CHAPTER 6: Summary & Recommendations

This chapter summarizes the results of the Squamish Estuary eelgrass transplant pilot project and provides recommendations for larger-scale eelgrass restoration projects in this region and other similar community-based projects. Furthermore, the community-based context and appropriateness of methodology and project design are discussed. Finally, the project's success is evaluated by re-examining the project objectives with regards to the results obtained.

6.1 Summary of Project Results

6.1.1 Eelgrass Transplanting

Within the limited monitoring time-scale for this project, it has been demonstrated that transplanted eelgrass can survive in the Squamish Estuary. Transplanted eelgrass from a donor source at Roberts Bank were able to survive for six months in the Squamish Estuary, although total project survivorship was relatively low (13.9%). No significant difference was found between the average number of surviving shoots at Cattermole (CAT) and Stawamus (STA) transplant sites, however high mortality rates at STA indicate that STA 2 and STA 3 are not recommended as future transplant sites. For those plants that survived, a general decrease in leaf length was observed between the transplant date and the last monitoring date. While the cause of this decrease in leaf length could not be determined, it is likely attributed to one or more of the following: (i) the shock of the transplant process, (ii) shoot growth, (iii) eelgrass phenological cycles and (iv) morphological change associated with plant adaptation to the transplant site.

Based on the physical variables measured, including water column and substrate characteristics, it appears that the transplant sites were well-selected, which is key to transplant success (Thom, 1990). However, it is recognized that other factors that were not monitored, including current velocity, substrate movement, and sediment chemistry, could also play a role in affecting the survivorship observed in this study.

6.1.2 Water Column Variables

The water column variables measured included Secchi depth, temperature, salinity, and dissolved oxygen. Their average measurements, recorded at the water quality stations (CAT 1, 2, 3 and STA 1, 2) on various monitoring dates throughout the timeline of the project fell within the tolerable range known to support eelgrass. No spatial difference was found between CAT and STA, except for salinity values, whose observed range was not above the tolerance range of eelgrass. All of the water column variables, except dissolved oxygen, showed significant temporal differences between monitoring dates. This illustrates the need for year-round monitoring to take the entire range of water column variability into account, as well as for determining the optimal time of year for transplanting.

6.1.3 Substrate Characteristics

Substrate analysis classified the sediment into different size classes and determined the organic content per size class. The preferred substrate type for eelgrass (i.e., sand-mud) was the dominant size class found at the transplant sites. No spatial difference between sites in size class composition, or organic sediment content (% DW) was found. However, a significant difference at the sub-site level was found for total sample organic content (% DW) and organic content in the gravel size class (% DW). While the total organic matter content per sample was, on average, high and variable, eelgrass was found surviving in a range of these conditions. Therefore, eelgrass in the Stawamus River seems to be able to grow in highly organic conditions, although its response to differing organic concentrations remains unknown.

6.1.4 Mapping & Videography

No naturally occurring eelgrass plants were documented as part of this project, either through ground-based observations or underwater videography. A map of transplant locations was created, georeferencing the transplant sites with GPS data.

6.2 Recommendations for Future Transplant Projects

The following key recommendations are drawn from the results and methodologies used in the Squamish Estuary eelgrass transplant project, and are meant to provide guidance and suggestions to future eelgrass transplant projects in this area and other community-based projects in the Pacific Northwest.

6.2.1 Eelgrass Harvesting and Transplanting

Squamish Transplant Design, Site Selection and Monitoring

Only two sites within the Squamish Estuary (CAT and STA) were compared in this transplant design. In order to determine the preferential habitats for transplants in a pilot project, an experimental design comparing a greater number of sites across a wider gradient of environmental conditions should be considered. As well, where possible, the number of transplant sub-sites per site should be increased in order to increase the statistical power of this analysis.

Time, cost and personnel constraints will undoubtedly limit the size of the project and influence its design, but where possible, an increase in replication at the site level should be made in order to obtain more powerful results. Furthermore, because measurements of continuous variables are recorded during monitoring, a regression analysis, such that sites vary along a gradient of environmental characteristics, should be considered instead of the ANOVA approach, with several replicates at two distinct sites, used in this project. Regression analyses are more powerful statistically, and the results obtained could determine the significance of the relationship between eelgrass survivorship and site environmental variables, as well as being more easily imported into models for site selection (Cottingham et al., 2005).

Key variables to consider in the selection of transplant sites in estuarine environments were determined in this pilot project. These variables should, when possible, be monitored prior to transplanting and used for site selection. While the physical variables monitored during this project did not appear to strongly affect the survivorship of eelgrass, other parameters such as current velocity, exposure to waves, bedload movement, and substrate chemistry are important to consider in future selection of transplant sites. If these parameters had been taken into account during this project, the deltaic regions associated with the Stawamus River (STA 2 and STA 3) would not have been considered as potential transplant sites because of their high rates of sediment deposition and movement associated with river run-off. Results from this project indicate that these are not suitable transplant sites to consider for future projects.

The monitoring program for transplanted eelgrass should occur for a minimum of 2 years in order to determine the ultimate success of the project (Thom, 1990). Frequency of monitoring transplant plots should also increase from those of this pilot project. It is recommended that monitoring occur once a week for the first two months post-transplant as this was observed to be within the timeframe of the greatest shoot mortality. Monitoring should continue every two weeks, or as frequently as possible following these initial months post-transplant. It should be noted that physical factors such as weather and tidal variation may limit the possibility of access to transplant sites, and should be taken into account when planning monitoring activities.

Transplanting Procedure

Planting at low tide is difficult due to the short time frame between the tidal ebb and flow and the difficulties in determining the timing of different tidal heights in the inner estuary based on tide charts, which are based on information from the outer estuary. If possible, planting should be conducted when the substrate is completely exposed, so as to reduce current drag and turbid water conditions that occur when transplanting in shallow waters. It is recommended that the eelgrass be planted at a slightly higher elevation in the estuary (greater than 0.5 m MLLW) so as to increase the duration with which the substrate is exposed. This will also increase the frequency with which plant monitoring is possible. However, plants should still be limited to low tidal elevations (1 m to 0.5 m MLLW) in order to prevent repeated exposure during daily tidal fluctuations.

If possible, the use of SCUBA and snorkelling should be considered as a means for both transplanting and monitoring as these techniques, while not evaluated here, may cause fewer disturbances to the sediment, and could be used at any tidal height. The use of volunteers for transplanting is often necessary as numerous people are needed to conduct this procedure in a very time efficient manner before the tide changes. If possible, the same volunteers should be used at all sites, so as to assure repeatability in the transplanting procedure and design, and to decrease the time needed to conduct the transplant. Finally, it is important to inspect the physical condition of the donor plants before they are planted. Only non-damaged plants with rhizomes 10 cm or 3 nodes long should be transplanted (Durance, pers comm.., 2005).

Transplant sub-sites, and even individual shoots should be marked in order to facilitate their relocation during monitoring. While yellow plastic stakes were used in this project, both at the transplant site and at a shoreline reference point, they were quickly covered in sediment and washed away. It is recommended that permanent metal rods be used to mark the locations of plots, with floats attached by string to the anchored markers in order to make them visible at all tidal heights. While this might increase the ease of transplant sight recognition and monitoring, it might also attract additional public attention to the experiment, resulting in increased disturbance to the sight. For this reason, it is recommended that good public relations be maintained with neighbouring communities to ensure that they are aware of the project. Signs might also be posted on the shore outlining the project's goals and experimental design.

Individual Plant Monitoring

Leaf length was the single quantitative measurement of individual plants monitored in this project. As has been discussed, changes in leaf length may be interpreted in a number of different ways. In order to more clearly ascertain the cause of changes in plant dimensions, it is important to measure other parameters of plant morphology and growth concurrently with leaf length. For instance, additional measurements of leaf width and leaf growth can provide a better indication of plant morphology and transplant site adaptability. Leaf widths at a distance of 0.5 cm away from the top of the basal leaf sheath should also be measured, as these are more accurate values for plant environmental adaptation than length (Phillips and McRoy, 1990). Furthermore, leaf width-to-length ratios can be calculated to construct a more accurate value for leaf dimensions than leaf length alone.

Leaf growth and turnover can also be used to determine if growth rates fall within the documented seasonal range for the region. If growth rates fall below the average rate for the area, this could indicate poor plant re-establishment to the transplant site. To measure leaf growth, a simple keyhole punch or needle prick can be notched into the leaf above the leaf sheath, and the distance that it moves away from the sheath can be used as a measurement of growth (Dennison, 1990). Furthermore, this marking technique should be used on the youngest leaf in the bundle (central leaf in the sheath) so that its age can be monitored through time with reference to the other leaves in the bundle. As well, the number of leaves produced by each shoot can be counted by the number of leaf scars (or shoot nodes) present below the leaf sheath, formed at production of every leaf (Hemminga and Duarte, 2000). These should be counted concurrently with measurements of leaf elongation/growth. In this manner, leaf growth, as well as leaf sloughing/death can be monitored. If possible, all of these plant characteristics should be monitored more frequently, preferentially at every monitoring date. Plant morphology and growth data should also be analyzed yearly by season in order to account for phenological changes.

For larger scale transplant projects, it is also recommended that other measures of eelgrass transplant success besides individual plant measurements be monitored. For example, shoot density and percent cover are often used and are recommended for future projects as they provide a better measure of long-term population dynamics (Thom, 1990).

Donor Sites

Assessment of eelgrass harvest sites should occur prior to harvesting in order to ensure that donor plants are suitable specimens for the transplant site, and that the donor site can withstand harvesting pressure. In order to prevent substantial damage to the site while harvesting, only donor stocks of eelgrass that are large and contiguous should be considered. Permission to harvest eelgrass is important to obtain for the donor site as eelgrass beds are considered a critical fisheries habitat, and therefore permission from the DFO, or other management agencies responsible for the nearshore environment is mandatory. Information regarding the size and density of the donor population is needed to estimate the total amount of shoots supported by this meadow. This can then be compared to the number of shoots planned for harvesting, as well as the total area affected by the harvesting procedure in order to provide an estimation of the impact to the donor site with the planned harvest. This information should be provided in written form to the management agency, as well as a description of the research objectives for the project. In the case of this project, a proposal containing this information was submitted to the FREMP committee for review, and the project was approved. Permission to transplant eelgrass from local community stakeholders and communications with these groups should also be established prior to harvest.

When possible, monitoring of the environmental conditions at the donor site, as well as the physical characteristics of the donor eelgrass plants should be documented. Furthermore, post-harvest response of the site to harvesting stress should be conducted. Establishing a 'control' site at the donor location is also recommended in order to provide growth and survival information to compare with the transplant sites.

6.2.2 Water Column Variables

Frequency of Monitoring and Use of Sensors

As mentioned above, physical variables should be monitored prior to transplanting in order to establish baseline estuarine conditions by which to select the most appropriate sites for transplanting, as well as the optimal time of year when transplanting should occur in the local area. If possible, monitoring should document changes in these variables throughout the year, the daily solar period, and the tidal cycle. While this elevated frequency of monitoring would not be feasible using the equipment and personnel employed by this project, the use of permanent sensors to record many of these values should be considered. If permanent markers are not employed, efforts should be made to standardize the tidal height and depth at which measurements are taken, which did vary considerably in this project.

Improvements to Monitoring of Water Column Variables

The physical variables measured in this project could be recorded with greater accuracy and precision if a number of recommendations were taken into account concerning the equipment used in monitoring. Measurements of surface conditions could be further refined to include indications of wave height and current velocity (recorded using a flow meter). Secchi depth could be taken from a boat so as not to disturb the sediment. While more costly, the amount of light needed for eelgrass growth and survival can also be measured more accurately and directly by measuring the incident sunlight (PAR) in the water with a submersible light meter (i.e., Zimmerman et al., 1995).

If monitoring is planned using a YSI–type probe, measurements for both salinity and temperature should be taken at various heights in the water column (i.e., substrate surface and an estimated average height of erect eelgrass leaves) in order to monitor variation between these depths. A permanent water level logger (i.e., Hobo Water Level Logger, Onset Computer Corporation, Maine) is recommended to aid with these measurements. Measurements of dissolved oxygen might also be excluded from monitoring as these concentrations did not vary throughout the monitoring period of this project. As well, dissolved oxygen values should not drop below the required levels in the Squamish Estuary, as turbulent mixing and input of freshwater to the water column continually oxygenate this environment (Hoos and Vold, 1975).

6.2.3 Substrate Analysis

General Recommendations to Substrate Analysis Design

In order to determine if seasonal changes in run-off cause temporal variation in sediment characteristics, the substrate should be sampled at different times throughout the year. While this will require additional labour, analysis time can be reduced by concentrating on the distribution of gravel and sand classes, and the proportion of organic matter within these classes. Using only one sieve to separate gravel from sand and all other smaller particles would save considerable time in both sieving and drying/burning processes. Furthermore, without further detailed study, areas with high organic deposition should be avoided as the effects of elevated organic matter on eelgrass are currently unknown, but are most likely negative at high concentrations.

Improvements to Substrate Methodology

As with the other components of this project, increased replication of the coring procedure is encouraged. If possible, particle size analysis of samples from different depths in the substrate is recommended in order to determine the variance in composition and organic content with depth. The anoxic or oxygenated state of the sediment can also be determined using a probe that can measure redox potential of the sediment (i.e.,Terrados et al., 1999). These measures would be far more accurate and more clearly related to growth and health of eelgrass than measurements of organic content alone. Sediment chemistry is also recommended, with emphasis on the detection and quantification of wood preservatives from logging industry and toxins from the chemical industry, which have been previously documented in the Squamish Estuary and at other log holding sites (Hoos and Vold, 1975, SEMP, 1981)

6.2.4 Mapping & Videography

Mapping of existing eelgrass beds is recommended as a component of planning and monitoring restoration activities. Once eelgrass transplant sites are established, their locations should be georeferenced with a GPS and mapped for future eelgrass restoration activities. In order to perform underwater videography, it is necessary to secure a boat that is very manoeuvrable in shallow depths, and can motor at very slow speeds on a consistent bearing in order to run accurate underwater transects with the video camera. The accuracy of an on-board depth finder and GPS is also important for mapping and relocating eelgrass beds. Before commencing any mapping excursion, the ability of the camera to maintain an upright position in the water column in order to follow bottom contours properly should be tested. A weight attached to the camera may facilitate the angle of inclination of the camera lens.

6.2.4 Areas of Future Research

Two primary areas on which to focus future investigation on eelgrass restoration in the Squamish Estuary were identified in this project. First, variables such as bedload movement, sediment chemistry and current velocity that were not measured during this project may be related to plant survivorship. Therefore, before commencing any future transplant projects, these factors should be studied in greater detail, and their monitoring protocol should be established. Second, before attempting to restore areas proximate to logging-related industry, the relationship between organic content and eelgrass growth and survival should be investigated further. The threshold levels of eelgrass tolerance to reduced surface sediment conditions and organic matter content should be determined and incorporated into transplant site selection protocol.

6.3 Community-based Research Components

Research at the community-based level by academic researchers is substantially different from traditional institutionally-based scientific research, and a number of the realities with which community-based projects are faced were confronted during this project. While these may not be unique to community-based research, they are often amplified when conducting research of this type.

6.3.1 Community-academic Collaboration

Many community-based habitat restoration and mapping initiatives have been conducted in British Columbia during recent years (for examples see Community Mapping Network, 2005). However, the majority of these have not been carried out in collaboration with academic institutions, nor have they involved the restoration of eelgrass habitats. This project, therefore, sets a precedent for such initiatives, which should be encouraged as a method of applied scientific investigation within the academic realm. Furthermore, with government funding cuts to both local restoration initiatives and universities, project collaboration can provide for cost and personnel sharing between partner groups. Moreover, increased local jurisdiction and co-management of resources, especially among First Nations, requires community support and cooperation. Nonetheless, time and cost are often constraints to community-based projects, and finding ways to work within these measures is important to consider in terms of establishing feasible project objectives and methodologies.

6.3.2 Establishing Community-researcher Relationships

The necessity of establishing working relationships with community stakeholder groups is imperative. While this is often a very time-consuming process, as an outsider to the community, it is important to gain the trust and cooperation of community groups, and to determine their goals for any collaborative project. It is advisable to initiate discussion with local groups at an early stage, both to encourage their support and to inform the scope, methodology and objectives of the project. This may often prove difficult, as community member opinions on restoration projects may vary, with the incoming researcher left to navigate the internal local political climate. It is important that the researcher maintain professional independence, while at the same time cooperating with a variety of stakeholder groups.

Many community members and groups were involved with the Squamish Estuary transplant project, and time spent at the project planning stage was therefore considerable. While correspondence and project planning primarily involved one group, the Squamish River Watershed Society, the participation of other groups was necessary for estuarine management approval, as well as for securing volunteers for the transplanting process and equipment for use in monitoring. The contact group in this situation had already established good working relations with other community groups, which contributed to support for the project. The relationships established with community groups should be continued after the completion of the project, whereby results of the scientific analysis are reported directly to the community groups and members associated with the project.

Results should be published, and accessible to the community at large through publication in local journals and newsletters, as well as the traditional form of academic publication in peer-reviewed journals.

6.3.4 Experimental Design and Personnel

Because community-based projects are often reliant on volunteers to conduct field work and monitoring, the scope and design of the project may also be affected, depending on the number of volunteers involved and their time dedication to the project. For instance, a greater monitoring frequency was planned for this project, but could not be enacted because of time and cost constraints associated with volunteering. Furthermore, the time involved in training volunteers for fieldwork, and the varying ability of different volunteers may impact the results of the project. Also, funding for projects may not include prolonged time frames associated with monitoring, therefore pre- and post-transplant assessment may not receive the necessary attention.

While the participating academic institution and the community group may establish similar project goals, the experimental design with which this is carried out might differ between parties. For instance, the establishment of control sites, and the need for high levels of replication necessary in most ecological experimental designs may not be fully understood by participating groups. If these groups do not understand the purpose of the experimental design, traditional scientific rigour may be compromised. In the Squamish Estuary design, community volunteers questioned the establishment of 3 sub-sites at each site, including transplants in locations that did not appear amenable to eelgrass growth. While the purpose of testing for eelgrass survivorship amongst a range of different environmental conditions was necessary, and yielded important results, it was difficult to persuade volunteers that transplanting eelgrass in substrate oozing black mud and covered with wood chips was merited. A compromise was made whereby the sub-sites were established as levels of replication, but only 2 sites were chosen for comparative purposes, based in part on their proximity and accessibility to volunteers.

These methodological issues are relevant not only to the undertaking and completion of this specific project, but have implications for future scientific research. The interdisciplinary, multiple-stakeholder and cost effective parameters of this type of research has the potential to provide more accurate and complete findings, more extensive and long-term research timelines, as well as to encourage community/public education. On the other hand, they may constrain efficiency and professional character of the research activity, lead to a loss of scientific rigour and deflect research objectives from their intended outcomes.

6.3.4 Determining the Need and Extent of Restoration

The ultimate goal of habitat restoration for this project, as well other community-based projects requires scrutiny. Restoration assumes that the “natural” extents of the habitat are re-established, and that the causative factors for the habitat’s decline have been eliminated. This is often difficult to establish as historical extents of habitat may be unknown and multiple factors, some of which are unknown, may be responsible for a habitat’s decline. For instance, oral accounts of eelgrass in the Squamish Estuary abound amongst community members (E.Tobe., pers. comm., May 2004), but the documented extent of this eelgrass remains minimal, both historically and presently. In this case, the extent and feasibility of restoration without naturally occurring habitats as guidelines should be taken into account during project planning, and will normally lead to greater uncertainty in site selection.

In the Squamish Estuary, many of the factors that may originally have led to eelgrass decline may still exist. These include active log booming and milling operations, as well as changes in estuarine hydrology and sedimentation as a result of dyking and diversion of the Squamish River. While the eelgrass transplant sites were located in areas recovering and re-adjusting to these impacts, it remains virtually impossible to eliminate negative factors from the larger environmental context in which the sites were established. The dynamics of environmental change caused by upstream resource harvesting, local development and climate change are unpredictable, and difficult to incorporate into restoration design when their cumulative effects on eelgrass are unknown. This points to the need for pilot projects and long-term monitoring to determine the success and long-term resiliency of restored habitats in dynamic environmental conditions.

Where the need exists, restoration projects should not be dismissed due to a lack of information, but their goals and design may be refined in order to establish preliminary information to ensure restoration success. Furthermore, not only is past information often lacking, but future management plans are often unpredictable, and may dictate the ultimate extent of restoration that can be conducted. For this reason, it is important to embed the goal of eelgrass restoration within the goals of local environmental management. Projects must also be flexible if they wish to endure within the changing environmental and political landscape of the region.

6.4 Conclusion: Realization of Project Objectives

In order to determine project success, an analysis of the project results in the context of its stated objectives and goals is discussed.

6.4.1 Objective 1

Determine if there is spatial differentiation in eelgrass survivorship between 2 potential transplant sites in the estuary, Cattermole Slough and Stawamus.

No difference was found between the two sites assessed for transplant survivorship. Therefore, based on results from this project, eelgrass transplantation is possible at both Cattermole Slough and Stawamus sites. This does not exclude the feasibility of transplanting in other intertidal and subtidal areas of the Squamish Estuary.

6.4.2 Objective 2

Determine if a relationship exists between eelgrass survivorship and spatial/temporal variability of the monitored parameters of the transplant sites.

All of the variables monitored were within the range known to support eelgrass, although the nature of the spatial and temporal relationship between these variables and survivorship were not established.

6.4.3 Objective 3

Collect baseline monitoring data for future projects in this region, including information on water column and substrate characteristics.

Information on variation in physical water-column variables was monitored throughout this project to determine their range and seasonal fluctuations. Characteristics of the sediment at the transplant sites were also established, including particle size composition and organic matter content. Results for the first six months of monitoring are reported and analyzed.

6.4.4 Objective 4

Establish a framework of procedures for community-based transplant projects in British Columbia.

A methodology for performing eelgrass restoration, within the average constraints associated with most community-based projects, was established. Suggestions were also made for methodological improvements to such projects.

6.4.5 General Project Goal

Establish the potential for transplanted eelgrass to survive in the Squamish Estuary based on results from this pilot project.

This pilot project has provided preliminary information to assist with future restoration projects in the Squamish Estuary and has contributed to the science of eelgrass restoration. However, before embarking on large-scale restoration planning, the results from additional monitoring of this pilot project and further investigation regarding the role of substrate organic matter and chemistry, bedload movement and current velocity must be taken into consideration and incorporated into site selection procedures.

The potential for restoration of habitat within the Squamish Estuary is great, given the large-scale changes that have occurred within this area as a result of industrial activity and coastal development throughout the past 50 years. Eelgrass restoration has the potential to remediate and restore some of the areas in the estuary negatively affected by such impacts. In doing so, transplanted eelgrass creates important habitat for many estuarine species, and can contribute to important estuarine processes. The feasibility of community-based eelgrass restoration, constrained by both time and money, was also deemed successful at this scale of investigation.

Given the dynamic conditions existing in the Squamish Estuary, the potential for restoration in other regions of Howe Sound which are less subject to high levels of turbidity and persistent winds, is very promising. While the extent of eelgrass beds in fjordal estuaries in coastal British Columbia is currently unknown, the potential for their survival in the Squamish Estuary indicates that their existence in shallow waters of fjords is likely. Ground truthing and mapping the present extent of this habitat in fjordal British Columbia, understanding current and historic impacts to this region and assessing restoration potential is still required. This pilot project has contributed to and affirmed this need by providing important scientific insights from project results, as well as recommendations for eelgrass restoration methodology and areas for future research. This will benefit other agencies and community groups interested in conserving and restoring this crucial habitat.