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).

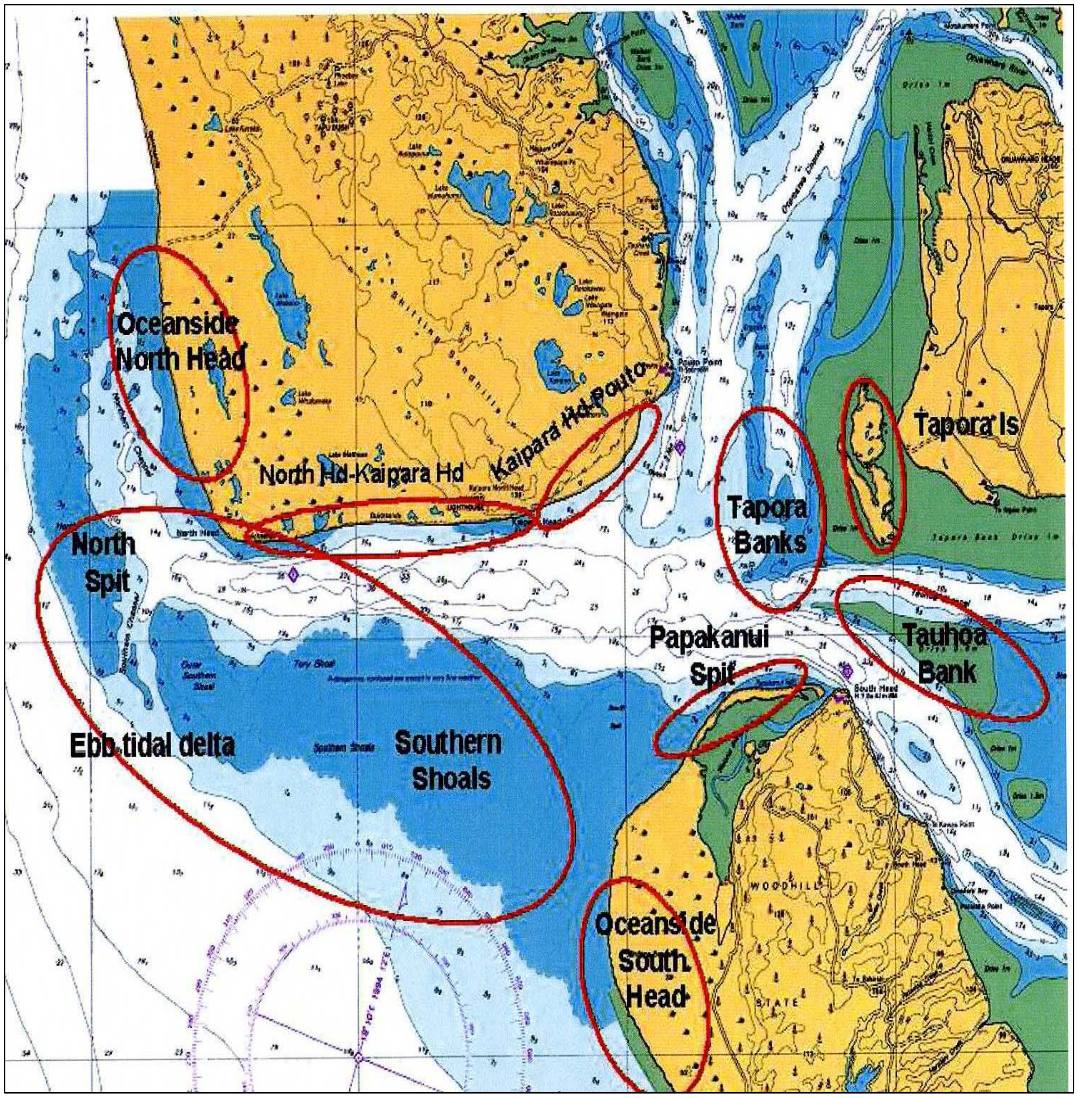


Table 14 Breakdown of estimated sustainable volume of sand for each site that passed the sustainability factors test (Hume et al. 2003). Factor F describes the fraction of the natural replenishment (A) that is deemed appropriate to extract. It reflects the degree of confidence Hume et al. (2003) have 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

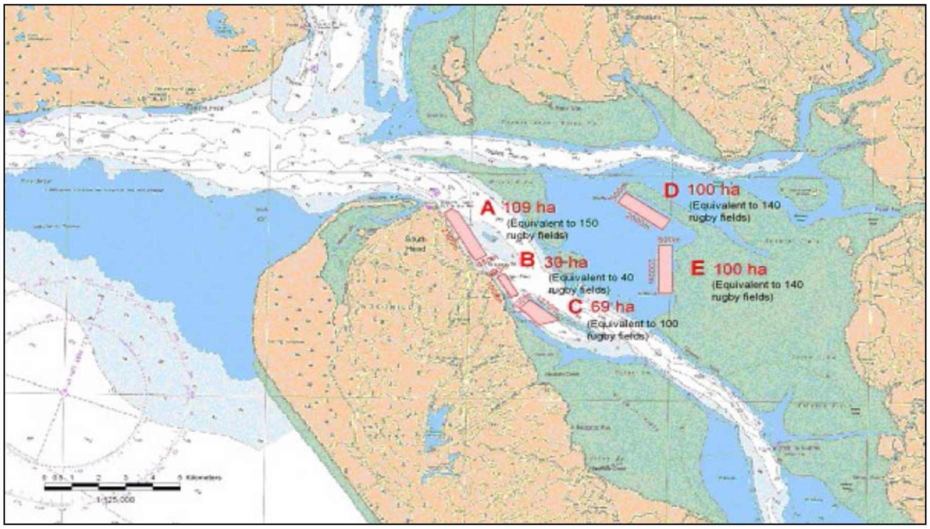
The possible impacts of seven potential aquaculture management areas (AMAs) on marine mammal populations were assessed in a desktop review by Fisher (2005). The AMAs included three sites near South Kaipara Head (A, B, C), two near Orongo Point (D, E), and two small existing farms in the Oruawharo River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

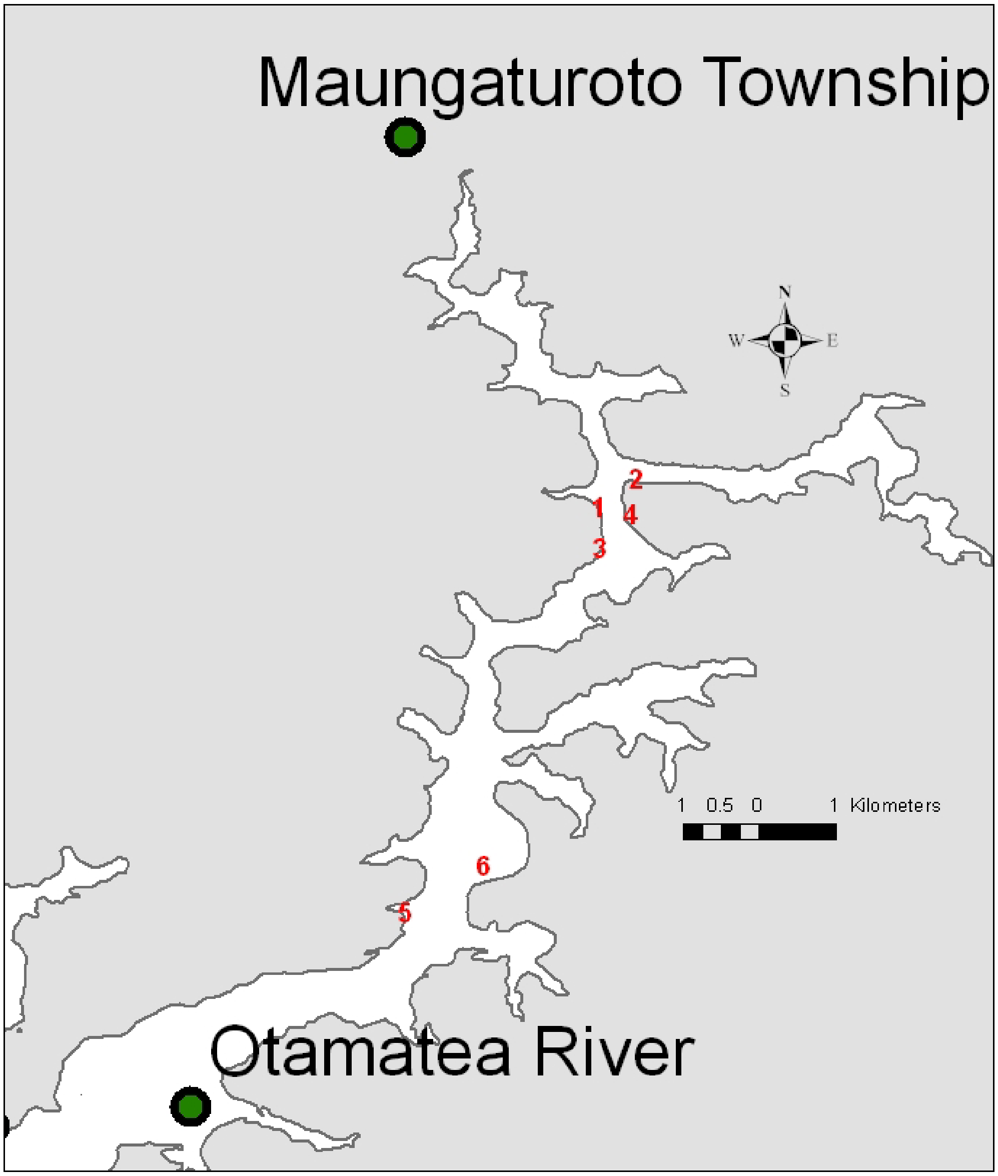
Mangrove data showed clear differences among the sites in terms of sapling density, but apart from site 004, the adult densities and % canopy cover were similar among sites. All mangrove trees (saplings and adults) were healthy in appearance and no senescent or dying trees were observed. There was no 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.

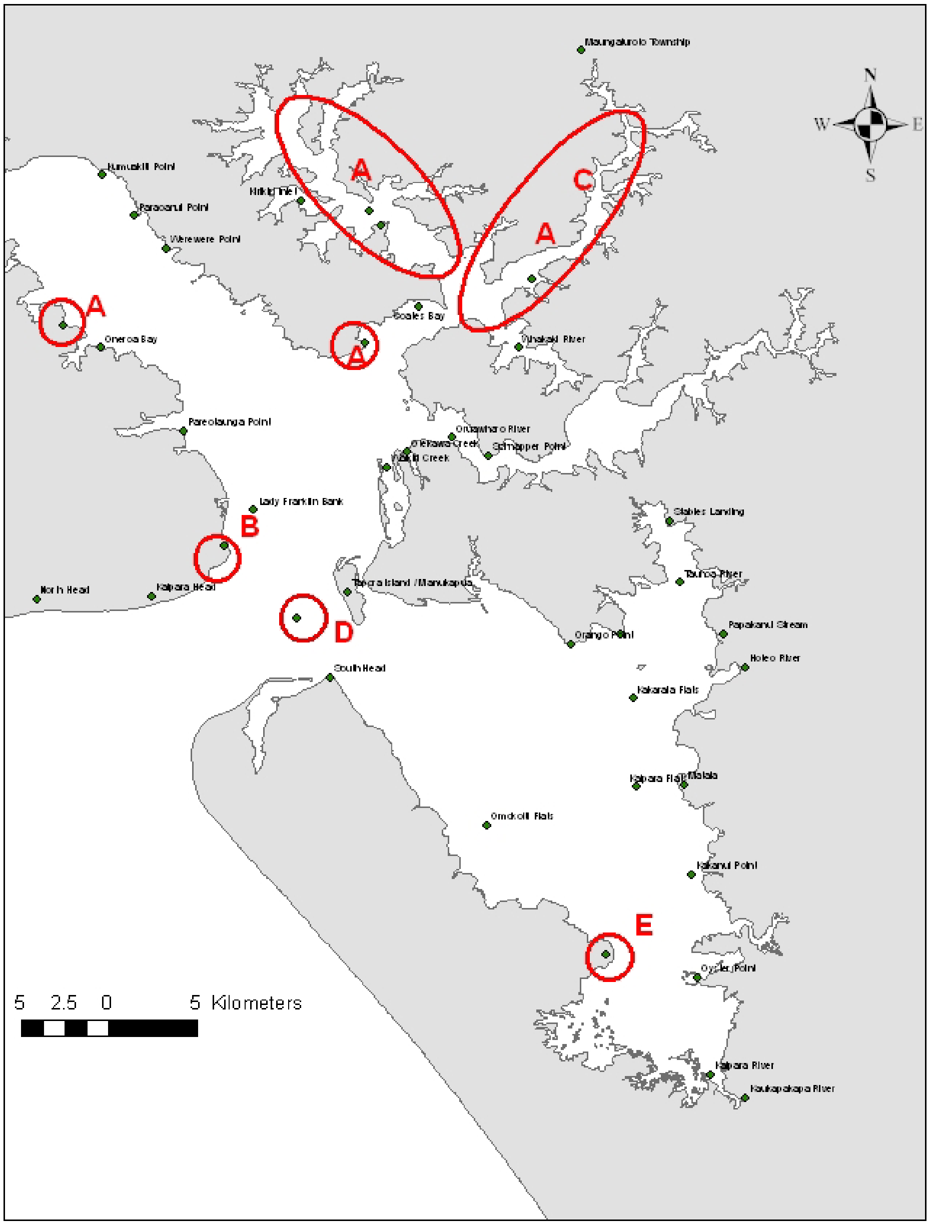


Table 16 Details of main monitoring programmes undertaken in the Kaipara Harbour, including potential synergies among existing and potential programmes that could be developed.

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.

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[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).

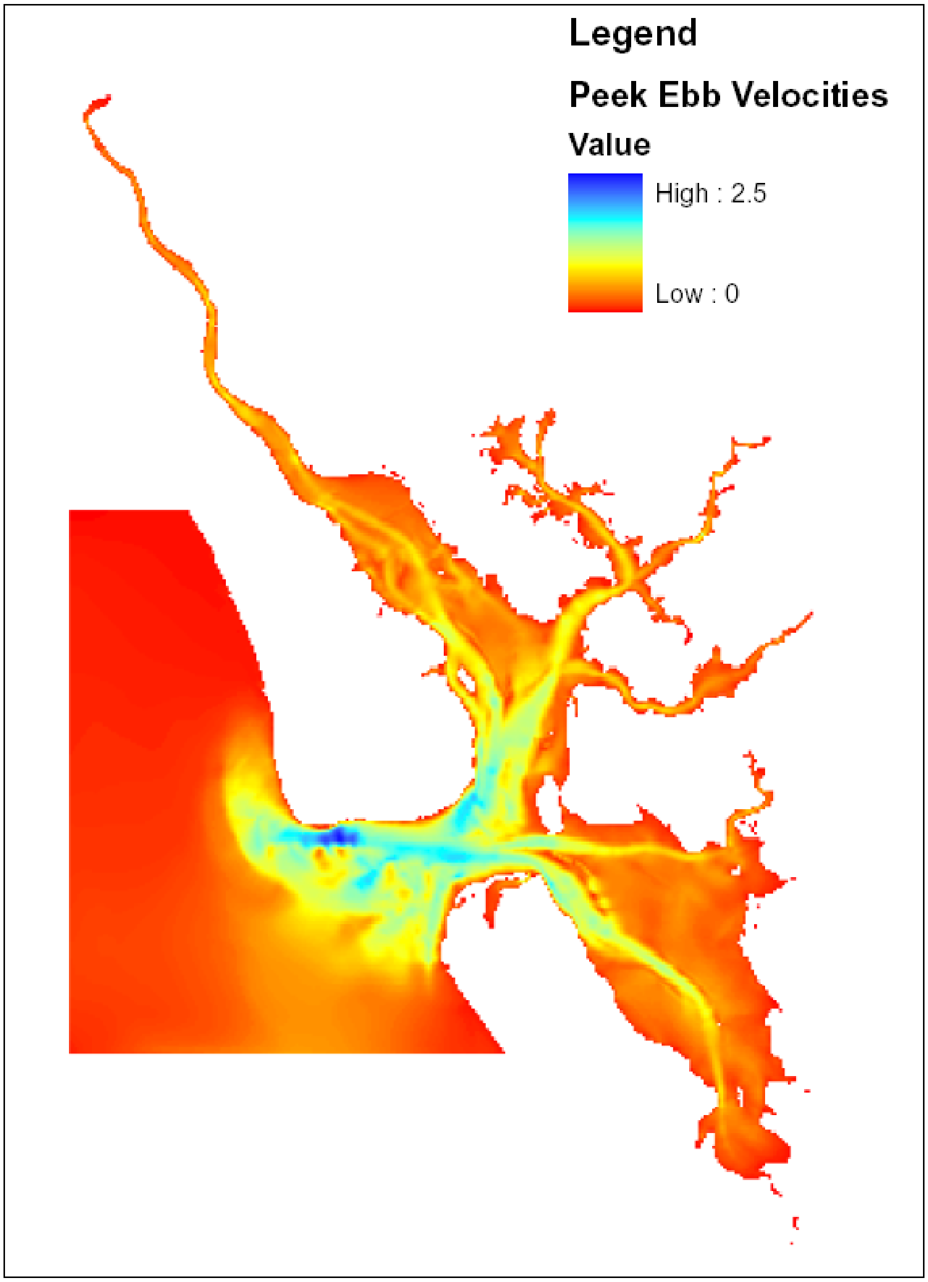
Fine sediments that settle in relatively sheltered estuarine areas, which are common throughout the Kaipara, are not easily remobilised and removed; therefore these environments are more at risk from sediment-related effects than exposed coastal areas. However, exposed areas commonly contain a mix of 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 potentially 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.