9 RESTORING AND PROTECTING NATIVE BIODIVERSITY

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9.4 INTRODUCTION

Biodiversity simply means ‘the variety of life’.

Biodiversity around the world, including New Zealand, is declining. Symptoms include the loss and fragmentation of habitat, overharvesting and introduction of pests, diseases and plants.

Human activities within the Kaipara catchment and coastal estuarine area have placed tremendous pressure on plants, animals, and even natural processes (e.g. sea temperature is increasing), such that some species have vanished and others are seriously threatened in their ability to persist.

Biodiversity provides incalculable benefits to humanity. Most directly, it comprises a vast genetic storehouse of medicines, foods and fibres. Strong evidence suggests that biodiversity endows stability to ecosystems (Naeem & Li 1997), shelters humanity from disease, and providing substantial economic value (Constanza *et al*. 1997), although most of these remain significantly undervalued.

Biodiversity

Refers to the number and variety of living organisms.

It includes diversity of species, between species, and of ecosystems and the processes that maintain them.

It also refers to genetic diversity, which is about the varied genetic make-up among individuals of a single species.

Addressing the decline of biodiversity is a key management issue for the IKHMG.

Although biodiversity offers enormous economic, environmental and spiritual value to humanity, providing services we want and need, it is being critically threatened by unsustainable consumption and rapid population growth (Department of Conservation 2000; MEA 2005; Ministry for the Environment 2007). Expanding agriculture, industry, mining and urbanisation are fragmenting, degrading and eliminating natural environments; exotic species are displacing and fundamentally changing indigenous communities; pollution and resource use activities such as fishing cause stress.

As a signatory to the Convention of Biological Diversity (CBD), the New Zealand government produced the New Zealand Biodiversity Strategy (NZBS) (Department of Conservation 2000). The NZBS recognises the two key threats to indigenous species on land as: (1) loss of biodiversity *pattern* (“insufficient and fragmented habitat”); and (2) loss of biodiversity *process* “introduced invasive species which damage their habitat and important ecosystem processes”. Objective 1.1 Action (d) is to “*prepare a national policy statement and related material to provide guidance to local authorities on implementing provisions of the Resource Management Act relevant to conserving and sustainably managing indigenous biodiversity*”. This has yet to be undertaken, but steps have been made towards addressing biodiversity protection on private land through voluntary measures, however there is still no overarching policy that exists to provide systematic protection and restoration of native biodiversity.

The following chapter outlines biogeophysical, Mātauranga Māori and socio−economic knowledge bases that were reviewed for information on biodiversity. Relevant spatial and temporal/occurrence data and literature were entered into the Kaipara Atlas database and information integrated using a matrix–based approach. In turn, this information was used to identify remaining information gaps.

9.5 MĀTAURANGA MĀORI AND BIODIVERSITY

> *"The holistic approach of traditional Māori environmental management has much to offer, and is receiving belated recognition of its essential similarity to the ecological approach"* (PCE 1999)
>
> *"Māori view the environment as a construct of physical (te taha kikokiko), mental (te taha hinengaro) and spiritual (te taha wairua) realities. The same applies of course to ecosystems. Māori see ecosystems beyond the terrestrial site in which an ecosystem might be located. That is, an ecosystem includes the air above, the earth below and the species of flora and fauna within. Further, the physical plane of an ecosystem is contained within and is possessed by corresponding mental (consciousness) and spiritual planes which are larger than the mental plane. Hence the physical plane of an ecosystem becomes the venue or locality in which the identities and entities of consciousness and spirit world may alight and reside…"* [1]

Over time, Māori have developed a wealth of knowledge (Mātauranga Māori) on the functioning and sustainability of ecosystems. Knowledge of ecosystems is based in part on the concept of whakapapa. Some Māori believe in the inter−connectedness of human beings to flora and fauna, thereby organising the natural world in a fashion similar to modern biological classification systems (Williams 2001). Human whakapapa is merely a leading example of this system. There are parallels between taxonomy and whakapapa in particular, taxonomy practiced by Māori was a taxonomy which related life forms and phenomenon back to their place in the ecology (Roberts *et al.* 1995). Whakapapa is an integral part of all traditional Māori institutions and is a major determinant of rights to use, access and manage natural resources (Mahuika 1998). The implementation of whakapapa is through kaitiakitanga (Kawharu 2000), traditional environmental and resource management. Tikanga such as tapu and rahui are the instruments used to regulate the physical and metaphysical relationship with natural resources.

Mātauranga Māori

A body of knowledge that was first brought to New Zealand by Polynesian ancestors of present-day Māori. It changed and grew with the experience of living in these islands. Following encounters with the European in the late 1700s and early 1800s, it grew and changed again before becoming endangered in many substantial ways in the 19th and 20th centuries. The elements that remain today – including the Māori language – have catalysed a renewed interest in this body of knowledge.

Tohunga apprentices in the area of environmental management were extensively tutored in whakapapa, and therefore understanding of the physical and environmental world and how to live in it.

[1] Charles Royal (1993). 'The perspectives of Māori knowledge holders,' in Geoff Park: 'The State of New Zealand's ecosystems: a questionnaire of ecologists, conservation managers, resource planners and iwi kaitiaki' (unpublished). Science & Research Unit, Department of Conservation, Wellington.

Conceptually, Māori cosmology differs from an ecosystem approach to understanding ecology of natural environments: *Tumatauenga*, domain of human society and mastery of fire and stone−rapping; *Tanemahuta*, domain of forest biota; *Tangaroa*, domain of aquatic biota; *Rongomaraeroa*, domain of cultivated and stored crops; *Haumiatiketike*, domain of wild staples (bracken fern root, flax, koromiko, nikau, ponga); *Tauhirimatea*, domain of physical forces. Basically, the land is partitioned by a different geographical paradigm. However, land, people, forest, birds, rivers, sea and sky all had a spiritual source in nature gods and other beings, having a familial relationship with Māori (Roberts *et al.* 1995). The sense of complete unity endured through fluctuations of tribal wars and resource possession (Park 2000).

Māori have an active relationship with ecosystems, based in part on the socio−economic outcomes of indigenous biodiversity, such as, agriculture, forestry, fisheries, aquaculture and ecotourism. Customary and contemporary use of biological resources is important to Māori maintaining cultural integrity, values and traditional knowledge (DoC 2000). However, the use and access of indigenous flora and fauna by Māori has been contested (Department of Conservation 2000).

Some Māori consider many animals, plants, landscapes, seascapes, swamps, lakes and foreshores as taonga, with rights to access and use of these taonga guaranteed under article 2 of the Treaty of Waitangi. As a result, a group of iwi in 1991 lodged a Waitangi Tribunal claim (Wai 262), generally asserting exclusive and comprehensive rights to flora and fauna, cultural knowledge and property. The claim seeks to protect, control, conserve, and manage the treatment, propagation, sale, dispersal, utilisation, and restriction on the use of and transmission of the knowledge of New Zealand's indigenous flora and fauna and the genetic resource contained therein (Te Puni Kokiri 1998).

The relevant passages of the two original versions of article 2 of the Treaty of Waitangi are"

- '*o ratou whenua o ratou kainga me o ratou taonga katoa*' (recently translated as 'their lands, villages and all their treasures'[2])
- '*their Lands and Estates Forests Fisheries, and other properties which they may collectively or individually possess'*.[3]

Therefore, the important terms in the Māori version of the Treaty, notably 'whenua' and 'taonga', have meaning in ecosystem terms. For example, 'fisheries' and 'forests' are more than fish and trees. Māori treat them as ecosystems that contribute to mauri, the elemental force that binds all things together and gives them their meaning (Mardsen 1975). This can be seen as a '..*quintessential evocation in tikanga māori of the ecosystem concept*…' (Park 2000). The importance of such ecosystems or taonga have become an essential aspect to Treaty negotiations and settlement, for example, for Te Uri o Hau, the Kaipara Harbour is a scared taonga containing culturally significant ecosystems hence, the TUOH Settlement Act 2002 provides the mandate for management action to restore the Kaipara Harbour ecosystems.

2 Professor Sir Hugh Kawharu's translation, Court of Appeal, 29 June 1987 (quoted in *Taking into Account the Principles of the Treaty of Waitangi,* Ministry of Environment, Wellington, 1988, p7).

3 Treaty of Waitangi Act 1975.

The acceptance of biodiversity as taonga has gained wide acceptance. The New Zealand Conservation Authority (NZCA), for example, considers mahinga kai to be taonga under article 2 of the Treaty; so too, the environments in which mahinga kai are sustained (New Zealand Conservation Authority 1997). The Manukau Claim is another example, in which the Tribunal found that a '*river may be a taonga as a valuable resource. Its mauri or lifeforce is another taonga. The mauri of the Manukau Harbour is another taonga*' (Waitangi Tribunal 1985).

The intimate, and reciprocal, relationship between ecosystem processes and indigenous biodiversity is well recognised scientifically, but has yet to fully influence management regimes. The use and integration of management regimes that is based on Mātauranga Māori and ecosystem−based management concepts are sorely lacking. Biodiversity is both an outcome of, and essential ingredient of, ecosystem integrity. New Zealand's unique biodiversity and human settlement creates localised challenges for managing the interaction between human activities and ecosystems.

9.5.1 MĀTAURANGA MĀORI & KAIPARA BIODIVERSITY

Indigenous flora and fauna are taonga tuku iho to the iwi/hapū of the Kaipara (Waitangi Tribunal 2006, Te Roroa Whatu Ora Trust 2008). For these iwi, maintaining a relationship with the indigenous biodiversity is part of their daily lives. The decline however, in the quality of mahinga kai and kai moana within the Kaipara has significant adverse effects on the well-being of iwi/hapū of the Kaipara (Environs Holdings Ltd 2007).

Utilisation of iwi/hapū based tools to restore and protect Kaipara indigenous biodiversity has been difficult to carry out. From discussions with kaumatua, kuia and kaitiaki of the Kaipara, concerns have arisen with regard to who controls and who uses Mātauranga Māori (J. Chetham, pers. comm., ex-Manager Environs Holdings Ltd, 2009). Some iwi/hapū are happy to share their traditional knowledge but only on the basis that they retain control over that information and the method in which it is applied. For example, Te Roroa Whatu Ora Trust have always stated that the Mātauranga of Te Roroa and the cultural, genetic or biological resources and practices to which that knowledge relates, is their intellectual property and must not be used without prior written consent (Te Roroa Whatu Ora Trust 2008).

This Mātauranga has been passed down through the generations and is considered a taonga by Kaipara Māori. This taonga was created and shaped from generations of living on small islands in close connection with the natural world and was subsequently adapted and enhanced to the unique conditions and resources of Aōtearoa (Park 2000).

For example, kaumatua regularly speak of the seasonal indicators (Table 1) that were used for harvesting kai from the Kaipara which achieved and maintained a healthy mauri and tikanga. The use of Mātauranga Māori in current fisheries and resource management remains subservient to western frameworks. However, the Te Uri o Hau Settlement Trust and the Te Roroa Whatu Ora Trust believe there is an opportunity to integrate their knowledge into the district planning for the Kaipara District (Environs Holdings Ltd 2009).

Table 1 Past and present seasonal indicators used for harvesting kai from the Kaipara by Te Uri o Hau hapū.

Plant Cycle	Maramataka	Kaimoana Harvested	Season
Kowhai	November	Snapper, stingrays	Spring
Pohutukawa	December	Kingfish, Mullet	Summer
Algal Bloom		Mullet	
	February	Tuna/Eel	
Heather		Toheroa (fattest)	

Kaipara Māori are concern with how Mātauranga Māori has diminished since colonisation. They also have concerns about the lack of acknowledgement by some local and central government planning agencies about the role of Mātauranga in the management of natural resources (J. Sherard, Ngā Rima o Kaipara Trust, pers. comm., June 2009; J. Chetham, pers comm., ex-Manager Environs Holdings Ltd., July 2009).

Under Article 8(j) of the Convention of Biological Diversity (CBD), parties to the Convention undertake to respect, preserve and maintain the knowledge, innovations and practices of indigenous and local communities embodying traditional lifestyles relevant for the conservation and sustainable use of biodiversity. Scientific research undertaken to date on the use of traditional Māori knowledge across the spectrum of biodiversity management, is a gap. Opportunities do exist within the planning component of biodiversity through partnerships like the IKHMG; Te Uri o Hau Claims Settlement Act 2002; Te Roroa Claims Settlement Act 2008, and the set of Memorandum of Understandings and Protocol Agreements established with government departments and territorial authorities under these Acts. Such opportunities have allowed local and central government resource managers to listen to Mātauranga Māori based environmental management tools. However, opportunities to carry out other aspects of biodiversity management such as monitoring and governance or even undertake methods to insure the persistence of Mātauranga within the iwi/hapū are still non−existent or in their infancy.

The NZBS offers an internationally recognised framework for the active acknowledgement and practice of kaitiakitanga (Te Puni Kokiri 1998) within the Kaipara Harbour (see Chapter 7 – Restoring the Mauri of the Kaipara). However, avenues for kaitiaki to pass down Mātauranga Māori to future generations are limiting. Most opportunities exist for educated, adult Māori in employment of iwi/hapu organisations, such as Ngā Rima o Kaipara Trust, Te Roroa Whatu Ora Trust or Te Uri o Hau Settlement Trust. Opportunities to practice kaitiakitanga for all age groups have yet to be scoped and implemented for Kaipara iwi/hapū. Regular wananga (schools of learning) with practical grass−roots participation would allow all age groups to practice kaitiakitanga, through the learning of whakapapa science, ecosystem health monitoring and restoration methods (e.g. riparian planting, farm nutrient budgets).

9.5.2 SCIENCE & RESEARCH

Science and research into Mātauranga Māori and biodiversity has been driven at a national level through the Ministry of Research, Science and Technology and Foundation for Research, Science and Technology Te Tipu Putaiao Fund and the Department of Conservations Nga Whenua Rahi Fund.

The Ministry of Research, Science and Technology (RS&T) Vision Mātauranga is specifically dedicated to unlocking the innovation potential of Māori knowledge, resources and people. This policy was implemented into Vote Research, Science and Technology in July 2005 and was developed in consultation with research funders, researchers and research users including māori communities. Four themes were developed to provide strategic research investment decisions for Vote RS&T funding: (a) Indigenous innovation: contributing to economic growth through distinctive R&D; (b) Taiao: achieving environmental sustainability through iwi and hapū relationships with land and sea; (c) Hauora/Oranga: improving health and social wellbeing, and (d) Mātauranga: exploring indigenous knowledge and RS&T (Ministry of Research Science & Technology 2007).

The establishment of the Nga Whenua Rahui Fund and the Mātauranga Kura Taiao Fund under the New Zealand Biodiversity Strategy has seen investment in building and strengthening partnerships with iwi/hapū to conserve and sustainably use indigenous biodiversity. Nga Whenua Rahui Fund establishes a private land covenant on Māori−owned land particularly to protect and restore their indigenous ecosystems and for owners to retain tino rangatiratanga. The legislative instruments used are: Nga Whenua Rahui kawenata pursuant to s77A Reserves Act 1977 and an Agreement for the Management of Land pursuant to s29 Conservation Act. The Fund will assist landowners with fencing and to seek a nil rating from Councils by confirming formal protection. However, any rates remissions on the protected land are up to the landowner and the relevant council.

There are currently two Nga Whenua Rahui covenants in the catchment (Figure 1).

Mātauranga Kura Taiao Fund seeks to support iwi/hapū initiatives to retain and promote Mātauranga Māori and its use in biodiversity management. There have been a number of projects funded throughout New Zealand and more recently in the Kaipara.

Te Uri o Hau Cultural Heritage Trail

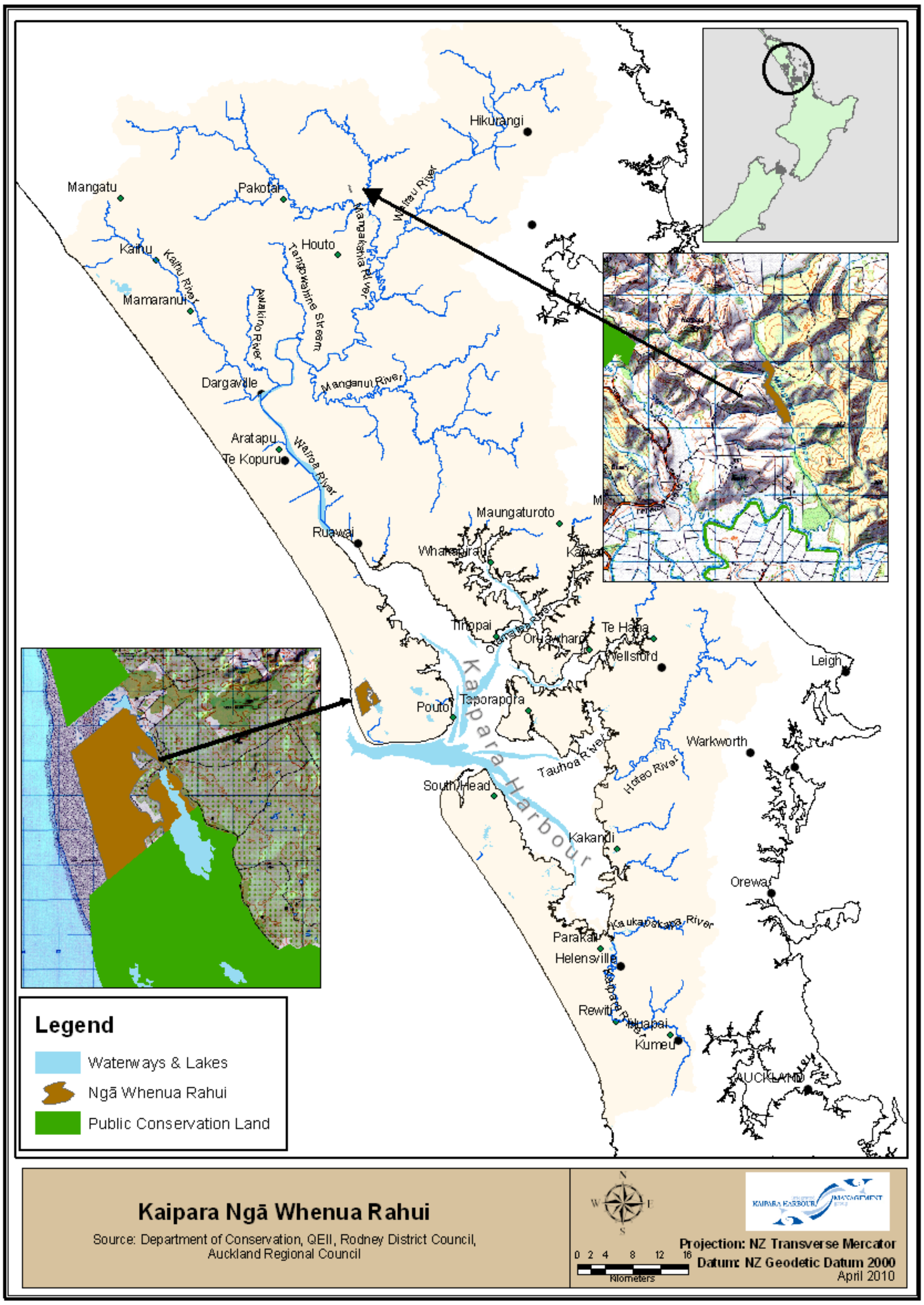
This project focuses on sharing technical biodiversity data and Mātauranga Māori knowledge back to the whanau and marae within Te Uri o Hau rohe. The Mātauranga Kura Taio fund will give Te Uri o Hau the opportunity to implement the transfer of this knowledge through the concept of creating a Cultural Heritage Trail utilising its Cultural Redress Properties.

Te Uri o Hau Settlement Trust cultural heritage project involves working with whanau and Taumatua to record Mātauranga Māori that portrays the linkage between biodiversity and the cultural landscape within the rohe. The project will enable Te Uri o Hau (TUOH) to engage with whanau, kaumatua, kuia, rangatahi, Kaipara District Council, Department of Conservation and archaeological experts, to establish a Focus group that will plan hikoi (visits) to each Cultural Redress Property. TUOH Ancestral marae (Ōtamatea, Ōruawharo, Waikaretu and Waihaua) will host wananga following the hikoi to share the korero to the wider whanau. TUOH will also pass on the existing information relating to biodiversity data and Mātauranga Māori through these wananga.

9.5.3 KAITIAKITANGA

Kaitiakitanga is addressed in Chapter 7 *Restoring Mauri of the Kaipara*.

Figure 1. Kaipara Nga Whenua Rahui



9.6 BIOGEOPHYSICAL INFORMATION

9.6.1 CATCHMENT – PHYSICAL CHARACTERISTICS

The Kaipara catchment is 6,400 km^2 and the river network flows from an elevation ranging between 200−770m, through various geology and landcover, covering a total distance of 9,075 km to eventually flow into the Harbour. The percentage or amount of freshwater entering the harbour is unknown. Like much of New Zealand, the Kaipara catchment has a temperate maritime climate. Compared to the north of the catchment the landscape is far more rolling and offers little major interruption to weather patterns (Ayres *et al.* 1984; Lux & Beadel 2006). The catchment flows into a drowned river valley which enters into the Tasman Sea.

The catchment contains rolling rather than steep country in the eastern portion, and no significant hills in the west, although terrain can be rugged in parts. The eastern and northern ranges rise to 430−440m (Table 2), but the majority of the land is 150m or less (Figure 2). There are no major bodies of water within the catchment, although north head and south head peninsula's support a series of unique dune lake ecosystems, the most substantial of which is Lake Humuhumu on north head.

Table 2. Significant Mountain Ranges of the Kaipara Catchment. For comparison Mt Ruapehu (tallest mountain in North Island) is included.

Mountain Range	Height (m)
Tutamoe Range	770
Dome Valley, Conical Peak	385
Mt Auckland, Atuanui	305
Tangihua Range	627
Manungaru Range	419
Brynderwyn Range *Cattlemount*	350 *430*
Riteakawarau	252
Mt Harriet	229
Mt Ruapehu	2,979

The northern parts of the catchment are influenced by its northerly location (latitudes 34ºS to 36ºS). At over 641,600 hectares (6,400km^2) the catchment of the Kaipara (excluding the harbour which is 947 km^2 of which 409 km^2 is exposed at low tide (43%)) (Heath 1976) has mild temperatures and does not experience wide seasonal extremes. Summer temperatures are warm and humid, with averages of 19ºC. Winters are mild with averages of 10ºC. Inland areas commonly receive frosts (<1 C at 2.5cm above ground) but air frosts are infrequent.

The average annual rainfall over the most of the catchment is 1200 to 2400mm/yr. Rainfall peaks in winter and is higher further inland and at elevation than on either the east or west coasts. It is drier in the western parts of the catchment (1000 to 1250mm/yr) with the highest mean annual rainfall in Dome Valley in the northeast (Hoteo River catchment) with most catchments receiving between 1700−2000mm/yr.

The predominant wind is from the southwest (27%), followed by the northeast (12%). In spite of over 90% of the winds coming from oceanic sources, high winds are not common and most of the area is well sheltered from the sea winds by proximity and terrain. Gale force winds can occur at any time, but are most common in winter. The occurrence of fog and thunderstorms varies from 1 to 75 and 3 to 16 days per year, respectively (Moir *et al*. 1986).

Catchment

A catchment can be defined by water flow. Rain landing on vegetation or the ground percolates into the ground, evaporates, or flows via creeks and streams into rivers, lakes, estuaries, swamps or coastal water bodies.

Catchments can be small for creeks or ponds, or large for rivers and lakes. Creek and pond catchments can be part of river and lake catchments, therefore forming subcatchments.

Usually catchments are divided into three parts: upper, middle and lower (close to sea level).

The catchment concept in New Zealand was primarily introduced to manage stormwater, flood and erosion/water quality management process, whereas integrated catchment management (ICM) has a far wider scope, including social, economic and ecological issues.

This concept is currently being practiced in the Motueka Catchment in the South Island (Davie *et al*. 2004), which is one of the inaugural pilot basins for the UNESCO/WMO global HELP project (*Hydrology, for the Environment, Life and Policy*).

Other examples of ICM are at Whaingaroa (Raglan) Harbour.

However, the ICM approach has limitations. The approach does not take into account the marine environment, however ICM does note that there is a strong connection between what happens on the land, and the impacts on water, including the coast and its flora and fauna.

Hence, the conflict arising between the RMA (1991) and NZCPS (1994). The RMA in several areas fails to provide for automatic inclusion of all biological parts within a system for example, fisheries and fish. The NZCPS and the NZBS advocate for an ecosystem-based approach, where the coast is recognised as an area of dynamic ecological processes (Park 2000).

Driving the hydrology of the catchment is climate and weather, the processes of evaporation, penetration, infiltration, transpiration, condensation precipitation and interception. Topography influences run−off characteristics and weather patterns that are intimately interlinked with the hydrologic cycle. Urban, pastoral, industrial, and forestry land uses can have substantial effects upon the hydrology of the Kaipara Catchment, which in turn is linked to the function and resilience of ecosystems throughout the catchment.

Climate change is believed to also have an impact on the hydrology of the catchment, through increased intensity of peak rainfalls, and increased sea levels.

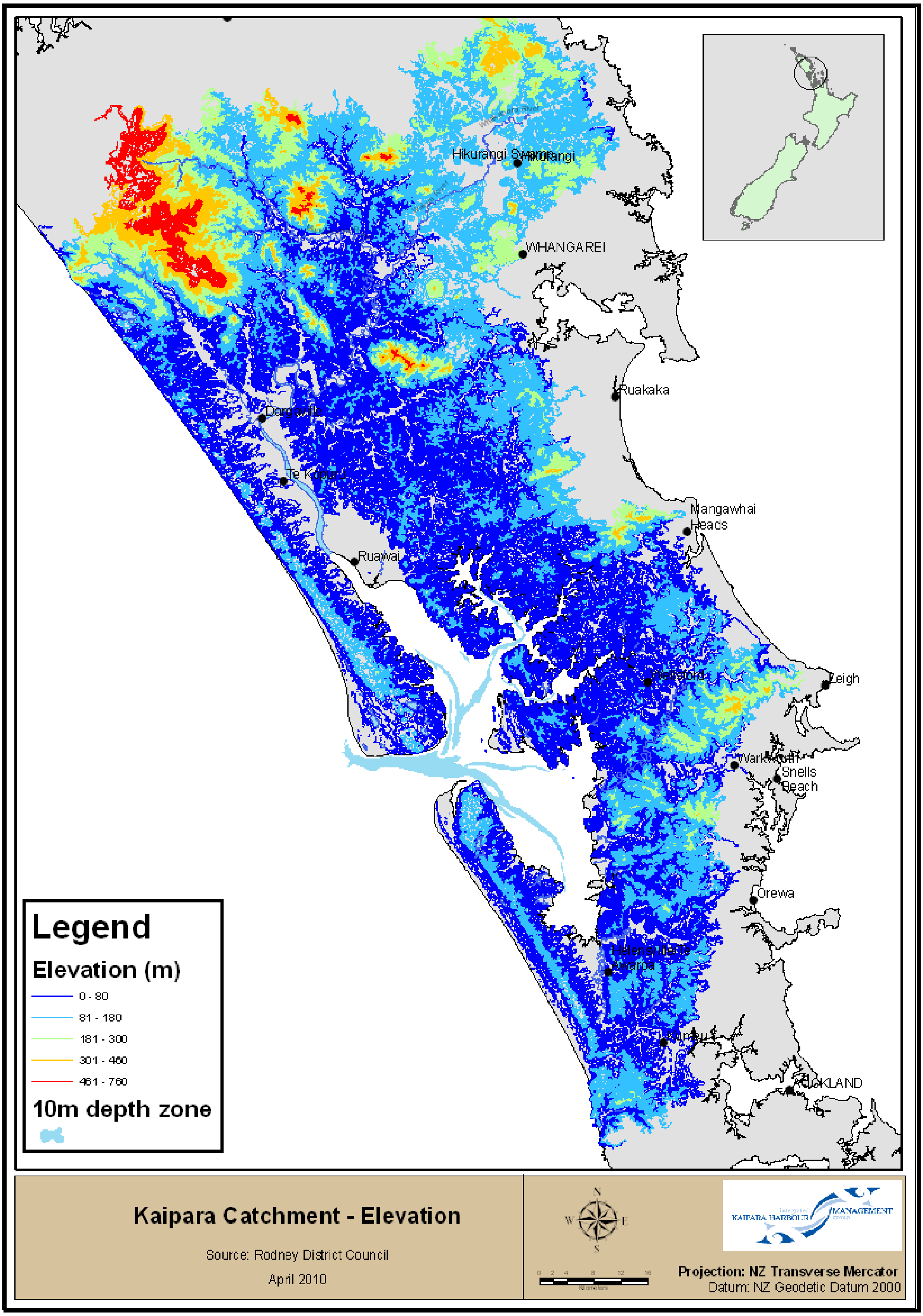
Hydrological studies of the entire Kaipara catchment have yet to be undertaken, however, certain sub−catchments, such as the Kaipara−Kumeu River (Opus International Consultants Ltd 2007), Kaihu River (Northland Catchment Commission 1979; Northland Regional Council 2006), Kaukapakapa River (Golder Kingett Mitchell Ltd 2007a) have been studied in detail. The purpose of the Kaipara River study was primarily for flood risk and stormwater management, whereas for the Kaukapakapa River, the study related to the recent resource consent and plan change proposal to develop a gas−turbine power station.

Being the largest catchments in the Auckland region, the Kaipara−Kumeu River drains essentially from the northern base of the Waitakere Ranges (just over 200m a.m.s.l) through the small townships of Waikatere and Taupaki, and out towards the Kaipara Harbour through Kumeu, Huapai, Waimaukau, Woodhill and Helensville.

Kaipara Harbour hydrodynamic modeling show that the impacts of the river flows on water levels in the harbour are expected to be small (DHI Water & Environment 2006). The model was primarily designed to assess extreme water levels and inundation in and around Helensville along the Kaipara River. The extreme scenarios reviewed 100−year storm surges, wind, climate change, ENSO and normal tide conditions. These results indicated that the influence of flow discharges from the Kaipara River on downstream water levels is negligible (DHI Water & Environment 2006).

Other physical data sources that exist across the entire catchment include annual solar radiation, mean annual temperatures, winter solar radiation, annual water deficit and water balance ratios. These have been detailed in the Kaipara Atlas, the integrated database component of this review and gap analysis.

Figure 2. Kaipara catchment elevation.



9.6.2 HARBOUR

The Kaipara Harbour is an extensive drowned river valley. It is a type of estuary that is considered a rare, usually transitory, feature of the New Zealand coast. The Kaipara is classed as a double−spit and its closest 'cousin' is the Manukau Harbour, a single−spit estuary type (Hume & Herdendorf 1988), 40km south of the Kaipara. Both are New Zealand's largest harbours. Hume & Herdendorf (1988) have geomorphically classified the Kaipara as a barrier−enclosed estuary. This type of estuary is formed by Pleistocene barrier double−spit landforms. The barriers are built from sand supplied by onshore transport of continental shelf sands and/or littoral drift. These types of estuaries are characterised by generally low freshwater inflow and tide dominated hydrology. They are well mixed and salinity stratification is only apparent in the narrow headwater creeks, although floods may push the stratification seawards. Low tide exposes extensive areas of low gradient intertidal flats drained by narrow tidal channels.

Geo-evolution: the ancient Kaipara estuary

Approximately 18,000 years ago sea level was 120m lower than today. The Kaipara was a maze of deep valleys with rivers flowing toward an open coast whose shoreline was located some 25km seaward of today.

This Holocene-Kaipara was located in the area now occupied by the inner continental shelf. The landscape and climate were vastly different to today, with cooler and drier conditions prevailing. Vegetation was sparse, allowing sand dune formation.

The sand dunes would have covered the exposed continental shelf back towards the Kaipara heads and up into the palaeo/ancient rivers. Today, these ancient dunes are partially exposed in the cliffs on Kaipara Heads as iron-stained semi-consolidated sands and shore platforms.

With rising sea level these expansive sand dune shelf's were buried in marine sands and the formation of the ebb (seaward)-tidal delta. Vast quantities of sand were transported onshore by waves and wind to form the massive dune barriers of North and South Heads and Taporapora.

Tidal currents and sand moving into the Kaipara, subtidal shoals and banks of sand (e.g. Lady Franklin Banks) were formed. Today these channels steer the flow of water in and out of the estuary. Sand was shifted and accumulated along shorelines to form intertidal flats, beaches, small dunes and spits.

Today the ancient river valley of the Kaipara is largely infilled with marine and catchment-derived sediment, and as a consequence it is about 40% intertidal flats.

(Source:Hume 2003b)

These Pleistocene barriers can be over 200m high, and are fronted to the west by small Holocene dunes, and marine sands flux through the Kaipara under tidal action. Older consolidated sand dunes of the barriers are essentially sandstone, and form a cliffed coast in the north, but towards North Head the recent sand dune area is extensive.

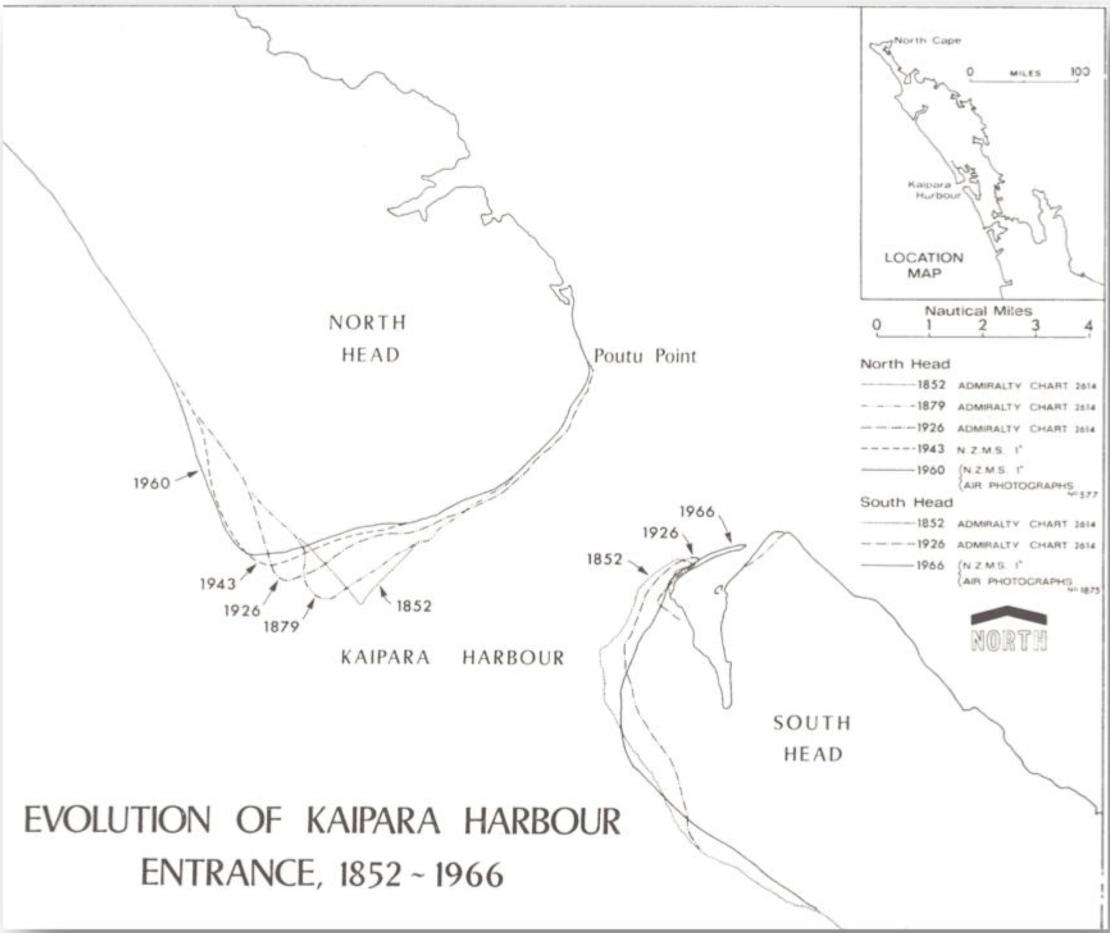
The whole area thus, consists of older former dunes, which have been overlapped by latter dune advances (Cameron *et al*. 1997). For example, on South Head, five belts of sand dunes have been added in the last 6,500 years. Throughout, dark lignite, also referred to as brown coal, and mud layers within the sand dune sequences tell of the temporary presence of swamps and dune lakes, and old forests over the older stablised dunes. Overtime, sand accumulated burying the lakes and forests, which of course contained large amounts of Kauri (Stallworthy 1916).

Because of the strong tidal movements that operate in tidal inlets like the Kaipara, over the past 160 years there has been significant change in the harbour entrance. This has been described by Smith (1999), Wright (1969), Brockbank (1983), and Ross (1996).

The present shape of the Kaipara Harbour has developed over the past 18,000 years (Cameron *et al.* 1997) (Figure 3). Current sea level inside the Harbour occurred about 6,500 years ago after climatic warming. For several thousand years after the sea reached its present level, vast quantities of sand were thrown up against the land to form beaches, barriers and dunes of the Kaipara.

Brothers (1954) describes the chronology of the South Head and attempts to classify the Kaipara along evolutionary scales.

Figure 3. Evolution of Kaipara Harbour Entrance, 1852−1966 (Source: Wright (1969)).



There are several studies that describe the hydrodynamics of the Kaipara Harbour which have been generated through the sandmining resource consent process. Sandmining operations currently occur at Taporapora Banks with an extraction volume of 780,000 to 1.3 million m^3 per year (Hume *et al*. 2003b). Main findings regarding sand movement, transport and distribution are found in the following reports:

- *Component 1* – Historical sand movement (Parnell 2003; Hume 2003a)
- *Component 2* – Present sand distribution (Hume et al. 2001).
- *Component 3* – Sand transport (Green *et al.* 2002; Osborne & Parnell 2002).
- *Final Report* – Hume (2003b).

Haggit, Mead *et al*. (2008) also go into detail about the hydrodynamic and physical characteristics of the harbour. Essentially, the Kaipara is a tidal inlet system, which has been well studied and the processes that operate them are well understood (Hume 2003b). To this end, a short summary is detailed here.

Sand movement, transport and distribution

The Kaipara tidal inlet is huge by world standards. Through the narrow entrance (8km across) of the Kaipara, 30−35m deep, strong (about 2m/s ~4 knots) reversing tidal currents flow and form banks of sand on both the seaward (ebb tidal) and landward (flood tidal delta) side of the Kaipara. Also occurring is the deposition of sand along the north and south peninsulas of the Kaipara Harbour.

There are huge amounts of sand stored in both the flood tidal shoals, specifically Taporapora Banks, and in the ebb tidal shoal at the entrance to the Kaipara. The massive size of the inlet, the large stores of sand, and strong tidal currents that push 1.99 billion cubic metres of water in and out of the entrance each spring tide (Heath 1976; Hicks & Hume 1996), equates to large volumes of sand movement and transfers throughout the Kaipara Harbour. Historical evidence and local hapū knowledge supports such findings (Parnell 2003).

Any mud that comes into the tidal inlet and settles is quickly shuffled from the seafloor by the strong currents and waves which turn over sediment and send it either back up into the tidal creeks where it settles or goes out to sea.

The large sand ridges documented by Hume (2003b) were found to reach 10−30cm high and 20m between crests, proving considerable sand movement in the tidal area. Taporapora Bank is evidence of the massive sand changes operating in the Kaipara over the past 150 years. Taporapora Bank lies between the two primary channels. The Ōtamatea Channel to the north and the Tauhoa Channel to the south, at the end of the Ōkahukura Peninsula, but does not extend as far west between the Kaipara Heads. The Bank however, appears to have broadened and lengthened southward some 2km, and now contains Manukapua Island, some 3.5 km in length, generally lying in a north−south direction, and perpendicular to the harbour entrance.

The Tauhoa Bank, separates flows between the Kaipara River and Tauhoa Channel. Tauhoa Bank dries at low tide and is significant in size, stretching out between 6−8km long. The Bank is also another area supplied with sand from the ebb tidal inlet.

There is strong linkage between the Kaipara tidal inlet and the open coast. Sand movement into the Kaipara is very dependent on open coast and ocean processes such as tides, open−coast littoral drift and ocean wave dynamics. The supply of sand from the coast is not regular; it is quite variable due to the direction of ocean swell. To a lesser extent the ebb tidal delta at the entrance to the Kaipara moves into the Kaipara, mainly during storms and swell.

This highly dynamic system produces large changes along shorelines and sandbanks, and beaches erode and accrete in response to tide and wave action. For instance, North Head has experienced 4km of deposition of sand over the last 6,000 years and the shoreline has seen a trend of erosion by 2km at the south−west tip since 1877, and built out by 1.5km at Oceanside Beach.

9.6.3 GEODIVERSITY: GEOLOGICAL FEATURES AND SOILS

Geologically, New Zealand is very mobile. It is being torn apart along its north−east/south−west axis because it lies on the junction of the Pacific and Indian−Australian Plates – two of the great moving plates that make up the crust of the earth. Volcanic activity is common, and the landscapes and soils of half of the north island owe their origin to the volcanic eruptions of the last two million years (Molloy 1998).

Consequently, New Zealand's landforms are still very youthful. Mountain−building continues at up to 10mm a year in many areas, a rate considered to be high on a geological scale.

The variation in local topography does have a noticeable effect on soil patterns, and while the variation may be subtle in some areas the influence of alluvial and valley soils, contrasted with the more rolling areas, is clear in terms of potential landuse.

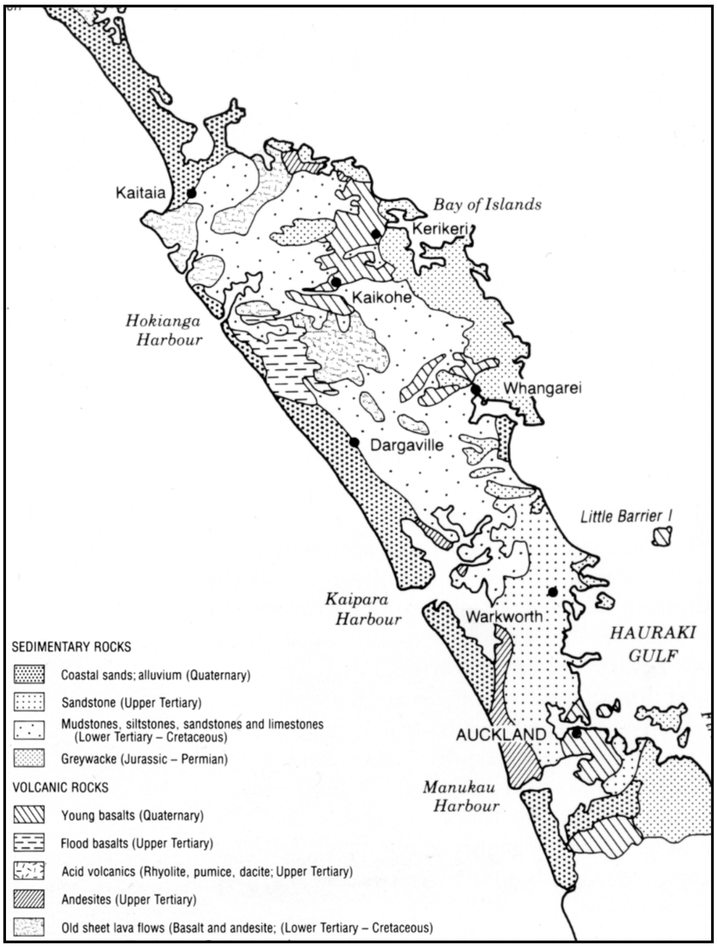
Geological Evolution & History

Collision of the Indian−Australian and Pacific tectonic plates created a wedge of rock, up to 3km thick, which was scraped off the seafloor and emplaced over the entire region. This jumbled mass of rock is called the Northland Allocthon, which is formed of marine sediments and very large slabs of marine basalts known as the Tangihua volcanics.

Following this collision, about 15 million years ago (Tertiary period), a chain of volcanoes emerged off the west coast giving rise to the thick basalt flows which now form the Tutamoe plateau and Maunganui Bluff, and outcrops at Tokatoka and Hukatere. The large Wairoa River drains the Tangihua volcanics, sandstones, mudstones, limestones and shales. The southern part of the catchment drains mainly Waitemata Group sandstones and mudstones and some volcanics, while continual shifting sand by wind and water currents has built up the large south and north Kaipara dune peninsulas (Brothers 1954) (Figure 4).

The geodiversity of the Kaipara catchment has drawn the attention of many geologists and as a consequence been well studied (Brothers 1954; Black 1964, 1966, 1967; Hayward 1976, 1979; Brook 1983; Brathwaite *et al.* 1991; Hayward & Smale 1992; Hayward & Stilwell 1995; Hayward *et al.* 1999; Hayward & Brook 2001). The special geological features of the Kaipara were also recognised by the first European naturalists visiting New Zealand (Dieffenbach 1843; Crawford 1865; Hochstetter 1867; Cox 1881; Ferrar 1934).

Figure 4. Parent rock material of the Kaipara catchment, Northland and Auckland. (Source:Brothers 1954).



9.6.3.1 ENVIRONMENT CLASSIFICATION

Using a comprehensive set of climate, landform and soil variables an ecosystem classification of New Zealand's landscapes was developed. Land Environments New Zealand (LENZ) (Leathwick *et al*. 2003) has classified the Kaipara Catchment into three land environments (Figure 5) out of 20, at the Level 1 classification:

1. Northern Lowlands

The climate is warm with very high annual and winter solar radiation. Winter minimum temperatures are high, with frosts occurring only infrequently from about Auckland north. This area is susceptible to drought. Landforms are generally flat to gently rolling, with parent materials that include deeply weathered sandstone and greywacke, older volcanic tephra, alluvium from various sources, peat and older basaltic rocks.

Most soils are poorly to moderately drained and of low natural fertility, reflecting the intense weathering caused by the warm, moist climate.

Original vegetation was almost entirely forest in which most species were range-restricted to Northland. This environment also supports coastal forest and unique areas of kahikatea forest with successional manuka stands, sandwiched between sand dunes and estuarine vegetation and mangroves (e.g. upper Kaihu Valley). On these estuarine alluvium soils were once extensive kahikatea forests (e.g. Ruawai flats, Kaihu Valley, Wairoa River valley). On wet ground, pukatea was also common; swamp maire was a characteristic smaller tree and kiekie, supplejack and *Gahnia xanthocarpa* a sedge−like plant, formed impenetrable understoreys. On drier ground matai was co−dominant and small−leaved trees and shrubs such as milk tree and rohutu were typical. Except for reserve portions of swamps, most are now drained and converted to pasture. Groves and scattered stands of kahikatea trees are all that remain of these forest types.

Kauri forests were the dominant ecosystem to cover the undulating hills of the catchment which had infertile and moderate draining soils (A6) (Leathwick *et al.* 2003). This environment is closely associated with a rolling hills environment (D1), such as Tutamoe Range and Brynderwyn Range which still contain forests, although accessible areas have experienced heavy deforestation.

2. Northern Hill Country

The Kaipara catchment is also characterised by the "Northern Hill Country" Level 1 environment (at the Level II environment has 4 levels: D1−D3). The catchment has environments classed as D1 which are closely associated with A6, Kauri forests. D1 environment has an average elevation to 217m, with rolling hills landform with moderate soil fertility and drainage. Parent material is deeply weathered basalts, andesites, rhyolites, with greywacke, sargillite and sandstone are locally important.

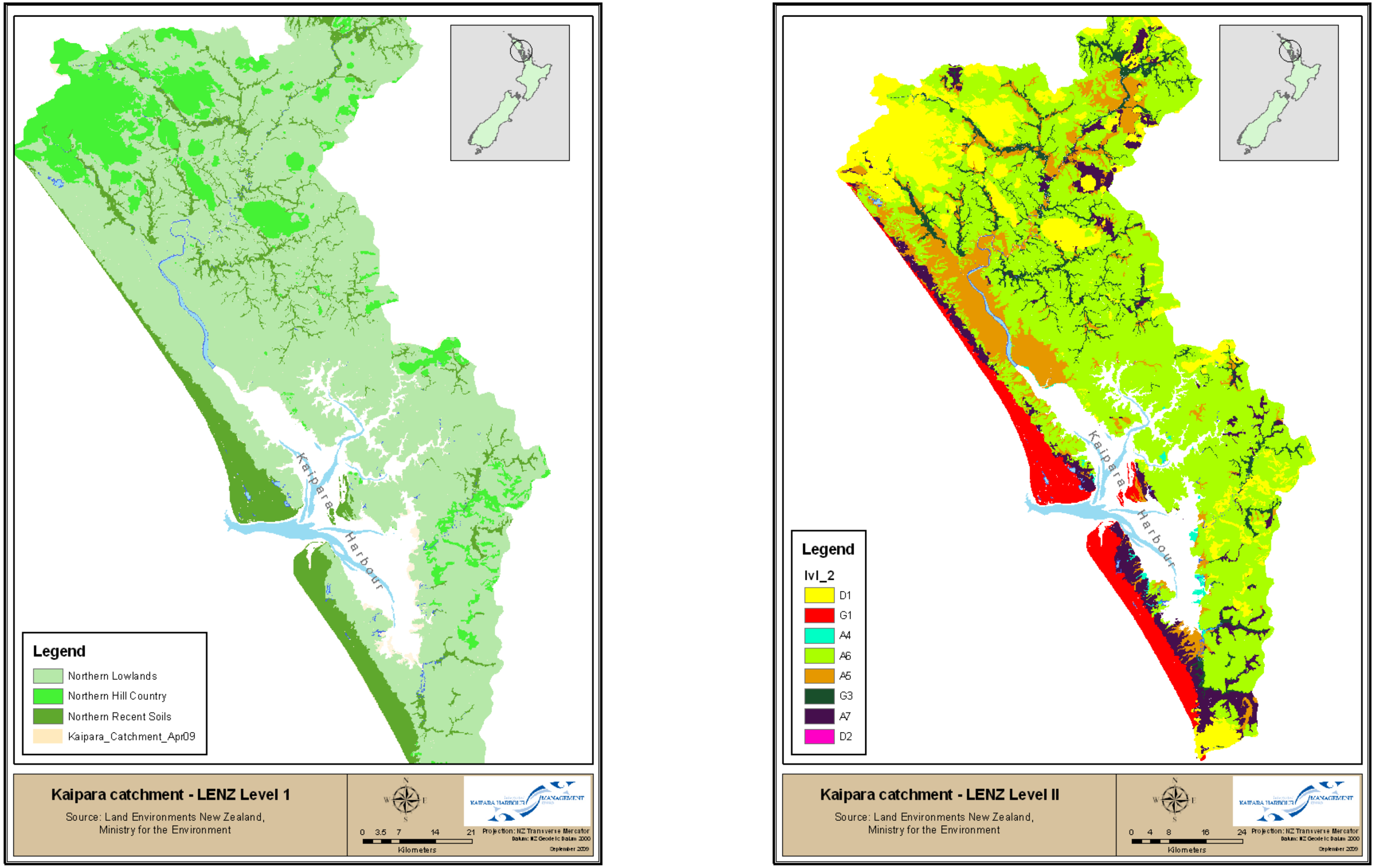
3. Northern Recent Soils

The Kaipara catchment is also characterised by the "Northern Recent Soils" Level 1 environment class. At the LENZ Level II environment class, the catchment has two classes; G1 and G3. G1 describes sand dune country along the west coast of the catchment – the Kaipara barriers. Indigenous vegetation is patchy, with the odd cover of native grasses, spinifex and pingao, but mostly dominated with marram grass and pine forests. Soils are fertile with good drainage. The Northern Recent Soils G3 environment is found north of Whangarei in the Hikurangi swamp area which feeds into the Wairua and Wairoa River and the habour. It is an area of gentle, undulating floodplain with fine textured alluvium. Soils have low fertility and moderate drainage.

The spatial quantification of these environment classes has yet to be completed for the catchment but the Kaipara District Council (KDC) commissioned a landscape assessment of the district in order to identify and prioritise threatened environments for their district plan review (Wildlands Consultants Ltd 2006). Other uses by resource managers, iwi or community groups were investigated and at the time of writing, such organisations were not utilising it for submissions, consultation processes, biodiversity or soil planning and policy development.

Other uses that LENZ can assist with include estimating the extent of indigenous ecosystem loss, analysis of forest loss and fragmentation as an indicator of indigenous biodiversity status within the district or region; or estimating realistic restoration goals for a degraded ecosystem and predicting pest distributions so surveillance priorities can be identified.

Figure 5. Land Environments New Zealand classification for the Kaipara catchment – Level 1 and Level II class.



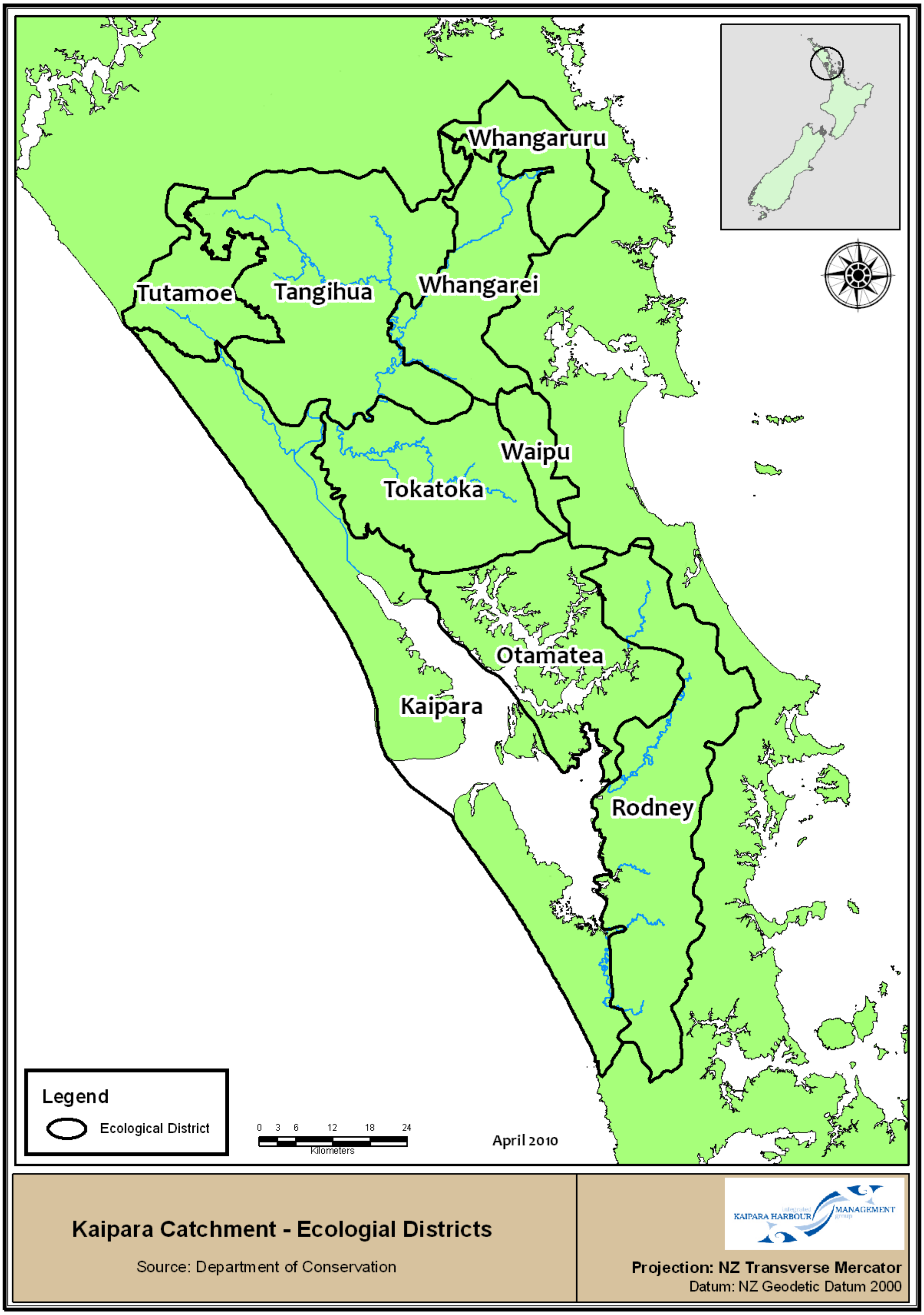
9.6.3.2 GEODIVERSITY AT THE ECOLOGICAL DISTRICT LEVEL

The geodiversity of the Kaipara catchment is described at the Ecological District (ED) level as to describe the geological pattern within the catchment. There are eight ED's (Table 3) that form the Kaipara Catchment (Figure 6). An ecological district has been classified based on areas with similarities in ecological attributes such as topography, geology, soils, altitude, climate, vegetation, and fauna (McEwen 1987). The boundary of these districts, which forms the analysis of this report, is based on Brook (1996).

Table 3. The eight ecological districts that occur in the Kaipara catchment and status of information collected for Protected Natural Areas Program.

Ecological District	%ED in Kaipara Catchment	Reconnaissance Report for Protected Natural Areas Program Published	Reconnaissance Report in Prep	Reconnaissance Survey
Kaipara	100%	√ (south & north)		√
Tokatoka	100%		√	√ 1998–99
Ōtamatea	100%	√ (south & north)		√
Tangihua	74.5%	√		√
Rodney	62.5%	√		√
Whangarei	63.2%	√		√
Tutamoe	41.4%	√		√
Waipu	28.3%	√		√
Whangaruru	25.4%	√		√ 1994–95

Figure 6. Kaipara catchment ecological districts.



Tutamoe Ecological District

The Tutamoe ED sits to the northwest of the Kaipara ED and includes Maunganui Bluff on the ED's west coast and contains one of the last remaining remnant stands of Kauri forest (Waipoua Forest). The ED's geology is characterized by an extensive eroded plateau of lower Miocene Waipoua Subgroup basalt flows. There are two main physiographic elements:

1. The steep and rugged, deeply dissected east−west trending Waima Range in the north of the ED rising to the highest point in Northland (Te Raupua 780m). This feature is outside the Kaipara catchment.
2. A gently south westward sloping, partly eroded basalt plateau incorporating the Parataiko Range, Tutamoe Range and Manganui Bluff, and reaching its highest point at Tutamoe (770m) in the southeast. The plateau is drained by three catchment systems namely the Waimamaku (drains to the coast), Waipoua (drains to the coast), and Waima−Kaihu Rivers (drains to Kaipara Harbour). Colluvial basalt boulders are common on steep slopes in valleys and on the escarpment along the eastern margin of the plateau, and there are several very large areas of landslide deposits in Waimamaku valley. The west coast has stretches of sandy beaches backed by dunes and small freshwater wetlands, interspersed with rocky headlands including the 459m high Maunganui Bluff in the south.

Tangihua Ecological District

This ED is characterised by the presence of isolated steep−sided and rugged allochthonous Tangihua Complex ophiolitic massifs ranges, surrounded by areas of allochthonous Mangakahia Complex. Motatau Complex sedimentary rock, with Quaternary alluvial and swamp deposits along river valleys.

The southern boundary of this landlocked district defines the southern limits of ophiolitic massifs in Northland.

Whangaruru Ecological District

The Whangaruru ED sits at the upper northeast reaches of the Kaipara catchment and its western boundary is with Whangarei ED. With only 24% of the ED sited in the catchment, it contributes east−west greywacke ranges elevating up to 450 metres (Booth 2005).

Tokatoka Ecological District

Tokatoka ecological district contains Mangakahia and Motatau Complex sedimentary rock classes, with abundant Lower Miocene subvolcanic basalt to dacite plugs, sills, dikes and 75 reccias pipes in the west from Turiwiri to Tokatoka, along with extensive Quaternary alluvial and swamp deposits along the Manganui River valley and feeder tributaries.

Whangarei Ecological District

The Whangarei Ecological District's main geological characteristics are the extensive (7,224 ha) Hikurangi Basin containing Quaternary[4] alluvial and swamp deposits and the

[4] Quaternary Period is roughly 1.8 MYA and contains three geologic epochs: Pliocene, Pleistocene, and Holocene (in chronological order). Quaternary covers the time period of glaciations, classified as the Pleistocene. The 1.8-1.6 million years of the Quaternary represents the time during which recognisable

volcanic landforms (Manning 2001). When assessing the geology across the catchment, the Whangarei Ecological District contains all of the volcanic landforms such as basalt lava flows and scoria cones (e.g. Hikurangi, Maungatapere, Maunu and Maungakaramea).

Waipu Ecological District

With only 28% of the Waipu ED represented in the Kaipara catchment, it contributes the east−west trending moderately dissecting ranges in the most western parts of the ED. Most of the ranges are composed of greywacke (Lux *et al*. 2007).

Ōtamatea Ecological District

Featuring moderate hill country up to 180m, the Ōtamatea district is divided into 3 large peninsulas extending into the Kaipara Harbour (Lux & Beadel 2006). Much of the eastern part of the district is underlayed by a structurally complex jumble of allochthonous Mangakahia Complex and Motatau Complex sedimentary rock units (including tectonic blocks of Cretaceous (145−65 million years ago) sandstone, mudstone and siliceous mudstone; and Paleogene mudstone, glauconitic sandstone and micritic limestone; incorporated within the melange). In the west are overlying sequences of Lower Miocene (23−5 million years ago) Waitemata Group sandstone and conglomerate, and Waitakere Group basaltic andesite lava flows, hyaloclasite, pumicesous tuff breccia, and associated volcaniclastic sediments (Brook 1996).

Rodney Ecological District

The geology of the Rodney Ecological District that is represented in the Kaipara catchment is relatively subdued lowland hill country that has been influenced by its coastal environment. It is bounded to the southwest by the Waitakere Volcanics and to the north by sandstones and mudstones of the Waitemata Group. Even though hot springs are represented in this District, none are found in the area located inside the Kaipara catchment.

This district lies south of the Brynderwyn hills, running south to Auckland east of the Ōtamatea and Kaipara Districts. 62.5% of the ED lies within the Kaipara catchment. Much of the ED is fluvial in origin, but most of its character is coastal. The drowned valleys of the Kaipara Harbour extend well within reach of the east coast of the Rodney ED (e.g. Hoteo River – originates in the Kaipara and extends over 30 km east).

The hill country is comprised of well dissected sandstones and mudstones of the Waitemata Group; bounded to the west by the Waitakere Volcanics and to the north by the oldest soil base, greywacke.

The northeast trending faultlines dissect the ED with associated narrow valleys and some minor volcanic intrusions (Ayres *et al*. 1984).

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humans existed. Far more geological information exists on the Quaternary than any earlier periods and is most relatable to the maps of today. Few major new animals evolved, again presumably because of the short – in geologic terms – duration of the period. There was a major extinction of large mammals in Northern Hemisphere areas at the end of the Pleistocene. Such as saber-toothed cats, mammoths, and mastodons, became extinct worldwide. Others, including horses, camels and cheetahs became extinct in North America. Modern humans evolved about 190,000 years ago.

Kaipara Ecological District

The main geological features of the Kaipara ED are the sand−dune sequences dating from early Pleistocene to the current day, and the extensive estuarine deposits (Davis 2002). This incorporates Quaternary dunefields bounding the Kaipara Harbour in the west, and peninsulas and low hill country of allochthonous Mangakahia and Motatau Complex sedimentary rocks, and overlying lower Miocene Akarana Supergroup sedimentary, volcanic and subvolcanic rock units in and adjacent to the northern Kaipara Harbour.

The sand dune systems are outstanding examples representing major stages of Earth's evolutionary history. Sand dune sequences, 3.5km wide by 50km long, are found along the north and south Kaipara peninsulas, and Taporapora. The northern Kaipara barriers incorporates core's of Pleistocene dune sands, shrouded in the west by Holocene dunefields, extensive Quaternary estuarine and swamp deposits along the Wairoa arm, alluvial and swamp deposits along the Kaihu River valley, and Pleistocene−Holocene[5] dunefields at the western end of Taporapora (Schofield 1975; Brook 1996; Davis 2002; Hume 2003a) (Figure 7). Brothers (1954) and Schofield (1975) describes these in detail, concluding that there were three main zones or dune belts, representing five main periods of sea−level fluctuations when sand accumulated and eroded. Therefore, the eastern part of the dune is older in age compared to the oceanic side of the south Kaipara harbour barrier. Sea−level fall was around 2.1m during last 4455 years (Schofield 1973) and fluctuations has been found to apply to the whole of Northland and Auckland.

The youngest belt/zone of the barrier is estimated to be formed about 500years ago and the oldest part is to have occurred about 1500 years ago. During this sea level fluctuations, erosion and accretion occurred.

A chronology has yet to be established for the northern Kaipara barrier which is also noted by Parnell (2004).

On the estuarine edges of the Pouto Peninsula there is more recent (Holocene) dune sand; much of this is stable, though unconsolidated. There are mobile dunes on the extreme coastal edge of the Peninsula which extend as far east as the dune lakes at the southern tip of the Pouto Peninsula. Much of the sand is covered with marram grass and *Pinus radiata*.

The Awhitu sand formation is the oldest sand sequence, with overlying layers of the Shelly Beach formation and then Waioneke formation. In the north of South Head peninsula a fourth sand sequence, the South Head formation developed. The last sand dune sequences to form were the Mitiwai formation, which includes the current day active sand dunes along Muriwai beach, Papakanui Spit, Taporapora and Waikiri Island. Today, the Shelly Beach and Waioneke formations have been eroded back so that they only reach the surface on the eastern side of the South Head Peninsula.

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[5] Holocene means less than 10,000 years in age. On the North and South Head of the Kaipara older Pleistocene sediments are visible as the iron-stained semi-consolidated dune sands. Holocene sand is currently being mined in the Taporapora Banks area.

The Waioneke formation occurs at the surface in limited areas, usually in gully bottoms, while the Shelly Beach formation has a much larger extent forming the cliffs along the Kaipara harbour western edge. The Awhitu formation reaches the surface along the high hills in the middle of the South Head Peninsula where it covers large areas.

The Kaipara Harbour contains extensive estuarine deposits of silty composition. In the southern part of the Kaipara ED around the lower Kaipara River and Parakai as well as along the eastern edge of the Kaipara Harbour and at Waioneke there are extensive areas of former estuarine flats. They have formed from the uplifting of land although some flats are no longer tidal due to reclamation. River alluvial terrace deposits are uncommon in the Kaipara ED because of the generally smaller river systems and the dominance of the tidal system of the Kaipara. However, the flood plain of the middle reaches of the Kaipara River valley (within the Kaipara ED) currently deposits silt on what was formerly estuarine flats/coastal terraces. More defined river terraces may form in the future in this location.

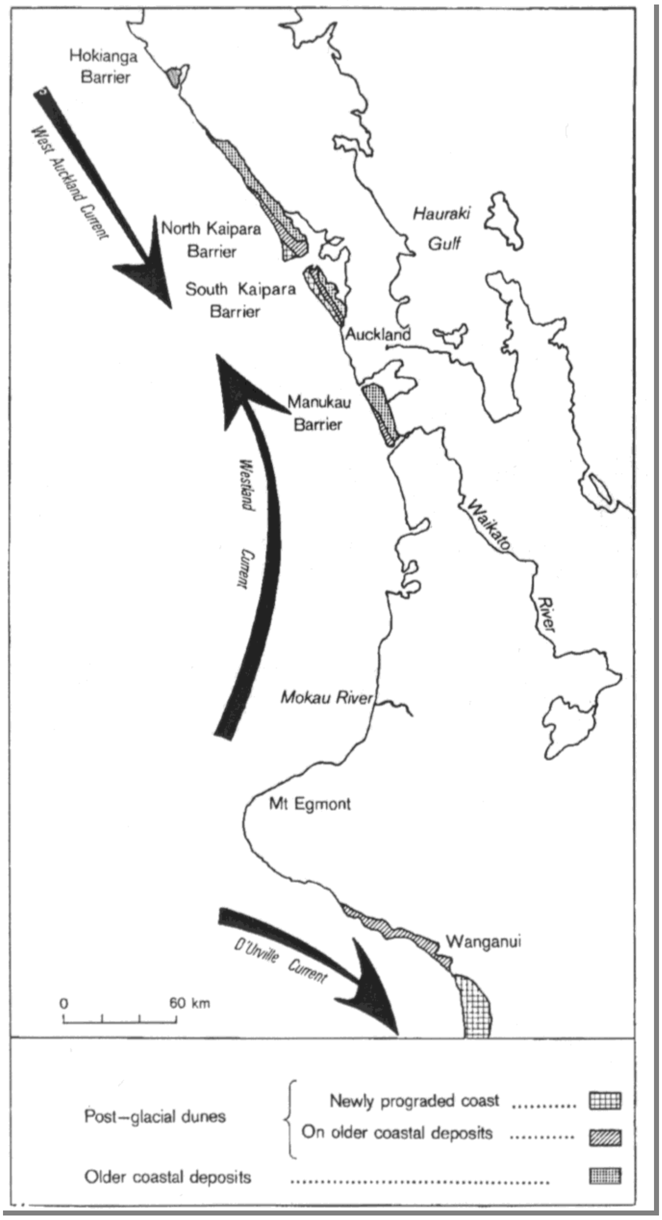


Figure 7. The Egmont−Kaipara sand system defined by Schofield 1975 illustrating the formation of the sand dune peninsulas of the Kaipara Harbour.

The Kaipara ED, while primarily defined by its sand dune country and estuarine deposits also has minor amounts of Tertiary−aged volcanic rocks and sedimentary sequences. Isolated outcrops of volcanic rocks are present among the sand dune sequences in the south of the ED around Muriwai. They are the northern extent of the Miocene−aged Waitakere volcanic centre. Three islands in the Kaipara Harbour, most notably Moturema Island, are Waitemata group sandstones−mudstones. The Waitemata group is a common geological sequence to the east of Kaipara ED within the Ōtamatea and Rodney Ecological Districts.

9.6.3.3 NEW ZEALAND GEOPRESERVATION INVENTORY (NZGI)[6]

The aim of the New Zealand Geopreservation Inventory (NZGI) is to identify and document all landforms, geological sites and soil sites of international, national and regional scientific and educational significance. The fundamental goal is to ensure the survival, through protection, of the best examples of the broad range of physical features and processes which best characterise each geological feature of New Zealand, including the ordinary as well as the unique and spectacular (Arand *et al.* 1993; Kenny & Hayward 1993a, 1993b).

Sites have been classified into 15 categories:

- Landform
- Igneous geology
- Fossil
- Mineral
- Sedimentary geology sites
- Metamorphic sites
- Geologically−related historic sites
- Caves and karst sites
- Geothermal fields and features
- Quaternary Volcanoes
- Soils of the South Island
- Soils of the North Island
- Structural geology sites

Each site in the NZGI has been given a vulnerability rating of 1 (= highly vulnerable to human modification) to 4 (=sites that could be improved by human activity), and 5 (= sites that have been destroyed), and assessed for significance across three spatial scales:

- International – site of international scientific importance
- National – site of national, scientific, educational or aesthetic importance
- Regional − site of regional, scientific, educational or aesthetic importance

This assessment of significance and vulnerability was carried out by experts familiar with the listing of the sites and collection of information for those sites. The inventory has been compiled using the combined knowledge and advice of a large sector of the geological, geomorphological, speleological and soil science community in New Zealand.

To date, the inventory has not been spatially displayed or analysed with other types of information, such as biodiversity, cultural landscapes and protected areas.

9.6.3.4 NEW ZEALAND GEOPRESERVATION INVENTORY & THE KAIPARA

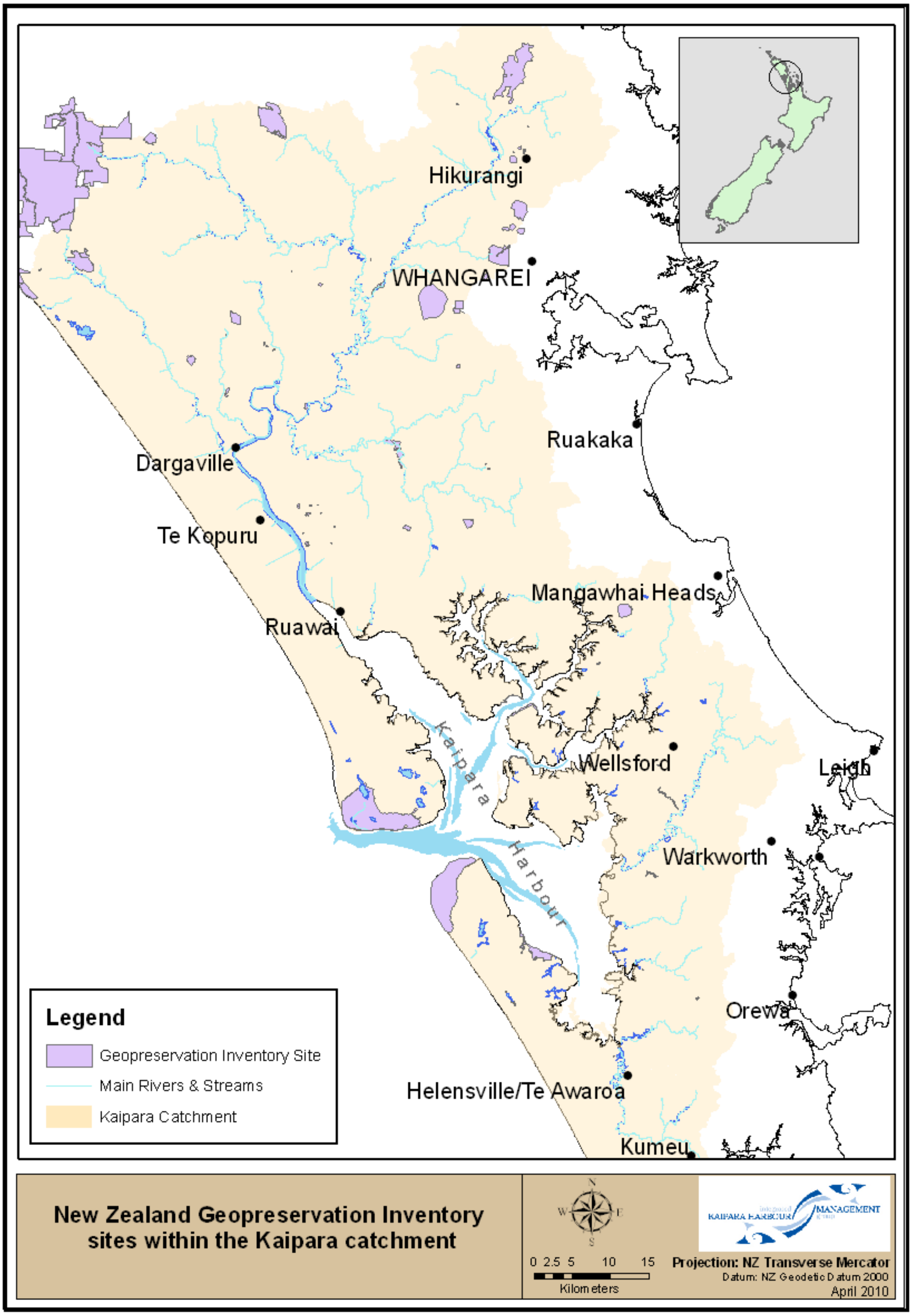
A review of what geopreservation inventory listed sites occur in the Kaipara catchment was undertaken, and information, was found in the following publications:

[6] http://www.gsnz.org.nz/; NZGI is coordinated by the Joint Earth Science Societies' Working Group on Geopreservation which consists of representatives of the Geological Society of New Zealand, NZ Society of Soil Science, NZ Geographical Society, Australia and New Zealand Geomorphological Group, NZ Speleological Society and the NZ Institute of Landscape Architects

- Kenny, J. A. & Hayward, B.W. (1993a). Inventory of important geological sites and landforms in the Auckland Region. 2nd Edition. Geological Society of NZ Misc. Publ. No. 68.
- Kenny, J. A. & Hayward, B.W. (1993b). Inventory of important geological sites and landforms in the Northland Region. 2nd Edition. Geological Society of NZ Misc. Publ. No. 67.

Information from Kenny & Hayward (1993a, b) was digitised and entered into the Kaipara Atlas database. Sites were geo-rectified in ArcMap to display what significant sites at an international, national and regional scale occur in the Kaipara catchment (Figure 8). The information was also spatially analysed with protected areas (e.g. national parks, scenic reserves) and private landowner covenants (Appendix 3).

Figure 8. New Zealand Geopreservation Inventory sites found in the Kaipara catchment.



Currently there are 3 internationally important sites, 25 nationally important sites, and 34 regionally important sites (Table 4) occurring in the Kaipara catchment. The 3 sites of international significance are the Puketotara eronite, Muriwai pillow lava's at Māori Bay and Muriwai volcaniclastic sediments. The Puketotara eronite, located on the northern side of Puketotara Peninsula facing the Ōtamatea River, is the most silica−poor eronite variety recorded (Sameshima 1978; Kenny & Hayward 1996a, 1996b). The two internationally significant sites found at Muriwai Beach Regional Park in the southwest corner of the catchment tell the story of the ancient undersea volcanic explosions that occurred along the west coast (Hayward 1979; Kenny & Hayward 1996b).

The Muriwai pillow lava's are amongst the best exposed and preserved in the World, and are interbedded with fossiliterous sediments that give an almost bathyal depth. This remarkable cross−section of the pillow lava has large pahohoe tongues and large diameter internal feeder tubes exposed.

Adjacent to the ancient bathyal pillow lava that hovers high above on the coastal cliffs, are the Muriwai volcaniclastic sediments. The sediments are well exposed in the cliff and form intertidal platforms. These are the best examples in New Zealand of submarine canyons and channels filled with volcaniclastic sediments (Hayward 1976, 1979; Kenny & Hayward 1993a).

Table 4. Geopreservation Inventory sites found in the Kaipara catchment that have international, national and regional significance. (Source: Kenny & Hayward 1993a, b)

Scale of significance	Number of Sites Kaipara	Number of Sites Northland	Number of Sites Auckland	Vulnerability	Number of Sites
International	3	4	8	1	7
National	25	73	60	2	16
Regional	34	107	121	3	36

At 14 sites the Quaternary Volcanoes category held the dominant category in the catchment (Table 5) sedimentary geology category was represented at 12 sites and igneous geology at 11.

The Quaternary volcanoes category includes all the important Quaternary (younger than 2 million years old) volcanic centre's, landforms, lava caves and volcano−related features and exposures in these areas. Sedimentary geology sites are usually rocks formed by the accumulation of sediment (e.g. mud, sand, gravel, peat, ash), often on the floor of the sea or lakes, river plains or even over hillsides. Sediments generally accumulate in layers, a characteristic of most sedimentary rocks. Alternatively, igneous geology sites (pre−Quaternary) are rocks formed by the cooling of molten magma. They include coarse and fine−grained rock varieties. This category contains examples of plutonic and volcanic rocks older than 2 million years, almost all of which no longer have any associated volcanic landforms and are therefore only known from their rock exposures. There was only one site representing structural geology, geothermal fields and features and earth deformation sites, respectively.

Table 5. The number of Geopreservation Inventory categories found in the Kaipara Catchment (Source. Kenny & Hayward 1993a, b)

Inventory Category:	Number of Sites in Kaipara Catchment:
Quaternary Volcanoes	14
Sedimentary geology sites	12
Igneous geology	11
Mineral	9
Landform	6
Fossil	5
Geologically−related historic sites	2
Earth Deformation Sites	1
Caves and karst sites	2
Geothermal fields and features	1
Structural geology sites	1
Metamorphic sites	0
Soils of the South Island	0
Soils of the North Island	0

Geopreservation Inventory sites were also reviewed across Territorial Authorities of the catchment (Table 6). The Kaipara DC had the 37.5% of inventory sites, followed by 29.2% found in the Whangarei DC. Rodney DC had only 18.1% of sites, but contained two of the three internationally significant geopreservation sites. The Kaipara DC had the majority of nationally significant sites at 23.6% of all 72 sites. Regionally significant sites were all stronger in the north of the catchment, where Whangarei DC had 23.6% of regionally significant sites.

Table 6. The location of the New Zealand Geopreservation Inventory sites in relation to district council.

Territorial Land Authority	International	National	Regional	Total
Kaipara District Council	1 (1.3%)	17 (23.6%)	9 (12.5%)	27 (37.5%)
Rodney District Council	2 (2.8%)	3 (4.2%)	8 (11.1%)	13 (18.1%)
Whangarei District Council		4 (5.5%)	17 (23.6%)	21 (29.2%)

Threats to Important Earth Science Sites

There are a wide variety of human activities that may threaten the natural character or continued existence of geological sites in New Zealand. Earthworks (often associated with road works, major developments, forestry, farming etc) and quarrying (for road metal, sand, limestone or minerals) may damage or destroy important small landforms (e.g. scoria cones, karst areas), geological or soil sites.

Other activities such as reclamations, dams, marinas and swamp drainage all have the potential to damage or destroy important examples of coastal, riverine and wetland landforms.

Extraction of geothermal steam or water has caused major damage to our surface geothermal areas and features. The stablisation and planting of sand dunes with exotic pine is so extensive that unmodified, active dune areas are rare.

9.6.4 KAIPARA CATCHMENT SOILS

The soils of the Auckland isthmus and Northland have always fascinated New Zealand's soil scientists, just as they were the despair of pioneer farmers. Compared to the rest of New Zealand with its youthful landforms, Northland has the subdued, rolling topography typical of older landscapes (Molloy 1988).

The contrasts are many: the region has a warm, humid climate which seems almost subtropical to visitors from the temperate south; the soils generally have clay−rich profiles over deeply weathered rocks whereas most of New Zealand has coarse−textured or shallow soils, often over weakly weathered bedrock or drift parent materials.

Also, in Northland, the forest was dominated by species such as kauri, taraire, puriri, mangeao and pohutukawa which were confined to this warmer northern region. Only scattered remnants of this kauri/podocarp[7]/broadleaf[8] forest now remain, generally on pockets of uplands and hill country (e.g. Waipoua Forest). Yet the imprint of the forest on the soil was considerable. In particular, kauri produced deep layers of highly acidic litter, which is implicated in the podzolisation and gleying (waterbogged) processes that have contributed to the poor physical properties of many of the Kaipara catchment soils.

Other factors contribute to this appearance of being an older landscape:

- Most landforms are of greater age and/or stability than those outside the region;
- The rejuvenating effect of the Pleistocene glaciations was much less pronounced;
- Soil rejuvenation by tephras[9] from volcanic eruptions, was confined to only a few small areas.

[7] Podocarps are totara, rimu and miro.
[8] Broadleaf are, for example, puriri and taraire.
[9] A general term for all solid (rather than molten) materials ejected from a volcano during an eruption (e.g. boulders, lapilli and ash).

In the half−century from 1860−1910 New Zealand underwent possibly the most rapid landscape transformation of any nation; over 6.5 million hectares of lowland indigenous forest were cleared (nearly 25% of the total land area) as much as destroyed in the previous 1000 years of the Polynesian era (Molloy 1988). Natural shrublands, tussocklands, wetlands and dunelands were also developed for agricultural, horticultural, forestry and settlement purposes.

Soils types: an example from the Kaipara Ecological District

Soils of the Kaipara ED are primarily classified into two broad categories: (a) sandy soils, and (b) organic soils of former estuarine flat and lake bed (Davis 2002, Smale *et al*. 2009). Soils are yet to form on the active sand dunes and sandy soils that have developed on the older sand dune sequences are recent (Holocene) and have formed yellow−brown earths. The youngest and most fertile type is Pinaki Sand, well drained and nearly neutral in acidity; the oldest and least fertile is Te Kopuru Sand, a poorly drained, acidic soil with a peaty subsoil. Also, is the Red Hill Sand, well drained and mildly acidic.

Organic or estuarine soils occupy extensive areas around the lower Kaipara River through to Parakai and Waioneke on the western edge of the southern Kaipara Harbour and up the eastern edge onto the west side of Ōkahukura Peninsula; lower flats of POutu Peninsula and the Ruawai Plains. Here the former estuarine flats have formed into saline gley soils which are very poorly drained. The middle reaches of the Kaipara River valley have flood plain soil deposits, and there is a small area of podsol soil on the terraces at the head of Gumstore Creek on the Ōkahukura Peninsula. Soils of the rolling and hilly land are confined to the volcanic areas in the southwestern part of the Kaipara ED, and on sedimentary islands in the Kaipara Harbour. Recent soils from alluvium occupy the floor of the Kaihu River valley (Smale *et al*. 2009).

Status of Geodiversity in the Kaipara

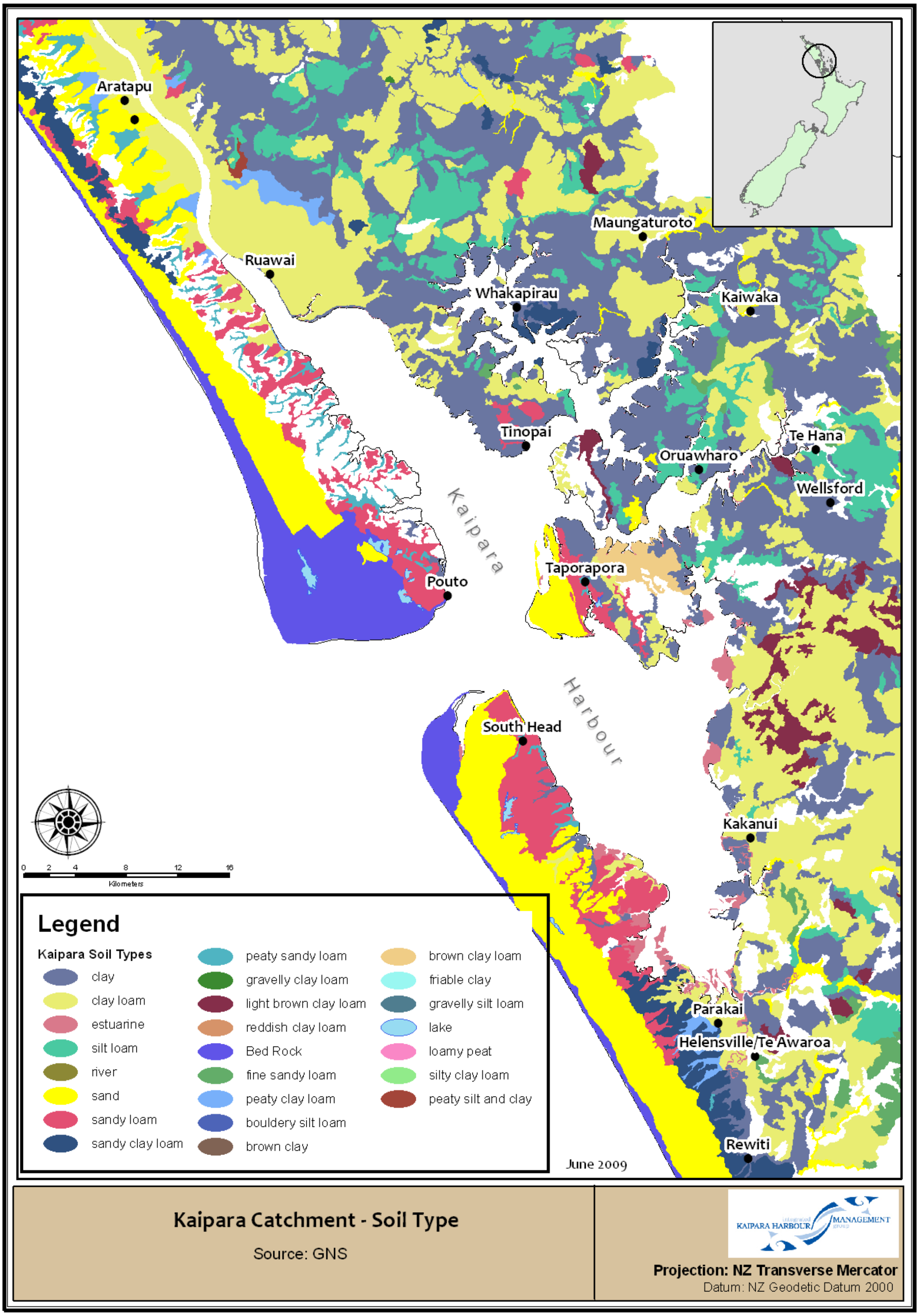
Until recently, the status of Kaipara catchment soils has had little attention. The Northland Catchment Commission (1977) under the *Soil Conservation and Rivers Control Act 1941* produced a series of reports concerning the frequent and severe incidences of soil erosion in the northern Kaipara catchment. Soil type, main rock group, stratigraphy, sequence, and rock class are just some of the information currently being spatially complied by the Institute of Geological and Nuclear Sciences (GNS). The New Zealand Land Resources Inventory or NZLRI database, developed with the objective to improve landuse, provides valuable information on soil type. It is based on field mapping at a map scale of 1:63,360, with units mapped according to variations in five parameters: rock type, vegetation, soils, slope and erosion. Additional information was added for areas such as lakes, rivers, riverbeds, quarries and mines and compiled into GIS. This comprehensive and detailed mapping of New Zealand's soil resources continues to be utilised for the development of many different classifications of the land and river environments today and to understand broadscale patterns of vegetation. Improvements have been made over the last decade in the quality of land resource mapping particularly in Northland and the spatial variation across Auckland and Northland has been consistent.

Detailed soil mapping tends to be greater in areas with high agricultural potential. However, for this information review, the NZLRI was accessed to provide an understanding of knowledge of soils in the Kaipara catchment. Other information was not acquired as more detailed surveys were not readily available.

Figure 9 describes the broadscale patterns of Northlands' and the Kaipara catchment soils and landscapes[10].

[10] Landscape is an association of landforms that can be seen in a single view. (**Landform** is any feature of the Earth's surface having a characteristic shape and produced by natural causes).

Figure 9. Kaipara catchment soil types.



New Zealand Soils Database

The National Soils Database (NSD) contains results from analyses of the chemical and physical properties of soil samples from nearly 1500 sites throughout NZ. Analyses from sub−soil samples, where the effects of fertilizer application are generally minimal, provided invaluable descriptions of the natural fertility of soils formed on different parent materials (Leathwick et al 2002, 2003).

New Zealand Soil Classification

Soil classification in New Zealand began with Māori who recognised and named classes that were relevant to the establishment and management of their gardens, in particular kumara gardens. They recognised classes such as *oneharuru* (a light but good sandy loam) and *onetea* (white soil from sandy volcanic material) (Molloy 1988). Soil classification has been part of human activity in New Zealand since the arrival of the first Polynesian canoe.

A comprehensive soil classification scheme was not developed until 1948, called the New Zealand Genetic Classification. This recognised “soil groups” and related them to the environmental factors that most influenced their character. Relationships were built between the soil groups and observations of geology, landscape, climate and vegetation. This led to the broadscale mapping of New Zealand soils.

The New Zealand Soil Classification was developed in the 1980s. The top three levels of the classification (orders, groups, subgroups) were described by Hewitt (1993) and the fourth level (soil forms) by Clayden and Webb (1994).

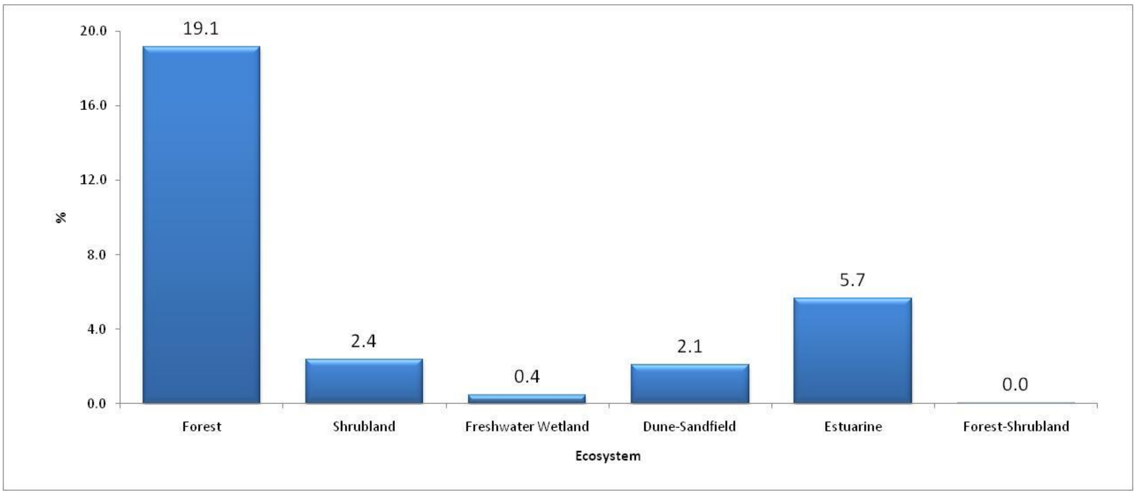
9.7 ECOSYSTEM CHARACTERISTICS

The Kaipara catchment is a mosaic of ecosystems that includes five broadly defined natural ecosystem types:

1. Freshwater ecosystems (0.4%)
2. Forest ecosystems (19.1%)
3. Shrublands ecosystems (2.4%)
4. Dunelands ecosystems (2.1%)
5. Estuarine ecosystems (5.7%)

Kaipara catchment forests, encouraged by a mild, wet climate, resemble tropical rainforests more than their temperate counterparts in the northern hemisphere. The most extensive forest types are podocarp/hardwood/kauri and shrublands (Conning 2001, NZ Landcare Trust 2007). The Kaipara has 19.1% (Figure 10) of this forest type where Northland as a whole accounts for 55% of the remaining Kauri forest.

Figure 10. Percentage of ecosystem types found in the Kaipara catchment.



New Zealand is internationally recognised as a biodiversity hotspot. That is especially true of its plants, with 80% of all New Zealand's native plants being endemic (found nowhere else on the planet). Many of New Zealand's plants are also threatened with extinction or in serious decline, and without proper management their persistence is unknown. The loss of terrestrial ecosystem biodiversity has occurred over the past 160 years through changing landuse as a result of European settlement, and over–hunting by Māori of flightless megafauna, large frogs, and giant reptiles. For Northland these practices has resulted in terrestrial ecosystem losses of 99% of podocarp forest, 96% of kauri and volcanic broadleaf forest, and 95% of freshwater wetlands and dune forests (Ogle 1982).

The Kaipara catchment's indigenous vegetation cover has been substantially modified, resulting in considerable loss of indigenous biodiversity of coastal, lowland, and rolling hill environments. Clearance of indigenous vegetation was historically concentrated on land of highest value for timber production, which was subsequently transformed into bare land for agriculture (e.g. sheep farming) (Figure 11).

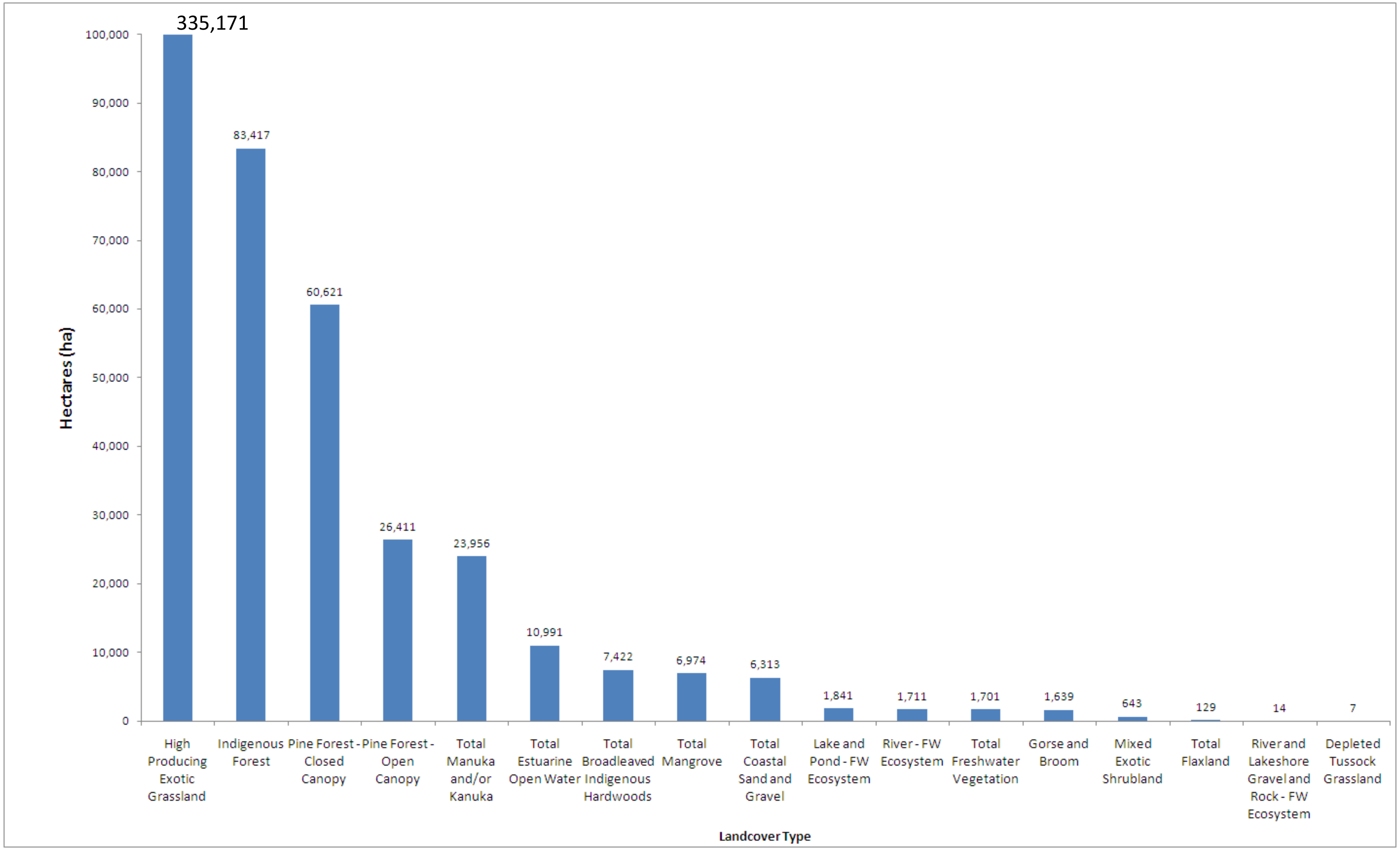
Quantitative and qualitative analysis of ecosystem patterns across the Kaipara catchment has yet to be carried out, however reconnaissance surveys at other spatial scales have been completed as part of regional and national analyses by Department of Conservation (1999) and the New Zealand Landcare Trust (2007); ecological district surveys by Davis (2002) for the Kaipara, Rodney and Ōtamatea ecological districts (Auckland region only); Ayres *et al.* (1984) for the Rodney ecological district; Manning (2001) for the Whangarei district; Booth (2005) for Whangaruru; Goldwater *et al*. (2009) for Tangihua; Lux *et* al. (2007) for Waipu; Miller & Holland (2008) for the Tutamoe ecological district, and more recently by Smale *et al*. (2009) – Kaipara (north only); a whole of Northland analysis by Conning (Conning 2001) (see Ogle 1982); at the New Zealand scale by Walker *et al*. (2005; 2006), Leathwick *et al*. (2002, 2003); and the Kaipara District (Wildlands Consultants Ltd 2006).

Most recorded information on ecosystem distribution and abundance status reviewed as part of the report comes from the following sources:

- Landcover Database II (2002) – spatial data
- Sites of Special Biological Interest (SSBI)
- Department of Conservation Threatened Plants Database
- Department of Conservation Bioweb Threatened Plant and Herptofauna Database
- NIWA Freshwater Fish Database
- Geopreservation and Soil Inventory
- Ornithological Society New Zealand
- Terrestrial and Freshwater Biodiversity Information System (TFBIS)

Existing published and unpublished information and consultation with land and sea managers, community and interest groups were also used. Large amounts of unpublished data still exist from previous ecological district surveys that could considerably expand the information base for the Kaipara catchment.

Figure 11. Current landcover (expressed in hectares) in the Kaipara catchment. High producing exotic grassland contained within graph for displaying other landcover types. Note its massive spatial extent of 335,171 hectares.



9.7.1.1 TUTAMOE ECOLOGICAL DISTRICT

Only 41% of the Tutamoe ED is located within the Kaipara catchment but this portion provides the last remaining tract of indigenous mature forest ecosystems in the catchment. The Kaipara catchment is fortunate to contain approximately 70% of the Mataura Forest, which forms the Waipoua−Mataraua−Waima forest, the largest remaining indigenous forest north of Auckland. This forest tract is of national and international significance, due to the presence of threatened and rare plants and animals and the comprehensive representation of intact, uninterrupted lowland and coastal ecosystems (Miller & Holland 2008) (Figure 12).

Figure 12. Agathis australis, the New Zealand Kauri tree, remnant and mature, which is found throughout the Tutamoe Ecological District.(Source: DoC).

The portion of the ED within the Kaipara catchment includes Maunganui Bluff in the west, Kaihu and Malborough Forest in the east, and Trounson Kauri Park, which is unfortunately not connected to the Waipoua and Kaihu forests. The lower altitudes of the Mataraua Forest also fall in the Kaipara catchment, which provides the catchment with valuable and representative areas of indigenous ecosystems.

The geology of the Tutamoe ED has been described by Miller & Holland (2008) and in more detail by Brook (1996). In brief, the district has been described and categorised as follows:

> *"Once heavily forested, with the plateau similar to what is present today. Coastal shrubland and forest along and near the coastline, with alluvial broadleaf and podocarp forests in the lowland valleys".* (Conning 2001, Miller & Hollard 2008).

Significant ecosystem values of this ED include:

- Contains the largest North Island brown kiwi population in New Zealand. Areas of note include Waipoua−Mataraua, Trounson Kauri Park, and Maunganui Bluff.
- Main vegetation type is broadleaf forest, with occasional emergent podocarps and kauri.
- Contains largest area of old growth remnant kauri forest in New Zealand.
- Significantly high value river systems with well−protected catchments containing high freshwater fish and invertebrate diversity[11]
- Trounson Kauri Park, a Department of Conservation 'mainland island', contains mature kauri trees, but is isolated from the main forest tracts.
- Locally extinct bird species include bellbird, North Island robin, whitehead, kakariki and the very rare North Island kaka.
- Nationally vulnerable long−tail bats are present in the Waipoua−Mataraua and Trounson Forests.
- The *Gradual Decline* classified kauri snail has significant populations in the kauri forests of Waipoua−Mataraua and Trounson Kauri Park.
- Breeding Northern New Zealand dotterel populations occur at Maunganui Bluff.
- Maunganui Bluff ecosystem is ecologically distinctive due to the presence of exposed west coast forest and coastal cliff communities. Threatened plants such as *Hebe speciosa* (Nationally Endangered) and *Coprosma* aff. *neglecta* (Range Restricted) occur.
- Three unnamed land snails are endemic to Maunganui Bluff.
- The ED is of significant cultural value to Te Roroa iwi.

Existing Protection

There is 33,000 ha of the Tutamoe ED within the Kaipara catchment, and of that 29% is under some form of protection (Table 7). Priorities for protection identified by Conning (2001) include:

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[11] NZ Freshwater Fish Database. Custodian NIWA.

- Broadleaf, podocarp and broadleaf−podocarp forest on alluvial soils.
- Coastal ecosystems including dunes, wetlands, shrubland and forest.
- Sites that support threatenend, declining and conservation dependent fauna species.
- Buffers for the Waipoua−Waima−Mataraua complex, especially upland broadleaf forest.
- Linkages between Mataraua, Marlborough and Kaihu forests on the Tutamoe Range.

Table 7. Current protection (ha) afforded to ecosystems within each ecological district of the Kaipara catchment.

ED	Area of ED in the Kaipara Catchment (Ha)	Public Conservation Land (DoC)	KDC	WDC	FNDC	NZ Fire Service	Pouto Rural Fire Service	QEII	RDC Covenant (Bushlot)	ARC Regional Park	TOTAL (% in brackets)
Tutamoe	33935	9609	15					158			9782 (29%)
Tangihua	122856	8249	53	104	4			476			8886 (7%)
Whangaruru	30255	948		442	4	9		75			1478 (5%)
Whangarei	53099	1205		123				155			1483 (3%)
Tokatoka	74121	537	49	62				270			918 (1%)
Kaipara	197489	4322	154			15	5481	123	780		10875 (6%)
Waipu	14007	1144		6				133			1283 (9%)
Ōtamatea	82611	559	115					1038 (0.01%)	115	839[12]	1827 (2%)
Rodney	111077	2173	34			20		613	2932	611	6383 (6%)

[12] The ARC Regional Park at Atiu Creek is also a listed QEII covenant

9.7.1.2 TANGIHUA ECOLOGICAL DISTRICT

Tangihua Ecological Districts occupies 74.5% of the Kaipara catchment. The landlocked Ecological District (ED) shares its boundary with Kaipara, Tutamoe, Tokatoka, and in the east, Whangarei ED. It is characterised by the presence of isolated steep−sided massifs up to 700 m high (e.g., Mangakahia and Tangihua Ranges), which are surrounded by lower rolling to moderately dissected and slump−prone hill country to 210 m (Conning 2001, Wildland Consultants 2006, Goldwater *et al*. 2009). Natural areas that remain have been categorised into three board habitat types: forest, shrubland and freshwater wetland (Goldwater *et al*. 2009). Most of these natural areas occur at high altitudes along north-west trending ranges. A lot of the former biodiversity has been lost.

The historical effects of landclearing for pastoral farming on the steep hillsides have created ongoing soil runoff and erosion. This has impacted on the extensive freshwater wetlands of the ED surrounding the northern Wairoa River, Awakino River, Tangowahine Stream, Kaikou River, Mangaraupo Stream and Mangakahia River.

It is assumed that the ED would have historically comprised a mosaic of broadleaf−podocarp forest, with a few areas of kauri. The fertile river valleys would have provided habitat for raupo, swamp shrubland, alluvial forest such as kahikatea, swamp maire and pukatea, and other wetlands.

Today, extensive forest tracts remain on the steeper massifs, often joined by plantation pine forests (e.g., Mangakahia Forest and Tokawhero Forest). Other ecosystems of note are the alluvial riverine forest remnants around Kaikou and Awarua. However, like most of the Kaipara catchment, Tangihua ED is dominanted by high producing grassland for the purposes of pastoral farming. There still remain some significant stands of kanuka−manuka shrubland, bordering indigenous forest.

Significant ecosystem values of the ED include:

- Extensive riverine freshwater wetlands and swamp forests in this ED include some of the best flood-plain wetland complexes remaining in the North Island (Goldwater *et al*. 2009).
- Several large, unmodified wetland ecosystems, particularly those of the Motatau wetland complex (e.g. Taikirau wetland and shrublands, and Taikirau swamp), which is probably the largest and most significant mineralized freshwater wetland ecosystem remaining in Northland (Goldwater *et al.* 2009).
- Undulating hills are the major landform unit in the Tangihua ED.
- Significant forest ecosystem tracts on the steeper massifs, however they lack any connection with the lowland ecosystems or the undulating landforms of the ED.
- Botanically diverse forest tracts such as Mangakahia Forest and Te Tarahiorahiri, Hikurangi and Tokawhero Forests, South Houto Forest and Maungaru Range, and Tangihua Forest are significant features of the ED (Goldwater *et al*. 2009).

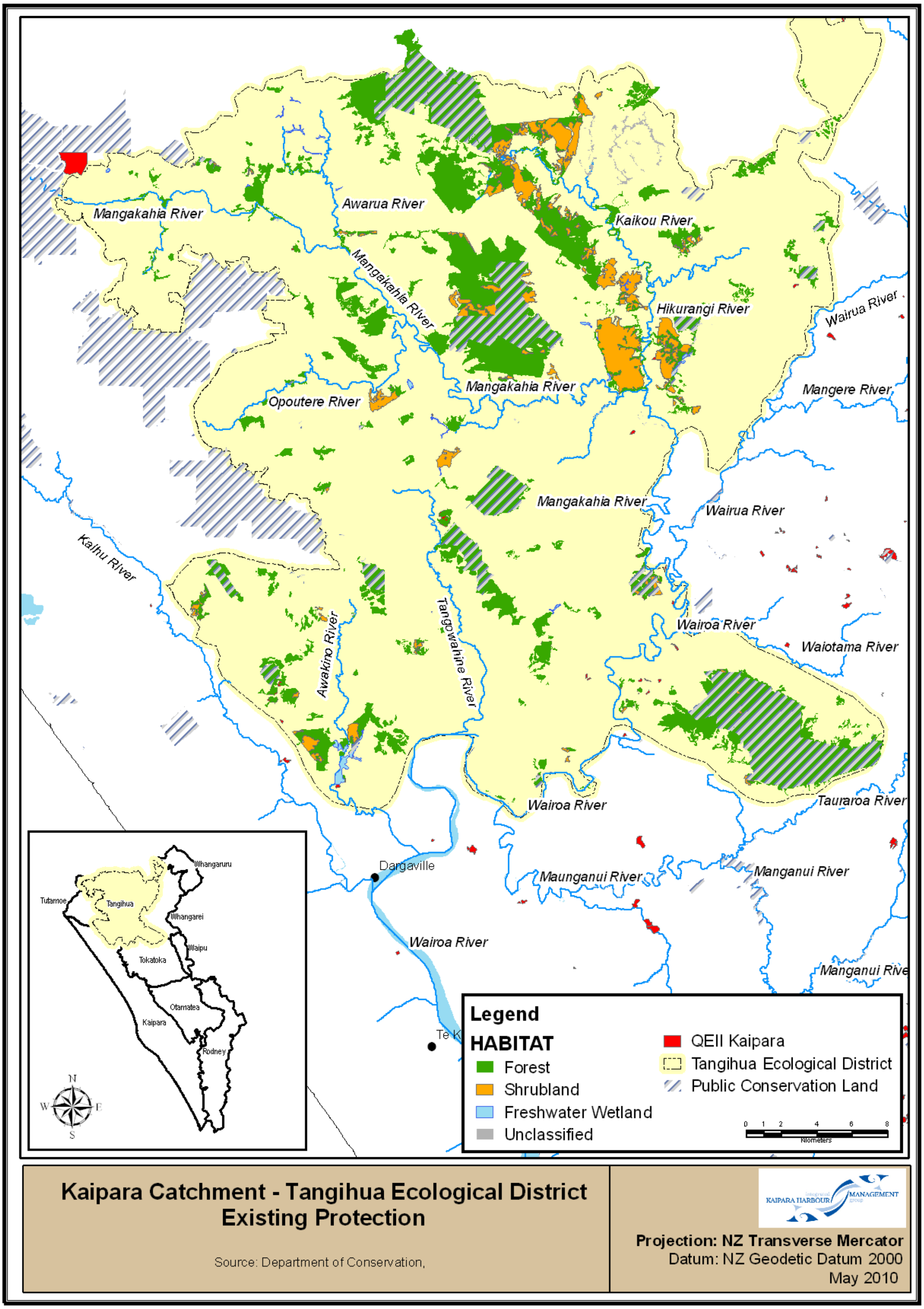
- Only 12.1% indigenous vegetation remaining, with only 44% protected under public conservation land.
- Critical lack of indigenous vegetation on the very gently undulating hills and floodplains, which are concentrated around the Northern Wairoa River and its tributaries (i.e. Awakino River, Tangowahine Stream, Kirikopuni Stream).
- The Awakino River catchment provides high freshwater fish values.
- Rare landsnails are known in the Tangihua Range (Brook 2002).

Existing Protection

There is 122,000 ha (74%) of the Tangihua ED contributing to the Kaipara catchment, with 7% of ecosystems under some form of protection (Table 7) (Figure 13). Priorities for protection discussed by Conning (2001) and Golderwater *et al*. (2009) include:

- Large wetland ecosystems in the northeast and the southwest of the District, particularly those sites supporting natural and semi-natural wetland.
- Alluvial and riverine forest, podocarp forest and gumland−shrubland ecosystems.
- Areas that would support linkages or corridors between natural habitats for North Island brown kiwi and other regionally significant bird species.
- Strategy to create an integrated protected area network that would include priority areas for protection, wildlife corridors, linkages and buffers to promote connectivity between inland hill country, alluvial plains and freshwater wetlands. This should be supported by robust ecological restoration for these ecological components of the network.
- Large natural areas with a diversity of ecosystems and vegetation types, especially areas adjacent to Tangihua, Mangakahia and Motatau forests.

Figure 13. Tangihua Ecological District existing public and private (QEII covenants) protection with distribution of significant natural areas of forest, shrubland and freshwater wetlands.



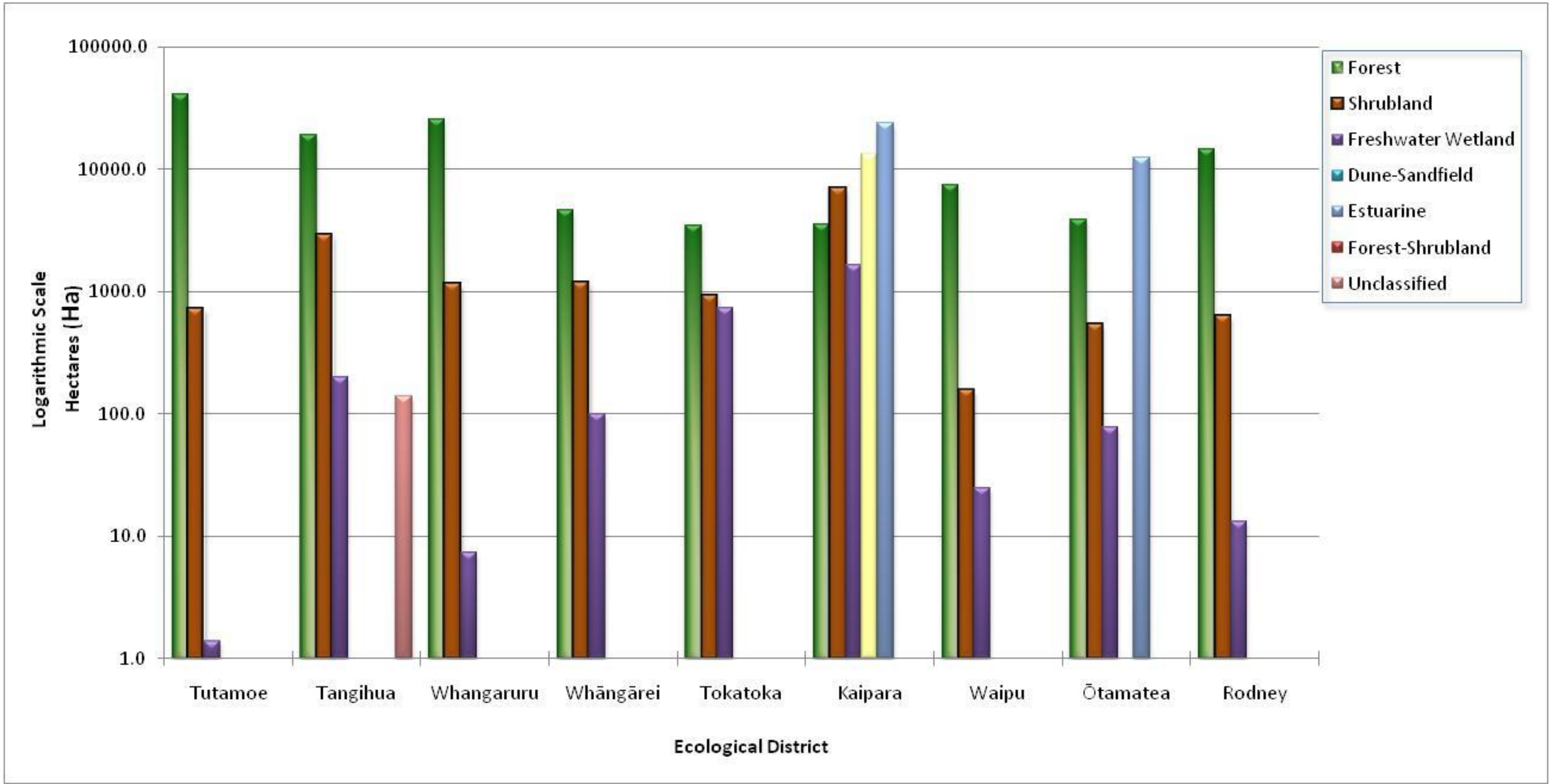
9.7.1.3 WHANGARURU ECOLOGICAL DISTRICT

Whangaruru ED (see Figure 6) occupies the upper northeastern corner of the Kaipara catchment characterised by steep, deeply dissected hill country up to 460 m elevation and includes the Russell Forest, Kaiikanui Forest, Papanui−Umuwhawha Forest, Hansens Hill Forest, Gibbs Road Forest remnant and the lower Taparahaia Stream riverine forest. Like much of Northland, kauri forest would have historically dominated much of the hill country, but today what remains is largely regenerating broadleaf−podocarp−kauri forest. Kiwi is also found throughout the ED mainly in the large natural areas across the hill country.

The 30,255 hectares of the ED that contributes to the Kaipara catchment, has 5% existing protection provided by public conservation land, QEII covenants, and Whangarei and Far North District Council reserves. The ED is predominantly represented by 84% significant forest ecosystems, and to a much lesser extent shrubland (3.8%), and freshwater wetland (0.02%) ecosystems. This follows the biodiversity trend across other ecological districts contributing to the Kaipara catchment (Figure 14). Booth (2005) and Conning (2001) identifies priorities for protection to be:

- Sites supporting declining plant species
- Breeding sites for indigenous fauna such as the brown teal
- Nationally under−represented ecosystems, such as alluvial and riverine forest, and remnant old growth forest.
- Connecting sequences from forest to lowland swamplands.

Figure 14. Hectares of significant natural ecosystems found in the ecological districts that contribute to the Kaipara Catchment. Note that data is provided on a log−scale to display other ecosystems other than just forest, which tends to dominant.



9.7.1.4 WHĀNGĀREI ECOLOGICAL DISTRICT

Whāngārei Ecological District contains the upper reaches of the Northern Wairua River, Mangakahia River, and Wairoa River. The Ecological District contributes 63% to the Kaipara Catchment which includes the Hikurangi Swamp in the north–west of the ED. The Hikurangi Swamp contains some of the last remnants of the once extensive wetland complex that contained swamps, peatbogs, intermediate wetlands and riverine flood forest associated with the Wairua River flood plain (Keene 1975; Conning 2001). Today only 200 ha remains, 4% of its original size, mainly in the public conservation land of the Wairua River Wildlife Management Reserve and Otakairangi Conservation Area.

A full list of flora and fauna found in the ED is given by Manning (2001). The entire ED lies within the lowland bioclimatic zone, so there are no major altitudinal sequences present (Manning 2001).

Significant ecosystem values of the Whāngārei Ecological District include:

- Waiotama Scenic Reserve (PNA site P07 030) is administered by Department of Conservation, and contains several threatened and endangered species, such as North Island brown kiwi (Pierce *et al*. 2006), banded kokopu, and kauri snail.
- Waiotama Scenic Reserve is a priority area for protection (Conning 2001, Wildland Consultants 2006).
- Nationally and regionally rare ecosystems exist along Waiotama River, which runs through private property at two sites.
- Several rare and threatened bird species occur in the ED, such as Australasian bittern, spotless crake and North Island fernbird (Pierce 2005).
- Hikurangi swamp wetland remnants.
- A unique feature is the stands of volcanic broadleaf forest dominated by tarire, which occur on the rich volcanic soils and cones of the mid−central and eastern areas of the ED. These features only occur in the Whāngārei and Kaikohe ED's (Manning 2001).
- Very few stands of remnant forest. Most forest ecosystems are regrowth or secondary vegetation.
- Most common vegetation types are taraire, totara or kahikatea forest, and taraire−totara, kahikatea−totara or puriri−taraire forest (Manning 2001).
- The threatened Kukupa/kereru occur only in broadleaf taraire forest remnants (Molloy & Davis 1994).
- North Island brown kiwi, a threatened endemic species, is found in low densities at Waiotama and Wairua Falls Scenic Reserves, Pukenui Forest (Figure 15).

- Regionally significant bird species are the North Island tomtit and spotless crake. North Island tomtit have been observed mainly in large forest tracts such as the Pukenui Forest, Maungatapere Mountain and Dunford Road bush along the Wairua River.
- Threatened mammals such as the long−tail bat have been recorded at Pukenui Forest.
- Threatened snails have been recorded at Pukenui Forest, Maungatapere and Otaika Scenic Reserve, and Mount Hikurangi,
- Threatened fish include black mudfish, banded kokopu, and giant bully.
- Regionally significant lizard species such as the Auckland green gecko, forest gecko, and ornate skink are present in the ED.

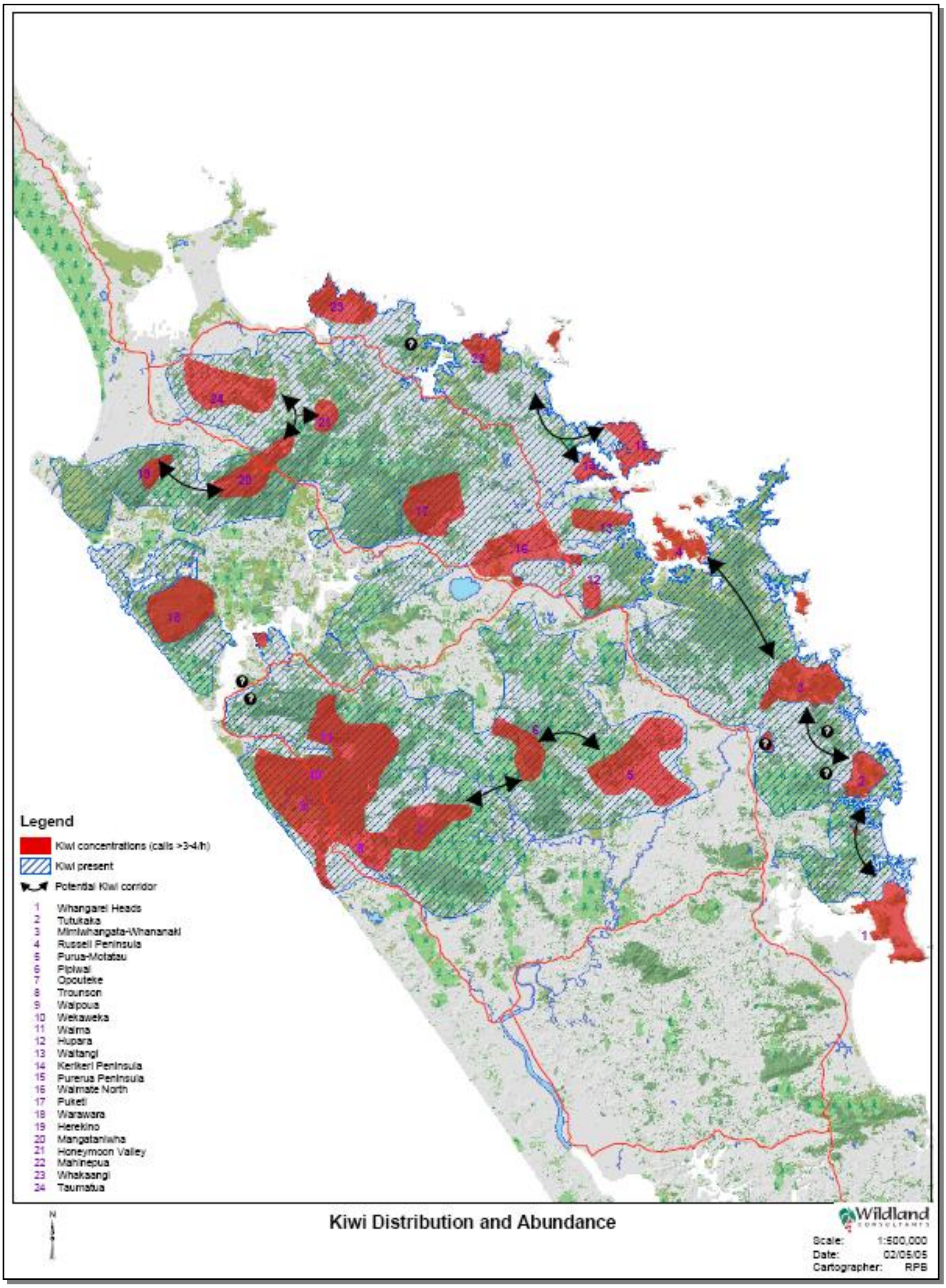
The ED is threatened by water drainage; landclearing of riparian and gully vegetation; nutrient enrichment of waterways from pastoral farming management practices; weir construction; grazing and trampling by stock; weed and pest fish invasion of wetlands; and quarrying of the unique volcanic scoria cones of the Ecological District.

Existing Protection

Only 3% of the districts ecosystems are under some form protection, and they are mainly concentrated on high altitude areas such as Pukenui Forest Conservation Park. Priorities for protection stated by Conning (2001) include:

- Buffering areas for the Otakairangi wetland
- Nationally rare riverine flood forest and shrubland, and volcanic broadleaf forest.
- Sites supporting North Island brown kiwi
- Freshwater wetlands and limestone ecosystems.

Figure 15. General kiwi distribution patterns based on data to 2005. (Source: DoC).



9.7.1.5 TOKATOKA ECOLOGICAL DISTRICT

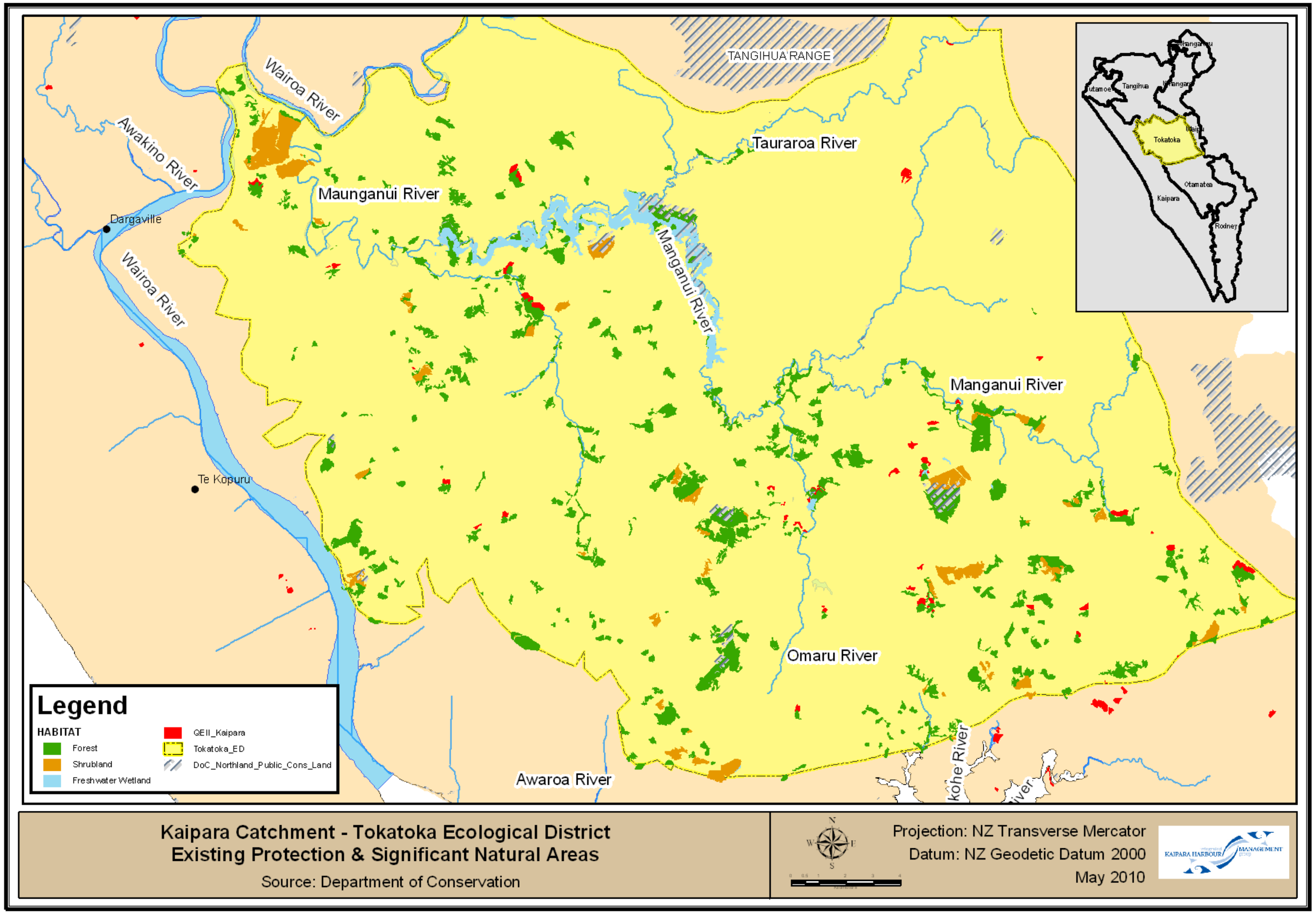
Located to east of Dargaville, the Tokatoka ED is 74,000 Ha and falls entirely within the Kaipara catchment (Figure 16). The Wairoa River and the Tangihua Range form the northern boundary with the Tangihua and Whangarei Ecological Districts. The Waipu ED borders to the east, with the boundary running from the eastern end of the Tangihua Range to the western boundary of Mareretu Forest and Waipu Gorge. The Ōtamatea ED lies directly south, where the boundary runs from Waipu Gorge west through Paparoa, and takes in the northern side of the Ruawai flats to the township of Tokatoka. Kaipara ED borders the western side of the ED.

A distinctive geological feature of the ED is the national significant landforms of Tokatoka peak and Maungarago dike. The Maungaraho Rock scenic reserve, which situated next to the dike, supports four nationally threatened plants, two Nationally Critical (*Hebe saxicola* and *Daucus glochidiatus*) and two Nationally Endangered (*Picris burbidgeae* and *Senecio scaberulus*) plant species. It is unknown whether North Island brown kiwi still occurs in the ED with the latest records being from DoC surveys in 1992-93. If kiwi are present, this ED would be there southernmost limit.

This ED was once dominanted by lush kauri forests in the entrance to the Manganui, Tauraroa and Waiotira rivers, and at Waikiekie, Rehia, Parahi and Tokatoka. Few remnants remain. The Tokatoka ED is characteristed today by a mosaic of mostly small forested remanants amongst a highly modified landscape. Today the ED is considered to be one of the most modified ED's in Northland (Holland, in draft) with only 7% of its total area covered in indigenous natural areas. In comparison with indigenous natural areas within surrounding ED's: Tangihua 19%, Whangarei 9%, Waipu 28.4%, Ōtamatea 9.8% and Kaipara 14%.

The riverine flood forest ecosystem and associated habitats of the Manganui River Complex contains the best remaining example of riverine flood forest in Northland and probably the North Island (Conning 2001Holland, in draft).

Figure 16. Tokatoka Ecological District distribution of existing public and private (QEII covenants) protected areas with significant natural habitats.



The Manganui River is the most significant ecological feature of the ED and is one of the best remaining examples of riverine flood forest in New Zealand (Conning 2001).

The ED is predominantly undulating hill country (84% of land area), with 10% being undulating floodplains (Wildland Consultants 2006).

Significant natural values of the ED include:

- Internationally and nationally significant as one of the best remaining examples of riverine flood forest (Conning 2001, Wildlands Consultants 2006, Champion & Townsend 2008). Vegetation types include kahikatea, kowhai and manatu.
- Contains many wetland fauna species, with high fish diversity and bird diversity, and is a naturally protected corridor for migration.
- Manganui River is an important site for the nationally endangered Australasian bittern.
- The ED contains regionally and nationally significant sites of geo−evolution. There are a number of volcanic plugs, sills, dikes and breccia pipes which are prominent cultural and geological landmarks of the district (Brook 1996)
- Remnants of taraire and totara forest are most common mature forest type, mostly on hillslopes.
- Distinctive vegetation such as nikau and puriri forest occur on the northern boundary of the Ruawai flats (Conning 2001).
- Kauri dominant forest occurs in approximately 22% of the sites, a few of which contain mature kauri.
- Populations of North Island brown kiwi are low compared to other parts of Northland. Kiwi continue to be low and declining (Conning 2001).

Existing Protection

Many of the forested areas are under some form of protection, but the most under−represented habitat types have little protection (Conning 2001, Wildlands Consultants 2006). Only 1% of the area of the ED is protected, with 15.1% of the ecosystems protected.

Priorities for protection include (Conning 2001):

- Riverine flood forest, floodplain forest and associated wetland ecosystems.
- Broadleaf forest on alluvium, volcanics and limestone, podocarp forest, nikau and kowhai forest and other wetland ecosystems.
- Kauri forest and large kanuka/manuka shrubland (particualyr important for kiwi) ecosystems.
- Sites contributing to retaining North Island brown kiwi.

9.7.1.6 KAIPARA ECOLOGICAL DISTRICT

The Kaipara Ecological District, like the Ōtamatea Ecological District, has not been surveyed in total, as the Ecological District is managed by two different regional councils (i.e., Auckland and Northland), and two Department of Conservation conservancies (Northland and Auckland). Approximately two−thirds of the Ecological District lies within the Northland region, and its unique feature is the Kaipara Harbour.

The Ecological District adjoins the Rodney, Ōtamatea, and Tokatoka Ecological District in the east and Tutamoe Ecological District in the north. Rodney Ecological District also abuts the southern boundary.

Historical Setting

Historically, the surrounding dunelands would have been a dynamic system of shifting sands, open sand flats, sand ridges, and hollows. Wetlands and lakes would have formed on the sand flats and in the hollows. Characteristic vegetation would have included jointed wire rush and spike sedge; and in deeper water, raupo, lake club sedge and kuta. Spinifex and pingao would have dominated the younger mobile sand dunes, while shrublands were dominated by toetoe; pohuehue and tauhinu would have grown on the younger, but more stable dunelands.

Where the sand was more stable, mixed broadleaf forest would have developed, including a mosaic of species such as puriri, kohekohe, pohutukawa, taraire, tawa, titoki, and mangeao. Further inland, on the older weathered sand dunes the mixed broadleaf forest would have dominated, but on the higher less fertile ridges there would have been kauri and tanekaha forest.

Freshwater wetlands in the older valleys would have been dominated by raupo, with a manuka−*Coprosma* shrubland buffer. On the coastal cliffs around the Kaipara Harbour pohutukawa and coastal forest/shrubland would have grown.

The Kaipara Harbour would have contained extensive areas of saline vegetation, although the mangrove communities were perhaps not as extensive as today. In many places there would have been a progression from the lower tidal flats to brackish areas consisting of mangrove shrubland, searush−jointed wirerush salt marsh, *Samolous−Stelleria* glasswort salt meadows, jointed wirerush−marsh ribbonwood rushland−shrubland, manuka−*Olearia solandri*−ngaio shrubland, *Baumea juncea*−jointed twigrush rushland to raupo−flax−*Carex virigata* rush−sedgeland (Davis 2002, Murton unpublished).

Previous studies

Past studies of the ED date back to the New Zealand Wildlife Service undertaking the first fauna survey between 1977 and 1985 (Davis 2002) in the southern Kaipara. In 1983/84, the Department of Conservation commissioned the first survey of significant natural areas for the newly established Protected Natural Areas Program of 1982 (Ayres *et al.* 1984). Bellingham & Davis (2000) provide information on site threats and management solutions for significant natural areas in the Kaipara ED. Ayres *et al*. (1984) provided the Protected Natural Areas Program baseline information for a more intensive ecological survey of the Kaipara ED by

Davis (2002). More recently, in the northern Kaipara ED, significant natural areas have only recently been surveyed by Smale *et al*. (2009), finally providing a completed picture of natural areas within the ED.

Other ecosystem studies that have occurred within the ED include the investigation of kahikatea forest fragments on the northern Wairoa floodplain (Calder 2000). The effects of land drainage, stock grazing, and increased edge environment on vegetation composition were quantified and analysed. The persistence of these kahikatea stands into the future was unlikely, because most occurred within an agricultural landscape being exposed to land drainage and stock grazing. Calder (2000) also found that for unfenced forest fragments, there was no establishment of seedlings, drastically reducing the regeneration process of the forest canopy. This regeneration failure in grazed forest remnants is widespread throughout New Zealand (Bergin *et al.* 1988). In contrast, undrained and fenced forests have a significant influence on the regeneration process.

The ecological process of ecosystem regeneration was also explored and recorded for the survey of significant natural areas (Davis 2002). Of the 331 sites examined only 14 were recorded to carry out the regeneration process. Davis (2002) also used a Tier Intactness Index based on tier height, tier cover, tier browse or foliage cover, and percent composition of native vegetation to understand regeneration and subsequently record the occurrence of ecological processes within the ED.

Estuarine Ecosystem of the ED

Northland and Auckland Regional Councils commissioned a joint review of environmental information on the Kaipara marine environment (Haggitt *et al.* 2008). The study determined the current state of the harbour, assessed threats, identified knowledge gaps, and examined synergies and gaps in existing environmental monitoring programs. These are examined in further detailed in section 9.7.4.

Ecosystem Values of the ED:

Significant ecosystem values of this ED include:

- The Kaipara Harbour and its sand dune ecosystem, including a complex dune barrier (sedimentary structure) extending up to 3.5 km inland from the west coast. The Kaipara Harbour was identified by the IUCN in 1981 as one of six wetlands for preservation (Forest & Bird 2001).

- Kaipara Harbour is New Zealand's largest estuarine ecosystem with very diverse habitats for wildlife such as open water, extensive exposed shellbanks, sand and mudbanks at low tides; islands form undisturbed hightide roosts; mangroves are abundant; and saltmarsh connects with freshwater swamp (Haggitt et al. 2008, Davis 2001, Wildland Consultants 2006, Fahy et al. 1991).

- Parakai geothermal field and hot springs – the hottest thermal water resource in the Auckland region.

- Taporapora sands – high quality silica sand.

- Presence of rare ecosystems, for the ED and New Zealand, include: (1) dune lakes (most notable are Papakaunui Spit and Waionui Lagoon; Pouto Peninsula−North Head); (2) extensive mobile dune vegetation (i.e. spinifex grass and pingao) on the

Pouto Peninsula; (3) the large coastal forest−shrublands−freshwater wetland sequence around Muriwai and Lake Ototoa; and the Pouto Peninsula dune lakes, especially Kai Iwi Lakes, Lake Kanono and Lake Humuhumu. The aquatic and surrounding terrestrial plant communities are considered to be highly distinctive. Kanuka is colonising more stable dune areas, and left undisturbed will in time become dune coastal broadleaf forest, an extremely rare and highly endangered vegetation type in New Zealand (Davis 2002).

- Dune lakes of both North and South Head peninsulas contain lakes on consolidated dunes, which are generally deeper (e.g. Lake Kanono, Lake Humuhumu, Lake Ototoa, Lake Kuwakatai, Lake Te Kanae, and Lake Kereta).
- Remnant indigenous forest on more stable gently undulating sand dunes replaced by exotic pine forest.
- Tapu Bush on Pouto Peninsula contains significant remnants of coastal−broadleaf and manuka−kanuka forest on consolidated duneland.
- Most remaining estuarine wetlands retain their natural character. Although an estimated 30–40% of estuarine wetlands have been reclaimed, extensive mangrove and saltmarsh habitats and successional sequences between mangroves−saltmarsh−saltmeadow−maritime rushes−coastal forests remain. The most notable include the Tauhoa Scientific Reserve, Hoteo River, and Mt Auckland Forest (Atuanui Conservation Area) (Chapman 1976; Shaw *et al.* 1990; Fahy *et al.* 1991; Morrisey *et al.* 2007).
- Nationally and regionally significant natural areas for coastal vegetation have been identified by ARC (Davis 2002; Haggitt *et al.* 2008) including: Papakanui Spit and Waionui Inlet (contains largest area of herbaceous saline vegetation, 284.1 ha; contains at least four threatened plants; and is one of very few estuarine areas in the Kaipara to have a non−pastoral catchment); Puharakeke Creek, (south of Shelley Beach, contains the largest area of mangroves within the Kaipara ED and the Auckland Region (729.5 ha) as it contains mangrove−scrub/indigenous shrubland tracts and at least 35 indigenous scrub−covered estuarine islands); Opatu River (eastern Kaipara Harbour, contains the largest area of estuarine vegetation in the Kaipara ED and Auckland Region (758.6 ha), extensive herbaceous saline vegetation, and ecological transitions from mangrove to herbaceous saline communities to indigenous forest); Kaipara River (has complex mosaic habitat types including estuarine islands) (Haggitt *et al.* 2008).
- Important wildlife corridors at upper Ōruawharo River, upper Tauhoa River and southern Kaipara Harbour. These corridors include mangrove−shrub−indigenous forest tracts that allow wildlife to move between habitats for roosting, foraging, and breeding.
- High diversity and unusual mixes of species (puriri, titoki, tawa, taraire, kohekohe, karaka, mangeao, and pohutukawa) in remnant forest patches, which may be due to the high fertility and good drainage at these sites.

- Very few podocarps present. Totara and kahikatea are the most common, and only a few individual matai, rimu and miro trees are currently present. Tree rata is scarce, and kahikatea swamp forest is virtually gone from the Kaipara ED.

- Kauri−tanekaha forest is very rare in the southern Kaipara ED, and only occurs as a small patch of kauri forest at Rimmer Road Bushlot.

- Most of the terrestrial vegetation left in the Kaipara ED is kanuka scrubland and treeland, often with a canopy exclusively of kanuka and very few other native species in the understorey tiers. It occurs in the predominatly pastoral and pine forest landscape in a pattern of small fragmented remnants.

- Lake Ototoa, on South Kaipara Head, has one of the highest water qualities of all lakes within the Auckland area and Kaipara ED. Davis (2002) also recorded bittern, kereru, and tui in the lake margin vegetation and the lake shrubland−forest. However, Gibbs & Spigel (2006) did state that water quality is declining due to landuse changes surrounding the lake. In 1997–98, harvesting of pine forest occurred on the shores of the lake which corresponded with a high Aeolian soil input to the lake in conjunction with the El Nino weather patterns. This highlighted the role of Aeolian inputs to the lake from within and outside the catchment, and the lack of knowledge about the effects of pine forest on this lake. Sediment cores should provide evidence of any link between landuse and lake water quality.

- Breeding location for the threatened[13] and endemic Fairy Tern at Papakanui Spit and Waionui Lagoon. With an approximate population of only 27 individuals, the entire population of fairy terns visit and use the Kaipara ED.

- The largest colony of Caspian Terns in New Zealand is present on an island east of Shelley Beach (Pierce 2005), which hunt for fish throughout the harbour.

- Reduced presence of forest birds include kaka, kokako, kakariki, white head, bellbird, robin, tomtit and falcon (Davis 2002). Forest habitat fragmentation, the small size of many patches and poor forest structure, as well as mammalian predation and possibly avian diseases has led to these absences. Without improved forest health, increases in patch sizes, improved connectivity between patches and active predator control restoration of a more representative forest bird community will not happen.

  While these bird species are still present today, their numbers are depleted from what they would have been in the past. Birds of open−fresh water wetlands and lakes including coot, dabchick, scaup, grey teal, grey duck, shoveller and paradise duck are still present, but probably in lower numbers than in the past, and share their habitat with a range of introduced water birds such as mallard duck and black swan.

Estuary and sand dune habitats are likely to have much the same diversity of species today as in the past. This includes coastal birds such as gulls, shags, herons, and terns, and wading birds such as godwit, knot, turnstones, oystercatchers, dotterels, stilts, wrybill, plovers, and sandpipers. However, a few species breeding in the Kaipara ED, notably fairy

[13] New Zealand Threat Classification System List 2007

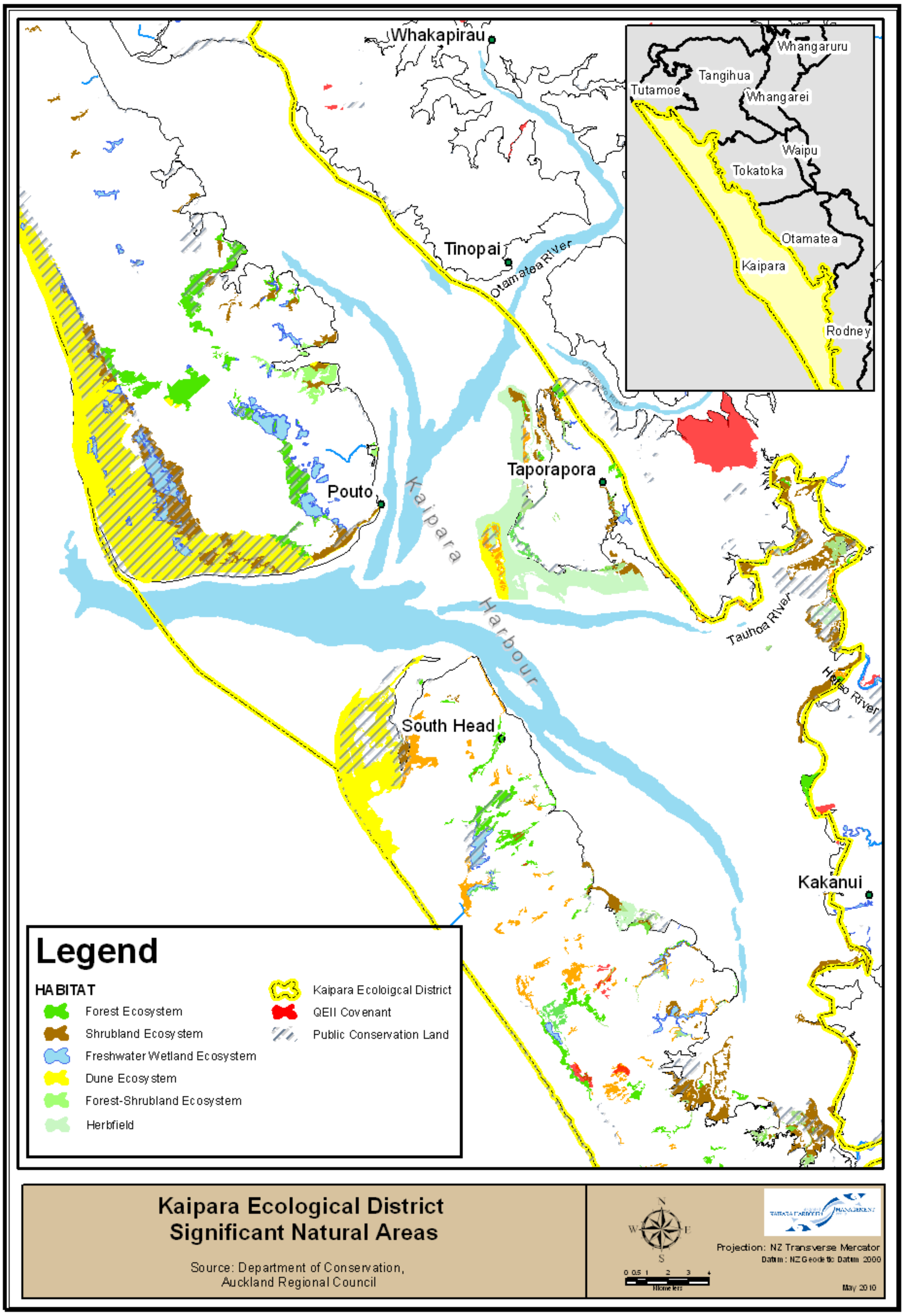
tern and NZ dotterel now have very small populations and are considered endangered species.

Existing Protection

6% of protection is provided by public conservation land, Rodney District Council bushlot covenants, QEII covenants and New Zealand fire service land (Figure 17). Priorities for protection identified by Conning (2001) and Smale *et al*. (2009) include:

- Under−represented ecosystems including dune cliffs, lakes and wetlands, dune forest, shrubland, estuarine areas, ephemeral wetlands, lowland podocarp, broadleaf and floodplain remnants including kahikatea−cabbage tree, puriri−nikau forest, peat bogs and shrublands, coastal broadleaf and pohutukawa forest.
- Large wetland complexes north of Dargaville
- Other wetland ecosystems
- Securing buffers and corridors to protected land on Pouto Peninsula
- Areas supporting threatened species (plant, NZ dabchick, fairy tern, dwarf inanga, kiwi)
- While the Papakanui Spit−Waionui Lagoon is a protected reserve, the Lagoon proper is an unprotected coastal marine area in Crown ownership. It is also an air weapons range for used for bombing exercises by the Ministry of Defence.

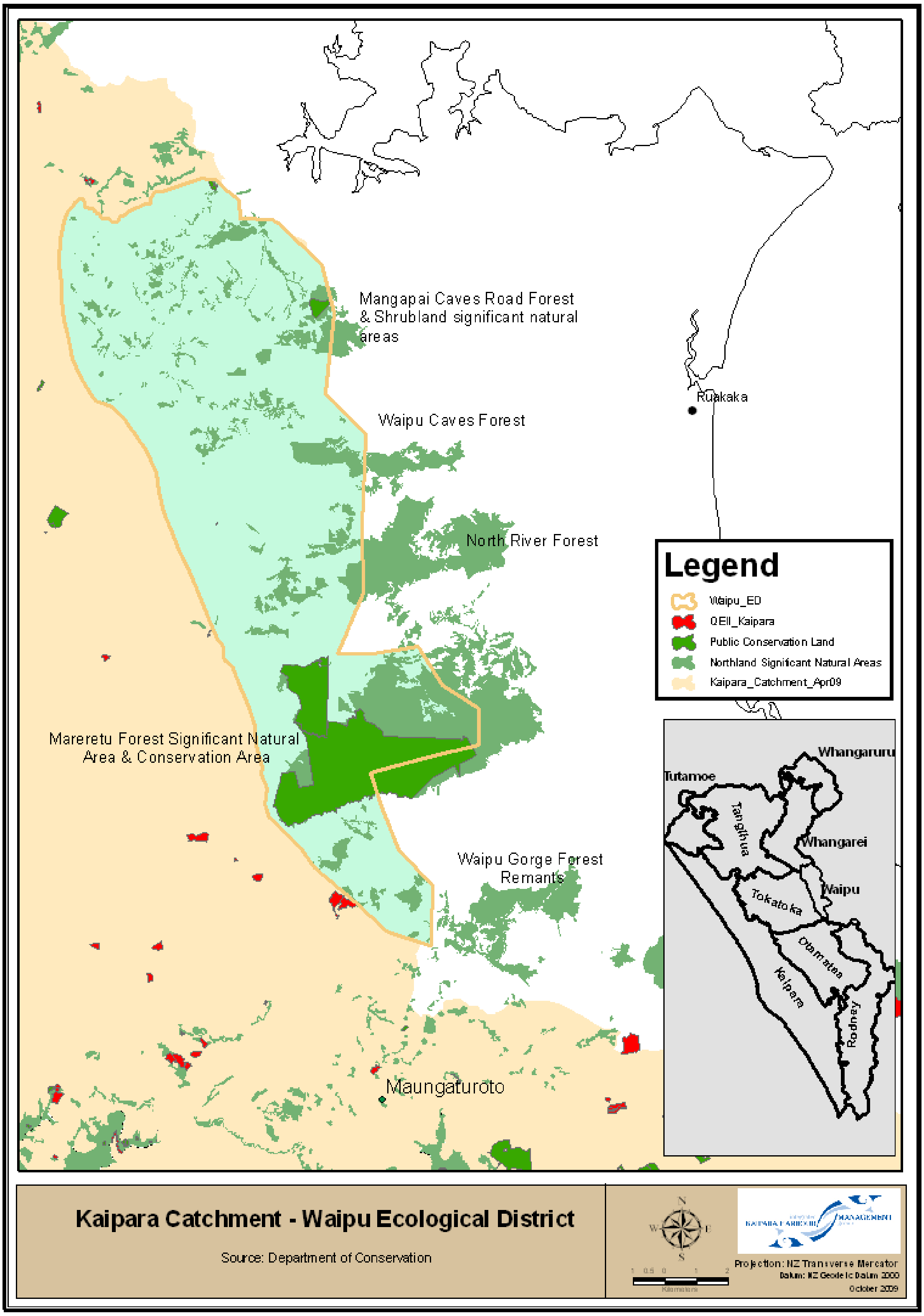
Figure 17. Kaipara Ecological District distribution of private (QEII covenants) and public protected areas with significant natural areas.



9.7.1.7 WAIPU ECOLOGICAL DISTRICT

The most western portion of the Waipu Ecological District occupies the Kaipara catchment and contributes the least (of all the ED's), with 14,000 ha, to the Kaipara catchment. Whangaruru and Whangarei ED lie to the north and Tokatoka to the west with Rodney and Ōtamatea ED to the south. The district is characterised by its coastal climate and rises to moderate hill ranges of 400m. The ED contributes mainly rolling hill country to the Kaipara catchment elevating to 300m (Figure 18).

Figure 18. Waipu Ecological District within the Kaipara catchment



Historically, this Ecological District was clothed in tall densely wooded kauri−podocarp−broadleaf forest on the hill country grading down (outside of Kaipara catchment) into alluvial plains covered in totara, taraire, and kahikatea forests. The hill country occupying the Kaipara catchment would have been dominanted by kauri forest and podocarps, especially across ridges (Conning 2001).

The current vegetation of almost the entire ED is regenerating, with the largest remnant ecosystems being forests, occurring on hill country above 100 m asl (Lux *et al*. 2007). Other ecosystems, such as freshwater wetlands and shrubland, have been highly modified and now only occur in isolated small patches. The area of the Waipu ED contains 53% of forest ecosystems with significantly less shrubland at 1.1% and freshwater−wetland ecosystems, at only 0.18% (Figure 14).

Significant ecosystem values the ED contributes to the Kaipara catchment include:

- Lowland forest tracts present on moderately−dissected east−west trending hill country: Mareretu Forest (2,820 ha) (Public Conservation Land); Brynderwyn Hills Forest Complex (733 ha); Waipu Caves Forest (370 ha); Millbrook Dam & Forest Remnants (13 ha). Kanuka, kauri, rimu, tanekaha, totara and rewarewa are common on ridges within these ranges.

- The ED is the northern limit for Hochstetter's frog with populations occurring quite densely in the Brynderwyn Hills (Lux *et al.* 2007). Waipu ED is the only part of Northland where this species occurs.

- There are relatively few shrubland ecosystems and freshwater wetlands, which are highly impacted from grazing, and nutrient enrichment through animal faeces and urine, and fertilizers.

- The Upper Mangawhai River wetlands have two large wetland remnants, each dominanted by harakeke flaxland with isolated patches of kahikatea−harakeke treeland and margins of grazed reed sweetgrass grassland.

The Waipu ED portion within the Kaipara catchment has 1,283 ha (9%) of protected areas, mainly provided from Public Conservation Land, Whangarei District Council and QEII covenants.

Priority areas for protection include forest and shrubland on alluvial plains, freshwater wetlands, forest and shrubland on hill country below 100m asl, forest adjacent to estuaries (Lux *et al.* 2007). Conning (2001) also recommends riverine forest and wetlands; habitat for Hochstetter's frog and linking fragmented reserves between the Bryndyrwyn ranges and Waipu Caves, and through to the coastal environment.

9.7.1.8 ŌTAMATEA ECOLOGICAL DISTRICT SURVEY

Ōtamatea Ecological District is approximately 82,000 ha and is entirely inside the Kaipara catchment. The Ecological District encompasses a broad ecosystem pattern of a variety of indigenous forest types (Lux & Beadel 2006). It also encompasses three convoluted arms of the Kaipara Harbour, which extends inland up the Arapaoa, Ōtamatea and Ōruawharo Rivers. The four major peninsulas are Hukatere, Puketotara−Oneriri, Ōkahukura−Taporapora and Whakapirau−Batley (Figure 19).

Significant natural values of the ED are:

- Extensive mangroves and saltmarshes,
- Home to a high number of threatened bird species. Also, the ED has threatened plant, fish and lizard species.
- Nationally and internationally important feeding and roosting sites for migrant waders such as wrybill, northern New Zealand dotterels, banded dotterels, lesser knots, variable oystercatchers, pied stilts and black stilts, and godwits. The intertidal mudflats and sandflats provide year−round residency for seabirds, such as white−faced herons, pied shags, black shags, little shags, little black shags, Caspian terns, white−fronted terns, and black−backed gulls and red−billed gulls.
- The largest and best connected indigenous forest remnants are on Hukatere Peninsula (west coast side), Pakaurangi (east coast side), and the Puketoara Peninsula.
- Hukatere Scenic Reserve (30 ha) contains the last remaining example of mature kauri forest left in the Ōtamatea ED (Davis 2002, Lux & Beadal 2006). All other remaining areas of forest type are secondary (i.e. less than 120 years old). Most have 1–2 mature kauri trees.
- Small but significant patches of coastal forest remnants occur along the estuarine margins of the Arapaoa, Ōtamatea and Ōruawharo rivers (Lux & Beadal 2006). These are rich in totara, kanuka, kowhai, puriri, kahitatea and kauri.
- Lack of natural freshwater wetlands, which is an essential habitat for indigenous water birds such as grey duck, paradise shelduck, grey teal, black shag, pied shag, little shag and Australasian shoveler, while reedland around the margins is important habitat for species such as spotless crake, marsh crake, Australian bittern and banded rail.
- The ED is geologically rich and diverse, with nine important geological sites, eight of which fall within areas of indigenous vegetation. For example, the exposed cliffs of the Puketotara Peninsula which face the Ōtamatea River, contain internationally significant erionite deposits underneath pohutukawa forest.

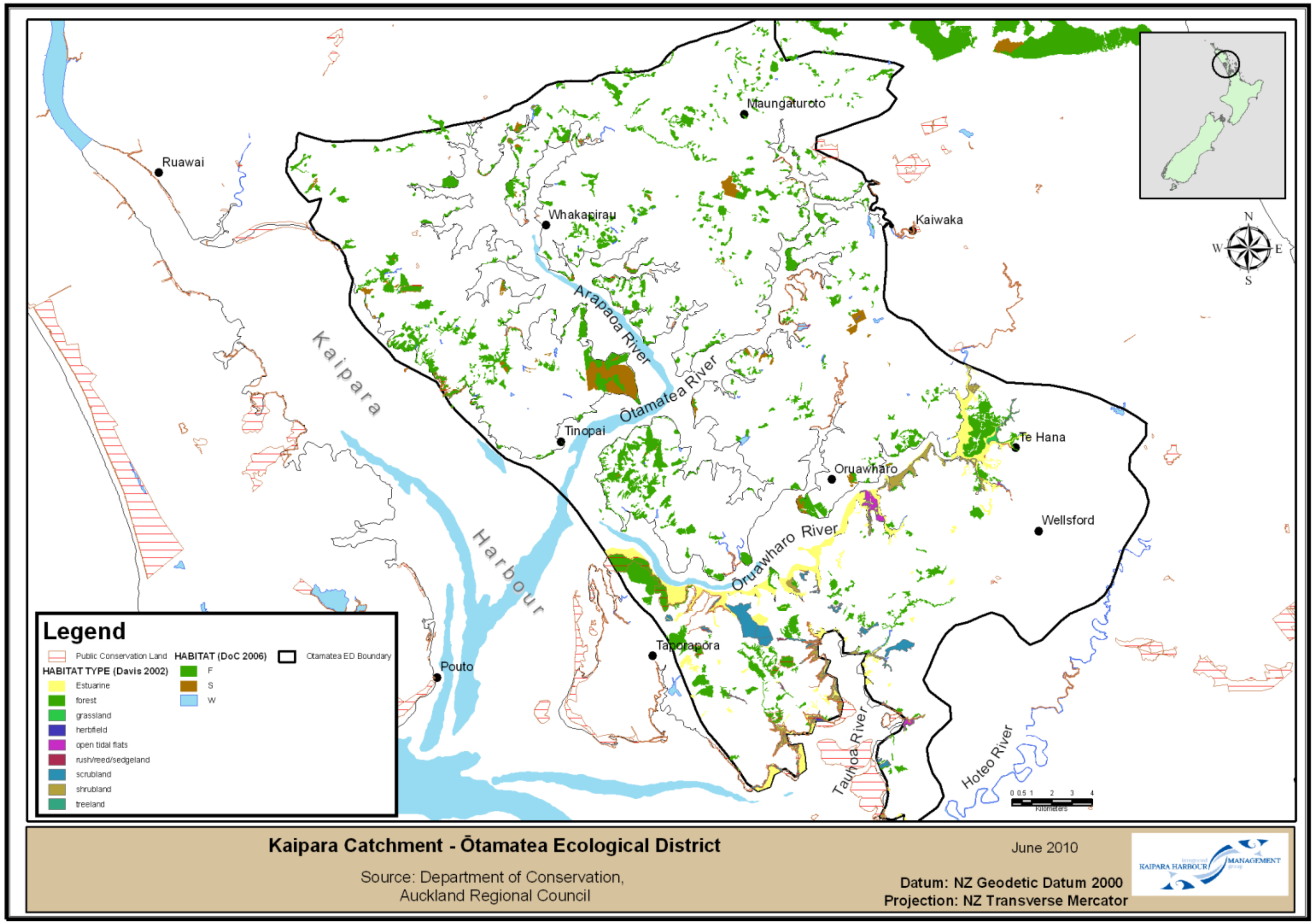
Broadscale Ecosystem Pattern
With over 80% of the ED being estuarine ecosystem, the ED contains the largest and best quality examples of mangrove forest in New Zealand (Lux & Beadal 2006). Indigenous shrublands cover only a small area and freshwater wetlands are very limited in extent, most of them being constructed by humans.

The ED has highly fragmented indigenous cover. There are no extensive tracts of indigenous forest or shrubland encompassing the full range of topography present (i.e. from the highest peaks down to the coast, over gullies, ridges, hillslopes and plains).

Almost all remaining forest is regenerating or secondary, having developed following the widespread decimation of the 1800's.

The mosaic today, is of remnant secondary forest (the majority) with regenerating secondary shrubland and occasional surviving mature, emergent trees (Lux & Beadal 2006). Appendix 4 lists the main vegetation types and fauna observed by Lux & Beadal (2006), and Davis (2002).

Figure 19. Ōtamatea Ecological District.



Existing Protection

Very few significant natural areas are legally protected for conservation, with 2% of ecosystems protected mainly via Public Conservation Land, District Council covenants and private QEII covenants. In 2008, a massive 839 ha area was gifted to the Auckland Regional Council (ARC) to create the Atiu Creek Regional Park on Taporapora−Ōkahukura Peninsula. Atiu Creek is also a QEII covenant property. Priorities for protection were analysed by Conning (2001) for the Ōtamatea ED who listed the following as priorities:

- Coastal ecosystems (estuarine, dune, shrubland, forest) including fencing of stock from the Kaipara Harbour (especially fairy tern habitat)
- Wetland ecosystems
- Broadleaf−podocarp forest on limestone, volcanic & volcaniclastic sedimentary rocks
- Kauri, kowhai, pohutukawa, karaka & puriri forest ecosystems
- Representative sites for all vegetation types present in the ED.

9.7.1.9 RODNEY ECOLOGICAL DISTRICT

The Rodney Ecological District contributes over 62% of its area to the Kaipara catchment, and is described as a fragmented forest landscape that contains numerous discrete natural areas (Cutting & Cocklin 1992). Mitchell *et al.* (1992) describe the natural biological character of the ED as being significantly depleted, with only a few large areas of original forest. Bellingham (2008) goes further and describes the northern and southern parts of the district as having 10–15% indigenous vegetation cover remaining, while the central part has 20−25% cover remaining.

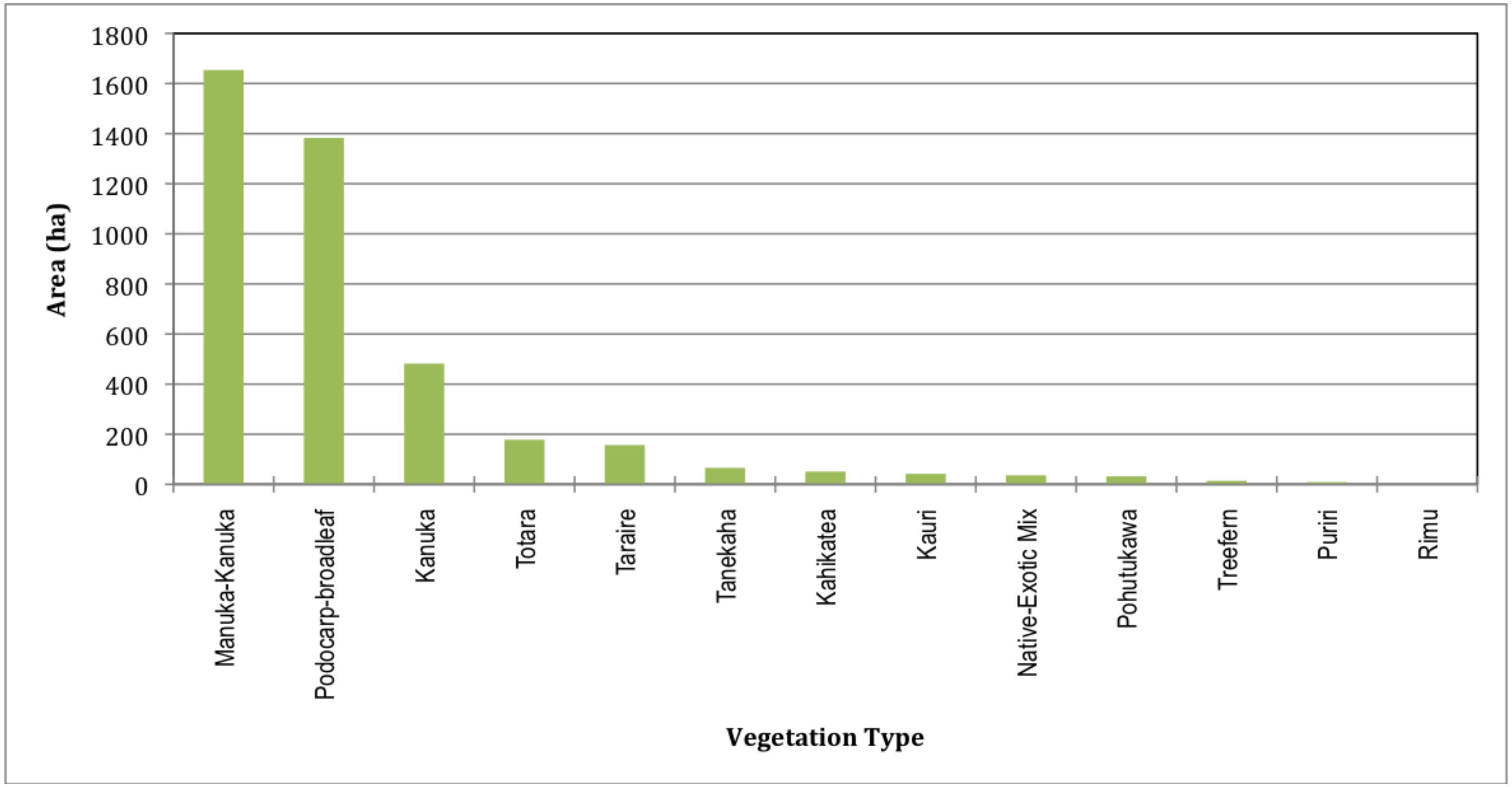
The district was once heavily forested with areas of dense mature broadleaf, kauri and podocarp forest; freshwater swamp of raupo, flax and rushlike plants along river margins; and lush and dense mangrove forests along the Kaipara shoreline (Beever 1981, Conning 2001). A pastoral farming landscape currently dominants with exotic forestry, peri−urban, and urban settlements increasing. These changes to the landscape have seen a rapid and on−going decline in the extent and quality of indigenous vegetation cover and fauna habitats in the district (Bellingham 2008).

Indigenous vegetation remnants are found scattered across the landscape occupying positions on different soils and slopes which vary in size, shape, isolation, ownership and management. The ecosystems that still exist include scattered, fragmented broadleaf−podocarp−kauri forest remnants, in which taraire and totara are the dominant species and podocarps are regenerating. Small kahikatea stands occur, while wetlands are small and depleted.

The results of past wildlife and ecological district surveys illustrate that the current existing protected areas in Rodney ED are inadequate to protect the full range of ecological classes (Wilton 1995). Regional and district council biodiversity planning objectives all seek to protect the extent of significant indigenous vegetation (Appendix 8). Bellingham (2008) investigated if these objectives were being achieved across the Rodney and Waitakere ED. During 1977 to 1983 there was no gain in indigenous forest or scrubland cover, but losses ranged between 0% and 4.84% (Ayres *et al.* 1984). The greatest rate of loss was due to landclearing for development of hill country farmland and exotic forestry. During 1984 to 1998, Rodney District Council did no monitoring of changes in indigenous vegetation cover although the Landcover Database, derived from satellite imagery, had recently been developed by Landcare Research. Bellingham's (2008) analyses identified significant increases in landclearing in the north and south−west of the ED, revealed by comparing vegetation plots between 1983 (Mitchell *et al* 1992) and a 1997−98 resurvey of potentially significant sites (Julian *et al.* 1998; Julian *et al.* 2000a, 2000b). Over the fifteen year period (Figure 20), 61% of mature forest types and 39% of regenerating forest and scrub had been cleared, and the highest cause of clearance was for pastoral farming (21.5%) and exotic forestry (2.3%).

The size, shape, current extent, degree of connectivity, condition and use of the remnant forest ecosystem are key indicators of forest function and health. Several authors have assessed the current extent of indigenous ecosystems in the ED since the early 1980's, revealing a general decline in biodiversity. Loss of wildlife species due to habitat fragmentation begins once clearing exceeds 20% or 30% of the landscape, and accelerates rapidly when less than 30% of the indigenous vegetation remains. The state of wildlife was by provided by Ogle (1982) for such iconic forest species as kiwi, bellbird, kaka; and then further by Mitchell *et al.* (1992), both noticing the reduced indigenous bird populations. The kereru (New Zealand wood pigeon) and tui keystone species that facilitate regeneration of forest remnants, appear to be most resilient to habitat loss and fragmentation (Clout & Hay 1980, Bellingham 2008). They eat the fruit of moderate to large−fruited tree species, and deposit the seed below their perch, contributing to the flow of energy between the scattered and isolated forest remnants. Rarer and threatened species such as the kiwi, and long−tail and short−tail bats have not been reported but may occur in the north and south of the ED (Mitchell *et al.* 1992). Hochstetter's frog is found in the headwaters of streams in forest areas, along with lizards, land snails, and insects.

Figure 20. Indigenous vegetation types cleared in Rodney Ecological District between 1983 and 1998 (Source. Bellingham 2008).



The majority of the Rodney ED remnant forest ecosystems is small in size (ha), lacks any interior forest, and is entirely affected by edge effects. Larger forest remnants are more compact, have greater biodiversity and better connectivity with other forest remnants. The status of this connectivity is significantly unbroken. Such a situation occurs on the Waikato Plains, where the common indigenous bird species are now rare, and moreporks have become locally extinct (Robertson *et al*. 2007). On the Manawatu Plains tui and kereru range out from the Tararua Ranges to forest remnants 10−20km away, but have not been reported in forests 40−50km away (Bellingham 2008).

The management of biodiversity in the district has been underpinned by the 1983 protected natural area survey (Mitchell *et al.* 1992). This survey, which assigned levels of significance to natural areas (i.e. Level 1 and Level 2), allowed for the identification of potential significant sites to be listed in the Rodney District Council (RDC) District Plan.

Monitoring of biodiversity condition and status has shifted from the PNAP listed sites to bushlot covenants. Nevertheless, there is minimal monitoring of terrestrial biodiversity in the ED. Bushlot covenants were introduced in 1987 to provide landowners the opportunity to subdivide in exchange for the physical and legal protection in perpetuity, the protection of indigenous vegetation, wetlands, and regenerating bush. The RDC has committed, as a key project, under the Long Term Plan 2006−2016. A pilot monitoring program was carried out in 2006 and found that 27% of bushlots were in good condition, 36% were fair, and 36% were in poor condition. The level of compliance with the subdivision consent and covenant is unknown, and there has been no district-wide monitoring of whether there have been any positive effects on the district's biodiversity values.

The bushlot covenant opportunity has encouraged the continued opportunistic and ad hoc protection of biodiversity in the ED, but forest remnants are being increasingly exposed to direct (drainage, felling, bulldozing) and indirect (introduced pests and weeds) stressors of development.

Current significant ecosystem values of the ED include:

- Coastal wetlands (i.e. mangroves and saltmarshes) and terrestrial ecosystems dominant the ED.

- Lower Hoteo River cliffs and gorges. The river is unique in the ED and Auckland region and is of high geomorphic value as the largest and most natural of wild rivers in the Auckland Region. It contains numerous meanders and rapids with deeply incised river gorges.

- The natural forest landscape associated with the Hoteo River, namely Atuanui (Mt Auckland) conservation land.

- The majority of natural areas lie on moderately steep land, with severe representation of north facing and flat land or on productive land.

- The ecological district survey of Rodney identified Priority Places for Protection (PPP) (Mitchell *et al.* 1992). This approach identified natural areas that best represented the ecological character and range of ecosystems using certain criteria: (1) Representativeness (this also included sites that were unique and rare); (2) Size and connectivity; (3) Resilience. Left alone, successional and regenerating forests will thrive and sites were chosen with such characteristics so that they could return to their 'natural' state. In the Kaipara catchment, PPP include, running from the north to the south of the ED, the following:

- Ryan Road – regenerating totara−kahikatea forest on lowland hill country buffering a stream (40 ha)

- Logues Bush has covenant protection with regenerating totara bordering a river and steep ridges. Presence of few old kauri and kauri rickers.

- Wayby wetland, Waiwhiu forest, Sunnybrook forest, and most of the Dome Valley−Conical Peak forest are found in the Kaipara catchment, which is one of the largest connected estuarine−lowland forest sites in the entire ED and the Kaipara catchment. The Sunnybrook forest and Dome Conservation Area includes over 400 ha of remnant and regenerating podocarp hardwood forest with a mature canopy of rimu, northern rata and kahikatea over rewarewa, hinau, tawa and taraire. There are plantation pine areas linking the Sunnybrook forest with Dome Valley forest and Mt Tamahunga, which has its west face draining into the Kaipara. Mt Tamahunga forest sits on the eastern boundary of the Kaipara catchment. Native frogs exist throughout the area along with kaka, pied tit and native parakeets.

- Hoteo River−Mt Atuanui is the largest Conservation Area (public conservation land, 615 ha) of indigenous vegetation on the west coast of the upper North Island between the Waitakere Ranges and Waipoua forest. Mt Atuanui Conservation Area has been protected since the early 1900's and retains most of its ecological character. The site provides the only continuous sequence of estuarine to hilltop vegetation (at 305 m). Taraire is common in the canopy along with tawa and rimu. Wayby Wetland is also located here which provides an example of intact raupo swamp with no open water bounded by kahikatea swamp forest. Kereru, tui, fantail, ruru and tomtits are some of the birds seen and heard throughout Atuanui. There are many hotspots of biodiversity within the site including king fern, stalked adders tongue fern, and several species of orchid (e.g. *Yoania australis*). The site also has cultural significance, as the summit was once a Pa with fortifications including defensive ditches, terraces, middens and pits. Pa sites were also established along the Hoteo River.

The Hoteo River is the longest river in the Kaipara ED and meanders through broken, steep hill country for some 30 km. The edge is heavily modified, with the remaining patches of indigenous vegetation being primarily taraire and kanuka.

The Atuanui Restoration Project[14] has been established to monitor and restore forest health, and is a community partnership project between the Kaipara branch of the Forest and Bird Society, local residents, Auckland Regional Council,

[14] http://www.kaiparaforestandbird.org.nz/Atuanui.html

Department of Conservation (DoC) and the Rodney District Council. Pest control is underway for possum, but not rodents and stoats. DoC issues hunting permits for goat and deer.

- The Moirs Hill site contains two large areas (~400 ha) of regenerating kanuka, and podocarp−broadleaf forest centred on the hill. Pine plantations border most of the site. This 'outstanding' ranked site is subject to 35% protection under a public conservation land scenic reserve. Kauri land snail, pied tit, and native frogs are known to occur here.

- The Haruru significant natural area is an extensive and spectacular 4 km long lowland hill country forest complex. Taraire and kahikatea extend to a cliff with some pohutukawa present, which is unusual for most coastal zone vegetation.

- At the mouth of the Kaukapakapa Estuary is a large, completely forested south facing hillslope, which extends down to alluvial areas on the river margin. This is the best example of coastal regenerating kauri forest on hills in the ED. Coastal taraire forest is also present along with kowhai occurring all along the river margin. The site is currently public conservation land.

- Mangakura Stream site provides the best example of kanuka forest on lowland hill country in the ED. There are large areas of regenerating kauri.

Existing Biodiversity Protection

Rodney ED currently has 6% of its area dedicated to the protection of ecosystems with the majority of this protection provided by RDC bushlot covenants (Figure 21). Mechanisms used to protect biodiversity in the ED include: (a) Public Conservation Land, (b) QEII covenants, and (c) RDC Bushlot Covenants. Priorities for protection discussed by Conning (2001) include:

- Under−represented ecosystems including gumland, estuarine, pohutukawa forest and broadleaf forest on volcanic soils, and wetland ecosystems

- Areas supporting Hochstetter's frog and fairy tern

- Kauri and podocarp forest ecosystems.

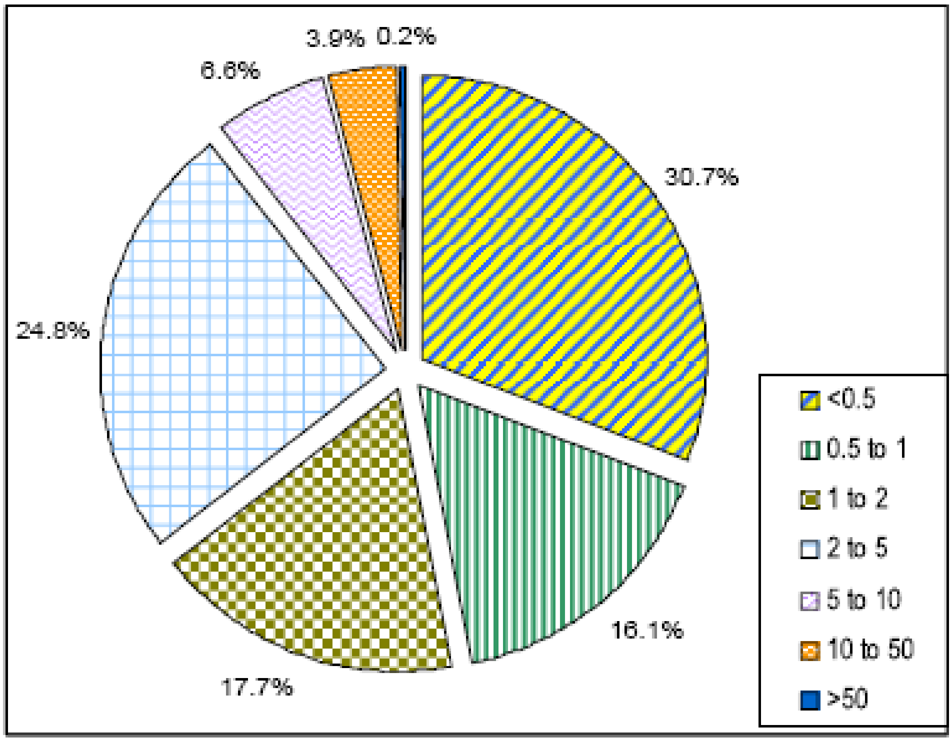
The only active protection of indigenous vegetation in the ED is through the ad hoc process of RDC bushlot covenants; however as noted above the effectiveness of this mechanism for protecting biodiversity are currently unknown. RDC are to undertake monitoring of bushlots through landowner participation, communication planning, and GIS analyses of ecological connections and spatial relationships of bushlot covenants.

9.7.2 SUMMARY OF TERRESTRIAL ECOSYSTEM INFORMATION

The Kaipara harbour is the receiving environment of a massive catchment area of 6,400km^2 and is considered New Zealand's largest estuarine system. McLay (1976) classified the Kaipara Harbour as "*grossly polluted"* and Haggitt et al. (2008) called the Kaipara Harbour "*environmental values continue to be degraded*". The landscape was a mosaic of "*landscapes and seascapes…richest of which along rivers, around estuaries, dune lakes, lagoons and inlets*" (Murton unpublished). Early settlers, explorers, naturalists, missionaries describe the vastness and denseness of primeval forest and wetland ecosystems (Diffenbach 1843, Colenso 1844, Hay 1882, Polack 1974(1838)). These ancient forest and estuarine ecosystems yielded to Kaipara hapū a sustained harvest of berries, birds, shellfish, fish, timber, cordage, matting, clothing, weapons, utensils and medicines.

The Kaipara catchment landscape has been significantly modified since European settlement with 15.6% of forest ecosystems remaining. This has resulted in considerable loss of indigenous biodiversity in coastal, lowland and rolling hill environments

Figure 21. Proportion of Rodney District Council bushlot covenants by size (Rodney District Council 2008c).



9.7.3 FRESHWATER ECOSYSTEMS

The Kaipara catchments' sole source of freshwater is precipitation in the form of rain. Like most other aspects of New Zealand's weather, Kaipara rainfall varies markedly across space and time. Kaipara rivers and streams are important for human and stock drinking water sources, and provide recreational, environmental and aesthetic, irrigation, industrial and customary uses.

For Kaipara Māori, rivers, streams and lakes of the catchment carry ancestral connections, which link to their identity, and wairua. When the exercise of kaitiakitanga is possible, the maintenance and restoration of the mauri of freshwater is carried out to ensure that this taonga is available for future generations.

Kaipara's freshwater ecosystems are in a highly degraded state (Ministry for the Environment 2007). While covering less than 2% of New Zealand's land area, wetlands support 22% of New Zealand's native bird species and 30% of native freshwater fish. They make up 2% of all natural areas remaining in the Kaipara catchment and are exposed to increasing rates of discharge from consented activities. In 2008, Northland Regional Council (NRC) had 1,072 applications for discharges (which is 49% of all NRC resource consents) and the Rodney District had 735 discharge consents (which is 36% of RDC consents; 435 (60%) entering the Kumeu−Kaipara river catchment alone), to land and water, in the Kaipara catchment.

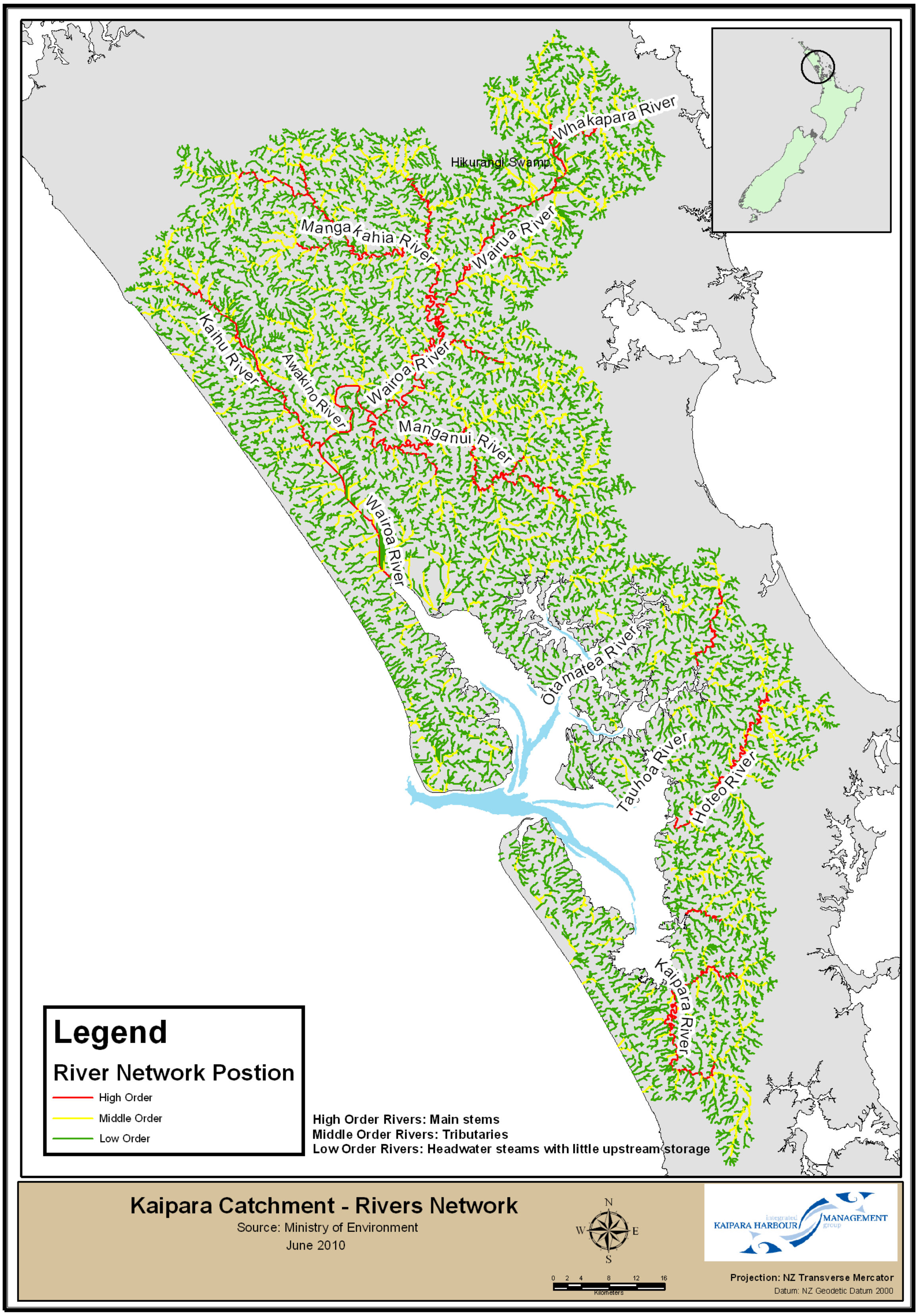
Freshwater ecosystems remain constantly under pressure from drainage, fertiliser run−off, invasive weeds, water abstraction, clearance of riparian and catchment vegetation, pine planting and logging, weir and dam construction, the grazing and trampling of marginal vegetation by stock and reclamation for urban development.

The management of freshwater ecosystems is a matter of national significance. A Proposed National Policy Statement (NPS) for Freshwater Management has been developed to improve and help guide decision−making of freshwater demand and allocation. A Board of Inquiry is currently underway[15], and seeks to hear public views via an open submission process. The NPS will not be a piece of legislation, but will require councils to give effect to the national significance of freshwater in their regional policy statements, regional and district plans. Councils must also develop local rules and standards for the day−to−day resource consent application process that align with the NPS.

The following sections review current knowledge of the Kaipara's freshwater ecosystems, namely major river systems, dune lakes and wetlands. Gaps in knowledge have been identified at the end of the chapter.

[15] http://www.mfe.govt.nz/rma/central/nps/freshwater-management.html

Figure 22. Kaipara catchment rivers and stream network.



9.7.3.1 RIVERS AND STREAMS

Kaipara's river and stream network (Figure 22) support many environmental values that include, biological and recreational resources; and biological processes such as diluting, assimilating and transporting nutrients. For Māori, rivers, creeks, streams, were passageways for mile−long shoals of eels, smelt, and inanga migrating to and from the sea. Stone weirs and side channels were used to divert eels, smelt, kokopu, and koaro. Eels were dried on racks, while smelt and whitebait (inanga) were, dried on rock pavements.

The largest river in the catchment is the northern Wairoa River, which drains a massive catchment area of 3,650 km^2 into the northern Kaipara Harbour. The Wairoa River occupies a drowned river valley system and is tidal for about 100km inland. Tributary rivers of the Wairoa are: Manganui River, draining a 90 km^2 catchment; Kaihū River north of Dargaville which includes the western edge of Tutamoe Ranges and southern foothills of the Waipoua Forest; Awakino River, which drains a catchment of 116 km^2; Tangowahine River with a catchment of 125 km^2; the Kirikopouni River which is the smallest river in the Wairoa catchment, draining a narrow valley between the Mangaru Range and Mangatipa and Houto Ranges; and the Mangakāhia River which drains a catchment of 800 km^2, including the Tutāmoe Ranges in the west, and is bordered by the Wairua River catchment in the east. The Wairua River is at the northeastern reaches of the Wairoa catchment and drains an area of 750 km^2 including the Hikurangi Swamp floodplains which was once a lake bed:

> *"The Hikurangi Block contains 12,000 acres of land of fair average quality, nearly two−thirds of which is hilly and covered with forest, a portion of which is kauri and kahikatea. One−third is composed of open fern land and swamp. This block adjoins and is situated on the north side of Kaurihohore Block, and is about eight miles distant from the European settlement at the head of the Whangarei River. "* (Turton 1883).

This large swamp was drained and turned into productive farming land in the 1970s, with about 300 ha of swamp remaining. The black mudfish *Neochanna diversus* was recently recorded in the Otaikarairangi swamp reserve in Hikurangi, for the first time in thirty years [16].

In the southern Kaipara, the dominant river systems are: the Hoteo River, being the largest river, draining a catchment of over 375 km^2 and which contains the greatest elevations in the southern catchment at Mt Atuanui through to Dome Valley−Conical Peak; the Kaipara−Kumeu River which drains a catchment of 301 km^2 has been heavily utilised for agriculture for over 150 years; the Kaukapakapa River (Figure 20), which is sited between the Kaipara−Kumeu River and the Hoteo River, drains a catchment of 118 km^2 ; between the Kaukapakapa River and Hoteo River are the Makarau River (113 km^2 catchment) and Araparera River (81 km^2).

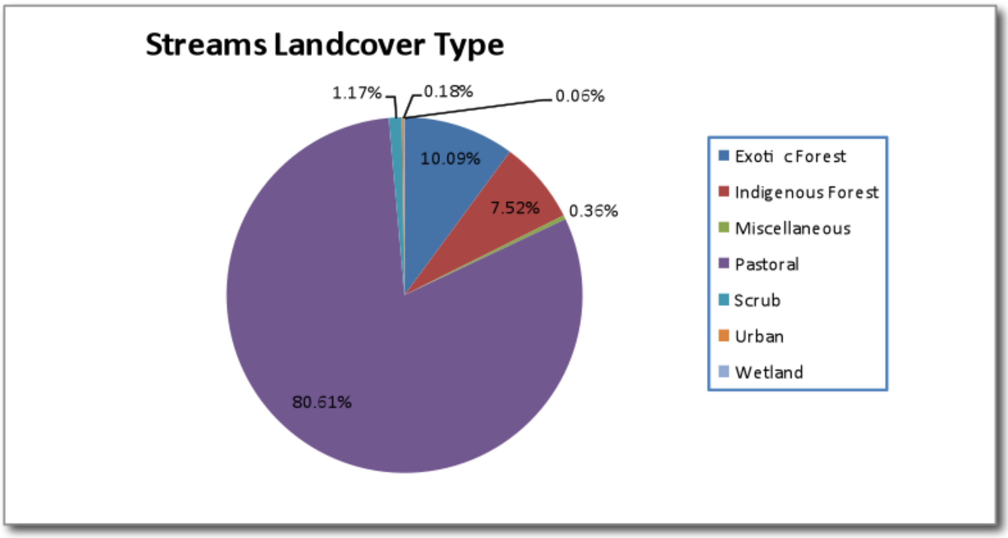
Little is known about the ecological health of the rivers that feed into the Kaipara Harbour (Kingett Mitchell Limited 2004). Generally, the abundance and distribution of virtually all indigenous fishes in New Zealand's freshwaters have declined since European settlement

[16] http://www.igrin.co.nz/trisha/black%20mudfish.htm

(McDowall 1990). Most Kaipara rivers and streams are surrounded by intensive landuse, particularly pastoral farming for diary cows, cattle, and sheep. Northland Regional Council (NRC) reported that a quarter of streams sampled are unsafe for swimming during summer, and over a third of the sites tested for water quality are not suitable for swimming in summer and winter (Northland Regional Council 2007).

The Kaipara freshwater river systems are nutrient enriched mainly due to non−point sources of pollution such as pastoral landuse. Over 11,000 (80.6%) stream sections pass through pastoral land prior to reaching the Kaipara Harbour, compared to less than 1,800 stream sections that pass through a mixture of exotic forest, indigenous forest, scrub, wetland, and urban areas (Figure 23). Kaipara streams tend to have higher temperatures, higher concentrations of nutrients, and high levels of faecal coliform bacteria and suspended sediments. Strong correlations between water quality parameters and landcover characteristics, suggest that these water quality issues are associated with intensive landuse (Northland Regional Council 2007; Scarsbrook 2007). Temperatures above 23º C are best avoided, causing adverse effects on macroinvertebrate and fish populations. Kingett Mitchell Ltd (2006) recorded a temperature range of 18.3 − 21.6ºC for the Hoteo River.

Figure 23. The percentage of stream sections landcover type within the Kaipara catchment. (Source: Rivers Environment Classification, Ministry for Environment)



9.7.3.2 RIVER ENVIRONMENT CLASSIFICATION

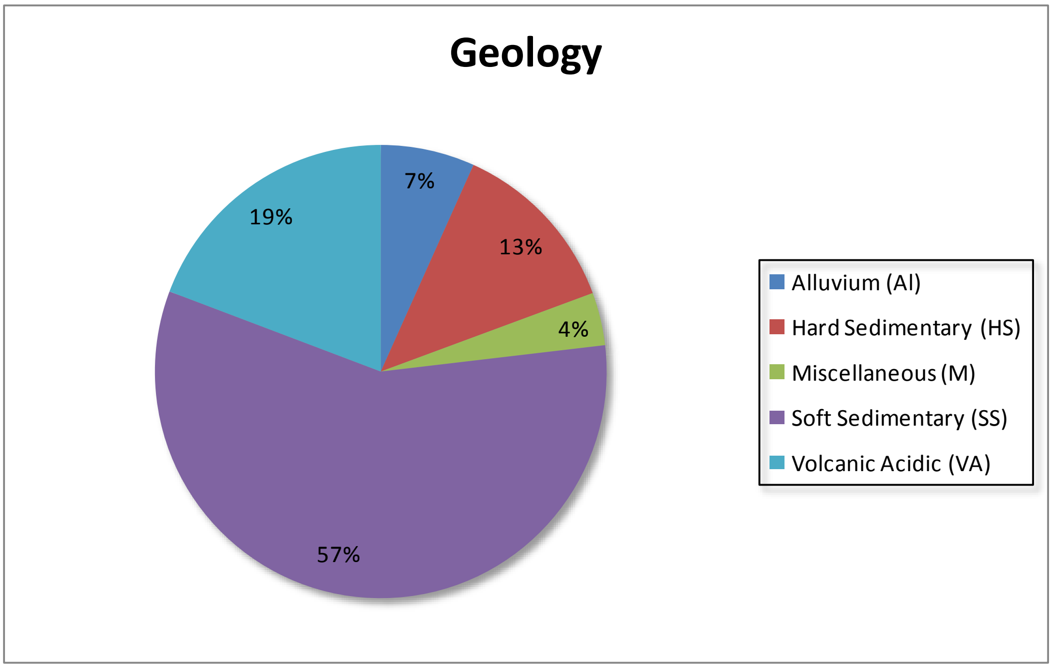
The River Environment Classification (REC) is a hierarchical classification of New Zealand's rivers. Rivers with the same class are expected to have similar physical environments and ecosystems, similar environmental and economic values and similar responses to human disturbance despite the possibility that they are geographically separated.

The development of the REC has been done within a spatial framework to enable management agencies to move towards ecosystem−based management of whole ecosystems. The REC was developed for resource managers to organise and stratify environmental data collection and monitoring of rivers, to aid data interpretation and reporting; along with carrying out functions under the Resource Management Act.

The REC group's rivers, and parts of river networks, according to several environmental factors, which strongly influence or create the rivers' physical and ecological characteristics (climate, topography, geology, source of flow, river network position, landcover). Rivers with similar physical attributes will be part of the same class and therefore the same management unit. Such management units can be linked to justifiable objectives, policies and methods in plans. They can also be utilised in evaluating conservation or implementing conservation reserve networks (Snelder *et al*. 2004).

The REC was applied to the Kaipara catchment's rivers and streams to provide an understanding of its climate variability, topography, stream geology, landcover, and source of flow. For example, the majority of Kaipara rivers and streams affected by human activities occur in "soft−rock" or soft sedimentary geology areas, including clay and sand (Figure 24)

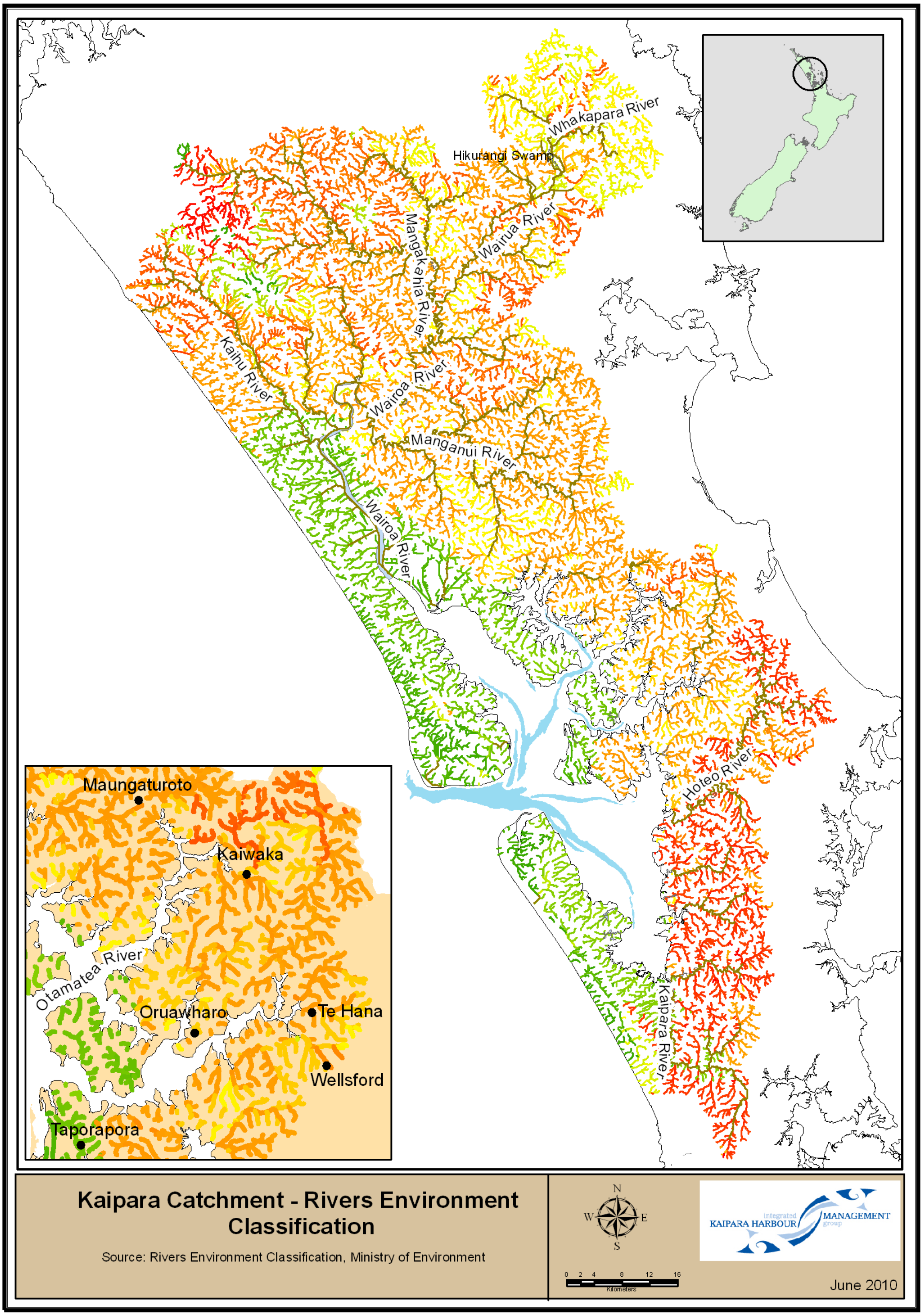
Figure 24. Geology characteristics of Kaipara catchment rivers and streams classified using the Rivers Environment Classification.



The REC was applied to the Kaipara catchment (Figure 25) using six controlling factors, source of flow, climate, landcover, geology, valley landform, and network position, that control physical patterns at different spatial scales in rivers. The REC classified the Kaipara into 219 unique river classes, delineated by hierarchical patterns that reflect the scales at which differences in particular physical characteristics could be discriminated. These patterns include seasonal flows, sediment loads, morphology (e.g. shape and size of stream), water chemistry, and stream substrate (e.g. silt, sand, gravel).

The REC assumes that ecological patterns are largely determined by these physical conditions. Tests of this assumption are limited, but one example, that of the frog species *Leiopelma hochstetteri*, and its habitat ecology in the Waitakere Ranges and Auckland region (E. Hillman, AUT University, pers.comm.,2009). The REC was used to test the habitat model of *L. hochstetteri* across the Auckland region, and found to adequately describe its distribution at this regional scale.

Figure 25. Classification of Kaipara rivers and streams using the six controlling factors.



9.7.3.3 PAST RIVER STUDIES

1. Northland Macroinvertebrate Monitoring Program

Macroinvertebrate monitoring involves the use of two indices: the Macroinvertebrate Community Index (MCI), and the Semi-quantitiative Macroinvertebrate Community Index (SQMCI). The MCI was designed to evaluate organic enrichment using macroinvertebrates as biological indicators of water quality. Macroinvertebrate taxa presence and absence is recorded and scored on tolerance to environmental changes. These scores range from 1 and 10 (1 being highly tolerant, and 10 being highly sensitive), and have been predetermined by aquatic ecologists. The final score for each sample is the sum of the tolerance scores for each taxon present divided by the number of taxa, and multipled by 20. A score of 120 or greater indicates “clean water”; scores between 100 and 119 indicate “possible mild pollution”; scores between 80 and 99 “probable moderate pollution”; and scores less than 80 are considered “probable severe pollution”.

The Semi-Quantitative MCI is similar but more robust as it accounts for the number of individuals belonging to each taxon thus, providing more accuracy of estimating stream health (Pohe & Hall 2007). The resulting score is a number between 1 and 10; scores greater than 6.00 indicate “clear water”; scores of 5.00 to 5.99 indicate “possible mild pollution”; scores between 4.0 and 4.99 are “probable moderate pollution”; and scores of 3.99 and lower indicate “probably severe pollution”.

Sampling protocols for both the MCI and SQMCI were developed by the New Zealand Macroinvertebrate Working Group. These methods outline separate protocols for semi-quantitative sampling on hard-bottomed and soft-bottomed streams (Stark *et al*. 2001). Protocols for soft-bottomed streams has not been implemented in Northland only in the Auckland region (Stark & Maxted 2004).

Of the 24 sites monitored across the Northland region using the Macroinvertebrate Community Index (MCI) only two were considered ‘clean water’ (score > 120) (Figure 26). The remaining sites ranged from “mild pollution” to “probable severe pollution” (Pohe & Hall 2007). However, results varied under the more robust and accurate Semi−Quantitative Macroinvertebrate Community Index (SQMCI) where 4 sites were considered “clean water” (score >6.0). Kaihu Valley was rated as ‘severe pollution’ (score <4.0) with the remaining sites in the Kaipara catchment rated ‘mild pollution’ (score 5.0−5.9) and ‘moderate pollution’ (score 4.0−4.9) (Pohe & Hall 2007). Sites of immediate concern identified within the Kaipara catchment include Opouteke River at Suspension Bridge (low SQMCI and considerable downward trend), and Waiotu at SH1 bridge (low SQMCI and considerable downward trend) (Table 8).

Figure 26. Northland macroinvertebrate monitoring sites and results for Macroinvertebrate Community Index 2007 and Semi Quantitative Macroinvertebrate Community Index 2007. The dotted line indicates the sites located in the Kaipara catchment.

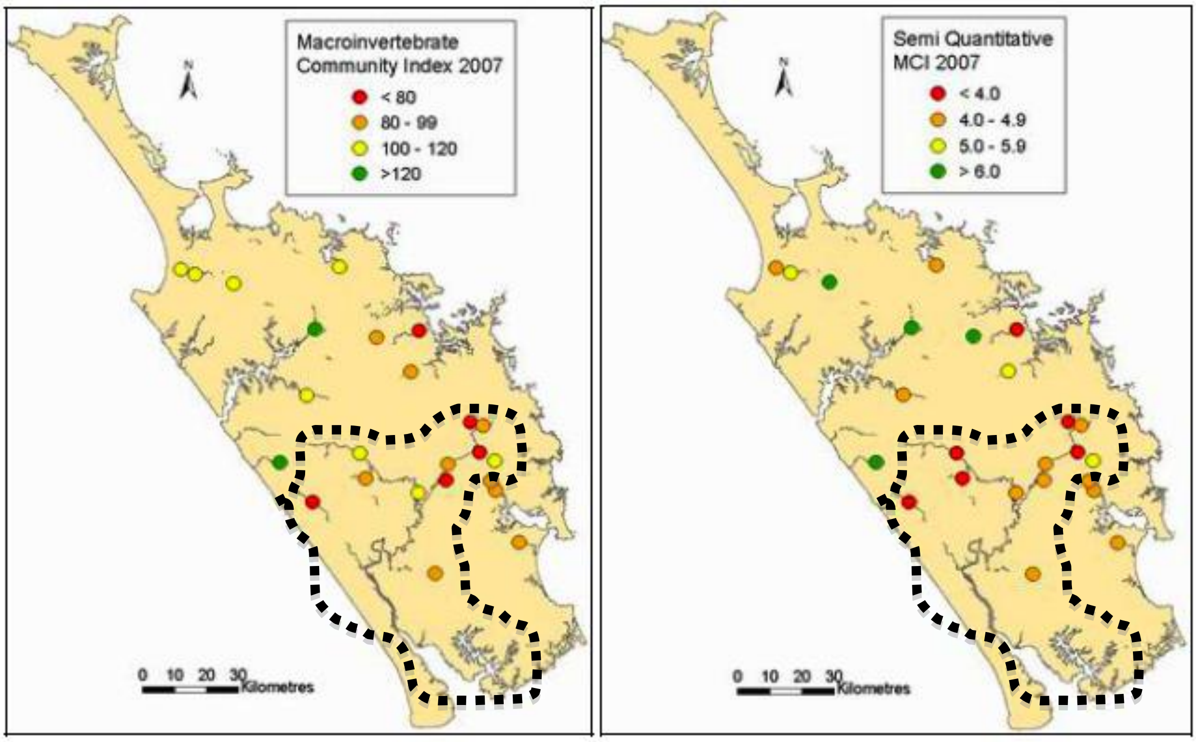


Table 8. Stream ratings for monitoring sites found in the Kaipara catchment.

Macroinvertebrate Monitoring Sites situated in the Kaipara Catchment	Rating
1. Kahiu Valley	Severe pollution
2. Waiotu River @ SHI Bridge, Hikurangi	Severe pollution
3. Mangaharuru @Apotu Road Bridge, Hikurangi	Severe pollution
4. Mangere River @ Knights Road Bridge	Severe pollution
5. Manganui @ Permanent Station	Moderate pollution
6. Wairua @ Purua	Moderate pollution
7. Otarao near Mangakahia River	Moderate pollution
8. Whakapara @ cableway	Moderate pollution
9. Opouteke River @ Suspension Bridge	Moderate pollution
10. Mangakahia @ Twin Bridges	Mild pollution
11. Mangakahia @ Titikoi Bridge	Mild pollution
12. Mangahahuru @ end of Main Road	Mild pollution

2. Northland Stream Habitat Assessments

Northland Regional Council (2008) reported on their freshwater monitoring state of the environment sites for 2007, and compared to these to 2004 and 2005 results, with ten out of twenty−four sites being in the Kaipara catchment (Table 9). Stream habitat, stream health or quality, and channel and stream stability are assessed nominally every two years. Water quality sampling is carried out monthly, with macroinvertebrates and periphyton/chlorophyll−a (selected sites only) monitored annually.

Table 9. Northland Regional Council freshwater State of Environment monitoring sites situated within the Kaipara catchment (Source: NRC 2007, 2008).

*# Sites in the National Monitoring Network. **Site sampled by NIWA.*

Site name	NRC Site Number	Grid Reference NZMS 260	Freshwater Habitat Assessment	Northland River Water Quality Monitoring Network Site
Whakapara Cableway	102249	Q06:260279	√	√
Mangaharuru Apotu Road Bridge	100281	Q06:248196	√	√
Mangaharuru end of Main Road	100237	Q06: 296170	√	√
Waiotu SH1 Bridge	102248	Q06:222291	√	√
Wairua Purua**	101753	Q06:150158	√	√
Mangere Knight Road Bridge	101625	Q06:143108	√	√
Mangakahia Titoki Bridge#**	101038	P07:058069	√	√
Mangakahia downstream of Twin Bridges#	109096			√
Kaihu Gorge	102256	P07:726042	√	√
Opouteke Suspension Bridge	102258	P06:891113	√	√
Mangakahia Gorge	103307	P06:873194	√	√
Manganui River				√

Quantitative and qualitative information is collected during the sampling months February to March, when streams are likely to be under most stress from low flow and high temperatures. Data is collected on:

- Streambed and channel stability: using Pfankuch's (1975) index of stability (scores out of 15) for upper and lower bank, and stream bottom. Summed scores are used, and range between 38−152, lower scores indicate more stream and channel stability.
- Periphyton (stone substrate only) – chlorophyll a. This index provides an overall picture of stream health, as stream and bank stability influences the presence of aquatic life and water quality.
- Stream substrate type: 10 variables are scored, including riparian canopy cover, understory vegetation at 0−5m and 5−20m distance from the stream; bank type (earth, rock, mixed, manmade); bank stability (stable/unstable); wetted width; maximum depth; flow type (run, riffle, pool, chute/waterfall); organic substrate (detritus, bryophyte, macrophytes, woody debris, algae, tree roots, none); and

inorganic substrate (bedrock, cobble, boulder, gravel, silt/sand/soft clay, hard packed clay, manmade)

- Riparian vegetation
- Composition of organic and inorganic substrate
- Surrounding landuse, presence of litter, evidence of livestock access, % shading, % filamentous algae cover, and presence of macrophytes (aquatic plants) (categorical − none, rare, common, abundant)
- Physiochemical: water temperature (°C), dissolved oxygen (mg/l), % saturation, conductivity (uS), and water clarity (m)
- Stream habitat quality: scores (range 0−20) are given to aquatic habitat abundance, aquatic habitat diversity, hydrological heterogeneity, channel alteration, bank stability, channel shade, riparian vegetation (0−5 scores indicate poor quality, 6−10 marginal, 11−15 suboptimal, 16−20 optimal quality).

Stream and bank stability as scored using the Pfankuch Stability Index, found that four out of the ten Kaipara SoE sites had scores in excess of 100, indicating poor to moderate stream stability (Table 10).

None of the SoE sites in the Kaipara catchment had relative habitat quality assessment scores indicative of optimal habitat for aquatic biota (Table 10). The Waipoua Forest SoE site has been included in Table 10, as this was one of two sites (out of 24) in Northland with suitable habitat for aquatic biota. The majority had marginal habitat quality, mostly as a result of limited riparian vegetation and associated channel shading (Northland Regional Council 2007). Overall, stream habitat quality was reported to have remained relatively stable over the past four years. Chlorophyll−a levels were reported on for the first time in 2007, and showed consistent responses with regard to surrounding landuse. For example, high levels of chl−a and nutrients were found at the predominantly pastoral sites, indicating probable organic pollution.

Table 10. Northland Regional Council freshwater State of Environment sites located within the Kaipara catchment (Source: NRC (2007).

Site name	Pfankuch Stability Index	Change in Pfankuch Stability Index since 2005	Habitat Quality (Total)	Predominant Landuse
Whakapara Cableway	100	+	61	Pasture
Mangaharuru Apotu Road Bridge	84	+	68	Pasture
Mangaharuru end of Main Road	75	−	86	Planted forest, pasture
Waiotu SH1 Bridge	102	−	70	Pasture
Wairua Purua	109	−	63	Pasture
Mangere Knight Road Bridge	83	+	75	Pasture
Mangakahia Titoki Bridge	109	−	63	Pasture
Kaihu Gorge	67	−	95	Scrub, forest, pasture
Opouteke Suspension Bridge	73	+	77	Pasture, planted forest
Mangakahia Gorge	80	−	103	Pasture
Waipoua	57	+	113	Native Forest

3. Overview of Aquatic Ecological Issues & Proposed Aquatic Ecological Zones in the Kumeu−Kaipara River and Kaukapakapa River Catchments

An investigation commissioned by the Rodney District Council of the ecological characteristics of the Kaipara−Kumeu and Kaukapakapa River catchments (Kingett Mitchell Limited 2004). An overview of the ecology of these rivers was presented and critical ecological issues summarised. A desktop ecological zoning of these catchments was also undertaken according to landuse, ecological characteristics, landcover and information from the Rivers Environment Classification.

Four ecological zones were proposed included:

(1) *Highly modified*, the most common environment in both river catchments. The main characteristics describing this zone were: minimal surrounding and riparian forest cover; and poor water quality and ecosystem health, as indicated by the presence of invertebrate communities and water quality.

(2) *Western Kaipara*, the western catchment of the Kaipara River, which contained sandstone geology, ephemeral streams, and unknown fish and invertebrate biodiversity.

(3) *Intact Native Forest Headwaters zone*, composed of small first and second order streams particularly the Kaukapakapa Scientific Reserve, Te Kura, Waitoki, and Mangakura streams. This zone contained some of the highest stream habitat quality as a result of riparian shading and diversity, but very limited ecological data exists on this zone.

(4) *Developed Riparian Forest zone* composed of river channels with intact native forest and scrub in lengths > 1 km. This zone was more common than the *Intact Native Forest Headwaters zone* as it included streams with modified landuse adjacent and/or upstream, but with higher quality habitat and better ecosystem health than open modified stream sections. Examples of this zone were found at Ararimu Stream and its tributaries up to the east behind the Kumeu−Huapai township; and the forested reaches of Wharauroa Stream.

Kingett Mitchell Ltd (2004) identified some of the critical aquatic ecological issues (Table 11) to the Kumeu−Kaipara River and Kaukapakapa Rivers, which have resulted in the characteristic poor quality, lowland stream habitat, with pockets of distinctive indigenous vegetation and geology still supporting indigenous freshwater ecosystems.

Table 11. Aquatic ecological stressors to Kaipara−Kumeu River and Kaukapakapa River catchment ecosystems. Adapted from KML (2004).

Critical Issue	Explanation
Loss of riparian vegetation	With no river/stream shading water temperatures increase causing proliferations in algal blooms and macrophytes reducing oxygen levels.
	Lack of organic matter or invertebrate food prey items or habitat.
	Poor bank stability, increased bank erosion and water turbidity and sedimentation of stream/river
	Reduced buffering from stormwater runoff and assimilation of contaminants.
Forest logging and clearing	Stress like above, plus reduction in pollination and re−colonisation of vegetation.
	Flood disturbances
	Sedimentation
Landuse intensification	Eutrophication due to nutrient runoff from pastoral farming and horticulture
	Increased presence of toxic and persistent pesticides
	Stock in waterways increasing bank erosion
Irrigation	Water abstraction reduces habitat availability and fish passage
Increasing urbanisation	Loss of riparian vegetation
	Modification of hydrodynamics such as flow in rivers and streams
	Increased levels of contaminants and sedimentation
	Increased move towards channelisation/drains
Increase pest fish and weeds	Smothering or eating native species
	Habitat quality reduced
Loss of uncommon and rare species	Habitat loss due to subdivision, introduced pest species and forest clearance
Reduced fisheries habitat	Obstructions to fish passageways during their migratory phases (e.g. eels) such as dams, culverts being poorly designed
	Poor water quality
	Increased number of dams. There are 406 dams on the Kaipara−Kumeu River and 314 on the Kaukapakapa River.

Kingett Mitchell Ltd (2004) also summarise past studies carried out on the Kaipara−Kumeu River, such as one−off studies of water quality (OPUS International Consultants Ltd 2003), and the Auckland Regional Council state of environment monitoring (Scarsbrook 2007), both describing the river as having low water quality with high suspended sediment levels and high temperatures due to the landuse activities of the catchment. Storey (1995; 1997) and also McBride *et al*. (1991) compared the macroinvertebrate communities between Kaipara−Kumeu tributaries describing species richness at sites along the Ararimu stream and Wharauroa streams as pristine for lowland streams. However, this rating was being degraded due to the presence of non−point source contaminants and run−off impacting on these freshwater stream ecosystems.

4. **Recreational Usage of the Kaipara−Kumeu River and Kaukapakapa River**

During December 2006 and February 2007 a recreational usage survey of the Kumeu−Kaipara and Kaukapakapa Rivers was made (Golder Kingett Mitchell Limited 2007b), to assist in planning for a new wastewater treatment system for the Kumeu−Huapai−Waimauku township. This was necessitated by the need to replace on−site septic systems found in many homes in these areas. Rodney District Council also wished to address long standing issues of stormwater and flooding of low lying areas in the Kaipara−Kumeu River catchment.

The survey identified what were termed “full contact” activities, mainly kayaking (5 responses), swimming (3 responses) and water−skiing (1 response). Partial contact activities included boating/motorboating/sailing, walking, and food gathering, with boating being the most frequent.

Most human activity was concentrated around the township of Helensville, with access made through walkways, boat ramps and public land, mainly during weekends. Most of the adjacent landuse to the Kaipara−Kumeu and Kaukapakapa rivers is farmland, which restricts public access to the rivers. Water quality issues were raised in the responses (Golder Kingett Mitchell Ltd 2007) and in previous surveys (Bioresearches Ltd 1998; Auckland Regional Council 2001). The linkage between the perceived value of the river and activity types were not evaluated but may denote a future research opportunity to explain the reasoning behind peoples activity preferences and the connection with the ecological, spiritual and intrinsic value of the rivers.

The lower Kaipara river is an important navigational waterway for both commercial and recreational uses, such as sand barging, charter fishing, tourism, and recreational boating.

5. **Ecological Health of Auckland Streams based on State of the Environment Monitoring 2000−04**

Using State of Environment monitoring information for Auckland streams ARC (2005) described the biological quality, physical quality, and water quality of aquatic systems, such as lakes, rivers and streams. Using this information and the Macroinvertebrate Community Index (MCI), ARC ranked each site from worst to best in stream health (Figure 27). The Hoteo and Kaipara−Kumeu river sites, both of rural landuse category, were ranked 59^{th} and 38^{th}, respectively. Recommendations provided in the report included limiting urban landuse and its footprint, and implementing riparian management across all landuse classes which includes forestry, urban, and rural. ARC (2005) also recommend full restoration of degraded rural streams using guidelines such as riparian zone management (Auckland Regional Council 2001b).

Figure 27. Water quality ranking from 'best' to 'worst' for the 16 soft−bottomed streams using data collected between1992−2003.

Site name	Land use	Ranking	
Mahurangi	forestry	75	best
Ngakaroa	rural	74	
West Hoe	native forest	73	
Wairoa	rural	71	
Matakana	rural	69	
Waiwera	rural	63	
Hoteo	rural	59	
Awanohi	rural	48	
Oakley	urban	44	
Vaughan	rural	43	
Kumeu	rural	38	
Oteha	urban	32	
Lucas	urban	30	
Papakura	rural/urban	28	
Puhunui	urban	27	
Otara	urban	20	worst

6. Report Card of Rivers and Streams in the Rodney District

The state of rivers and streams (Kingett Mitchell Limited 2006) in the Rodney District were reported on which include the Hoteo, Kaukapakapa and Kaipara rivers. Auckland Regional Council (ARC) has been operating a long-term water quality monitoring program in the Hoteo and Kaukapakapa Rivers for 31 and 14 years, respectively. The purpose of 'report cards' was to firstly provide state of ecological aquatic information on the rivers and streams and, secondly, to inform a future monitoring regime for the Kaipara-Kumeu river to coincide with the upgrade of the Kumeu-Huapai township wastewater treatment facility.

Forty-three sites were monitored across the District with fourteen sited within the Kaipara-Kumeu and Kaukapakapa rivers. An additional 15 sites were sampled in the Hoteo River catchment. Data collected on the state of streams and rivers included: dissolved oxygen (DO), water temperature, pH, conductivity, ammonia, nitrate and nitrite and phosphorus, dissolved zinc and copper, which are common in untreated sewage; habitat quality, such as stream depth and width, flow regime, streambank characteristics, inorganic and organic substrate composition, aquatic macrophyte cover, periphyton cover, stream shading and stream bank modification; and presence-absence of macroinvertebrates and fish.

Again the Kaipara−Kumeu River aquatic ecosystem was described as having low dissolved oxygen concentrations and elevated temperatures, which were attributable to the highly modified nature of the catchment for pastoral landuse. Poor water quality has a direct impact on the survival of aquatic species as aeration for organisms is essential for the health of the waterway. KML (2006) did not quantify or 'report card' pressures or stressors operating on the aquatic ecosystems of the rivers. With increasing stream modification and urbanisation the ecological quality of rivers and streams has decreased in the Rodney District (KML 2006). Most biodiversity was found in the upper reaches of the streams where native forest or mature exotic pine forest dominated. However, none of the Kaipara catchment sites were found to have high numbers of invertebrate species compared to other Rodney District sites, a key indicator to describe ecosystem function and health.

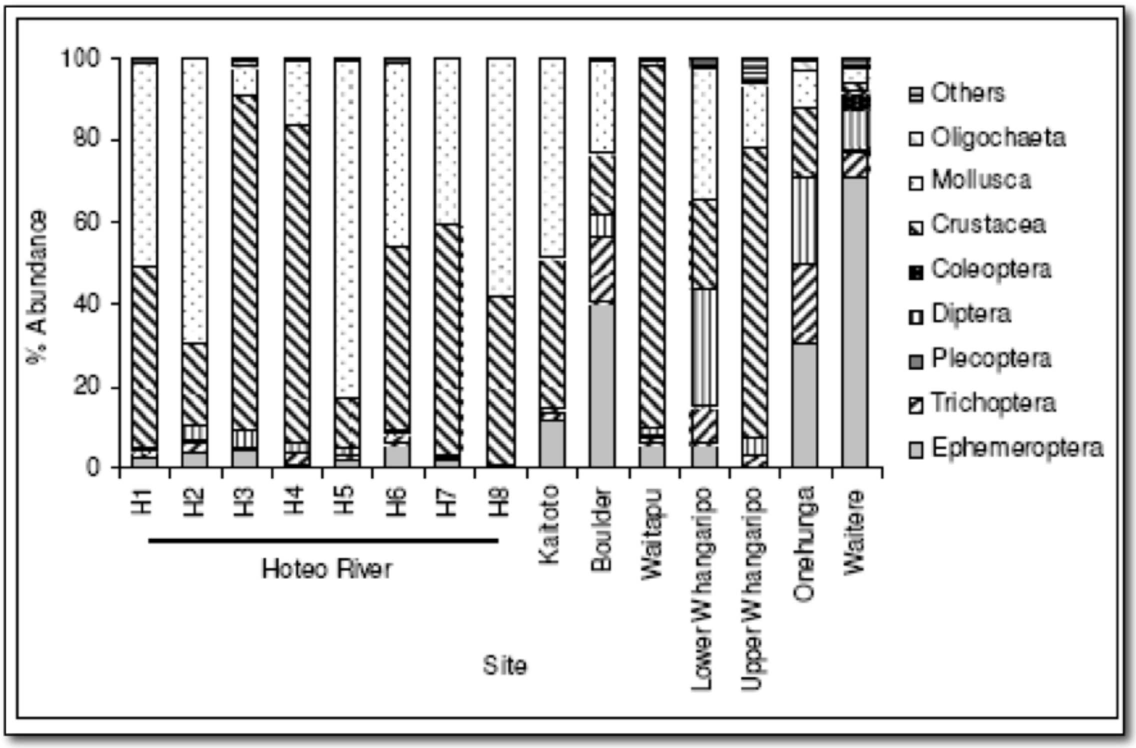
Hoteo River

The Hoteo River has the largest (375 km^2) catchment in the Auckland region, stretching its way for more than 25 km from near the east coast to drain into the Kaipara Harbour. Sampled by KML (2006), it is highly enriched with the highest water temperature (24.5 C) of monitored rivers in the Auckland region and has a significant trend over time towards decreasing dissolved oxygen saturation.

Kingett Mitchell Ltd (2006) reported on water quality, habitat characteristics, and macroinvertebrate and fish abundance at 15 sites throughout the river and catchment. Unfortunately, landcover was not recorded as part of the habitat assessment.

The Hoteo River has similar width (range 8−15m) and depth (>1.5m) characteristics throughout its length, with variability in substrate type (silt−sand, silt and gravel). Most sites sampled were dominanted by molluscs and crustaceans (Figure 28) with all sites containing the amphipod *Paracilliope sp.*. Shortfin eels (*Anguilla australis*) were the most common and abundant species recorded. Koura, crans bully and the common bully were also recorded. The pest fish species *Gamfusia affinis* was also recorded.

Figure 28. Invertebrate relative abundances for the Hoteo River and catchment sites (Source: Kingett Mitchell Ltd 2006).



9.7.3.4 FRESHWATER ECOSYSTEM MONITORING

Monitoring of the state and trend of freshwater ecosystems is carried out at a regional level for the Kaipara catchment. Both Auckland and Northland Regional Council have established longterm river water quality monitoring networks and there are thirteen sites situated in the Kaipara catchment. Details of the types of different monitoring are summarised in Table 12. Auckland region monitoring is conducted by NIWA at the Hoteo and Kaipara-Kumeu Rivers and Northland Regional Council (NRC) conduct their own Regional Water Quality Monitoring Network (RWQMN) monitoring. The objective of this RWQMN is to provide information that underpins state of the environment reporting required under s35 of the RMA (1991); assist with understanding the performance of Regional Council policy and initiatives; and assist with identification of large−scale and/or cumulative impacts of contaminants associated with different landuses.

Auckland Regional Council (ARC) has been operating a long-term water quality monitoring program in the Hoteo and Kaukapakapa Rivers for 31 years and 14 years, respectively. This is not consistent across all water quality variables such as *E. coli* and pH. The longest record is for river level and water temperature. This monitoring program is discussed in the next section.

NRC initiated monitoring of 24 sites in September 1996, ten of which are situated in the Kaipara catchment, and their status and trends were recently reported on in their State of Environment Report 2007 (Northland Regional Council 2007b).

Water Quality Guidelines used in the Kaipara for reporting and monitoring
Government has published various non−regulatory guidelines and standards since the late 1990s to help regional councils assess the quality of freshwater. These include:

a. Australian and New Zealand Guidelines for Freshwater and Marine Water Quality (ANZECC 2000). These guidelines provide 'trigger' values for lowland and upland rivers for such parameters as dissolved oxygen (% saturation), water clarity (m), turbidity (ntu), dissolved reactive phosphorus (mg/L), total phosphorus (mg/L), Nitrate−Nitrite Nitrogen (mg/L), ammoniacal nitrogen (mg/L), total nitrogen (mg/L) and pH.
b. Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (MFE 2003). Establishes suitable guideline for *E. coli* at 550 *E. coli*/100ml of sample.
c. Drinking−Water Standards for New Zealand 2005 (MoH 2005). Sets drinking water guideline of 1 *E.coli*/100ml as safe water to drink.
d. Regional Water and Soil Plans also establish guidelines, mainly using a−c above.
e. National Environmental Standard for Drinking Water. The NES is intended to reduce the risk of contaminating drinking water sources such as rivers and groundwater. This is provided for by the requirement of regional councils to consider the effects of activities across the catchment on drinking water sources in their decision−making. Previously there was no clear mandate. This came into effect on 20 June 2008 under the RMA 1991.

Status of freshwater

The Kaipara has an extensive hydrometric system monitors and records rainfall, flow, surface level, groundwater lake, saline/coastal and general water quality parameters. Table 12, 13 and 14, and Figure 29 and 30 provide a summary of monitored river flow stations in the Kaipara catchment, which varies from stream to stream and across temporal scales. Analysis of water quality data by both ARC and NRC (Scarsbrook 2007, Northland Regional Council 2007b) clearly show strong correlations between most water quality parameters and landcover characteristics. Due to the intense landuse activities, particularly agricultural or pasture landcover, within most of the Kaipara subcatchments river water quality is poor. However, rivers in catchments that have little or no farming have good water quality and meet or exceed ANZECC and/or MfE guidelines. Table 13 provides details on water quality parameters collected during the period 1995−2005 (ARC 2007, NRC 2007b), contrasted against national median parameters for 2005 and the ANZECC guidelines.

The results for Kaipara rivers are not good, with many sites not meeting ANZECC guidelines at all, which usually triggers an investigative response by Council into the threats to aquatic ecosystems. Of concern are the Mangere, Mangahahuru, Kaipara−Kumeu, and Wairua rivers.

State of Environment report on surface water quality includes freshwater rivers, lakes and streams, and concluded that none of the Kaipara catchment RWQMN sites comply with the water quality guideline range for dissolved oxygen (% saturation); Mangere river had the highest nutrient levels of all sites for 2006. NRC (2007b) stated that areas for management improvement included knowledge of freshwater biodiversity, particularly of native and pest fish.

The regional trend for Auckland region streams, which includes Hoteo and Kaipara-Kumeu River, are warming water temperatures, decreasing faecal bacteria and nutrient (NO−N, P and TP) were observed for the combined water quality dataset. The validity of this regional trend is questionable when describing the Hoteo river as the catchment has one sampling station.

Water quality trends are associated with landuse. Even though the Kaipara catchment has a rural setting, sites in urban catchments have poorer water quality than sites in forest or rural settlements (Scarsbrook 2007).

Interesting findings for flow-adjusted data for both Northland and Auckland include the strong correlation (r_s=0.72; P<0.01), and approximately linear relationship between % native forest and relative trends in suspended solids (SS). This was the same for turbidity and % native forest (r_s=0.51; P<0.05), but there were no other statistically significant correlations with other landcover categories such as % urban and % pasture.

Concerns have been noted regarding the LOWESS flow-adjustment model's performance across parameters and sites, with regard to faecal coliforms and ammoniacal nitrogen. Scarsbrook (2007) suggests using a more rigorous approach by running a series of flow-adjustment models such as log-log, General Additive Models, LOWESS, and to use the "best-fit model".

Table 12. Freshwater ecosystem monitoring characteristics of the Kaipara catchment.

Tidal (sea level)	Helensville	Northern Wairoa @ Dargaville Kaipara Harbour @ Pouto Point (NRC-NIWA)
Flow	Waiteitei River @ Sandstones Hoteo River @ Gubbs (ARC) Kaipara River @ Waimauku Ararimu River @ Old North Rd Bridge Kumeu River @ Maddrens Weir Kaukapakaupa River @ Taylors Makarau River (NIWA)	Kaihu River @ Gorge Waiotu River @ SH1 Bridge Whakapara @ Cableway Mangahahuru River @ Apotu Rd Bridge Mangahahuru River @ end Main Rd (County Weir) Mangakahia River @ Titoki Bridge Opouteke River @ Suspension Bridge Hikurangi @ Moengawahine Mangere River @ Knights Rd Waipao @ Draffins Rd Manganui River @ Permanent Station Wairua River @ Purua Wairua River @ Wairua Bridge Northern Wairoa @ Dargaville Kaipara Harbour @ Pouto Point Mangakahia River (NIWA)
Groundwater	Parakai Geothermal Aquifer Kumeu Aquifer	Ruawai Aquifer Whangarei Aquifers
Rainfall	Hoteo River @ Kaipara Hills Hoteo River @ Oldfields Kaipara South Head @ Wallers Makarau River @ Folder Hills Farm Kumeu River @ Maddrens Ararimu River @ Zanders	Opouteke River @ Brookvale Mangakahia River @ Twin Bridges Kaihu River @ Paraoe Wairoa-Wairua River @ Dargaville Awaroa River @ Ruawai Kaipara Harbour @ Pouto Point Paparoa River @ Maungaturoto Paparoa River @ Taylors Otamatea River @ Tara (telemetry) Wairua River Catchment @ Okarika Wairua River Catchment @ Puhi Puhi (telemetry) [*see Figure 29 for location of other Rainfall sites*]
Water Quality – ***Rivers –***	Kumeu River @ No. 1 Bridge (ARC) Hoteo River @ Gubbs (ARC)	Kaihu River @ Gorge Waiotu River @ SH1 Bridge Whakapara @ Cableway Mangahahuru River @ Apotu Rd Bridge Mangahahuru River @ end Main Rd (County Weir) Mangakahia River @ Titoki Bridge Opouteke River @ Suspension Bridge Manganui River @ Permanent Station Wairua River @ Purua Wairua River @ Wairua Bridge

Lakes –	Northland Lake Water Quality Monitoring Network (LWQMN) – 31 lakes in Northland sampled every 3 months. Kai Iwi Group: • Kai Iwi • Taharoa • Waikere South Head Group: • Ototoa Lake (ARC) • Kuwakatai (ARC) • Kereta (ARC)	Pouto Group: • Humuhumu • Kahuparere • Kanono • Kapoai • Karaka • Mokeno • Rotokawau • Rototuna • Wainui • Wairere • Whakaneke • Swan−Rotootuauru • Waingata
Sediment –	Kaukapakapaka River Hoteo River Kaipara River	
Recreational Bathing –	Hoteo River Kumeu River @ Kumeu	Lake Taharoa @ Promenade Pt Kaihu River Mangakahia River @ Twin Bridges Lake Taharoa @ Pump House Kaipara Harbour @ Kellys Bay Kaipara Harbour @ Tinopai Kaipara Harbour @ Whakapirau Kaipara Harbour @ Pahi
Shellfish Gathering –		Kellys Bay Tinopai Whakapirau Pahi
Coast –	Shelley Beach	Pahi Raepare Creek & Kaiwaka River Wairau-Otamatea River
Biological – Flora Only	None SOE	
Biological – Fauna Only	None SOE for fish ARC Invertebrate Monitoring Sites – Waiwhui @ Firth Hoteo River @ Kraak Hill Awarere River @ Dibble Mt Auckland Kaukapakapa River Ararimu River Kumeu	NRC Macroinvertebrate Community Index (MCI) – Mangakahia River @ Twin Bridge Mangakahia River @ Titoki Bridge (SoE) Manganui River @ Permanent Station Wairua River @ Purua Kaihu River (SoE)
Biological – Overall Habitat		NRC Habitat Assessment

Figure 29. Kaipara hydrometric and coastal monitoring sites. Name of water quality sites given.

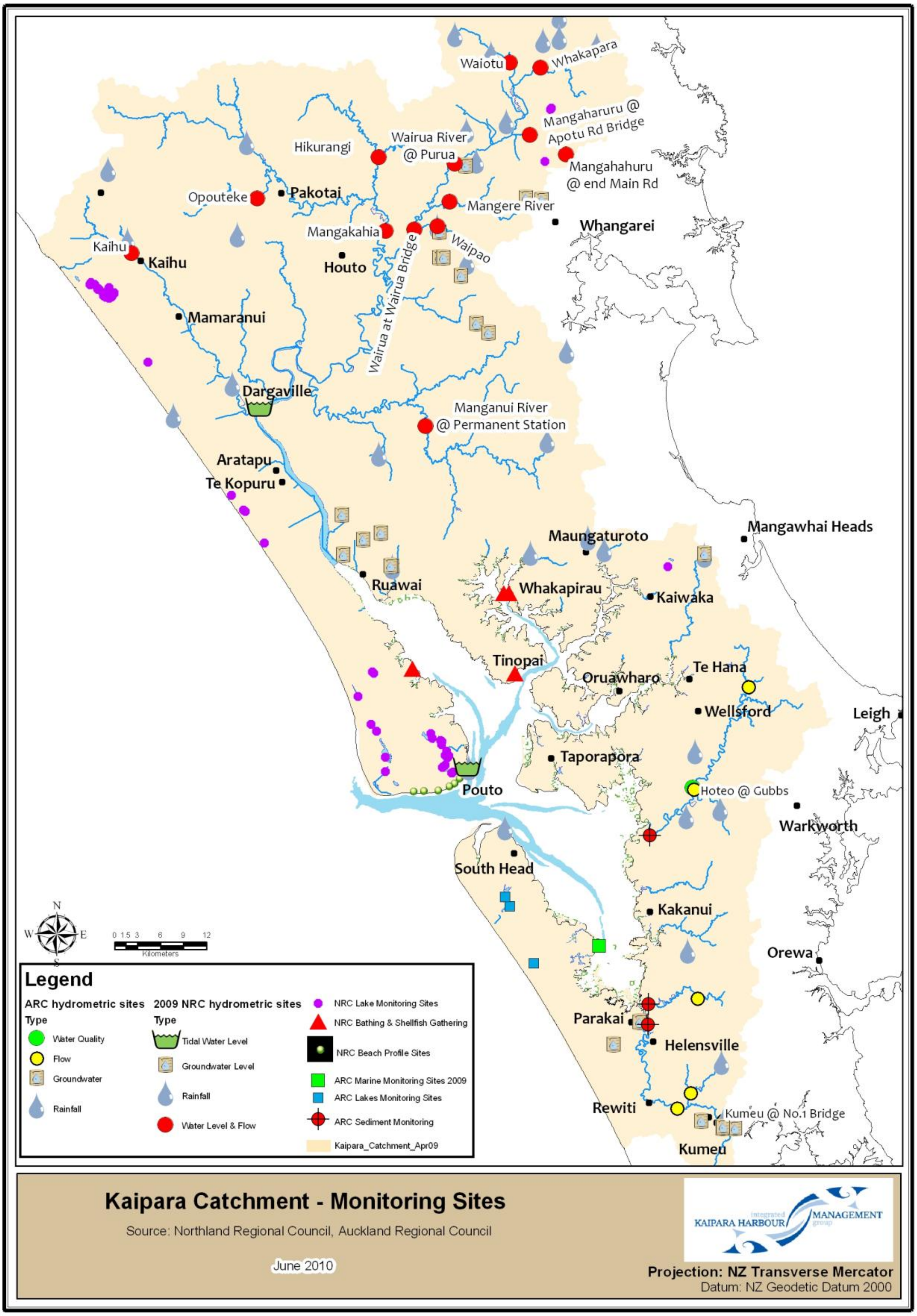
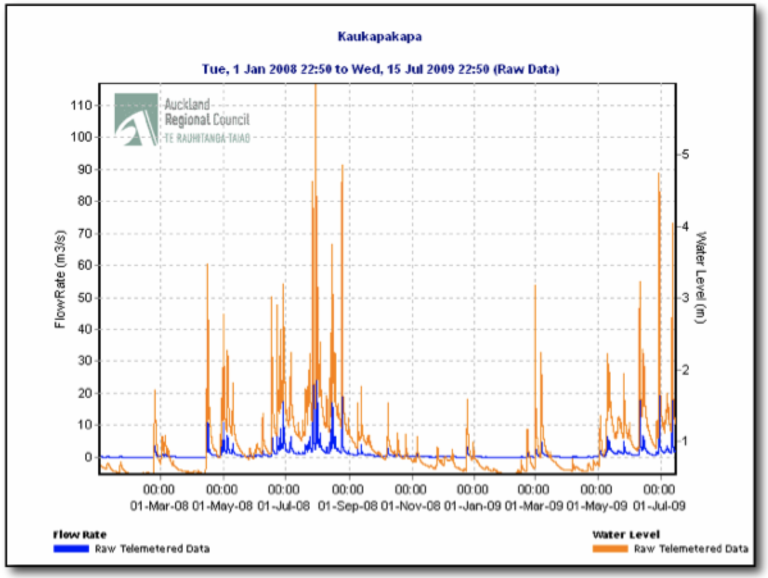
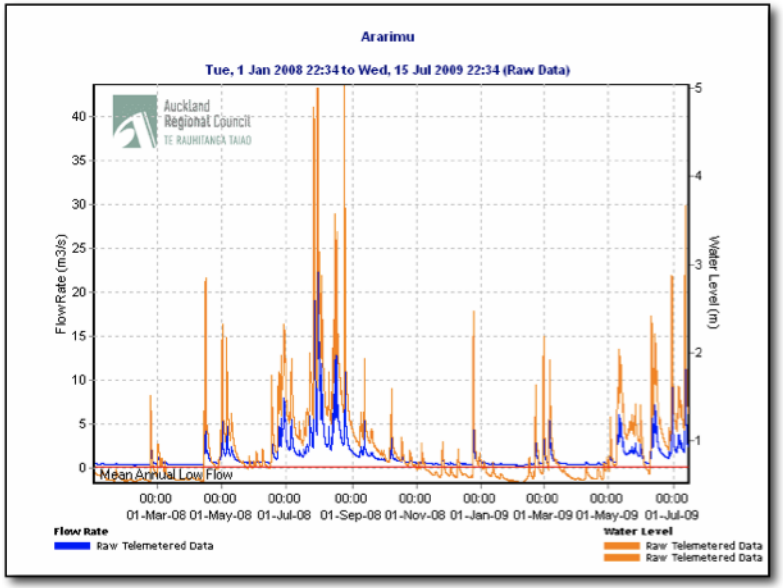
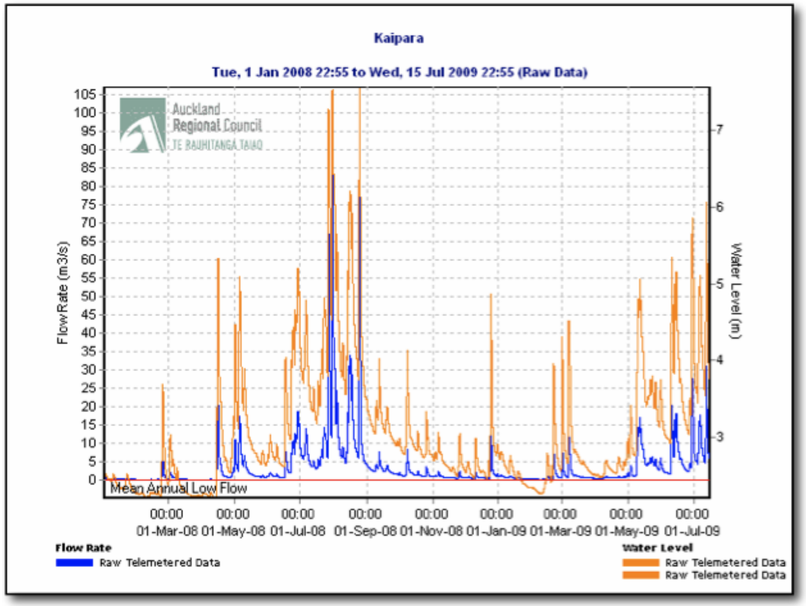


Figure 30. Examples of flow rates at monitored sites in the Auckland region. Please note differences in y−axis. Source: Auckland Regional Council website sourced July 2009







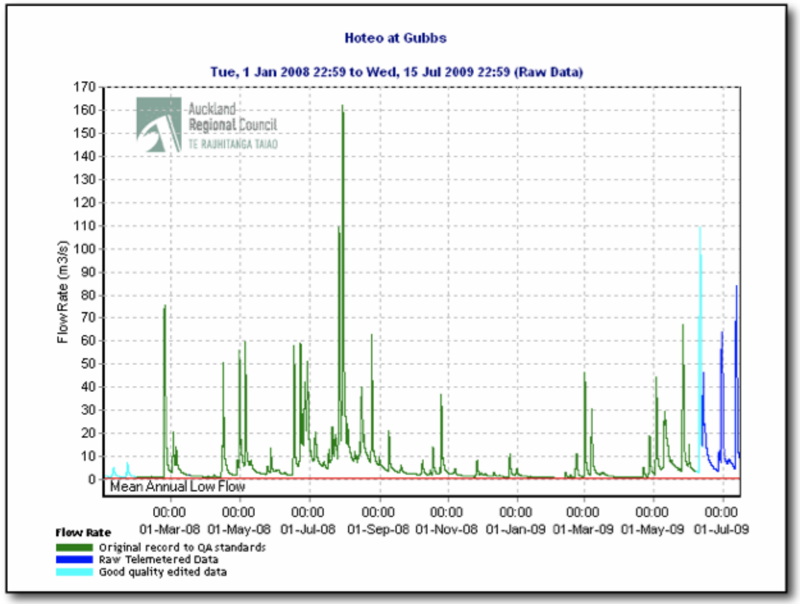


Table 13. Median values (monthly data for 1995−2005) for a range of water quality variables monitored.

(Source: ARC 2007, NRC 2007b). DO (Dissolved Oxygen), TEMP (Temperature), FAEC (Faecal Coliforms – good indicator pathogen causing bacteria usually produced from animals and humans), NH_4−N (Ammonical Nitrogen), NO_x−N (Nitrate−Nitrite nitrogen or oxides of nitrogen – product of nitrogen breaking down in the nitrogen cycle), DRP (Dissolved reactive phosphorus), TP (Total Phosphorus), SS (Suspended Solids), Turb (Turbidity), COND (Conductivity – good indicator of nutrients), CL (chloride). National Medians for 2005 are sourced from Scarsbrook (2006).

 # This site had the highest value for 2006 (NRC 2007b) ϕ This site had the lowest value for 2006 (NRC 2007b)

River	DO (%)	TEMP (°C)	FAEC (*E.coli*/100ml)	NH_4−N (mg/L)	NO_x−N (mg/L)	TN (mg/L)	DRP (mg/L)	TP (mg/L)	PH	SS (mg/L)	Turb (ntu)	COND (@ 25°C mS/m)	CL (mg/L)
National Medians 2005	101	12.9	49	0.004	0.115		0.005	0.016	7.7			9.5	
ANZECC Guideline (lowland rivers)	98−105		<550	<0.021	<0.444	<0.614	<0.01	<0.033	7.2−7.8		<5.6		
Auckland Region													
Kumeu River	8.4 (mg/L)	15.6	800	0.047	0.426		0.020	0.060	7.3	9.1	11.7	15.90	28.80
Hoteo River	8.7 (mg/L)	15.8	170	0.040	0.406		0.020	0.060	7.5	7.5	8.9	18.10	25.90
Northland Region												(mSm/cm)	
Mangaharuru@ Apotu Road Bridge	95.6	16.1	494	0.040	0.426	0.730	0.040	0.098	6.8		7.5	7.5	
Mangaharuru end of Main Road	97.6	13.9	181	0.005	0.037	0.137	0.005	0.018	7.2		3.5	3.5	
Kaihu @ Gorge	104.6	14.4	146	0.005	0.275	0.435	0.008	0.020	7.5		3.5	3.5	
Mangakahia Titoki Bridge	96.6	17.1	182	0.015	0.106	0.320	0.008	0.028	7.4		6.8	13.5	
Mangakahia d/s of Twin Bridges	106.5	16.8	180	0.010	0.064	0.261	0.044	0.072	7.4		3.6	3.6	
Manganui River	85.3	15.8	122	0.020	0.250	0.712	0.035	0.092	ϕ7.2		#8.6	8.6	
Mangere Knight Road Bridge	83.2	15.3	#561	#0.100	#0.720	#1.341	#0.110	#0.175	6.9		7.2	7.2	
Opouteke Suspension Bridge	106.9	16.8	121	0.020	0.043	0.215	0.036	0.078	7.5		2.6	2.6	
Waiotu River @ SH1 Bridge	92.3	15.5	323	0.020	0.344	0.667	0.015	0.068	6.9		5.4	8.9	
Wairua River @ Purua	89.4	17.0	111	0.041	0.470	0.828	0.023	0.075	ϕ6.8		8.8	#11.9	
Whakapara River @ Cableway	96.5	15.9	177	0.020	0.308	0.504	0.025	0.057	6.9		6.0	6.0	

Table 14. River flow data, mean and maximum, for monitored rivers that are situated in the Kaipara catchment. Data in brackets is NRC flood warning levels.

River	Median Flow (L/s)	Longterm Annual Average Flow (L/s)	Largest Recorded Water Level (m)	Location (GPS N, E)	Source:
Kaihu River @ Gorge	2,505		5.14 (2.0)	6604200, 2572500	www.nrc.govt.nz
Mangakahia River @ Titoki Bridge	13,340		13.95 (7.5)	6606800, 2605700	www.nrc.govt.nz
Wairua River @ Bridge	11,224		5.6 (3.8)	6607200, 2609600	www.nrc.govt.nz
Manganui River	2,797		8.51 (6.5)	(6581600, 2611100)	www.nrc.govt.nz
Kaipara River		2,940		(5939510, 1729150)	(Auckland Regional Council 2010)
Kaukapakapa River		1,215		(5943500, 1729000)	(Auckland Regional Council 2010)
Hoteo River		5,892			(Auckland Regional Council 2010)
Makarau River		1,009		NZTM Q10:459 150	http://edenz.niwa.co.nz/ accessed June 2009

Recreational Bathing

Recreational bathing sites are monitored to ensure rivers and streams are not contaminated with human and animal effluent, which can lead to illnesses. Sampling has been carried out during summer for the past five years in Northland. Sites monitored by NRC that are located within the Kaipara catchment include the Kaihu River, which has a very poor and unsafe record; and Mangakahia River at Twin Bridges, rated as poor. This trend is slightly worse than national, with 40−50% of sites being safe for swimming. Both Lake Taharoa (Kai Iwi Lakes) monitoring sites sampled in the 2005−06 summer were highly suitable for recreational bathing and achieved 100% compliance for *E. coli*.

Groundwater and Surface Water Quality and Allocation

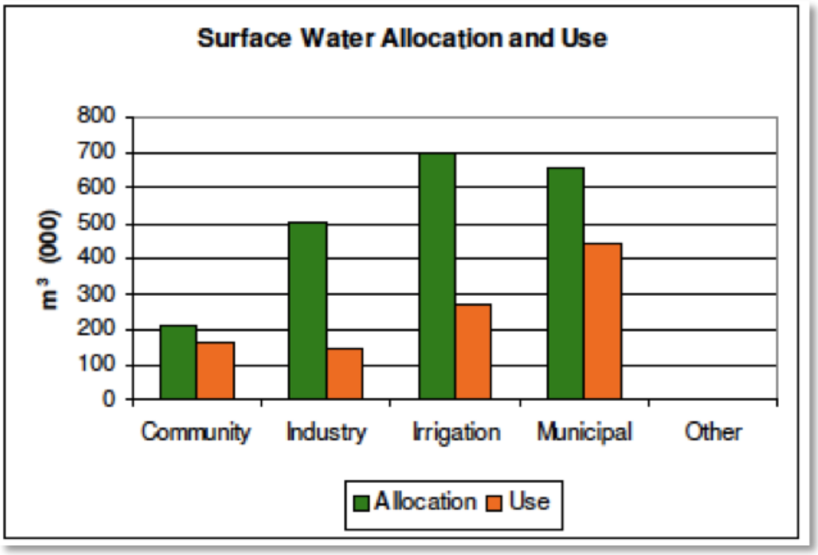
Groundwater is monitored at sixteen sites within the Kaipara catchment. Groundwater monitoring in the Auckland region includes assessments of rainfall, stream flow, groundwater level data and resource consent data with comparisons against methods identified in the Regional Air, Land and Water Plans (Auckland Regional Council 2007b). Northland Regional Council (2007c) groundwater monitoring includes groundwater level and collecting information on quality parameters such as cations, anions, *E. coli*, nutrients and minor elements such as magnesium, chloride, bromine, calcium, fluorine and iron. Northland Regional Council has carried out specific investigations of groundwater in the Ruawai and Maungakaramea aquifers. The main findings for the Ruawai aquifer investigation are included in the Northland Regional Council (2007c) report. Situated on sand lithology, this aquifer is influenced by tidal saline water and landuse activities. This shallow aquifer is linked to surface water in drains and may have water quality characteristics of the surface. The groundwater of this aquifer is used for stock and domestic town supply such as Ruawai township. The deeper aquifer is estimated to be greater than 50 years old with generally good water quality and has little chance of being contaminanted by landuse activities. However, it is a concern if artesian pressure declines due to inappropriate bore usage, as it may then be exposed to contamination. The Northland Regional Council (2007b) recommended that research be carried out using realtime bore groundwater monitoring, to assess the connection between surface and shallow groundwater water quality; and that management options be determined regarding the protection of the artesian flow regime.

Whangarei Basalt groundwater resources peaked in 1989 and 2000, and were considered at their lowest during 1992, 1994 and 2005. There are seasonal variations in groundwater levels in the Whangarei Basalt aquifers as a direct result of rainfall variations, as was seen in the winter of 2004 and 2005 when below average rainfall was recorded.

Groundwater aquifers are monitored at Parakai (near Helensville) and Kumeu. Groundwater is mainly abstracted for agricultural, horticulture, public water supply, industry and other purposes. This places large demand on groundwater resources, and understanding the cumulative effects is limited. Other than State of Environment reporting, understanding groundwater supply and condition with changing landuse, climate change and increasing demand is limited. State of Environment monitoring is carried out for groundwater to ensure the maintenance of sufficient water for present and future generations, and protecting ecosystems, natural character, and intrinsic values of water bodies.

Northland Regional Council has identified groundwater “acquifers at risk” and those that occur in the Kaipara catchment include Ruawai, Matarau, Maungakaramea, Maungatapere, Kumeu−Waitemata zone 1, 2 and 3; and Parakai Geothermal aquifer. The Proposed Auckland Regional Policy: Air, Land, and Water (PARP:ALW) plan has set a maximum availability that can be abstracted from a highuse aquifer at risk from over pumping or water abstraction; or an average minimum groundwater level. Kumeu−Waitemata zone 1 high use aquifer is currently fully allocated (Figure 31). The Parakai groundwater has large allocations for irrigation but only 10% was used during 2005−06. Other groundwater allocations including community, industry and other uses were very little used. Groundwater quality at the majority of sites monitored in Northland meets the *Drinking Water Standards for New Zealand 2005*.

Figure 31. Kumeu−Waitemata Zone 1 aquifer surface water allocation and use.



The Kaipara and Kaukapakapa rivers are highuse abstraction streams particularly the Waimauku and Kumeu streams which flow into the Kaipara River; and the Waipapakara, Whangaripo and Waititoki streams that flow into the Kaukapakapa River. Environmental monitoring is undertaken of the Kaipara River during times of high demand (i.e., summer periods) - there were 26 days below mean annual low flow during the 2005−06 (Auckland Regional Council 2007b). There are currently no monitoring sites for the Waipapakara, Whangaripo and Waititoki streams; however flow monitoring is undertaken in the Kaukapakapa River. These highuse streams of the Kaukapakapa River catchment has large surface water allocations for pasture irrigation with only 3.5% (Auckland Regional Council 2002) of this being used. Municipal water supply to Helensville is also from this catchment.

9.7.3.5 FRESHWATER FAUNA & FLORA

Our understanding of the freshwater fauna and flora of Kaipara rivers and streams is unclear, particularly their status and health. State of Environment monitoring of macroinvertebrates provides an overview of species presence, habitat quality and water quality, but currently no State of Environment monitoring is carried out for freshwater fish or birds. Resource consent applications have provided a snapshot of site−specific fauna and flora (e.g. Rodney Power Station (Golder Kingett Mitchell Ltd 2007a) and wastewater management for the Kumeu−Kaipara (Kingett Mitchell Limited 2004, 2005). Freshwater fish are managed by the Department of Conservation, particularly mudfish, dwarf inanga, dune lake galaxiids, shortjaw kokopu; and the occurrences of these fish are recorded in the NIWA managed Freshwater Fish Database[17]. Data includes the site location, species present, fishing method, abundance, size and physical description of site such as substrate type, catchment vegetation, riparian vegetation, waterway widths and depths.

[17] http://www.niwa.co.nz/our-services/online-services/freshwater-fish-database

Freshwater species that occur in the Kaipara catchment that were recorded from Protected Natural Area surveys are listed in Appendix 4. Species that have been recorded include shortfin and longfin eel, galaxids, bullies, smelt, mosquitofish (Hickey *et al*. 1991), banded kokopu, giant kokopu, shortjaw kokopu (Northland Regional Council 2007, Smale *et al*. 2009, Kingett Mitchell Ltd 2004). Freshwater fish have been recorded to occur throughout the Kaipara catchment predominantly in its main rivers (Figure 32). Over 500 records were retrieved from the New Zealand Freshwater Fish Database (NZFFD) for the Kaipara catchment.

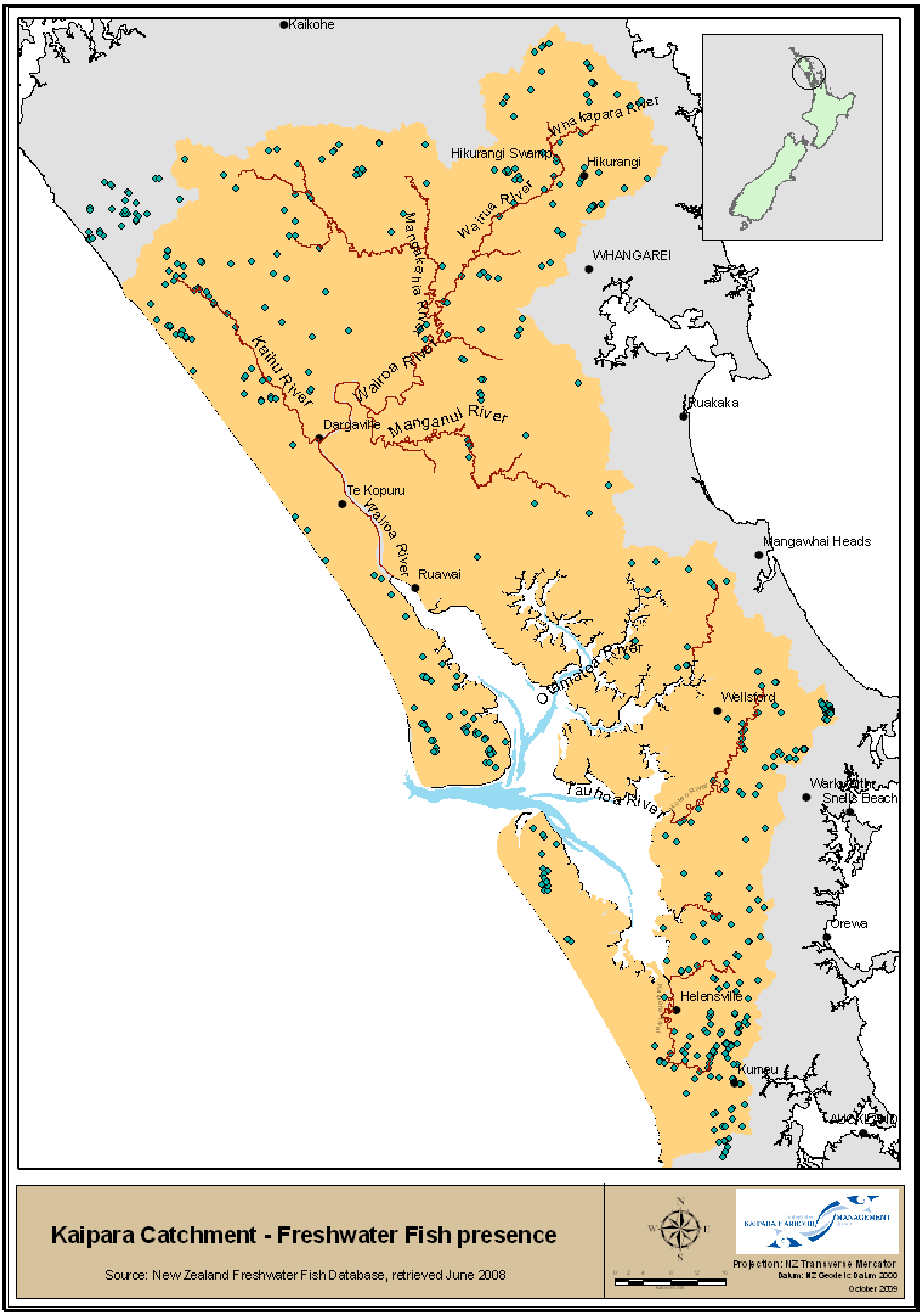
Longfin eels are found throughout streams of the Kaipara catchment but are threatened by overharvesting (especially of large females) and habitat modification. Eels are very slow growing (15−25 mm a year depending on food availability and temperature) and breed only once, at the very end of their lives, after undertaking a long spawning migration to an unknown destination in the southwest Pacific Ocean. Current status of longfin eel stocks in the Kaipara are not known but are believed to be in decline (Ministry of Fisheries 2007) (more about fisheries status in the Kaipara see Chapter Restoring Sustainable Fisheries). Eel have also been recorded in the Kai Iwi, Waikere, and Pouto dune lakes. Eel fishing for Māori is a traditional practice and a highly valued food source and was traditionally managed using rahui.

The rare and endangered endemic dwarf inanga (*Galaxias gracilis*) and whitebait (native galaxiid juveniles) have been recorded in dune lakes and Ararimu Stream (Kingett Mitchell Ltd 2004), respectively. The dwarf inanga has a restricted geographic distribution only occurring in the Kaipara north head dune lakes (Rowe & Chisnall 1997). The species found in the Kai Iwi lakes is currently regarded by the Department of Conservation as a separate species, dune lakes galaxid (Pingram 2005).

McBride *et al*. (1991) found invertebrate communities of the Kumeu-Kaipara and Kaukapakapa rivers had lower insect densities, with greater dominance of molluscs and crustacean, than similar lowland streams sites free of point source discharges. They concluded that the diffuse and point-source pollution discharges are degrading the fauna in these rivers compared to Ararimu stream (feeds into Kumeu river), which had the characteristics of a pristine lowland stream site, with mayflies, blackflies and various cased caddisflies. Ararimu Stream had fewer upstream dairy shed effluent discharges, and healthy riparian vegetation with freshwater mussels present (a indicator of good habitat quality).

OPUS (2003) undertook an ecological and water quality assessment for the Kumeu−Waimauku Structure Plan. Concerns were raised as to the high sediment and nutrient loads in the Kumeu−Kaipara River as a result of the large number of bank slips and slumps resulting in erosion. This had resulted in a higher density of emergent weeds which leads to water flow obstruction and fish passage. OPUS (2003) found that most streams were dominanted by snails (*P. antipodarum*), amphipods and shrimps (*Paratya sp.*).

Figure 32. Presence of freshwater fish species recorded by the New Zealand Freshwater Fish Database in the Kaipara catchment. Information retrieved June 2008.



9.7.3.6 EXISTING BIODIVERSITY PROTECTION

Systematic Conservation Planning

The Kaipara catchment forms most of the Northland−western freshwater ecosystem biogeographic unit (Leathwick *et al*. (2007) (Figure 33), which also includes the Hokianga and Whangapae Harbour catchments. Each unit has been classified based on similar biotic distributions, particularly those of non-diadromous fish, genetic similarity between different populations and physical disturbances such as the Last Glacial Maximum and volcanic eruptions in the central North Island. This work was developed to enhance the integrated approach to sustainable management of New Zealand's freshwater resources and the New Zealand government's commitment to protect a comprehensive and representative range of freshwater ecosystems (Department of Conservation 2000). This approach is also based on systematic conservation planning principles (Margules & Pressey 2000) using data, transparent criteria and planning processes.

Chadderton *et al*. (2004) identified the Kaihū and Manganui rivers catchments as being Type II category, with Wairau River catchment and Lake Mokeno−Wahakaneke catchment being Type I category of national importance for freshwater biodiversity. Type I waters or subcatchments are the most valuble freshwater ecosystems for sustaining New Zealand's freshwater biodiversity. These two Type I subcatchments of the Kaipara represent just over 5% of the 4,500 subcatchment units assessed across New Zealand, but contained 75% of all river classes found in New Zealand rivers environment classification. Type II subcatchments of national importance are identified because they contain sections of river, special features or populations of threatened species that are of national significance. For example, the Manganui River contains floodplain forest and has meander river classes, which the Kaihu River in its upper reaches of the Maritahi Branch, contains threatened plants.

The Northland−western unit was distinct based on biological evidence provided by the non−diadromous fish the Crans bully (*Gobiomorphus basalis*) and three species of freshwater snail, all of which are much more widespread in this unit than in the eastern Northland units. This unit is also distinctive because of the occurrence of two regionally endemic species of non−diadromous fish, the dwarf inanga, *Galaxias gracilis*; the macro−invertebrates caddisfly restricted to the west; and the short−jawed kokopu which is only present here and not the eastern unit, with the Kaipara catchment represents its most northern distributional limit.

Waters of National Importance

The Waters of National Importance (WONI) project, which is part of the Sustainable Development Program of Action for Freshwaters, being led by DoC, required the identification of water bodies (i.e. lakes, rivers, wetlands) that would protect a full range of freshwater biodiversity. This program builds on the biogeographic unit classification where by spatial conservation prioritisation techniques are used to identify candidate lists of nationally important rivers, lakes and wetlands for protection and restoration of ecosystem integrity (Ausseil *et al.* 2008; Leathwick & Julian 2008).

A candidate list of important rivers, lakes and wetlands found in the Kaipara catchment was provided by DoC (Figure 34 (river sub-catchments), Figure 35 (wetlands)).

The conservation analysis for river sub-catchments (~10km^2) was carried out at both the national and regional contexts (Leathwick & Julian 2008). Combinations of different spatial datasets were used, including: freshwater environments of New Zealand (FWENZ) classification using freshwater fish and macro-invertebrate databases; river environmental data; river pressures (e.g. spatial data of human pressures on riverine biodiversity; predications of species distributions; and rankings of importance using Zonation software.

The outputs (Figure 34) of the analysis for sub-catchments within the Kaipara catchment when considering distribution of biodiversity data, including human pressures and present protected areas, illustrates the top 10% of river sub-catchments required to restore ecosystem integrity.

The wetland assessment did not include estuarine wetlands and did not include vegetation or threatened species data, thus the classification may underestimate the full range of wetland biodiversity (Ausseil *et al*. 2008). Also, the rankings are a guide only for decision-making and results where produced at a national scale without local knowledge of conservation priorities, other socio-political, cultural and ecological drivers. The wetlands in the Kaipara catchment that deserve the most conservation effort are those with the high ranks and threatened by additional or increasing pressures (Figure 35). Wetlands found on North Head Pouto peninsula have the highest ranking followed by South Head wetlands. A high rank reflects a potential to protect both a diverse range of hydroclasses (i.e. swamp, marshes, fens) and a high proportion of what remains of each.

This spatial analysis has been developed to assist with future conservation and restoration decision-making and directing effective use of limited resources.

Figure 33. Northland−western biogeographic unit freshwater ecosystems of national importance type I and type II (Source: Chadderton et al. 2004).

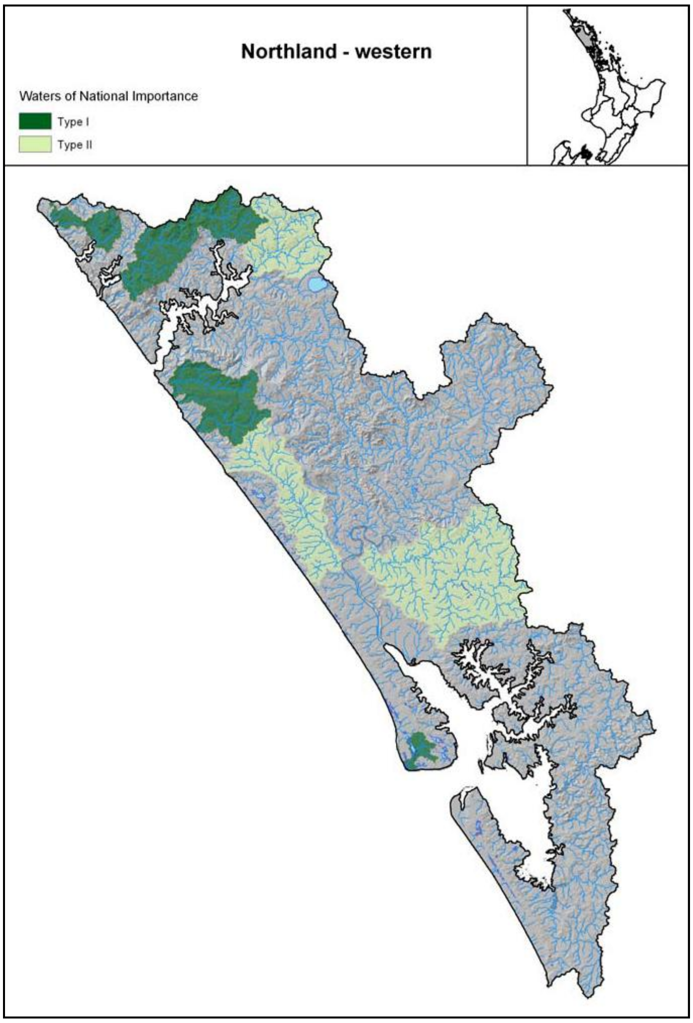


Figure 34. Waters of National Importance (WONI) for the Kaipara river sub-catchments.

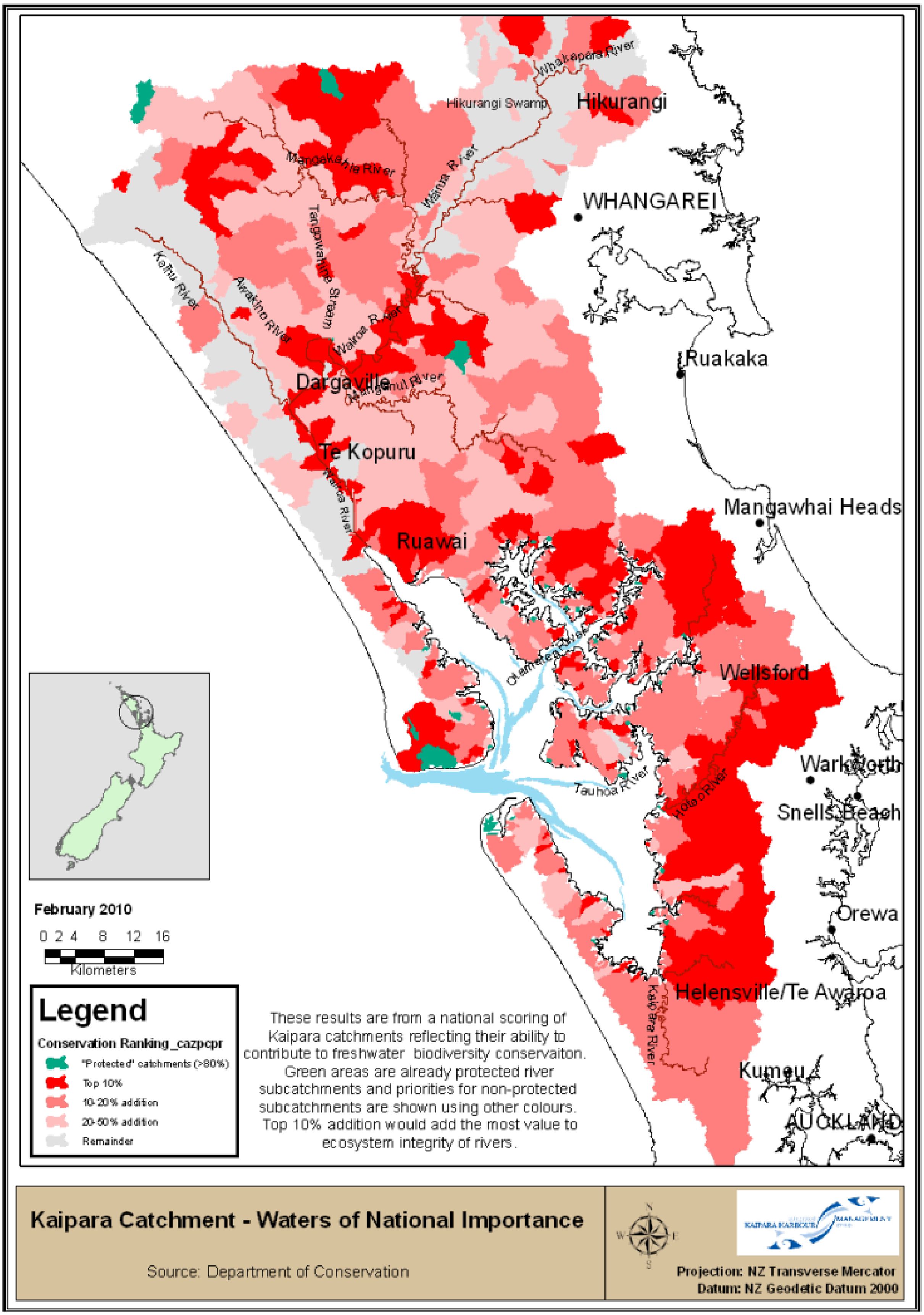
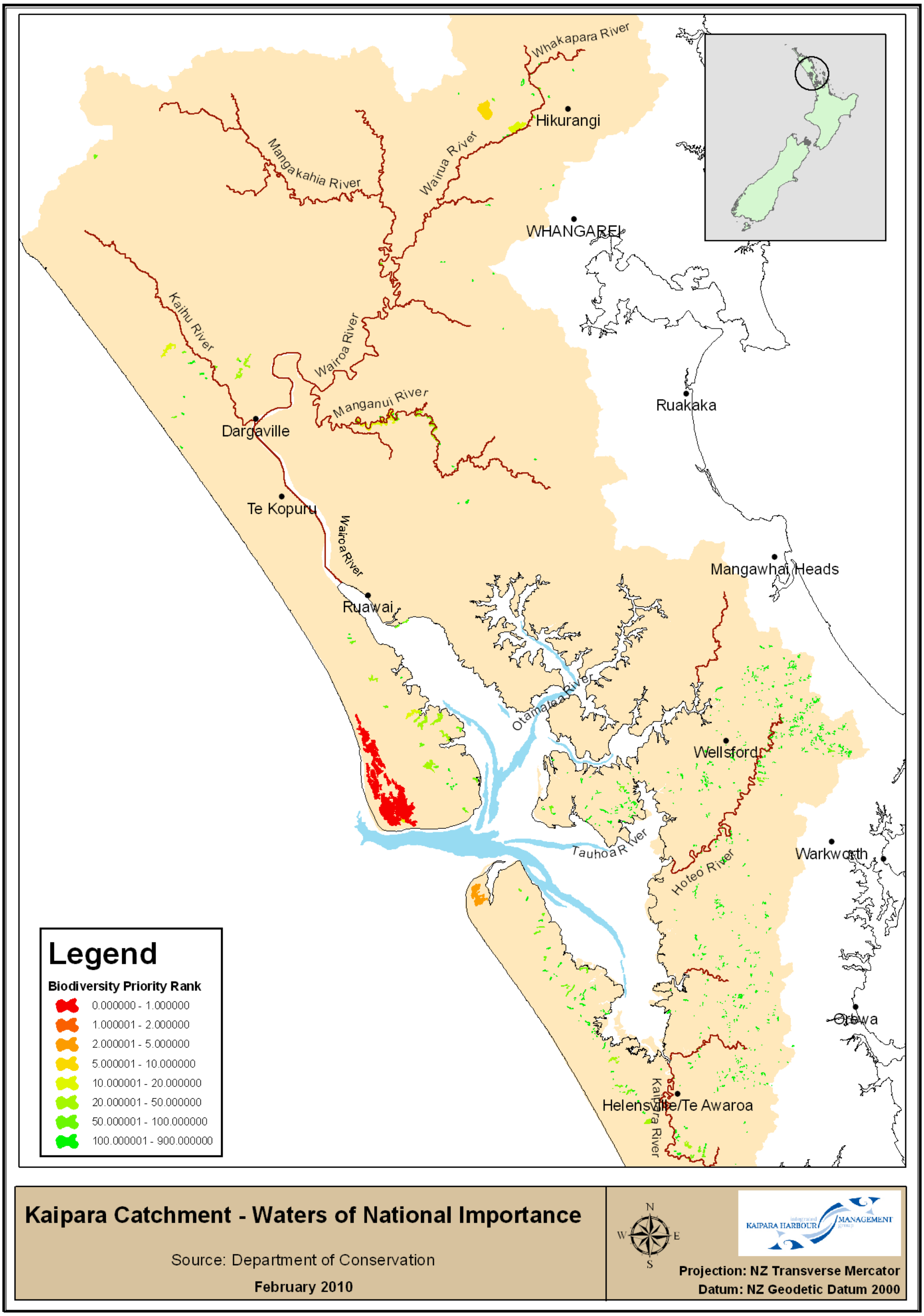


Figure 35. Waters of National Importance (WONI) for Kaipara catchment wetland ecosystems which have been ranked that would protect a full range of wetland biodiversity.

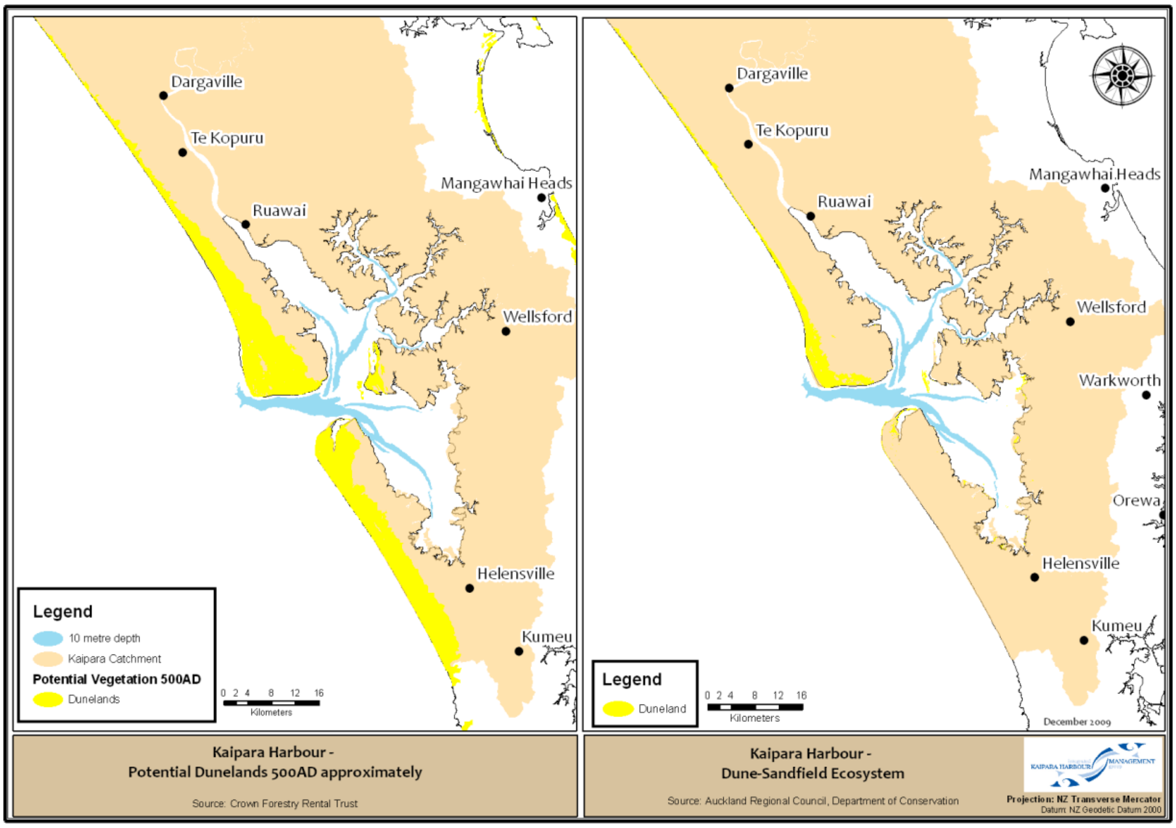


9.7.4 DUNE-SANDFIELD ECOSYSTEMS

Dune-Sandfield ecosystems are a significant ecological feature of the World of Kaipara. Found within the Kaipara Ecological District, sand dune ecosystems are nationally and regionally threatened. Up to 99% of this ecosystem has been modified with an estimated 2% remaining within the catchment (Figure 36).

The geodiversity of these ecosystems is discussed in section 9.6.3 and associated biodiversity in section 9.7.1.6 and dune lakes specifically in section 1.7.3.1 below.

Figure 36. Comparison between the current spatial extent of dune-sandfields today and at approximately 500AD.



Significant natural values

- Pouto or North Head Peninsula contains one of the largest unmodified dune-sandfield ecosystems remaining in New Zealand (~600 hectares), with regional, national and international significance. It contains a mosaic of natural landscapes: active mobile sand dunes, consolidated dunes recording earths geological past, sand flats, impounded, ephemeral and permanent wetlands and dune lakes; with patches of coastal scrub and forest.

- Pouto's dune-sandfield ecosystem rises to 214m above sea level.

- Contains nationally threatened and regionally significant species of fish and plants. Threatened birds at North and South Head peninsula include: New Zealand dab chick (*Poliocephalus rufopectus*), Australasian Bittern (*Botaurus poiciloptilus*), Brown Teal (*Anus* aucklandia) and New Zealand Dotterel (*Charadrius obscures*). At South Head (i.e. Papakanui Spit), it is home to the critically endangered New Zealand Fairy Tern (*Sterna nereis davisae*) and once the entire population overwintered on the Kaipara Harbour, but uncertain whether they still do (Smale *et al*. 2009); they have also been recorded at Manukapa Island, Taporapora dune-sandfields (pers. comm. Dr M. Bellingham, 2009).

- Threatened invertebrates include: *Notoreas* sp. 'northern', a small, brightly coloured diural moth that lives on a widespread sub-shrub of consolidated dunelands on the west coast of North Head peninsula. Its habitat is threatened by invasive weeds such as pines, berry heath and pampas (Smale *et al*. 2009). The black katipo (*Latrodectus atritus*) has also been recorded on west coast of North Head peninsula dunelands. A survey conducted by DoC in January 2008, found that black katipo densities were higher at Pouto than in most other areas surveyed in Northland (Smale *et al*. 2009).

- The chronically threatened longfin eel (*Anguilla dieffenbachia*), Giant kokopu (*Galaxias argenteus*), freshwater mussel (*Hydriella menziesii*), black mudfish (*Neochanna diversus*), and Koura/freshwater crayfish (*Parenephrops planifrons*) occur in Pouto dunelakes

- Threatened plants at Pouto-North Head include: Swamp Fern (*Thelypteris confluens*), Tuatara Plant (*Hydatella inconspicua*), Pingao (*Desmoschaenus spiralis*).

- Threatened freshwater fish Dwarf Inanga (*Galaxias gracilis*) is found at Pouto dune-sandfields.

- Old-growth forest remnants at Tapu Bush, Lake Humumumu Island and Pretty Bush at Pouto; and in small areas within Lake Ototoa catchment, which is extremely rare and highly endangered vegetation type in New Zealand (Davis 2002, Smale *et al*. 2009).

- The wetlands, ephermal and permanent, at Pouto Peninsula, contain some of the best biodiversity representation in New Zealand.

9.7.4.1 DUNE LAKES

Dune lakes are a rare ecosystem in New Zealand and are nationally significant (Williams et al. 2007), rare meaning:

> *"Originally we take to mean the ecosystem type was present when Māori arrived and still exists today (although we acknowledge our ignorance of pre−Māori ecosystems). Rare can encompass ecosystem types that are small in size (for example, 25m^2 to 100s of hectares), but geographically widespread (for example, dune deflation hollows along the New Zealand coast) to those that are larger (for example, 1000s of hectares), but geographically restricted (such as, frost flats on the volcanic plateau). Total extent would be <0.5% (that is, <134,000 hectares) of New Zealand's total area (of 268, 680 km^2)."*

Dune lakes occur along the north and south peninsulas of the Kaipara Harbour and only in the Kaipara Ecological District (Figure 37). They occur in fossil dune depressions along the western coast of Northland. Few have inlets or outlets, being fed predominantly by groundwater inflows. The origins, general features and limnology of these lakes are discussed by Cunningham *et al*.(1953) and Cunningham (1957).

There are around 44 dune lakes in the Kaipara catchment which vary considerably in their physical, chemical and biological characteristics'. Lake sizes vary from 237 ha (Lake Taharoa of the Kai Iwi Lakes Group) to 1 ha (Lake Phoebe's of the Pouto Group). The lakes are inextricably linked to their catchments. Landuse activities contribute quantities of nutrients, sediment and other pollutants to varying degree's. The run−off from the catchment can alter water quality and affect ecological diversity of the lake habitat. Nutrients, sediment and pollutants can enter the lake from point−sources such as stormwater, treated effluent or factory wastewater, or via non−point sources such as groundwater or agriculture runoff.

Most of the dune lakes exhibit accelerated eutrophication (nutrient enrichment) as a result of these sources of inputs. Lakes Ototoa, Kai Iwi and Tahoroa have the highest water quality in the Auckland and Northland region, respectively (Wells *et* al. 2006, Auckland Regional Council 2007c).

Kaipara dune lake ecosystem supports annual habitat requirements for waterbirds, particularly ducks, and the threatened New Zealand dabchick and Australasian bittern (Holland 2002). Dune lakes have been identified as protected natural area program sites (Davis 2002, Holland 2002). Other information regarding the physical and ecological characteristics of Kaipara dune lakes was compiled from:

Author	Lake	Type of Study
Auckland Regional Authority (1976)	South Head Peninsula	Characterisation of coastal physical and ecological resources of the area.
Northland Catchment Commission (1985)	Kai Iwi Pouto Dune lakes	Water resources report – hydrology, water quality. No ecological assessment.
Wells *et al*. (2006) **Northland Regional Council (2007d)**	Northland Lakes	Status State of Environment Water Quality & Ecological Monitoring
Gibbs & Spigel (2006) **Auckland Regional Council (2007c)**	Lake Ototoa Dune Lake	Status State of Environment water quality monitoring
Barnes & Burns (2005) **Auckland Regional Council (2010)**	Auckland region lakes	Status State of Environment

Gibbs (2006) reported on Lake Ototoa, assessing the limnological condition of the lake over the past 10 years. Other ecological information is reliant on the Sites of Special Biological Interest (SSBI) database. Table 15 lists the characteristics of the dune lakes located in the Kaipara Catchment.

Table 15. Dune Lakes Characteristics of the Kaipara catchment (Source: Northland Catchment Commission 1985, Barnes & Burns 2005, Gibbs 2006, Wells et al. 2006, Auckland Regional Council 2010). Lake SPI is lake submerged plant indicators.

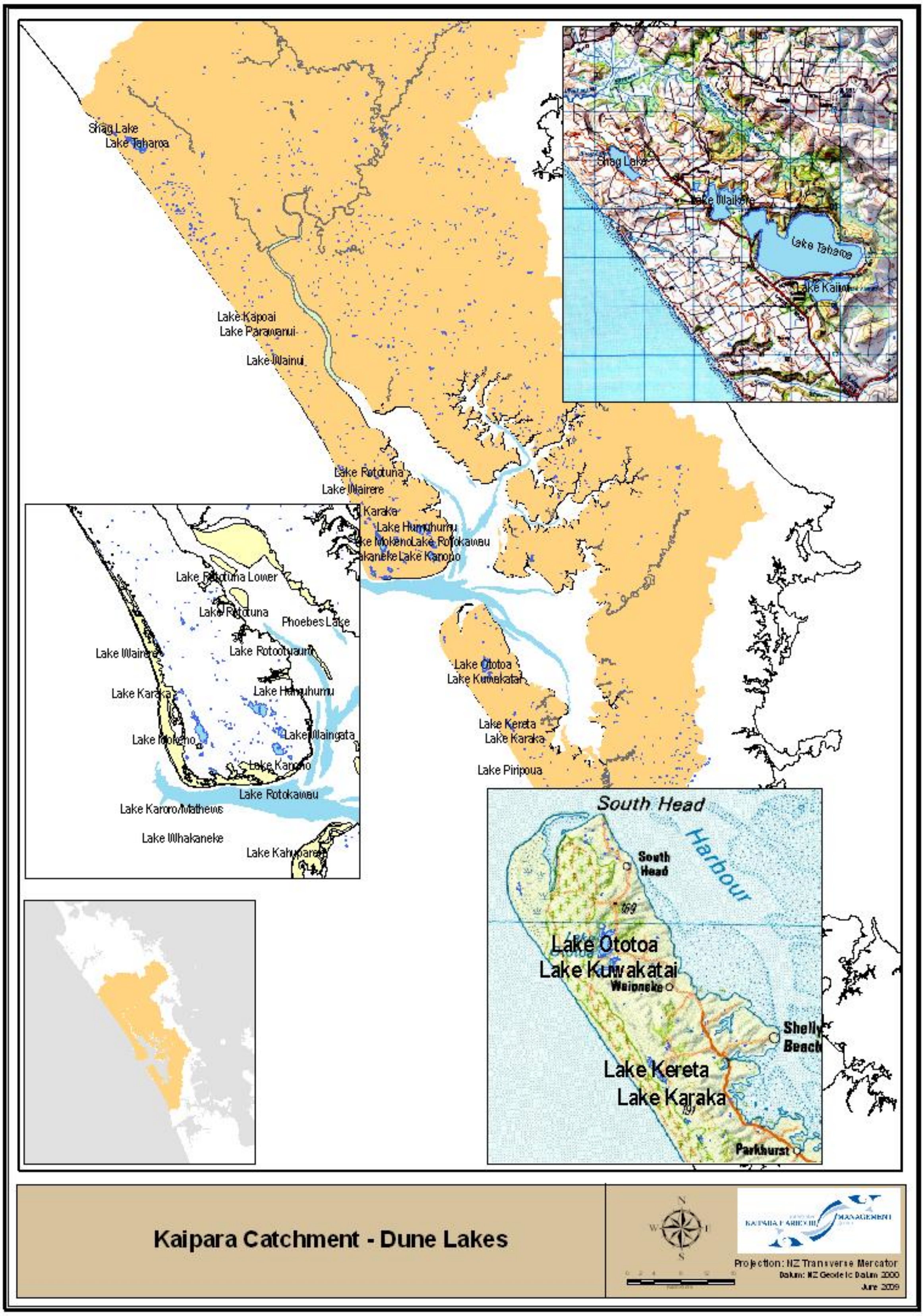
Dune Lake	Size (ha)	Approx Catchment Area (ha)	Max. Depth (m)	Native Forest/Scrub	Exotic Forest	Pasture	Urban	Ranking NIWA (2006)	Comments
Pouto Group:									
Kanono	74.4	600	15.5		x	x		Outstanding	Margin fenced. Diverse submerged & emergent vegetation with no significant weed species. Large habitat for waterbirds (black swan, scaup, dabchick, bittern, Caspian tern spotless crake), dwarf inanga, common bulies, koura, freshwater mussels
Humuhumu	139.4	423	16	x	x			Outstanding	Large, deep, clear lake; diverse biota including nationally rare plants, fish (dwarf inanga) & birds (dabchick, bittern, scaup, Caspian tern, fernbird spotless crake), with no major pest species. High risk of introduction of invasive pests & nutrient enrichment from pine plantation activities (e.g. logging, fertilizing) and pastoral land.
Mokeno	148.3		6.1	x	x			Outstanding	Large lake with native vegetation. Part of wetland−scrub−dune complex covering southwestern Pouto Peninsula. Contains nationally significant populations of endangered biota. Fish access to sea
Whakaneke	20.5		2.5	x				High	Isolated & set within indigenous vegetation & dense emergent margins, excellent bird habitat (dabchick, scaup, spotless crake, bittern, banded rail, fernbird, brown teal), but with poor submerged vegetation & water clarity.
Kahuparere	9.4	83	7.5		x	x		High	Emergent wetland vegetation rings lake. Stock access. No pest species. Poor visibility & filamentous algae covering submerged vegetation probably due to stock defecation & urine
Karaka	11.1		6	75% (flax−sedge−raupo wetland)	0%	25%	0%	High	Presence of indigenous vegetation & fauna; wetland surrounding lake contains nationally endangered plants & birds
Rotokawau	26.4	125	12	x (Shrubland)	x	x		High	Nationally rare dwarf inanga, poor emergent beds & submerged vegetation invaded *Egeria densa*. Presence of nationally endangered *Hydatella inconspicua* turf community.
Rototuna	6.6	28	5.5		x	x		High	Restoration project here. Fenced margin. Endangered biota present. Pest fish gambusia & rudd.
Wairere	16.5		2	x	x	x		Moderate−High	Isolated and set within mostly indigenous vegetation. Extensive wetlands to west of Lake. Provides excellent bird habitat – dabchick, bittern, scaup, spotless crake. No fish. Water clarity poor because of algal bloom probably because of nutrient run−off from exotic pine forestry area in the east.
Roto−otuauru −Swan	17.4	140	5.5		30%	x		Moderate	Degraded due to pest plant invasion. Presence of dwarf inanga & several threatened birds (dabchick, bittern, fernbird). Should be designated as a 'restricted place' under Biosecurity Act (1993) (NIWA 2006) before becomes algal dominated lake.
Wainui	4.8		11.8			x		Moderate−Low	Stock access. Native submerged vegetation, prone to nutrient enrichment
Kapoai	1.6		−			x		Low−Moderate	Margin fenced. No vegetation & marginal submerged. Birds include mallard, black swans, black shags, dabchick & scaup. Shortfin eel,

Dune Lake	Size (ha)	Approx Catchment Area (ha)	Max. Depth (m)	Native Forest/Scrub	Exotic Forest	Pasture	Urban	Ranking NIWA (2006)	Comments
									pest fish rudd, & goldfish.
Waingata	9	47	9.5			x		Low	Grass carp so no vegetation. Introduced in 1995 to eradicate elodea. Common bully & Dwarf inanga present. Minimal bird habitat.
Phoebe's Lake	0.9		4			x		Low	Heavily impacted by exotic submerged weed. Fenced. Manuchurian rice grass dominants lake margin, emergent vegetation. 
Parawanui	5.8	122	20			x		Low	Degraded; stock access and grazed margins. Loss of submerged vegetation
Kai Iwi Group:									
Taharoa	237	418	37	x[18]	x	x		Outstanding	Best clear−water lake with deepest submerged vegetation in North Island. Not suitable for water birds because of high recreational use of lake. Dwarf inanga. Pest fish (Gambusia, , rainbow trout)
Kai Iwi	22.6	88	16	70% (margin)	30% (margin)	x		Outstanding	Native plant dominated lake, no pest plants & presence of nationally rare plant species. Common bully but no dwarf inanga; pest fish gambusia, rudd & rainbow trout. Enrichment indicators.
Waikere	26.5	189	30	50%	45%		0%	Outstanding	Native plant dominanted. Presence of nationally rare plants (*Hydatella inconspicua*) & fish (dwarf inanga). Biggest threat is nutrient enrichment of lake from catchment landuse (e.g. pine plantation harvesting & fertilizing)
Shag	15	40	7			x		Low	Severely degraded. No emergent vegetation & limited submerged vegetation. Gambusia. Turbid water.
South Head Group:									
Ototoa	110	510	29	34%	27%	39%	0%		Highest water quality in Auckland Region. Bittern, tui, kereru, pukeko, spotless crake recorded here. Predominantly forest catchment. Broadleaf forest contains podocarps which is rare for the Kaipara ED and Auckland region. Threatened king fern also present in forest. Forest is in public conservation land. Monitored since 1988

[18] x indicates presence rather than % as indicated for the South Head Group (Barnes & Burns 2005 used LCDB2 to generate catchment vegetation composition)

Dune Lake	Size (ha)	Approx Catchment Area (ha)	Max. Depth (m)	Native Forest/Scrub	Exotic Forest	Pasture	Urban	Ranking NIWA (2006)	Comments
Kereta	32	430	1.5	18%	28%	54%	0%		Predominatly rural catchment. Bittern, tui, kereru, pukeko, spotless crake recorded here. Macrophyte vegetation monitored. Poor Lake SPI. Invasive weeds.
Kuwakatai	29	410	19	11%	4%	85%	0%		Predominatly rural catchment. Invasive weeds. Pukeko, tui, kereru, recorded here. Is one of largest shag breeding sites in Auckland. Macrophyte vegetation monitored.
Karaka									Water quality not monitored. Pukeko recorded here. Have significantly high ecological & cultural values. Rual catchment with stock grazing margins. Macrophyte vegetation monitored. Not vegetated. Water quality poor.
Te Kanae									Macrophyte vegetation monitored. Invasive weeds. Poor Lake SPI.
Poutoa									Pukeko recorded here. Macrophyte vegetation monitored. Excellent Lake SPI for macrophytes.
Paekawau									Tui, kereru recorded here. Macrophyte vegetation monitored. Non-vegetated with poor water quality.
Okaihau									Good waterfowl habitat. Stock grazing to margins. Macrophyte vegetation monitored. Invasive weeds and poor Lake SPI.

Figure 37. Dune lakes of the Kaipara catchment.



Significant ecosystem values

Significant ecosystem values include:

- Dune lakes are a rare ecosystem in New Zealand: Papakaunui Spit and Waionui Lagoon; and Pouto North Head lakes.
- Dune lakes and dune-sandfield wetlands of both South and North Head are considered Waters of National Importance.
- Papakanui Spit and Waionui Inlet is one of very few lakes to have non-pastoral catchment.
- Lake Ototoa, on South Head, has one of the highest water qualities of all lakes within the Auckland region and Kaipara Ecological District. The dune lake(s) across the catchment that has the highest water quality are the Kai Iwi Lakes.
- Pouto Peninsula lakes are important habitat for dwarf inanga (Serious Decline), a small freshwater fish species which is endemic to Pouto and is considered New Zealand's rarest native fish (Rowe & Chisnall 1997).
- Pouto dune lakes form two complexes: southeast complex and southwest complex.
- Pouto dune lakes provide habitat for a number of threatened plant, bird and crustacean species (Holland 2002) and many of these species are dependent on these dune lakes for their persistence. For example *Hydatella inconspicua*, is only found in dune lakes in New Zealand, and *Thelypteris confluens* centre of abundance is Pouto dune lakes. The abundance of these threatened species continues to decline (Holland 2002).

Monitoring

Lake water quality has been routinely monitored quarterly in the Auckland Region since 1988 (Barnes & Burns 2005). A review of the Auckland Region lakes monitoring program was also undertaken in 1999 by Gibbs *et al.* (1999). The Lake Water Quality Monitoring Network was established for Northland in 2005−06 where lakes from the Kai Iwi Group and Pouto Group are monitored four times a year. Monitoring of water quality is consistent with the New Zealand Lakes Water Quality Monitoring Program (Burns *et al*. 2002). Parameters measured include secchi disk depth (water clarity), chlorophyll−a (algal biomass), temperature, dissolved oxygen, pH, suspended soilds (total and volatile), total nutrients (phosphorus (TP) and nitrogen (TN)) and dissolved nutrients, including dissolved reactive phosphorus, organic phosphorus, nitrate nitrogen, ammoniacal nitrogen and organic nitrogen.

The life supporting capacity of a lake can be estimated using the Trophic Level Index (TLI) (Table 16) which is estimated for all dune lakes monitored in the Kaipara catchment, across regions. The four variables that are used to obtain the trophic level of a lake are secchi disk depth (m), chlorophyll−a (mg/m^3), TP and TN (Burns *et al.* 2002).

Table 16. Values of key variables which define the boundaries of different trophic levels and types.

Lake Type	Trophic Level	Chl−a (mg/m^3)	Secchi Depth (m)	TP (mg P/m^3)	TN (mg N/m^3)
Microtrophic	<2.0	<0.82	>15	<4.1	<73
Oligotrophic	2.0−3.0	0.82−2.0	15−7.0	4.1−9.0	73−157
Mesotrophic	3.0−4.0	2.0−5.0	7.0−2.8	9.0−20	157−337
Eutrophic	4.0−5.0	5.0−12	2.8−1.1	20−43	337−725
Supertrophic	5.0−6.0	12−31	1.1−0.4	43−96	725−1558
Hypertrophic	6.0−7.0	>31	<0.4	>96	>1558

Lake SPI (Submerged Plant Indicators) is measured every five years in the Northland Lake Monitoring Network which assesses the ecological condition of a lake or how close a lake is to its potential un−impacted state (provided in a percentage, the closer to 100% the less impacted and more pristine the lake). Wells *et al*. (2006) provides a baseline of the Lake SPI for 65 lakes in the Northland region, which includes the dune lakes of the Kaipara catchment. Information is collected on wetland vegetation descriptions, fish, bird and invertebrate observations.

Lake Waingata is the only lake in the Kaipara catchment being ecologically monitored. From 2004, Lake Ototoa has been surveyed for aquatic weeds. Table 17 provides a list of what lakes are monitored in the Kaipara catchment; of the 44 dune lakes in the Kaipara, 17 (38%) are monitored.

Lakes chosen for monitoring best represents the various influences of landuses on water quality, and are representative of the region as a whole (ARC 2006).

Lakes Ototoa, Kai Iwi and Taharoa have the highest water quality in the Auckland and Northland region. Ototoa and Kai Iwi are moderately enriched (mesotrophic) with Whakaneke being the most degraded lake. Most other lakes are showing evidence of eutrophication (Northland Regional Council 2007d), meaning they have high nutrient, and algae levels, and poor sediment and water quality.

Barnes & Burns (2005) found that Lake Ototoa water quality was deteriorating when parameters were compared to 1995, 2004 and 2005. This led to a detailed limnological assessment of Lake Ototoa to determine its recent condition (Gibbs 2006). Ototoa Lake SPI was estimated by de Winton *et al.*(2005) which showed that the lake was in good condition and had not changed in 17 years.

Table 17. Trophic Status for the Kaipara catchment dune lakes as of 2005−06 State of the Environment reporting by Auckland Regional Council and Northland Regional Council.

(Source: Northland Regional Council 2007d, Auckland Regional Council 2007c). M = Mesotrophic, S=Supertrophic, E=Eutrophic, O=Oligotrophic

Monitored Lake	2005−06 Trophic State	2006−07 Trophic State	Change in Trophic State (+ positive change; − negative change)	Comments
South Head Group:				
Ototoa	M	M		
Kuwakatai	S	S		
Kereta	E	S		
Kai Iwi Group:				
Kai Iwi	M	M		
Taharoa	O	O		
Waikere	M	O	+	
Pouto Group:				
Humuhumu	E	M	+	
Kahuparere	E	E		
Kanono	E	E		
Kapoai	S	H	−	
Karaka	E	E		
Mokeno	E	M	+	
Rotokawau	M	M		
Rototuna	E	E		
Wainui	E	E		
Wairere	S	S		
Whakaneke	H	S	+	
Swan – Roto−otuauru		M		Irregular monitoring
Waingata		S		Irregular monitoring
North Peninsula Group:				
Parawanui		H		Irregular monitoring

9.7.4.2 WETLANDS

Wetlands are precisely that: wet lands. They usually have poor drainage or are areas where water accumulates; interfaces where land meets stream, rivers or lakes and estuaries; and can be freshwater, brackish or saline. Wetlands are areas permanently, periodically or intermittently covered in water. The definition varies. The RMA (1991) identifies "Wetland" as permanently or intermittently wet areas, shallow water and land water margins that support a natural ecosystem of plant and animals that are adapted to wet conditions. The Ramsar Convention on Wetlands, signed in Ramsar Iran in 1971, identifies wetlands as "areas of marshland, fen, peatland or water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.'

A wetland classification has been developed for New Zealand wetlands primarily based on wetland function (Johnson & Gerbeaux 2004). This was produced to facilitate international reporting under the Ramsar Convention and state of environment reporting under the RMA (1991).

Wetlands are a threatened habitat type in the Kaipara catchment, Northland and Auckland regions. Kaipara catchment currently has 0.2% freshwater wetlands and 5.6% estuarine ecosystems significantly intact and considered natural. According to the wetland type classification of Johnson & Gerbeaux (2004), the Kaipara contains four types at the broad hydrosystem level, which is based on hydrology and landform (Table 18).

Table 18. Wetland types and classes based on Johnson & Gerbeaux (2004).

Hydrosystem	Wetland Class
Estuarine	Marsh
Lacustrine	Swamp
Palustrine	Epemeral wetland
	Saltmarsh
	Fen
	Shallow water
	Gumland

Raupo wetland is widespread throughout the Kaipara ecological district as lacustrine fringes of natural lakes and man−made farm ponds (Smale *et al*. 2009).

The total area of the Kaipara Harbour is 94,700 ha containing various wetland types. This includes: permanent shallow marine waters, in most cases less than six metres deep at low tide; intertidal mud and sandflats; intertidal marshes; includes saltmarshes, salt meadows, saltpans, raised saltmarshes, tidal brackish and freshwater marshes; and intertidal forest wetlands and mangrove swamp.

Significant wetland areas of the Kaipara include:

• Omamari Government Purpose Wildlife Management Reserve and surrounds (177.5 ha)	Largest remaining wetland in the northern part of the Kaipara. Extremely important site (Smale *et al*. 2009) for its size, diversity, intactness, presence of threatened and regionally significant species. Contains 59.1 ha of Acutely Threatened land environments.
• Maitahi Wetland Scientific Reserve and surrounds (323 ha)	Most significant mesotrophic−oligotrohpic wetland remaining in Northland because of its size, intactness, range of wetland types that it supports. Contains largest remaining gumland remaining in the Kaipara ecological district.
• Atuanui Conservation Area (607ha)	Is the largest area of indigenous forest left adjoining the harbour
• Papakanui Stewardship Area (1,113.5 ha)	One of the largest relatively unmodified coastal sand dune systems left in New Zealand and a key breeding sites for a number of coastal bird species, including two endangered and one threatened species.
• Ōkahukura Stewardship Area & Taporapora Wildlife Management Reserve (1,320 ha)	Significant bird breeding and roosting areas
• Tauhoa Scientific Reserve (301 ha)	Contains 75% mangroves in Kaipara Harbour and contains associated saltmarsh and saltmeadows.
• Pouto Peninsula (6,000 ha)	Pouto wetlands are particularly good representative examples of freshwater sand dune lakes and swamps, ephemeral wetland characteristic of Northland. Contains threatened and endemic plant and bird species. Special habitat to waterfowl at critical stage in their lifecycle.
• Taporapora Big Sand Island	Significant breeding areas.
• Rat Island	Significant breeding areas.
• Moturemu Island	Last wild population of kakabeak and significant colony of oi or grey−faced petrel.

Disturbances and threats

Threats to these habitats include: ongoing overgrazing of wetland vegetation around the margins of the wetland; pest plants and animals; eutrophication from fertiliser application on farmland; and the influence of pine plantations on surrounding wetlands and their water levels particularly dune lake wetlands and freshwater wetlands.

Past and Current Wetland Research in Kaipara

Hydrological, archaeological, botanical, chemical and ornithological studies have been carried out throughout all wetland types of the Kaipara, particularly the sand dune lake wetlands at Pouto and South Head peninsulas (Irwin *et al.* 1978; McKenzie 1980; Ogle 1982; Tanner *et al.* 1986; Kokich 1991).

Kaipara Harbour A Wetland of International Significance
Ramsar Nomination

Developed by Te Uri o Hau, Ngati Whaata o Kaipara Nga Rima and Royal Forest and Bird Society

A nomination for the Kaipara Harbour to be designated a Coastal Wetland of International Importance under the Ramsar Convention is in its final stages before being presented to the Department of Conservation so they can present it to the Convention – correct title is *Convention on Wetlands of Internaitonal Importance especially as Waterfowl Habitat*.

New Zealand currently has no direct supporting legislation for the Ramsar Convention and has only gazetted 5 Ramsar sites compared to over 56 in Australia and 162 in the United Kingdom.

Kaipara Harbour is already unofficially considered internationally significant for its birdlife. Over 150,000 migrant waders visit New Zealand most of which pass through the Kaipara to other parts of New Zealand, but about 35,000 remaining in the Kaipara.

Article 2.2 of the Convention states that wetlands should be selected for their "international significance in terms of ecology, botany, zoology, limnology or hydrology". The Kaipara Harbour meets the following nomination criteria:

1. Criterion 1 – contains representative, rare or unique example of a natural or near-natural wetland type.
2. Criterion 2 – wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
3. Criterion 3 – wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biodiversity of a particular biogeographic region.
4. Criterion 4 - wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
5. Criterion 5 - wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds
6. Criterion 6 - wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
7. Criterion 7 - wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biodiversity.
8. Criterion 9 - wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

9.7.5 ESTUARINE, COASTAL & MARINE ECOSYSTEMS

The Kaipara is New Zealand's largest estuarine ecosystem and is considered the second largest in the southern hemisphere. At 947 km^2 and a shoreline of 3,500km, the Kaipara is the receiving environment of a massive catchment area of 641,600 hectares (Figure 38). Further details of the Kaipara's geological formation are discussed in section 9.6.3 and in Haggitt *et al*. (2008).

Although estuaries are considered short−term features of the landscape on a geological timescale, they are often highly productive areas that play important roles at the boundary between land and sea. They provide a link between terrestrial and marine ecosystems, and nourish the marine food web (Gillespie 1983).

Due to their position at the foot of catchments, on the coastal interface, estuaries are dynamic, complex and variable environments. New Zealand estuaries, in particular, are generally characterised by extensive intertidal zones, (in this case, 40% of the Kaipara estuary is intertidal flats); that provide productive, high−value habitat for a variety of plant (e.g. mangrove, saltmarsh, seagrass) and animal (e.g. fish, shellfish, waterfowl) species. Estuaries and their resources are also highly valued in human terms. They often provide transportation arteries and accessible locations for a wide variety of recreational pursuits, particularly fishing and shellfish gathering.

Status of Information

Northland and Auckland Regional Councils commissioned a joint review of environmental information on the Kaipara coastal marine environment, being the coastal marine area (CMA), active coastal zone and landward component (Haggitt *et al.* 2008). The study determined the current state of the harbour, assessed threats, identified knowledge gaps, and examined synergies and gaps in existing environmental monitoring programs. The physical environment (water quality and physical oceanography), intertidal and subtidal benthic habitats and communities, fish and fisheries, coastal birds, and coastal vegetation were included in the study.

The main findings of the report were:

- The Kaipara Harbour is an extremely important ecological system that is home to many high value species, communities and habitats which provide important ecosystem services and functions across all scales (local, regional, international).
- Environmental values have been, and continue to be degraded.
- More environmental information exists for the southern Kaipara Harbour (compared to the Northland region) (Figure 39 and 40).
- Limited information on marine mammals and fish distributions and utilisation for entire Harbour
- Information on habitat quality is variable in coverage, quality and temporal patterns.
- Cumulative impacts of Resource Management Act activities (such as, aquaculture, sand extraction, tidal energy generation) at an individual and in combination scales with other activities managed under other legislation (e.g. Fisheries Act,

Crown Minerals Act, Marine Reserves Act). Very little understanding exists regarding the scale and magnitude of individual effects due to the difficultly in isolating and quantifing their effects. Thus, it is not possible to reliably quantify the cumulative effects of multiple activities, although many activites (current and future) have the potentialt ocause large-scale cumulative impacts. This is a significant knowledge gap creating a barrier to integrated ecosystem-based management.

- Lack of knowledge regarding areas that require protection and conservation due to their ecological significance and contribution to persistence of biodiversity at the harbour and eco-region (i.e. the wider North Island west coast eco-region) scales.
- Effects of large-scale energy generation from tidal power.
- Aquaculture carrying-capacity of the harbour.
- Effects of fishing are significant because of a combination of sustainability limits, habitat degradation, demographic changes and other indirect impacts to grey mullet, school shark, rig and scallop.
- State of Environment monitoring of water quality, recreational bathing and shellfish gathering is not integrated and varies temporally and spatially. Avaliable data suggests that water quality is poor in many areas.
- No temporal, harbour-wide ecological monitoring is undertaken proving difficult to understand the true state of ecosystem health and integrity.
- Fisheries assessments are undertaken for target species but not at a consistent temporal or spatial scale. Information on habitats important to fishery species (e.g. snapper, trevally, grey mullet, flounder, rig, school shark, kahawai) is also very limited considering the significant role the Kaipara Harbour plays in the wider North Island West Coast SNA 8 commercial fishery, and quite possibly other fisheries.
- Many critical knowledge gaps which impede effective resource management and biodiversity persistence. Haggitt *et al*. (2008) outlined these as: effects of large-scale energy harvesting (i.e. tidal power generation), scale and magnitude of sediment impacts on the Kaipara Harbour (direct and indirect); areas that require proteciton for a variety of seabird species, fish and critical habitats; effects of sand extraction on sediment-transport processes operating in the entrance; uncertainity about the volume of sand arriving into Taporapora banks and amount extracted; spatial and temporal scale of sedimentation patterns with mangrove expansion.

Significant natural values

Significant natural values of the Kaipara estuary and coastal-marine area include:

- Critically important nursery ground for recreationally and commercially important fish species. It has been found that the Kaipara harbour contributes the majority of snapper recruits to the adult fishery on the West Coast North Island.

- It is within the home range of the critically endangered Maui dolphin (*Cephaloryhnchus hectori maui*) and the protected Great White Shark (*Carcharodon charcharias*) or White Pointer (which the kaipara is also a nursery ground).

- Internationally important for supporting vulnerable, endangered or critically endangered species and threatened ecological communities. The Kaipara regularly supports more than 20,000 migratory wading birds from the northern hemisphere (Alaska, Russia, China, Japan and Korea) and from within New Zealand. The extensive sandy tidal flats around the entrance and south-eastern part of the harbour together with the open muddy tidal flats in the northern arms of the harbour is the habitat for these migratory and resident wading birds (Royal Forest & Bird Protection Society Inc *et al.* 2008).

- Presence of the rare marine habitat, *Zostera* seagrass meadows found in intertidal and subtidal sandflats, particularly in the southern Kaipara harbour (Figure 41). Seagrass surveys have yet to be conducted in the entrance or northern Kaipara. Both intertidal and subtidal seagrass meadows are considered to be important for juvenile snapper recruitment within the harbour.

- Within the southern Kaipara Harbour there are a number of taxa (e.g. sponges, ascidians, bryozoans, pipi, hydroids, echinoderms) which are commonly associated with pristine environments (Hewitt & Funnell 2005).

- High biologically diversity areas found in the entrance and South Head region (i.e., subtidal H, Figure 39)

- Largest natural spat producing area for pacfic oyster and quite possibly green-lipped mussel.

- Largest estuarine ecosystem in New Zealand and the southern hemisphere.

- The highly dynamic sand transport and movement system operating between the Kaipara Harbour and adjacent coastline forming the large ebb tidal delta at the entrance to the Kaipara. It is believed that the number of safe passages into the Kaipara varies between 3-7.

Existing Protection

There are currently no protected areas within the Kaipara harbour in depths greater than 1.5m and priorities for protection in intertidal and subtidal areas of the Kaipara Harbour have not been identified to the same extent to which they have been conducted for the Ecological Districts of the Kaipara catchment. Further investigation on assessing what areas of the Kaipara Harbour deserve protection is required to ensure biodiversity persistence and halt the decline.

Figure 38. Bathymetry (depth) of Kaipara Harbour.

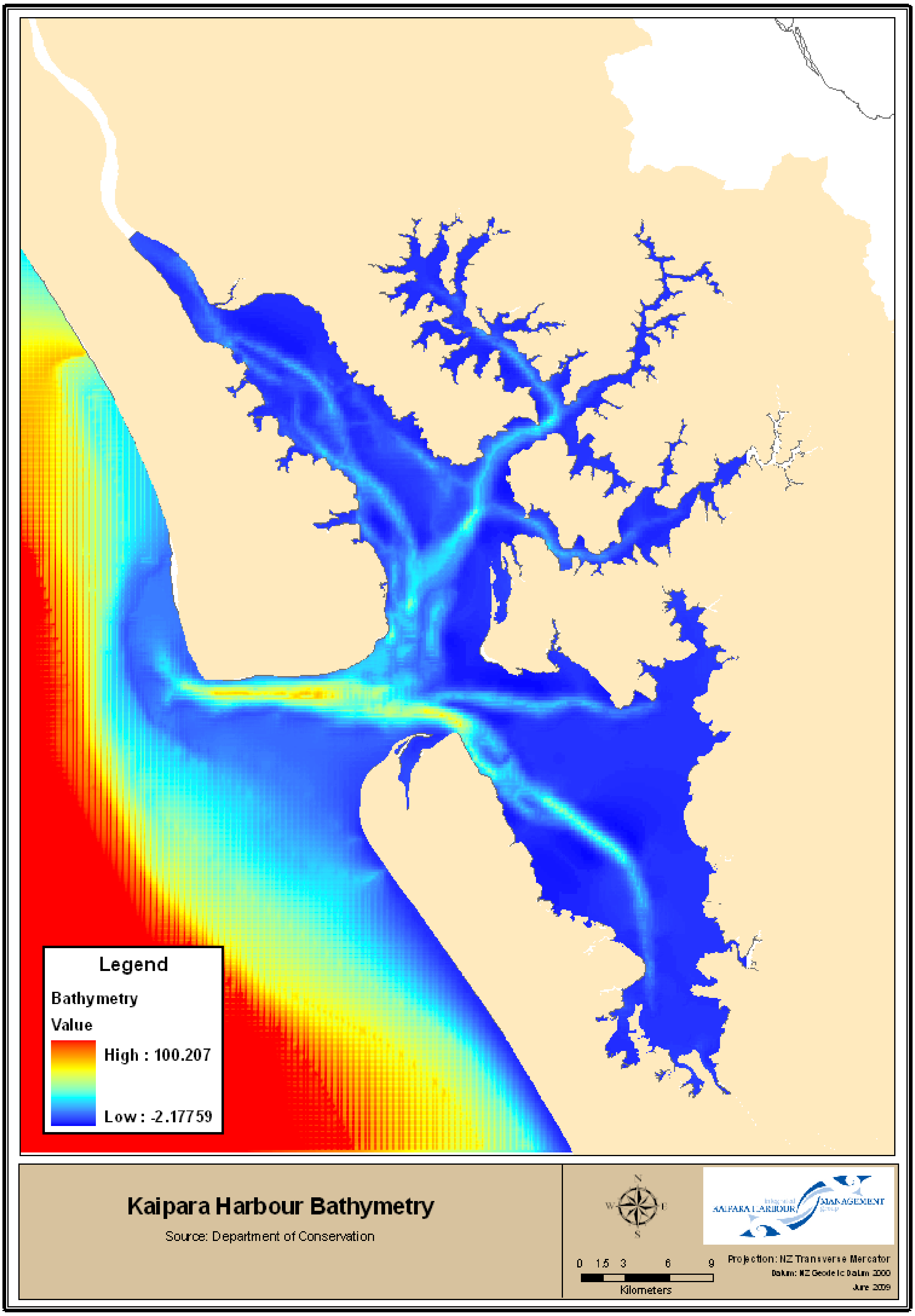


Figure 39. Marine habitats described for the southern Kaipara Harbour (Auckland region).

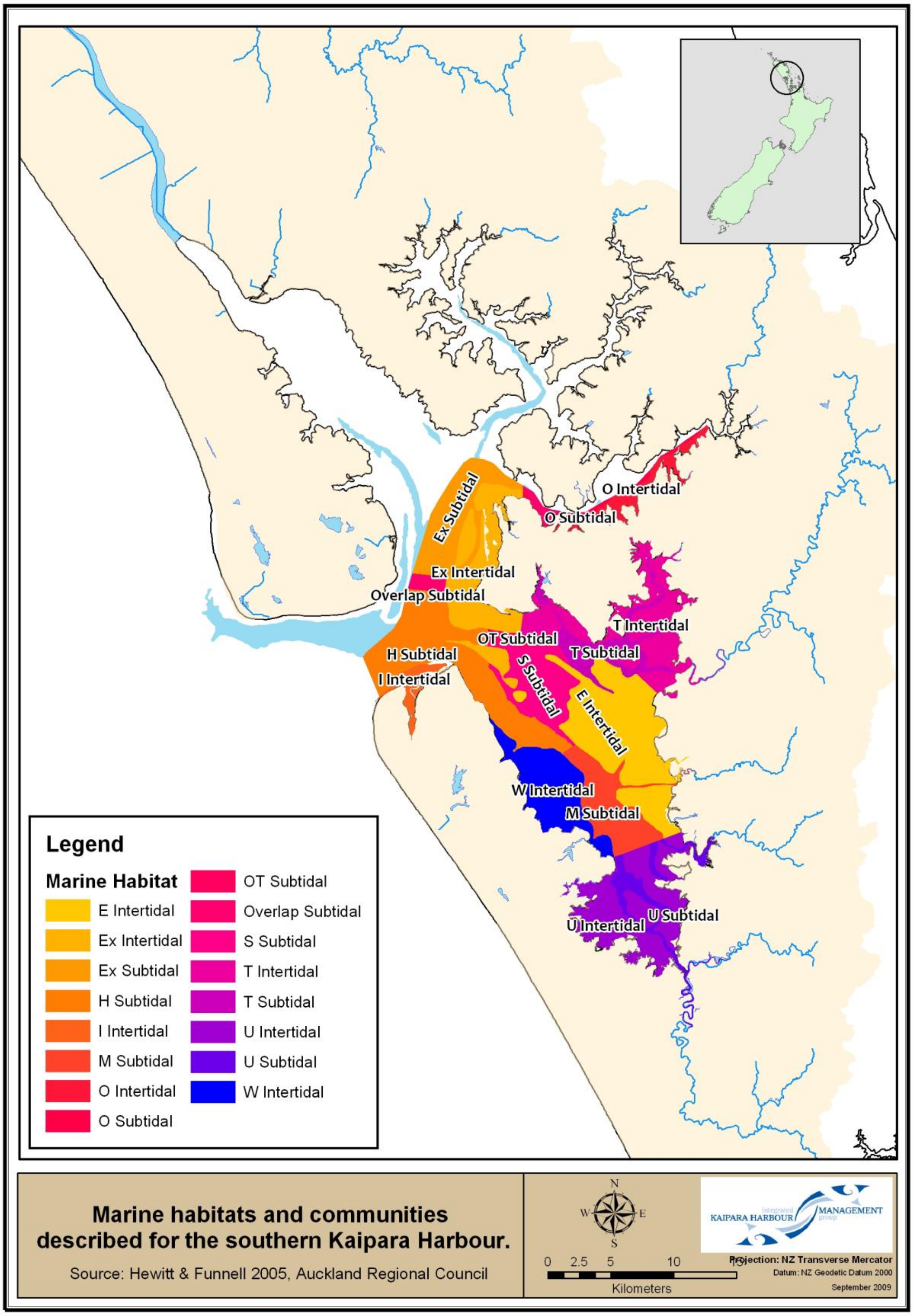


Figure 40. Sediment samples collected from the southern Kaipara Harbour (Auckland region).

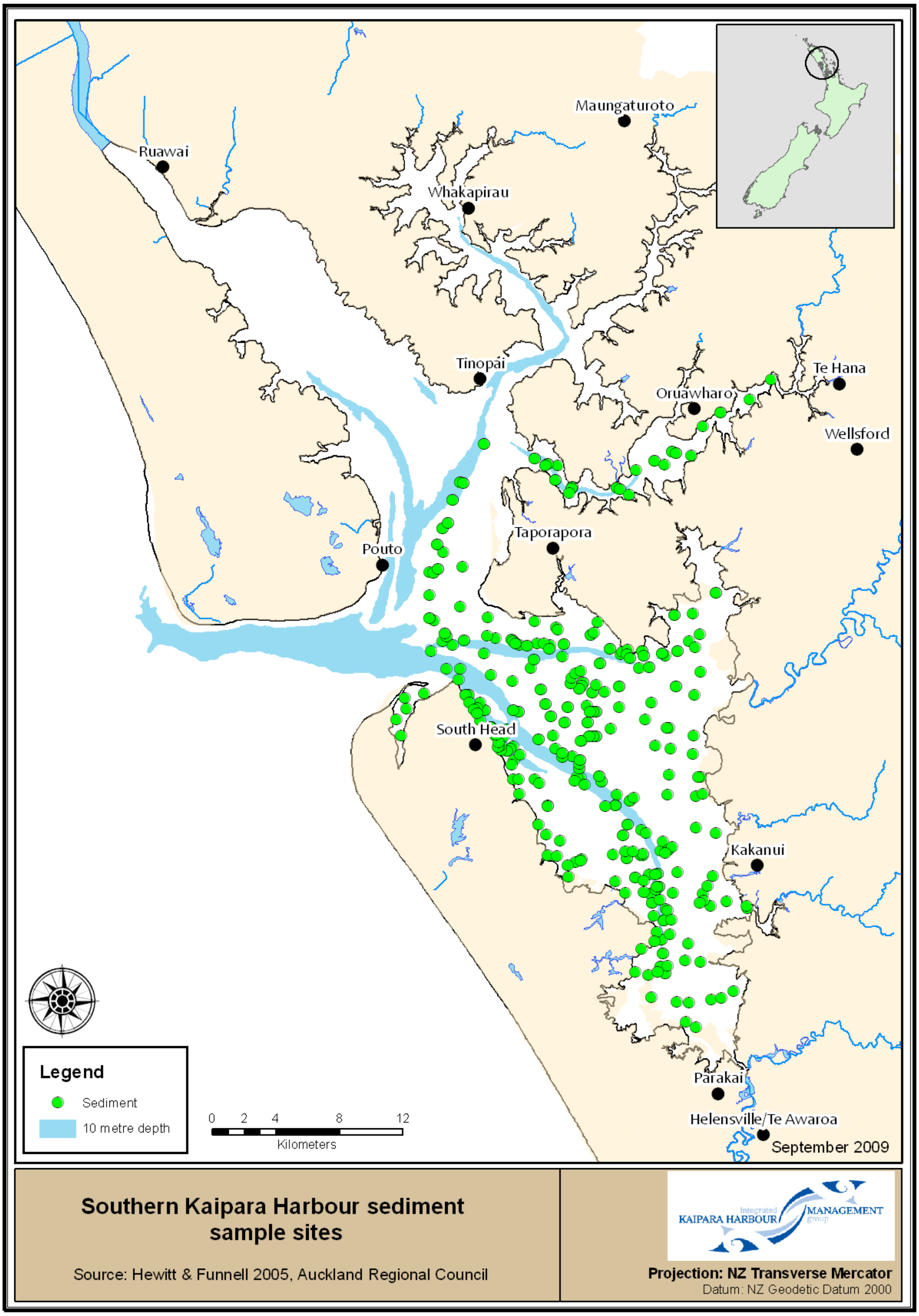
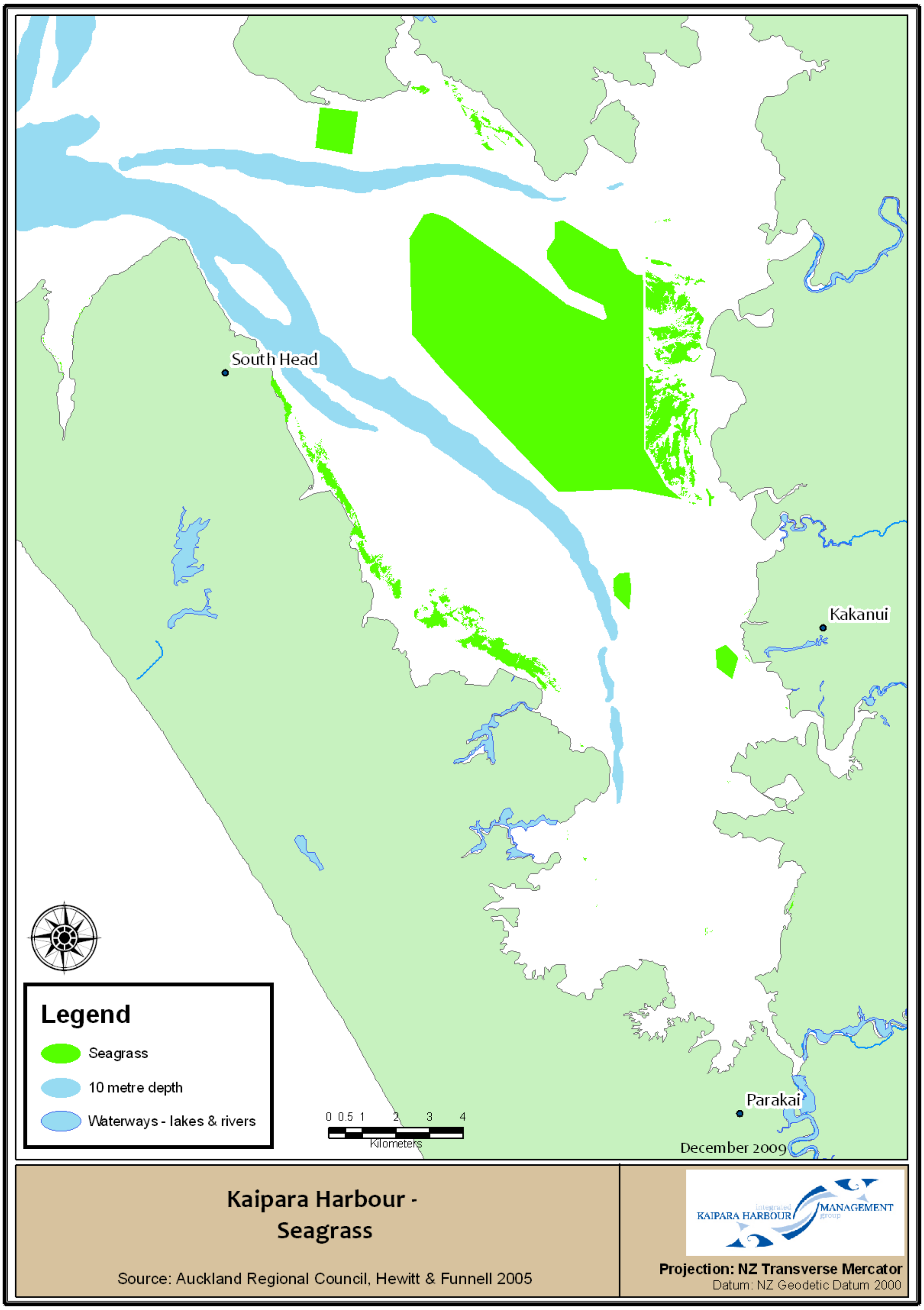


Figure 41. Seagrass communities currently found in Kaipara Harbour.



9.8 ECOLOGICAL PROCESSES

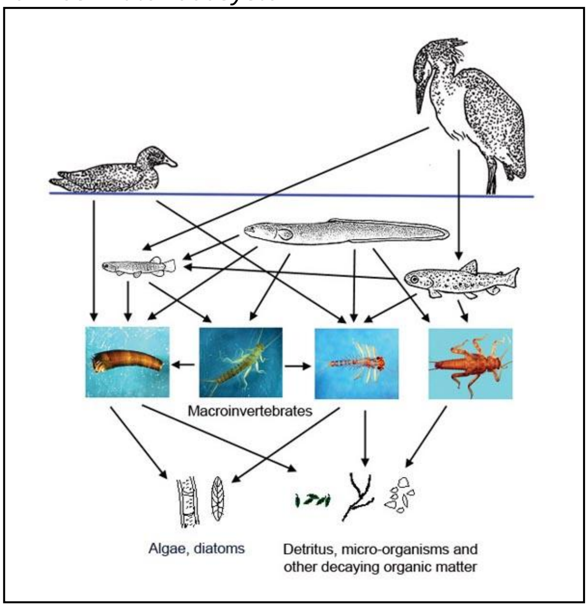
'Biology without its ecology context is dead' (Rowe 1989)

Ecosystems are defined not only by the species, habitats and their interactions, but are also defined by the ecological processes and linkages which connect them. As the focus has moved from representing the range of nature's ecological diversity to 'holding the line on damage to ecological processes' (Ministry for the Environment 1994), where New Zealand is increasingly seen as being *ecosystems* – diverse, interacting and constantly changing. Ecological processes are dynamic, driven by biological, physical and chemical cycles and characterised by the changes of matter, energy and living tissues. There is a constant interaction between plants, animals and the non−living environment, so organisms do not stand by their own; they evolve and exist in the context of ecological systems (Park 2000).

The holistic approach to environmental management by Māori has much to offer how ecosystems are understood, conserved and managed for in the Kaipara. With this in mind, there is a need to focus on the processes actually going on, such as, birds striving to find the surviving remnants of their ancient forest habitats; the seeds they do not carry on their flyways, blowing, like the pollen, out of the remnants' trees and away; the constant movement of insects, water (some of it polluted from adjoining land), nutrients and energy; seasonal migration of elvers from the ocean to the freshwater wetlands (today constructed wetlands); the forging and roosting between forest and estuarine ecosystems; the kanuka−manuka seedlings struggling to regenerate pasture.

Habitat loss is the main stress driving biodiversity loss. Conservation biology, fisheries science, and population dynamics research findings have discovered that one of the main likely processes driving biodiversity loss due to habitat decline is the destablisation of marine and terrestrial food webs (Pauly *et al.* 1998; Myers & Worm 2003; Folke *et al.* 2004) (Figure 42). Reduction in habitat can act to affect patterns of biodiversity in three ways: (1) Reduction in movement of organisms concentrates species interactions such as competition and predation; (2) Reduction in renewal of prey resources means that areas can only support smaller population sizes. Smaller populations are more vulnerable to stochastic effects such as major disturbances; and (3) Reduction in habitat size can limit refuges for prey, increasing the effects of predation

Figure 42. An example of a food web structure for freshwater ecosystem.



Such processes are thought to reduce foodweb stability, shifting ecosystems from a desired to a less desired state in their capacity to generate ecosystem services, but there has been a general lack of studies exploring the impacts of reduced habitat despite the importance of these processes (Cowling & Pressey 2001; Possingham *et al.* 2005; Klein *et al.* 2009; Richardson & Thompson 2009).

Food web monitoring of functional food groups of consumers and producers is not readily reported on for State of Environment reporting even though human impacts can change natural species distributions and therefore community structure. For example, commercial fishing can alter energy flow through marine trophic levels; while clearing forest can alter the flow of nutrients and energy through terrestrial trophic levels - instead of nutrients being stored in plant biomass and utilised by birds and other wildlife, it is incorporated into grass and eaten by stock, with much of the animal biomass being removed (Thompson & Townsend 2004). In New Zealand, pastoral farming includes regular land application of superphosphate fertiliser. This unnatural scale of harvesting and release of phosphorus to the environment has been described as paralleling the release of carbon by the burning of fossil fuels. This application in combination with other farm management practices has resulted in the input of excessive phosphorus to receiving waterways. As this is the nutrient in shortest supply in most ecosystems, it is often the 'limiting nutrient'. The amount of phosphorus being recycled in biological systems is much smaller than what is stored (McKinney & Schoch 2007). It has been found that approximately 40% of potential terrestrial net primary productivity (NPP) and about 2% of oceanic NPP is directly used, diverted, or lost due to human activities. This has been directed at causing the simplification of food webs and decline in biodiversity.

The Macroinvertebrate Community Index (MCI) has been used by regional councils as an indicator of stream and river health. The Northland Regional Council State of Environment report (Northland Regional Council 2007), recorded only two sites that were considered clean water and healthy. They were the Waipoua Forest stream and Waipapa stream at Puketi forest which were recorded to have MCI scores of >120 and a SQMCI score of >6.0. In the Auckland region, freshwater invertebrate monitoring sites are: Mt Auckland, Awarere (Dibble), Hoteo (Kraak Hill), Hoteo−Waiwhui (Firth), Kaukapakapa, Ararimu, and Kumeu. MCI results have yet to be released.

Describing the ecological integrity of Kaipara ecosystems using large−scale ecological processes has yet to be undertaken. The reconnaissance survey of significant natural areas of the Kaipara Ecological District by Davis (2001) begins to bring into assessments an understanding of Kaipara ecosystems, by recording the regeneration stage or canopy status. This assessment only applied to sites with forest canopy and excluded wetlands or shrubland (Table 19). Of the 778 sites assessed, 331 sites were assessed for regeneration in the Ecological District with 1.8% having an original forest canopy, with most (14%) at a young stage of regeneration. The 'intactness of tiers' was also recorded, where 9.8% of sites having all tiers (i.e. canopy, mid−tier, ground tier) intact.

Table 19. Vegetation dynamics of significant natural sites in the Kaipara and Ōtamatea Ecological Districts (southern only). Source: Davis 2001.

Stage of Regeneration	Number of sites (%)	Intactness of Tiers	Number of Sites (%)
Original	1.8	All tiers intact	9.8
mature canopy	4.2	Canopy & mid tiers intact	1.5
mature	4.3	Canopy & ground intact	1.4
mid−aged	6	Canopy intact	5.5
younger to mid−aged	13	None intact	2.4
Younger	14	Unknown or not applicable	76
No data	57		

Seabird roosting and breeding locations

The linkage between seabirds and waders roosting, feeding and breeding areas has been intrinsic to studying significant sites in the Kaipara Harbour for seabirds and waders. The spatial and temporal dynamics of the ecosystems used by waders in the Kaipara is the subject of a Ramsar nomination being proposed by the Royal Forest & Bird Society of New Zealand and Ngāti Whatua o Kaipara. One of the most notable ecosystems in the Kaipara is the mangrove−saltmarsh and the successional sequences from tidal channels to near−shore mangrove, saltmarsh, saltmeadow, maritime rushes, and full forest habitats. This is particularly in the Tauhoa Scientific Reserve, Hoteo River and Mt Atuanui Conservation Area (Chapman 1976, Fahy *et al*. 1990, Morrisey *et al*. 2007) (Figures 43). The endangered New Zealand fairy tern is also being assessed by linking important roosting, breeding and feeding areas with ecosystems of the Kaipara (Figure 44). This has highlighted the significance of Kaipara coastal ecosystems for New Zealand fairy tern, in terms of their future management, given their resource use of the Kaipara.

Figure 43. Southern Kaipara seabird and wader roosting sites at Tauhoa River, Hoteo River and near Omokoiti Flats.

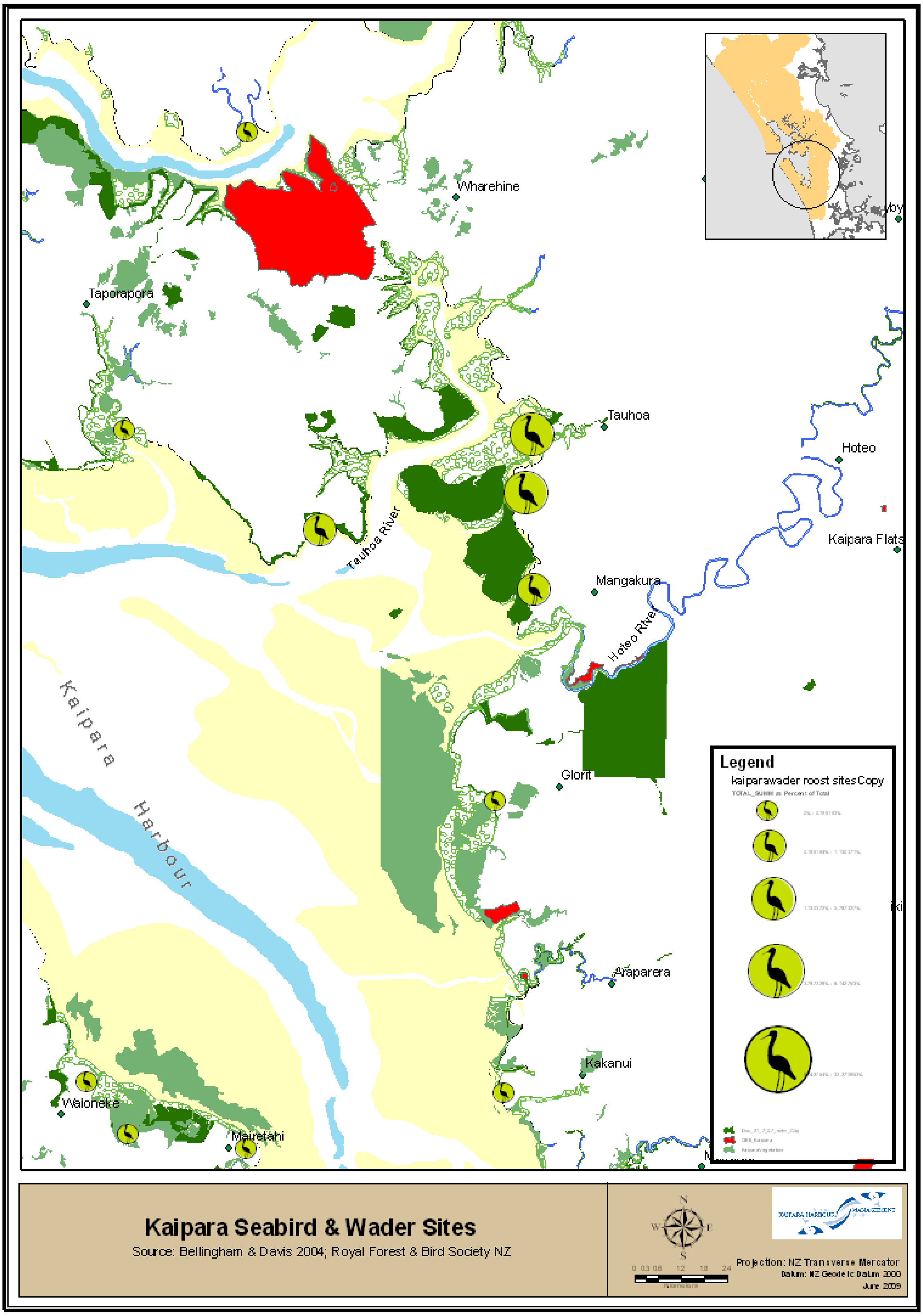
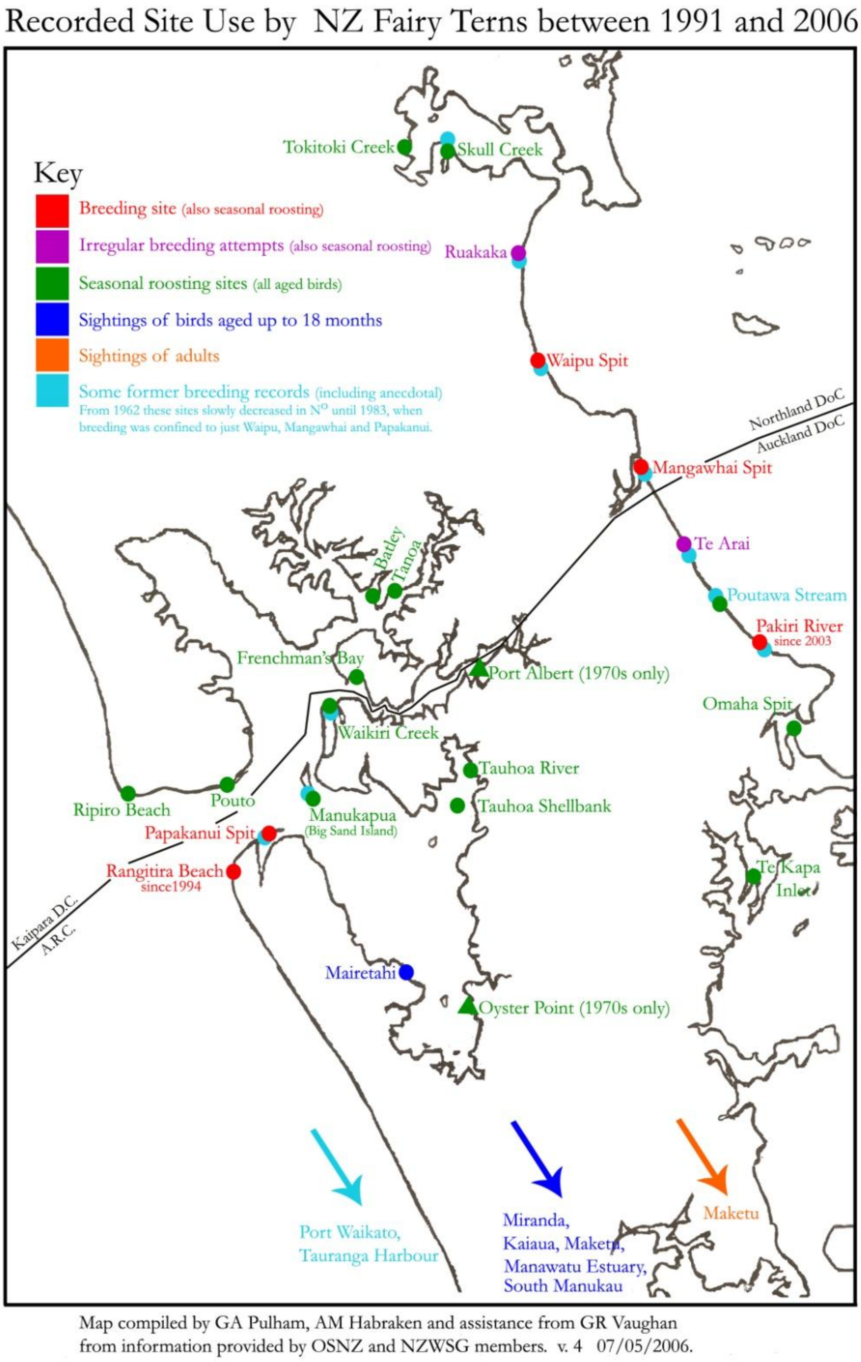


Figure 44. Recorded site use of New Zealand fairy terns between 1991 and 2006. Source: Orthniological Society of New Zealand.



Kaipara and West Coast North Island Snapper

Recent research of juvenile snapper *Pagrus auratus* populations along the West Coast of the North Island and harbours found that adult populations are effectively supported by recruitment from the Kaipara estuarine system. Evidence presented revealed that the majority of the west coast adult snapper stock (SNA8) originates from the Kaipara estuarine ecosystems, particularly biogenic habitats such as horse mussel beds and subtidal seagrass meadows (Morrison, Lowe et al. 2009, Morrison *et al.* in prep). Field surveys inside the Kaipara and other west coast harbour systems quantified the presence of juvenile snapper (less than 1 year in age, < 100 mm), which were rare on the open coast (as shown by Ministry of Fisheries trawl surveys). This suggested a movement model where juvenile fish recruited to estuaries, and then moved with age and size out onto the open coast. The use of otolith chemistry linked natal elemental signatures from the 2003 year class, sampled initiallty inside the estuaries in 2003 as 0+ age fish (less than 1 year old), and then in 2007 as 4 year old fish, from the open coast environment. The majority of adult fish sampled were linked back to the Kaipara Harbour as a nursery estuary. These adult snapper came from a large spatial zone ranging from Ninety Mile Beach, down to Wellington. However, while the Kaipara Harbour appears to sustain most of the adult population along the coast however, the habitats within the harbour that support most of the juvenile snapper (horse-mussel beds and subtidal seagrass meadows) are under increasing stress from anthropogenic impacts, particularly those occurring on the adjacent land catchment.

This research is an example of one type of ecological process – connectivity - operating across large spatial and temporal scales, between the Kaipara Harbour and the open coast, where adult fish populations utilise habitats and areas spatially discrete from those of juvenile populations.

Other Ecological and Evolutionary Processes

The above three examples (forest regeneration, seabird roosting and breeding linkages, juvenile-adult snapper habitat shifts) are only some of the ecological processes operating that define the ecosystems of the Kaipara. The spatial and temporal scale at which these ecological and evolutionary processes occur is another question that remains unanswered in order to truly define and manage ecosystems. Other processes that occur include:

- Succession
- Seasonal migrations
- Dispersal; source−sink population dynamics
- Migratory pathways
- Connectivity between land and coastal environments (e.g. Forest−estuarine ecosystems)
- Migration and exchange between land and coastal biotas
- Adult−juvenile habitats
- Spawning aggregations
- High movement water bodies
- Upwelling events
- Water, carbon, & phosphorus cycle
- Plankton production
- Flow of energy
- Cycling of nutrients
- Ecological diversification of plant and animal lineages
- Predator−prey processes involving top predators

Trying to capture such ecological processes like the water cycle or upwelling events into conservation, and resource and fisheries management and planning drastically increases the biological and ecological complexity for managers.

Ecological and evolutionary processes also maintain and generate biodiversity (Pressey et al. 2003) at various spatial and temporal scales. Most ecologists now appreciate that if we are to conserve and understand species, communities and ecosystems, we must understand and maintain the ecological processes that sustain them. However, our understanding of the status of such processes in the Kaipara is limited. To compensate for this, this project focuses on the catchment−sea planning which is believed to facilitate the representation of ecological and evolutionary process operating at the meso−scale. This approach also integrates freshwater, terrestrial and marine biodiversity conservation planning which are typically treated independently, and addresses the restoration of the mauri of the Kaipara, which Māori have continued to accentuate for over a hundred years.

9.9 STRESSORS TO KAIPARA ECOSYSTEMS AND VALUES

The majority of the catchment is highly modified, with minimal riparian vegetation, poor water quality and ecosystem health being generally poor (Opus International Consultants Ltd 2007). The Kaipara marine environment is and continues to be degraded from both indirect and direct stressors operating cumulatively or in isolation (Haggitt, Mead *et al.* 2008). Humans depend on the Kaipara Harbour and catchment ecosystems for important and valuable goods and services, but human use has also altered the harbour and catchment through direct and indirect means.

Land−based activities affect the runoff of pollutants and nutrients into coastal waters and remove, alter, or destroy natural habitat. Harbour activities extract resources, add pollution, and change species composition. These activities vary in intensity and their range of influence on the ecological condition of communities and in their spatial distribution across the landscape and seascape. The range of current stressors on the ecosystem values of the coastal marine area was summarised by Haggitt *et al.* (2008) and includes:

- Landuse and coastal development in the catchment
- Sand extraction
- Fishing
- Invasion and spread of marine pests
- Shellfish aquaculture and other commercial activities in the coastal marine area.

Morrison *et al.* (2009) completed a national scale review of landuse activities and the impacts on fisheries, which highlighted the need for fisheries management to address and influence landuse activities and planning. The possible effects of environmental and habitat degradation on fished populations has largely been ignored, with most fisheries research being focused on the species themselves, in terms of growth, mortality and population modeling, and to a much lesser extent on the influence of fishing impacts.

Arguably, the most important stressor operating in the Kaipara catchment and harbour is sedimentation, a stressor that has been operating in the Kaipara since the arrival of Europeans and the subsequent wholesale landclearing of catchment vegetation. Other stressors identified from the literature, resource managers, iwi/hapū, and community spokespersons are summarised below.

Urbanisation

Urbanisation leads to an increase in the area of solid surfaces (e.g., roads, roofs and carparks) in a catchment and the development of drainage systems that rapidly transport rainwater run−off into waterways and decrease the infiltration of rainwater into underlying groundwater systems. Consequently, surface water is quickly transported to nearby waterways. This rapid transportation of stormwater reduces groundwater retention and lowers the baseflow conditions for urbanised streams and increases flood peaks.

The increased proportion of solid, impermeable surfaces in a catchment has been proposed as a general indicator of modifications to urban waterway, e.g., the greater the degree of catchment imperviousness, the greater the impact on stream biota. However, the efficiency of stormwater drainage systems must also be considered while investigating the efficiency of stormwater transport to nearby waterways.

Urbanisation of river catchments also leads to the reduction of riparian vegetation, which increases the impacts from impervious surface run−off due to a reduction in the buffer zone between the land and stream environment (i.e., riparian zone). The reduction in the riparian strip also increases a streams direct exposure to sunlight, thereby increasing water temperatures and aquatic plant proliferation. Greater stream temperatures are often compounded by lower baseflows in relation to more impervious surfaces. Thus, elevated water temperature, which can be detrimental to aquatic life, can be a common feature of the urban stream environment.

Urbanisation and the associated impervious surface run−off may also introduce contaminants and sediment created from urban and industrial activities. The contaminants can be deposited onto roads (e.g., Cu, Pb, Zn, & PAH's), building roofs (e.g., trace metals) and other hard surfaces before being collected by run−off water on its journey to nearby streams.

Very little specific information on the effects of urbanisation on waterways in the Kaipara River catchment is available. Studies in the neighboring cities of Waitakere and North Shore have shown the effects of urbanisation on the ecology of streams is related to catchment modification.

Climate Change

In 2007 the Intergovernmental Panel on Climate Change (IPCC) delivered its fourth assessment. This report projected that New Zealand's climate is "virtually certain" (greater than 99% probability) to be warmer with noticeable changes in extreme events (IPCC 2007):

- Heat waves and fire are virtually certain to increase in intensity and frequency.
- Floods, landslides, droughts and storms are likely to become more frequent and intense.
- East Northland and Auckland is likely to have lower than average soil moistures.
- Increase in frequency of high intensity, short duration rainstorms
- Sea level rise
- Increased storm surges

Natural ecosystems are identified as being most vulnerable to these changes as the projected rates of climate change are likely to exceed rates of evolutionary adaption for many species and communities. Habitat fragmentation is likely to limit species ability to adapt to climate change events and subsequently species persistence. Research suggests that New Zealand will experience changes in the frequency of droughts, rainfall patterns, and evaporation rates, which are likely to change water flows and worsen existing problems with water availability. Water quality is likely to deteriorate in some areas because of lower flow rates in rivers and streams. Algal blooms may occur more frequently because of higher water temperatures. More analysis of climate change images and responses by authorities are discussed further in Chapter12 Understanding Climate Change.

Invasive Species – Animals Pests and Weeds

Pests and weeds, as well as valued introduced species, are present throughout the Kaipara ecosystem (Davis 2001, Lux & Beadal 2006, Manning 2001, Lux *et al.* 2007, Miller & Holland 2008) (Figures 45 and 46) and have modified the landscape and coastal seascape to some degree. Animals modify the ecosystem through browsing and, predation on, and/or competition with, native species – examples include goats, cats, cattle, sheep, possums, rats, mustelids (e.g. stoats), and pigs[19]; while plant species can outcompete native species, changing or eliminating resources that animals may rely on. Invasive pest and weed species are capable of causing serious impact economically, recreation activities; to endangered species, species diversity, conservation values, Māori values, trade, production and soil resources and water quality.

Figure 45. Examples of pest species found in the Kaipara catchment. Clockwise from top: Manchurian rice grass, fallow deer, possum, stoats, cats, gambusia.

Most freshwater ecosystems in the Kaipara catchment have well established pest fish[20] and other fauna, but their impacts are not well quantified. There is evidence of pest fish species causing a decline in native fish abundance and diversity through competition and abundance; changes in the distribution of native fish due to interactive segregation; changes to submerged aquatic plant community structure; parasites and diseases; hybridisation; food web impacts through changes to plankton community composition; and water quality impacts and habitat degradation from de-vegetation or bio-perturbation (Auckland Regional Council 2007).

Apart from Lake Ototoa, the Kanono, Humuhumu, Mokeno and Kai Iwi group lakes, Kaipara freshwater lakes are highly impacted by pest plants (Champion & de Winton 2005). Pest plants have invaded islands, urban−open space, production/agriculture areas, plantation forest, terrestrial coastal sites, lakes, rivers, stream edges, coastal wetlands, inland wetlands, shrubland/scrub, and native forest within the Kaipara (ARC 2007). Some species are very invasive and difficult to eradicate, particularly for estuarine areas and waterways where the use of chemical management is difficult.

Pest management is mandated under the Biosecurity Act 1993 and managed using Regional Pest Management Strategys (RPMS). RPMS provide for the maintenance and enhancement of natural environments such as indigenous ecosystems, water quality and soil resources. The overall goal of the RPMS is to create and maintain sustainable pest−free habitats. An integrated pest management approach is advocated and implemented by both Northland Regional Council and Auckland Regional Council RPMS documents.

[19] http://www.nzpcn.org.nz/animalpests/index.asp

[20] Pest fish include under the Auckland RPMS: brown bullhead catfish, gambusia, gudgeon, koi carp, marron, Perch, rudd and tench are declared pests within High Conservation Value waterbodies and their catchments.

Pest control is usually planned using a cost−benefit analysis for a species[21], Assessment of Effects Impact Level, invasiveness of species (measured using DoC and Meister Analysis), nomination by regional community, feedback from consultation, any additional relevant information, whether species meets requirements of section 72 Biosecurity Act, whether species is declared a pest in adjoining regions and whether the species was declared an '*Unwanted Organism'* by the Ministry of Agriculture and Forestry (MAF) or was listed on the National Pest Plant Accord.

Control and eradication of a species can occur at four levels: total control, containment, surveillance, and community initiative programs:

Control Method:	Whom:	What:
Total Control (ARC) **Service Delivery (NRC)**	Regional & District Councils, Biosecurity NZ, DoC Pest plants targeted are those that are limited distribution or density within the region/district or defined areas and are considered to be high potential threat which Regional Council shall assume responsibility for funding & implementing appropriate management programs.	ARC RPMS (2007): http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Plants%20and%20animals/RPMS/RPMS%20Total%20Control%20Pest%20Plants.pdf For example, African feather grass, marshwort, scrambling lily, water poppy, asparagus species, broomsedge, cathedral bells, climbing, spindle berry, green cestrum, Manchurian wild rice grass, Mexican feather grass, needle grass, old man's bread, royal fern, Sagittaria species, sengal tea. NRC service delivery species include: lantana, African feathergrass, Manchurian wild ricegrass, Nassella tussock, spartina
Containment (ARC) **Total Control Pest Plants (NRC)** **Boundary Control**	Landowners/occupiers Carry out control work for Containment Pest Plants on their property All Containment Pest Plants are banned from sale, propagation, distribution and exhibition.	Wild ginger, wild kiwifruit, woolly nightshade, smilax, ragwort, rhamnus, moth plant, nodding thistle, gorse, bushy asparagus, Bathurst bur, Australian sedge

[21] Cost Benefit Analysis and Assumptions, Animal and Plant Species Considered for Inclusion in the Proposed Auckland Regional Pest Management Strategy 2007-2012, a supporting document to satisfy the requirements of section 72 of the Biosecurity Act 1993. Auckland Regional Council, October 2006.

Control Method:	Whom:	What:
Pest Plants (NRC) **Quarry Control Pest Plants (NRC)**		
Surveillance	No control Surveillance Pest Plants banned from sale, propagation, distribution and exhibition.	Most pest species http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Plants%20and%20animals/RPMS/RPMS%20Surveillance%20Pest%20Plants.pdf
Community Initiatives Program or Community Pest Control Areas	Community groups Group nominates pest plant and carries out control work. Species declared in RPMS. South Kaipara Peninsula is a **Possum Control Area** under the Auckland RPMS.	For example: gorse, Himalayan honeysuckle, Japanese honeysuckle, german ivy, giant reed, grey willow, pampas, privet, palm grass, ragwort, rhamnus, smilax, wild ginger, woolly nightshade

Road and rail corridors, quarries and saleyards are significant vectors for weed spread. Wind, movement of roading material, machinery and livestock are all common distributors of pest plant species. Weed encroachment from nearby development is a cause of concern, as many garden plants escape the garden, invade other areas and as many are highly competitive and eventually exclude indigenous species. Subdivisions and coastal development for life−style blocks are vectors for pest and weed invasion, bringing them closer to remaining indigenous vegetation and threatened species.

There are well over 110 plant pests within the Auckland Region (RDC 2008) and at least 21 wild mammal species. The most prevalent animal pests include the possum, four species of wasp, rabbits, wallaby, feral (wild) goats and deer, stout, ferret, weasel and the magpie.

Current site led pest control programs in the Rodney District include: council land adjoining significant natural areas, Ōkahukura Peninsula, dune lakes and riparian areas. Species led programs in the District include privet, pampas and wild ginger (RDC 2008). Community Pest Control Areas (CPCA) are declared at Oneriri−Puketotara Peninsula, Linton Road (Whakapirau), Petly Road (Matakohoe), Takahoa Bay Puketotara Peninsula, Lake Te Kuri and Maungaraho Rock.

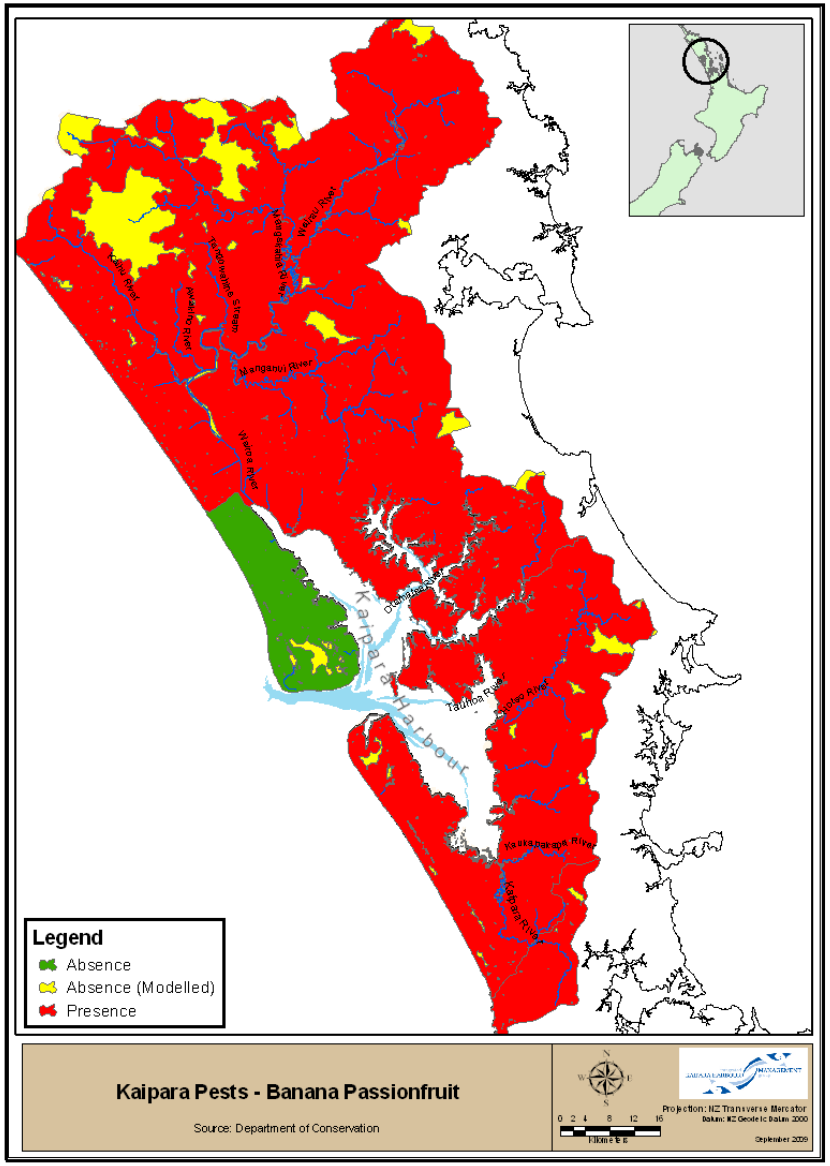
Possum invasion into Northland was relatively late and it was not until the early 1960s that possums were apparent in the Waipoua Forest area (Payton *et al*. 1996) and was well established throughout Auckland and Northland by the 1980s (Ogle 1982). This was also the case for deer, wild pigs, feral goats, myna, house sparrow, starling (Ogle 1982).

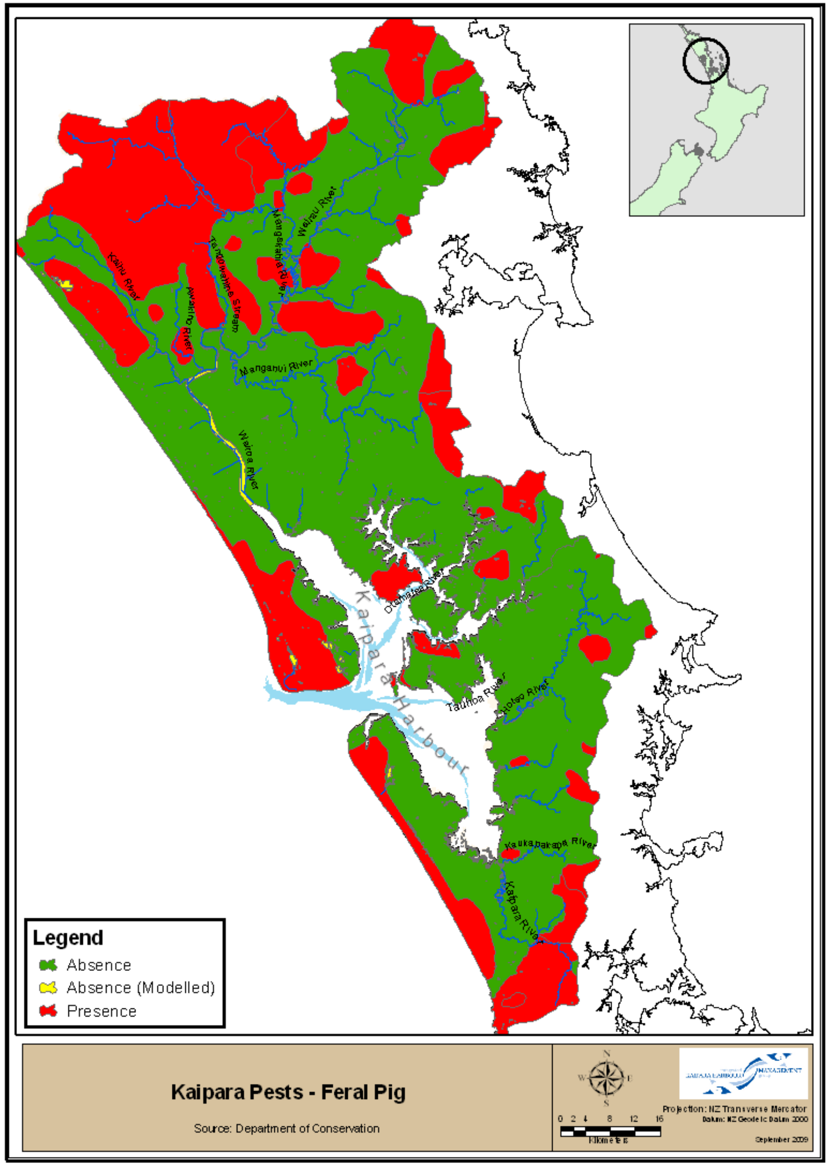
The invasion of pest plants and animals has the potential to compromise the intrinsic values and viability of all native areas. Davis (2001) noted that 25% of significant natural areas had no invasive weeds but goes on to state that the presence of weeds was low compared to other natural areas in other Ecological Districts of the upper North Island. This absence is explained by the absence of residential areas in the Kaipara ED. The weediest forest sites were found by Davis (2001) to be around Muriwai. Pampas and woolly nightshade are the most widespread weed species in the Kaipara ED, primarily invading scrubland and shrubland habitats. Freshwater wetlands and duneland habitats have a relatively high abundance and spatial extent of invasive weeds.

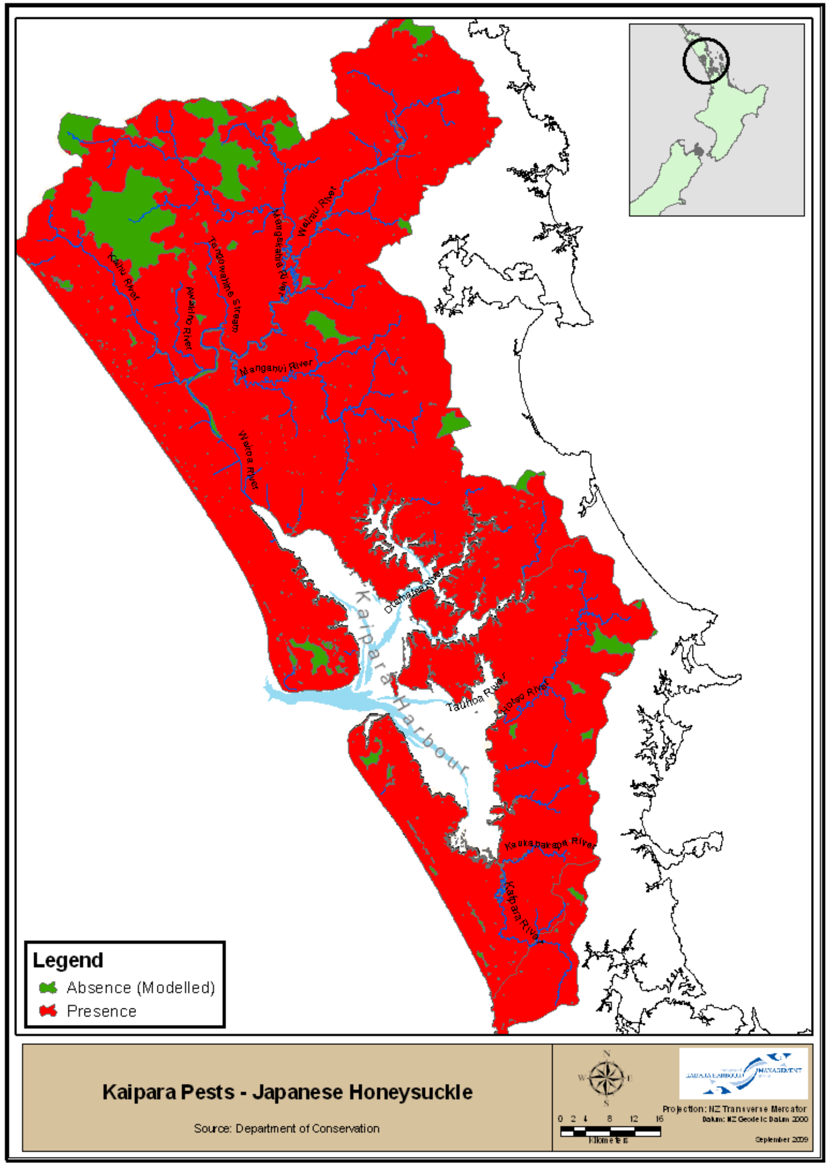
Introduced grasses are the main weed of wetlands, especially if they have been grazed by stock (Davis 2001). Manchurian rice grass is present throughout the margins of Wairoa River, marram are both highly invasive weed species now present in all dunelands and around margins of a number of dune lakes.

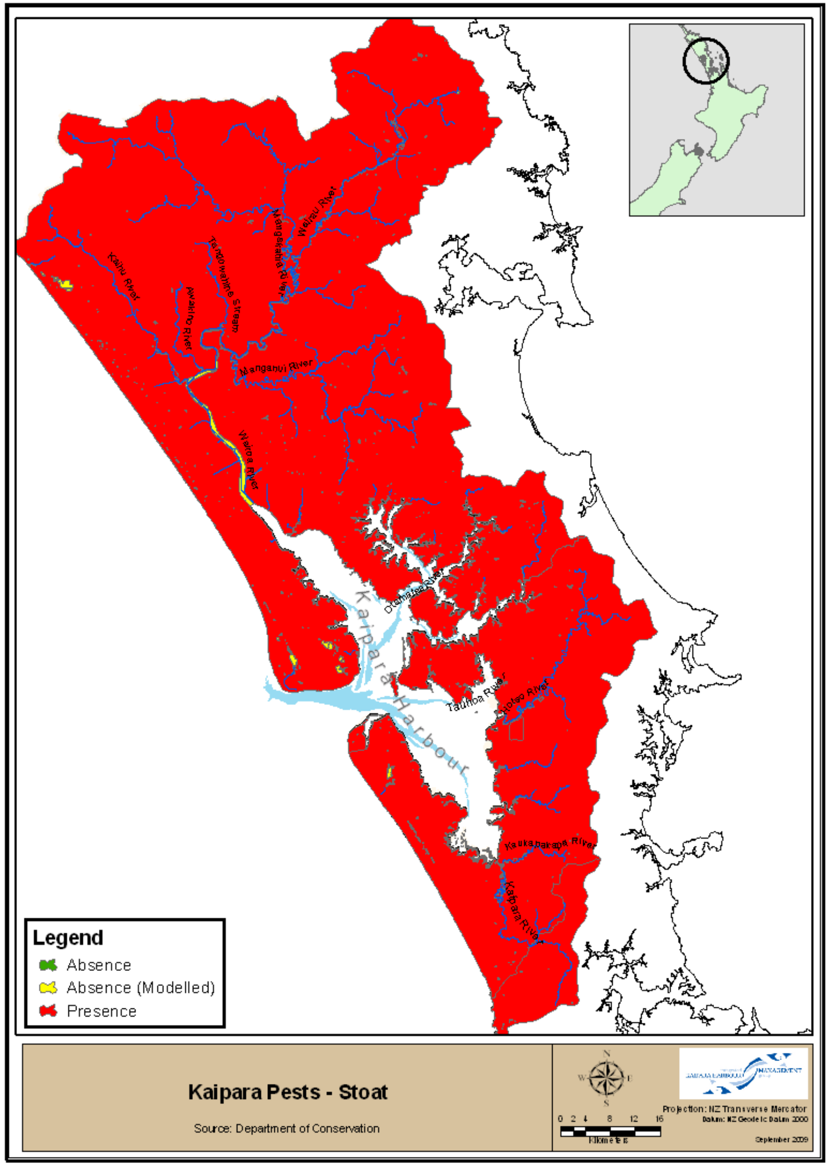
Some of the most prominent weed species threatening forest ecosystems in the Kaipara catchment include kahili/wild ginger, mistflower, Mexican devil, and wandering willy and many more. Gorse and *Hakea* spp. are particularly invasive in gumlands, as also wilding pines, as they seed easily and spread rapidly.

Figure 46. Distribution of examples of pest species found in the Kaipara catchment (a) Banana passionfruit, (b) Feral pig, (c) Japanese honeysuckle and, (d) Stoats. (Source: Department of Conservation).


Legend
Absence
Absence (Modelled)
Presence
Kaipara Pests - Banana Passionfruit
Source: Department of Conservation
Wairau River
Manganui River
Wairoa River
Kaipara Harbour
Kaipara River
Kaukapakapa River
Hoteo River
Tauhoa River
Otamatea River


Legend
Absence
Absence (Modelled)
Presence
Kaipara Pests - Feral Pig
Source: Department of Conservation
Wairau River
Manganui River
Wairoa River
Kaipara Harbour
Kaipara River
Kaukapakapa River
Hoteo River
Tauhoa River
Otamatea River


Legend
Absence (Modelled)
Presence
Kaipara Pests - Japanese Honeysuckle
Source: Department of Conservation
Kaipara Harbour
Manganui River
Wairoa River
Kaihu River
Otamatea River
Tauhoa River
Hoteo River
Kaukapakapa River
Kaipara River
Projection: NZ Transverse Mercator


Legend
Absence
Absence (Modelled)
Presence
Kaipara Pests - Stoat
Source: Department of Conservation
Kaipara Harbour
Manganui River
Wairoa River
Kaihu River
Otamatea River
Tauhoa River
Hoteo River
Kaukapakapa River
Kaipara River
Projection: NZ Transverse Mercator

Agriculture

'the biggest impact to the [Kaipara] harbour has been farming' (Respondent 33, Peart 2007)

Agriculture activities such as the use of fertiliser, stock manure and urine impact on waterways and provide the biggest non−point source of pollution. There is evidence that levels of nutrients in rivers increase in proportion to the levels of agricultural activity in river catchments (Ministry for the Environment 2007). The amount of nutrients, such as nitrogen and phosphorus, going into the land from fertiliser application and livestock continues to increase in New Zealand as farming becomes more intensive.

The Northland Regional Council 2008 State of the Environment report states that overall, biodiversity is still declining, with a decrease in indigenous vegetation between 1997 and 2002. This is a result of the increasing fragmentation of habitats across the Kaipara catchment landscapes, from over 160 years of landclearing for timber, agriculture, exotic forestry and horticulture.

In June 2008, national Agricultural Production Statistics[22] showed dairy cattle numbers increased to a record 5.6 million, up 6% from 2007. The number of dairy milking cows and heifers numbered 4.3 million in 2007, up 8% from 2002. For sheep, there was a decrease from 2007 down by 34.1 million (11%) and back to 1950 levels. In 2006, using spatial technology with landcover data and land environments classification (LENZ)[23], threatened environments were identified throughout New Zealand (Walker *et al.* 2006) (Figure 47). Walker *et al*. (2005) defined six "threatened environment" categories on the basis of past habitat loss and current legal protection (Table 20).

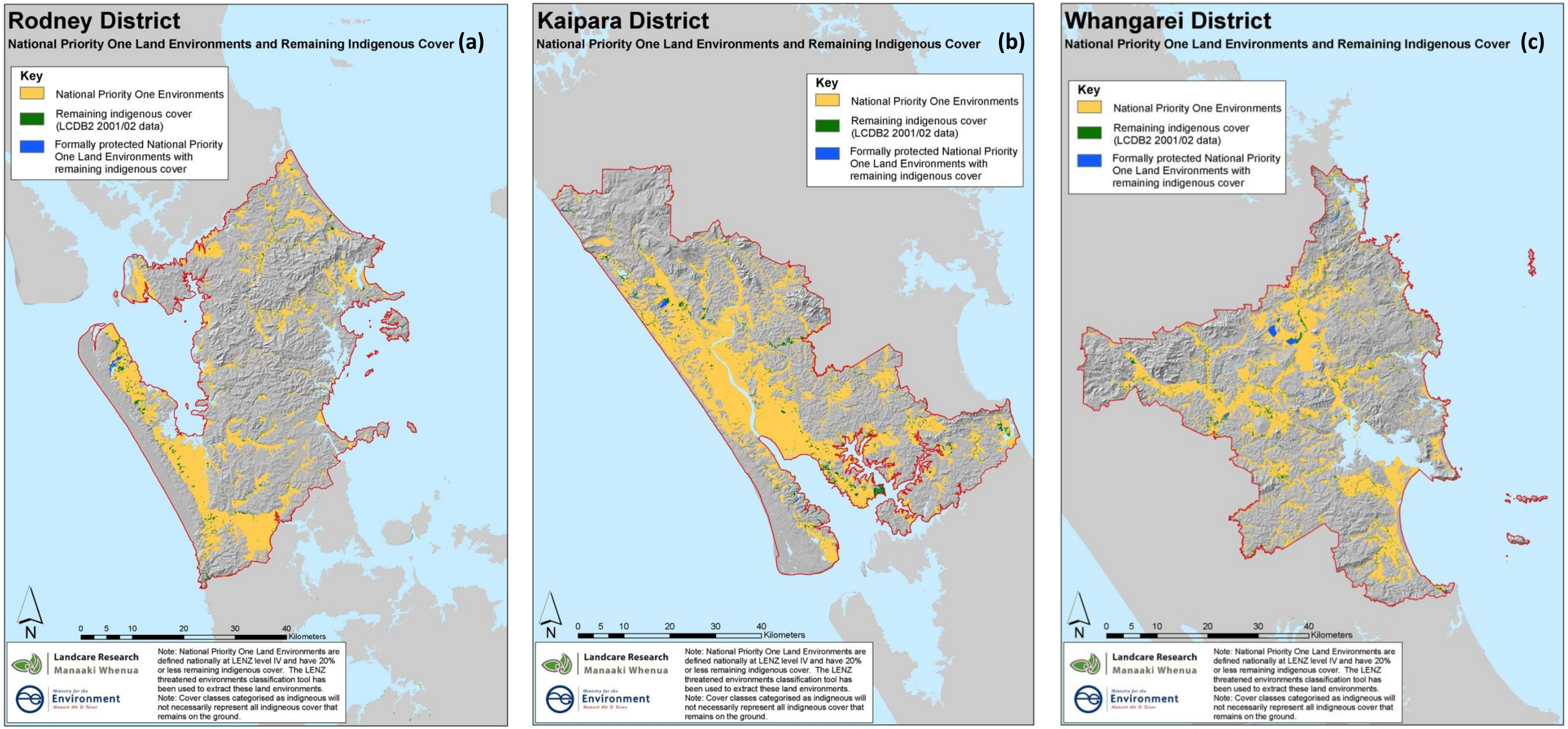
Table 20. Threatened Environment categories and defining criteria (Walker et al 2005).

Category	Criterion
Acutely Threatened	0−10% indigenous cover remaining
Chronically Threatened	10−20% indigenous cover remaining
At Risk	20−30% indigenous cover remaining
Critically Underprotected	>30% indigenous cover remaining <10% legally protected
Underprotected	>30% indigenous cover remaining 10−20% legally protected
No Threat Category	>30% indigenous cover remaining >20% legally protected

[22] http://www.stats.govt.nz/products-and-services/info-releases/ag-prod-stats-info-releases.htm

[23] Leathwick *et al.* 2003. Land Environments New Zealand (LENZ) is an ecosystem classification of New Zealand's landscapes using a comprehensive set of climate, landform and soil variables chosen for their roles in driving geographic variation in biological patterns

Figure 47. National Priority One Land Environments: (a) Rodney District and (b) Kaipara District and (c) Whangarei District.



And in 2007, the Ministry of Environment released the 'Statement of National Priorities for Protecting Rare and Threatened Native Biodiversity on Private Land'[24] (see Chapter Co-Management of the Kaipara for review of this work program). Walker *et al*. (2006) found an extreme (greater than 70%) loss of indigenous cover in 57% of land environments, and poor protection (less than 20% land protected) between 1996/97 and 2001/02. They identified the Resource Management Act and provisions within the Act as being at fault for failing to halt the decline on private land.

Stock Grazing

Stock grazing on estuarine vegetation has been assessed in the southern Kaipara during field surveys in 2002 and 2008 (Davis 2002, Bellingham & Davis 2008). The surveys focused on grazing impacts and the state of fencing within the surveyed areas. All information was added to GIS, including vegetation types which include: mangroves, coastal bush, coastal scrub, freshwater wetland, grass, saltmarsh, seagrassa and Spartina. Stock are able to graze on all these vegetation types except Spartina, and were found to do so throughout most of the coastal marine area of the southern Kaipara. Stock grazing is not permitted in Coastal Protection Areas 1 or Public Conservation land; for example, in the Tauhoa River area and the Department of Conservation Tauhoa Scenic Reserve. This area also has rare vegetation successional sequences from tidal channels to near−shore mangrove, saltmarsh, saltmeadow, maritime rushes, and full forest habitats.

Bellingham & Davis (2008) did find that stock grazing had reduced (Table 21) at two of twenty−three sites assessed, but there are a considerable amount of coastal margins in the southern Kaipara that is still being grazed by farm stock (e.g. cattle and sheep).

[24] http://www.mfe.govt.nz/issues/biodiversity/initiatives/private-land/work-programme.html

Table 21. Presence and absence of stock grazing in the southern Kaipara Harbour coastal area. Source: Bellingham & Davis 2002, 2008.

Site	Stock Grazing + no stock − stock grazing		Comments
	2002	**2008**	
Mairetahi Creek Estuary	−	+	
Parekawa Creek	−	+	North side of lower Parekawa Creek not rechecked 2008
Puharakeke Creek	−	−	
Otakinini Creek Coastal Area	−	−	
Makarau River Estuary	−	−	
Ngapuke Creek (Jordon Rd)	−	−	
Tauhoa Creek Estuary (East)	−	−	
Papakanui River estuary (Tauhoa Scenic Reserve)	−	−	
Opatu River Estuary (Millets Island)	−	−	
Gumstore Creek	−	na	
Hiki Creek Estuary	−	na	
Maeneeae Creek Estuary	−	na	
Kaukapakapa River	+	+	
McLachlan Road Coastal Area	na	−	
Waikiri Creek Estuary	+	+	
Omokoiti Flats Coastal Area	+	+	
North Taumata Creek	+	+	
Upokonui Creek	+	+	
Omaumau Coastal Area	+	+	
Taporapora WMA Coastal Area	+	+	
Taporapora WMA Otekawa Creek Estuary	+	+	
Kaipara River	+	+	Access hard to assess entire river
Tupare Peninsula & Tikitu Creek	na	+/−	New Sites for 2008 Only 80% fenced. One property still has stock access to CMA

Tanner (1992) reviewed cattle grazing effects on the lake margin vegetation of dune lakes. Lake margin vegetation is highly valued habitat for wildlife, and is an essential buffer of sediment and nutrient inputs from the surrounding lake catchment. Not all dune lakes and freshwater wetlands within the Kaipara catchment are fenced, allowing stock to graze in these areas. Stock pugging, urination and faecal matter leads to erosion of lakeshores, nutrient addition, bacterial contamination and promotion of weed invasions (Tanner 1992, Wells *et al*. 2006).

Diarying and Clean Streams Accord

Signed in May 2003 by Fonterra, Ministry for the Environment, Ministry of Agriculture & Forestry and Local Government NZ, the voluntary Accord acknowledged that the ongoing intensification and expansion of dairy farming increased the importance of addressing impacts on waterways. The industry−backed Accord priorities and performance targets include:

- Fonterra and Regional Councils to develop Regional Action Plans for the main dairying regions to implement this Accord by June 2004
- Diary cattle excluded from 50% of streams, rivers and lakes by 2007, 90% by 2012
- 50% of regular stock crossing points have bridges or culverts by 2007, 90% by 2012
- 100% of farm dairy effluent discharges to comply with resource consents and regional plan immediately
- 100% of dairy farms to have in place systems to manage nutrient inputs and outputs by 2007
- 50% of regionally significant wetlands to be fenced by 2005, 90% by 2007

A review for 2008/09 on the performance targets found some improvement in meeting targets to fence and bridge waterways and for nutrient budgets (Table 22). Deans & Hackwell's (2008) independent assessment of the Accord found that even in the five closely monitored "best practice" catchments, managed above Accord standards, water quality had not improved, or declined prior to and during the period of the Accord. The Accord has consistently failed to meet a number of its principal targets and even Regional Councils have expressed concerns that they have been unable to verify statistics collected for Accord reporting. Reporting is carried out by the farmers themselves and there is no independent audit of their accuracy (Deans & Hackwell 2008).

Table 22. Summary of the current performance of dairy farms in the Northland and Auckland regions. (Source: Deans & Hackwell 2008, Fonterra et al. 2008)

Accord Performance Target	Northland	Auckland
Regional Accord Plan	Yes	Yes
Total Number of Dairy Farms 2004/05 Season	1128	380
Cattle excluded from 50% of water bodies by 2007	No	No
50% of open stock crossings eliminated by 2007	unknown	unknown
100% compliance with effluent consents or rules now	No	No
100% farms have nutrient management systems by 2007	Yes	98%
90% of regionally significant wetlands fenced by 2007	unknown	unknown

Of great concern is the 100% compliance with effluent consents or rules in regional council plans. In the 2006/07 season, Fonterra *et al.* (2008) reported a 96% compliance for the Auckland region, and 77% compliance for Northland. Non−compliance meant a farm's water quality results did not meet consent conditions. However, there may be inaccuracies in the data due to varying interpretation and reporting by regional councils. The national average of serious non−compliance is more than 14% of dairy farms, and it was recorded to be 7% in the 'snapshot' report of Fonterra *et al*. (2008). This may also be the case for "*nutrient management systems*" performance targets such as: nutrient budgets of nutrient inputs and outputs or a written nutrient budget plan, which is operational.

Sedimentation

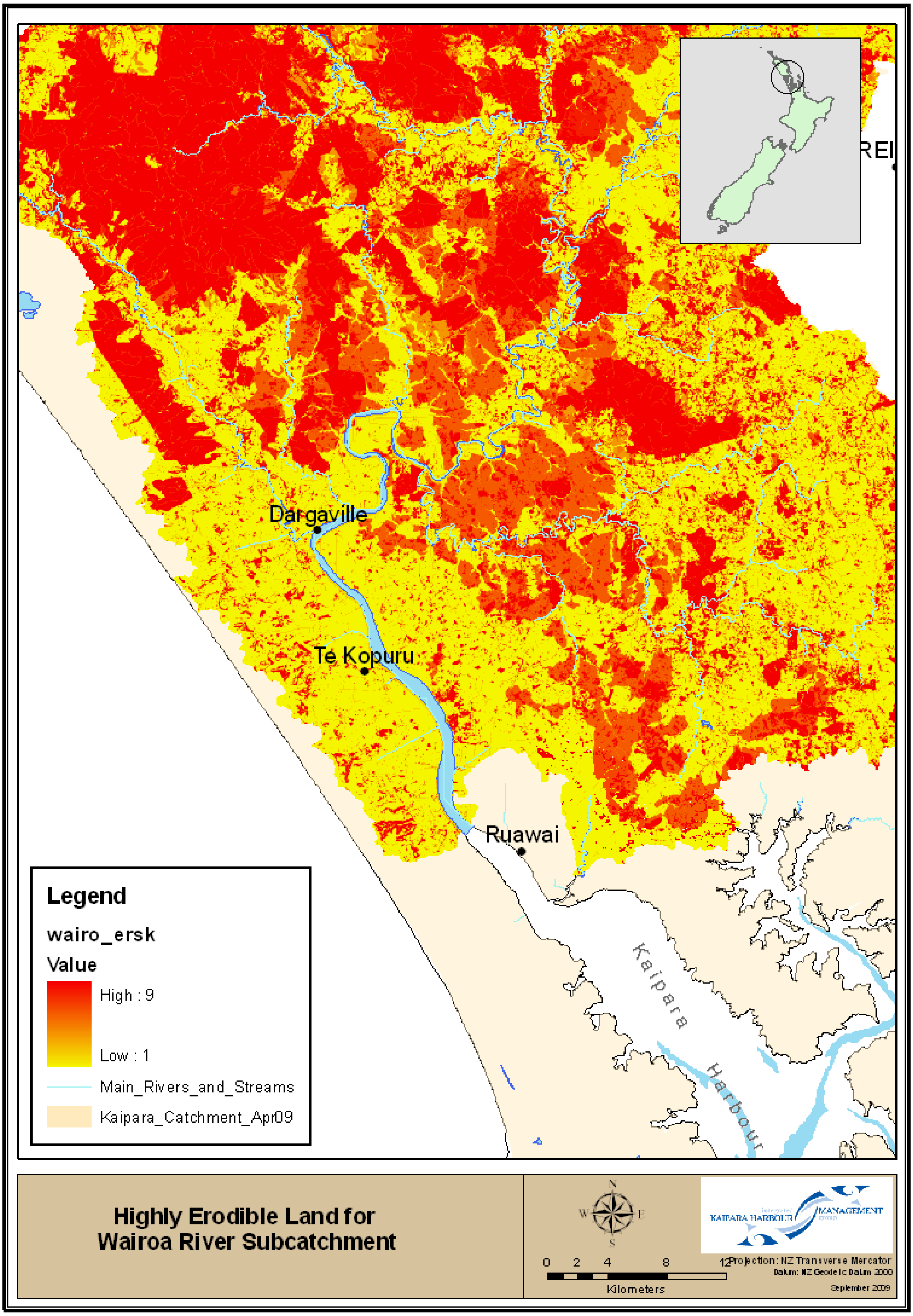
New Zealand's history with land management has lead to soil erosion, silted−up streams, rivers and estuaries, loss of biodiversity, eutrophication creating algal blooms and dense growth of aquatic weeds and loss of productive land. Elevated levels of suspended sediments can reduce diversity and species abundance of pelagic and benthic invertebrates for both freshwater and estuarine ecosystems (Quinn *et al.* 1992; Gibbs & Hewitt 2004; Swales *et al.* 2005) by reducing light penetration and hence photosynthesis and primary productivity, reduced visibility for predators, clogged gills, physical abrasion, lower oxygen levels, and reduced habitat availability. Suspension feeding shellfish or bivalues are especially vulnerable because of their water filtering activities causing some shellfish beds to disappear entirely (P. Yardley & S. Clyde, pers. comm..), in many areas of the Kaipara such as in the Ōruawharo River, Arapaoa River, and the southern Kaipara Flats. Sediment also covers rocky stream bottoms reducing spawning habitat for fish. Particles transported with stream flow cause scouring and removal of small aquatic algae. Sediment particles smother fish eggs and can be acutely toxic to young amphipods (Morrison *et al*. 2009) and can reduce survival rates (Schwarz *et al*. 2006). This could possibly cause a cascade effect for juvenile fish in estuarine habitats where research has shown that amphipods are an important component of juvenile fish diets (Morrison *et al*. 2009, M. Lowe, Auckland University/NIWA, unpubl. data).

Morrison *et al*. (2009) reviewed landbased effects on coastal fisheries and associated biodiversity, including the direct and indirect influences of sediments. Direct effects include death, alteration of community and assemblage structure, and longterm effects such as change in animal communities. Indirect effects include the loss of nursery habitat (e.g. seagrass, seaweeds/kelps, bivalves, and sponges) and reduction in prey abundance. These effects do not act independently from each other but may produce multiple stresses and cumulative effects on ecosystems.

A literature review by Reeve *et al*. (2009) found that quantitative information on sediment accumulation rates (SAR) in the Kaipara Harbour does not exist and there is a general paucity of information on particle size distributions. Hewitt & Funnell (2005) did collect detailed information on bed sediments at a coarse level, but only in the southern Kaipara. Sediments were classified into size classes only: percentage weight of gravel/shell hash (> 2000 µm), coarse sand (500-2000 µm), medium sand (250 – 500 µm), fine sand (62.5 –500 µm) and mud (<62.5 µm).

Predicative modeling has been carried out at the regional council level across New Zealand including Auckland and Northland (Dymond *et al*. 2008). NZeem®, a model of erosion rates, gives a quantitative spatial picture of where sediment in rivers is sourced. The model of highly erodible land produces detailed spatial picture of where severe erosion is occurring (Figure 48). Both models can assist with prioritising soil conservation planning, but do not directly translate into the degree of ecological impact on river and estuarine ecosystems.

Figure 48. Spatial modeling of highly erodible land in the Wairoa River catchment.



A GIS decision-support tool, modeling system was developed to assess the effects of land use change on water quality (nitrogen, phosphorous, sediment) and socio-economic factors (e.g. GDP of $/year arising from farming landuse) at regional and national scales, known as CLUES − Catchment Land Use Enviroment Sustainabily — was funded by Ministry of Environment and Ministry of Agriculture and Forestry; and developed by NIWA, AgResearch, HortResearch, Landcare Research, Lincoln Ventures and Harris Consulting (Woods *et al.* 2006; Semadeni-Davis *et al.* 2009). CLUES can run scenarios to assess land-use, land-use change and catchment effects on water quality (both surface and groundwater).

The CLUES model (3.0) was tested on the Kaipara catchment stream network to understand the type of outputs, particularly for nutrient and sediment loads, concentrations and yields, and microbial health (i.e. *E. coli*) generated from current landuse (diary farming Figure 49, sheep & beef farming Figure 50). For a scenario run on dairy farming CLUES generated several outputs. For the Kaipara catchment dairy farming produces extremely high loads of sediment (kt/year) (Figure 51) predominantly in the Wairoa-Wairau River subcatchment. This same pattern is shown for *E. coli* loads (peta *E. coli*/year) (Figure 52).

The CLUES tool can assist with understanding how loads, yield and concentrations change, together with socio-economic information (e.g. GDP, FTE), with land-use change. CLUES can also allow the identification of stressed sub-catchments aiding in developing suitable land-use controls and catchment planning.

Figure 50. Percentage of dairy farming in the Kaipara catchment.

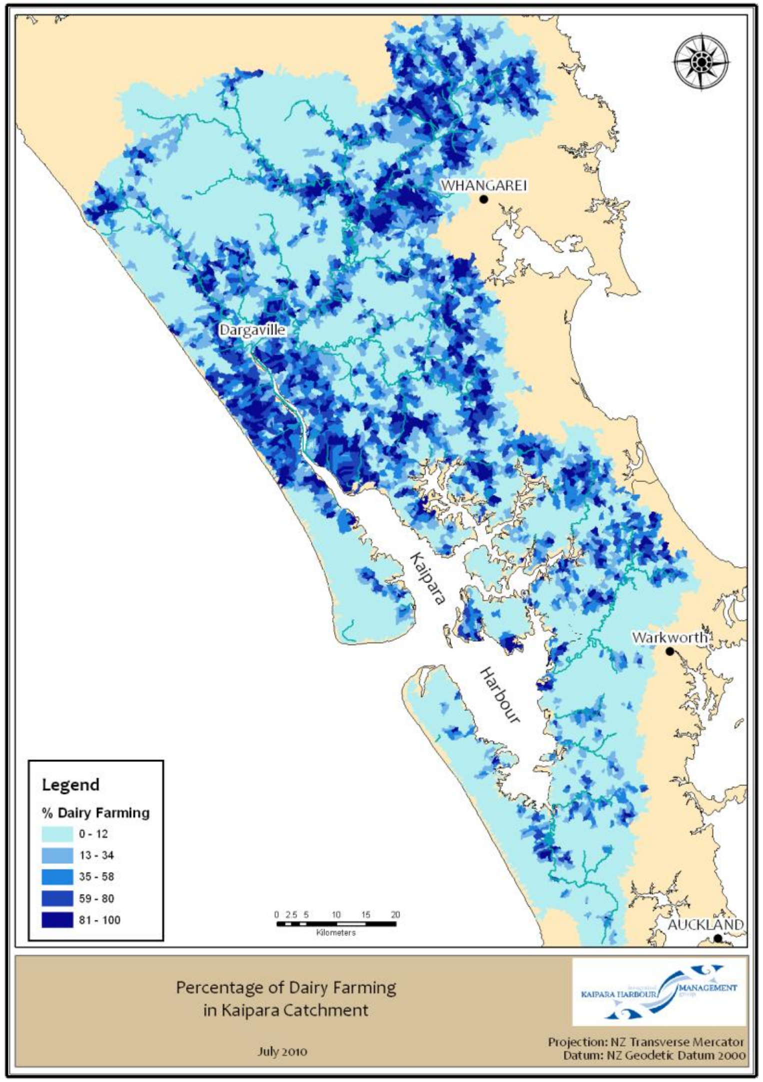


Figure 49. Percentage of intensive sheep and beef farming in the Kaipara catchment.

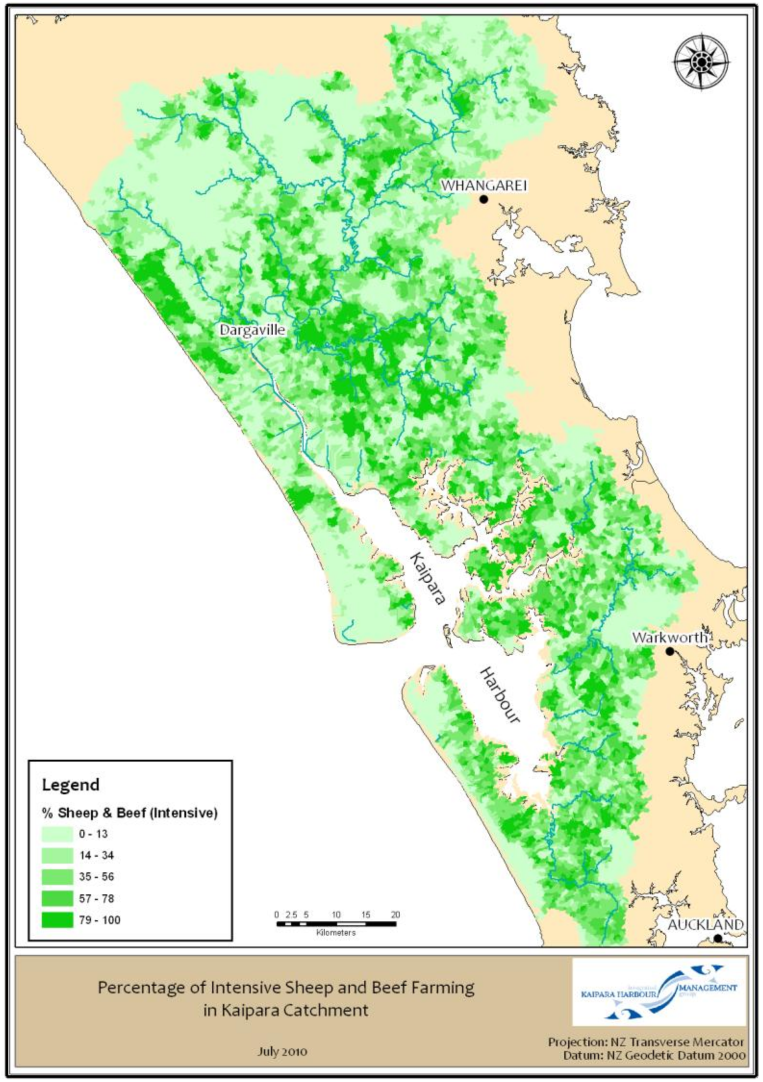


Figure 51. Sediment load (kt/year) for the Kaipara catchment generated from the CLUES model.

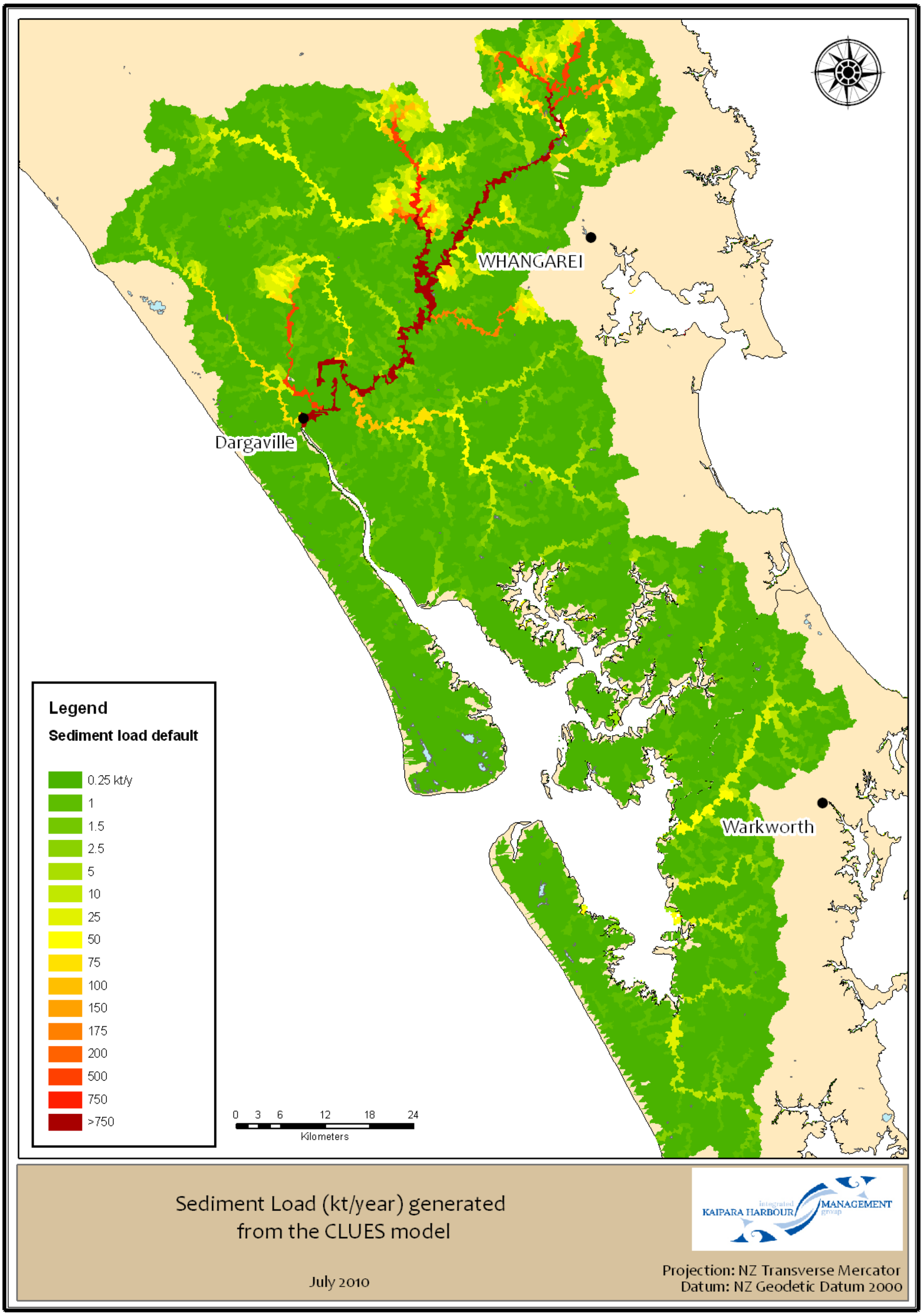
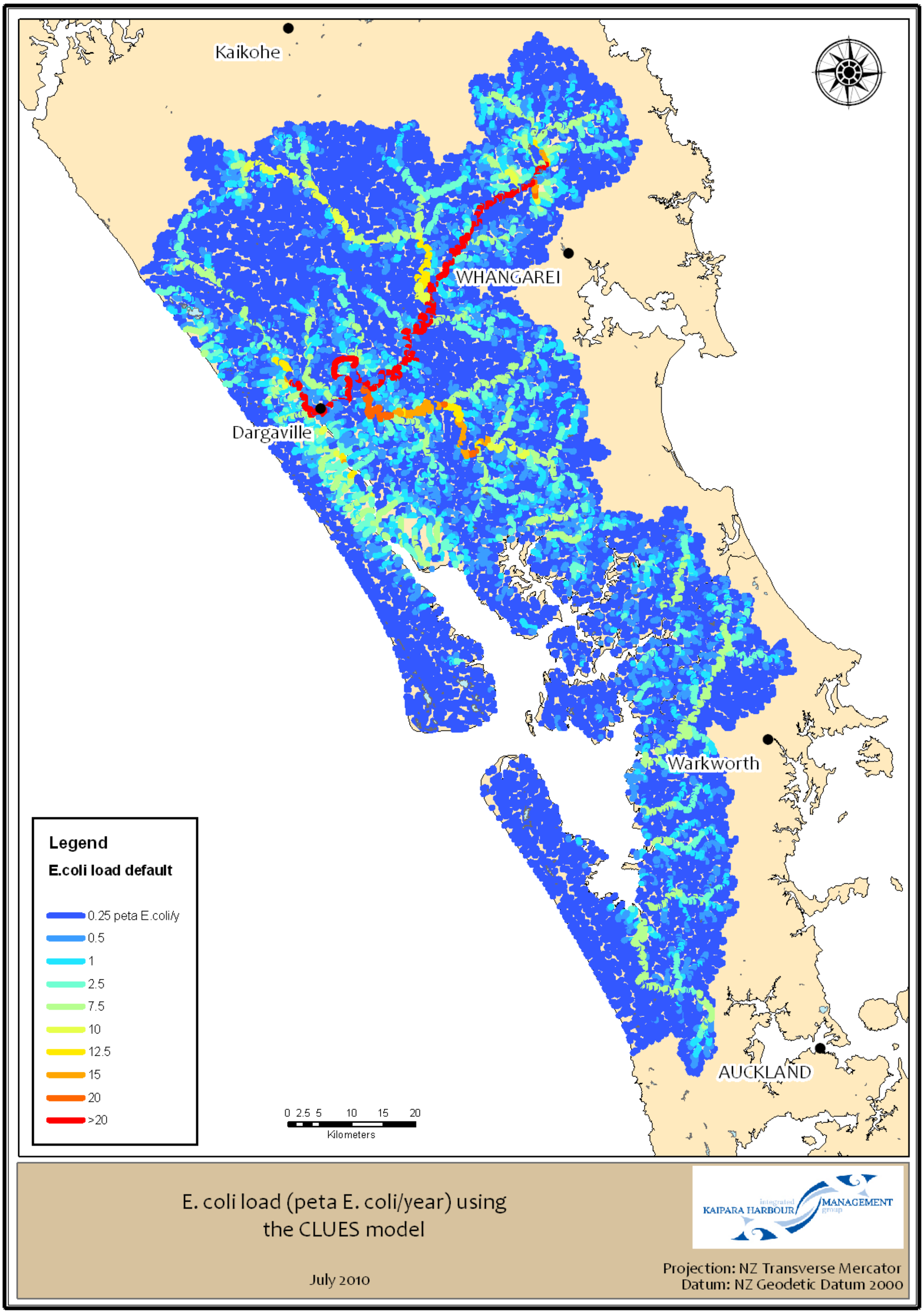


Figure 52. E. coli load (peta E. coli/year) for the Kaipara catchment generated using the CLUES model.



Other Stressors to Ecosystems

Human activities are affecting nearly every part of the Kaipara Harbour and catchment, creating a difficult challenge for kaitiaki, managers and conservationists, particularly when allocating limited resources to provide efficient and effective results. There are various methods available to assess ecosystem vulnerability to current stressors, and provide a threat−ranking or an evaluation (Zacharias & Gregr 2005; Halpern *et al.* 2007; Halpern *et al.* 2008) that are standardised, replicable, and quantitative methods using expert judgment. Marine environments in particular lack any sort of quantitative method for delineating areas that are sensitive or vulnerable to particular stresses, both natural and anthropogenic (Zacharias & Gregr 2005).

A global analysis on the scale of threat impact from single species to the entire ecosystem has been achieved in response to the recent emphasis on ecosystem−based management (Halpern *et al.* 2007, 2008[25]). Vulnerability scores were produced for 874 threat-ecosystem combinations using five vulnerability measures (i.e. scale (km^2), frequency of threat, functional impact of threat to trohpic levels, resistance to threat, recovery time (years)) and a measure of certainity. Hard shelf, rocky reefs, epipelagic offshore waters, and the rocky intertidal ranked as the ecosystems most vulnerable to threats compared to deep−ocean ecosystems ranked as least threatened. The most threatened ecosystems ranked high because they are afflicted by many threats, particularly multiple types of fishing. The largest-scale threat was climate change, species invasion and hypoxia; and the stressor with the highest impact to trophic levels was sedimentation.

The IKHMG, in its efforts to achieve an integrated ecosystem-based approach to managing biodiversity, fisheries, socio-economic opportunities, climate change, research and planning could utilise similar methods to gain significant insight for prioitising resources and conduct a finer−scale ranking analysis for the Kaipara harbour.

Table 23 is an initial step in such a process, where current stressors are assessed, using current and past literature and expert knowledge, for major ecosystems for the Kaipara Harbour and catchment. With 84 threat−ecosystem combinations reviewed here (8 threats multipled by 12 ecosystems), and using current literature, research and information, this will be a substantial (yet acheiveable) task. This table simply provides a possible framework on which to proceed. Physical processes such as localised upwellings and, currents; particularly important species such as kiwi and Maui dolphin; or biogenic habitat formers such as green-lipped mussel beds, could also be added and assessed against different stressors.

Proposed Research in the Kaipara

Recent proposed research by the Ministry of Fisheries (Project Code BEN200705) to develop a coastal risk assessment framework is underway by NIWA. The project has two objectives: (a) to collate existing information on the distribution, intensity and frequency of anthropogenic disturbances in the coastal zone that could be used in a risk assessment model to estimate their likely aggregate effect on ecosystem function across habitats and different scales; and (b) develop a risk assessment framework in conjunction with scientists and, stakeholders.

[25] http://www.nceas.ucsb.edu/GlobalMarine

Proposed FRST research into understanding the cumulative effects of stressors on estuarine/aquatic ecosystems has been developed by Landcare Research, Cawthron Institute and NIWA, with the purpose of moving towards quantitative targets for catchment management of contaminants and controlling non−point source pollutants. The proposed project has four objectives: (a) determine how ecosystem structure, function and resilience respond to contaminant stress gradients, particularly sediments, and multiple stressors, and identify ecosystem tipping points; (b) develop methods for evaluating resource capacity; (c) develop methods for converting contaminant loads into ecological relevant metrics. This third objective will focus on developing an estuarine suspended−sediment "climatology" to underpin risk assessment, and new tools for evaluating nutrient attenuation in catchments (DairyNZ 2009); and (d) Determine obstacles and opportunities for applying aspects of resource capacity in regional planning.

Table 23. Summary of current, rather than future, major direct and indirect stressors to the Kaipara Harbour and catchment ecosystems.

A review of the literature and summary of current (rather than future) major direct and indirect stressors to the Kaipara harbour and catchment ecosystems. + Indicates a stress. The intensity of the stress and influence distance of the stress was considered. For example, the stress of catchment development or landuse has a small scale influence distance and does not really stress pelagic ecosystems. There are a multiple of stressors operating on the various ecosystems, such as coastal waters and soft shallow seafloor. Climate change will be another stress for all ecosystems through sea level rising, sea temperature rising, acidification, rainfall and evaporation patterns changing. Such an exercise using an experts survey may assist with developing a weighted score based on particular vulnerability measures, such as scale, resistance, recovery time (years), and frequency of threat.

Kaipara Ecosystem	**Human Activity**						
	Current Landuse (sedimentation, eutrophication, pollution)	**Sand extraction** (physical & community disturbance)	**Fishing** (physical & community disturbance)	**Invasive Species** (community disturbance)	**Aquaculture** *(physical & community disturbance)*	**Urbanisation/ Coastal Development** *(sedimentation, eutrophication)*	**Climate Change**
Seagrass	+			+	+	+	+
Pelagic Waters			+				+
Coastal Waters	+	+	+	+	+		+
Estuarine Waters	+			+			+
Freshwater Wetlands	+			+		+	+
Sand dunes	+			+		+	+
Forest	+			+		+	+
Scrubland	+			+		+	+
Mangroves	+			+		+	+
Soft shallow	+		+	+	+	+	+
Hard shallow	+	+			+		+
Saltmarsh	+			+		+	+

9.10 SOCIO−ECONOMIC LINKAGES WITH BIODIVERSITY

Our understanding of the socio−economic linkages between biodiversity, and human values and needs is very limited for the Kaipara. In fact, we have limited (no) understanding of stakeholder, iwi/hapu, and communities' perceptions and value of the natural biological resources of the Kaipara. This includes the Kaipara's intrinsic value – the value of being the Kaipara. With the placement of "intrinsic value" in the RMA (section 7 (d)) the use of it by planners and managers, suggests it is a minor principle (Park 2000). In terms of measuring ecosystem integrity, the concept creates one of the biggest hurdles for political and legal attempts to cope with this concept.

Putting an economic value to natural capital and the services it provides through direct and indirect values (Table 24) is difficult but when tried it makes economic sense. The indirect value of the world's ecosystems, such as intact catchments and intact mangroves, have been estimated annually to provide at least $US33 trillion dollars worth of services (Constanza *et al.* 1997). According to their study the world's oceans have a total global value of $US8381 trillion for ecosystem service, including food production, nutrient cycling and regulation of atmospheric chemical composition. Coastal ecosystems, including estuaries and seagrass beds, were calculated to have a value of $US12568 trillion. In 2003, the New Zealand marine economy, through direct activities such as, offshore minerals, fisheries and aquaculture, contributed $3.3 billion towards the economy, almost 3% of total GDP (Statistics New Zealand 2003). In 1999, New Zealand's ecosystem services were valued at $183 billion (PCE 1999). It has been estimated that the indirect contribution has normally been double that of the direct figure.

Table 24. The indirect and direct values of biodiversity.

	Use Values			Non−use values
	Direct value	**Indirect value**	**Future value**	**Existence/Intrinsic value**
Definition	The resources and services provided directly to you by the natural area or by direct harvesting and exploiting wildlife	The indirect functions which support the economic activity which are provided by the natural area	Amount people/organisations are willing to pay to conserve the ecosystem for future use	No economic value. This would include worth of wildlife, natural areas and overall biodiversity as having intrinsic value and stewardship value
Examples	Harvested products, such as, water, meat, fish, timber, plants, tourism, recreation, genetic material, education, water transport	Ecological functions & roles Protection functions Waste assimilation Carbon store	Future use of direct & indirect value	Maintenance of biodiversity Species diversity Cultural heritage Traditional values of taonga for tangata whenua Nitrogen fixation Weed suppression Soil generation & protection riparian protection pollination nutrient cycling Identity and sense of place (e.g. national icon such as silver fern). Aesthetic, amenity & landscape values

Drawing from national and international literature sources, economic assessments of the value of biological resources (also referred to as ecosystem services) have only recently entered the decision−making process. One of the more recent ecosystem services assessments has been carried out for addressing the global climate change issue (Fischlin *et al.* 2007; IPCC 2007) and in 2005 the Millennium Ecosystem Assessment[26] (MEA) was

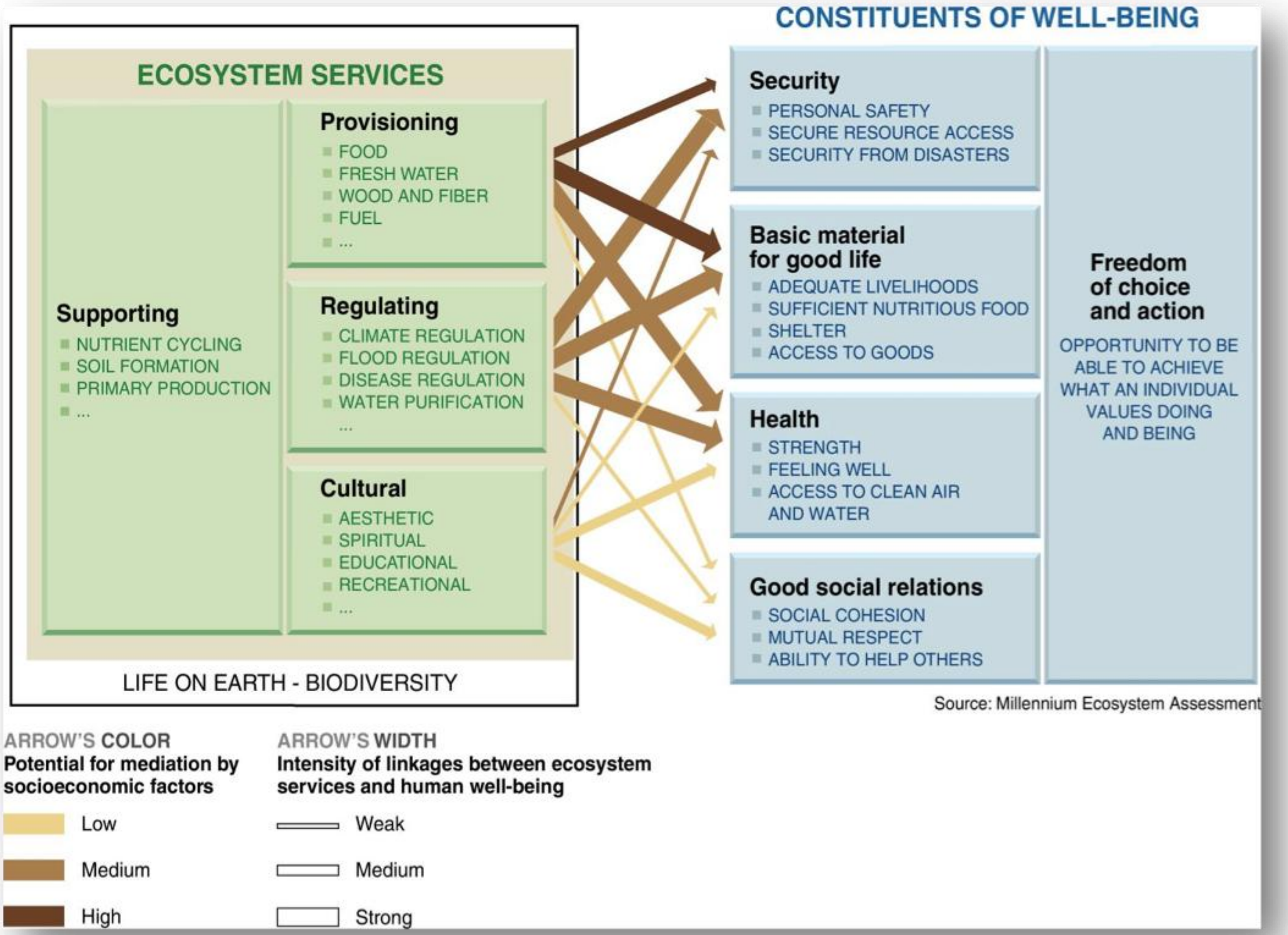
[26] http://www.millenniumassessment.org/en/index.aspx The Millennium Ecosystem Assessment assessed the consequences of ecosystem change for human well-being. From 2001 to 2005, the MEA involved the work of more than 1,300 experts worldwide. They undertook a scientific appraisal of the condition and trends of the world's ecosystems and services they provide, and provided the scientific basis for action to conserve and use them sustainably.

released. Both documents state the linkages among biodiversity, ecosystem services and human well−being. Many people derive a sense of well−being from being close to nature. This applies to people of many spiritual traditions as well as secular culture (Wild & McLeod 2008). Contact with nature and a sense of place may be a basic need for human well−being and the urban parks movement in the USA has demonstrated the value of planted green space. It is even reported that a picture of a beautiful landscape can enhance well−being.

The MEA identified four categories of ecosystem services: (1) *supporting,* such as primary and secondary production, and biodiversity, a resource that is increasingly recognised to sustain many of the goods and services that humans enjoy from ecosystems; (2) *provisioning,* such as products or food including game, roots, seeds, nuts, fruts, fibre including wood and medicinal and cosmetic products; (3) *regulating,* which are of paramount importance to human society, such as, carbon sequestration, climate and water regulation; and (4) *cultural,* services which satisfy human spiritual and aesthetic appreciation of ecosystems. Figure 53 depicts these categories and the strength of linkages between categories of ecosystem services and components of human well−being that are commonly encountered. Ecosystems are affected by changes in human well−being, and in turn influence human well−being. For Māori, the Kaipara's geological, topographic, climatic, and biological features and processes produce a characteristic landscape and unique range of biological communities.

There are still substantial gaps in our understanding of these four services provided by Kaipara ecosystems and with climate change predicted to increase and biodiversity continuing to decline, plus the intensification of land use, the relevance of addressing intrinsic values and economically valuating ecosystem services of biodiversity is likely to increase.

Figure 53. Linkages among biodiversity, ecosystem services and human well−being (Source: Millennium Ecosystem Assessment (2005)).



9.10.1 ENVIRONMENTAL CARE GROUPS

The presence of landcare groups, coastcare groups, harbourcare and rivercare groups (Table 25), and Wai−care community organisations, indicates a groundswell of community need to participate in the environmental management and restoration of their local environment. Grass−roots action or participation has been found to be the greatest opportunity to educate oneself about environmental issues and management. Here awareness about such issues can physically be experienced through professional, scientifically researched methods and findings. For example, the Oneriri Community Pest Control project, arose from adjoining landowners vision for kiwi becoming part of their neighbourhood. The Kiwi, is effectively our national branding, yet a critically endangered species that only occurs in New Zealand.

Table 25. Some examples of environmental care groups and their activities in the Kaipara.

Group Name	**Location**	**Focus** Weed Control	Possum/Rat Control	Predator Control	Revegetation	Dune Restoration	Kiwi Recovery	Dune Lake Restoration	Other:
Ōtamatea Harbourcare	Arapaoa River, Otamatea River				☺				
Ōtamatea High School Enviro Group	Ōtamatea River-Wairua River				☺				Wetland broadwalk
Oneriri Community Pest Control Area	Oneriri Peninsula		☺	☺					
Taporapora Landcare Group	Taporapora Peninsula		☺	☺					
South Head Landcare Group	South Head Peninsula				☺				
Tauhoa Landcare	Tauhoa River (upper catchment tributaries)				☺				
Glinks Gully Coastcare	Glinks Gully				☺	☺			
Mangakahia Landcare	Mangakahia	☺			☺				Integrated Catchment Management
Maungakaramea Landcare Group	Maungakaramea	☺	☺	☺	☺				
Omamari Beachcare Group Hua Rakau ki Omamari Trust	Omamari					☺			
Pahi Possum Patrol	Pahi		☺						
Paparoa Lions	Paparoa		☺		☺				
Waipoua Forest Trust	Waipoua Forest		☺	☺	☺		☺		

Group Name	**Location**	**Focus** Weed Control	Possum/Rat Control	Predator Control	Revegetation	Dune Restoration	Kiwi Recovery	Dune Lake Restoration	Other:
Jack Bisset Wetland Standholders Committee		☺	☺	☺	☺				
Waiotira Landcare Group			☺						
Poutu Topu A Trust	Poutu Peninsula				☺			☺	
Forest & Bird NZ - Atuanui Restoration Project	Atuanui/Mt Auckland, Hoteo River		☺	☺	☺				
NZ Native Forest Restoration Trust	Marie Neverman Reserve, Tupare, South Head		☺						Wetland restoration Monitoring Longterm planning for restoration (e.g. purchase 100 hectares more)

9.11 GAPS & OPPORTUNITIES TO RESTORE & PROTECT NATIVE BIODIVERSITY

Biodiversity simply means 'the variety of life'. Biodiversity is both an outcome of, and essential to, ecosystem integrity and health.

Biodiversity remains in a state of rapid decline across Kaipara ecosystems. The Kaipara catchment indigenous vegetation cover has been substantially modified, resulting in considerable loss of indigenous biodiversity of coastal, lowland and rolling hill environments.

The Kaipara catchment contains four ecosystems: forest, freshwater, shrublands, dunelands and estuarine. All ecosystems have suffered significant losses of up to 90% since European settlement. Māori cosmology describes these ecosystems differently: *Tumatauenga*, domain of human society and mastery of fire and stone−rapping; *Tanemahuta*, domain of forest biota; *Tangaroa*, domain of aquatic biota; *Rongomaraeroa*, domain of cultivated and stored crops; *Haumiatiketike*, domain of wild staples (bracken fern root, flax, koromiko, nikau, ponga); *Tauhirimatea*, domain of physical forces.

The concept of ecosystem is not unfamiliar to Ngāti Whatua ke Kaipara. They have gained a wealth of knowledge (Mātauranga Māori) on the functioning and sustainability of ecosystems.

Multiple stressors are impacting on biodiversity and the ability of ecosystems to function. Symptoms include the loss and fragmentation of habitat, overharvesting and introduction of pests, diseases and plants.

General understandings of important knowledge and management gaps gathered from this information review are listed below. A prioritisation excercise was undertaken by the IKHMG at a workshop convened on 18th February 2010. Therefore, top priority gaps and opportunities that were confirmed are outlined first followed by other gaps and opportunities identified from the analysis.

9.11.1 PRIORITY GAPS & OPPORTUNITIES

Systematic Spatial Strategies for Conservation & Restoration
A need exists for systematic conservation and restoration planning strategies to be developed to address the consistently poor water quality throughout the catchment; the inadequate protection and restoration of riverine ecosystems, dune sandfield ecosystems, freshwater and dune wetlands; and a large proportion of threatened land enviornments.

The Waters of National Importance (WONI) project, which is part of the Sustainable Development Program of Action for Freshwaters, identifies lakes, rivers and wetlands that would protect a full range of freshwater biodiversity. WONI freshwater ecosystems (apart from dune lakes and ecosystems) have been applied to the Kaipara at a national and regional/biogeographic scale.

Protection and restoration strategies should be guided by integrated principles of the IKHMG – Mātauranga Māori and western scientific knowledge.

Particular attention should be given to the following when developing a systematic strategy for restoration and conservation:

- Establish shared objectives and goals for specific ecosystems so to establish a transparent and fully accountable process.
- Founded on the integrated spatial prioritisation analysis of WONI (that includes dune lakes, rivers, streams, wetlands and lakes). Various decision-support tools exist to conduct such analysis utilising ecological information on fish and macroinvertebrates, pressure estimates that indicate likely loss of biodiversity values and other spatial databases.
- Document conclusion/outputs of spatial prioritisation analysis (that includes a ranking and scenario exercise) to identify priority areas for action thus, moving towards a cost-effective approach to restoration and protection.
- Include a multi-pronged and integrated approach that includes riparian planting, land purchasing, stream and river fencing; catchment nutrient budget planning; with the most efficient and effective strategies implemented that will focus on the most highly stressed and/or polluted and threatened environments in the catchment.
- Identify partners and their interests and responsibilities to promote coordinated action and integration.

Robust Freshwater Ecosystem Management

The Gap Analysis found that only 0.3% of freshwater wetlands remain in the Kaipara catchment and up to 99% of the catchments rivers and streams are polluted. They are also surrounded by a large propotion of threatened land environments. Freshwater connects the land to the sea presenting an opportunity for restoration and management that could benefit other ecosystems, particularly: terrestrial, wetlands, estuaries, and dune-sandfield.

Particular attention should be given to the following opportunities:

- Investigation of a core network of protected areas supported by integrated management arrangements, such as land purchasing to promote good land management. Further discussion of this opportunity is given below.
- Understand the Persistence of Freshwater Fauna. Using the commercially and customary important longfin eel, Tuna, (*Anguilla dieffenbachia*) as an example of a species that utilises spatially different habitats during its lifecycle, robust freshwater management requires information on such species as eel and typical fauna of freshwater ecosystems. It is unclear what quantity (kilometres) of rivers/streams allows unimpeded or man-made assisted fish passage in the Kaipara.
- Robust freshwater management requires strategies to ensure migratory corridors, ecological processes and, habitat protection (retention of swamplands, riparian vegetation, estuarine reserves, headwater reserves, fish passes) exists within the Kaipara Harbour and catchment

- Build relationships and partnerships. Kaipara Māori co−management of freshwater fish, such as tuna, is lacking and requires meaningful discussions to meet particular statutory acknowledgements under Settlement legislation and also under the Treaty of Waitangi. Of particular integration are Māori practices such as taking fish only for food, trapping at times of optimal food value, and maintaining purity of the mauri and waterways, practices based on long experience and knowledge.

- We currently have a very poor understanding of Māori priorities and cultural values in the Kaipara. Improving that knowledge would assist with methods to protect, or sustainably manage, tāonga species or other natural resources of cultural importance.

Integrated Protected Area Network for Biodiversity Persistence

The existing terrestrial protected areas occur in only a few landscapes particularly at high altitudes and across hilltops, although threatened environments have been identified for freshwater wetlands, gumland, and lowland coastal areas. Large number of indigenous plant and animal species are extinct in the lower catchment areas (e.g. kiwi, kokako, robin, tomtit).

Protected areas for the persistence of marine biodiversity do not exist for the coastal marine environment greater than the 2 metre depth zone of the Kaipara Harbour or its adjacent coast. Protected areas under the Reserves Act do exist but were not purposely established to protect biodiversity and ensure its persistence.

Our understanding of whether the current protected area network across land and sea is protecting, restoring and maintaining (persistence) biodiversity across ecosystems is unknown. Our understanding of whether the current protected area network accommodates large-scale and long-term ecological processes and change across the catchment is also unknown.

Particular attention should be given to the following opportunities:

- The Information Review and Gap Anlysis has provided a brief overview of what terrestrial ecosystems are currently under formal protection for the purposes of biodiversity but, our understanding of the spatial connectivity within and between ecosystem types is unknown.

- Investigate the use of spatial decision-support tools (e.g. Marxan, Zonation, C-Plan) to assist with identifying important areas for the persistence of biodiversity and require subsequent integrated ecosystem-based protection. Different scenarios should be investigated that address various objectives, criteria and values (e.g. ensure important areas for fishing are not impacted; include all threatened environments; protect all seagrass ecosystems and other rare ecosystems).

- Gaps in our knowledge also exist in terms of what existing biogeophysical data sources will be sufficiently consistent to serve as surrogates of biodiversity across the Kaipara planning area. This may be achieved through a Rapid Biodiversity Assessment (methodology also known as BioRap).

- Establish shared objectives and goals for specific ecosystems that inform the criteria used in the decision-support tools. These could include: protect all rare and threatened ecosystems.

- Promote scientific investigation of land-sea ecological processes; trophic relations at regional scales; animal migration; dispersal, and other largescale movements of individuals and propagules; forms of disturbance (e.g. erosion, drought, flooding, forestry or landclearing) at regional scales; climate variability in space and time and human forced rapid climate change; hydro-ecological relations and flows at all scales; coastal zone fluxes of organisms, matter and energy; and spatially-dependent evolutionary processes at all scales.

Biodiversity surrogates:

Because biodiversity is not completely known anywhere, planning for biodiversity restoration or protection is always based on surrogates for which data are available. For the marine environment, habitats are commonly used as surrogates.

Ecosystem Stressors: Addressing Sedimentation & Eutrophication of aquatic and marine ecosystems

We have a general understanding of the causes and sources of sedimentation and eutrophication, but little understanding of the frequency, scale and intensity dynamics of these two stressors. Both are a major cause of continued degradation of the Kaipara aquatic ecosystems. The management of these non-point sources of pollution and stress is widely recognised. Despite best land-management practices, incentives, community involvement, environmental standards for building and development, these two sources of stress are still having an impact on Kaipara aquatic and marine ecosystems.

Particular attention should be given to the following opportunities to address sedimentation and eutrophication includes:

- Understand the Sedimentation Accumulation Rates (SAR) and determine linkages with historical landuse changes.

- Acquire a baseline measure, spatial and temporal, of the level of contaminants (e.g., pesticide residues, heavy metals, suspended solids, nitrogen, phosphorous) in: (1) Harbour−bed, (2) upper river(s) sediments, (3) water-ways, (4) Harbour.

- Understanding and measuring transport pathways of contaminants across various landscapes (both natural and altered for landuse, particularly agriculture) at both spatial and temporal scales. This should include path from origin to final settlement for sediments and nutrients. From the evidence collected for this review, it appears that patterns of sediment and/or pollution differ across the entire Kaipara catchment and within individual sub-catchments. Carrying out spatial modeling across the entire catchment would assist in understanding these patterns and pathways.

- Formulate quantitative targets for catchment rivers (e.g., tonnes per year or tonnes per cubic kilometre of average annual discharge of water from the river) with a focus on contaminants, particularly pesticide residues, heavy metals, total suspended solids, total nitrogen, total phosphorous, based on current and new data sources.
- Understanding and quantifying (i.e. mapping) the spatial distribution, range of influence and intensity of land-based stressors. This can assist with improving and rationalising spatial management of human activities within the Harbour and catchment.
- Identify potential 'hotspot' areas of pollution by sediments and other contaminants like phosphates, nitrogen and pesticide residues (e.g. mercury, dioxins, dieldrin) that are having most impact, that will achieve all objectives of IKHM project and subsequently inform restoration strategies.
- Also, important to identify and understand which sub-catchments are most at ecological risk; building on rare and threatened environments identified at the Territorial Authority scale and applying an understanding of spatial and temporal patterns of pollution. Difficulties may arise due to the lack of "near natural" or undisturbed catchments that reflect natural circumstances.
- There are substantial gaps in knowledge of how land-based stressors affect coastal fisheries through sedimentation. Morrison *et al*. (2009) provides key recommendations for research, including connectivity between habitats and systems at large spatial scales where impacts operate at various scales through different fish movements, and the role of river plumes in affecting indirectly through impacts on nursery habitats.
- Activities that influence the delivery of pollutants, contaminants suspended solids or sediments need to be prioritised; catchments that influence the Kaipara the most need to be understood/identified; the connection between the catchment and marine ecosystems in assessing risks needs to be considered, for example, the impact to marine biodiversity from land-based contaminants.

9.11.2 OTHER GAPS & OPPORTUNITIES

Knowledge & understanding

- **Modelling of entire sand transport system from open coast/longshore transport, across the ebb tidal delta, through inlet to flood delta and up channels.**

  A chronology for the deposition of sand has not been established (Parnell 2004). The deposition of sand during the Holocene, against the Pleistocene cliffs of North and South Head, is of particular interest. It has not been confirmed from dating if these features have developed over the entire 6500 years since sea level reached is present position, or if they have develop more recently.

Parnell (2004) provides geomorphic evidence that indicates the Kaipara tidal system has undergone considerable change in historical times. Sand bodies on the North and South heads have certainly been deposited in the last 6,500 years, and probably in the last few hundred years. Since 1887 there has been erosion from the southern end of North Head, and accretion to the north. This is supported by an anecdotal report on the finding of Māori canoe remains near the Pleistocene cliff line, hundreds of metres from the present shoreline. The Holocene sand body on the western side of South Head has prograded massively in the Holocene but has retreated since 1943 (Hume *et al*. 2003). The Holocene sand bodies at North and South Head have therefore probably developed fairly recently, over the past few hundred years. Major sand deposition in the southern shoals has been accompanied by erosion of North Head, and a move of the deepwater channel to the northern side of the tidal throat. This is consistent with a sediment supply of at least 175,000m^3/year from the south (Hume *et al*. 2003) and a very low slow translation northward of the tidal inlet system.

Improvements on data sources to depend and remedy such uncertainties are vital to the future sustainable management of sandmining in the Kaipara. This includes updating bathymetry data currently from 1993 and wave movement data. Both data sets will enable the modeling of sand transport through the ebb tidal delta to be more accurate.

- **Ecological Information Data Gaps**

The following is a list of ecological information, notably spatial information, data gaps for Kaipara ecosystems:

Ecosystem	Data gap identified	Other comments
Freshwater Wetlands	Threatened plant communities represent some of the greatest data gaps as they have few comprehensive inventories compared with rare or threatened animal species. Hard to find inventories need compiling into the Kaipara Atlas Database, e.g. DoC threatened plant communities' inventories.	Development of a GIS layer for 'threatened ecosystems' (DoC currently define as: lake margins, coastal cliffs, marine mammal haulouts, gumland)
	Sand dune lake vegetation spatial distribution for both submerged and emergent vegetation. This needs to include endemic species locations and threatened classified species.	
	Weeds and Pests spatial distribution of pest vegetation in dune lakes.	
	Impact(s) of pest plants and animals on freshwater ecosystems requires quantification.	
	More detailed mapping and ground−truthing of this rare ecosystem. Could be included in with other rare ecosystem types such as dune lakes.	
Intertidal mudflats and	Spatial extent of coastal birds for roosting and breeding areas and the migratory pathways between them. Specifically for	ARC Plan Change 4 – Mangrove

Ecosystem	Data gap identified	Other comments
sandbanks	northern hemisphere migratory visitors/species, threatened classified species and regionally significant species.	Management has identified significant roosting & feeding areas for wading birds in Kaipara Harbour. These need to be placed on Kaipara Atlas Database.
	Marine habitat map of northern Kaipara Harbour. Habitat mapping of coastal−marine−offshore environments.	Some being addressed by Leane Makey's PhD research.
	Impacts of stock grazing in the northern Kaipara Harbour estuarine ecosystem needs to be baseline mapped and subsequently quantified to support southern Kaipara work on stock grazing distribution (Bellingham & Davis 2008).	
Seagrass	More detailed spatial information on distribution of seagrass beds in the Kaipara harbour, and its spatial and temporal population dynamics.	
Forest	Tokatoka Ecological District significant natural areas reports and associated databases need to be completed to undertake a catchment wide assessment of spatial conservation priorities and restoration strategies.	
	Rare plant communities represent some of the greatest data gaps as they have few comprehensive inventories compared with rare or threatened animal species.	
	Spatial distribution of native species. This will require expert opinion and modelling.	
	Map distribution of animal pest and weed species, including abundance information. May require expert opinion and workshop.	
Estuarine & Marine Biodiversity	Formal biodiversity survey of the northern Kaipara Harbour, to equal work in the southern Kaipara by Funnell & Hewitt (2005).	Some being addressed by Leane Makey PhD.
Fish Populations	Comprehensive fish habitat maps required for the harbour, along with quantification of what species are found where, at what sizes, and when. Also needed is knowledge of linkages through movement with the open coast (both ontogentic and seasonal migrations), trophic relationships, spawning locations and aggregations, the location of nursery grounds, and the impacts of marine (e.g., fishing) and land-based stressors (e.g., sedimentation) on these processes and areas.	The MFish ENV200907 project habitats of particular significance to fisheries will address some of this.
Ecological Processes that drive ecosystems	Persistence of biodiversity is dependent on both spatial and temporal scales. Gaps include: processes governing ecosystems; identify and report on surrogates of processes, such as eco-corridors (e.g. lowland-coastal gradients); sand movement corridors; subtidal-intertidal marine habitat interfaces; interfaces between soil types to encourage speciation; historical range of flux in the system; evolutionary and physiological limits of the system's species.	Should look to include in future Protected Natural Area surveys.
Marine Pests	Spatial and temporal distribution, density and impacts of marine pests, e.g., Asian Date Mussel	
Ecosystem	Understanding the contribution natural ecosystems that play a	

Ecosystem	Data gap identified	Other comments
linkages with Māori values	key role in supporting species & ecosystems of cultural importance.	
Socio-economic linkages with Biodiversity	Most of the Kaipara's industries such as timber, fisheries, sandmining, tourism and agriculture depend directly or indirectly on ecosystems and their services. Understanding spatial and temporal patterns of human uses of biodiversity in the Kaipara is a gap. Our understanding of ecosystem services provided by Kaipara ecosystems is a gap. The relevance of addressing intrinsic values and economic value of ecosystem services is likely to increase as the intensification of landuse continues, spatial demand for resources and access increases, climate change and biodiversity continues to decline.	

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