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Whangateau Catchment and Harbour Study

Review of Marine Environment Information

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Whangateau Catchment and Harbour Study

Review of Marine Environment Information

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Contents

Preface

Funding was allocated to scope the development of a Whangateau Action Plan during 2008/09. Three technical reports were commissioned to inform the development of the action plan. These reports document catchment and harbour state, record issues and values, and identify existing and potential threats. The three background studies (1) collate and summarise existing environmental information on the harbour, (2) describe the environmental and social characteristics of the catchment, and its management and planning framework, and (3) document initial consultation to identify iwi and community's views on the values, threats and pressures on the Whangateau harbour and catchment. The principal findings from the three reports are synthesized in a summary document.

The studies indicate that the current state of the harbour is relatively healthy and that there is no single, overall dominant physical threat to the harbour; rather there is a range of small threats that cumulatively have potential to affect the harbour health. All three background studies, furthermore, identified the opportunity to improve integrated planning and co-ordination between stakeholders. Additional work is required to clearly determine the threats and most effective manner to intervene in the catchment and harbour to make short term improvements that contribute to the overall long term protection and enhancement of the catchment and harbour.

Technical background reports

Technical Report TR2009/003

Whangateau Catchment and Harbour Study - Review of Marine Environment Information

Technical Report TR2009/004

Whangateau Catchment and Harbour Study - Review of Environmental and Socio-economic Information

Technical Report TR2009/005

Whangateau Catchment and Harbour Study - Review of Stakeholder Information

Technical Report TR2009/006

Whangateau Catchment and Harbour Study - Summary and Discussion

1 Executive Summary

Whangateau Harbour is arguably Auckland region's most valuable mainland estuary. Near complete tidal flushing by clean, outer Hauraki Gulf waters means that water quality and clarity in the harbour is excellent. The intertidal and subtidal seabed generally consists of firm sandy sediments, with a number of isolated and ecologically valuable reefs. Muddy areas are mainly confined to sheltered side branches in northern parts of the harbour. Septic tank leaching at Point Wells (which is being addressed) and a small, isolated area with moderate levels of contamination below the disused landfill at Whangateau are the only known contaminant issues in the harbour.

The harbour is notable for its range of high-quality habitats that are contained within a relatively small area. These include: a variety of reef types; sandy intertidal and subtidal seabed; muddy habitats; mangrove forests; a variety of algae beds; seagrass beds; large areas of rush and saltmarsh; a nationally significant vegetation sequence running from kahikatea swamp forest to saltmarsh and intertidal sandflats; and a coastal dune system. It is also used by a variety of coastal birds, including one species classified as nationally critical and four species classified as nationally vulnerable. A resident population of nationally vulnerable, North Island dotterels nest on the tip of Mangatawhiri Spit (commonly called Omaha Spit).

The variety and quality of marine and coastal habitats are reflected in the harbour's ecological diversity and productivity. The harbour's dense shellfish beds are exploited by harvesters, who come from throughout the Auckland region and beyond, to collect shellfish. Reefs and intertidal algae beds in the harbour act as fish nurseries, and may sustain adult fish populations in surrounding coastal areas. Rush and saltmarsh habitats in the harbour are highly valued, because of their size, relatively undisturbed nature, and lack of introduced plants. They also protect against coastal erosion and provide important habitat for coastal birds such as banded rail.

Many habitats and species associations have very discrete and isolated distributions. A number of ecological communities within the harbour depend on the presence of habitat-forming species, which provide substrate and structural complexity (eg mangroves, seagrass, Neptune's necklace, pipi) and/or food (eg pipi). These communities are likely to be particularly fragile, as a number of the habitat-forming species are sensitive to harvesting, direct physical disturbance, or the adverse effects of sediment and other contaminants. The loss of these communities would have a significant impact on the overall biodiversity values of the harbour.

The cumulative impacts of existing land-based and coastal activities on the ecological, conservation, landscape and natural character values of the harbour are already significant. These impacts are likely to increase dramatically, unless measures are taken to prevent further degradation and, where necessary, remediate existing problems. Key issues facing the harbour include:

- The effects of the existing causeways at Birdsall Rd, Tramcar Bay, and Omaha on the hydrodynamics of the harbour, sedimentation and mangrove expansion. The long-term effects of the Omaha causeway are of particular concern, and could lead to mangrove expansion and the associated loss of large areas of highly valued, intertidal habitat in the upper harbour. However, sea level rise may offset these effects.
- The loss of natural coastline due to the cumulative effects of reclamation, the construction of seawalls and other coastal structures (wharves, boat ramps etc.).

- Pressure to increase the number of swing moorings and/or develop a marina within the harbour. Note that the existing mooring management areas are located in discrete, high-value, habitat-forming shellfish beds. The ecological effects of both activities have not been quantified, but could be substantial.
- Increases in shellfish harvesting.
- Potential health risks to bathers and seafood gatherers due to wastewater contamination from septic tank seepage at Point Wells and possibly Whangateau settlement. Note that plans to include Point Wells in the Omaha wastewater treatment system should significantly reduce this risk.
- Threats to coastal birds associated with development and population growth. These threats include direct disturbance, habitat loss, impacts on food availability, and an increase in mammalian predators (including cats and dogs).
- Physical disturbance of the foreshore and coastal vegetation from vehicles and farm animals.
- Sediment run-off and accumulation in northern parts of the harbour and in Omaha River, where mangrove expansion has already occurred.
- Litter, particularly around the Ti Point Wharf.

Stormwater contamination does not appear to be a significant issue, but the potential effects of horticultural chemicals have not been assessed.

It is recommended that clearly defined objectives for the environmental management of the harbour's resources be developed. These objectives need to take into account the special ecological, conservation, natural character and landscape functions and values of the harbour. The objectives can form the basis for ongoing management that addresses the cumulative effects of existing activities, plus those related to future population growth, changing land use, and catchment and coastal development.

2 Introduction

Whangateau Harbour is regarded as one of the highest quality estuaries in the Auckland region. It is the Auckland region's northern-most east-coast mainland estuary[1] and differs from other (mainland) estuaries in that it is connected to a relatively exposed coastal system, and is tidally flushed by the clean, coastal waters from the outer Hauraki Gulf. It contains a regionally-rare mix of habitats, and is well-known for its abundant shellfish beds. As a result, the harbour is an important food gathering area for local iwi, and it also used by a large number of recreational shellfish harvesters.

The potential impacts of land use intensification and the increasing pressure on harbour resources has led to concern about the long-term sustainability of the harbour ecosystem. Intensification and associated land use activities generate sediment, stormwater and wastewater contaminants, which can negatively affect coastal waterways such as Whangateau Harbour. Intensification also leads to coastal and foreshore modifications, which negatively affect the ecology and natural character of an area. Land use in the Whangateau catchment has gradually intensified since the 1960s. Today a significant proportion of the foreshore is urbanised, and the wider catchment contains a mix of agricultural, horticultural, residential and commercial development. At the same time local population growth and changing demographics (local and regional), together with roading improvements that have significantly eased access to the area, are likely to be increasing pressure on the natural resources and conservation values of the harbour.

In response to community concerns about the potential for significant degradation of Whangateau Harbour, the Auckland Regional Council (ARC) is considering the development of a plan which would identify and implement actions required to maintain or enhance its values. Preliminary studies have been undertaken to (1) collate and summarise existing environmental information on the harbour, (2) describe the environmental and social characteristics of the catchment, and its management and planning framework (Boffa Miskell 2009), and (3) conduct initial consultation to identify the community's view on the values, threats and pressures on the Whangateau catchment (Lees and Cole 2009). This review relates to item (1), ie the collation and summary of marine environment information and is broken into three components:

1. a general description of the physical and ecological characteristics of the harbour,
2. a consideration of threats to the quality and values of the harbour, and
3. an analysis of knowledge gaps.

[1] Pakiri river-mouth could nominally be classed as an estuary, but is not included here because of its intermittent connection to the sea.

A range of available resources were used in this review. These included scientific publications, technical reports, theses, council policies and plans, unpublished data, and personal correspondence. Several site visits were also carried out to "ground truth" information provided by the available literature and to identify additional issues that may not have been captured elsewhere.

3 General Description

Whangateau Harbour is a sandspit estuary, which drains into the northern end of Omaha Bay in the outer Hauraki Gulf. Key features of Whangateau Harbour that are referred to in the report are shown in **Figure 1**. The estuary was produced when the western portion of Omaha Bay was enclosed by the formation of Mangatawhiri Spit (commonly called Omaha Spit) during the Holocene (ie recent) geological period (Titchener 1993). The northern shore of the harbour entrance consists of a rocky headland (Ti Point), which shelters the entrance from ocean generated sea and swells. The inner estuary consists of a large, broadly curved main body running approximately 6.5 km in a north-south direction (Waikokopu Creek), with two small, northern offshoots (ie Tramcar Bay and Birdsall Road), and a larger side branch running approximately parallel to the main body (Omaha River). The latter is produced by an older, Pleistocene barrier spit (Omaha Flats) with Point Wells on its tip, which splits the estuary and forms the eastern bank of the lower Omaha River (Titchener 1993). A permanently exposed sand bar forms a small mangrove fringed island (Horseshoe Island) at high tide, that is located directly off Whangateau Motor Camp.

Whangateau Harbour is largely infilled (Harris 1993), with extensive intertidal sandflats that are drained by relatively simple channels running up the main body of the estuary and Omaha River. The harbour has an area of approximately 750 ha with an adjoining catchment of approximately 4350 ha (based on catchment boundaries provided by the ARC). Bedforms of Mangatawhiri Spit suggest it was created by the northward migration of littoral (ie seabed) sediment (Schofield 1973). The spit is approximately 4 km long, with land use in the southern 3.4 km mainly consisting of residential development (Omaha), a golf course running down the western-central part of the spit, and a 1.9 km strip of native swamp forest running along the south-western, coastal margin (Taniko Wetlands Scientific Reserve). Land use on Omaha Flats is dominated by horticulture, with a small area of urban development at Point Wells. Other, small areas of residential development on the margins of the estuary are located at Whangateau, Tramcar Bay and Ti Point. Significant areas of native forest remain on steeper, hilly parts of the northern catchment, with the remaining land use being dominated by agriculture. Remaining parts of the southern catchment are also predominantly used for agriculture (dry stock and dairy).

The estuary and adjoining coast has been physically modified by a number of human activities and man-made structures. Between 1942 and 1963 a total of 380,000 m^3 of sand was mined from the Whangateau ebb tide delta and from the end of Mangatawhiri Spit. The sand deficit created by this mining is thought by many to have been responsible for coastal erosion on Mangatawhiri Spit, which began accelerating in the mid 1960s[2]. Subdivision on Mangatawhiri Spit began around 1971, and by 1975 marked erosion of Omaha Beach was occurring. Erosion from the beach, and subsequent northward drift led to the accretion of around 400,000 m^3 of

[2] This conclusion was not supported by Schofield (1985), who concluded that the erosion of sand from Omaha Beach was caused by the build up of the ebb tide delta, rather than dredging. He also concluded that a change in the predominant wind direction was also likely to have been a contributing factor.

sand in the area between the end of Mangatawhiri Spit and Ti Point from 1966 to 1977. Severe beachfront erosion during storms in April 1976 and July 1978 prompted urgent remedial action to be taken by the Ministry of Transport in October of that year. This included the construction of three groynes at the north-eastern end of Mangatawhiri Spit, and the dredging of 400,000 m^3 of "coarser than native" sand from the entrance of Whangateau Harbour. The groynes provided stability to the end of the spit, which increased wave refraction and decreased beach erosion potential. The northern groyne was installed to reorientate the ebb jet to a southerly direction to enhance natural beach renourishment, and to prevent large sea waves from entering the estuary. The southern groyne was installed to help contain beach sediment, and in particular the 400,000 m^3 dredged from the harbour entrance. The central "swash" groyne was installed to prevent wave erosion between the northern and southern groynes, which would undermine spit stability (summarised from Titchener 1993).

Omaha causeway was constructed in the 1970s to provide access to the subdivisions on Mangatawhiri Spit. The causeway dissects the main body of the estuary: splitting off an upper compartment (of approximately 194 ha) approximately half way along the length of Waikokopu Creek (see **Figure 1**). It is likely to have a major influence on circulation patterns in the harbour, as water flow between the upper estuary south of the causeway and the lower estuary north of the causeway is restricted to the main channel. The coastline is highly modified on the north-eastern side of the causeway, with the loss of a significant area of coastal vegetation, which was infilled to create a section of Omaha Golf Course, and the construction of a ca. 1.8 km seawall (**Figure 2**). Other man-made structures on the north-western margin of Mangatawhiri Spit include a wharf, a boat ramp, stormwater outfalls, access steps, and fences.

Similar modifications of the coastal margin have also occurred at Point Wells, where there is approximately 0.5 km of seawall (with apparent infilling behind, **Figure 2**), two public boat and vehicle ramps that provide access to the coastal marine area, a wharf and several sets of access steps. Other constructed, public wharves, ramps and seawalls are located at Big Omaha, Ti Point and Lew's Bay.

The sheltered nature and depth of the main channel makes it a safe mooring area, which is utilised by a range of pleasure and commercial vessels. Accordingly, two mooring management areas are designated in the Auckland Regional Plan: Coastal for the harbour. An area between 36° 19.9' S (ie approximately south of the golf course clubhouse) and the causeway has also been designated for the use of power driven vessels towing skiers, or involved in motorised sport (ARC 2008).

Figure 1

Key features of Whangateau Harbour that are referred to in the report.

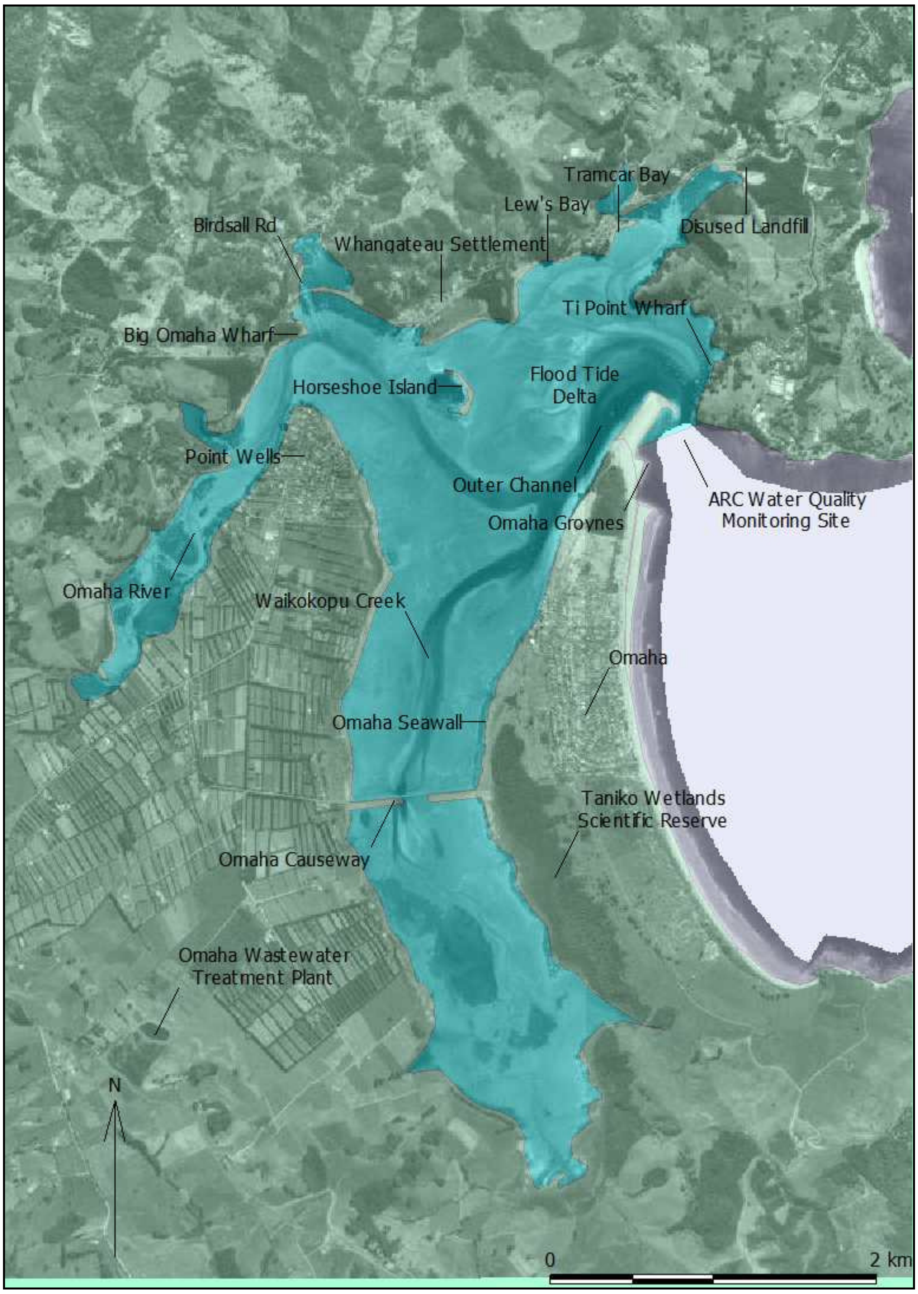
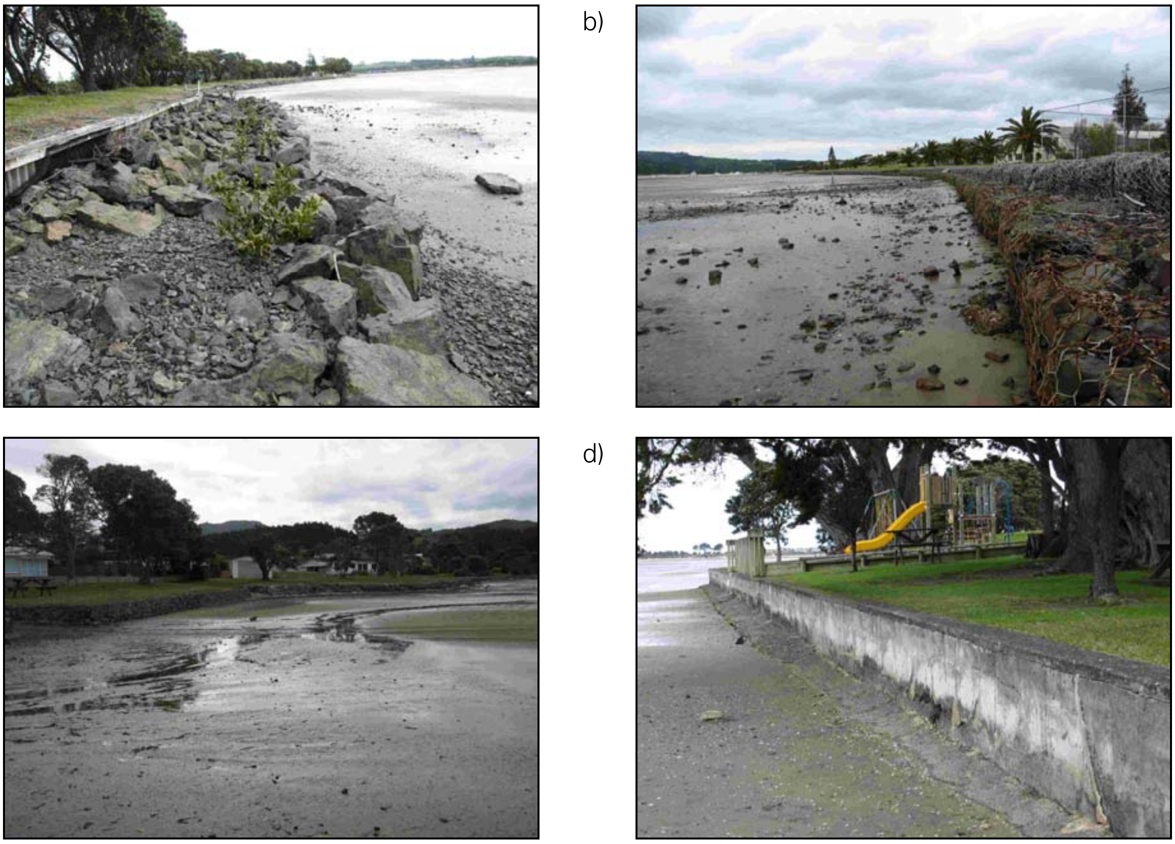


Figure 2
Seawalls along the foreshore at Omaha (a and b) and Point Wells (c and d).

a) b) c) d)



The harbour contains a regionally unique mix of high-value, high-quality habitats that include tidal creeks with their associated mud flats and mangrove forests, large intertidal sandflats, seagrass beds, large areas of coastal vegetation which in some areas grade into kahikatea swamp forest, subtidal channels, and intertidal and subtidal rocky reefs. A number of the harbour's features are recognised through specific designations in the Auckland Regional Plan: Coastal (**Figure 3**). These include:

- The recognition of outstanding landscapes near the entrance to the harbour (ratings 6 and 7).
- The identification of coastal protection areas in and around the harbour (Schedule 3, 83a to 83d). The reasons for these designations are given as: Whangateau Harbour is "an important east coast harbour characterised by a sequence of depositional sands including a large unconsolidated Holocene barrier sandspit which provide a number of different habitats for a variety of animal and plant communities. The intertidal sand banks (CPA 83a) are a rich feeding ground for many international migratory and New Zealand endemic wading birds including a number of threatened species. Many of the migratory birds use the estuary as a stepping stone in their journeys. The waters of the harbour (CPA 83a) are

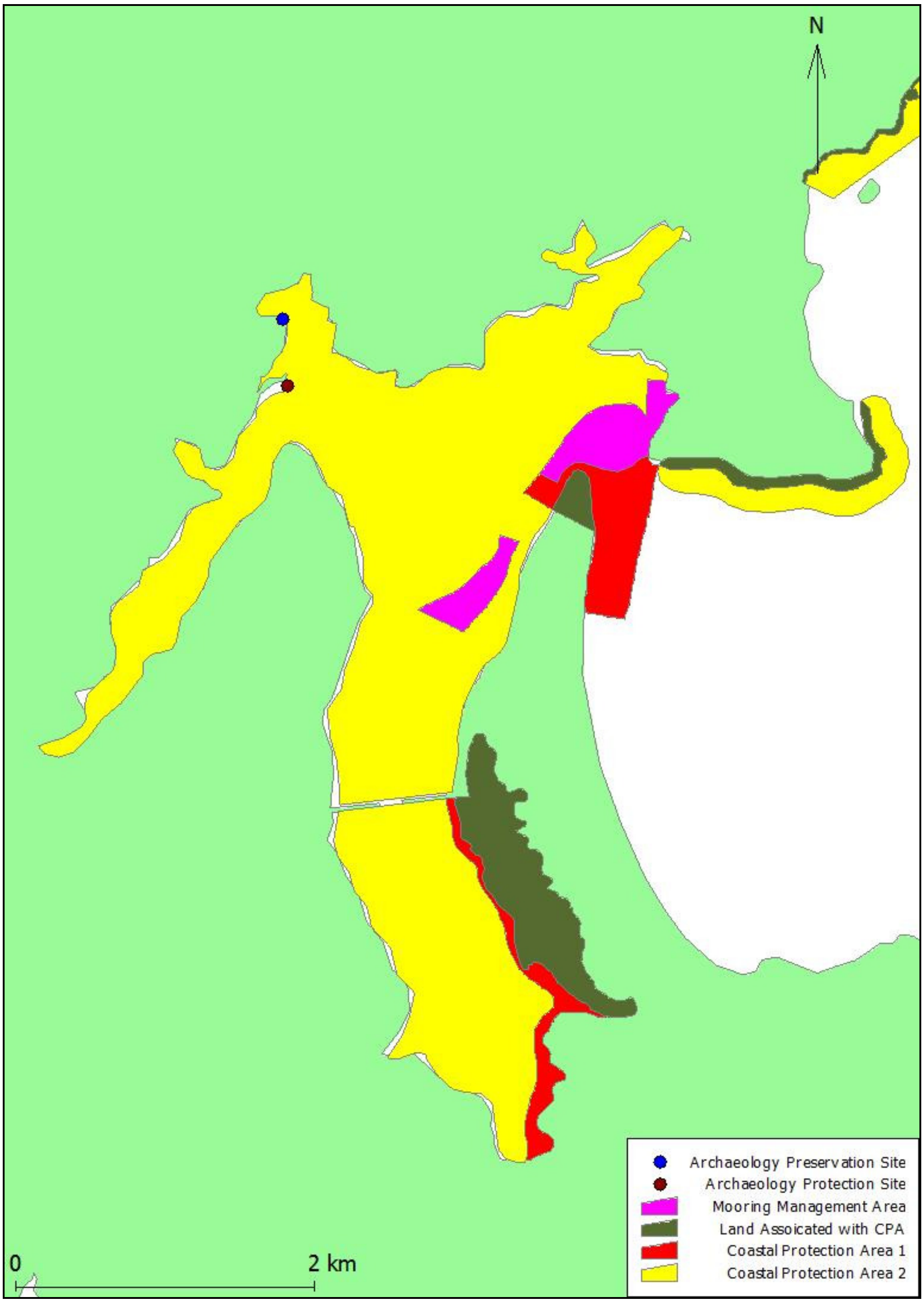
a feeding ground for a variety of coastal birds. The tip of the large barrier sandspit (CPA 83b) has a number of important natural values. It is a high tide roost for the wading and coastal birds, a key breeding ground for the threatened New Zealand dotterel, and a threatened plant habitat. In the lee of the sandspit grow areas of saline vegetation including eelgrass, which appears to be spreading. South of the causeway there are important areas of mangroves and saltmarsh (CPA 83c) much of it judged to be amongst the best in the district. There is an important gradation from this significant saline vegetation (CPA 83c) into a large and rare area of coastal kahikatea swamp forest beyond the coastal marine area. The saline vegetation both here (CPA 83c) and in other parts of the harbour provides high-quality habitat for threatened secretive coastal fringe birds, particularly in saltmarshes where there is terrestrial vegetation which provides roosts for the birds and potential nesting sites. Ti Point (CPA 83d) contains both ecological and geological values. This area is the location of the Ti Point volcanic exposure. The reefs offer habitat for the threatened reef heron, and the coastal pohutukawa forest, which is identified in the plan as "Land Associated with a Coastal protection Area" are identified in the Rodney District Protected Natural Areas Programme.

- The designation of David McKay Darroch's Shipyard at the entrance to Omaha River as a cultural heritage place for preservation (Schedule 1, Site 66).
- The designation of Big Omaha Wharf as a cultural heritage place for protection (Schedule 2, Site 200).
- The identification of land associated with coastal protection areas (ie coastal kahikatea swamp forest in Taniko Wetlands Scientific Reserve).
- The designation of two mooring management areas (Schedule 5, number 11 and 12), which nominally contain 38 and 27 existing moorings respectively with capacity for 45 and 50 moorings respectively (ARC 2008).

A continuous esplanade reserve owned by the Rodney District Council (RDC) runs along the western shore of Mangatawhiri Spit. South of Omaha causeway the esplanade reserve passes through an area of saltmarsh (in the coastal marine area) between the Taniko Wetlands Scientific Reserve (which is administered by the Department of Conservation) and the estuarine sandflats. A significant area of saltmarsh in southern parts of the harbour is privately owned.

Due to its proximity to the University of Auckland's marine laboratory (ie Leigh Marine Laboratory), the Whangateau Harbour has been relatively well-studied. Studies have included: various aspects of bird, fish, shellfish, crab, plankton, mangrove and benthic ecology; contamination from stormwater, wastewater and historic landfills; and, coastal processes.

Figure 3
Sites designated in the Auckland Regional Plan: Coastal as coastal protection areas (1 and 2), archaeological protection sites, archaeological preservation sites and mooring management areas in Whangateau Harbour. Land associated with the coastal protection areas is also shown.



3.1 Geophysical characteristics

The harbour is a Category E estuary according to Hume et al. (2007). Category E estuaries are described as circular to slightly elongate basins with simple shorelines and extensive intertidal areas. They have narrow entrances which are generally constricted by a spit or sand barrier, and tend to be well-flushed, with the tidal prism making up a large proportion of the estuary basin volume. River flows are small relative to the total volume of the estuary, so ocean forcing dominates hydrodynamic processes, although wind generated circulation, mixing and resuspension can occur at high tide. They tend to have fairly homogeneous, sandy substrates and are well-mixed, so salinity is close to that of the sea.

Key hydrological statistics for the harbour were obtained from the New Zealand estuarine classification database compiled by the National Institute of Water and Atmospheric Research (NIWA) and are provided in **Table** 1. The database is used in the Estuarine Environment Classification (EEC) to classify New Zealand's estuaries. Variables were derived from various sources including NIWA's digital elevation model (30 m cell size) of New Zealand, the 1:50,000 Digital Topographic Database, New Zealand Land Resource Inventory (NZLRI), the New Zealand EEZ Tidal Model (Walters et al. 2001), digital files of the Royal New Zealand Navy hydrographic charts, and various publications and reports. The EEC is described in Hume et al (2003, 2007).

Of particular note are the high proportion of relatively stable intertidal areas (85.4 per cent) and the contribution of the tidal prism to the total estuary volume during spring tides (81.4 per cent), which reflect the shallow, well-flushed nature of the estuary.

Empirical hydrological data has also been obtained for some parameters. Titchener (1993) recorded tidal ranges of 1.4 m to 2.8 m, and current flows of up to 1.2 $m.s^{-1}$ in the main channel of the harbour, which classified the harbour as meso to microtidal. Note that the maximum tidal range recorded by Titchener (1993) is 0.58 m greater than the estimate obtained from the estuarine classification database.

Whangateau Harbour has asymmetric flood and ebb tide deltas[3]. The flood tide delta is a major feature of the outer harbour, which is located on the western margin of the main estuary channel and extends 800 m into the estuary (see **Figure 1**). The morphology of the flood tide delta is not significantly influenced by freshwater inflows, oceanic wave, swell activity, or local wind generated waves. Rather, its form is determined by tidal currents which are channelled into the harbour at an obtuse angle by the configuration of Ti Point and Mangatawhiri Spit on the flood tide. In contrast, the ebb tide jet exits the harbour at a very small angle to Omaha Bay, and the ebb tide delta (seaward of the entrance), is much less prominent in size and shape. Wave action maintains a sediment transport loop, which carries sediment deposited on the ebb tide delta ashore, where it is moved back into the estuary through littoral transport and flood tide currents (Titchener 1993).

[3] A delta is a body of sediment deposited at river or estuary mouths. Estuaries can have deltas formed on the estuary side of their entrance by the incoming (flood) tide, and on the seaward side of the estuary by the outgoing (ebb) tide.

Significant changes to morphology of the flood tide delta have occurred in the past. The inlet-throat of the estuary was very mobile from the early-1960s to 1980, and the delta underwent a high degree of morphological change. However, following the installation of groynes to prevent coastal erosion of Mangatawhiri Spit in the late-1970s (and an initial adjustment period), the delta became extremely stable (Titchener 1993).

Table 1

Key geophysical and hydrological statistics for Whangateau Harbour obtained from the Estuarine Environment Classification data base (1 September 2009) (data provided by Terry Hume, NIWA Hamilton).

Variable	Value
Co-ordinates of middle of mouth easting (NZMG)	2670475
Co-ordinates of middle of mouth northing (NZMG)	6540741
Land catchment area	4243 ha
Estuary water area at high tide MHW	746 ha
Intertidal area (% of HW area)	85.4
Estuary shoreline length	31961 m
Spring tidal prism	9,491,105 m^3
Estimated total estuary volume at spring tide	11,663,589 m^3
Mean annual discharge of river to estuary	2.13 m^3s^{-1}
Estimated estuary mean depth	1.56 m
Spring tide range	2.22 m
Width of estuary mouth	444 m

3.2 Environmental quality

3.2.1 Water quality

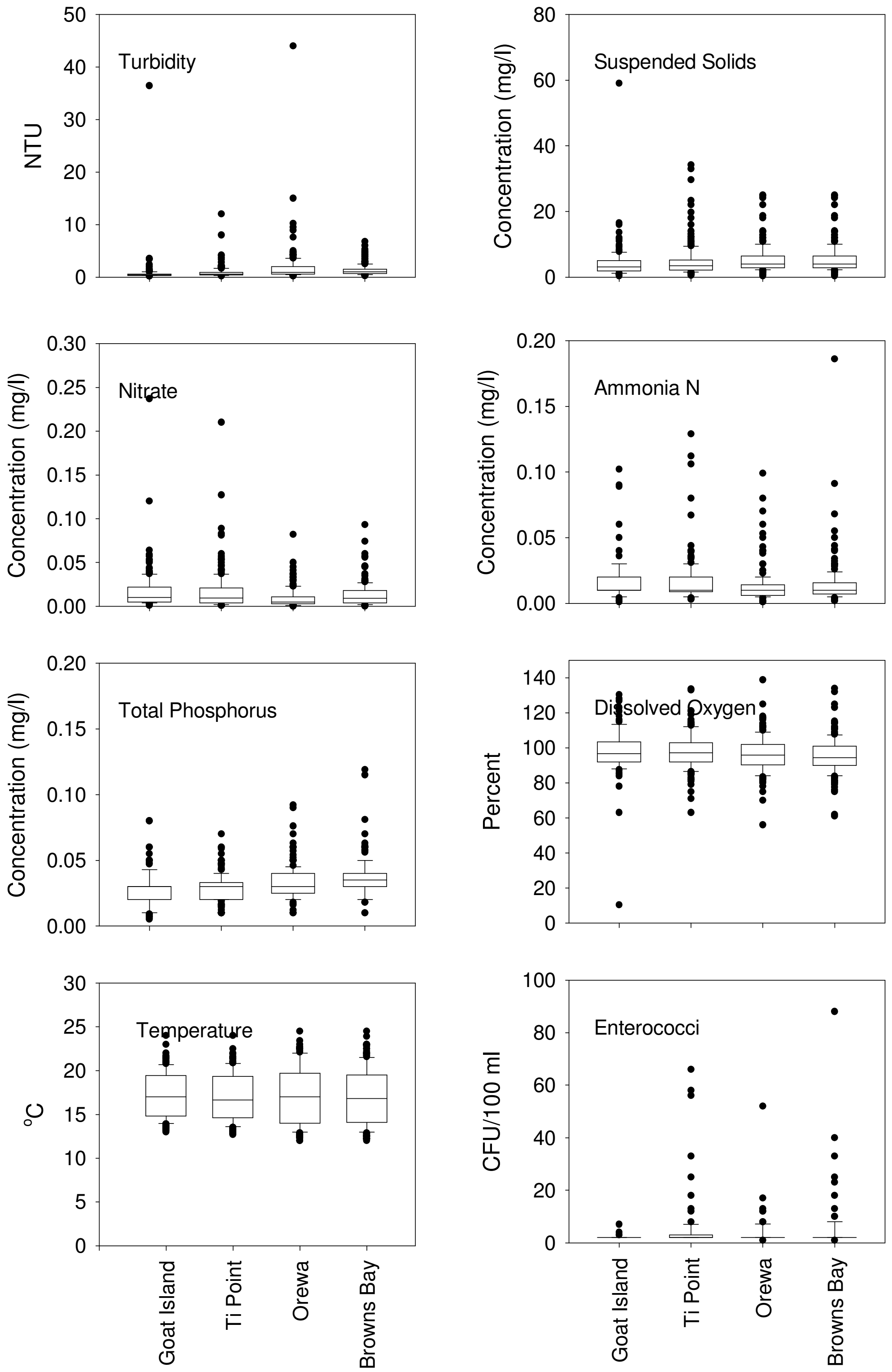
The ARC has continuously monitored water quality from the entrance to Whangateau Harbour (ie the Ti Point site) since 1991 (see **Figure 1**). Monthly samples are collected approximately 50 minutes after high tide by helicopter, and samples are analysed for: temperature; salinity; turbidity; suspended solids; nitrate; nitrite; ammonia N; total and soluble phosphorus; faecal coliforms; enterococci; and, chlorophyll *a*. Water quality data from the Ti Point monitoring site were plotted to present temporal trends and contrast with data from other semi-exposed, east coast sites. Where available, variables were also compared against ANZECC (2000) water quality guidelines.

Water quality at Ti Point generally mirrors that of other inshore coastal sites (Figure 4) with low nutrient concentrations (nitrate, ammonia-N and total phosphorus) that are well below ANZECC (2000) water quality guideline values[4]. Low turbidity levels and suspended solids concentrations, high dissolved oxygen concentrations and low enterococci levels, also indicate

[4] ANZECC (2000) water quality guidelines recommend a nitrate low reliability trigger value of 0.7 mg/l and moderate reliability trigger value for ammonia-N of 0.91 mg/l at pH 8.0 (see ANZECC (2000) section 8.3.7.2).

Figure 4

Boxplots of water quality parameters from the ARC's east coast monitoring sites: ie Goat Island, Ti Point (in the entrance to Whangateau Harbour), Orewa and Browns Bay (1991 – 2008) (data obtained from ARC water quality database).

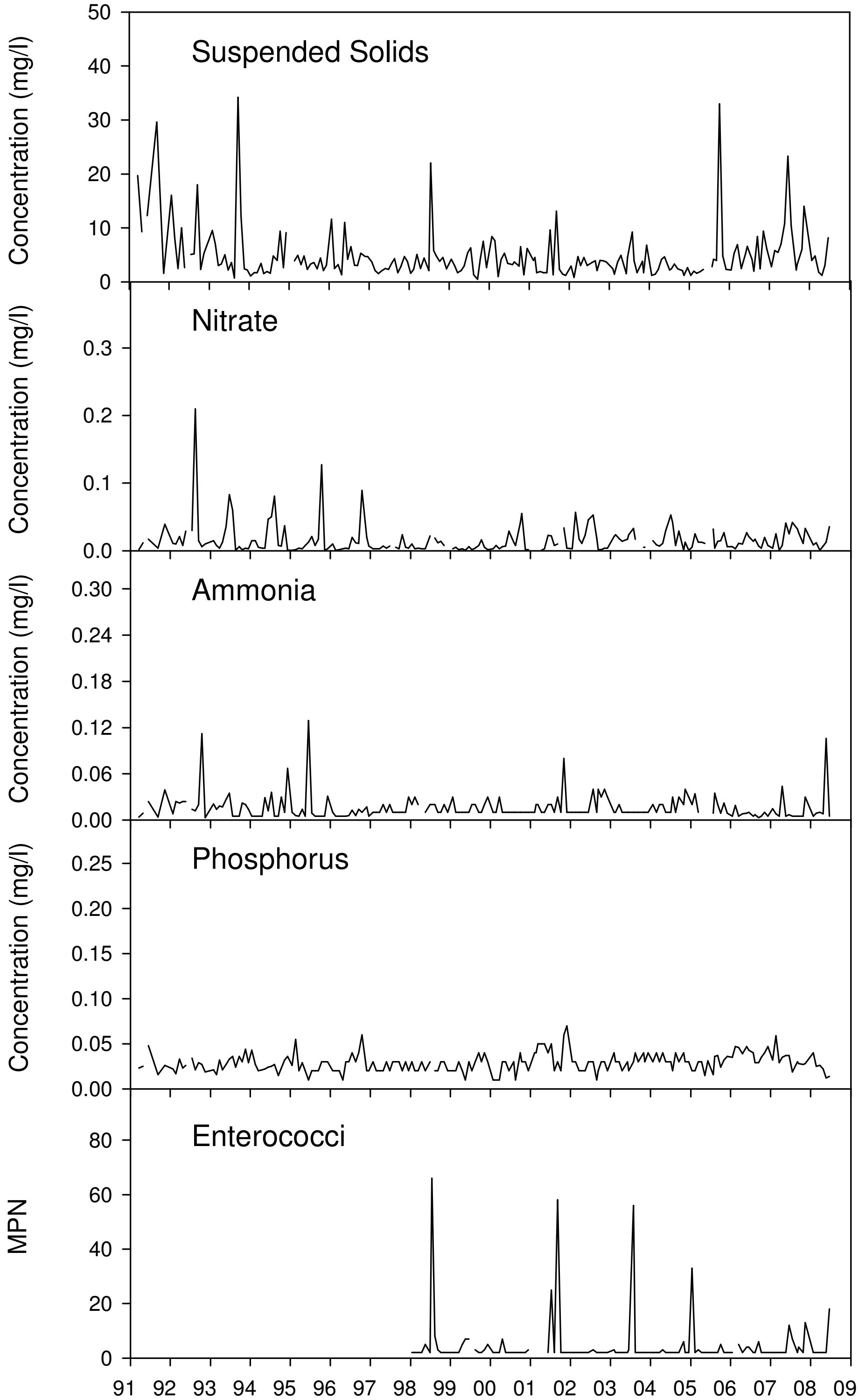


that water quality at the entrance to the harbour is good. Concentrations of suspended solids and nitrogen based nutrients have remained relatively static since 1991 (Figure 5) and have not displayed any significant temporal trends (Scarsbrook 2008). However, total phosphorus and chlorophyll *a* concentrations increased significantly between 1991 and 2007 (Scarsbrook 2008).

The conclusion that Whangateau Harbour has high water quality in also supported by Barr (2007), who compared nitrogen levels in Whangateau with those in Okura Estuary, and five urban sites in the Waitemata Harbour. From December 2002 to February 2004, monthly samples were analysed for the concentrations of nitrogen in seawater (ammonium and total inorganic nitrogen (TIN)) and the concentrations of potential indices of nitrogen enrichment in the seaweed *Ulva* sp. (tissue nitrogen, chlorophyll, total free amino acids, glutamine, proline and an unknown amino acid). All sites showed increases in seawater TIN concentrations and the nitrogen indices in winter, but Whangateau Harbour consistently had low TIN concentrations and nitrogen index levels.

However, localised wastewater contamination does occur in some parts of the harbour, due to poorly performing septic tank systems (E-cogent 2007), and small spikes in enterococci levels occasionally occur at the ARC's water quality monitoring site (Figure 5) (although these have never exceeded microbiological guidelines for contact recreation (Ministry for the Environment 2003)). De Luca (2000), examined enterococci concentrations in stormwater, seawater, marine sediments, cockle (*Austrovenus stutchburyi*) tissues and wedge shell (*Macomona liliana*) tissues around Point Wells. Bimonthly samples collected between January 1996 and August 1998 indicated that peak concentrations in shellfish occurred over winter, when rainfall was greatest. Further intensive, daily sampling around Point Wells proved that high enterococci concentrations in stormwater, seawater, sediment and shellfish tissues were related to rainfall. Stormwater concentrations peaked on the same day as a 40 mm rainfall event occurred, but there was a one day lag for peak concentrations in seawater and cockles. Concentrations in these three environmental compartments dropped fairly rapidly after the rainfall event. In contrast, concentrations in sediments and wedge shells were slower to respond and recover. Spatial patterns in the concentration of enterococci around a stormwater outfall at Point Wells were highly variable between events: indicating that dispersal patterns are event specific.

Figure 5
Temporal trends in suspended solids, nutrients (nitrate, ammonia-N and total phosphorus), and enterococci at the ARC's Ti Point monitoring site in the entrance to Whangateau Harbour (1991 – 2008) (data obtained from ARC water quality database).



3.2.2 Sediment texture and quality

A number of studies carried out in Whangateau Harbour have included assessments of sediment contaminants and/or texture. Boyd (1972) analysed sediment samples from 69 sites in the main body of the harbour for sediment texture, total organic carbon (TOC), water content and benthic fauna. Analysis of the raw data presented by Boyd (1972) indicates that the mud (<63 µm) content of sediments in the main body of the estuary was generally low (mean = 3.83 per cent, SD = 2.87 per cent), with only two sites having values above 10 per cent. The organic content of sediments was also uniformly low, with all sites having TOC contents of <1 per cent. Note that, this study was carried out prior to the installation of the Omaha causeway and sampling of the upper estuary (south of the causeway) has not been repeated.

Grace (1972b) examined patterns of sediment texture in the entrance to the harbour. Sediments were generally coarse and poorly sorted around the main entrance channel, where strong tidal currents and more wave action occur. Grace (1972b) concluded that the sediments in this area were primarily composed of sand-sized mineral grains from Omaha Bay and gravel-sized shells from shellfish beds near the entrance to the harbour. Silt and clay-sized particles were not found in large quantities. Shell lag covers much of the subtidal channel and central bank of the outer harbour (Titchener 1993). This is a significant geomorphological feature because it is extremely stable. Large shell fragments are not easily moved by tidal currents because of their size, and because they pack into a position of least resistance to current flows (and therefore greatest stability). Abrupt boundaries occur between shell lagged areas and linear sand bodies that are characterised by sand sized particles. Three large, linear sand bodies form important features of the flood tide delta, ie the flood channel, flood ramp and ebb spit.

Gowing (1994) and Klien (1994) examined the effects of discharges from two disused landfills at the upper end of the Tramcar Bay side-branch. Control sites were also sampled near the outlet of Omaha River, in the tidal creek adjoining Birdsall Rd, and at Whangateau. At each location samples were taken from upper inlet, mid inlet and lower inlet sites, and most cases these occurred within mangrove forests. The mud content of sediments was relatively high (≥80 per cent) in most of the upper sites (the exception was Whangateau, where it was 16 per cent) and in most cases showed a trend of upper > mid >lower (the exception was Birdsall Rd where mid > upper > lower). The total organic carbon contents were also relatively high, ranging from 1.1 per cent to 8.5 per cent[5], with similar trends to mud content. The concentrations of a number of heavy metals were also analysed following strong acid digestion of the total sediment fraction (assumed to be <2 mm). Average mercury concentrations exceeded ANZECC (2000) ISQG-L sediment quality guideline values at two sites, ie the impact mid site and the Birdsall Rd mid site. Highest zinc concentrations were obtained from the site closest to the landfills. At 155 mg/kg, zinc concentrations in Klein's sediment samples were slightly above the ARC's environmental response criteria's (ERC) red threshold (which is 154

[5] Values were taken from graphs and are therefore approximate.

mg/kg), and average copper concentrations slightly exceeded the ERC's amber threshold in the upper Birdsall Rd (20.7 mg/kg) and upper Tramcar Bay (20.3 mg/kg) sites (see ARC 2004).

The influence of sediment characteristics on crab (*Helice crassa*) burrowing was investigated at three sites in the harbour: two at Whangateau and one north-west of the Omaha causeway (Sivaguru 2000). Sediments at all four sites had low proportions of organic matter (~1 per cent) and were dominated by fine sand (ie 125-250 um) (~60 per cent), with <10 per cent mud. Stewart (2005) measured sediment texture and contaminant concentrations in sediments from three sites within the harbour: Lew's Bay, Point Wells and on the Omaha shore, approximately 250 m north of the causeway in November 1999 and 2002. Sediments at all three sites were sandy and contaminant concentrations extremely low, indicating that sediment quality at all three sites was very good. The sites had a low proportion of sediments in the mud fraction (<1 per cent) and sediments dominated by fine (125 to 250 μm) to medium (250 to 500 μm) sands, which contributed around 80 to 95 per cent to total sediment weight. Sediment total organic carbon (TOC), polynuclear aromatic hydrocarbons (PAH) and metal concentrations were very low, with:

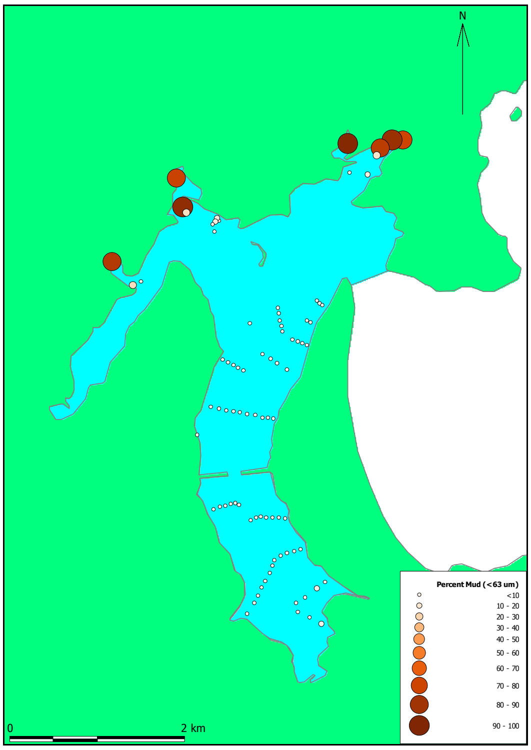
- TOC contributing <1 per cent to total sediment weight,
- none of the 16 PAHs analysed being detected,
- mean zinc concentrations were < 10 mg/kg, and
- mean cadmium, copper and lead concentrations were < 1 mg/kg.

The data on mud content (ie proportion of sediment < 63 μm in size) were collated and plotted (Figure 6). The general patterns shown in these plots are likely to be broadly representative of current conditions in the harbour, but care must be taken in the interpretation because these data were collected over a 35-year period and sample collection and analytical methods varied among studies. Patterns of sediment texture obtained from these studies are consistent with expectations for E type estuaries (Hume et al. 2007), ie sediments in the main body of the estuary are sandy, with low proportions (<10 per cent) of mud (Figure 6a). High proportions of mud (ie >20 per cent) have only been recorded in mangrove forests located in small, sheltered side-branches of the harbour (Gowing 1994). Data were therefore re-plotted with these sites excluded to examine patterns in the main body of the harbour (Figure 6b). This indicated that the proportion of mud tends to be slightly higher above the Omaha causeway (note that data from this area were collected prior to the construction of the causeway) and in adjoining channel margins, which is a common feature in estuarine systems (ARC 2004). Sediments above the causeway remain sandy in most areas (pers. obs.), although localised accumulation of muddier sediments appears to have occurred on the eastern intertidal, immediately south of the causeway. Consequently, mangroves have become established along the southern margin of the causeway; while the northern margin remains mangrove free (**Figure 7**).

Figure 6

Plots of sediment texture a) obtained from the University of Auckland MSc and PhD theses reviewed, and b) from University of Auckland MSc and PhD theses reviewed excluding Gowing (1994).

a)



b)

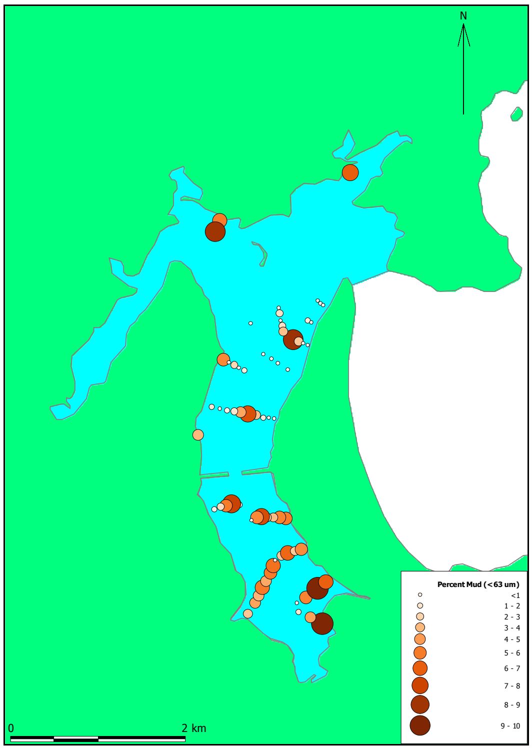


Figure 7
Photo of the a) north-eastern and b) south-eastern margin of the Omaha causeway showing mangrove growth on the southern margin, but not on the northern margin.

a)

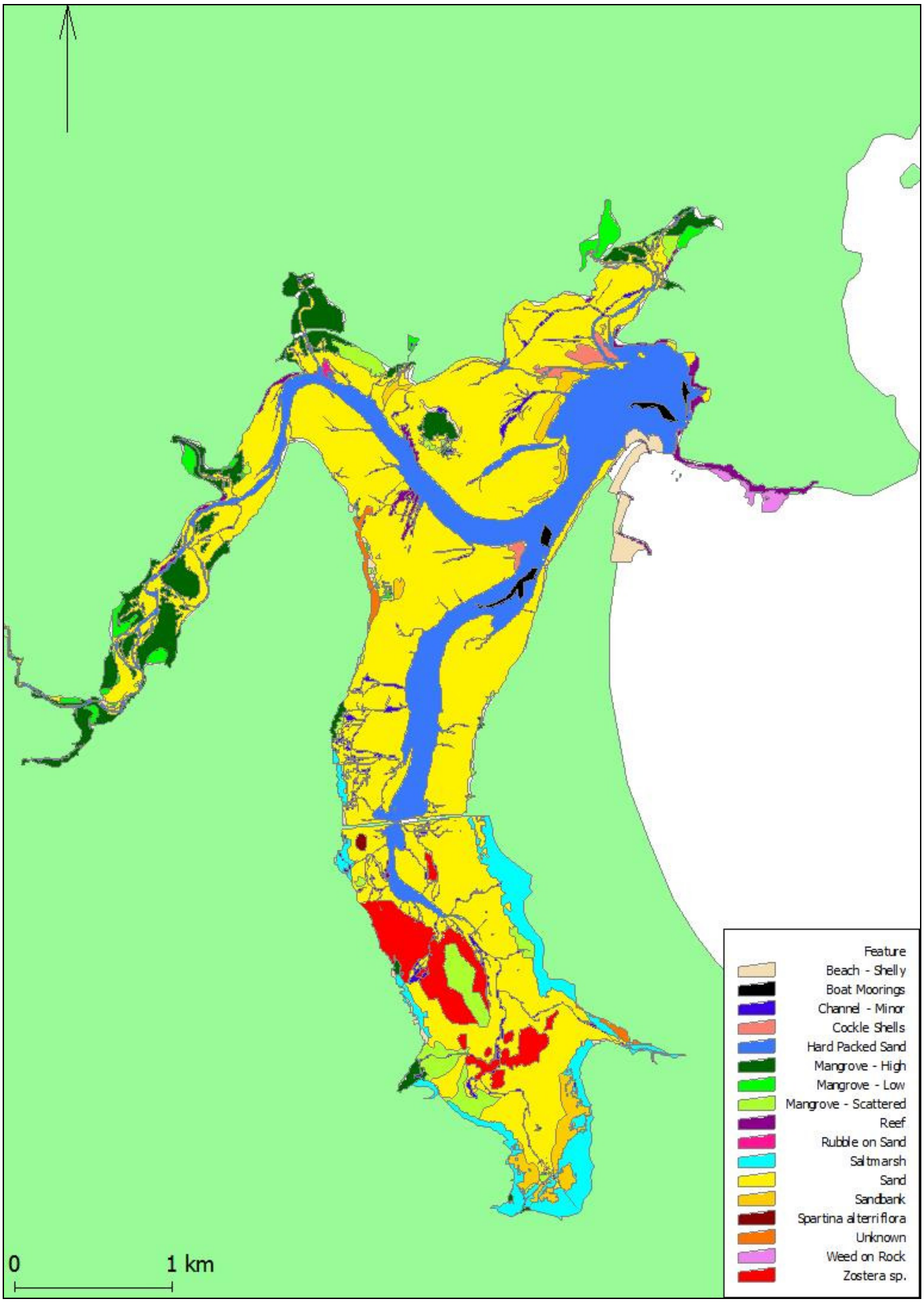
b)

3.3 Ecology

Whangateau Harbour contains a relatively diverse range of habitats, which transition from the open, semi-exposed coastal system of reefs and soft sediments in Omaha Bay, through a system of shallow subtidal and intertidal channels and broad, open sandflats in the central section of the harbour, to saltmarsh flats, muddy tidal creeks and mangrove forests on the estuary margins and in upper parts of the harbour (Figure 8).

Figure 8

Broad scale intertidal habitat map of Whangateau Harbour (from Hartill 2000).



3.3.1 Benthic communities of the outer harbour

Intertidal and shallow subtidal reefs extend from the open coast into the northern shore of the harbour entrance. The subtidal reefs consist of fractured metamorphic rock that is largely covered in coralline paint (*Corallina* spp.), with a *Carpophypyllum flexuosum* macroalgae forest canopy (**Figure 9**a). The reef has a relatively diverse echinoderm assemblage, which includes predatory sea stars (**Figure 9**b and e), grazing urchins (**Figure 9**c) and grazing sea cucumbers (**Figure 9** d). It provides a substrate for a number of conspicuous, colony-forming sponge species (**Figure 9**d to g) and supports a range of predatory and grazing molluscs (**Figure 9**h and i). Sediments along the reef margin contain a variety of infauna, including bivalves and polychaetes (pers. obs. eg fan worms **Figure 9**j). The Ti Point reefs also hold unusually high numbers of the sea slug *Scutus brevicus* and in the summer months high densities of octopus are also found around the bases of the reefs in the harbour entrance (Mark Morrison pers. com.).

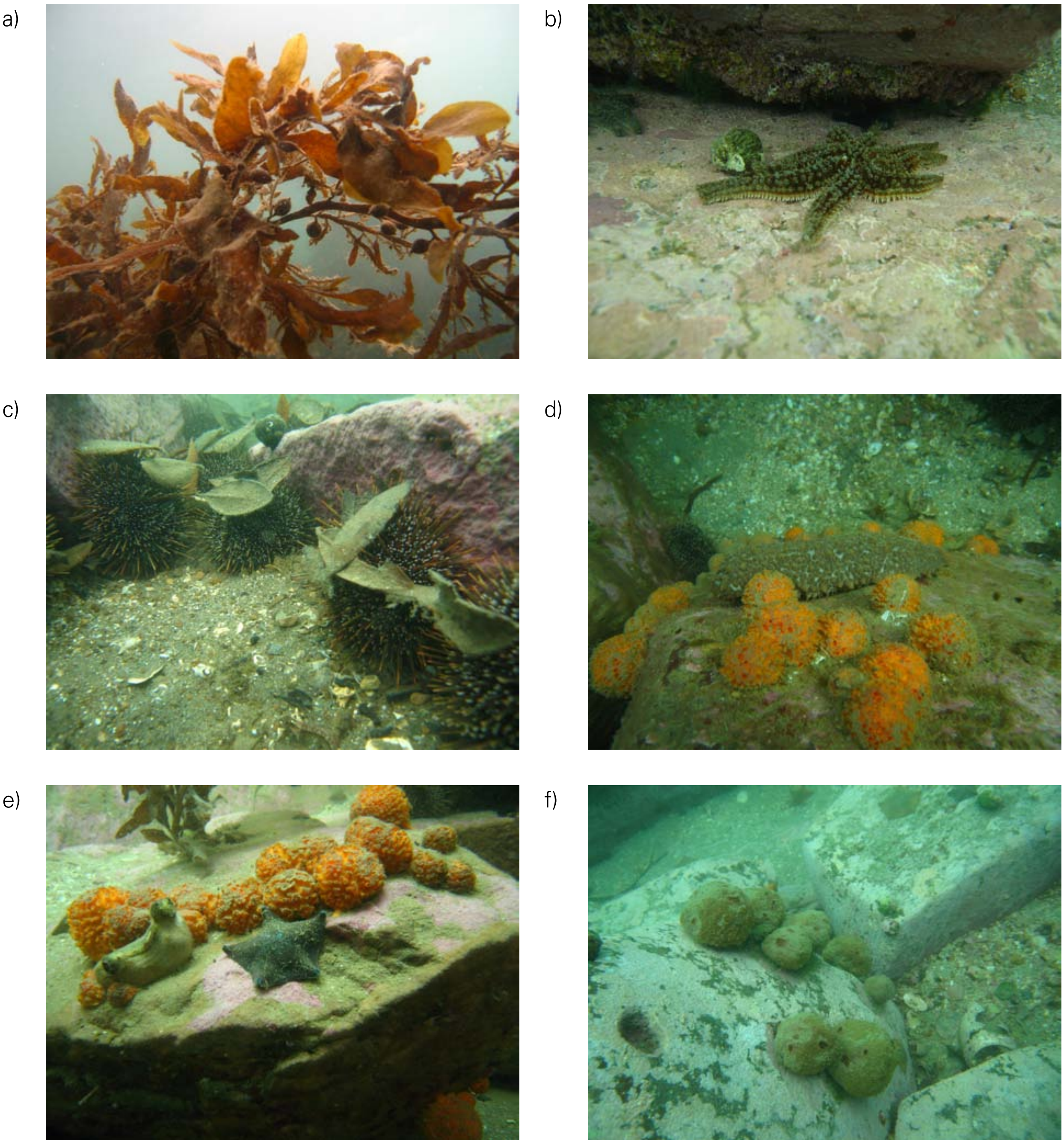
Sea cucumbers (*Stichopus mollis*) are a conspicuous component of the subtidal reef fauna (**Figure 9**d). Sea cucumbers emerge from hiding and commence feeding on the sides of rock as night approaches, and continue to feed throughout the night. *Stichopus mollis* at Ti Point, displayed a strongly, unimodal reproductive cycle, with spawning observed from September to March, and their gonads being almost completely reabsorbed during winter. Spawning occurred between 20 min and 1.5 hours after sunset, with individuals standing erect and releasing gametes directly into the water column, where fertilisation and larval development occurs (Archer 1996).

The main, subtidal channel of the harbour entrance is characterised by near-coastal water quality, high current flows, dense shellfish beds and a mix of shell lagged and sandy bottom. Hooker (1995) found that a subtidal bed of pipi (*Paphies australis*) ran continuously from near the entrance of the harbour to approximately 1 km upstream (Figure 10). The bed had very sharp boundaries, with densities dropping from many hundreds per m^2 within the bed to zero within 2 to 3 m of the bed margin. Other, common shellfish species also found in the channel and the adjoining intertidal margin include the clam *Ruditapes largillierti*, the sunset shell *Gari stangeri*, *Corbula zealandica*, and the nut shell *Nucula hartvigiana* (Gribben 1998). Grace (1972b) broadly indentified six soft sediment community associations in the channel and on intertidal flats near the entrance of the harbour. These included:

1. A cockle (*Austrovenus stutchburyi*), nut shell (*Nucula hartvigiana*) and wedge shell (*Macomona liliana*) assemblage on the northern intertidal embayment.
2. A horse mussel (*Atrina zelandica*), oblong Venus shell (*Ruditapes largillierti*), turret shell (*Maoricolpus roseus*) assemblage in north-eastern parts of the channel.
3. A pipi (*Paphies australis*) dominated assemblage in southern and western parts of the entrance channel.
4. A tuatua (*Paphies subtriangulatum*) dominated community on the north-eastern end of the Mangatawhiri Spit.

Figure 9

Example species assemblages on subtidal reefs at near the Ti Point wharf a) Carpophyllym forest; b) eleven armed starfish (*Cosinasterias calamaria*) and topshell (*Turbo smaragdus*); c) urchin *Evechinus chloroticus;* d) sea cucumber *Stichopus mollis* in sponge colony; e) sea squirt and cushion star *Patiriella regularis*; f) and g) sponge colonies (unidentified); h) grazing noble chiton (*Eudoxochiton nobilis*); i) predatory lined whelk and grazing limpet and top shell; and j) fan worm (unidentified).



g)

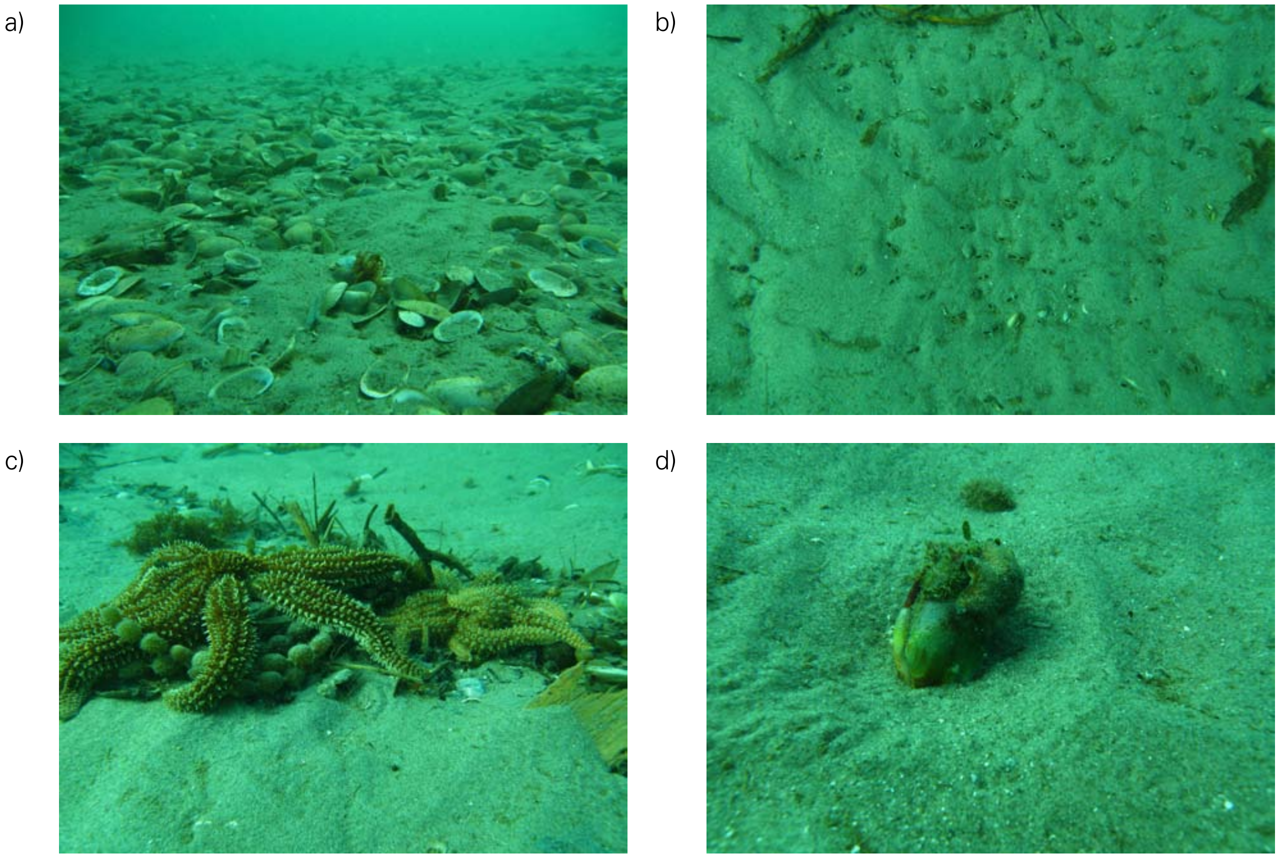
h)

i)

j)

Figure 10

Main channel of the lower Whangateau Harbour showing a) shell lagged substrate; b) pipi buried in the substrate with siphons showing; c) predatory eleven armed starfish; and, d) an emergent pipi with cushion star attached.



5. A sunset shell (*Gari stangeri*) dominated assemblage in the harbour mouth channel.
6. A *Tawera spissa* and *Dosinia maoriana* assemblage running out from Ti Point peninsula, outside of the harbour.

The dominant species listed above contain a high proportion of species that have been identified as being sensitive to fine sediment, including *A. zelandica*, *P. australis, A. stutchburyi*, *M. liliana* and *N. hartvigiana*, (see Gibbs and Hewitt 2004).

The life history and population characteristics of pipi within the main channel of the harbour entrance were examined by Hooker (1995). Adult pipi in Whangateau had an extended spawning season, which ran from early spring through summer. The planktonic phase of larval pipi lasted 18 to 22 days, and once settled pipi took approximately three to four years to reach the population maximum size of 55 to 60 mm shell length.

Pipi shape and the size varied within the channel bed. For instance, juvenile pipi were found in high densities near the entrance to the harbour, but were rare further up, while small pipi were found at either end of the bed, but were absent from the middle. Tagging indicated that pipi gradually move toward the centre of the channel and toward the harbour entrance as they grow. Adult and juvenile pipi were found to move by drifting, using mucus threads to create buoyancy. This behaviour appears to be relatively common amongst bivalves, with three other species also being caught in collectors (ie the sunset shells *Solletellina* sp. and *Gari strangeri*, and the wedge shell *Macomona liliana*).

Hooker (1995) developed the following model of pipi population dynamics based on the information gathered on distribution and movement in the outer Whangateau. The key elements of this model are summarised below.

1. An eddy concentrates pulses of pipi recruitment in a discrete, mid-intertidal band on the northern side of Omaha Spit. Large pipi do not occur in this area.
2. Tidal currents carry juvenile pipi toward the harbour entrance through passive and active transport (ie mucus drifting).
3. Juveniles (10 to 40 mm) accumulate in dense adult beds on a shallow subtidal bank near the entrance. Many of these juveniles probably remain in this area and grow in-situ.
4. A proportion of juvenile and small pipi move upstream by actively drifting on flood tides, to the northern edge of the main channel where current velocities slow down.
5. Pipi grow and gradually move toward the deepest parts of the channel where only adult pipi are found, and back towards the harbour entrance.

The oblong Venus shell, *Ruditapes largillierti* also forms a narrow subtidal band running approximately 1.1 km along the eastern shore of the main channel (Gribben 1998). Gribben (1998) found that the *R. largillierti* population was dominated by larger adults with low numbers in smaller size classes. Populations were stable between February and October 1997, with highest densities in areas with coarse surface material and a shallow anoxic layer. Extended spawning occurred, starting in July with a major peak in December, but no recruitment was apparent during the study. Gribben (1998) concluded that harvesting of *R. largillierti* in Whangateau is likely to be sustainable, only if natural populations are enhanced by seeding.

Grant (1994) examined aspects of tuatua (*Paphies subtriangulata*) ecology near the mouth of the harbour. Tuatua extend along Omaha Beach from a pipi-tuatua transition zone in the mouth of the Whangateau Harbour (Grant et al., 1998). Grant (1994) found that south of the southern groyne on Omaha Beach, tuatua were patchily distributed in a band at about 1.5 m water depth at high tide (ie they were exposed at low tide). Densities fluctuated from month-to-month, with highest densities occurring in October to November, coincident with observed spawning times. This suggested that tuatua may aggregate for spawning.

The high-density, highly productive, shellfish beds in the outer Whangateau channel attract a number of predators (see Grace 1972b). The most conspicuous of which is the eleven armed starfish, Cosinasterias calamaria Figure10c). The cushion star Patiriella regularis is also abundant, but is of little importance as a predator of large molluscs. Rather, it tends to feed on small molluscs and microscopic algae growing on sand and shells

Figure10d). The whelks *Cominella adspersa*, *C. virgata* and *C. maculosa* also attack pipi and other bivalves, but tend to be more frequent in the intertidal where they, together with *C. glandiformis*, are important predators of cockles. A variety of other carnivorous gastropods are also found in the harbour entrance, but are likely to be of lesser importance as predators.

Octopus are also common in the main channel, particularly around boat mooring blocks, which they utilise for shelter. A study of the feeding behaviour and population dynamics of the octopus *Octopus gibbsi* in Whangateau Harbour between May 1998 and July 1999 indicated that octopus abundance was highly seasonal (Managh 1999). Numbers declined from May 1998 to zero in July 1998, after which octopus did not reappear until January 1999. Following their reappearance, the number and mean size of octopus steadily increased from January to June 1999. Numbers then dropped suddenly in July 1999, in a similar fashion to the previous year's disappearance. Individual octopus tended to forage close to their dens. Octopus middens examined by Managh (1999) contained a total of 21 different prey species, although 73 per cent of the middens contained only four or less species. The bivalves *Gari stangeri*, *Ruditapes largillierti* and *Paphies australis* were consumed in large numbers and made up almost 90 per cent of all prey collected (as indicated by midden shells). Comparisons between the size of empty shells in octopus middens, and living shellfish in surrounding beds, also indicated that octopus preferentially selected large shellfish.

The most important bottom feeding fish is likely to be the eagle ray, *Myliobatis tenuicaudatus* (Grace 1972b, Le Port 2003), but snapper predation may also be significant (Grace 1972b). Flatfish also retreat to channels during low tides and tend to remain in them or in deeper intertidal areas during bright conditions (Grogan 1982). Flatfish feed on a wide range of bottom dwelling organisms such as isopods, amphipods, decapods and polychaetes, but little, if any, feeding occurs at low tide when their distribution is restricted to channels (Grogan 1982). Small flocks of oystercatchers have also been observed feeding on pipi, cockles and Venus shells as well as other sediment dwelling organisms at the entrance to Whangateau (Grace 1972b).

3.3.2 Fauna of sandflats in the central harbour

The broad intertidal sandflats and feeder channels of the central harbour provide habitat for benthic infauna and epifauna (mangroves, seagrass and other coastal vegetation is considered elsewhere). One of the most detailed studies of intertidal ecology in Whangateau Harbour was carried out in the early 1970s by Boyd (1972). The benthic community composition was determined in samples collected from 69 stations in the south-eastern arm of the harbour. Samples consisted of 0.5 m^2 x 25 cm deep quadrats sieved through 2 mm mesh. Counts of common macrofauna were analysed using a number of multivariate techniques (infrequently occurring fauna were discarded)[6]. In addition, data on grain size, and the organic and water content of sediments were collected for each site. Five "communities" were discriminated based on species composition and environmental characteristics (Figure 11). These were:

[6] Raw data for species counts and environmental variables were included in the thesis.

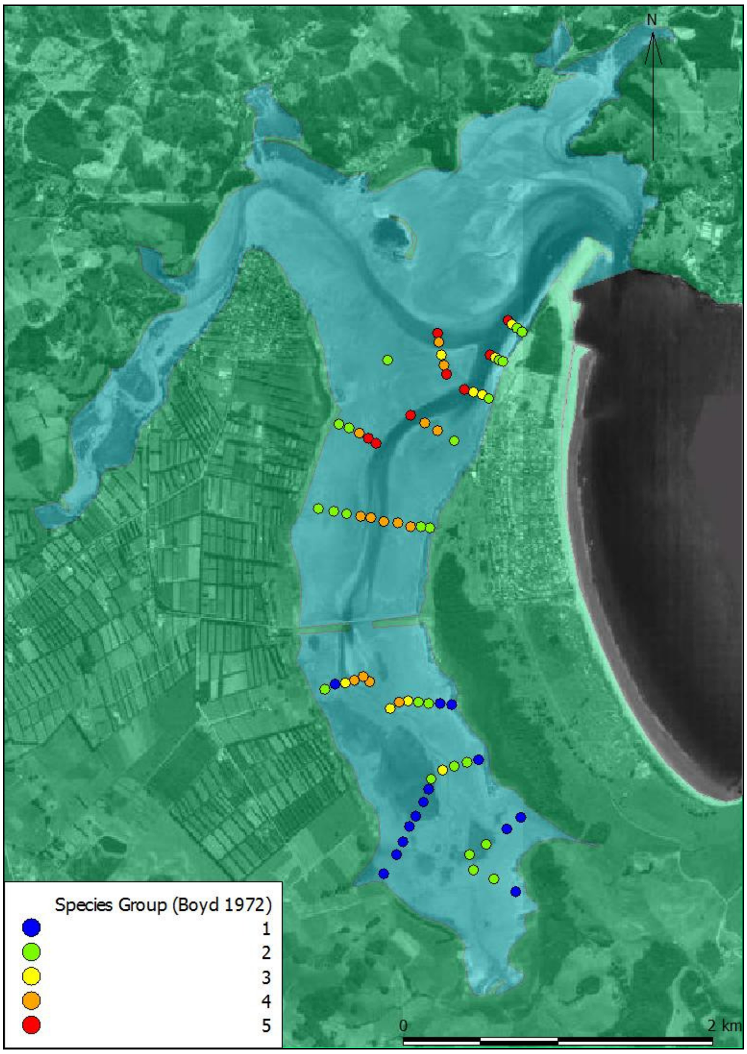
1. A high tide community at the upper end of the harbour comprised of species that are positively correlated with fine sediment.
2. A community associated with clean sand that is devoid of bivalves, which occurs in the upper intertidal around the periphery of the harbour.
3. A community comprised of the nut shell *Nucula hartvigiana*, *Zeacumantus subcarcinatus*, *Diloma subrostrata* (*Zediloma subrostrata*), the spionid worm *Prionospio aucklandica*, cockles and wedge shells.
4. A cockle and wedge shell dominated community (albeit with lower absolute numbers of cockles than in community 3).
5. A low tidal community near the entrance to the harbour dominated by pipi (*Paphies australis*), *Pervicacia tristis*, and *Owenia fusiformis*.

Ecological patterns in the harbour may have changed from those presented in Boyd (1972), as the survey is over 26 years old and has not been repeated. However, the ecological distributions presented in his thesis closely match the current location of channels, and it is likely that the observed patterns were, at least partially, related to tidal height. As such, it would be reasonable to expect that today's ecological patterns are broadly similar to those originally presented. The inclusion of raw ecological and environmental data in Boyd's (1972) thesis is a particularly valuable resource, which could be used for confirming whether, or not, this is the case.

A variety of published and unpublished information was sourced on individual benthic species associated with sandflats in the central harbour.

Cockles are widespread in sandy, intertidal parts of the harbour. Stewart (2005) compared spatial and temporal trends in cockle populations from three sites running along a gradient from opposite the harbour mouth (ie Lew's Bay) to the Omaha causeway. A consistent trend of declining cockle size and density with increasing distance from the harbour mouth was detected in 1999 and 2002 (albeit cockle size between the mid-harbour and upper harbour sites was not significantly different). Most cockles were reproductively mature, but two juvenile cohorts (below 18 mm in size) were detected at the outer and mid sites in 1999 and 2002. Sampling carried out at three monthly intervals in from November 1999 to August 2000 showed a clear juvenile cohort in each sampling period, with the largest number of new recruits occurring in August 2000. Highest, overall densities were obtained in November 1999. The sex ratio of cockles at the three sites was even, and spawning occurred over summer: possibly with two spawning events: one in November/December and a later one around February. Statistically significant differences were not detected in the ratios of male to female cockles from the three sites.

Figure 11
Species groups identified by Boyd (1972). Descriptions of the species groups are provided above. Site locations are taken from original maps and should be considered approximate.



Kearney (1999) found cockles throughout Lew's Bay, but larger animals, of harvestable size, generally occurred in discrete bands adjacent to intertidal channels. Shellfish harvesting was concentrated in the areas where high densities of large cockles occurred, and the largest individuals (generally bigger than 30 mm wide) were specifically targeted. Harvesting effort was greatest on public holidays and weekends in summer, particularly when low tides occurred in mid-early afternoon. The majority of harvesters were Maori (54 per cent), followed by New Zealand European (26 per cent), Asians (15 per cent) and Pacific Islanders (four per cent). Although Pacific Islanders were least numerous, they tended to harvest shellfish more frequently than other ethnic groups. Most harvesters collected cockles two to five times per year, but 29 per cent gathered shellfish more than nine times per year. Most did not comply with the legal daily bag limits (150 cockles per day at time of study – subsequently reduced to 50 cockles per day in the Auckland and Coromandel area, which includes Whangateau Harbour). However, between October 2007 and July 2008 only two warnings were issued by Ministry of Fisheries enforcement officers for harvesting in Whangateau and no infringement notices or prosecution actions were issued or taken (Moore 2008). In contrast, during the same period 14, 41 and 28 infringement notices were issued and four, zero and 38 prosecutions were taken at Okoromai, Clarks Beach, and Cockle Bay, respectively. It is not known whether the low incidence of enforcement notices and prosecutions at Whangateau was due to lower enforcement effort, better compliance with fisheries regulations or less harvesting pressure.

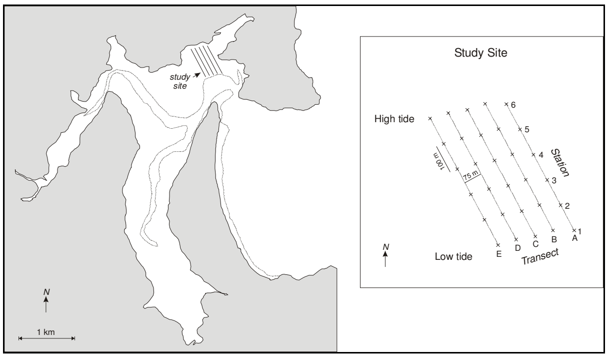
Kearney (1999) found that most harvesters did not come from the Rodney District. The points of origin for the harvesters surveyed were: Manukau City (54 per cent); Rodney (18 per cent); Papakura (eight per cent); North Shore (six per cent); Auckland City (four per cent); Waitakere City (two per cent); Franklin (one per cent) and elsewhere (seven per cent). The high proportion of harvesters from south Auckland (63 per cent) is notable because cockle harvesting has subsequently been banned from most, east coast beaches in that area. Consequently, harvesting effort could be redirected toward Whangateau.

Cockle size and abundance data from Lew's Bay was collected by University of Waikato marine science students during surveys in June/July 1997-2000, and then in April 2001-2003. On each occasion, samples were collected from three to five transects running perpendicular to the shore (spaced 75 m apart), with six sampling stations per transect at 100 m intervals, starting at the low tide mark (Figure 12). The total number of transects sampled varied between survey dates, depending on the number of students enrolled in the course. Cockles from three, randomly placed 0.25 m^2 quadrats were collected and then sieved on a 1 mm mesh at each station. Shell height (maximum linear dimension) of each cockle was measured to the nearest 1 mm, and the wet weight and density of cockles in each quadrat was also recorded. Large cockles were consistently obtained from stations closest to the low tide mark. Cockle size decreases up the shore, but densities generally increase between Station 1 and Station 3 (ie ~ 200 m inshore from the low tide mark), then decline shoreward. Greatest cockle biomass tends to occur between 100 m and 200 m (Station 2 and 3) inshore from the low tide mark, due to the combination of moderate sized cockles and high abundance. Distinct recruitment pulses were detected at Station 1 (ie low tide) in 1998 and 2003, suggesting that recruitment is episodic.

The Ministry of Fisheries surveyed cockle beds in 12 beaches/harbours (including Whangateau) in the greater Auckland, Northland and Bay of Plenty in February 2006 and July 2007. The purpose of the survey was to estimate the distribution, abundance and size frequency distribution of pipi and cockles, and determine if populations had changed since previous surveys were conducted. Four sites were surveyed within Whangateau (Figure 13) using stratified random sampling (Pawley and Ford 2007). The sites were estimated to contain between 234.3 and 335.6 million cockles, and there was no evidence of total cockle numbers declining between 2004 and 2006. Nor was there evidence of any difference in the number of harvestable-sized cockles, which made up 16.3 per cent and 13.7 per cent of the 2004 and 2006 populations respectively.

Figure 12

University of Waikato cockle survey design and annual means of cockle density, size and biomass (Pilditch, unpublished).



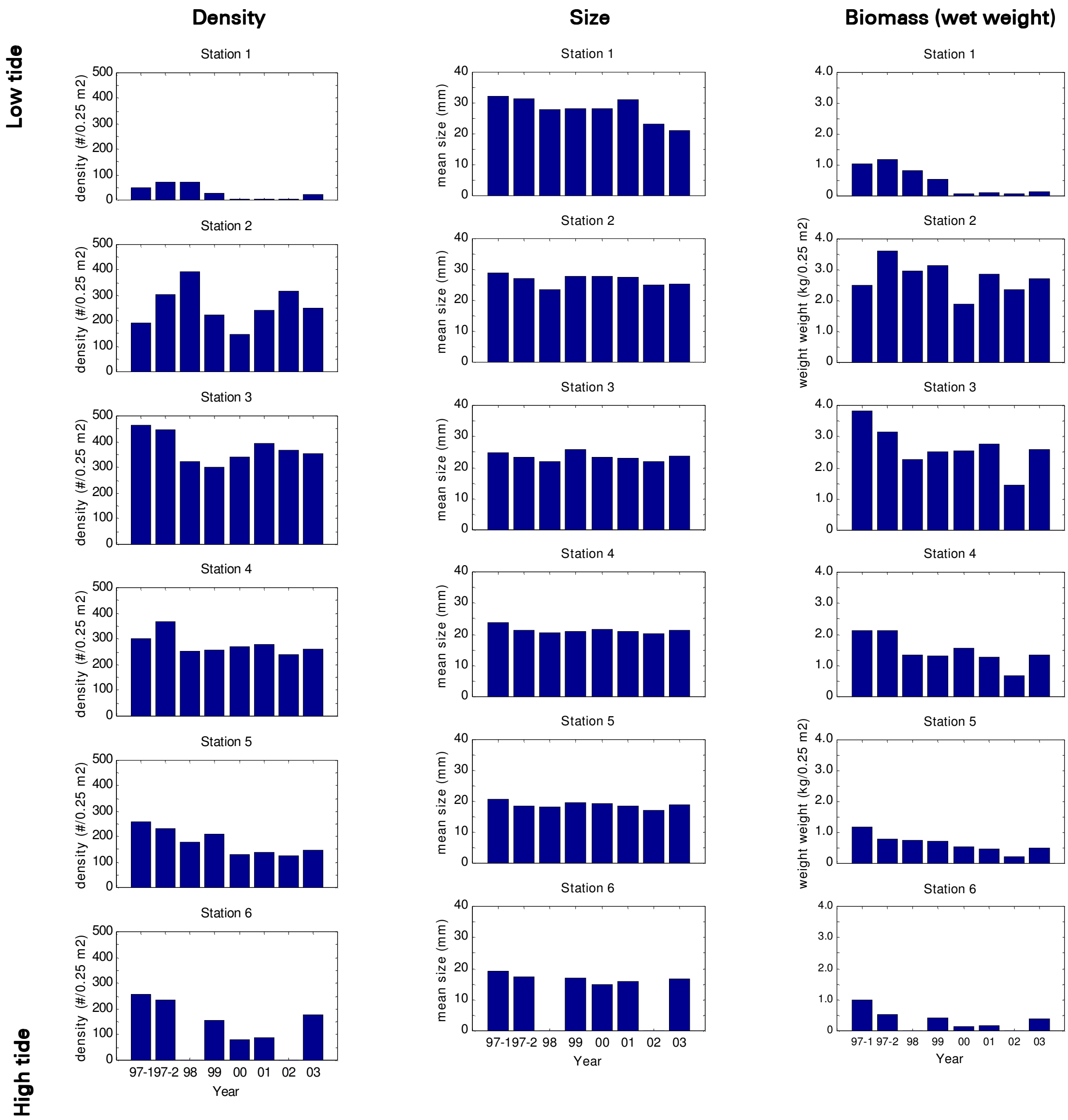


Figure 13
Approximate cockle and pipi sites (orange blocks) surveyed by Pawley and Ford (2007).

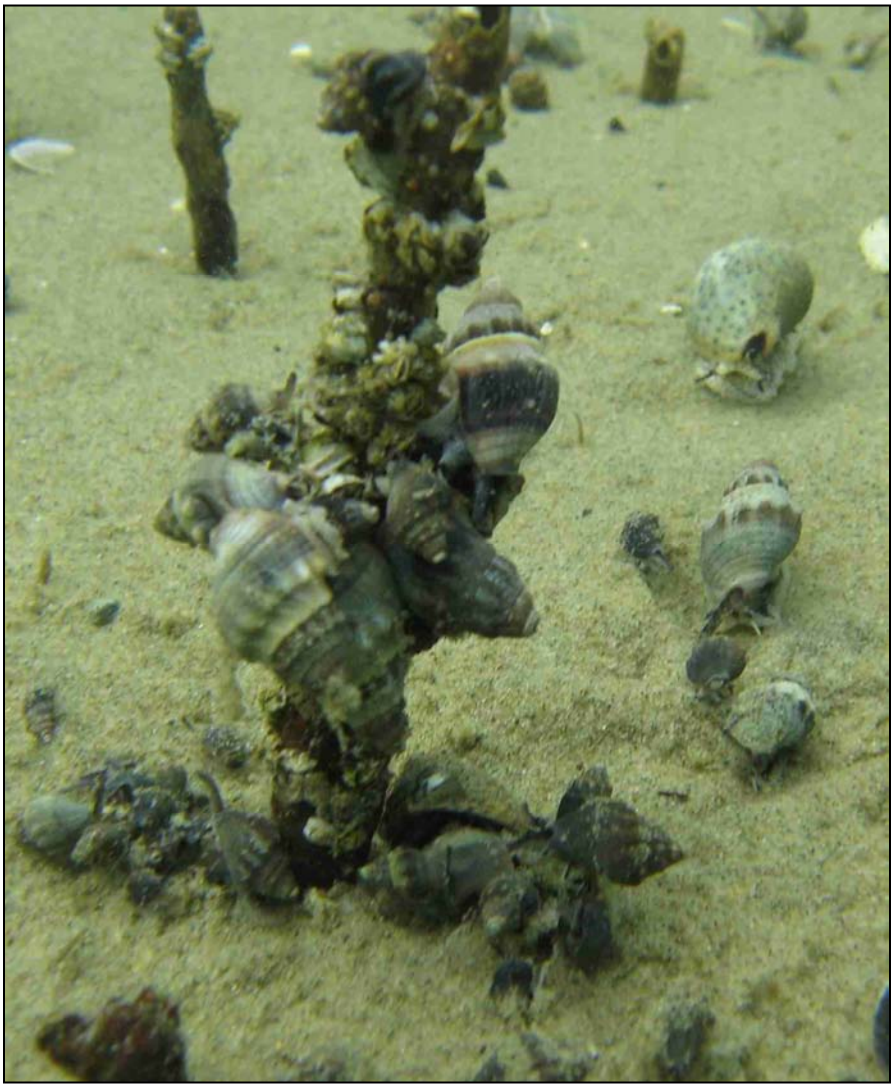
In contrast, Pawley and Ford (2007) estimated that the sites contained between 4.0 and 19.7 million intertidal pipi, and there was strong evidence that pipi abundance had increased since 2004. This increase was driven by the recent recruitment of two cohorts of pipi, with peak sizes of around 8 mm and 28 mm. However, very few pipi were of harvestable size in 2006, and there was very strong evidence that the number of harvestable pipi had actually decreased. Pawley and Ford (2007) noted that the majority of pipi population in Whangateau Harbour is likely to be subtidal, and therefore outside the sampling area.

Annual surveys of shellfish and other species in Lew's Bay and on the north-western side of Omaha causeway have been carried out by the Whangateau Harbour Care group since 2006. Summary data are available, but formal analysis or reporting has not been carried out. Ministry of Fisheries will assist with this (Cryer pers. com., Ross pers. com.).

Stewart and Creese (2004) examined whelk predation on cockles in Lew's Bay, and in particular the potential for predation to counter efforts to re-seed cockle beds. Aggregations of whelks feeding on cockles were regularly observed in the Whangateau with four species of the buccinid whelks *Cominella* (*C. virgata, C. glandiformis, C. maculosa* and *C. adspersa*) observed along with oyster borer *Haustrum scobina. Cominella glandiformis* accounted for 95–99 per cent of whelks encountered, with other species of *Cominella* and *Haustrum scobina* rarely comprising more than 1 per cent of the sample population. Whelks fed in aggregations (Figure 14), which increased in size as the amount of food increased. *Haustrum scobina* were generally observed preying upon, rather than scavenging on, cockles. In contrast *C. glandiformis*, *Cominella virgata* were nearly always observed scavenging, even though they were capable of predation in laboratory experiments. *Cominella maculosa* were only observed scavenging. Stewart and Creese (2004) concluded that *H. scobina* or *C. adspersa* could prey on re-seeded cockles and recommended on-growing clams to a larger size before seeding out to reduce their impact.

Figure 14

A trail of straggling whelks "rush" toward a whelk pack that is attacking barnacles growing on mangrove pneumatophores. Whelks are attracted by the scent of injured and dying prey.



3.4 Fish

Grace (1971) provided a checklist of 37 fish for the harbour entrance, together with their associated habitats and a qualitative score of their abundance. Five more fish species were added by Grace (1972a). Grace's (1971) observations are summarised below.

Sandy areas west of the harbour entrance – Clingfish (*Trachelochismus melobesia*) were particularly common, often taking refuge in dead, articulated shells. The variable triplefin *Forsterygion varium* was also common in this area, and was typically associated with shellier sediments. Small bastard red cod (*Pseudophycis breviusula*) were occasionally seen, as were spotted stargazers (*Genyagnus monoterygius*). On one occasion a number of small, sand divers (*Tewara cranwellae*) were seen, with their heads protruding from the sand.

Sandy areas outside the harbour entrance – Goatfish (*Upeneichthys porosus*) were commonly observed by Grace (1971) and fishers reported catching red gurnard (*Chelidonichthys kumu*) further out.

Coarse shell in main channel – Red gurnard (*C. kumu*) and clingfish (*T. melobesia*) were common.

Macroalgae forest on reefs of the Ti Point shore – Large numbers of parore (*Girella tricuspidata*) occurred amongst the weed, while the variable triplefin (*F. varium*), common triplefin (*Forsterygion* sp. (formerly known as *Forsterygion capito* and *Tripterygion capito*) and spotty (*Notolabrus celidotus*) were common amongst the weeds or on rocks. Juvenile yellow-eyed mullet (*Aldrichetta forsteri*), koheru (*Decapterus koheru*), and juvenile blue maomao (*Scorpis aequipinnis*) swam around the algal belt. Juvenile leather jackets (*Parika scaber*) occurred seasonally in the weed belt, but adults were not found in this habitat. The rock cod *Acanthoclinus fucus* (formerly *Acanthoclinus quadridactylus*) was sometimes seen in holes in the reef, while John dory (*Zeus faber*) were frequent visitors.

Rock patch in the harbour entrance – Numerous fish aggregated around this rock. Closely associated demersal species included: goatfish (*U. porosus*), spotty (*N. celidotus*), banded wrasse (*N. fucicola*), red moki (*Cheilodactylus spectabilis*), hiwihiwi (*Chironemus marmoratus*), variable triplefin (*F. varium*), and common triplefin (*Forsterygion* sp.). Pelagic or semi-demersal species included snapper (*Pagrus auratus*), John dory (*Z. faber*), blue maomao (*S. aequipinnis*), parore (*G. tricuspidata*), and butterfly perch (*Caesioperca lepidoptera*).

Surface and mid-water in the harbour – Koheru (*D. koheru*) were the most common pelagic species and were frequently accompanied by juvenile trevally (*Pseudocaranx dentex*) and juvenile kahawai (*Arripis trutta*). Juvenile yellow-eyed mullet (*A. forsteri*) were often observed, forming schools just below the surface. Piper (*Hyporhamphus ihi*) were also observed in schools, and kingfish (*Seriola lalandi*) were frequently seen chasing small schooling fish. Barracuda (*Thyrsites atun*) sometimes entered the harbour in groups of two or three, swimming just below the surface.

Whangateau Harbour also contains important fish nursery hot-spots, centred on the soft sandstone reef complex next to Horseshoe Island (Figure 15), and a smaller area just above the Omaha causeway bridge (Morrison pers. com., Grace pers. com.). These reefs are intertidal, with a cover of Neptune's necklace (*Hormosira banksii*) around their crests. At high tide, the reefs and adjoining sand flats are fully accessible by fish, and are heavily utilised by juvenile parore, with the highest densities along the edge of the reef crest, where Neptune’s necklace occurs (Morrison 1990, Morrison pers. com.). Numbers are commonly in the thousands, and a number of size cohorts may be present, representing different spawning events in the same spawning season. These fish feed on passing zooplankton, especially copepods, and may be found as schools in the water column just out from the reef (larger

Figure 15
Adult parore on reefs and amongst mangroves adjacent to Horseshoe Island.

juveniles), as well as on the reef proper (smaller juveniles). The Neptune's necklace is used as cover from predators. At low tide these fish disperse into the adjacent channels, and may be found several hundred metres away from the reefs, in very shallow waters.

Juvenile parore are present on the inner harbour reefs from January through March. Around the end of March, they move down the harbour to the *Carpophyllum* forests along the face of Ti Point. Initially, they are found at the interface between the kelp forest and the bare intertidal rock zone, but as the year progresses they move down into the kelp forest proper, and eventually occupy the interface between the lower kelp forest boundary and the channel floor, where broken rock habitat is found. A switch from purely zooplankton, to proportions of benthic prey such as hydroids, also occurs through this time. At an age of around one year, they move out to the reefs in the entrance to the Whangateau Harbour, and then over the following two years appear to disperse to more coastal reef systems, including the Leigh Marine Reserve (Morrison 1990, Morrison pers. com.).

Large expanses of bare sand appear to present a dispersal barrier to parore less than 200 mm in length. It is suspected that the nursery areas in Whangateau Harbour are critical sources for parore on the adjacent coastal reefs, where individuals less than 150 mm are rare, and no fish less than 100 mm have been surveyed. Large numbers of adult parore are also found in the summer months on the Whangateau sandstone reefs, and in the *Carpophyllum* forests. There is also some indication, through hard to document with visual census methods, that during large storm events adult parore densities inside Ti Point increase significantly, perhaps as fish migrate into the harbour to avoid the storm conditions (Morrison 1990, Morrison, pers. com.).

A current Foundation for Research, Science and Technology Biodiversity Fund project (ZBD200509 - Rocky Reef functioning) is looking at the otolith chemistry of parore (and snapper) to assess what proportion of the adult populations on rocky reefs come from direct larval settlement to the reefs versus later life stage ontogenetic shifts such as those described above. Whangateau fish, as well as adults from the Leigh Marine Reserve and Tawharanui Marine Park form part of the larger data-set being used. Note that this study is not about matching fish back to their natal estuaries per se, but rather about demonstrating that connectivity does occur, and is important, between different ecosystem elements (eg estuaries/soft sediment systems, and rocky reefs) (Morrison pers. com.).

The sandstone reefs in Whangateau Harbour are also focussing points for the juveniles of other species. Relatively large schools of juvenile trevally occur in the water column adjacent to the reefs over the summer months, while at the bottom of the reefs relatively small schools of juvenile snapper (20 to 70 mm) can also be seen. Large numbers of spotties (both juveniles and adults), and goatfish (juveniles and small adults) are also present, along with triple-fins. To a lesser extent, similar patterns are also apparent along the Ti Point reefs inside the harbour, and around the structure provided by the mooring blocks of vessels.

While there are currently no empirical data on the value of these nurseries to the local systems (eg how important they are to eventual adult population sizes), for parore at least it appears they are critical to Greater Omaha Bay, and the Leigh Marine Reserve (Mark Morrison pers. com.).

Limited beach seines from the harbour also show the presence of juvenile sand flounder, and to a lesser extent yellow-belly flounder, in the harbour, on the less structured soft sediment areas. Clear water, coarser substrate harbours do not tend to support high abundances of these species, although adult populations are present, and do contribute to fisheries catches (Morrison pers. com.). During daytime low tides flounder (*Rhombosolea leporina* and *Rhombosolea plebeia*) remain in channel areas that are deeper than those used during night-time low tides, presumably to avoid predators such as shags (Grogan 1982). Grogan (1982) found the use of intertidal sandflats by flatfish seemed to be related to factors affecting light levels and visibility (eg turbidity and cloud cover) and was patchy during daytime high tides.

Night-time high tide distributions tended to be more uniform, with fish consistently using shallow water close to the shore. Gut sampling showed that little, or no feeding occurred during low tide, but feeding did occur both during the day, and at night when the tide was in. Small flounder (<1-year-old) preyed heavily on small food items such as isopods, whereas large flounder consumed a wider range of prey, dominated by polychaetes and crustaceans. Gut contents also included a large proportion of detritus (which contained planktonic material).

Juvenile kahawai also occur in the summer months, although no targeted sampling for this semi-pelagic species has been undertaken, apart from multi-panel gill nets, which show that they are present in some numbers. Yellow-eyed mullet are ubiquitous in the harbour, and juvenile speckled sole also occur in high numbers (note that beach seine data from Whangateau are incorporated in the analyses of Francis et al. 2005, as one of the 25 harbours surveyed) (Morrison pers. com.).

Highly cryptic and relatively rare seahorses are found in the reef, kelp forests around Ti Point wharf (Van Dijken 2001). Sea horses tagged in this area were found to be relatively sedentary, and appeared to maintain an association with particular algal stands. Counts in *Carpophyllum* forests at the entrance of Whangateau Harbour were generally low throughout the year, but numbers were lowest in late autumn and increased slightly from October to February. Seasonal size frequency estimates suggested that the increase was due to recruitment, which tended to occur over summer months.

Tagged eagle rays, *Myliobatis tenuicaudatus,* tracked for 22 to 198 days in Whangateau Harbour also showed a relatively high degree of fidelity to the harbour, spending between 96.5 per cent and 100 per cent of their time inside the estuary (Le Port 2003). Movement patterns were strongly influenced by tides, with rays mainly found near the entrance at low tide and in intertidal foraging areas during high tide. Day-night activity varied between rays, but feeding intensity tended to be greater at night. Eagle rays displayed selective use of the sandflats, utilising patches with higher prey densities and penetratable sediment. Surveys of eagle ray feeding pits indicated that discrete, intertidal areas were used on a rotational basis, where rays sequentially moved between feeding areas in the harbour.

The invasive Australian bridled goby, *Arenigobius bifrenatus*, was discovered in Whangateau Harbours in 1998, and is assumed to have been introduced by release of ballast water from passing ships (Willis et al. 1999). Subsequent surveys indicated that *A. bifrenatus* occurred between Matapouri Bay, north of Whangerei Harbour, to Tamaki River, and in Tauranga Harbour (Usmar 2003). *Arenigobius bifrenatus* are benthic feeders that form complex burrows with interconnecting structures (Usmar 2003). Tagged individuals have been observed to occupy the same burrows (or one very close by) for up to a year (Usmar 2003), indicating that they maintain a strong site attachment. In Whangateau Harbour they appear to occupy a previously vacant niche, and are only found in: muddy habitats; in or adjacent to seagrass beds; within the pnematophore zone and very soft mud adjacent to mangroves; or in muddy channels (Francis et al. 2003, Usmar 2003).

3.5 Birds

Whangateau provides feeding and roosting habitat for a number of sea and shorebird species

Figure 16). Bird use of the harbour was assessed by searching publications produced by the Ornithological Society of New Zealand, science journals and theses (Table 2). A nominal species list for the harbour indicated that at least 24 sea and shorebirds use the estuary.

Mangatawhiri Spit is a particularly important nesting and flocking site for the nationally vulnerable, New Zealand dotterel *Charadrius obscurus*. New Zealand dotterels of the northern population commonly nest, roost and form post-breeding flocks on sandspits at the mouths of tidal estuaries or streams. The establishment of the present flock on Mangatawhiri Spit appears to be relatively recent, although it is likely that dotterels used the spit before humans began exploiting the area (Dowding and Chamberlin 1991). Most wading species in the area quickly adopted the spit as a high tide roost following its expansion after the installation of groynes to control erosion on Omaha Beach. New Zealand dotterels and variable oystercatchers (*Haematopus unicolor*) also adopted it as a breeding and post-breeding flocking site (Dowding and Chamberlin 1991). More recently, the area has also been frequented by fairy terns, which are New Zealand's rarest bird, with a total population of < 50 individuals (Rodney District Council 2003).

Dowding and Chamberlin (1991) found that dotterels began arriving on the spit in January with greatest numbers occurring during February to March. Dotterels started to develop their nuptial plume in April, and non-resident breeders started leaving for their breeding grounds toward the end of March, with departures lasting through to July. Non-resident breeders returned to the same stretch of coast to breed each year, and most occupied the same, or similar, territories in consecutive years. Overall numbers (adults and juveniles) on Mangatawhiri Spit continued to fall through to September, and from September on, nearly all adult birds on the spit were resident breeders. Juveniles were more mobile than adults and their movements made the greatest contribution to fluctuations in flock size.

Resident breeders remained within, and defended, their nesting territories from conspecifics during the breeding season, but moved short distances (up to 400 m) to roost with visiting birds in flocks, once the season had finished. Bonded pairs remained together for most, if not all of the year and fidelity of individual dotterels to the Omaha flock was very high: all birds observed in one autumn returned in the next. No, or very limited, movements occurred between "distant" coastal areas (eg Mangawhai and Wade River), but shorter movements (eg to Pakiri) regularly occurred. However, the range of resident breeders was more restricted than non-resident breeders and was generally limited to <2 km (Dowding and Chamberlin 1991).

Fernbirds have a strong association with the band of emergent vegetation between the outer sedgeland and inner coastal manuka forest, on the seaward side of Taniko Scientific Wetlands Reserve (Parker 2002) (see Section 3.6). Fernbirds are reluctant fliers, which forage by scampering through thick vegetation, feeding on small invertebrates such as spiders and insects, and berries. Parker (2002) found that fernbirds maintain nesting territories ranging in size from 2271 m^2 to 8244 m^2 (n = 15). Nesting occurs from October to late-February, with

Figure 16

Pied shags (*Phalacrocorax varius*) and bar-tailed godwits (*Limosa lapponica baueri*) on the tip of Mangatawhiri Spit.

fledging occurring from mid-November onwards. Two to four eggs are laid per clutch. During the 2000/2001 nesting season Parker (2002) observed four nests that fledged chicks and seven nests that failed due to predation and flooding. In the following year, six nests fledged chicks and four failed due to predation and abandonment. Overall, predation accounted for 73 per cent of fernbird nesting failures. Similarly, of eight banded rail (*Rallus philippensis*) nests found in reed beds in the upper harbour by Parker and Brunton (2004), at least five showed signs of predation (62.5 per cent). A video camera installed on a disturbed banded rail nest captured images of a stoat visiting and feeding on egg and chick remains.

Predator monitoring also detected frequent ferret and stoat tracks and occasional rat and possum tracks in sand and mud throughout the saltmarsh adjoining Taniko Scientific Wetlands Reserve (Parker 2002). Thirty-three per cent of artificial nests set by Parker (2002) were attacked by predators between December 2001 and January 2002. Mice were responsible for

78 per cent of attacks, with birds, rats and unknown predators accounting for the remainder. Mice were considered to be both potential predators and competitors of fernbirds. Asian wasps were also considered to be potential competitors.

Table 2

Sea and shorebirds recorded in Whangateau and their conservation status.

Common name	Species name	Reference	Origin	Status	Status code
NZ fairy tern	*Sterna nereis davisae*	3, 14	Endemic	Nationally critical	1
Wrybill	*Anarhynchus frontalis*	7	Endemic	Nationally vulnerable	3
NZ dotterel	*Charadrius obscures*	1, 2, 3	Endemic	Nationally vulnerable	3
Reef heron	*Egretta sacra*	8, 13	Native	Nationally vulnerable	3
Caspian tern	*Sterna caspia*	13	Native	Nationally vulnerable	3
Banded dotterel	*Charadrius bicincrus bicinctus*	2, 3, 4, 12	Endemic	Gradual decline	5
Red-billed gull	*Larus novaehollandiae scopulinus*	13	Endemic	Gradual decline	5
White-fronted tern	*Sterna striata*	13	Native	Gradual decline	5
North Island fernbird	*Bowdleria punctata vealeae*	11, 14	Native	Sparse	6
Black shag	*Phalacrocorax carbo novaehollandiae*	13	Native	Sparse	6
Banded rail	*Gallirallus philippensis assimilis*	6, 14	Native	Sparse	6
Little black shag	*Phalacrocorax sulcirostris*	13	Native	Range restricted	7
White-faced heron	*Ardea novaehollandiae novaehollandiae*	13	Native	Not threatened	-
South Island pied oystercatcher	*Himantopus ostralegus finschi*	1, 13	Endemic	Not threatened	-
Variable oystercatcher	*Haematopus unicolor*	1, 3, 13	Endemic	Not threatened	-
Kingfisher	*Todiramphus sanctus*	9, 13	Native	Not threatened	-
Pied stilt	*Himantopus himantopus leucocephalus*	13	Native	Not threatened	-
Black-back gull	*Larus dominicanus dominicanus*	13	Native	Not threatened	-
Australasian gannet	*Morus serrator*	13	Native	Not threatened	-
Pied Shag	*Phalacrocorax varius varius*	13	Native	Not threatened	-
Little egret.	*Egrefta garzetta*	6, 10, 12	Migrant	Migrant	-
Eastern bar-tailed godwit	*Limosa lapponica baueri*	1, 2, 6, 13	Migrant	Migrant	-
Black-tailed godwit	*Limosa limosa sp.*	2	Sraggler	Migrant	-
Pacific golden plover	*Pluvialis fulva*	2	Migrant	Migrant	-

Data sources: 1 – Parrish (2001); 2 – Parrish (2000); 3 – Parrish (2002); 4 – Pierce (1999); 5 – Parrish and Lock (1997); 6 – Edgar (1977); 7 – Edgar (1976); 8 – Edgar (1978); 9 – Anonymous (1953); 10 – Sibson (1979); 11 – Howell (1987); 12 – Sibson (1978); 13 - Larcombe (1968), Parker and Brunton (2004), Parker (2002),; 14 – Rodney District Council (2003).

Parker (2002) provided a number of recommendations for the management of the Omaha fernbird population, including:

1. The establishment of bait stations to control rodents and possums.
2. The establishment of a perimeter line of traps to control cats and mustelids.
3. The extension and modification of the predator fence on the eastern side of Taniko Scientific Wetlands Reserve to exclude mustelids and rodents.
4. Monitoring and research on invertebrates, vertebrates and plant communities.

3.6 Seagrass, intertidal algal beds, mangrove forests and coastal vegetation

Patches of seagrass, *Zostera novazelandica* and *Spartina alterniflora* occur above the Omaha causeway (see Figure 8). *Spartina alterniflora* is a pest species that has been in Whangateau Harbour since, the early-1960s (Larcombe 1968). *Spartina* (there are three species in New Zealand) takes over coastal marine areas, particularly in estuaries and harbours where was introduced to "reclaim" land for pasture and for bank stabilisation and erosion control (Nicholls 1999). The ARC's Regional Pest Management Strategy (RPMS) specifically identifies *Spartina* as: a **total control pest plant** in the Waitemata and Manukau Harbours, and all water bodies of the east coast of the Auckland region; and, a **surveillance pest plant** throughout the remainder of the Auckland region (ARC 2007).

A number of large seagrass beds are located on the central to western side of the harbour, above the causeway. Smaller patches are also found in, and around, the channel and associated tidal creek at the southern end of Omaha Golf Course (**Figure 17**).

Nitrogen fixation (acetylene reduction) by *Z. novazelandica* and *S. alterniflora* in Whangateau was examined by Hicks and Silvester (1990). Nitrogen fixing activity appeared to be associated with the roots of both species. Acetylene reduction rates for sediments containing either *Z. novazelandica* or *S. alterniflora* were five to six times higher than for adjacent sediment without plants. Hicks and Silvester (1990) estimated that nitrogen fixation by *Z. novazelandica* results in inputs of 8.3 kg $N.ha.^{1}.y^{1}$ for vegetated areas compared with 1.6 kg $N.ha.^{1}.y^{1}$ for adjacent open areas. For *S. alterniflora,* the equivalent rates were 13.5 and 2.5 kg $N.ha.^{1}.y^{1}$ in vegetated and unvegetated areas, respectively.

After colonisation, *Spartina* may go through a lag phase which can last up to 30 years as seedlings establish, followed by vigorous expansion (Nicholls 1999). Using aerial photos, Nicholls (1999) estimated growth of two patches of *Spartina* in Whangateau Harbour between 1978 and 1999. During this period one patch increased in size from 0.26 ha to 0.9 ha, and the other increased from 0.01 ha to 0.03 ha. The habitat map of the Whangateau Harbour indicate that overall *Spartina* habitat covered around 6 ha and seagrass covered around 33 ha when data for the map was collected (Figure 8, Hartill et al. 2000). Measures have been taken to eradicate *Spartina* from the harbour, but a limited patch is still growing terrestrially and a few plants remain in the tidal zone. Further control measures are planned for the remaining patches (Galloway, pers. com.).

Figure 17

Examples of coastal vegetation found in Whangateau Harbour: a) dense saltmarsh area south of Omaha causeway; b) patch of glasswort on the edge of saltmarsh at Point Wells; c) and d) mangrove lined channel and mangrove tree in Birdsall Rd inlet; e) mix of introduced plants on the Omaha foreshore in the outer harbour; f) seagrass patches along Waikokupu Creek in the upper harbour; g) Neptune's necklace growing of soft reef southwest of the causeway and; h) Large turfing algae patch in the upper harbour.

a)

b)

c)

d)

e)

f)

g)

h)

Mangroves are most prevalent in Omaha River, between Big Omaha Wharf and Whangateau settlement (including Birdsall Rd. inlet), northern parts of Tramcar Bay, and around the estuary margin south of Omaha causeway (**Figure 17**). Whangateau is in the mid- to northern range for mangroves in New Zealand (*Avicennia marina australasica*), and contains forests with a variety of tree densities and sizes (Osunkoya and Creese 1997). The habitat map of the Whangateau Harbour suggest that mangrove habitat covered around 89 ha of the harbour when data for the map was collected (Figure 8, Hartill et al. 2000). This consisted of 11 ha of low mangrove habitat, 54 ha of high mangrove habitat and 24 ha of scattered mangrove habitat.

New Zealand mangroves, (*Avicennia marina australasica*) appear to be relatively productive primary producers, which pass energy to adjacent food webs mainly through the export of detritus (Morrisey et al. 2007), primarily in the form of leaf litter. Mangrove forests between Big Omaha Wharf and Whangateau settlement and in Tramcar Bay were estimated to shed 1.51 tonnes of leaves.ha^{-1}.year^{-1} (dry weight) (Oñate-Pacalaoga 2005). A large proportion of shed leaves remained within well established mangrove forests, but retention was lower in smaller mangrove patches. The decomposition of leaves was faster in autumn, when air temperatures were high, than in winter or spring when air temperatures were low. Decomposition was enhanced by the feeding activity of benthic organisms, which fragmented leaves and promoted microbial decay. Successional changes in the composition of meiofaunal and macrofaunal species assemblages were observed during the decomposition of mangrove leaves. Benthic communities beneath the mangrove forests were dominated by crustaceans, but overall species richness was relatively low.

The eastern margin of the upper harbour contains a valuable vegetation sequence running from scattered mangroves through to a large and rare area of kahikatea (*Metrosideros excelsa*) swamp forest (**Figure 17**). The Auckland Regional Policy Statement notes that "because of its high ecological and scientific values, this example of this sequence is of national importance and is worthy of preservation" (ARC 1999). From the lower shore, scattered mangroves give way to saline sedgeland characterised by oioi (*Apodasmia similis* (previously called *Leptocarpus similis*)), the sedge, *Baumea juncea*, and sea rush (*Juncus kraussi*), with scattered knobby clubrush plants (*Isolepis nodosa*). A narrow strip of emergent vegetation consisting of scattered manuka, marsh ribbon wood (*Plagianthus divaricatus*), flax (*Phormium tenax*) and New Zealand broom (*Carmichaelia* spp.), with an understory of *B. juncea*, *J. krausii*, and *A.*

similis, occurs between the sedgeland and a band of coastal manuka forest, above. The manuka forest then gives way to the kahikatea swamp forest (Parker 2002). A variety of other saltmarsh species also occur on elevated hummocks in the coastal zone. These including sea primrose (*Samolus repens*) *Selliera radicans*, marsh ribbon wood (*P. divaricatusi*), and glasswort (*Salicornia australis*) (Larcombe 1968).

The habitat map of the Whangateau Harbour indicate that saltmarsh habitat in the upper, eastern arm of the harbour covered around 41 ha (Figure 8, Hartill et al. 2000). The width of the rush dominated saltmarsh is greatest along the southern margin of the harbour, where it forms a band of up to 200 m around the harbour's edge. Smaller areas of saltmarsh also occur in other parts of the harbour, which are not shown on Hartill et al. (2000). Asquith et al. (2001) recorded the "usual" saltmarsh plants around Horseshoe Island, including the glasswort *Sarcocornia quinqueflora*, *S. radicans* and sea primrose (*S. repens*), with buggar grass (*Austrostipa stipoides*), knobby clubrush (*I. nodosa*), sand Spinifex (*Spinifex sericeus*), and shore bindweed (*Calystegia soldanella*) on hummocks. Asquith et al. (2001) also noted the presence of the succulent sea blite (*Suaeda novae-zelandiae*), which is not common in the district, and a hybrid of *Carpobrotus edulis* x *Disphyma australe*. A significant area of saltmarsh is also present between Point Wells and the Omaha causeway and small pockets occur up Omaha River.

Saltmarsh in Whangateau is notable for its lack of invasive species, although introduced pampas grass is found in the esplanade reserve bordering the harbour and gorse extends down to the coastal margin in many places (Parker 2002, Wilson pers. com.). Ice plant, gorse and a variety of other introduced plants also occur on consolidated dunes that form the Omaha foreshore in outer parts of the harbour (**Figure 17**). Marram is also found in a number of locations on the Omaha dunes but has not proven to be a problem to date (Rodney District Council 2003).

Patches of intertidal algae also occur in a number of places in the harbour. Neptune's necklace, *Hormosira banksii*, and turfing algae (*Corollina* spp.) are found south of Omaha causeway, on hard or semi-consolidated platforms (**Figure 17**). Dense *Hormosira banksii* beds are also found on similar substrates around Horseshoe Island.

3.7 Summary of harbour values: special areas and features

Available information indicates that Whangateau has a number of important values and significant features. The key ones include:

- Excellent water quality, which is similar to that found in coastal sites in the outer Hauraki Gulf.
- Sediments that are largely sandy, with very low proportions of mud.
- Natural, background concentrations of heavy metals and other contaminants, except in a very localised area near the disused Whangateau landfill, where concentrations are only

slightly elevated. Note however, that this conclusion is based on limited sampling and other hotspots may occur elsewhere (eg around the traditional boatyard in Tramcar Bay).

- Reef in the harbour entrance, which contains a species assemblage that reflects a strong coastal influence, and is "stepping stone" between fish nurseries in the harbour and adult habitats on the open coast.
- The subtidal channel, particularly around the harbour entrance, which contains extremely dense shellfish beds and an ecologically distinct marine community.
- Dense and extensive intertidal shellfish beds that are highly valued by recreational harvesters.
- A diverse mix of intertidal reef and soft sediment communities, which often have discrete, clearly defined boundaries.
- Soft reef and intertidal algae beds (*Hormosira banksii*) in the upper harbour and adjoining Horseshoe Island, which provide extremely important nursery and adult habitat for fish, and habitat for invertebrate species.
- Mangrove forests around Horseshoe Island (and perhaps elsewhere), which provide high tide shelter for fish.
- A resident population of endangered dotterels.
- Roosting, nesting, and feeding areas for coastal birds, particularly on the northern end of Mangatawhiri Spit and in coastal saltmarsh.
- A regionally unique vegetation sequence from kahikatea swamp to saltmarsh and mangrove forest that is largely free of introduced species.
- Relatively large seagrass beds in the upper harbour.
- Large, dense rush beds and saltmarsh that are largely free of introduced species.

4 Threats

4.1 Physical structures, reclamation, and loss of natural shoreline

The harbour has been significantly modified by reclamation and the construction and placement of structures within the coastal marine area (see **Figure 2** and **Figure 7**). Reclamation associated with the Omaha Golf Course led to the loss of a significant area of saltmarsh on the north-eastern side of the Omaha causeway (estimated from Goggle satellite photos to be ca. 9.5 ha). Similar, albeit smaller, losses are also likely to have occurred at Point Wells and along the rural fringe. "Creep" into the coastal zone is still occurring in places. This is leading to the ongoing loss of fringing habitat, which typically contains intertidal sandflats, saltmarsh and other coastal vegetation.

Barriers created by the causeways crossing the Birdsall Rd and Tramcar Bay inlets appear to have restricted flushing and enhanced sediment trapping. This together with increased sediment erosion from forest clearance and farming (and perhaps warmer conditions) has resulted in both inlets becoming completely overgrown by mangroves. Photos of the Darroch's shipyard on Birdsall Rd that were taken in the early-1900s indicate that this inlet was largely mangrove free at the start of the twentieth century (Clifford Hawkins Collection). Today the site is inaccessible from sea, because of mangrove growth (**Figure 1**8).

Figure 18
Original site of Darroch's shipyard on Birdsall Rd showing mangrove forests that now block seaward access.

The Omaha causeway has enclosed a much larger portion of the upper harbour. The area south of the causeway still contains mainly sandy substrates and has large areas that are free of mangroves. However, the causeway is likely to have a significant effect on hydrodynamics and sediment transport in the upper harbour. These effects are apparent immediately south of the causeway, where fine sediments have accumulated and mangrove colonisation is occurring (see **Figure 7**). The long-term impacts of the causeway are unknown, but there is potential for fine sediment accumulation and mangrove expansion to continue in the upper harbour. The rates of mangrove expansion (and subsequent loss of other habitat types) and infilling are likely to accelerate, as seed production in the upper harbour and elsewhere increases. Conversely, long-term sea level rise may counter these effects by reducing the area available, with water depths suitable for mangrove colonisation (Swales et al. in press).

Seawall design and quality varies around the harbour, resulting in marked differences in performance and visual impact of these structures. Construction materials and methods include: timber, poured concrete, old concrete material, gabion baskets, rip-rap, mixed concrete and rip-rap, fibrolite and asbestos sheeting, mudcrete and hard rubbish. The use of some seawall materials and techniques has a significant impact on aesthetic values in parts of the harbour, particularly the use of hard rubbish and old concrete materials. Similarly, deteriorating seawalls made of other materials is affecting the visual appeal of the foreshore, and is exacerbating coastal erosion.

In particular, the southern fibrolite and rip-rap section of Omaha seawall is deteriorating badly and erosion is occurring in many places. The northern Omaha gabion baskets are relatively effective at preventing coastal erosion, but they have a limited life and have also failed in a number of isolated locations (Rodney District Council 2003). These walls are expected to continue to slowly deteriorate, so Rodney District Council is carrying out staged remediation work over a number of years. Rehabilitation of the Omaha seawall includes the installation of a mudcrete bund, which encloses a raised band of native saltmarsh along its seaward margin of the original seawall (**Figure** 19a). Sand replenishment and sand retention groynes have also been installed in the north-eastern corner of Omaha causeway (**Figure** 19b). The modified seawall design and sand replenishment should enhance the coastal vegetation and aesthetic values of the area. However, establishing coastal vegetation in an area of open sandflats does result in a net loss of sandy intertidal habitat.

Foreshore erosion is also occurring on old dunes in northern sections of Mangatawhiri Spit between the boat ramp and the northern groyne. Land immediately at the top of the dunes is in esplanade reserve, but there is concern that private property will be affected if erosion continues unchecked. A building setback of 23 m from mean high water spring (MHWS) has been imposed, which should ensure that buildings are not threatened in the foreseeable future (Rodney District Council 2003). The Omaha Sand Cliff's Coastcare Group and Rodney District Council monitor dune erosion, and some fencing and planting work has been carried out to direct foot traffic and help stabilise the dunes (Rodney District Council 2003) (**Figure** 20).

Approximately 50 swing moorings are located in the main channel of the harbour. The potential effects of swing moorings include localised smothering or disturbance by mooring weights and chains, contamination associated with the leeching of toxins from antifoulants, and the provision of substrate for the establishment and growth of invasive species. Moorings also increase the potential for the discharge of untreated wastewater from boats. The existing mooring management areas are located in zones with discrete and dense shellfish beds (mainly pipi), which have very high ecological and intrinsic values, and are likely to be particularly sensitive to disturbance. The cumulative impacts of the existing or additional moorings have not been assessed.

Whangateau Harbour has been considered as a potential site for marina development(s). The effects of marina developments are likely to be significant, particularly if they involve dredging to deepen or widen access channels and construction and use of hardstands where boat maintenance is carried out. Potential impacts could include: direct disturbance or destruction of channel habitats and fauna; release of environmentally significant quantities of contaminants; degradation of natural character and landscape values; and, the disturbance or destruction of intertidal habitats and saltmarsh.

Figure 19

Rehabilitation of the Omaha seawall which includes a) installation of a mudcrete bund enclosing a raised bed of coastal vegetation, and b) sand replenishment and installation of a sand retention groyne.

a)

b)

Figure 20
Fencing and beach access stairway installed prevent dune erosion in the northern section of Mangatawhiri Spit.

4.2 Stormwater, litter and wastewater discharges

Whangateau has a range of high-value, good quality habitats that contain a mix of sensitive species. Consequently, the potential consequences of stormwater contamination are significant. Urban stormwater is discharged into Whangateau Harbour from Omaha, Point Wells and Whangateau settlement. However, near-complete harbour flushing, coarse sediments, limited urban development and stormwater treatment reduce the risk of stormwater contamination becoming a significant problem, and at present, it does not appear to be a key issue. Available data suggests that ambient concentrations of typical urban stormwater contaminants are close to natural background concentrations, except in an isolated "hotspot" associated with the disused Whangateau landfill (see Section 3.2.2)[7].

A variety of horticultural chemicals are likely to be used in Whangateau catchment, which could enter waterways and affect marine and freshwater biota. Omaha Flats contains substantial areas of horticultural land use, with an increasing amount of viticulture. Various chemicals are likely to be used by growers, for weed and pest control. Chemicals are also likely to be used to maintain the green on Omaha Golf Course. Published information on the types of chemicals used in the Whangateau catchment, or their environmental fate is not available.

[7] It should be noted that existing contaminant data were obtained from areas that are relatively remote from the main discharge points for urban stormwater.

Available information indicates that nutrient levels in Whangateau Harbour are low, but an upward trend in phosphorus and chlorophyll *a* was detected at the ARC's Ti Point water quality monitoring site between 1991 and 2007 (Scarsbrook 2008). Nutrient and microbiological contaminants can enter the harbour from treated wastewater, septic tanks and rural run-off. Septic tank seepage has been identified as a significant problem for Point Wells, where high enterococci concentrations have been recorded in cockles and wedge shells following rainfall (De Luca-Abbott 2000). Poor septic tank performance is caused by small sections, poor soakage and the low-lying nature of the area. Wastewater is unable to soak away during wet weather and high ground water conditions, and is discharged to the estuary through open drains (E-cogent 2007). To address this problem, Rodney District Council plans to connect Point Wells, and Matakana Township, to the Omaha waste water treatment plant. Treated wastewater from Omaha is disposed of on land, in a dedicated area of Omaha Flats and onto the Omaha golf course. Rodney District Council also plans to treat wastewater from Matakana at the Omaha plant. The addition of Matakana wastewater (plus increased development) will increase **potential** nutrient loads to Whangateau Harbour, but the **actual** loads will depend on the efficacy of wastewater treatment. These matters will be considered during the resource consent process.

Gross litter is an issue in some subtidal areas of Whangateau Harbour. Ti Point is particularly problematic, due to public use of the wharf and rocky shore Interestingly, golf balls, which presumably originate from the Omaha Golf Course, are also common in Omaha Bay at depths of >15m (Kelly pers. obs.).

Figure 21
Litter accumulation on Ti Point reef.

4.3 Sedimentation

The risk of elevated sediment accumulation in central parts of the harbour is likely to be relatively low because of the limited size of the catchment, low sediment generation capacity of Omaha and Omaha Flats and the flushing dynamics of the system. However, areas in the lee of causeways and other structures (which restrict tidal flushing and allow sediments to accumulate) or in upper harbour reaches may be at risk. Side branches and the foreshore in northern parts of the harbour and in Omaha River are likely to be most sensitive to sedimentation, because their upper catchments are steep and erodible, and they tend to be sheltered receiving environments. The latter characteristic is likely to enhance sediment trapping. The potential consequences of increased sediment run-off are significant, given the value of Whangateau ecosystem and presence of sensitive species. Sedimentation could lead to an increase in mangrove cover, increase muddiness, reduce community and habitat diversity and lead to the direct loss of sensitive species.

4.4 Invasive species

Whangateau Harbour is relatively "natural" in terms of the incidence and effects of introduced or invasive species. Invasive and introduced species may predate on native species, or compete for food, space or other resources. Marine invasive species known to be present in the harbour currently include (what appears to be) a relatively innocuous goby (*Arenigobius bifrenatus*) and localised, small patches of Pacific oysters. Small, isolated patches of cord grass (*Spartina*) occur in places, but coastal saltmarsh in the harbour remains relatively weed free (Wilson pers. com.).

However, introduced plants are prevalent on dunes and in the surrounding catchment, and introduced predators are a significant threat to coastal birds in the area. A number of marine pests already present in New Zealand could have a significant impact on the harbour if they became established. These include: the Asian paddle crab *Charybdis japonica*, the tunicate *Styela clava*, Asian date mussels *Musculista senhousia* and the parchment worm *Chaetopterus* sp. (native or introduced status uncertain). Note that Asian date mussels (Kelly unpublished data) and *Chaetopterus* sp. (Tricklebank et al. 2001) occur in coastal areas surrounding Whangateau, and the shells of Asian date mussels are have been found in the harbour (Stewart pers. com.).

A number of introduced plants could also compete with native saltmarsh species if they became established.

4.5 Fishing, shellfish harvesting and habitat disturbance

Whangateau Harbour is a popular area for shellfish harvesting and land-based fishing. These activities could have a significant impact on target species and the broader ecological values of the harbour. Fish and shellfish populations have declined at many locations in the Auckland region (Grant and Hay 2003); with over-harvesting being a key causal factor (eg Willis 2001, Moore 2008).

Many east coast beaches in the Auckland region have been closed for shellfish harvesting due to declining populations or pollution, including most in South Auckland (eg Eastern Beach, Karekare Beach, Cheltenham Beach, Cockle Bay, Umupuia (Duders), and Kawakawa Bay (due to microbiological contamination)). Consequently, there is significant potential for harvesting pressure in Whangateau to increase, as non-resident harvesters look for alternative areas to exploit and the local population grows. It is therefore a concern that Kearney (1999) found the majority of harvesters collecting shellfish in Whangateau came from South Auckland, and that most did not comply with the legal daily bag limits.

The most recent Ministry of Fisheries survey found no evidence of total cockle numbers declining between 2004 and 2006 (Pawley and Ford 2007). However, there was strong evidence that the number of harvestable pipi had decreased in intertidal pipi beds. Whangateau is relatively isolated from other estuaries, so shellfish recruitment from other areas is likely to be limited. Consequently, recovery of shellfish beds may be slow if substantial depletion or habitat disturbance occurs.

Finfish in Whangateau are caught using a variety of methods including spear fishing, netting and line fishing (Kelly pers. obs.). Fishing is likely to have its greatest impact on species that spend extended periods in the harbour and have strong associations with specific habitats (see Section 3.4.). These species are also likely to be very sensitive to fishing and habitat disturbance. Recovery following the fish-down of resident populations or the disturbance of sensitive habitats (eg *Hormosira* beds) may be slow, and in some cases the effects of such impacts may extend beyond the harbour. For example, the loss of nursery habitat for parore may affect adult populations on the adjoining coast.

4.6 Disturbance and predation of waders and shore birds

Whangateau contains habitat for, and is used by, a number of endangered birds, including the nationally critical New Zealand fairy tern. It also supports a breeding population of the nationally vulnerable New Zealand dotterel.

Published information indicates that predators, such as mustelids, pose a significant threat to coastal birds in the area. However, documented information on the other effects of human disturbance in Whangateau was not obtained during this review. People using undeveloped parts of Mangatawhiri Spit are likely to encounter coastal birds and have an impact on them. Direct human impacts probably include (but are not limited too) the induction of defensive behaviour during nesting, and the disturbance of flocking and roosting birds, and nests. Indirect effects could also include habitat disturbance, particularly through the introduction of plants, and increasing disturbance and predation by dogs and cats. The potential for disturbance of coastal birds is likely to increase as the population and development of adjoining settlements increases, and residency becomes more permanent (ie as residencies change from holiday homes to permanent dwellings). The construction of structures that alter the physical or biological characteristics of the environment (eg increased muddiness and the prevalence of mangroves) could also have a significant effect on birds.

4.7 Physical disturbance of the foreshore

Saltmarsh and intertidal areas are directly affected by vehicles and stock in some parts of the harbour. Public and private vehicle access to, and use of, the coastal marine area is most apparent at Point Wells (Figure 22), where vehicles are used to obtain access to the low tide channel. Vehicles have damaged coastal vegetation and are likely to be directly affecting soft sediment communities.

Purpose-built gates provide stock access to the coastal marine area at the southern-end of the Waikokopu Creek branch of Whangateau Harbour, into areas of mangrove and salt marsh (**Figure** 23). Stock access may also occur through poorly maintained fences in other areas of the harbour. Note that stock access is mainly an issue in privately owned areas of saltmarsh and mangrove[8]. Rules in the Auckland Regional Plan: Coastal apply equally to privately owned areas of coastal marine area (CMA). Rule 16.5.23 prohibits cattle grazing of Coastal Protection Area (CPA) 1 areas. In CPA-2 areas, cattle grazing requires resource consent unless it meets the tests of being a permitted activity. Chapter 16 of the Auckland Regional Plan: Coastal (16.5.7) makes disturbance of the foreshore and seabed (not covered by other rules) a permitted activity as long as the disturbance is remedied by natural processes within seven days (ARC 2008). The impacts of cattle on soft sediment shores and in areas of coastal vegetation are unlikely to be remedied within this period, and are therefore likely to require resource consent.

[8] A comprehensive survey has not been carried out to confirm the degree of stock access.

Figure 22
Vehicle tracks through intertidal and coastal vegetation at Point Wells.

Figure 23

Gate allowing stock access to saltmarsh and mangrove areas at the southern end of Waikokopu Creek branch of Whangateau Harbour, and evidence of trampling in rush and mangrove areas.

5 Knowledge Gaps

Research and investigations carried out in Whangateau Harbour over the past 40+ years has provided a valuable base of environmental information. However, a number of fundamental gaps remain if the values of the harbour are going to be sustainably managed. Key gaps are listed below.

1. Detailed and accurate maps showing the location and spatial extent of key species and ecological communities within the harbour. Spatial information contained in existing studies is limited and is generally not sufficient to examine changes in spatial coverage. Previous community maps are also too coarse for this purpose.
2. Detailed and accurate maps showing the location and spatial extent of high-value and sensitive habitats. Spatial information contained in existing studies is limited and is generally not sufficient to examine changes in spatial coverage. Previous community maps are also too coarse for this purpose.
3. An assessment of the long-term effects of Omaha causeway and options for reducing its impact.
4. The potential for, and processes involved, in mangrove growth and expansion, particularly south of the Omaha causeway. This evaluation should include cumulative effects of increasing (mangrove) seed production and entrapment within the upper harbour.
5. Predictions of likely changes in harvesting pressure on the harbour and in particular the effects of population growth and displacing fishing activity from other areas.
6. The carrying capacity of the harbour with respect to pipi and cockle harvesting.
7. Landscape values and factors affecting those values.
8. The effects of direct and indirect human disturbance on coastal birds and options for minimising impacts.
9. Rates of sediment accumulation, particularly in Tramcar Bay, Omaha River and south of Omaha causeway.
10. The effectiveness of septic systems in Whangateau settlement, Tramcar Bay, Lew’s Bay and Ti Point;
11. Horticultural and agricultural chemical use in the catchment: types, quantities and environmental fate.
12. The extent of stock access to the harbour and an assessment of the effects of stock entering the coastal zone.
13. Changes in contaminant concentrations at known hotspots (ie below the Whangateau landfills), and testing of other potential hotspots (eg around the traditional boatshed in Tramcar Bay and around Ti Point Wharf).

14. Potential issues arising from plans to increase the capacity of the Omaha Wastewater Treatment Plant. Note that these should be addressed through the resource consenting process.

6 Discussion

The quality and ecological values of Whangateau Harbour arguably make it the Auckland region's most valuable mainland estuary. The clear waters of the harbour reflect the strong influence of coastal waters from the outer Hauraki Gulf, and the high degree of tidal flushing (**Figure** 24). The harbour is uncontaminated, apart from an isolated hotspot near the disused Whangateau landfill (where minor contamination has occurred), and septic tank leaching at Point Wells, which is being addressed (and possibly Whangateau settlement). Its productive shellfish beds are highly valued by local iwi and recreational shellfish harvesters throughout the Auckland region.

Figure 24
Mangrove seedlings growing in clean, coastally influenced waters of Whangateau Harbour.

Habitats within the harbour include: a variety of reef types, sandy intertidal and subtidal seabed, muddy habitats, mangrove forests, a variety of algae beds, seagrass beds, large areas of rush and saltmarsh, a nationally significant vegetation sequence running from kahikatea forest to saltmarsh and intertidal sandflats, and a coastal dune system. The harbour is also used by a range of coastal birds, including one species classified as nationally critical and four species classified as nationally vulnerable.

The quality and range of habitats in the harbour is reflected in high species diversity and abundance. Many habitats and species associations have discrete and isolated distributions. A number of communities depend on the presence of habitat-forming species, which provide substrate and structural complexity (eg mangroves, seagrass, Neptune's necklace, pipi) or food (eg pipi). In several cases the habitat-forming species are considered to be sensitive to harvesting, direct physical disturbance (eg Brown and Taylor 1999), or disturbance by sediment (Gibbs and Hewitt 2004) and other contaminants (Thrush et al. 2008). It is likely that a number of these habitat systems are fragile, and their loss would lead to a significant reduction in the biodiversity values of the harbour.

Whangateau Harbour has a relatively small, partially developed catchment that is facing a great deal of additional development pressure. The cumulative impacts of existing activities on the ecological, conservation, landscape and natural character values of the harbour are already significant. These impacts are likely to increase dramatically, unless measures are taken to prevent further degradation and, where necessary, remediate existing problems. Unlike many coastal areas, preventing further impacts or remediating many of the existing impacts in Whangateau Harbour should be relatively straightforward from a technical perspective. However, in some cases, the environmental actions required could conflict with community or development objectives.

The Omaha, Birdsall Rd. and Tramcar Bay causeways are the most environmentally significant structures in Whangateau Harbour and are likely to have had a significant impact on the harbour through sediment trapping and the promotion of mangrove growth. The ongoing, long-term effects of the Omaha causeway are of particular concern, and could lead to mangrove expansion and the associated loss of large areas of highly valued, intertidal habitat in the upper harbour.

The cumulative effects of reclamation, the construction of seawalls and other coastal structures (wharves, boat ramps etc.) has led to the loss of a relatively large proportion of the natural harbour coastline. Pressure is also mounting to increase the number of swing moorings and/or develop a marina within the harbour. The ecological effects of both activities could be substantial. Potential impacts include habitat loss, direct physical disturbance during construction and maintenance, the release of toxic chemicals and increasing biosecurity risks. These, potential effects should be considered within the context of other impacts on the harbour.

Wastewater contamination from septic tank seepage at Point Wells and possibly Whangateau settlement poses a potential health risk to bathers and seafood gatherers. Plans to include Point Wells in the Omaha wastewater treatment system should significantly reduce this risk. Sediment run-off and accumulation may be an issue in northern parts of the harbour and in Omaha River, where mangrove expansion has already occurred. Stormwater contamination does not appear to be a significant issue, but the potential effects of horticultural chemicals have not been assessed. Litter is a significant issue in parts of the harbour, particularly around the Ti Point Wharf.

Coastal birds in Whangateau are threatened by a mix of direct disturbance, habitat loss and mammalian predators (including cats and dogs). Population growth will increase the potential risk to coastal birds, but education and active management may reduce the actual risk. Similarly, population growth, roading improvements, and the displacement of harvesting effort from other areas to Whangateau (due to beach closures) are likely to increase shellfish and finfish harvesting pressure on the harbour. Effective enforcement of fisheries regulations is required to ensure the ongoing sustainability of seafood resources.

6.1 Conclusions

Whangateau Harbour is arguably the Auckland region's most valuable mainland estuary. Unfortunately the natural values of the harbour are being degraded by the cumulative impacts of numerous activities that are carried out in the coastal marine area and in the adjoining catchment. Further degradation is inevitable if preventative and, in some cases, remedial action is not taken.

Management actions should be underpinned by clearly defined objectives for the environmental management of the harbour's resources. These objectives need to take into account the special ecological, conservation, natural character and landscape functions and values of the harbour. It is recommended that these objectives form the basis for developing an integrated strategy that addresses the cumulative effects of existing activities, plus those related to future population growth, changing land use, and catchment and coastal development.

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