Ministry for the Environment
Manatū Mō Te Taiao
Sustainable Management Fund

# Decision making document

**NIWA Client Report: AKL2005-015**
**February 2005**

**NIWA Project: NRC05101**

# Decision making document

Anne-Maree Schwarz
Jacquie Reed
Mark Morrison

*Prepared for*

Sustainable Management Fund
Northland Regional Council

NIWA Client Report: AKL2005-015
February 2005

NIWA Project: NRC05101

National Institute of Water & Atmospheric Research Ltd
Gate 10, Silverdale Road, Hamilton
P O Box 11115, Hamilton, New Zealand
Phone +64-7-856 7026, Fax +64-7-856 0151
www.niwa.co.nz

The Minister for the Environment's Sustainable Management Fund, which is administered by the Ministry for the Envionment . The Ministry for the Environment does not endorse or support the content of the publication in any way.

# Contents



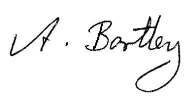
*Reviewed by:*

F. Matheson

*Approved for release by:*

P. Lee

*Formatting checked*



# Executive Summary

Seagrass beds in Whangarei Harbour have been demonstrated to have declined in areal extent since the 1960's and now local communities are interested in exploring ways of reversing that decline. This report fulfils tasks 3 and 4 of SMF project 2209, which has the overall aim of assessing the feasibility and techniques for restoration of seagrasses in Whangarei Harbour.

In this document we draw on overseas experiences as well as local knowledge about New Zealand's seagrass biology, to provide advice on the best practicable options for designing a seagrass restoration trial in Whangarei Harbour.

There is evidence to suggest that adverse environmental conditions, such as low water clarity, which were possible causes of seagrass loss in Whangarei Harbour in the past, have improved sufficiently as to provide a rationale for continuing with preparations for a restoration trial. Restoration of seagrass beds has received considerable attention elsewhere in the world; however, with the exception of NIWA trials in Manukau Harbour, we are not aware of structured trials here in New Zealand. As New Zealand has only one species of seagrass, which is predominantly intertidal, and probably primarily reproduces vegetatively, not all overseas experiences are relevant for consideration.

The document includes three decision making trees (presented at the end), which outline a series of actions required by managers in attempting seagrass restoration. Flow Chart I deals with identifying a restoration site and requirements for environmental enhancement. Considerations include ensuring sufficient light, moderate nutrient loads, and protecting plantings from disturbance. Flow Chart II outlines the steps required to conduct a trial, and links with Flow Chart III, which details requirements for monitoring the success of the trial.

Successful restoration of seagrass beds will be a long process (years) and there will be lessons about the local environment to learn as the process proceeds. We recommend that monitoring of seagrass bed extent and water clarity in the harbour be undertaken as a matter of course to provide background information for future restoration attempts. This would be in addition to specific monitoring of restoration trials.

# 1. Introduction

Community groups around Whangarei Harbour have expressed a desire for a locally-designed, scientifically robust approach to estimating the loss of seagrass beds in the harbour and improving conditions for seagrass restoration. A previous study (Reed et al. 2004) demonstrated that the areal extent of seagrass beds in Whangarei Harbour declined considerably between 1963 and 1983.

This report combines tasks 3 and 4 of SMF project 2209 which has the overall long-term objective of developing a strategy for restoration of seagrasses to areas where they have been lost due to human activities in Whangarei Harbour. We review and critique seagrass restoration techniques that have been used elsewhere in the world, and provide advice on the best practicable options to consider for Whangarei Harbour. We outline a series of steps required to make decisions on embarking on a seagrass restoration plan by:

1. Identifying a suitable restoration site and requirements for environmental enhancement (Flow Chart I).

2. Assessing techniques for transplanting including requirements for local trials (Flow Chart II).

3. Outlining monitoring requirements (Flow Chart III).

Most seagrass restoration attempts have been conducted in the United States and Australia with other examples from Europe and Japan. As far as we are aware, with the exception of a NIWA trial in Manukau Harbour (Turner, 1995; Morrisey and Turner, 1996) there are no formally documented re-planting trials in New Zealand. Transplant attempts in the United States, where the majority of seagrass transplants have occurred, have had mixed success. To date it is estimated that >50% of transplantation efforts have failed. However, much has been learned in the process and it is important to consider the findings from both the failures and the successes, particularly for taxa with similar growth forms to *Zostera muelleri*, and apply them to any trials that are designed in New Zealand. In addition, each of the steps in this project, and any future trials, must be seen as opportunities to gather information. From this we can learn how to improve techniques and success rates for the New Zealand situation and, specifically, Whangarei Harbour.

As a result of the publication of failures and successes of various attempts, transplanting and restoration techniques have progressed to where they have been included as a chapter in a recent publication, Global Seagrass Research Methods (Short and Coles, 2001). A review of this document and other published case studies enables us to highlight relevant considerations for trials related to restoration of *Zostera muelleri*, in Whangarei Harbour.

International research is used extensively but is supplemented with what we know about the required growth conditions for *Zostera* in New Zealand. To that end, it is intended that this document be updated as further information comes to hand (i.e., results of transplant trials, and additional environmental data such as secchi disc records). The intent is that Northland Regional Council will organise updates when funding is available.

# 2. Required environmental conditions for seagrass habitats in Whangarei Harbour

## 2.1 Rationale for restoration approach

In the context of this study, restoration of seagrass meadows refers specifically to re-establishment of a meadow at a former site of growth. It is widely acknowledged that it is difficult to determine whether a site will be self-sustaining for seagrass (Fonesca et al. 1998). Potential sites for seagrass restoration are generally those with a prior history of their existence (Fredette et al. 1985). The chronic absence of seagrass from a site, especially when there are propagule sources nearby, usually indicates that the site cannot consistently support seagrasses.

If a potential restoration site is known to have suffered a loss of seagrass (e.g., Table 2 in Reed et al. 2004), the activity which originally caused the loss must have ceased and conditions improved. Under such improved conditions, the restoration approach is supported by overseas findings that suggest that natural recolonisation is almost always a chance occurrence, strongly influenced by disturbance events, and management practices should not rely totally on natural recolonisation to restore coverage.

In Phase 1 of the feasibility study to investigate the replenishment / re-instatement of seagrass beds in Whangarei Harbour, Reed et al. (2004) conducted a thorough review of the current and historical extent of seagrass in Whangarei Harbour. The historical loss of seagrass from specific sites was documented, and historical decreases in water clarity, through markedly increased sediment loadings, were attributed to causing this loss. However, data collected since 1994 for Whangarei Harbour indicate there has been a subsequent improvement, and that water quality, water clarity, temperature, and metal contamination in sediments have not been at levels that are known to limit seagrass growth in areas where seagrass beds were once located. Anecdotal evidence suggests that where pockets of seagrass are found today in Whangarei Harbour, these beds started to recover naturally about 4–5 years ago. This is encouraging in that it suggests the low water clarity and changing sediment conditions identified by Reed et al. (2004) as possible causes of seagrass loss in the past, have improved sufficiently as to provide a rationale for continuing with preparations for a restoration trial.

## 2.2 Environmental conditions

Ensuring sufficient light, moderate nutrient loads (Dennison et al. 1993; Fonseca et al. 1996; Kenworthy and Fonseca, 1996; Short and Burdick, 1996) and protecting plantings from disturbance are major considerations for developing a persistent seagrass bed. In task 2 of this project we reported on environmental conditions at three sites in Whangarei Harbour. These conditions included water clarity, substrate, water column nutrients, organic matter, salinity and temperature. A list of environmental considerations relevant to New Zealand's *Zostera* is given in Table 1. Table 1 lists selected environmental parameters in a nominal order of priority. The first three parameters: water depth, elevation and water clarity, are discussed in more detail here with reference to New Zealand (focussing on Whangarei Harbour) conditions.

At the top of the list is water depth, which for an intertidal seagrass (the predominant growth form in mainland New Zealand estuaries) is inextricably linked to elevation, number of hours the plants are exposed at low tide and water clarity.

*Zostera* in New Zealand can carry out photosynthesis and grow both while exposed and while covered with water (Schwarz, 2004), however the extremes of these two conditions can sometimes be limiting for photosynthesis and growth. For example, at the upper end of the tidal range where plants are exposed for the longest duration during any one tidal cycle, plants are exposed to high light levels and the chance of there being insufficient light for photosynthesis is small. There is, however, a much greater chance of plants drying out, especially on hot summer days, and this can result in photosynthesis becoming inhibited. Conversely, at the lower end of the tidal range where plants may only be exposed for periods of less than an hour on some tides, reduced water clarity may mean there is insufficient light over the course of a day for the plants to achieve a net photosynthetic gain. Somewhere in the middle is therefore likely to be optimal (Figure 1).

While some quantitative data exist on the relationship between light availability and photosynthesis for New Zealand seagrasses (Schwarz, 2004), and therefore an ability to estimate the potential downslope (sub tidal) limit, there are no quantitative models anywhere in the world to describe the relationship for the upslope limit. This limit is likely to depend on features such as how sheltered the bay is, elevation, number of hours plants are exposed at low tide, suitability of substrate etc. In practice, the upslope limit for seagrass growth is somewhere lower than the high tide mark and for the purposes of planning a re-planting trial we are best served by observing extant seagrass beds in nearby locations (e.g., Figure 2).

**Table 1:** Key environmental parameters requiring consideration when selecting seagrass restoration sites. The approximate ranges of suitable conditions for *Zostera spp.* in Whangarei Harbour are summarised or extrapolated from a number of general references including Larkum et al. 1989; [1] Hemminga and Duarte, 2000; [2] Hemminga 1998; [3] Erftemeijer and Koch 2001; [4] Fonseca et al. 1996; [5] Turner and Schwarz, 2003. Where actual values are cited the specific references are noted with superscripts.

| Parameter | Too little | Suggested optimum relevant to Whangarei Harbour | Too much |
|---|---|---|---|
| Water depth (m) (average high tide) | wave exposure/ desiccation | Approx 0.5 to 2.0 m | Insufficient light |
| Elevation / Emersion [5] (hours) | 6 hours desiccation | Moderate 2 – 5 hours | 0-1 hour insufficient light |
| Water clarity (secchi depth (m)) | < 0.5 | > 0.5 (depending on the location of the seagrasses on the intertidal zone) | N/A |
| Wave and current exposure[4] | N/A | Current speeds < 0.5 m $s^{-1}$ | Exposed site = uprooting of plants and/ or excessive sediment movement. Storms can uproot large areas of seagrass. |
| Sand in substrate[5] | Clay/silt | Silt/sand | Sand |
| Nutrients[2] | Limiting | Average water column concentrations for seagrasses Ammonium 3.1µM<br>Nitrate 2.7 µM<br>Phosphate 0.35 µM | Toxic (> 25µM ammonium) |
| Organic matter[3] | <0.5% | 0.5 – 6% | High organic content (>16.5%) = reduced compounds such as sulphide that are toxic to plants |
| Salinity[1] | Fresh water | Tolerant of a wide range of salinity | Full strength seawater will not pose a problem |
| Temperature | Unlikely for frost damage at low tide to be a major issue in Whangarei Harbour | Likely to be acclimated to ambient harbour temperature | Extreme temperatures can affect growth via photosynthesis, respiration, nutrient uptake etc. |

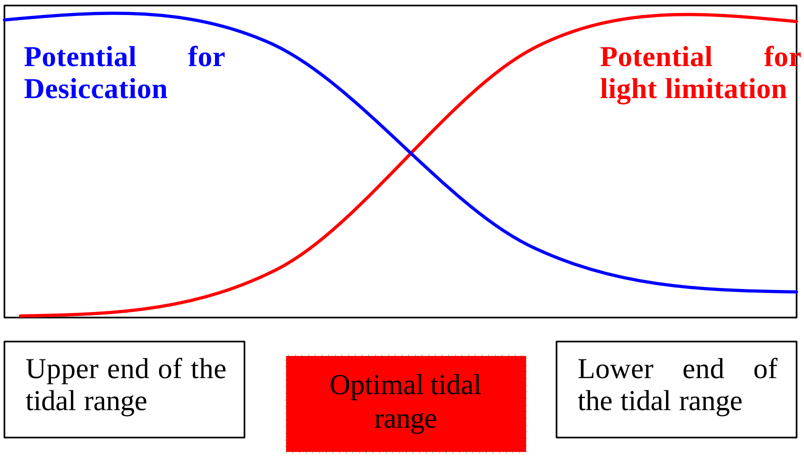



**Figure 1:** Stylised depiction of constraints on intertidal seagrass growth at the upper and lower parts of the intertidal.

**FIGURE REMOVED**

**Figure 2:** The shallow depth zone or upslope limit (white line) within which seagrasses have not established to date at One Tree Point West in Whangarei Harbour. The reasons may include too long an exposure time at low tide, excessive wave disturbance, unsuitable substrate etc. For the purpose of Figure 3 this has been approximated as the upper 20 cm depth range of a mean high tide.

As a relatively simple way of visualising the intertidal zone for Whangarei Harbour sites, we refer to water depths at high tide as a reference point. This is relevant for seagrasses because of the importance of water clarity to seagrass growth. As highlighted in the preceding report (Reed et al. 2005), intertidal seagrasses experience 100% of incoming irradiance when exposed at low tide (notwithstanding that some leaves will shade others when lying flat on the sediment), however, they are also able to carry out photosynthesis when submerged, depending on water clarity.

An average tidal range for Whangarei Harbour (neither neap nor spring) is around 2 m. Hence we have assumed that the intertidal zone to a maximum depth of 2 m on such a tide is available for seagrass growth. This depth range is illustrated by the green zone on Figure 3. In Figure 3 we have drawn the line which equates to the secchi depth required to ensure 40% of incident irradiance reaches the sediment surface (and therefore the seagrasses) at a range of water depths over the intertidal zone at high tide. 40% is a conservative estimate (based on the author's unpublished data) expected to provide ample light for growth of intertidal seagrass beds in New Zealand.

Two intersecting lines are drawn on Figure 3 as an example of how the 40% line can be used to estimate where seagrass beds could grow if all other environmental conditions were suitable (sediment type, organic matter, exposure etc.). The dotted line shows that if secchi depth was on average 2 m, we predict that seagrasses could only be maintained at a tidal level equivalent to 1.2 m water depth or shallower at high tide. Another way of using the diagram is to say that if the aim is to maintain seagrass growth at a water depth of 2 m at high tide (i.e., the full intertidal range) an average secchi depth of 3 m is the target (red line).

These values are only approximate as water clarity varies markedly over time in a harbour environment and a requirement for 40% of incident irradiance at high tide is a very conservative estimate. However, this is the sort of relationship that could be revisited for Whangarei Harbour, once a long term data set on secchi depth has been collected along with regular recording of the location of the lower limit of seagrass growth at the water clarity monitoring sites.

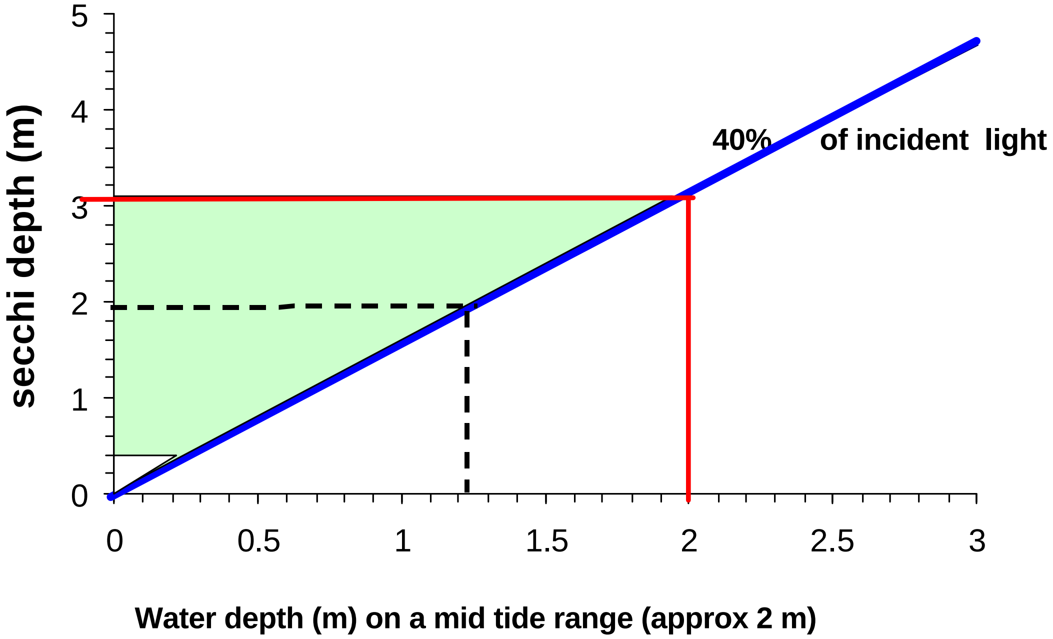



**Figure 3:** The intertidal zone in Whangarei Harbour on an average tide (excluding the shallowest 20 cm) and the outer limits for consideration of the intertidal area available for a transplant trial (green area). The blue line indicates the secchi depth required to maintain 40% of incident for a given water depth during high tide. See text for explanation of red line and dotted line.

# 3. Assessing suitable sites for restoration of seagrass beds in Whangarei Harbour

## 3.1 Site selection

Six sites were selected in the earlier phase of this project and three were investigated in detail (Reed et al. 2005). The sites were One Tree Point-west where seagrass exists as stable beds, Takahiwai where seagrass grows as patches (or have been transitional over many years) and One Tree Point- east (Marsden Point) where seagrass no longer exists but was once present in the mid-1940s.

**Table 2:** Suitability of three sites in Whangarei Harbour. Two of the sites currently support some seagrass beds, providing a test for the environmental conditions we are proposing as being required.

| | Site 1. One Tree Point West | Site 2. Takahiwai | Site 3. One Tree Point East |
|---|---|---|---|
| Water depth (m) (average high tide) | v | v | v |
| Elevation Emersion (hours) | v | v | v |
| Water clarity (secchi depth) | v | v | v |
| Wave exposure | v | v | v |
| Sediment type | v | v | — |
| Nutrients | v | v | v |
| Organic matter | v | v | — |
| Salinity | v | v | v |
| Temperature | v | v | v |

Using the findings from Reed et al. (2005) and Flow Chart I we propose that Site 1 be used as a donor site and Site 2 (where seagrasses exist, albeit at low cover, and apparently have only recovered in recent years) be used for initial replanting trials to assess technique suitability for Whangarei Harbour. Should replanting be successful at site 2, then site 3 could be considered as a future restoration site. Replanting is likely to be successful at site 3 only if the techniques used enable the seagrasses to persist long enough to modify the environment, i.e., by trapping fine sediment and retaining organic matter.

All three sites listed above had a secchi depth > 2.85 m on 30 November 2004 (Reed et al. 2005). According to Figure 3, if this was an average value, conditions would only be suitable for seagrass growth to a depth of 1.8 m on a mean high tide. We recommend regular water clarity monitoring to better quantify average water clarity at the three sites. The NRC is planning to measure secchi depth routinely in their bi-annual surveys at all sites, however, for the restoration attempt, we recommend measuring water clarity monthly for a year.

### 3.2 Source material

We recommend that material for replanting trials is sourced from within Whangarei Harbour. Elsewhere, concerns regarding genetic diversity have been considered best met by selecting planting stock from beds throughout the water body that are closely connected with the planting site (Fonesca et al. 1996). In addition, conditions at the donor site should be matched as closely as possible to the receiving site (i.e., sediment type, exposure, water depth, water clarity, temperature salinity) and for any trials in Whangarei Harbour we recommend that One Tree Point: West, where stable beds exist, is considered as a donor site for trials.

# 4. Techniques for transplanting and requirements for trials

## 4.1 Choose donor and transplant site

Once a suitable donor and transplant site have been identified (FLOW CHART I) the next step is to choose a transplant method. Relevant considerations include identifying a suitable transplant unit and technique and considering the potential for habitat enhancement (Campbell, 2000). A transplant or planting unit, is the group of shoots that will be monitored for success, i.e., one sod, one mesh of defined area (e.g., 1.0 $m^2$) with many sprigs, or 1 group of peat pots (e.g., within a 1.0 $m^2$ area).

## 4.2 Choose transplant method

The first decision to make on replanting is whether to use a seed propagule or a vegetative propagule. Given that *Zostera* in New Zealand appears to reproduce primarily through vegetative reproduction (reviewed in Turner and Schwarz, 2003), vegetative propagules are the natural choice for replanting trials. Currently there is insufficient knowledge of the frequency, success and growth conditions required for seedling production and survival for *Zostera* in New Zealand.

A summary of transplanting methods for vegetative propogules from the international literature is presented in Table 2 and those potentially suitable for trials for *Zostera* in New Zealand and in particular, for Whangarei Harbour, are identified. There are some essential considerations that are fundamental to maximising the potential for replanting success. Some of these aspects are related to the biology of *Zostera muelleri* and so will be directly applicable to the New Zealand situation, others are generalised from the literature. A better understanding of the relative importance of each consideration will be an important objective of any Whangarei re-planting trials.

Considerations include:

1. Removal of plant from donor area, possible cultural issues for iwi.

2. *Bioturbation.* Prior to rooting and coalescence of plantings, seagrasses are especially vulnerable to bioturbation (Fonseca et al. 1994). In New Zealand, bioturbation may result from birds, rays or infauna, and we recommend the use of cages, as one treatment of a trial.

3. *Time of year.* The recommendation for planting time is that it be just after the period of highest seasonal stress. In northern New Zealand this could be hot, dry summer days or it could be winter storms and low temperatures. Currently we have insufficient information to be definitive about which is the best option for Whangarei Harbour. However we recommend that autumn or spring be the planting time of choice. If sufficient resources were available then both could be built into a transplant trial.

4. *Choice of planting stock.* Ensure sufficient young shoots and growing meristems (see Figure 4) to make up for mortality as well as seasonal influences that might affect planting successes (i.e., storms, high temperatures/ desiccation). Ensure growing apical meristems in all planting units, maximise number of shoots on horizontal rhizome.

5. *Handling of material.* Collect and plant on same day, handle gently, avoid desiccation. Less stress and disturbance if plants and sediment remain intact.

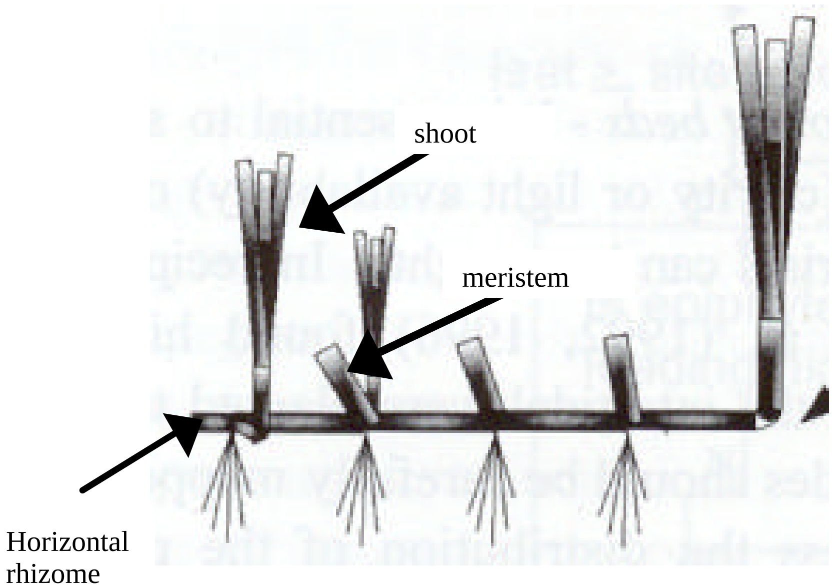



**Figure 4:** Stylised diagram from Short and Short (2000) showing the relevant parts of a *Zostera* plant to be considered in selecting transplant units.

**Table 2:** Methods for restoring seagrass from Hemminga and Duarte (2000); Campbell (2000); Morrisey and Turner (1996).

| Transplant Method | Brief description | Advantage | Disadvantage | Suitable for using in Whangarei Harbour |
|---|---|---|---|---|
| Sods/turf | Shovelful of seagrass with sediment and rhizomes intact, placed into a new hole dug at restoration site | Simple method especially for relatively shallow rooted species such as *Zostera* may be easier than plugs to target actively growing shoots | Transporting plants and sediments results in heavy weights | Yes |
| Sprigs | Dig out material, rinse sediment off, keep wet, plant directly into the new bed or anchor in the surface with appropriate device, preferably biodegradable. | Suitable if density of active growing shoots (apical meristems) is not high and so must be carefully selected from donor material | Important to avoid damage and desiccation. Require some sort of attachment method. Shown to be more successful for sub tidal transplants rather than dynamic intertidal zone, however, some success in a NZ trial. | Yes |
| Plugs in peat pots | 15 cm diameter plugs containing whole plant including leaf blades, roots, rhizomes and surrounding sediments. Collect from edges of patch to ensure inclusion of at least one apical rhizome meristem. | Plugs can be extruded into a biodegradable peat pot which can be stacked and easily planted, amount of material collected is less than sods keeping weight down. | Important to ensure an apical meristem is included. For *Zostera* in New Zealand, this varies from place to place. Removal of plugs also removes sediment from the donor site which may become susceptible to erosion. | Yes if suitable density of active meristems can be found at donor site |
| **Habitat enhancement method** | | | | |
| Artificial seagrass (ASG) mats* | Plastic mesh with an artificial (plastic) seagrass plant attached. Mats are anchored in place for a period of months prior to transplanting of live material into the 'new' habitat. Stabilises sediment, minimises erosion and increases accretion rate so plants can establish roots. | If habitat is sub-optimal, enhances habitat so transplant success rate increases. Can be used with sprigs or plugs | 50% survival rate, variable growth rate (low – high). Expensive; ASG mats are plastic mesh base units (mesh size 60 x 40mm) with an artificial plastic shoot attached to each cross bar (864 shoots $m^{-2}$) (Campbell & Paling, 2003). | May be necessary to consider eventually at One Tree Point East |
| Mesh only | Weave individual or clumps of sprigs to mesh | May enhance stability in early stages of establishment | Increases time required to conduct transplants, care needed with small fragile *Zostera* plants not to damage meristem. | Yes |
| Integrated catchment management | This approach addresses downstream impacts of land runoff. | Best Management option to control water quality (nutrients, runoff from land, burial (coastal dev / dredging), erosion, turbidity and storms. | Long time to implement. May require long time- scales for Harbour to recover. | Yes, good for future recovery. Important for successful replanting. |

Rhizome growth rates for *Zostera* in New Zealand measured by Turner et al. (1996) were around 86 cm $yr^{-1}$. Although for a different taxa, this magnitude of extension rate exceeds that considered by Campbell (2000) as high for *Posidonia australis* and so on the basis of Campbell's (2000) decision tree for planting units suggests that sprigs or plugs are a suitable transplanting unit to trial. Of these, plugs have been the most successful transplant method in overseas examples (Campbell, 2002). After much trial and error most projects currently use either small sods or sprigs of sediment free planting units (Calumpong and Fonseca, 2001). In New Zealand, Turner (1995) and Morrisey and Turner (1996) used methods equivalent to sprigs and sods in the Manukau Harbour with some short term success. They reported that sprigs were the most cost-effective method in terms of the likelihood of success in relation to labour required.

## 4.3 Design trial and conduct transplants

Provision of the specific details of a suitable planting trial in Whangarei Harbour are beyond the scope of this proposal, however, using the information provided in this document the Kaitiaki group and Regional Council should be able to design such a trial in collaboration with a suitable research provider. On the basis of work done to date we recommend that: a trial be undertaken to evaluate and develop three methods for replanting of *Zostera* in Whangarei Harbour in the following order of priority:

1. Sprigs with and without mesh.
2. Sods / turf.
3. Sprigs with and without artificial seagrass mat.
4. Peat pot method with and without artificial seagrass mat.

The size and number of transplant units needed at the receiving site depends on the scale of restoration. This proposal suggests trials should be small scale (several $m^2$) at this stage.

# 5. Development of a monitoring plan

Suitable indicators are required to establish growth/expansion of transplants and the success of any habitat enhancement (erosion and accretion and sediment grain size if appropriate) and transplant success, which can be measured using several parameters (e.g., survival, percent cover, shoot density). We have chosen to adopt the definition of Fonseca et al. (1998) and define seagrass planting success as the unassisted persistence of the required area of seagrass coverage. This method is non-destructive, cost-effective and relatively simple. In addition, it answers the most important question, are plants surviving and are they growing and increasing in the area? More detailed questions such as "*how are they spreading*?" and "*what are their habitat values?*" are questions better addressed once a successful transplant technique has been developed for Whangarei Harbour.

In order to promote effective restoration and mitigation, one must have an unambiguous definition of success. In a critical review of various techniques, Fonseca et al. (1998) concluded that simple measures of seagrass coverage and persistence are the most practical and informative choices of monitoring parameters. An important reason for this choice is that many habitat functions (e.g., animal abundance) appear to relate simply to coverage and persistence of that coverage; parameters that are inexpensively monitored (Fonseca et al. 1990; Meyer et al. 1990; Fonseca et al. 1998).

The measures that we recommend are:

1. Number of planting units surviving.

2. Areal coverage of planting units.

3. Quantifying shoot number requires destructive sampling and is unlikely to be recommended as part of a small scale trial, however, it may be included if trials are scaled up at a later stage. This technique is recommended in addition to measurements of the actual area that the plants are covering because it is a more accurate means of assessing the vigour of the plantings. An non-destructive alternative to shoot number for the case of Whangarei Harbour is to assess % cover within the newly expanding areas. Examples of such estimates are shown in the photos from Takahiwai in Whangarei Harbour (Figure 5).

**FIGURE REMOVED**

**Figure 5:** Quadrat method for assessing percent cover of seagrass at Takahiwai.

## 5.1 Monitoring frequency

A range of recommendations for the timing of monitoring are made from different case studies. Some studies suggest monitoring transplants every month for the first year and then once yearly for 5 years. Others suggest monitoring restoration or natural recovery in the first year over a quarterly or seasonal scale and then annually. As part of the details of the trial design it will be necessary to develop a suitable monitoring strategy that evaluates an appropriate frequency of monitoring. The monitoring plan will also measure the recovery of the donor site.

For *Zostera* in Whangarei, we suggest that monitoring of the number of planting units and the area covered by each planting unit, should at a minimum, be done quarterly for the first year after planting and twice a year thereafter. Fonseca et al. (1998) propose that for *Zostera* spp, monitoring should continue for a minimum of three years (FLOW CHART III).

After planting units begin to coalesce and individual units can no longer be discerned, then the area covered by plants and shoot density (or % cover within quadrats) should continue to be recorded, but counts on a planting unit basis can be suspended. In a programme designed to monitor transplant success it is important to consider how to deal with loss / death of planting units. Ultimately mistakes may be made in selecting the site and repeated plantings may fail therefore there needs to be a time at which a decision is made to terminate a cycle of continual replanting. Fonseca et al. (1998) recommend that only rarely should any additional replanting be allowed on the original site after two remedial tries. At that point a new site should be considered. Ideally, an alternate site would be selected in the initial site-selection process. When replanting occurs then the monitoring clock and frequency of monitoring is reset to time zero as in FLOW CHART III. When replanting has already occurred twice, it is recommended that no further replanting occurs. Depending on the scale of loss, the remaining plants can continue to be monitored or the site can be discarded.

### 5.2 What do we already know for New Zealand?

Turner (1995) and Morrisey and Turner (1996) report on one of the only other seagrass restoration trials that has been undertaken in New Zealand. Sod techniques, core (or plug) techniques and sprig techniques (see Table 2) all yielded some degree of success in Manukau Harbour, however, after 6 months that success started to decline. In that case it was thought that autumn storms had increased sediment transport and scouring as well as sediment re-suspension and reduced water clarity. This experience highlights the importance of site selection and of continuing to conduct site specific trials before any extensive transplanting occurs.

## 6. Flow charts to use in decision making

The following three flow charts summarise the steps to be taken in:

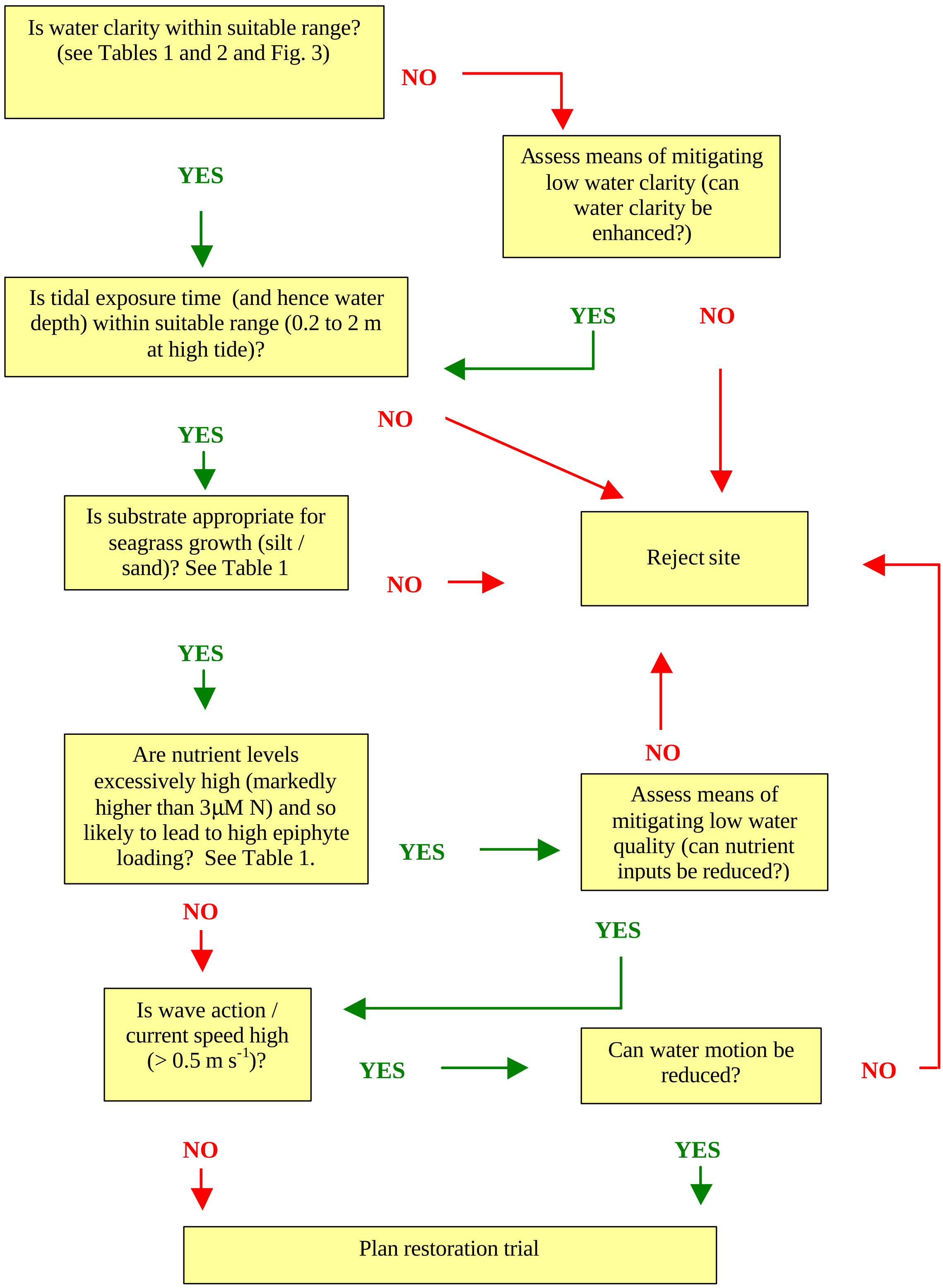
FLOW CHART I: Identifying a restoration site.

FLOW CHART II: Planning a restoration trial.

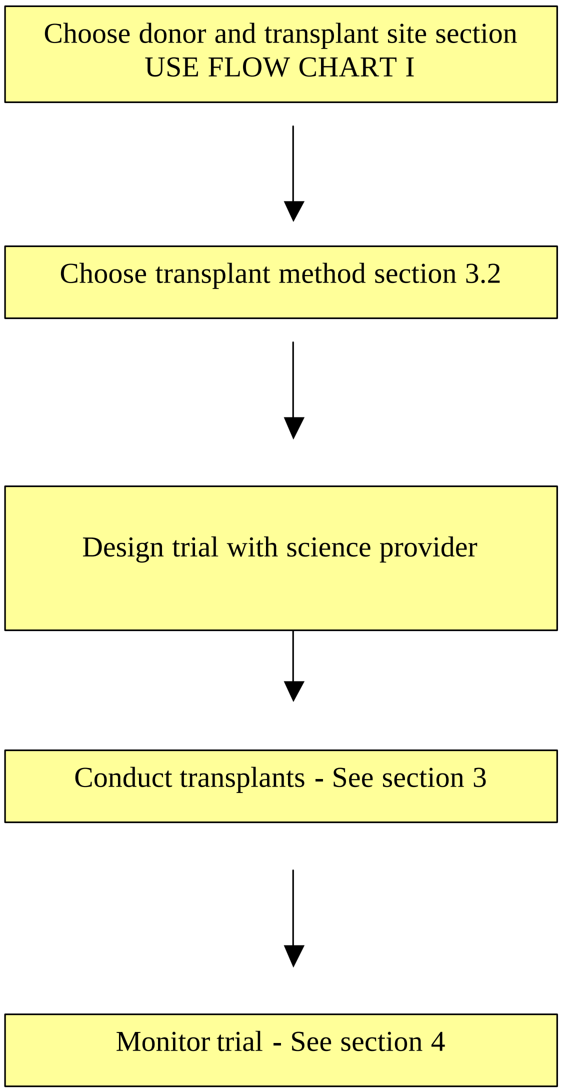
FLOW CHART III: Monitoring a restoration trial.

The details for each of these steps are outlined in the preceding document, and referenced accordingly. At the time of a trial being designed for Whangarei Harbour we recommend that consideration be given to the scale of the trial and available resources in order to specifically define the frequency of monitoring and trigger points for action.

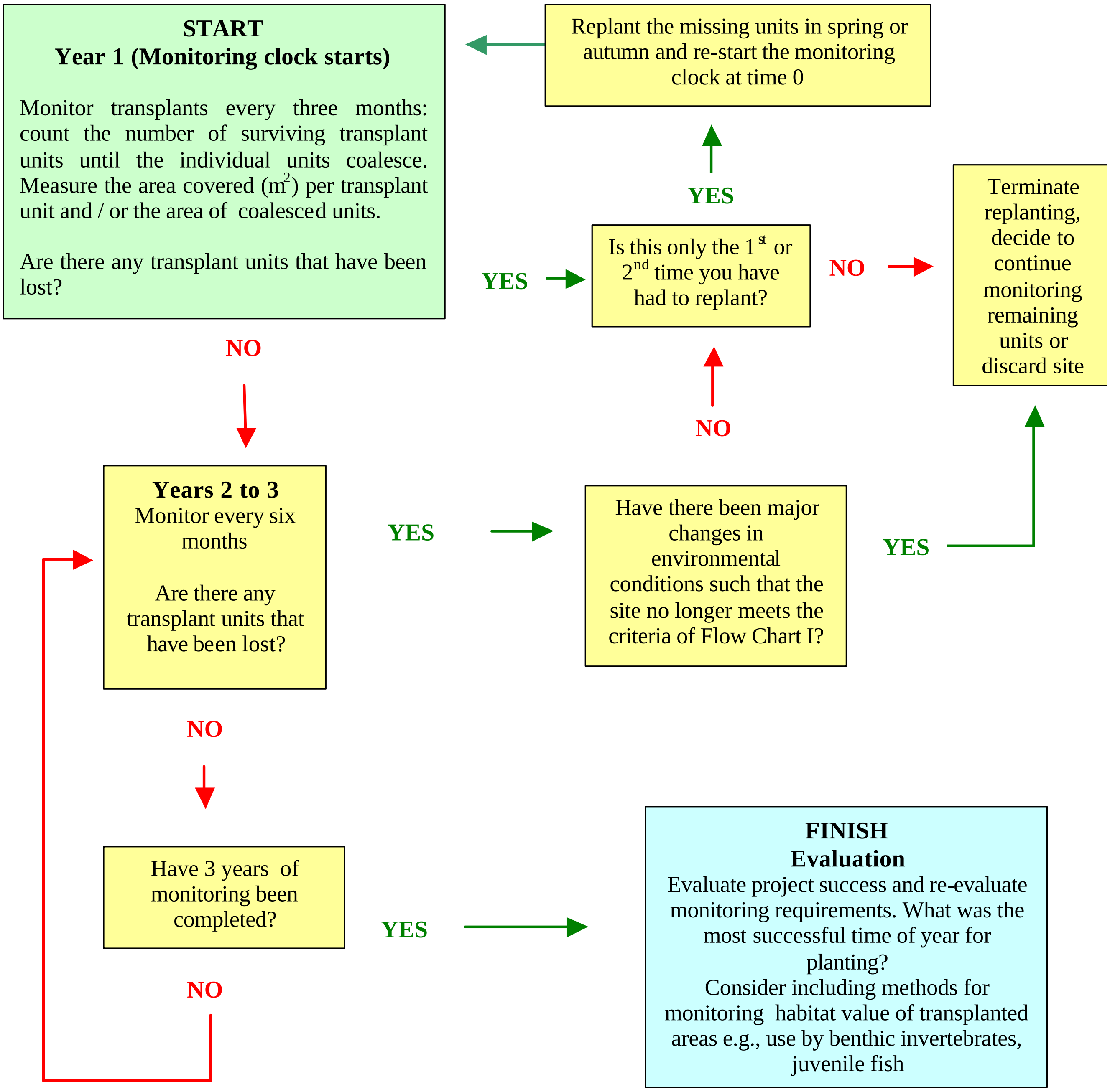
**FLOW CHART I: IDENTIFYING A RESTORATION SITE AND REQUIREMENTS FOR ENVIRONMENTAL ENHANCEMENT: Use Tables 1, 2 and Figure 3 to make these decisions.**



## FLOW CHART II: RESTORATION TRIAL



## FLOW CHART III: MONITORING A RESTORATION TRIAL



# 7. Conclusions

There have been a wide range of techniques tested for the restoration of different seagrass species throughout the world, however there have been no large scale attempts at restoration in New Zealand. Much has been learnt overseas in recent decades and we are able to draw on that knowledge to set the boundaries for designing a restoration trial in Whangarei Harbour.

In this document we aim to maximize the chance of success of any restoration trial, hence a rather conservative approach to defining environmental requirements (particularly water clarity) has been taken.

We have presented three decision-making trees that we recommend are followed if and when a restoration trial is designed. Each of the trees is backed up by explanatory detail in the preceding pages of the document.

Initially we recommend that a restoration trial be attempted at site 2: Takahiwai. The choice of a site where seagrasses are currently re-establishing helps maximize the chance of replanting success and enables an evaluation of cost effective techniques to occur before moving to locations where no seagrasses currently grow.

We recommend that the following methods be included in a trial. They are listed in order of priority to be determined by resources available.

- Sprigs with and without mesh.
- Sods / turf.
- Sprigs with and without artificial seagrass mat.
- Peat pot method with and without artificial seagrass mat.

We also recommend in the first instance that the location of current seagrass beds in the intertidal zone and water clarity be incorporated into NRC's biannual monitoring programme. In the second instance, if a restoration trial is initiated a commitment to monitoring as outlined in flow chart III must be included. In general, environmental conditions at some sites within Whangarei Harbour appear to be conducive to attempting a seagrass restoration trial. Other sites, apart from One Tree Point- east, ought to be included in an assessment of suitable restoration sites if the trial at Takahiwai is successful.

# 8. Acknowledgements

The authors would like to thank the Ministry for Environment and Northland Regional Council for funding this project (SMF 2209) and the Kaitiaki Group for their involvement and support. The authors are especially grateful to Dr Marnie Campbell at Biosecurity New Zealand for her advice regarding this document.

# 9. References


Calumpong, H.P.; Fonesca, M.S. (2001). Seagrass transplantation and other seagrass restoration methods. In; Short, F.T.; Coles, R.G. (editors). Global seagrass Research Methods, Elsevier Science B.V.

Campbell, M.L. (2000). A decision-based framework to increase seagrass transplantation success. *Biologia Marina Mediterranea*. Proceedings Fourth International Seagrass Biology Workshop, 7:336-340.

Campbell, M.L. (2002) Getting the foundation right: a scientifically based management framework to aid in the planning and implementation of seagrass transplant efforts. *Bulletin of Marine Science 71, 3*: 1405-1414.

Campbell, M.L.; Paling, E.I. (2003). Evaluating vegetative transplant success in Posidonia australis: a field trial with habitat enhancement. *Marine Pollution Bulletin 46*: 828-834.

Dennison, W.C.; Orth, R.J.; Moore, K.A.; Stevenson, J.C.; Carter, V.; Kollar, S.; Bergstrom, P.W.; Batiuk, R.A. (1993). Assessing water quality with submersed aquatic vegetation. *BioScience 43*: 86–94.

Erftemeijer, K. (2001). Sediment Geology Methods for seagrass habitat. In Global Seagrass Research Methods, Elsevier 473 p.

Fredette, T.J.; Fonseca, M.S.; Kenworthy, W.J.; Wyllie-Echeverria, S. (1985). An investigation of eelgrass (*Zostera marina*) transplanting in San Francisco Bay, CA. U.S. Army Corp. of Engineers, San Francisco District. 33 pp.

Fonseca, M.S.; Kenworthy, W.J.; Colby, D.R.; Rittmaster, K.A.; Thayer, G.W. (1990). Comparisons of fauna among natural and transplanted eelgrass *Zostera marina* meadows: Criteria for mitigation. *Marine Ecology Progress Series 65*: 251-264.

Fonseca, M.S.; Kenworthy, W.J.; Thayer, W. (1998). Guidelines for the Conservation and restoration of Seagrasses in the United States and Adjacent Waters NOAA'S COASTAL OCEAN PROGRAM. Decision Analysis Series No. 12.

Fonseca, M.S.; Meyer D.L.; Hall, M.O. (1996). Development of planted seagrass beds in Tampa Bay, Florida, USA. II. Faunal components. *Marine Ecology Progress Series 132*, 141-56

Fonseca, M.S.; Kenworthy, W.J.; Courtney, F.X.; Hall, M.O. (1994). Seagrass planting in the Southeastern United States: Methods for accelerating habitat development. *Restoration Ecology 2*: 198-212.

Hemminga, M.A.; Duarte, C.M. (2000). Seagrass Ecology. Cambridge University Press. 298 p.

Hemminga, M.A. (1998). The root/rhizome system of seagrasses: An asset and a burden. *Journal of Sea Research 39*: 183-96.

Kenworthy, W.J.; Fonseca, M.S. (1996). Light requirements of seagrasses *Halodule wrightii* and *Syringodium filiforme* derived from the relationship between diffuse light attenuation and maximum depth distribution. *Estuaries 19, 3*: 740-750.

Larkum, A.W.D.; McComb, A.J.; Shephard, S.A. (1989). Biology of Seagrasses. A treatise on the biology of seagrasses with special reference to the Australian Region. Elsevier 841p.

Morrisey, D.J.; Turner, S.J. (1996). Experimental Restoration of seagrass beds. *Conservation Science Newsletter* No. 20.

Meyer, D.L.; Fonseca, M.S.; Kenworthy, W. J.; Colby, D.R.; Thayer, G.W.; LaCroix, M.J.; Murphy, P.L.; Currin, C.A.; Ferguson R.L.; France B.A. (1990). SWIM Final Report. Florida Dept. Nat. Res. St. Petersburg, Fla. Contract No. C4488. 31 pp.

Reed, J; Schwarz, A.; Gosai, A.; Morrison, M. (2004). Feasibility study to investigate the replenishment/reinstatement of seagrass beds in Whangarei Harbour – Phase 1. p 22.

Reed, J; Schwarz, A.; Morrison, M. (2005). Feasibility study to investigate the replenishment/reinstatement of seagrass beds in Whangarei Harbour-Phase 2. NIWA client report to Northland Regional Council.

Schwarz, A. (2004). The contribution of photosynthetic gains during tidal emersion to production of *Zostera capricorni* in a North Island, New Zealand estuary. *New Zealand Journal of Marine and Freshwater Research 38*: 809-818

Schwarz, A.; Matheson, F.; Mathieson, T. (2004). The role of sediment in keeping seagrass beds healthy. *Water and Atmosphere 12 (4)* 18-19.

Short, F.T.; Burdick, D.M. (1996). Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. *Estuaries*, *19*: 730-739.

Short, F.T.; Coles, R. (2001). Global Seagrass Research Methods. Elsevier 473 p.

Short, F.T.; Short, C.A. (2000). Identifying seagrass growth forms for leaf and rhizome marking applications. *Biologia Marina Mediterranea.* Proceedings Fourth International Seagrass Biology Workshop. 7:131-134.

Turner, S.J. (1995). Restoring seagrass ecosystems in New Zealand. *Water and Atmosphere 3*: 9-11.

Turner, S.J.; Thrush, S.F.; Wilkinson, M.R.; Hewitt, J.E.; Cummings, V.J.; Schwarz, A.; Morrisey, D.J.; Hawes, I. (1996). Patch dynamics of the seagrass *Zostera novazelandica* (?) at three sites in New Zealand. *In*: Kuo, J.; Walker, D.I.; Kirkman, H. (eds). Seagrass Biology: Scientific Discussion from an International Workshop in Rottnest Island, Western Australia: 21-31.

Turner, S.J.; Schwarz, A. (2003). Information for the management and conservation of seagrass in New Zealand. DOC Report Project 3350. 27p.