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.

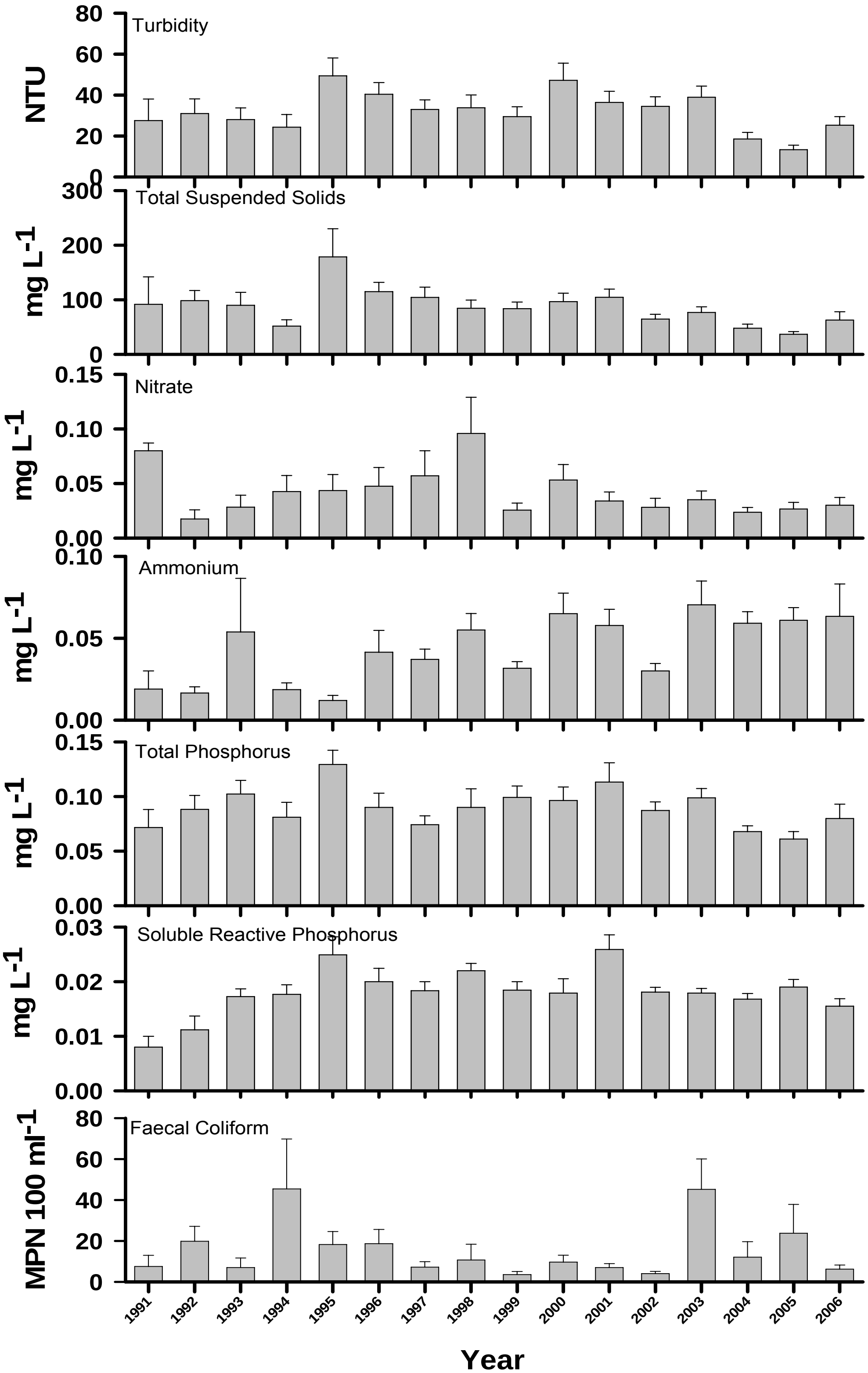
Table 9 Description of parameters commonly measured to assess water quality (HDC 2002, ANZECC 2002).

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
Microbiologica l 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).

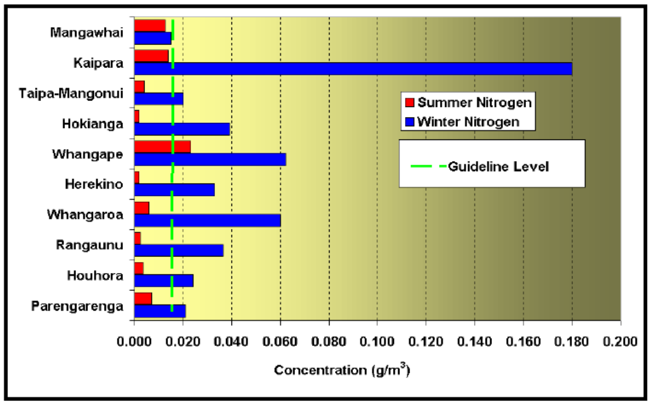


Figure 40 Median phosphorus levels for a selection of Northland harbours over summer and winter (Data from NRC 2002a).

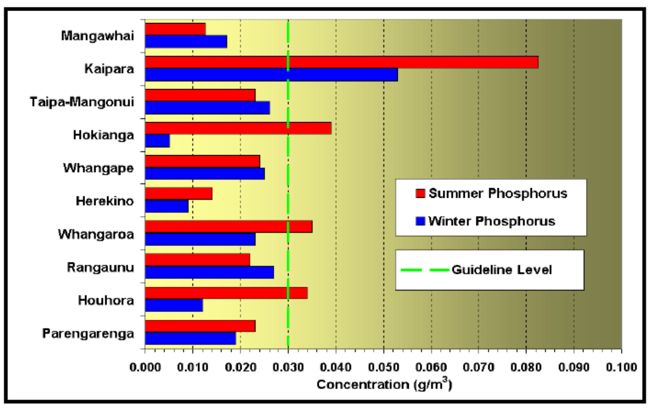


Figure 41 Median ammonia levels for a selection of Northland harbours over summer and winter (Data from NRC 2002a).

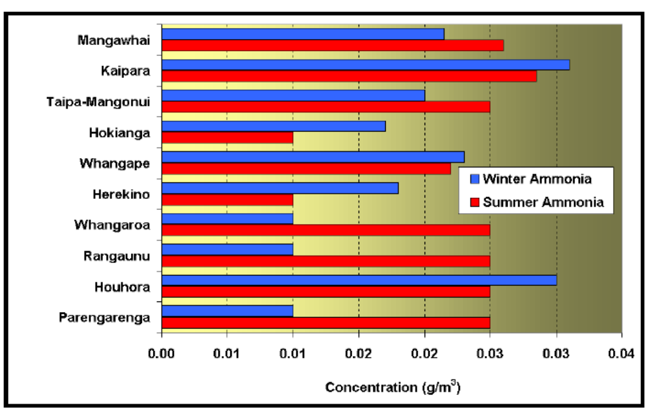


Figure 42 Median levels of indicator bacteria (Faecal Coliform) over summer and winter (Data from NRC 2002a).

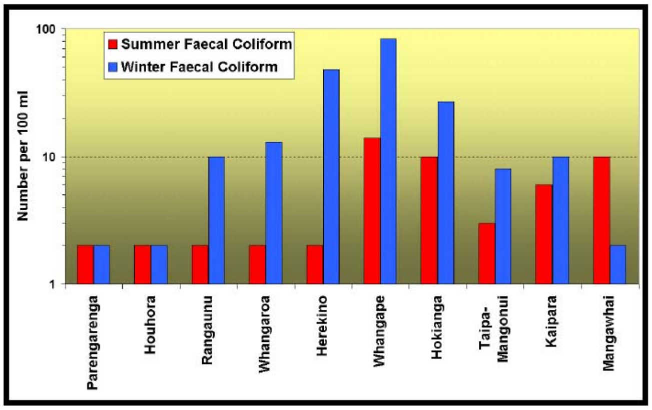
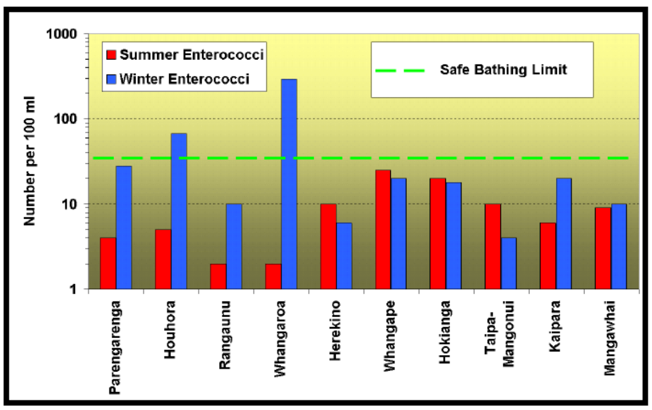


Figure 43 Median levels of indicator bacteria (Enterococci) over summer and winter (Data from NRC 2002a).

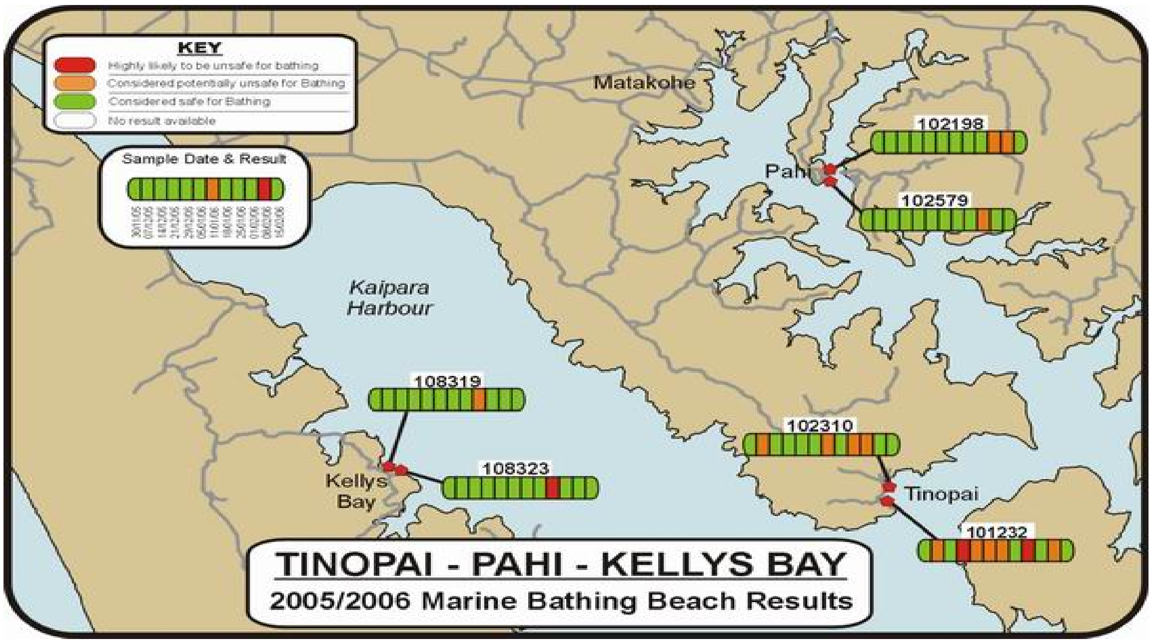


4.1.4 Recreational bathing water quality (northern Kaipara Harbour)

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.

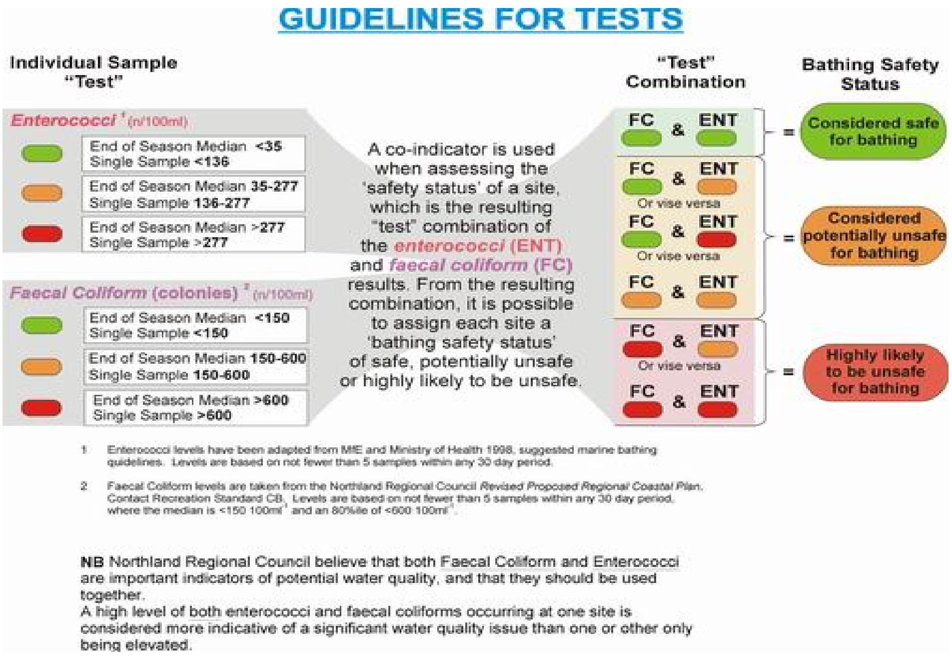


General trends in bathing water quality, analysed from the most recent monitoring reports (NRC 2001-2005), are presented in Table 10.

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).

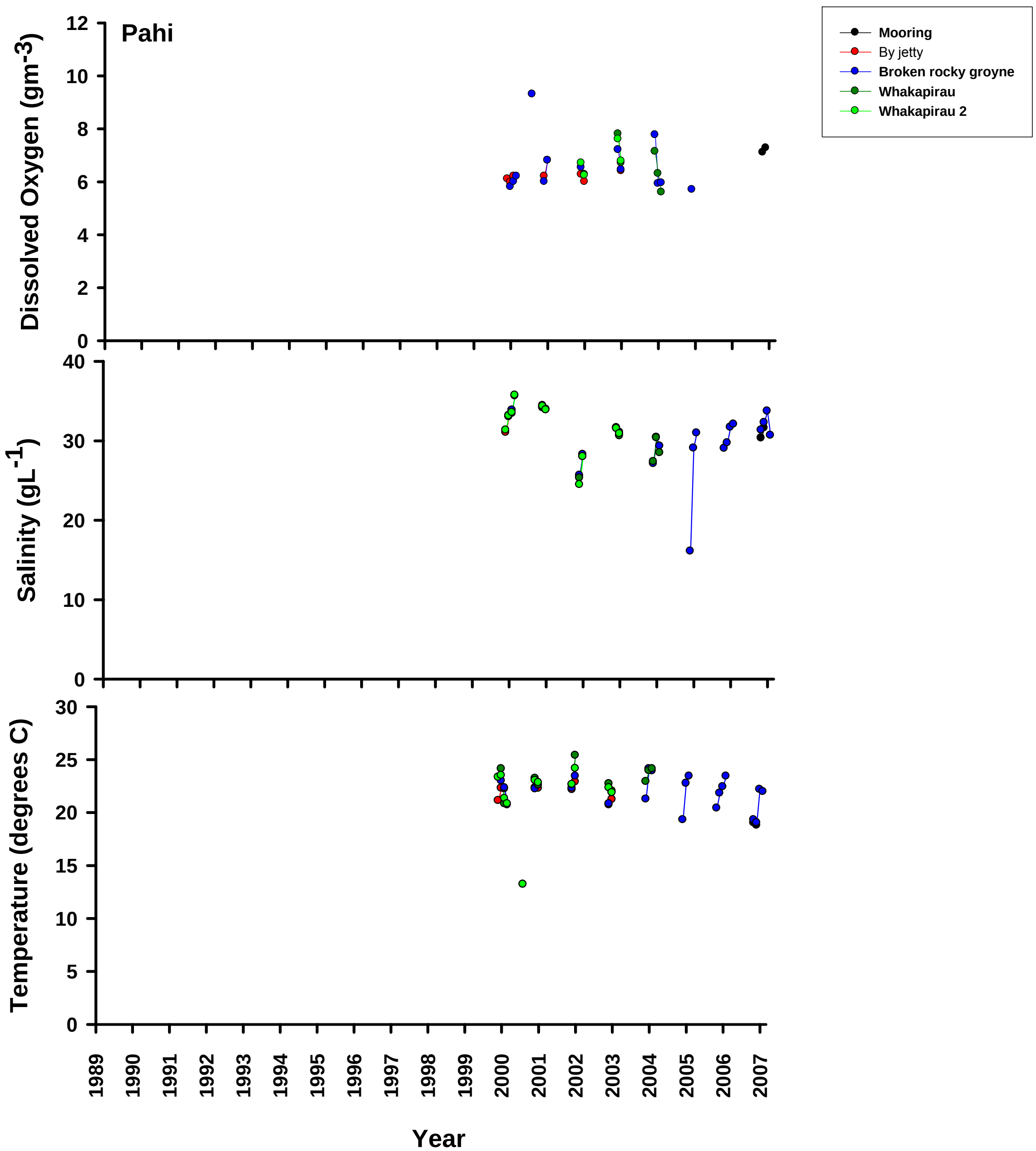


Figure 46b Water quality parameters (Dissolved oxygen, salinity and temperatures) measured for Raepare Creek and Kaiwaka Rive, Kaipara Harbour (NRC unpublished data).

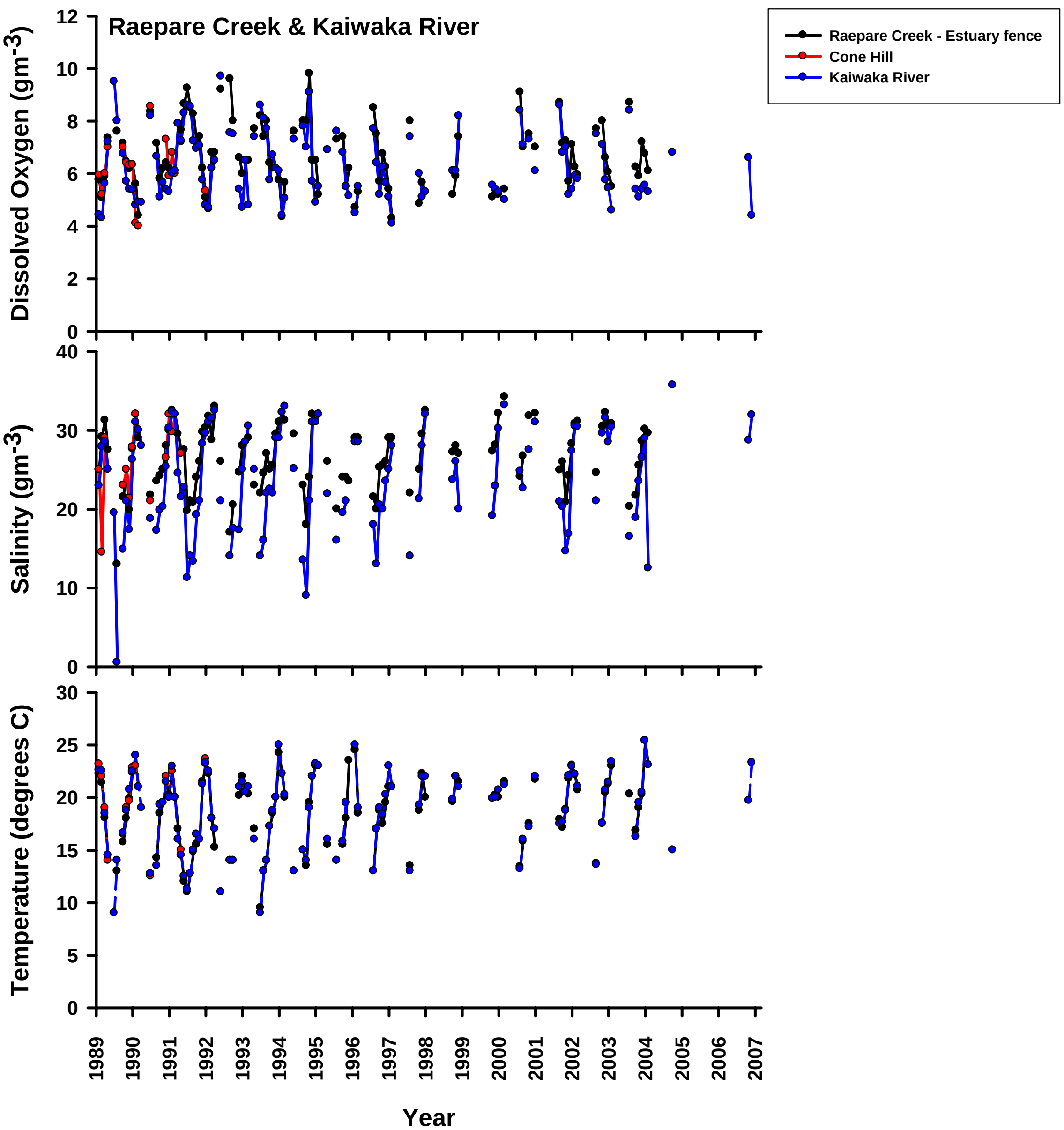


Figure 46c Water quality parameters (Dissolved oxygen, salinity and temperatures) measured for Wairau River, Kaipara Harbour (NRC unpublished data).

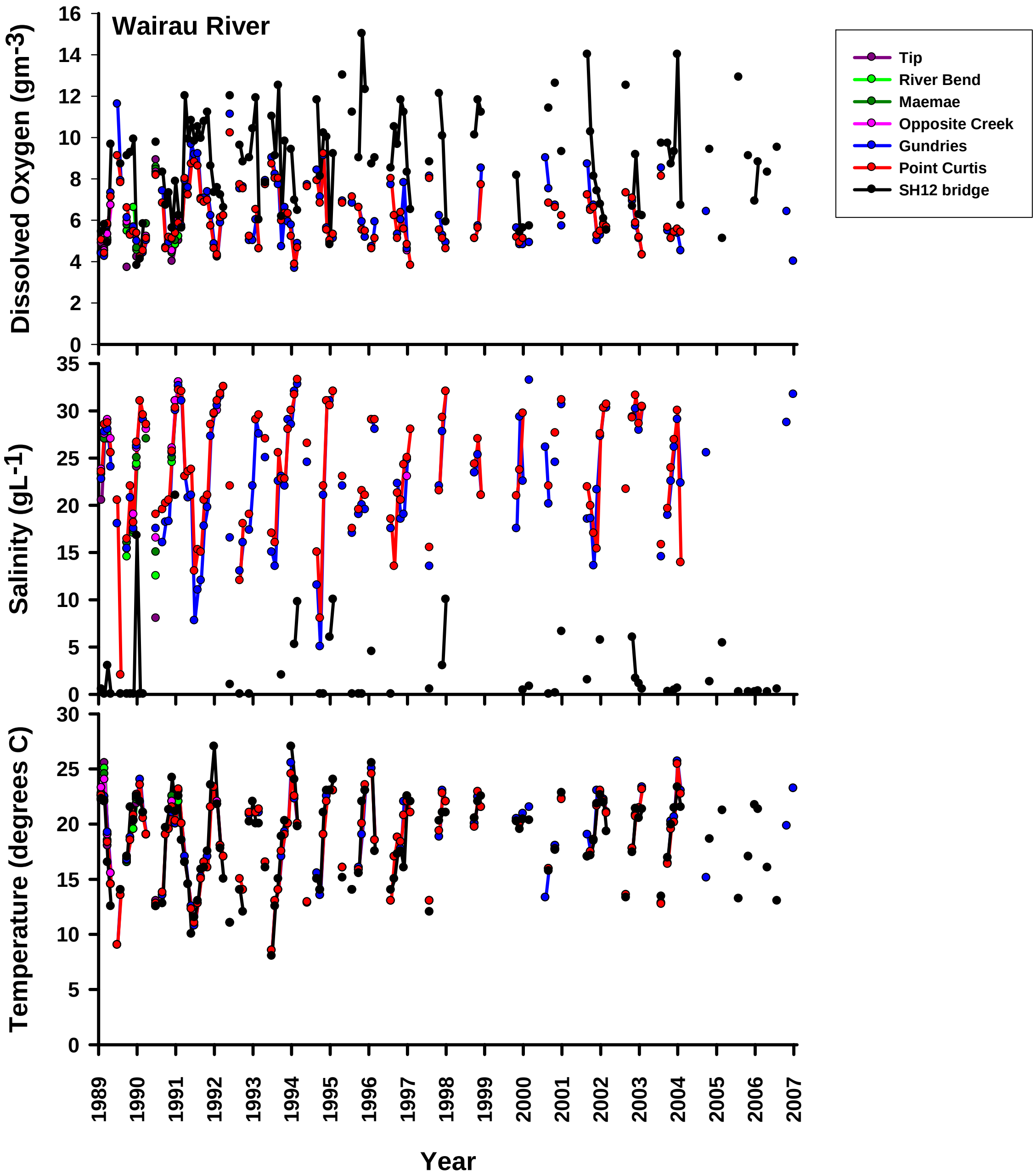


Figure 46d Water quality parameters (Dissolved oxygen, salinity and temperatures) measured for Otamatea River, Kaipara Harbour (NRC unpublished data).

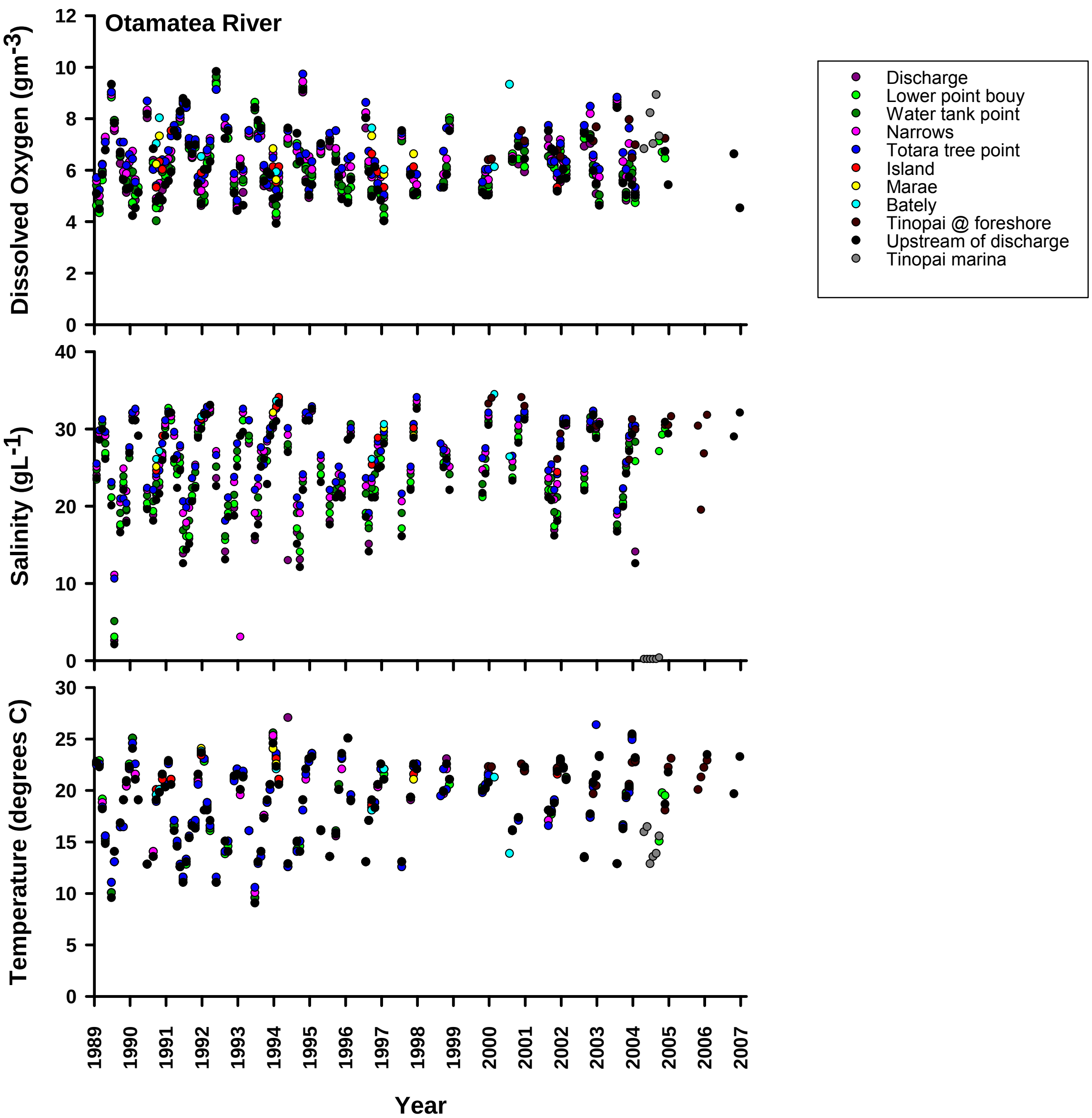


Figure 47a Water quality parameters: ammonia (NH4), total inorganic nitrogen (TIN) and total phosphorus (TP) measured within the Otamatea River, Kaipara Harbour (NRC unpublished data).

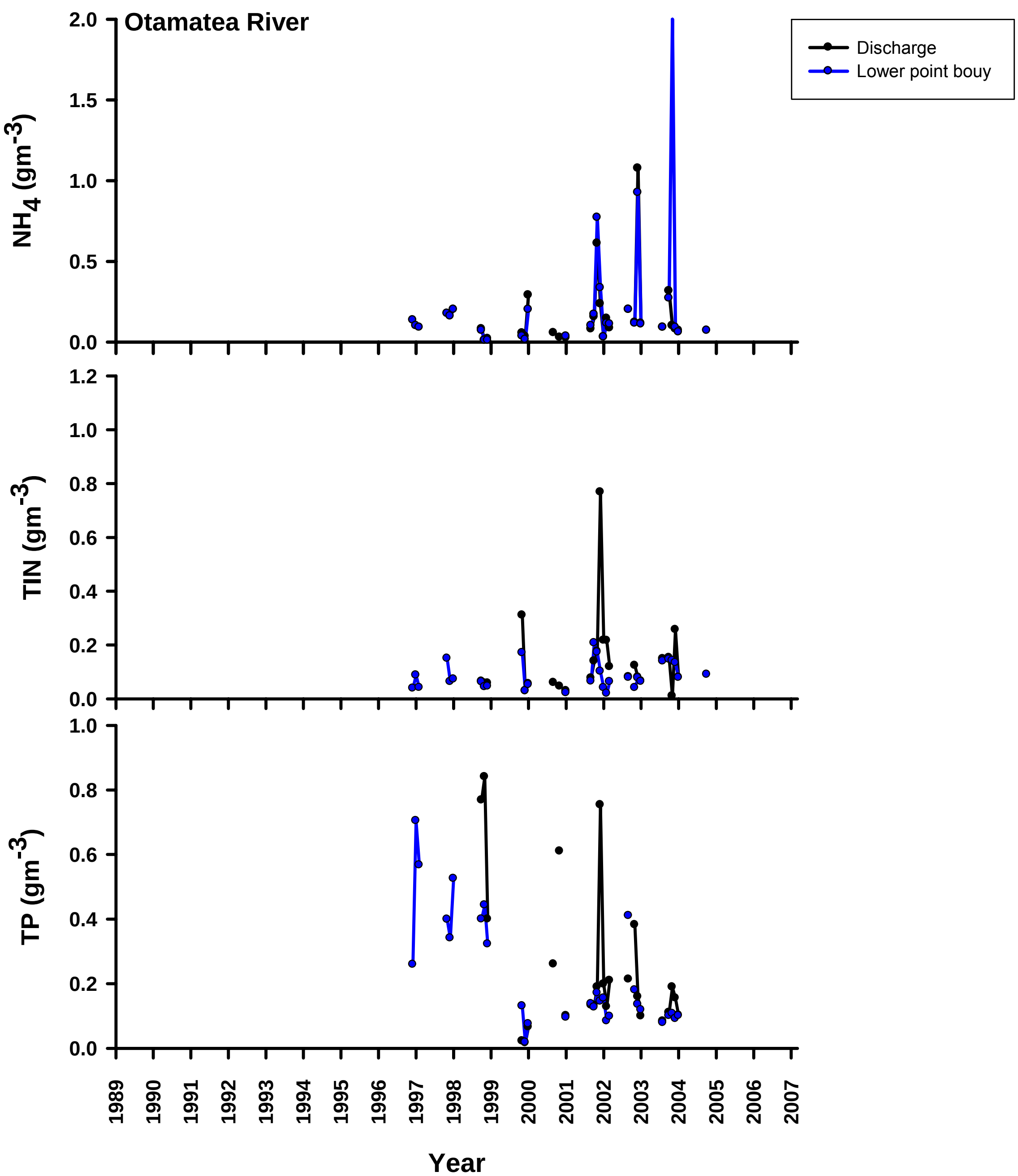
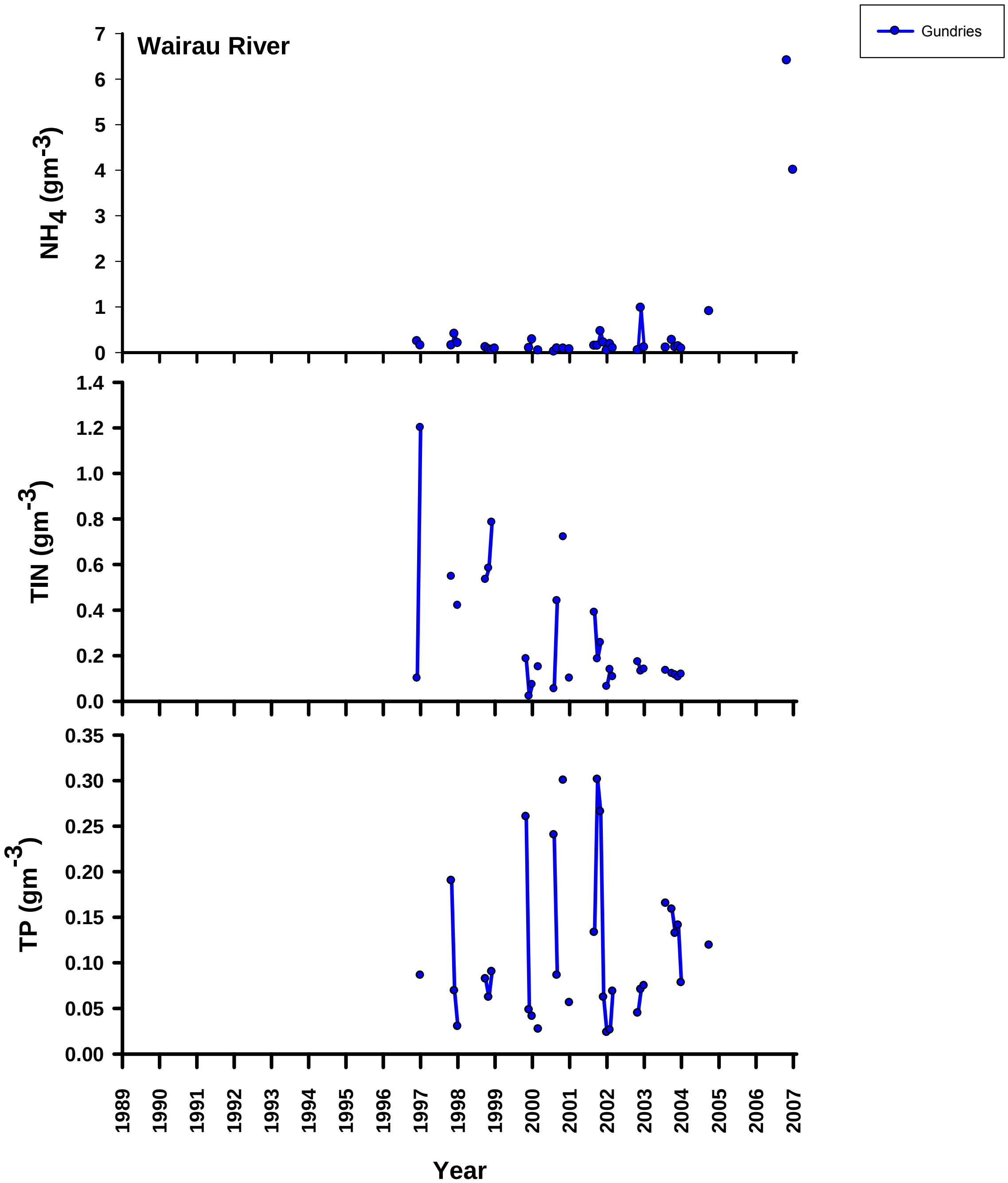


Figure 47b Water quality parameters: ammonia (NH4), total inorganic nitrogen (TIN) and total phosphorus (TP) measured within the Wairau River, Kaipara Harbour (NRC unpublished data).



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).

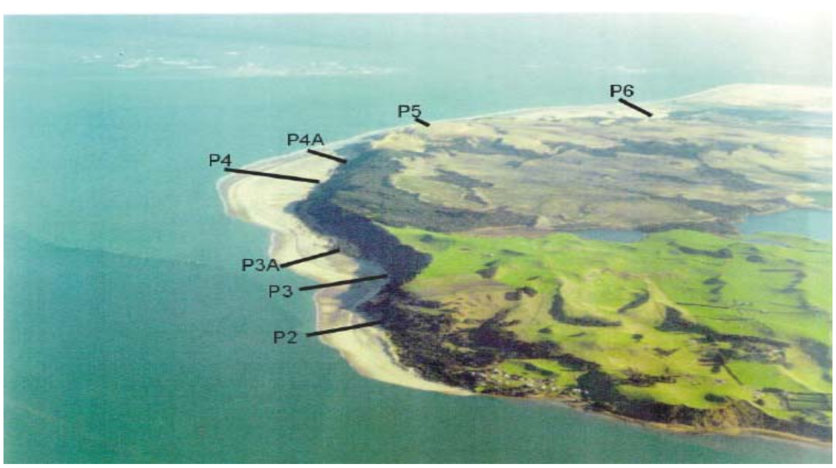
4.1.7 Beach profile analysis (northern Kaipara Harbour)

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.

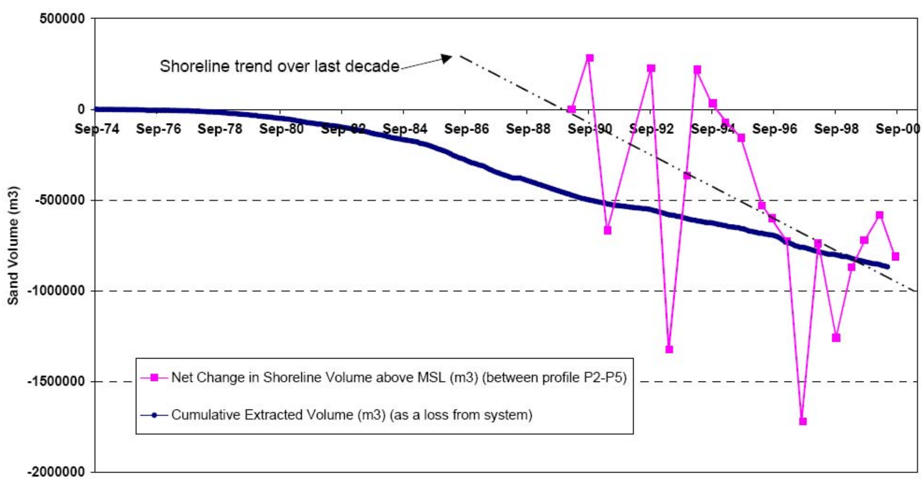


Results

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).

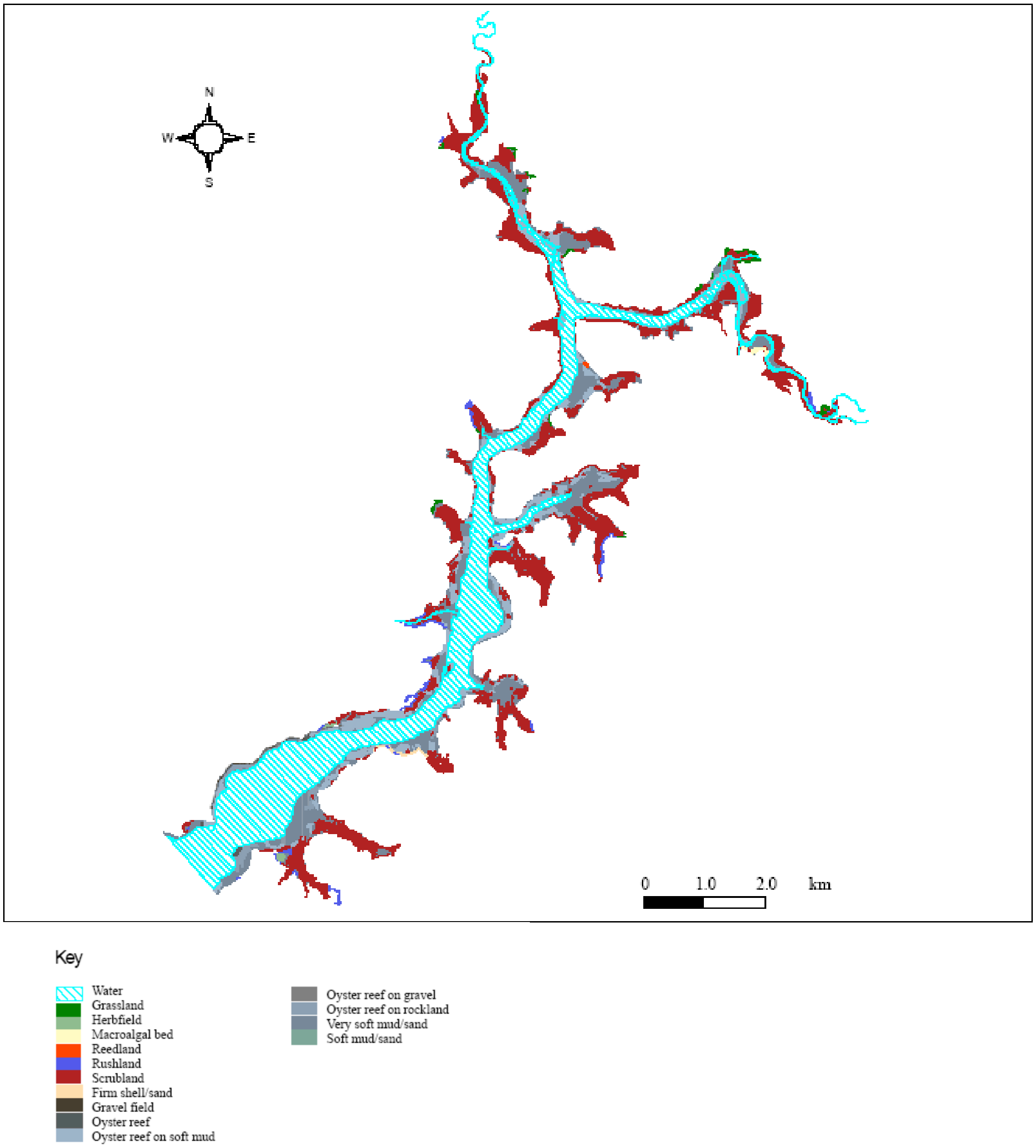
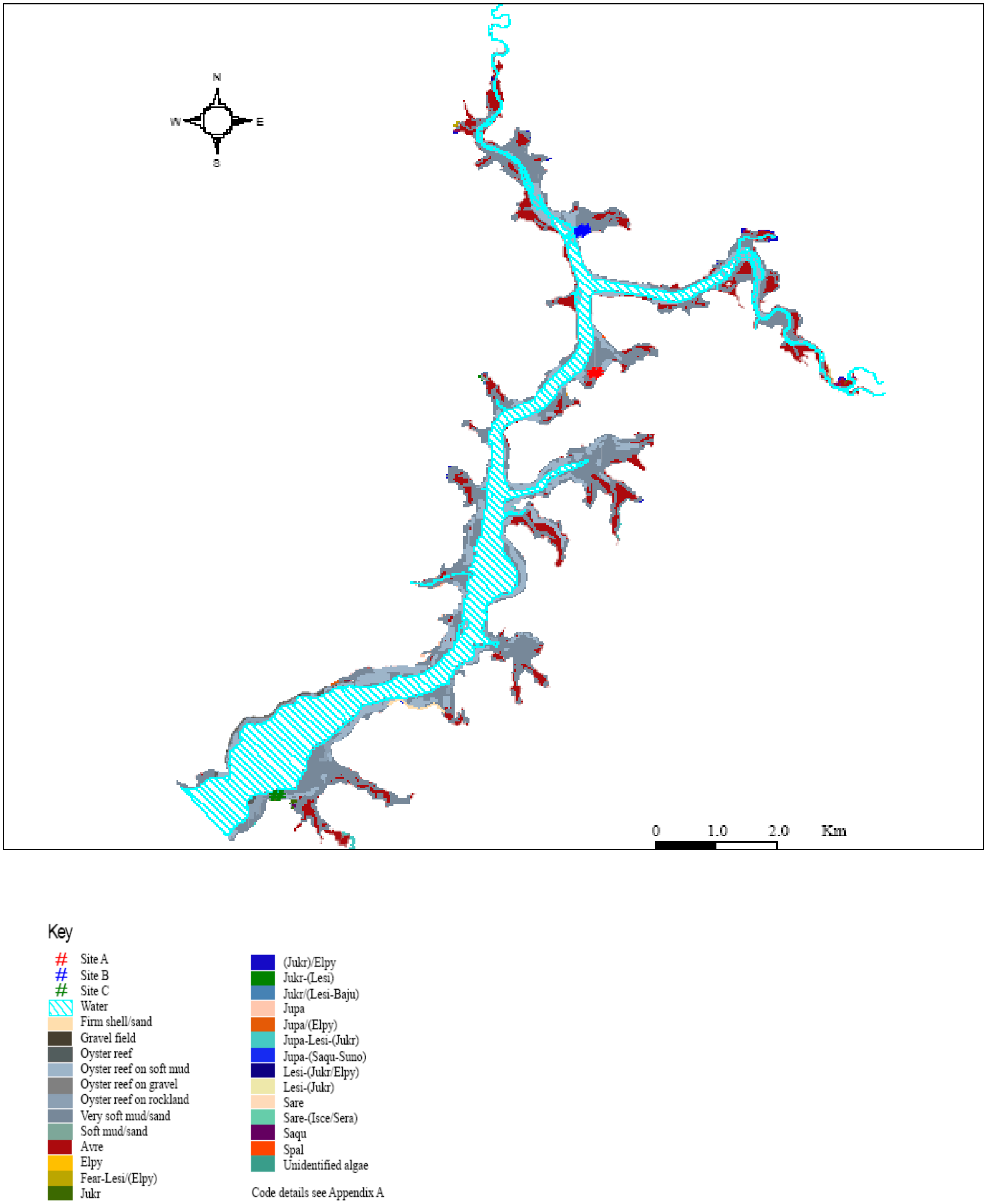


Figure 49 Otamatea Arm – Dominant cover habitat (from Robertson et al. 2002).



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

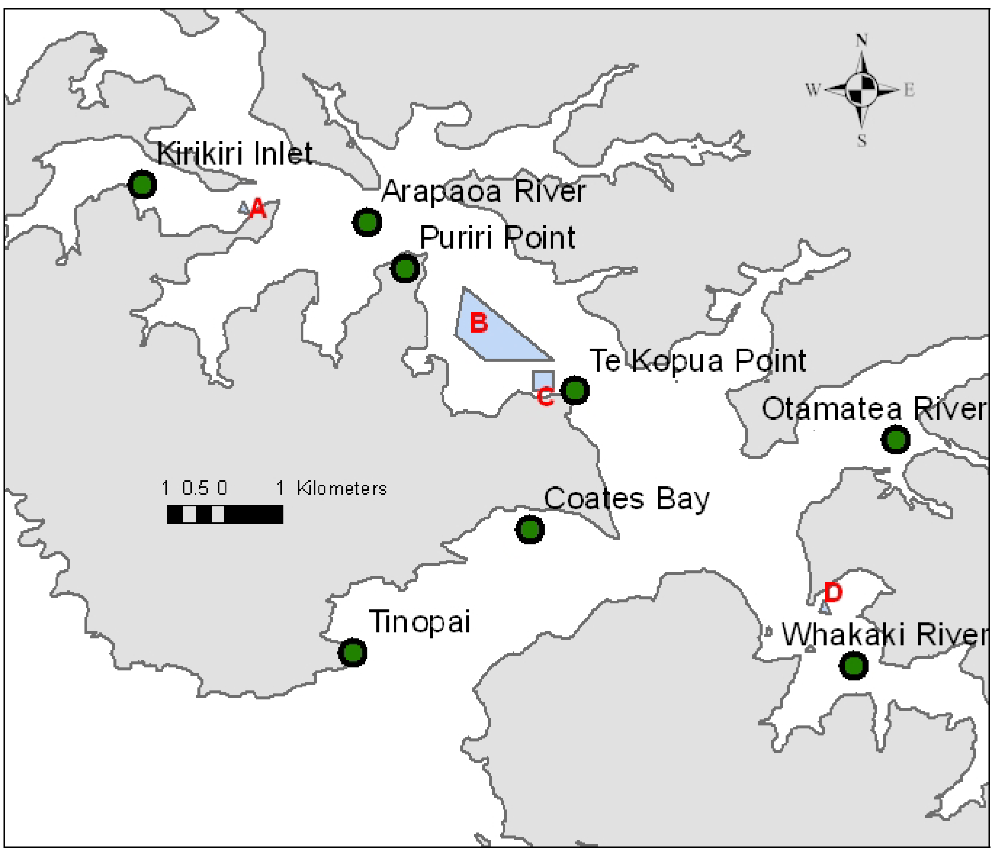
All AMAs were characterised by homogeneous tidal mudflats with a low substratum complexity rating (i.e. 1). The 4 ha AMA was flanked by a decommissioned oyster farm to the northwest and debris from this was evident within the area. Shallow tidal mudflats extended to a shallow channel ~1 m (MLWS). Severe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