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

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

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

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

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

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

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

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

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

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

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

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

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

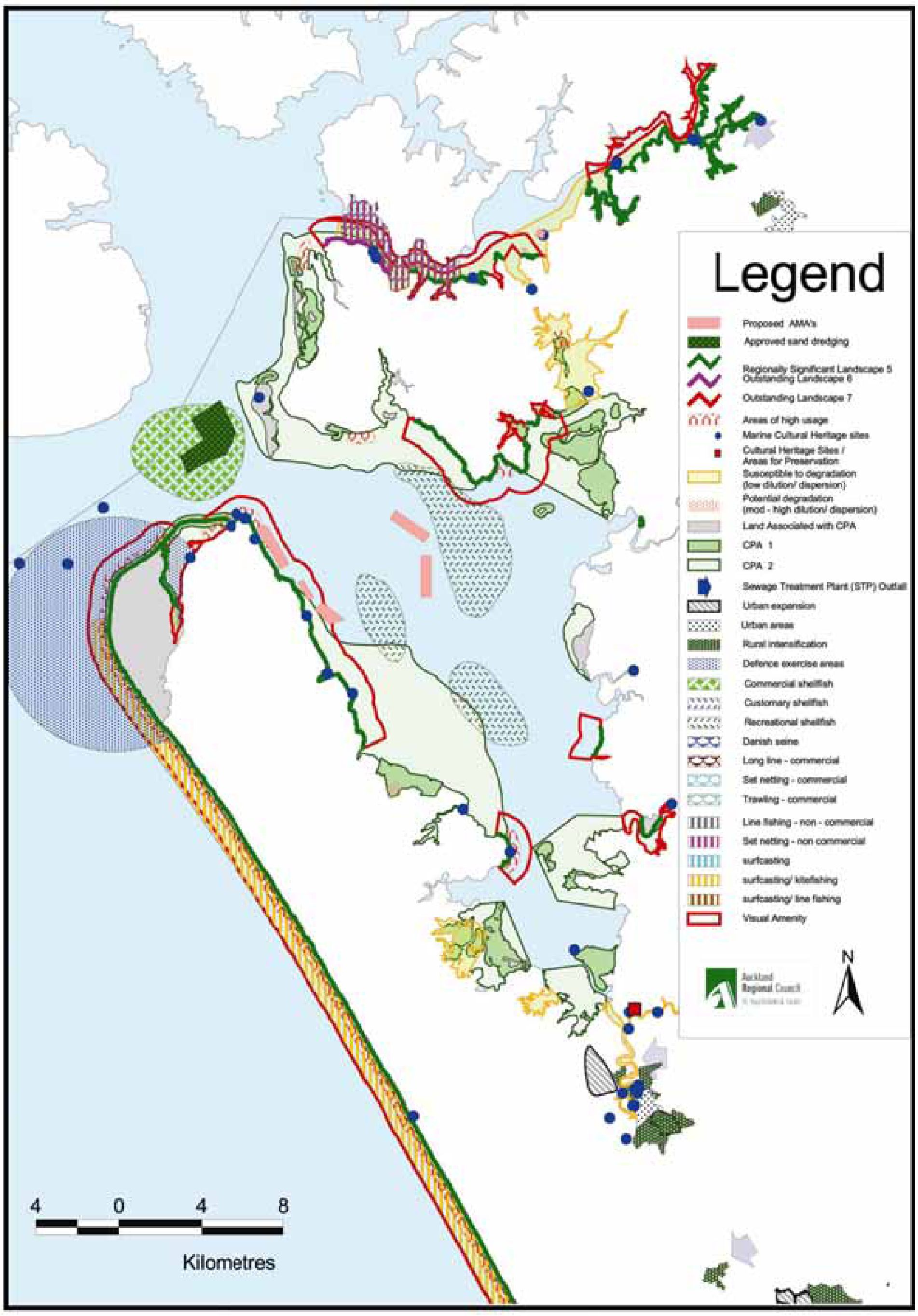
In comparison to the southern Kaipara, only a first order assessment of four proposed oyster AMAs has been carried out for the North Kaipara. One of the key criteria used in the first order assessment was that AMAs should not contain species likely to be sensitive to the effects of sedimentation such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

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

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

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

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



5.1.5 Fisheries

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

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

5.1.6 Sand mining

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

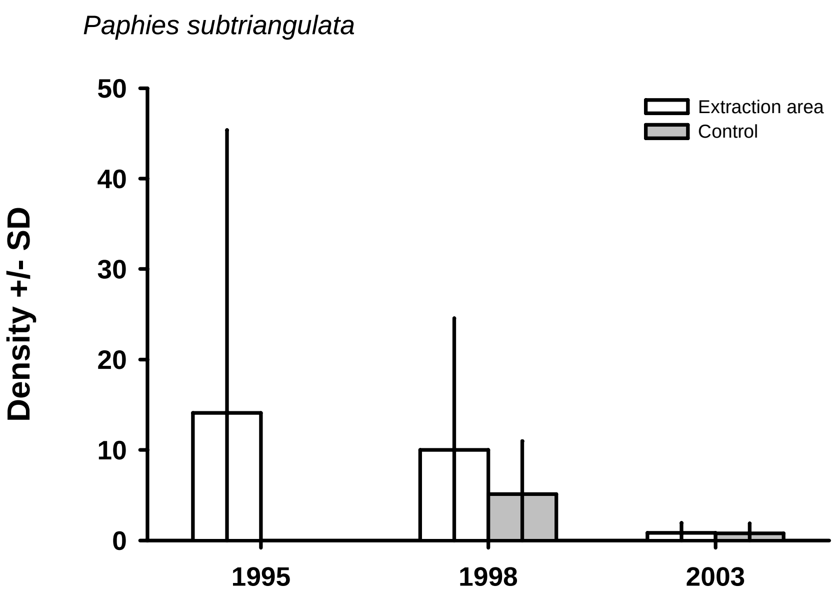
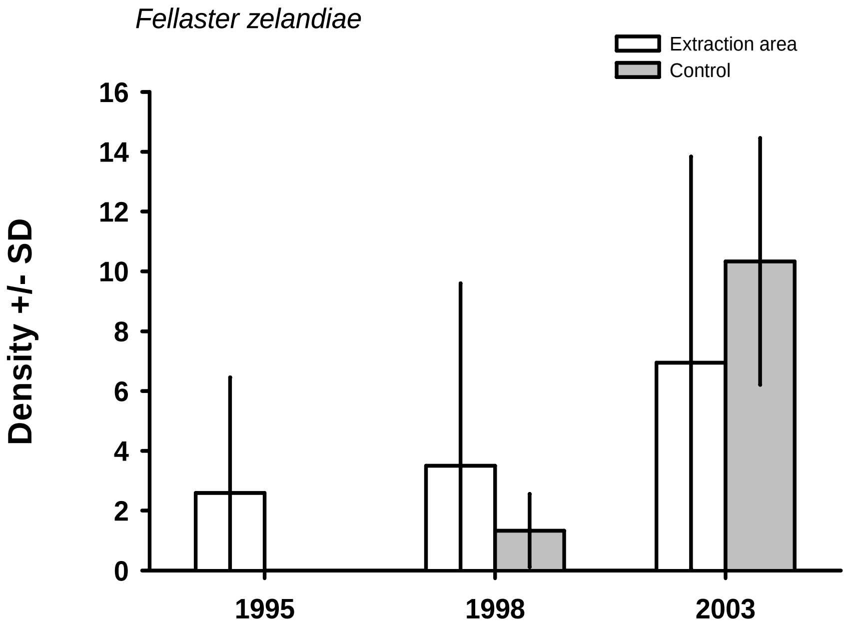


Figure 60 Mean density per 6 m2 ± standard deviation of the sand dollar (*Fellaster zelandiae*) in the extraction and control areas. Data from Grace (1995, 2000, 2004).



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

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

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

5.1.7 Genesis Energy Rodney power station

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

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

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

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

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

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

5.1.8 Tidal power generation

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

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

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

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

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

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

5.1.9 Invasive species

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

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

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

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

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

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

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

Spartina

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

Saltwater paspalum

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

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

Manchurian wild rice

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

Sharp rush

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

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

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

6 Comparative impact of activities

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

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

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

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

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

6.1 Linkages between activities managed under the RMA and other Acts

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

6.1.1 Fisheries

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

6.1.1.1 **Spatial conflicts**

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

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

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

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

6.1.1.2 Direct and indirect impacts

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

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

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

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

6.1.1.3 Fishery restrictions

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

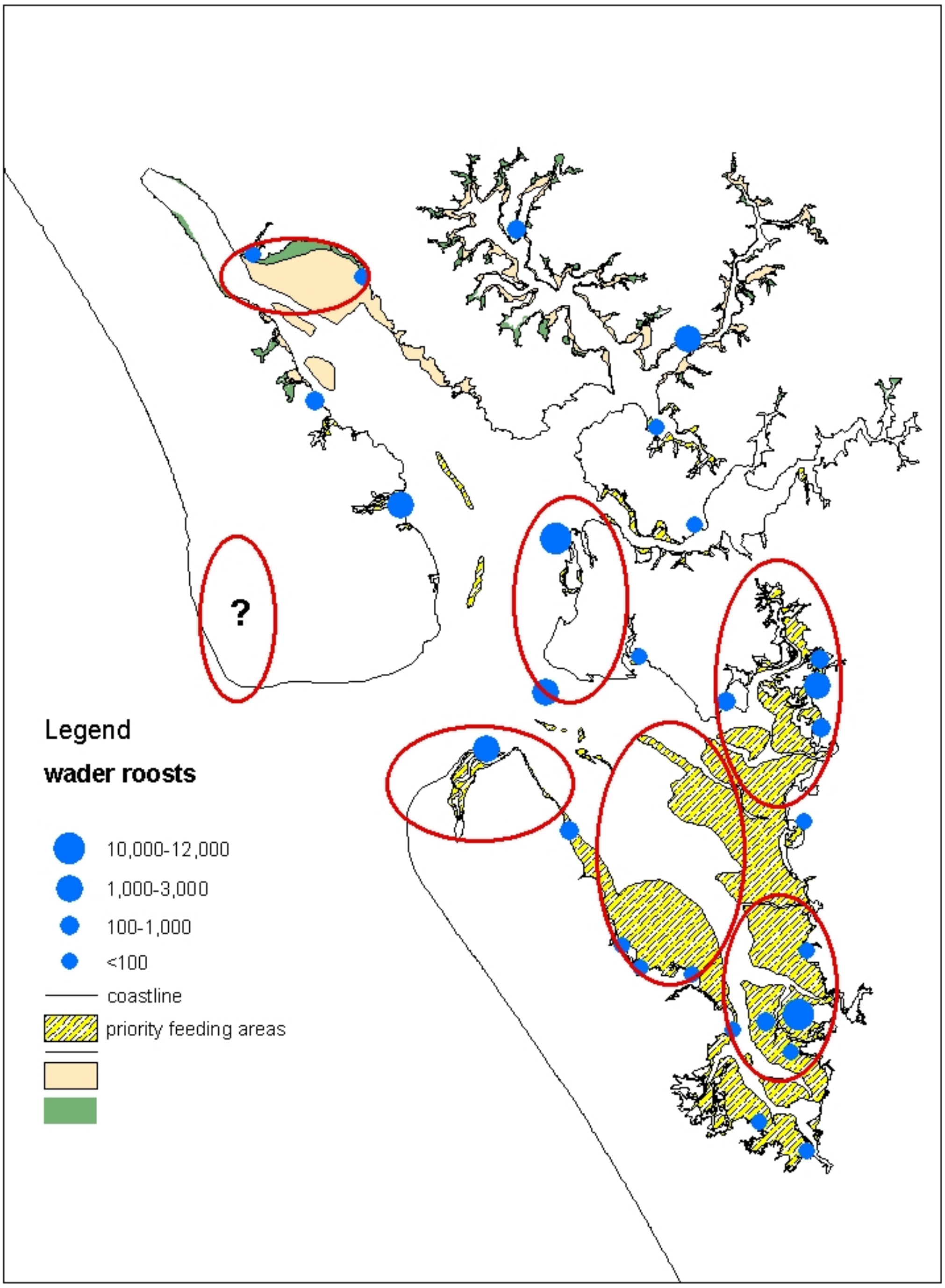
6.1.2 Conservation

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

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

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

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



6.1.3 Biosecurity

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

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

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

7 Cross-boundary effects

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

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

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

Land disturbance and land use

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

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

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

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