Review of Environmental Information on the Kaipara Harbour Marine Environment

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Review of Environmental Information on the Kaipara Harbour Marine Environment

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Prepared for

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This report is one of a series funded by Auckland Regional Council but part of a joint Auckland Regional Council/Northland Regional Council evaluation of the Kaipara Harbour, its environmental values, management issues and options.

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Executive Summary

The Kaipara Harbour is one of the largest estuaries in the world, and is thought to be the largest estuary in the Southern Hemisphere. It is recognised as an area of international importance for coastal birds, has a high diversity of marine organisms, and contains ecologically significant marine communities that provide a wide variety of functions and services. Due to the abundance of natural resources within and around the Kaipara (e.g. timber, seafood, and sand), the harbour has been utilised extensively for more than 150 years.

Regulatory authorities are concerned that the quality of the harbour may be decreasing due to human activities in both the harbour and the surrounding catchments. The impacts of these activities could be exacerbated by a number of new, large-scale developments that have been proposed. Successful mitigation of the subsequent environmental impacts is hampered by the lack of a comprehensive management strategy, which would consider the cumulative effects of all the activities and integrate the functions of the key management agencies.

This report summarises the environmental information that is available for the Kaipara Harbour coastal environment, with a primary focus on the coastal marine area. The aims of the study were: to determine the current environmental state of the harbour, assess threats to the harbour, identify knowledge gaps, and examine synergies and gaps in existing environmental monitoring programmes. The report also reviews the effects of activities managed under different statutes and considers the relative influence of various pressures on the environmental values and sustainability of the harbour. It also identifies resource management issues that potentially affect fisheries, conservation management, and/or biosecurity in the harbour; and discusses environmental issues that cross planning boundaries.

The marine components evaluated were: the physical environment (water quality and physical oceanography), intertidal and subtidal benthic habitats and communities, fish and fisheries, coastal birds, and coastal vegetation. Data were obtained from a range of sources, and varied widely in terms of currency and detail.

Current state of the Kaipara Harbour marine environment: The evaluation confirmed that the Kaipara contains many high value species, communities and habitats and that the environmental values of the Kaipara have been, and are continuing to be, degraded. It also highlighted a lack of core environmental information for the majority of the key marine components that were evaluated. More information is available for the southern Kaipara than for the northern Kaipara; in particular, the Tier II Ecological State of the Environment (SoE) monitoring survey undertaken by the ARC, which provides maps showing the distribution and abundance of intertidal and subtidal benthic habitats and communities throughout much of the southern harbour.

Current studies: Environmental studies presently being carried out within the Kaipara include: assessments of benthic communities and invasive species at discrete locations throughout the harbour, the role of seagrass (*Zostera capricorni*) in primary production and in supporting secondary (animal) production, fish habitat utilisation throughout the harbour, and marine mammal use of the harbour (particularly Maui's dolphin). In addition, the Ministry of Fisheries is investigating options for assessing scallop numbers in the harbour, following a ban on harvesting that was initiated in July 2005. Findings from these studies will add significantly to understanding the harbour.

Monitoring: Time series monitoring is undertaken in the Kaipara Harbour for SoE assessments of general water quality (including bulk water quality, bathing water quality and shellfish monitoring), fisheries assessments, and as a condition of resource consents. Currently, water quality monitoring within the Kaipara Harbour is characterised by a lack of spatial coverage in the southern Kaipara and a lack of temporal detail in the northern Kaipara. The limited data that is available indicates that water quality is relatively poor in many areas, but the overall lack of coverage and detail makes it difficult to assess whether broad environmental changes have occurred. The resource consent monitoring studies currently being undertaken for sand mining and discharges provide data relevant to those specific activities but do not capture any cumulative impacts and are not very useful for assessing the overall environmental quality of the harbour. Therefore, although the resource consent monitoring studies are related to specific activities, they could have wider relevance if the monitoring was standardised as far as practicable. Modifications to the existing monitoring studies, and synergies amongst them, are identified.

Threats: Many activities threaten the environmental values of the Kaipara coastal marine area. Key issues include: landuse activities which generate sediment and other contaminants, fishing, sand extraction, tidal energy generation, aquaculture, and the spread of invasive species (marine and terrestrial). Attempts were made to assess the scale of influence that these activities have had on the Kaipara Harbour, although this was seriously hampered by a lack of detailed information on many of the activities. Activities managed under the Resource Management Act (1991), Fisheries Act (1996), and Biosecurity Act (1993) all appear to be affecting the environmental quality and values of the harbour in multiple ways. The impacts of existing landuse activities are evident in many parts of the harbour (e.g. high turbidity and sedimentation, and elevated levels of wastewater contaminants) and are likely to increase in scale and intensity if not managed appropriately. Recent reviews also indicate that the grey mullet, school shark, rig, and scallop fisheries all have sustainability issues within the Kaipara. Problems with biosecurity resulting in the spread of invasive species are also apparent. The potential impacts of activities such as sand mining, aquaculture and tidal power generation are poorly understood but, potentially, magnify the cumulative or indirect impacts of other activities. All of the above threats, both individually (e.g. landuse) or when combined (e.g. sand mining and tidal energy extraction together impacting on the flood tidal delta) have the potential to cause large-scale cumulative impacts that cross planning boundaries.

Integrated management and knowledge gaps: The general lack of environmental information about the Kaipara coastal environment is a genuine barrier to the integrated management of the Kaipara Harbour. The following information gaps were identified:

- Lack of an integrated, harbour-wide, water quality monitoring programme.
- Detailed information on long-term plans for catchment development and the sediment-related effects on the harbour.
- Ecological maps for the northern Kaipara (similar to those produced by Tier II monitoring of the Southern Kaipara).
- Utilisation of Kaipara Harbour by Maui's dolphins.
- Biosecurity risks of consented activities; particularly construction and aquaculture.
- Aquaculture carrying-capacity of the harbour.
- Extent and nature of fishery interactions between the West Coast and the Kaipara Harbour.
- Uncertainty about the volume of sand being deposited in the Tapora area, relative to the amount being extracted.
- The effects of sand extraction on the sediment transport processes operating in the entrance of the Kaipara Harbour.
- The cumulative impacts of Resource Management Act activities; both individually and in combination with fishing and biosecurity threats.
- The effects of large-scale energy generation from tidal power.
- Lack of knowledge regarding areas that require protection because of their importance to a range of species (birds, fish, critical habitat).

Future studies: An investigation into the benthic marine habitats and communities of the northern Kaipara Harbour, similar to the Tier II SoE monitoring programme already performed for the southern Kaipara, is a priority. Amalgamation of data from both studies would provide an overview of the whole harbour, which would benefit a variety of end-users and help to guide resource management decisions.

Integration and expansion of the existing water quality monitoring carried out in the northern and southern areas of the Kaipara, instigation of short-to-medium term Tier I SoE monitoring in selected locations, development of standardised methods for resource consent monitoring, and assessment of the long-term, cumulative impacts of various landuse scenarios on the entire harbour (in order to guide policy and plan provisions) would help to fill critical knowledge gaps. This improved knowledge would aid the development of a comprehensive management strategy which, in turn, will ensure the sustainability of the harbour.

1 Introduction

The Kaipara Harbour is the largest harbour and estuary complex in New Zealand. It is nationally significant for its intrinsic and amenity value, natural and physical resources, and cultural and historical importance. It occupies a total area of 94,700 ha, including 40,900 ha of intertidal mudflats and sandflats, and has a coastline estimated to be around 900 km long (Heath 1975, Fahy et al. 1990). A number of local and national government organisations share responsibility for the management of the harbour, its catchments, and resources.

Despite its size, the harbour has not been studied in great detail when compared to adjacent large harbours in the Auckland Region such as the Manukau or Waitemata. This is possibly due to its size, its distance from major population centres, and its dangerous bar which extends ~7 km out to sea. In comparison, the entrances to the Manukau and Waitemata Harbours, which provide access to Auckland's ports, are more navigable.

The limited number of environmental studies carried out within and around the Kaipara have made it clear that the harbour is extremely important for a range of birds, mammals, and fish; and that it contains many important and comparatively rare ecological communities, particularly in southern areas (Hewitt and Funnell 2005). It has recently been suggested that ~80% of the West Coast snapper emanates from within the Kaipara (FRST 2003).

Due to the abundance of natural resources (timber, seafood, and sand) within and around the Kaipara, the harbour has been utilised extensively for more than 150 years. Consequently, a variety of sustainability issues have developed over this time. Communities in the Auckland and Northland regions have a range of concerns over the impacts of human activities on the harbour, including their cumulative effect. These concerns include: the effects of extractive process such as fishing, sand mining, tidal energy, and aquaculture; the destruction or modification of habitats due to reclamation; and landuse activities that generate sediment and other contaminants.

Community concern has recently been heightened by an increase in resource consent applications for activities within the harbour, intensified catchment development, and a growing awareness of the causes and effects of sediment and other contaminants. For example, in the Auckland Region within the past five years, the ARC has received applications for:

- Large-scale sand extraction (several applications, some of which have been granted).
- A 30 Ha mussel farm and a 104 Ha oyster farm.
- Components of a tidal power generation 'farm', subsequently lodged with Northland Regional Council.

In addition:

- The Auckland Regional Growth Strategy has advocated the expansion of several rural centres draining into the Kaipara.
- Private plan changes have been proposed for urban expansion in the Waimauku catchment which drains into the Kaipara.
- Small-scale residential developments have occurred in a number of rural settlements such as Shelly Beach.
- Rural subdivision and associated development has increased in the Kaipara catchment.
- Plans for a gas-fired power station on the banks of the Kaukapakapa River have been scoped.

Project aims and scope

The ARC required a predominantly desktop study to collect available environmental information on the Kaipara Harbour, with the following objectives:

- Collate and summarise environmental information on the whole Kaipara Harbour and coastal environment, and assess what is known about the current environmental state of the harbour and its coastal environment.
- Identify any significant environmental studies proposed or currently being carried out by key agencies.
- Determine what monitoring is carried out in the Kaipara Harbour and assess whether it is sufficient to assess broad changes in the environmental quality of the harbour. This includes monitoring carried out by local and regional councils, government departments, and resource consent holders.
- Identify the potential for synergies between independent programmes being carried out by various parties.
- Identity issues which potentially threaten the environmental values of the harbour and provide (at least) a qualitative assessment of their scale of influence and likely impacts on environmental values.

A primary interest of the ARC was to understand the cumulative effects of activities managed under the Resource Management Act that may be leading to a deterioration in the quality of the harbour. However, the effects of other non-Resource Management Act activities also required consideration in order to:

- Provide a broader context to the study by assessing the relative influence of various pressures on the environmental values and sustainability of the harbour (e.g. the relative influence of activities managed under the Resource Management Act compared with those managed under the Fisheries Act).

- Identify resource management issues that potentially affect fisheries, conservation management, or biosecurity.
- Identify environmental issues that cross planning boundaries and assess their significance to the overall harbour quality.
- Identify knowledge gaps that are critical barriers to integrated management associated with the above issues, and make recommendations on what information is required to fill those gaps.

The review is concerned solely with the coastal environment and focussed primarily on the factors that affect the quality or values of the coastal marine area. For the purposes of this review, the coastal environment is considered to include three interrelated parts. These are the:

- coastal marine area,
- active coastal zone,
- landward component.

2 Methodology

A range of environmental information exists for the Kaipara Harbour coastal marine area, although much of this information is diffuse 'grey literature' ranging from unpublished data through to technical reports and a few published peer-reviewed articles. This review attempts to bring together this existing information.

A comprehensive literature review and interviews with government departments were undertaken. Some of the information used included the ARC, NRC, and university libraries and databases; and the Department of Conservation, Ministry of Fisheries, Forest and Bird, and Guardians of the Kaipara libraries. Environmental information collected for this study consisted of:

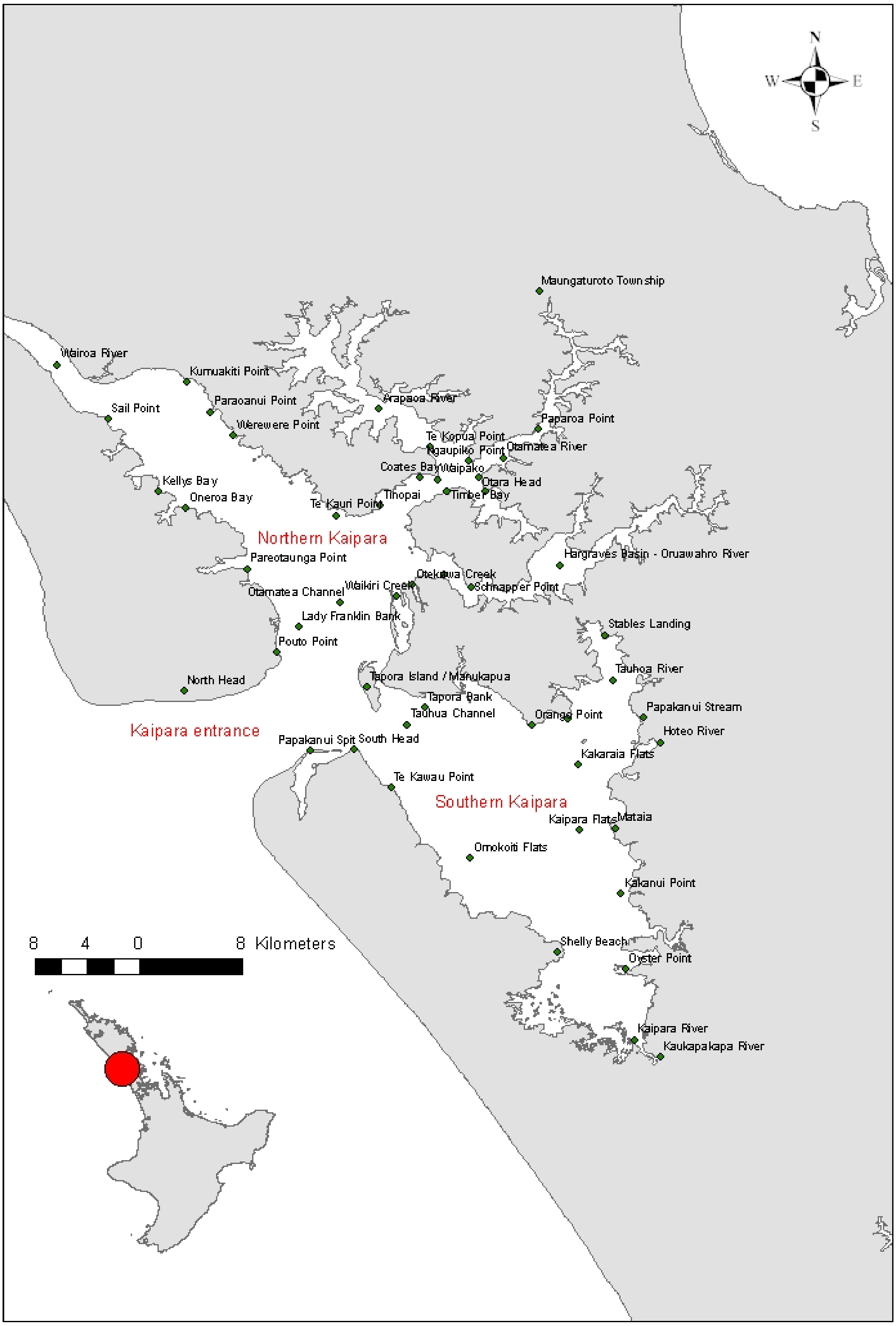
- Ecological information regarding coastal, intertidal, subtidal habitats and sub-habitats, vegetation, birds, fish, shellfish, invasive species, and so on.
- Fisheries' catch rates and stock status.
- Physical oceanography information concerning water quality, hydrology, tidal currents, and sediment movement.
- Geological and geographical properties of the main catchments, and catchment-related properties.
- Local knowledge of culturally significant areas such as fishing grounds and habitats.
- Local knowledge concerning the locations of activities such as recreational fishing (this is not comprehensive data).

In addition, during this review, tidal modelling of the Kaipara Harbour was undertaken for a separate ARC project and provided some insight into the physical processes operating in the harbour (mainly the current circulation patterns and potential for sedimentation) by investigating the maximum water velocities and residual currents. Hume et al. (2003) also undertook a comprehensive study of the sand distribution in the harbour entrance, which built upon other investigations of the area (e.g. Wright 1969, Smith 1999). These reports provided information about the physical environmental at the entrance area.

Bird data were accessed from the Ornithological Society of New Zealand on wading bird counts (2000-2006) and observation data from Mark Bellingham and Alison Davis (1982-2002). Other data on bird habitats around the harbour was also made available by the Rodney District Council and the Auckland Regional Council (significant natural areas data). Data from the Department of Conservation's Protected Natural Areas Programme for the Kaipara Ecological District were not available at the time of writing and information on the Pouto-Ruawai area of the harbour may need to be amended later, with reference to that data.

The various Kaipara Harbour locations referred to throughout this report are shown in Figure 1.

Figure 1 Kaipara Harbour locations referred to in this report.

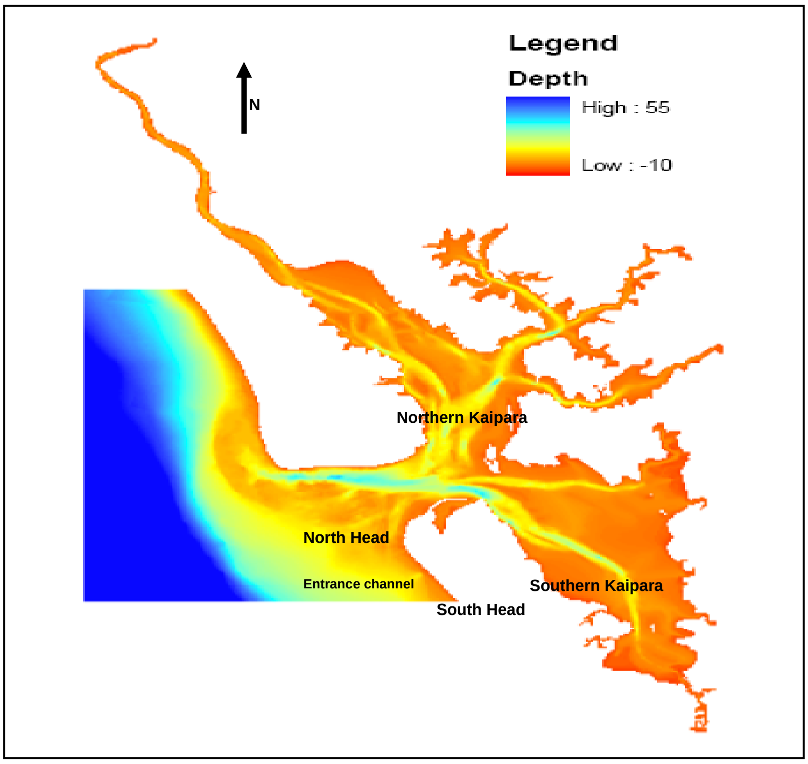


3 Summary of environmental information

3.1 The physical environment of Kaipara Harbour

Kaipara Harbour is one of the largest harbours in the world, and is claimed to be the largest in the southern hemisphere (Royal Forest and Bird Protection Society of New Zealand Inc, 2006). The harbour is an extensive drowned valley system with a combination of steeply cliffed margins and low, swampy Holocene flats (Heath 1975). It is very broad and shallow, although parts of the entrance channel are over 50 m deep, and covers 947 km^2 (including the entrance channel), of which some 409 km^2 is intertidal (Heath 1975, Fahy et al. 1990, Robertson et al. 2002). It has more than 900 km of shoreline and extends for some 60 km from north to south. The harbour entrance to the Tasman Sea constricts from approximately 13 km wide at the coast to 6 km at its narrowest point. The seaward margin of the harbour is bounded by two barrier spits, mainly comprised of post-glacial dune sand: one in the north, which forms the northern arm of the harbour; and one in the south that forms the southern arm of the harbour (Figure 2). Several large side branches also extend inland in the north-east. One of them ends near the town of Maungaturoto, just 10 km from the East Coast. The other is an extension of the Wairoa River, which flows into the northern end of the harbour (Figure 2).

Figure 2 Bathymetry grid of the Kaipara harbour showing depths to 55 m.



The harbour is characterised by strong tidal currents resulting from large volumes of water flowing through the restricted channels, giving a maximum tidal range of ~4.2 m and a tidal prism of approximately 1990 million m^3 during a spring high tide. Current speeds exceeding 2 m/s (~4 knots) have been recorded in the harbour entrance channel, and this resource is currently the target of a resource consent application for a tidal power generation development (Crest 2007). The harbour is ebb-dominated; that is, the ebb current is of shorter duration and higher velocity than the flood current.

The arms of the harbour are shallow and well flushed by the tides, although water circulation in the harbour is unlikely to be dominated by tidal flow alone: the large fetches inside the harbour and the shallow average depths are conducive to wind-driven circulation patterns. In addition, the harbour entrance is exposed to large, and sometimes extreme, wave conditions. This part of New Zealand's West Coast has an average wave height of 2.7 m (with annual return wave heights of almost 7 m) meaning that waves can penetrate to Tapora Island and the northern Kaipara during large wave events and higher tidal phases.

Hewitt and Funnell (2005) provide the following broad description of the South Kaipara substrates: Most of the intertidal area of the Southern Kaipara is mid- to low-intertidal, with few areas exposed for more than 7 hours on a tidal cycle. Extensive mangroves (often densely packed) fringe much of the southern Kaipara, with the exception of the South Head area and the sand dunes opposite the mouth. Extensive *Zostera capricorni* beds stretch over the intertidal flats (which are mainly sandy) in the middle of the main harbour and near the mouth. Much of the intertidal area between Helensville and just south of Sandy Beach is predominantly muddy. Seaward of this point, mud is generally confined to the mangrove edges and small drainage channels. In more exposed areas, firm packed rippled sand is common and in a few areas intertidal rocky reef occurs (e.g. inner channel of South Head).

Similar broad-scale trends in sediment distribution are found in northern areas of the Kaipara. However, the North Kaipara has a relatively lower percentage of intertidal flats (Figure 2) and coarser sediments penetrate further into the northern branch of the harbour than the southern (Hume et al. 2003, Hewitt and Funnell 2005). Coarser sediment fractions are found towards the entrance of the harbour and in the fast flowing channels. This is probably due to the orientation of the harbour entrance along a southwest-northeast axis that allows the predominant waves and winds to penetrate further into the northern arm. Initial tidal modelling indicates that mixing between the north and south parts of the Kaipara Harbour is not great (Mead et al. in prep.). Interestingly, the Kaipara Harbour entrance represents the terminal point of the black ironsands of the West Coast on the South Head and the beginning of the yellow beach sands characteristic of North Head.

The most detailed studies of physical processes in the Kaipara have focused on the entrance area of the harbour. Previous studies have found that a great deal of sediment moves around the Kaipara Harbour entrance and that the positions of the channels and sandbanks have changed greatly over the past century. Hume et al. (2003) presents a review of the changes recorded on nautical charts since 1877 and incorporates other studies of the physical processes at the Kaipara Harbour entrance (e.g. Wright 1969, Smith 1999). The interaction of strong tidal currents and extreme wind and wave events in the entrance area make this part of the harbour difficult to understand in terms of physical processes. While the seabed of the swift-flowing main channel is either scoured mudstone or shell-lagged compact sand, many other areas are characterised by large bed-forms (mega-ripples and sand-waves), which indicate a great deal of sediment movement (Hume et al. 2003, Hewitt and Funnell 2005). The main changes to the entrance morphology since the 19th century have been a northward progression of the South Head through accretion, a northward progression of the North Head by erosion, a seawards widening of both the North and South Heads, and changes in the size and position of the channels and Tapora Island, which is located inshore of the flood tidal shield.

Physical properties of the Kaipara Harbour catchment are presented in Figure 3 to Figure 6 and include soil induration (i.e. compactness/hardness), geology, particle size, and drainage. From these maps it can be seen that the areas of fine sediments and poor drainage (i.e. those most likely to provide a source of sediment runoff in the harbour) are prevalent in the inner regions of the harbour, in the north of the harbour between Ruawai and Oruawharo River, and in southern areas between Oruawharo River and Shelly Beach. In contrast, the massive barrier spits of the harbour, which terminate in the North and South Heads at the entrance, are composed mainly of well-draining sands.

Figure 3 Soil induration for the Kaipara Harbour catchment area (source: Land Environments New Zealand).

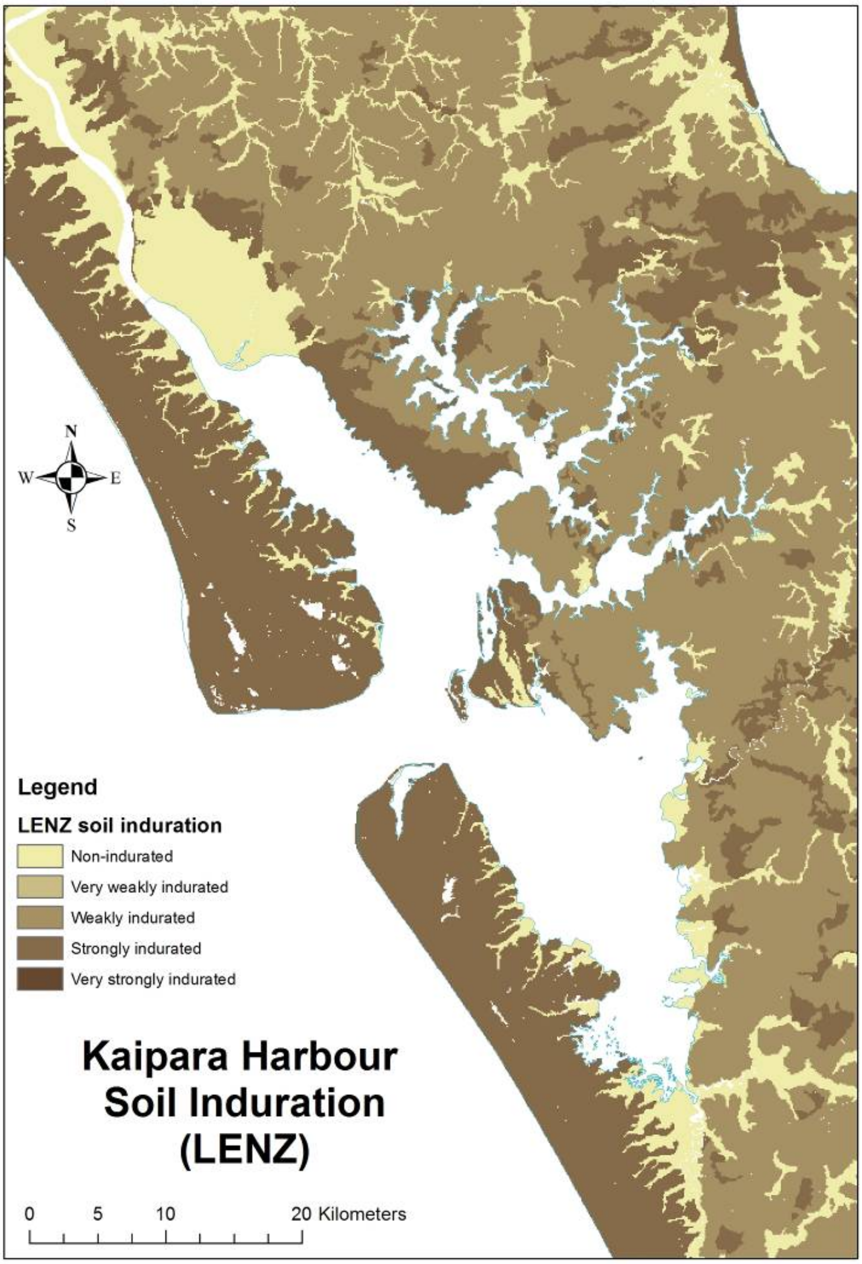


Figure 4 Geology of the Kaipara Harbour catchment (available information, source: Land Environments New Zealand).

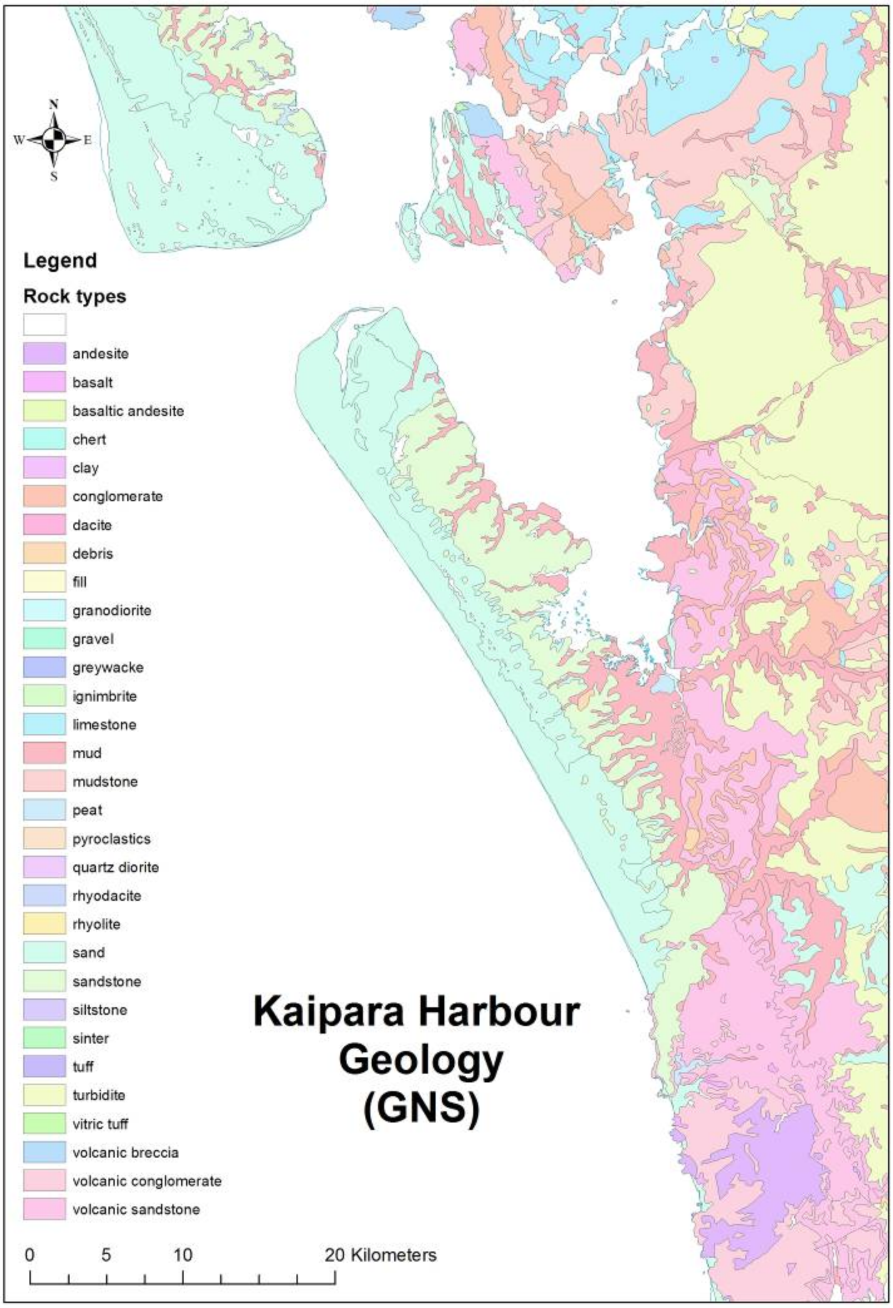


Figure 5 Sediment particle size for the Kaipara Harbour catchment (source: Land Environments New Zealand).

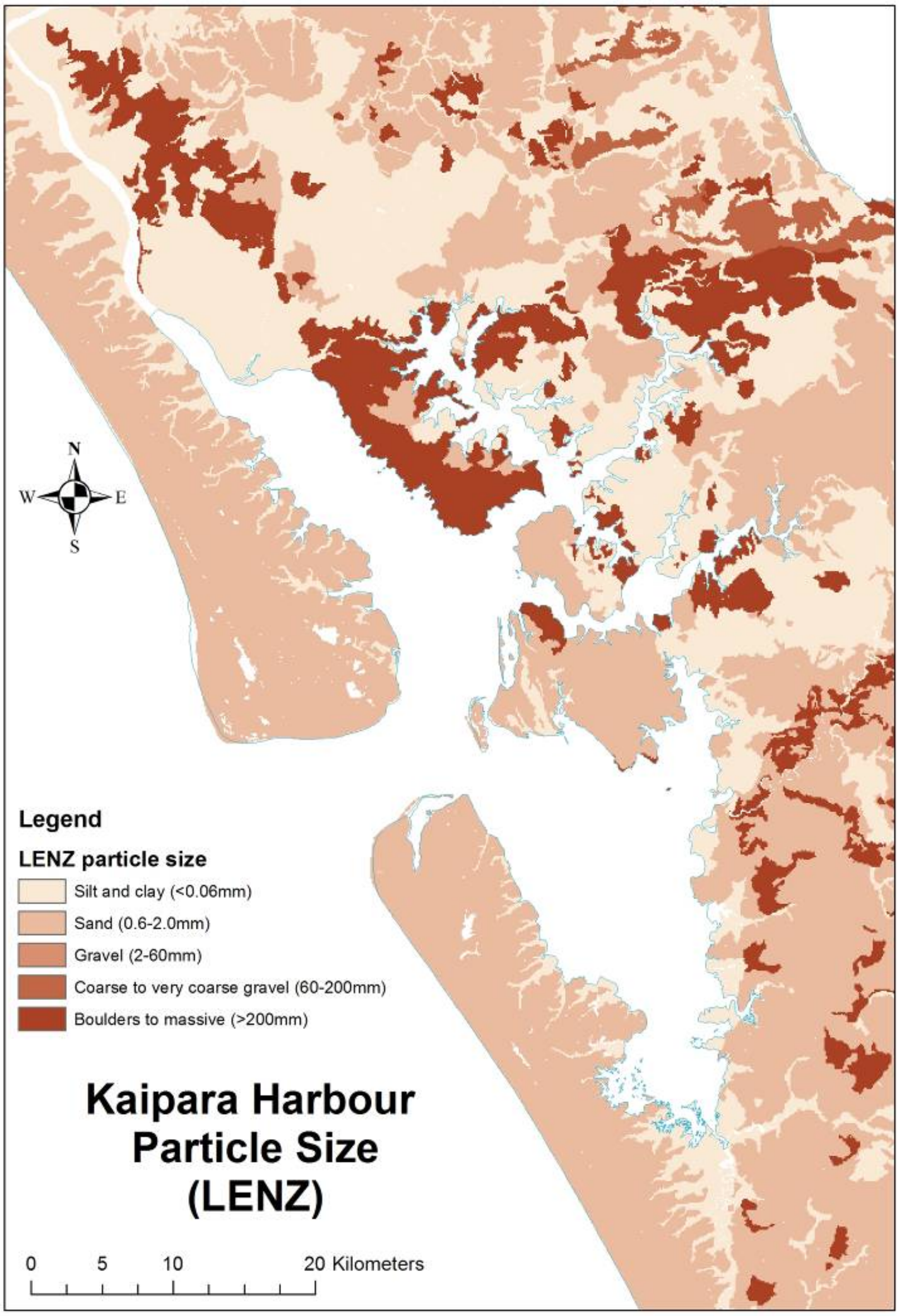
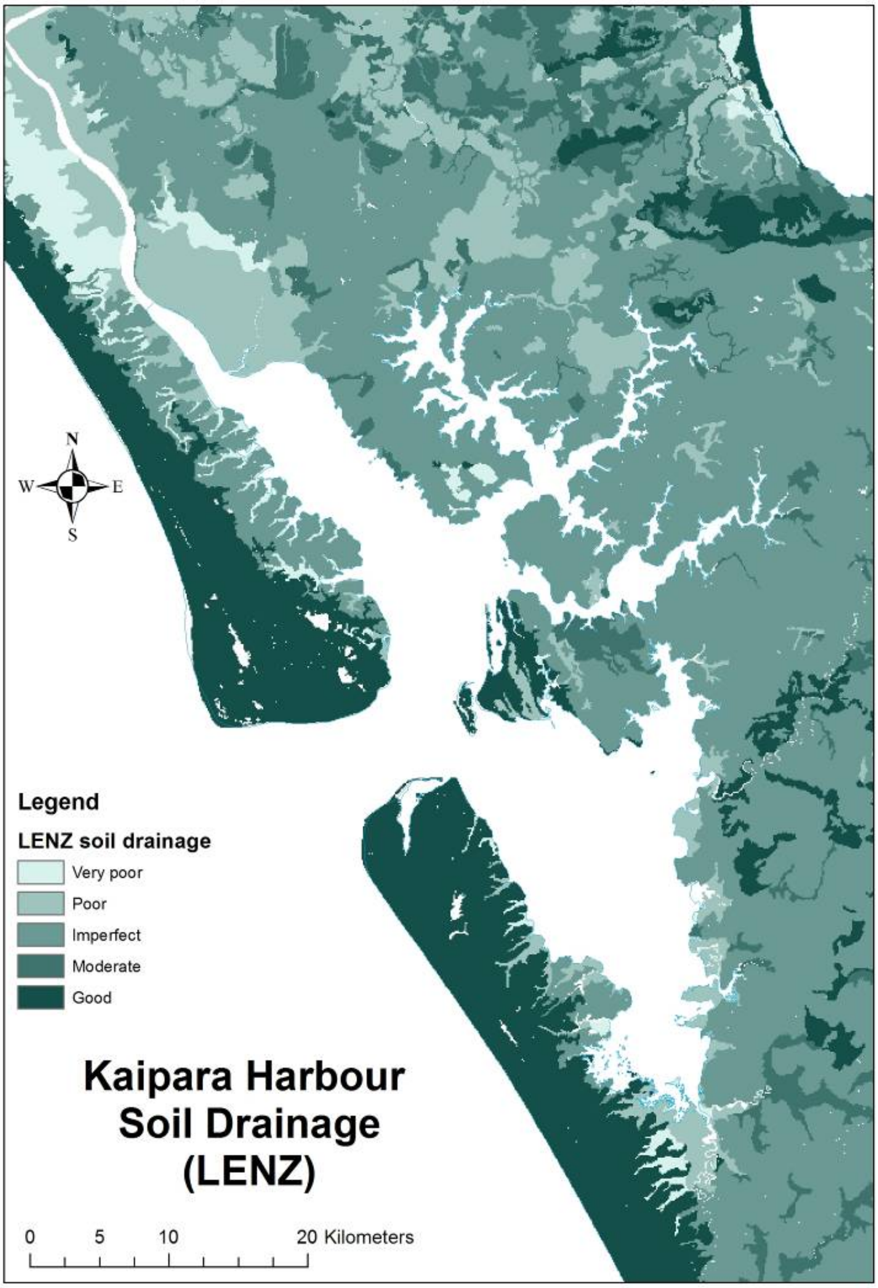


Figure 6 Soil drainage for the Kaipara Harbour catchment (source: Land Environments New Zealand).



3.2 Benthic communities

3.2.1 Southern Kaipara Harbour

Information on the benthic marine habitats and communities of Kaipara Harbour as a whole is relatively limited. The main sources of information are from a recent State of the Environment study of the South Kaipara (Hewitt and Funnell 2005), resource consent monitoring reports (e.g. Grace 1995-2004), mangrove studies (Morrisey et al. 2007), several studies carried out for aquaculture (Kelly et al. 2001, Biomarine 2005), and assessments of environmental effects (AEEs).

General intertidal and subtidal habitat types diagnosed by Hewitt and Funnell (2005) are presented in Figure 7. From their analysis, the harbour was divided into seven intertidal and eight subtidal areas. The seven intertidal areas were: the Oruawharo (O) and Tauhoa (T) arms, the upper part of the Kaipara River arm (U), the eastern (E) and western (W) areas of the outer Kaipara River arm, the area of sand dune in the Tapora region opposite the mouth (Ex), and the Waionui Inlet (I) (Figure 7). The eight subtidal areas were the Oruawharo (O) and upper Tauhoa (UT) arms, the upper (U) and middle (M) areas of the Kaipara arm, the high current area near South Head (H), the shallow subtidal area between the Kaipara River and Tauhoa arm (S), the exposed deep area in the mouth (Ex), and the outer area of the Tauhoa arm (OT) (Figure 7). A concise description of the main taxa within these habitats is provided in the following sections.

The marine habitats within the southern Kaipara are comprised of extensive intertidal and subtidal mud and sandflats, channels, and a limited amount of intertidal and subtidal reef. The area is also influenced by several relatively large rivers including the southernmost Kaukapakapa and Kaipara rivers, and the northernmost Hoteo, Tauhoa, and Oruawharo rivers (Figure 1). Biological communities across the area contain a mixture of common species found in many harbours and estuaries throughout the Auckland Region, but also include several rare and ecologically significant taxa and/or assemblages that are unique in the Auckland Region (e.g. tube building worms). Hewitt and Funnell (2005) indicate that a number of taxa (sponges, ascidians, bryozoans, hydroids, pipis, and echinoderms) within the southern Kaipara are commonly associated with pristine environments.

3.2.1.1 **Area U: Kaipara River arm**

Area U has five main habitat types: mangroves of varying densities, unvegetated intertidal mudflats that range from muddy to very muddy (>50% mud), sandflats, a small area of intertidal *Zostera,* and subtidal muds (Hewitt and Funnell 2005). The intertidal area south of Shelly Beach and Oyster Point is generally of modest diversity (Figure 8 to Figure 12), dominated by beds of the wedge shell *Macomona liliana* with the mudflat areas to the south typified by deposit-feeding bivalves and polychaetes, surface bioturbators, tube-dwellers, and polychaete predators/scavengers. Areas of mangrove are dominated by burrowers (e.g. the mud crab *Helice crassa*). Invasive bivalves such as *Musculista senhousia* and/or *Crassostrea gigas* also occur throughout this area. The intertidal sandflats between the Kaipara River and Oyster Point contain *Macomona liliana* in tandem with cockles (*Austrovenus stutchburyi*), high densities of deposit-feeding polychaete worms, suspension-feeding bivalves and tube dwellers. Moderately diverse tube-building polychaete worms are present adjacent to Oyster Point, co-occurring with low densities of large organisms such as nemertean worms and holothurians. The subtidal region is composed of four ecological communities: deposit-feeding bivalves, tube-dwellers, sedentary epifauna, and surface bioturbators.

Figure 7 Intertidal and subtidal habitat types in the southern Kaipara (Hewitt and Funnell 2005).

3.2.1.2 Area M: Subtidal region between Omokoiti Flats and Kaipara Flats

Area M, the middle subtidal area of the Kaipara River arm, has a low ecological diversity relative to other subtidal areas of the South Kaipara (Figure 8 to Figure 12). Main community types within this area range from suspension-feeding bivalves, tube-dwellers, surface bioturbators, large fauna (i.e. gastropods, crabs and predatory/scavenging polychaetes), hydroids, epifaunal complexes (typified by sponges with hydroids, bryozoans and/or anemones), filamentous seaweed, and areas dominated by *Fellaster*. Scallops (*Pecten novaezelandiae*) occur both intertidally and subtidally within and adjacent to the Kaipara Flats area (P. and C. Yardley, pers. comm. 2007) (Figure 20) but in recent years have declined in abundance and distribution. All scallop harvesting is restricted within the Kaipara Harbour (Ministry of Fisheries 2005).

3.2.1.3 Area W: Western intertidal flats (Omokoiti Flats)

Area W, the Omokoiti Flats area of the harbour, has a high ecological diversity typified by seagrass meadows together with *Austrovenus stutchburyi* and *Macomona liliana* communities. Unvegetated areas support a variety of community types including suspension-feeding bivalves, deposit-feeding polychaetes, tube-dwellers, polychaete predators/scavengers, surface bioturbators, and *Macomona liliana*. Mangrove habitat in this area is dominated by burrowers, with an *Austrovenus-Macomona* community also apparent.

3.2.1.4 Area E: Eastern intertidal flats

Area E, the eastern intertidal areas of the harbour containing the Kakaraia Flats and Kaipara Flats, is similar to the Omokoiti Flats. It is covered by extensive meadows of intertidal *Zostera*, concomitant with *Austrovenus stutchburyi* and *Macomona liliana* communities. Unvegetated sandflats within this area differ from the seagrass habitat, with suspension-feeding bivalves, deposit-feeding polychaetes, tube-dwellers, polychaete predators/scavengers, surface bioturbators, large fauna, and areas dominated by *Fellaster*. The unvegetated sandflats have a lower diversity than the areas dominated by seagrass, whereas muddy areas are typified by tube-dwellers. Mangrove habitat was not sampled within this section of the harbour but, based on equivalent habitat sampled in adjacent areas of the harbour (Kaipara River, Omokoiti Flats), Hewitt and Funnell (2005) suggest that the mangrove habitat is likely to be dominated by burrowing animals.

3.2.1.5 Area T: Tauhoa Arm

Area T, the Tauhoa arm, contains a similar suite of habitat types to that of the upper part of the Kaipara River arm. Mangrove and *Zostera* communities within this area are dominated by burrowers and *Macomona liliana,* with sandflat communities composed of deposit-feeding polychaetes, *Macomona liliana* and tube-dwellers. The subtidal upper reaches of the Tauhoa River are composed of finer sediments and have a diverse range of ecological communities including deposit-feeding bivalves, surface bioturbators, tube-dwellers, predatory/scavenging polychaetes, large fauna, and invasive species (*Musculista senhousia* and/or *Crassostrea gigas*). The outer subtidal areas of the Tauhoa arm are dominated by burrowing, tube-dwelling, and large faunal communities. Both the upper and outer reaches of the Tauhoa arm have high 'order' diversity.

3.2.1.6 Area S: Subtidal area adjacent Tauhoa and Kakaraia Flats

Area S, the shallow (<10 m depth at MLWS) subtidal area adjacent to the Tauhoa arm and Kakaraia Flats, is one of the most biologically diverse areas of the south Kaipara (Hewitt and Funnell 2005). This area contains fine sand with deposit-feeding bivalves, sedentary epibenthos, sponges, tube-dwellers, large fauna, surface bioturbators, subtidal *Zostera,* and *Atrina zelandica* beds. Subtidal seagrass beds are considered to be important for juvenile snapper recruitment within the harbour (FRST 2003).

3.2.1.7 Area OT: Tauhoa River

Analogous to other intertidal areas of the southern Kaipara, Area OT, the intertidal mudflats of the outer Tauhoa arm (the Tauhoa channel) is characterised by *Macomona liliana* at the entrance between Karaka Point and Breach Point. The subtidal areas at the mouth of the river are typified by epifaunal complexes and contain a high diversity of large animals (polychaete predators and scavengers), hydroids, and subtidal *Zostera capricorni,* with patches of *Musculista senhousia* adjacent to Stables Landing (Figure 8 to Figure 12) (Hewitt and Funnell 2005).

3.2.1.8 Area H: South Head and entrance region

Area H, the subtidal region adjacent to South Head has a high biological diversity (Figure 12) with rocky reef supporting diverse encrusting communities including: green-lipped mussels (*Perna canaliculus*), sponges, barnacles, and anemones. Surface bioturbators, tube-dwellers, large fauna, and *Fellaster* dominate the soft sediment habitats adjacent to South Head while the extensive sandy substratum characteristic of the harbour entrance is characterised by patches of *Fellaster zelandiae*, tuatua (*Paphies subtriangulata*), and a polychaete fauna with low biological diversity (Grace 2004).

3.2.1.9 Area I: Waionui Inlet

The intertidal sandflats characteristic of Area I, the Waionui Inlet, are of high-to-moderate diversity; typified by *Austrovenus stutchburyi*, surface bioturbators, and deposit-feeding polychaetes. The mudflat areas are dominated by deposit-feeding polychaetes.

3.2.1.10 Area EX: Intertidal and subtidal area adjacent Tapora Peninsula

Area EX, the intertidal areas adjacent to the mouth of the Oruawharo River, is typified by three main habitats: intertidal seagrass, sand, and subtidal sand. The seagrass habitat is dominated by a mix of large animals and dead cockle shells, whereas the intertidal sand contains a variety of communities such as: *Macomona liliana*, tube-dwellers, surface bioturbators, deposit-feeding bivalves, and polychaete predators/scavengers. The subtidal sandy habitat within this area is dominated by *Fellaster* and gastropods and the area as a whole has low-to-moderate biological diversity.

3.2.1.11 Area O: Oruawharo arm

The mudflat habitats in Area O, the Oruawharo arm, are dominated by polychaete predators/scavengers and deposit-feeding bivalves, with sandy areas dominated by *Austrovenus stutchburyi* in tandem with *Macomona liliana*. The mangrove areas in the Oruawharo arm have a different fauna to other regions of the South Kaipara, being dominated by the deposit-feeding bivalve *Arthritica* spp., polychaete predators/scavengers, and burrowers. Subtidal areas are generally muddy and dominated by deposit-feeding bivalves, sedentary epifauna, and *Fellaster* communities. Towards the mouth, surface bioturbators, tube-dwellers, and large fauna are common. Discrete patches of the horse mussel *Atrina zelandica* are present north of Schnapper Point (Hewitt and Funnell 2005). Subtidal mats of *Musculista senhousia* are extensive and widespread across the Oruawharo River. Patches of deposit-feeding bivalves, such as *Nucula hartvigiana,* and other smaller bivalves occur in the subtidal upper reaches of the river (Hewitt and Funnell 2005). The area between Raekau Wharf (Te Raekau) and Waingopai (Waingohe) Creek within the Oruawharo River (northern Kaipara) is presently designated as an oyster reserve (see section 3.3.2).

Figure 8 Distribution of ecologically significant intertidal communities found in the Southern Kaipara (from Hewitt and Funnell 2005).

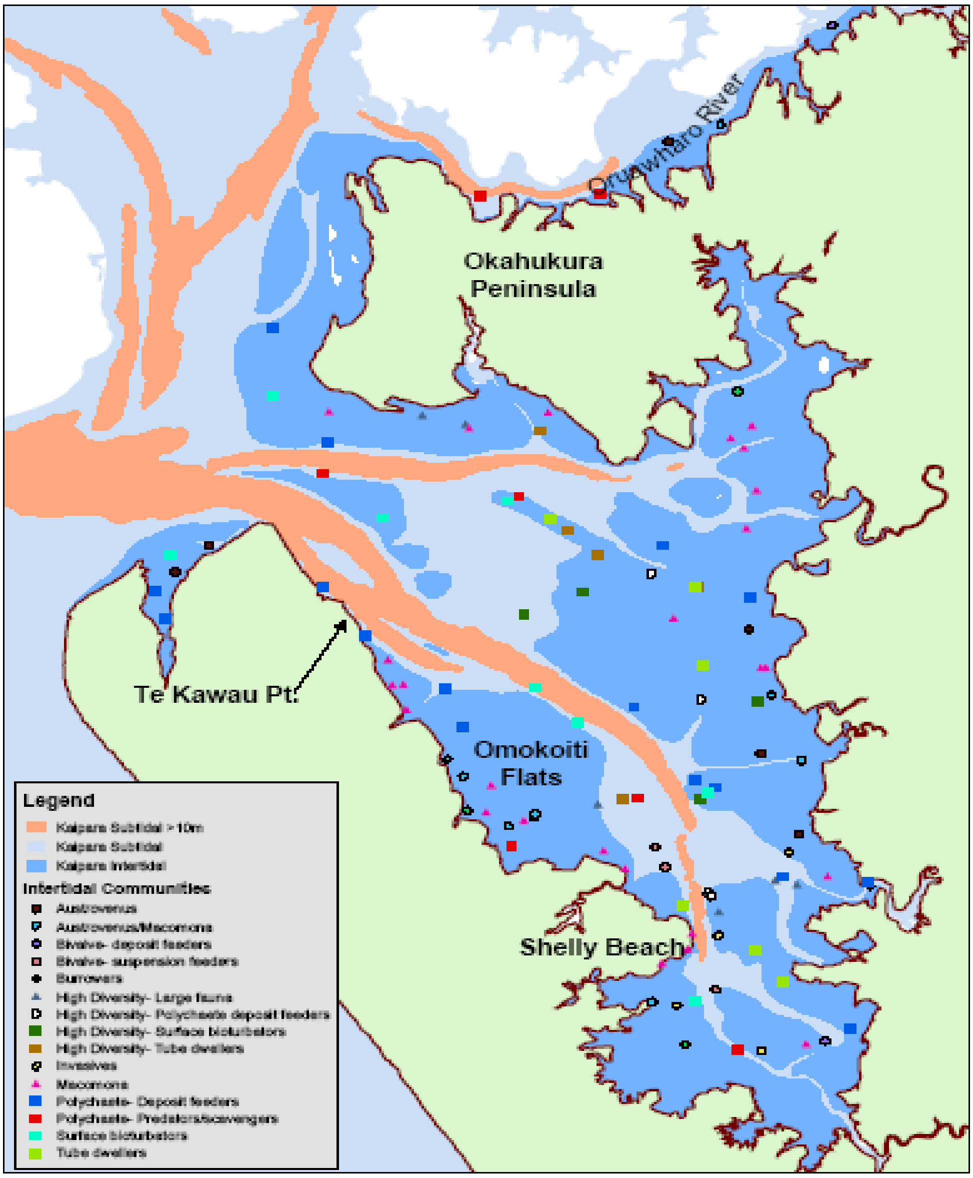


Figure 9 Interpolated plots of the distribution of total numbers of individuals (A), number of taxa (B), and number of orders (C) found in the cores taken from the intertidal sites (from Hewitt and Funnell 2005).

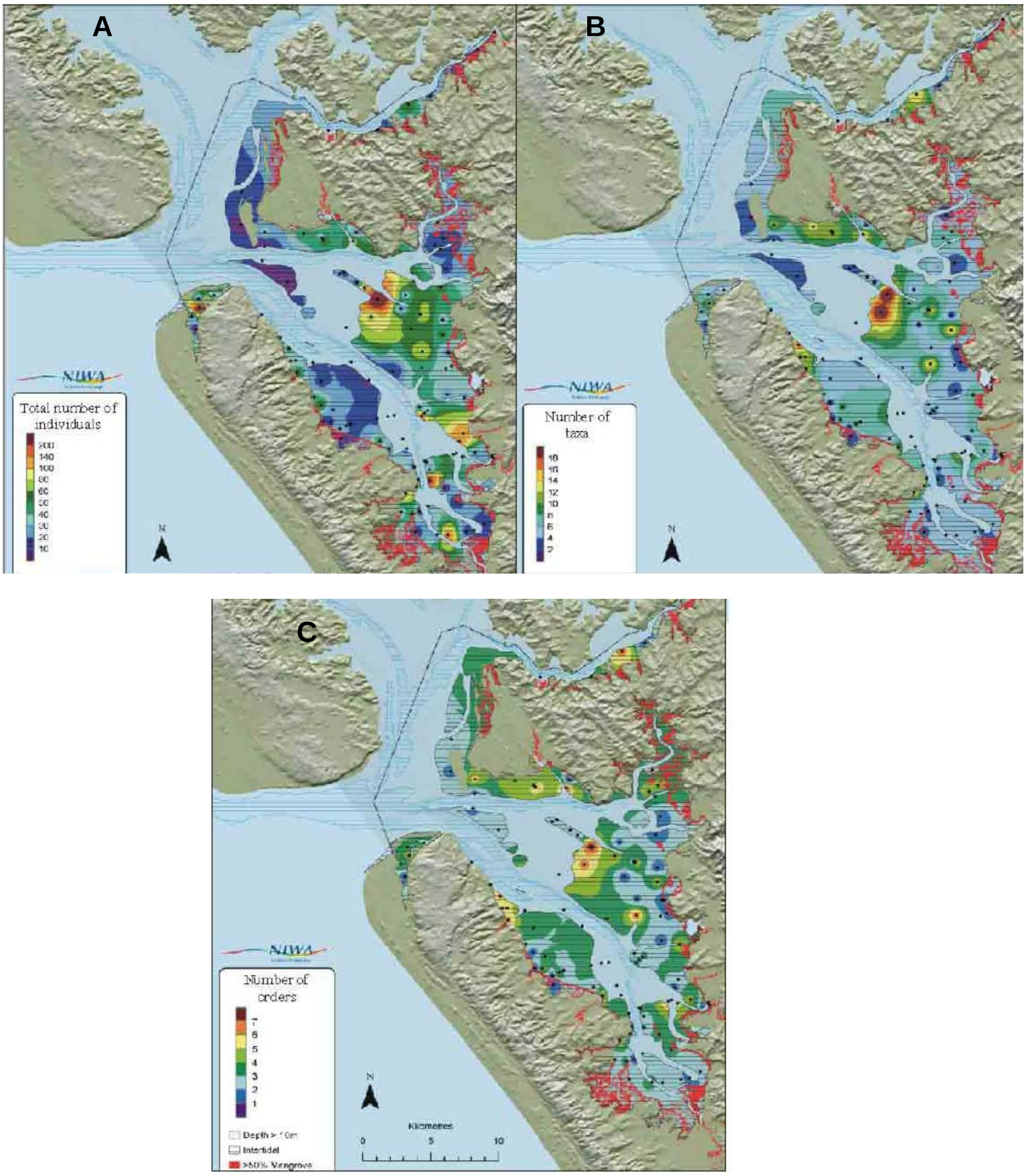


Figure 10 Distribution of subtidal epibenthic habitats found in the Southern Kaipara (from Hewitt and Funnell 2005).

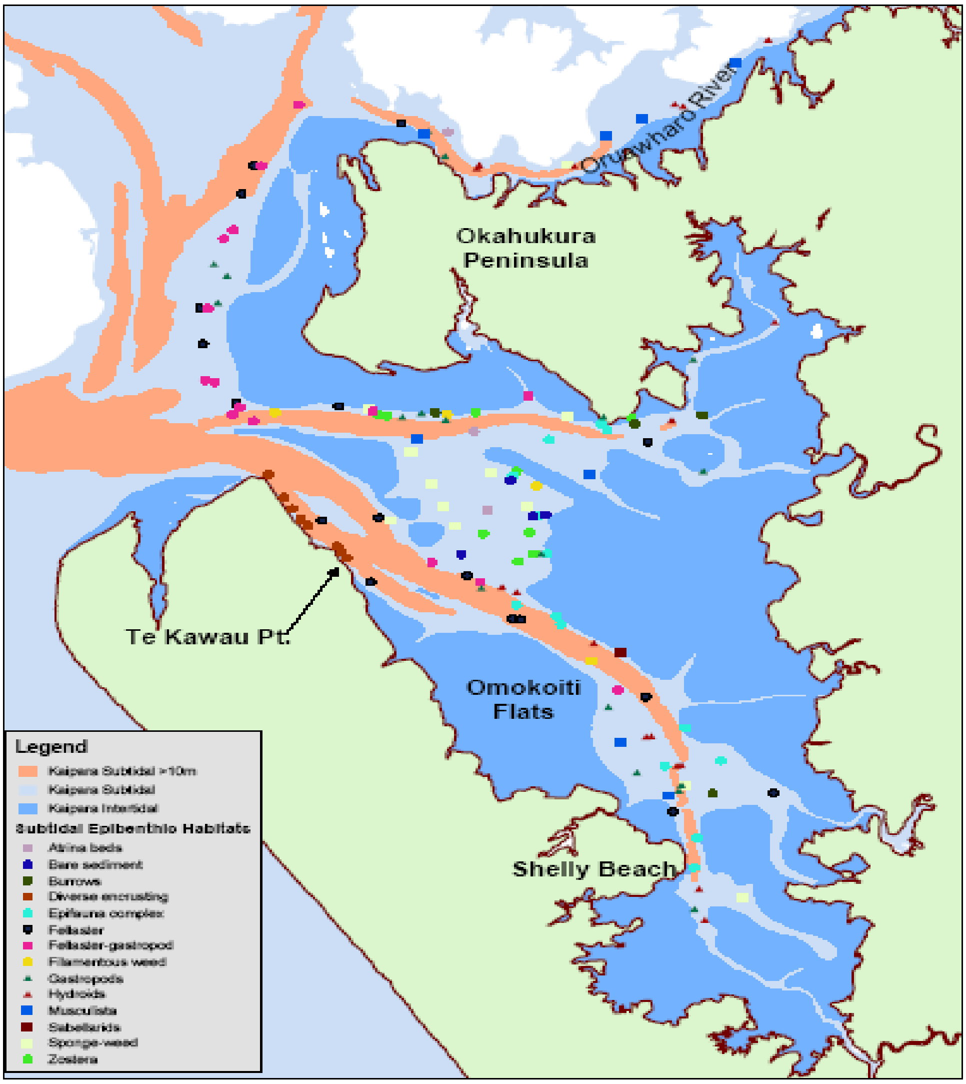


Figure 11 Distribution of ecologically significant subtidal communities found in the Southern Kaipara (from Hewitt and Funnell 2005).

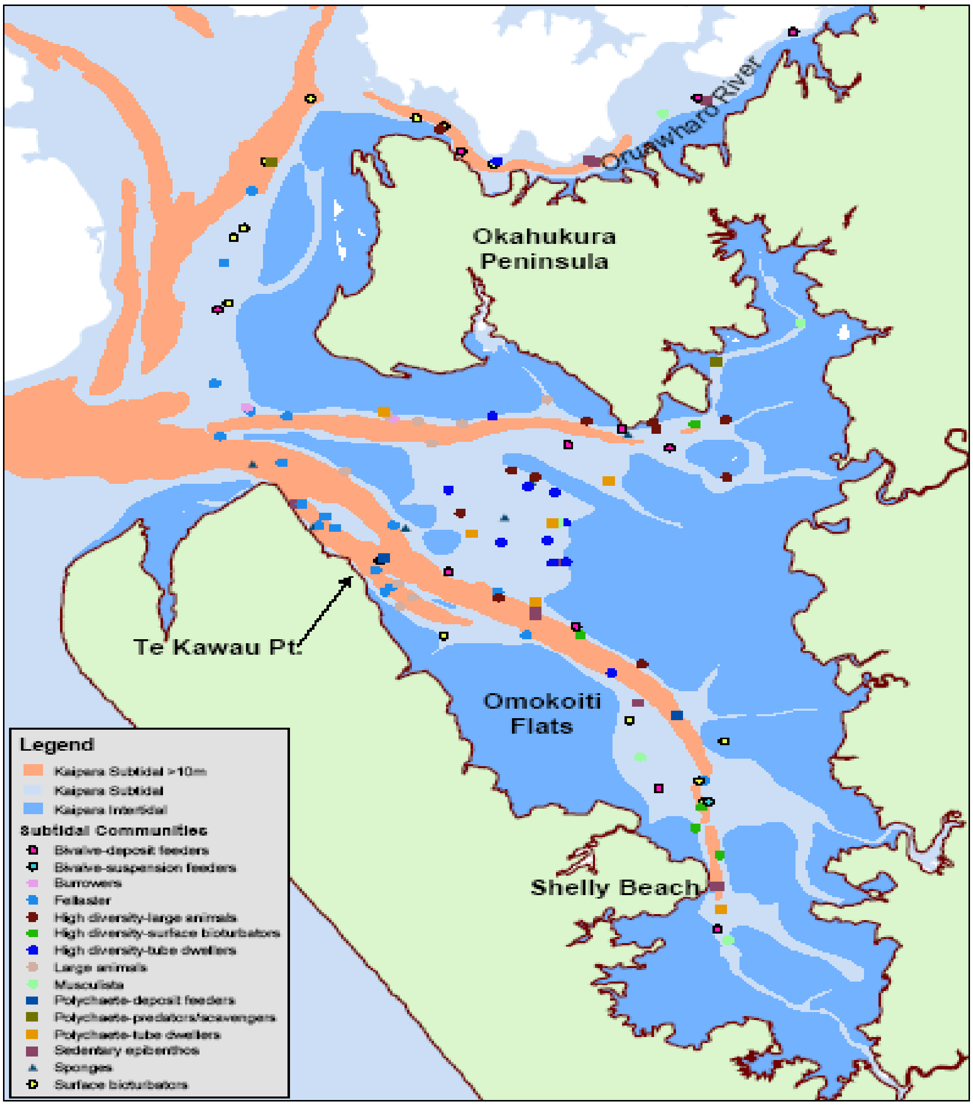
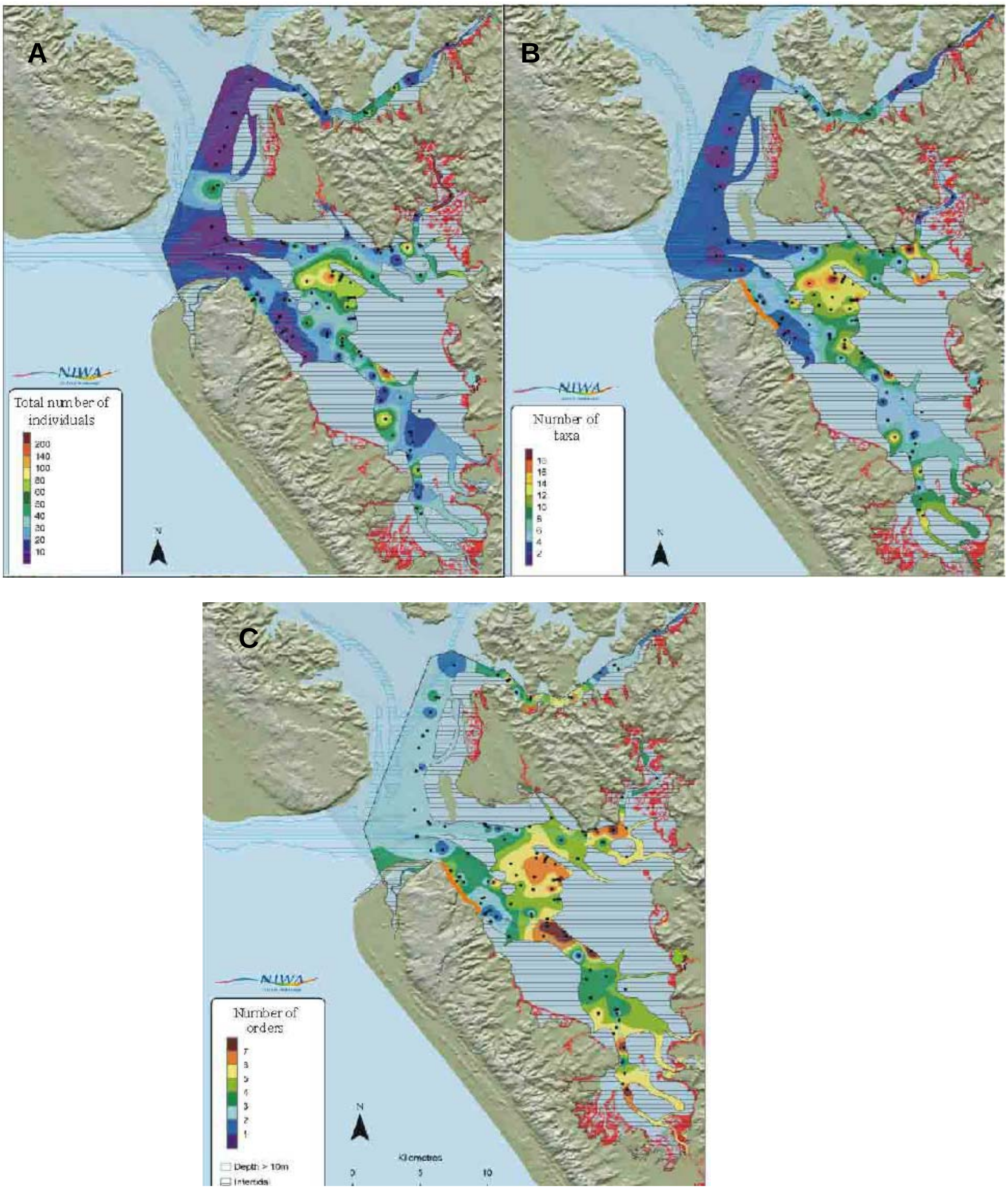


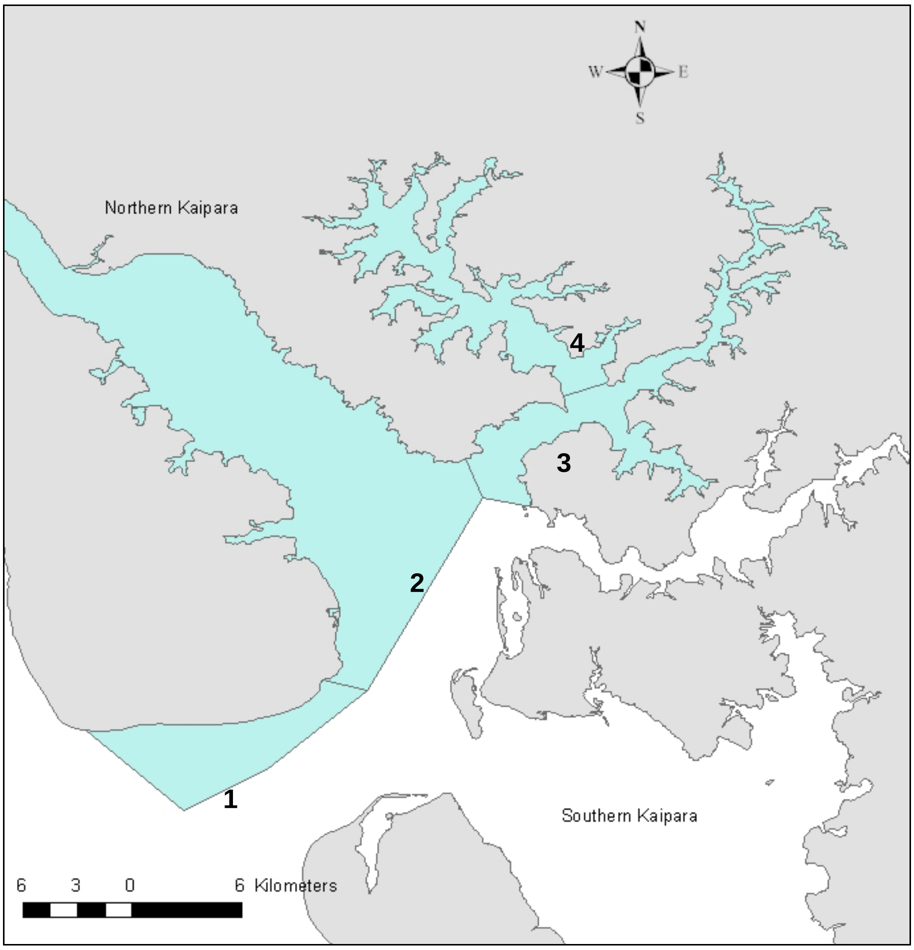
Figure 12 Interpolated plots of the distribution of total numbers of individuals (A), number of taxa (B), and number of orders (C) found in grabs taken from the subtidal sites (from Hewitt and Funnell 2005).



3.2.2 Northern Kaipara Harbour

The intertidal and subtidal areas of the northern Kaipara are influenced by several relatively large rivers including the Arapaoa River, Otamatea River, Oruawharo River and Wairoa River (Figure 1). Compared to the southern Kaipara, the northern Kaipara has been studied in far less spatial detail. Several studies have focused on benthic communities within discrete locations (e.g. the Otamatea River; see Robertson et al. 2002 and Poynter 2002) with only one-off studies being carried out in other regions. Findings from these studies suggest that the abundance and distribution of dominant taxa are, largely, characteristic of a degraded environment. In order to summarise the dominant benthic communities, the northern Kaipara was divided into four discrete areas (Figure 13). The following sections contain a concise description of the habitats present in these areas.

Figure 13 Four discrete areas within the northern Kaipara used to describe benthic marine habitats and communities: 1 Harbour entrance; 2 Wairoa Arm; 3 Otamatea River including Whakaiki River; 4 Arapaoa River.



3.2.2.1 Area 1: Harbour entrance to Pouto Point

The central area of the harbour (<30m) is characterised by sandstone outcrops with occasional deposits of sand. The sandstone outcrops are dominated by a diverse mussel reef community, with the dominant species being green-lipped mussel (*Perna canaliculus*) and a range of gastropods, amphipods, and carnivorous polychaetes (CREST 2007). The eastern areas of the harbour are dominated by tuatua (*Paphies subtriangulata*), sand dollar (*Fellaster zelandica*), polychaetes, and amphipod communities. Gordon et al. (2006) report an invasive bryozoan, *Membraniporopsis tubigera*, around Pouto Point that caused problems for local flounder fishers in 2003 due to net fouling. The present abundance and distribution of this species within the harbour is unknown.

3.2.2.2 Area 2: Northern Kaipara, Wairoa arm

The coastal area north of Pouto Point is characterised by numerous muddy embayments (e.g. Oneroa Bay and Kellys Bay) and extensive reclamations, particularly around Dargaville (Shaw and Maingay 1990). The area between Pouto Point and Sail Rock is presently designated as an oyster reserve (see section 3.3.2). The eastern coastal areas of the Wairoa arm are characterised by extensive intertidal sand and mudflats between Kumuakiti Point and Paraoanui Point, with numerous muddy embayments present between Werewere Point and Te Kauri Point. The benthic communities of the Wairoa River arm have been poorly described. Subtidal mussel (*Perna canaliculus*) beds occur adjacent to Pareotaunga Point (T. R. Haggitt., pers. obs. 2006), although the spatial extent of these is presently unknown. The occurrence of intertidal mudflats and muddy embayments suggests that the common benthic communities found in the Otamatea River and Arapaoa River (see the following sections) are likely to be found throughout the Wairoa River arm.

3.2.2.3 Area 3: Otamatea River including Whakaki River

The Otamatea and Whakaki River areas are typified by numerous muddy embayments and intertidal mudflats. Many creeks drain into the Otamatea River (e.g. Kaiwaka River, Awaroa Creek, Takahoa Creek) and into the Whakaki River (e.g. Paki Creek, Stony Creek). Robertson et al. (2002) describes the general abundance patterns of dominant taxa, with cockles (*Austrovenus stutchburyi*) and the nut shell *Nucula hartvigiana* common in the lower reaches of the rivers and Oligochaete worms more abundant in the upper reaches. It is suggested that these distribution patterns are due to the sediment characteristics (which increase in muddiness from lower to upper reaches) of the sites surveyed. Common gastropods in the river include *Zeacumantus lutulentus*, *Diloma subrostrata*, *Diloma zelandica,* and *Cominella glandiformis*. Areas surrounding Coates Bay are characterised by large monospecific patches of the tubeworm *Pomatoceros caerulus* whereas numerous boulders within the bay (known as the 'Mussel Ring') are encrusted with oysters (both live and dead) and low densities of mussels (*Perna canaliculus*) (Poynter 2002). Large patches of *Hormosira banksii* are typical of the mid-shore regions of the bay, with *Xenostrobus pulex* and *Zeacumantus* *lutulentus* common in upper reaches (Poynter 1992). *Musculista senhousia* occurs in dense patches throughout the Otamatea River, particularly around The Bluff (Tinopai) and adjacent to Otara Head at the entrance to the Whakaki River (P. & C. Yardley., pers. comm. 2007). Within the Otamatea River, oyster reserves are presently designated between Batley Wharf and Tanoa Point, and between Paparoa Point and Onoke Point (see section 3.3.2).

3.2.2.4 Area 4: Arapaoa River

The Arapaoa River is characterised by numerous embayments, rocky headlands, and extensive intertidal mudflats. Numerous creeks drain into the Otamatea River. Morton and Miller (1968) describe the basic zonation pattern of the dominant organisms within the Whakapirau Creek area, noting that oysters (*Crassostrea gigas*) are predominant on the upper shore and eventually give way to large reef-like clumps of *Pomatoceros caerulus* raised above the muddy and silty substratum. This area is also characterised by the common gastropod fauna of mudflats (*Zediloma subrostrata*, *Micrelenchus huttoni, Xymene plebeius*, *Zeacumantus lutulentus,* and *Cominella glandiformis*). Morton and Miller (1968) noted a general absence of zoning algae, with no trace of *Corallina* spp. or *Hormosira banksii*. The species associations observed by Morton and Miller (1968) are common throughout the Arapaoa River (Haggitt and Mead., pers. obs. 2004). Jeffs et al. (1992) also noted the occurrence of the Chilean oyster, *Tiostrea chilensis*, within the Pahi Bank area of the Arapaoa River. Oyster reserves occur between Wakaiti and Tahupo Creek (Arapaoa River), and between Te Kopua Point and Waipako (encompassing the Arapaoa and Otamatea Rivers) (see section 3.3.2).

3.3 Fisheries

Information on fish within Kaipara Harbour includes:

- Research on fish in estuarine and coastal habitats – including the Kaipara Harbour, funded by the Foundation for Research Science and Technology (FRST). (Morrison and Francis 2004). See project summaries for contract C01X0222 (Fish usage of estuarine and coastal habitats) on the FRST website (http://www.frst.govt.nz/database/).
- Sampling associated with an AEE for an oyster farm (Kelly et al. 2001).
- Ministry of Fisheries catch and catch per unit effort data.
- Two reviews on commercially targeted species (Hartill 2002, Paulin and Paul 2006).
- Data contained within the New Zealand Freshwater Fish Database (NZFFD).

The FRST funded studies have been focused on determining the juvenile fish usage of estuarine and coastal habitats throughout New Zealand. Preliminary results indicate that within the Kaipara harbour:

- Juvenile yellow-eyed mullet (*Aldrichetta forsteri*) and grey mullet (*Mugil cephalus*) are common in most areas of the Kaipara, with grey mullet generally found in higher abundances (NIWA 2003).
- The invasive sand goby (*Papillogobius exquisitus*) occurs within and around the Kaipara River (NIWA 2003).
- There was a high association of juvenile grey mullet (20–40 mm length) with mangrove habitat (Table 1) and intertidal seagrass meadows in the Kaipara Harbour. Other species found to occur in mangrove habitat were red gurnard, anchovy, and flounder. The sparid *Pagrus auratus* (i.e. snapper), which utilises northern New Zealand estuaries and sheltered coastal embayments as nursery grounds, was absent from mangrove habitat within the Kaipara.
- The Kaipara Harbour has been estimated to provide almost three-quarters of estuarine-based snapper recruitment to the West Coast of the North Island. Snapper utilise New Zealand estuaries and sheltered coastal embayments as nursery grounds, with high densities reported (thousands per km^2) of snapper less than one-year old associated with subtidal horse mussel beds, and a strong association with seagrass meadows in the extreme low intertidal / upper subtidal areas (Morrisey et al. 2007).

Table 1 Average fyke net catches for Kaipara Harbour fish species associated with mangroves. Abundances are expressed as average numbers of individuals (SE) per 14.5 m net set (day and night catch combined). Data extracted from Morrisey et al. (2007).

Common name	Scientific name	Kaipara Harbour
Yellow-eyed mullet	*Aldrichetta forsteri*	84.8 (28.8)
Grey mullet	*Mugil cephalus*	24.2 (18.0)
Estuarine triplefin	*Grahamina nigripenne*	0.3 (0.2)
Smelt	*Retropinna retropinna*	03 (03)
Short-finned eel	*Anguilla australis*	10.5 (2.5)
Anchovy	*Engraulis australis*	24.8 (24.0)
Sand flounder	*Rhombosolea plebeia*	1.2 (0.8)
Yellow-belly flounder	*Rhombosolea leporina*	1.5 (0.5)
Exquisite goby	*Favonigobius exquisitus*	1.2 (0.8)
Garfish	*Hyporhamphus ihi*	0.5 (0.5)

While much of the data from the FRST funded studies are yet to be formally published, preliminary results indicate that the West Coast adult snapper population is principally comprised of 4 to 8 year old fish whereas historical populations were dominated by fish aged 10 to 30 or more years. Successful snapper recruitment from harbours such as the Kaipara is seen as essential for supporting the adult stocks on the West Coast. Accordingly, data collected from surveys of juvenile snapper in the West Coast harbours of the North Island (particularly the Kaipara) could provide an early warning of snapper recruitment problems. The research also indicates that environmental degradation of important fish nursery habitats (e.g. seagrass in the Kaipara Harbour) could have a significant cascading effect on fish, including the West Coast snapper population.

Another investigation concerning fish (Kelly et al. 2001) was carried out, as part of an assessment of the environmental effects, for an oyster farm consent application. This investigation described a low diversity of fish (Table 2) within the vicinity of Aquaculture Management Area D that was originally proposed by the ARC.

Table 2 Dominant subtidal fishes and crustacea identified by Kelly et al. (2001).

Common name	Species
Anchovy	*Engraulis australis*
Goby	*Acentrogobius lentiginosus*
Gurnard	*Chelidonichthys kumu*
Garfish	*Hyporhamphus ihi*
Long Snouted Pipefish	*Stigmatophora longirostris*
Smelt	*Retropinna retropinna*
Sand Flounder	*Rhombosolea plebia*
Speckled Sole	*Peltorhamphus latus*
Common Shrimp	*Palaemon affinis*
Sand Shrimp	*Pontophilus australis*
Pill Box Paddle Crab	*Ovalipes punctatus*
Crab	*Halicarlinus cookie*
Tunneling Mud Crab	*Helice crassa*

Numerous elasmobranches (sharks, skates, and rays) have been reported to use the Kaipara Harbour for breeding and foraging. Important shark species include the great white shark (*Carcharodon carcharias*), rig (Hartill 2002, Ministry of Fisheries 2006), and school shark (*Galeorhinus galeus*) (Ministry of Fisheries 2006d, NABIS 2007).

The New Zealand Freshwater Fish Database (NZFFD 2007) suggests that the Kaipara Harbour is also used by a relatively high number of native freshwater fish species (12) and a low number of exotic fishes (3) compared to other harbours in the Auckland Region. Important species include the nationally vulnerable galaxiid (*Galaxias* spp.) mainly recorded in the South Kaipara (Hoteo, Omaumau, and Araparera Rivers) and the long-finned eel (*Anguilla dieffenbachii*) which has experienced a gradual decline in abundance across the Auckland Region in recent years (NZFFD 2007).

Kaipara Harbour Fisheries

The Kaipara Harbour has been an important source of fish for Māori since the fourteenth century and for European settlers since the early nineteenth century. Despite a range of sustainability issues and management conflicts for many species over time, the harbour continues to support customary, commercial, and recreational fisheries. However, there is continual, and even escalating, concern from all three of these fisheries over the present state of various fish stocks within the Kaipara Harbour (Kaipara Harbour Sustainable Fisheries Management Study Group 2003).

3.3.1 Commercial fishing

Currently, commercial fishing occurs throughout the Kaipara Harbour. Historically, the harbour has supported major commercial finfish fisheries for rig, flatfish (most commonly yellow-belly and sand flounder), school shark, and grey mullet; as well as shellfish fisheries for oysters (*Crassostrea gigas*), tuatua (*Paphies subtriangulata*), and mussels (*Perna canaliculus*) Table 3. Rig, flatfish, and mullet form the bulk of the commercial catch within the Kaipara at present.

In addition to Ministry of Fisheries plenary reports (Ministry of Fisheries 2006a-e) which detail the current state of commercial fisheries in large fisheries management areas (FMAs) including the Kaipara Harbour, several recent reviews assess the status of important commercial species, specifically for the Kaipara. Hartill (2002) described the commercial status of grey mullet, rig, and flatfish fisheries in the Kaipara Harbour based on Ministry of Fisheries set net and ring net data. Paulin and Paul (2006) describe, in detail, both the historical and current status of the grey mullet fishery within the Kaipara.

Commercial fishing is undertaken by both a local and non-local fleet, with the local fleet making up approximately 90% of the commercial fishers (Hartill 2002, Peart 2007). Over the last decade, there has been increasing spatial conflict between commercial fishers on the harbour (Kaipara Harbour Sustainable Fisheries Management Study Group 2003).

3.3.1.1 Grey mullet

One of the first commercial fisheries in New Zealand caught mullet; these were heavily targeted within the Kaipara between 1880 and 1895. During this time, commercial operations supported three canning factories and fishing occurred throughout the year. There was no management or monitoring of the fishery and wastage was common (Paulin and Paul 2006). Following a perceived decline in stocks and concerns about overexploitation, a petition to the government by fishermen led to a closed season between December and February; this was later amended to cover only a small area of the Kaipara. A formal study was carried out in 1895 in response to continued concern over stock declines and to investigate the need for a closed season, . The study recognised that mullet spawned in the open sea outside the harbour but there was a general lack of information on mullet biology, which limited the conclusions of the study.

By 1900, the Kaipara mullet fishery had largely collapsed due to a combination of factors: reduced stocks, reduced market demand, fishermen targeting more favourable species in the Hauraki Gulf, and a lack of government subsidies to canneries.

Consequently, the grey mullet stocks had largely recovered by 1910. Between 1930 and 1974, average mullet landings were 45 tonnes per year, based on records from Annual Fisheries Reports, with no evidence of stock limiting the supply. With an increase in local market demand for mullet in the late 1970s, mullet landings increased quickly and have since fluctuated between 200 and 400 tonnes, with the Kaipara fishery contributing between 25 and 50% of the total New Zealand take (Paulin and Paul 2006).

Both set- and ring-netting techniques are currently used to target grey mullet within the Kaipara (Quota Management Area GMU 1, Ministry of Fisheries 2006a), with the majority of the catch in recent years being obtained by ring-netting. Following the highest grey mullet take within the Kaipara in 1996-97 (385 t), set-net data illustrate a decline in local and non-local catches from 1996-97 onwards (Figure 16), with a simultaneous decline in local set-net fishing effort. Conversely, ring-net fishing has increased within the harbour since 1998-99 and grey mullet catches using this method have also increased (Figure 16), with the majority of grey mullet landed as a consequence of the specific targeting of this species (Hartill 2002, Paulin and Paul 2006). Data presented by Hartill (2002) from 1989-90 up to 2000-01 suggests catch rates are declining in the harbour, although recent data presented by Paulin and Paul (2006) indicate increased mullet landings between 2002-2004 that are comparable with grey mullet landings in the late 1990s (i.e. >200 tonnes). However, Paulin and Paul (2006) highlight sustainability concerns for grey mullet within the Kaipara and identify problems that make it difficult to determine the maximum sustainable yield for this species. These include:

- Changes in catch efficiency due to alteration of fishing methods (set-net / ring-net).
- Fishermen targeting other commercial species and obtaining grey mullet as by-catch.
- A lack of information on the unfished (virgin) stock size.
- Lack of basic biological information for this species (e.g. it is not known if the mullet within the Manukau and Kaipara Harbours are the same biological stock).

These problems are also relevant to other commercial species in the Kaipara Harbour.

3.3.1.2 Flatfish

The yellow-belly flounder, *Rhombosolea leporina,* and the sand flounder, *Rhombosolea plebeia,* are commercially fished within the Kaipara Harbour (Figure 14) (Quota Management Area FLA 1). Unlike the majority of quota species, the eight commercially fished flatfish species are managed as a single fishery; one catch limit is set for the total catch of the eight species in each QMA. The Kaipara Harbour flatfish fishery, as a proportion of FLA 1 landings, has steadily increased from 1993-94.

Set nets are used to catch flounder and recent surveys suggest that three-quarters of the West Coast catch is taken from the Kaipara and Manukau Harbours (Hartill 2002, Ministry of Fisheries 2006b). Within the Kaipara, flatfish catches were high for the

1996-97 and 1997-98 fishery years and peaked at 316 t for the 2000-01 fishing year (Figure 16).

3.3.1.3 Rig

Rig (*Mustelus lenticulatus*) is landed in coastal waters throughout New Zealand, with the Kaipara Harbour (within Quota Management Area SPO 1) accounting for between 10 and 20% of the total New Zealand catch. Within the Kaipara, rig is caught by set-netting (see Figure 15 for areas where rig are targeted), and fishing effort and catches by both local and non-local fleets increased substantially between 1990 and 2000 (Figure 16). These increases were accompanied by a downward trend in catch per unit effort within the harbour, suggesting a decline in Kaipara rig abundance (Hartill 2002) since the early 1990s. In the mid 1990s, the local fishing fleet was responsible for ~80% of catches but by 2000 local catches had declined to between 60-65% of the total catch. It is currently unknown whether the current total allowable commercial catch (TACC) is sustainable within SPO1 (Ministry of Fisheries 2006c).

Figure 14 Areas targeted for flounder and grey mullet by commercial fishers within the Kaipara Harbour (Information from commercial fishers P. and C. Yardley., pers. comm. 2007).

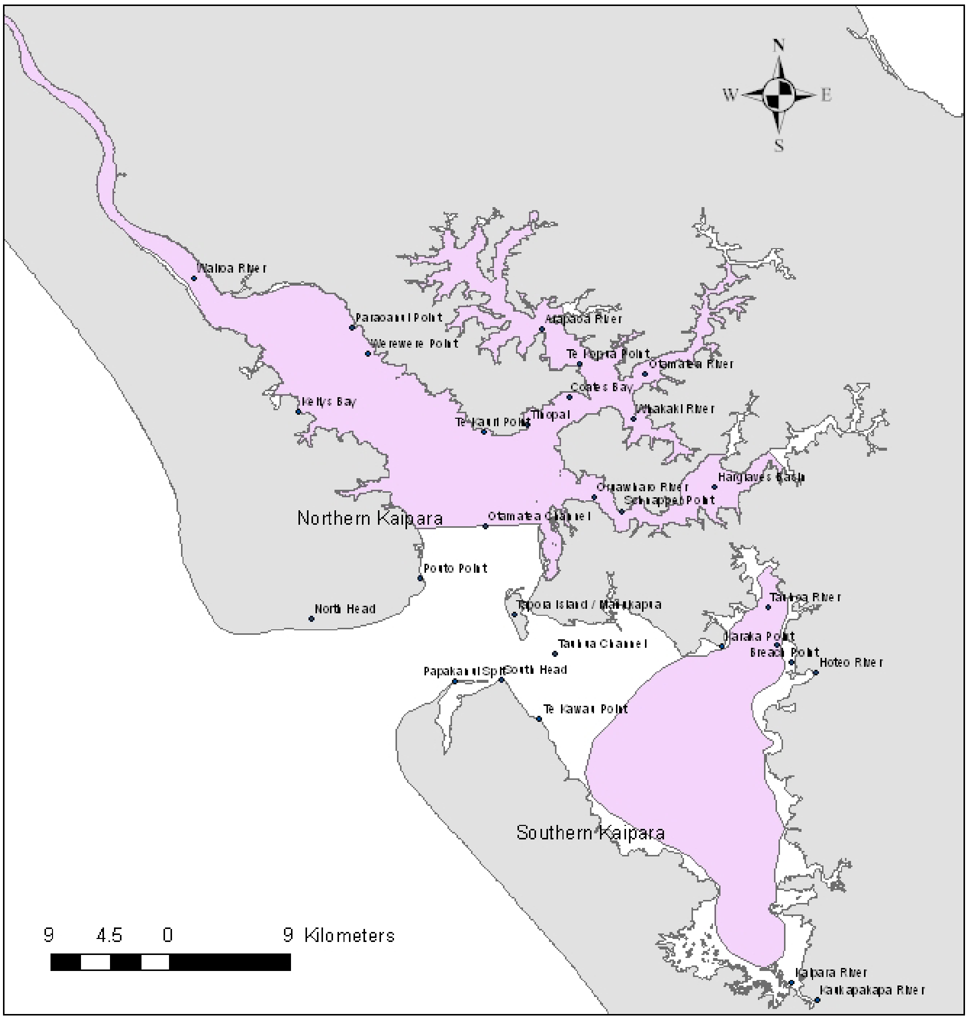


Figure 15 Areas targeted for rig by commercial fishers within the Kaipara Harbour (Information from commercial fishers P. and C. Yardley., pers. comm. 2007).

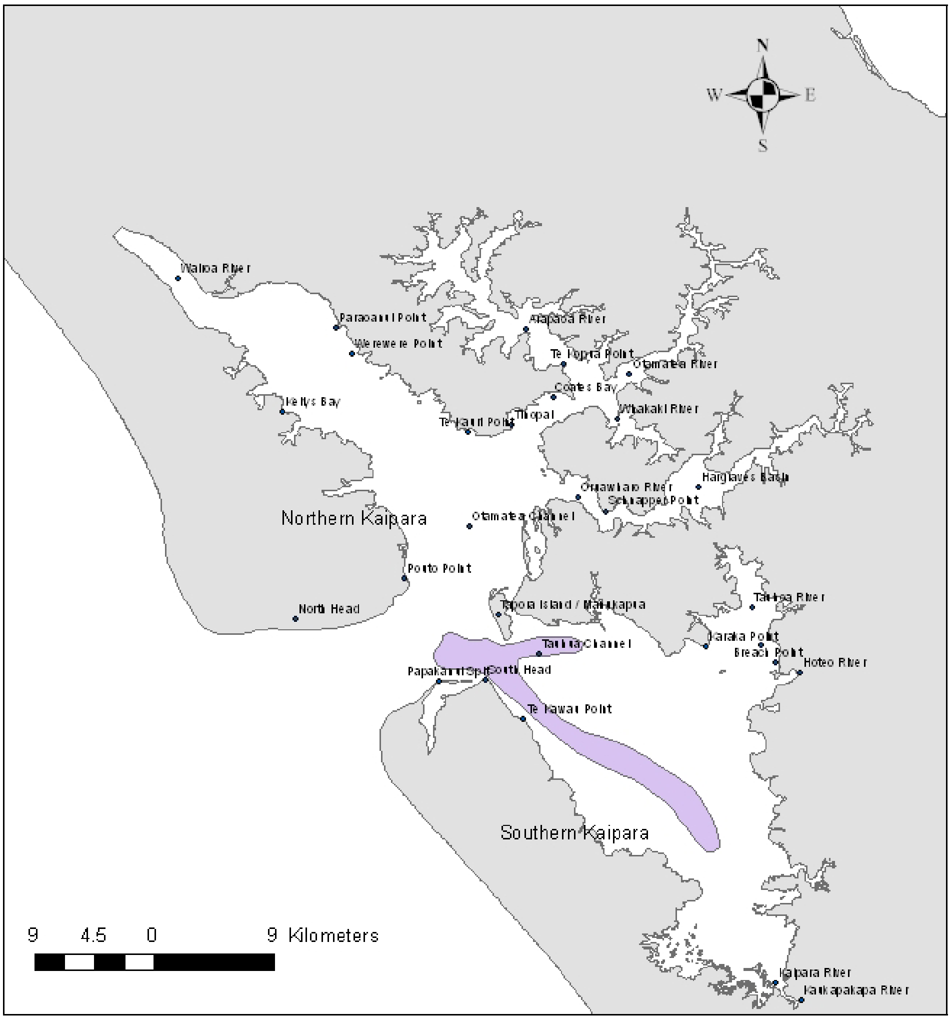
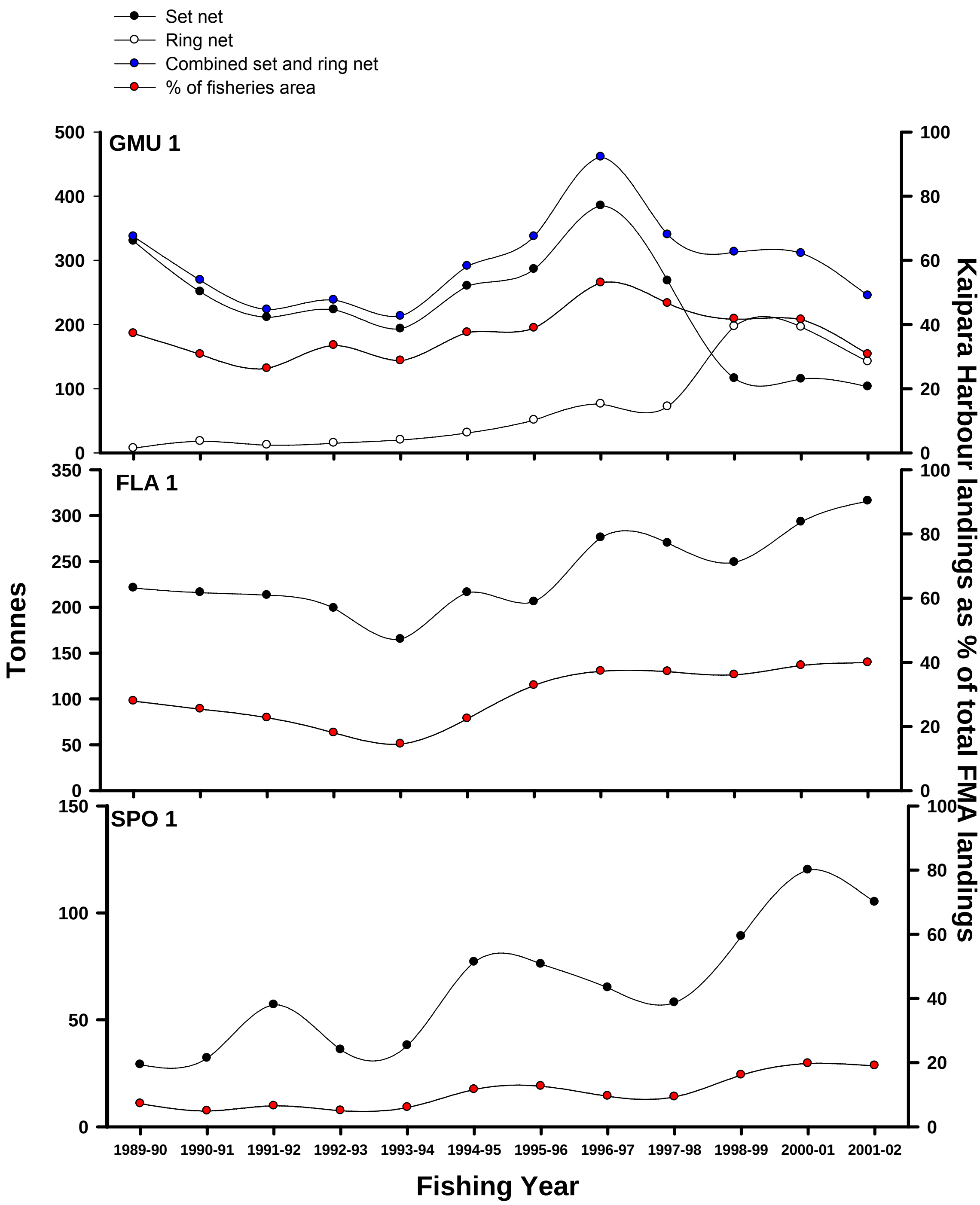


Figure 16 Annual set-net and ring-net landings (tonnes) for the Kaipara Harbour; and Kaipara Harbour landings as a percentage of total landings within each fisheries management area (FMA) for grey mullet (FMA = GMU 1), flatfish (FMA = FLA 1), and rig (FMA = SPO 1) from 1989-90 to 2001-02. Data summarised from Hartill (2002). Note: Ring-net data applies only to grey mullet, and y axis for tonnage data differs among graphs.



3.3.1.4 School shark

School shark (*Galeorhinus galeus*) catches within the Kaipara Harbour declined from 35 tonnes in 2001-02 to 6 tonnes in 2005-06 but this decline is reported as being due mainly to fishers retiring from the fishery (Ministry of Fisheries 2006d). Approximately 1% of the total Quota Management Area SCH 1 commercial catch is currently caught in the harbour. Despite this low percentage of overall catch, the Ministry of Fisheries is concerned about the impacts that school shark fishing within the Kaipara Harbour (statistical area 044) may have on the wider SCH 1 stock, and suggests that the harbour may be a habitat of particular importance to the school shark fishery as pupping females migrate there to give birth. Not surprisingly, results from modelling indicate that removing the larger females from the population poses a significant risk to the sustainability of the stock. In response, the Ministry of Fisheries has put forward for discussion possible measures to protect pregnant school shark in the Kaipara. One suggestion is that it may be prudent to prohibit their taking in the Kaipara from November to January, when school sharks give birth. In their plenary report for the 2005-06 year, the Ministry of Fisheries invited stakeholders to comment on this suggestion and make any alternative suggestions for the protection of pregnant school shark in the Kaipara.

Measures that restrict fishing at certain times of the year would help to protect pregnant females. However, school shark caught as by-catch is probably the most significant issue that needs to be addressed. The Ministry of Fisheries data suggests that over the last five years approximately 60% of catches in SCH 1 were from by-catch, with only 40% as target stock. As a result, commercial landings from SCH 1 have exceeded the Total Allowable Commercial Catch in all fishing years since 1994-95 (except in 2005-06). Of the target fishery, 64% has been taken by set-net and 34% by bottom longline. Where school shark were taken as a by-catch, 45% was taken by bottom trawl (mainly while targeting tarakihi with some snapper and trevally), 32% by bottom longline (mainly while targeting häpuku with some snapper) and 19% by set-net (mainly while targeting rig with some red gurnard and tarakihi). Around 30% of the total SCH 1 catch emanates from the East Coast with around 70% from the West Coast.

In 2000, *Galeorhinus galeus* was listed as Globally Vulnerable in the IUCN (i.e. World Conservation Union) Red List and that status remains unchanged. School shark are considered to be Critically Endangered in the south-west Atlantic, Vulnerable in Australia and South Africa, Near Threatened in New Zealand, and Least Concern in the Eastern North Pacific (see: http://www.iucnredlist.org/).

3.3.1.5 Tuatua

Tuatua (*Paphies subtriangulata*) is closely related to *P. australis* (Pipi) and *P. ventricosa* (Toheroa). However, unlike pipi, tuatua and toheroa are surf clams and prefer to live on more open exposed sandy beaches with an easily perceptible slope and direct wave access unimpeded by land (Morton and Miller 1968). Tuatua is the most inshore New Zealand species of surf clam and its distribution verges on the intertidal zone (Dr. Coral

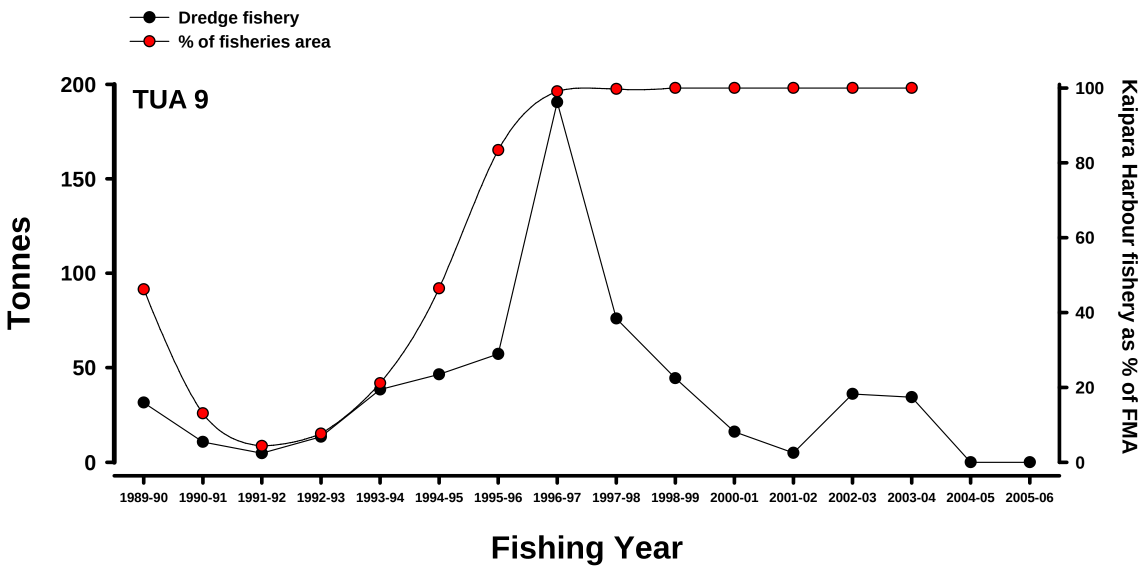
Grant., pers. comm. 2005). Tuatua can occur on a large range of beach types ranging from high energy, dissipative beaches to sheltered, reflective beaches.

Historically, subtidal tuatua beds have been the most prolific within the harbour mouth between North Head and Kaipara Head, Kaipara Head and Potu Point, and around Manukapua Island (Tapora) (Grace 1995-2004). Intertidal beds are found only around Manukapua Island.

Tuatua was introduced into the quota management system in 1 October 2005, with the boundaries of the tuatua quota management areas being similar to those of the previous fishery management areas. Since then, commercial fishing has been allowed to continue only in a specified commercial area of the Kaipara Harbour entrance within the TUA 9 quota management area (Figure 17). A total allowable commercial catch (TACC) of 43 tonnes, representing the average of reported landings taken from the Kaipara fishery between 1990–91 and 2003–04, was allocated to this area (Ministry of Fisheries 2006e).

Tuatua can be harvested throughout the year and there is no minimum legal size (MLS) although fishers are most likely to favour large individuals (J. Williams., pers. comm. 2007). The commercial fishing year runs from 1 October to 30 September, and commercial catches are measured in greenweight. The Kaipara catch increased over the 1990s, peaking in 1996-97, but has subsequently declined. This decline may reflect a decrease in fishing effort, as commercial fishing in the Kaipara is intermittent with only one or two fishers involved, but there is insufficient information to assess the sustainability of the Kaipara tuatua stocks. For example, there are no estimates of fishery parameters or abundance for the Kaipara or any other tuatua stocks. Similarly, there are no biomass time series for tuatua that could indicate whether tuatua populations are changing in response to past and current levels of harvesting. Consequently, the status of all tuatua stocks is unknown (Ministry of Fisheries 2006e). A draft plenary report has been submitted to the Ministry of Fisheries regarding the tuatua fishery but was not available at the time of writing.

Figure 17 Annual landings of tuatua within the Kaipara Harbour (tonnes), and Kaipara Harbour tuatua landings as a percentage of total landings within Fisheries Management Area TUA 9 (now called Quota Management Area TUA 9). Data are from 1989-90 to 2005-06.



3.3.1.6 Mussels

Green-lipped mussel (*Perna canaliculus*) dredging was carried out within the Kaipara Harbour entrance between the 1970s and early 1990s. Presently *P. canaliculus* is within the quota management system and Kaipara is within quota management area GLM 9. The total allowable commercial catch for GLM 9 in 2005-06 was 180 tonnes with reported landings of 229 tonnes (Ministry of Fisheries 2007). Specific information for the Kaipara is not readily available. There are no stock assessments or biomass estimates for green-lipped mussels, nor is it known if the current catch limits will allow the stocks to move towards a biomass that will support the maximum sustainable yield.

3.3.2 Customary fishing

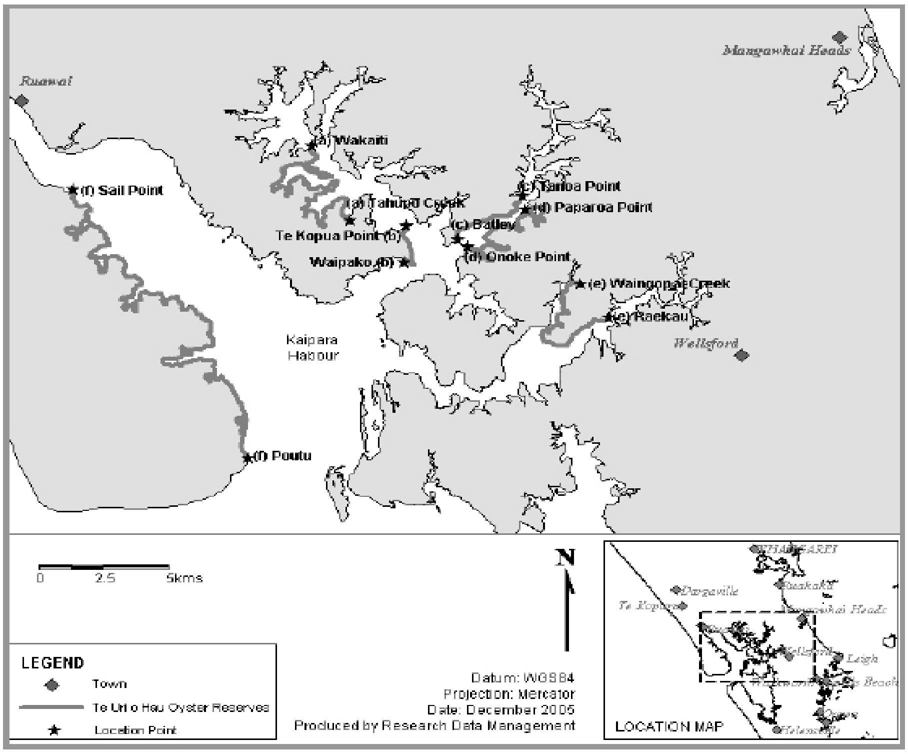
The Kaipara Harbour is a significant customary fishery that is a primary source of food for the large number of Marae located along the harbour edge. Traditionally, large fishing camps were set up around the harbour with snapper, kawhai, and shark being the main species targeted. The 2002 Deed of Settlement between the Crown and Te Uri o Hau recognises that the northern Kaipara is the traditional fishing ground of the Te Uri o Hau hapu. As part of the cultural redress, the Deed of Settlement states that Te Uri o Hau will be appointed as an Advisory Committee to the Minister of Fisheries, which will provide advice on the management of fisheries in the Te Uri o Hau area of interest. This includes the customary interest of Te Uri o Hau in those fisheries generally; and in the toheroa, shark, ray, flounder, snapper, kahawai, and mullet fisheries in particular. The Crown also agreed to:

- Consult with Te Uri o Hau and safeguard Te Uri o Hau's existing customary fishing rights, if the numbers of toheroa rise to commercial catch levels.
- Make regulations which define the existing oyster reserves (Figure 18) in parts of the Kaipara Harbour (established in 1913 as a reserve exclusive to Te Uri o Hau), and provide for a management structure nominated by Te Uri o Hau to manage customary food-gathering of oysters in the reserves.

In response to the Deed of Settlement, an initial position paper on the Kaipara oyster reserves was released by Ministry of Fisheries in December 2005. The paper invited public submissions but its current status is unknown.

Te Uri o Hau has also been proactive in developing a Customary Take Management Plan for the harbour (Kaipara Harbour Sustainable Fisheries Management Study Group 2003). Presently, there is concern over the protection of customary fishing rights and the difficulty that customary fishers have in catching snapper, grey mullet, flounder, and sharks (both rig and school shark), coupled with depletion of shellfish beds (tuatua and scallop). Alterations in fisheries habitats and the environmental impacts associated with increased coastal development are also causing concern (Kaipara Harbour Sustainable Fisheries Management Study Group 2003).

Figure 18 Location of six oyster reserves in the Kaipara Harbour (Ministry of Fisheries 2005).



3.3.3 Recreational fishing

Line fishing is the primary method used by recreational fishers in the Kaipara. Snapper (*Pagrus auratus*) form the bulk of the recreational take, with gurnard (*Chelidonichthys kumu*), kahawai (*Arripis trutta*), and kingfish (*Seriola lalandi*) caught to a lesser extent. Local fishers also target flounder and mullet on the edges of channels (Kaipara Harbour Sustainable Fisheries Management Study Group 2003).

Focal areas for recreational fishing within the southern Kaipara include The Graveyard (near the harbour entrance) and the area between Shelly Beach and the entrance (Kaipara Harbour Sustainable Fisheries Management Study Group 2003) (Figure 19). Important recreational areas in the northern Kaipara include parts of the Oruawharo River, the Otamatea Channel (east of Lady Franklin Bank) into the Otamatea River as far as Paparoa Point, and north of Pahi in the Arapaoa River.

Historically, scallop (*Pecten novaezelandiae*) beds within the Kaipara Harbour have also been targeted heavily by fishers. Scallops are commonly found in the northern Kaipara at the mouth of the Otamatea River including Timber Bay (and areas to the south) and north of Ngaupiko Point; and in the southern harbour between Shelly Beach and Oyster Point to north of Kakanui Point (Kaipara Flats) (Figure 20) but in recent years have declined greatly in abundance. In response to concerns from local Tāngata Whenua and the Kaipara Harbour Sustainable Fisheries Management Study Group, all non-commercial (customary and recreational) scallop harvesting within the harbour was banned for a two-year period from 15 July 2005 in an effort to improve the fishery. This ban has since been extended through to 13 September 2008.

Intertidal tuatua (*Paphies subtriangulata*) are also targeted by recreational and customary fishers on the extensive intertidal sandflats between Waikiri Creek and Otekawa Creek (Tapora), and between Manukapua Island and Waikiri Creek Spit (Tapora). There has been recent concern regarding a decline in tuatua abundance within this area (Thomas De Thierry., pers. comm. 2006).

Historically, intertidal mussels have been harvested at Coates Bay in the area known as the "Mussel Ring' (Poynter 1998), while subtidal mussels (*Perna canaliculus*) occur in dense beds in the Wairoa River Arm of the Kaipara Harbour, adjacent to Pareotaunga Point. These beds are periodically dredged (T. Haggitt., pers. obs. 2006).

The native rock oyster (*Saccostrea cucullata*) has been important within the Kaipara Harbour for customary, recreational, and commercial fishers but has been largely superseded by harvesting of the Pacific Oyster (*Crassostrea gigas*) which is ubiquitous throughout much of the harbour. Presently there are no obvious concerns regarding abundance, although in recent years there have been issues with water quality for shellfish gathering (refer to Section 4.1.2).

Figure 19 Areas of the Kaipara Harbour (blue) targeted by customary and recreational fishers (Information from commercial fishers P. and C. Yardley., pers. comm. 2007).

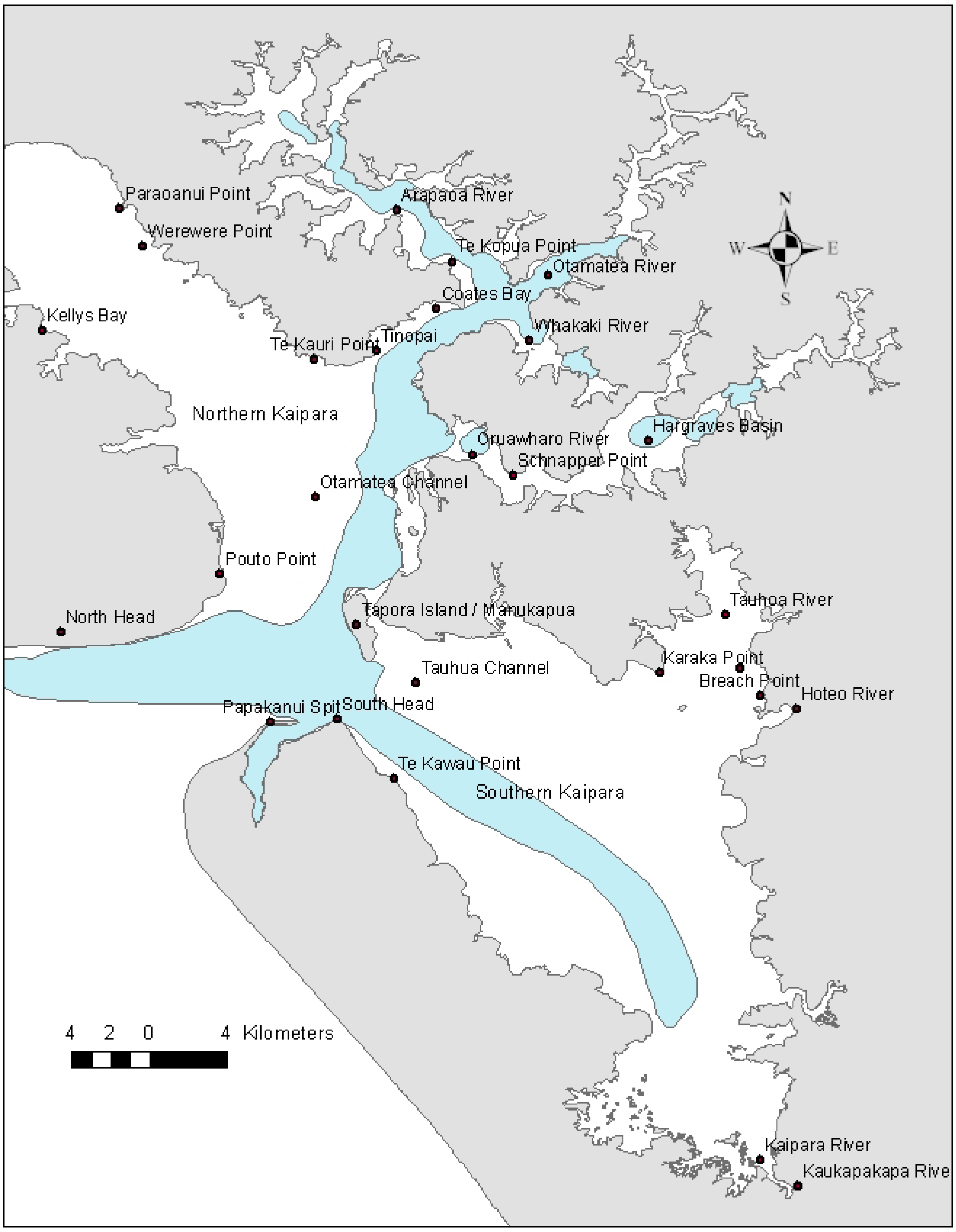


Figure 20 Areas of the Kaipara Harbour (yellow) targeted for scallop harvesting.

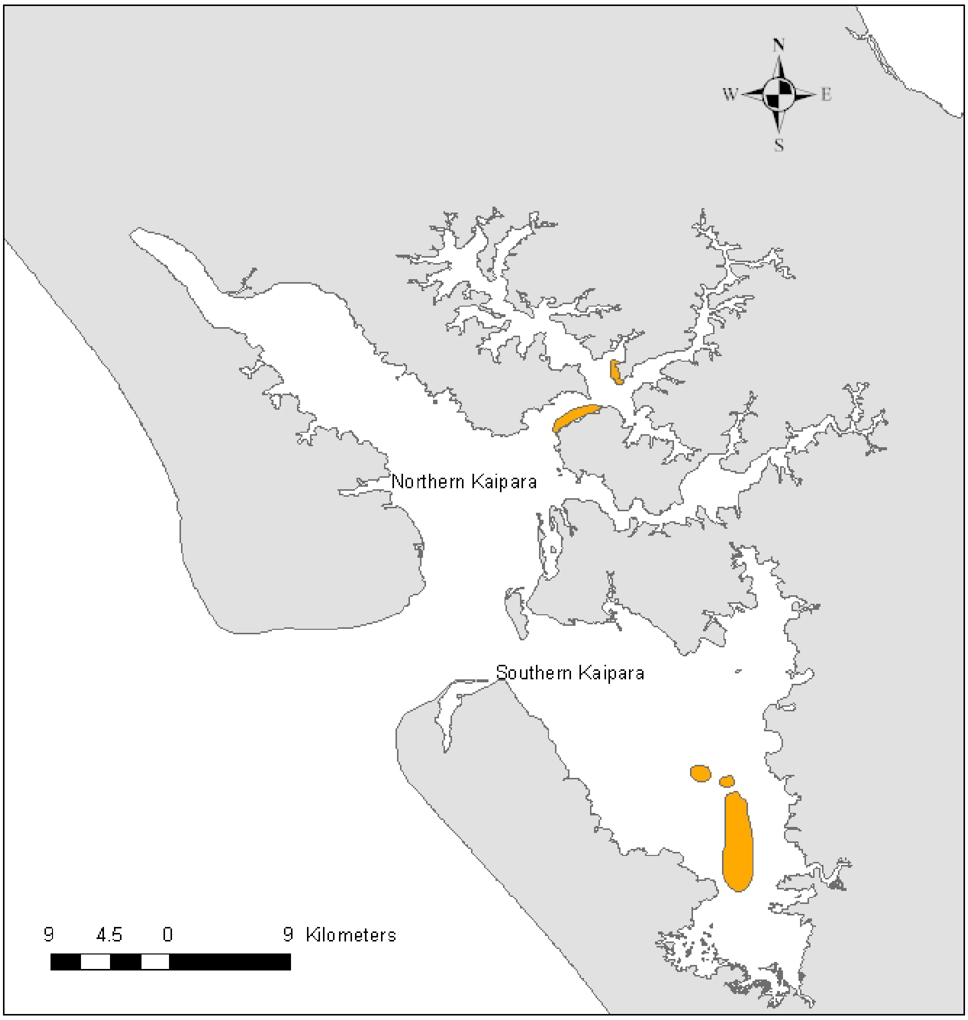


Table 3 Summary of important fisheries within the Kaipara Harbour.

Species	Common name	Fishery	Biological Characteristics	Kaipara Harbour catch characteristics
Mustelus lenticulatus	Rig	Commercial Customary	Rig are born with a total length (TL) between 25–30 cm. They grow moderately quickly, reaching maturity at 75–110 cm TL (depending on sex and stock) and aged 4–5 years. Females reach a maximum length of 151 cm and males 126 cm TL. Longevity is not known, but estimated to be >20 yrs.	Commercial: Steady decline in catch per unit effort and green weight (tonnes) from 1989-90 to 2001-02. Recreational: Estimated at 100 t in GMU 1 (includes Kaipara Harbour). Customary: No qualitative or quantitative information available, although 100 t allocated by Minister of Fisheries beginning 1989-99.
Mugil cephalus	Grey mullet	Commercial Recreational Customary	Grey mullet has a worldwide distribution, with complex movement patterns. Both sexes mature at 3 yrs at an average size of 33 cm fork length (FL) for males and 35 cm FL for females. Females spawn in northern New Zealand between November and February, and are likely to spawn at sea. Small post-larval grey mullet occur seasonally in estuaries. Longevity is estimated at 12-14 yrs, with the commercial fishery comprised of 5-9 year old fish.	Commercial: Steady decline in catch per unit effort and green weight (tonnes) from 1989-90 to 2001-02. Recreational: Estimated at 100 t in GMU 1 (includes Kaipara Harbour). Customary: No qualitative or quantitative information available, although 100 t allocated by Minister of Fisheries beginning 1989-99.
Rhombosolea leporina, Rhombosolea plebeia	Yellow-belly flounder, Sand flounder	Commercial Recreational Customary	The New Zealand flatfish species studied are fast-growing and mainly short-lived, generally surviving to 3–4 years of age with very few reaching 5–6 years. Juveniles congregate in sheltered inshore waters (e.g. estuarine areas, shallow mudflats and sandflats) where they remain for up to two years. Juvenile survival rates are highly variable. Flatfish move offshore for first spawning aged 2–3 years during winter and spring. Adult mortality is high with many flatfish spawning only once, and few spawning more than two or three times. However, fecundity is high (e.g.from 0.2 million eggs to over 1 million eggs) in sand flounders.	Commercial: Utilises set netting. Recreational: Utilises set netting, drag netting and spearing. Customary: No qualitative or quantitative information available.

Galeorhinus galeus	School shark	Commercial Recreational Customary	School shark are late maturing and slow-growing, with low fecundity and productivity and are predicted to have a slow rate of recovery (rebound potential) from overfishing (Ministry of Fisheries 2006). Age at maturity has been estimated at 12-17 years for males and 13-15 years for females. Breeding occurs once every two or three years. These factors suggest that the stock is less productive and hence more susceptible to overfishing than many other fisheries. The Kaipara Harbour habitat may be of particular importance to the school shark fishery as pupping females migrate there to give birth.	Commercial: Fishery has moderate value but is a predominantly by-catch fishery with a port price that is relatively low compared to other stocks. Recreational: Of moderate importance (see below). Customary: Sharks, including school shark, are an important taonga species and anecdotal information suggests that school shark formed part of a significant, traditional, customary fishery. Ministry of Fisheries proposes to set allowances for customary and recreational catches based on estimates of current catches by recreational fishers. Ministry of Fisheries proposes to set the TACC based on either the existing TACC or recent commercial catch levels.
Paphies subtriangulata	Tuatua	Commercial Recreational Customary	Tuatua reach a maximum shell length of approximately 75 mm. Tuatua greater than 50 mm are sexually mature (Grant 1994, Marsden 1999) and tend to have an annual breeding cycle with semi-continuous spawning over the spring/summer months (Grant & Creese 1995). Larval tuatuas spend about 20 days in the water column before they are ready to settle. Tuatua settlement and recruitment occurs into the mid intertidal zone, with individuals moving to lower tidal heights over time (Grant 1994, Marsden 2000). Tuatua play an important ecological role in New Zealand coastal waters by filtering phytoplankton from the water column (and subsequently converting phytoplankton biomass to growth) and also as prey for a variety of organisms, including large fish such as snapper, octopus, and paddle crabs (Dr. Coral Grant, pers. comm. in 2006).	Commercial: Recreational: Customary: No qualitative or quantitative information available.

3.4 Mammals

There is little detailed information on marine mammal distribution and abundance within the Kaipara Harbour. Most of the information comes from stranding records and casual sightings (Fisher 2005). Commonly reported cetaceans within the Kaipara Harbour include: southern right whale (*Eubalaena australis*), orca (*Orcinus orca*) (Visser 1999), bottlenose dolphin (*Tursiops truncatus*), and common dolphin *Delphinus delphis* (Fisher 2005), although stranding records suggest that the Kaipara is important for a range of taxa. Maui's dolphin (*Cephaloryhnchus hectori maui*) are also reported to frequent the harbour.

The Kaipara Harbour entrance and surrounding coastline has had a high occurrence of whale strandings for a range of cetacean species (Stephenson 1975, Brabyn 1991, Fisher 2005) (Table 4). Stephenson (1975) suggests that the 'treacherous' shifting sand bar that extends 3-7 km seawards from the Kaipara Harbour entrance, coupled with strong surf, are probable local factors likely to disrupt near-shore migration.

Nineteen species of whale and dolphin have been recorded in strandings (beached as live and dead animals) within the coastal approaches to the Kaipara Harbour, with three strandings that were too decomposed to be identified to species level (Fisher 2005). Of the total 69 records, 21 occured within the Kaipara Harbour (Table 4).

The Kaipara Harbour is, potentially, an important area for Maui's dolphin (*Cephaloryhnchus hectori maui*); a morphologically and genetically distinct subspecies of Hector's dolphin. Maui's dolphin is classed as Critically Endangered by the IUCN-World Conservation Union and by the New Zealand Ministry of Fisheries under the Marine Mammals Act, 1978, Section 2(3). Fisher (2005) reports of two sightings of Maui's dolphin in the Kaipara, one in May 1990 and the other in March 2002. In a more recent study conducted in the Kaipara, only one animal was sighted within the inner harbour over a two-year period but acoustic recordings indicate that between one and three may have penetrated into the harbour entrance.

A study to investigate the distribution of Maui's dolphins along the West Coast of the North Island (Ferreira and Roberts 2003) indicated that most sightings of Maui's dolphin were between the Manukau Harbour and Port Waikato, with no dolphins sighted along the coastline between Ahipara and the Kaipara Harbour mouth. The number of dolphins occupying the coastal region between the Kaipara and Manukau Harbour mouths was estimated to be ~10 individuals.

A draft Hector's and Maui's Threat Management Plan has been prepared (Ministry of Fisheries and Department of Conservation 2007) that seeks to describe the nature and extent of threats to Hectors and Maui's dolphins, and implement strategies to reduce human-induced threats. Submissions on the draft closed on 24 October 2007.

Table 4 Cetacean stranding records for the Kaipara Harbour and seaward coastline between Dargaville and Muriwai (all).

	Number of stranding records	
Species	All	Kaipara Harbour
Bryde's whale (*Balaenoptera edeni*)	1	0
Pygmy right whale (*Caperea marginata*)	1	0
Minke whale (*Balaenoptera acutorostrata*)	2	0
Sperm whale (*Physeter macrocephalus*)	13	4
Pygmy sperm whale (*Kogia breviceps*)	9	2
Gray's beaked whale (*Mesoplodon grayi*)	2	1
Blainville's beaked whale (*M. densirostris*)	1	1
Straptoothed whale (*M. layardii*)	1	1
Unidentified beaked whale (*Mesoplodon* spp.)	2	0
Shepherd's beaked whale (*Tasmacetus shepherdi*)	2	1
Cuvier's beaked whale (*Ziphius cavirostris*)	1	0
False killer whale (*Pseudorca crassidens*)	1	0
Long-finned pilot whale (*Globicephala melas*)	5	2
Short-finned pilot whale (*G. macrorhynchus*)	1	1
Killer whale (*Orcinus orca*)	1	0
Dusky dolphin (*Lagenorhynchus obscurus*)	1	0
Bottlenose dolphin (*Tursiops truncatus*)	7	4
Striped dolphin (*Stenella coeruleoalba*)	1	0
Short-beaked common dolphin (*Delphinus delphis*)	13	4
Maui's dolphin (*Cephalorhynchus hectori maui*)	3	0
Unidentified cetacean spp.	1	0
Total	69	28

3.5 Birds

3.5.1 Wading birds

The wading bird habitat on the Kaipara Harbour can be generally divided into two distinct habitats:

- Sandy tidal flats around the entrance of the harbour and the southern expanse of tidal flats in the south-eastern part of the harbour.
- Open muddy tidal flats in the northern arms of the harbour and the mangrove-covered mud flats of the upper reaches of rivers in the southern part of the harbour.

The Kaipara Harbour is one of the five most important areas in New Zealand for wading birds and a case is currently being prepared by the Royal Forest and Bird Protection Society and Ngāti Whatua to nominate the Kaipara as a Wetland of International Importance under the Ramsar Convention. In midsummer, 16% of New Zealand's wading birds use the harbour, equating to an average of 35,400 waders (Table 5).

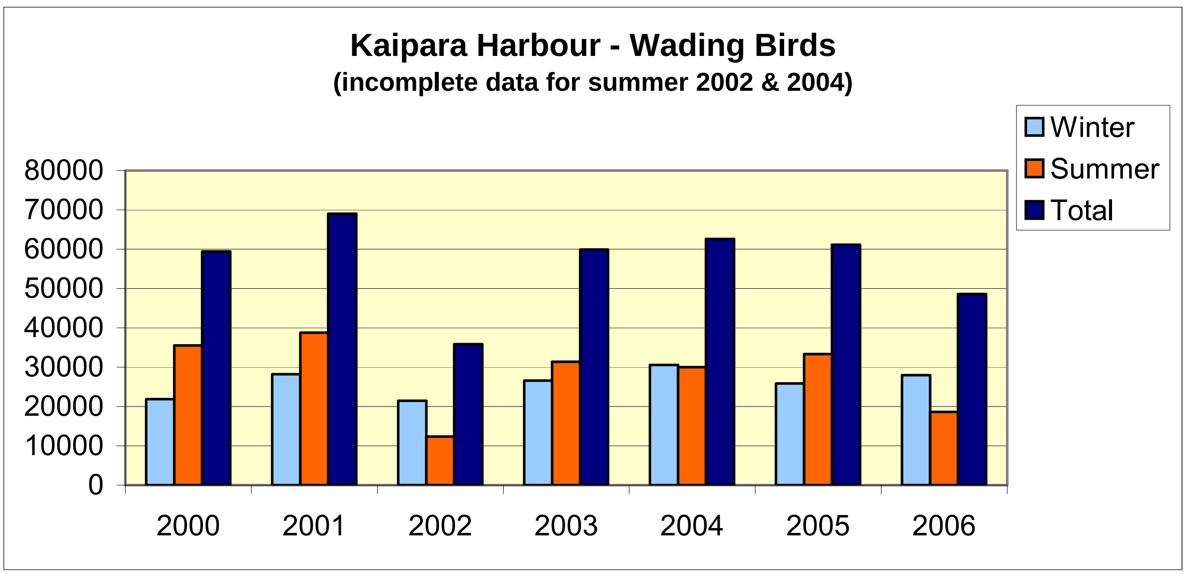
In September each year migratory wading birds arrive from their breeding grounds in Siberia, Alaska, China, Korea, and Japan. Most of the 150,000 migrant waders that visit New Zealand probably pass through the Kaipara on their way to feeding grounds throughout New Zealand, and some of them remain at the harbour for the summer. In March, these migrant waders return to their breeding grounds in the northern hemisphere. Coastal wetlands appear to be particularly important as staging points during the spring and late summer migrations, as the birds congregate at these wetlands on arrival and departure (Bellingham and Davis 1984).

Table 5 Wading birds (Average abundance within the Kaipara Harbour, and as a percentage of the NZ population).

Species	Average Kaipara Harbour (2000-2006)	% of NZ Population
Bar-tailed godwit	10,380	14.8%
South Id pied oystercatcher	13554	19.4%
Knot	7840	14.4%
Pied stilt	2651	20.4%
Banded dotterel	450	7.5%
Turnstone	420	8.9%
Wrybill	115	3.0%
TOTAL	35,410	16.0%

Wading birds also migrate within New Zealand between the rivers and uplands of the South Island and the harbours in the North Island; and there are local migrants within the Northland / Auckland Region. South Island pied oystercatchers, wrybills, banded dotterel, and the Critically Endangered black stilt breed in the South Island and all migrate to the Kaipara in January/February, remaining until August/September. Local migrants include: New Zealand dotterel that breed on beaches in the Northland / Auckland Region and return to the harbour in March/April, pied stilt that breed on damp pasture in spring and return to the harbour in December, and white-faced herons that breed in spring in tall trees within the catchment.

Figure 21 Wading bird census data 2000-2006 (source: Ornithological Society NZ).



Although there are lower total numbers of wading birds on the Kaipara Harbour on the roosts (Figure 21) in winter, there are other birds on minor roosts around the harbour that are not counted. To some extent, this reflects the preference of New Zealand migrant and local waders for the muddier substrates on the harbour, and these birds disperse to adjacent farmland at high tide. Consequently, there are more birds on roosts in the northern Kaipara and on roosts in the upper reaches on the southern Kaipara. .

In summer the wading birds are more concentrated on the larger roosts at Papakanui Spit, Tapora and Manukapua, Glorit and Jordans Farm (Figure 22 and Figure 23), where they aggregate and can be counted at high tide. These birds are, predominantly, northern hemisphere migrant waders that prefer to feed on the sandy flats in the central and southern parts of the harbour. These roosts are safe sites that are close to the prime feeding areas.

Pierce (2005) provides a list of key bird species that utilise the tidal flats within Kaipara Harbour, with their conservation status (Table 6).

Table 6 Key bird species utilising intertidal flats in the Kaipara Harbour (Pierce 2005).

Species	Status	Distribution throughout the Kaipara Harbour
Reef heron	T	Low numbers throughout the harbour.
White-faced heron	C	Common on tidal flats throughout the harbour.
Several waterfowl (Anseriform) species	C	Common and widely distributed throughout the harbour.
South Island pied oystercatcher	E, M	Common (mean winter count 13,554; 24% North Island total) throughout the harbour flats.
Variable oystercatcher	E	Present on the southern and central tidal flats.
Bar-tailed godwit	IM	Common (mean summer count 10,381; 12% New Zealand total) throughout the harbour flats.
Lesser knot	IM	Common (mean summer count of 7,846; 15% New Zealand total) mainly on the southern and central tidal flats.
Turnstone	IM	Present on the southern and central tidal flats.
Pied stilt	M	Common (mean winter counts of 2,651; 17% of North Island total) throughout the harbour on tidal flats.
Black stilt	E, T, M	Small numbers (but up to 10% of the entire population) that frequent the tidal flats near Mairetahi in late summer / winter.
Banded dotterel	E, T, M	Common (mean winter count of 459; 11% of North Island totals) mainly on the southern and central tidal flats.
Northern NZ dotterel	E, T	Present on the southern and central tidal flats.
Wrybill	E, T, M	Present on the southern and central tidal flats.
Black-backed gull	C	Present throughout the harbour.
Red-billed gull	R	Present throughout the harbour.
Caspian tern	T	Largest New Zealand colony is present on an island east of Shelly Beach, but hunt for fish throughout the harbour.
NZ fairy tern	E, T	Present on central tidal flats and roosts. The entire New Zealand population visits the harbour.
Eastern little tern	IM	Small numbers.
White-fronted tern	E, T	Present throughout the harbour.

Status: C = Common, E = Endemic, G = Gradual decline, M = Migrant, IM = International Migrant, NE = Nationally Endangered, NC = Nationally Critical, NV = Nationally Vulnerable, S = Sparse, T = Threatened , R = recently classified as Threatened. (New Zealand Threat Classification System Lists 2007; Hitchmough 2002, Threatened Species Occasional Publication 23, DOC, Wellington. Revised 2007).

Figure 22 Winter numbers of wading birds counted at roosts on the Kaipara Harbour between 2000-06 (source: Ornithological Society NZ).

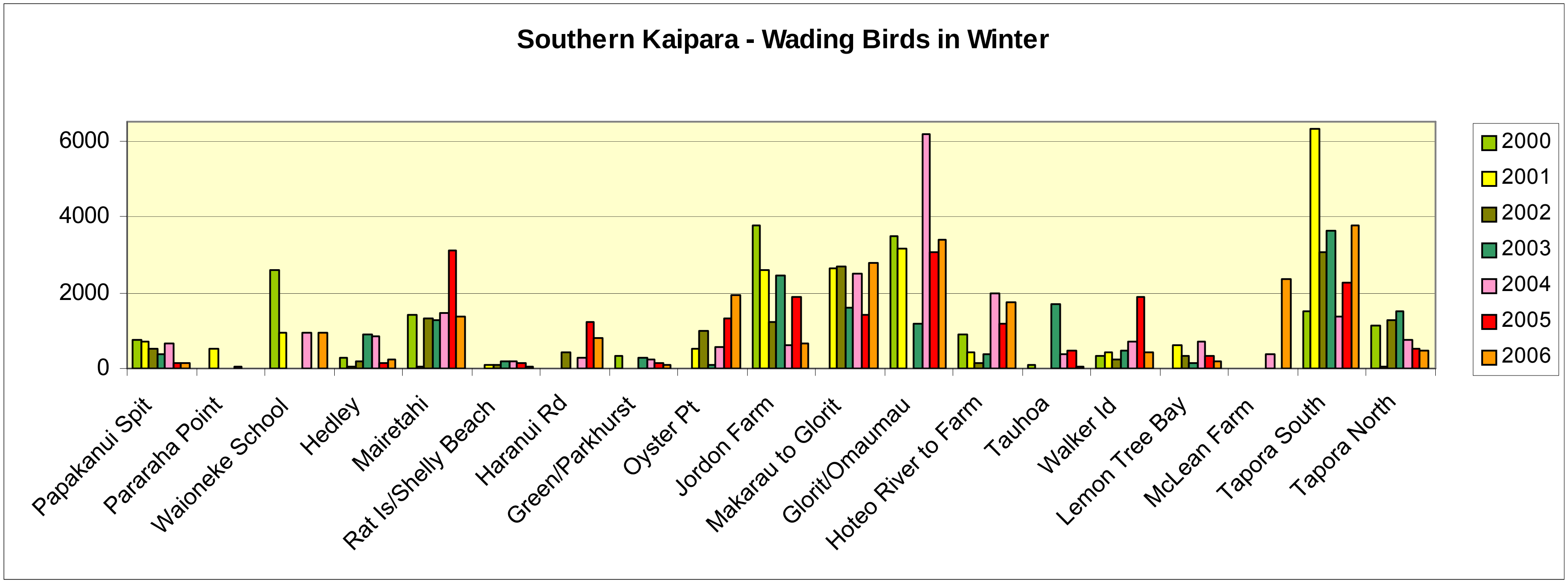
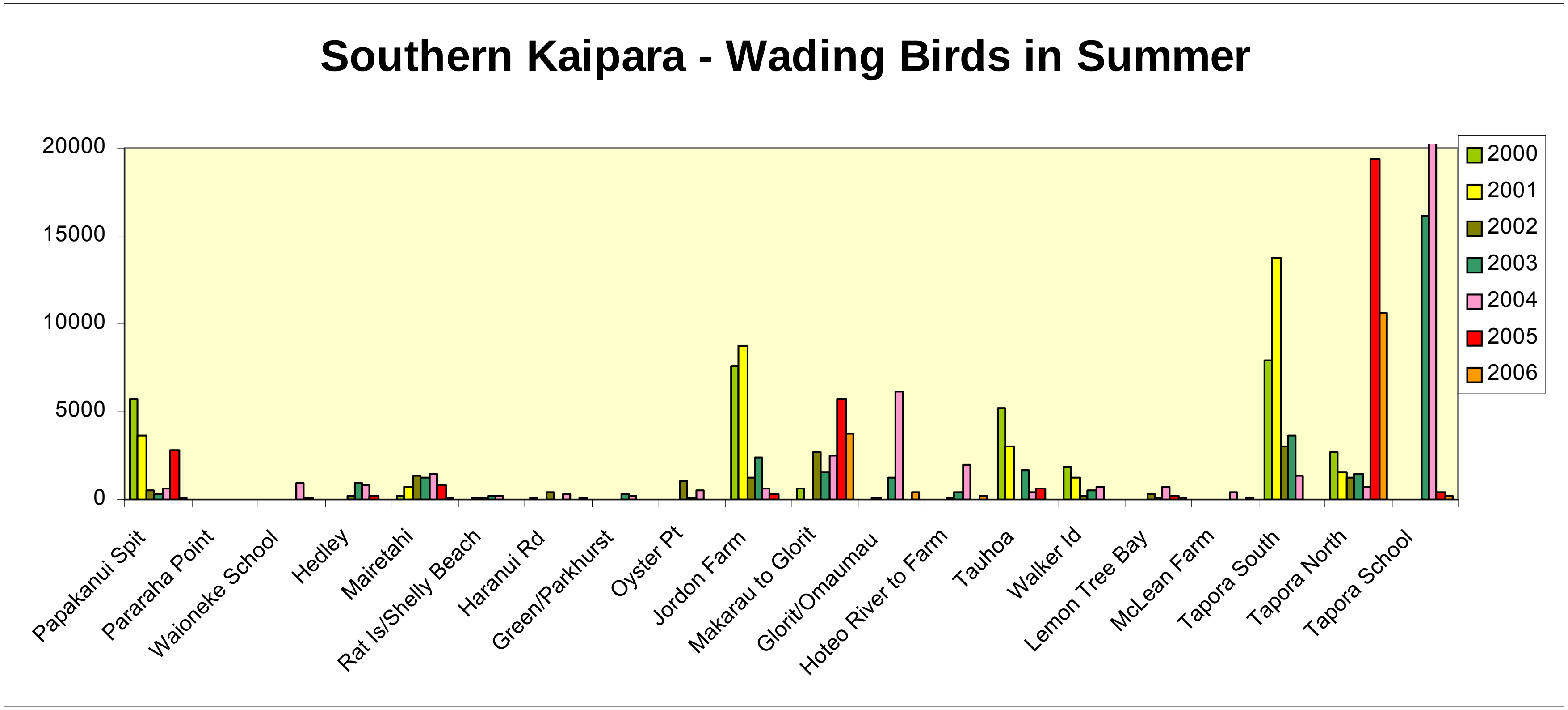


Figure 23 Summer numbers of wading birds counted at roosts on the Kaipara Harbour between 2000-06 (source: Ornithological Society NZ).



3.5.2 Rare northern hemisphere migratory waders

A modest number of records exist for rare migratory wading birds on the Kaipara, considering the high number of birds that spend summer at the harbour. The more regular uncommon, migratory wading bird species are large sand dotterel, Mongolian dotterel, tattlers, and whimbrels, along with gull-billed and sooty terns. This may reflect a lower survey effort as most of the wading bird roosts in the Kaipara are difficult for humans to access when compared to roosts at other sites such as Miranda and the Manukau Harbour.

3.5.3 New Zealand species for which the Kaipara is a critical habitat

Black stilt

The Black stilt is categorised by DOC as Nationally Critical (Hitchmough et al. 2007). There are currently 87 adult black stilts, of an even sex ratio, in the wild. The Black Stilt are now restricted to one breeding area, the Upper Waitake (Makenzie) Basin in the South Island (Dowding and Moore 2006), and a few migrate regularly to the Kaipara for winter feeding.

New Zealand dotterel

The New Zealand dotterel is an endemic Endangered species. The North Island subspecies was once widespread and common; nowadays there are only about 1700 birds left, resulting in a threat ranking of Nationally Vulnerable (Hitchmough et al. 2007). This serious decline in numbers is due to a combination of habitat loss, predation by introduced mammals, and disturbance during breeding. The breeding and roosting sites for NZ dotterel on the Kaipara are extremely important, as these sites are among the least threatened of any in Northland and Auckland from disturbance by vehicles, dogs, and / or land development. NZ dotterel also form large, non-breeding flocks on the Kaipara in autumn and winter that can number about 70 birds (M. Bellingham., pers. obs.).

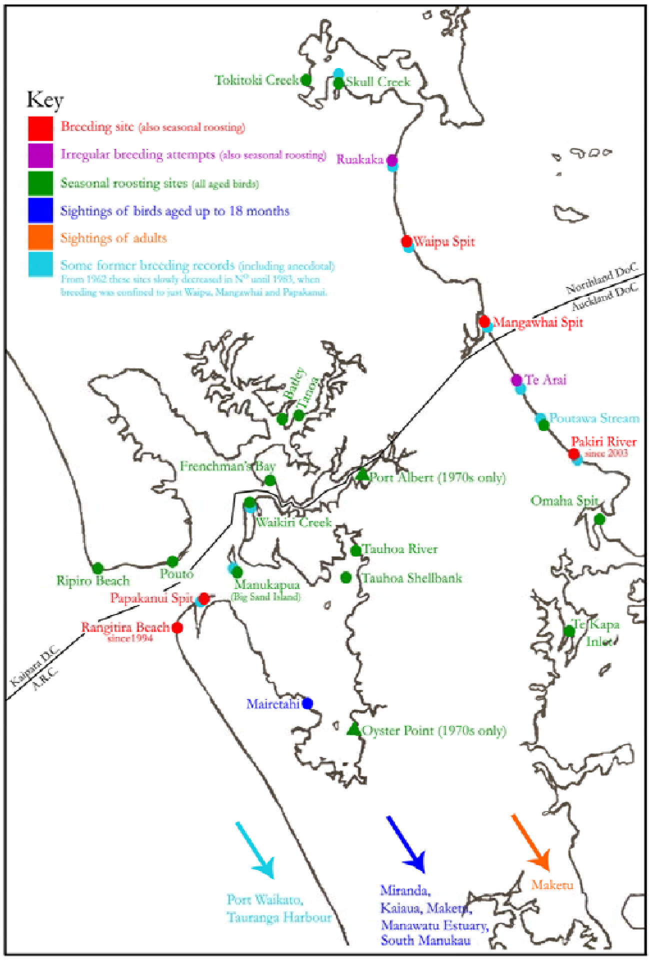
Wrybill

The wrybill is Nationally Vulnerable. The main breeding rivers in the South Island are the Rakaia, Rangitata, Waimakariri, and upper Waitaki and these are all threatened by irrigation and hydroelectric development. After the breeding season they head to the tidal harbours of Northland, Auckland, South Auckland, and the Firth of Thames. The Kaipara supports 4% of the national wrybill over-wintering population.

New Zealand fairy tern

This small endemic tern has a population of 35 to 40 individuals that includes only ten breeding pairs. Consequently, the New Zealand fairy tern is probably New Zealand's rarest breeding bird. It is ranked by DOC in the highest threat category of Nationally Critical (Hitchmough et al. 2007). The NZ fairy tern breeding sites on the Kaipara are extremely important, as these sites are the least threatened by disturbance from vehicles, dogs, and development (Ferreira et al. 2005) (Figure 24) for this species. All of their East Coast breeding sites have housing developments proposed and suffer significant disturbance from dogs, people, and vehicles. In addition, most, if not all, fairy terns in New Zealand spend the autumn and early winter around the Kaipara Harbour, particularly in the Waikiri Creek area and the Papakanui Spit region (Medway 2000).

Figure 24 Recorded sites used by NZ fairy terns between 1991 and 1996 (source: Ornithological Society NZ).



Map compiled by GA Pulham, AM Habraken and assistance from GR Vaughan from information provided by OSNZ and NZWSG members. v. 4 07/05/2006.

3.5.4 Key habitats for wading birds

Key habitats for wading birds within the Kaipara include: intertidal flats and subtidal areas, Papakanui Spit and Waionui Estuary, Omokoiti Flats, Rat Island and Jordan's, Tauhoa and Manukapua (Tapora) Island) to Waikiri Creek.

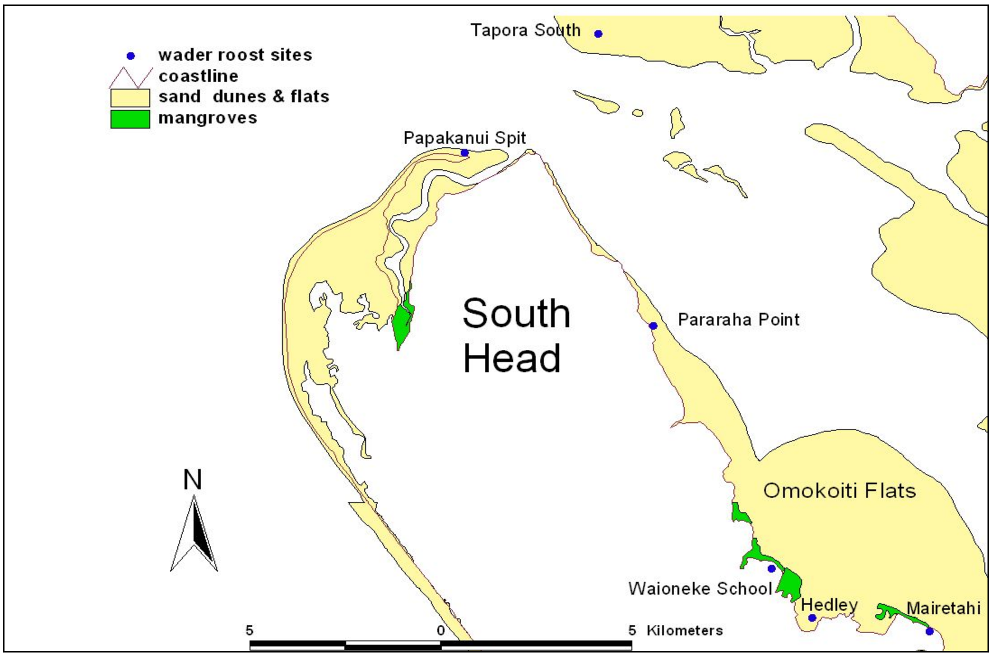
Papakanui stewardship area and Waionui Estuary (South Kaipara Spit)

Papakanui is located at the end of South Kaipara Head. A large area of sand dunes further inland tapers off into a spit that encloses the Waionui Inlet (Figure 25). Papakanui is recognised in the Directory of Wetlands in New Zealand (Department of Conservation 1996), the Coastal Resources Inventory (DOC 1994), and the Auckland Regional Plan: Coastal (ARC 2004) as being a key nesting area within the Kaipara Harbour. Along with the Waionui Estuary, Papakanui offers a roosting site for up to 10,000 migratory waders (Shaw and Maingay 1990), harbouring the greatest number of birds in late September and prior to migration in March. The intertidal areas within Waionui Inlet are an important feeding ground for these migratory birds.

The area offers a vital roosting site for rare and endangered native and endemic species. It is an important breeding and roosting area for terns, including the white-fronted tern and the fairy tern; with most, if not all, fairy terns in New Zealand spending the autumn and early winter around the Kaipara Harbour, particularly at Papakanui Spit (Medway, 2000).

The Endangered New Zealand dotterel, the Threatened variable oystercatcher, the Critically Endangered fairy tern (Parrish and Pulham, 1994a; Parrish and Pulham, 1994b; unpublished Department of Conservation and Wildlife Service wardens' reports), the banded dotterel, and the northernmost colony of black-billed gulls are among other species that nest on the Papakanui Spit. It is also the northernmost breeding site for the New Zealand dotterel. In addition, the Threatened spotless crake, North Island fernbird, banded rail, and possibly the Australasian bitten also breed in the freshwater wetlands, shrublands, salt marshes and mangroves of the spit and Waionui Lagoon.

Figure 25 Wading bird roost sites on South Head.



Omokoiti Flats

Omokoiti Flats is less muddy than the Papakanui Spit and Waionui Estuary and contains a greater amount of shell than any other area in Kaipara Harbour (Figure 26). Consequently, it acts as an important feeding ground for migratory waders such as black stilts. Four or five black stilts (the equivalent of 5% of the entire population of this Endangered species) spend the winter on the Omokoiti Flats. In bad weather, especially during strong westerlies, this area is also used as a high tide roost site by New Zealand endemic wading birds and a variety of other coastal bird species, including several Threatened species. In addition to the black stilts, around 3000 knots, 3000 godwits, thousands of oystercatchers, 500 to 1000 pied stilts, and a range of other wading bird species use the Omokoiti Flats.

Waioneke School is a significant winter roost for waders (pied stilt and oystercatchers). During spring tides, storms, and easterly winds the birds are found entirely on the paddocks below the school.

Figure 26 Omokoiti Flats looking North.

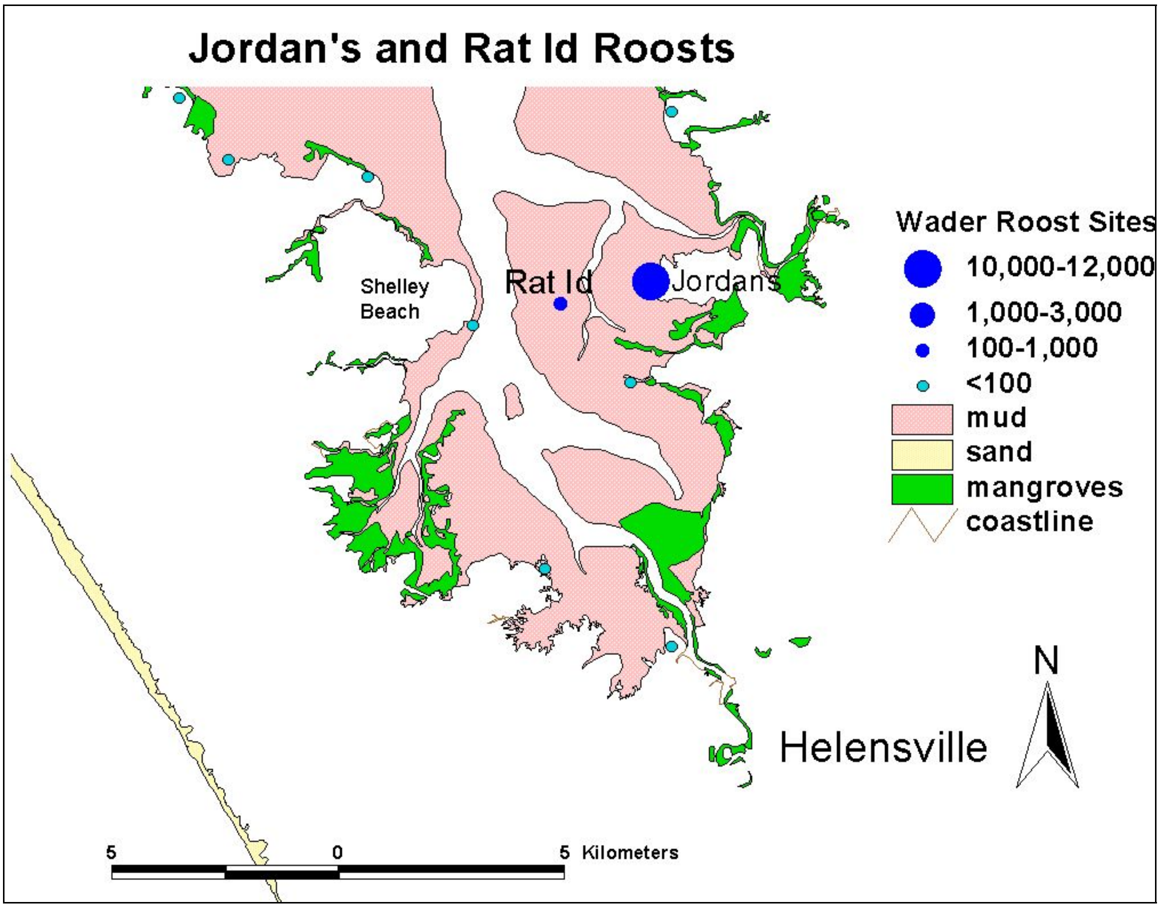
Rat Island

Rat Island provides an important high tide roost on the Kaipara due to its proximity to significant areas of tidal flats where birds are able to feed near Shelly Beach. Of vital importance to the birds during migration time, the proximity of the roost and the feeding grounds allows the birds to conserve valuable energy by minimising travel. Rat Island has become the main nesting site for Caspian terns within the Kaipara after they stopped nesting at Papakanui, probably due to continual disturbance from trail bikes during their summer breeding period. Pied stilt are also known to breed here.

Jordan's, Kaipara Flats, and Kakaraia (Kakarai on chart) Flats

During the summer, Jordan's is a key roosting site for up to 10,000 international migratory and New Zealand endemic wading birds, including a number of Threatened species (Figure 27). Bird species include the South Island pied oystercatcher, New Zealand dotterel, banded dotterel, wrybill, godwit, turnstone, knot, grey plover, whimbrell, pied stilt, and eastern golden plover. The Kaipara and Kakaraia Flats are important feeding areas for these wading birds.

Figure 27 Wading bird roost sites in the southern Kaipara Harbour.

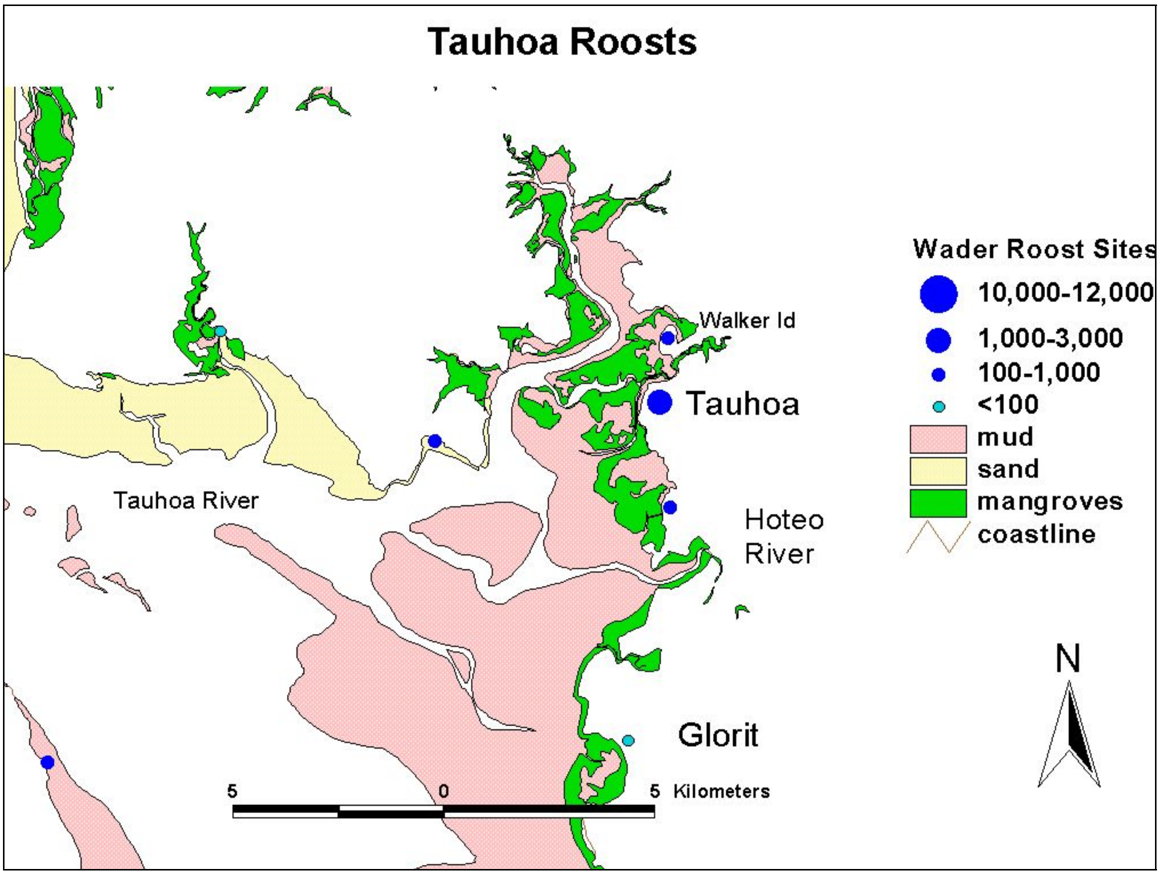


Tauhoa River (from Karaka Point to Breach Point, out to and including Moturemu)

The Tauhoa River area is an important feeding and roosting area for tern. In summer it is particularly important to the migratory Little Tern (Figure 24) and in winter it is equally important for the Critically Endangered New Zealand fairy tern. Grazing within the coastal marine area has inhibited mangrove growth in this area (relative to other parts of the Kaipara) creating excellent roost sites and this may, at least partially, contribute to its importance. The Walker Island roost is also important for fairy terns.

The tidal flats along the adjacent coastline and around Moturemu Island provide important feeding areas for wading birds. These feeding areas, along with the sand flats around Tapora and the Omokoiti Flats, are the most significant on the harbour for wading birds, particularly the international migratory waders.

Figure 28 Wading bird roost sites at Tauhoa River.

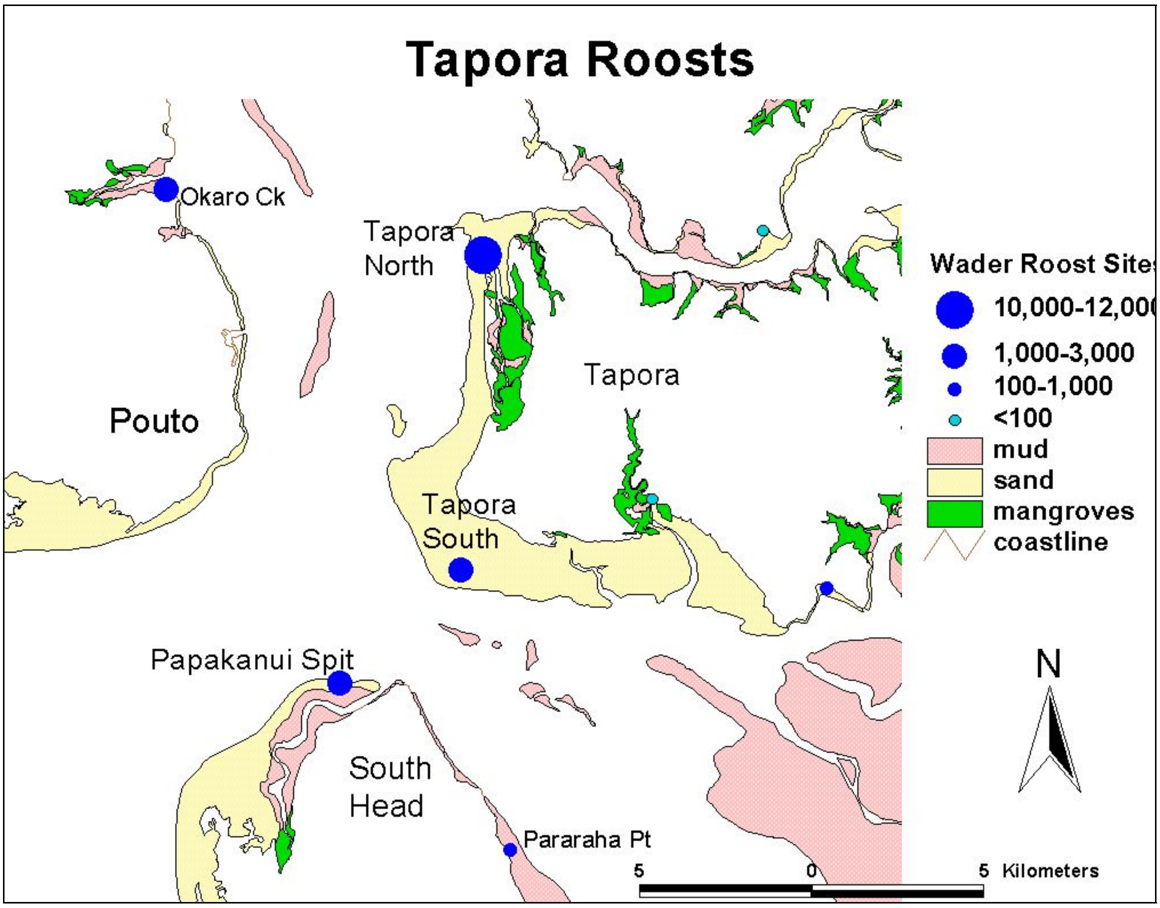


Tapora bank, including Manukapua (Big Sand Island) to Waikiri Creek

The end of the Tapora peninsula (Figure 29) and the surrounding area is one of the most important roost sites for coastal wading birds in the Northland and Auckland regions and in New Zealand (Medway 2000). New Zealand dotterel, banded dotterel, godwit, knot, pied stilt, grey plover, and eastern grey plover roost here; and more than 1% of New Zealand's turnstones, oystercatchers, wrybills, curlew sandpipers, and red-necked stints also roost here. The curlew sandpipers and red-necked stints are rarely found in other areas of the Kaipara Harbour.

Approximately 5% of the New Zealand dotterel population use the end of the Tapora Peninsula as a post-breeding roost site. Until the 1990s, New Zealand fairy terns used to breed here. The Tapora Wildlife Management Reserve is listed by the Department of Conservation as a Site of Special Wildlife Interest (SSWI) due to its habitat value for wrybill and dotterel as well as several other birds (Department of Conservation 1995). Additionally, the sand and mudflats on the southern coast of the peninsula are an important feeding area for waders. Gum Store Creek on the tip of the Tapora peninsula has a rich assemblage of habitats including mangroves, mudflats, sandbanks, scrub, and freshwater wetlands that combine to offer pied (*Phalacrocorax varius*), black (*Phalocrocorax carbo*), and little shags (*Phalocrocorax melanoleucos*) an important roosting site.

Figure 29 Wading bird roost sites in the central Kaipara Harbour.



Northern Kaipara

The northern Kaipara (Northern Kaipara and Northern Wairoa roost sites) (Figure 30) has significant numbers of local migratory waders (NZ dotterel, pied stilt, and banded dotterel) and resident bird species, but fewer numbers of international migratory waders. This area of the harbour has less variety of feeding substrate, consisting mainly of mudflats with only a few areas of sandflat. Wading birds from the roosts at Ruawai and Tinopai mainly feed on the large expanse of mudflats west of Tinopai and along the Northern Wairoa River.

The Ruawai roost is particularly important even though it is located entirely on open farm paddocks along the Northern Wairoa River. Birds shift around this area, depending on disturbance from farming activities and weather conditions but the expanse of open paddocks ensures sufficient, flexible, roost sites.

In the north-eastern Kaipara, birds spread out from a number of small roosts (Figure 31) onto the mudflats that fringe this area. Bird feeding in this area has been studied less than elsewhere, mainly because this area is accessible only by boat.

Figure 30 Wading bird roost sites in the northern Wairoa River.

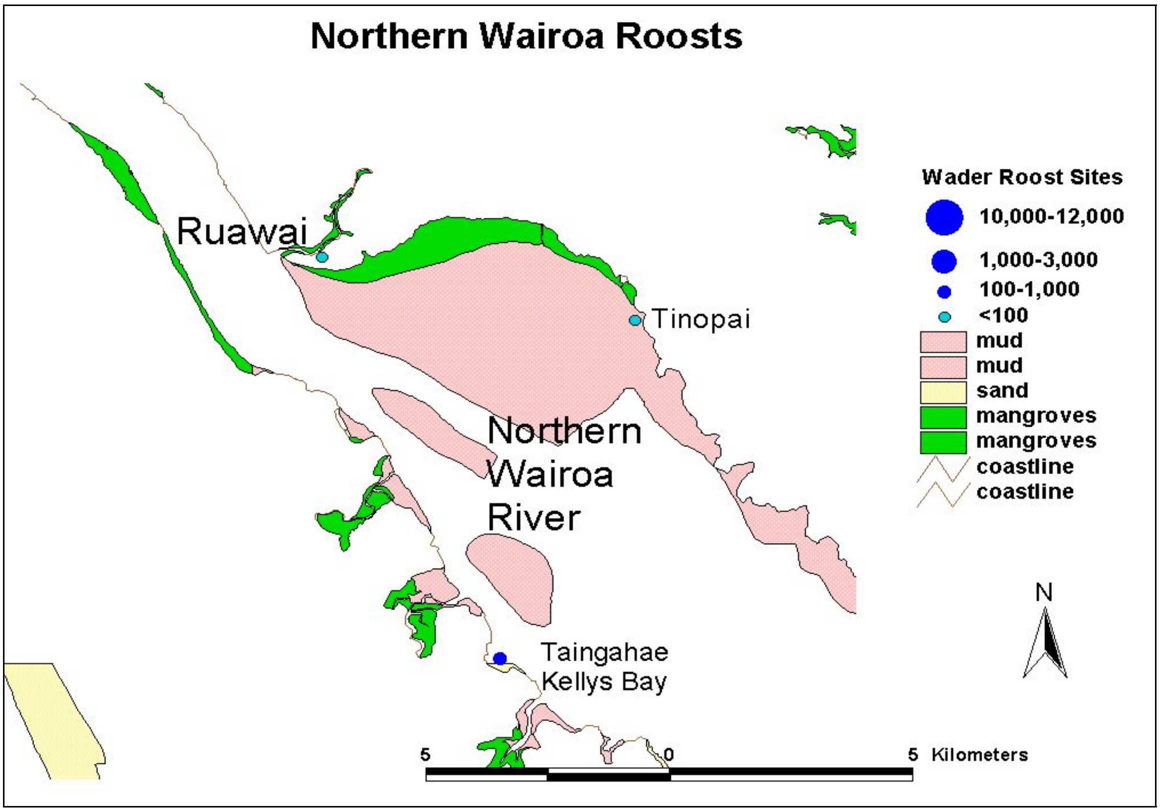
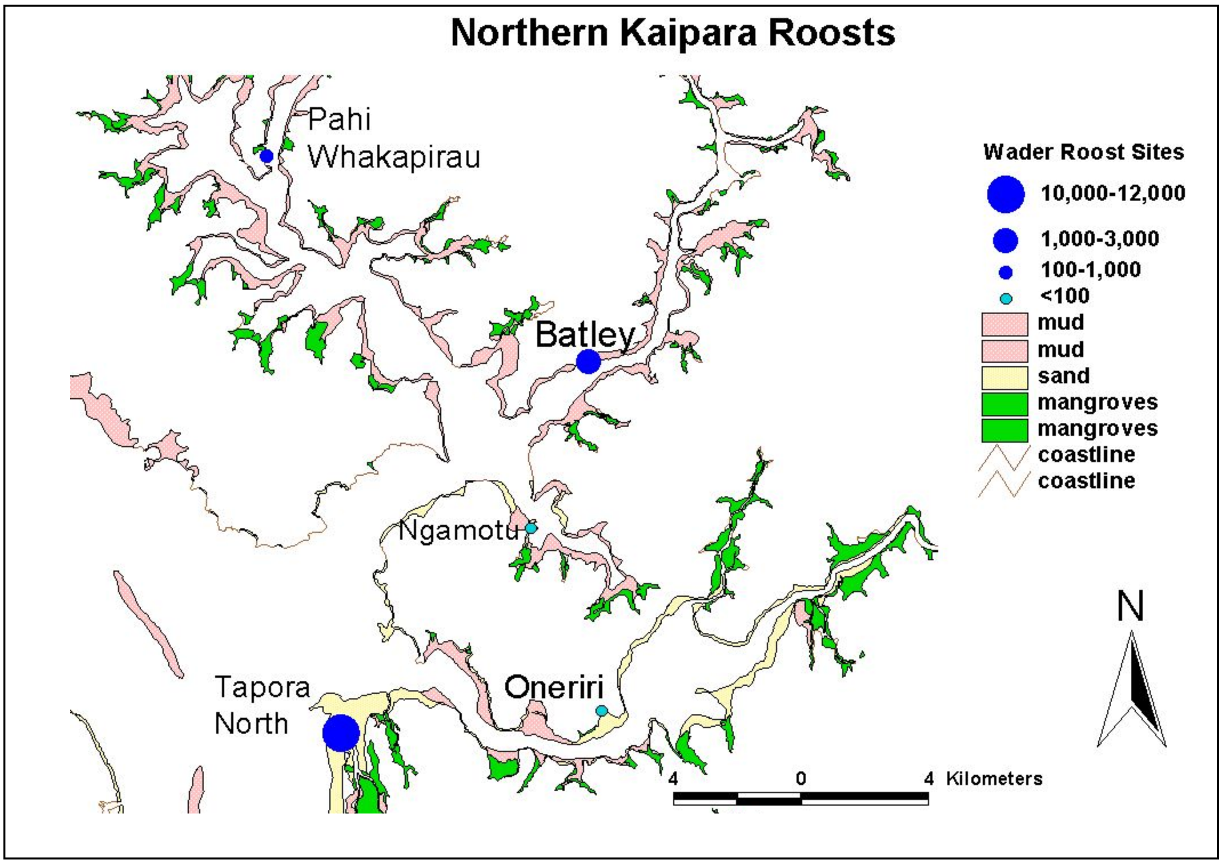


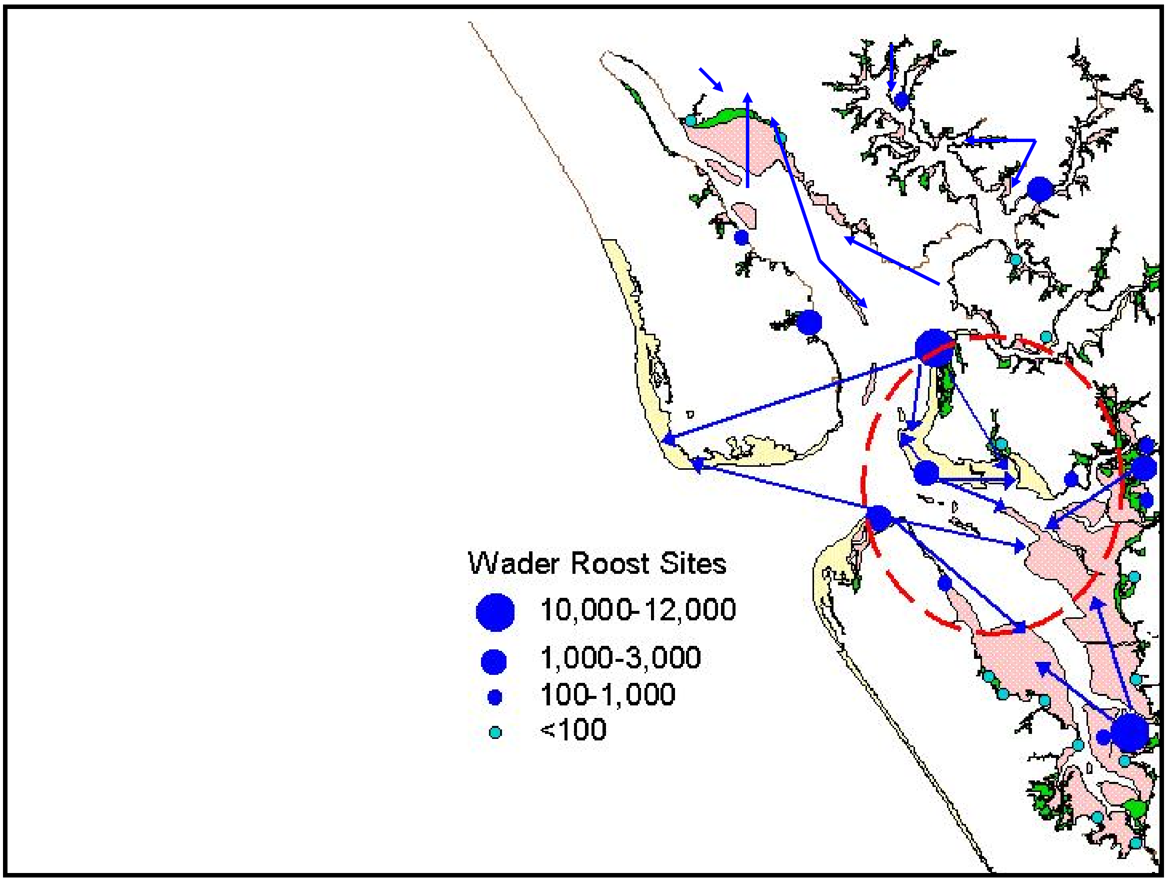
Figure 31 Wading bird roost sites in the north-eastern Kaipara Harbour.



3.5.5 Movement of waders from roosts to feeding areas

Wading birds roost on the harbour according to the height of the high tide: they prefer to roost close to their main feeding areas (Figure 32). At neap tides there are more roosting places available closer to the prime feeding areas, whereas at spring tides many smaller roosts are inundated, forcing birds to roost further from their feeding areas. This situation can be exacerbated when a spring tide is combined with stormy weather, forcing birds into a small number of roosts, with some birds having to roost on nearby farmland. Oystercatchers, pied stilts, dotterels, plovers, herons, and spoonbills are species that are regularly seen roosting on paddocks, particularly in winter storms.

Figure 32 Movement between summer wader roosts and feeding grounds on the Kaipara Harbour. Wader feeding areas shaded pink, sand dunes yellow, and mangroves green (Bellingham and Davis 2004).



3.5.6 Wetland birds

Australasian bittern

Australasian bittern are nationally endangered in both New Zealand and Australia, where they are threatened by human-induced changes to their habitat. They favour wetlands with tall, dense vegetation; particularly raupo (*Typha* spp.) and spikerushes (*Eleocharis* spp.). During the day they hide amongst dense reeds or rushes then feed mainly at night on frogs, fish, large spiders, insects, and snails. Breeding occurs in summer from October to January. The nests are built in secluded places, on a platform of reeds, within the densely vegetated wetlands.

Banded rail

Banded rail are spread sparsely in the estuaries of the upper North Island and Nelson-Marlborough. The Kaipara Harbour has the largest banded rail population in New Zealand due to its size.

Spotless Crake

Spotless crake are found mainly in the raupo swamps of the northern part of the North Island and the Manawatu/Horowhenua dune lakes. At the Kaipara they are found in dense, brackish, marshes that contain tall raupo and spike-rushes.

Marsh crake

The marsh crake inhabits both fresh and saltmarshes, and the marshy banks of rivers. Marsh crake run quickly amongst the vegetation and on floating raupo. There are sparse records of marsh crake in the North Island and only a few records at the Kaipara Harbour.

North Island fernbird

Fernbird are found in saline and freshwater wetlands, particularly in the tall shrubby fringes. At the Kaipara they occupy the landward fringe of marsh ribbonwood, manuka, and coprosma in the saltmarshes. The Kaipara Harbour probably has the largest North Island fernbird population in New Zealand. North Island fernbird territories found at Omaha Estuary were about 0.6 ha (Parker 2002). Based on this comparable estimate and the available habitat within the Kaipara Harbour, the population is likely to contain between 3000 and 4000 birds.

3.5.7 Oceanic birds

Oceanic birds also breed around the harbour and include: little blue penguin, grey-faced petrel, and sooty and flesh-footed shearwater.

Little blue penguin

The population and range of the blue penguin has been declining in Auckland and Northland (Geurts., pers. com.) where they are not protected from predation, resulting in the Department of Conservation ranking them in the threat category of Gradual Decline. Blue penguins have a rather variable breeding season; the main egg-laying period occurs between September to November and only one clutch is laid. They nest in many localities around the Kaipara, but generally within 5 km of the harbour entrance.

Blue penguins usually feed outside the harbour on a variety of surface schooling fish, squid, and crustaceans. Although dive depths of 60 m have been recorded, 10-20 m is more common. They usually feed within 25 km of the coast and may make daily round trips of up to 75 km (Houston 2007). They are more commonly seen around the entrance of the harbour at dawn and dusk, on their way to and from the feeding grounds.

Grey-faced petrel

Grey-faced petrel nest at Pouto and at other localities in the harbour such as Motu Rimu, an islet in the harbour just west of the Tauhoa River (S. Phillips., pers. comm.). They feed on surface schooling fish, squid, and crustaceans, often 50 km or more offshore on the West Coast, returning to their burrows in the nesting season at dusk and departing for their feeding grounds before dawn each day. Grey-faced petrel have been in general decline on the Auckland / Northland West Coast for the past 50 years and all of the viable colonies that remain require active predator control to ensure their survival.

Sooty and flesh-footed shearwater

Sooty and flesh-footed shearwater share nesting burrows with grey-faced petrel and feed in similar localities at sea on the West Coast. The shearwaters nest in summer and the grey-faced petrel nest in winter.

3.5.8 Birds that forage in deep water

Pierce (2005) provides a summary of key bird species that forage in the deep waters of the Kaipara Harbour (Table 7).

Table 7 Key bird species foraging in deep water in the Kaipara Harbour.

Species	Status	Distribution at the Kaipara
Northern little blue penguin	E, T	Unknown.
Australasian gannet	C	Throughout the Kaipara.
Pied shag	T	Throughout the Kaipara.
Black shag	T	Throughout the Kaipara.
Little black shag	T	Throughout the Kaipara.
Little shag	C	Throughout the Kaipara.
Tern	E, M, T	Refer to Table 1 in Pierce (2005).

Status: E = Endemic, T = Threatened, C = Common.

3.5.9 Terrestrial birds

Terrestrial birds such as: herons, shags, banded rail, tui, grey warbler, silvereye, morepork, kingfisher, welcome swallow, and shining cuckoo, as well as a range of introduced passerine species, regularly use the mangrove habitat for feeding and, to a lesser extent, as breeding sites (Pierce 2005, M. Bellingham., pers. obs.) (Table 8). Frequent movement of these bird species from nearby forest and scrubland into mangrove shrublands has been observed (M. Bellingham., pers. obs.). It is likely that mangrove shrublands are a critical feeding habitat for birds that forage for insects among the foliage and take nectar from mangrove flowers. Saltmarshes also provide food for these birds as they are rich in insects and spiders, and Coprosma and pohuehue fruit. These terrestrial bird species commonly nest in denser thickets within the mangroves and saltmarshes, especially where the land adjoining the Kaipara is devoid of forest and scrub, or where the forest occurs only in small remnant areas. These intertidal mangrove forests and shrublands provide valuable habitat for terrestrial birds by linking the small remnants of forest above the coastal marine area.

Table 8 Key bird species foraging in and adjacent to mangroves in the Kaipara Harbour.

Species	Status	Distribution throughout the Kaipara
Australasian bittern	T	Mangroves and saltmarsh areas.
Banded rail	T	Mangroves and saltmarsh areas throughout the harbour.
Kingfisher	C	Mangroves and adjacent areas throughout the harbour.

Status: T = Threatened, C = Common.

3.6 Coastal vegetation

The Kaipara Harbour has long been recognised for its mangrove and saltmarsh habitats and successional sequences from tidal channels to near-shore mangrove, saltmarsh, saltmeadow, maritime rushes, and full forest habitats; the most notable being the Tauhoa Scientific Reserve, Hoteo River, and Mt Auckland Forest (Atuanui Conservation Area) (Chapman 1976, Fahy et al. 1990, Shaw and Maingay 1990, Morrisey et al. 2007). Numerous other sites are also significant with regard to mangrove remnants, with associated maritime wetland on the landward side.

Areas of coastal vegetation within the southern Kaipara are presented in Figure 33 (ARC, GIS vegetation data). An assessment of coastal vegetation in the southern Kaipara Harbour was undertaken by Wildlands Ltd using aerial photographs (Figure 34) (Mead et al. in prep.) and found that the southern Kaipara Harbour contains areas of coastal vegetation that are nationally or regionally significant. These areas are:

- Waionui Inlet, which met many of the criteria for significant coastal vegetation and was ranked as both regionally and nationally significant. Waionui Inlet contains the largest area of herbaceous saline vegetation within the Kaipara Ecological District and the Auckland Region (284.1 ha), is an outstanding example of representative habitats, contains ecological sequences from marine to terrestrial environments, and has at least four threatened plants.
- Puharakeke Creek, which contains the largest area of mangroves within the Kaipara Ecological District and the Auckland Region (729.5 ha). It is typified by transitions from

mangrove or herbaceous saline to scrub or indigenous shrubland, and contains at least 35 indigenous scrub-covered estuarine islands.

- Opatu River in the eastern Kaipara Harbour, which contains the largest area of estuarine vegetation in the Kaipara Ecological District and Auckland Region (758.6 ha), extensive herbaceous saline vegetation, and ecological transitions from mangrove to herbaceous saline communities to indigenous forest.
- Kaipara River, which has a complex mosaic of vegetation types including estuarine islands.

A number of smaller sites are also significant, usually because they contain threatened species or complete ecological sequences from marine to terrestrial environments. These sites include, but are not limited to: Kaukapakapa River, Okahukura Peninsula, and Te Karaka Creek, which contain ecological sequences and support threatened plant species; Makarau River, Atiu and Takahe Creek, Lower Oruawharo River, Upper Tauhoa River, Hoteo River, and Otekawa Creek, which contain ecological sequences; and Sand Island and Omaumau River, which support threatened plant species.

Areas within the Kaipara that form important wildlife corridors are summarised in Figure 35 to Figure 37.

Figure 33 Areas of coastal vegetation within the southern Kaipara (ARC, GIS vegetation data).

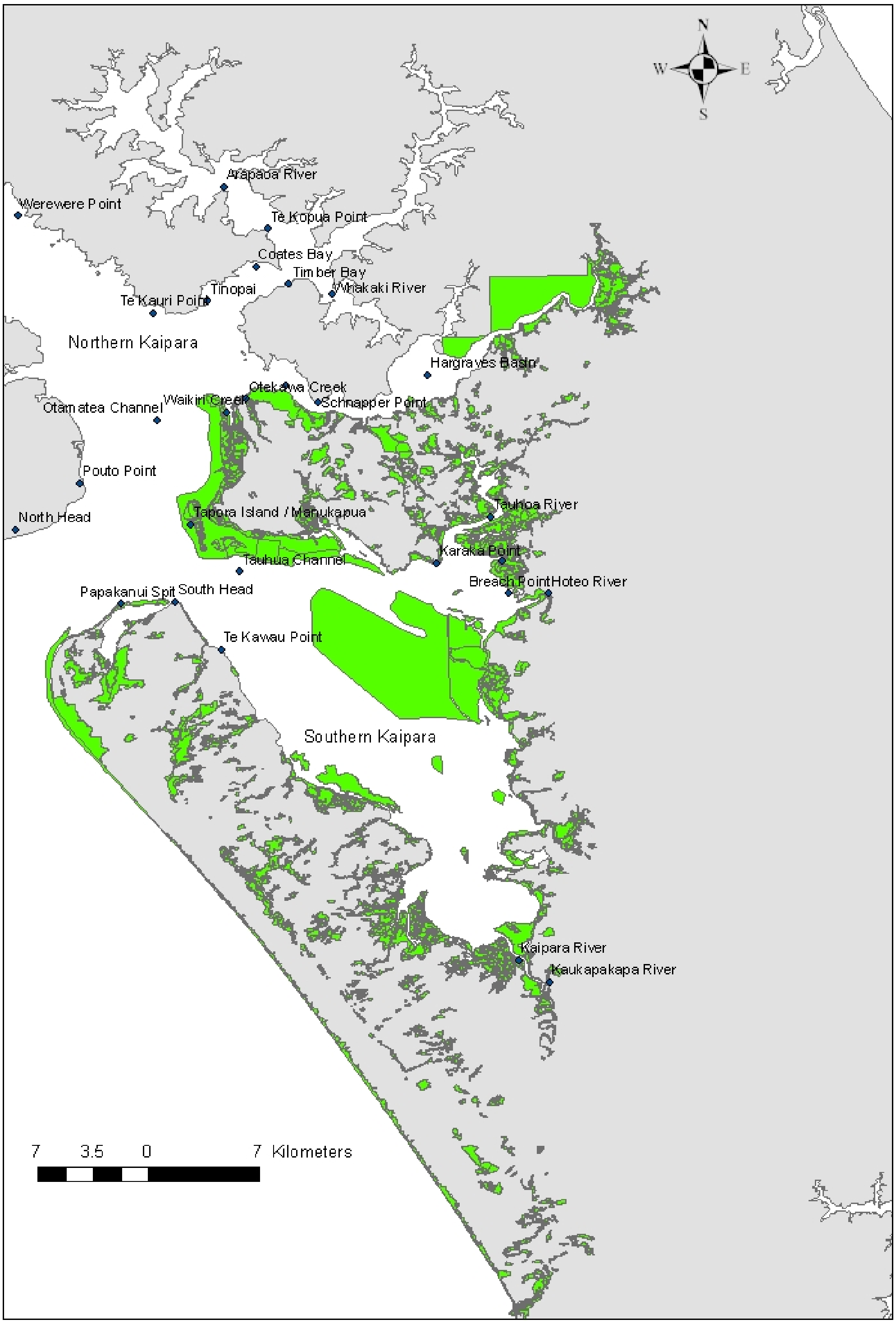


Figure 34 Areas of coastal vegetation of regional and national significance within the southern Kaipara (Mead et al. in prep.).

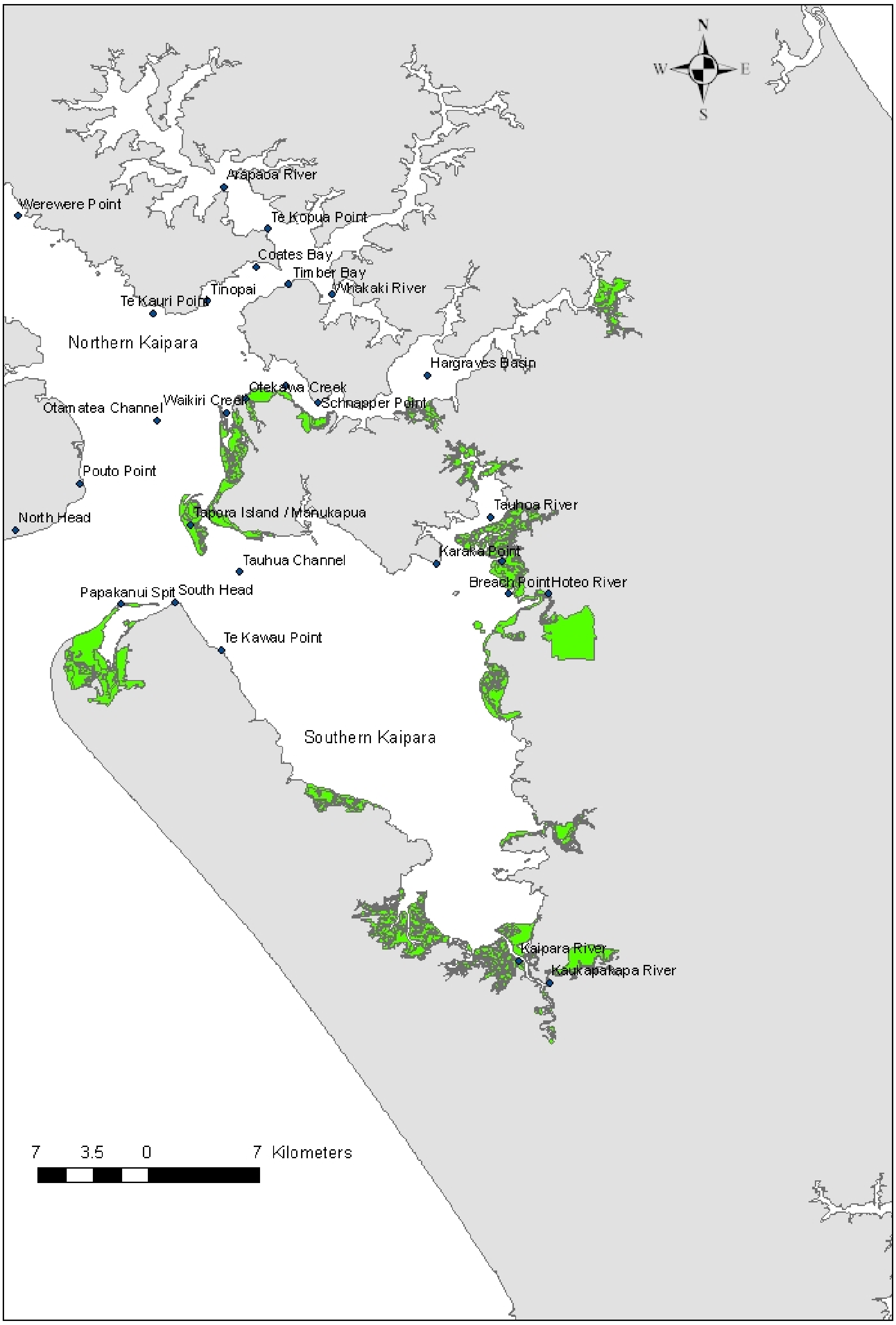


Figure 35 Mangrove, shrub, and indigenous forest forming wildlife corridors across the southern Kaipara Harbour.

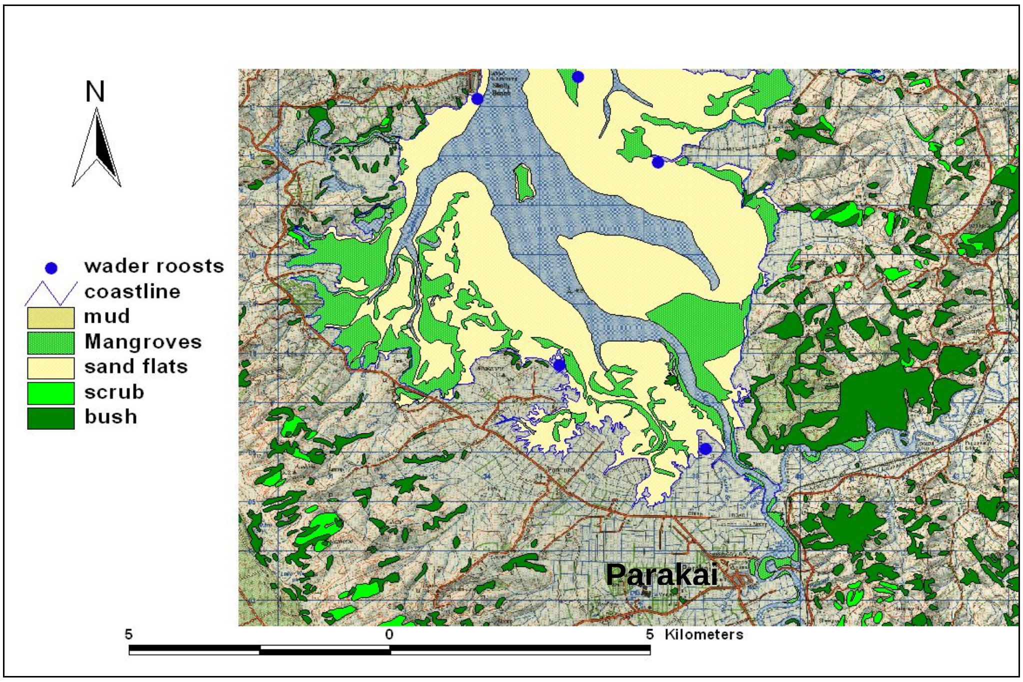


Figure 36 Mangrove, shrub, and indigenous forest forming a wildlife corridor of semi-continuous habitat in the upper Tauhoa River.

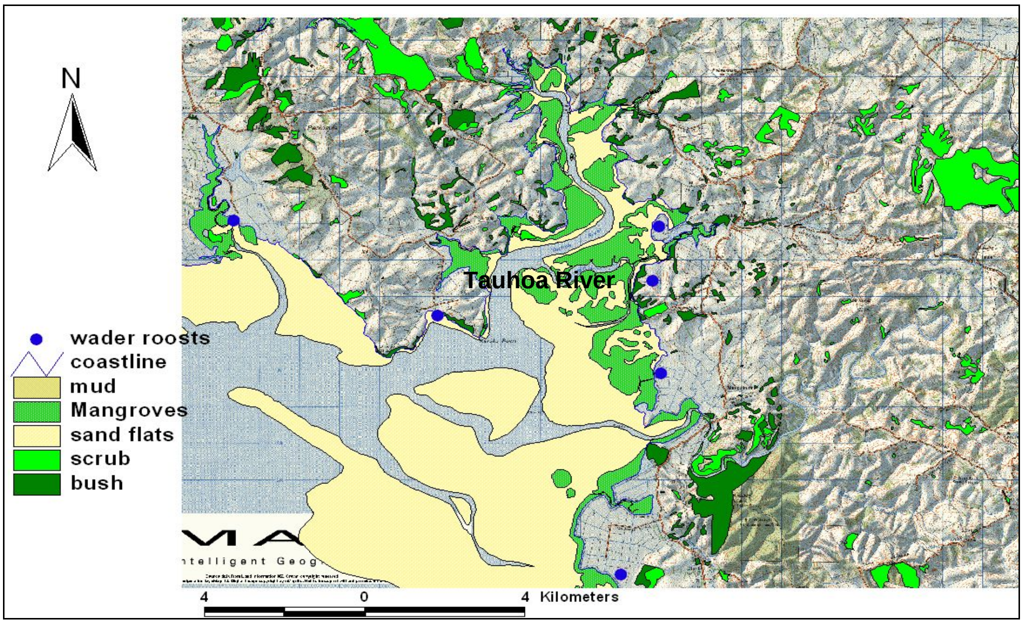
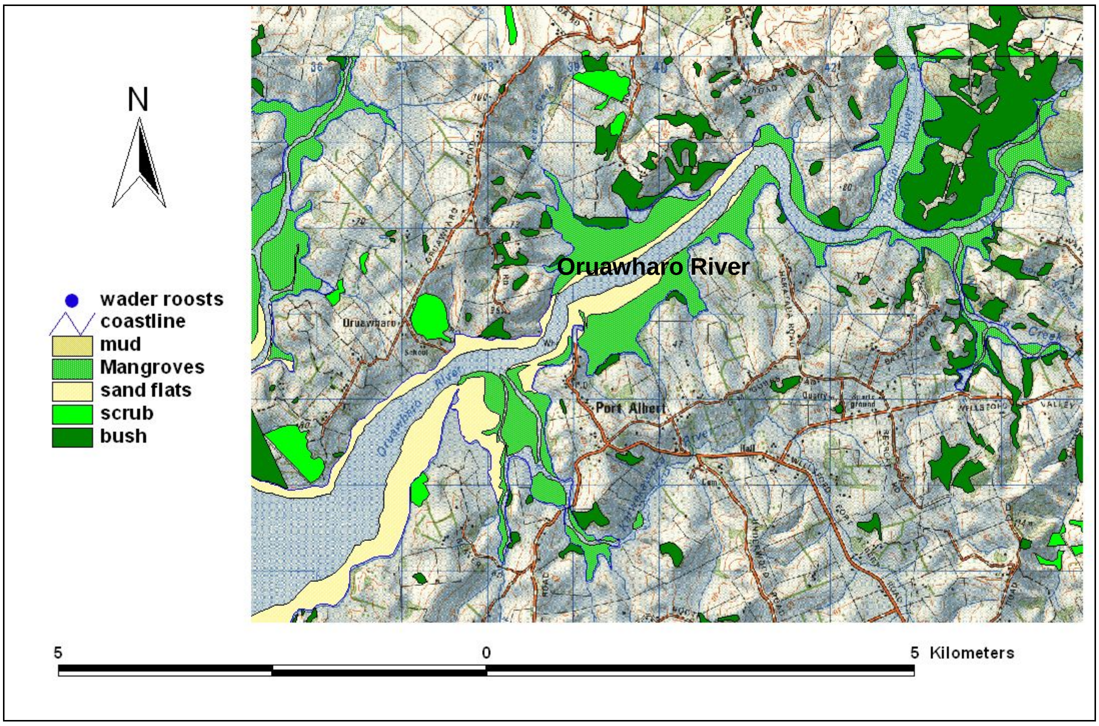


Figure 37 Mangrove, shrub, and indigenous forest forming a wildlife corridor along the upper Oruawharo River.



4 Summary of monitoring and investigations

This section of the report provides information on the monitoring and investigations carried out in the Kaipara Harbour and assesses whether they are sufficient to capture broad changes in the environmental quality of the harbour. The assessment includes the temporal monitoring carried out by regional councils, government departments, and consent holders; and also presents information from one-off studies conducted within the harbour.

Monitoring and investigations within the harbour that have been, and are presently being undertaken, are:

- Ecological State of the Environment (SoE) Tier II monitoring for the Auckland Region. For the southern Kaipara, this aimed to map habitats and describe the ecological communities present in intertidal and near-shore (<20 m depth) areas and in subtidal areas (Hewitt and Funnell 2005).
- Environmental quality SoE monitoring, consisting of repeated measurements of environmental parameters (e.g. water quality monitoring) at the same locations to provide baseline information against which long-term changes (trends) may be detected.
- Resource consent condition monitoring to assess environmental impacts of consented activities (e.g. sand-mining) on the marine environment.
- One-off studies to investigate specific issues, e.g. risk assessment for aquaculture.
- Fisheries catch per unit effort (CPUE) monitoring, to track the stock status of specific fisheries.
- Assessments of roosting and wading bird abundance and distribution (NZ Ornithological Society).

4.1 State of the Environment monitoring

4.1.1 Benthic marine habitats and communities of the South Kaipara

The SoE Tier II monitoring being performed by the ARC includes an extensive spatial survey of benthic habitats and ecologically significant communities in the southern Kaipara Harbour at 10–16 year intervals. Tier II monitoring is designed to examine large, long-term changes in habitats or communities (Hewitt and Funnell 2005).

Sampling methodology

Tier II monitoring utilises a wide range of techniques to document physical habitats and benthic communities. These techniques include intertidal and subtidal sampling using cores, quadrats, video, dredge, side-scan sonar, remote underwater vehicle, and benthic grab samples.

Results

Importantly, the southern Kaipara Harbour contains: a high diversity of habitats, high taxonomic diversity (at both species and order level), a number of organisms that are large and long-lived, a number of species commonly associated with pristine environments, subtidal *Zostrea capricorni* (comparatively rare in New Zealand), and a unique association of tube-building worms (Hewitt and Funnell 2005; see Section 3.2.1).

Large differences in taxa were recorded from different areas of the harbour, with the Oruawharo Arm and Waionui Inlet being distinct from that of the main harbour. Invasive bivalves including the Pacific oyster (*Crassostrea gigas*), Asian mussel (*Musculista senhousia*), and *Theora lubrica* were also recorded in the southern harbour with *Musculista* frequently found in small, high-density patches.

The study also commented on the likely effects on benthic marine communities of five proposed Aquaculture Management Areas (now withdrawn by the ARC - see Box 2, Section 5.1.4) within the harbour. Due to the diversity of the benthic habitats and taxa within many of the AMAs, Hewitt and Funnell (2005) recommended that a detailed assessment of the risks associated with aquaculture be undertaken (see Section 4.4.8).

4.1.2 Water quality monitoring (southern Kaipara Harbour)

Shelly Beach

The Auckland Regional Council undertakes monthly water quality monitoring at Shelly Beach as part of its regional water quality monitoring programme (a further 26 sites across Auckland are also assessed). Water quality parameters measured include: temperature, pH, salinity, chlorophyll *a*, dissolved oxygen, turbidity, total suspended solids (TSS), nitrate, nitrite, ammonium, phosphate, total reactive phosphate, enteroccoci and faecal coliform levels (refer to Table 9 for generic descriptions). Data collected between 1991 and 2006 for Shelly Beach are presented in Figure 38.

At present, water quality guidelines have not been developed specifically for New Zealand estuaries. The ANZECC Water Quality Guidelines (ANZECC 2000) therefore suggest that the south-east Australian trigger values may be suitable for New Zealand estuaries. However, the mean concentrations of ammonium, nitrate, and phosphates exceed the south-east Australian trigger values at most of the ARC's water quality monitoring sites so their application within New Zealand is questionable.

Statistical[1] analysis indicates that Shelly Beach has similar water quality values to semi-degraded sites in the Manukau Harbour (Titirangi, Mangere Bridge, Puketutu Island) (ARC unpublished data).

As part of their assessment of the effects of aquaculture within the Kaipara Harbour, Elmetri et al. (2006) analysed SeaWIFS (Sea-viewing Wide Field-of-view Sensor) satellite data for chlorophyll *a*. This data suggested higher chlorophyll *a* levels in the upper reaches of the harbour (Shelly Beach) and a general pattern showing that levels decreased as distance towards the harbour entrance increased. They also concluded that water quality data exceeded the trigger values (but see comment above) and suggested that the southern Kaipara should not be regarded as a pristine harbour, as suggested by other authors, describing the harbour as somewhat degraded based on water quality parameters.

None of the ARC's stormwater contaminant monitoring, shellfish contaminant monitoring, or Tier I ecological monitoring sites are located in the Kaipara Harbour.

Hoteo River

While not specifically classified as coastal in terms of this study, the water quality of the Hoteo River, which drains into the Kaipara, is routinely monitored as part of the National Rivers Water Quality Network (NRWQN) and has been monitored each month by the ARC since 1986. The dominant land cover of the catchment is pasture and the data from this monitoring site shows very high annual means of total phosphorus which exceed the trigger value recommended for New Zealand lowland rivers (ANZECC 2000).

[1] Using cluster analysis of total suspended sediment, nitrate, ammonium, total phosphorus, and faecal coliforms.

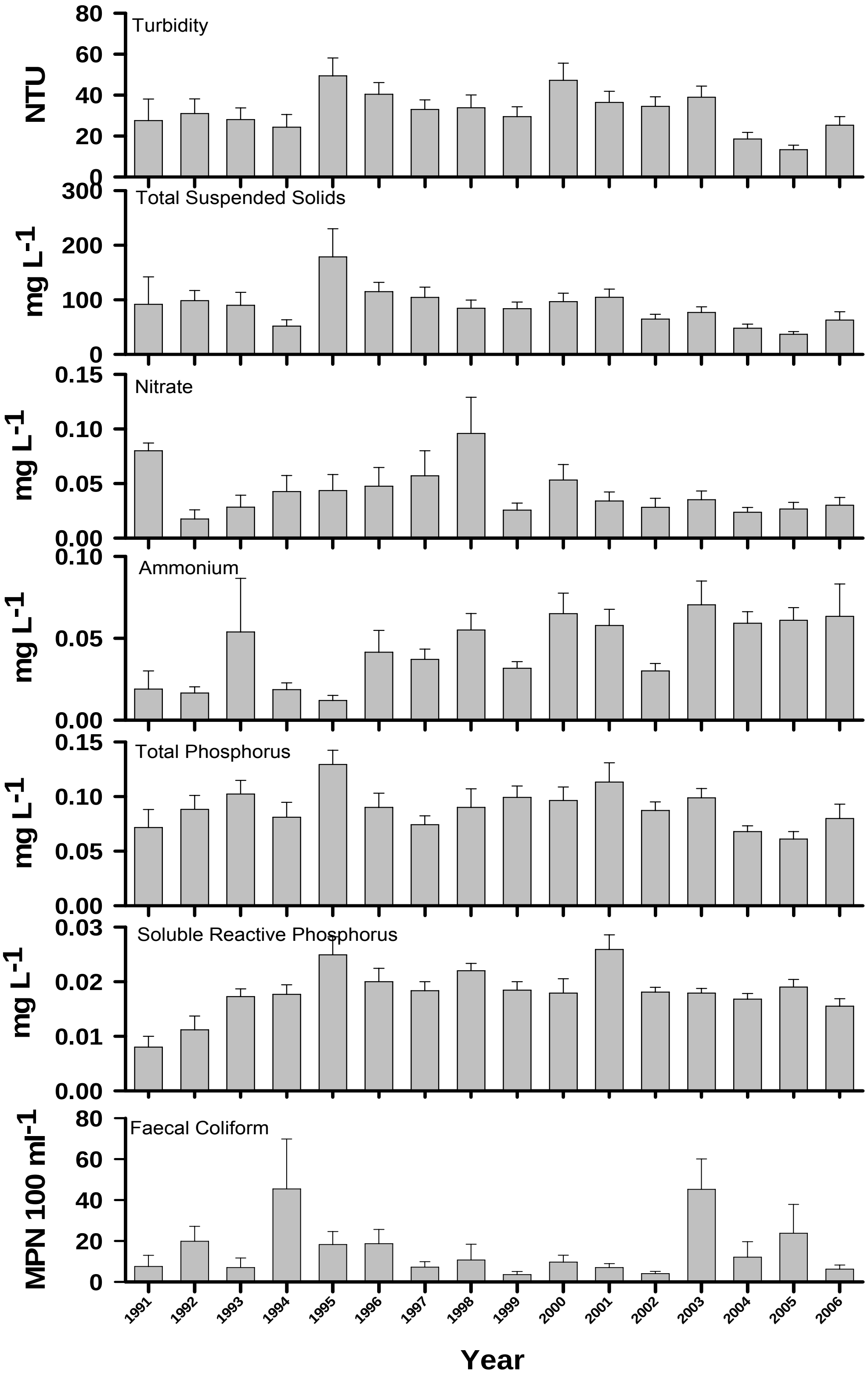
Table 9 Description of parameters commonly measured to assess water quality (HDC 2002, ANZECC 2002).

Component	General Information	Source	Problems
Nitrogen	Nitrogen may be present in the inorganic form of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3 and NH_4) or in combined forms such as proteins and humic acids. In low oxygen and slightly acidic environments, e.g., swamps, high nitrate levels are generally converted back to ammonia with the release of nitrogen gas.	Important sources of nitrogen associated with human activity are fertilisers and organic material (including farm runoff and wastewater inputs). Nitrogen levels also vary naturally in the marine environment, generally in response to upwelling which brings nutrient-rich deep water to the surface, or down-welling which limits nutrient levels in surface waters.	Excess nitrate can result in algal blooms in larger water bodies and proliferation of aquatic weeds (often termed macrophytes). When these plants breathe at night, oxygen is removed from the water thereby reducing the ability of other life to survive. During the day these plants pump oxygen into the water as they photosynthesise resulting in super-oxygenated water (>110% saturation). Photosynthesis also results in a shift in the carbonate/bicarbonate balance of the water toward a more alkaline pH (up to pH9 in summer). When these plants die, oxygen is used in the decay process. This oxygen demand may restrict the invertebrate species that can inhabit a waterway to those tolerant of low oxygen levels. Ammonia is produced by the decay of organic material, and in well oxygenated waters it converts to NO_3 (through NO_2). This conversion process uses up oxygen leaving less in the waterway to sustain aquatic life. Ammonia also exerts a toxic effect on aquatic life with chronic impacts being experienced by sensitive aquatic life at levels around 0.77 mgN/l.

Component	General Information	Source	Problems
Phosphorus	Phosphorus is a naturally occurring nutrient derived from the weathering of rocks and the decay of vegetation or other organic matter. Phosphorus occurs in natural waters in either dissolved or particulate form. Dissolved phosphorus may occur as simple inorganic soluble reactive phosphorus (SRP) or in more complex forms such as organic phosphates excreted by organisms. Particulate phosphorus includes that bound to clay particles that are suspended in the water column or deposited on a stream bed.	Increases in phosphorus levels in streams are usually caused by human activities. Most of the phosphorus in soils is bound to soil particles or is part of soil organic matter. Stream banks in urbanised areas that are not stabilised by planting or engineering measures, are prone to erosion due to increased stream velocities. Surface runoff may also wash soil particles into waterways during rainfall, particularly from areas of disturbed soil within subdivisions. Discharges of sewage from overloaded or failed sewerage infrastructure, unauthorised discharges of industrial/commercial wastewater, and contaminated stormwater may also result in increased phosphate loads in waterways. Under certain conditions high levels of phosphorus in water may result from re-suspension of bottom sediments which have accumulated over many years.	In pristine conditions phosphorus is often a nutrient that limits plant growth. When phosphorus levels increase dramatically (eutrophication), plant growth often accelerates rapidly. This can result in problems such as algal blooms and excessive plant (macrophyte) growth. When these plants die, oxygen is used in the decay process and the resulting lack of oxygen in the water may become a limiting factor for aquatic life.
Dissolved O_2 (DO)	Dissolved oxygen (DO) is a measure of the quantity of oxygen gas present in water. Oxygen is also measured as dissolved oxygen saturation (the relative percentage of oxygen present in a water sample compared to full saturation). This measure takes into account other influences on the oxygen-carrying capacity of water, such as temperature and salinity.	Dissolved oxygen (DO) content depends on four main factors: how quickly oxygen is transferred into the water from the air, how quickly oxygen is used up by organisms in the water, water column mixing, and water temperature.	Sewage effluent, decaying aquatic vegetation, contaminated stormwater discharges and wastewater from human activities all reduce DO levels as they are decomposed by micro-organisms. Waterways that have adequate levels of DO can usually sustain a robust and diverse aquatic community.
pH	pH is the measure of the acidicity or alkalinity of a body of water.	The usual pH range for freshwater aquatic systems is 6 to 9, with most waterways around 7. Saline waters with a pH around 8 require a large amount of acidic or alkaline material to effectively change the pH. Toxic effects on biota are rarely due to high or low pH, but most biota are sensitive to rapid changes even though these may be within accepted ranges.	Excessive growth of algae and aquatic plants in-stream can lead to an elevated pH at certain times of the day. These fluctuations can be quite large and can limit the number of species to those that are tolerant of such changes. Industrial wastewater or contaminated stormwater can cause significant changes to the acidicity or alkalinity. For example, concrete batching plants produce stormwater runoff with a high pH due to the lime used in cement.

Component	General Information	Source	Problems
Microbiological indicators	For marine waters, the preferred indicator for health risk is enteroccoci. Faecal coliforms and *Escherichia coli* (*E. coli*) concentrations are not as well correlated with health risks, although they are useful in monitoring estuarine and brackish waters where enterococci levels alone may be misleading.	Sources of faecal contamination in streams, estuaries and coastal areas include: waste water discharges (treated and untreated), domestic and wild animals, and stormwater runoff.	Elevated levels of faecal bacteria and associated pathogens present a health risk and can cause disease. They can also cause cloudy water; emit unpleasant odours, and may increase oxygen demand (see Dissolved Oxygen).

Figure 38 Water quality parameters (Mean values + SE) measured at Shelly Beach, Kaipara Harbour (unpublished ARC data). Note: units and y axis scale differs among graphs.



4.1.3 Water quality monitoring - Arapaoa and Otamatea

The surface waters of the two northern arms of the Kaipara Harbour (Arapaoa and Otamatea) were sampled in 1999/2000 by Northland Regional Council (NRC 2002a). The purpose of the sampling was to provide baseline information on the quality of these waters, in comparison to other harbours and estuaries in Northland.

Sampling methodology

The monitoring was conducted in summer then repeated during the winter months to allow comparison of both low and high inflow (runoff) into these areas. Specific variables measured were: faecal coliform, enterococci bacteria, chlorophyll *a*, and nutrients (total phosphorus, ammonia, and total nitrogen). Samples were collected on an ebb tide.

Results

Main findings of the study for nutrients levels within the northern Kaipara Harbour, relative to the other harbours, were:

- Nitrogen levels for the Kaipara were elevated in winter but not in summer (Figure 39). Winter nitrogen levels were the highest measured among all of the Northland harbours surveyed.
- Phosphorus levels for the Kaipara Harbour were higher in summer than winter (Figure 40). Phosphorus levels for both seasons were the highest measured among all of the Northland harbours surveyed.
- Ammonia levels were higher in winter than summer. On a seasonal basis, ammonia levels were the highest measured among all of the Northland harbours surveyed (Figure 41).
- Both faecal coliform and enterococci levels were higher in winter than summer (Figure 42 and Figure 43), but, unlike nutrient levels, concentrations were comparable to those in other Northland harbours. On the basis of the results presented, NRC (2002a) suggest that the Kaipara Harbour would be considered safe for contact recreation. However, NRC (2002a) notes that these were not nearshore samples and, therefore, the results may differ from bathing water quality surveys.

Figure 39 Median nitrogen levels for a selection of Northland harbours over summer and winter (Data from NRC 2002a).

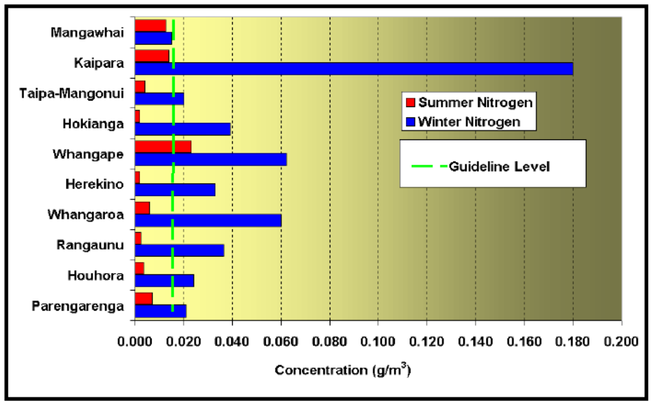


Figure 40 Median phosphorus levels for a selection of Northland harbours over summer and winter (Data from NRC 2002a).

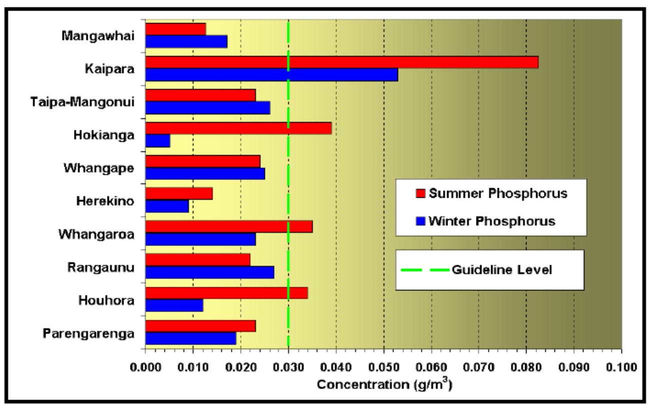


Figure 41 Median ammonia levels for a selection of Northland harbours over summer and winter (Data from NRC 2002a).

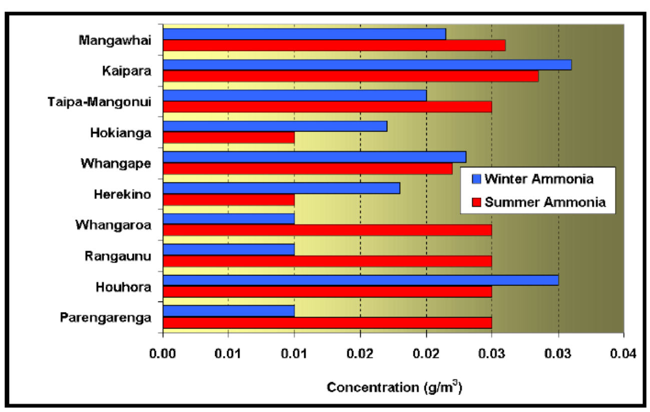


Figure 42 Median levels of indicator bacteria (Faecal Coliform) over summer and winter (Data from NRC 2002a).

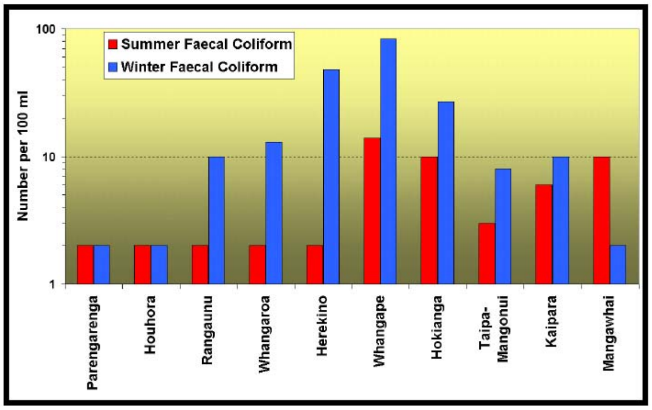
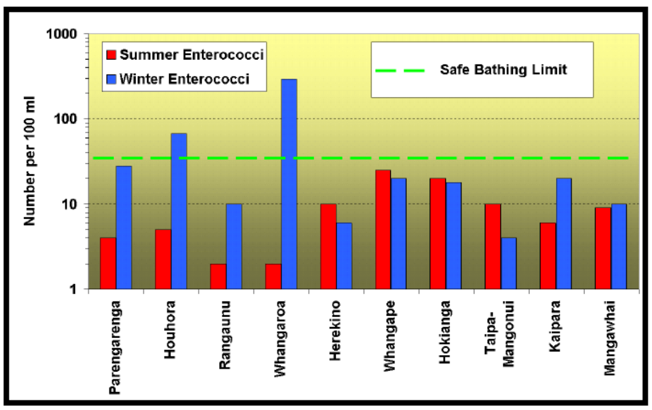


Figure 43 Median levels of indicator bacteria (Enterococci) over summer and winter (Data from NRC 2002a).

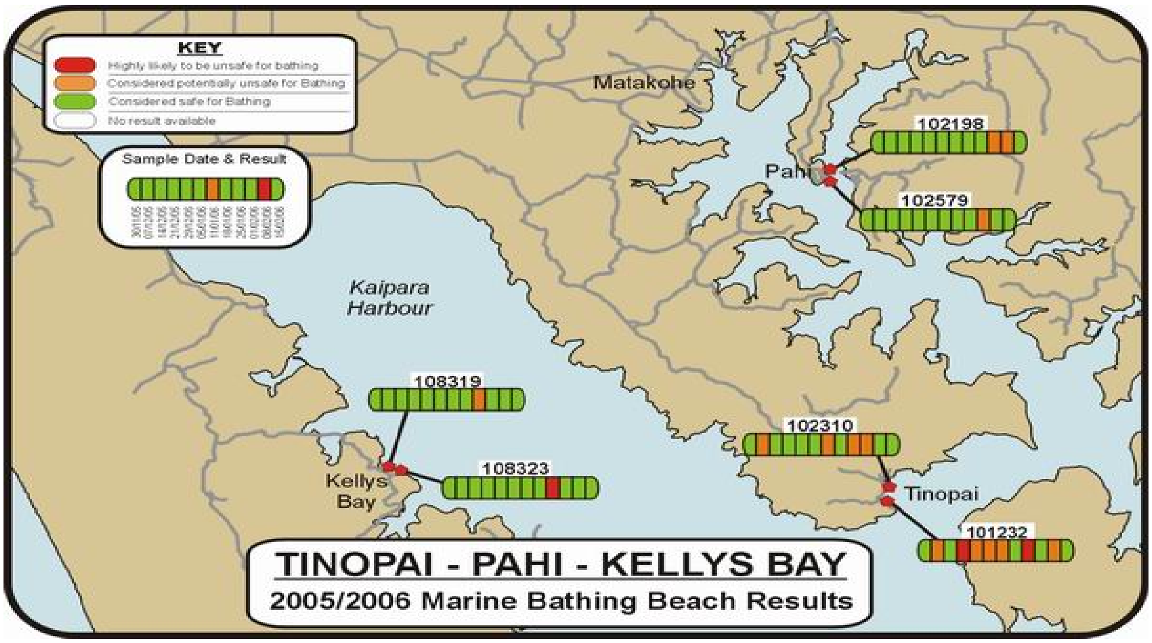


4.1.4 Recreational bathing water quality (northern Kaipara Harbour)

The Northland Regional Council (NRC) undertakes a recreational bathing water quality monitoring programme every summer for 12 weeks during the peak bathing season (late-November to mid-February) (NRC 2000-2006) (see Figure 44 for sampling locations). Both enteroccoci and faecal coliform levels are measured separately but the results are amalgamated to derive a weekly 'Bathing Safety' status rank for each site. The status rank is presented using a traffic light scale; where green is considered safe for bathing, amber is considered potentially unsafe for bathing, and red is considered highly unlikely to be safe for bathing (Figure 45).

Sampling within the Kaipara Harbour is undertaken at three sites: Kellys Bay, Pahi, and Tinopai, with two locations sampled at each site. The water quality for Kellys Bay and Tinopai in 2005-06 (the most recent survey) complied with the bacteriological guidelines for recreational bathing on most occasions; however, Tinopai had numerous non-compliances possibly related to semi-brackish waters present during sampling (Figure 44) (NRC 2006).

Figure 44 Water quality rankings for recreational bathing for Kellys Bay, Tinopai, and Pahi within the northern Kaipara Harbour in 2005/2006.

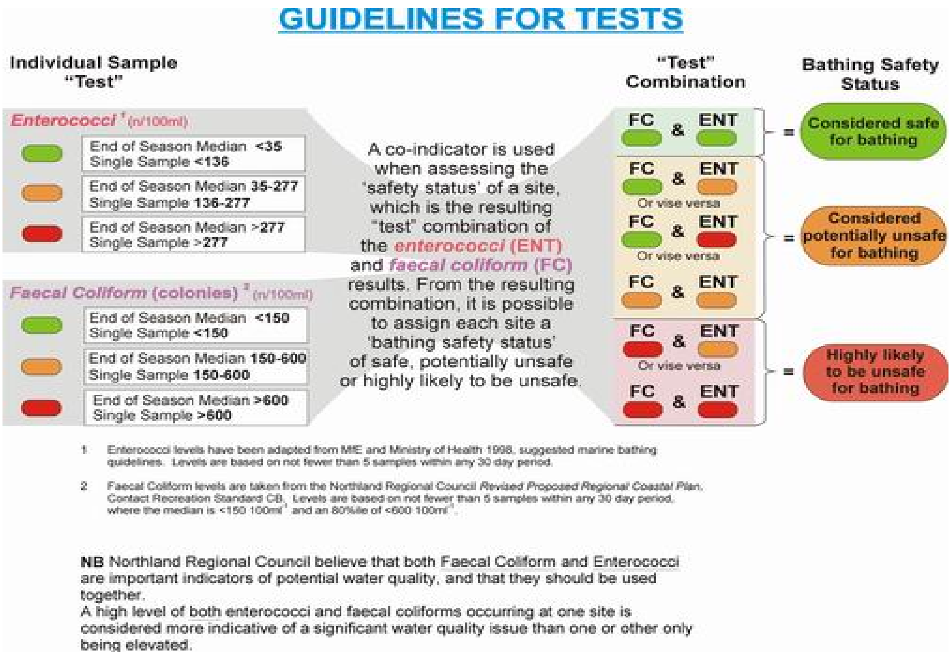


General trends in bathing water quality, analysed from the most recent monitoring reports (NRC 2001-2005), are presented in Table 10.

Table 10 Bathing water quality for three sites in the northern Kaipara Harbour. Data from NRC (2001-2006) and expressed as percentage (%) of samples safe for bathing.

Site	2001-02	2002-03	2003-04	2004-05	2005-06
Tinopai	75 %	83%	75 %	100%	46%
Whakapirau	100 %	89%	78 %	N/A	N/A
Pahi	77 %	78%	88 %	100%	88%
Kellys Bay	N/A	N/A	N/A	100%	92%

Figure 45 Traffic light status ranks used by NRC to measure bathing water quality.



4.1.5 Shellfish water quality (northern Kaipara Harbour)

In tandem with recreational bathing water quality, shellfish water quality is also tested at Kellys Bay, Pahi, and Tinopai. The water quality guideline for recreational shellfish-gathering is a median faecal coliform count not exceeding a median value of 14 FC per 100 ml over a shellfish-gathering season, with not more than 10% of samples exceeding 43 FC per 100 ml. Non-compliance with either of these guidelines indicates that the water is not suitable for recreational shellfish-gathering (NRC 2006). Temporal patterns suggest an increasing problem: in 2003-04 all three sites were below guideline levels, whereas in 2004-05 Pahi failed to comply with guideline levels, and in 2005-06 all three sites failed to comply (Table 11).

Table 11 Water quality results for recreational shellfish gathering 2003-2006 (NRC 2006).

Area	Median FC (per 100ml (MPN))	% of samples exceeding 43 FC per 100 ml	No. of Samples Collected	Guideline compliance
2003-2004				
Tinopai	6	N/a	9	Pass
Kelly's Bay	N/a	N/a		
Pahi	13	N/a	9	Pass
2004-2005				
Tinopai	8	2	9	Pass
Kelly's Bay	4	0	9	Pass
Pahi	65	5	8	Fail
2005-2006				
Tinopai	300	58	12	Fail
Kelly's Bay	5	25	12	Fail
Pahi	17	27	11	Fail

It is acknowledged that these results are indicative only, as they were not collected over an entire shellfish-gathering season (which can be all year in Northland), and more samples are required to provide reasonable certainty when testing for compliance with the standard. Nevertheless, these data provide a reasonable snapshot of the suitability of water quality for recreational shellfish-gathering in these areas.

4.1.6 Estuarine and river water quality (northern Kaipara Harbour)

Long-term time-series monitoring of a range of parameters for estuarine and river water quality is carried out by the NRC for several sites (Pahi, Raepare Creek, Kaiwaka River, Wairau River, and Otamatea River). Data from this programme are presented in Figure (a-d) and Figure 47 (a-b) (NRC unpublished data). Monitoring varies considerably in terms of temporal resolution and the parameters measured among sites.

Figure 46a Water quality parameters (Dissolved oxygen, salinity and temperatures) measured for Pahi, Kaipara Harbour (NRC unpublished data).

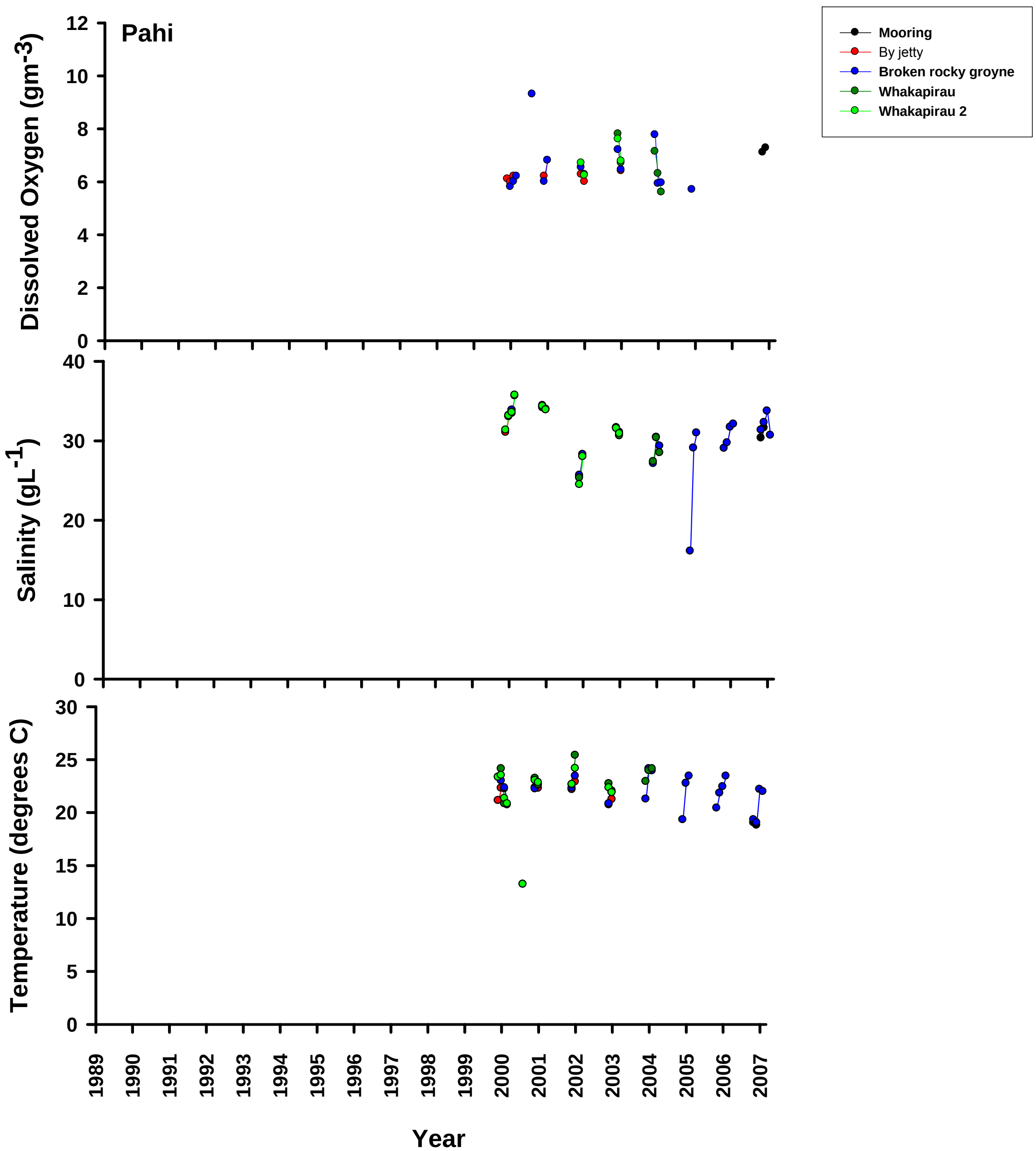


Figure 46b Water quality parameters (Dissolved oxygen, salinity and temperatures) measured for Raepare Creek and Kaiwaka Rive, Kaipara Harbour (NRC unpublished data).

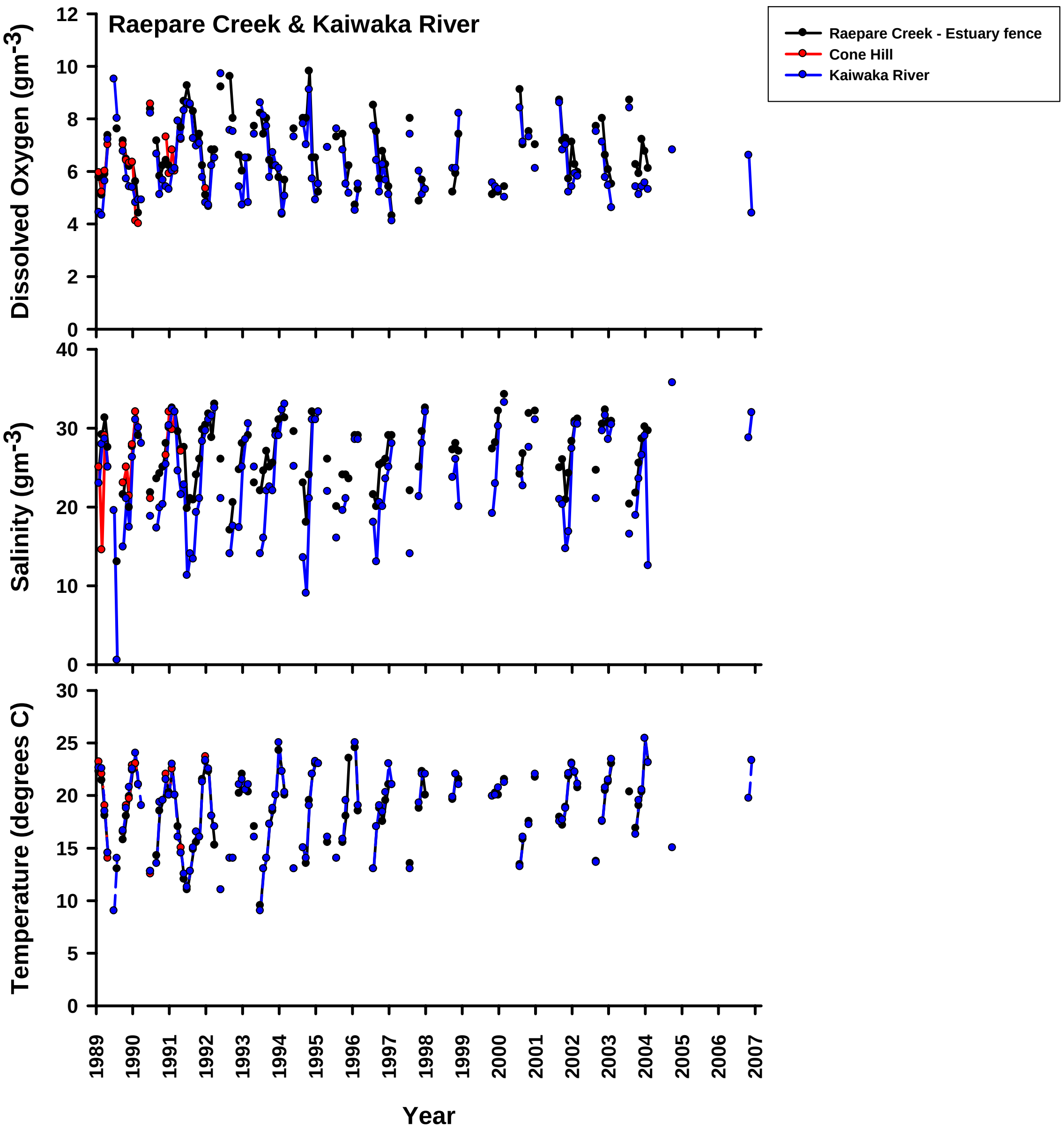


Figure 46c Water quality parameters (Dissolved oxygen, salinity and temperatures) measured for Wairau River, Kaipara Harbour (NRC unpublished data).

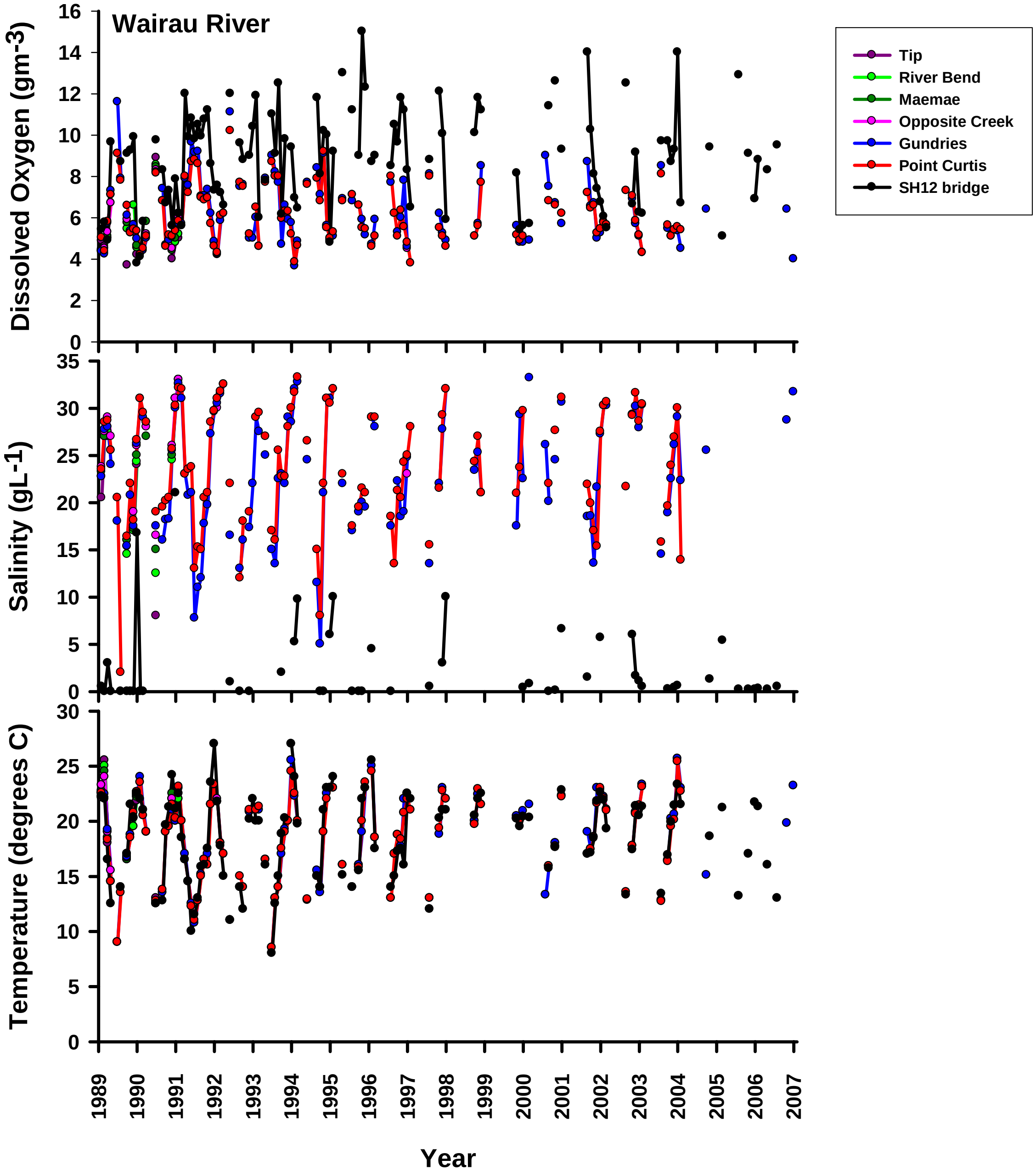


Figure 46d Water quality parameters (Dissolved oxygen, salinity and temperatures) measured for Otamatea River, Kaipara Harbour (NRC unpublished data).

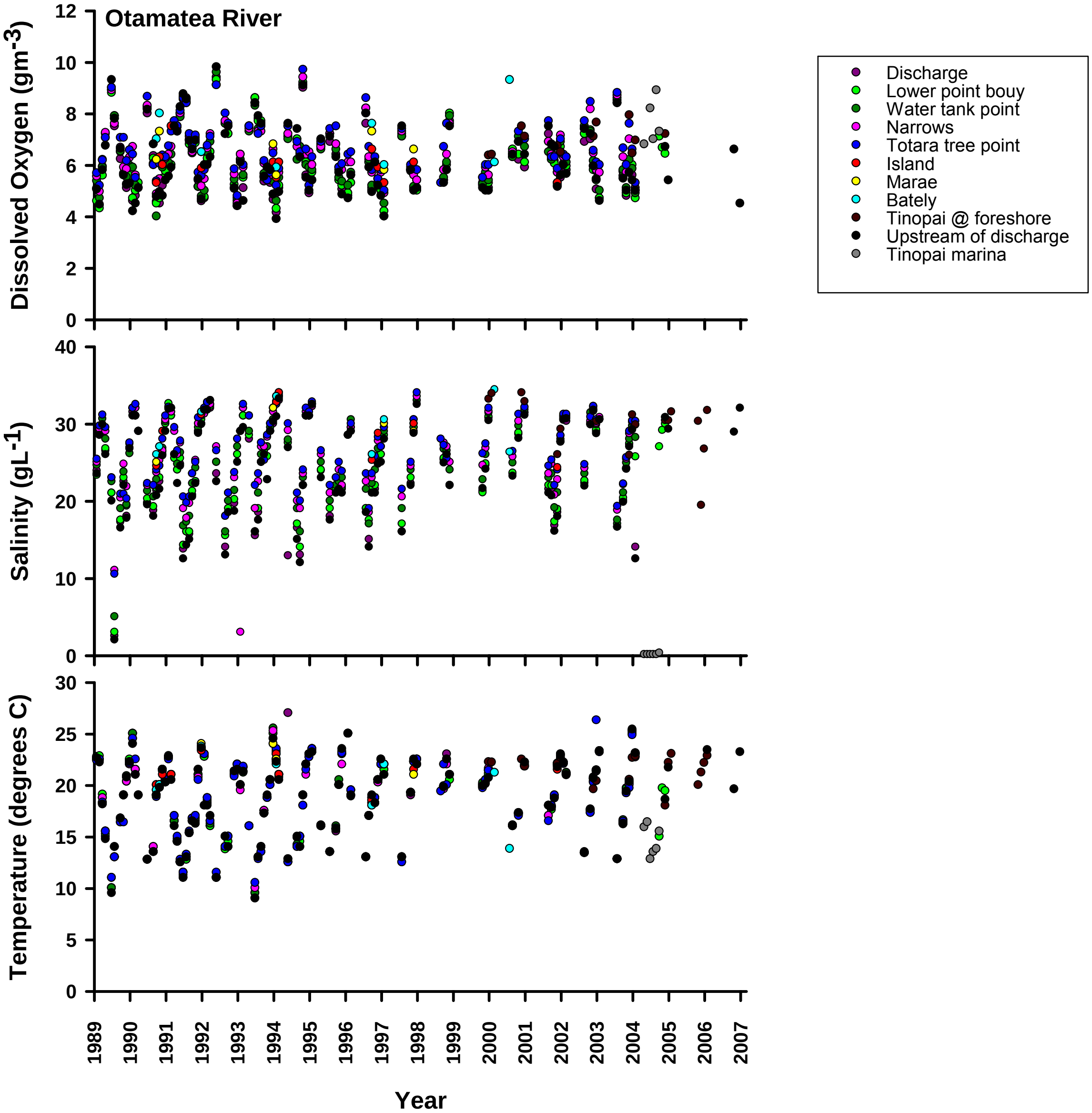


Figure 47a Water quality parameters: ammonia (NH4), total inorganic nitrogen (TIN) and total phosphorus (TP) measured within the Otamatea River, Kaipara Harbour (NRC unpublished data).

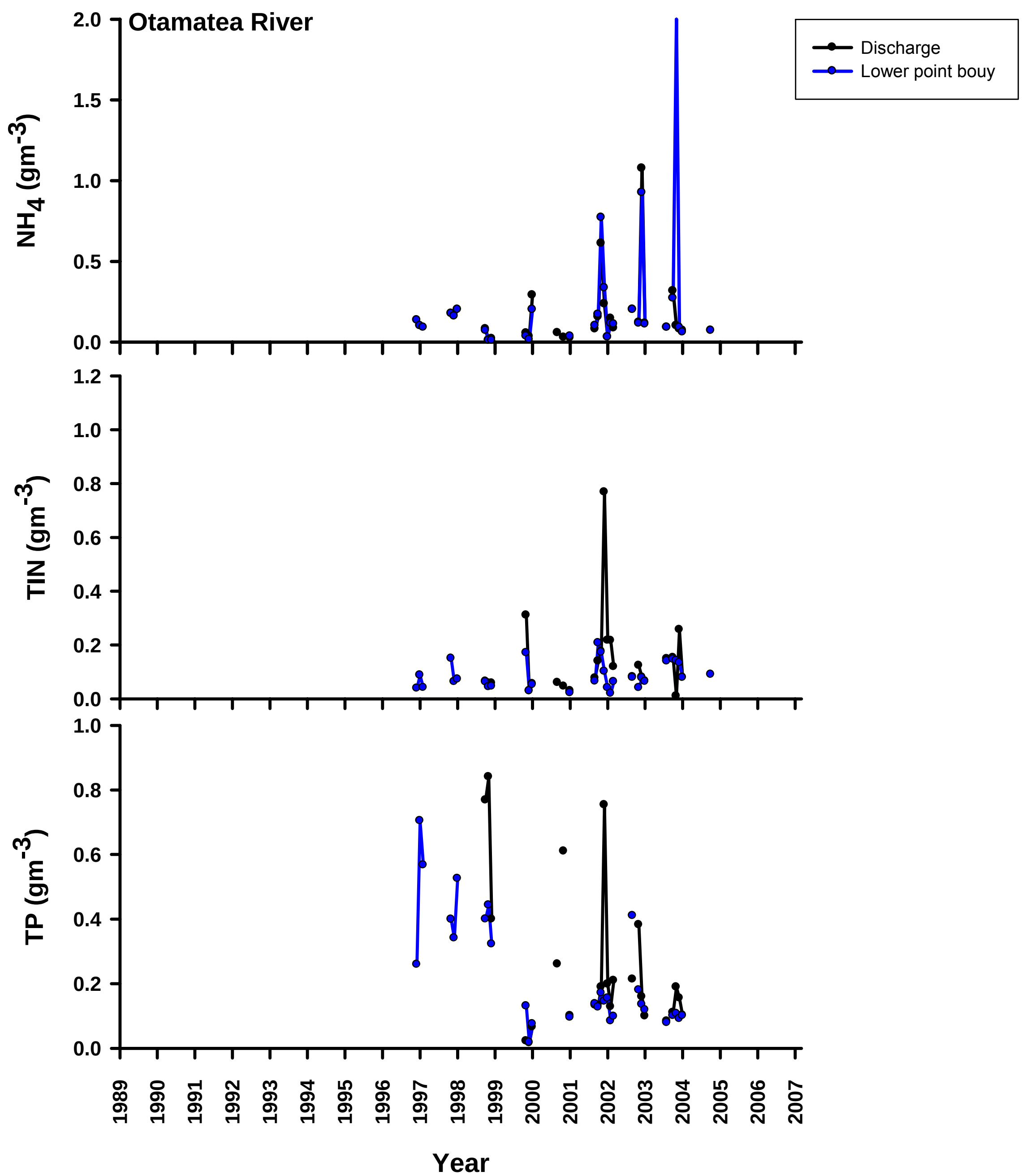
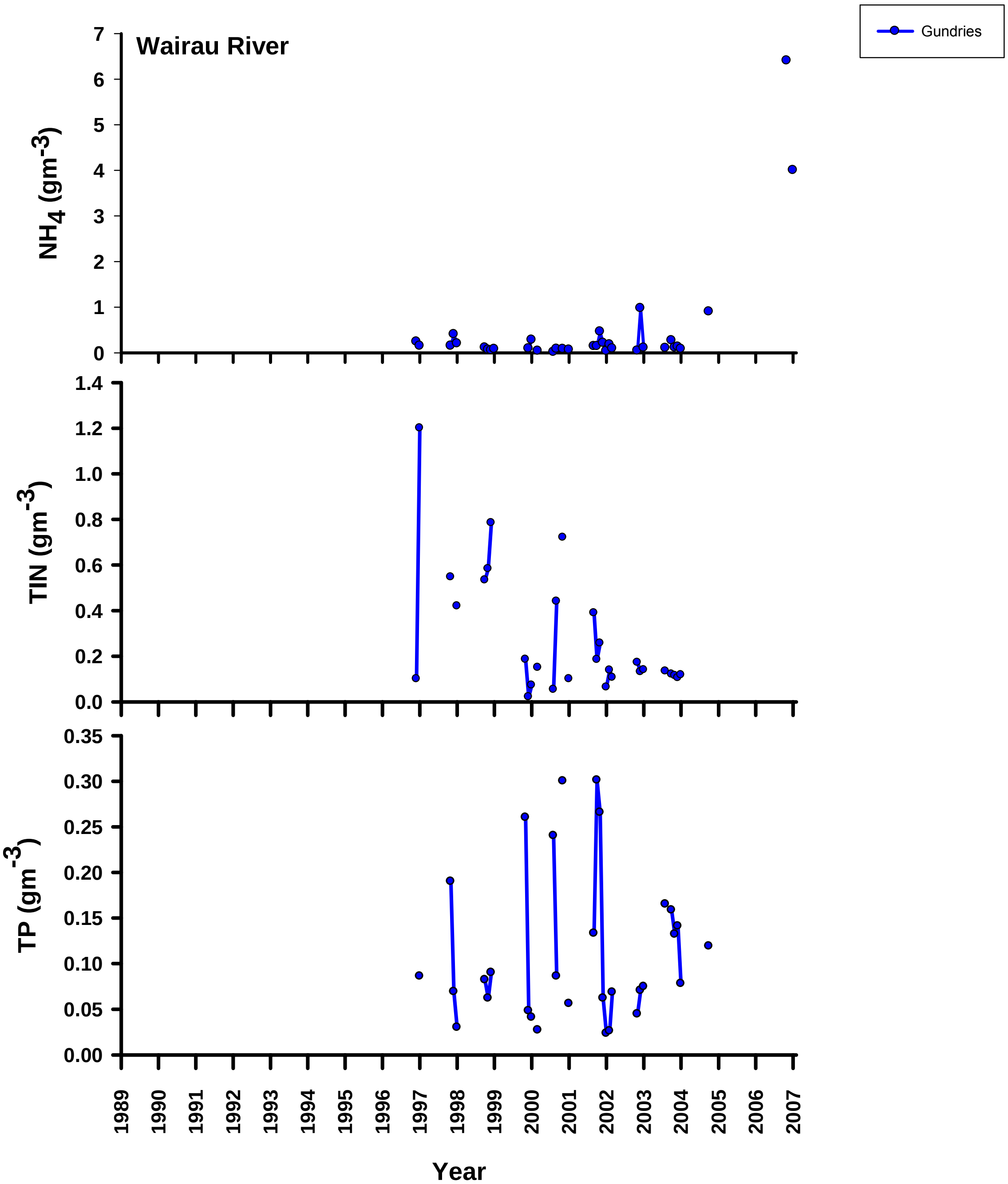


Figure 47b Water quality parameters: ammonia (NH4), total inorganic nitrogen (TIN) and total phosphorus (TP) measured within the Wairau River, Kaipara Harbour (NRC unpublished data).



Ammonium levels within both the Otamatea and Wairau Rivers between 1996 and 2005 (Figure 47a-b), were above the South East Australian trigger guidelines proposed in the ANZECC water quality guidelines (ANZECC 2000). Similarly, total inorganic nitrogen (TIN) was often above the South East Australian guideline levels within both rivers while the total phosphorus (TP) was above the South East Australian guideline levels within Otamatea River only (but see comments in Section 4.1.2). As for Shelly Beach, the data suggest that water quality levels have been impacted by land-based activities for both of these areas (but see comments in Section 4.1.2).

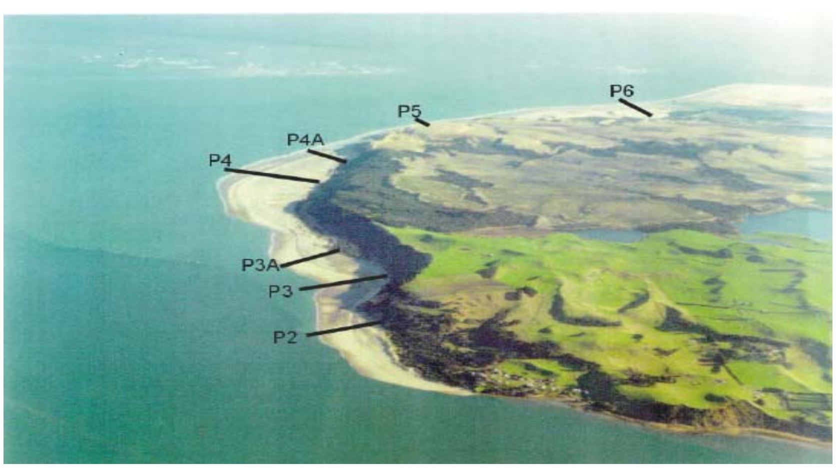
4.1.7 Beach profile analysis (northern Kaipara Harbour)

Beach profile monitoring is undertaken by NRC at 24 locations around Northland, including Pouto Point, Kaipara Harbour. The programme was established to provide information on the positional stability (i.e. erosion, equilibrium, accretion) of the foreshore and foredune or cliff areas at selected coastal areas. Data gathered from the beach profile monitoring are used to delineate coastal hazard zones and assist the NRC to assess both the effect of developments within coastal areas and whether such developments are appropriate (NRC 2006).

Sampling methodology

Formal beach profile monitoring was initiated at Pouto in 1990 then undertaken at six-monthly intervals at sites P2-P6 (Figure 46). The study was requested by the Department of Conservation several years prior to granting a sand mining consent (1992-2004) to Mt Rex for the extraction of a maximum of 60,000 m^3 per year adjacent to the Pouto shoreline, with the main extraction occurring along the shoreline between P3A and P4 (Figure 46).

Figure 46 Locations of beach profile monitoring undertaken along the Pouto shoreline.

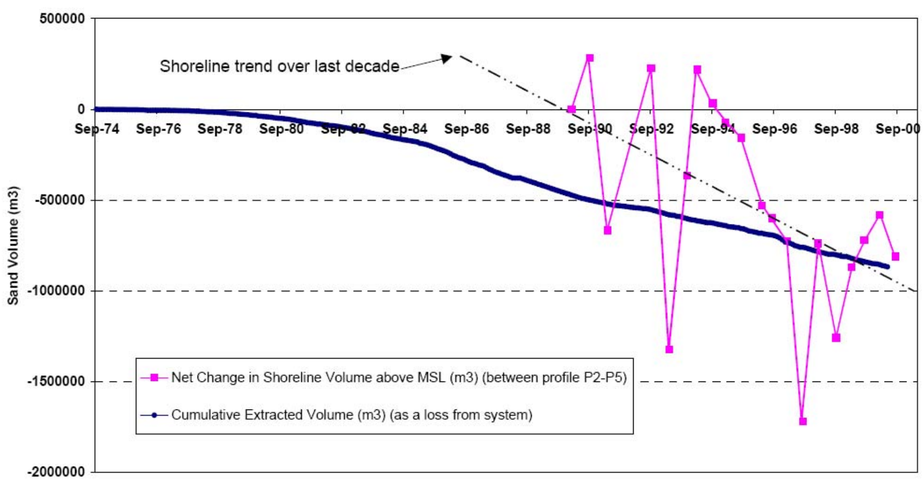


Results

Monitoring revealed that the shoreline of Pouto was extremely dynamic, with changes in volumes above mean sea level (MSL) of up to 1.5 million m^3/yr between P2 and P5. Oscillations in erosion and accretion regularly occur, but the most significant trend between P2-P5 is one of net long-term retreat (erosion) (Figure 47).

There were also significant cycles of accretion and erosion at profiles P2, P3, P3A and P4 and eastward migration along the shoreline of an embayment was observed; this was shown to be a cyclic event with a period of 7-10 years. Furthermore, the total cumulative volume of sand extracted by sand mining from the Pouto shoreline (based on known records) was just under 1,000,000 m^3. The net change in shoreline volume (above MSL) over the last decade has been a loss of approximately 1,000,000 m^3, approximately equal to the total volume that has been extracted (NRC 2002a). It remains unclear whether the recorded change in shoreline was the result, of sand extraction, however, sand extraction ceased in May 2002 (Hume et al. 2003).

Figure 47 Extracted sand volume and change in shoreline volume between profiles P2-P5 for the period 1990-2000 (NRC 2002a).



Main conclusions (NRC 2002) from the beach profile analysis across the Pouto shoreline were:

- The Pouto shoreline displays significant natural changes and some of these are cyclical.
- The Pouto shoreline is currently displaying a period of long-term retreat (erosion).
- It is reasonable to assume that the extraction of large quantities of sand immediately adjacent to the shoreline is likely to affect the shoreline.

- It is not known what proportion of the erosion is due to natural causes or sand extraction.
- The Pouto shoreline is undergoing natural erosion and is not, therefore, an appropriate area for sand extraction.

4.2 Fisheries (catch per unit effort data)

The Ministry of Fisheries collects data about catch (tonnage and size) and effort (e.g. net length per km) to assess the current status of commercial fisheries throughout New Zealand, including those in the Kaipara Harbour (statistical reporting area 044). The data acquired from reporting and from specific research studies (e.g. Hartill 2002) are used to assess sustainability and determine the catch levels for species that are allocated to the commercial and customary sectors in the quota management system. Catch levels are reviewed regularly as part of the Ministry's sustainability round (see Section 3.3.1 for information on commercial species in the Kaipara Harbour).

The data are also used to gauge the level of fishing activity that occurs within the harbour relative to other locations that have designated Fisheries Management Areas, e.g. the Hauraki Gulf, in order to assess if catch per unit effort is increasing or decreasing within a given location and to gauge trends in fleet characteristics, e.g. catch statistics for local fleets relative to non-local fleets (Hartill 2002). The Ministry of Fisheries also collects data from the recreational fishing sector in the Kaipara (Area 22) and this information is incorporated into a national database of recreational catch.

4.3 Birds (Ornithological Society of New Zealand)

The distribution and abundance of wading birds are studied within the Kaipara Harbour twice each year (in winter and spring) by the Ornithological Society of New Zealand (refer to Section 3.5). The studies provide detailed information on waders, including the numbers of Arctic migrants that summer in New Zealand and how many remain over the winter. It also provides counts of New Zealand waders that form flocks in winter, e.g. South Island pied oystercatcher, wrybill, and pied stilts. In addition to these studies, a range of species-specific studies have been undertaken within the Kaipara (refer to www.osnz.org.nz).

4.4 Studies to address specific issues

4.4.1 Sedimentation impacts at Coates Bay

A one-off monitoring study was undertaken by Poynter (1992) for the NRC in response to concerns expressed by Miru Whānau Trust about sedimentation affecting the shellfish beds at Coates Bay in 1991. The sedimentation was thought to be related to forest clearance in the winter of 1991.

Sampling methodology

To monitor the sediment and its associated effects, field surveys were undertaken on three occasions between February and August 1992. Sampling was carried out on three shore-parallel transects, with main species (e.g. *Hormosira banksii*, *Pomatoceros* spp., oysters, and mussels) and physical features (e.g. boulders and substratum characteristics) noted. Sediment samples were also taken for mineralogical analysis.

Results

The biological surveys did not indicate that sedimentation-related impacts were occurring, nor did mineralogical analysis point towards significant sediment loads emanating from the streams feeding into Coates Bay.

4.4.2 Estuarine environmental assessment and monitoring

The physical and chemical properties of sediments, and macrofaunal and infaunal biological communities were sampled at three locations within the Otamatea Arm (Northern Kaipara) in 2002; in conjunction with eight other estuaries throughout New Zealand. The study was part of a nationwide estuary survey conducted by Cawthron (Robertson et al. 2002), with the focus on developing a national protocol for surveying and comparing estuaries. Components investigated were: a comparison of estuaries, an examination of environmental parameters, and determining the optimum sample size to monitor changes within the estuaries.

Sampling methodology

A total of eight estuaries were assessed for broad habitat descriptions and at each estuary between two and four sites were selected for monitoring. Within the Otamatea River three sites were sampled: an upper site approximately 2 km above the Fonterra Maungaturoto discharge, a mid-estuary site approximately 600 m downstream of the discharge on the opposite side of the estuary, and a lower site approximately 10 km downstream from the discharge.

At each site, a series of cores samples were collected and analysed to discriminate broad habitats, characterise sediments, measure contaminant concentrations, and determine macro-invertebrate abundance. The results of the sampling were presented for individual estuaries and comparisons were made among estuaries using a suite of appropriate univariate (e.g. ANOVA) and multivariate (e.g. ANOSIM, PCA, MDS) statistical analyses.

Results

Analyses indicated that significant variation existed; both among the sites within an estuary and between different estuaries, with regard to infaunal and epifaunal assemblages and physical and chemical data. The following section present results from the Otamatea River component.

Broad habitats, sediment attributes and macrofauna

The survey of broad habitats in the Otamatea Arm of the Kaipara Estuary (Figure 48 and Figure 49) indicated narrow intertidal habitat types dominated by unvegetated substrate covering ~40% of the estuary area (primarily very soft mud). The other extensive habitats included mangrove scrubland covering nearly 20% of the estuary (330 ha), and oyster shellfish beds covering 10% (165 ha) of the estuary. Minor habitats were small areas of rush and grassland. Subtidal water in the Otamatea arm was found to permanently cover ~40 % of the total area of the estuary.

Analysis of sediment attributes indicated that all sites within the Otamatea were typically muddy gradients (70% for two upper sites and 35% for the more seaward lower site) and whole sediment samples had elevated organic matter (ash free dry weight) and nutrient (nitrogen and phosphorous) concentrations (Table 12 and Table 13). This was in general contrast to the other estuaries surveyed. Analysis of sediment trace metal contaminants (Cd, Cr, Cu, Zn, Pb, Ni) were low, and all below their respective ANZECC interim sediment quality guideline values (ANZECC 2000), suggesting a low probability of toxicity-related effects in this area of the harbour ((Table 12 and Table 13).

Macro-invertebrate sampling revealed that sites had a moderate infauna species richness (n = 40) and low-medium mean infauna abundance (510 m^{-2}). However, no epifauna were present/recorded at the two upper sites and abundance and richness were relatively low nearer the mouth. Gradients in some species were evident across the estuary from the seaward lower site to upper sites; with cockles (*Austrovenus stutchburyi*) and the nut shell (*Nucula hartvigiana*) more abundant at the lower site and Oligochaete polychaete worms more abundant in the upper sites. Patterns of this nature are likely to be due to the nature of the surficial sediment (increasing muddiness) among the sites surveyed. Common gastropods in the estuary (only one site, 'Site C', was surveyed) included *Zeacumantus lutulentus*, *Diloma subrostrata*, *Diloma zelandica,* and *Cominella glandiformis*. Overall, the mud within the estuary was described as 'very fluid', providing a generally unstable habitat, suggesting that this may inhibit burrowing and the occurrence of tube-building polychaetes due to the difficulty of keeping tubes open. Finally, visual assessment of chlorophyll *a* and phaeophytin at all three sites indicated moderately productive benthic microalgal communities on the muddy sediments, with high phaeophytin concentrations observed at Site C.

Table 12 Physical and chemical sediment properties determined at the Kaipara Estuary (Otamatea Arm).

Parameter	Site A	Site B	Site C	Estuary mean (±1SD)	Estuary range (min - max)	ANZECC mg/kg (dry)	
						ISQG- Low	ISQG- High
Gravel (%w/w) >2mm %w/w	10.1	0.4	17.2	9.2 ± 8.4	0.05 - 33.8	n/a	n/a
Sand (%w/w) < 2mm & >63µm %w/w	22.8	31.6	49.6	34.6 ± 13.7	14.9 - 57.5	n/a	n/a
Mud (%w/w) <63um % w/w	67.2	68.1	33.3	56.2 ± 19.8	21.3 - 77.6	n/a	n/a
Ash free dry weight %w/w	5.9	6.7	4.5	5.7 ± 1.1	1.7 -7.8	n/a	n/a
Total Nitrogen mg/kg (dry)	1942.0	1758.0	1192.0	1630.6 ± 391	800 - 2400	n/a	n/a
TP mg/kg (dry)	537.3	468.3	572.4	526 ± 53	443 - 619	n/a	n/a
Cadmium mg/kg (dry)	0.1	0.1	1.0	0.4 ± 0. 5	0.1 - 1.2	1.5	10
Chromium mg/kg (dry)	22.4	20.6	18.6	20.5 ± 1.9	14 - 33	80	370
Copper mg/kg (dry)	16.3	16.1	9.0	13.8 ± 4.2	7.7 - 18	65	270
Lead mg/kg (dry)	10.4	8.8	14.8	11.4 ± 3.1	7.3 - 17	50	220
Nickel mg/kg (dry)	11.0	9.2	7.9	9.4 ± 1.6	5.5 - 14	21	52
Zinc mg/kg (dry)	61.8	58.3	43.4	54.5 ± 9. 7	37 - 71	200	410

Table 13 Physical and chemical sediment properties determined (standardised to 100% mud) at the Kaipara Estuary (Otamatea Arm).

Parameter	Site A	Site B	Site C	Estuary mean (±1SD)	Estuary range (min - max)
Ash free dry weight %w/w	8.9	10.0	14.0	10.94 ± 0.26	2.37 - 18.78
Total Nitrogen mg/kg (dry)	2918.0	2602.0	3733.0	3084.3 ± 583.5	2100 - 6000
TP mg/kg (dry)	808.8	692.0	1849.8	1116.9 ± 637.4	605.67 - 2840.38
Cadmium mg/kg (dry)	0.2	0.1	3.3	1.2 ± 1.8	0.13 - 5.63
Chromium mg/kg (dry)	33.7	30.1	58.7	40.8 ± 15.5	24.39 - 84.51
Copper mg/kg (dry)	24.6	23.8	28.7	25.7 ± 2.6	17.6 - 41.31
Lead mg/kg (dry)	15.7	13.1	48.8	25.9 ± 19.9	10.1 - 79.81
Nickel mg/kg (dry)	16.6	13.5	25.2	18.5 ± 6.1	11.3 - 37.09
Zinc mg/kg (dry)	93.3	86.3	138.9	106.2 ± 28.6	70.54- 206.57

Figure 48 Otamatea Arm – Structural class habitat (from Robertson et al. 2002).

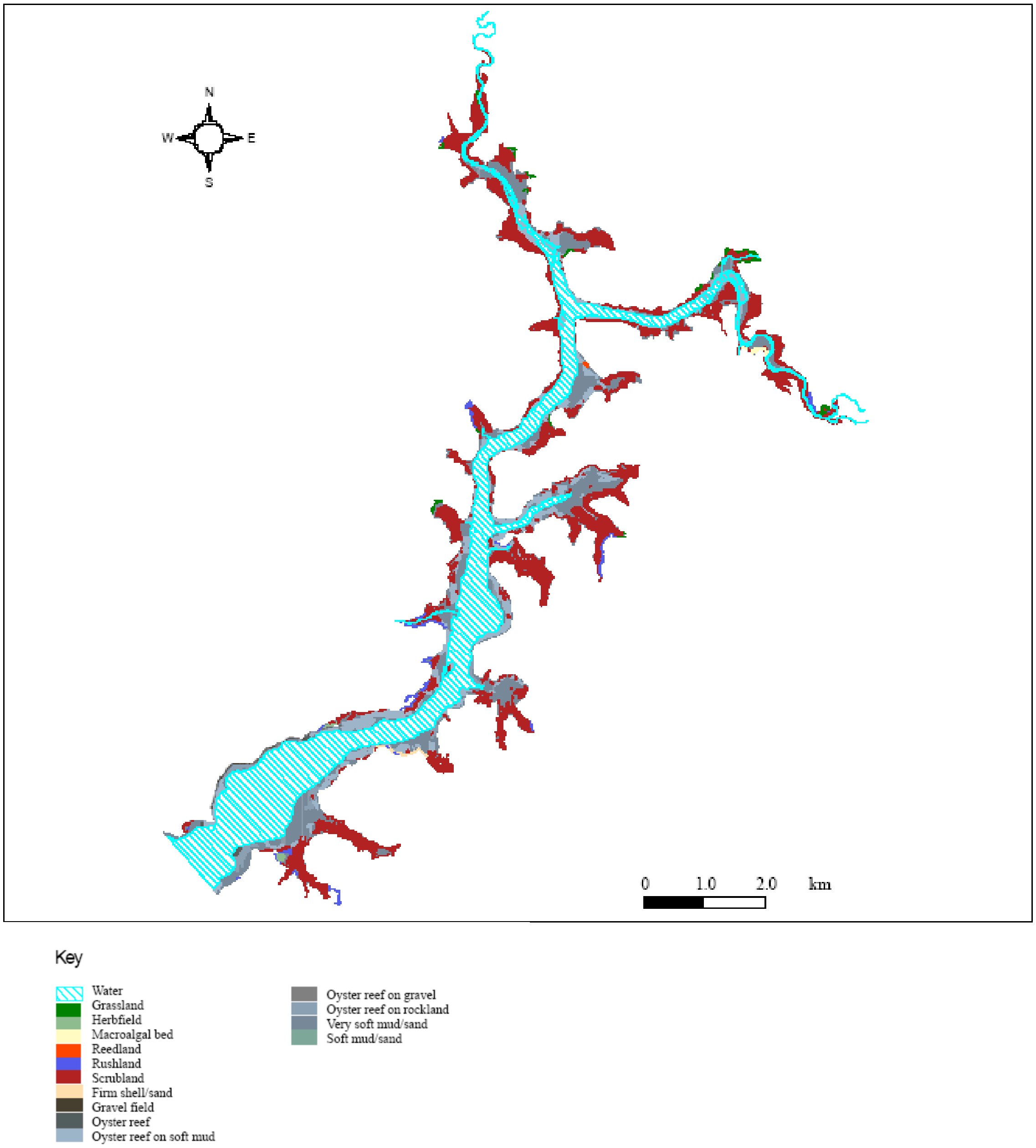
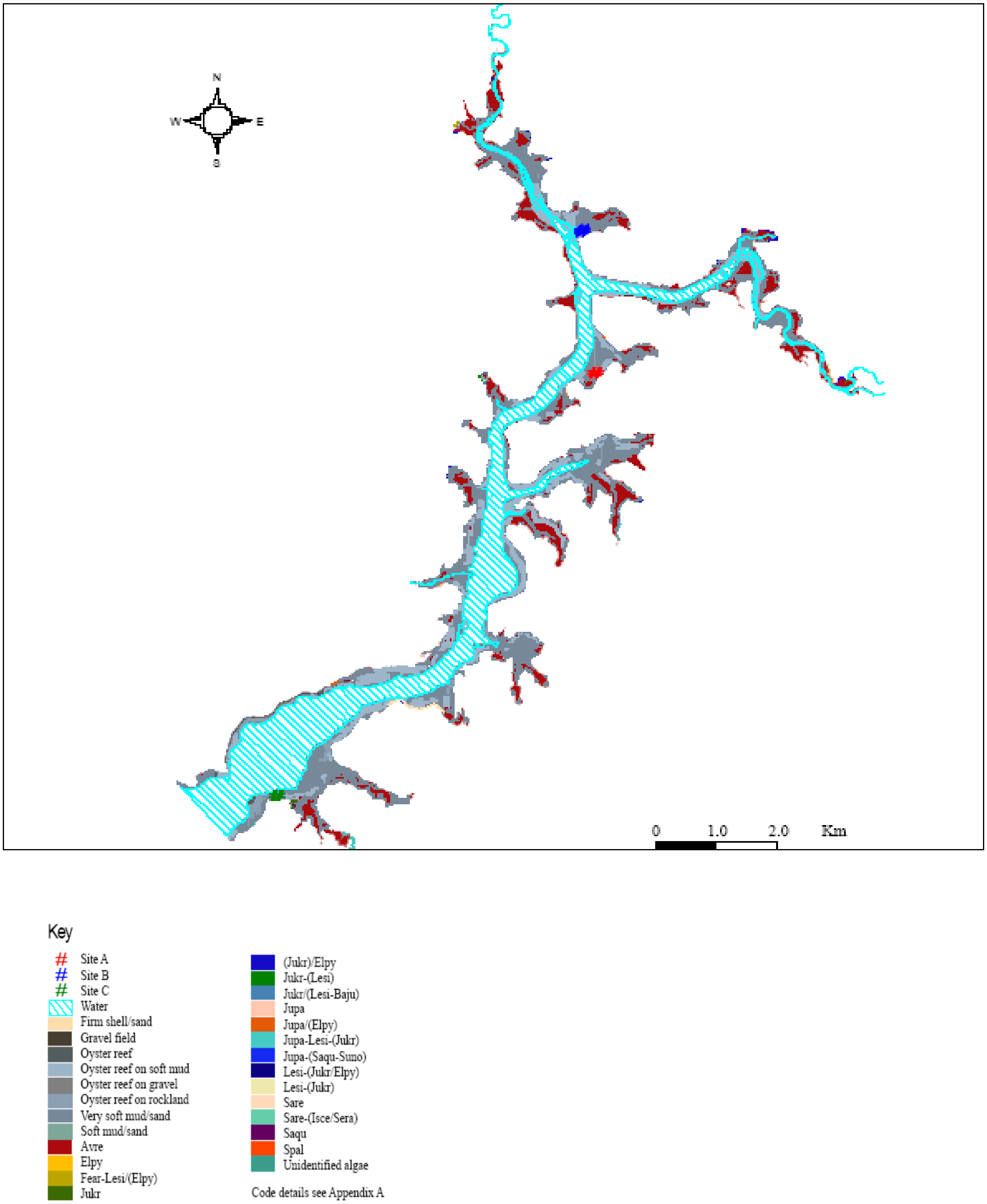


Figure 49 Otamatea Arm – Dominant cover habitat (from Robertson et al. 2002).



4.4.3 Northland Aquaculture Management Area (AMA) study: First order survey and assessment of potential environmental effects

Four potential intertidal aquaculture management areas in the northern Kaipara Harbour were investigated in 2004, as a part of an assessment of a further 15 potential aquaculture management areas throughout Northland (Haggitt and Mead 2005).

The four areas assessed were: one 4 ha intertidal area between Karakanui Point and Kapua Point (Kirikiri Inlet), one 84 ha intertidal area between Puriri Point and Te Kopua Point (Arapaoa River), one 10 ha intertidal area adjacent Te Kopua Point (Arapaoa River), and one 6.7 ha intertidal area within the Whakaki River, north-east of Ngamotu Island (Figure 50).

Sampling methodology

All Kaipara AMAs were divided into a grid format, with GPS coordinates selected at random within the grid. These coordinates were then used to position quadrats and transects for sampling and/or to take video samples. Intertidal sites were surveyed approximately three hours either side of mean low water spring.

To quantitatively sample soft-sediment communities, 0.25 m^2 quadrats were used. The area within each quadrat was removed down to a depth of 100 mm, and sieved in situ using a 1 mm mesh. All marine organisms (primarily macro-invertebrates) retained on the sieve were identified to a species level (where possible) and counted. Representative faunal samples were preserved in buffered 5% formalin and further identifications made in the laboratory (i.e. microscopic analysis).

Additional notes were taken on the site characteristics such as sediment nature, whereas substratum complexity was assessed using a ranking scale form 1 to 4. These components were also documented with photographs and video. No sediment samples were taken for size-fraction analysis, nor were any water quality samples taken.

Results

Physical

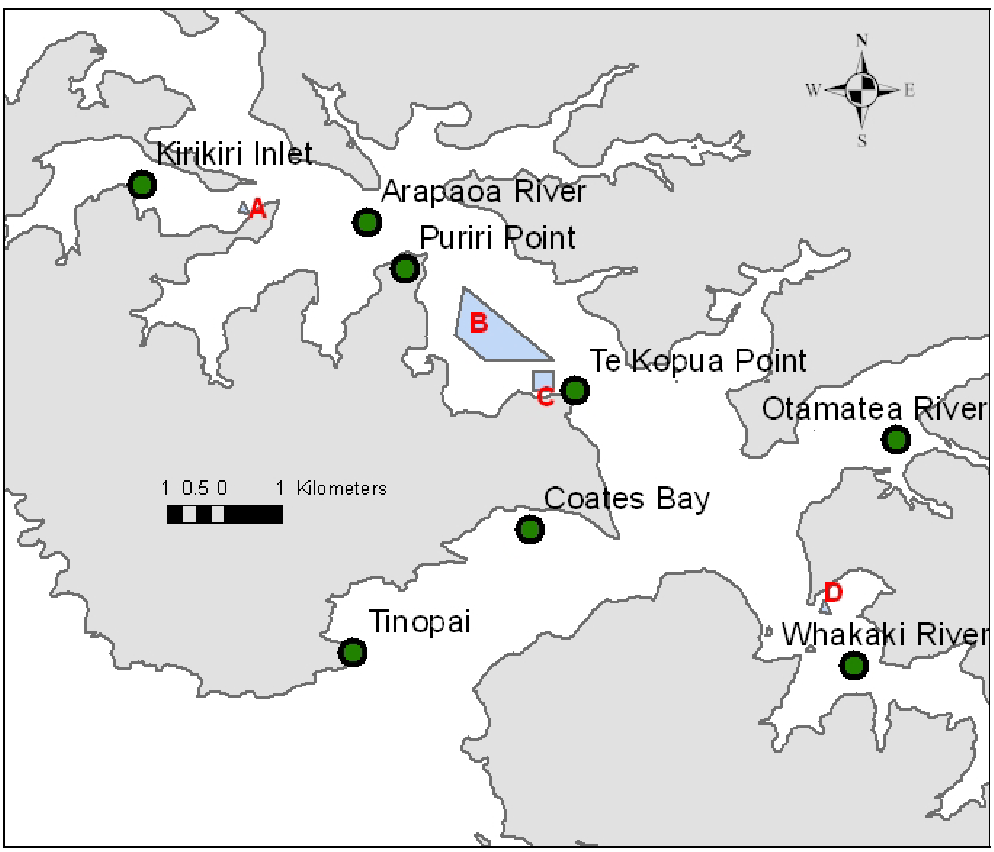
All AMAs were characterised by homogeneous tidal mudflats with a low substratum complexity rating (i.e. 1). The 4 ha AMA was flanked by a decommissioned oyster farm to the northwest and debris from this was evident within the area. Shallow tidal mudflats extended to a shallow channel ~1 m (MLWS). Severe land erosion was evident adjacent to the AMA.

Biological habitats and species distributions

The 4 ha intertidal AMA was dominated by polychaete worms including *Glycera americana*, *Orbinia papillosa*, and Nereid/Nicon worms; the mud crab *Helice crassa*, *Alpheus* sp. and the nut shell *Nucula hartvigiana* (Figure 51). Numerous dead cockle shells (*Austrovenus* *stutchburyi*) were present in samples although no live specimens were observed. There were no obvious community boundaries across the AMA.

The 10 ha intertidal AMA was dominated by polychaete worms including *Glycera americana*, *Orbinia papillosa*, and Neried/Nicon worms; the mud crab *Helice crassa*, the shrimp *Alpheus* sp., and the nut shell *Nucula hartvigiana* (Figure 51). As for the 4 ha intertidal AMA, dead cockle shells (*Austrovenus stutchburyi*) were abundant in samples although no live specimens were found. For the majority of communities there were no obvious zonation boundaries within the AMA; however, dense patches of the Pacific oyster (*Crassostrea gigas*) were present on intertidal reef along the inshore boundary of the proposed AMA. The oyster borer (*Lepsiella scobina*) and cat's eye (*Turbo smaragdus*) were also conspicuous within this zone.

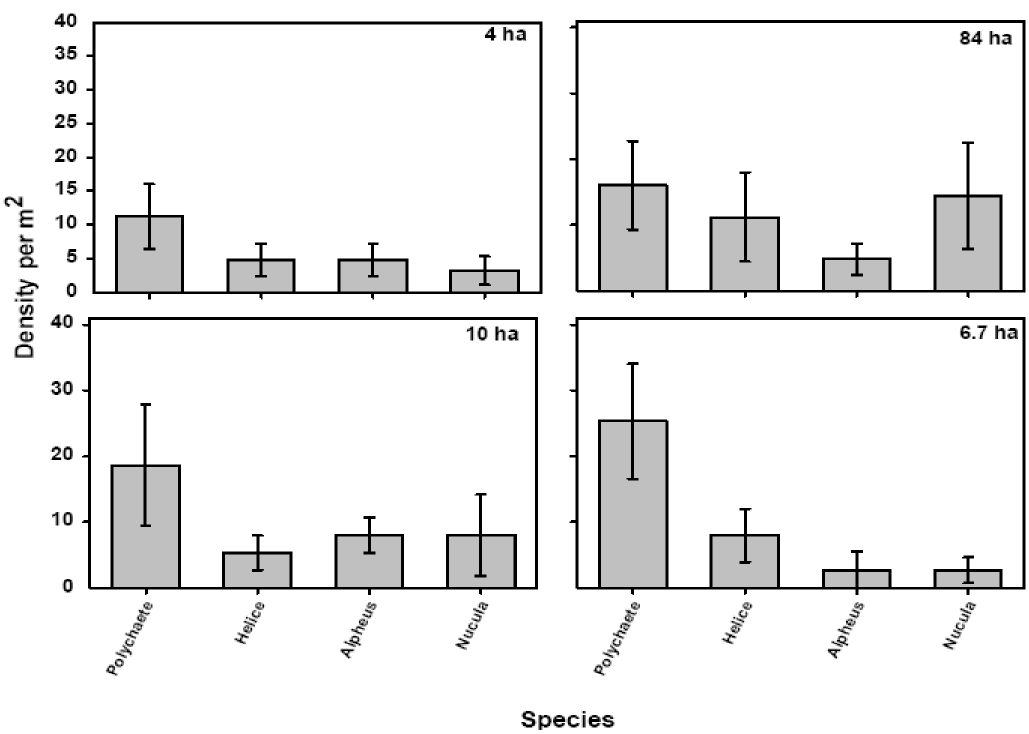
Figure 50 Location of four Aquaculture Management Areas in the northern Kaipara Harbour: A = 4 ha, B = 84 ha, C =10 ha, D = 6.7 ha.



The 84 ha intertidal AMA between Puriri Point and Te Kopua Point along the Arapaoa River had the characteristic flora and fauna of the other AMAs, dominated by extensive tidal mudflats with a habitat complexity of 1. The south-eastern arm of the AMA, bordering the main channel, was dominated by extensive mats of the Asian date mussel (*Musculista senhousia)*; these extended halfway along the outer boundary of the proposed AMA. The estimated density of mussels within the mat was ~3,200 0.25 m^{-2}. Inshore regions of the AMA were dominated by polychaete worms including *Glycera americana*, *Orbinia papillosa*, and Neried/Nicon complexes; the mud crab (*Helice crassa)*, shrimp *Alpheus* sp. and low densities of the nutshell (*Nucula hartvigiana)* (Figure 51).

The 6.7 ha intertidal AMA within the Whakaki River was also dominated by polychaete worms including *Glycera americana*, *Orbinia papillosa*, and Neried/Nicon worms; the mud crab (*Helice crassa)*, *Alpheus* sp. and the nut shell (*Nucula hartvigiana)* (Figure 51). The horn shell (*Zeacumantus lutulentus)* and purple-mouthed whelk (*Cominella glandiformis*) were also conspicuous on the intertidal mudflats and the Pacific oyster (*Crassostrea gigas*) was abundant on intertidal rocky reef adjacent to the aquaculture management area.

Figure 51 Density of the four most abundant macro-invertebrates within the proposed intertidal Aquaculture Management Areas within the Kaipara Harbour. Data are means ± S.E. (4 ha n = 6 quadrats; 84 ha n = 15 quadrats; 10 ha n = 10 quadrats; 6.7 ha n = 12 quadrats). Species include: Polychaete worms, mud crab *Helice crassa*, shrimp *Alpheus* sp. and the nut shell *Nucula hartvigiana*.



Environmental/Ecological effects

The main environmental effects associated with the addition of the four oyster farms were considered to be those arising from the direct smothering of resident species during farm construction, and increased sedimentation and modification of the surficial sediment over time during farm operation. The existing high abundance of *Helice crassa* and *Alpheus* within each of the AMAs was proposed to be somewhat indicative of the already modified nature of the harbour. The seemingly high abundance of fine mud throughout all the AMAs was also flagged as being potentially problematic due to its potential to cope with increased organic enrichment (Hartstein and Rowden 2004). While this study was first-order in nature (i.e. sampling was not spatially intensive), the Kaipara Harbour areas were the most degraded of all the locations surveyed in the Northland Region; mainly due to erosion on the landward margin of the coastal marine area and the abundance of invasive species.

The carrying-capacity (with respect to food availability) and the hydrodynamics of the AMAs were not assessed as part of this study.

4.4.4 Kaipara sand study

A study of the sand movement, storage, and extraction across the Kaipara tidal inlet was undertaken between 2000 and 2003. The study had five components and the main findings are summarised in Hume et al. (2003).

Sampling Methodology

The five components investigated included: anecdotal evidence of sand movement and morphological changes in the harbour (Parnell 2002), geomorphic evidence (Hume et al. 2003), sediment mapping (Hume et al. 2001), measuring sand transport in subtidal areas (Green et al. 2002), and sand transport along the shoreline (Osborne and Parnell 2003).

Results

Main findings of the study were:

- Tapora Banks is a zone of sediment transport-convergence and is actively accreting at a nourishment rate of ~100,000 m^3 per spring-neap cycle (~14 days) along a 1.5 km^2 front (or ~2,600,000 m^3 per year).
- Sand within the inlet is derived from the open coast, with considerable recirculation among the various components (the open coast, tidal deltas, inlet shorelines, and deeper channels). Sand moves into the estuary in a series of jumps over large distances associated with storms and large tides: the net result is that some sand is trapped in the estuary to build up banks and shoals whereas some sand moves back out to the open coast.

- Sediments in the inlet range from fine sand (0.125-0.25 mm) to a patchy distribution of medium sand (0.25-0.5 mm).
- The volume of sand in storage within the system is several orders of magnitude greater than the sand extracted at the Tapora Banks.
- Holocene sand storage (sand accumulated in the last 6500 years) is estimated to be: 266 million cubic metres (M m^3) at North Head, 159 M m^3 at South Head; 12.3 billion M m^3 ebb tide delta (North Spit and Southern Shoals); 240,000 m^3 Kaipara Head-Pouto Point Shore; 11 M m^3 and 15 M m^3 (above the level of -5 and -10 chart datum respectively) at the southern area of Tapora Banks; 2 M m^3 and 16 M m^3 (above the level of -5 and -10 chart datum respectively) at the northern area of Tapora Banks (Lady Franklin Bank).
- Current and potential areas of the harbour that have the potential to sustain extraction include: Tapora Banks; Tauhoa Bank; the shorelines of North Head (North Head Oceanside, North Head-Kaipara Head, Kaipara Head-Pouto); and the South Head Oceanside area comprising the ebb tide delta deposits (southern shoals and North Spit). Details for sand extraction from these sites are presented in Table 14 (Hume et al. 2002) and Figure 54 shows the site locations.

Figure 52 Current (Tapora Banks) and alternative extraction sites assessed for the Kaipara tidal inlet. Hume et al. (2003).

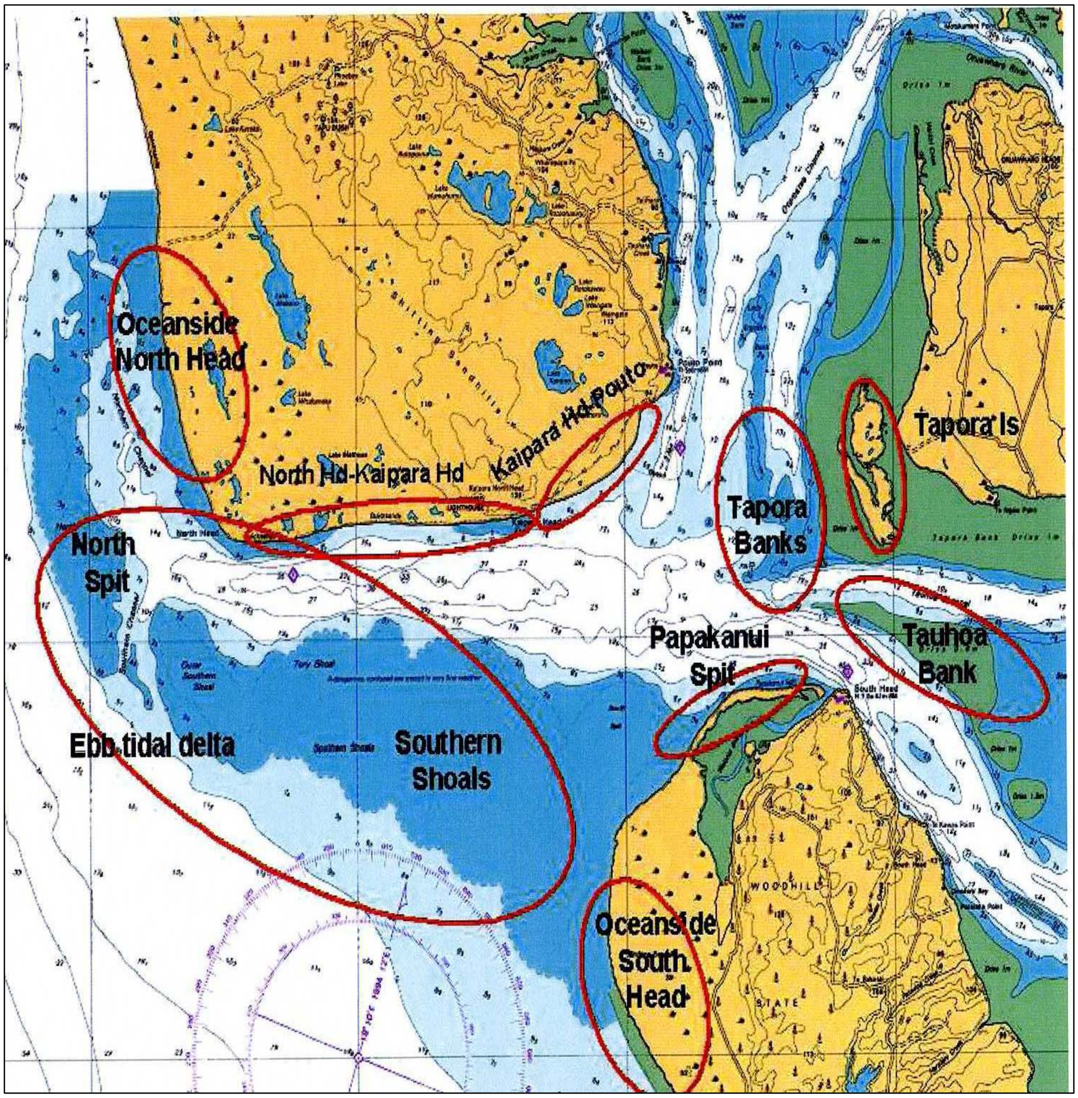


Table 14 Breakdown of estimated sustainable volume of sand for each site that passed the sustainability factors test (Hume et al. 2003). Factor F describes the fraction of the natural replenishment (A) that is deemed appropriate to extract. It reflects the degree of confidence Hume et al. (2003) have in understanding of the Kaipara system (i.e. possible physical effects, mechanisms, rates of sand replenishment, and buffer size). As new information becomes available in the future these figures can be revised along with the sustainable volumes of extraction.

Extraction site	Status of Extraction	Natural replenishment rate A (m^3 per year)	Factor *F* (number of units)	Reasons for choice of *F*	Sustainable volume of sand extraction V (m^3 per year)
Tapora Banks	Current 150,000 m^3 / yr consented	2,600,000	0.3-0.5	Large buffer Reasonably confident estimate of A, but no information of how that may vary for the Tapora depositional complex Reasonably confident that possible physical effects can be discounted Link to Tapora Island is not completely understood Unanticipated effects on Tapora Island can be managed by monitoring	780,000 to 1,300,000
Oceanside shoreline (North Head)	Alternative	60,000	1	Large buffer *A* large Accreting shoreline Low likelihood of physical effects in highly energetic environment	60,000
Inlet shoreline (North Head – Kaipara Head)	Alternative	?	0.1-0.3	Larger buffer than Kaipara Head-Pouto Pt, but not smaller than Oceanside shoreline Larger *A* than Kaipara Head-Pouto Pt, but not smaller than Oceanside shoreline Uncertain of estimate of A (could improve with more detailed model)	?
Inside shoreline (Kaipara Head-Pouto Point)	Suspended in May	Zero	< 1	Small buffer *A* could be highly variable Uncertain of estimate of *A* (could improve with more detailed model) Extraction should be restricted to times when the shoreline is actively accreting	Zero
Oceanside shoreline (South Head)	Alternative	Zero	1	Large buffer *A* small, as little net build-up on this eroding shoreline Low likelihood of physical effects in highly energetic environment	Zero
Ebb tide delta	Alternative	500,000	>1	Large buffer *A* very large Low likelihood of physical effects in highly energetic environment	500,000 +

4.4.5 Review of marine mammal impacts in relation to proposed aquaculture in the South Kaipara Harbour

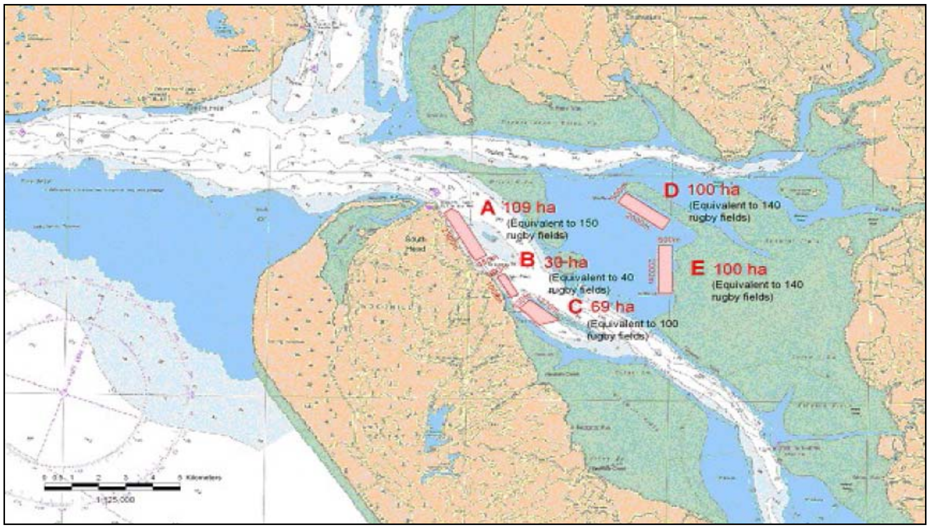
The possible impacts of seven potential aquaculture management areas (AMAs) on marine mammal populations were assessed in a desktop review by Fisher (2005). The AMAs included three sites near South Kaipara Head (A, B, C), two near Orongo Point (D, E), and two small existing farms in the Oruawharo River near Port Albert that appeared to have been abandoned.

Details of the five proposed AMAs (Figure 53) (which have now been withdrawn by the ARC) were:

- A. Proposed mussel farm - 109 ha
- B. Mussel farm - 30 ha (Biomarine Limited)
- C. Proposed mussel farm - 69 ha
- D. Oyster farm - 100 ha (Biomarine Limited)
- E. Proposed oyster farm - 100 ha

At the time of the review, Biomarine Limited was applying for resource consent in relation to AMA B. The purpose of the review was to provide more information on potential and cumulative effects (as defined in Section 3 of the Resource Management Act 1991 – RMA), mainly in relation to the proposed mussel farm but also in relation to the other proposed Kaipara AMAs. The assessment of effects on marine mammals accompanied two other related assessments concerning the Biomarine Limited application and other proposed AMAs. These were the effects on waders and other coastal birds (Section 4.4.6) and the effects on plankton, benthos, and water column properties (Section 4.4.7).

Figure 53 Location of potential Aquaculture Management Areas in the southern Kaipara (now withdrawn by the ARC).



Methodology

The study of marine mammal impacts had two components:

- A review of existing information on marine mammal use of the proposed AMAs and adjacent areas within the Kaipara, together with information on non-target areas. Information sources used were primarily Department of Conservation databases and reports.
- A review of existing information on the positive and negative effects of aquaculture on marine mammals in New Zealand and internationally.

Results

The potential effects associated with aquaculture that may impact marine mammals are outlined in Table 15.

Table 15 Potential effects associated with aquaculture that may impact on marine mammals (summarised from Fisher 2005).

Factor	Description	Potential Impact(s)
Structures: entanglement and stranding	Oysters: 100 mm posts ~4 m, connected by a single 4 mm plastic wire. The mesh cages (approximately 130 mm diameter) are suspended from this wire. The rows (consisting of two wires about 900 mm apart) are approximately 20 m apart. Mussels: Typical mussel longlines consisting of backbones with attached vertical growing lines.	Oysters: It is unlikely that marine mammals would regularly feed over shallow subtidal mudflats because of the likelihood of stranding, unless attracted to the area by fish. The risk of entanglement at proposed oyster farms is therefore considered low. Mussels: Entanglement in mussel longlines is generally considered low for dolphins and large whales, the latter due to their infrequent forays into the Kaipara Harbour. The potential risk of entanglement in mussel farm longlines gear might increase when large aggregations of animals are present, particularly at feeding bouts when most effort is focused on capturing prey.
Litter	Rope, growing lines, ties for securing growing lines to backbones, and whole mussel floats.	Plastic debris constitutes a potential threat as it may be ingested by, or entangle, marine mammals. Ingested litter can cause mortality by dehydration or drowning from immobility, gut blockage, or chronic poisoning by toxins released in the intestines.
Shell waste	Deposition of shell waste on the seabed during harvesting and from storm events.	Shell waste deposition on the seabed could form a reef and attract marine wildlife but, conversely, could disturb and exclude a range of important species.
Artificial lighting	All marine farms have lighting for navigational requirements, and some have sufficient lighting to allow operations to continue through the hours of darkness.	Lighting at marine farms might have some impact on fish distribution and availability, or other organisms that respond to ultraviolet radiation. Sheltered bays and sounds used for aquaculture may be used as resting, breeding, or nursery sites for whales and dolphins and in these situations lighting over a large area could have a detrimental (disturbance) effect.
Disturbance by boats	Boat activities are associated with aquaculture for deploying and maintaining gear, stocking cages, feeding, and harvesting.	Marine mammals respond differently to the presence of vessels, resulting in changes in behaviour. Hector's and Maui's dolphins can be attracted to vessels and may become used to the presence and noise, particularly from ferry boats, coastal fishers, and tour boats that regularly ply the same stretch of waters. Boats may temporarily disturb fish from the seabed, disperse shoals, or change the distribution of fish prey, which may be beneficial or detrimental to marine mammals. Changes in the macrofaunal community structure in the access corridors to farms may occur due to the compaction and dispersal of sediment by the physical disturbance of heavy boat traffic.
Noise disturbance and stress	Main noise sources include mussel farm workboats and other marine craft	Marine mammals are acoustically sensitive, vocalising over a wide range of frequencies from 40 Hz to 150 kHz. Marine mammals may alter their behaviour in response to noise from mussel farm workboats and other marine craft. This may disrupt social bonds, disturb biologically significant behaviour, result in reduced habitat occupancy, or move animals into hazardous situations. The nature and extent of behavioural responses to underwater noise will depend on a variety of factors, including the inherent sensitivity of a species, an individual's experience of the noise concerned, and any learned association with that sound or other similar signals.

Factor	Description	Potential Impact(s)
Habitat fragmentation	Occurrence of structures within marine mammal habitat range	A decline in available habitat (and associated prey) could lead to an increase in foraging times, competition for local resources, and increased inter-specific competition between marine mammals and other higher marine predators. Chronic stress from disturbance, habitat fragmentation, or competition can act through the pituitary-adrenal axis to suppress the immune response. Fragmentation effects are intensified when they affect rare or threatened species that are already at risk. Habitat fragmentation could have significant detrimental effects on the health, fecundity, and longevity of individuals, particularly for Hector's and Maui's dolphin and other species on the edge of their ecological range.
Habitat exclusion	Occurrence of structures within marine mammal habitat range	Some species of marine mammals may be excluded from areas used for the cultivation of mussels and oysters as a consequence of several factors: a preference for open water (access to the surface and seabed, and ability to echolocate prey), increased boat and noise disturbance, and reduced food supply from changes in the abundance or availability of prey.
Habitat creation	Occurrence of structures within marine mammal habitat range	Oyster and mussel farms may benefit some species by providing them with new resting areas and feeding opportunities, however, they may disadvantage other species. It is not known what effects the new habitats associated with mussel and oyster farms will have on particular marine mammal species.

Main findings of the study in relation to the proposed AMAs within the Kaipara were:

- There was insufficient information available to determine whether Maui's dolphin will overlap with the proposed marine farms in the Kaipara, or to determine what extent such developments might have upon the species as a whole.
- Potential cumulative effects from several marine farm sites and the effects on the ecology of marine communities (competition with other plankton grazers, fish larvae recruitment, etc) need to be considered.
- Monitoring of Maui's dolphin in harbours has been inadequate in the past, with a lack of site-based habitat studies and surveys over a number of seasons. Any habitat used by the Critically Endangered Maui's dolphin should be considered important to the recovery of the species. A long-term monitoring programme for Maui's dolphin should be devised in collaboration with each AMA to study the habitat use and possible impacts on this and other marine mammal species that may frequent the area.

Key information requirements (including data and related methods) needed to assist with decisions on the Kaipara AMAs are:

- Passive acoustic monitoring of dolphins using autonomous data loggers and visual surveys from land and boat. Monitoring should commence prior to the installation of any aquaculture developments. A minimum of six monitoring stations are recommended to increase the detection range for echolocating dolphins; two in the deep-water channel and others at the proposed mussel and oyster sites. Each station should be chosen to avoid shipping lanes and known fishing areas.

- The acoustic monitoring should be supplemented with timed land-based watches to survey marine mammals at various tidal states and times of the day.
- A steering group should review all data before approving any development within the proposed AMAs, with particular consideration given to Maui's dolphin if these are found regularly in the Kaipara Harbour.
- The approval of any marine development should include a clear course of action that the farm must follow if negative or compounding impacts are identified.
- A staged development (e.g. permitting one small farm <10 ha) in each AMA could be used to investigate the interaction of marine mammals with farms in areas where impacts on marine mammals are considered to be low risk. At such experimental sites, researchers could work in collaboration of marine farmers to monitor key wildlife species before, during, and after the development.
- One method to evaluate any changes in marine mammal habitat use of the Kaipara as a result of the placement of mussel farms would be to compare habitat use at similar locations in the harbour with no farms. Experimental design should be discussed with stakeholders to ensure that any marine mammal monitoring is logistically workable with the proposed aquaculture activity.
- An assessment of fish stocks using a full BACI (Before, After, Control, Impact) experimental design could be employed using techniques such as sonar and diver transects.

4.4.6 Review of the potential effects of proposed aquaculture farms on birds in the South Kaipara Harbour

A desktop review focused primarily on the potential impacts on the waders and other coastal birds of the five proposed aquaculture management areas (AMAs) (Figure 53) in the south Kaipara was undertaken by Pierce (2005).

Methodology

There were two components to the study:

- A review of literature on waders in Kaipara Harbour. This included existing information on the use by coastal bird species of the proposed AMAs using data from the Ornithological Society of New Zealand (OSNZ), specialist reports (including NIWA) on bird use of the harbour, and other scientific reports.

- Existing information on the impacts of aquaculture on avifauna, including an international literature review and case studies of New Zealand aquaculture in Mahurangi, Houhora, and Parengarenga Harbours.

Results

Key findings and recommendations of the review were:

- The South Kaipara is an internationally important area for waders and other avifauna species.
- The selection of large (e.g. 100 ha) aquaculture sites in this harbour needs to take full account of the ecological values of the potential sites and the associated risks to those values, including risks to avifauna.
- For AMAs with intertidal areas, key avifauna species that need to be considered include: oystercatchers, bar-tailed godwit, lesser knot, banded dotterel, black stilt, Caspian tern, and the New Zealand fairy tern. It was suggested that while the roosting areas for these species are well known within the harbour, the main feeding areas are poorly known for all species.
- In general, intertidal areas should be avoided for aquaculture in the Kaipara Harbour unless structured, seasonal sampling indicates low bird use.

The following recommendations apply to subtidal sites:

- Determine the precise boundaries of the area(s) inundated at MLWS and the area(s) in which wading birds will forage (MLWS minus ~20 cm).
- Assess local current and sedimentation patterns to determine whether sandbanks in the proposed farm area(s) are stable, eroding, or accreting.
- Maintain a wide buffer of ~100 m between any approved farm and potential foraging areas of wading birds, and allow for subtidal foraging to 0.2 m below MLWS.
- Ensure that no damage or disturbance occurs to tidal flats outside of farms, i.e. access to and from farm(s) should be by boat only.
- Monitor bird use in and around any farmed site to determine the responses of key bird species over time.
- For subtidal sites that are to be assessed as potential mussel farm locations, determine the proximity of colonies of birds that might be at risk of entanglement. Birds that could be at risk include: northern little blue penguin, Australasian gannet, and terns. These species are best surveyed during the spring breeding season and fairy terns should also be surveyed in autumn-winter when the population in the harbour is greatest. In addition, determine the extent of feeding undertaken by individuals of these species in and around the proposed AMAs.

4.4.7 Desktop assessment of potential and cumulative effects on plankton, benthos, and water column of the proposed AMAs in the South Kaipara Harbour

In order to provide additional information on the potential and cumulative effects of the proposed aquaculture management areas (AMAs) (Figure 53) on plankton dynamics, benthic communities, and water column properties, a desktop review was undertaken by Gibbs et al. (2005).

Methodology

The review focused on two main components:

- Direct effects on high value species, populations, and communities.
- General effects on ecosystems.

The main sections of the review were:

- A summary of the current state of knowledge of the baseline southern Kaipara Harbour environment.
- A detailed discussion of the current state of knowledge regarding interactions between marine shellfish farms and the environment, and the minimum information required for an assessment of the effects of shellfish culture on the environment. This section encompassed information collected from both national and international studies.
- A description of the potential and likely effects of the proposed AMAs, including the Biomarine applications, on the surrounding environments in the South Kaipara Harbour.
- A discussion of the findings of the previous section, and an analysis of the gaps and deficiencies in the information provided.
- Recommendations to further assist in the assessment of potential effects.

Results

With regard to direct effects to high value species, populations, and communities, Gibbs et al. (2005) suggest that while interactions between the shellfish culture and the major commercial finfish species in the Kaipara were likely, it was difficult to quantify the level of these likely interactions due to a lack of information available on the distribution of taxa in the harbour.

For general ecosystem effects, it was suggested that:

- Three sustainability performance indicators (clearance efficiency, filtration pressure, and regulation ratio) used to assess the impact on suspended particulate matter were low.

This indicates that the proposed level of bivalve culture to be introduced in the AMAs will not be able to control the suspended particulate matter, particularly the phytoplankton dynamics in the South Kaipara Harbour.

- Due to the strong current flows that were expected at the proposed sites, it was unlikely that the proposed level of shellfish culture would have significant effects on the benthos through direct enrichment of the seabed.
- Due to the predicted strong current flows at the various sites, no major shifts in the nutrient recycling characteristics of the seabed environment were envisaged.
- The presence of significant aquaculture structures may potentially alter local water flows and current movements that may, in turn, possibly influence seagrass beds through the changes in hydrodynamics and sediment transport. However, the degree to which this may occur would depend on the design and density of the structures.
- Some consideration should be given to an assessment of biosecurity risk.
- The majority of interactions between the proposed bivalve cultures and the general ecosystem would occur immediately after the establishment of the farms, and the environment would adapt to the introduction of the activity reasonably quickly.

Gap analysis carried out as part of the assessment identified a range of shortfalls that gave rise to the following suggested actions:

- The lack of environmental data from the region could be used as an excuse to apply the Precautionary Principle in its narrowest interpretation and halt the establishment of any AMAs or delay establishment until new information comes to hand. However, given that the proposed activity is not incompatible with the marine environment and new information would take a long time to obtain (and the uncertainty surrounding this information would still be very high), it was recommended that some thought be given to the level of precaution that stakeholders would want to take regarding the proposed AMAs.
- In order to establish the appropriate level of precaution required, it would be beneficial to obtain more information on the desired balance between the economic and the environmental status of the region, and then investigate the real risks of the proposed aquaculture to this desired status.
- Fine-scale commercial and recreational fishing catch, effort, and location data (if available) should be analysed to identify the location of fishing hotspots relative to the proposed farms. This information would greatly assist in assessing the possible impacts on fishing activities.

- A desktop nutrient and detritus budget for the South Kaipara Harbour, predominantly in relation to intertidal mudflat habitats, would give insight into possible effects of the proposed AMAs on these important habitats.

4.4.8 Assessment of the risks of possible AMAs on key benthic habitats in the Kaipara

In response to some of the information gaps identified in Gibbs et al. (2005) (Section 4.4.7) and based on recommendations from the ARC's SoE study (Hewitt and Funnell 2005) (Section 4.4.1), Elmetri et al. (2006) used a staged approach to assess the risks of the five potential aquaculture management areas (AMAs) (Figure 53) on key benthic habitats within the Kaipara Harbour.

Methodology

A staged approach looked at defining high value communities and habitats, defining the footprint for each AMA (A to E), and assessing the risks to high value communities. The assessment used a range of approaches including a mix of quantitative (Bayesian approaches), semi-quantitative (scaling analysis), and expert opinion.

Results

The footprints of AMAs A, B, and C (Figure 53) were found to cover areas that were comparatively low in habitat complexity and biodiversity, whereas the infaunal communities within the footprints of AMAs D and E were highly diverse and considered to be more productive.

The environmental end points considered the effects of aquaculture on the dominant and sensitive habitats, communities, and organisms that were identified within the footprints. These included: *Zostera* habitat, bivalve beds, macroalgae, sand flats, gastropods, tube-worm beds, and rock wall communities.

The analysis suggested that for AMAs D and E, where seagrass was present, the risks posed from direct smothering were low (maximum *Zostera* mortality of around 2%). Elmetri et al. (2006) also concluded that the rates of organic enrichment in these two areas (which include some of the high value tube-worm communities) were unlikely to lead to substantial mortality within benthic communities. The potential effects of smothering in AMAs A, B, and C were also considered to be relatively low.

Boat grounding effects from propeller scars and shading from structures were flagged as potential impacts on *Zostera*. While it was outside the scope of the study, the analysis suggested that reductions in light could further restrict seagrass distribution (this was considered to be a major risk.

The deposition of shells, live animals, and biofouling were also identified as issues that may change the benthic habitat and alter macrofaunal assemblages beneath the farms. The main determinant of this risk was considered to be the farm operational procedures and compliance with environmental management systems.

Scaling analysis suggested that the farms would remove significant amounts of nitrogen, but would not affect the overall nitrogen budget of the southern Kaipara system.

4.5 Resource consent monitoring

4.5.1 Fonterra Maungaturoto monitoring (NRC resource consent monitoring)

Resource consent conditions related to wastewater discharges form the Fonterra Maungaturoto plant (estimated as a maximum of 3000 m^3 day^{-1}) requires annual monitoring in the Otamatea River. Monitoring is undertaken by Poynter and Associates Environmental Ltd, in alignment (as far as practicable) with the National Protocol for Estuarine Monitoring developed by Cawthron (Robertson et al. 2002) (see Section 4.4.2).

The initial monitoring was intended to provide a baseline to which future monitoring can be compared. The Fonterra Maungaturoto monitoring has three components: the seabed community, mangrove habitat, and sediment quality. Data are available only for the 2006 survey (a baseline survey) (Poynter 2006).

Sampling methodology

For benthic sampling a total of four sites are sampled within the Otamatea River; two sites (sites 003 and 004) are approximately 500 m below the Fonterra discharge (on opposite shores of the river) and an additional two control sites are approximately 5 km downstream from the estuary (sites 005 and 006) and also on opposite shores of the river (Figure 54).

To determine and compare dominant fauna among sampling sites, a total of 12 random replicate core samples are taken within a 2 m^2 block at each site. For mangrove surveys, two sites 500 m up river (sites 001 and 002) as well as sites 003 and 004 are sampled. Within each site, three 10 m^2 areas are sampled and the mangrove density, height, and diameter at chest height are determined. Additional information on the percentage canopy cover, the visual health of the mangroves, the width of mangrove forest edge, and the relative abundance of mud snails (*Amphibola crenata*) and mud crabs (*Helice crassa*) are also obtained. Finally, grain size analysis and sediment chemical analysis (ash free dry weight, total organic carbon, total nitrogen, and total phosphorus) is undertaken for sites 003, 004, 005 and 006.

Results

Data are presented and summarised with basic statistical procedures (totals, averages, and ranges) in tables within the monitoring report.

Seabed community

Infaunal diversity and abundance across survey areas was fairly limited. Polychaete worms dominated the samples (both numerically and in terms of diversity) with amphipods and the invasive rice shell bivalve *(Theora lubrica)* also common. The shrimp *(Callianassa filholi)* was common at lower estuary sites whereas the mud crab *(Helice crassa)* was common at upper estuary locations.

Mangrove habitat

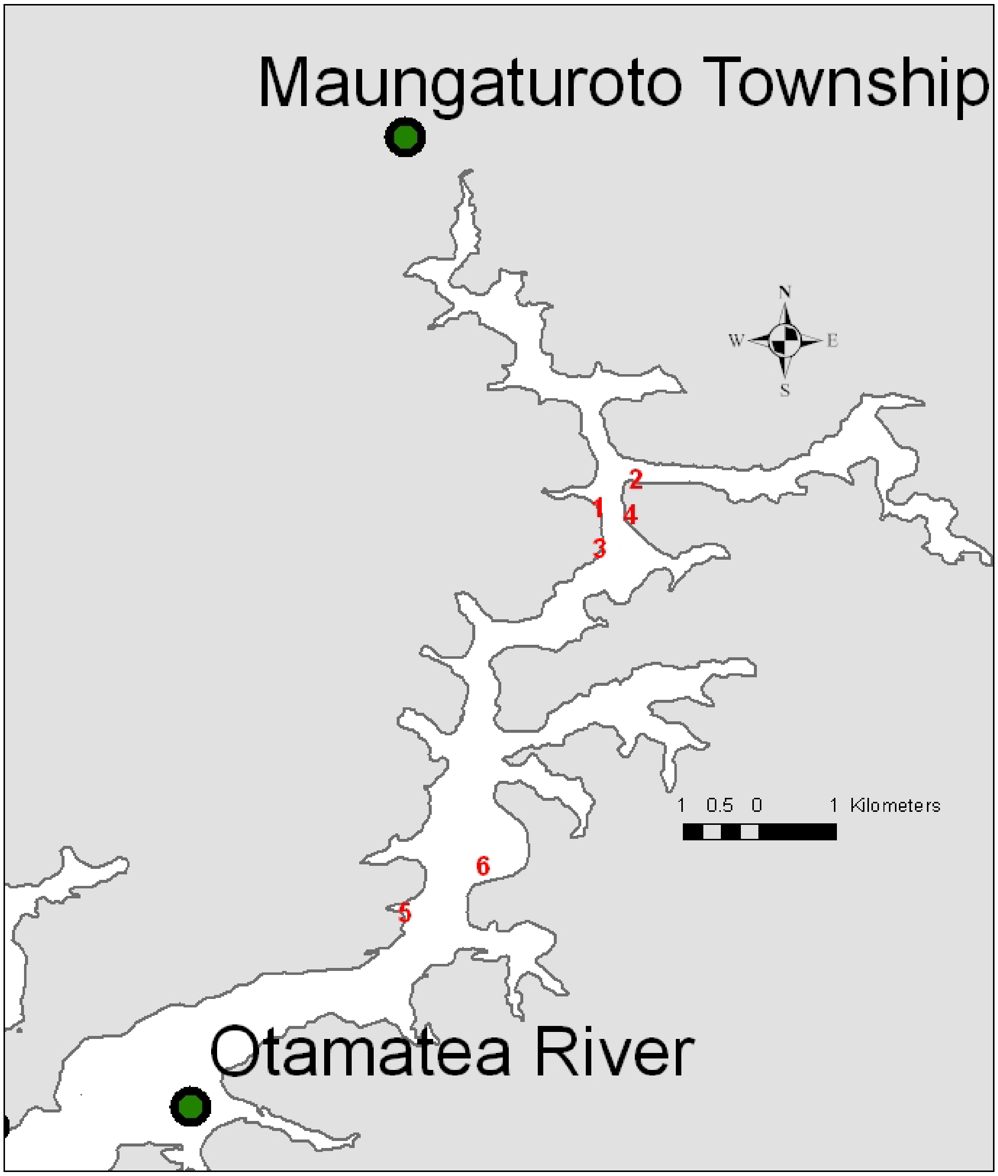
Mangrove data showed clear differences among the sites in terms of sapling density, but apart from site 004, the adult densities and % canopy cover were similar among sites. All mangrove trees (saplings and adults) were healthy in appearance and no senescent or dying trees were observed. There was no obvious impact of the discharge having an impact on mangroves in the area. Stock access to the mangrove habitat was reported at site 002.

Sediments

Sediment samples from each site were mainly silts and clays. The two sites on the western side of the estuary had similar sediment profiles, as did the two eastern sites.

Measurements of total organic carbon, total nitrogen, and total recoverable phosphorus varied among sites, although there was no indication of different sediment chemistry at the site closest to the discharge.

Figure 54 Sampling locations within the Otamatea River.



4.5.2 Sand extraction (ARC resource consent monitoring)

As part of the resource consent conditions for sand extraction (5.237 km^2 area) undertaken by both Mt Rex and Winstone Aggregates Ltd, both biological and coastal monitoring are required within the Fitzgerald Bank region (Grace 1995-2004).

Sampling methodology

Biological monitoring for the sand extraction is carried out periodically and occurred in 1998 and 2003 (Grace 1995, 1996, 2000, 2004). The monitoring undertaken by Grace in 1995 was done in support of sand extraction applications.

The monitoring design used in the 1998 and 2003 sampling periods uses fixed sites within the extraction area and one control area. These are quantitatively sampled using the Mt Rex barge and siphon (i.e. the same methodology used to extract sand). Six sites are sampled within the extraction area and three sites are sampled in the control area. At each sample station, three replicate samples are taken. For each sample, the siphon is extended to the seabed for one minute, sampling an area of approximately 6 m^2. All sand removed for each sample passes through a 9 mm mesh and all fauna retained on the mesh are identified and enumerated.

Results

Main findings of the 1998 study (Grace 2000) were:

- A total of 14 benthic taxa and four main species associations (tuatua, sand dollars, hermit crabs, and olive shells) were found within the extraction area.
- Tuatua was the only species of major fisheries significance within the area.
- Sampling of predetermined locations was hampered by changes to the seabed topography (depth).
- Approximately 50% of sand dollars and 80% of tuatua passing through the dredge during sampling were mortally damaged.

Main findings of the 2003 study (Grace 2004) were:

- A decline in tuatua numbers in both the extraction and control areas between 1998 and 2003. The decline was attributed to low population recruitment rather than the effects of sand extraction[2].
- A marked increase in sand dollars in both the extraction and control areas between 1998 and 2003. *Fellaster zelandiae* is a species that is particularly vulnerable to the

[2] We note that this hypothesis has been not been substantiated, and therefore feel that the possibility of dredging as a causal factor cannot be ruled out.

effects of sand mining. The increase in *Fellaster zelandiae* was attributed to a trophic cascade resulting from a reduction in snapper numbers from overfishing.

- As for previous surveys (1996 and 1998), 50% of sand dollars and 80% of tuatua passing through the sampling dredge during sampling were mortally damaged.

The main conclusion of the monitoring studies (Grace 2000, 2004) was that no obvious adverse changes in species diversity or in population densities were detected that could be attributed to sand extraction (but see footnote[2]).

4.6 Current and/or proposed monitoring studies (2008)

Several studies are currently being conducted within the Kaipara Harbour. These include:

- A baseline survey undertaken in late 2006 for Biosecurity New Zealand, to assess the distribution and abundance of benthic and introduced species throughout the harbour.
- The University of Otago and University of Auckland (in conjunction with the Department of Conservation) have been undertaking an assessment of marine mammal movement within the harbour (primarily dolphins and Maui's dolphin) using acoustic detectors within the Kaipara Harbour over the last two years.
- NIWA have been carrying out a Foundation for Research, Science and Technology (FRST) funded research programme, looking at estuarine fish abundance in relation to estuarine habitats. The study has included a detailed survey of the Kaipara Harbour, with some of the findings presented in Morrisey et al. (2007).
- As part of a project on seagrass meadows, stable isotopes are presently being used to assess how seagrass primary production may support secondary (animal) production. The study is being carried out in Rangaunu Harbour and Kaipara Harbour within extensive seagrass meadows (Morrisey et al. 2007).
- The Ministry of Fisheries are assessing the risk posed to Maui's dolphin (*Cephalorhynchus hectori maui*) from fishing off the West Coast of the North Island. A draft threat management plan was released for comment in August 2007.
- The Ministry of Fisheries is proposing to undertake a research study of scallop (*Pecten novaezelandiae*) distribution, size, and abundance within the Kaipara harbour in response to the closure of the Kaipara scallop fishery in July 2005.

4.7 Effectiveness of monitoring to assess broad-scale environmental changes within the Kaipara.

Both recent and present-day monitoring studies within the Kaipara Harbour vary considerably according to their specific purpose and include: baseline/trend and performance monitoring for water quality (NRC 2000-06, ARC 2007), SoE monitoring (Hewitt and Funnell 2005), resource consent monitoring (Grace 2003, Poynter 2006), one-off studies to address specific issues such as sedimentation (Poynter 1992), aquaculture management areas (Fisher 2005, Peirce 2005, Haggitt and Mead 2005, Gibbs et al. 2005, Elmetri et al. 2006), and fisheries monitoring (Hartill 2002, Ministry of Fisheries plenary reports).

Table 16 provides a breakdown of the major monitoring programmes undertaken within the Kaipara Harbour. The main monitoring sites/areas within the Kaipara Harbour used by the ARC and the NRC are presented in Figure 55. Data obtained from the monitoring programmes differ considerably in terms of comprehensiveness and quality, therefore the usefulness of individual programmes to assist in an assessment of broad-scale changes within the Kaipara also varies widely.

4.7.1 Ecological State of the Environment monitoring

The Tier II Ecological SoE study of benthic communities within the southern areas of the harbour (Hewitt and Funnell 2005) has a predicted return period of 10-16 years. This type of monitoring will, potentially, be valuable in determining broad-scale environmental changes to the main benthic communities (bivalves, mangroves, *Zostera capricorni*) within the southern Kaipara over time. The main limitation is that the study will not be able to determine short-to-intermediate term rates of change and/or the drivers of change, due to the long period between sampling events. The broad spatial scale also means that the study is not capable of detecting subtle small-scale changes. The other limitation is that the programme is confined to the southern Kaipara, rather than covering the Kaipara as a whole.

4.7.2 Water quality State of the Environment monitoring

The water quality information collected by the ARC and NRC varies noticeably in both temporal and spatial extent across the Kaipara Harbour and in the parameters measured. For example, Shelly Beach sampling is temporally intensive and regular, but this is the only saline site in the southern Kaipara that is routinely sampled. In comparison, more sites are monitored by the NRC in the northern Kaipara, but much of the data is temporally irregular, which makes it difficult to detect trends.

As a result, available data can be used only to provide a fairly limited assessment of water quality for the entire harbour. The majority of parameters measured suggest that water quality is degraded at most of the sites where SoE monitoring is undertaken (Figure 55). Additional one-off studies in other parts of the harbour also suggest that water quality issues are more widespread (Elmetri et al. 2006).

4.7.3 Fisheries monitoring

The fisheries catch per unit effort data collected and collated by the Ministry of Fisheries provides information on the commercial species targeted within the Kaipara. Primarily, the information is used to determine stock levels, establish maximum sustainable yield, and gauge the effects of fishing for these species. It is limited in its ability to determine broader environmental changes and does not consider effects on non-target species. This is because aspects of the habitats utilised by the fished species, changes in climate, or other activities that may be affecting fisheries are generally not evaluated. However, the NIWA, Ministry of Fisheries, and Foundation for Research, Science and Technology studies of habitat utilisation within the harbour are starting to bridge the knowledge gap for several commercial species.

4.7.4 One-off studies

As the one-off studies conducted within the Kaipara provide only a 'snap-shot' of environmental conditions at a specific time and have varying goals, they generally have limited value in assessing broad-scale environmental changes within the Kaipara. Mostly, the one-off studies presented above, e.g. Robertson et al. (2002) and Elmetri et al. (2006), are conducted with a high degree of rigour and provide a benchmark for future monitoring studies.

The methods used in one-off-studies vary depending on the purpose of each investigation. The value of these investigations could be enhanced by employing, where possible, standardised methods of sample collection and analysis. For example, standardised methods could be developed for: core and sieve sizes for ecological sampling; collection and analytical techniques for sediment, shellfish, and water quality samples; and analytical techniques for the determining sediment grain size. Standardised methods would also allow complimentary monitoring programmes and enable one-off studies to provide a more robust assessment of the overall condition of the harbour.

4.7.5 Resource consent monitoring

Resource consent monitoring associated with resource consent conditions is activity-specific and is of limited use for assessing broad-scale environmental quality and changes through time, due to the associated spatial and temporal limitations. In addition, there are marked differences in the quality (methods, analysis, and interpretation) of these monitoring programmes. Standardised methods that could be applied to resource consent monitoring would improve the usefulness of the information gathered.

The quality of information provided from impact assessments and subsequent resource consent monitoring conditions could also be strengthened by following (what are considered to be) best practices for environmental assessment. These include:

- Inclusion of appropriate control areas (Underwood 1991, 1992, 1994).
- If measuring for an impact, the most favourable approach is to sample before the impact takes place (if possible, multiple times before the impact takes place) in order to assess the magnitude and type of natural variability in the control and impacted sites.
- Adequate replication of every level in the sampling design (e.g. site) and an assessment of precision at the replicate level.
- Determining the level of effect that the study wants to detect (e.g. 20% change in abundance).
- Directing sampling towards the biology of the organism(s) most likely to be affected, and determining the most appropriate units (e.g. to measure abundance, size, biomass, etc). Consideration should also be given to the methodologies used for similar studies undertaken in the region, and links made where possible.
- Ensure samples are collected either randomly or haphazardly to ensure assumptions of analytical techniques are not violated. However, if fixed samples are used, sample units must be analysed with repeated measures analysis (Kingsford 1998).
- Analytical techniques should be determined at the design stage, to ensure variables of interest can be analysed and to ensure that statistical power is sufficient to detect trends, etc.
- The sampling design should be peer-reviewed before sampling is undertaken.

4.8 Synergies

It would be difficult to amalgamate or align many of the existing monitoring programmes because of differences in their purpose, the methods used (sampling design, spatial and temporal scales) and parameters measured (single species, communities, water quality).

However, modifications could be made to improve the synergies between some of the current programmes, and opportunities should be considered in future monitoring programmes. Potential synergies between existing programmes are summarised in Table 16.

4.8.1 Water quality monitoring

Water quality is measured in its various forms by the ARC and the NRC, mostly to provide information on the state of the environment, assess impacts from land-based activities, and broadly assess the impacts of new activities within the coastal marine area.

Parameters measured

Because many of the water quality parameters currently measured by the ARC and the NRC are relatively similar, there is potential for developing a synergy between the two monitoring programmes to provide a more robust measure of water quality within the Kaipara Harbour. Key parameters that should be measured jointly include:

- Turbidity and suspended solids.
- Nutrients (ammonium, nitrate, nitrite, total phosphorus, soluble reactive phosphate).
- Water temperature and salinity.
- Faecal coliforms and enterococci.

Measurement of turbidity and suspended solids needs to be a harbour-wide priority because catchment development leading to sedimentation is one of the biggest threats to estuarine systems. Measurement of nutrients and microbiological contamination are also important for determining where impacts from activities such as farming, forestry, and sewage are likely to be having an impact within the harbour. Faecal coliform and enterococci data can also be used to assess the water quality trends in areas used for bathing and shellfish gathering.

Spatial extent and temporal monitoring

To provide a clearer picture of water quality within the Kaipara, it would be beneficial to increase the spatial extent of water quality monitoring in both the northern and southern areas of the harbour, and to maintain the same temporal scale of monitoring as that presently undertaken at Shelly Beach by ARC (i.e. monthly).

Southern sites that would provide good coverage include: Shelly Beach, South Head, Kaipara Flats, Kakaraia Flats and the Oruawharo River (two sites). Within the northern Kaipara, sites that would provide good coverage include: Pouto Point, Kellys Bay, Tinopai, Otamatea River, and Arapaoa River (two sites). Consistent monitoring of these sites would provide a more complete and robust overview of water quality within the harbour. In addition, a water quality database could be developed for the whole harbour to allow comparisons to be made among areas with the same, or different, adjacent landuse type(s) (e.g. urbanised compared to rural), as well as helping to identify areas within the harbour that may require immediate attention. An extended water quality monitoring programme will also have added value for other monitoring in the harbour, such as ecological SoE monitoring and resource consent monitoring. Sampling by helicopter, using the ARC water sampling protocols, would be a cost-effective method of collecting samples within a narrow timeframe from the whole harbour.

Since the present-day sampling is insufficient to evaluate the water quality of the harbour as a whole, amalgamating and improving the two water quality monitoring programmes performed by the NRC and the ARC would be extremely valuable, irrespective of the final sampling design. This amalgamation and improvement should be viewed as a priority for the Kaipara Harbour. By extending the monitoring into other areas of the harbour and undertaking similar timing, methodologies, and target measurements, and by developing a joint water quality database between the ARC and the NRC, a more complete picture of water quality in the harbour would be provided with greater benefit to multiple end-users.

4.8.2 Resource consent monitoring

Resource consent monitoring is likely to increase in relation to proposed development pressures on the Kaipara Harbour (e.g. the expansion of large-scale sand extraction, development of tidal power generation, increases in aquaculture, and rural and urban intensification). The potential therefore exists to develop a standardised toolbox of methods for resource consent monitoring that will improve the activity-specific outputs from the monitoring programmes and make the information more useful.

Some of the tools that may be applied include: taking samples at similar times of the year, using similar sample units (core samples, grabs etc), and employing similar statistical techniques to interpret findings. In addition to detecting effects and improving the robustness of the resource consent monitoring, the use of standardised methodologies would enable the findings of several monitoring studies to be amalgamated, thereby providing a more complete picture of the environmental state of the harbour and assisting in the evaluation of cumulative impacts.

4.8.3 Ecological State of the Environment monitoring

Habitat mapping (Tier II)

The SoE study of Hewitt and Funnell (2005) has been instrumental in increasing the overall knowledge of ecologically significant habitats, biodiversity, and species abundance within the southern area of the harbour. The study has also been useful in prompting additional studies concerning aquaculture (Elmetri et al. 2006) and the habitat maps should be of value for fisheries management.

Unfortunately, the level of description in Hewitt and Funnell (2005) is not presently available for the northern Kaipara. A similar study utilising the same kinds of sampling methodology for the northern Kaipara is strongly recommended (i.e. a Tier II study as defined in Hewitt and Funnel, 2005) to provide an understanding of the geospatial patterns of habitats and communities present in intertidal and subtidal (<20m) areas. If undertaken, the data derived could then be incorporated with the Hewitt and Funnell (2005) data, providing a coarse-scale baseline map of benthic communities throughout the whole harbour. The combined results would provide an important guide for resource managers working on policies, plans, and resource consents (for both the harbour and its catchments). Habitat maps of the whole harbour would also help to determine which (if any) sites in northern and southern parts of the harbour require Tier I temporally intensive ecological monitoring, as used by the ARC.

Temporally intensive ecological monitoring (Tier I)

No Tier I monitoring is presently carried out within the Kaipara Harbour. Tier I monitoring is temporally detailed and undertaken at a few sentinel sites to detect short-to-medium term trends. Considering the range of ecologically significant communities found within the southern harbour (Hewitt and Funnell 2005), and that may exist in the northern Kaipara, Tier I monitoring is warranted in order to:

- assess changes to soft sediment and rocky reef habitats,
- determine changes in important biological communities and taxa,
- help identify factors responsible for any changes (natural cycles, sedimentation, etc), determine whether changes are site-specific or cover a greater area of the harbour (e.g. Halliday et al. 2006).

Sites that would be beneficial to monitor include those with ecologically significant communities (intertidal and subtidal *Zostera capricorni*, *Atrina zelandica,* etc) and sites that are likely to be affected by land-development (primarily through increased sedimentation). Suitable reference (control) sites should be included in any monitoring programme.

An added benefit of Tier I monitoring within the Kaipara is that the information generated would be beneficial to other sectors such as fisheries, biosecurity, and aquaculture, and could be used to enhance the integrated management of the Kaipara.

4.8.4 Summary

The temporal and spatial extent of monitoring programmes (predominantly water quality monitoring) are different between the NRC and the ARC regions (i.e. the North and South Kaipara Harbour respectively).

The existing spatial and temporal water quality monitoring programmes are presently insufficient to allow detailed comparisons between monitored sites or to greatly add to the overall understanding of the existing quality and health of the whole Kaipara Harbour.

Establishing an expanded water quality monitoring programme, with similar timing and the measurement of key parameters across the harbour, should be a priority.

Similarly, the current resource consent monitoring undertaken within the Kaipara is insufficient to provide information other than the specific impact(s) of the proposed activity. While this is the primary objective of resource consent monitoring, the advent of further resource consent monitoring in the near future provides the potential to develop synergies among the various monitoring studies. This can be achieved by developing and employing methodologies that are comparable among the studies, e.g. species targeted, sampling and analytical techniques, and temporal frequency of sampling. If this can be achieved then, collectively, resource consent monitoring is likely to provide a more complete picture of the environmental state of the harbour, be useful to a variety of end-users, and be helpful for evaluating the cumulative impacts and cross-boundary effects of a range of activities.

To provide baseline data on ecological communities within the northern areas of the harbour, a Tier II monitoring study equivalent to that recently carried out in the southern Kaipara (Hewitt and Funnell 2005) should be undertaken. The results of this study could then be amalgamated with the existing information for the southern Kaipara and be used to aid resource use or protection, determine areas of ecological significance, and identify sites for Tier I monitoring within the harbour. Considering the various threats associated with development within the catchments adjacent the Kaipara coastal marine area, Tier I monitoring for the Kaipara Harbour should be seen as a high priority.

Figure 55 Repetitive monitoring locations within the Kaipara Harbour. A = water quality monitoring undertaken by NRC; B = assessment of Pouto Shoreline undertaken by NRC; C = ecological monitoring of the Maungaturoto discharge in the Otamatea River undertaken by Poynter (2006); D = ecological monitoring of sand extraction in Tapora Banks area (Grace 2004); E = water quality monitoring undertaken by ARC.

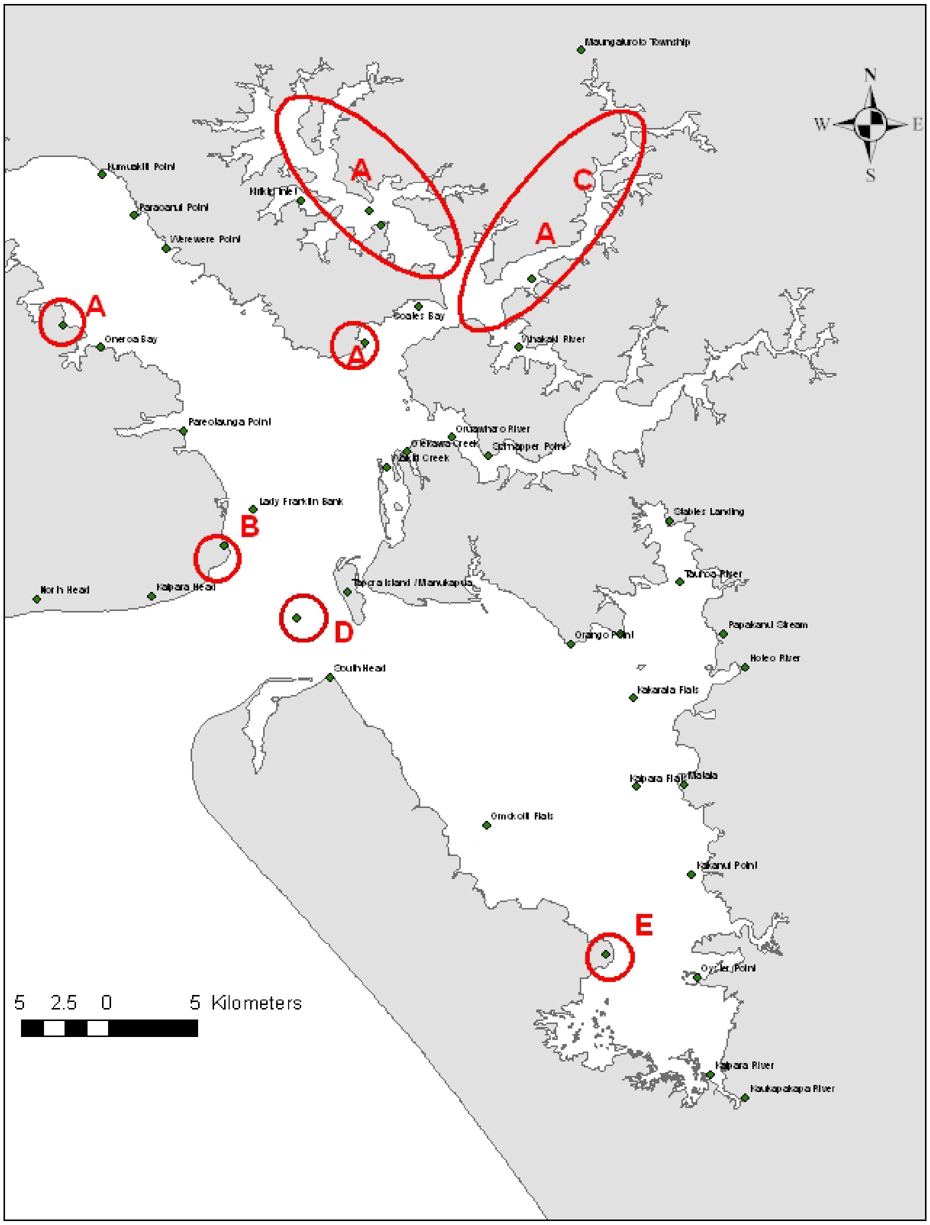


Table 16 Details of main monitoring programmes undertaken in the Kaipara Harbour, including potential synergies among existing and potential programmes that could be developed.

Type	Purpose	Location	Parameters measured	Limitations	Potential for synergies
Water quality SoE monitoring (ARC)	Trend monitoring – assessment of long-term changes in environmental quality.	South Kaipara, Shelly Beach	Temperature, pH, salinity, dissolved O_2, nutrients (NH_4, NO_3, NO_2, DRP, Total P), chlorophyll a, turbidity, suspended solids, faecal coliforms, enterococci.	Spatially limited	Yes – with NRC WQ monitoring.
Water quality SoE monitoring (NRC)	Trend monitoring - assessment of land-use impacts and habitat degradation.	North Kaipara, Wairau River, Otamatea River, Raepare Creek, Kaiwaka River, Pahi	Temperature, salinity, dissolved O_2, nutrients (NH_4, TIN, TP), faecal coliform, enterococci, shellfish, water quality.	Temporally limited	Yes – with ARC WQ monitoring.
Ecological SoE monitoring (ARC)	Habitat mapping and the assessment of broad-scale, long-term changes in ecological communities.	South Kaipara	Physical nature of habitats (sediment characteristics and extent of rocky reef habitat), biodiversity, location of ecologically significant communities and the spatial extent of these communities (e.g. mangrove and *Zostera*).	Temporally limited	Yes – with fisheries, invasive species, aquaculture. Yes – if similar sampling is undertaken in the northern Kaipara.
Consent monitoring - sand extraction Tapora Banks	Detect impacts associated with sand extraction within the Fitzgerald Bank region.	South Kaipara, Tapora Banks	Benthic faunal abundance and distribution.	Sample design	Yes – with fisheries and SoE information. Yes – with future consent monitoring in the harbour, if a harbour-wide consent monitoring framework is developed.
Consent monitoring - Fonterra Maungaturoto Plant discharge	Detect impacts associated with sand extraction within discharge of wastewater from Fonterra's Maungaturoto Plant discharge on biological and physical components of the Otamatea Estuary.	North Kaipara, Otamatea Estuary	Benthic faunal abundance and distribution Mangrove habitat Sediment quality	No "before impact" data	Yes – with future consent monitoring in the harbour, if a harbourwide consent monitoring framework is developed.

5 Identification of environmental issues

Currently, a wide range of issues potentially threaten the environmental values[3] of the Kaipara Harbour coastal marine area. The most significant of these issues include:

- Catchment disturbance and development (subdivision, urbanisation) and current landuse (farming) impacting the coastal marine area through sedimentation.
- Sand extraction.
- Fishing.
- Incursion and spread of invasive species.
- Tidal power generation.
- Shellfish aquaculture and other commercial activities in the coastal marine area.

Each of these is discussed and assessed for the probable scale of influence and associated impacts on the environmental values of the harbour.

5.1.1 Catchment development, disturbance, and land use

One of the most significant negative impacts on the coastal marine environment, associated with catchment development and disturbance, is increased terrigenous sediment runoff. This is a New Zealand-wide problem which has yet to be effectively addressed.

The adverse effect(s) of sediment on estuarine and coastal systems has received a large amount of attention in the ecological literature of the last 5-6 years (e.g. Airoldi 2003, Gibbs and Hewitt 2004). There is now a strong body of evidence that increased sediment loads within the coastal marine area can cause a variety of effects, ranging from slow cumulative impacts to catastrophic events. The main impacts include direct smothering of organisms, disruption to feeding (filter-feeding bivalves), habitat modification leading to reduced community and habitat heterogeneity, increased muddiness, and increased turbidity (Airoldi 2003, Gibbs and Hewitt 2004).

Increased sedimentation is primarily driven by changes in catchment use, often proceeding from native vegetation being converted to farmland or exotic forest, then into lifestyle blocks, and finally, urbanisation. Gibbs and Hewitt (2004) list a range of estuarine taxa deemed to be sensitive to changes in sedimentation rate and % mud content (summarised in 17), many of which are found within the Kaipara Harbour. The effects on taxa from sedimentation are summarised in Box 1.

[3] Environmental values include the physical, biological, and chemical components of the environment that together result in a self-sustaining natural system and include, but are not limited to water quality, habitat quality, biodiversity, and the abundance of flora and fauna.

Table 17 List of common macrofaunal taxa sensitive to changes in sedimentation rate and % mud content (Gibbs and Hewitt 2004).

Faunal group	Taxa
Anemone	*Anthopleura aureoradiata*
Ascidian	*Styela plicata*
Cumacean	*Colurostylis lemurum*
Bivalve	*Atrina zelandica*
Bivalve	*Paphies australis*
Bivalve	*Pecten novaezelandiae*
Bivalve	*Macomona liliana*
Gastropod	*Amphibola crenata*
Gastropod	*Notoacmea helmsii*
Gastropod	*Cominella glandiformis*
Gastropod	*Diloma subrostrata*
Polychaete	*Travisia olens*
Polychaete	*Waitangi* sp.
Polychaete	*Aonides oxycephala*
Polychaete	*Exogoninae*
Polychaete	*Scoloplos cylindrifera*
Polychaete	*Asychis* sp.
Polychaete	*Goniada emerita*
Polychaete	*Orbina papillosa*
Sponge	*Aaptos* sp.
Echinoderm	*Echinocardium australis*
Echinoderm	*Fellaster zelandiae*

Recent studies indicate that the threat to the coastal marine area from catchment development is often more dependent on the catchment characteristics (such as proximity to water bodies, soil type and slope, and environmental conditions e.g. rainfall), than the actual activity itself (Hicks et al. 2003). However, during development (e.g. from rural to urban) the relative impacts can be greatly increased; e.g. sediment runoff will peak during the subdivision and construction of services for urbanisation projects, and will then reduce as the development matures (Swales et al. 2002).

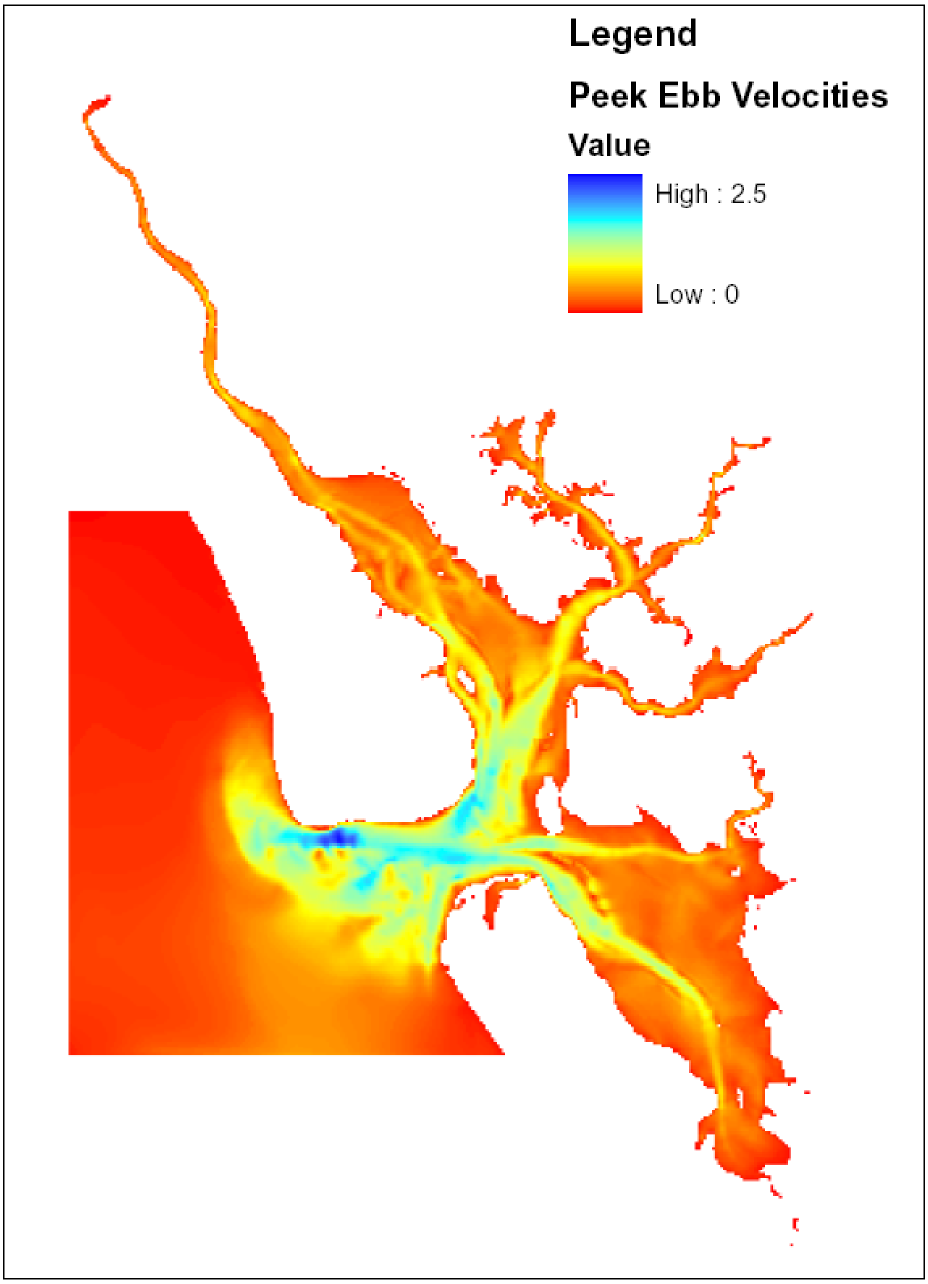
Fine sediments that settle in relatively sheltered estuarine areas, which are common throughout the Kaipara, are not easily remobilised and removed; therefore these environments are more at risk from sediment-related effects than exposed coastal areas. However, exposed areas commonly contain a mix of species that are more sensitive to sediment than those in sheltered side branches. Consequently, the effects of relatively small, infrequent sedimentation events can be more pronounced in exposed areas.

Prolonged exposure to increased sedimentation may alter the abundance and distribution of key species or communities (seagrass, bivalves, and polychaetes) and indirectly affect the other fauna that depend on them (e.g. juvenile and adult fish, and coastal birds). Furthermore, sustained sediment-loading in the coastal environment may lead to changes in dominant habitats, such as a change from sandy to muddy substrates and/or an increase in mangrove extent. The large and rapid increase in the extent of mangroves within the Kaipara over the last 10 years (Morrisey et al. 2007) has been attributed to increased sedimentation.

Sediment-related impacts within the Kaipara are not a recent concern. Fahy et al. (1990) considered terrigenous sediment to be problematic within the Kaipara Harbour as a result of catchment characteristics, an increase in both realised and potential subdivisions, and clearance of exotic forest (*Pinus radiata*) around the harbour. This is supported by a recent study for the ARC (Mead et al. in prep), which indicates that sediment runoff from the Okahukura, Hoteo, and Oruawharo catchments within the southern Kaipara is likely to pose a significant threat to coastal marine communities and environments. This threat is due to both sediment input and the propensity for sediments to settle in nearshore areas directly adjacent to the catchments. A basic assessment of the geological characteristics of the northern Kaipara indicates an even greater potential for terrestrial sediment input in this area. Evidence for sediment-related impacts in the northern Kaipara is supported by anecdotal studies, such as Haggitt and Mead (2005), which documented a very muddy substratum within a 4 ha area (i.e. a proposed Aquaculture Management Area) of the Kirikiri Inlet that contained numerous dead cockles (*Austrovenus stutchburyi*). Considerable coastal erosion was visible immediately adjacent to the Aquaculture Management Area and no riparian vegetation buffer separated the land from the intertidal mudflats of the inlet.

A calibrated tidal model for the Kaipara Harbour (Figure 56) has been developed (for both a tidal energy assessment and an investigation into significant marine receiving environments commissioned by the ARC). By considering maximum water velocities and residual currents due to tidal cycles, a simple assessment of the areas where sedimentation is likely to occur was undertaken (note that a detailed study would be required to confirm these predictions).

Figure 56 Peak velocities in the Kaipara Harbour during ebb tide. Note this does not take into account wave-driven currents which can, at times, be extensive across the large open distances in the Kaipara. Strong winds will generate waves that are capable of re-suspending sediment over the shallow mudflats.



Using basic principles (e.g. maximum velocities of <0.1 m/s results in the accumulation of fine sediment, velocities of <0.3 m/s results in the deposition of sediments up to coarse sand, and velocities between 0.3 and 0.7 m/s result in bedload transport) and consideration of soil types and drainage properties, areas within the Kaipara that are <u>potentially</u> prone to sedimentation from catchment disturbance include:

Northern Kaipara

- The upper reaches and side arms of the main tributaries (Arapaoa, Otamatea, and Whakaki Rivers).
- Much of the coastal margin of the Wairoa Arm.

Southern Kaipara

- Oruawharo River.
- Tapora Bank (extensive area of intertidal sand and mudflats).
- Tauhoa River area.
- Kakaraia and Kaipara Flats (extensive area of intertidal sand and mudflats).
- Intertidal areas south of Oyster Point and Shelly Beach (extensive area of intertidal and subtidal sand and mudflats).
- Waionui Inlet.

It is important to note that this assessment is based on tidal currents, not wave-driven currents which are likely to be important in open areas of the harbour (e.g. Black et al. 1997). Wave-driven currents increase re-suspension, directly affecting turbidity, and may potentially redistribute and deposit sediment in other parts of the harbour.

The majority of areas identified within the southern Kaipara contain important ecological communities that carry out key functions and services. These include: areas of high biological diversity, bivalves, macroalgae, and seagrass meadows. Of particular concern is the entire area between Oyster Point (south) and Tapora Banks (north) in the southern Kaipara, which is characterised by high species diversity and high abundances of functionally important communities, e.g. *Zostrea capricorni*, bivalves (*Atrina zelandica, Austrovenus stutchburyi, Paphies australis*), and associated species.

The major impacts associated with increased sedimentation for intertidal *Zostrea capricorni* meadows in the Kakaraia Flats area are direct smothering and increased muddiness; whereas for subtidal meadows both sediment deposition and light attenuation from increased turbidity is likely to lead to reduced abundance, biomass, and productivity (Turner and Schwarz 2006). Similar impacts are also likely for macroalgae adjacent to subtidal *Zostera* in this area. Other benthic organisms in this area that are sensitive to sedimentation (based on the findings of Gibbs and Hewitt 2004,

Table 17) are the high diversity tube-dwellers, high diversity polychaete fauna, *Macomona liliana*, and *Austrovenus stutchburyi* in the intertidal areas, and subtidal *Atrina zelandica* beds (Hewitt and Funnell 2005).

Intertidal areas from Oyster Point north (Kaipara Flats) and the Tapora Bank intertidal area, which are also likely to be threatened by sedimentation, are characterised by the presence of *Macomona liliana*, *Austrovenus stutchburyi*, and areas of high diversity tube-dwelling organisms. Scallops occur subtidally adjacent to Kaipara Flats and *Atrina zelandica* beds occur within the Tapora River.

Hewitt and Funnell (2005) assert that if mud habitats were to expand within the harbour the most sensitive intertidal species that would decrease first and that are widespread would include *Notoacmea helmsi*, *Cominella glandiformis*, and *Diloma subrostrata*. With further increases in mud, less sensitive taxa such as Lysianassid and Phoxocephalid amphipods, orbiniidae polychaetes, *Aonides oxycephala,* and *Macomona liliana* would be expected to decrease. If siltation or muddiness increased even further, species that show preferences for intermediate amounts of mud such as *Austrovenus stutchburyi*, *Athritica bifurca*, and Glycerid and Syllid polychaetes could also decrease.

Subtidal organisms including *Atrina zelandica*, *Paphies australis*, *Pecten novaezelandiae*, *Echinocardium australis*, *Fellaster zelandiae*, Glycerid and Syllid polychaetes, *Macroclymenella stewartensis*, *Heteromastus filiformis,* and *Boccardia* spp. are also likely to exhibit changes in abundance with increased sedimentation in areas of low tidal flow, although Hewitt and Funnell (2005) suggest that determining the degree of change is difficult as less work has been done on these taxa.

Degradation of these ecologically important communities and taxa through sediment deposition and increased muddiness (i.e. higher fractions of fine silts) may also affect the broader environmental values of the harbour. Potential effects are loss of biodiversity, alteration of food webs affecting predators such as birds and fish, and loss of key habitats important to fisheries (such as seagrass meadows and horse mussel beds).

Increased sedimentation may also result in the spread of mangroves. Mangrove expansion has already been observed in the Kaipara and other harbours such as Manukau, Waitemata, and Whangarei (similar patterns have been reported in the Waikato Region (Mead and Moores 2004). Morrisey et al. (2007) suggest that increased rates of sedimentation in estuaries and harbours have resulted in the spread of mangroves through elevation of intertidal areas, which creates suitable habitat. The structural elements of mangroves (pneumatophores, prop roots, low branches and trunks) also play a part in increasing the elevation of intertidal areas by damping currents, attenuating waves, and altering patterns of water flow, which enhances the settlement of fine silts, clays, and organic-rich sediments. Morrisey et al. (2007) suggest that highest sedimentation rates within a mangrove stand usually occur at the seaward fringe or along the banks of tidal channels, resulting in a deeper accumulation of sediment often with higher mud content.

Increases in the spatial extent of mangroves are considered to be problematic in terms of benthic biodiversity, primarily because of changes in the sediment structure. Hewitt and Funnell (2005) suggest that, as muddy areas transform into mangrove forest, there is likely to be a sequential loss of biodiversity. Typical fauna of mangroves include the mud crab (*Helice crassa*), Nereids, and *Arthritica* (Hewitt and Funnell 2005). The NIWA study on fish utilisation of mangroves (Morrisey et al. 2007) suggests that fish diversity is generally low in mangrove forests but they may be important for short-finned eels (*Anguilla australis*), and provide juvenile habitat for yellow-eyed mullet (*Aldrichetta forsteri*) and grey mullet (*Mugil cephalus*).

Depending on their proximity, mangroves may also be beneficial to species such as seagrass (*Zostera capricorni*), by buffering the effects of sedimentation from adjacent catchments. Conversely, mangroves could have a detrimental effect if they expand into areas occupied by seagrass.

The potential effects of sediment can be surmised from the available information on the habitats within the harbour, and the geophysical characteristics of the harbour and surrounding catchments. However, it is important to note that the modelling and assessments of sediment effects in the Kaipara Harbour have been fairly rudimentary, largely observational, and/or based on studies carried out in other harbours; therefore the scale and magnitude of sediment impacts on the Kaipara Harbour (both direct and indirect) remains a significant knowledge gap. If integrated management is to be successfully achieved, these effects need to be understood and addressed for the harbour as a whole.

Box 1. Summary of sedimentation-related impacts on major faunal groupings.

Macroalgae

Predominant stressors to macroalgae connected with terrigenous sediment loading are both direct and indirect. Direct effects relate to those associated with smothering and scour, which negatively affects gametophyte (microscopic) growth and survival (Reed et al. 1988, Airoldi 2003), whereas indirect negative effects are generally those associated with light attenuation, which influences productivity (photosynthesis and growth), species composition (diversity), and depth-distributions (Lobban and Harrison 1997, Airoldi 2003). Macroalgal stands may also positively influence invertebrate recruitment and survival due to the effect of canopies reducing the rate of sediment reaching the substratum.

Seagrass

As for macroalgae, primary threats to seagrass are considered to be those associated with sedimentation (from catchment development reclamation and aquaculture) that may cause direct smothering (e.g. Cabaco 2007) or increased light attenuation (turbidity), which negatively affects primary productivity (Gordon et al. 1994, Ruiz et al. 2001).

Sponges

Recent experiments carried out in north-eastern New Zealand have established that large erect sponges such as *Aaptos aaptos* can be adversely affected by terrigenous sediment within estuarine and coastal systems – principally a reduction in size and condition (Lohrer et al. 2006). Lohrer and co-workers predict that these types of effect may ultimately affect ecosystem function through loss of structure, particularly if the frequency or magnitude of terrigenous sediment loading and resuspension increases within a given area; and suggest that effects of this nature may be more prevalent in coastal areas where exposure to sediment stress is likely to be less common.

Polychaete worms

The greatest stressor to polychaete worms associated with catchment development, as for the above communities, are likely to be those associated with terrigenous sediment (Hewitt and Gibbs 2004). Experiments have demonstrated that changes in sedimentation rate and increased % mud content, (particularly when sediment cover was >3 mm thick) adversely affected a range of polychaete fauna including Oligocheate *species*, *Asychis* sp, *Aonides oxycephala*, *Scoloplos cylindrifera*, *Boccardia syrtis, Heteromastus filiformis* and *Lumbrineris* sp.

Bivalves

Potential anthropogenic stressors to bivalves from catchment development include elevated exposure to sediment (both suspended and depositional) (Hewitt et al. 1996, 2001, Cummings et al. 2001, Cummings and Thrush 2004). The effects of sedimentation are likely to vary according to species feeding type, with deposit-feeders potentially less likely to be vulnerable to increased suspended sediment loads than suspension-feeders (Gibbs and Hewitt 2004). Because sediment particles bind various contaminants, other effects associated with sedimentation include elevated exposure to contaminants such as organotin compounds and organic booster biocides (those associated with marine antifoulants) (Grant and Hay 2003), heavy metals (Roper et al. 1994, 1995), organochlorines and PAHs (Ahrens et al. 2002). Indirect effects such as nutrient enrichment, that potentially influence food abundance and composition, may also be important. Note: interactions between stressors and bivalves are complex and may affect different life-history stages (i.e. larvae, juveniles, adults) in varying magnitudes (Grant and Hay 2003).

5.1.2 Urbanisation

As a result of increased subdivision and urbanisation within the Kaipara catchment, a range of impacts associated with urban pollution are likely to occur within the coastal marine area unless managed appropriately. The main effects associated with urbanisation include: litter, sediment generation, stormwater contamination of the coastal marine area, and the effects from wastewater discharges (sewage), with contaminant loads often increasing as urban areas mature (Swales et al. 2002).

While contaminants reaching the coastal environment (from catchment sediment run-off) may be discharged to sea, it is likely that part of the load will be deposited in the estuarine environment. Contaminants associated with sediments and stormwater that are considered to be problematic to the ecological health of the coastal environment (e.g. Kelly 2007) are predominately the heavy metals: copper (Cu), lead (Pb), and zinc (Zn) (Roper et al. 1994, 1995) originating from a range of industrial and residential sources. Polycyclic aromatic hydrocarbons (PAHs), originating largely from vehicle emissions, are also an issue (Ahrens et al. 2002).

Species most likely to be most affected by contaminants (and which also show commonality with sedimentation-related sensitivity) include: bivalves (*Paphies australis*, *Austrovenus stutchburyi, Macomona liliana*), polychaetes (*Orbina papillosa*, *Magelona* spp., *Aonides oxycephala,* Glyceridae), the amphipod *Corophium* spp., and the limpet *Notoacmea* spp. The effects of heavy metals on bivalves are generally considered to be sub-lethal, influencing growth and reproduction, and are generally more toxic to infaunal bivalve embryonic and larval stages than to adults (Grant and Hay 2003).

Analysis of contaminant data collected for harbours in the Auckland region by the ARC (Kelly 2007) show a strong relationship between copper, lead, and zinc concentrations and benthic community structure, indicating that current levels of contamination (or a covariate of copper, lead, and zinc) are affecting the ecological function of many urban estuaries, with effects likely to increase if contaminant discharges are not controlled. While data is generally sparse on contaminant loadings for the Kaipara (Poynter et al. 2002), current levels are probably low. However, long-term deleterious effects on ecosystem functions and health could result from urban stormwater contaminants, depending on the amount of development and urbanisation within the Kaipara catchments in future years.

Wastewater discharges are also a potential issue affecting the environmental values of the Kaipara coastal marine area. Treated sewage discharges are often a major point source of organic matter, nutrients, ammonia, suspended solids, and pathogens (Hickey et al. 1989). Treated and untreated wastewater discharges can impact commercial operations, such as aquaculture, and pose a serious risk to recreational pursuits, such as bathing and shellfish gathering. Monitoring in the northern Kaipara indicates that wastewater is degrading water quality in some parts of the harbour (Section 4.1). At present, sewage treatment plants in Kumeu, Huapai, and Helensville discharge into the Kaipara River and sewage from the

Dargaville treatment plant is discharged into the Wairoa River. Issues with septic tank pollution have also been reported in the northern Kaipara (Peart 2007).

Direct human disturbance to vulnerable ecosystems that is associated with increased urbanisation is also an issue that has the potential to affect environmental values within the harbour. Recreational activities involving off-road use of four-wheel-drive vehicles, quad bikes, and motorbikes have damaged the natural vegetation on Muriwai Beach and South Head (Cameron & Bellingham 2002) and appear to have reduced the breeding ability of birds in the Papakanui Spit Wildlife Refuge and Tapora area (Buick and Paton 1989, ARC 1999, DOC 1996, Dowding and Chamberlain 1991). Caspian terns have deserted their traditional breeding site at Papakanui and fairy tern breeding has been sustained with the Department of Conservation warden presence. Vehicles are also having detrimental impacts on other species, coastal landscapes, and coastal habitats (e.g. Stephenson 1999, Environment Waikato 2001).

Reclamation (particularly in the North Kaipara) has been an issue, as shallow areas were progressively drained and reclaimed to create flat farmland around the fringes of the harbour (Chapman 1976, Fahy et al. 1990, NRC 2002a) and at one stage, government agencies were investigating reclaiming a large proportion of the harbour (NRC 2002a). In the future, with potential sea level rise, some of these areas could return to the harbour, although it is likely that rehabilitation would be required for them to contribute value to the coastal ecosystems.

Increased urbanisation also has the potential to impact greatly on the landscape values of the Kaipara Harbour. These impacts can be wide-ranging and may include: poorly located buildings, various structures and associated infrastructure, large infrastructure such as pylons, earthworks and vegetation removal, aquaculture, monoculture forestry and other cultivation activities, and poor land management practices (EDS 2007). Some of the other main impacts to landscape values from increased urbanisation are:

- Changes to the geological, topographical, and dynamic components of the landscape.
- Loss of aesthetic values including memorability and naturalness.
- Loss of landscape expressiveness (how obviously the landscape demonstrates the formative processes leading to it).
- Impact to transient values: These may include occasional presence of wildlife; or its values at certain times of the day or year (EDS 2007). For the Kaipara Harbour, increased urbanisation could impact on natural roosting and foraging areas. In turn, this may affect the presence and abundance of migratory birds at certain time of the year, which could be considered as an impact to transient values.

Presently, much of the Kaipara catchment is pasture or forest with a high degree of naturalness (Shaw and Maingay 1990), particularly when compared to the neighbouring large harbours in the Auckland Region (Manukau and Waitemata), therefore the impacts on landscape values due to increased urbanisation are potentially significant if not managed carefully.

5.1.3 Stock grazing and disturbance

There is both reported (Poynter 2006, Peart 2007) and anecdotal (T. Cassidy., pers. comm. 2007; T. Haggitt and S. Mead., pers. obs.) information of stock entering the coastal marine area within the Kaipara Harbour. Specific impacts relating to stock entering the coastal marine area are: damage to native plants (saltmarsh, mangroves and other estuarine and harbour edge vegetation), trampling and crushing of crabs and shellfish, disturbance of whitebait breeding grounds, and damage to seagrass beds (NRC 2007). Animal waste (faeces and urine) contains viruses and bacteria which, if they enter the coastal marine area, can build up in filter-feeding shellfish and endanger the health of local food gatherers, recreational users, and impact the aquaculture industry (Peart 2007). In addition, damage to riparian vegetation and ground disturbance increase direct sediment runoff into the coastal marine area. From July 2009, unauthorised access to, and use of, the coastal marine area by stock will become a prohibited activity under the Regional Coastal Plan for Northland (NRC 2007). The stock exclusion rule is designed to protect the ecological health and water quality of the coastal marine areas.

5.1.4 Aquaculture

The Kaipara Harbour has a relatively long history of aquaculture, particularly within the northern areas. At present there are 31 marine farm licences/permits for the Kaipara Harbour and a total of eight small farms, mostly associated with collecting oyster spat (Table 18). All the existing farms within the Kaipara Harbour were licensed under the Marine Farming Act (1971) by the Ministry of Fisheries prior to the enactment of the Resource Management Act (1991). Together, the farms occupy approximately 190 ha and are located predominantly in the northern Kaipara (Handley and Jeffs 2003). A brief history of oyster aquaculture in the Kaipara Harbour is presented in Box 2.

In the North Kaipara, the oyster farms are principally located in the Arapaoa and Whakaki arms of the harbour. The farms vary in condition from currently in use to abandoned (Haggitt and Mead 2005, Biomarine 2005).

In recent years, there has been a high demand for more aquaculture within the Kaipara Harbour, particularly in the southern areas due to perceived high water quality and high tidal currents. The responsibility for designation and allocation of aquaculture management areas (AMAs) lies presently with regional councils, and both the ARC and the the NRC have investigated the possibility of further AMAs within the Kaipara (Sections 4.4.3, 4.4.5 to 4.4.8; also see Peart 2007 for the AMA legislative framework).

Table 18 Oyster and mussel farms within the Kaipara Harbour. Data from Handley and Jeffs (2003).

Site	Type of Aquaculture	MAF Licence/lease	CPT permit	MAF area (ha)
Kaipara Harbour			9	
Pahi River	Oysters	5		13.17
Paparoa Creek	Oysters	3		19.34
Arapaoa River	Oysters	6		39.39
Whakaki River	Oysters	2		6.7
Kirikiri Inlet	Oysters	1		4.0
Hargreaves Basin	Oysters	4		100.9
Arapaoa River	Mussels	1		2.31
Otamatea River	Mussels	1		7.3
			Total Area (ha)	193.11

Table 19 Potential ecological impacts of mussel and oyster aquaculture.

Positive Impacts	Negative Impacts
Release of nutrients (N). Increased phytoplankton growth. Increased secondary production (cultured, fouling, and associated species). Provision of habitat utilised by fish. Increased biomass and biodiversity of hard substrate species. Attraction of a few bird species (foraging).	Alteration of nutrient balances (particularly N). Depletion of phytoplankton and zooplankton. Increased sedimentation (through biodeposition and alteration of hydrodynamic flows). Increased biological and human debris. Organic enrichment of sediments. Changes in macrofauna (e.g. reduced diversity of benthic species). Habitat modification. Entanglement and exclusion of marine mammals. Avoidance by birds. Provision of habitat for invasive species. Shading of photosynthetic species. Physical disturbance of the seabed through construction and operational activities.

Box 2: Summary of aquaculture history within the Kaipara Harbour.

Oyster farming in the Kaipara Harbour has occurred since the early 1900s, when management protocols for oyster beds were developed by the Marine Department in response to the depletion of oyster stocks. Key reasons that contributed to the localised depletion of oysters were harvest pressure and the burning of oysters for lime (MFish 2005). Management protocols included banning all public harvesting from rocks, removing predators and seaweed, and harvesting oysters (as instigated by the Marine Department) in rotation. Between 1913 and 1933 Māori oyster reserves were provided in Kaipara, Whangaruru, Whangaparoa, and Mangonui Inlet (Waitangi Tribunal 1987, 1988) but Māori generally were not allowed to sell, purchase, or barter any oysters taken from these Māori oyster reserves. Under 1946 regulations, oyster reserves within the Kaipara included the area from Potu Point to Sail Point, Arapaoa River (Rapere Creek and Kirikiri Inlet), and Gittos Point (Oruawharo River).

By the early 1930s the Marine Department began early experimental oyster farming. Farms were built in Kerikeri Inlet (Bay of Islands) and Kaipara Harbour by placing rows of rocks covered with oysters on the intertidal shore, creating an artificial reef (SEAFIC 2004).

Commercial oyster farming of the native rock oyster (*Saccostrea glomerata*), began in earnest within the Kaipara Harbour in the 1960s when oysters were farmed on wooden or "fibrolite" sticks placed across wooden racks built in the intertidal areas. Oyster spat were settled on sticks in a Marine Department farm in Mahurangi Harbour and this farm supplied spat to farms in other areas (SEAFIC 2004).

With the introduction of the Pacific oyster (*Crassostrea gigas*) into New Zealand waters in the early 1970s, aquaculture farmers began switching to this species. The change in species was made for a number of reasons including faster growth rate, higher meat yield, and a greater and more reliable spatfall. Farmers found Pacific oysters would grow to market size in 12-18 months, compared to 2-2.5 years for the New Zealand rock oyster.

At present, oyster farming activities (spat collecting and farming) within the Kaipara Harbour occurs within the Pahi River (13.17 ha), Paparoa Creek (19.34), Arapaoa River (39.39), Otamatea River (6.7), Kirikiri Inlet (4 ha), and Hargreaves Basin (100.9 ha) (Table 1 in Handley and Jeffs 2003).

Handley and Jeffs (2003) note that the Kaipara Harbour suffers from problems of over-catch with oyster spat, mudworm pests, and flatworm predation but the area has potential for future development, with technological advances of growing systems for single seed oysters, primarily the BST™ longline method of farming (www.bstoysters.com). The BST™ longline method is thought to be best suited to the Kaipara Harbour and, as a consequence, oysters are handled more frequently and the problems associated with mudworms, flatworms, and over-spatting can be addressed as part of farm management.

The ARC identified five potential aquaculture management areas (AMAs) within the southern Kaipara in its proposed 2002 variation to the coastal plan. This variation was subsequently withdrawn in 2005. Since then the Environment Court has declined an application for a 30 ha mussel farm, partly due to the negative effects on the natural character of the area (Newhook 2006) and has granted a consent for a 75 ha oyster farm adjacent to Kakaraia Flats.

In 2003, the NRC proposed four potential AMAs within the northern Kaipara based on constraints mapping. Since then, the process has been lengthy and involved. Refer to NRC website (www.nrc.govt.nz) for the current timeline.

Hewitt and Funnell (2005) suggest that intensive aquaculture could seriously affect environmental values in parts of the Kaipara Harbour, particularly southern areas where there is high species diversity and a range of species likely to be sensitive to the effects of aquaculture. The deposition of organic material below marine farms (in the form of faecal and pseudofaecal material) and the accumulation of living and dead shells and associated epibiota, is a common impact of oyster and mussel cultivation (Kaspar et al. 1985, Forrest 1991, Grant et al. 1995, Grange and Cole 1997, Christensen et al. 2003). This can have a detrimental impact on the abundance, diversity, and biomass of species beneath marine farms; and on the sediment quality, nutrient cycling, and productivity of benthic phytoplankton. The level of impact is inherently site-specific and depends on: the type of aquaculture, stocking densities, depth, hydrodynamic properties of the area, the types of habitats and communities present, and farming practices.

Another key issue is the flow-on effects of phytoplankton depletion caused by the intensive culture of filter-feeding bivalves (i.e. mussels and oysters), particularly with large farms or multiple farms in a small area. Mussel and oyster farms utilise naturally-occurring phytoplankton as a food source and can significantly reduce phytoplankton abundance and change the phytoplankton species composition in the adjacent water column. This could limit food availability for natural ecosystems in the vicinity of mussel and oyster farms.

In contrast, the release of ammonium, a natural product of direct excrement and/or stress in shellfish, may stimulate phytoplankton growth. Ogilvie et al. (2000) documented occasions when chlorophyll *a* concentrations were higher inside mussel farms than outside, which was attributed to phytoplankton growth being enhanced by ammonium excreted by the mussels. While this may be beneficial and lead to higher food production, in some cases it has led to blooms of nuisance phytoplankton species that are not suitable as food (Prins et al. 1994).

Aquaculture is now recognised as a significant vector for the spread of invasive species (e.g. Naylor et al. 2001). Recent arrivals to the Auckland Region, that are currently not found in the Kaipara Harbour but have the potential to be spread through aquaculture activities, include the Asian kelp *Undaria pinnatifida* and the ascidian *Styela clava*. Both species can potentially displace native organisms and cause heavy fouling on natural and artificial structures. Mussel farms are known to provide an attractive substrate for *Undaria pinnatifida* and appear to be one of the key activities associated with its spread in New Zealand (Figure 57).

Marine farms can also affect fish, mammals, and birds. Fish may be attracted to farms by the presence of physical structures and food. This is potentially a positive impact, but can also make fish more susceptible to capture, thereby increasing fish mortality. Some birds may benefit from the provision of structures and food but many tend to avoid marine farms and are, therefore, displaced from feeding and roosting grounds. Impacts on marine mammals are more likely to be negative and could include entanglement (in mussel farms) or avoidance.

The potential ecological impacts of marine farms are summarised in Table 19.

In light of the potential impacts of aquaculture on the values of the Southern Kaipara Harbour, the ARC commissioned a number of assessments on the potential impacts of the five AMAs originally proposed for the southern Kaipara (ARC 2002, McCarthy 2002, Fisher 2005, Pierce 2005, Gibbs et al. 2005, Elmetri et al. 2006). These reports covered the potential effects of aquaculture on: other activities and values (ARC 2002, McCarthy 2002), the benthic environment (Elmetri et al. 2006), phytoplankton depletion (Gibbs et al. 2005), nutrient budgets (Gibbs et al. 2005), marine mammals (Fisher 2005), and birds (Pierce 2005).

Figure 57 Growth of the invasive seaweed species *Undaria pinnatifida* on a mussel farm in Port Fitzroy, Great Barrier Island (photo courtesy of Shane Kelly).

Elmetri et al. (2006) concluded that fine organic material (faeces and psuedofaeces) is unlikely to build up beneath farms in proposed AMAs A, B, C (Figure 55) but that the deposition of shell material could affect benthic communities beneath farms in these areas. The areas contain diverse rocky reef (sponges, bryozoans, and mussels on rubble and rock walls) and soft sediment communities (*Fellaster* / gastropod dominated) within the footprint of the farms. Together, AMAs A and B were estimated to cover approximately 29% of the diverse rocky reef habitat in the harbour (Hewitt and Funnell 2005). The main determinant of risk for shell deposition was considered to be operational procedures and compliance with environmental management systems.

AMAs D and E were located in the shallow subtidal area adjacent to Kakaraia Flats and lay across subtidal seagrass, filamentous seaweed, and high diversity patches of sponges, suspension feeding bivalves, and a unique tube-dominated community (Hewitt and Funnell 2005). Elmetri et al. (2006) concluded that the effects of biodeposits on tube worm communities would be relatively minor because of the relatively low level of enrichment expected and high current flows. They also suggested that the risk of damage to seagrass habitat through biodeposits was likely to be low (maximum mortality of around 2%) but shading could pose a significant risk. Boat grounding and propeller scars were also identified as having the potential to cause adverse effects.

Phytoplankton depletion was also considered to be a potential issue by Hewitt and Funnell (2005) because naturally occurring suspension-feeders, which feed on phytoplankton, are abundant in the southern Kaipara. They indicated that benthic communities in AMAs A, B, C were likely to be particularly sensitive to phytoplankton depletion because of the number of suspension-feeding taxa present. Gibbs et al. (2005) assessed the potential influence of farms (within the five proposed AMAs) on suspended particulate matter, which includes phytoplankton. They estimated that the proposed level of bivalve culture to be introduced in the AMAs would require around 9% of the southern Kaipara pelagic carbon budget to maintain production and concluded that, at this level of consumption, aquaculture would not be able to control the phytoplankton dynamics in the South Kaipara Harbour. However, localised effects in the vicinity of the farms were not considered in this assessment and could be far more pronounced. Hewitt and Funnell (2005) acknowledged that high current flows were likely to reduce the likelihood of phytoplankton depletion becoming an issue but cautioned that this would depend on stock density, water column productivity, and exchange rates.

The potential effects of marine farms in the Kaipara Harbour on marine mammals remain largely unknown (Fisher 2005). However, the potential for interactions between marine farms and Maui's dolphins has been identified as a particular issue that requires further consideration.

Studies conducted on oyster farms in Houhora and Parengarenga Harbours indicate that marine farms can have a significant impact on bird behaviour (Pierce 2005). These studies showed that oyster farms had clear, species-specific impacts on avifauna, with all wader species (except South Island pied oystercatcher and pied stilt) avoiding the farms. Species showing avoidance behaviour included: banded dotterel, New Zealand dotterel, golden plover, wrybill, bar-tailed godwit, Asiatic whimbrel, lesser knot, and turnstone. In New Zealand, a typical oyster farm occupies at least 5-10 ha but recent changes in farming practices have seen new farms in subtidal channels, with some proposals for farms covering hundreds of hectares, such as the oyster farm originally proposed for AMA D (note that consent for a 75 Ha farm was approved). These structures are likely to disturb the feeding and roosting activity of birds, and have the potential to impede site-lines for birds (who prefer open areas for feeding and roosting). Shorebirds can also be affected by the operation and maintenance of marine farms, both at the farm site and at shore-based facilities. The highest impact appears to be from the operation and maintenance of oyster farms; waders, in particular, seldom come within 50-100 m of marine farms on the tidal flats when people are present (M. Bellingham., pers. obs.).

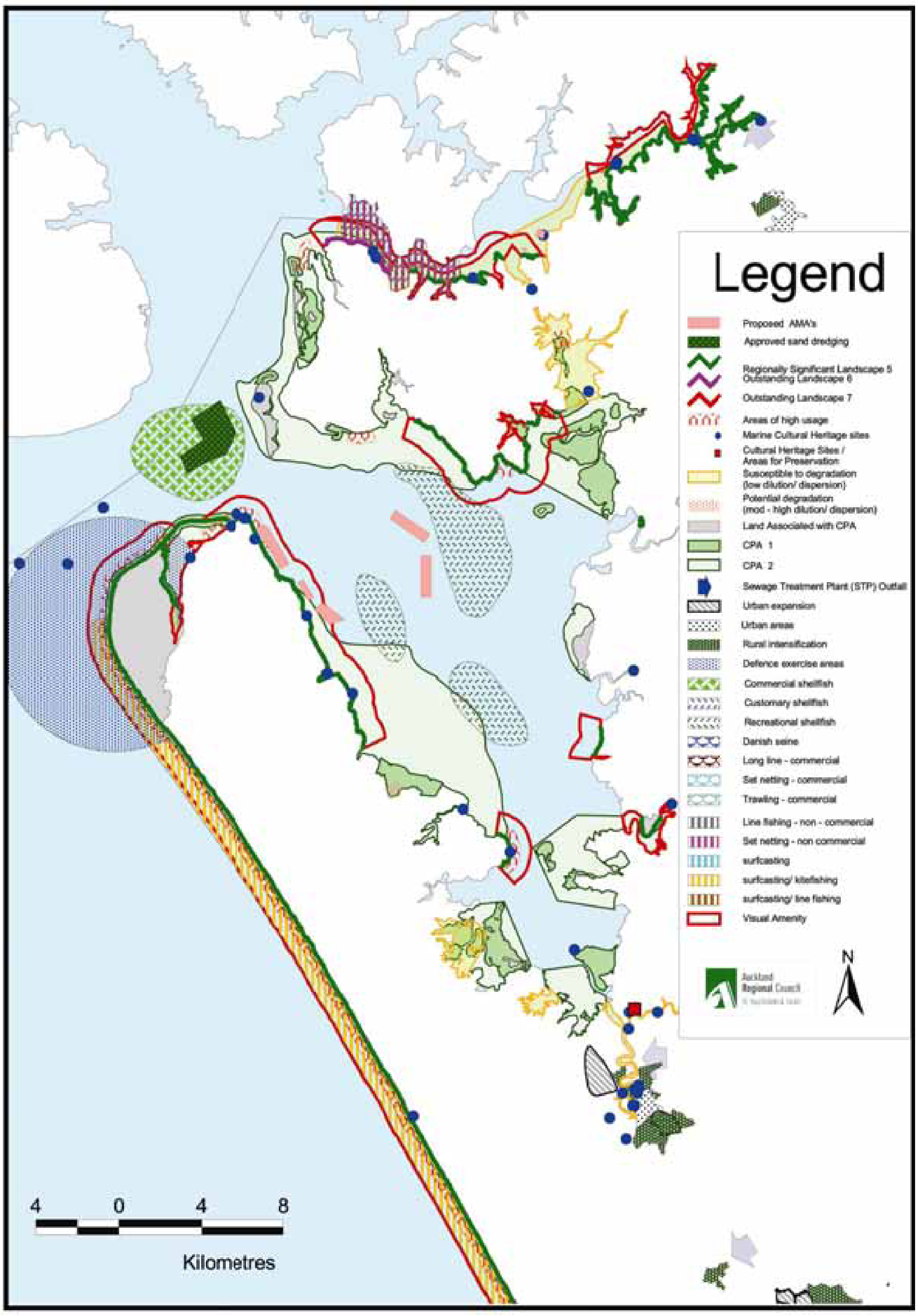
In comparison to the southern Kaipara, only a first order assessment of four proposed oyster AMAs has been carried out for the North Kaipara. One of the key criteria used in the first order assessment was that AMAs should not contain species likely to be sensitive to the effects of sedimentation such as scallops, horse mussels, and marine vegetation (e.g. macroalgae and seagrass). Haggitt and Mead (2005) found low biodiversity across all the AMAs investigated and anecdotally reported environmental degradation associated with sedimentation and invasive species, primarily *Musculista senhousia*. The AMAs in the northern Kaipara were all considered to be potentially suitable for aquaculture, based on the abundance of dominant species. However, the first order assessment used a rapid method to identify suitable AMAs for the whole of Northland; consequently, detailed investigations were not carried out in any of the potential AMAs identified. The study therefore recommended that additional assessments, analogous to those employed by Elmetri et al. (2006), should be carried out prior to confirming the suitability of individual AMAs. These more detailed assessments should, amongst other things, assess the impact of adding another factor to a system already stressed by high sediment loads and invasive species. In particular, the authors note that the impacts of biodeposits are likely to be more apparent in northern Kaipara AMAs, due to reduced tidal currents. However, because of the degraded state of these AMAs (low biodiversity, muddy substratum) any additional impacts may not be so obvious. The ability of the already impacted substratum to cope adequately with the increased nitrification and waste from aquaculture is of concern.

Aquaculture can also have a significant impact on the natural character, landscape, amenity, and recreational values, which are not covered in detail here. However, consideration of those values underpinned a recent Environment Court decision to overturn the granting of resource consent for a 30 Ha mussel farm in the southern Kaipara (Newhook 2006). In that case, the court accepted that the proposed mussel farm would not have a significant adverse effect on marine ecology and birdlife.

Spatial constraints on aquaculture with respect to other activities have also been assessed in the southern Kaipara (ARC 2002, McCarthy 2002) see Figure 60. This analysis indicates that the potential for spatial conflicts limits the potential for marine farming in many parts of the southern harbour.

In summary, available information indicates that aquaculture may cause a variety of ecological effects ranging in magnitude from highly localised to large-scale, depending on the type, scale, location, and operation of the marine farms. Landscape, natural character, amenity and recreational values may also be compromised and therefore need to be considered, as does the potential for spatial conflicts. A robust and well-planned strategy for aquaculture management, which takes into account the combined effects of marine farming and other activities occurring in the Kaipara Harbour, is therefore required. Failure to develop and implement such a strategy could lead to ongoing, uncoordinated development which ultimately compromises the functions and values of the broader harbour.

Figure 58 Aquaculture Management Areas originally proposed in the southern Kaipara, shown against a background of marine farming constraints (from McCarthy 2002).



5.1.5 Fisheries

The Kaipara Harbour is considered important for commercial, recreational, and customary fisheries and the majority of areas within the harbour are actively fished throughout the year (Hartill 2002, Kaipara Harbour Sustainable Fisheries Management Study Group 2003, Paulin and Paul 2006). Evidence suggests that many of the fisheries within the harbour have (previous or current) sustainability concerns. These species cover a range of trophic levels and include: mussels, tuatua, scallops, pipi, grey mullet, rig, and school shark (see Section 3.3.1 for more detailed information on commercial species in the Kaipara Harbour). Possible fishing-related impacts on the broader environmental values of the Kaipara include: trophic cascades (i.e. changes to food web dynamics) through the removal of higher order carnivores, direct impacts on sea-birds and marine mammals (e.g. Maui's dolphin), direct impacts on benthic habitat structure through dredging, and angler-generated pollution. The issue of by-catch also appears to be significant, particularly in regard to the school shark fishery within and adjacent to the harbour.

Traditionally, fisheries research had been focussed on assessing the abundance and sustainability parameters of target species. It is now acknowledged that fishery managers need to consider the broader ecosystem effects of fishing and, in particular, preserve vulnerable habitats, conserve biodiversity, and protect ecosystem goods and services (Fogarty 2005). However, the lack of fundamental information on the biology of fisheries and non-fisheries species makes it very difficult to determine the role of target species within the broader ecosystem or the scale of impact that fishing is having on the Kaipara. Research from other locations indicates that the indirect effects of fishing can be significant; e.g. Thrush and Dayton (2002) suggest that fishing-related impacts which restrict the size, density, and distribution of target organisms can also threaten the overall biodiversity, ecological resilience, and/or provision of broader ecosystem services. Therefore it is likely that the indirect effects of fishing in the Kaipara Harbour are considerable, regarding the number of target species with sustainability concerns.

5.1.6 Sand mining

The extraction of sand from the Pouto shoreline occurred for many decades but has now ceased. At present, sand is being extracted from the Tapora Banks area by Mt Rex Shipping and Winstone Aggregates Ltd. Resource consent conditions for Mt Rex Shipping within the Tapora Banks area (Permit No 29193) are as follows:

The volume of sand to be extracted by the Consent Holder shall not exceed:

a) 150,000 cubic metres per annum averaged over the first 5 years of the permit; unless, following a review pursuant to conditions 3 or 4, the Manager and/or the Minister of Conservation authorise either a temporary or permanent adjustment of the maximum extraction volume. Unless amended following a review pursuant to conditions 3 or 4, the total sand extracted by the Consent Holders of Permit No's 29193 and 29202 will not exceed 400,000 cubic metres in any one year, and;

b) 392,000 cubic metres per annum, with an average rate of 336,000 cubic metres per annum over the remaining life of the permit unless, following a review pursuant to conditions 3 or 4, the Manager and/or the Minister authorise either a temporary or permanent adjustment to the maximum volume to a lower volume

Current resource consent conditions for Winstone Aggregates (Permit No 29193) are:

Coastal Permit 29202: The volume of sand to be extracted by the Consent Holder shall not exceed:

a) 250,000 cubic metres per annum averaged over the first 5 years of extraction unless, following a review pursuant to conditions 3 or 4, the Manager and/or the Minister of Conservation authorise either a temporary or permanent adjustment of the maximum extraction volume. Unless amended following a review pursuant to conditions 3 or 4, the total sand extracted by the Consent Holders of Permit No's 29193 and 29202 will not exceed 400,000 cubic metres in any one year, and,

b) 308,000 cubic metres per annum, with an average rate of 264,000 cubic metres per annum over the remaining life of the permit unless, following a review pursuant to conditions 3 or 4, the Manager and/or the Minister of Conservation authorise either a temporary or permanent adjustment of the maximum extraction volume to a lower volume.

Sand extraction uses barges and suction dredges, and monitoring is carried out every 3 to 4 years to gauge the effects on the dominant fauna within the extraction area and control area (Grace 2004).

The occurrence of biological communities and dominant taxa within the harbour is linked to physical factors such as the hydrodynamics and substrate type, with many of the substrate types being a direct result of the hydrodynamic characteristics. For example, coarser, cleaner sediments occur in areas with strong currents and wave action, and have different ecological communities when compared to sheltered locations with fine, silty sediments (Hewitt and Funnell 2005).

The existing extraction site on the Tapora Banks is fairly exposed, has fine-to-medium grain sediment, and comparatively low biological diversity (Hewitt and Funnell 2005) compared to other areas of the harbour. This suggests that impacts associated with extraction would be comparatively low. Grace (2004) also describes the extraction area as having low ecological diversity (Grace 2004), but tuatua (*Paphies subtriangulata*), sand dollars (*Fellaster zelandiae*), and polychaete fauna are found throughout. Tuatua have a fairly restricted distribution within the Kaipara Harbour, generally occurring within the Fitzgerald and Tapora Bank regions. They are also patchily distributed within the main channel entrance and adjacent to South Head (Grace 2004), therefore the sand extraction area is particularly important to this species.

In 1995 (Grace, 1995) tuatua were spatially variable across the extraction area but were generally widespread, occurring in moderate densities in some areas (e.g. up to 19 / m^{-2}). Tuatua were found to reach their highest density and largest size in the north-west of the Winstone application area, although smaller individuals were widespread in both the Winstone and Mt Rex application areas. Since the initial 1995 study, biological monitoring data (Grace 2000, 2004) has indicated that tuatua abundances have declined in density within the extraction and control area (i.e. from 14 to 0.8 per 6 m^2 in the extraction area, and from 5 to 0.8 per 6 m^2 in the control area); conversely, there has been an increase in *Fellaster zelandiae* abundance (Figure 61 and Figure 62). During all the sampling events (1995, 1998, 2003), approximately 80% of tuatua and 50% of *Fellaster zelandiae* passing through the suction pump were mortally damaged (Grace 1995, 2000, 2004). Due to problems with sampling (Grace 2004), many of the sampling sites could not be sampled sequentially over the separate monitoring events, which makes trend detection relatively difficult. However, it is clear that the extraction process has the potential to impact on both tuatua and sand dollar populations.

The main reasons given for changes in tuatua abundance in the monitoring studies were a lack of juveniles in the population as a result of low recruitment into the population, concomitant with a decline in numbers of large tuatuas attributed to death due to 'old age' (Grace 2004). However, no data on the age structure of tuatua populations are given in the monitoring reports to support this hypothesis. Increases in *Fellaster zelandiae* in the extraction and control areas were suggested to be due to a decline in snapper predation because of fishing pressure in the harbour. Again, little data is given in the study to support this theory.

The high mortality of tuatua passing through the suction pump and the decline in tuatua numbers within the extraction area and control areas raise concerns about the direct effect of sand extraction on tuatua populations within the consented area and the indirect effects beyond the extraction area. Juveniles and adults of the closely related pipi (*Paphies australis*) occupy separate areas of Whangateau Harbour, with juveniles settling in intertidal areas and moving to subtidal adult beds as they grow (Hooker 1995, Healy et al. 1996). Anecdotal evidence suggests a decline in intertidal tuatua in and around the Tapora Banks area (Thomas DeThierry., pers. comm. 2006) and there are concerns that this may be due to their association with subtidal beds in the sand extraction area of Tapora Banks. Effects within the extraction area may not be limited to tuatua, as the extraction process is also likely to affect the other benthic fauna in the area (Table 20).

Table 20 Dominant subtidal species identified by Grace (2004).

Species	Common name
Fellaster zelandica	Sand dollar
Hermit crab	Hermit crab
Amalda australis	Olive shell
Paphies subtriangula	Tuatua
Siphunculus maoricus	Siphon worm
Aglaophamus macoura	Wriggling worm
Soletellina nitida	Bivalve wedge shell
Ovalipes catharus	Paddle crab
Echinocardium cordatum	Heart urchin
Capitellid worm	Bristle worm
Lumbrinereis sp.	Bristle worm
Nemertine worm	Ribbon worm
Glycera sp.	Carnivorous worm
Travisia olens	Stink worm
Umbonium zelandicum	Wheel shell
Squilla armata	Mantis shrimp
Pontophilus australis	Sand shrimp
Balanus decorus	Pink barnacle
Tewara cranwellae	Sand diver
Sole (undetermined sp.)	Sole
Philine sp.	Sand slug

Figure 59 Mean density per 6 m^2 ± standard deviation of tuatua (*Paphies subtriangulata*) in the extraction and control areas. Data from Grace (1995, 2000, 2004).

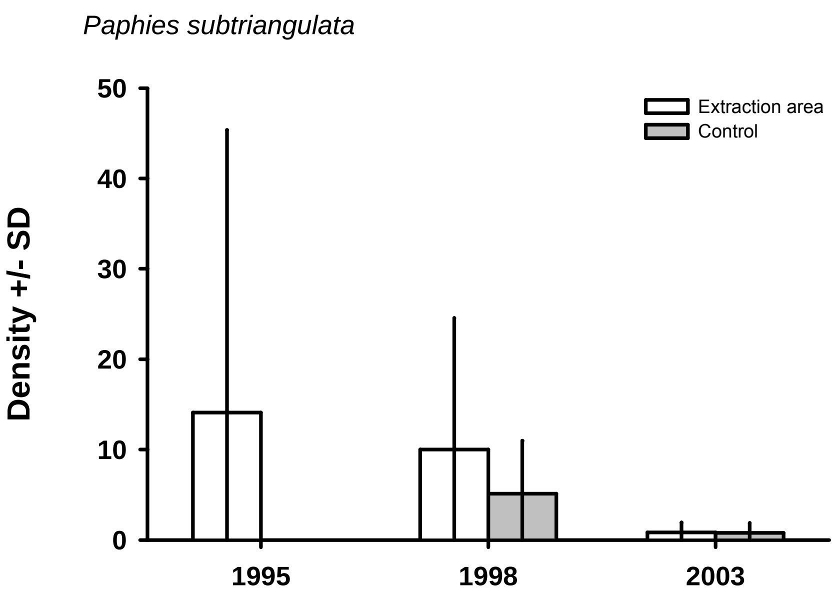
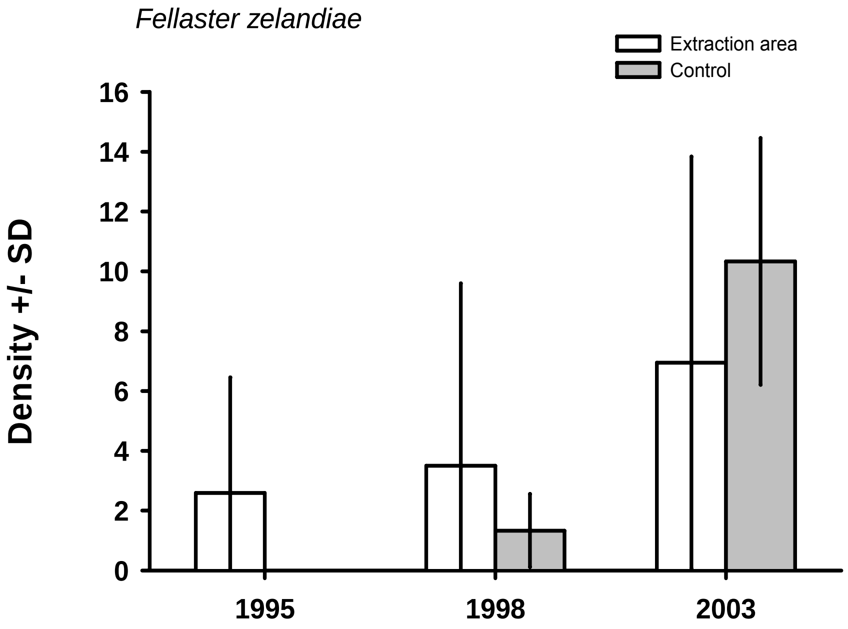


Figure 60 Mean density per 6 m2 ± standard deviation of the sand dollar (*Fellaster zelandiae*) in the extraction and control areas. Data from Grace (1995, 2000, 2004).



Sand extraction may also significantly affect the physical nature of the dredged area and adjacent habitats by altering coastal processes (erosion) due to the changes in bathymetry and sediment transport. These types of effects may have occurred in the Pouto region in the past (NRC 2002). With regard to the current sand extraction at Tapora, it has been suggested that up to 2.6 M m^3 of sand is arriving at Tapora Island each year, with the subtidal banks extending off the island and into the northern arm of the Kaipara (Lady Franklin Banks) being the areas targeted for sand extraction for the building industry. However, these volumes were extrapolated from a single instrument measurement over a two week period (an acoustic backscatter sensor, ABS) and, while it is likely that such large volumes are moving around the harbour, no sediment transport modelling has been undertaken for the Tapora region. Several studies have calculated sediment transport on the open West Coast to be in the range of 150-170,000 m^3 per annum (McComb 2001), an order of magnitude different from that thought to be arriving at the banks inside the harbour entrance. Therefore, there is a great deal of uncertainty with respect to sediment transport and pathways in the Kaipara Harbour entrance.

Additional sand extraction is being scoped by McCallum Brothers Ltd in an area immediately adjacent the Kaipara Heads, known as the Kaipara ebb tide delta. The proposed area is approximately 20,000 ha in extent with an annual extraction of up to 300,000 m^3 being suggested. Both the size of the area and volume of sand have the potential to impact greatly on environmental values, in the same way that current sand mining may be impacting the Kaipara environment.

Future monitoring connected to the sand extraction operations and sediment transport modelling for the tidal power development being proposed by Crest Energy (section 5.1.8), may provide more information on the sediment transport processes operating in the extremely energetic entrance of the Kaipara Harbour. This information is a critical knowledge gap and requires clarification, since the flood shield around the Tapora region has a great influence on the flow of water into both the northern and southern arms of the harbour. Changes to the physical nature of this area may have many subsequent impacts (e.g. changes to the sandbanks and channels that characterise the northern and southern arms of the harbour). Possible alteration of the physical nature of the harbour in this way will also have ramifications for the dominant biological communities within the harbour. Although historic nautical charts show that the entrance channels to the Kaipara Harbour have changed over the past 150 years, it is the rate of change that needs to be considered, since if sand extraction rates exceed the sustainable natural accumulation rates, would changes to channels and sandbanks be accelerated and, if so, would the organisms and communities in the modified areas be able to respond and/or adapt to such changes?

5.1.7 Genesis Energy Rodney power station

Genesis Energy proposes to use a staged approach to construct a 240-480 Megawatt combined-cycle gas turbine power station at Kaukapakapa. At the time of writing, a draft assessment of environmental effects had been submitted to the ARC and the RDC but was not available for review, although a series of resource consents are being sought for:

- Helensville Wastewater Treatment Plant discharge (future process).
- Gas pipeline installation from Taipei (currently being sought).
- ARC consent for a power station site.
- RDC consent for structures in the Kaukapakapa River.
- Change to the operative Rodney District Plan.

The development requires approximately 450,000 m^3 of earthworks to construct the power station platform and associated infrastructure (e.g. roading). Abstraction of water from the Kaukapakapa River is also required.

During construction of the power station, sediment generation is probably the main concern with respect to the coastal environment. The magnitude and scale of impact will depend on the sediment controls and operational practices implemented during the construction phase, and could range from negligible to significant. Various impacts associated with sedimentation are summarised in Section 5.1.1.

During operation of the power station, thermal loading on the marine environment from the plant discharge into the Kaukapakapa River is probably the key concern. Lardacci et al. (1999) suggest that benthic species are the ecological communities most sensitive to thermal effects as they have limited ability to escape due to their sessile or sedentary nature. The magnitude and extent of impact will, however, depend of the volume and temperature of the discharge relative to the assimilative capacity of the receiving environment.

The potential effects of the power station on the Kaukapakapa Estuary Scientific Reserve (administered by The Department of Conservation) should also be considered. The reserve is located north of the river estuary and extends from sea level to 158 m, covering a total of 210 ha. It contains an important marine and terrestrial ecotone, with terrestrial vegetation ranging from kahikatea, swamp-maire, to kauri-broadleaf forest that provides habitat for a range of species, including a colony of shags and other nesting birds.

5.1.8 Tidal power generation

Crest Energy Limited has applied to the Northland Regional Council for resource consents associated with the Kiapara Harbour tidal generation project. The associated environmental effects will be assessed pursuant to the Resource Management Act (1991) by the NRC when processing those applications.

The project proposes that 200 tidal generator arrays would be located in the entrance of the Kaipara Harbour, with the turbine units occupying water deeper than 35 m and having a minimum surface clearance of 10 m (CREST 2007a). The units would be deployed in a staged approach (Stage 1 - up to 20 units in total; Stage 2 - up to 40 units in total; Stage 3 - up to 80 units in total; Stage 4 - up to 200 units in total). Impact monitoring will be undertaken before moving to the next stage, if considered appropriate.

Two parallel sub-sea cables ~7 km in length and buried to a depth of at least 1 m will be connected to the turbines and have a shore-based landing adjacent to Pouto Point. The sub-sea cables (of up to 150 mm diameter) will consist of shielded DC cables designed to avoid generating potentially harmful electromagnetic fields (EMF) (CREST 2007b).

There is concern that the placement of the generators in the deep channel areas will affect the movement of cetaceans (orca, whales, and particularly Maui's dolphin), shark, and other fish species which may use the deep water channel when moving into and out of the harbour. The effects of electromagnetic fields created by the generators and associated cables on the sensory systems of elasmobranchs (i.e. sharks and rays) are also unknown. Elasmobranchs use highly sensitive electro-sensory systems for prey detection and, potentially, navigation. The presence of a large, artificial, electromagnetic field may cause discomfort by overstimulating their sensory apparatus (similar to bright light or loud noise causing discomfort in humans) and/or interrupt their ability to feed and navigate.

Although not considered a major area for commercial fishing, the entrance area is utilised by customary and recreational fishers, and the area considered for the transmission cable (Pouto Point) is utilised by both commercial and recreational fishers.

The medium to long-term impacts of tidal power generation also require consideration. For example, it is not known how the abstraction of tidal energy will affect tide and sea surface levels, tide duration, sediment transport, and/or other coastal processes in the vicinity and downstream of the generators. The modification of sediment transport due to energy extraction is difficult to assess without detailed evaluation (e.g. using tools such as numerical modelling or appropriate empirical techniques) and could lead to impacts similar to those discussed for sand extraction and/or have impacts on sand extraction activity (e.g. less sediment may reach the sand extraction sites due to a reduction in total energy), thus having a cumulative impact on the physical and biological environment.

5.1.9 Invasive species

Invasive species can have a significant impact on the coastal environment through: competition with native species for space and other resources, fouling of natural and man-made structures, alteration of food web dynamics, and alteration of habitat quality (e.g. by trapping sediments or through toxic effects such as toxic algal blooms).

Invasive species arrive in, and move around, New Zealand by a variety of means including:

- hull fouling,
- attached to flotsam or animals,
- ballast water,
- transportation by currents,
- attached to equipment or towed structures such as ropes, buoys, oil-rigs, barges,
- introductions through the aquarium trade (e.g. *Caulerpa taxifolia*),
- deliberate introductions, possibly for food/harvest (see www.fish.govt.nz).

Based on recent studies (e.g. Hewitt and Funnell 2005), many areas of the Kaipara Harbour have been affected by the introduction of exotic species including the bryozoan (*Membraniporopsis tubigera*) (Gordon et al. 2006) and three bivalves: Pacific oyster (*Crassostrea gigas*), Asian date mussel (*Musculista senhousia*), and the rice shell (*Theora lubrica*) (Poynter 2006). Arguably, in recent years the most conspicuous of these has been the spread of *Musculista senhousia*. An early study conducted in the Tamaki Estuary in the 1990s suggested that *M. senhousia* mats were associated with a reduction in native species distribution (Creese et al. 1999) but also concluded that, largely due to their ephemeral nature, environmental effects were most probably local and short-lived. Within the Kaipara Harbour, anecdotal evidence suggests that *M. senhousia* has spread throughout northern and southern areas (Hewitt and Funnell 2005, P. and C. Yardley., pers. comm. 2007) and Hewitt and Funnell (2005) implied a possible inverse relationship between *M. senhousia* and polychaete tubeworm abundance.

The long-term effects of invasive species are not well understood. In the Waitemata Harbour, Hayward et al. (1997, 1999) documented a decline in native species and an increase in adventive species which has occurred over the last sixty years, and 66 invasive species have now become established. The majority of these occur in low numbers and have had little effect on the harbour ecosystem; the largest impacts emanate from the Pacific oyster, Asian date mussel, and bivalve *Theora lubrica* (which are all found throughout the Kaipara) and file shell (*Limaria orientalis*).

Other notable exotic species that have been introduced within the Auckland area include: the laminarian alga *Undaria pinnatifida*, fucalean alga *Dictyota furcellata*, file shell bivalve *Limaria orientalis*, ascidian *Styela clava,* and paddle crab (*Charybdis japonica*) (Ministry of Fisheries 2007). These species have not been reported within the Kaipara Harbour. However, given the type of habitats and physical structures in the harbour and the variety of activities carried out, there is the potential for these species to become established.

Four invasive plant pests also pose a great threat to the Kaipara coastal environment (excluding the subtidal areas); these are *Spartina*, saltwater paspalum (*Paspalum vaginatum*), Manchurian wild rice, and sharp rush.

Spartina

The invasive exotic cordgrass *Spartina* spp. is present on mudflats near Oyster Point at the southern edge of the harbour and is spreading. In the past, this grass has been planted deliberately to assist reclamation of land for farming. It out-competes native species and reduces the diversity of the wetland environment, and is now considered a weed. Pampas and a range of other ecological weeds are also present.

Saltwater paspalum

A review of the impacts of saltwater paspalum (*Paspalum vaginatum*) by Graeme and Kendal (2001) noted that it has ecological effects similar to cord grasses (*Spartina* spp.) in New Zealand estuaries. Specifically, it changes the composition and structure of indigenous vegetation, excludes burrowing fauna, reduces access to feeding and roosting sites of shore birds, alters fish spawning and feeding grounds, and changes estuarine hydrology by accumulating sediment. In the Kaipara Harbour, saltwater paspalum grows amongst mangroves, in rushland, salt meadow, and upper saltmarsh shrubland communities, and has overtopped and displaced vegetation of a lower stature (M. Bellingham., pers. obs.).

In the Kaipara, saltwater paspalum has been mis-identified as Mercer grass (*Paspalum distichum*). Mercer grass can be distinguished from saltwater paspalum by its soft leaf blade and its intolerance of saline soil conditions (Edgar & Connor 2000).

Manchurian wild rice

Manchurian wild rice (*Zizania latifolia*) grows in dense clumps up to 3 m tall. This grass invades waterways and displaces native wetland vegetation such as raupo reedland. It is common along the Northern Wairoa River and scattered localities around the Kaipara Harbour on riverbanks, tidal flats, roadside ditches, and damp paddocks.

Sharp rush

Sharp rush (*Juncus acutus*) is a perennial rush that forms stout, dense, prickly clumps. It displaces native rushes and sedges. It is scattered around the Kaipara Harbour but is becoming common at Tapora, where the visual and recreational quality of the habitat is being seriously degraded because this plant is both conspicuous and extremely prickly.

Improved information on the loss of biodiversity, the rates and processes of change, and on the interactions between native and adventive species is required for many harbours and coastal areas, including the Kaipara. Biosecurity New Zealand is currently investigating the distribution and abundance of invasive species throughout coastal and estuarine areas in New Zealand, and developing tools to determine invasion pathways and eradicate invasive species.

In November 2006, NIWA were commissioned by Biosecurity New Zealand to undertake a survey to provide baseline information on the distribution and abundance of native and invasive species within northern and southern areas of the Kaipara Harbour. Areas surveyed included: Ruawai slipway, Ruawai landing, Sail Point, Middle Channel, Pakaukau Point, Matihe Point, Bushy Point, Five Fathom Channel, Te Whau Point slipway, Mussel Rock, The Funnel, Te Hoanga Point, Pahi landing, Pahi slipway, Kapua Point, Motukumara Point, Hargreaves Basin, Pouto Point, Karaka Point, Kaipara River (three sites), Shelly Beach slipway, Shelly Beach landing, Ngapuke Creek, Waionui Inlet, Kaipara Head (conditions permitting), and Rangitira Beach. At the time of writing, the field work was complete but the identification of all of the species was not, therefore NIWA were not in a position to release any of the results (B. Hayden., pers. comm. 2007). The findings of this research project will provide more detailed information on the extent of adventive species within the Kaipara Harbour.

6 Comparative impact of activities

The main environmental pressures within the Kaipara Harbour coastal environment are managed under the Resource Management Act (1991), Fisheries Act (1996), and Biosecurity Act (1993). Based on the available information, environmental pressures on the Kaipara Harbour include, but are not limited to: land-use, fishing, sand mining, aquaculture, and biosecurity issues as well as proposed new developments (e.g. tidal energy extraction), all of which pose a threat to the environmental values and sustainability of the harbour.

Due to lack of specific information on many activities and their effects on the Kaipara (including a lack of knowledge about the links between activities and their associated impacts), it is not possible to determine the relative influence of the various environmental pressures. However, some generalisations can be made based on professional judgement and the information that is available.

At present, the two activities that are likely to be having the greatest impact on the Kaipara Harbour are landuse and fishing. The dominant landuse issue is sediment runoff but wastewater impacts also appear to be significant in some areas. The effects of invasive marine species are also substantial and relatively widespread. Other existing activities within the coastal marine area are also likely to be having a significant effect on the harbour but their impacts are probably more localised. The cumulative impacts of recent proposals/approvals for aquaculture, power generation, and sand mining are unknown but could also be significant. Existing and proposed sand mining, together with proposed tidal power generation, could have a major impact on the physical nature of the harbour, altering sediment transport and hydrodynamic processes. Therefore, these activities could have significant direct and indirect impacts on benthic communities, fish (grey mullet, snapper, and sharks) and marine mammals (dolphins) that utilise the harbour and open coast. Importantly, the impacts of these (and other) stressors should not be assessed in isolation from each other or from existing stressors. The lack of reliable information on the cumulative impacts is seen as a significant gap that will compromise the sustainable management of the harbour.

The direct impact of fishing (when combined with indirect impacts of habitat degradation in the Kaipara Harbour) is of particular concern because the impact on fish stocks extends well beyond the harbour itself. For example, in 2005 the West Coast snapper stock (SNA8) was estimated to be well below (~50%) the maximum sustainable yield. The total allowable commercial catch and recreational bag limits were therefore cut to allow the stock to rebuild more quickly (estimates predict that the SNA8 snapper stock biomass will reach 20% of the unfished biomass sometime after 2018). However, West Coast estuaries are considered to provide a crucial supply of snapper recruits to the coast. The Kaipara Harbour is especially important and is estimated to produce almost three-quarters of those recruits (FRST 2003). Consequently, the degradation and loss of juvenile snapper habitat in the Kaipara (e.g. horse mussel beds, subtidal seagrass) could compound the effects of fishing and inhibit the rebuilding of West Coast snapper stocks. Of particular concern is the potential loss of intertidal and subtidal seagrass meadows from increased sedimentation and turbidity (due to catchment disturbance) and shading effects (due to aquaculture). Loss of this community would, potentially, have a serious affect on fisheries within and beyond the harbour; additional effects include reduced primary productivity and loss of biodiversity.

Smaller-scale impacts such as stock grazing within the coastal marine area, small point source discharges, small structures, and reclamations are also important in terms of their effect on the natural values of the harbour because their effects tend to be cumulative.

6.1 Linkages between activities managed under the RMA and other Acts

Due to the range of activities that utilise the resources of the Kaipara Harbour, a number of resource management issues have the potential to affect fisheries, conservation management and biosecurity. These issues are often interrelated.

6.1.1 Fisheries

Resource management issues that have the potential to affect customary, recreational, and commercial fisheries within the Kiapara Harbour range from spatial conflict with other activities carried out in the coastal marine area (e.g. aquaculture, tidal power generation, sand mining), the direct effects of those activities on fished species, and the indirect effects such as the loss of nursery habitat (seagrass and horse mussel beds) because of sedimentation, pollution, or the alteration of physical processes.

6.1.1.1 Spatial conflicts

Fishing in a variety of forms occurs throughout most of the harbour (Figure 14, Figure 15, Figure 18) and can be in direct spatial conflict with other activities that occupy the coastal marine area, such as aquaculture and sand mining. The area identified for the proposed tidal power generators falls largely outside of the areas known to be targeted by commercial fisherman but coincides with areas popular for recreational and customary fishing. Power turbines and cables will lead to restrictions on anchoring and fishing, thus limiting all forms of fishing within the area. Similarly, sand mining around Tapora Banks and aquaculture in the northern and southern arms of the harbour will also invoke spatial conflicts where these activities coincide with fishing (Figure 63).

Conservation management can also restrict fishing in certain areas (see Section 6.1.2). In order to protect Maui's dolphin, Forest and Bird are seeking a set-net ban, through the creation of a marine mammal sanctuary throughout the Maui's dolphins' range. The proposed marine mammal sanctuary will include the entire Kaipara Harbour, effectively prohibiting set-net fishing within the harbour (Figure 61). As well as protecting dolphins from set-nets, the marine mammal sanctuary would also seek to protect them from other human-induced threats such as trawling, boat strikes, marine farming, pollution, sand mining, and the potential threat from tidal energy generation. This has direct implications for the resource management functions of the Northland and Auckland Regional Councils.

There is very little information on the utilisation of the Kaipara Harbour (or Manukau Harbour) by Maui's dolphins, therefore it is difficult to determine what activities should be controlled and the spatial extent of those controls. This is seen as a critical knowledge gap which needs to be addressed.

Figure 61 Proposed marine mammal sanctuary. (Source: www.forestandbird.org.nz.)

6.1.1.2 Direct and indirect impacts

Sedimentation from catchment disturbance due to urbanisation, farming, forestry, and other land-based practises that result in poor water quality and habitat deterioration may also impact on important fisheries species within the harbour. Prime examples within the harbour include both tuatua and scallops, which are extremely sensitive to sedimentation (Gibbs and Hewitt 2004). Many of the sub-catchments of areas within the harbour where scallops, and bivalves and tube dwellers are found (the Kaipara Flats intertidal area adjacent Kakanui Point and Tapora Banks, respectively) have erodible soils of silt and clay coupled with poor soil drainage. In addition, sedimentation may also damage or impact important biogenic habitat for juvenile fishes (snapper, grey mullet) or species that are an important food source for fished species. Examples of the types of habitat that may play important fishery roles within the harbour are horse mussel and seagrass beds, and sponge and hydroid habitats (see below). These habitats may require specific management measures to ensure their long-term viability.

Based on the data contained within the monitoring studies of Grace (1996-2004), there is some evidence that sand mining may impact on adult (50-70 mm) tuatua abundance both in and around Tapora Banks, which may also impact on the tuatua fishery within the harbour. Reductions in tuatua numbers may also have trophic-level impacts for species (such as snapper) that utilise tuatua as a food source and other species that feed on the benthic species (polychaete worms, gastropods, crustacea) that occur within the sand-mining areas. Sand mining may further impact on fish abundance by reducing the complexity of the substratum (depressions, burrows, shells, and sand waves) within the harbour, which has been recognised as an important habitat structure for juvenile snapper (Thrush et al. 2002). Similarly, fishing practises that utilise dredging (e.g. dredging for scallops, tuatua, and mussels) within the harbour may also disrupt the complexity of the substratum.

Tidal power generation has the potential to affect fisheries in multiple ways by impeding the pathway used by fish between the harbour entrance and harbour proper; for example, grey mullet actively spawn outside the harbour (Paulin and Paul 2006) and school shark are also considered as transient within the harbour (Ministry of Fisheries 2006d). Further impacts to the shark fishery (rig and school shark) may occur due to potential electromagnetic interaction with the sensory systems of elasmobranches and disturbance caused by constructing undersea foundations, placement and maintenance of turbines, while the laying and maintenance of transmission cabling may also adversely impact fisheries.

Aquaculture has the potential to affect important habitats used by fish through biodeposition and disturbance to the seabed during farm operations (Elmetri et al. 2006). Conversely, structures associated with aquaculture such as longlines and anchors may attract fish and provide habitat for juveniles, thereby reducing predation.

6.1.1.3 Fishery restrictions

There are a range of restrictions on fishing activities that can occur in and around the Kaipara Harbour. These address the requirements of the Fisheries Act (1996) and its associated regulations, the Submarine Cables and Pipeline Protection Act (1996); and areas gazetted or established by Order in Council under the Conservation Act (1987), Marine Reserves Act (1971), Marine Mammals Protection Act (1978), Reserves Act (1977), and Wildlife Act (1953) (Froude 2004). These measures include: preventing or restricting the use of a variety of fishing methods, preventing the commercial and/or premature harvesting of a variety of species, restricting size and bag limits, and restrictions on when fishing can occur and who can collect oysters.

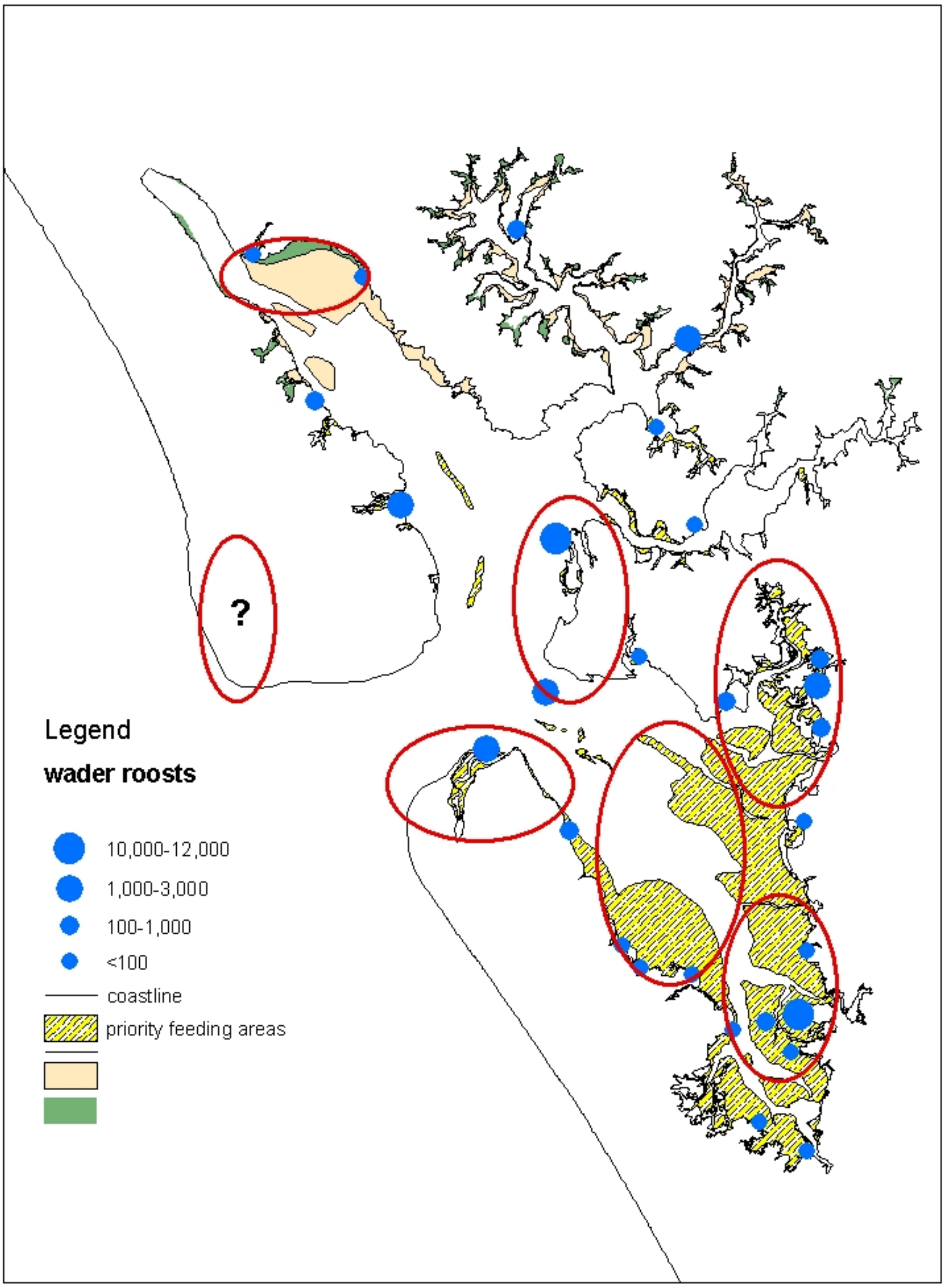
6.1.2 Conservation

Resource management issues that potentially effect conservation objectives for the harbour include spatial conflicts between activities managed under the Resource Management Act and conservation areas, and habitat degradation from activities occurring adjacent to and within the coastal marine area such as aquaculture, sand mining, fisheries, and sedimentation.

A number of feeding and roosting sites for wading birds and areas of coastal marine vegetation can readily be identified on the Kaipara Harbour that would benefit from controls on development and other activities that could degrade these sites and threaten the viability of bird populations on the harbour. These sites are:

- Priority wading bird feeding and roosting sites (Figure 62).
- All of the fairy tern nesting and roosting areas (Figure 24).
- Significant areas of mangrove-saltmarsh indigenous forest and scrub mosaic (Figure 33 to Figure 37).
- Other nesting colonies of wading birds, gulls, and terns (all at wading bird roosting sites).

Figure 62 Priority wading bird roosting and feeding areas on the Kaipara Harbour.



6.1.3 Biosecurity

Activities such as aquaculture, construction, and fishing have the potential to increase and exacerbate the spread of invasive species which could have a significant impact on the marine ecosystems of the Kaipara Harbour.

In addition, invasive species could adversely affect fishing and Resource Management Act controlled activities, through the fouling of hulls and equipment, interactions with target species, and the alteration of physical or biological habitats.

The spread of invasive species is an important cross-boundary issue for the Kaipara Harbour. Controlling the spread of invasive species, once established, is difficult. However, specifiying conditions to ensure that vessels or equipment used for Resource Management Act controlled activities (e.g, construction barges, sand dredging tugs and barges, or aquaculture harvesting vessels) were free of fouling would help to prevent the spread.

7 Cross-boundary effects

The Kaipara Harbour is locally governed by the Auckland Regional Council (ARC), Northland Regional Council (NRC), Kaipara District Council (KDC), Rodney District Council (RDC), and Whangarei District Council (WDC). The major division between the ARC and the NRC runs from the mouth of the harbour (separating North and South Head), north through the Otamatea Channel, splits the Oruawharo River along its entire length, and then runs out to Mangawhai on the East Coast. This boundary also separates the Northern and Auckland Conservancies of The Department of Conservation.

Cross-boundary effects can be viewed in two different ways that are not necessarily mutually exclusive: first, those effects that cross jurisdictional boundaries (i.e. regional councils and district councils) and second, those effects from activities that essentially occur outside of the coastal marine area but can have a significant effect on the coastal marine areas (e.g. increasing sediment runoff or increasing hazard risk). The latter impacts have largely been identified within earlier sections.

Environmental issues associated with main activities within the harbour that have been identified previously, and that have the potential to cross planning boundaries within the harbour are: catchment development and land disturbance that results in deterioration of water quality or increased sedimentation of the harbour, incursion and spread of invasive species, large-scale aquaculture, sand mining, tidal power generation, and fishing (commercial, recreational and customary). The cumulative impacts of multiple small-scale activities could also lead to large-scale effects on the ecological landscape and natural character values of the harbour, which cross jurisdictional boundaries. The locations of the various activities that have the potential to produce cross-boundary effects are presented in Figure 65 and the significance of each activity/issue in relation to cross-boundary effects is evaluated.

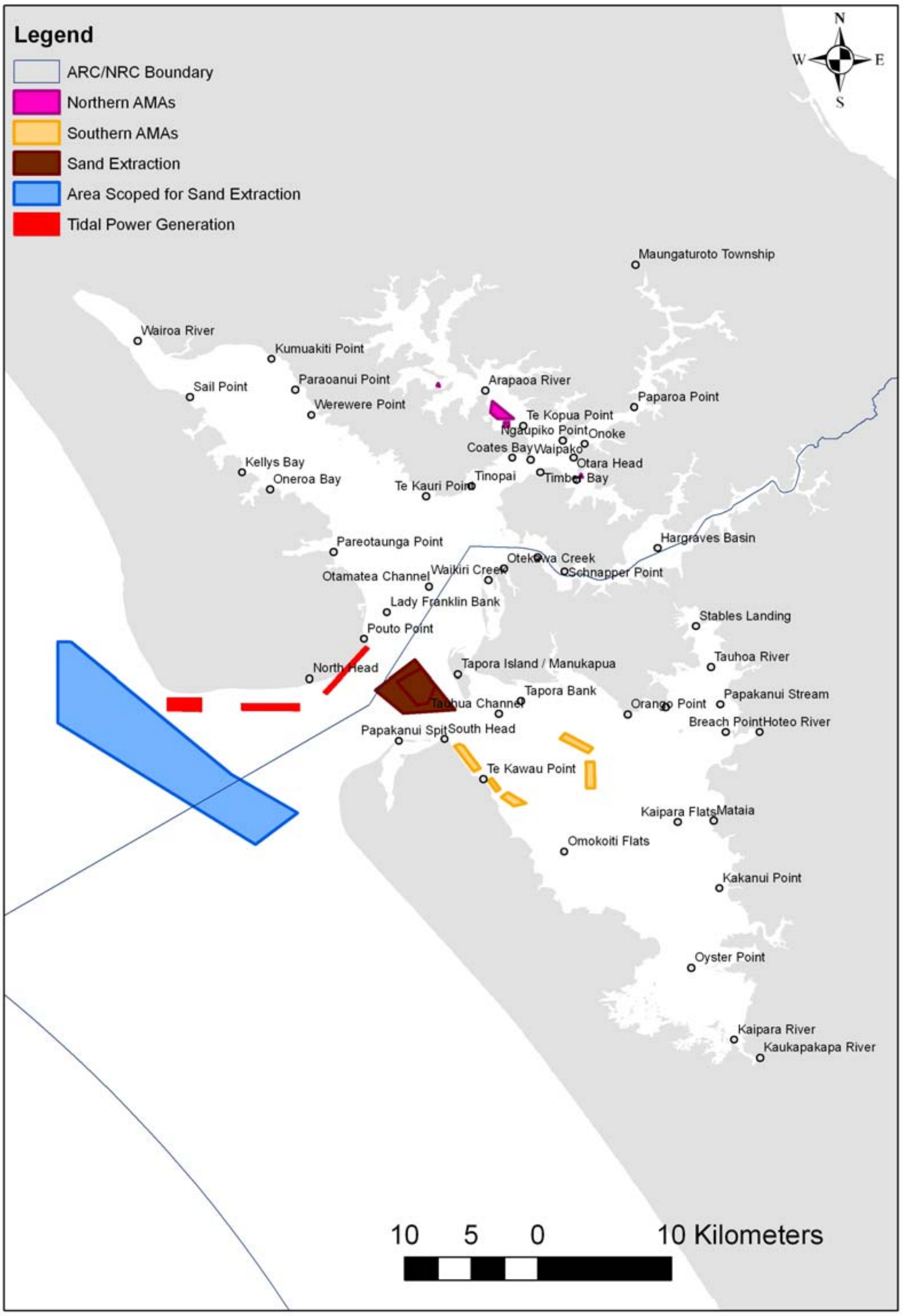
Land disturbance and land use

The hydrodynamic properties of the harbour suggest that mixing between the northern and southern areas of the harbour may not be great, so the cross-boundary dispersal of sediment and contaminants may be fairly limited. The most significant catchments for cross-boundary effects are those adjoining the ARC/NRC boundary, i.e. catchments draining into the Oruawharo River. Many sites along both sides of the Oruawharo River (Oruawharo and south of Point Albert and parts of Tapora) are characterised by silt and clay soils with largely imperfect drainage. These factors are likely to be problematic for land disturbance activities and pose a significant threat to ecological communities within the river (Mead et al. in prep.)

While the direct effects of runoff may be fairly localised, the indirect effects could be much broader and extend across planning boundaries. This could occur where the species, communities, or habitats that are directly affected provide important functions and services for other species. For example, extensive intertidal and subtidal seagrass meadows are located adjacent to the Hoteo River, which has a very high annual sediment yield (sediment discharge has been calculated at 354 tonnes per square kilometre per year, Mead et al. in prep) and sediment impacts on the seagrass beds could adversely affect the snapper population in the harbour, as well as on the open coast. Furthermore, the loss of small areas of seagrass and the subsequent effects would be cumulative across the harbour.

Fragmentation of coastal vegetation is also a significant cross-boundary issue for the Kaipara Harbour, particularly with respect to the provision of suitable habitat for birds.

Figure 63 Activities that may cause cross-boundary effects in the Kaipara Harbour. Note the largest impact that may cause cross-boundary effects (landuse activities) incorporates the entire Kaipara catchment area.



Sand mining

Sand mining currently undertaken by Mt Rex Ltd and Winstone Aggregates Ltd on the Tapora Bank and Fitzgerald Bank regions occurs adjacent to the NRC/ARC boundary (Figure 65) and has the potential to cause several cross-boundary effects. Ultimately, environmental issues associated with sand extraction are related to the frequency of dredging, the volume of sand being extracted, and the physical characteristics (substratum and water column) of the dredged area.

Dredging may affect the physical environment by altering bathymetry and changing the current velocities and wave conditions (Jensen and Mogensen 2000) which, in turn, affect sedimentary processes leading to erosion. Previous sand extraction adjacent to Pouto Point was abandoned due to possible effects of the sand extraction on shoreline erosion (NRC 2002). With regard to the existing sand extraction activities, there is uncertainty about the volume of sand arriving into the Tapora area relative to the amount extracted. This is viewed as a critical knowledge gap, since this area (the flood delta or shield) has a great influence on the flow of water into both the northern and southern arms of the Kaipara Harbour. Changes associated with this part of the harbour, resulting from sand extraction, may consequently impact both the southern and northern areas of the harbour (e.g. disruptions in the physical processes in an area which may have implications for the dominant ecological communities within the harbour).

Another significant environmental issue arising from sand extraction is the disturbance to benthic communities and dominant species within the dredged area, particularly tuatua with their distribution restricted to the harbour entrance. At present, it is unknown how the various tuatua populations are connected within the harbour, and whether the tuatua beds located in and around the extraction area (which may be impacted by sand mining) are an important brood-stock for maintaining other tuatua populations in the harbour entrance, such as those found adjacent to North Head.

Temporary decreases in water clarity, increased concentrations of suspended matter, and increased rates of sedimentation are additional environmental issues associated with sand extraction within the harbour that have the potential to cross the ARC/NRC boundary during periods of calm weather and reduced wave action. However, due to the physical nature (high wave energy) of the dredged area, these type of environmental issues are unlikely to be great.

At present, McCallum Brothers Ltd is scoping the feasibility of sand extraction in area of seabed immediately adjacent to the Kiapara Heads, the ebb tidal delta. The proposed area is approximately 20,000 ha in extent with a proposed annual extraction of up to 300,000 m^3. While estimates of sand arriving at the entrance to the harbour are uncertain, as are the sediment transport volumes and pathways into the Kaipara Harbour proper, both the size and volume of sand have the potential to create significant cross-boundary effects related to coastal processes. These include alterations to the North and South Head coastlines and impacts on sediment transport into the harbour (as for tidal power generation, discussed below). Furthermore, as the sand extraction area encompasses almost the entire harbour entrance, issues associated with fish and mammal disturbance between the open coast and harbour could have significant cross boundary implications within the harbour.

Fishing

Unsustainable fishing within the Kaipara Harbour has the potential to result in environmental effects that cross the various planning boundaries of the harbour. However, management of these effects are removed from council responsibilities by the exemptions of Section 12(1)(c) and (e) of the Resource Management Act (1991), with fishing-related impacts being managed by the Ministry of Fisheries.

Fishing-related issues that may potentially result in cross-boundary effects within the harbour include:

- Changes in the abundance, population characteristics, and reproductive output of target species.
- Changes in the abundance, population characteristics, and reproductive output of by-catch species.
- Risks associated with the incidental capture of threatened species such as Maui's dolphin.
- Damage to the seabed and associated habitats (which may include breeding, spawning, and nursery habitats).
- Flow-on effects of harvesting target species to other parts of the food web (e.g. trophic cascades).

Ecosystem-level impacts may not be restricted only to the harbour, as many of the species move outside it.

Destruction or deterioration, by fishing, of habitats that are important spawning and nursery areas or that aggregate fish due to their structure (e.g. sponges) also has the potential to greatly alter species abundance and distribution, resulting in cross-boundary effects. The main fishing methods associated with direct habitat destruction are trawling and dredging; with dredging applying only to the scallop, tuatua, and mussel fisheries within the Kaipara. The latter two species are presently not fished commercially within the harbour and the recent ban on scallop harvesting suggests that dredging impacts are unlikely to be a major issue within the harbour at present. This situation could change when the ban on scallop harvesting is lifted.

Historical declines in fisheries (such as the mussel dredge fishery in the early 1990s) coupled with a general lack of understanding on trophic interactions within the harbour, suggests that many fishing-related impacts that have ecosystem-level and cross-boundary impacts may have gone undetected.

Aquaculture

Cross-boundary issues associated with aquaculture include landscape, natural character, and biosecurity. The small oyster farms within the Hargreaves Basin (Oruawharo) River (total 200 ha) potentially have visual effects and small-scale ecological impacts due to sedimentation and biodeposition but are unlikely to cause large-scale, cross-boundary effects. However, the effects of large-scale aquaculture may extend across planning boundaries and the potential effects on functionally important habitats are of particular concern. Ideally, aquaculture planning should be integrated across the harbour and involve more detailed assessments of the associated and cumulative risk.

Invasive species

In conjunction with habitat deterioration and fragmentation, the spread of invasive species within the coastal marine area is a significant environmental issue with the potential to cross jurisdictional boundaries. Currently, invasive species such as *Musculista senhousia* and *Theora lubrica* occur throughout the northern and southern arms of the harbour. The initial incursion periods of these species is difficult to determine. Due to the number of activities (e.g. fishing, aquaculture, dredging, construction), structures (marine farms, wharfs), and habitats within the harbour, the potential for introducing new invasive species is relatively high. The spread of invasive species is also influenced by the hydrodynamics, the availability of suitable substratum, and the life-history characteristics of the species. Accordingly, it is not simple to predict where incursions are likely to occur; although popular fishing spots, structures such as wharfs, and marine farms are likely to be high risk areas.

Tidal power generation

Tidal power generation planned for the northern Kaipara has associated environmental issues with the potential to cause significant cross-boundary effects. Although the proposed location of the tidal generator arrays is within the Northland Region, the removal of tidal energy (potentially 5% of total tidal energy) from the tidal stream is an issue that could impact on both the southern and northern areas of the harbour. At present, the effect(s) of tidal dampening are not known with respect to coastal processes and sediment transport within the harbour. Of particular concern are the potential impacts of reduced sediment deposition on the flood tide delta, which essentially governs the hydrodynamics and thus the presence of physical features (sand banks, tidal channels) and biological communities within both arms of the harbour. Additional far-reaching impacts on tidal current velocities and water levels (i.e. impeding the tidal current may reduce or increase water levels inside the harbour) may also affect the whole harbour. Due to a lack of current information about the effect of tidal generators on the tidal stream, the various impacts associated with a loss of tidal power across planning boundaries are generally unknown.

8 Identification of knowledge gaps that are critical barriers to integrated management

Management of the Kaipara Harbour resources is undertaken by a range of regulatory bodies, notably the regional councils, district councils, Department of Conservation, Ministry of Fisheries, and MAF-Biosecurity New Zealand. Knowledge about the current environmental quality of the Kaipara Harbour as a whole is extremely fragmented, due in part to its size, but also to the different objectives amongst the various regulatory bodies, and the availability of resources for addressing management issues in the harbour (Peart 2007). Consequently, there are a variety of environmental knowledge gaps that act as barriers to successful and integrated management of the Kaipara Harbour. These are identified and discussed below.

8.1 Landuse and development

The enclosed nature of the Kaipara Harbour makes it particularly vulnerable to activities carried out in the adjoining catchments. However, information on landuse impacts is largely anecdotal or inferred from studies that were not specifically designed to examine these impacts. Key information gaps include:

- Long-term plans for catchment development and its associated effects on the harbour.
- Changing patterns of landuse.
- The effectiveness of current plans, policies, and non-statutory tools designed to maintain the quality of the harbour appears to be largely unknown.
- Ecological changes that would provide feedback on policy effectiveness (ecological monitoring is not carried out routinely in the Kaipara Harbour).
- The current scale and magnitude of sediment-related effects.
- The long-term cumulative impacts of sediment and contaminant runoff (individually and in combination with other stressors).

Tools are available which allow the effects of different landuse scenarios to be modelled (e.g. as applied to Whitford, the Upper Waitemata Harbour, Central Waitemata Harbour and south-east Manukau Harbour) and could be used to assess the long-term cumulative impacts of various landuse scenarios on the entire harbour. They would also allow 'problem' sub-catchments, where special landuse controls may be required to prevent erosion or contaminant generation, to be identified. Information generated from these models would provide a strong foundation for policy and plan provisions, or non-statutory methods, which would seek to ensure the long-term sustainability of the harbour.

8.1.1 Water quality

Available evidence suggests that water quality in some parts of the harbour is relatively poor (Elmetri et. al. 2006), but assessment of harbour-wide water quality and tracking changes over time is hampered by the poor spatial resolution of the sampling and/or interrupted time-series data.

An integrated, harbour-wide, monitoring programme that established a robust water quality dataset would greatly improve the usefulness of the information collected. The programme should:

- Increase the number of water quality monitoring sites within the harbour, to cover key environmental compartments.
- Maintain a regular sampling frequency (preferably monthly).
- Measure the temperature, pH, salinity, chlorophyll *a*, dissolved oxygen, turbidity, total suspended solids (TSS), nitrate, ammonium, phosphate, total reactive phosphate, enteroccoci and faecal coliforms,

Sample collection by helicopter would be efficient, consistent, and cost-effective.

8.1.2 Fisheries

The Kaipara Harbour is particularly important for local fishers and the broader West Coast fishery. A number of species that are harvested for commercial, recreational, and cultural purposes have sustainability concerns but, in many cases, information which would assist management decisions is lacking. Key information gaps are the:

- General lack of biological information on the life histories, distribution, and habitat utilisation of fishery species within the harbour.
- Effects of non-fishing activities on fish (e.g. sand mining, tidal power generation).
- Effects of habitat loss or degradation, particularly on juvenile fish.
- Effect that changes in fishing methods have had on the calculation of maximum sustainable yields (Paulin and Paul 2006).
- Extent and nature of fishery interactions between the West Coast and the Kaipara Harbour.
- Connectivity between marine receiving environment health and freshwater fish populations.
- Effects of removing target fishery species on the broader harbour ecosystem.
- Efficacy of bans on scallop harvesting.

Studies funded by the Foundation for Research, Science and Technology, and the Ministry of Fisheries are addressing some of these knowledge gaps. Preliminary data indicates that structurally complex biogenic habitats such as seagrass and horse mussel beds are particularly important to the juvenile stages of many fish species (e.g. snapper). Habitat forming species such as horse mussels are known to be sensitive to sediment (Gibbs and Hewitt 2004). Therefore, the implication for resource managers is that sediment-generating landuse activities could have an indirect effect on the early stages of commercial and non-commercial fish species, through biogenic habitat destruction. This is particularly important for the Kaipara Harbour, as it is estimated to provide around three-quarters of West Coast snapper recruits.

8.1.3 Sustainable aquaculture

Pressure for the expansion of aquaculture in the Kaipara Harbour is likely to continue into the future and there is a risk of slow, long-term aquaculture 'creep' if clear guidance is not provided in planning documents. The effects of aquaculture will be specific to the location, type, and scale of the marine farms and information requirements will vary accordingly. A reasonable level of information is available for the southern Kaipara, which can underpin a broad assessment of the areas that may be suitable for aquaculture. More detailed studies are likely to be required to assess the specific impacts of particular aquaculture proposals (note that ecological concerns may not be the key driver for aquaculture planning). A number of key information gaps remain for the northern Kaipara. These include:

- A lack of detailed information on the habitats and communities present.
- Information on the ecological habitats, communities, and species that are likely to be most vulnerable to the effects of aquaculture.
- Constraints due to spatial conflicts with other values and activities.
- Information on nutrient budgets, primary production, and the aquaculture carrying-capacity.

In addition, it would be useful to have a better understanding of the cumulative impacts of aquaculture in combination with other activities. Ideally, planning for aquaculture should be done on a harbour-wide basis, with consideration of the cumulative effects and consistency in the standard of assessment.

8.1.4 Spread of invasive species

Due to a general lack of long-term ecological monitoring within the harbour, it is impossible to determine any changes that may have occurred due to invasive species. This is problematic for management, as evidence is emerging from other harbours (where historical data is available) of the negative effects of invasive species on the distribution and abundance of native species (e.g. Waitemata Harbour, as documented by Hayward et al. 1997, 1999). Knowledge gaps that pose difficulties for successful integrated management in relation to invasive species include:

- Biological (particularly reproductive) characteristics of invasive species.
- Impacts of invasive species on native community structure and on specific native species. i.e. knowledge of the stressors (invasive species), receptors (communities and habitats affected), and the various linkages between them (see Arenas et al. 2006). For example, the loss of *Pomatoceros caeruleus* from Meola Reef in the Waitemata Harbour due to an increased abundance of Pacific oysters (Hayward et al. 1999, Ford et al. 2006).
- Effect of invasive species on food chains and, in particular, the effects on higher order predators (e.g. birds, fishes, marine mammals) and on trophic linkages among dominant species.
- Identification of invasive species and knowledge of the invasion history.
- Appropriate tools to eradicate invasive species.
- Identifying main vectors and activities responsible for introducing invasive species.

The findings of a baseline study currently being undertaken for Biosecurity New Zealand will provide an important inventory (including abundance and distribution) of invasive species within the harbour. Additional studies also being commissioned by Biosecurity New Zealand include conceptual modelling of stressor-response relationships to explore the flow-on effects of invasions in the Waitemata, and the development of methods for eradication. The results of these studies will be applicable to the Kaipara.

When information from the baseline study is available, with additional information from other studies, an invasive species detection and response programme could be developed for the Kaipara Harbour. This should include routine surveillance of 'at-risk' areas within the harbour which would be the responsibility of Biosecurity New Zealand.

Management of established invasive species is very difficult. Consequently, the best approach is to prevent the introduction of invasive species through the identification and management of vectors and high-risk activities. Key vectors and high-risk activities that require biosecurity control by regional councils include: aquaculture (movement of stock, vessels, and equipment), marine construction (movement of vessels and equipment), and ports and marinas (vessel movements). The ability of regional councils to restrict vessel movements is fairly limited. However, a number of questions should be considered when consenting to biosecurity high-risk activities. These include:

a. Are the biosecurity risks adequately understood in terms of their likelihood of occurrence and potential consequences?

b. Is the regional council confident that the biosecurity risks of the activity can be controlled, and are the proposed control mechanisms adequate?

c. Should the consent be granted if the biosecurity risk is deemed to be significant?

8.1.5 Protection of critical habitats and taxa

The Kaipara Harbour contains a number of habitats, communities, and taxa that are rare or endangered and likely to provide critical ecological functions and services for the harbour and broader West Coast. Their identification and protection is hampered by: the lack of information on their distribution; the ecological processes involved in the provision of functions and services; threats, and protection measures.

The classification of coastal bird habitats and coastal bird taxa is well established and provides a basis for the development of protection strategies related to birds. Similarly, coastal vegetation has been mapped in the southern Kaipara and a variety of controls are available to protect, or preferably, expand its range. In contrast, much less is known about important marine habitats, communities, and taxa, and methods of protection. Key knowledge gaps for important marine habitats, communities, and taxa therefore include:

- Distribution (although reasonable information is available for the southern Kaipara, little is known about the northern Kaipara).
- Spatial and temporal changes in distribution and abundance.
- The ecological functions and services they provide.
- Individual and cumulative threats.
- Methods for protection.

8.1.6 Protection of marine mammals

Currently there is little detailed information on marine mammal distribution, abundance within the Kaipara Harbour or information on how marine mammals utilise the Kaipara Harbour. Most of the information comes from stranding records and casual sightings (Fisher 2005).

9 Conclusions

This report summarises the available environmental information on the Kaipara Harbour coastal environment, with a primary focus on the coastal marine area (CMA). The Kaipara Harbour is an extremely important ecological system that contains many high value species, communities, and habitats which provide local, regional, and international functions and services. However, the environmental values of the Kaipara have been, and continue to be, degraded. More detailed information tends to be available for the marine ecological communities and birds in southern parts of the harbour (compared to the northern Kaipara) but information on fish and marine mammal distributions is fairly limited for the entire harbour. Available information on habitat quality is variable in coverage, quality, and temporal integrity.

Threats to environmental values

The environmental quality and values of the harbour are potentially under threat from a variety of activities managed under the Resource Management Act (1991), Fisheries Act (1996), and Biosecurity Act (1993).

Landuse activities that generate sediment appear to be particularly problematic. The scale and magnitude of these impacts is likely to increase if sediment (and in some areas, contaminant) discharges are not managed appropriately. It is recommended that sediment accumulation models be developed for the Kaipara Harbour to allow the long-term effects of various landuse options to be predicted. These models would provide a strong foundation for policy and plan provisions, or non-statutory methods, which seek to ensure the long-term sustainability of the harbour.

The spread of invasive species (biosecurity) is a harbour-wide issue, with a number of well-established species already occurring in many areas. The transfer of vessels, stock (aquaculture), and equipment between infested areas elsewhere and the Kaipara exposes the harbour to a substantial risk of further infestation by new species.

The effects of fishing are also significant and recent reviews and fisheries assessments indicate that grey mullet, school shark, rig, and scallop fisheries all have sustainability issues within the Kaipara. Fishing down populations of target species can have marked effects on other parts of the marine food chain. The indirect effects of fishing are poorly understood but, given the status of local fish stocks, they could be quite significant in the Kaipara Harbour.

The potential effects of aquaculture, sand extraction, and tidal energy generation on the environmental quality and values of the harbour are also poorly understood. These activities could have a direct affect on the harbour but the scale and magnitude of their individual effects is difficult to isolate and quantify with the information available. It is therefore not possible to reliably quantify the cumulative effects of multiple activities, although many activities (both proposed and existing) have the potential to cause large-scale cumulative impacts that cross planning boundaries, both individually (e.g. land-use) or in combination with other activites (e.g. sand-mining and tidal energy extraction). Further work on assessing the cumulative impacts of multiple activities is needed.

Monitoring

Time-series monitoring is undertaken in the Kaipara Harbour for: State of the Environment assessments of general water quality (including bulk water quality, bathing water quality, and shellfish monitoring) and benthic communities; fisheries assessments; and as a condition of resource consents.

Water quality monitoring in the Southern Kaipara is temporally intensive but intentionally lacks spatial coverage, whereas water quality monitoring in the Northern Kaipara includes a number of sites but is temporally episodic. The available data suggests that water quality is relatively poor in many areas but the limited nature of monitoring makes it is difficult to assess whether broad-scale environmental changes have occurred or what the magnitude of change has been. Integrating and improving both the spatial and temporal coverage of the water quality monitoring programmes carried out by the ARC and the NRC would provide a more robust and useful dataset, which would assist in the harbour-wide management of water quality.

A broad-scale State of the Environment survey has been carried out in the southern Kaipara. A similar survey of the northern Kaipara would give a harbour-wide overview of benthic ecology and provide an extremely valuable foundation for resource management decisions. More frequent ecological monitoring of a few high-risk sites should also be considered to provide an early warning of undesirable trends in ecological health. Results from the broad-scale State of the Environment survey should assist in the selection of high-risk sites.

Fisheries monitoring in the harbour is specific to target species and tends to be fairly limited in scope. Information on habitats important to fishery species is also limited (e.g. nursery habitats) and the extent and quality of key habitats is not systematically monitored. This is a significant concern, given the importance of the Kaipara Harbour to the West Coast snapper and, possibly, other fisheries.

Resource consent monitoring provides data relevant to the specific activities but is not particularly useful for assessing cumulative impacts in the Kaipara Harbour. A standardised toolbox of sampling methods for resource consent monitoring would enable data from individual activities to be amalgamated, and assist in the evaluation of broad-scale cumulative effects.

Knowledge gaps for effective integrated management:

The general lack of environmental information on the Kaipara coastal environment serves as a significant barrier to the integrated management of the Kaipara Harbour system.

There are many critical knowledge gaps which impede effective resource management. These include, but are not limited to:

a. A lack of consistent, spatially extensive, and regularly collected water quality data.

b. Detailed information on long-term plans for catchment development and its associated effects on the harbour.

c. Ecological maps for the northern Kaipara (similar to those produced by Tier II SoE monitoring of the Southern Kaipara).

d. Fundamental information on sedimentation patterns and mangrove expansion.

e. Utilisation of Kaipara Harbour by Maui's dolphins (when and where).

f. Biosecurity risks of consented activities, particularly construction and aquaculture.

g. Aquaculture carrying-capacity of the harbour.

h. Identification of fish nursery areas and an understanding of their susceptibility to Resource Management Act activities.

i. Extent and nature of fishery interactions between the West Coast and the Kaipara Harbour.

j. Effects of removing target fishery species on the broader harbour ecosystem.

k. Uncertainty about the volume of sand arriving into the Tapora area, relative to the amount extracted.

l. The effects of sand extraction on sediment transport processes operating in the entrance of the Kaipara Harbour.

m. Linkages between tuatua populations at the harbour entrance and the impacts of sand extraction on commercial harvesting.

n. The cumulative impacts of Resource Management Act activities, both individually and in combination with fishing and biosecurity threats.

o. The effects of large-scale energy harvesting (i.e. tidal power generation).

p. The scale and magnitude of sediment impacts on the Kaipara Harbour (both direct and indirect).

q. Areas that require protection for a range of species (birds, fishes, critical habitat).

Investigations currently being carried out on: invasive species, the productivity of seagrass beds, fish habitat utilisation; the efficacy of scallop protection measures, and marine mammal use of the harbour (particularly Maui's dolphin) will help fill some of these knowledge gaps. However, a range of additional work is required to provide the information base needed for effective management of Kaipara Harbour.

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