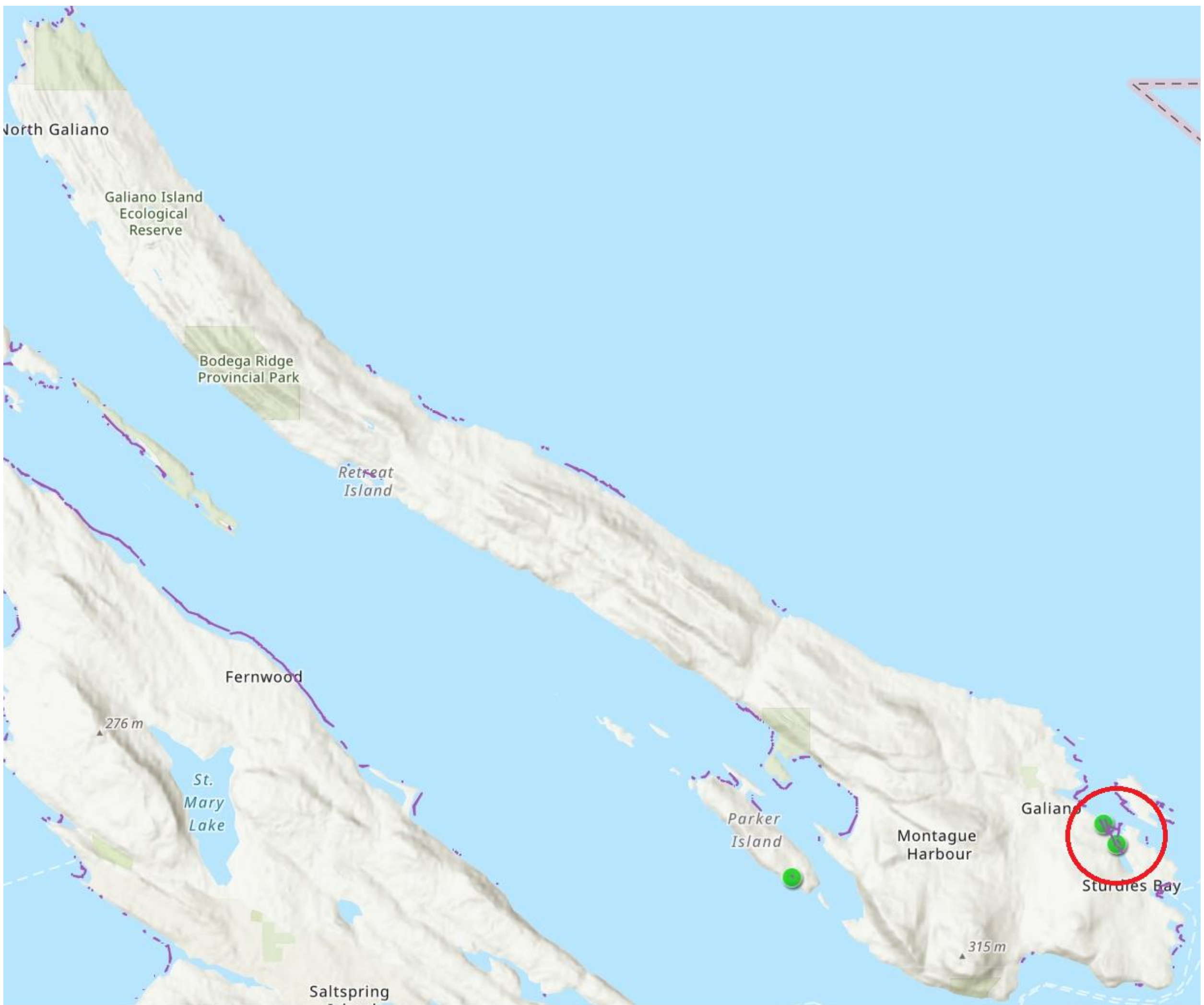

Figure 2 Map showing the three priority sites in the Galiano are, the two Whaler Bay priority restoration sites are circled in red [all maps are retrieved from Island Trust's online mapping application MapIT unless otherwise indicated].

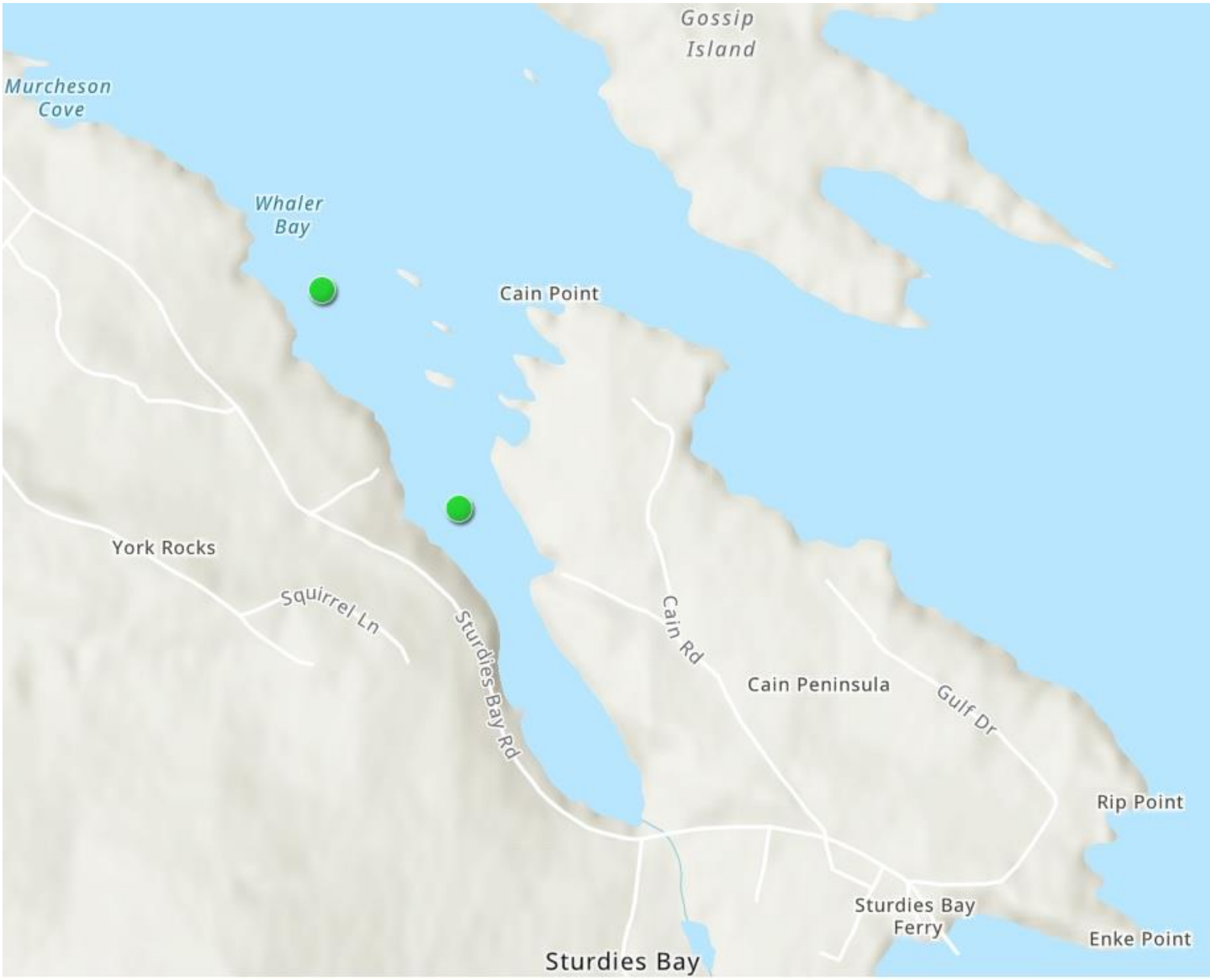

Figure 3 The two priority eelgrass restoration sites in Whaler Bay, marked in green.

Figure 4 Shoreline mapped Eelgrass beds in Whaler Bay, the red lines indicate eelgrass beds with 25% or less coverage.

Figure 5 Whaler Bay at low tide, note the marine debris and lifeless mudflats in place of a healthy intertidal ecosystem.

4.2 History and Crown Tenure

There are two crown leases, two crown licenses, and at least thirteen permissions (likely residential docks) in Whaler Bay (see Figure 6). The large rectangular Lease ‘A’ in Figure 6 is a log handling and storage lease owned by Galiano Timber Limited; although the lease expires June 25th 2022, it appears that the lease has been inactive recently (see Figure 7). Lease ‘B’ (Figure 6) is a residential mooring lease, permission ‘C’ is a public wharf meant for transportation, and ‘D’ is a provincial land inventory. All other leases, permissions, and licenses in Whaler Bay are for residential docks or private mooring. There is also a public dock owned by the federal Fisheries and Oceans Canada in the bay, managed by the local Whaler Bay Harbour Authority (Coulthard, 2019). The public dock is used by commercial vessels, recreational boats, and small, personal boats used by owners of property on nearby Gossip Island (Coulthard, 2019).

We recommend that the GCA contact Galiano Timber Limited to ensure that no more activity will be taking place in the old log handling and storage lease before it expires on June 2022.

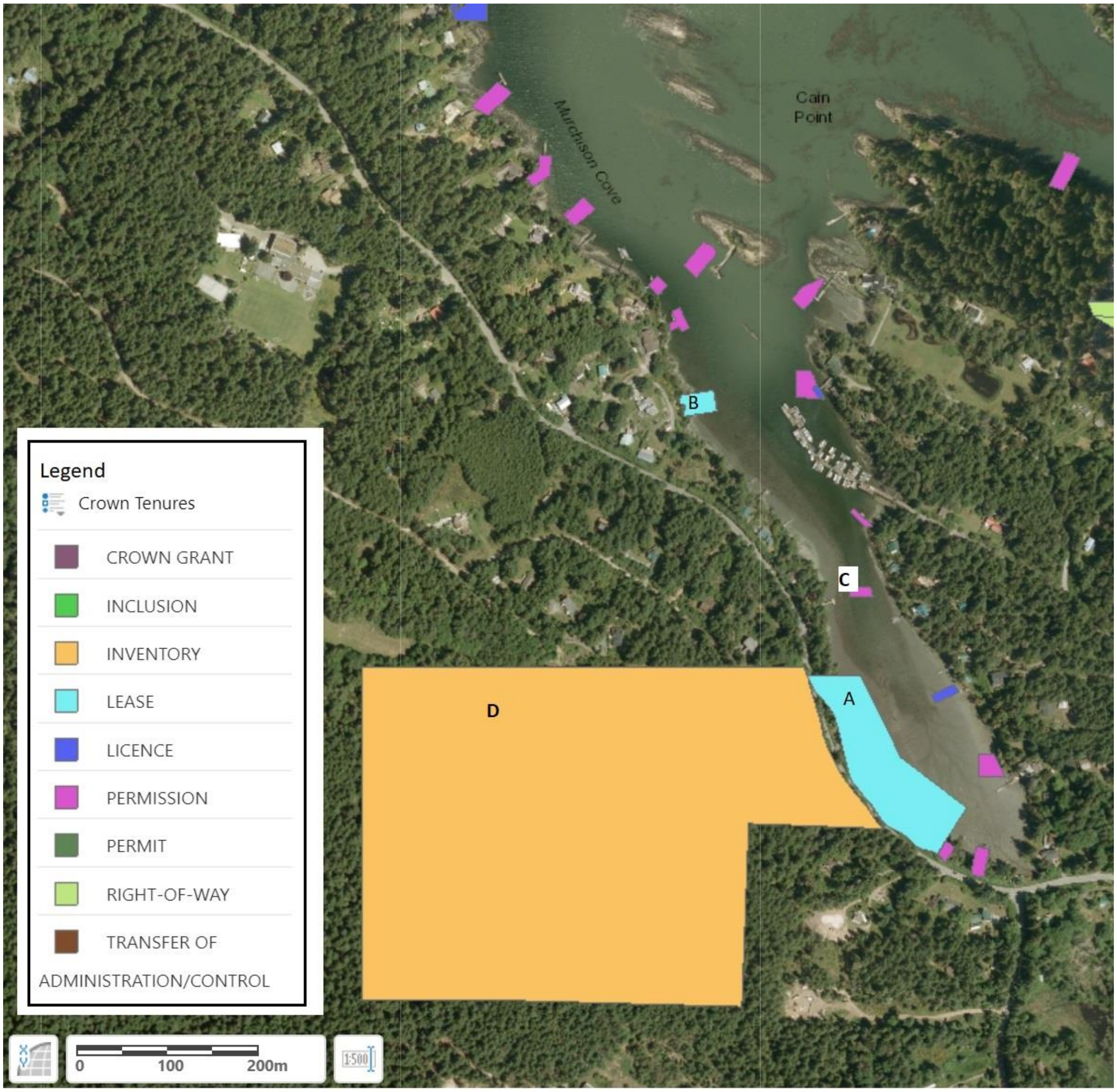

Figure 6 The Crown Tenures of Whaler Bay, A is a log handling and storage lease, b is private mooring, c is a public transportation wharf, d is a provincial land inventory.

Figure 7 The site of the log storage lease in Whaler Bay, A is a photo from 2013 and B is a photo from 2017. Note that in 2013 the lease seems active.

4.3 Substrate Composition and Visibility

The substrate in the Whaler Bay area is primarily mud (Figure 8), while the secondary and tertiary substrate in the Bay is a mix of shell and sand (Figure 9). This substrate composition is conducive for *Z. marina*; however, it is likely that the substrate contained within the old logging lease was dredged and may need further restorative action. The majority of the bay has very low visibility, with a small section in the mid-bay at medium visibility (Figure 10). The low visibility in the Bay is likely due to silt content in the water. With little vegetation to stabilize the substrate, silt is easily turned up via recreational and commercial bay use. Heavy silt content does not allow sunlight to penetrate into the water and inhibits photosynthesis. Although this is not ideal for eelgrass health, once eelgrass is restored it will work to filter silt and debris from the ocean water. Thus, it is likely that the substrate is a viable habitat for *Z. marina*.

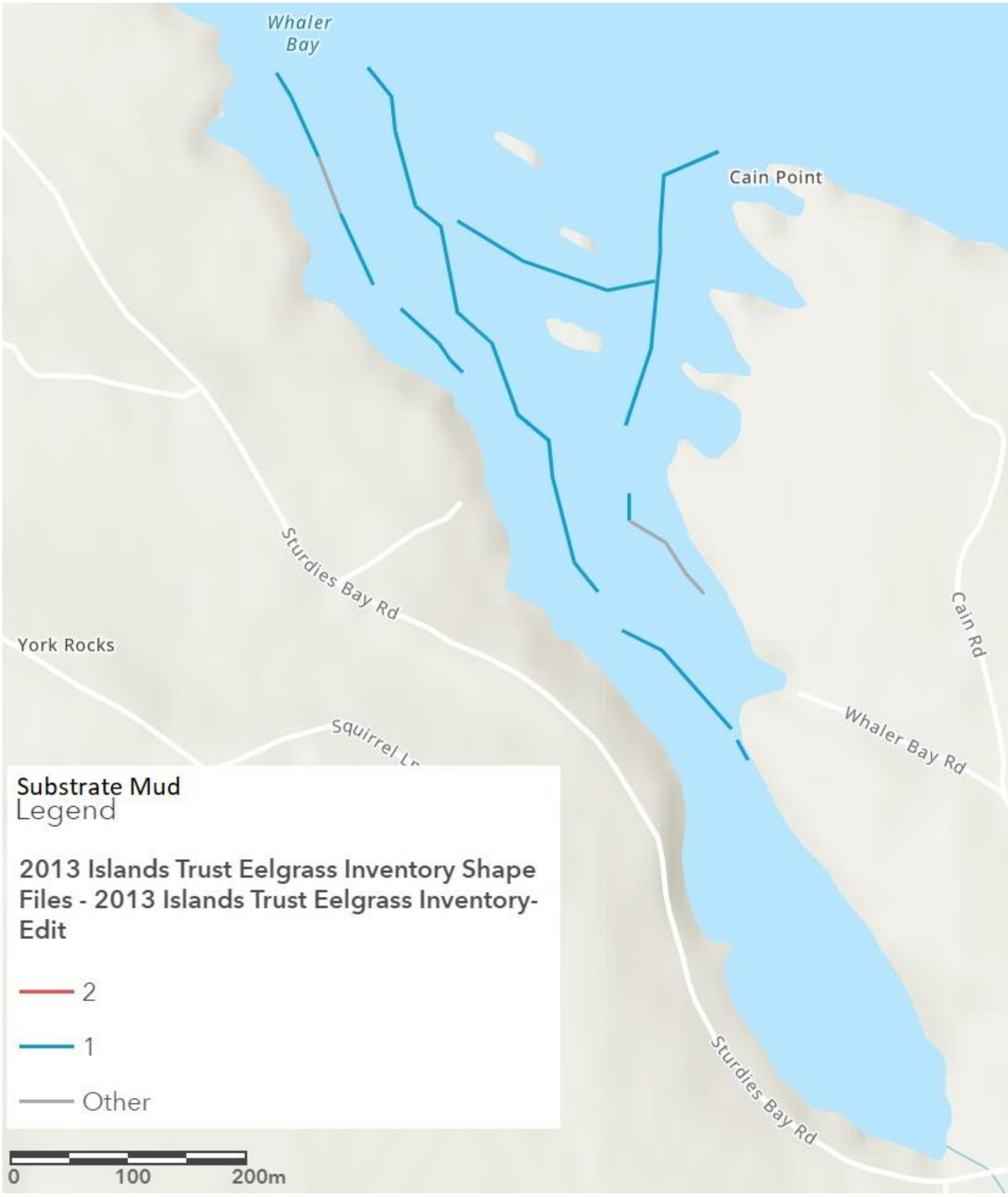

Figure 8 Substrate mapping of mud in Whaler Bay. Both the blue and red line are mud substrate, muds status as primary substrate is indicated by line 1 (blue), while muds status as secondary is indicated by line 2 (red). The 'other' line (grey) indicates substrate that is something other than mud.

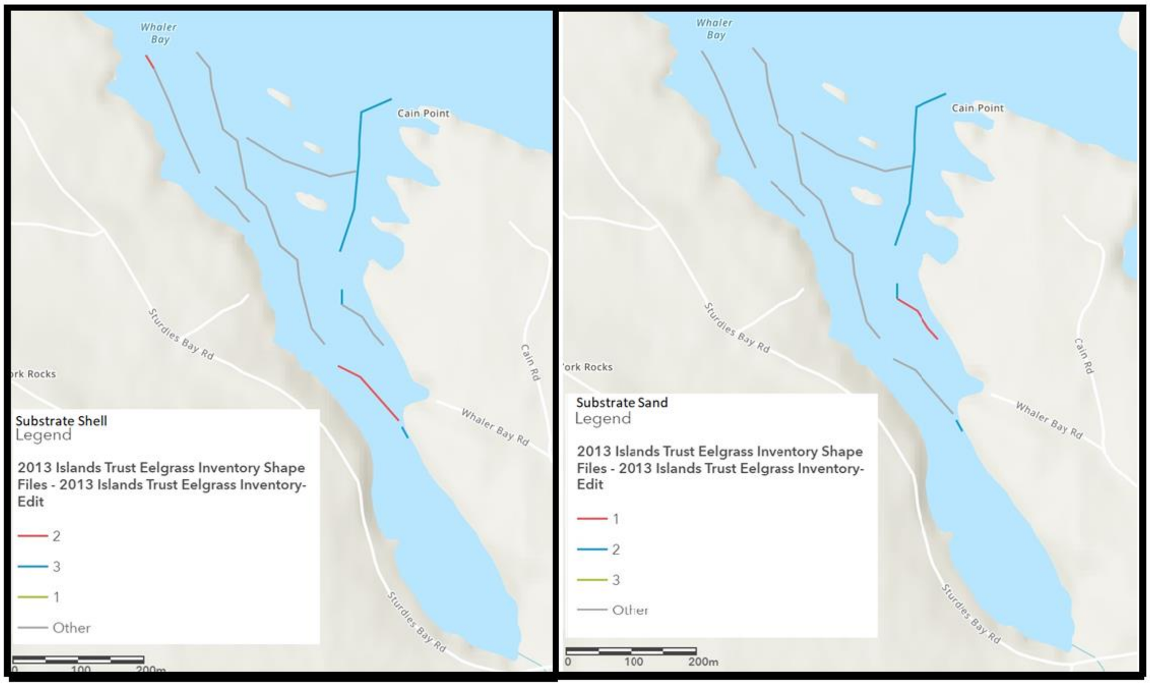

Figure 9 Substrate mapping of shell (left) and sand (right) in Whaler Bay. Primary (1), secondary (2), and tertiary (3).

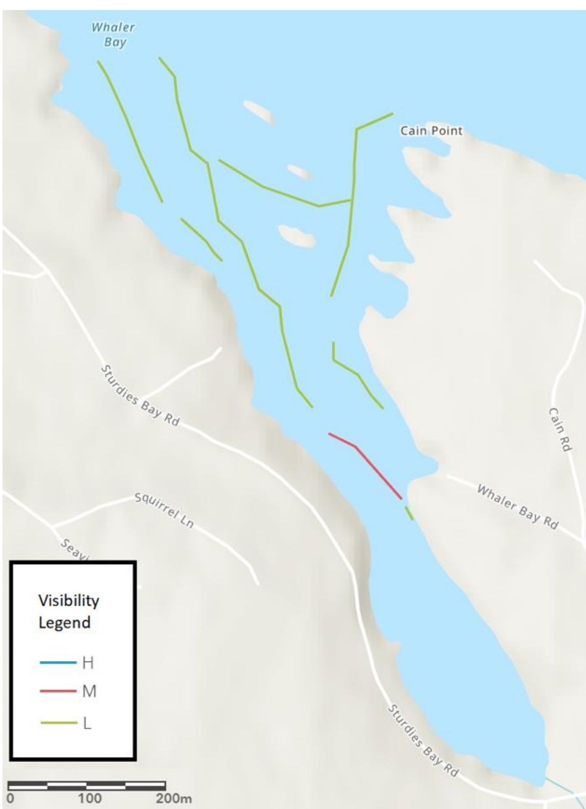

Figure 10 Visibility in Whaler Bay, the red lines represent medium visibility and the green lines represent low visibility.

Figure 11 The South arm of Whaler Bay at low tide, note the muddy bottom that is revealed.

Figure 12 Note the low visibility in the murky water under a large vessel at the Whaler Bay public dock, evidence of high silt content in the water.

4.4 Logging and Marine Debris

The southern arm of Whaler Bay is littered with evidence of past human activity: logging and marine debris are present throughout the Bay from the old log dump and storage lease. The debris inhibits vegetation from thriving by taking up space, changing water flow and thus increasing scour, erosion, and sediment deposition, which can bury SAV, and continue to leach contaminates into the water and substrate.

We recommend cleaning up the logging and marine debris from the Bay, and testing the substrate and seawater for forest industry contaminants from fertilizers, pesticides, and nutrient loading before the transplanting process takes place.

Figure 13 Marine debris at Whaler Bay.

Figure 14 Debris from the old logging lease revealed at low tide in Whaler Bay.

4.5 Docks, Construction, and Shadows

The British Columbia Ministry of Forests, Lands, and Natural Resource Operations and Rural Development (FLNRORD) published a report on the impact of docks on the marine ecosystems of Pender Island and found that "dock construction results in permanent loss of marine and foreshore habitats wherever the dock makes direct contact with the substrate" (2018, p. 14). Furthermore, floating docks or dock pilings permanently destroy the vegetation that is shadowed under their footprints, and the foot traffic and machinery that construction necessitates compacts the substrate and destroys the root systems of SAV, including *Z. marina* (FLNRORD, 2018).

Although different types of dock construction have varying degrees of damage and reparability (pile installation by jetting, which utilizes a pressurized flow of water to liquefy the soil/sediments before the pile is inserted, is more harmful than pile driving, which uses blunt force to drive the pile into the soil/sediment), the shading from docks has also proven harmful to

SAV (FLNRORD, 2018). Furthermore, eelgrass is rarely found thriving under docks (Burdick and Short, 1999; FLNRORD, 2018). The biomass of seagrass is reduced under

Figure 15 Abandoned docks, machinery, and timber at the site of the old logging lease in Whaler Bay.

docks, and the seagrass that is present is inefficient as it compensates for the lack of sunlight by increasing blade chlorophyll content and length compared to unshaded areas (Shafer, 1999; FLRNORD, 2018). Dock piling and dock structures also change water flow which can cause scour, erosion, and sediment deposition which can have extremely negative effects on eelgrass

(FLRNORD, 2018). "Eelgrass burial of 25% of the above ground shoot length has been shown to result in 50% mortality to eelgrass over 24 days (this equates to a burial thickness of 4 cm)" (FLRNORD, 2018, p. 16).

There are 13 active residential dock permissions in Whaler Bay; however, it is not uncommon for docks to be constructed without gaining crown permissions. With the ever-increasing value of ocean-front housing it is likely that dock construction will continue to persist. We recommended education for the community on less harmful docks, anchorage, moorage, and approaches to construction.

Figure 16 A dock in Whaler Bay, casting a dark shadow unto the water.

4.6 Recreational Bay Use

Whaler Bay is a popular recreational site, with motorized boats being particularly common in the area. Boat propellers, traditional anchorage traditional moorage can cause direct damage to *Z. marina* resulting in the loss of vegetation cover and consequentially substrate instability. Substrate instability then increases silt content and decreases visibility in the water, which in turn diminishes the likelihood of recovery for damaged SAV and the reduces the ability for existing eelgrass to photosynthesize (FLRNORD, 2018).

Boat traffic also increases the mobilization of bottom sediment (FLNRORD, 2018). While large, heavy (often commercial) boats cause more sediment disruption than small, quick (often

Figure 17 A public dock piled with treated wood is evident in the foreground of this picture of Whaler Bay, while various residential docks and vessels rest in the background.

personal) boats, both have a negative impact on habitat quality (FLNRORD, 2018). Furthermore, Whaler Bay hosts both large, heavy, commercial boats and smaller, quick, personal vessels.

Boats are also a source of contaminants that degrade marine habitats, contaminates include "PAHs [Polycyclic aromatic hydrocarbons] from fuel spills and outboard motors, which release unburned fuel with exhaust gases, and leaching of heavy metals and TBT [Tributyltin] from antifouling paints" (FLNRORD, 2018, p. 16). Additionally, although dumping sewage from boats is illegal within three nautical miles of the shore, it is possible that raw sewage is pumped into the bay from boats that utilize pump toilets (Georgia Strait Alliance, n.d.).

Paddling (kayaking, canoeing, rowing, etc) can also have a negative impact on *Z. marina*. If paddlers are not cautious or are ignorant about eelgrass beds, a paddle or oar can get caught in eelgrass shoots and dislodge them from the substrate. Additionally, crab-traps and other marine animal traps can get stuck in eelgrass, and dislodge shoots when the trap is reeled in.

We recommend the educational sessions on sustainable boating practices and conservation anchorage and moorage be provided to the community. Conservation mooring reduces the habitat impact mostly by reducing he contact between the mooring components (chains, anchors, etc) and the seafloor.

Figure 18 The public dock in Whaler Bay, showing a diversity of commercial and personal boats.

Figure 19 An industrial lift located on the Whaler Bay Public dock, indicative of heavy commercial and federal dock use.

Figure 20 Note the large shadow cast by a commercial fishing boat at the Whaler Bay public dock, inhibiting photosynthesis.

4.7 Wave Energy, Currents, and Tides

It is important to consider the wave energy, currents, and tides of a transplant site when planning eelgrass restoration. High wave energy and strong currents can dislodge *Z. marina* shoots and creates an environment in which eelgrass may not be able to establish itself (Paulo et al., 2019). Tides are also a necessary consideration as *Z. marina* in the intertidal zone vary compared to *Z. marina* in the subtidal zone: the donor site must match the tidal zone of the transplant site (Paulo et al., 2019). Whaler Bay site does not have notably strong currents nor wave energy; however, the majority of the tides in Whaler Bay are running (as opposed to slack), which can increase the likelihood of error of percent of eelgrass cover predictions and thus extra care is necessary in monitoring eelgrass beds in running tides (Figure 21). Low tide at Whaler Bay reveals a lifeless mudflat in the southern arm, however the two priority eelgrass restoration sites are farther up the bay in the subtidal zone.

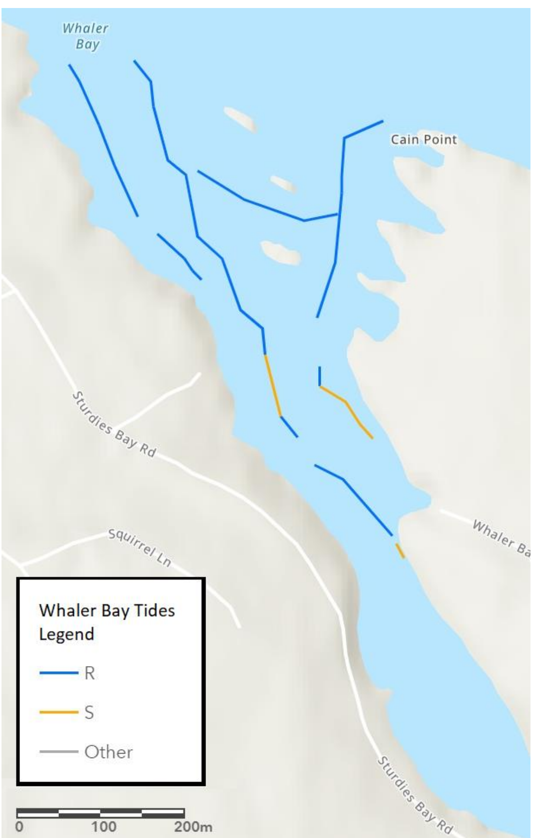

Figure 21 Tide patterns of Whaler Bay, describes whether the tide is running (R) or slack (S).

We recommend that the wave energy and current in Whaler Bay be tested and recorded, and that the wave energy, current, and tides from the donor site match the wave energy, current, and tides in Whaler Bay priority restoration sites as closely as possible.

4.8 Riparian Zone and Constructed Barriers

The riparian zone of the banks of infeeding creeks and other draining is important to consider at Whaler Bay as shoreline vegetation works to stabilize cliffs and shoreline sediment and filter road runoff. Without a healthy riparian zone silt and sediment will easily be carried into the water and slopes along the bay may collapse. Furthermore, riparian zone vegetation works to filter water and runoff from the road. A multitude of riparian zone vegetation can sequester heavy metals and other pollutants from runoff before it enters the bay, befittingly many of these heavy metals are leaked from automobiles in the form of oils and fuel (Evans, Ryswyk, Los Huertos & Srebotnjak, 2019). In comparison, constructed barriers, while they do work to stabilize the shore, can cause water flow to change and thus increase scour, erosion, and sediment deposition which inhibits photosynthesis and decreases the likelihood that *Z. marina* will thrive. Any coastal land alterations can inadvertently cause increased siltation and thus inhibit sunlight penetrating the water and photosynthesis.

We recommend the riparian zone vegetation be analyzed for health, ability to stabilize the shoreline, and ability to filter runoff. If the riparian zone is in need of restoration, we suggest planting native vegetation that are known for their ability to absorb heavy metals from road runoff and that are known to be beneficial at stabilizing banks.

4.9 Water and Sediment Contaminants

Whaler Bay has a multitude of contaminate sources that may be polluting the water and substrate. Some of the factors that may be feeding contaminates into the Bay include: logging debris from the old log dump, marine debris from old and/or sunken boats, oil and fuel leaks for motorized vessels, docks and construction, raw sewage from boat pump toilets and houses in the bay that do not utilize a septic system, contaminants from septic fields, and road runoff.

The operations of the logging industry in close approximation to marine ecosystems has shown to be detrimental to the health of *Z. marina* (Phillips, 1984). Siltation occurs from sediment runoff when heavy rains run over land that has been destabilized via tree removal (Phillips, 1984). Dredging often occurs in bays utilized as log dumps and log storage areas and is extremely detrimental to pre-existing *Z. marina* beds (Phillips, 1984). Dredging involves

Figure 22 Riparian zone vegetation and marine debris at the south end of Whaler Bay.

scooping out the substrate and any submerged aquatic vegetation that is growing there (Phillips, 1984). The removal of the plants changes the physical, chemical and biological composition of the substrate and increases siltation in the water, which makes recovery difficult for plants, such as *Z. marina*, that require photosynthesis (Phillips, 1984). “The ultimate result [of dredging] is the reversal of the entire nutrient-flow mechanics of the ecosystem” (Phillips, 1984, p. 62).

The inorganic fertilizers and chemical pesticides that are associated with the logging industry also likely have a negative effect on eelgrass habitat, we recommend testing the water in the bay for chemical polluters (Campbell, 2017). Fertilizers promote the growth of aquatic algae and specific plants, which leads to lowered levels of oxygen as bacteria breaks down plant matter (Campbell, 2017). Additionally, chemical pollution from treated wood, dock and boom construction from the log storage site is likely taking place at Whaler Bay (see s4.4).

Figure 23 Logging debris and abandoned infrastructure at the old log storage site in the Southern Arm of Whaler Bay.

Urban, industrial, and agricultural land use in the watersheds that feed into the bay also cause water and sediment pollution, as heavy rains carry contaminants into the bay (Murphy et al., 2019). Urban, industrial, commercial, and agricultural land use have all shown to have a detrimental effect on eelgrass health (Murphy et al., 2019). Several watersheds feed into Whaler Bay that host some of the most industrially developed areas on Galiano Island as well as an agricultural land reserve (see Figure 25). These factors must be taken into consideration to ensure successful restoration of *Z. marina* in Whaler Bay.

Nutrient pollution, specifically nitrogen loading**,** from direct atmospheric deposition, wastewater discharge, sewage, seafood processing plants, finfish aquaculture, indirect atmospheric deposition, septic systems, and fertilizers has shown to have a negative impact on eelgrass beds (Murphy et al., 2019). Nitrogen loading often leads to an overproduction of algae which inhibits sunlight from penetrating the water and leads to decline of eelgrass beds (Wright et al., 2002). There are currently two crown licenses in Whaler Bay, it is important to know what these licenses are and, if they are aquaculture, the potential impact they will have on the success of eelgrass restoration. Whaler Bay has a (relatively) large urban population, some residences may pump untreated waste water and/or grey water into the bay, another source of untreated wastewater in vessels residing in the bay. The residences in the Bay area that use septic systems, though certainly better than untreated waste water, can further cause nutrient pollution in the Bay. Additionally, organic and inorganic fertilizers from residential gardens may accelerate nutrient pollution.

We recommended the water and substrate in Whaler Bay be tested for chemical and nutrient pollution in order to confirm the viability of successful eelgrass restoration.

4.10 Salinity and Fresh Water Sources

Z. marina often thrives in estuaries, where fresh water and salt water mix. Sites with freshwater creeks, rivers, or streams are ideal for eelgrass restoration; however, fresh water sources can also carry contaminants from land activity (agriculture, logging, urban use, automobile pollutants) into the bay. There is a small, seasonal creek running into Whaler Bay (Figure 24) which indicates that Whaler Bay may be an ideal restoration site for *Z. marina*, however, the creek runs through several watersheds, one which includes an agricultural land reserve (Figure 25) and others that house the heavily developed urban area of Whaler Bay.

Figure 24 The creek that feeds in Whaler Bay, reappearing from where it was diverted under the road.

Figure 25 Watersheds (outlined in red), streams (blue lines), and agricultural land reserve (light green shape) in the Whaler Bay area.

4.11 Predators and Invasive Species

Predators that actively consume eelgrass include snails and migratory birds such as ducks, geese, and swans, when there is an abundance of migratory waterfowl *Z. marina* beds can quickly decline (Rivers & Short, 2007). While eelgrass beds are an important food source for these birds and can often recover from heavy grazing, recovery for recently transplanted eelgrass is not assured (Rivers & Short, 2007). Intertidal *Z. marina* is at greater risk of decline from grazing than subtidal *Z. marina*.

Invasive species, such as algae, tunicates, and other encrusting marine invertebrates can also destroy eelgrass habitat (Centre for Coastal Studies, n.d.). These species often reproduce quickly and can dominate an area, causing shading or colonizing habitat that eelgrass is trying to grow in. Invasive species are often spread by boats as they stowaway, stuck to boat bottoms unbeknown to boat owners. Whaler Bay has heavy commercial and non-commercial boat traffic and thus any restored or existing *Z. marina* beds may be in danger from invasive species.

Figure 26 Canadian geese, a migratory bird species that grazes on Z. marina*, in Whaler Bay.*

We recommended that, due in part to the presence of migratory birds, eelgrass restoration in Whaler Bay concentrate on the subtidal zone. Furthermore, the community should be engaged in education on invasive species carried by boats, and how to prevent spreading them.

5.0 Community Engagement

5.1 Define Stakeholders

According to the International Union for Conservation of Nature (IUCN), successful ecological restoration initiatives require the support and collaboration of all key stakeholders related to a project (Keenleyside, Dudley, Cairns, Hall & Stolton, 2016). An effective approach to stakeholder engagement involves consent, participation/inclusion, education, and transparency on the goals and objectives of the project. Stakeholders for the restoration of eelgrass in Whaler Bay may include the following: the GCA, SeaChange Marine Conservation Society, FLNRORD, Islands Trust, property owners around the Bay, holders of active and future leases/permits, and Coast Salish Nations (see s5.4).

The various people and groups mentioned represent diverse, and potentially opposing, worldviews. Additionally, the scope of this project requires shifts in how Industry and the local community interact with Whaler Bay, in order to avoid repetition of degradative practices. Thus, we recommend prioritizing the appropriate time to build positive relationships with all potential stakeholders, through effective communication and education. Throughout this report, we discuss multiple necessary actions prior to the actual transplanting of eelgrass; therefore, there are strategic opportunities to streamline stakeholder engagement alongside other steps (e.g., donor site assessment, marine riparian restoration, transplant site debris cleanup etc.).

5.2 Community Consultations

Beyond the identification of key stakeholders is the process of public consultation and education on the reasons for eelgrass restoration. Hosting a ‘Community Meeting’ early in the stages of the project will provide an opportunity for the GCA to assess current levels of awareness among citizens, as well as open the door for volunteer opportunities throughout the project. Further strategies for increasing public awareness may include: signage at Whaler Bay harbour & public access points; communicating with boaters and local residents about the locations of eelgrass beds, and how to avoid damage; and educating boaters on responsible anchoring, mooring, dock-construction, and fishing practices (Wright, Boyer & Erikson, 2014; Cullen-Unsworth & Unsworth, 2016). Figure 27 provides an example of a legible format for signage, when placed in an accessible location.

Figure 27 Eelgrass Information Display for public awareness in the Cowichan Estuary (Wright, 2014, p. 31).

5.3 First Nations Consultations & Relationship Building

Galiano Island is situated within the lands of sc̓əwaθenaʔɬ təməxʷ (Tsawwassen), Hul'qumi'num Treaty Group (Hul'qumi'num, Halalt First Nation, Penelakut Tribe, Lake Cowichan First Nation, and Lyackson First Nation), Stz'uminus (Stz'uminus First Nation, Penelakut Tribe, and Halalt First Nation), and W̱SÁNEĆ (Tsawout First Nation, Pauquachin First Nation, Tsartlip First Nation, Tseycum First Nation, and Malahat Nation) (Native Land, n.d.). We recognize that the information on these traditional territories is gained primarily through the online forum https://native-land.ca/, which only reveals a partial story (Figure 28). However, our intention for this section is to acknowledge the rich and complex relationships that define the land and seascape in which we aim to restore, as well as recognize the gaps in our own knowledge and understanding.

In various sections of this report, we reference the significant degradation that has taken place in Whaler Bay as a result of colonial extraction and exploitation. Log storage & transport, unregulated dock construction, and commercial & recreational boating have persisted throughout settler occupation of the Island. Thus, restoration of eelgrass and the surrounding riparian ecosystem in the Bay is a potentially significant act of settler responsibility and relationship-building with the peoples that share these lands.

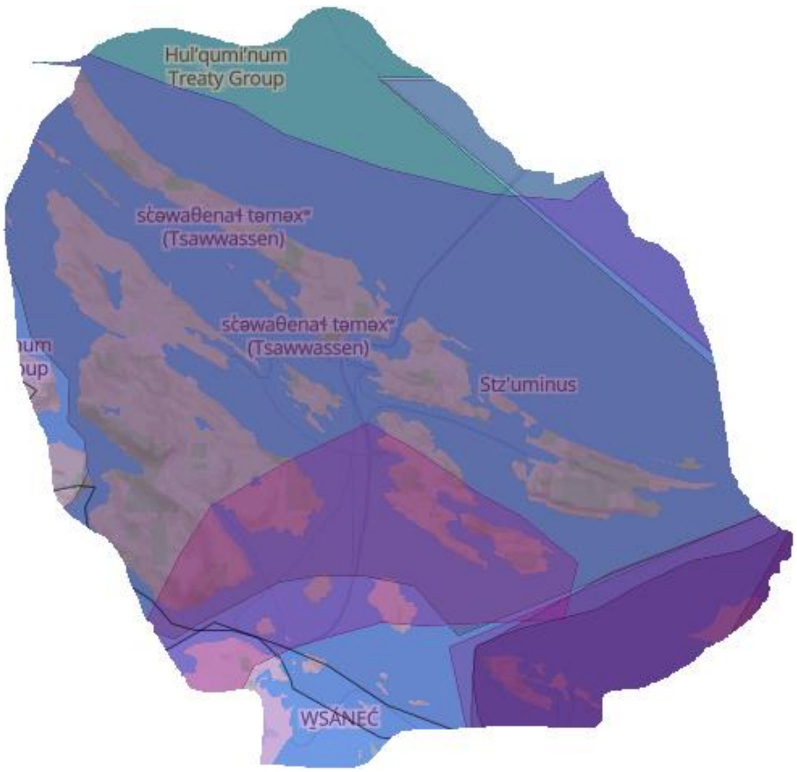

Figure 28 The unofficial boundaries of First Nations Territories in the Gulf Islands (Native Land, n.d.)

Two of the key stakeholders for this project, SeaChange Marine Conservation Society and the GCA, strongly prioritize respect and inclusivity with Coast Salish Nations in their restoration and conservation efforts (Galiano Learning Centre Management Plan, 2013; SeaChange Society, 2016). Given that eelgrass restoration is a recent initiative on the Island, we recommend drawing on the experiences of the 'Salish Sea Nearshore Habitat Recovery Project': working in four different regions of the Salish Sea, this project is an example of community-based work that aims to conserve important ecological and cultural marine areas (SeaChange Society, 2016). Eelgrass rhizomes are traditionally cultivated as a food source by multiple Coast Salish Nations (Fretwell & Starzomski, 2014); therefore, restoration of healthy meadows - in partnership with local First Nations - offers an opportunity to sustain cultural food systems and increase awareness of the multiple functions of eelgrass.

5.4 Community Participation

As a popular recreational harbour and historic log storage site, Whaler Bay fits within a framework of social-ecological restoration; as such, meaningful and active community participation throughout the project is a necessary component. Helen Fox and Georgina Cundill

(2018) situate local participation in restoration efforts as an effective 'social strategy' for fostering deeper learning, connection, and investment among citizens with the ecological landscape. This approach is reflected throughout multiple local eelgrass restoration projects, including those of the Cowichan Esturary, Gulf Islands, and K'omoks Estuary. Depending on the conditions of the project site, eelgrass restoration hosts a variety of community volunteer opportunities, such as: harvesting and transplanting shoots (in intertidal zones only); preparing harvested shoots for transplant (i.e., tying & bundling in groups of ten - see s6.5); restoring surrounding marine riparian areas; and cleaning up marine debris (Hodgson & Spooner, 2016; SeaChange Society, 2016). The post-transplant monitoring stage of the project (see s7.0) is also fundamental for community engagement and participation; frequent observations from concerned citizens on the growth and health of restored eelgrass meadows will offer valuable insight for the GCA, while increasing public awareness on indicators of degradative activity. Another method for promoting community participation is to network with the Gulf Islands School District (SD64), in order to provide local youth with valuable hands-on restoration experience and education, and install interpretive voluntary eelgrass protection zone signs.

Figure 29 Voluntary no-anchor zones interpretive sign at the Fort Townsend State Park, these signs draw the attention of the public and increase understanding of what is at stake and what people can do to protect nearshore environments [retrieved from https://www.jeffersonmrc.org/projects/education-outreach/].

6.0 Transplanting Protocol

6.1 Donor Site

Successful restoration of eelgrass meadows relies on careful selection of both the transplant and donor site. Donor sites are recommended to match the biophysical and chemical characteristics of the desired area(s) of restoration (including, but not limited to: proximity, wave exposure, depth range, salinity, substrate, temperature, and light availability) (Durance, n.d.; Short et al., 1999). In British Columbia (BC), there are 3 existing ecotypes of eelgrass that are each suited to different tidal zones: *typica*, the least common in BC, is found in intertidal zones with weaker currents; *phillipsi* is suited to depths between 0-4m with moderate currents; lastly, *latifolia* is located in subtidal zones with a 0.5-10m depth range and has the highest tolerance for stronger currents (MarineBio, 2014).

Ronald Thom et al. (2008) suggest that the closer proximity of a donor site is positively correlated with transplant success, as it is an indication that the region is suitable for eelgrass growth. Ensuring habitat suitability through closer proximity is also important for reducing the risk of unintentionally translocating other species that are not typical to the area, and that may have ecological consequences. For example, eelgrass meadows located at, or near, shellfish aquaculture sites or global shipping ports may contain higher densities of non-native introduced species (Mach, Levings & Chan, 2017) that could negatively impact transplant success. In addition, closer proximity may increase the chances of harvesting the most suitable ecotype, as described above, for the depth range of Whaler Bay (Durance, n.d.).

Based on the available data for site attributes of Whaler Bay, we recommend that Montague Harbour and Campbell Bay, Mayne Island are further surveyed as potential donor sites (Islands Trust, 2013). Figure 29 presents the raw data on the characteristics of the proposed donor and transplant sites organized into a chart.

6.2 Transplant Site Debris Clean up

Although eelgrass has been described as a resilient species, it nonetheless responds sensitively to anthropogenic disturbances (e.g., boat anchoring, shading from docks, marine debris etc.), with recently transplanted shoots at an even higher risk of damage (Kim, Kim, Park & Lee, 2019; Thom, Diefendorfer, Vavrinec & Borde, 2012). At present, the extent of marine debris and degradation in the two proposed transplant sites (#152 & #157) is unclear in the available raw data. Further surveying via underwater video footage (e.g., using kayaks or divers) is required in order to assess the possible damage and establish a plan for clean up.

	Substrate: *Mud, Sand, Shell*	**Cover**	**Tide**	**Visibility**	**Form**	**Distribution**
Whaler Bay: Transplant Site (#157)	Mud Primary (1)	Primary (<25%)	Running (R)	Low (L)	Flat (FL)	Patchy (P)
Whaler Bay: Transplant Site (#152)	Mud (1)	Primary (<25%)	(R)	(L)	Fringing (FR)	Continuous (C)
Campbell Bay, Mayne Island: Donor Site (Islands Trust Mapping)	Sand (1)	Secondary (26 -75%) Tertiary (>75%)	(R)		(FL) & (FR)	(C)
Montague Harbour: Donor Site (#209 - 214)	#209 - 212: Sand (1) Shell (2) #213 - 214: Mud (1) Sand (2)	#209, 211: Primary (<25%) #210, 212, 213: Secondary (26-75%)	Slack (S)	#209: High (H) #210-214: Medium (M)	(FL)	(C)

	Shell (3)	#214: Tertiary (>75%)				

Figure 30 Visual comparison of characteristics among the two proposed restoration sites in Whaler Bay and our recommended donor sites. The data comes from public eelgrass mapping and raw data provided by "Islands Trust Eelgrass Inventory Raw Data"

The previous location for log storage in the southern-most intertidal zone of Whaler Bay is visually the most degraded of the entire area. While this is currently not a priority site for eelgrass transplantation, restoration of the area, particularly in the form of debris clean-up from logging use, would enhance the overall health of the Bay. Restoration of the intertidal zone is also an opportunity for local volunteers to engage meaningfully in the project, specifically by providing the necessary labour for removal of degrading docks and boat parts. As noted by Nikki Wright (2005), volunteer involvement of this nature increases the investment of community members in the long-term stewardship of the area.

6.3 Eelgrass Harvesting

When harvesting eelgrass shoots for transplant, there are several important considerations to keep in mind. As mentioned in s6.1, closer proximity to the transplant site will ensure the proper storage of donor shoots in cool, shaded, fresh seawater for a maximum of 24 hours (Durance, n.d.). In addition, care should be taken to match the ecotype (*latifolia, phillipsi*, or *typica*) with the appropriate depth range of the transplant site (Durance, n.d.). Eelgrass should be harvested with a minimum of 3 nodes intact and be at least 3'' in length (Durance, n.d.; Hodgson & Spooner, 2016). While there is still ongoing research to establish a recognized standard for harvesting eelgrass, Thom et al. (2008) advise harvesting ≤10% of the donor meadow and to spread collection over wide range, in order to avoid damage such as fragmentation to the donor beds.

6.4 Eelgrass Transplanting

Best practices for transplanting methodology vary depending on the characteristics of the site. Preliminary steps prior to planting typically include checking each shoot for signs of wasting disease (see s8.0) and overall health of the roots and blades (Hodgson & Spooner, 2016). In the context of Whaler Bay, the proposed sites are located in subtidal zones and will require contract divers and a licensed diving boat for hand planting (Hodgson & Spooner, 2016).

Preparation of eelgrass for transplanting can be done, with the help of volunteers, by securing each healthy rhizome to a ⅝’’ steel washer with a biodegradable twist-tie. According to Christine Hodgson and Angela Spooner (2016), washers should not be stainless steel so that, upon degradation, iron is provided to the rhizomes in the form of rust. After anchoring, eelgrass shoots should be bundled together in groups of ten, and stored in cool, fresh seawater until planting. Finally, each bundle of ten shoots can be planted per square meter (m2) following a standard grid pattern (e.g., 10 shoots x 250m2 transplant area = 2,500 shoots required) (Hodgson & Spooner, 2016).

7.0 Monitoring

7.1 Monitor for Health and Growth

Following the IUCN’s guideline, we recommend that a planned and maintained monitoring program be established to track the progress of the eelgrass restoration project in Whaler Bay (Keenleyside et al., 2018). This step ensures a regular opportunity to check that the transplanted eelgrass is fairing well at the newly restored locations, and to observe any changes, positive or negative, in the growth rate or survival of the eelgrass. For example, prior restoration projects in the Puget Sound found that for newly transplanted eelgrass, the rate of germination is typically greatest in the first three months; therefore, long-term monitoring is critical to gain an accurate understanding of average growth rates (Phillips et al., 1983).

7.2 Timeline of Monitoring

Continued monitoring of the site is important to ensure the health of the transplanted *Z. marina*. Monitoring every six months for five years allows for any new hazards or potential threats, such as new docks shading out the eelgrass or other possibilities such as invasive species, or damage by boats and anchor, to be identified and addressed so they do not endanger the overall survival of the eelgrass. For an eelgrass bed to be considered fully restored and the project deemed successful, the eelgrass bed must have the same or higher density of the eelgrass donor bed.

8.0 Additional Considerations

8.1 Eelgrass Wasting Disease

Eelgrass wasting disease has caused large-scale declines in the health of *Z. marina* in the Salish Sea (Catanzaro, n.d.; Brakel, Jakobsson-Thor, Bockelmann, & Resusch, 2019). Warming oceans, anthropogenic contamination flowing in into nearshore environments, sea level rise, and increased salinity are all stressors that weaken *Z. marina* and make them more susceptible to the marine pathogen *Labyrinthula zosterae*, endophytic net slime molds, which causes eelgrass wasting disease (Catanzaro, n.d.; Brakel, Jakobsson-Thor, Bockelmann, & Resusch, 2019). Devastation from the wasting disease was seen during the 1930s on the Atlantic coasts of North America and Europe where there was a 90% loss of all eelgrass (Ralph & Short, 2002, p. 265). Eelgrass wasting disease can be spread by direct contact to an infected plant or to a drifting/detached plant segments (Ralph & Short, 2002). Black-brown streaks and dots are a symptoms of the disease, they are a result from a pathogen or protist that moves quickly through the plant destroying the cell walls and leading to the destruction of the cytoplasmic leaf cell content and the eventual death of eelgrass organisms (Ralph & Short, 2002). Despite the widespread devastation of eelgrass wasting disease, there are new methods and ideas emerging to attempt to combat this disease and mitigate its effects. One such method of increasing the resiliency of newly transplanted eelgrass patches has involved increasing the genetic diversity of the transplanted eelgrass (Thom et al., 2008). Increased genetic diversity is accomplished via taking eelgrass from more than one area of an eelgrass patch at the donor site; harvesting shoots for transplant from the centre of the patch as well as from the fringes. There is a higher likelihood of genetic diversity on the fringes of eelgrass patches, thus harvesting shoots that are farther away from the centre increases genetic diversity (and thus increasing resiliency to eelgrass wasting disease) while simultaneously reducing cumulative stressors on donor eelgrass beds (Thom et al., 2008).

We recommended that special care be taken to ensure that eelgrass wasting disease is not present when selecting a donor site to retrieve shoots for the transplantation process, and that eelgrass shoots be harvested from the centre and the fringes of the donor site patches.

8.2 Consequences of a Changing Climate

The primary effects of the increase of global temperature on eelgrass will be a consequential alteration of growth rates and of other physiological functions (Short & Neckles, 1998). Short and Neckles (1998) warned that changes in temperature (i.e., determining a tipping point), salinity, sea level, atmospheric CO_2 levels and UV radiation could have profound and impactful effects on eelgrass and other ecosystems. They hypothesized that with a rise in global air and water temperatures, *Z. marina* may become outcompeted by algae and algal production would accelerate and could eradicate seagrass from many eutrophic estuaries where it is currently struggling to survive(Short & Neckles, 1998, p. 174). Therefore, a possible outcome of increased global temperatures could be accelerated eutrophication of shallow estuarine environments and a resulting decrease in eelgrass habitats. We recommended considering the potential of seasonal algae blooms in Whaler Bay that could wreak havoc on newly restored eelgrass and negate the efforts of restoration groups.

8.3 Invasive Species

According to Fisheries and Oceans Canada, invasive species have the capacity to disrupt coastal eelgrass ecosystems and severely damage the structure of ecological communities (Keenleyside et al., 2012). One of these invasive species Fisheries and Oceans Canada has deemed a threat to *Z. marina* are the *Carcinus maenas*, commonly called European green crabs. *C. maenas* are easily able to out-compete native crab species that live in and require eelgrass for sustenance and habitat, such as *Pugettia producta*, due to their ability to breed quickly, aggressive nature and lack of predators in the Salish Sea. Fisheries and Oceans Canada state that this invasive crab species has becomes so prevalent, that nearly all bottom dwelling organisms are affected by its predation or competition (Keenleyside et al., 2012). The large population of invasive European green crabs can severely damage eelgrass ecosystems as they dig for food or shelter in eelgrass beds which can destroy the eelgrass and damage habitat for bivalves and other infaunal and epifaunal species. The potential for future damage to eelgrass ecosystems by European green crabs is an increasing concern for marine ecosystems in this region, for their long term health plans for green crab damage mitigation or removal must be considered.

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