A Thorough and Accessible Method for Eelgrass Restoration Site Selection
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Introduction

Restoration of eelgrass beds is becoming a growing need as human activities result in significant impacts to nearshore ecosystems. Eelgrass provides a wide variety of ecosystem services, including food, shelter and refugia for invertebrates and fish, feeding habitat for birds, nutrient cycling, carbon sequestration and carbon storage. It provides surface area for epiphytic algae that serve as the base of the food web for salmon and forage fish, stabilize shorelines and buffer wave energy. They also serve as excellent areas for science and education (Orth et al. 1984, Thompson 1994, Bostrom and Bonsdorff 2000, Duarte 2000, Molnar 2015). The rates at which eelgrass beds capture and store carbon can be up to 90 times that of forests (Campbell 2010) and continue for up to 40 years following restoration (Thom et al 2012). From an economic perspective, eelgrass meadows around the Lower Mainland provide $80,929 in ecosystem services per hectare per year (Molnar et al. 2012).

Natural limiting factors for eelgrass growth include temperature (0° to 30°C but ideally 10° - 20° C; Phillips 1984), light availability, depth, substrate (usually mud or sand), wave action (relatively low) and salinity (20 - 32 ppt in the Salish Sea; Durance 2002).

Human impacts on eelgrass include dredging and filling (Levings and Thom 1994); turbidity, smothering and anoxia from woody debris generated by forestry activities (Phillips 1984, BC/Washington Marine Science Panel 1994); pollution (BC /Washington Science Panel 1994, Beak Consultants 1975, Lyngby and Brix 1989); shading, damage and reduced circulation due to overwater structures such as docks (DFO et al. 2003); damage from boating and mooring (*pers. obs.*) and spread of invasive species such as *Spartina* sp. and the European green crab (*Carcinus maenas*). Coastal development pressures are likely to increase impacts on eelgrass as the climate changes, due to coastal squeeze during landward movement (Nicholls et al. 2007) and increased erosion and scouring associated with amplified wave impacts on hardened shorelines.

There is growing recognition that restoring eelgrass beds can improve habitat connectivity and resiliency, and contribute to mitigating climate change effects. With competing priorities restricting government budgets for eelgrass restoration, however, communities and non-profit organizations are playing a greater role in eelgrass restoration. It is important to identify how such efforts can be supported to maximize their success.

Success of both small- and large- scale eelgrass restoration projects has been variable (Fonseca et al. 1998, Short et al. 2002, *pers. obs.*). Reasons include the dynamic nature of the marine environment, especially in areas suitable for eelgrass, and poor site selection (Fonseca et al. 1998; Thom 1990; Short et al. 2002; Thom et al. 2012). Selected sites may be inadequate due to physical, biological (Short et al. 1995, Short et al. 2002, Zimmerman et al. 1991, Reid et al. 1993, Zimmerman et al. 1995, Thom et al. 2012) and social factors. Furthermore, ideal sites for restoration may not be available due to development pressures. Thom et al. (2012) emphasize the consideration of factors contributing to resiliency when planning restoration projects. Some of these factors are relevant at the transplant stage, and others at the site selection stage, for example an understanding of local ecosystem processes and other limiting factors, cumulative stressors, and proximity of existing eelgrass beds.

Frequently cited eelgrass restoration site selection methods such as Short et al. (2002), as well as others implemented in North America (e.g. Boyer and Wylie-Echeverria 2010, Cape Cod 2011, Thom et al. 2012) focus on biophysical attributes that in some cases (Short et al. 2002) involve attribute ratings that culminate in a score used as a predictor of site suitability and thereby a system for eliminating and prioritizing restoration sites. Some biophysical attributes are relatively straightforward to assess but others require technical capabilities and financial resources that are unavailable to small organizations and communities.

Thom et al. (2012) suggest that eelgrass restoration requires habitat restoration at a landscape level, via habitat connectivity. Increasingly, restoration practitioners are recognizing that landscape-level considerations must also include the human landscape. As such, as with other restoration projects, political, social and economic factors also affect success and should also be considered at the site selection stage. Political, social and economic factors can be complex contributors to site suitability ratings, although some tools have been developed in this regard (e.g. Coastal Resources Management Council et al. n.d.). Short et al. (2002) use the presence of human activities only to eliminate sites, as did eelgrass restoration projects in Cape Cod (Cape Cod 2011).

Analysis of political and social factors is also a means of engaging local communities since community members are often the best placed to provide realistic assessments of these factors. Combining biophysical and socio-political site assessments with community involvement increases the likelihood of restoration project success.

After observation and participation in eelgrass restoration site selection and restoration implementation in Sechelt Inlet, British Columbia, in this paper I summarize the site selection method utilized by SeaChange Marine Conservation Society for small scale eelgrass restoration projects undertaken with strong awareness of and connections to local communities. SeaChange has developed and refined this site selection method over 20 years of work and has applied it in many locations along the Canadian Pacific coast. I present its application in Sechelt Inlet on the south coast of British Columbia in 2014-2018 as a case study. The purpose of this paper is to summarize this method and make it accessible to the community of researchers and practitioners, particularly to community-based organizations. I also analyze monitoring results from the restoration sites selected in Sechelt Inlet to determine success of eelgrass transplants and, therefore, the success of this site selection method.

This site selection method takes into consideration the biophysical considerations used in the literature cited above, as well as social parameters. It is intended to be accessible to small organizations and involve community partners. Appropriate site selection is particularly important for eelgrass restoration projects undertaken by small organizations with limited time and budgets, and a need to demonstrate success to secure future funding.

Although certain criteria can be strengthened with quantification and some require the use of resources such as divers and technical specialists, many are assessable by local communities and non-scientists and can be used as a starting point by anyone interested in identifying sites for eelgrass restoration. They can then precisely identify additional resources required prior to embarking on restoration projects. This site selection method is intended to be low cost and require minimal training (Wright

2005). As such, it is broadly accessible to all restoration practitioners. It can also be adapted for other ecosystem types, both marine and terrestrial.

Methods

Selecting restoration sites

Eelgrass restoration site selection took place at four different scales: 1) coast-wide, selecting an overall section of the coast, 2) local or regional, selecting a community or specific area, and 3) site-level, selecting a particular eelgrass bed to restore, and 4) planting orientation, deciding at which depth and location to insert transplants.

Coast-wide, the south coast of British Columbia was chosen due to its accessibility as well as the historical impacts due to generations of industrial use, and resulting need for eelgrass restoration overall. Regionally, Sechelt Inlet on the Sunshine Coast of British Columbia was chosen due to the historical and current presence of eelgrass, the success of previous restoration efforts and the availability of a community liaison. Eight sites were chosen for consideration based on suggestions by Indigenous organizations and the community liaison. Planting orientation at each selected site is outside of the scope of this paper.

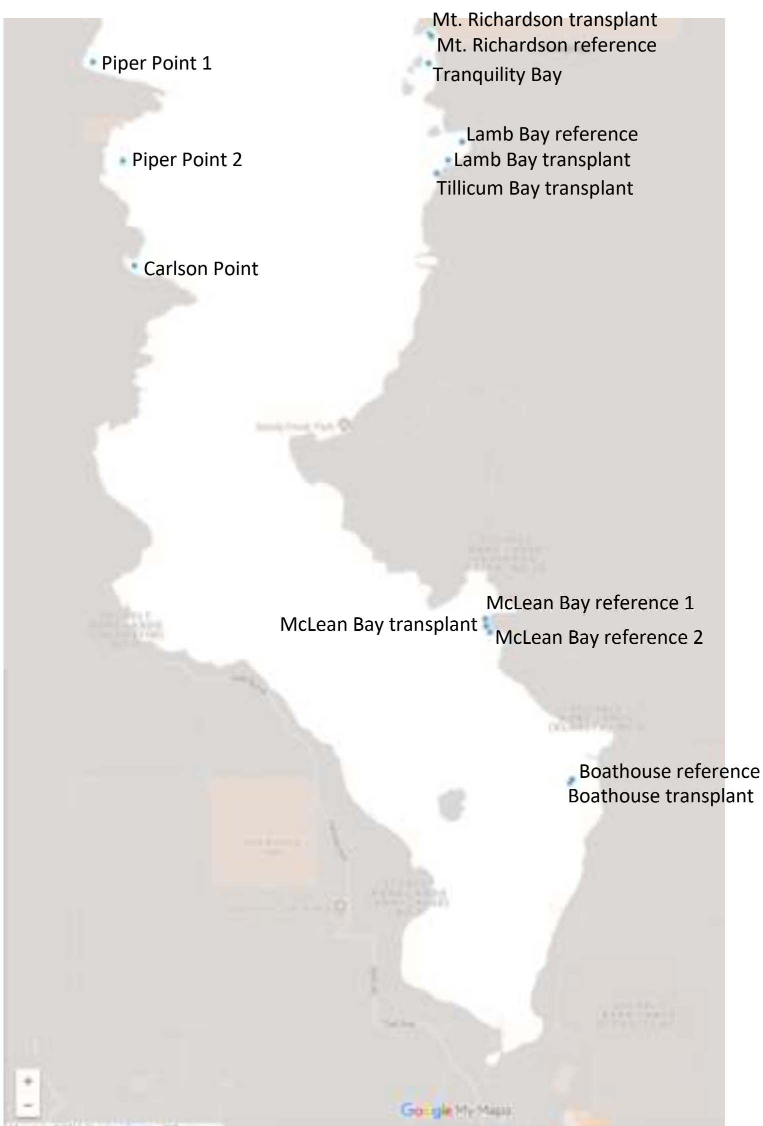
Site-level selection is conducted in two phases. Phase 1 includes assessments of socio-political, economic, ecological or biological and physical criteria, and is used to determine sites for test plots, and is the primary scope of this paper. I have compiled and summarized the categories used in these assessments as a decision matrix provided in Table 1. Rather than a quantitative or score-based assessment, this matrix is used as a checklist with required and optional criteria to assist in predicting likelihood of restoration success.

Following Phase 1 site selection, test plots are planted with a few hundred shoots at each site for Phase 2 site selection, involving an assessment of site suitability for a larger transplant. If 50% of transplanted shoots survive after the first year, a larger transplant project could be planned. If there is less than 50% survival, an investigation of the causes takes place. Mean densities, leaf area index and areal coverage is also measured within test plots; an observed increase in these measurements is also used to select sites at which to undertake larger transplants. Socio-political factors are also reassessed prior to transplant expansion.

The study area for the application of this site selection decision matrix was Sechelt Inlet on the south coast of British Columbia, Canada (Figures 1 and 2). Surrounding mountains provide protection and numerous stream outflows to the inlet. Eight potential eelgrass restoration sites were identified after a general overview of the inlet, test dives and discussion with local community liaisons (Table 2). The decision matrix outlined in Table 1 was applied to each of the potential restoration sites, characteristics were recorded at each site (Table A1) and sites were accepted or rejected for restoration test plots.

Figure 1. Study area (red box indicates location of study sites)

Figure 2. Sites under consideration



Transplanting

Eelgrass transplants began with delineation of a test plot and an estimation of the number of shoots needed for the test plot to be effective. In most cases, transplants were located between existing eelgrass patches to provide shelter for the transplanted shoots.

Shoots of the same ecotype as what would be found at the transplant site were obtained from a donor site located close enough to the transplant site that harvesting, transport and transplanting could be carried out in a single day. Shoots were planted 1 m apart in areas with small or moderate fetch and staggered at every 0.5 m in areas with greater fetch.

Monitoring

Parameters recorded during monitoring enable determination of restoration success, and assess the productivity of transplanted eelgrass beds.

Restoration success of each eelgrass transplant site is measured with a quantitative assessment of shoot density (number of eelgrass shoots per 0.25 m^2), as well as a qualitative assessment of areal extent. Both are compared to a reference bed, often the eelgrass donor site, in the vicinity of the transplant area. Efforts are made to maintain consistency between ecotype and depth of eelgrass for comparison.

An ideal monitoring schedule is every six months for five years to enable comparison between seasons and trends over time, including at the end of the summer which is the period of full eelgrass growth. Monitoring restoration sites and their adjacent terrestrial areas ideally takes place in multiple seasons to identify natural and anthropogenic limiting factors. In reality, monitoring schedules are dependent on funding availability and requirements.

Leaf area index is also calculated to measure productivity and compare the relative value of eelgrass beds, compare eelgrass beds in different areas and assess the overall utility of a restoration project on an ecosystem level; this aspect of the restoration project is outside the scope of this paper.
A 10 m monitoring transect was set in each area to be planted at the depth at which eelgrass in the adjacent reference areas was densest. Eelgrass bed density, and shoot width and length were recorded along transects at similar depths in the transplant and reference sites prior to transplant, immediately after the transplant, then twice per year after the transplant, as resources allowed. Video was also taken by divers at each of these times along the transect, during which the diver also showed their depth gauge at the 0 m, 5 m and 10 m marks. Video was also taken of the area to be transplanted from a broader angle before and after transplant, and at each monitoring visit. A diagram of each transplant site was also drawn. Restoration sites were evaluated for success based on percent survival of transplanted shoots, bed density, or percent of gap in bed filled, as applicable to each case.

Monitoring results were used to determine if any of the applied criteria were misinterpreted or changed over the course of the restoration project.

An eelgrass restoration project is considered successful if the transplanted eelgrass beds persist over several years of monitoring, increase in areal extent and resemble a reference bed with respect to density over several years of monitoring. Comparison of each transplant to a reference site accounts for natural variability (Thom et al. 2012). SeaChange also judges eelgrass restoration success based on the degree of engagement of the local community.

Table 1. Decision matrix for phase 1 site-level selection

Criterion	Desired	Major resources required	Required/ Optional
Socio-political			
Support of local Indigenous government and/or community	Direct involvement and relationship of mutual trust (pre-existing and/or under development)	Culturally knowledgeable liaison Time	R
Local Indigenous government and/or community's knowledge (of historical and current state of the area)	Trust relationship with project and community coordinator; Indigenous community is comfortable sharing their knowledge	Culturally knowledgeable liaison Time	O
Historical use or damage (e.g. logging operations)	Any damage has ceased and is reversible / No damage (e.g. log booming activity ceased and log lease retired)	Land use research or knowledge	R
Backshore use	No/manageable potential for damage; relationship with landowners Storm water drainage would not wash away eelgrass	Land use research or knowledge Access to municipal info Liaison	R
Foreshore use	No/manageable potential for damage; relationship with adjacent landowners and tenure holders	Land use research or knowledge Access to tenure info Liaison	R
Nearshore use	No/manageable potential for damage; relationship with tenure holders and marine users	Land use research or knowledge Access to tenure info Liaison	R
Local knowledge (of historical and current state of the area)	Trust relationship with project and community coordinator; community members comfortable sharing knowledge	Liaison	O
Community connections	Strong	Liaison	O
Community coordinator	Available and active to organize volunteers and build connections and understanding within the community	Liaison Time Local volunteers	O
Planned uses or activities in area (land, foreshore, nearshore)	Any planned uses are compatible with maintaining or enhancing eelgrass habitat	Land use research or knowledge	R
(Pre-existing) Interest of institutions and scientists	Interested or already involved in area in compatible way	Contacts with institutions and scientists	O
Strategic contributions	Contributes to at least one of the	Contextual and	O

Criterion	Desired	Major resources required	Required/ Optional
	following: - solving an overall problem - scientific understanding - topic of public interest	ecological knowledge	
Permission to work in area	Jurisdiction understood and permission obtained from all relevant authorities	Contacts at relevant authorities	R
Community engagement potential	Strong, e.g. via volunteers	Liaison Local supporters	O
Economic			
Time restrictions	Possibility for planting in spring/fall; monitoring ideally in fall, but can be done in spring if needed	Time	R
Budget scope available	Budget available for project coordination, community and volunteer coordination, divers, on-site assessment, restoration, monitoring	Funding	R
(Pre-existing) Interest of potential funders	Interested	Contacts with funders	O
Budget and capacity relative to site size	Size of site will enable effective restoration without exceeding budget or organization capacity	Funding Human resources	R
Ecological / Biological			
Eelgrass presence: current	Present in/adjacent to area	Underwater camera and/or commercial SCUBA divers Boat and operator	R
Eelgrass presence: historical	Variable. Previous presence could indicate a good site, but not necessarily, if substrate or conditions have changed over time to increase eelgrass habitat suitability based on other criteria.	Local or historical knowledge and/or scientific records	R
Epiphytes on adjacent eelgrass	At levels that don't show evidence of degradation to the bed	Underwater camera and/or commercial SCUBA divers Boat and operator	O
Success of nearby restoration projects, in areas with similar conditions	Success achieved nearby	Previous experience or knowledge thereof	O
Ecotype of eelgrass in adjacent areas	Same as what would be planted in restoration site (i.e. same depth range)	Underwater camera and/or commercial SCUBA divers Boat and operator	O

Criterion	Desired	Major resources required	Required/ Optional
Reason why eelgrass not growing/healthy	Reason does not preclude restoration success	Local and/or scientific knowledge of area (may include laboratory analysis of substrate)	R
Reasons why eelgrass is growing in nearby areas	Reasons indicate likelihood of success at potential restoration site	Local and/or scientific knowledge of area	R
Need for active restoration	Site unlikely to fill in naturally without active restoration	Local and/or scientific knowledge of area	R
Proximity of nearby donor bed	Potential donor bed of same ecotype present in same general area (similar conditions); closer sites make for more effective and logistically easier restoration	Underwater camera and/or commercial SCUBA divers Boat and operator	R
Characteristics/health of any eelgrass growing within site to be restored	Shows promise that planted eelgrass could survive and be healthy: specific indicators = shoot density and area extent over 5 years	Underwater camera and/or commercial SCUBA divers Boat and operator	O
Species of eelgrass in adjacent areas	Zostera marina (not Z. japonica)	Ability to harvest and distinguish samples	R
Wildlife presence	Wildlife that could benefit from eelgrass bed observed in area. Wildlife capable of destroying eelgrass bed, e.g. Canada Geese, not present.	Local knowledge or observation	O
Identification of specific potential site for planting	Clarity about location enables restoration crew to understand the area and needs	Ecological knowledge	R
Ecological value of area / of eelgrass restoration to area	Backshore, foreshore and other area characteristics indicate that eelgrass restoration would enhance existing ecological values. Eelgrass always enhances ecosystem value, but being able to emphasize this can assist with sourcing funds or prioritizing sites.	Ecological knowledge Previous ecological assessments Observation	O
Physical			
Freshwater input	Present	Ecological knowledge or observation	O
Substrate quality	Variable. Personal knowledge and experience indicate that eelgrass grows in similar substrate elsewhere. Qualitative observation	Grab samples and/or commercial SCUBA divers Boat and operator	R

Criterion	Desired	Major resources required	Required/ Optional
	indicates sediment is not anoxic.	Knowledge of eelgrass ecology	
Substrate type	Sand, mud	Underwater camera and/or commercial SCUBA divers Boat and operator	R
Substrate type relative to substrate in which eelgrass is growing nearby	Substrate is same or similar to substrate in which eelgrass nearby is growing	Grab samples and/or commercial SCUBA divers Boat and operator Knowledge of eelgrass ecology	O
Substrate consistency	Muddy and consolidated	Grab samples and/or commercial SCUBA divers Boat and operator Knowledge of eelgrass ecology	R
Substrate oxygenated	Normal colouration, other biota present	Grab samples and/or commercial SCUBA divers Boat and operator Knowledge of eelgrass ecology Chemical analysis	R
Slope	Relatively flat or moderate, at least for the width of a fringing bed	Boat and operator Depth measuring device (e.g. sounder)	R
Slope relative to adjacent eelgrass	Restoration site is same or similar to slope at which eelgrass nearby is growing	Underwater camera Boat and operator Depth measuring device	O
Depth below chart datum	Depth range is ~0.5 to 4.0 m	Boat and operator Depth measuring device	R
Depth range of adjacent eelgrass	Restoration site selection based on depth gradient of existing native beds	Underwater camera Boat and operator Depth measuring device	O
Aspect relative to dominant (especially winter) winds	Restoration site is protected from predominant winds/wave energy	Local knowledge Nautical charts Observation	R
Fetch	Presence of sheltering islands or barrier reefs; Fetch dependent on aspect	Nautical charts Local knowledge Observation	R

Criterion	Desired	Major resources required	Required/ Optional
Backshore characteristics	Natural backshore preferred but not necessary if existing or planned developments or activities will not negatively impact eelgrass health. Any erosion is at a rate that would not smother eelgrass bed.	Local knowledge Slope stability assessment Land use research or knowledge	O
Size of area to be restored	Restoration restores lost or damaged marine wildlife and when possible connects wildlife corridors	Knowledge of budget and project needs Ecological knowledge	O
Physical and chemical composition of sediment in existing bed and gap	Physical: % wood fibre content Chemical: Thresholds for sulfides and dissolved oxygen met	Laboratory analysis	O
Sediment outflow from nearby source, e.g. stream	Sediment input source observed	Maps Observation	O

Results

Site Selection

The decision matrix in Table 1 was applied to each of the proposed restoration sites in Sechelt Inlet. It was not possible or relevant to assess each criterion at each site. The following primary reasons were used to reject sites:

- Continued impact e.g. derelict vessel, active use of area by boaters
- Interruptions to bed, e.g. series of docks
- No permission to conduct restoration activities
- No eelgrass in area

In addition, the historical absence of eelgrass at a certain site suggests that it is unlikely that an eelgrass transplant would succeed at that site. A site where eelgrass occurred historically could be suitable for eelgrass restoration if the stressors that led to its elimination (at and adjacent to the site) are removed (Thom et al. 2012).

Once a site was rejected following these basic criteria not being filled, proceeding through the entire decision matrix was deemed unnecessary for that site, in order to conserve human resources for their application to the more feasible sites.

As a result of the initial application of the decision matrix, the initial set of eight possible sites was narrowed down to five sites chosen for restoration test plots (summary in Table 2, details in Table A1). The characteristics of these five sites are summarized below.

Table 2. Potential eelgrass restoration sites in Sechelt Inlet assessed using the decision matrix

Site number	Name	Decision
1	Porpoise Bay East (Boathouse)	Accept
2	Tillicum Bay	Accept
3	Lamb Bay	Accept
4	Mount Richardson	Accept
5	McLean Bay	Accept
6	Piper Point	Reject
7	Carlson Point	Reject
8	Tranquility Bay/Irwin	Reject

In the case of all sites, a local coordinator was already actively liaising with communities and governments, including the local First Nation government, which had provided a letter of support for eelgrass restoration projects. Other sites in the area had been successfully restored. The presence of other *Zostera marina* beds was confirmed in areas near all sites. Sechelt Inlet overall is relatively sheltered and experiences inflow-outflow winds.

Site assessments are summarized below, with details presented in Table A1:

Site 1: Porpoise Bay East (Boathouse)
The site was formerly a log booming area. The backshore is residential, and contains a spawning creek. Forage fish habitat is located in the area. Current activities include possible shoreline dredging for a private boat house, which may be impeding eelgrass growth. Eelgrass restoration in the area could increase salmonid habitat. The identified restoration site was a gap between existing continuous eelgrass beds; this gap existed historically, likely due to log booming activities which have since ceased. Donor sites for transplants were available from the immediate area, within those continuous beds. The substrate included some woody debris, but was the same in both the gap and the existing beds. The slope is relatively flat. The site is fed by sedimentation from a stream and quarry runoff.

Site 2: Tillicum Bay (Tuwanek)
The site was formerly a log booming area but the wood fibre on the sea floor appears to be degrading, suggesting natural recovery. Other substrate is sandy silt that is gelatinous and consolidates when squeezed. The extent of historical impact is not yet clear. An adjacent business is aware of the interest in the area for eelgrass restoration. Further development of the foreshore and backshore may take place. Eelgrass restoration in the area has the potential to increase availability of salmonid habitat. There was no eelgrass growing in the immediate area, but eelgrass growing in nearby areas was patchy yet healthy. The area is sheltered throughout the year. Observed wildlife included an abundance of moon jellies. The area is fed by two freshwater sources; sediment is provided by at least one creek. There is minimal slope. An artificial reef provides some shelter. The backshore is forested. Derelict cement structures remain in the backshore area from the logging industry.

Site 3: Lamb Bay
The area is under a water lease for log storage and booming, although it had not been used for this purpose for more than ten years. The adjacent land is owned by a developer, with tourism developments possible in the area. The lease holder is opposed to eelgrass restoration due to impacts on future development plans; however, local ratepayers are interested in eelgrass restoration. Nearby

eelgrass beds appear very healthy. Freshwater and sediment input come from Lamb Creek. The sediment at the site has been heavily impacted by historical log booming. The substrate is oxygenated and silty with some wood fibre, mushy but not gelatinous. The slope is gradual and similar to that at the nearby native eelgrass beds. The south end of the test plot became fouled, but the reason for this was not clear.

Site 4: Mount Richardson
This site is located within an embayment at the bottom of Mount Richardson with a steep conifer forest in the backshore. The site is adjacent to a provincial park and roads do not extend into the area. The foreshore is cobble and gravel. A creek flows into the area. There are no marine tenures or docks in the area, although it is close to Site 3 (Lamb Bay). A recent off-grid residential development has been created north of Lamb Bay. The nearest dock was 75m from the edge of the potential restoration site. The area has potential as salmonid habitat, and also as a reference site to compare against sites that have been impacted by log booming. Eelgrass already existed in fringing patches that could be joined through transplants. The bed becomes patchier as the substrate becomes rockier. There is no apparent damage to the existing eelgrass bed; eelgrass transplants would represent enhancement of the site, rather than restoration. The area is close to the native eelgrass beds at Lamb Creek. A direct source of freshwater and sediment input was not identified. Wildlife observed at the site included juvenile rockfish, crabs, cockles, perch and moon snails. The substrate was sandy and oxygenated. The slope in the area includes a steep drop off, although the slope at both the transplant and native beds is gradual.

Site 5: McLean Bay
This site was recommended for restoration by the local First Nation and a federal government representative, and was the site of a previous eelgrass transplant. This area had previously been used as a transfer station for industrial marine activity; a gravel spit made of landfill was an old barge landing site. There had been no log booming in this area, so no visible evidence of chemical or biological substrate alteration. Previous eelgrass restoration resulted in a continuous fringing eelgrass bed interrupted by the spit; this gap had been identified as a potential restoration site. There is a dock and launch ramp at the north end of the site. Cobble, gravel and sand lie below riprap. There is sediment suitable for forage fish spawning habitat on either side of the transplant. Historical maps show the presence of a large continuous bed. Extensive development is proposed for the backshore area by the property owner. Nearshore and foreshore access and docks have the potential to damage eelgrass. The community advisor to the restoration project is currently in discussions with the property developer. Healthy eelgrass beds exist to the north and south of the proposed restoration site. The site is sheltered from the northeast by a point of land. Two creeks provide sediment and freshwater.

Measurements of Restoration Success

As a test of the application of the decision matrix, monitoring data from the transplant and reference sites were analyzed to measure restoration success at each of the five sites (Figure 3). The observed characteristics and trends at the sites are explained below and a summary is presented in Table 3.

Site 1: Porpoise Bay East (Boathouse)
A total of 3,134 eelgrass shoots were transplanted between 2014 and 2016 between two existing beds. 90% of the test plot survived. In 2017 the two beds that had been initially transplanted in 2014 and 2015 converged, so the area began to be monitored as one large, continuous bed. Bed density was lower and showed larger fluctuation between spring and summer compared to the reference bed (Figures 3a, 3b). There was an observed decrease in density when comparing the same season in different years, and the

transplant density of the transplant bed remained consistently lower than the density of the reference bed. The gap between the beds was filled by the transplant (a measure of areal extent), however, so restoration at this site is considered successful.

Site 2: Tillicum Bay
600 shoots were transplanted in July 2015. There was no reference bed for comparison at this site. Despite an initial decrease in density from 2015 spring to 2015 summer, an overall increase in shoot density was observed between 2015 spring and 2019 spring (Figure 3c), indicating restoration success.

Site 3: Lamb Bay
400 shoots were transplanted in 2014 and 100 in 2015. An increase in density was observed between spring and summer of 2015, compared to a decline at the reference site (Figures 3d, 3e). Additional monitoring and expansion of the restoration site had been planned for 2016, but the work was aborted when a foreshore lease holder interrupted the divers. At the time of site assessment, the restoration team had not known about a foreshore lease application existing for Lamb Bay. The team had not developed a clear enough understanding of existing and potential foreshore and nearshore uses in the area. No further eelgrass restoration is planned for this site until the lease application process is resolved. Restoration at this site is considered not successful.

Site 4: Mount Richardson
444 eelgrass shoots were transplanted in 2014. A decrease in bed density was observed between spring 2015 and spring 2016 in both the transplant and reference beds. There was a decrease in density from summer 2015 to summer 2017 in the transplant bed, although the reference bed increased in density during this same time. The transplant bed density was similar to the reference bed density. No shoots were observed at all in the transplanted and reference eelgrass beds in spring 2019 (Figures 3f, 3g). Herbivory by Canada Geese and light limitations from the shadow of Mt. Richardson may be impacting the bed. Predation at the ends of shoots was observed in 2017. Below-freezing temperatures in this shaded area with runoff from a steep slope may have resulted in freezing and death of the beds in 2019. During the application of the decision matrix there was not a complete understanding of the existing limitations to eelgrass growth in the area. As of spring 2019, restoration at this site was considered not successful; however, continued monitoring is recommended for a better understanding of this site, and to see if the beds recover naturally.

Site 5: McLean Bay
A total of 3,130 eelgrass shoots were transplanted from 2013 to 2015. Eelgrass regrowth occurred quickly, and transplanted shoots expanded in areal extent to fill the gap between existing beds by summer 2017. The average shoot density at the transplant site was greater than at the reference site at most monitoring times (Figures 3h, 3i). Restoration at this site is considered successful.

Table 3. Summary of restoration results

Site name	Restoration results
Porpoise Bay East (Boathouse)	Successful (gap filled)
Tillicum Bay	Successful (increased density over 4 years of monitoring)
Lamb Bay	Not successful (conflict with water lease holder)
Mt. Richardson	Not successful (site limitations)
McLean Bay	Successful (gap filled)

Figure 3. Eelgrass restoration monitoring results from 5 selected sites in Sechelt Inlet

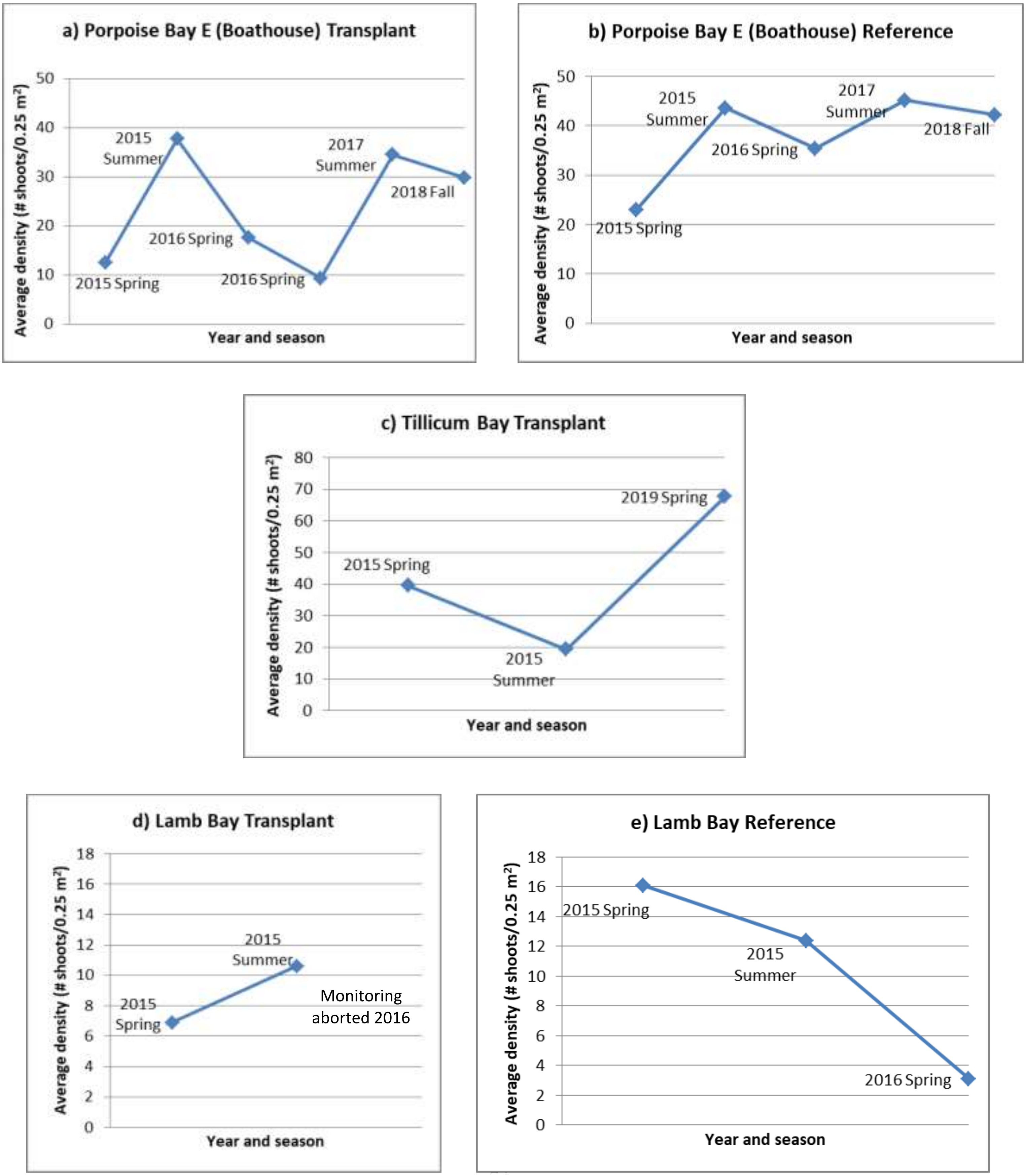
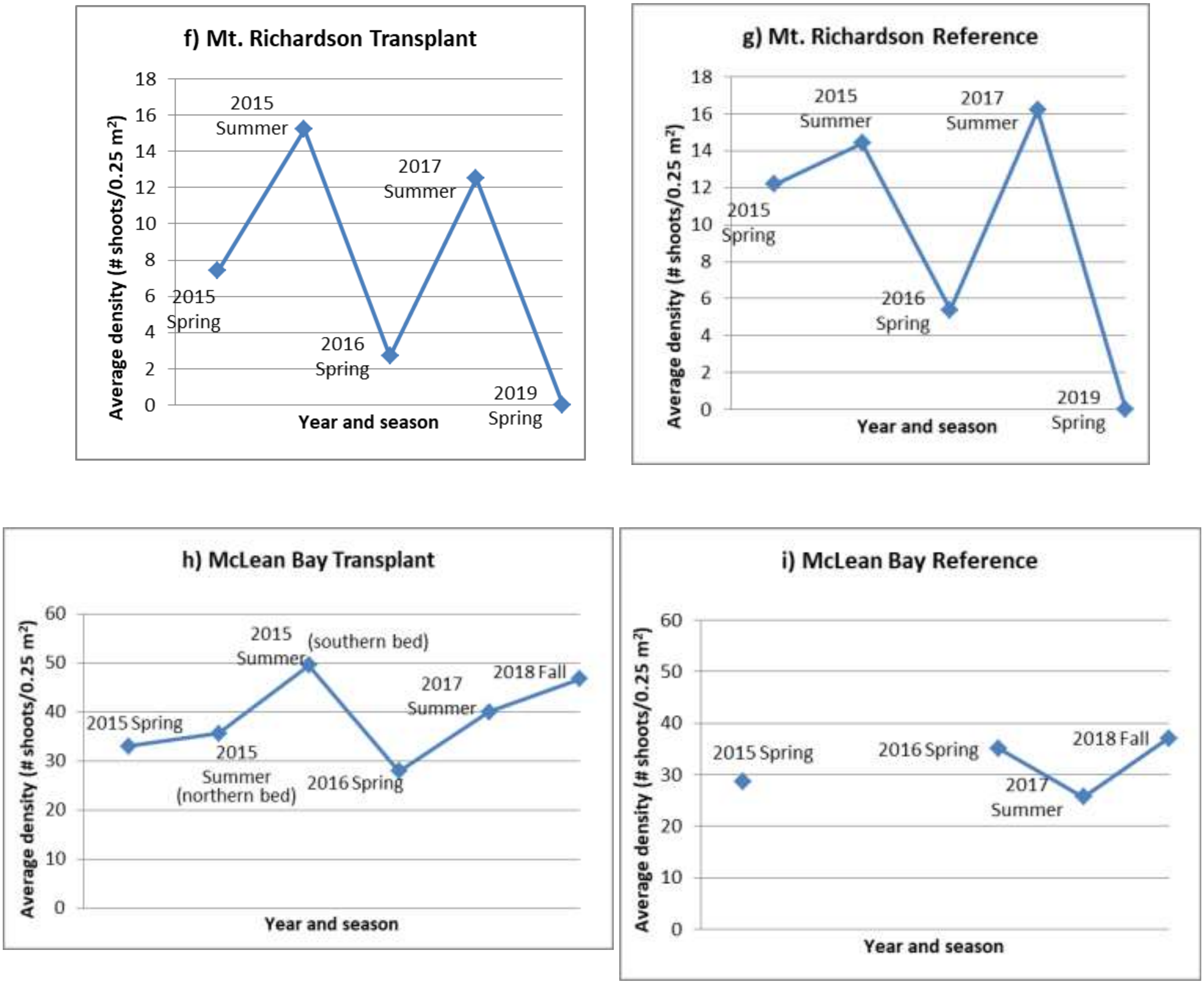


Figure 3 (cont'd)



Discussion

The decision matrix was used to narrow down potential restoration sites based on their feasibility.

Monitoring results show that as of 2018, restoration at Porpoise Bay East (Boathouse), McLean Bay and Tillicum Bay was successful; the transplant at Mt. Richardson is limited by biological and physical factors; and the transplant at Lamb Bay failed due to social factors.

At Mt. Richardson there had not been a complete understanding of the light conditions and potential for herbivory that could limit eelgrass in the area. The status of the reference bed should have indicated that conditions were not ideal. At Lamb Bay, it is not clear whether the the sediment was unsuitable or if the eelgrass transplant was pulled by an unsupportive water lease holder. There had not been a full understanding of the status of the water lease in the area and degree of support of the water lease holder. This site demonstrates that social conflict can be a barrier to restoration success, despite the suitability of a site from a biophysical perspective.

Use of this decision matrix provides a pathway towards developing a clear understanding of the biological, physical and social contexts of potential eelgrass restoration sites to enable site prioritization and selection. Assessments of restoration success or failure based on monitoring results can also be understood in the context of the components of this matrix. The major components of the matrix are accessible to a diversity of restoration practitioners, including those with limited technical resources such as community groups.

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Table A1. Detailed site assessments

Criterion	Site 1: Porpoise Bay E (Boathouse)	Site 2: Tillicum Bay	Site 3: Lamb Bay	Site 4: Mount Richardson	Site 5: McLean Bay	Site 6: Piper Point	Site7: Carlson Point	Site 8: Tranquility Bay / Irwin
First Nation / community support			Letter of support for restoration received from shíshálh Nation 2014	Letter of Support Applies to restoration projects	Recommended by First Nation (old hatchery site adjacent) and DFO community advisor			
First Nation knowledge (of historical and current state of the area)					First Nation property north of estuary (Shannon Creek)			
Historical use or damage (e.g. logging operations)	Log booming; dolphins (pilings) as evidence	Old skidway for log booming Broken down wood fibre (black = anoxic), industrial debris on sea floor Possible that slope of substrate has led to less debris in some areas, as it has fallen deeper Skid is in deeper water Degree of degradation of wood fibre suggests that site is undergoing natural recovery	Water lease area – log storage and booming. Lease expires October 2016. Lease hasn't been used for lease purpose for >10 years. Query sent to FLNRO Land Officer and information given to them re. this. Letter of support for eelgrass restoration from Sechelt Nation added to their file.	Road ends before this area; likely pristine. Adjacent to Provincial Park	Now owned by SSC properties. Landing site (old) Entire spit is landfill	Large derelict vessel still impacting		

Criterion	Site 1: Porpoise Bay E (Boathouse)	Site 2: Tillicum Bay	Site 3: Lamb Bay	Site 4: Mount Richardson	Site 5: McLean Bay	Site 6: Piper Point	Site7: Carlson Point	Site 8: Tranquility Bay / Irwin
Backshore use	Active gravel quarry in distance (Stockwell Gravel) Possible dredging of shore for private boat house Houses along shore. Provincial Park		Land now owned by a developer – speculation that property is being held with thoughts of developing at later date, possibly hotel.	Road ends before this area; likely pristine. Adjacent to Provincial Park	Proposed development (SSC Properties). Much publicity and 2 public meetings held to glean community wishes for the area. Current zoning allows large scale development (>160 units).			
Foreshore use	Provincial Park, recreation			Provincial Park	Development plans include marina, paddle club use, potential waterfront walkway and restaurant		Located in provincial marine park (management intent is recreational)	
Nearshore use	Recreation			No tenures, no docks, but close to Site 3	Potential for eelgrass damage due to pressure from nearshore/foreshore docks/access		Located in provincial marine park (management intent is recreational)	Current bed continuously interrupted by docks; area actively used by boaters
Local knowledge (of historical and current state of the area)		Must try to find someone who worked in the area to understand historical impact						

Criterion	Site 1: Porpoise Bay E (Boathouse)	Site 2: Tillicum Bay	Site 3: Lamb Bay	Site 4: Mount Richardson	Site 5: McLean Bay	Site 6: Piper Point	Site7: Carlson Point	Site 8: Tranquility Bay / Irwin
Community connections		Adjacent shop made aware of the work	Lease holder doesn't want eelgrass transplants due to perception this will negatively impact future development plans		Meeting with principals at SSC Properties and attended one public meeting. Assurance that eelgrass offshore will be taken into consideration (?)			
Community coordinator	Available and active							
Planned uses or activities in area (land, foreshore, nearshore)	Not sure what boat house owner's plan is for future dredging	Speculative – future development	Speculative – boutique hotel or similar	Provincial Park	Village/housing and amenities			
(Pre-existing) Interest of institutions and scientists					Original eelgrass transplant site in Sechelt Inlet – recommended by DFO community advisor			
Strategic contributions	Potential to increase salmonid availability	Potential to increase salmonid availability		Potential to increase salmonid availability Can use this as comparison site vs. sites that have been damaged by log booming	Possible comparison site			Potential to increase salmonid availability
Permission to work in area	Yes	Yes	Water lease held by backshore property owner; expiring October 2016	Yes	Need to get permission from SSC Properties and First Nation		Not clear whose jurisdiction it is to give permission for restoration; provincial government won't give guidance	

Criterion	Site 1: Porpoise Bay E (Boathouse)	Site 2: Tillicum Bay	Site 3: Lamb Bay	Site 4: Mount Richardson	Site 5: McLean Bay	Site 6: Piper Point	Site7: Carlson Point	Site 8: Tranquility Bay / Irwin
Community engagement potential			Local ratepayers association have keen interest		Strong – volunteers and First Nation are currently involved			
Time restrictions	Spring and fall monitoring budgeted							
Budget scope available	Funding available for small-scale project							
Funder interest	Funding available							
Budget and capacity relative to site size	Funding available for small-scale project							
Eelgrass presence: current	Present S and N of gap; some eelgrass within the gap	Patchy eelgrass	In adjacent areas	Patches; possibility of joining them	Restoration planning has reinstated a continuous fringing bed in the area disrupted by creation of gravel landing spit		Patches	Continuous bed, fringing because growth limited due to interruption by docks
Eelgrass presence: historical	Historical maps show major continuous bed in the 2000s, but with gap (BCMCA 2011)	Historical maps show major continuous bed in the 2000s (BCMCA 2011)	Historical maps show major continuous bed in the 2000s (BCMCA 2011)	Historical maps show major continuous bed in the 2000s (BCMCA 2011)	Historical maps show major continuous bed in the 2000s (BCMCA 2011)			
Epiphytes on adjacent eelgrass		No adjacent eelgrass	A few; some in native and transplant	Both transplant and native with epiphytes				
Success of nearby restoration projects, in areas with similar conditions	Near sites restored previously	Yes	Yes	Yes	Yes			
Ecotype of eelgrass in adjacent areas	Same	Same	Same	Same	Same	Same	Same	Same

Criterion	Site 1: Porpoise Bay E (Boathouse)	Site 2: Tillicum Bay	Site 3: Lamb Bay	Site 4: Mount Richardson	Site 5: McLean Bay	Site 6: Piper Point	Site7: Carlson Point	Site 8: Tranquility Bay / Irwin
Reason why eelgrass not growing/healthy	Smothered by dredge spoils from boat house by private land owner?	Looks good. Former industrial area	South end fouled – substrate issue? Impacted by past log storage and booming	Patchier as substrate changes to rocks. No damage apparent; planting would be enhancement rather than restoration	Former barge landing site; spit created to enable this industry		Don't know reason for patchiness	
Reasons why eelgrass is growing in nearby areas	Part of continuous beds	Speculation: warm winter? No large winter waves	Undisturbed by log sort and booming?	Unsure	Sechelt Inlet experiences a mainly sheltered environment			
Need for active restoration	Yes	Yes	Yes	Yes	Yes			
Proximity of nearby donor bed	Donor site in immediate area, adjacent to gap	Yes. We didn't know about it originally, so transplants were from McLean Bay	Close proximity to vibrant eelgrass beds	A few hundred metres to Lamb Creek	Healthy beds to north and south of site			
Characteristics/health of any eelgrass growing within site to be restored	Part of a large continuous eelgrass bed area; some impacts from docks and developments	Existing eelgrass patches are large and healthy/high quality (based on length, width and number of shoots off a single rhizome). Some smaller patches						
Species of eelgrass in adjacent areas	*Z. marina*	*Z. marina*	*Z. marina*	*Z. marina*	*Z. marina*	*Z. marina*	*Z. marina*	*Z. marina*

Criterion	Site 1: Porpoise Bay E (Boathouse)	Site 2: Tillicum Bay	Site 3: Lamb Bay	Site 4: Mount Richardson	Site 5: McLean Bay	Site 6: Piper Point	Site7: Carlson Point	Site 8: Tranquility Bay / Irwin
Wildlife presence		Many moon jellies		Very productive: juvenile rockfish, crabs, cockles, perch, moon snails observed by divers				
Identification of specific potential site for planting	Yes	Yes	Yes	2 potential sites in V-shaped gap between existing patches; other small gaps.				
Ecological value of area / of eelgrass restoration to area		Salmon habitat Restore to better post-industrial state of health		Enhancement by existing smaller beds being joined				
Freshwater input	Ephemeral surface flow?	In middle of 2 sources about 1 km apart	Lamb Creek	Not a creek as close				
Substrate quality	Some fibrous wood debris	Broken down wood fibre; black = anoxic; industrial debris. Amount of degradation suggests it's still in the process of decay. Surface to 6" depth = wood fibre, chips and sediment mixed 6-12" = sediment Below 12 " = hard gravel	Suitable	May be more rock in areas where it doesn't thrive in deeper area	Suitable			

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Substrate type	Suitable	Sandy silt; consolidates when squeezed. Differences between north and south side	Silt with wood fibre; mushy in hand	Sand	Suitable			
Substrate type relative to substrate in which eelgrass is growing nearby	Same	Gelatinous in areas with and without eelgrass	Not gelatinous					
Substrate consistency	Suitable	Consolidates when squeezed	Mushy in hand when squeezed	Sandy	Suitable			
Substrate oxygenated	Normal colour	Normal colour	Normal colour	Normal colour	Normal colour			
Slope	Relatively flat	Minimal	Gradual drop off	Steep drop off	Suitable			
Slope relative to adjacent eelgrass			Same for native and transplant	Both transplant and native site are gradual slope				
Depth below chart datum	Suitable	Suitable	Suitable	Suitable	Suitable			
Depth range of adjacent eelgrass	Similar	Similar	Similar	Similar	Similar			Fringing, so inherently narrow depth range
Aspect relative to dominant/winter winds	Winds in Sechelt Inlet are inflow/outflow							
Fetch	Sheltered	Artificial reef	Sheltered	Sheltered	Sandy Hook point shelters McLean Bay from NE			

Criterion	Site 1: Porpoise Bay E (Boathouse)	Site 2: Tillicum Bay	Site 3: Lamb Bay	Site 4: Mount Richardson	Site 5: McLean Bay	Site 6: Piper Point	Site7: Carlson Point	Site 8: Tranquility Bay / Irwin
Backshore characteristics	Housing	Former log dump/sorting site			SSC properties proposed large community development including housing, village centre and amenities. Possible waterfront walkway and restaurant. Timeline unknown.			
Size of area to be restored				~ 20 m^2 around native patches				
Physical + chemical sediment composition in existing bed and gap	Resources unavailable to assess							
Sediment outflow from nearby source, e.g. stream	Sediment from stream to S with quarry runoff	Grey Creek is closest source of sediment flow	Lamb Creek at head of bay. Small creek	Not much	Shannon Creek in close proximity and Angus Creek further S			