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# Feasibility study to investigate the replenishment/reinstatement of seagrass beds in Whangarei Harbour – Phase 1

**NIWA Client Report: AKL2004-33**
**September 2004**

**NIWA Project: NRC04101**

# Feasibility study to investigate the replenishment/reinstatement of seagrass beds in Whangarei Harbour – Phase 1


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# Executive Summary

This report has been prepared for the Northland Regional Council and is Phase 1 of a larger project which has the aim of determining the feasibility of restoring seagrass beds in Whangarei Harbour and, if so, to ascertain the best practicable option and method/s for doing so. The purpose of this report is to assess the current and historical distribution of seagrass in the harbour, to review the environmental conditions that influence the distribution, growth, and resilience of seagrass beds, and to identify the factors potentially affecting these conditions at specific sites.

Seagrass beds in Whangarei Harbour are estimated to have covered ~1400 ha (14km²) prior to the 1960s. This extensive area included both intertidal and subtidal beds. Studies elsewhere in New Zealand and local knowledge suggests that these beds had significant ecological importance as habitat for marine invertebrates, nursery for juvenile fish (e.g. snapper, trevally) and for bird foraging. Today, only small pockets of seagrass are evident in the intertidal zone. Hence restoration of even a modest proportion of the historical beds may well be of significant ecological value to both the harbour ecosystem, and the broader marine environment.

Potential factors that contributed to the loss of seagrass in Whangarei Harbour are an increased rate and degree of sedimentation, accumulation or erosion / removal of sediment at specific sites, increased suspended sediment levels (especially of fine material), changes in sediment texture, and changes to local bathymetry. The potential environmental effects from these factors are likely to have included higher turbidity levels, lower water clarity, exposure to anoxic sediments, and burial of plants, resulting in reduced photosynthesis and growth of seagrasses. Other environmental stressors include contaminant discharges to the Hatea River (from Town Basin to the Port of Whangarei), such as treated (sewage) effluent, industrial spills, leachates from refuse tips, discharges from industrial processes, oil spills and stormwater runoff. The key environmental parameters to target for habitat restoration are water clarity, water quality and sediment condition. We suggest ways that such improvements might be achieved including catchment initiatives involving riparian planting, waste water treatment wetlands and erosion control measures. Identification of appropriate sites for seagrass restoration within Whangarei Harbour will require collection of baseline information on environmental conditions.

# 1 Introduction

Deterioration of seagrass beds has occurred in many places throughout the world as a result of various environmental changes. Such changes are a result of anthropogenic impacts, including pollution, urbanisation and accelerated sediment transport, as well as sea level rise and climate change (Hemminga and Duarte, 2000). Coincident with land use changes, and in concert with other changes in the estuarine landscape, intertidal and subtidal seagrass beds have, in many places, been recorded as either retreating or disappearing entirely from estuarine areas. In New Zealand, while there is insufficient quantitative historical data to quantify the rate or extent of change in seagrass habitats nationally, in some locations sufficient information exists to suggest that similar large declines have happened here (e.g. in Tauranga Harbour; Park, 1999). This is correlated with considerable development of the coastal zone in the last century, which is continuing at a rapid rate through ongoing urbanisation.

Aerial photographs suggest that earlier this century extensive seagrass beds were present in Whangarei Harbour but that many of these beds have since disappeared. This project was commissioned by the Northland Regional Council (contract No. 2209) in September 2003 to determine whether it is feasible to restore seagrasses in Whangarei Harbour and, if so, ascertain the best practicable method for successful regeneration. This report outlines the first phase of this project which has the following three objectives:

1. To assess the current and historical distribution of seagrass beds in Whangarei Harbour.

2. To review and assess environmental conditions that influence the distribution, growth, and resilience of seagrass beds.

3. To identify environmental parameters necessary for optimum seagrass growth in Whangarei Harbour; including an assessment of factors potentially affecting these parameters at specific sites within the harbour.

The second phase of the project (to be reported on separately), has the following objectives:

4. To identify case studies elsewhere in the world where transplanting seagrasses has been successful; and highlight problems and/or limiting factors that should be considered prior to transplanting.

5. To identify the best practical method to trial for restoration of habitat and transplanting of seagrass.

6. To identify suitable sites for transplanting seagrasses (including donor and replenishment sites) in Whangarei Harbour and to provide site specific advice on catchment and environmental initiatives that might be needed prior to transplanting being undertaken.

7. To provide advice on the techniques necessary for monitoring the success of restored and replenished trial areas.

# 2 Methods

To address objective 1, we conducted a digital (Geographic Information Systems - GIS) assessment of aerial photographs, maps and other historical reports of the locations of seagrass beds, to determine their historical distribution and changes in area/coverage over time. In addition, discussions with tangata whenua and other community groups were undertaken to formulate a knowledge-based historical distribution map.

To address objectives 2 and 3, we conducted a desk-top study to review the existing information on seagrass ecology and the environmental conditions that affect the distribution, growth and resilience of seagrass beds. We also collated and reviewed the existing literature specific to Whangarei Harbour, including primary publications, local reports and survey documents, to identify the environmental parameters most relevant to this location and assess the factors affecting these parameters.

# 3 Ecological importance of seagrasses

In the latter half of last century, the ecological importance of seagrasses became recognised in the scientific literature, and is now reasonably well documented worldwide (Hemminga and Duarte, 2000). There are more than 50 species identified globally, which occupy a wide ecological range, from the intertidal zone down to depths of greater than 50 m where water clarity is sufficiently high. Internationally, seagrass beds are considered to be an important marine ecosystem, and one of the most productive, with high biodiversity and habitat value, and playing a vital role in supporting fisheries, protecting other components of the ecosystem (including coral reefs) by binding sediment and reducing turbidity, and providing defence from coastal erosion (Hemminga and Duarte, 2000). Although seagrasses in New Zealand are largely intertidal, similar roles have been recognised here (Inglis, 2003).

Recent research has found that seagrass beds in New Zealand (especially those that remain permanently submerged) are a particularly important habitat for juvenile fish, including snapper, trevally, parore, spotties and pipefish (Morrison and Francis, 2004). Seagrass plays an important role both as a transition habitat for these species, as they move from their larval pelagic phase to settle onto the seafloor as juveniles, and as a protective nursery habitat until they grow large enough to survive in other habitats. Consequently, seagrass is an important estuarine habitat that influences not only the diversity and abundance of small fish found in our estuarine systems, but also the abundance of larger fish on the open coast, including important harvested species. Seagrass beds in New Zealand also support shellfish populations, are considered important feeding grounds for wildfowl, and provide a transitional habitat for migrating birds (Mason and Ritchie, 1979; Inglis, 2003). Seagrass beds thus support a range of animal and plant species, and are a key component of the New Zealand estuarine landscape. Significant loss in extent of this habitat is likely to have negative impacts on ecosystem functioning.

# 4 Seagrass growth rates

The overall growth rate of seagrasses can be an indicator of water quality, and elsewhere in the world relationships between environment and seagrass growth (including leaf length and biomass of shoots, roots and rhizomes) are being developed to use seagrasses as a signal of overall environmental health (Dennison *et al.*, 1993). Biomass is a measure of the net production of a plant and will reflect the environmental conditions under which it has grown.

Seagrass growth rates and production of shoots/roots in New Zealand were summarised by Turner and Schwarz (2003), including a comprehensive study of rhizome growth rate and branching pattern, shoot and leaf production, biomass, plant cover, and patch dynamics of three New Zealand intertidal seagrass beds (Turner *et al.*, 1996). This review suggested that *Z. capricorni* growth and biomass parameters varied among sites and estuaries over time, but were within the ranges measured for the same species elsewhere in the world. The New Zealand average above and below-ground biomass for seagrasses from Turner and Schwarz (2003) are reproduced in Table 1.

Surveys of intertidal seagrass beds within Coromandel Peninsula estuaries, and Otago and Manukau Harbours, have found seagrass leaf length to average 39–113 mm, with 3-5 leaves per shoot. The longest intact leaf was measured as 39.22 mm at Wiroa Island and 54.6 mm at Clarks Beach. Average leaf widths are 1.1–1.8 mm. In the Manukau Harbour and Whangapoua Harbour, Turner *et al*. (1996) measured a mean rate of rhizome growth of 2.05–2.67 mm $day^{-1}$, and mean daily leaf growth rates of 1.89–2.59 mm $day^{-1}$. The greatest rate of patch extension (3.2–3.5 m) occurred in alignment with the prevailing summer wind direction. The rate of extension in winter was around one third (1.2 m) of the summer maximum. Seasonal differences in growth have been reported elsewhere in the world, but there are insufficient annual studies in New Zealand to state definitively the magnitude of seasonal variability. However, Turner and Schwarz (in press) showed that the below-ground biomass in Coromandel Harbours was highest in summer and lowest in winter, and it is likely that seasonal patterns for *Z. capricorni* will mimic those for the same taxa at similar latitudes in Australia. Measurements of shoot growth in New Zealand are similar to those of Australia; 13 days on average for one new leaf in Botany Bay, New South Wales (summer: January/February) compared to 8.1–11.2 days in New Zealand (Larkum *et al*., 1984, Turner and Schwarz, 2003).

Table 1. **Shoot density, above- and below-ground biomass, proportional leaf growth rate and above-ground production of *Zostera* at various locations in New Zealand and Australia (Turner and Schwarz 2003).**

| Species | Location | Shoot density (no. m²) | Above-ground biomass (g DW m²) | Below-ground biomass (g DW m²) | Proportional leaf growth rate (g DW $g^{-1}$ $day^{-1}$) | Above-ground production (g DW m² $day^{-1}$) |
|---|---|---|---|---|---|---|
| *Zostera capricorni* | Port Hacking (NSW) | - | ≈ 22– 65 | 160–200 | Feb/March: 0.035 June/Sept: < 0.01 | Feb/March: 2.5 June/Sept: 0.3 |
| *Zostera capricorni* | Botany Bay (NSW) | Jan: 2176 (±82) July: 1797 (±93) Range of 19 sites Jan: 688 (±144) – 4106 (±320) | Jan: 290 (±9.6) July: 64 (±3.5) | Jan: 707 (±50) July: 610 (±54) | Jan: 0.031 July/Aug: 0.021 | Jan: 8.9 July/Aug: 1.4 |
| *Zostera capricorni* | Moreton Bay (Queensland) | Range of 3 sites: 1135(±90)–5037 (±198) | Range of 3 sites: 38 (± 2.3) – 68 (±4.5 | - | - | - |
| *Zostera capricorni* | Literature compilation | - | 191 | 176 | - | 1.9 |
| *Zostera capricorni* | Cairns Harbour (Queensland) | | Range of 4 sites: Feb: 7 & Nov: 243 | Range of 4 sites: Feb: 15& Nov: 658 | - | - |
| *Zostera novazelandica* | Otago Harbour | 4800-8700 | March: 93-97 Oct: 40-50 | 180-235 | Dec/March: 0.021-0.028 June/July: <0.01 | Dec/March: 1.8-2.0 June/July: 0.2-0.7 |

**Table 1. (contin.) Shoot density, above- and below-ground biomass, proportional leaf growth rate and above-ground production of *Zostera* at various locations in New Zealand and Australia (Turner and Schwarz 2003).**

| Species | Location | Shoot density (no. m²) | Above-ground biomass (g DW m²) | Below-ground biomass (g DW m²) | Proportional leaf growth rate (g DW $g^{-1}$ $day^{-1}$) | Above-ground production (g DW m² $day^{-1}$) |
|---|---|---|---|---|---|---|
| *Zostera capricorni* | Whangamata Harbour | Jan: 3365 (±166) – 4270 (±417)<br>July:2759 (±349) – 2889 (±279) | Jan: 49 (±15.5) – 51 (±7.6)<br>July: 48 (±4.1) – 54 (±4.8) | Jan: 165 (±32.1) – 168 (±23.1)<br>July: 120 (±11.9) – 133 (±14) | Jan: 0.031-0.041<br>July: 0.022-0.028 | Jan: 1.6-2.0<br>July: 1.1-1.5 |
| *Zostera capricorni* | Wharekawa Harbour | Jan: 3202 (±347) – 3564 (±223)<br>July:2040 (±222) – 2318 (±248) | Jan: 65 (±10.8) – 69 (±6.4)<br>July: 49 (±8.2) – 164 (±27.7) | Jan: 256 (±30.2) – 260 (±51.5)<br>July: 223 (±49.7) – 310 (±65.2) | Jan: 0.033-0.037<br>July: 0.016-0.027 | Jan: 2.3-2.4<br>July: 0.8-4.4 |
| *Zostera capricorni* | Whangapoua Harbour | Jan: 3136 (±540) – 3931 (±617)<br>July:2048 (±213) – 3069 (±429) | Jan: 85 (±10.1) – 101 (±19.7)<br>July: 47 (±3.6) – 123 (±8.7) | Jan: 638 (±96.6) – 665 (±110.0)<br>July: 479 (±82.5) – 587 (±123.1) | Jan: 0.029-0.033<br>July: 0.027-0.028 | Jan: 2.4-3.3<br>July: 1.3-3.5 |
| *Zostera capricorni* | 10 central North Island harbours | Jan: 437 (±108) [Manaia]- 5365 (±1505) [Whangapoua] | Jan: 19 (±2.4) [Coromandel] – 150 (±21.4) [Wharekawa] | Jan: 78 (±5.0) [Coromandel] – 481 (±116.3) [Whangapoua] | - | - |

# 5 Seagrass distribution in New Zealand

The focus of this project is on *Zostera capricorni*, currently considered to be the only species found in New Zealand (Les *et al*., 2002). *Zostera capricorni* can be found throughout the North and South Islands, from Parengarenga Harbour to Stewart Island (Inglis, 2003). Despite their wide distribution, seagrasses are sensitive to changes in certain environmental conditions (e.g light, nutrients, sediment type) and the loss of seagrass beds has been recorded in both the North and South Islands. Some seagrass beds in New Zealand's harbours and estuaries (apparently those most impacted by human development) have either disappeared, or been severely degraded, including beds in Tauranga Harbour, Waitemata Harbour, Manukau Harbour, Whangarei Harbour and Avon-Heathcote Estuary (Inglis 2003). Research in Tauranga Harbour suggests that subtidal beds are most at risk with a 90% loss reported for the period 1959 to 1996, compared to 34% for all beds for the same period (Park, 1999). Losses have been variously attributed to excessive sedimentation from catchment development and dredging and/or increased levels of nutrients and contaminants from urbanisation stormwater runoff, wastewater and other discharges. However, the relative influence of these factors on the loss of seagrass beds in New Zealand is not well known, and is likely to differ among estuaries. In Tauranga Harbour, sediment and nutrient runoff is suggested as the main factor involved in seagrass loss (Park, 1999). The environmental conditions most suitable for optimum seagrass growth and health have been reported in the international literature, but only recently have studies been undertaken in New Zealand (Inglis, 2003; Turner and Schwarz, 2003; Schwarz, in press).

Extensive areas of intertidal seagrass still occur in New Zealand, including Parengarenga Harbour, Farewell Spit, Whanganui Inlet and estuaries of the eastern Coromandel Peninsula (Inglis 2003). Notably these sites are located in less urbanised areas.

# 6 Current and historical extent of seagrass in Whangarei Harbour

The Whangarei Harbour is a nationally significant ecosystem, with its habitats being heavily utilized by a range of migratory birds (Ogle 1984; SSBI: Q07/H050). Part of the harbour has been designated as an Area of Significant Conservation Value in recognition of these values (Anderson *et al*., 1994), incorporating an area below mean high water spring from Busby Head to downstream of the Hatea River (excluding the Port Management Areas). Estuarine habitats found in the harbour include seagrass beds, mangrove forests, saltmarsh, intertidal and subtidal muds, sands, shell gravels, and rock substrata.

Historical aerial photographs from the 1940s show extensive seagrass beds seaward of Papich Road, in Marsden Bay, and in isolated pockets close to the causeway (Poynter 1997). Large areas of Snake and MacDonald Banks and the Takahiwai-Skull Creek sandflats, were also covered with seagrass in the late 1940s (Parrish, 1985). The approximate aerial extent of seagrass beds in 1942 was 14.34 km² (Figure 1). This value is based on aerial photos taken in May 1942 and is approximate because photos are not geo-rectified. Examples of seagrass beds taken from aerial photos in May 1942 are shown in Figure 2. Seagrass beds were obviously once very extensive and included subtidal beds which have been shown through recent studies elsewhere in New Zealand to be disproportionately important as a habitat for marine invertebrates and as juvenile fish nurseries (particularly for snapper and trevally).

The location and areal extent of seagrass beds in 1966 are shown in Figure 3 and Table 2, as captured by aerial photography (5032/18-19; 12 June 1966) (Bioresearches, 1976; Dickie, 1984). Most of these seagrass areas had disappeared by 1971 (Bioresearches 1976, 1979). Aerial photos taken in 1970 show that there are no obvious seagrass beds remaining in the harbour.

A field survey undertaken in 1983 found small patches of seagrass at a low percentage cover in Blacksmiths Creek, near Onerahi, and at Waikaraka in the Oakleigh Creek (Whangarei Harbour Study 1983), with no extensive beds being located. A report by Bioresearches Ltd (1979) documented seagrass patches under mangroves in Parua Bay and south of Rabbit Island. This report also documented local increases in seagrass cover in the One Tree Point area. No recent surveys have been undertaken.

In Whangarei Harbour, losses in seagrass extent have been identified as a priority concern for iwi and local community groups. The Regional and District councils have recognised these concerns, and are committed to investigating the possible restoration and maintenance of seagrass beds. Community groups and iwi are prepared to actively participate if restoration is possible. The Kaitiaki Group of Whangarei has identified some areas of the harbour that were once covered in seagrass beds. Specific timescales of these areas are shown in Figures 4-7. This is the first community knowledge-based map of seagrass for this area. Additional information will be added to this GIS layer as information becomes available.

**FIGURE REMOVED**

**Figure 1.** **Distribution of seagrass beds in Whangarei Harbour in 1942. (From Aerial photos supplied by DOC, Whangarei).**

**FIGURES REMOVED**

**Figure 2.** **Seagrass beds at (a) One Tree Point and (b) Snake Bank in Whangarei Harbour in 1942. (From Aerial photos supplied by DOC, Whangarei).**

**FIGURE REMOVED**

**Figure3.** **Distribution of seagrass beds in Whangarei Harbour in 1966. (From: Morrison, 2003).**

**FIGURE REMOVED**

**Figure 4.** **Distribution of seagrass beds in Whangarei Harbour between 1940-1970 based on Kaitiaki knowledge.**

**FIGURE REMOVED**

**Figure 5.** **Distribution of seagrass beds in Whangarei Harbour between 1950-1970 based on Kaitiaki knowledge.**

**FIGURE REMOVED**

**Figure 6.** **Distribution of seagrass beds in Whangarei Harbour between 1950-1980 based on Kaitiaki knowledge.**

**FIGURE REMOVED**

**Figure 7.** **Distribution of seagrass beds in Whangarei Harbour between 1962-1970 based on Kaitiaki knowledge.**

# 7 Environmental conditions that influence the distribution, growth, and resilience of seagrass beds

Restoration of seagrass beds through habitat improvement and / or transplanting has been used with varying degrees of success internationally, but at present there is no precedent for extensive restoration in New Zealand. As a first step towards both halting seagrass declines, and potential restoration efforts, the environmental conditions necessary for healthy seagrass growth must be understood.

Only a limited number of studies have focussed on the habitat requirements of seagrasses in New Zealand, and few seagrass beds have been mapped. Here we summarise relevant New Zealand studies, and use overseas examples to provide additional information.

## 7.1 Light

Light levels are recognised as one of the primary resources limiting the growth of most seagrasses (Hemminga and Duarte, 2000). Highest above-ground biomass, number of leaves per shoot and shoot density are typically associated with spring-summer-autumn periods, coincident with higher light intensities and associated higher photosynthetic rates. Intertidal seagrasses have been shown to carry out photosynthesis both while exposed at low tide, and at high tide when covered in water (Schwarz, in press). Photosynthesis of intertidal *Z. capricorni* in New Zealand has been recorded as becoming light saturated at an irradiance intensity of ~200 µmol photons $m^{-2}$ $s^{-1}$, typical of high light adapted aquatic plants (Schwarz, in press). The amount of light that seagrasses receive to enable photosynthesis can be affected by water clarity and, for intertidal specimens, the degree of exposure to air and attachment of sediment and epiphytic algae to plant leaves.

Water clarity affects the amount of light reaching subtidal plants, as well as those in the intertidal zone during high tide. Deposition of silt and growth of epiphytic algae on plant leaves will also affect the amount of light available to the plants for photosynthesis. In turn both water clarity and leaf deposits/growths are likely to be related to the amount of suspended matter (sediment and algal material) and nutrients (stimulant for algal growth) in the overlying water.

Another factor that is likely to affect the ability for seagrasses to accumulate biomass is the timing of exposure to air. While this ensures sufficient irradiance for photosynthesis, it also exposes the plants to desiccation and high temperatures, both of which tend to reduce photosynthetic gains. The extent of this effect is related to the elevation of the intertidal above mean low water (Turner and Schwarz, in review). However there have been no local studies to quantify this relationship.

## 7.2 Nutrients

While nutrients (i.e. nitrogen and phosphorus) have been implicated as a factor affecting water clarity and epiphyte accumulations on leaves, they also play a direct role in stimulating seagrass growth. Seagrass plants can acquire nutrients for growth from both the sediment through their roots or from overlying water through their leaves. However, at high concentrations some nutrient forms can become toxic to seagrass growth. Ammonium, a common form of nitrogen present in soil and water, has been shown to produce toxicity symptoms in seagrass plants at concentrations of 25 μM or higher (van Katwijk *et al*., 1997).

## 7.3 Toxins

Seagrasses can be exposed to a number of potentially toxic substances both in the overlying water and in the sediments. High levels of sulphides, ammonium and other toxins associated with anaerobic conditions can affect the amount of uptake of nutrients and survival (Mills and Fonseca, 2003). International studies suggest that these conditions may be linked to the accumulation of large amounts of organic matter as a result of eutrophication of coastal and estuarine areas (Azzoni *et al.*, 2000). However, toxins can also be present in stormwater, industrial or wastewater discharges.

## 7.4 Sediment texture

In New Zealand seagrasses tend to be associated with soft-sediment environments consisting of sand and organic material. Sediment composition (i.e. texture) can affect the amount of biomass of roots, rhizomes and shoots. For example, in Whangapoua Harbour (Coromandel Peninsula) New Zealand, roots are present to 7 cm below the surface in sandy sediments (with similar examples documented in UK to 10 cm, Reed Pers. comm. 2004) while in beds in Whaingaroa (Raglan) Harbour, roots penetrate to only 3 cm in fine (muddy) sediment (Turner and Schwarz, 2003).

Sediment texture is identified as an important factor regulating aquatic plant growth in freshwater environments with reduced plant growth on high density sands and also on low-density (flocculent) substrates. Nutrient limitation is considered the causative factor due to the lack of organic material in high density sands and the low diffusion distances in low density (but usually organic-rich) substrates (Barko and Smart, 1986). However, to our knowledge no investigation of this nature has been conducted in marine environments in New Zealand.

### 7.5 Physical disturbances

Seagrass beds can be removed by physical disturbances, either naturally through storm related waves and swells or by anthropogenic activities, such as dredging, or construction in the coastal zone. Increased sediment movement associated with such activities may cause additional losses of seagrass. Compared to some seagrass species, *Zostera capricorni* is not well adapted to rapid change, having relatively moderate to slow recovery/reproduction rates, due to its usual overwhelming reliance on vegetative propagation (Ramage and Schiel, 1998).

## 8 Environmental parameters affecting optimum seagrass growth in Whangarei Harbour

In Whangarei Harbour the suspected cause of seagrass loss has previously been attributed to one of two theories; (1) episodes of increased sediment load in the estuary; including capital dredging operations in the main shipping channels and at Port Whangarei, and discharges from cement works at Portland, (2) infection and subsequent mortalities by a marine fungus (*Labyrinthula*) (Whangarei Harbour Study, 1986).

The lack of recovery of some of these beds suggests that altered environmental conditions are probably responsible for the decline in seagrass. Potential factors affecting environmental conditions and thus seagrass growth at specific sites within the harbour and causing this loss are shown in Table 2.

During 1966-69, a major dredging programme was undertaken to deepen the main channel and sediments were removed and pumped on to Snake Bank and Takahiwai shoreline (754,000 $m^3$), in "zone 4" (Dickie 1984) off Limestone Island (200,000 $m^3$) and at the entrance to Parua Bay (144,500 $m^3$). The latter was an alternative dumping ground to Peach Cove during bad weather. Anoxic sediments re-suspended in the bay were attributed to the demise of the seagrass beds there (Dickie 1984). On an ebb tide, water and entrained sediments leave Parua Bay and cross north of MacDonald Bank (Venus, 1984). During 1967-68, the majority of the dredgings (mostly sand) were dumped above the mean low water spring tide level along the Onerahi foreshore to the south of Kaiwaka Point. Increased turbidity and deposition of sediments could have caused the loss of seagrass indirectly through reduced photosynthesis and growth, or directly by smothering or erosion (Whangarei Harbour Study, 1983). Modification to the hydrology may also have contributed to the overall disappearance of seagrasses in areas impacted by these discharges.

**Table 2: Estimated areas of seagrass beds from aerial photos in Whangarei Harbour, 1966 and factors potentially affecting seagrass growth at these sites (Source: Whangarei Harbour Study 1983).**

| Location | Area (ha) | Factors potentially affecting seagrass growth |
|---|---|---|
| Snake Bank | 100 | Deposition of sediments and burial of plants |
| MacDonald Bank | 109 | Increased sedimentation |
| Parua Bay | 65 | Deposition of sediment at entrance to bay including anoxic sediment. High percentage of fines (<10µm) increasing likelihood of high suspended sediment loads |
| Tamaterau Coast | 134 | Deposition of sediment further upstream at Onerahi foreshore |
| Takahiwai | 622 | Changes to hydrology and bathymetry, deposition of sediments and burial of plants |
| Mair Bank | 26 | Accumulation of sediments, movement of bank, burial of plants. |
| Marsden Point – One Tree Point | 128 | Hydrological changes, increased depth in channel (north of One Tree Point) and increased sedimentation |
| Calliope Bank | 21 | Unknown |
| McLeods Bay | 8 | Increased sedimentation |
| TOTAL | 1,213 | |

During the same time period, discharges from the cement works were estimated to be 10,000 tonnes of sediment per year (Cromarty and Scott, 1996). In 1967, approximately 250,000 tonnes of sediments were discharged into Whangarei Harbour from the cement works, the most discharged in any one year (Dickie, 1984). The sediments from this discharge account for much of the superficial sediments in the upper sections of the harbour (~50% in zone Onemama Point to Port Whangarei, and ~20% in Parua Bay) (Dickie, 1984). The majority of the cement processing waste sediments were discharged between 1958 and 1971 (Dickie, 1984). Overall, nearly 3 million m³ of sediment (of which 90% was <10 µm in diameter) was discharged into the harbour. In 1978, Bioresearches Ltd measured water clarity and water depth and found water clarity to be only 0.2 m at a site adjacent to the cement works. Six years later, improvements were slow with an increase in clarity of only 0.05 m. In the deeper channels, such as the main ebb channel of the Portland arm east of Limestone Island, water clarity had greatly improved (doubled) since 1977 (Dickie, 1984).

To assess the changes in depth of the seafloor, hydrographic surveys were undertaken in 1959/1961 and 1981 in the Lower Whangarei Harbour by the Royal New Zealand Navy. The largest depth changes of 4 m and 2.2 m were recorded where the Shell Cut Reach Channel (north of One Tree Point) was dredged through an existing sand bank to link with the Main Shipping Channel. The accretion to the south of Reserve Point was the dredged spoil (Black *et al.*, 1989). Changing depth in the north and south were attributable to alteration in hydrodynamics after dredging. Venus (1984) highlights a study by the Danish Hydraulics Research Institute, which concluded that there were only small changes to the bathymetric soundings taken in the lower harbour in 1959 and 1981. During this time, sediment had accumulated at Mair Bank at a rate of 100,000–150,000 m³ per year on the southern side and the bank had moved northwards. At Port Whangarei, measurements of suspended sediments were reported as 50 mg/L for maximum dry weather periods and 60-70 mg/L for wet conditions (Millar, 1980). In 1983 during a flood, suspended sediment were measured at >100 mg/L upstream of Limeburners Creek (Venus, 1984).

Overall, the potential factors contributing to the loss of seagrass in Whangarei Harbour are considered to be; an increased level of sedimentation, accumulation or erosion / removal of sediment at specific sites; increased suspended sediment levels (especially of fine material); changes in sediment texture, and changes to local bathymetry. The potential environmental effects from these factors are likely to have included; higher turbidity levels, lower water clarity, exposure to anoxic sediments, and burial, resulting in reduced photosynthesis and growth of seagrass plants. Other stresses on environmental quality include contaminant discharges to the Hatea River (from Town Basin to Port of Whangarei), such as historic treated effluent, industrial spills, leachates from refuse tip, discharges from industrial processes, oil spills and stormwater runoff (Webster *et al.*, 2000). Previous problems with high nutrient loads were documented in the Hatea River by Dickie (1984) and low dissolved oxygen and the presence of faecal coliforms were reported by Venus (1984). The flushing time of the upper harbour has been reported to be approx 10.5 days, and 0.6 days for the lower harbour (Venus, 1984). Williams (1983) estimated that 20% of water leaving the harbour on an ebb tide will return on the following flood.

# 9 Conclusions and recommendations

On the basis of our knowledge of seagrass growth requirements and changed environmental conditions in Whangarei Harbour, the following are the key environmental parameters to target for habitat restoration: water clarity, water quality and sediment condition. Improvements in these parameters are usually achieved by minimising the amount of suspended sediment, nutrients and other contaminants in runoff and discharges to the harbour from the catchment. Council-led catchment management plans and/or community initiatives such as riparian plantings, treatment wetlands and erosion protection measures are the sort of methodology that can be considered to minimise these inputs.

A quantitative survey of existing (or baseline) environmental conditions (e.g. water clarity, chemical contaminants, sediment texture and organic carbon content) at specific sites in the harbour is recommended so areas with the greatest potential for restoration of seagrass beds can be identified and prioritised. By using a targeted locally-designed and scientifically-robust approach we can estimate the loss of seagrass beds and provide methods to improve conditions for seagrass bed restoration.

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