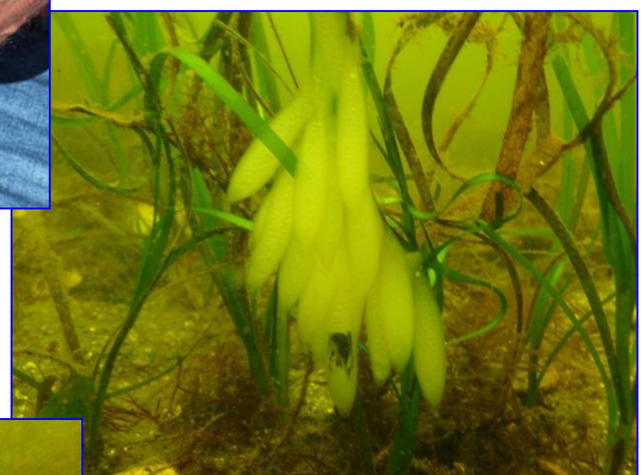
A Strategy for Community Eelgrass Restoration in British Columbia



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Executive Summary

This document serves as a final report to the Pacific Salmon Commission, the funding contributor for the *BC Three Estuaries Project,* an investigation into the potential for restoration of eelgrass habitats (*Zostera marina)* within three estuaries in the southern Georgia Basin. These sites were historically locations for log storage. The four test plots were planted in the summer of 2007 and monitored after one growing season, during the summer of 2008.

The monitoring results are included in this report. However, from discussions with coastal conservation groups that have mapped eelgrass beds in twenty-seven communities in British Columbia since 2002, it became apparent that the project concept could expand to a wider geographical area and include more community involvement. Therefore a description of a possible strategy to make a net gain of salmonid habitat in BC is included with this report.

The stewardship groups that compose the *B.C. Community Eelgrass Network* are part of the Seagrass Conservation Working Group (SCWG), a consortium of scientists, stewardship groups, governmental agencies and researchers committed to the conservation and protection of seagrasses in B.C. This network of eelgrass mappers and the Working Group are strategically positioned to create a different way of doing business with eelgrass habitat restoration in B.C. By working closely with scientific advisors and federal and provincial agencies, coastal communities can have a more significant role in creating a net gain in fish and bird habitat in this province. This report is dedicated to them.

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1.0 Introduction

> "The discipline of restoration ecology aims to provide a scientifically sound basis for the reconstruction of degraded or destroyed ecosystems, and to produce self-supporting systems that are, to some degree, resilient to subsequent damage." (1)

In recent years, there has been a burgeoning interest in what lives in estuaries in British Columbia by those who live, work or play on or near marine waters. Estuaries attract attention for the opportunities they offer to bird watchers and kayakers alike; recreational boaters find respite from the impetuous winds of the open coast; school children wait on the shore to watch the incoming spawning salmon they released as fry the previous year. Over the last two decades, the values of these estuaries to marine wildlife and people have been well documented. (2)

However, there is a paucity of information on the state of health of these rich and biologically diverse ecological resources. Locations of eelgrass beds, for example, from the large flat meadows of the Campbell River estuary to the narrow fringe beds of Prince Rupert, have been documented just recently. We may very well be losing much of this valuable habitat before we have a full understanding of its density and distribution.

One thousand volunteers mapped 12,000 hectares of eelgrass habitat since 2002. As these volunteers made use of their GPS units and quadrats to pinpoint the locations and densities of these beds, they realized there were many areas where the plants should be, and weren't. Thus began the movement to bring back these beds to self-supporting systems.

An argument will be made that coastal community groups, who themselves have great resilience, are in a prime position to take on more of a responsibility for locating, assessing and assisting with transplanting lost or damaged eelgrass beds as a net gain in salmonid and other marine species habitats.

2.0 Ecological Value

E.O. Wilson first proposed the importance of "wildlife corridors" in the 1980s. Habitat reduction and fragmentation at a variety of spatial scales has been widely acknowledged as a primary cause of the decline of many species worldwide. (3) Habitat fragmentation generally leads to smaller and more isolated animal populations. Smaller populations are then more vulnerable to local extinction, due to stochastic events. (4) To reduce the isolation of habitat fragments, many conservation biologists have recommended maintaining landscape "connectivity" - preserving habitat for movement of species between remaining fragments. (5)

Moving into the marine environment, eelgrass beds (*Zostera marina*) function as wildlife corridors for a large array of fish, bird and invertebrate populations. They have been described as "salmon highways", providing respite from strong ocean currents and unrelenting predators, and as nutrient rich nurseries for young marine organisms. Across the globe, seagrass meadows cover about 177,000 square kilometers of coastal waters – larger than the combined area of the Maritime provinces. (6)

2.1 Economic Value

Eelgrass meadows serve humans well. As an ecosystem service (7), seagrasses are as productive as a marsh, a temperate agricultural farm or a coniferous forest. The meadows act as estuarine filters, removing sediments and nutrients from coastal waters; they produce oxygen, act as a carbon dioxide sink, trap sediments, pollutants and nutrients, and protect coastal areas from erosion. (8)

The global economic value of seagrass/algae beds is estimated to be US \$3801 x 10^9 year $^{-1}$. (9) This figure does not take into account gas regulation, disturbance regulation, erosion control, waste treatment, habitat, food production and recreation. (10)

The true value of the multiple functions of seagrasses has ironically been discovered through disasters resulting in massive declines in the habitat. For example, the sudden disappearance of eelgrass along the Atlantic coast during the 1930's showed the world the significant ecosystem services eelgrass habitats provide. An epidemic infestation of the parasitic slime fungus (*Labyrinthula spp.),* called 'wasting disease" literally destroyed the rich eelgrass meadows. This had catastrophic results. Populations of cod, shellfish, scallops and crabs were greatly diminished, and the oyster industry was ruined. There was also a serious decline of over-wintering populations of Atlantic Brant geese. (11) Areas formerly covered by dense growths of eelgrass were completely devastated. Beaches formerly protected from heavy wave action were exposed to storms. Without the stabilizing effects of eelgrass rhizomes, silt spread over gravel bottoms used by smelt and other fish for spawning. This resulted in a decline in waterfowl populations that fed on the fish. Without the filtering action of eelgrass beds, sewage effluent from rivers caused further water pollution, thus inhibiting the recovery of eelgrass plants. (12)

2.2 Cultural Value

Several coastal aboriginal groups, including the Salish, Nuu-chah-nulth, Kwakwaka'wakw and Haida ate crisp sweet rhizomes and leaf bases of the eelgrass blades. The Saanich placed the rhizomes in steaming pits to flavor deer, seal and porpoise meat. The Songhees formed thin cakes and dried them for winter food. (13)

Among the Kwakwaka'wakw, uncooked rhizomes, stems and attached leaf-bases were a favorite feast food. They gathered the plants in canoes by turning long hemlock poles in the eelgrass bed until the eelgrass leaves were wrapped around them, and then pulled up the entire plants. After breaking off the green leaves, they washed and carried home the rhizomes and leaf-bases. Usually the entire tribe was invited to an eelgrass feast. The pieces were spread out on mats and each person took four, plucking off the small roots and peeling off the outer leaves. They broke the four pieces to the same length, tied them together in a bundle with the leaves, dipped the bundle in grease, and ate it all with their fingers. Guests could not drink water after an eelgrass feast, but they could take left-overs home to their wives. This feast was an important one, because the Kwakwaka'wakw believed eelgrass to be food of the mythical ancestors. (14)

The Nuu-chah-nulth gathered and prepared eelgrass in much the same way. The Haida preferred to eat it when it had herring spawn on it. In the Haida language, the name for eelgrass (t'anuu) is also the name of a Haida village on the east coast of Moresby Island. (15)

2.3 Social Value

It has been estimated that thirty thousand Coast Salish peoples lived in the Puget Sound-Georgia Strait Basin on the eve of European epidemics, or approximately the number of people living presently in the San Juan Islands south of the Canadian border in Puget Sound. (16) The Coast Salish economies and ecology remained dynamically stable for 1,500 years or longer.(17) Reef net fishing was the dominant harvesting gear used to fish adult migrating sockeye salmon as they traveled inshore to feed in nearshore eelgrass meadows by the Coast Salish in the island archipelago of the San Juan and Gulf Islands as far south as Bellingham Bay. Other means for fishing were traps and weirs. (18)

The first run of sockeye would arrive in June. After the salmon were harvested, they were processed near reef-net sites by removing their heads, tails and backbones. The refuse was returned immediately to the beach and bay. The fish were then smoked and dried over beach fires fueled with local wood. Afterwards, the salmon remains, charcoal and ash were deposited into the eelgrass meadows and shoals from which the sockeye had been removed. Thus, a reef net harvest recycled nutrients from the sea and surrounding forest and concentrated them at approximately 40 sites in the San Juan and Gulf Island archipelagos. (19)

Nutrient feeding of reef-net grounds fed the next generation of sockeye on the remains of their parents. Each operation site sustained its own supplies of sockeye by recycling the remains into salmon prey, feeding the emerging salmon fry and crustaceans that fed on the carcasses. These "fertilized" eelgrass meadows then attracted the next generation of fish to the site. Sound stewardship of the harvesting sites were recognized by making the local households responsible for the site well known and popular through feasts and the sharing of access to the fishing sites with other households. The greater the care for the fish and habitat, the greater the prestige. (20)

In contrast to this long history, wetland areas such as eelgrass meadows have been perceived narrowly either as wastelands or as areas providing little benefits beyond support of waterfowl populations. (21) "Canada has drained, filled, paved, and polluted most of our wetlands, resulting in the loss of 65 percent of Atlantic coastal marshes, 70 percent of southern Ontario wetlands, 71 percent of Prairie wetlands, and 80 percent of the Fraser River delta." (22)

However, in the last decade and half there has been an increasing recognition that wetlands are not only essential to waterfowl; they also protect fisheries, shellfisheries, drinking water supplies and flood-prone areas. As more endangered and threatened species are added to the Species at Risk list, making the links between habitat protection and species biodiversity is critical.

3.0 Habitat Losses

Although seagrass ecosystems are widespread around the globe, they are one of the most vulnerable to human disturbance . In the past ten years (before 2003), 15% of the world's total seagrass areas have been lost. (23)

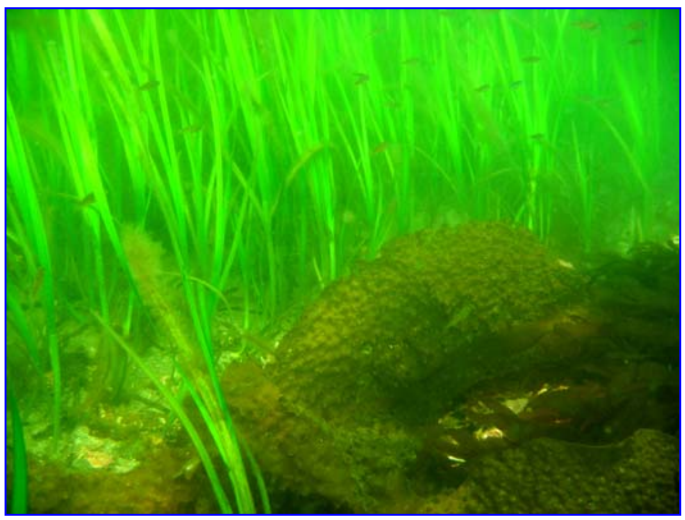
Water Quality in Coasts and Estuaries

"Of the 72 percent of the (US) estuarine waters surveyed, (Environment Protection Agency's) 1996 *National Water Quality Inventory* found that 58 percent were fully supporting their designated uses, 28 percent were impaired, and 4 percent were threatened. The most widespread causes of impairment were nutrients and bacteria, which affected about half of the impaired area. Oxygen depletion from organic wastes, habitat alteration, oil and grease, toxic chemicals, and metals were also were significant environmental problems. Urban runoff, including CSOs (*sic*: Combined Sewer Outfalls), discharge from municipal and industrial sewage plants, and agricultural runoff were significant sources of pollution. (24)

Harbour facilities, industrial activities and log storage are some of the activities that have caused decline in eelgrass populations in the Strait of Georgia and Puget Sound. (25) For example, the ports of Vancouver and Seattle have radically altered natural substrates. Estuarine shore habitats are significantly modified. In 1992, only 58% of the shoreline of the North Arm of the Fraser River estuary was currently considered high quality fish habitat. Industrial development is concentrated in these estuaries because of the availability of flat land at river mouth deltas. (26)

Reduction in the distribution of seagrasses reduces ecosystem services by reducing the areas available for food webs and habitat (27) The loss of habitat is a compounding process. Once die-off begins, secondary effects such as re-suspension of sediments, increased turbidity and reduced light penetration intensify the loss, in certain situations leading to autocatalytic decline. (28)

Coastal eutrophication is one of the main causes for decreased light availability, leading to the world-wide decline in seagrasses. (29) As excess nutrients stimulate phytoplankton growth, light penetration to the plants growing at depth is reduced. Increased epiphytic macroalgae growth from excessive nutrient loading can shade and suffocate the plants as well. (30) As light diminishes, the plants develop thinner blades, leading to lower rates of productivity and a decrease in biomass and lower shoot densities. (31)



A healthy eelgrass meadow   Photo: S. Jeffery

> "We (Department of Fisheries and Oceans) have a certain amount of control over development, but…people mooring their boats or moving houses from island to island, churning up the bottom with tugs trying the push the barges ashore, or people fishing illegally – there is a whole number of different things over which there is no control."
>
> R. Russell, A/Area Chief, Habitat Management, South Coast Area (interview, 2002)

Some conservation groups address water quality issues while they are planning for restoration of eelgrass habitats within an estuary. The goal of restoration, in such cases, is a net gain in ecological conditions, including an improvement in water quality.

3.1 Impacts of Log Storage

Log abrasion, grounding, sediment scouring and the activity of boom boats affect extensive areas of plant communities. These activities make direct impacts on herring populations and other food prey for salmonids. For example, in the Mamquam Channel in the Squamish River estuary, logs have been stored for over 50 years, resulting in extensive deposits of bark and other wood debris in some areas of formerly vegetated marsh. Populations of benthic invertebrate species important in juvenile salmon diets have been compared between wood debris accumulation and reference habitats. Overall, salmon prey species were less abundant in wood habitats than in reference areas. Researchers attributed these differences in abundance of salmonid prey between habitats to the availability of food species consumed by the invertebrates. (32) Micro-organisms such as bacteria, fungi and micro-algae are important items for these invertebrates. Bacteria and fungi convert plant matter to forms that benthic invertebrates can more easily ingest. The ability of these micro-organisms to take up food is largely dependent on the type of plant matter. They are less capable of assimilating nutrients from wood than other plant material such as eelgrass. Wood debris habitats are less productive than other types of plants because the nutritional value of woody debris is not readily transferred to benthic invertebrates and then to salmonids. (33)

The effects of log storage have also been studied in the Nanaimo River estuary. As in the Squamish River estuary, the primary objective of research was to evaluate changes in population of salmon prey species, specifically harpactacoid copepods, the major food of juvenile chum salmon. (34) Extensive intertidal wood debris accumulations were not evident in these studies due to the relative exposure and flushing of this estuary compared to that in Squamish. However, another study in 1984 in the Nanaimo River estuary evaluated habitat and benthic invertebrate changes following removal of log booms from the Nanaimo estuary. After one year, oxygen penetration into the sediments at the log storage site was significantly less than that observed at the reference site. “The persistence of these chemical habitat differences may have been reflected in the different benthic communities between the two sites which also did not change over the duration of the study.” (35)

It can be said, then, that effects of wood debris accumulations do not directly change fish populations so much as change the infaunal (animals living within the seabed sediments) and epifaunal (animals living on the surface of the seabed) communities. The larval stage of most these species are planktonic and may occasionally be important prey for salmon species, particularly sockeye and pink salmon.

4.0 What the Law Requires

> "Development impacts on eelgrass and mitigation of these impacts currently are the most pressing environmental issues facing the U.S. Army Corps of Engineers, Seattle District, as well as the regional shipping ports. Approximately $100 million in development projects have been stopped or stalled in Washington State from 1990 to 1993 because of these issues. A perception that eelgrass cannot be successfully transplanted as mitigation has largely been responsible for denial of development permits." (36)

In Canada, estuaries are considered sensitive habitat by Fisheries and Oceans Canada (FOC). The Federal Fisheries Act section 35 (1) states "*No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat*." However, Section 37 (2) allows FOC to grant permits for damage to fish habitat. Authorizations are not unconditional – they permit harmful alteration and damage to fish habitat only under carefully prescribed conditions. (37)

One particularly important condition is that losses to habitat caused by a development project must be balanced by gains elsewhere. Section 35 of the *Fisheries Act* under which this process operates is not about protection of fish but of *fisheries*. It means that fish habitat that directly or indirectly supports – or has the potential to support – subsistence, commercial or recreational fisheries is required to be protected. Since eelgrass supports at least 80% of commercially important fish at some part of their life cycle, *Zostera marina* beds are an important fisheries resource under this Act. The "no net loss" of fisheries habitat under this Act means that eelgrass habitat loss on one side of the ledger must be balanced by eelgrass habitat gain on the other. (38)

In 2000, Canada's Auditor General observed that Fisheries and Oceans seldom follows up on projects after issuing letters of advice, although these projects often result in damage to fish habitat. As a result, FAO fails to monitor the cumulative impacts on fish habits. (39) The Auditor General warned that "an accumulation of small habitat losses could result in a significant impact; indeed, such losses are probably the source of the slow net loss of habitat that is occurring." (40)

4.1 Damage Control

Mitigation, compensation or enhancement projects instigated by a development company or individual are required if damage is inevitable during the completion of a project. Compensation for damage to a fish habitat is required preferably close to the shore development. If this is not feasible, off site compensation must occur, with approval by Fisheries and Oceans, most often at a 2:1 ratio (twice the area is planted in relation to the area damaged to compensate for temporal and spatial loss of habitat.). Compensation should be used only in cases where restoration is not possible (41)

"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 the discrepancy." (42)

4.2 History of Eelgrass Transplants

In the Pacific Northwest, the history of success for *Zostera marina* transplanting projects was dismal prior to 1985. Initially transplant techniques were used that were developed and successful on the Atlantic coast. However, these techniques were not well suited to the Pacific north coast environment and eelgrass. Many of the early transplants were conducted without a thorough understanding of eelgrass physiology and ecology; the donor stock was not always well suited to the area where they were transplanted, and the biophysical conditions of the transplant site were not always appropriate for the species. (43)

Ron Thom of the Battelle Research Centre in Squim, Washington collected the results of mitigation projects completed from San Francisco Bay through British Columbia from 1974-1990. (44) Total documented plot sizes ranged from 0.1 m^2 to 11,000 m^2. Transplanting methods included plugs of various sizes, individual shoots that were anchored or planted directly into the substrate, and bundles of shoots (planting units).

The most commonly used standard for monitoring the beds was shoot density, which measured plug, shoot or bundle survival. Percentage cover was also used in some cases to indicate the area of substrate covered by the plants. Duration of the monitoring varied widely from a few months to five years. More than half of the 17 projects either failed completely or were only marginally successful. (45) (**Table 1**: Appendix 1)

Since 1985, knowledge and experience from adaptive management practices have resulted in a higher success rate for focused mitigation and enhancement projects along the Pacific coast. (46) In an assessment of 17 eelgrass transplant projects that were completed between 1985 and 2000 in British Columbia, Cynthia Durance (Precision Identification) rated seven projects as successful, four as failures, and five recently planted projects were deemed most likely successes within several years. Since that time the five recently transplanted sites have been documented as successful. The majority of projects surveyed were motivated by the *No Net Loss* policy of Fisheries and Oceans Canada. The success of one site could not be determined due to an absence of interim monitoring data and the expansion of the surrounding natural eelgrass population. (47)

Factors that led to a higher success rate included the correct selection of physical attributes for the compensation area, including elevation, substrate composition and light and current regime. The selection of the most suitable ecotype or genotype increased the likelihood for success and rate of production. (**Table 2**) The criteria for success included shoot density and area revegetated (48).

Table 2: Three Ecotypes on the Coast of B.C. (49)

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 to 15	0 to -4	large, plant length reduced in winter	moderate
latifolia	large	12 to 20	-0.5 to -10	minimal variation	strongest

4.3 Causes for Failures

In all projects assessed over twenty years (1980-2000) in the Pacific Northwest, inappropriate site selection was a major factor contributing to failure. Factors that led to survival failure of the four transplant projects in British Columbia were primarily caused by human activities (dock placement, propeller wash, trampling by kayakers at low tide, dumping of rocks leading to shading by kelp plants) and inappropriate elevation. (50) In addition, coarse substrate and shading may have reduced the success of transplanted eelgrass at several locations.

Combined with the selection of the appropriate ecotype for the donor plants, and barring unforeseen stochastic events, the success rate of restoration projects has climbed steadily since 1985. A comprehensive review of thirty- nine eelgrass restoration efforts in the United States by the National Marine Fisheries Service verifies that knowledge about eelgrass ecology has improved. (51)

Table 3: Summary of Eelgrass Projects in California 1976-1999 (52)

Year	No. Projects	Mean Size (ha)	Max. Size (ha)	Success (%)
1976-79	4	0.4	1.6	25
1980-84	3	0.6	107	33
1985-89	12	0.6	3.8	58
1990-94	9	0.3	2.0	56
1995-98	11	1.0	4.8	All pending
1999	2	2.0	4.0	Planned

The projects were considered successful if there was a net increase in eelgrass coverage. Thirty six percent of the projects were considered successful, 13% partially successful; 18% not successful, and 33% were pending the results of monitoring surveys. **Table 4** (Appendix 2) outlines the conclusions from a study of three eelgrass restoration projects in Washington State since 1997. (53)

Key factors that influenced the success of these eelgrass transplants were primarily related to site selection, including substrate, depth, current or wave disturbance, light energy, scale or size of the plot, salinity and temperature. Other factors included proximity to a natural bed, quality of donor stock, time between removal from the donor site and transplanting, mode of spreading (i.e., seeds or rhizomes), grazing by animals, and unusual weather events (e.g., severe storms, freezes). The smaller the project, the greater the success. (54)

4.4 Criteria for Success

Eelgrass plantings that persist over time and meet the size criterion provide many of the functional attributes of natural eelgrass beds. The definition of functional performance is the measurement of abundance of selected marine animal types (e.g., crabs, eelgrass associated fish, shorebirds) or species (e.g., juvenile Chinook salmon) in the restored site. (55) In British Columbia, the criteria for success is based upon 1. the mean shoot density equals or is greater than the area of adjacent natural beds and 2. area coverage. Projects are thus considered successful if the habitat that was created provided habitat equal in eelgrass productivity (shoot density) to that which it was designed to replace. (56) The BC transplant review found a similar diversity and abundance of fauna in transplanted and natural (control) beds. **Table 5** shows the number of years needed to approximate the shoot density of the donor population at eight transplant sites in British Columbia: (57)

Table 5: Shoot Density (#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
Campbelton	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

* Comox Harbour was naturally re-vegetated

For every eelgrass compensation project, there is a temporal loss. Productivity is lost each time development along the coast affects an eelgrass habitat. The creation of an area greater than that area which is lost may be used to compensate for the temporal loss. (58)

A transplant project aims to achieve:

- A self-sustaining system
- Resilience to disturbance
- A structure similar to natural bed
- Functional performance similar to the natural bed. (59)

In most cases, however, monitoring data for projects is not available to determine the average number of years required to achieve a self-sustaining system most comparable to a natural bed. Although it may seem likely that older transplanted eelgrass beds are functioning similar to that of a natural bed, there remains a paucity of comprehensive data to substantiate this notion. (60) In all cases except one for the transplant sites in British Columbia, the compensation areas attained plant densities comparable to natural populations in less than five years. (61)

The main criteria for successful transplanting lies with site selection with the appropriate biophysical characteristics (salinity, sediment type, current velocity, light/depth, temperature, and pH), using suitable plant donor stock (ecotype), using an appropriate transplanting technique and handling the donor plants with care. (62)

5.0 Monitoring Schedule

For mitigation projects it is recommended that the area of potential impact should be monitored prior to the disturbance and shortly after the habitat changes have been completed. (63) Conservation groups could assist with gathering information such as maximum depth or width of the bed from shore, mean density of shoots and a description of the eelgrass coverage that indicates the bed's uniformity or patchiness.

Eelgrass that has been relocated can live for several months on the energy stored in the rhizomes. In order for them to survive over time, it is essential that they grow roots and branches. Therefore it is important to monitor a transplanted site several months after the transplant to gauge whether there are any physical or biological causes that will affect the success of plant survival. A set schedule following the initial transplant date is also crucial. (64).

Table 6: 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

If a transplant fails, in the case of a restoration project in particular, it is critical to determine the reasons before a replanting takes place. Conditions such as suspended sediments during prolonged rainfalls, for example, may limit the available light during a time that the transplanted eelgrass requires the most sunlight. Mean shoot density in a reference site (a natural eelgrass bed situated near a transplant site) varies between years and between seasons, so it is important to compare data between the two sites at the same time. (65)

6.0 Project Design

Once the goals of an eelgrass transplant project are established, site selection is the next critical step. A site selection model has been created to select optimal areas for eelgrass habitat transplants on the Atlantic coast of the United States. (66) The process is divided into 3 phases. The first phase makes use of available environmental information to formulate a preliminary transplant suitability index, or PTSI, for pre-screening and for eliminating unsuitable sites. The second phase includes field measurements of light availability and bioturbation as well as survival and growth of test transplants; and the third phase pulls the information together to rate the site for its appropriateness for a transplant, ranging from a score of 0 to 2. (67)

The following tables suggest a method for assessing sites in British Columbia by community groups, based on the above mentioned model combined with experience of Cynthia Durance who has worked for over twenty years transplanting eelgrass in BC. The method has been designed to be low cost and requires minimal training. *Phase 1* includes measurements of physical attributes, historical data and environmental conditions; *Phase 2* includes measurements of survival and mean densities within test plots, and *Phase 3* rates the final score (PETI or Potential Eelgrass Transplant Index) to determine the suitability for a larger transplant project at the site. The highest score is 28.

Potential Eelgrass Transplant Index

Assessment of Physical Characteristics

Parameters	Range	Assessment Method	Rating Score
Substrate type	Firm sand to soft mud to boulder/cobble	Direct observation	2: entirely fine (Sand and/or mud) 1. mixed (gravel or cobble with sand or mud) 0: entirely coarse (boulders, cobble etc.)
Elevation	0.0 m to - -10m	Direct observation	2: Within range of ecotype 0: Beyond range
Salinity	Freshwater to 42 ppt	Hydrometer	2: 10 to 30 ppt 1: Freshwater year round (Measured on a monthly basis would be recommended)
Current velocity	Waves to stagnant water	Local knowledge	2: Little wave action 0: Steady fetch
Light	1.8 m above MLLW to –30m(this is depth, the plants need about 20% of surface light)	Local knowledge	Ranges to be determined
pH	7.3 to 9.0	Lab analysis if wood waste present on surface	2: 7.3 to 9.0 0: 1-6/10-14

ppt – parts per thousand   MLLW – mean low low water
Elevation is dependent upon ecotype of donor plants

Assessment of Site History

Parameters	Range	Assessment Method	Rating Score
Reference site	Close to potential restoration site to non-existent	Maps of subtidal area	2: Close to potential restoration site 1: Not available
Donor site	100 m to non-existent	Maps, boat observation	2: Available: 0: Within 100 m *
Historical records	Accessible and accurate to none	Government agencies	2: Accessible 1: Not accessible or non-existent
Local knowledge	Accessible and accurate to none available	Communications with community members	2: Accessible & accurate 1: Not available

*If a site is less than 100 m from a natural eelgrass meadow, it is considered within the range of natural re-vegetation and receives a rating of 0 (68)

Assessment of Environmental Conditions

Parameters	Range	Assessment Method	Rating Score
Availability of suitable ecotype	*Typica/phillipsi/latifolia*	Direct observation of plant and distribution range	2: Available 1: Not available
Near by land use	None to heavy use	Observation, local knowledge	2: Best practice management 0: Heavy run-off
Activities on the water	None to intense activities (ex: boat anchoring area)	Observation, local knowledge	2: Minimum impact from boats 1: Area of heavy boat traffic
Protection status	None to marine protected area	Government agencies	2: Protected status 1: No protection in place
Type of freshwater inputs	None to heavy flows (ex: heavy flow from stormwater discharges)	Observation Maps	2: Natural 1: Stormwater discharge

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Test plots would be planted with a few hundred shoots at each site to assess the suitability of the site for a larger compensation project. Data on turbidity and salinity would be submitted to the scientific advisor. If 400-500 shoots (~50%) survive after the first year, a larger transplant project could be planned. If there were less than 50% survival, an investigation of the causes would take place.

7.0 Summary of Test Plot Transplants

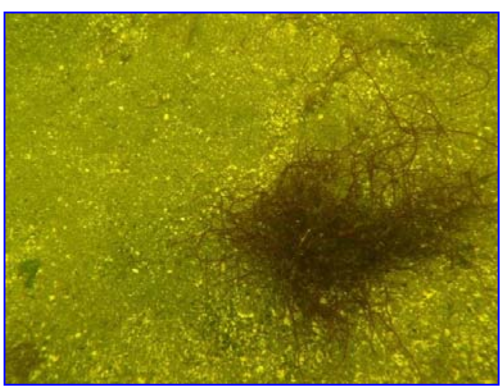
<u>McKenzie Bight</u>

lies in the southern area of Saanich Inlet within the Gowlland Tod Provincial Park, established in 1994 as part of the Commonwealth Nature Legacy. Old logging roads surrounding the Bight within the 1,219-hectare Park now provide hiking trails for visitors.

The WCB Dive Team, with scientific advisor, Cynthia Durance, assessed an area within the nearshore of the Bight (48° 33.205'N, 123° 30.344'W) and, using the criteria listed above, deemed the site a suitable transplant area for a small number of eelgrass shoots. A small patch of eelgrass was discovered near this site, an indication that conditions within the area are favorable for a transplant.

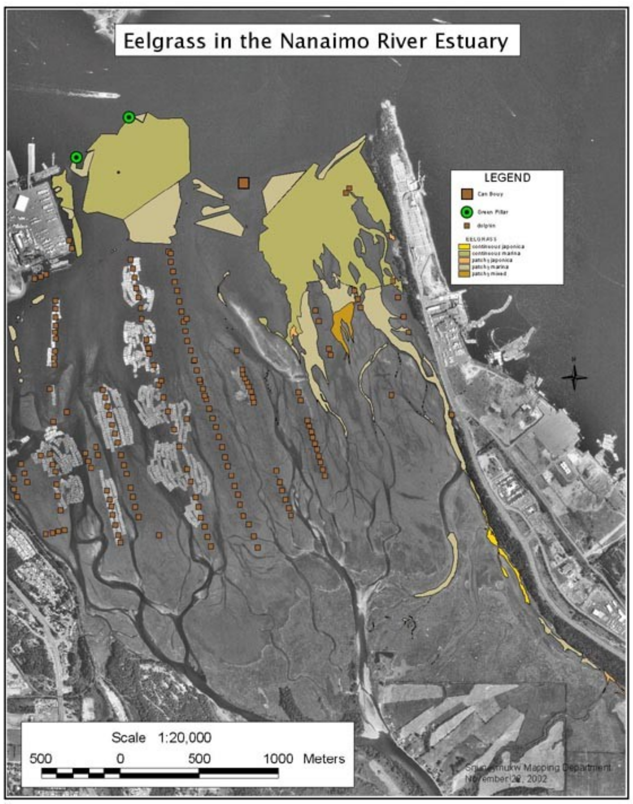
In July, 2007, 700 shoots were harvested from Coles Bay in the Saanich Inlet. The conditions (elevation, salinity, pH, light availability, current velocity and substrate) of the donor site resembled those of the transplant site. The planting was installed in three small plots of approximately 230 shoots each at a density of 10 shoots/metre ^{2}.

Before and After Transplant



One year after the transplant. This site showed the most marine biodiversity of all the sites at the time of monitoring. The first photo is of a kelp crab, the second of squid eggs deposited on the blades of the transplanted shoots.

Nanaimo River Estuary



is the largest on Vancouver Island and the fifth largest in British Columbia. It is estimated that the majority of the estuary (~1000 ha) was once covered with eelgrass, before urbanization, industrial activity and hydrological changes impacted the area.

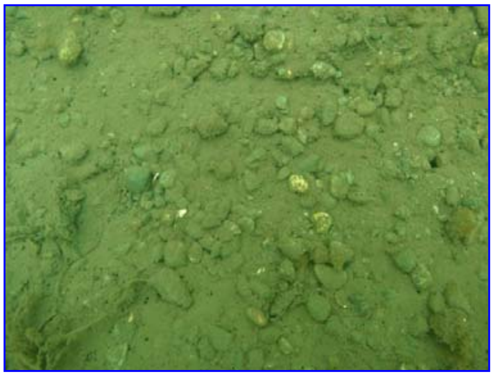
Approximately 200 ha of eelgrass habitat was mapped recently by the Snuneymeux First Nations as part of the work of the BC Community Eelgrass Network.

About 200 ha of the estuary is used for log storage, though the size of the storage is decreasing over time. Some of this area has the potential to support eelgrass. The log storage leases are under the jurisdiction of the Provincial Minister of Sustainable Resource Development.

The Snuneymuxw First Nation is located on the Nanaimo River estuary and has taken an active part in decision-making processes regarding the use of the estuary. The First Nation has completed some mapping of resources within the estuary, including eelgrass. They have both GPS and GIS resources and expertise at identifying and mapping resources.

The WCB Team assessed an area within a nearshore channel just south of the Snuneymeux First Nations Reserve (UTM 0432663,5543573) on the advice of a fisheries biologist who has worked with the Band for many years. Seven hundred shoots were harvested and planted in July of 2007. Three small plots were installed of 200, 300 and 200 shoots in each plot north to south.

Substrate of the channel: After one year, there was no evidence of transplanted eelgrass.



In August of 2007, a compensation eelgrass transplant took place in front of the Snuneymeux Reserve for BC Ferries. Approximately twenty community volunteers came out to help with the project. Because of funding support from the Pacific Salmon Commission, the stewardship component of this event was very successful. Nikki Wright and others on the WCB Dive Team spent time orienting and training the volunteers, emphasizing the importance of their work in helping to restore lost eelgrass habitats.

The transplant area was monitored in August of 2008 and appears to have increased in mean shoot density.

Squamish River Estuary

Historically the eelgrass beds in the estuary have provided important habitat to spawning herring, which form an integral component of Squamish Nation culture. The Squamish River Watershed Society, working with Squamish Nation, has a big interest in re-establishing thriving communities of eelgrass, especially in regards to providing herring spawning sites and providing increased habitat for salmonids as well as other marine life that benefits from eelgrass habitats.

Squamish is uniquely situated at the mouth of the Squamish River where it empties into Howe Sound. The town site itself is established on what was once estuarine habitat. In the past the shoreline was a primary spawning ground for herring as there were beds of eelgrass throughout. At this time, the eelgrass populations have declined and there is no firm documentation as to their current location, status, and usage. It is known that the herring continue to migrate annually to Howe Sound seeking places to spawn. Shore birds and diving birds are abundant throughout the estuary and the upper reaches of Howe Sound. The herring are of particular importance to the Squamish Nation both culturally and as part of their current daily life.

Eleven hundred eelgrass shoots were harvested off site and planted in two locations in the estuary in September, 2007. Four hundred were installed at the Nexen Lands (10 U 488301 5503594 8 m) in a 10 m x 4 m plot 42 m from shore with the help of 15 community volunteers, who anchored the shoots to steel washers.

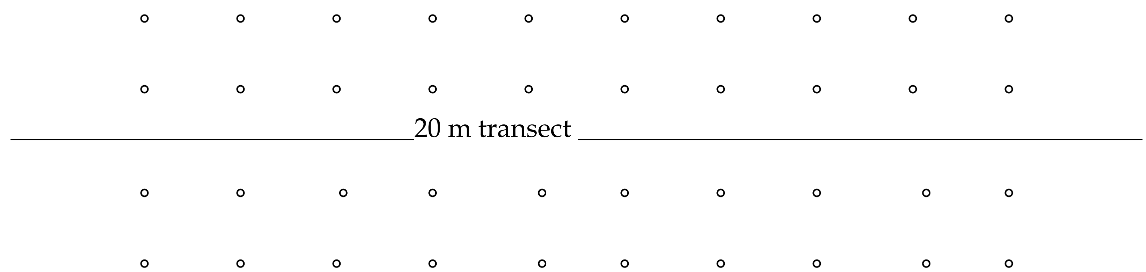
Nexen Land Site

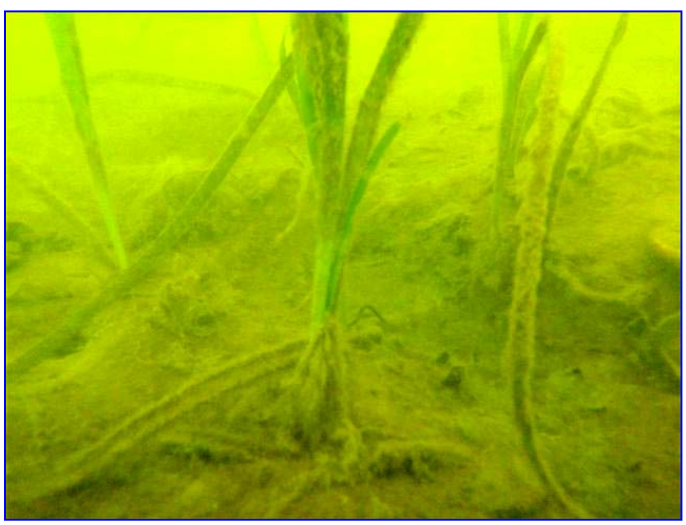
400 shoots were installed in front of the dive flag.

Eelgrass transplants after one year

Seven hundred shoots were planted in front of the Squamish First Nations Reserve along a 20 m transect in groups of 10 one metre apart.

Planting Design Example:





New growth arises out of the base of the transplanted shoots.

7.1 Monitoring Results

Site	Mean Average # of Shoots/Patch	Area Planted
McKenzie Bight (northern plot)	26.4	23 m^2
McKenzie Bight (southern plot)	24.6	30 m^2
Nanaimo River Estuary	0	70 m^2
Nexen Lands	17.33	40 m^2
Squamish Reserve Site	13.13	70 m^2

The criterion for success is based upon the mean shoot density that equals or is greater than the shoot density at the time of the transplant. Of the five test plots planted, three succeeded in increasing > 50% mean density over one growing season, The range of increase varied from 131% to 264%. Some of the plots in the McKenzie Bight and Squamish sites were coalescing, giving promise that eelgrass meadows were forming. Approximate area coverage for net gain in salmonid habitat for all three sites was 174 m^2.

The Nanaimo site within the channel did not succeed. Speculation is that there may be issues with high turbidity and high current velocity within the channel.

7.2 A Model for Community Based Restoration

"Restoration is the business and the spirit of the 21st century"
Storm Cunningham, author *The Restoration Economy*, 2002

Storm Cunningham, in his book *The Restoration Economy*, describes the 21st century as being at the "tipping point", an inevitable transition from an economy based on new development to one based on restorative development. This economy will be a reflection of a turn in direction, from creating more built environments to restoring old ones, reversing the one-way direction of forests into farms, wetlands into factories. (69)

Examples of a turn towards estuarine conservation/restoration are evident in the United States. The National Oceanic Atmospheric Administration's (NOAA) Community-based Restoration Program (CRP), started in 1996, applies a grass-roots approach to restoration by "actively engaging communities in on-the-ground restoration of fishery habitats around the nation. The CRP emphasizes partnerships and collaborative strategies built around restoring NOAA trust resources and improving the environmental quality of local communities" (70). The national program:

- Provides seed money and technical expertise to help communities restore degraded fishery habitats
- Develops strong partnerships to accomplish sound coastal restoration projects
- Promotes significant community support and volunteer participation
- Instills stewardship and an abiding conservation ethic
- Leverages resources through national, regional, and local partnerships (71)

The CRP is a partnership between environmentalists, the fishing industry and communities that depend on fisheries. In 2002, it expanded its partnerships to include national and regional NGOs that have "resources and expertise in the restoration of marine, estuary and freshwater habitats. (72) In the Pacific Northwest, the CRP has funded wetland and estuarine restoration projects in Washington, Oregon and California.

7.3 A Model for British Columbia

> "The depth of site specific knowledge amongst local people is often staggering, and comes from inhabiting a place for many years and becoming active observers and participants in the functions and processes of the ecosystem." (73)

Restoration connects individuals and communities to place. The social engagement required to create a successful restoration project, such as a well designed and executed eelgrass transplant, requires community commitment and creativity, scientific expertise, good working relationships with government agencies, strong partnerships with local and provincial industries and businesses, and excellent communication skills, to name a few factors. *Zostera marina* is being lost due to human impacts along the BC coast; it is the ingenuity, co-operative nature and commitment from communities and science and government working together that will bring them back.

7.4 Recommendations for Eelgrass Restoration in B.C.

Community conservation groups can successfully carry out eelgrass habitat assessments, transplanting and monitoring projects with professional scientific supervision and with authorization from Fisheries and Oceans Canada. The prototype for such activities is the eelgrass mapping project involving 27 community groups. From 2002-2008 well over 1,000 volunteers mapped over 12,000 hectares of eelgrass habitat from Haida Gwaii to Boundary Bay. They are trained in mapping protocols and received stewardship materials beforehand. Some of the mapping data can be viewed on the Community Mapping Network web site:
http://www.bc.ca/atlases/atlas.html

This eelgrass network influences the culture of volunteer based environmental conservation organizations by placing them in an active rather than reactive position regarding shoreline development. Many of the twenty-seven groups use their maps for locating eelgrass habitat to influence decisions regarding the development and use of the nearshore. Progressing from mapping to restoring damaged or destroyed eelgrass habitats can further strengthen the capacity of grass roots stewardship organizations to affect positive environmental change.

It is proposed that this eelgrass network be utilized to make the next step towards habitat restoration. The groups can assist with restoration by providing labour for shoreline work and assisting with monitoring for restoration projects.

The more work that is accomplished by volunteers, the larger the share of the budget the community would receive for the restoration work. Volunteers have a double incentive in knowing that their time, skills and/or equipment are contributing both to habitat renewal and financial support of a community conservation organization. Volunteer involvement in restoration also increases a community's investment in making sure the restoration site is well stewarded. By making use of the skills and commitment of stewardship groups, more can be accomplished. For example, the municipality of White Rock funded a transplant project in 2003 for 100 plants. The Friends of Semiahmoo Bay, a local conservation group, augmented the project. They donated their labour on shore, increased the number of plants transplanted, and raised awareness of the importance of the habitat in the community.

7.5 Habitat Recovery Teams

> "Scientific knowledge acquired through actual participation becomes a part of a people's culture, no longer an alien product to be accepted as an article of faith." (74)

The following steps are suggested for the creation of *Habitat Recovery Teams*:

1. Create a catalogue of potential eelgrass transplanting sites by using the Potential Eelgrass Transplant Index (PETI). The Index would provide data needed for assessments of suitable sites for eelgrass off-site compensation projects.

2. Establish communications with staff of Department of Fisheries and Oceans who receive requests for permits to develop an area that will require eelgrass restoration.

3. A scientific advisor conducts training workshops on eelgrass habitat transplanting and monitoring methods in coastal communities that have assisted

with site assessments. The workshops would include the distribution of stewardship materials for community education campaigns.

4. A team of certified Workers' Compensation Board (WCB) SCUBA divers accompanies the trainer to each site location to complete the transplanting project. (SCUBA would not be needed if the project is intertidal).

5. Some of the funds available from the proponent for the eelgrass restoration project are distributed to the community conservation groups for their labour, materials and equipment.

6. Interested groups, with the assistance of their regional coordinator, will also attempt to secure their own funding for projects.

7.6 Conclusion

> "Regrettably, we have ample places to examine the slow degradation of an ecosystem, but very few where we can witness and study the reverse – the rebirth of the environment from decades of mistreatment".
>
> Dr. Kennedy Paynter, professor, Univ. of Maryland Chesapeake Biological Lab

A diverse and viable network of volunteer conservationists has been created since 2002. This network with an organizational structure that allows for regional input provides the avenue for the dissemination of scientific and local knowledge, and the sharing of resources in the form of field equipment, educational brochures, videos and the like.

The volunteers who participate in the eelgrass network suggested restoring the habitat where they had found it had been historically. The proposed strategy for restoring habitat by connecting restoration funds with conservation organizations is a positive next step to coast wide net gain of this valuable marine resource.

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Appendix 1:

Table 1: Summary of Eelgrass Transplant Projects San Francisco Bay to British Columbia, 1974-1989 (Thom 1990)

Location	Start Date	Approx. area	Monitoring Duration	Success Rate	Conclusions
Hidden Harbour, BC	1987	1,900 m2	1 year +	28% shoot survival; 23% decrease in transplanted area	Eelgrass can survive in marina, but lush vegetation not expected
Gibsons Harbour, BC	1985	-	4 years +	Low in gravel, cobble; moderate in fine sands	Substrata is critical; water clarity critical
Roberts Bank BC	1981-1983	-	5 years +	Good in most areas	Eelgrass survived best in areas with standing water at low tide
Blaine Marina, WA	1987	-	8 months	8% of plugs evident after 8 months	Steep slope reduced survival; deepest plugs had best growth
Padilla Bay, WA	1988	70 m2	1 year +	Up to 100% survival of shoots in pots; 20% survival of shoots in plots	Donor plots recovered rapidly; potted shoots survived well
Dakota Creek, WA	1988	60 m2	1 year	80% survival at lowest elevations; <30% survival at higher elevations	Coarse substrata; high elevation of tide flat and disturbance by boats affected survival
Sequim Bay, WA	1985	8,000 m2	5 years +	800 m2 of bed remains after 5 years; very dense in surviving area; total shoot abundance = 200,000	Planting methods gave similar results; finer substrata and deeper areas with standing water had greatest survival
Bangor, WA	1987	46 m2 (total of 5 plots	1 year +	4 of 5 plots died; remaining plot is subtidal	Steep slope of intertidal area (where planted) may cause losses
Anderson Pt., Battle Pt.,	1977	Several 1 m2 plots per site	2.5 years	Good survival	Techniques give good survival if planted in

Manchester, WA				(plugs, unanchored and anchored shoots)	proper habitat
Smith Cove, WA	1987, 1988	230 m2 (total of 147 plots)	2 years +	No survival by March 1989	Drifting sand and silt covered plots
Magnolia Bluff, WA	1988	260 M2	1 year	No survival by April 1989	Drifting sediment covered plots
Seacrest, WA	1988	50 0.6 m2 planters	1 year	Some plants survived in some boxes	-
Puget Sound, WA (several sites)	1974	Various plots, 0.1 –1.5 m2	5-11 months	25-100% cover	Small plots placed in appropriate habitat do well; disturbance by waves reduced survival; all techniques worked well (plugs, anchored and unanchored shoots); long-term success of large-scale projects unproven
Siuslaw River, OR	1976,1977	290 m2 (total of 5 plots)	1 year	90% survival	Low fencing around plots reduced flows and helped survival; standing water at low tide over plots helped survival
Humboldt Bay, CA	1982	-	Several months	Good survival in first several months; severe storms destroyed plots	Transplanting success is enhanced if below-ground production of shoots is good
Bodega Harbor, CA	1984	11,000 m2	2 years	40% survival and 90% cover on tidal flat; 5% survival and 10% cover on channel banks	Low current, low disturbance, low turbidity areas did best
Richmond Harbor, SF Bay, CA	1985	9 m long linear plots (total no. plots = 25)	13 months	Approx. 100% mortality by end of study	Mature transplants did the best; transplant shock may have contributed to the losses

Appendix 2:

Table 4: Lessons Learned from Three Restoration Projects in Washington State (1997-2001)

• Conduct experimental transplanting should be conducted, when possible, under conditions where the full transplant project will take place. Pre-tested sites may satisfy performance criteria prior to development.
• Monitor newly constructed site for at least two years on a quarterly basis is strongly recommended.
• Select sites with low turbidity, medium-grained sand and moderate organic content
• Select sites with low disturbance from boat wakes, waves, sediment movement, etc.
• Plant on flat areas rather than steep slopes
• Plant in areas that form pools at low tides
• Transplant into an area larger than the target area desired for mitigation
• Minimize holding time of the donor stock. Plant donor plants within a few hours (maximum 24 hours) after removal from the donor site and keep plants under water during transport
• Understand the ecosystem into which the transplants are to be placed and the ecosystem from which the donor stock was taken.

Glossary

Compensation for Loss: The replacement of natural habitat, increase in the productivity of existing habitat, or maintenance of fish production by artificial means in circumstances dictated by social and economic conditions, where mitigation techniques and other measures are not adequate to maintain habitats for Canada's fisheries resources. (Dept of Fisheries and Oceans, http://www.dfo-mpo.gc.ca/canwater-eauxcan/infocentre

Ecosystem function: Refers to system properties or processes occurring within and between ecosystems, such as nutrient recycling.[1]

Ecosystem goods and services (or Ecosystem Services – ES): Those processes and attributers of an ecosystem (or part of an ecosystem) that benefit humans (Costanza et al. 1997).[2]

Ecosystem structure: Refers variously to the aggregate of species composition, population and community structure and inter-relationships, climate, soils and plant form (or habit)[3]

Estuarine: Deepwater tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open, partially obstructed, or sporadic access to the ocean and in which ocean water is at least occasionally diluted by freshwater runoff from the land. Examples of estuarine classes include subtidal and intertidal emergent wetlands, forested wetlands and rock bottom.[4]

Eutrophic: Over-rich in nutrients, either naturally or artificially as a result of pollutants.[5]

Fish Habitats: Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes." (*Fisheries Act*, sec. 34(l)).

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Mitigation: Actions taken during the planning, design, construction and operation of works and undertakings to alleviate potential adverse effects on the productive capacity of fish habitats. (*Fisheries Act* op. cit.)

Net Gain: An increase in the productive capacity of habitats for selected fisheries brought about by determined government and public efforts to conserve, restore and develop habitats.

No Net Loss: A working principle by which Fisheries and Oceans Canada strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis so that further reductions to Canada's fisheries resources due to habitat loss or damage may be prevented.[6]

Restoration: The return of an ecosystem to a close approximation of its condition prior to disturbance.[7]

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