A Review and and Assessment of Eelgrass Transplant Projects In British Columbia

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Executive Summary

The following study was commissioned to evaluate the viability of transplanting eelgrass to restore or create habitat. The majority of sites that were assessed had been monitored for several years subsequent to planting, however, the long-term success of these areas was unknown. Several sites were not monitored subsequent to planting.

The study assessed 15 eelgrass transplant projects that were completed between 1985 and 2000. The assessment included a review of the supporting documentation and a field survey. Video footage of each site was recorded to provide a visual record of the physical conditions at the time of the assessment.

The study rated seven projects as successful and three as failures. Four of the recently planted sites have demonstrated good development and are expected to be classified as successes within several years. The success of one site could not be determined due to an absence of interim monitoring data and the expansion of the surrounding natural population.

The correct selection of physical attributes for the compensation area including elevation, substrate composition, light, and current regime were the main factors responsible for successful transplants. Selection of an ecotype suited to the area increased the chances of survival and rate of production. Anthropogenic impacts were responsible in several cases for failure. Natural impacts from severe browsing by Canada Geese and green urchins lead to a significant loss at two of the sites; however the remnant populations are expected to recover providing no additional impacts occur.

Mean shoot density and length of transplanted eelgrass was comparable to that of adjacent natural beds in all cases.

The results from this study demonstrate that eelgrass transplanting can be used as an effective method to restore or create eelgrass habitat. However, one must consider many factors to achieve success. A series of recommendations and conclusions are provided to assist with eelgrass restoration and compensation planning.

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1.0 Introduction

Fisheries and Oceans Canada implemented a No Net Loss policy in 1986 to protect and maintain productive fish habitat. Coastal development which involves harmful alteration and/or disruption of fish habitat will continue to occur, and is unavoidable. In order to resolve this apparent paradox, various habitat restoration and enhancement techniques have been developed to mitigate or compensate for unavoidable losses.

Eelgrass beds provide valuable fisheries habitat. Coastal development in British Columbia has eliminated a significant amount of eelgrass habitat. In an attempt to prevent further loss of eelgrass habitat, Fisheries and Oceans Canada has issued precedent authorizations to allow for HADD[1] on the condition that eelgrass beds be restored or created. The success of re-establishing eelgrass beds through transplanting has been variable. Many of the successful projects were monitored for several years, following which it was assumed that the communities had re-established. However, current ecological theory suggests that many years are required in order to develop fully functioning ecosystems, often in excess of 10 or 15 years (Dawes et al., 2000), and that monitoring of created habitats should extend beyond several years.

Fisheries and Oceans Canada funded the research documented in this report to determine whether those eelgrass habitats created from transplantation have been successful over the longer term, and to identify factors which have contributed to the success or resulted in failure of these projects.

2.0 Approach

Fifteen compensation sites were selected for this study by the Habitat Division and Small Craft harbours. Background documentation (videos, reports, and letters) associated with each project was reviewed and summarized.

Field surveys included an assessment of each transplant site, and whenever possible an assessment of adjacent natural populations (reference sites). Eelgrass morphology and density varies significantly with minor changes in elevation, exposure, substrate, and water clarity; therefore it was necessary to select reference sites that were very similar to the transplant sites to avoid misleading conclusions.

SCUBA was utilized to survey the subtidal sites; the intertidal sites were visited during extreme low tides. Quadrat sampling (0.25 m^2) was used to determine the density of plants at each of the compensation and reference sites. The density at many sites (compensation and reference) varied according to depth, in which case the area was divided into zones, and each zone sampled. A minimum of twenty (20) quadrats was counted within each zone.

The conditions of each site were recorded using a digital underwater video camera.

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[1] Harmful alteration, disruption or destruction

A casual faunal inventory of fish, shellfish, and invertebrates that were observed during the assessments of transplant and reference sites was compiled (Appendix 1).

3.0 Transplant Review

The majority of transplants surveyed in this study were motivated by DFO's Policy for the Management of Fish Habitat conservation goal (i.e. No Net Loss in productive capacity of fish habitat). Two of the recent transplants were sponsored by SeaChange, an environmental organization in Victoria which is attempting to re-establish eelgrass throughout Saanich Inlet. Information concerning each of the transplant sites is summarized below.

Table 1. Summary of Eelgrass Transplant projects.

Site	Goal	Transplant Date	Area (m^2)	Number of Transplants	Monitoring Dates
Lower Mainland					
Tsawwassen	NNL	1991	114600	202842	1992-1994
Vancouver Island					
Nanaimo	NNL	1994	5420 m^2	15,000	1995-1997
Comox Harbour[2]	enhancement	1990[1]	18,000m^2	0	1995
Campbellton	NNL	1996	-	12,000	1997
Campbell R. Discovery Marina	NNL	1994 March	810 m^2	2525	1994
	NNL	1994 April	540 m^2	750	1994
	NNL	1994 November	600 m^2	1,100	1995
Menzies Bay	NNL	1996	24 m^2	1,200	none
Port McNeil	NNL	1996	-	10,000	none
Bazen Bay	NNL	1998-1999	-	6,000	1999-2001
Tofino	NNL	1990	700 m^2	15,100	none
Tofino	NNL	1990	370 m^2	3990	1990
Tofino	NNL	1999	200 m^2	2,000	2000-2002
Tod Inlet	enhancement	2000	-	1,800	2000, 2001
Tod Inlet	enhancement	2000	-	2,300	2001
Sunshine Coast					
Gibsons	NNL	1985	164 m^2 (estimate)	1,223	1987
Gibsons	research	1987-1988	250m^2	450	1988-1989

[2] A bench was created to provide eelgrass habitat through natural recolonization.

4.0 Eelgrass Transplant Assessments

The following sections summarize the available background information, reports current status as determined by field surveys, and assesses the relative success of each project. A summary of assessments is provided at the end of the section 4.2.

4.1 Tsawwassen – Adjacent the BC Ferries Terminal

Background

An eelgrass transplant in excess of 11.46 ha was completed in 1991 as compensation for the development of the ferry terminal. The compensation area was delineated on a plan prior to development (Delcon, 1991). The area that was transplanted exceeded that shown on the plan. The additional area was located at a slightly higher elevation. The reason for planting the additional area is unknown.

The compensation area provided three different types of eelgrass habitat. The majority of the site was located at –0.3 to 1 m and usually covered by water, even at low tide. Subtidal dendritic channels provided high-energy habitat at depth of –0.3 to –0.8 m. An intertidal area, that included the additional area discussed above, provided habitat at elevations ranging from 1 to 1.7 m. The plants in the intertidal habitat are frequently exposed at low tide.

The transplanted site was divided into three zones to reflect the three types of habitat that were planted. The transplants were monitored in June, July, August, September, and December from 1992 to 1994. The monitoring included density and percent cover assessments within large permanent plots, as well as within the adjacent natural populations. The depth of the channels exceeded that provided by the natural bed, thus a comparison between the transplants and a natural population was not possible. Biomass, shoot dry weight, and mean shoot length were assessed annually within the transplanted and available natural populations.

The final site assessment that included both shoot density and biomass was conducted in September 1994, three years subsequent to transplanting. The mean shoot density and biomass for each of the areas included in this study are provided in Table 2.

Table 2. Mean shoot density and biomass of transplanted and natural eelgrass in September 1994, three years after transplanting.

Elevation (m)[1]	Mean shoot density ($\#m^{-2}$)		Biomass ($g\,m^{-2}$)	
	Transplant	Natural	Transplant	Natural
high (1 to 1.7)[2]	35.00	86.21	27.30	75.0
mid (-0.3 to 1)	104.86	81.50	208.67	168.71
low (-0.8 to –0.3)	94.00	n/a	232.18	n/a

[1] soundings T & C Datum (ECL Envirowest, 1995).
[2] elevation of the high natural population ranged from1 to 1.4 m

Current Status

The high and mid elevation transplant sites and adjacent control population were monitored on August 19, 2001. Table 3 summarizes the data collected in previous studies with that collected in 2001.

Table 3. Density of shoots ($\#.m^{-2}$) in the compensation and natural populations at high and mid elevations in August 1991, 1992, 1993, 1994, and 2001.

Year	Mid Elevation		High Elevation	
	Transplant	Natural	Transplant	Natural
1991	1.77	n/a	1.77	n/a
1992	26	60	16	72
1993	59	69	49	95
1994	126	100	47	109
2001	102	92	60	76

Discussion

The transplant project produced eelgrass habitat comparable to the adjacent natural population within only three years at the mid and low elevations. The small portion of the area that was located at a higher elevation was less productive than the adjacent natural population. The higher elevation transplant area extended to a greater elevation than the natural population, which may account for the difference.

The factors that contributed to the success of this project included; optimal elevation, optimal substrate, and suitable donor stock.

4.2 Nanaimo

Background

The construction of Newcastle and Channelview Marinas required dredging an area (2548 m^2), which, at the time, supported eelgrass. A compensation agreement was developed with DFO to replace the eelgrass habitat at a ratio of 2:1. A mudflat, adjacent to the proposed development, was dredged to provide substrate at a shallow subtidal depth suitable for eelgrass. Eelgrass shoots (15,000) were removed from the area destined for marina development and transplanted to the compensation area in plots of 10 in August 1994.

The transplant was monitored for three years (1995-1997) as per the DFO agreement. After three years the plots had increased in area with resulting coverage ranging from 10% to 70%; average cover was estimated at 60%. The shallowest portion of the transplanted area was slightly less than zero metres chart datum. This area demonstrated the lowest percent cover;. most of the plots survived but cover was estimated at only 10%. The average density of shoots was approximately 48 shoots$\cdot m^{-2}$ in September 1997.

Current Status

The density of plants in the deeper areas resembles that of very robust natural populations, with a mean shoot density of 88 shoots$\cdot m^{-2}$ and average shoot length of 79 cm. Eelgrass coverage ranged from 95 to 100%. The density of plants in these areas exceeded that of the compromised habitat by more than 400%.

Eelgrass is present throughout the shallow areas, however, it is sparse and patchy. The shoot density was estimated at 6.1 shoots$\cdot m^{-2}$ with the mean shoot length at 29 cm.

A healthy remnant of the donor bed was located in the middle of the marina between berths. Shoot density in this same area ranged from 8-12 shoots$\cdot m^{-2}$, similar to that recorded prior to marina development. The mean shoot length was 36 cm.

Discussion

The objective of no net loss of productive habitat has been successfully achieved. The deeper portion of the compensation area provides excellent eelgrass habitat. The transplanted population is composed of larger plants at a greater density than that of the donor population.

The productivity of eelgrass beds is often assessed in terms of leaf area indices (LAI). The LAI is a measure of the leaf area per unit of substrate area. It is defined as the mean shoot density (shoots·m^{-2}) times the mean leaf area (m^2, one side) per vegetative shoot (Bulthius, 1990). LAI values reflect fisheries value as they provide an estimate of the surface available for epibenthic crustaceans, especially harpacticoid copepods, which are in turn important prey species for juvenile chum salmon, Pacific herring, Pacific sand lance, and surf smelt (Norris and Echeverria, 2001). LAI values were not determined for the transplanted and natural population, however a conservative estimate, based solely on mean leaf length and mean shoot density would indicate that the LAI of the deeper portion of the transplant site is at least twenty times that of the remnant natural population.

The shallower half of the compensation area has been less successful. It is possible that the eelgrass growth is inhibited by shading from the adjacent condominiums and marina. In addition, the donor stock was harvested from a lower elevation. The morphology of the plants when harvested was within the range of the ecotypes *phillipsi* and *latifolia*. However, once the stock was transplanted to a greater depth the leaf size increased indicating that the stock was *latifolia*. The elevation of the upper area is marginally within the range for this ecotype, and likely too high for optimal growth.

4.3 Comox Harbour

Background

Plans for the redevelopment and expansion of Comox Harbour included the loss of 12,900 m^2 of eelgrass habitat. A compensation agreement was developed in the early 1990s that included the creation of a dredgeate bench (15,455 m^2) to provide habitat conducive to natural colonization by eelgrass. The bench was constructed at an elevation suitable for eelgrass using native materials from the eelgrass habitat which was destined to be lost. There were several large eelgrass beds within the harbour and it was hoped that these populations would naturally recolonize the constructed bench.

A brief survey of the area in 1995 revealed that although a meadow had not formed in the area, eelgrass was present but only in small patches scattered throughout the bench.

Current Status

The recent 2001 survey revealed that eelgrass has successfully colonized the entire dredgeate bench. The density of shoots was variable; likely reflecting the amount of time since colonization. The areas of highest density most likely represent the areas that were colonized first, while the areas of sparse growth may have been only recently colonized. There are a few small unvegetated areas on the bench, however this is also commonly observed in other eelgrass beds, and may be the result of disturbance by boats passing over the area at low tide.

The mean density of shoots in the majority of the bed was 44 shoots·m^{-2}, although in some areas the plants were less dense averaging 16 shoots·m^{-2}. The shoot length ranged from 10 to 45 cm with a mean of 30 cm. Overall, the resulting eelgrass meadow was comparable to other eelgrass populations located at similar elevations.

An evaluation of the natural eelgrass bed that was removed to enlarge the harbour was completed prior to impact (ECL Envirowest, 1991). The density of eelgrass in the area that was slated for dredging varied from 4 to 207 shoots·m^{-2}. Densities of this magnitude are typical of the small narrow leaved eelgrass, ecotype *typica*. The eelgrass that has colonized the dredgeate bench is much larger, within the range of ecotype *phillipsi*. Since the leaf area per plant of *phillipsi* is usually at least five times that of *typica* it is likely that the biomass production per m^2 of the dredgeate bench exceeds that historically produced by the area which was dredged.

Discussion

The objective of No Net Loss was achieved at this site, however it required many years to attain. The 1995 monitoring reported a bench that was virtually devoid of eelgrass, demonstrating that natural eelgrass colonization, which is dependant on random events, may require many years.

Design considerations that lead to the eventual success of this project included;

- The sediment composition (sandy mud) and depth (slightly subtidal) were within the optimal range for the species.
- Numerous populations of eelgrass are located within close proximity to the created habitat, which maximized the probability that the area would be naturally colonized.
- The absence of current in the protected harbour enhanced the chances for free floating eelgrass that had been uprooted elsewhere in the estuary, to settle and re-establish.

4.4 Campbell River – Discovery Marina

Background

Three eelgrass transplant projects were completed in the Discovery Marina in 1994, two were located along the inside of the breakwater and the third near shore.

The Northern and Southern Breakwaters

Eelgrass was transplanted along the length of the northern breakwater (3.1 shoots·m^{-2}) and at three sites along the southern breakwater (1.4 shoots · m^{-2}) in March and April of 1994. The site was assessed three months after the transplant at which time survival along the northern bench was determined to be 22.6% while the eelgrass along the southern bench had multiplied resulting in a 64% increase. Casual surveys by DFO in subsequent years determined that none of the transplants along the northern breakwater had survived, while a few small patches of eelgrass were evident along the southern breakwater.

Southwest Corner

A transplant of 1100 shoots within a 600 m^2 area was completed on November 2 and 3, 1994. The site was monitored after one year, at which time a survival rate of 56% was recorded. The final monitoring was completed in January 1997. A total of 131 eelgrass shoots were present, approximately 12% of the original number. A large horseshoe shaped depression in the sand substrate was noted which had essentially eradicated 75% of the surface from the transplant site. The marina manager indicated that, in September of 1996, a barge offloaded a crane from the southwest corner of the marina, above the location of the transplant site. It is likely that the propeller wash from a tugboat manoeuvring the barge caused the scouring in the sand. The crane was to be offloaded onto a barge in the same manner during the spring of 1997 (Archipelago, 1997). Subsequent verbal reports from DFO revealed that the site was additionally impacted by the unauthorized mooring of a vessel over the site for several months (R. Russell, pers. com.).

Current Status

The three transplant areas were surveyed on March 11, 2001.

The Northern and Southern Breakwaters

The survey along the northern breakwater failed to locate any eelgrass.

Eelgrass was present in each of the three transplant areas along the southern breakwater. Rebar that had been used to anchor the shoots and mark plots was found in the vicinity of each surviving patch of eelgrass. The three areas were referenced as S1, S2, and S3 in the original transplant report (Fisheries & Oceans, 1994). S1 and S2 were located along the eastern extension of the southern breakwater and had a westerly aspect; S3 was located adjacent to the southern arm of the breakwater and had a northerly aspect.

Eight distinct patches of eelgrass containing a total of 2021 shoots were located along the eastern arm of the breakwater. Two patches of plants were thought to have originated from S1 and six from S2. The largest patch of eelgrass along eastern arm of the south shelf covered 7.5 m^2 and contained an estimated 420 shoots of eelgrass. The shoots ranged in length from 24 to 31 cm with a mean of 28 cm. The density of shoots within the vegetated patches ranged from 48 to 84 shoots·m^{-2}, with a mean of 72 shoots·m^{-2}; comparable to natural populations at similar elevations.

Six patches of eelgrass containing a total of 102 shoots were observed along the southern arm of the breakwater. The largest patch contained 38 shoots of eelgrass. The shoots ranged in length from 15 to 30 cm, with a mean of 21 cm.

Table 4 compares the number of shoots planted in 1994 and the number present in 2001 at each of the sites along the breakwater.

Table 4. Number of shoots transplanted along the breakwater at each of three locations in 1994 and the number present in 2001.

Site (aspect)	Depth (m)*	1994	2001
N (W)	2.2 to 0.7	2525	0
S1 (W)	0.8 to 0.5	300	360
S2 (W)	0.6 to 0.0	175	1559
S3 (N)	1.0 to 0.1	275	102

* adjusted to chart datum

Southeast Corner

This area was devoid of eelgrass although the area appeared to provide excellent habitat.

Discussion

The success of transplants varied between sites at Discovery Marina. The most successful sites (S1, S2) were those located at the lowest elevation with a westerly aspect. S3 was slightly higher, and with a northerly aspect may have received less light resulting in diminished growth.

The primary factor responsible for the failure at N1 was likely elevation; the plants were planted at 0.5 to 2.2 metres, slightly higher than the optimal range for this species. The area was planted in April, therefore the plants were subjected to exposure at low tide during the day before they had a chance to recover from transplanting stress. In addition, the substrate was a combination of boulder, cobble, gravel, and sand as opposed to silt and sand which is the optimal substrate composition for eelgrass.

The substrate at sites S1, S2, and S3 were primarily sand and silt. Boulders and cobble were common along the eastern arm bench of the southern breakwater; these may directly and indirectly limit the expansion of eelgrass on site. Directly, the rock forms a physical barrier, and indirectly it provides an attachment site for laminarians which may function to eliminate eelgrass through shading during the summer months. The density of plants within the vegetated areas was comparable to that of natural populations, however there were large unvegetated areas within the transplant site which may have been a result of shading by laminarians.

The available habitat in the southwest corner appeared well suited for eelgrass, with appropriate depth and substrate. The rapid decrease in shoot number over the first year may indicate that there was a problem with the condition of donor stock. However, the eelgrass that survived the first year had successfully established and should have been able to multiply. The absence of eelgrass in the area indicates that the subsequent anthropogenic impacts that the site was subjected to were of sufficient severity to eliminate the few surviving shoots of eelgrass.

4.5 Campbellton

Background

A marine pipeline was constructed to discharge effluent from the new sewage treatment facility north of Campbellton, B.C in 1996. The pipeline bisected a large productive eelgrass meadow. A trench was dredged through the eelgrass bed into which the pipeline was placed. Sediment that was removed to construct the trench was used to bury the pipeline. The placement of the pipeline resulted in a corridor, devoid of vegetation, over the pipeline and on either side. Eelgrass from the adjacent population was transplanted into the dredged material several months later, to assist with the re-establishment of a continuous eelgrass bed. The shallow areas were planted with small shoots collected from shallow areas, whereas the mid and deeper areas were planted with larger plants from the mid and deeper areas of the adjacent bed. Twelve thousand shoots of eelgrass were transplanted from the adjacent population into the area that had been impacted by construction and burial of the pipeline.

To increase their chances of survival in the strong currents, the anchored shoots were planted in plots of twenty to forty shoots depending on current and elevation at each specific location within the impacted area. The average number of shoots planted per plot was 25.

The transplant site was monitored in 1997. The site was divided into three areas based on relative elevation (upper, mid, and lower) for the purposes of assessment. The majority of the transplant site was located within the mid elevation area. The plants in this area were large and robust. Many of the plots had expanded and coalesced with adjacent plots. The number of shoots per plot ranged from 15 to 200, with a mean of 64. The upper bed forms a band ranging in width from approximately 2-5 metres. The plants in this bed were small, typical of eelgrass (ecotype *typica*) growing at this elevation. Discrete plots of eelgrass were distributed throughout the zone. The plants appeared healthy and were branching, producing additional shoots. The average number of shoots per plot in this area had increased from 20 in 1996 to 30 in 1997. The lower bed was located at depths exceeding that which is optimal for eelgrass. Eelgrass was transplanted at this depth in 1996 to ensure that all potential eelgrass habitat was planted. There were only a few plots that had survived, and these supported relatively few plants. However, the plants that had successfully established there were large and healthy.

Current Status

The compensation area and the adjacent undisturbed natural eelgrass beds were surveyed on March 12, 2001.

Thousands of green sea urchins were grazing on the eelgrass in the transplant area. The area occupied by urchins extended into the natural bed although the greatest density was located within the transplanted site. In some areas the eelgrass had been browsed to a uniform height. There were also large areas completely devoid of eelgrass that appeared to be the result of more severe browsing. Eelgrass flourished in the areas that had not been browsed. The mean density of shoots in these areas was 84 shoots $\cdot$ m^{-2}, identical to that of the adjacent natural population at a comparable elevation. The shoot length in each of the mid areas averaged 1.1 metre.

The upper area, which was devoid of urchins, was indiscernible from the natural population on either side. The mean density of eelgrass in the transplanted area was 28 shoots $\cdot$ m^{-2}, while that of the adjacent natural population was 27.6 shoots $\cdot$ m^{-2}.

The lower elevation supported a sparse population of very large shoots (>1m) which were comparable in size and density (<1 shoot $\cdot$ m^{-2}) to the adjacent natural population at comparable depths.

Discussion

The transplant was successful, however the eelgrass may require several years to recover from the impacts sustained as a result of intensive urchin browsing. An informal survey of eelgrass ecologists from the Pacific Northwest revealed this behaviour as previously unobserved. A literature review found one report of green urchins grazing on eelgrass in Alaska. An assessment, conducted a month subsequent to the invasion would have been unable to identify the cause of eelgrass loss and may have concluded that the transplant was only partially successful.

There was speculation prior to the transplant that strong currents and large tidal exchanges over the compensation area would limit the potential for re-establishment of the eelgrass. However, the primary current flow is alongshore, and therefore travels over the natural beds on either side of the compensation area prior to reaching the transplant site. This would diminish the force near the substrate-water interface. In addition, the heavy anchoring devices (rebar) used to anchor the transplanted shoots likely contributed to their successful establishment.

The recognition that the natural bed is comprised of at least two ecotypes, and the selection of appropriate stock for various sites within the compensation area also contributed to the success of this project.

The objective of no net loss was achieved.

4.6 Menzies Bay - Marine Link

Background

Eelgrass was salvaged from an area to be modified by the Marine Link Development in Menzies Bay and transplanted July 1 and 2, 1996 to the northwest corner of the Bay. Twelve hundred (1200) shoots were relocated. The shoots were planted in four plots (2m x 3m), spaced approximately 3 metres apart.

The DFO authorization for this project did not include monitoring, due to the small scale of the project. The compensation area had been historically impacted by log booming activities; the foreshore lease that included this area expired prior to 1996, and will not be renewed. The transplant site appeared to provide good eelgrass habitat, in terms of both elevation and substrate. Although the number of shoots planted was limited, it was hoped this transplant would provide valuable information with regards to the potential of re-establishing eelgrass beds in other locations formerly used for booming activities.

Current Status

The compensation area was surveyed at low tide on May 8, 2001. The transplants survived and multiplied from an area of approximately 50 m^2 metres to create a bed that exceeds 3600 m^2. The mean density of shoots within the bed was 56 shoots · m^{-2}, and the mean shoot length was 31 cm; these values are typical for eelgrass at this elevation on the east coast of Vancouver Island.

Eelgrass has started to colonize other areas of the adjacent substrate; there were many small patches averaging 4m^2. The density within the small patches averaged 26 shoots · m^{-2}. Seedlings were observed throughout the area.

Discussion

The project was highly successful, and provided a net gain in fisheries habitat. The success of the transplanted shoots demonstrates that it is possible to re-establish eelgrass populations in former log booming areas. It is possible that some of the eelgrass that has colonized the site may have drifted in from other locations, however the greatest density of shoots was within the area that was planted in 1996.

The substrate at the compensation area in Menzies Bay was not as highly degraded as is often observed under former booming grounds. Additional research is recommended to determine the thresholds of sediment degradation in which eelgrass can survive.

Factors that contributed to the success of this project included; optimal elevation for the ecotype, optimal substrate, and very little current.

4.7 Port McNeil – Broughton Strait Resort

Background

The owners of Broughton Strait Resort approached DFO for permission to develop a breakwater as beach protection from waves generated by passing cruise ships. The proposed breakwater was to be located in an area partially occupied by eelgrass. The area between the proposed breakwater site and the beach had been heavily impacted, allegedly by cruise ship wakes, which had resulted in significant erosion.

Dense patches of eelgrass covered approximately 40% of the area. DFO approved the proposal on the condition that 10,000 eelgrass shoots from the area to be covered by the proposed breakwater be relocated to the area affected by erosion adjacent to the beach. It was hoped that the breakwater would reduce erosion in this area, and that the transplanted eelgrass would survive and expand to provide complete coverage of the area.

A compensation site was selected along the upper intertidal edge of the existing eelgrass bed, where the habitat had been most severely degraded. Ten thousand eelgrass shoots were removed from the area within the footprint of the proposed breakwater, and planted into the compensation area ($90m^{-2}$) in 1996. The local First Nations Community expressed concern that the proposed breakwater could possibly affect local sediment transport and negatively impact the adjacent estuary. A coastal geomorphologist was consulted to investigate these potential changes and reported that their concern was valid, hence the construction of the breakwater was vetoed and the site was never monitored. It was thought that without the breakwater in place for protection, the transplanted eelgrass would not survive. In 1998, an informal site visit was conducted. Eelgrass densities in the area that had been planted demonstrated dramatic increases.

The intertidal and shallow subtidal habitats of this site were mapped prior to the transplants in 1996.

Current Status

The compensation area and the adjacent natural population of eelgrass were surveyed at low tide on May 9, 2001. The 1996 survey recorded percent cover and mean density within the vegetated areas. To facilitate comparisons, similar parameters were used to assess the population in 2001.

The compensation area exhibited 75% cover and a mean density, within vegetated areas, of 1440 shoots $\cdot$ m^{-2}. The mean shoot length was 43 cm.

The mean density and percent cover of eelgrass in the adjacent population, 10 to 15 metres away from the compensation area at a comparable elevation, were 640 shoots · m^{-2} and 55% respectively. The mean shoot length of plants in this area was the same as that of plants in the compensation site. The data from 1996 and 2001 is summarized in Table 5.

Table 5. Density and cover of eelgrass in the compensation area prior to transplant in 1996 and five years later in 2001.

Location	Winter 1996		Spring 2001	
	Density (shoots · m^{-2})	Cover (%)	Density (shoots · m^{-2})	Cover (%)
compensation area	410	40	1440	75
adjacent population	410	40	640	55

Discussion

There has been a definite increase in eelgrass density within the compensation area and the adjacent natural community. The pre-transplant surveys were conducted in mid winter whereas the survey for this study was completed in late Spring. Part of the increase may be due to seasonal variability, especially since the area is intertidal and ice scour could have reduced the density of shoots during the previous survey. The higher density within the compensation area indicates that the transplant was successful, however since the density in the adjacent population has there may be other environmental factors that have increased the growth at this site. Cruise ship wash was cited as the factor responsible for the patchy distribution of eelgrass at the site in 1995. The proposed breakwater was designed to protect the intertidal area and the transplanted eelgrass. The breakwater was never constructed, but perhaps the frequency, speed, or route of the cruise ships has been altered. The increase in percent cover and density of the adjacent natural population indicates that the environment has improved for eelgrass relative to 1995.

4.8 Bazen Bay

Background

The development of a new wastewater treatment plant for the Saanich Peninsula required installation of a marine outfall pipeline through a productive eelgrass bed in Bazen Bay, Haro Strait. The original plan entailed excavating a trench through the eelgrass bed into which the pipeline would be buried and covered with the native substrate. Eelgrass habitat was to be restored over the pipeline through transplanting with donor stock from the adjacent population. Engineering difficulties were encountered during construction which necessitated a change in methodology; the pipeline was laid on the surface and the section closest to shore was covered with rip rap. The installation of the pipeline resulted in the loss of eelgrass from an area averaging 15 metres perpendicular to the pipeline along each side of the rip rap covered portion.

An eelgrass transplant was completed in February 1999, approximately two months after the pipeline was installed. All areas that could potentially be restored were planted. The area that could not be restored, including that covered by the pipeline and rip rap were compensated for at a ratio of 1:1.5 by the development of reefs seaward of the eelgrass bed. One year later during transplant monitoring, it was found that although the majority of the compensation site was doing well, part of the area had been covered by a layer of small angular rock which had eliminated the transplanted eelgrass. Kelp had colonized the crushed rock producing a canopy under which the eelgrass was unable to survive. Attempts were made to remove the crushed rock and the area was replanted in March 2000. The area was assessed in July 2000, demonstrating that kelp was present but at much lower densities and the recently transplanted eelgrass had survived and multiplied. The overall success of the recently transplanted eelgrass could not be adequately assessed as it was obscured by the blades of kelp. The eelgrass in the portion of the compensation site that had not been covered by rock has flourished and in some areas reached densities comparable to the adjacent natural, undisturbed population.

Current Status

The northern side of the compensation area progressed faster than the southern side. The transplanted eelgrass that was planted to the north 7 to 15 metres away from the rip rap multiplied quickly and within one year resembled the surrounding donor bed. The individual plots within the transplanted area were no longer discernable. The density of shoots in the southern area increased over the first year, and after two years the eelgrass that had been planted 10 to 15 metres from the rip rap resembled the adjacent natural population.

Due to the variation in shoot density within the compensation site the area was subdivided into four zones for monitoring and assessment. The zones were defined as follows:

Area A – North side of pipeline, 7 to 15 metres from pipeline & rip rap

Area B - North side of pipeline, 0 to 7 metres from pipeline & rip rap

Area C - South side of pipeline, 0 to 10 metres from pipeline & rip rap

Area D - South side of pipeline, 10 to 15 metres from pipeline & rip rap

The transplants were planted in plots of 10 at 1 metre intervals; resulting in an average density of 10 shoots $\cdot$ m^{-2}. The mean number of shoots per plot was determined in Areas B and C. It would not have been appropriate to randomly sample quadats within Areas B and C due to the clumped distribution of eelgrass in these areas and the limited time available for sampling. In Areas A and D the plots had coalesced and thus random quadrat sampling was used to determine the mean density.

Table 6 summarizes the data collected from February 1999 to May 2001. In order to estimate the mean number of shoots · m^{-2} for Areas B and C it was assumed that each plot represented 1 m^2. This assumption may slightly overestimate the density of shoots as it is possible that not all of the plots were successful. The eelgrass shoots travel through the sediment as the plant grows, thus after two years the distance between plots was variable, however it appeared that virtually all of the plots had survived.

Table 6. Density of eelgrass in each of the transplanted areas and the adjacent natural population.

Location	Date				
	February 1999	February 2000	July 2000	May 2001	August 2001
Area A	10	67	71	102	115
Area B	10	17	38	64	70
Area C	10	0*	15.5	37	56
Area D	10	16.5	42	99	110
Natural	70	72	72	104	114

Discussion

The eelgrass that was planted in Areas A and D, away from the influence of the pipeline and rip rap are indistinguishable from the adjacent natural population. The success of the transplants in these may likely have been enhanced by their proximity to the natural bed. The physical structure of the natural bed could reduce currents flowing over the transplants, and the plants along the border of the natural bed may have contributed shoots to the adjacent edges of these areas.

The transplanted eelgrass along both sides of the rip rap is inhibited by competition for light from kelp which has established on the rip rap. The eelgrass that was planted closer to the rip rap along the northern side has multiplied seven fold over two years, and in some instances has survived within 1 metre of the rip rap. The new transplants along the southern side, from which crushed rock was removed in 2000, have multiplied but not in close proximity to the rip rap. There is an area several metres in width, immediately beside the rip rap which appears incapable of supporting eelgrass. The reason for the variable success is unknown, however it may be that the currents on tidal exchanges or during storm events differs along the southern and northern sides of the rip rap.

Reports indicate that transplanted eelgrass beds require a minimum of five years to become established and stable, thus it is far too soon to determine the long term success of this project. However, the rapid development of Areas A and D, and the significant increases in Areas B and C are encouraging.

The inhibition of eelgrass growth by the presence of rip rap and the abundance of kelp has been identified as a factor worthy of consideration in future planning. Annual monitoring enabled the identification of additional impacts to Area C which were quickly rectified.

4.9 Tod Inlet

Background

Seachange Marine Conservation Society has initiated two eelgrass transplant projects in Saanich Inlet in an attempt to re-establish historic eelgrass beds.. The transplants were conducted by volunteers from the local community under professional guidance. The first transplant of approximately 1,800 shoots was completed in April 2000 adjacent to Goward Tod Park. The second transplant of approximately 2,300 shoots was completed in October 2000, in a bay adjacent to the Tsarlip Reserve. Historically, an eelgrass bed extended across the bay however intense shellfish harvesting in the centre of the bay eliminated the eelgrass from that area (230 metres in width) leaving a residual population on either side.

Current Status

The transplants at Goward Tod Park and the Tsarlip Reserve were surveyed on May 3, 2001.

Goward Tod Park

Canada Geese were observed foraging on the transect of transplanted eelgrass that was located closest to shore, at the highest elevation in the fall of 2000.

The site was surveyed for this study on May 3, 2001. Visibility at the time of the survey was extremely poor (<50cm), making it challenging to locate the transplants, and to conduct an overview assessment. The extreme turbidity and concomitant reduction of light through the water column would significantly limit eelgrass growth.

The transplant was comprised of three transects; shoots were planted in groups of 10 at one metre intervals. A few shoots were noted along the transect closest to shore; they were healthy and robust. It appeared that most of the plots along the deeper transects had survived. The number of shoots per plot along Transect 1 ranged from 2-34 with a mean of 13.3. The number of shoots per plot along Transect 2 ranged from 16 to 37 with a mean of 20.6. It is possible that there may have been several plots without any surviving shoots however this could not be determined conclusively given the poor visibility and limited amount of time available for the survey. The high variability in number of shoots per plot may be due to the condition and handling of the plants that were planted. The large number of volunteers assisting with transplants led to problems with quality control. However, the fact that most plots supported eelgrass after one year indicates that it is possible for eelgrass to survive at this site. It is anticipated that the surviving eelgrass will reproduce and eventually create a bed at this site; although the rate of expansion may be reduced relative to other populations due to the high turbidity. It is important to note that although the success rate may have been reduced by quality control, the exercise provided an excellent opportunity for members of the community to learn about eelgrass and its value to the local ecology.

Tsartlip Reserve

Eelgrass shoot survival at the Tsartlip Reserve transplant site was poor. The fetch at the site is in excess of 5 kilometres and during the assessment, divers experienced moderate wave action despite relatively calm wind conditions. Winter storm events, particularly during lower tidal cycles, may be responsible for the observed uprooting and exposure of the transplanted shoots and rhizomes.

The shoots were planted in November and therefore were subjected to winter storm conditions prior to new root development. Eelgrass growth is slow during the winter although plants can survive by metabolizing energy stored in the rhizomes. Transplant success is not typically limited by season, however, when planted during the winter they may be dependant upon anchoring devices to hold them in the substrate until spring when root development accelerates. In this case, the anchoring devices may not have been of sufficient weight to hold the eelgrass in position. Although survival was poor, evidence of the transplant remained. The remaining plots were scarce. The number of shoots in these plots varied between 1 to 20 shoots of eelgrass, with a mean of 10.5.

If the remaining shoots are able to endure and multiply to form a meadow, the leaf blades will lead to a reduction in current velocity within the plots creating a more suitable environment for eelgrass and an accelerated rate of growth.

Discussion

It will take several years before the success of these transplants can be determined.

Goward Tod Park

The transplants that have endured for a year should be able to survive and multiply. The rate of increase may be limited by light as evidenced by the extremely poor visibility during the survey. The site is located close to the mouth of Tod Creek which may contribute to the high turbidity.

Tsartlip Reserve

Factors that should contribute to the success of the transplant include; suitable substrate, optimal elevation, and selection of the appropriate ecotype. The current regime may limit the ability of eelgrass to persist in the area. The transplant was located in the centre of the bay, equidistant from the two remaining populations. The eelgrass from the two remaining beds should branch into the adjacent unvegetated area and over time coalesce to form a single bed across the bay. However, at a rate of 0.5 metres per year this would require centuries. The centre of the bay was selected as the site for the transplant to enable plants to branch towards the remnant populations simultaneously. However, given the marginal survival of the transplants it may be more productive to locate future transplants in closer proximity to the natural beds where they would be protected to some degree by baffling affects of the existing eelgrass.

4.10 Tofino – Fourth St. Dock

Background

An eelgrass transplant was required by DFO to compensate for an area that was dredged near the Fourth Street Docks. The compensation plan included construction of a 700m^2 bench at minus 1.0 metre (C.D.) to provide habitat for eelgrass. Eelgrass was transplanted at 25 cm intervals throughout the compensation bench, and over an additional 70 m^2. It was noted during the transplant that crabs were uprooting a substantial number of recently planted eelgrass shoots. A casual survey, several months following the transplants, found an unquantified amount of eelgrass on the bench.

Current Status

The site was surveyed on March 26, 2001 during a storm. The gale force winds had suspended sediments reducing light penetration to the extent where a video record could not be acquired.

A large floating dock was moored over the compensation site. Local residents report that the floating structure was installed shortly after the transplant was completed. The entire compensation area was surveyed during which time two live shoots of eelgrass were noted.

Discussion

Shading from the floating dock is likely responsible for the failure of the transplant. The sediment and elevation provide suitable habitat for the species. Other factors may have contributed to the failure, such as donor vigour, planting technique, or uprooting by crabs, however, even with all other factors conducive to a successful transplant, the shading imparted by the floating structure would likely have led to failure.

4.11 Tofino – Long Beach Shellfish Ltd.

Background

Eelgrass was transplanted into an area between Deadman's Island and Beck Island in 1990 as compensation for a fill project. Eelgrass was present in the vicinity but not in the immediate area that was selected for transplanting. Five plots of various sizes were planted; the total area planted covered $370m^2$. 3990 shoots of eelgrass were transplanted. The site was monitored once, 75 days after planting. The survival at that time ranged from 1%-50%. The monitoring report noted that the surviving plants were producing new shoots (Bruce, I., 1990)

Current Status

The site was surveyed on March 26 and 27, 2001. The entire area between Deadman's Island and Beck Island has been colonized by eelgrass. It was impossible to determine the exact location of the plots given the available maps; however it was possible to ascertain that all of the substrate in the vicinity of the plots was colonized by eelgrass. The majority of the plants are of the small narrow leaved variety (ecotype *typica*), commonly found at higher elevations around Tofino. Small depressions several centimetres deep in the substrate were colonized by clumps of the larger ecotype *phillipsi.* The percent cover ranged from 50% at the highest elevations to 95% in the deeper areas. The density of shoots ranged from 60 to 840 shoots m^{-2}, with a mean of 616.

Discussion

It is unfortunate that the site was not monitored in previous years as it is not possible to determine whether the colonization was a natural phenomena (as it was in Comox) or the result of the transplant project.

4.12 Tofino - Tofino Air Lines Ltd.

Background

Tofino Air Lines Ltd. requested authorization from the Department of Fisheries & Oceans to propwash dredge 100m^2 of low intertidal eelgrass habitat, adjacent to their floatplane dock. The dredging was required to enable safe tie-up of floatplanes at the dock, within the existing lease. The Department of Fisheries & Oceans granted a Precedent Authorization. The conditions provided in the Authorization included the establishment of compensatory eelgrass habitat, at a 2:1 ratio in an adjacent waterlot, and a monitoring program that consists of an annual assessment for three years (2000-2002). The eelgrass was planted in plots of ten plants, at one-metre intervals.

The 2000 monitoring revealed that majority of transplants within the compensation area have survived and multiplied. The eelgrass that was planted along the lowest elevation of the compensation area has reproduced at the greatest rate; the enhanced growth may be attributed to the fact that the donor stock was collected from a similar elevation. In some areas the transplant plots had merged with naturally colonizing plants resulting in shoot densities similar to that of the natural populations at similar elevations. Subsequent to the transplant, a cement ramp was constructed adjacent to the compensation area to provide Kayak access to the water. During low tides, the path from the ramp to the water travels over a portion of the compensation site. Trampling from use of this path has resulted in the loss of eelgrass from that section of the compensation site.

Current Status

The transplanted and natural eelgrass populations were surveyed on June 27, 2001. The transplant area was divided into three zones based on elevation and eelgrass density for assessment purposes. Areas A and C are located at similar elevations, Area C lies in the path of kayak access. Area B is located adjacent to Area A but at a slightly higher elevation.

The percent cover of eelgrass in June 2000 ranged from 10% to 100% within Area B. By 2001 eelgrass provided cover to 85% of the entire area. In addition, the eelgrass from Area B has extended into the substrate shoreward of the transplanted area. Area C is slightly higher in elevation that Area B, and many of the shoots that were transplanted into this area in 1999 were unable to survive. However, the shoots that did survive the first year have adapted to the site and multiplied. Eelgrass now covers 60% of Area C. The dramatic increase in shoot density may be due in part to seeding from the adjacent bed (Area B). Area A has been the least successful; likely due to trampling by boaters as it lies directly in line with the new kayak access dock built on shore. The portion of Area A that lies adjacent to Area B continues to support eelgrass. Although the percent cover is low in this area, the density of plants within the patches is quite high. The percent coverage data is summarized in Table 7.

Table 7. Percent cover of Eelgrass in each of the transplanted areas and the adjacent natural population.

Area	2000 (% cover)	2001 (% cover)
A*	15	25
B	45	85
C	<1	60
Natural	95	95

* not including the section of Area A from which eelgrass has been eliminated

The mean density of eelgrass in each of the Areas was determined in 2000 and 2001 (Table 8).

Table 8. Mean density of Eelgrass shoots in each of the transplanted areas and in the adjacent natural population.

Area	1999 (# shoots·m^{-2})	2000 (# shoots·m^{-2})	2001 (# shoots·m^{-2})
A*	10	28	70
B	10	48-244	428
C	10	<1	240
Natural		244	448

* not including the section of Area A from which eelgrass has been eliminated by trampling.

Discussion

The transplanted eelgrass has survived and multiplied. The density of shoots has increased dramatically. The density of shoots within the natural eelgrass bed adjacent to the floatplane dock was also much greater than previously recorded. Exceptionally high eelgrass densities have been recorded at several locations around Vancouver Island recently, indicating that climatic conditions have been optimal for the species this year.

The only area that has sustained a loss is along the eastern side of the compensation site. It is speculated that this is likely a result of trampling by people dragging kayaks to the water at low tide. However, the recovery of eelgrass in Area C more than compensates for the recent loss in Area A, and the total area still exceeds the minimum requirement. Although the long-term success of this project cannot be determined after only two years, it is anticipated that the area of eelgrass habitat created will exceed the amount stipulated in the precedent authorization.

Factors that have contributed to the success of this transplant include suitable substrate and appropriate elevation for the ecotype.

4.13 Gibsons

Background

A small (ca. 250 m^2) eelgrass bed in Gibsons Harbour was partially covered by a rip rap breakwater that was constructed as part of a marina development. An eelgrass transplant was completed in 1985 as compensation, however, the sediment composition was not conducive to eelgrass growth (gravel & cobble) and transplant survival was poor. Additional transplants were completed along sandy benches that formed adjacent to the original transplant site, in July 1987 and in January 1988. The project was experimental and designed to compare the success of transplants completed in winter vs. summer, three planting techniques, and three elevations. The site was monitored frequently until January 1989. The transplanted shoots were multiplying and appeared healthy, however log booms were anchored adjacent to the transplants, and there was some bark debris covering the plants.

Current Status

The site was surveyed on February 29, 2001. The eelgrass that was transplanted in 1987 and 1988 has survived and multiplied. There was no evidence of eelgrass in the area of the 1985 transplant. One series of plots have coalesced to form a small healthy bed, approximately 35m^2. The area of the bed appeared limited by the dense layer of bark chips that blanket the substrate surrounding it. Occasional eelgrass shoots were observed within the area covered by bark. The mean density of shoots within the bed was 56 shoots $\cdot$ m^{-2}, with an average length of 60 cm. Records indicate that the density of shoots within the natural population from which the donor stock was collected in 1987 and 1988 varied seasonally from 14 to 41 shoots · m^{-2} in 1988. Three distinct plots were noted landward of the main bed; these plots contained 146, 20, and 43 shoots, with an average of 44 shoots · m^{-2}, and mean shoot lengths of 40 cm.

Discussion

The density and distribution of eelgrass at this site is limited by the presence of bark debris from booming activities at the site. The plants appear healthy and have multiplied to densities comparable with natural populations in areas where there the sediment is free of debris. There are occasional eelgrass shoots within the areas blanketed by debris which may indicate some recent bark deposition, or that the areas covered by bark are dynamic and may change in response to current and tides.

4.14 Transplant Summary

Research indicates that eelgrass beds require a minimum of five years to become established and stable (Olesen & Sand-Jensen, 1994). The results from this survey indicate that failure can generally be detected in less time. All of the sites that were successful after two or three years maintained their viability over the longer term.

The projects assessed during the field survey have been assigned ratings of success, probable success, or failure. Projects were considered successful if the habitat that was created provided habitat equal in eelgrass productivity to that which it was designed to replace. The rating of probable success was assigned to recent projects where success is anticipated. The term failure was assigned to projects which failed to meet the productivity goals. In all but one case, eelgrass loss was complete in the projects that failed.

The following summary reviews the projects that were assigned each of the ratings.

4.2.1 Success

The rating of success was assigned to projects which established a population of comparable density to that which they were designed to replace, and which covered the intended area. The successful projects are listed in Table 9.

In every case there is a temporal loss that must be addressed. Generally, creating an area greater than that which is lost compensates for the temporal loss. Unfortunately, in most cases monitoring data is not available to determine the average number of years required to achieve natural density. However, in all cases except Comox Harbour which relied on natural recolonization, the compensation areas attained densities comparable to natural populations in less than five years.

It should be noted that the Gibsons transplant included in Table 9 was conducted for research purposes thus there was only a density criteria by which to rate the success. The Gibsons transplant was approaching natural densities two years after planting and likely achieved densities comparable to natural populations by the third year. However, since the site was not monitored until this study, twelve years hence, it is impossible to determine the number of years that were required.

Table 9. Shoot density ($\#\cdot m^{-2}$) of the donor population and the transplants in 2001.

Site	Donor Population	Transplants	Years to Achieve
Tsawwassen	82	105	3
Nanaimo -deep	5-20	88	3
Nanaimo - shallow	5-20	6.1	3
Campbellton	84	84	<5
Comox Harbour	30-60*	44	<9
Menzies Bay	32	56	<5
Port McNeil	262	352	<5
Gibsons	14-41	44-56	unknown

* estimate

4.2.2 Probable Success

The Bazen Bay and Tofino Airlines projects were recently completed. The transplants are multiplying and the results to date indicate that these projects should achieve No Net Loss.

The Tod Inlet projects were completed within the year, and although survivorship is relatively low the plants that have survived may multiply and produce beds at both locations. The objective of these transplants was to re-establish eelgrass at various locations in Saanich Inlet and should therefore be viewed as successful irrespective of low survival

A natural population of eelgrass surrounded the transplant at Deadman's Island in Tofino. Due to the amount of time that has elapsed between when the area was planted and when it was monitored (11 years) it is impossible to determine whether the transplanted eelgrass survived or whether the natural population expanded into the transplant area.

4.2.3 Failure

The factors that led to the survival failure of transplanted eelgrass were primarily anthropogenic disturbance and inappropriate elevation. Coarse substrate and shading may have reduced the success of transplanted eelgrass at several locations.

The first set of transplants at Discovery Marina in Campbell River were planted above 0 m in substrate that was marginal for eelgrass. The ecotype that was planted was *phillipsi* which can tolerate some exposure but is generally found between 0 and –4 metres. The ecotype *typica* might have survived at this location however it is not common in the Campbell River area. Although the Tsawwassen transplants were considered successful, the portion of the transplant area that was located above 0 metres was significantly less successful than the transplants at lower elevations. Similarly, the transplants located at higher elevations in Nanaimo Harbour failed to multiply as quickly as those planted at greater depths.

Anthropogenic disturbance was likely responsible for failed transplants at the 4th Street location in Tofino, the third set of transplants in Discovery Marina, and for partial loss at the Tofino Airlines site. The unauthorized mooring of a dock over the 4th Street transplants would have resulted in the loss of the plants even if all other factors were suitable. The third set of transplants in Discovery Marina were shaded in a similar manner, and uprooted by propeller wash. A corner of the compensation area at the Tofino Airlines site was destroyed through trampling by kayakers at low tide.

The substrate at the first Discovery marina transplant site was marginal for the species. The substrate at the second transplant site was variable, however the presence of cobble and boulder would physically limit eelgrass propagation and provide suitable habitat for macroalgae that could shade the eelgrass reducing its productivity. This effect was documented in one area of the Bazan Bay site where a dense canopy of kelp developed on rock leading to the loss eelgrass. Removal of the rock and replanting mitigated the problem. The second Discovery Harbour transplant is included in this category since the transplanted area is smaller than intended. The first Gibsons transplant likely failed due to the gravel cobble substrate into which the shoots were planted.

Shading may be partially responsible for reducing propagation of transplanted shoots at a section of the second Discovery Marina transplant and for a portion of the Nanaimo harbour transplant.

5.0 Conclusions and Recommendations

Eelgrass habitat can be created and restored through careful design and transplanting. In order to achieve success it is necessary to:

- select a site with the appropriate biophysical conditions,
- use suitable plant donor stock,
- use an appropriate transplanting technique, and,
- handle the donor plants with care.

The following sections provide information regarding the physical and biological factors that need to be assessed to determine whether a site is capable of providing habitat for the species. A review of transplanting methodologies is provided along with recommendations based on the author's experience. Guidelines for developing restoration and compensation plans are also suggested.

5.1 Physical factors

The primary environmental parameters that determine the suitability of a site for eelgrass include; salinity, sediment type, current velocity, and light availability. Temperature and pH may also limit eelgrass establishment, however these factors are generally within the acceptable range for the species in British Columbia. A summary of the range and optimal levels for each of these factors is summarized in Table 10.

Table 10. Environmental requirements for vegetative growth of eelgrass (Phillips, 1974).

Parameter	Range	Optimum
salinity	freshwater to 42 ppt	10 to 30 ppt
sediment type	firm sand to soft mud	mixed sand and mud
current velocity	waves to stagnant water	little wave action gentle currents to 3.5 knots
light/depth	1.8 m above MLLW to –30 m	MLLW to – 6.6 m
temperature	-6 °C to 40.5 °C	10 °C to 20 °C
pH	7.3 to 9.0	7.3 to 9.0

MLLW- mean low low water   ppt – parts per thousand

5.1.1 Salinity

Eelgrass may grow near stream mouths where salinity levels may approach zero at low tide and during periods of high discharge, but cannot survive in persistent freshwater. In one report eelgrass maintained an osmotic resistance to salinity changes from freshwater to 93 ppt (Biebel & McRoy, 1971). Although eelgrass has the ability to adapt to a wide range of salinities it is recommended that whenever possible, donor stock be collected from locations that are subject to salinity ranges similar to the area where they are to be planted.

5.1.2 Substrate

Eelgrass reproduces to form dense homogenous meadows in a mixture of sand and mud. Eelgrass may also grow in areas of gravel mixed with coarse sand, however these populations are generally patchy. The plants entrap fine particles from the water, and form and retain particles that are produced within the bed, thereby affecting the mean grain size, sorting, skewness, and shape of sediment particles in the bed over time (Phillips, 1984). Eelgrass growing in coarse substrate tends to produce rhizomes that are sturdier than those growing in a softer substrate. Transplant projects should be located in areas that provide a sand/mud substrate, whenever possible, to increase the chances of success and rate of vegetative reproduction. If transplanting is attempted at a site demonstrating significant gravel content the donor stock should then also be harvested from an area with a similar textured substrate, as the rhizomes will be better suited for that environment.

5.1.3 Light / Depth

Desiccation at low tide limits the distribution of eelgrass in intertidal areas (Phillips, 1974). Intertidal eelgrass is generally less robust than subtidal eelgrass; this adaptation enables the shoots to lay flat on the substrate at low tide, reducing the effects of exposure to the air. The introduced *Zostera japonica* produces short narrow leaves that are well suited to the intertidal environment in which it thrives. See Biological Variables below.

Light is often cited as the factor that limits the lower distribution of eelgrass. The amount of sunlight that penetrates the water column is reduced with depth, and is dependent on the clarity of the water. Increased turbidity often results in the decline of eelgrass beds (Giesen et al., 1990a, b). A study in Willapa Bay, Washington State, found that the maximum depth distribution of eelgrass increased with distance from river mouths in response to turbidity and associated light levels (Norris & Wyllie-Echeverria, 1997). Eelgrass has been observed at depths of 30 meters in very clear water, although this is not common. Locally, within Southern British Columbia, a reduction in light level starts to inhibit growth around 10 or 12 metres below chart datum, as evidenced by a marked decrease in shoot density.

Studies have been conducted to determine the minimum amount of light or photosynthetically active radiation (PAR) that is required by eelgrass for survival. A literature review of the light requirements of eelgrass determined that 'when integrated irradiance falls below about 3 to 5

$Mm^{-2}d^{-1}$, growth will be limited and the plants may die if this level of irradiance persists for an extended period' (Olsen & Thom, 1997). The growth rate of eelgrass is greatest from spring through fall, followed by a slow but measurable rate during the winter. Eelgrass stores carbon in rhizomes during the higher light period for use during the period of very low light (Kraemer & Alberte, 1993). Thus, it is believed that light conditions during spring through fall may be more important than in winter in terms of long-term maintenance. Activities that would significantly reduce light levels in eelgrass beds for more than several days, either through shading or increased turbidity, should be scheduled during the winter whenever possible.

5.1.4 Current Regime

Eelgrass beds typically occur in physically sheltered environments such as estuaries, bays, and shallow inlets. Research indicates that moderate currents enhance eelgrass growth (Phillips, 1984). Strong currents break leaves and may scour the substrate from around the rhizomes, uprooting the plants. Proctor et al. (1980) report that when currents are too slow eelgrass grows poorly and algae dominate. This may be the case in general, however, there are some very luxuriant eelgrass beds in B.C. in areas of very slow current. Evidence suggests that a current across the eelgrass leaves breaks down diffusion gradients increasing the amount of CO_2 and nutrients available to the plant (Conover, 1968).

Eelgrass growth is either patchy or absent in areas subjected to wave shock, depending on the severity and duration of the waves (Phillips, 1974; Tutin, 1938).

A study investigating the impacts associated with ferry terminal siting and design on eelgrass habitat, found evidence that propeller wash from ferries arriving and departing restricted eelgrass growth from adjacent areas that were otherwise suitable (Simenstad, et al., 1997). The data collected for this study demonstrated that current speeds were increased by 1.0 to 2.5 ms^{-1} over background, within 5 to 20 seconds, depending on the rate of approach or departure of the ferry.

5.2 Biological Factors and Interaction

5.2.1 Ecotypes

Five 'ecotypes' of *Zostera marina* with varying ranges of phenotypic plasticity have been described for the Pacific Coast, one appears restricted to deep channels in the Gulf of California and one has only been identified in Alaska. Each ecotype has a specific set of morphological characteristics that predispose it to survive and flourish under a specific set of environmental conditions. There is some disagreement in the literature as to whether one ecotype can adapt morphologically to survive in habitat associated with a different ecotype (Backman, 1984). A study to determine the source of the variation in leaf size found that genetic variation accounted for 14%, environmental (phenotypic plasticity along temporal and spatial gradients) accounted for 32%; and the interaction between genotype and environmental accounted for 35% (Backman, 1991). There is a high degree of overlap between the environmental conditions suitable for the various ecotypes; however some are better suited to certain habitats than others.

In order to maximize the probability of survival, transplant projects should attempt to use ecotypes best suited to the habitat whenever possible. The following table summarizes the growth habitat of the three ecotypes common in British Columbia. The values provided in Table 11 are intended to provide general guidelines and ecotypes may vary beyond the given ranges under certain conditions. *Zostera marina latifolia*, for example, is frequently found at depths exceeding –10 metres in British Columbia.

Table 11. The habitat and morphological attributes associated with the three ecotypes of *Zostera marina* common in British Columbia. (adapted from Backman, 1984)

Ecotype	Relative leaf size	Leaf width (mm)	Depth range (m)	Seasonal variation in size	Current tolerance
typica	narrow	2 to 5	primarily intertidal	small variation	low
phillipsi	intermediate	4 to15	0 to –4	large, plant length reduced in winter	moderate
latifolia	large	12 to 20	-0.5 to –10	minimal variation	strongest

5.2.2 Kelp

Eelgrass grows best in areas with a sandy mud substrate; however it is often found in areas that also contain a small percentage of gravel, cobble, or boulders. The growth of eelgrass can be inhibited by a reduction in light caused by a canopy of kelp, which may develop on the rock. Rip rap adjacent to an eelgrass bed may provide habitat for kelp and potentially inhibit eelgrass survival on the adjacent substrate.

5.2.3 Grazing Pressure

Many species of birds, invertebrates, molluscs, crustaceans, echinoderms, annelids, and fish forage on both the plants and on the associated fauna in eelgrass beds (epifauna and infauna) (Phillips, 1984). Destruction of eelgrass beds by overgrazing is uncommon in British Columbia, however, there are several documented reports of serious destruction caused by Canada Geese (*Branta canadensis*) or green urchins (*Strongylocentrotus droebachiensis*).

There have been reports in Tod Inlet and Cortes Island of Canada Geese uprooting large quantities of eelgrass resulting in a significant decline of eelgrass in the local eelgrass populations. This phenomenon has also been observed in Alaska where eelgrass may account for up to 100% of the diet of Canada Geese (Phillips & McRoy, 1980). Eelgrass constitutes a major part of the diet of Black Brant (N. Dawes, pers. com.) and american widgen (S. Boyd, pers. com.).

Green urchins were observed to cause extreme damage to an eelgrass bed during the course of this study. The only reference found in the literature to eelgrass browsing by green urchin was also reported from Alaska, where eelgrass accounted for up to 100% of their diet (Phillips & McRoy, 1980).

5.2.4 Infauna Burrowing

Dense populations of burrowing shrimp (may uproot transplanted shoots before they develop roots (Durance, 1985). Crabs have been observed uprooting recently transplanted shoots and passing the leaves through their mandibles to remove the attached fauna (R. Russell, pers. com.).

5.3 Anthropogenic Factors

A number of anthropogenic factors may affect the ability of a site to support eelgrass. The following factors should be considered when selecting a location for transplanting.

- Eelgrass beds are sensitive to such physical impacts as trampling, bivalve harvesting, and disturbance by boat propellers; anchors may also degrade or eliminate habitat (Fonseca, 1992).

- Excessive nutrient enrichment from sources including aquaculture, agriculture, and sewage can damage eelgrass beds. In some cases, when eelgrass growth is limited by available nitrate, local nutrient loading has been reported to have a positive affect (Fonseca et al, 1987, Kenworthy & Fonseca, 1992, Fonseca et al., 1992). Eutrophication, however, is more frequently cited as the cause of decline than of improvement (Borum 1985; Wetzel & Neckles, 1986; Orth et al, 1983; Shepard et al., 1989; Kikuchi, 1974). Nutrient enrichment may lead to; metabolic imbalances (Burkholder et al. 1992), proliferation of phytoplankton, epiphytic, or blanketing algae (Borum 1985; Orth et al, 1983; Shepard et al., 1989), and increased susceptibility to wasting disease (Buchsbaum et al., 1990; Burkholder et al., 1992).

- Coastal development may lead to increases in water turbidity, sediment erosion, or sediment accretion, any of which can have adverse effects on eelgrass beds. The activities most commonly associated with these impacts, as summarized by Davidson & Hughes (1998) include:

    - construction of docks, piers, coastal defences, and marinas,
    - pipeline installation,

- channel dredging,
- land reclamation, and,
- seabed or water extraction.

Eelgrass is resistant to several types of impacts that are known to negatively affect other types of habitat. There is little evidence of harm caused by heavy metals or antifoulants (Davidson & Hughes, 1998). Eelgrass is not highly sensitive to chronic oil pollution, such as refinery effluent (Hiscock, 1987). Major oil spills will result in damage and loss of leaves, however the plants recover relatively quickly (Jacobs, 1980; Zieman et al., 1984; Fonseca, 1992). The chemical dispersants that may be used to control the spills are much more detrimental to the plants (Holden et al., 1980; Howard, 1986) and if possible the application of these compounds should be avoided in the vicinity of eelgrass.

5.4 Transplanting Methodology

Factors that should be considered when designing a transplant program include:

- the selection of an appropriate site for the transplant,
- identification of a suitable source of eelgrass (Donor Population), and,
- selection of the most appropriate transplanting technique.

Issues to consider regarding each of these factors are discussed in the following sections.

Eelgrass can be transplanted at any time of the year. It may be prudent to avoid planting intertidal areas during the summer; the plants are stressed by the transplanting process and may not be able to tolerate the additional stress of exposure at low tide.

5.4.1 Site Selection

The area to be planted should provide the physical characteristics required for eelgrass (Section 5.1). These will, to some degree depend on the ecotype of eelgrass that is available for transplanting (Section 5.2.1). The potential for anthropogenic impacts to the transplanted area should be considered (Section 5.3). Impacts from grazing pressure are difficult to forecast, however in locations where Canada Geese, Black Brant, or American Widgeon are known to congregate on a seasonal basis the transplant should be timed to coincide with the departure of these species to allow the plants time to establish before the birds return.

Transplant projects that are designed to provide fish habitat compensation should attempt to re-create habitat similar to that which has or will be impacted or lost, in terms of depth and eelgrass ecotype. The species composition and use of subtidal eelgrass beds that are constantly submerged would be significantly different from intertidal eelgrass beds that are frequently exposed at low tide.

5.4.2 Donor Population

The donor population should possess attributes appropriate for the elevation of the transplant site (Section 5.2.1).

Transplants that are designed to compensate for projected eelgrass habitat losses should utilize eelgrass from the area of projected loss. In other cases, a donor bed should be selected that appears healthy and stable. The bed should be able to provide the required number of plants without any signs of disturbance; there should not be any obvious signs that shoots have been removed. In sparse to moderately dense beds, with densities less than 60 shoots·m^{-2}, the removal of one (1) shoot ·m^{-2} is a safe guideline to follow. In beds of greater densities, more plants may be harvested per unit area, as long as the removal of the eelgrass does not cause visible changes to the density of the bed or the stability of the sediment.

Eelgrass seeds rarely manage to produce plants in nature (Section 5.2.1). Researchers have attempted to use seeds to establish eelgrass populations without success (Phillips, 1984, Phillips, 1972, Churchill et al., 1978).

5.4.3 Transplanting Techniques

It is essential to minimize the amount of physical and physiological stress that eelgrass is subjected to during transplant. The plants should be kept in cool seawater from the time that they are harvested to the time that they are planted. Care should be taken to ensure that the leaves are kept moist and that they are not crushed during transport. Plants may be stored over night, however it is best if they are planted as soon as possible after harvesting.

Shoots should always be planted in clusters as small patches of plants have a greater survival rate than do individuals. As a general rule, each cluster should contain a minimum of ten shoots. In areas of greater current the number of shoots per cluster should be increased.

The shoots should be planted at the same depth as they were found at the donor site. The plant tissue which was located below the substrate surface will be white or pale green, whereas that which is exposed to sunlight will be dark green.

Various techniques have been developed to transplant eelgrass. The following review of transplanting methodology is based on the authors' experience. A brief description of each method is followed with an assessment of the technique.

Anchored Shoots

Individual eelgrass shoots are gently tugged from the sediment of the donor bed. Each shoot must have a minimum of three nodes, and if the rhizome is very thin then a greater number is preferable. Eelgrass leaves are buoyant; roots develop from nodes on the rhizome that anchor the plant in the sediment. Most of the roots are lost or damaged when the plant is removed from the substrate. Anchoring devices serve the function of roots, ensuring that the rhizome remains in the sediment while new roots form. The strength of current at a site dictates the weight of anchor that is required; stronger currents necessitate the use of heavier anchors. Metal washers of various sizes and short pieces of rebar are effective anchors. A single washer may be used to anchor one or two shoots, whereas five to ten shoots may be attached to a piece of rebar, depending on the size of the shoots and the length of the rebar. Paper covered twist ties can be used to hold the shoot to the anchor. The anchored shoots may be pushed into very soft substrate (mud); tools such as trowels are required to plant in coarser, firm substrates. This technique has proven very effective in British Columbia.

TERFS™

TERFS™ were developed at Jackson Estuarine Labs in New Hampshire. A TERF is a square mesh basket, (2 x 2 ft.) 6 inches deep with side baskets that contain brick weights. The mesh of the baskets have a grid of 2" x 2" squares. Two plants (removed in the manner described above) are secured at the intersection of each of the squares with ties made of white crepe paper twisted on a drill. Each basket holds 50-100 plants. The baskets are lowered to the substrate at the recipient site and left until the ties disintegrate and the plants develop roots, after which the baskets are removed. This technique has been effective in New Hampshire, however, the eelgrass which is being transplanted is much shorter than that which is common in B.C., longer shoots may complicate the process of TERF removal without uprooting the plants. This technique provides an anchoring device that can later be removed, which is a definite advantage over the other types of anchors. A pilot research project investigating the effectiveness of TERFS™ in B.C. will be conducted in 2001-2002.

Sprigs

Sprigs is the term given to individual shoots of eelgrass that are planted without anchors. This technique is effective in the absence of current. Eelgrass shoots are gently removed from the donor site and transported to the recipient site where they are planted. Sprigs may be gently pushed into muddy substrates; coarser substrates require the use of a trowel. The sediment must be firmly packed over the rhizome to ensure that the plant's own buoyancy will not uproot the new transplant.

Sods

Sods of eelgrass, similar to sods of lawn grass, may be removed from intertidal and slightly subtidal populations of eelgrass at low tide. A shovel is used to remove the sod which is then placed in a container; usually a rubber dishpan. The sods are covered with seawater and transported to the recipient site where a hole is dug into which a sod is firmly packed. This technique has been very successful on the east coast and but has shown limited success in B.C. where the shoots tend to be more robust. A sod of eelgrass generally contains numerous shoots, however, only the shoots in the centre of the sod are likely to have rhizomes long enough to support the shoot. The shoots situated towards the edges of the sod do not usually survive.

This method is more destructive than the other techniques, as it leaves visible scars on the donor bed.

Cores

People have tried adapting marsh transplant technology to eelgrass by extracting cores of shoots with sediment for transplant. Typically tin cans (with both ends removed) are pushed into the sediment surrounding eelgrass. The can is slowly extracted, bringing with it sediment and eelgrass. The cores are transported and planted at the recipient site. This process is labour intensive, and often the rhizomes are severed and therefore too short to enable survival of the shoots.

5.5 Compensation & Restoration Plans

The majority of the eelgrass transplant projects that have been completed in British Columbia have been in response to the unavoidable alteration or destruction of eelgrass habitat. Compensation is only used in cases where restoration is not possible. Recently, stewardship groups have completed several transplants in an attempt to re-establish eelgrass in areas that historically supported the species. The following section discusses the issues that should to be considered when developing an eelgrass compensation or restoration plan. Guidelines based on the author's experience in British Columbia are provided.

5.5.1 Area of Impact

The area of eelgrass habitat that will be impacted by a proposed project is often underestimated due to unforeseen circumstances. The compensation plan must be adaptive to ensure that the compensation is adequate. A pre-impact and post-impact assessment of the eelgrass bed is necessary to guarantee that the impact is accurately quantified. Suggestions for monitoring eelgrass beds are provided in Section 5.5.3.

Pipelines, Cables, and other Utilities

The installation of a pipeline or cable through an eelgrass bed generally results in a corridor devoid of vegetation. These should be replanted as soon as construction is completed. Not only may the corridor alter the migration of fish and invertebrates that are hesitant to leave the protective canopy of the eelgrass meadow, but the unvegetated condition may also lead to additional habitat losses through erosion. Sediment composition may be altered by pipeline installation. This must be considered when determining the eelgrass restoration method.

The plants within established eelgrass beds reduce currents, leading to increased sediment and organic detritus deposition. The dense rhizome network of the plants, in conjunction with the enhanced deposition rate assists in stabilization of the substrate. 'If an established, continuous bed becomes fragmented for any reason, the bed will tend to become less stable and more vulnerable to the normal forces of erosion. Channels may form, the cover may become patchier and if the trend continues, isolated patches will develop which are more likely to be washed away. It would appear that there is a threshold of loss, below which destabilization and further losses of beds can occur '(Holt et al., 1997).

The Southern California Eelgrass Mitigation Policy (revision 8) requires active restoration of these corridors if the impact corridor exceeds 0.5 metre in width. A pre-impact survey is required prior to project approval. In cases where the impact corridor is less, a post-project survey must be completed within 30 days, from which the actual area of impact is determined. An additional survey is required after 1 year to ensure that the corridor does not exceed 0.5 metre in width. If either post-construction survey demonstrates a corridor greater than 0.5 metre then a transplant will be required.

Habitat Creation

Fill and dredging may be used to provide a suitable substrate and elevation for eelgrass. However, it must be remembered that these methods will result in a loss of some other habitat type. An assessment of the area to be altered should be conducted to determine whether the benefits associated with establishing eelgrass habitat outweigh the losses. The benefits to consider include; most commercial fish species utilize eelgrass beds, eelgrass beds are extremely productive, and eelgrass rhizomes stabilize sediments. Another factor to consider is that there have been significant reductions in the area occupied by eelgrass through anthropogenic disturbance (dredging, booming activities), and thus there is justification to create additional eelgrass habitat.

Restoration of Historical Habitat

There are many opportunities to re-establish eelgrass populations where they have been eliminated. However, the reason for the loss and present ability of the site to provide suitable habitat needs to be determined prior to planning a transplant program. Temporal impacts that may have lead to the loss of eelgrass include;

- increases in water turbidity,
- intense harvesting of shellfish,
- use of the area to moor vessels,
- trampling by humans (e.g. kayak launch), and,
- shading by structures over or on the water, including log booms.

In all of the cases listed above, eelgrass may naturally re-establish in the area. However, this is dependant on a number of random events and may require decades. Eelgrass reproduces primarily vegetatively, thus natural recolonization is dependant on a shoot with rhizomes settling on the site and remaining undisturbed by currents and tides while roots develop. This phenomenon was observed at the Comox harbour site as discussed in this report (Section 4.3).

Eelgrass flowers annually and produces many viable seeds, however very few successfully mature into plants. Phillips (1972) tagged numerous eelgrass seedlings in the subtidal areas of Puget Sound and reported 100% mortality. Nielsen (1990) studied intertidal seedling success at Roberts' Bank and reported minimal survival over a period of several months.

5.5.2 Timing

In all cases there will be an unavoidable temporal loss of habitat. Attempts should be made to reduce this loss to the minimum amount of time practical.

Ideally, eelgrass transplants designed for compensation should be completed prior to the disturbance in order to minimize the temporal loss of habitat. The transplanted area will not initially provide habitat comparable to the area for which it is intended to compensate, as the density of eelgrass will be much lower. Habitat compensation ratios greater than 1:1 (lost: created) are recommended to reduce this discrepancy.

Transplants intended as restoration should be completed as soon as possible following the impact or disturbance.

5.5.3 Monitoring

The area of potential impact, or habitat loss should be monitored prior to the disturbance and shortly after the habitat alterations have been completed. The composition and morphology of eelgrass beds are highly variable by nature. A detailed assessment is usually financially prohibitive. In order to be cost effective and yet obtain enough information to adequately assess impacts to the eelgrass bed, the following information should be collected:

1. Maximum depth of eelgrass colonization or width of the bed from shore.

2. Mean density of shoots. This may be highly variable or very uniform, thus the number of counts required is dependant on the nature of the bed. Also, density often varies with depth therefore in many instances the bed should be divided into several zones based on relative elevation and the mean density assessed independently within each zone.

3. A description of the eelgrass coverage that notes the bed's uniformity or patchiness.

Transplanted eelgrass can survive for many months by utilizing the energy stored in the rhizomes. The plants may appear healthy but in order to survive in the long term it is essential that they produce roots and branches. There are many reports of transplanted eelgrass that appeared healthy for months after transplant, then suddenly died. It is likely that these plants were senescening from the date of transplant without obvious visual signs. Thus, in order to determine the viability of the transplant, monitoring should be conducted a year following the transplant. However, it may be useful to monitor the transplant after several months to determine whether there are any physical or biological factors that will affect the success of the project. A failed transplant may be replanted, however, the reason for the failure must be identified so that the methodology can be adapted to ensure success. Factors that are best identified within a few months of transplanting include; the transplant methodology - was it appropriate (e.g. did the plants float away), crustaceans uprooting the plants, or is there a sedimentation problem that will bury the plants and possibly eliminate them. A survey one year after the transplant can establish that the plants died but may not necessarily determine the cause.

Eelgrass rhizomes grow though the sediment branching to produce additional shoots. For this reason it is best not to establish permanent transects or plots as the plants will migrate away from their original location. In order to detect increases in the transplanted population it is recommended that the number of shoots per plot be determined. If the area was divided into zones for the preliminary assessment then each of the zones should be assessed during subsequent monitoring. Eventually, the plots should expand and coalesce at which time the mean density can be assessed by quadrat or transect sampling. If there is an adjacent natural population it should be monitored to provide reference data. The maximum density of eelgrass within the transplant should eventually mirror that of the adjacent population. It is important to note however, that the mean density in natural eelgrass beds varies between years and in some populations between seasons, therefore comparisons between the transplants and the adjacent natural population must be made based on data collected at the same time.

Southern California has adopted an eelgrass mitigation policy (National Marine Fisheries Service et al., 1991). The term 'mitigation' in the US includes compensation. According to their policy, 'the project applicant must map the area, distribution, density, and relationship to depth contours of any eelgrass bed likely to be impacted by project construction. This includes areas immediately adjacent of the project site which have the potential to be indirectly or inadvertently impacted as well as areas having the proper depth and substrate requirements for eelgrass but which currently lack vegetation.' A post-project survey that includes the same parameters must be completed within 30 days of project completion. The area and density of transplanted eelgrass must be monitored at 3, 6, 12, 24, 36, 48, and 60 months after transplanting. However, all monitoring must be completed between March and October, thus some flexibility is necessary. Monitoring of an adjacent population is required to account for natural variation.

Success is assessed relative to area that was impacted, using the area of eelgrass cover and shoot density as criteria. The area of eelgrass cover is defined as 'that area where eelgrass is present and where gaps in coverage is less than one meter between individual turion (shoot) clusters'. The specific criteria are summarized in Table 12.

If the transplant fails to meet the established criteria then a Supplementary Transplant Area (STA) must be constructed. The size of the STA is determined by the following formula:

$STA = MTA \times (\langle A_t + D_t \rangle - \langle A_c + D_c \rangle)$

MTA= mitigation transplant area

A_t=transplant deficiency or excess in area of coverage criterion (%)

D_t= transplant deficiency in density criterion (%)

A_c= natural decline in area of control (%)

Dc=natural decline in density of control (%)

'Any required STA must be initiated within 120 days of the monitoring event that identifies a deficiency in meeting the success criteria.'

Any transplant project that exceeds the minimum requirement after 5 years may be considered as credit in a "mitigation bank".

Table 12. Criteria used in Southern California to determine the success of transplants (National Marine Fisheries Service et al., 1991)

Years after transplant	Area covered	Density
1	70	30
2	85	70
3-5	100	100

A report by Olesen & Sand-Jensen (1994) suggested that new *Z. marina* beds required a minimum of five years to become established and stable. The frequency of monitoring between year 1 and 5 should be determined on a project by project basis. There may be problems that occur between year 1 and 5 that could be rectified if identified; waiting until year 5 to assess the success would result in a significant temporal loss of habitat. For example, the unauthorized mooring of a vessel over the site and dredge scour contributed to the failure of a transplant in Discovery Harbour. After 5 years there was no evidence of dredge scour and the vessel had been removed. Without the monitoring reports it would not have been possible to identify all of the factors that contributed to the loss of eelgrass. Unauthorized dumping of crushed rock at the Bazen Bay site eliminated a significant portion of the transplant area. Without interim monitoring the loss of eelgrass would not have been detected until year 5, resulting in a large temporal loss of productivity.

The frequency of monitoring should be negotiated with the proponent. Consideration should be given to the size of the project; the amount of monitoring that is required should be commensurate with the scale of the project. The proponent should be advised that by identifying and rectifying problems at the onset, it may be possible to avoid the expenses associated with a complete re-transplant program later.

Proposed Monitoring Schedule

The following proposed monitoring schedule is based on the results of this review. Transplant failure was generally detected within six months. Success (natural shoot density and area coverage) was achieved between 3 and 5 years after transplanting. All of the transplants that achieved 'success' within this period continued to survive. Therefore, it is recommended that transplanted areas be monitored approximately 6, 12, and 36 months after transplanting (Table 13). If the density or area achieved is less than that required to fully compensate or restore the habitat after 36 months, additional monitoring should be completed after 60 months. New transplant locations or techniques may be required depending on site condition.

In order to reduce costs, the results from the 6 month monitoring may be summarized in a brief letter, eliminating the expenses associated with a report. The 12 month monitoring should include an assessment of the donor population to verify that the removal of plants did not have a detrimental effect on the population, and include a brief report. The assessment of the donor population would not be possible in cases where the donor plants were salvaged from an area to be dredged or otherwise destroyed. The 36 month monitoring should assess whether the restoration and/or compensation goals have been achieved, and provide a habitat balance sheet. The 60 month monitoring, if required, should be similar in scope to the 36 month report. Photographic or video documentation of the areas monitored is strongly recommended at 12 and 36 months, and if necessary at 60 months.

Table 13. Rationale for the proposed monitoring schedule.

Time since Transplant (months)	Rationale
6	To demonstrate the survival of transplanted eelgrass
12	To document increased density of transplanted eelgrass
36	To demonstrate that success has been achieved
60	If success at 36 months was partial, to demonstrate complete success

5.5.6 Stewardship

Stewardship groups, under professional guidance, and with authorization from Fisheries and Oceans Canada can successfully implement and monitor eelgrass transplant programs. These initiatives have proven an effective method for educating local communities about the value of eelgrass habitat. The survivorship of the transplanted eelgrass may be less than optimal, however when tempered with the benefits gained through community involvement, these projects translate into significant success stories. SeaChange Marine Conservation Society, a community stewardship group based in Victoria, is actively involved in restoring eelgrass throughout Tod Inlet. They have involved members of the First Nations, commercial and recreational fishermen, boaters, and students along with other members of the local community. Through these programs, the public have learned about eelgrass habitat values and sensitivity. As a result, the perception of eelgrass being viewed as an annoyance has given way to an understanding of its rich ecological value and the diverse marine life which it supports.

Stewardship groups may also assist in the protection of eelgrass habitat by developing programs to inform the public regarding the potential impacts associated with;

- boat anchoring,
- shellfish harvesting,
- non-point source pollution from residential and business properties,
- stormwater run-off, and,
- sedimentation from erosion of stream and foreshore banks.

Visuals are recommended as an effective method to encourage people to protect eelgrass beds by appealing to their sense of aesthetics and desire to protect beauty. SeaChange Marine Conservation Society has effectively used videos of eelgrass habitats underwater and photography of subtidal areas in front of shoreline properties to encourage property owners to protect adjacent eelgrass beds. Other tactics that have been successful include; focus groups, neighbourhood by neighbourhood educational campaigns, and public forums including speaker's panel.

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Appendix 1 Species Lists

A casual list of the species noted within transplanted eelgrass beds, and adjacent natural beds was recorded.

Tsawwassen August 19, 2001

The survey was conducted during low tide, there may have been more species noted had the survey been conducted during high tide.

Common Name	*Scientific Name*	Eelgrass Bed	
		Transplant	Natural
Mollusca (bivalves, snails, nudibranchs)			
Nuttall's cockle	*Clinocardium nuttallii*	√	√
haminoea	*Hamineoa*	√	√
dire whelk	*Lirabuccinum dirum*	√	√
whelk eggs		√	√
hooded nudibranch	*Melibe leonina*	√	√
Arthropoda (crabs, shrimp, barnacles, & isopods)			
Dungeness crab	*Cancer magister*	√	√
shore crab	*Hemigrapsus nudus*	√	√
bay ghost shrimp	*Neotrypaea californiensis*	√	√
blue mud shrimp	*Upogebia pugettensis*	√	√
isopod	*Idotea sp.*	√	√
Annelida (worms, tubeworms)			
lug worms	*Abarenicola sp.*	√	√

Nanaimo Harbour March 9, 2001

Common Name	Scientific Name	Eelgrass Bed	
		Transplant	Natural
Chordata (fish & mammals)			
rock sole	*Pleuronectes bilineatus*	√	√
starry flounder	*Platichthys stellatus*	√	-
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)			
leather star	*Dermasterias imbricata*	√	-
mottled star	*Evasterias troschelli*	√	-
ochre star	*Pisasterochraceus*	√	-
spiny mud star	*Ctenodiscus crispatus*	√	√
spiny pink star	*Pisaster brevispinus*	√	√
sunflower star	*Pycnopodia helianthoides*	√	-
Mollusca (bivalves, snails, nudibranchs)			
butter clam	*Saxidomas gigantea*	√	-
fat gaper clam	*Tresus capax*	√	-
Manilla clam	*Venerupis philippinarum*	√	-
Pacific littleneck clam	*Protothaca staminea*	√	-
bubble snail	*Hamineoa sp.*	√	√
moon snail	*Polinices lewisii*	√	-
alibaster nudibranch	*Dirona albolineata*	√	-
hooded nudibranch	*Melibe leonina*	√	√
Arthropoda (crabs, shrimp, barnacles, & isopods)			
Dungeness crab	*Cancer magister*	√	√
helmet crab	*Telmessus chieragonus*	√	-
hermit crab	*Pagurus sp.*	√	-
red rock crab	*Cancer productus*	√	√
kelp crab	*Pugettia producta*	√	√
bay ghost shrimp	*Neotrypaea californiensis*	√	√
isopod	*Idotea sp.*	√	√
Annelida (worms, tubeworms)			
lug worms	*Abarenicola sp.*	√	-
tube worms	*Species unidentified*	√	-
Cnidaria (hydroids, anemones, jellyfish, soft coral)			
plumose anemone	*Metridium giganteum*	√	√
small green anemone	*Epiactus prolifera.*	√	√
tube-dwelling anemone	*Pachycerianthus fimbriatus*	√	-

Comox Harbour March 10, 2001

Common Name	*Scientific Name*	Eelgrass Bed Transplant
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)		
ochre star	*Pisaster ochraceus*	√
spiny pink star	*Pisaster brevispinus*	√
mud star	*Ctenodiscus crispatus*	√
eccentric sand dollar	*Dendraster excentricus*	√
Mollusca (bivalves, snails, nudibranchs)		
butter clam	*Saxidomas gigantea*	√
Nuttall's cockle	*Clinocardium nuttallii*	√
bubble snail	*Hamineoa sp.*	√
moon snail	*Polinices lewisii*	√
hooded nudibranch	*Melibe leonina*	√
Arthropoda (crabs, shrimp, barnacles, & isopods)		
Dungeness crab	*Cancer magister*	√
red rock crab	*Cancer productus*	√
bay ghost shrimp	*Neotrypaea californiensis*	√
blue mud shrimp	*Upogebia pugettensis*	√
isopod	*Idotea sp.*	√
Annelida (worms, tubeworms)		
lug worms	*Abarenicola sp.*	√
tube worms	*Species unidentified*	√
Cnidaria (hydroids, anemones, jellyfish, soft coral)		
plumose anemone	*Metridium giganteum*	√
small green anemone	*Epiactus prolifera.*	√
water jellyfish	*Aequorea victoria*	√
moon jellyfish	*Aurelia aurita*	√

Campbell River – Discovery Marina   March 11, 2001

Common Name	Scientific Name	Eelgrass Bed Transplant
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)		
mottled star	*Evasterias troschelli*	√
sunflower star	*Pycnopodia helianthoides*	√
green urchin	*Strongylocentrotus droebachiensis*	√
sea cucumber	*Parastichopus californicus*	√
Mollusca (bivalves, snails, nudibranchs)		
butter clam	*Saxidomas gigantea*	√
fat gaper clam	*Tresus capax*	√
geoduck clam	*Panopea abrupta*	√
Nuttall's cockle	*Clinocardium nuttallii*	√
bubble snail	*Hamineoa sp.*	√
moon snail	*Polinices lewisii*	√
hooded nudibranch	*Melibe leonina*	√
yellow margin dorid	*Cadlina luteomarginata*	√
Arthropoda (crabs, shrimp, barnacles, & isopods)		
Dungeness crab	*Cancer magister*	√
bay ghost shrimp	*Neotrypaea californiensis*	√
Annelida (worms, tubeworms)		
tube worms	*Unidentified Species*	√
Cnidaria (hydroids, anemones, jellyfish, soft coral)		
plumose anemone	*Metridium giganteum*	√
tube-dwelling anemone	*Pachycerianthus fimbriatus*	√

Campbellton March 12, 2001

Common Name	Scientific Name	Eelgrass Bed	
		Transplant	Natural
Chordata (fish & mammals)			
shiner perch	*Cymatogaster aggregata*	√	-
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)			
leather star	*Dermasterias imbricata*	√	√
rose star	*Crossaster papposus*	√	√
sunflower star	*Pycnopodia helianthoides*	√	√
green urchin	*Strongylocentrotus droebachiensis*	√	√
purple urchin	*Strongylocentrotus purpuratus*	√	√
sea cucumber	*Parastichopus californicus*	√	√
Mollusca (bivalves, snails, nudibranchs)			
butter clam	*Saxidomas gigantea*	√	√
Nuttall's cockle	*Clinocardium nuttallii*	√	√
bubble snail	*Hamineoa sp.*	√	√
moon snail	*Polinices lewisii*	√	√
hooded nudibranch	*Melibe leonina*	√	√
yellow margin dorid	*Cadlina luteomarginata*	√	
Arthropoda (crabs, shrimp, barnacles, & isopods)			
Dungeness crab	*Cancer magister*	√	√
hermit crab	*Pagurus sp.*	√	√
kelp crab	*Pugettia producta*	√	√
isopod	*Idotea sp.*	√	√
Annelida (worms, tubeworms)			
tube worms	*Species unidentified*	√	√
Cnidaria (hydroids, anemones, jellyfish, soft coral)			
hydroids	*various species*	√	√
aggregate green anemone	*Anthopleura eligantissima*	√	√
small green anemone	*Epiactus prolifera.*	√	√
tube-dwelling anemone	*Pachycerianthus fimbriatus*	√	√

Menzies Bay May 8, 2001

The survey was conducted during low tide, there may have been more species noted had the survey been conducted during high tide.

Common Name	Scientific Name	Eelgrass Bed Transplant
Mollusca (bivalves, snails, nudibranchs)		
butter clam	*Saxidomas gigantea*	√
fat gaper clam	*Tresus capax*	√
geoduck clam	*Panopea abrupta*	√
Manilla clam	*Venerupis philippinarum*	√
Nuttall's cockle	*Clinocardium nuttallii*	√
bubble snail	*Hamineoa sp.*	√
moon snail	*Polinices lewisii*	√
periwinkle	*Littorina sp*	√
whelk eggs		√
Arthropoda (crabs, shrimp, barnacles, & isopods)		
Dungeness crab	*Cancer magister*	√
hermit crab	*Pagurus sp.*	√
shore crab	*Hemigrapsus nudus*	√
bay ghost shrimp	*Neotrypaea californiensis*	√
isopod	*Idotea sp.*	√
Annelida (worms, tubeworms)		
lug worms	*Abarenicola sp.*	√

Port McNeil May 9, 2001

The survey was conducted during low tide, there may have been more organisms present during high tide.

Common Name	Scientific Name	Eelgrass Bed	
		Transplant	Natural
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)			
blood star	*Henricia leviuscula*	-	√
Mollusca (bivalves, snails, nudibranchs)			
bubble snail	*Hamineoa sp.*	√	√
moon snail	*Polinices lewisii*	√	√
periwinkle	*Littorina sp.*	√	√
Arthropoda (crabs, shrimp, barnacles, & isopods)			
hermit crab	*Pagurus sp.*	√	√
Annelida (worms, tubeworms)			
tube worms	*Species unidentified*	√	√

Bazan Bay May 02, 2001

Common Name	Scientific Name	Eelgrass Bed	
		Transplant	Natural
Chordata (fish & mammals)			
cabezon	*Scorpaenichthys marmoratus*	-	√
kelp greenling	*Hexagrammos decagrammus*	√	√
ling cod	*Ophiodon elongatus*	-	√
tubesnout	*Aulorhynchus flavidus*	√	-
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)			
leather star	*Dermasterias imbricata*	√	√
mottled star	*Evasterias troschelli*	√	√
sunflower star	*Pycnopodia helianthoides*	-	√
Mollusca (bivalves, snails, nudibranchs)			
butter clam	*Saxidomas gigantea*	√	√
Nuttall's cockle	*Clinocardium nuttallii*	√	√
moon snail	*Polinices lewisii*	√	√
alibaster nudibranch	*Dirona albolineata*	√	√
hooded nudibranch	*Melibe leonina*	√	√
opalescent nudibranch	*Hermissenda crassicornis*	-	√
yellow margin dorid	*Cadlina luteomarginata*	√	-
Arthropoda (crabs, shrimp, barnacles, & isopods)			
decorator crab	*Oregonia gracilis*	-	√
Dungeness crab	*Cancer magister*	√	√
red rock crab	*Cancer productus*	√	√
kelp crab	*Pugettia producta*	√	√
slender kelp crab	*Pugettia gracilis*	√	-
isopod	*Idotea sp.*	√	√
Cnidaria (hydroids, anemones, jellyfish, soft coral)			
small green anemone	*Epiactus prolifera.*	√	√
moon jellyfish	*Aurelia aurita*	-	√

Tod Inlet – Goward Tod Park May 3, 2001

The visibility during the site assessment was limited (<1 metre), it is likely that many of the species present in the area were not seen.

Common Name	*Scientific Name*	Eelgrass Bed Transplant
Chordata (fish & mammals)		
Pacific harbour seal	*Phoca vitulina richardsi*	√
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)		
mottled star	*Evasterias troschelli*	√
ochre star	*Pisasterochraceus*	√
spiny pink star	*Pisaster brevispinus*	√
sunflower star	*Pycnopodia helianthoides*	√
Mollusca (bivalves, snails, nudibranchs)		
butter clam	*Saxidomas gigantea*	√
fat gaper clam	*Tresus capax*	√
rough piddock	*Zirohae pilsbryi*	√
Arthropoda (crabs, shrimp, barnacles, & isopods)		
Dungeness crab	*Cancer magister*	√
helmet crab	*Telmessus chieragonus*	√
red rock crab	*Cancer productus*	√
bay ghost shrimp	*Neotrypaea californiensis*	√
blue mud shrimp	*Upogebia pugettensis*	√
Annelida (worms, tubeworms)		
tube worms	*Species unidentified*	√

Tsartlip Reserve May 3, 2001

Common Name	Scientific Name	Eelgrass Bed	
		Transplant	Natural
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)			
spiny pink star	*Pisaster brevispinus*	-	√
sunflower star	*Pycnopodia helianthoides*	-	√
sea cucumber	*Parastichopus californicus*	-	√
Mollusca (bivalves, snails, nudibranchs)			
butter clam	*Saxidomas gigantea*	√	√
fat gaper clam	*Tresus capax*	√	√
Nuttall's cockle	*Clinocardium nuttallii*	√	√
bubble snail	*Hamineoa sp.*	√	√
moon snail	*Polinices lewisii*	√	√
dire whelk	*Lirabuccinum dirum*	√	√
whelk eggs		√	√
Arthropoda (crabs, shrimp, barnacles, & isopods)			
Dungeness crab	*Cancer magister*	-	√
red rock crab	*Cancer productus*	-	√
bay ghost shrimp	*Neotrypaea californiensis*	√	√
blue mud shrimp	*Upogebia pugettensis*	√	√
Cnidaria (hydroids, anemones, jellyfish, soft coral)			
plumose anemone	*Metridium giganteum*	√	√
small green anemone	*Epiactus prolifera.*	-	√
tube-dwelling anemone	*Pachycerianthus fimbriatus*	-	√

Tofino – 4th Street Docks March 26, 2001

Common Name	Scientific Name	Eelgrass Bed	
		Transplant	Natural
Arthropoda (crabs, shrimp, barnacles, & isopods)			
Dungeness crab	*Cancer magister*	√	√
Mollusca (bivalves, snails, nudibranchs)			
butter clam	*Saxidomas gigantea*	√	√

Tofino – Long Beach Shellfish March 27, 2001

There was an extremely strong current flowing though the site at the time of the assessment. The strong current may be the reason for the low number of species visible during the dive. The only species observed, a crab, was hiding in the sand.

Common Name	Scientific Name	Eelgrass Bed Transplant
Arthropoda (crabs, shrimp, barnacles, & isopods)		
Dungeness crab	*Cancer magister*	√

Tofino – Tofino Airlines June 27, 2001

The survey was conducted at low tide, there may have been more organisms present during high tide.

Common Name	*Scientific Name*	Eelgrass Bed	
		Transplant	Natural
Arthropoda (crabs, shrimp, barnacles, & isopods)			
Dungeness crab	*Cancer magister*	√	√
bay ghost shrimp	*Neotrypaea californiensis*	√	√
Annelida (worms, tubeworms)			
tube worms	*Unidentified Species*	√	√

Gibsons Harbour February 29, 2001

Common Name	*Scientific Name*	Eelgrass Bed Transplant
Echinodermata (seastars, urchins, sand dollars, & sea cucumbers)		
leather star	*Dermasterias imbricata*	√
ochre star	*Pisasterochraceus*	√
sunflower star	*Pycnopodia helianthoides*	√
sea cucumber	*Parastichopus californicus*	√
Mollusca (bivalves, snails, nudibranchs)		
butter clam	*Saxidomas gigantea*	√
fat gaper clam	*Tresus capax*	√
Pacific littleneck clam	*Protothaca staminea*	√