Manaaki Taha Moana: Enhancing Coastal Ecosystems for Iwi

Report No. 1
June 2011

Health of Te Awanui Tauranga Harbour

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ISBN 978-0-9876535-0-5

ISSN 2230-3332 (Print)

ISSN 2230-3340 (Online)

Published by the Manaaki Taha Moana (MTM) Research Team
Funded by the Ministry for Science and Innovation
Contract MAUX0907
Main Contract Holder: Massey University
www.mtm.ac.nz

* Employed by Massey University for the early stage of work on this report, and contracted by Waka Taiao for the latter stage.
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Reviewed by: Professor Chris Battershill

Approved for release by: MTM Science Leader Professor Murray Patterson

Issue Date: June 2011

Recommended citation:

Sinner J, Clark D, Ellis J, Roberts B, Jiang W, Goodwin E, Hale L, Rolleston S, Patterson M, Hardy D, Prouse E, Brown S. 2011. Health of Te Awanui Tauranga Harbour. Manaaki Taha Moana Research Report No. 1. Cawthron Report No.1969. Palmerston North: Massey University.

Mihi

He hōnore, he kororia ki te Atua
He maungarongo ki te whenua
E rere ana nga whakaaro ki a rātou kua peka atu ki tua o Pairau
Haere, haere, hoki atu rā
E tangi tonu ki a rātou Otautahi whānui
Ngāti Rarua, e mihi nei
Tauranga moana, e mihi nei
Ko Ngāti Ranginui, Ngaiterangi, Ngāti Pukenga me tou tātou whānau a Waitaha whānui tonu.
Otira ki te waitai o Te Awanui
E rerere – te au kume o Tangaroa e
Tihei Mauri Ora.

Published by the Manaaki Taha Moana Research Team

MAUX 0907 Contract Holder:

Massey University

Private Bag 11052

Palmerston North

New Zealand

Revision history

1	Revised caption for Figure 2. Re-scanned and re-inserted Figure 5 Minor formatting and typographical corrections. Reference changed from Wildland Consultants Ltd. (2003) to: Beadel S., Maseyk F., Garrick A., Pierce R., Bawden R., Honey M. (2003).	7 July 2011
2	Correction on p.ix. "non-commercial catch" changed to "commercial catch". Various other minor formatting and typographical corrections.	28 Nov 2011

EXECUTIVE SUMMARY

This report summarises what is currently known about the ecological health of Tauranga Harbour – traditionally known to local iwi as Te Awanui – in order to inform the Tauranga community, iwi and stakeholders of the 'state of the harbour' and to identify information gaps and priorities for field research. The report is based on a literature review of published scientific papers and technical reports; it did not extend to new field work or new analysis and interpretation of data.

Manaaki Taha Moana (MTM) is a six-year programme, running from October 2009 to September 2015, with research being conducted primarily in two areas: Tauranga moana and coastal rohe of Ngāti Raukawa on the Horowhenua coast. The wider research project aims to restore and enhance coastal ecosystems and their services of importance to iwi/hapū, by working with iwi to improve knowledge of these ecosystems and the degradation processes that affect them.

This report begins with a description of land use in the catchment and the history of development, because water quality and the ecological health of the harbour are directly affected by land use within the catchment. We then review current information on water quality, factors that influence water quality, the flora and fauna of the harbour and the ecosystem services provided by the harbour. These subjects are considered in turn before identifying current information gaps and priorities for future research.

Physical description of the harbour

Tauranga Harbour is a large estuary (approximately 200 km^2) protected from the Pacific Ocean by a barrier island (Matakana Island) and two barrier tombolos, Bowentown at the northern entrance and Mount Maunganui to the south. Two harbour basins are separated by large intertidal flats in the central area of the harbour and, although the two basins are connected, there is little water exchange between the two. The two main entrances to the harbour are at either end of Matakana Island where the tide flows strongly through deep channels. The rest of the harbour is shallow, typically less than 10 m deep, with intertidal flats comprising approximately 66% of its total area. The Port of Tauranga, established in 1873, is located near Mount Maunganui and maintenance dredging has been regularly required to maintain adequate channel depths.

Land use, wetlands and sediments

The Tauranga Harbour catchment covers 1,300 km^2 and is home to about 150,000 people. It receives discharges from many separate catchments originating in the Kaimai-Mamaku range. The northern harbour catchments cover an area of 270 km^2 while the southern harbour catchments cover 1,030 km^2. As of 2004, the land cover in the Tauranga Harbour catchment was predominately pasture and indigenous forest.

Wetlands have many ecological functions including the provision of fish and wildlife habitat, flood storage, shoreline erosion protection and natural water quality treatment. Specifically, wetlands improve coastal water quality by acting as a physical and biochemical filter to immobilize sediment and pollutants from water as it runs off the land. In the North Island, only 5% of original wetland area remains intact.

Between 1840 and 1991, freshwater wetland area around Tauranga Harbour declined by 84% while estuarine wetland area in Tauranga Harbour increased by 17%, reflecting a marked increase in mangrove vegetation. Approximately 700 ha of saltmarsh have been lost since 1840 due to land reclamation.

Sedimentation rate depends primarily on land slope, soil type, rainfall and land use. Land in pasture currently makes the largest contribution to sediment load in Tauranga Harbour (63% of total). Forested areas contribute 27% of the total sediment load. In the southern half of the harbour, the highest rates of deposition occur in the following sub-estuaries: Te Puna inner, the mouth of the Waipapa River and Mangawhai Bay inner.

Sedimentation affects many aspects of harbour ecology. It makes sheltered estuaries muddier and shallower and reduces water clarity. Direct impacts are likely to include clogging the gills of filter feeders (e.g. cockles, pipi, scallops), reductions in the settlement success and survival of larval and juvenile phases of shellfish (e.g. paua), reductions in the foraging abilities of finfish (e.g. juvenile snapper) and decreases in the food available to benthic species. The accumulation of nutrients, pesticides, heavy metals and hydrocarbon residues in shallow estuaries can also adversely affect marine organisms.

Chronic sedimentation will eventually lead to changes in the species mix of benthic communities and modification of ecologically important habitats, especially those composed of habitat forming species such as seagrass beds, green-lipped and horse mussel beds, bryozoan and tubeworm mounds, kelp forests, sponge gardens and mangrove habitats.

While sediment accumulation rates on intertidal flats in Tauranga Harbour are low compared to other North Island estuaries, sedimentation in more sheltered areas with higher accumulation rates has been implicated in the decline of seagrass and expansion of mangroves, as noted below. Climate models have projected a 43% increase in mean annual sediment load to the southern harbour by the year 2051. The projected increase is even larger in many sheltered estuaries (e.g. Bellevue 94%, Matakana (1) 48%, Waitao 47%).

Nutrients and other pollutants

Recent studies have found that levels of nitrogen and phosphorus have shown little change within Tauranga Harbour between the early 1990s and 2005. Most major point source discharges of nitrogen and phosphorous were removed from the harbour in the early to mid 1990s. In many rivers and streams entering the harbour, nutrient levels have declined due to improved rural practices and better control of surface runoff and land use changes. However, many of these rivers still have elevated nutrient levels, and some show increasing trends associated with agriculture and runoff from recently harvested forest. Omanawa, Kopurererua, Waimapu and Rocky streams had elevated nitrogen concentrations while phosphorus levels were highest in the Rocky and Kopurererua streams.

Despite frequent bacterial contamination in rivers and streams within the catchment, the microbiological water quality standards for recreation are rarely exceeded in Tauranga Harbour, although shellfish contamination can occur. Bacterial contamination in Tauranga has many possible sources: wastewater treatment plants and leaky pipes, septic tanks, livestock farming, birds, marine vessels and meat processing plants. Seepages have been detected from Te Maunga oxidation ponds, while Tanner's Point, Ongare Point and Te Puna have been identified as areas with on-site wastewater treatment systems (e.g. septic tanks) that pose a risk to water quality.

A number of studies have examined pollutants within Tauranga Harbour, including plastic particles, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs, commonly derived from incomplete combustion of petroleum and coal products), DDT, resin acids and heavy metals. While most of these substances were deemed to be within Australian and New Zealand Environment and Conservation Council (ANZECC) guidelines, exceedances were noted for some heavy metals and PAHs. Stormwater outlets that drain from industrial areas were identified as the key source of pollutants to the Tauranga Harbour. Te Maire Rd industrial area was an area of high contamination, exceeding at least the lower ANZECC guideline value for every metal except mercury. Zinc levels exceeded at least the lower guideline value for all sites bar one. PAHs and also exceeded the lower ANZECC guideline value in sediments surrounding stormwater drains.

It is difficult to determine accurately what constitutes low and high risk contamination because the effect of a pollutant on aquatic organisms depends on the habitat environment and the sensitivity of the species, and may only manifest itself over time. Heavy metals are generally toxic and tend to accumulate and persist in harbours and estuaries due to restricted water circulation and on-going inputs from the surrounding catchment. Areas with multiple toxins may be exposed to greater environmental risk due to compounding effects of pollutants.

There can also be problems in the food chain where higher order predators consume contaminated organisms and accumulate toxins (bioaccumulation), creating the potential for human health impacts via contaminated seafood. Shellfish monitoring indicates that copper and zinc levels were higher in shellfish from the Plumbers Point/Te Puna site than other locations in the harbour.

Marine flora

Phytoplankton biomass in Tauranga Harbour varies over time and is dominated by diatoms. Monitoring of phytoplankton in Tauranga Harbour commenced in 2003. Since 2008, shellfish collection closures have regularly occurred in the harbour as a result of toxic phytoplankton species.

At least 23 species of macroaglae have been identified within the harbour, with red turf-like algae identified as the most common. Sea lettuce blooms have occurred in the harbour as far back as the 1940s and monitoring since 1991 shows large blooms occurred in 1991-1993, 1998 and 2003-2007. Sea lettuce blooms peak in spring and decline over late summer, when growth appears to be nutrient limited. Greater sea lettuce abundance was recorded during El Niño years when nutrient-rich deep waters upwell offshore and enter the harbour; further research is required to understand the factors that affect sea lettuce growth.

Seagrass beds enhance primary production and nutrient cycling, stabilize sediment, protect the coast from erosion and support a number of animals and plants. They also provide a nursery habitat for juvenile fish. Seagrass beds declined by 34% from 1959 to 1996, with a 90% decrease in subtidal areas. Sub-estuaries with large catchments showed greater loss of seagrass, with sedimentation and nutrient loading implicated as the main factors causing seagrass decline in Tauranga Harbour. There are currently no proposed restoration plans but studies in Whangarei Harbour show this may be a viable option in the future.

Finally, while area in mangroves is declining globally, in New Zealand it is increasing. Mangroves in Tauranga Harbour have expanded from 240 ha in 1943 to 623 ha in 2003. Two main mechanisms account for the spread of mangroves, both directly driven by increased sedimentation. More sediment settling in the harbour raises the level of the intertidal seabed, allowing mangroves to colonise areas that were once too frequently inundated by the tide. Once established, mangroves reduce water movement and wind, further enhancing fine sediment deposition and creating a positive feedback as the extent of suitable habitat for mangrove colonization increases.

In Tauranga Harbour, approximately 90 ha of mangroves have been removed in the past few years, in response to community concerns over the spread of mangroves (reduced access to the water, loss of views, unpleasant odours, change in marine life, etc). Mangrove management initiatives are becoming more catchment focused, to reduce sedimentation that contributes to spread of mangroves. Although their expansion can be seen as a problem, mangroves provide many important ecological functions including trapping sediments, reducing coastal erosion, providing important nursery habitats for some species (short-finned eel, parore, grey mullet) and in nitrogen cycling. The removal of mangroves has been linked with mortality of epifauna and infauna, anoxic sediments and associated decreases in oxygen in the water column in cleared areas. Further research is being conducted to determine the ecological consequences of both mangrove removal and expansion on these habitats.

Marine fauna

Marine fauna include macroinvertebrates (e.g. sponges, anemones, worms, shellfish, crabs, starfish and sea urchins) fish, birds and mammals. Within Tauranga Harbour, soft sediment macrobenthic communities are similar to those in comparable habitats elsewhere in northern New Zealand. Polychaetes are the dominant taxonomic group in subtidal areas while bivalves dominate intertidal areas.

Shellfish and other marine invertebrates

A 1994 study reported that subtidal species diversity was limited by sediment mobility with fewer species in areas with low silt deposition (due to strong currents). Intertidal species diversity showed a strong negative correlation with silt content. Macroinvertebrate diversity was higher in seagrass beds than on bare sand. Studies of the rocky communities at the harbour entrance indicated these areas are very diverse with high densities of filter feeding species. Cockles, wedge shells and pipi all showed a pattern of larger individuals near the harbour entrance with progressively smaller ones in the upper harbour. Cockles showed no change in length frequencies between 1974 and 1994 and macroinvertebrate species richness, an indicator of ecosystem health, remained stable over the 1990-2000 period. Evidence of extensive former mussel beds has been found near the Bowentown entrance to the harbour; the loss of these beds has been attributed to overfishing.

Cockles and pipi have been monitored by the Ministry of Fisheries at Otumoetai, near the southern entrance to Tauranga Harbour, five times between 2001 and 2010. Pipi from Otumoetai exhibited a negative trend, with estimated total numbers down by 50% in 2010 compared to the 2006 survey. In contrast, the total number of cockles in 2007 and 2010 was significantly higher (up about 200%) compared to 2006 and earlier surveys, although the proportion of cockles of harvestable size was still low, around 1%.

Fish

Studies have found that yellow-eyed mullet are the most abundant fish species in Tauranga Harbour. Within the mangrove forests, yellow-eyed mullet remains the dominant species, followed by smelt and short-finned eel.

Commercial catch is reported at a scale not useful for assessing fisheries in Tauranga Harbour, so there is little quantitative evidence of trends in the status of most fish stocks. Both commercial and recreational harvests of snapper have fallen, but the recreational catch is still over 40 tonnes, dwarfing the commercial catch. Tangata whenua have noticed a decline in many fish species including flounder, shark, snapper, kingfish, trevally and mullet. They have raised concerns over the amount of bycatch being wasted by commercial fishers and fishing methods, such as drag netting, which they believe to have adverse effects on benthic habitat. A commercial fisher has also noted changes in fish communities. No new permits are being issued by the Ministry of Fisheries for dragnetting inside the harbour. A mataitai reserve of 6 km^2 was established in 2008 around Mt Maunganui; commercial fishing is prohibited within this area and restricted in many other parts of the harbour.

Marine mammals

New Zealand fur seals are common visitors to the harbour and leopard and elephant seals are occasionally sighted. More than 30 cetacean species (whales, dolphins and porpoises) have been observed in the Bay of Plenty and at least eight mammal species have been observed within the harbour. There is no statistically robust data that would enable population trends to be determined.

Birdlife

Tauranga Harbour is recognized as a wetland of international significance for the protection of migratory and resident bird species. These include birds whose population status is "nationally critical" (black stilt, grey duck and white heron), *nationally endangered* (bittern and black-billed gull), and several that are *nationally vulnerable*. During summer, Matakana Island hosts the largest breeding colony of New Zealand dotterel in the country, as well as a large post-breeding flock during winter.

Wading bird species showed mixed population trends over the period 1984-2010. Of 11 species that have been counted biannually, four had an increasing population trend, five had a decreasing trend, and others were mixed or insignificant. Dotterel numbers increased significantly, thought to be attributable to protection on Matakana Island.

Mount Maunganui hosts one of the few remaining mainland colonies of grey-faced petrel. Research indicates that the Mount Maunganui petrel population has been stable since at least 1990, although predation from rats and mustelids are a concern given the petrel's low reproduction rate. Black swan and paradise shelduck populations show no significant trend, but there was a significant increase in Canada geese in the Bay of Plenty region during the past decade.

Invasive species

Surveys at the Port of Tauranga have found twelve non-native marine species including three that were new to New Zealand. Noteworthy among these are the Asian date mussel, *Didemnum vexillum*, the Asian kelp *Undaria* and a dinoflagellate. Another non-native species, the sea squirt *Styela clava*, is well established in the Hauraki Gulf and is a potential threat to Tauranga Harbour because of the amount of vessel traffic between the two areas. The Port of Tauranga also remains vulnerable to new pest incursions from overseas, given the high level of incoming vessel traffic.

While some of these invasive species have the potential to cause significant ecological, social or economic harm, there is no evidence that they have yet caused significant harm in Tauranga Harbour. The extent of spread beyond the port environment is generally unknown but there are no indications of invasive species causing significant problems in the wider harbour.

Health of Tauranga Harbour

There is limited recent scientific evidence describing the overall condition of the harbour, and the indications are mixed. Time series data is available only since the early 1990s, and only for some indicators, and does not reveal any significant trends for nutrients and benthic communities. However, intertidal seagrass beds have declined significantly, and sub-tidal beds were almost gone by 1996; their fate since then is unknown. Sedimentation has been linked to expansion of mangroves and is almost certainly causing other changes to harbour ecology, but these have not been documented. Changes to fish and shellfish abundance have been noted anecdotally but there is no time series data with which to assess the extent of change.

Priorities for further research

While studies have been conducted on a wide range of topics about the ecology of Tauranga Harbour, understanding of the overall processes that drive the estuarine ecosystem is far from complete. In summarising this body of literature, a number of information gaps have become apparent.

The spatial scale over which information has been collected varies greatly from one study to the next. In order to understand more fully the role of various anthropogenic stressors on biodiversity, we suggest conducting a broad scale survey of Tauranga Harbour. In contrast to a fine scale survey, which provides detailed information on a relatively small area, a broad scale survey would involve sampling flora and fauna over the larger spatial scale of the entire estuary and collecting associated sediment samples to quantify sedimentation, nutrients and pollutants at each site. The survey would provide more current and detailed information to quantify macroinvertebrate communities, biodiversity and the presence or loss of functional groups such as shellfish species across the harbour. The collection of physical data at the same sites as biological data would enable changes in community composition to be linked with changes in key anthropogenic stressors such as sediments, nutrients and pollutants. This information could then also be used by iwi and researchers to prioritise research questions for further study.

Specific case studies could focus on shellfish, seagrass beds and mangrove expansion. Shellfish, seagrass beds and mangrove habitats are identified for further research due to their cultural and ecological importance and due to documented impacts on these ecosystem components. Other knowledge gaps and possible research topics are also identified in the report.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. INTRODUCTION

1.1. Background

Tauranga Harbour – known to local iwi as Te Awanui – is an estuary of great cultural significance to the iwi of Tauranga moana – Ngāti Pūkenga, Ngāiterangi and Ngāti Ranginui.

This report summarises what is currently known about the ecological health of Tauranga Harbour from a western science perspective. A separate report is planned to provide a cultural perspective based on mātauranga Maori.

Together, the two reports form a scoping exercise to summarise what is known about the health of the harbour, in order to identify the main information gaps and priorities for field research in Tauranga Harbour. This will help both to understand better the causes of the decline in the harbour's ecological health and to develop strategies for restoration.

This report is based on information that has been collected and published by other scientists and agencies. Detailed information from those previous studies has been included here where it has particular relevance for Tauranga Harbour, but readers interested in research methods and other detail from those studies should refer to the source material.

1.2. The Manaaki Taha Moana project

This report is one in a series of reports and other outputs from the research programme "Enhancing Coastal Ecosystems for Iwi: Manaaki Taha Moana" (MAUX0907), funded by the Ministry for Science and Innovation (previously known as the Foundation for Research Science and Technology, and the Ministry of Research, Science and Technology).

1.2.1. Study areas and personnel

Manaaki Taha Moana (MTM) is a six-year programme, running from October 2009 to September 2015, with research being conducted primarily in two areas: Tauranga moana and the Horowhenua coast. This programme builds upon Massey University's previous research with Ngāti Raukawa in the lower North Island: "Ecosystem Services Benefits in Terrestrial Ecosystems for iwi" (MAUX0502).

Professor Murray Patterson of Massey University is the Science Leader of MTM. A number of different organisations are contracted to deliver the research: Waka Taiao Ltd with support of Manaaki Taiao Trust in the Tauranga moana case study; Te Reo a Taiao Ngāti Raukawa Environmental Resource Unit (Taiao Raukawa) and Dr Huhana Smith in the Horowhenua coast case study; WakaDigital Ltd; Cawthron Institute; and Massey University. The research team seeks to engage with local communities and end users through a variety of means. Readers are encouraged to visit the MTM programme website (http://www.mtm.ac.nz) to read more about this research programme.

1.2.2. *MTM objectives*

The central research question is: "how can we best enhance and restore the value and resilience of coastal ecosystems and their services, so that this makes a positive contribution to iwi identity, survival and welfare in the case study regions?" Thus, our research aims to restore and enhance coastal ecosystems and their services of importance to iwi/hapū, through a better knowledge of these ecosystems and the degradation processes that affect them.

We are utilising both western science and mātauranga Māori knowledge to assist iwi/hapū to evaluate and define preferred options for enhancing/restoring coastal ecosystems. This evaluation of options will also be assisted by the development of innovative Information Technology and decision support tools (such as, for example, simulation modelling, interactive mapping, 3D depiction, real-time monitoring) by WakaDigital Ltd. Action Plans will be produced for improving coastal ecosystems in each rohe.

The research team works closely with iwi/hapū in the case study regions to develop tools and approaches to facilitate the uptake of this knowledge and its practical implementation. Mechanisms will also be put in place to facilitate uptake amongst other iwi throughout New Zealand. The key features of this research are that it is: cross-cultural, interdisciplinary, applied/problem solving, technologically innovative, and integrates the ecological, environmental, cultural and social factors associated with coastal restoration.

Manaaki Taha Moana has three specific research objectives:

* **Objective 1:** *Develop a Knowledge Base of Coastal Ecosystems and their Services in the two case study regions.*
This objective is focussed on determining the extent of critical coastal ecosystems and their services in both of our case study regions (Tauranga moana and the Horowhenua coast). The relevant research questions are: What are they? Where do they occur? How can they be measured in biophysical, cultural and other terms? How culturally significant are they? How much are they worth or valued?

* **Objective 2:** *Determine how to Enhance and Restore Specified Coastal Ecosystems and their Services in the case study regions.*
We are working directly with WakaTaiao, Taiao Raukawa and other agencies in the local communities to harness and build on the knowledge from Objective 1 to answer the central research question of: "how can we best enhance and restore the value and resilience of coastal ecosystems and their services, so that this makes a positive contribution to iwi identity, survival and welfare in the case study regions?" This will be achieved through detailed case studies in both regions, on topics of most importance to local iwi and hapū in ascertaining how to go about restoring coastal ecosystems and their services. We will work in with other groups and local councils who may also be undertaking complementary-focussed research.

* **Objective 3:** *Implementation and Benefit Transfer to other Iwi.*
A condition of involvement of both Tauranga moana iwi and Ngāti Raukawa in this research programme is that the research be implemented to bring about real change in the state of coastal ecosystems in their rohe. Both Tauranga moana iwi and Ngāti Raukawa have catalogued the poor state of many coastal ecosystems in their rohe - recalling, for example, accounts from tribal elders of the abundant kaimoana found 40 to 50 years, but not today. Both iwi groups are committed to arresting these trends and keen, through this research programme, to put in place Action Plans and other mechanisms to improve the quality of the coastal environment. Further, the tools and frameworks developed in this project will be made available to iwi and other end user groups nationally through information and communication technology and other means.

1.2.3. Fit with other MTM work

The initial research activities for this first phase of MTM have focussed on Objective 1, 'Building Up a Knowledge Base of Coastal Ecosystems and their Services', in both case study regions. In summary, we have been engaged in an ecological stocktake of "what is already known" about the state of coastal ecosystems in each rohe including both mātauranga Māori and western science knowledge; creating a mediated model of Tauranga Harbour and the inter-relationships between the various factors that contribute to its health; and the development of initial information technology tools to help us capture and utilise this critical knowledge and information to bring about restoration to coastal ecosystems. Collectively, these components will help inform the research team and tangata whenua in the selection case studies for more in-depth study and tool development in subsequent stages of MTM.

Thus, this initial "stocktake" phase has involved a number of inter-related components:
an ecological 'stocktake' of the Tauranga moana and Horowhenua coast (from the Hokio Stream to Waitohu Stream). The purpose of this ecological stocktake was to summarise all information on the past and current state of the ecological health of the Tauranga Harbour and the Horowhenua coast case study regions. This stocktake was undertaken to provide a basis for selecting our case studies for Objective 2, and is also a mechanism to communicate our assessment of the ecological health of the respective coasts to our stakeholders. The results of this 'ecological stocktake' will be made available in two main formats – written reports (such as this report for Tauranga Harbour and a report on the ecological and cultural health of the Horowhenua coastal area), and a searchable on-line data repository on the MTM website that anyone can use to discover what information exists about the state of coastal ecosystems in the case study regions.

For the Tauranga moana case study, a mātauranga Māori interpretation of the coastal ecosystems will be published to complement this report. We hope to work on the integration of the Māori knowledge with the information contained in this report, which is predominantly based on western science. In the MTM programme, we endeavour to find appropriate ways of utilising both mātauranga Māori and western science to solve ecological problems in the case study regions, hence the importance of having a robust mātauranga Māori research framework.

Mediated Modelling of the Tauranga Harbour. Mediated modelling is a tool whereby stakeholders can be involved in the model development and eventually use the model to identify and solve problems. We have initiated a study on Tauranga moana, which will be one of the first applications of 'mediated modelling' in a cross-cultural research programme anywhere in the world. The primary purpose of mediated modelling is to understand the dynamics of the harbour in a 'holistic' and 'integrated' way with an eye to assisting the selection of case studies for Years 2-6 of MTM. More information can be found on our website: http://www.mtm.ac.nz/mediated-modelling/.

Information Technology (IT) tools. One of the key aspects of MTM is the development of IT tools to better communicate research results and to support decision-making by iwi/hapū end-users and other stakeholders. This IT development is being undertaken and led by WakaDigital Ltd, in conjunction with the other partners in MTM. The initial focus has been on developing:

- a web-based central information repository (our Digital Library can be accessed online at http://www.mtm.ac.nz/client/knowledge_centre-digital_library.php);
- a communication portal/website for the research team and iwi/hapū end-users, and
- updating the efish database to include new data.

Future IT development is likely to involve simulation modelling (what would happen in 20-30 years if we implemented 'xyz' management option), interactive mapping, and 3D depiction (where are the problems occurring). One of the objectives of using these IT tools is to critically assess their efficacy and appropriateness in the context of Māori-focussed research.

1.2.4. Next steps

The present stocktakes are helping to inform our research team about what knowledge gaps exist regarding the state of the coastal ecosystems and their services in our case study areas, and what the most critical areas are for ongoing investigation. In close collaboration with local tangata whenua, we will shortly select and begin detailed case study research in both Tauranga moana and the Horowhenua coast. Further reports will be produced on these case studies.

1.3. Outline of this report

This report describes the health of Tauranga Harbour from the bottom up, that is, starting with the land and history of its development (chapter 2), then the water and impacts upon it (chapter 3).

Chapter 4 reviews what is know about the flora and fauna of the harbour, starting at the bottom of the food web with phytoplankton and macroalgae, moving up to the fish and eventually the marine mammals. In chapter 5, we conclude by identifying gaps in our understanding about Tauranga Harbour and outlining some potential research to address these during this project.

2. DESCRIPTION OF THE HARBOUR

2.1. Location and hydrodynamics

Tauranga Harbour, or Te Awanui, is a large estuary (approximately 200 km^2) located on the western edge of the Bay of Plenty on New Zealand's North Island (37° 40'S. 176° 10'E) (Inglis et al., 2008). The harbour is protected from the Pacific Ocean by a barrier island (Matakana Island) and two barrier tombolos, Bowentown at the northern entrance and Mount Maunganui to the south (Figure 1).

Two harbour basins are separated by large intertidal flats in the central area of the harbour. At mean high water the Katikati (northern) basin has an approximate volume of 178 million m^3 and the Tauranga (southern) basin a volume of 278 million m^3 (Park, 2009). While the two basins are connected there is little water exchange between the two (Barnett, 1985; de Lange, 1988). Some reports mention a third smaller basin that includes several bays and sub-estuaries(Park, 2003); this most likely refers to the estuarine area to the south of the Port of Tauranga.

The two main entrances to the harbour are at either end of Matakana Island where the tide flows strongly through both channels (Figure 1). Tidal flow generates up to four knots at the south eastern Tauranga entrance and up to seven knots at the north western Katikati entrance (Ellis et al., 2008). Both harbour entrances are approximately 800 m across, with tidal scour ensuring that deep channels are maintained (Inglis et al., 2008). The rest of the harbour is shallow, typically less than 10 m deep, with intertidal flats comprising approximately 66% of its total area (Inglis et al., 2008). Tidal currents and wind-generated waves dominate the hydrodynamics of the harbour (Davies-Colley and Healy, 1978). Tidal flows have a residence time ranging from a few hours up to a month (Heath, 1976).

The Port of Tauranga, established in 1873, is located near Mount Maunganui at the southeastern end of the harbour (Inglis et al., 2008; Thompson, 1981). Dredging occurred from 1968 to 1978, and again in 1991 to 1992, to deepen and widen shipping channels and reclaim land to establish a container terminal. Since 1992, maintenance dredging has been regularly required to maintain adequate channel depths (Healy et al., 1991).

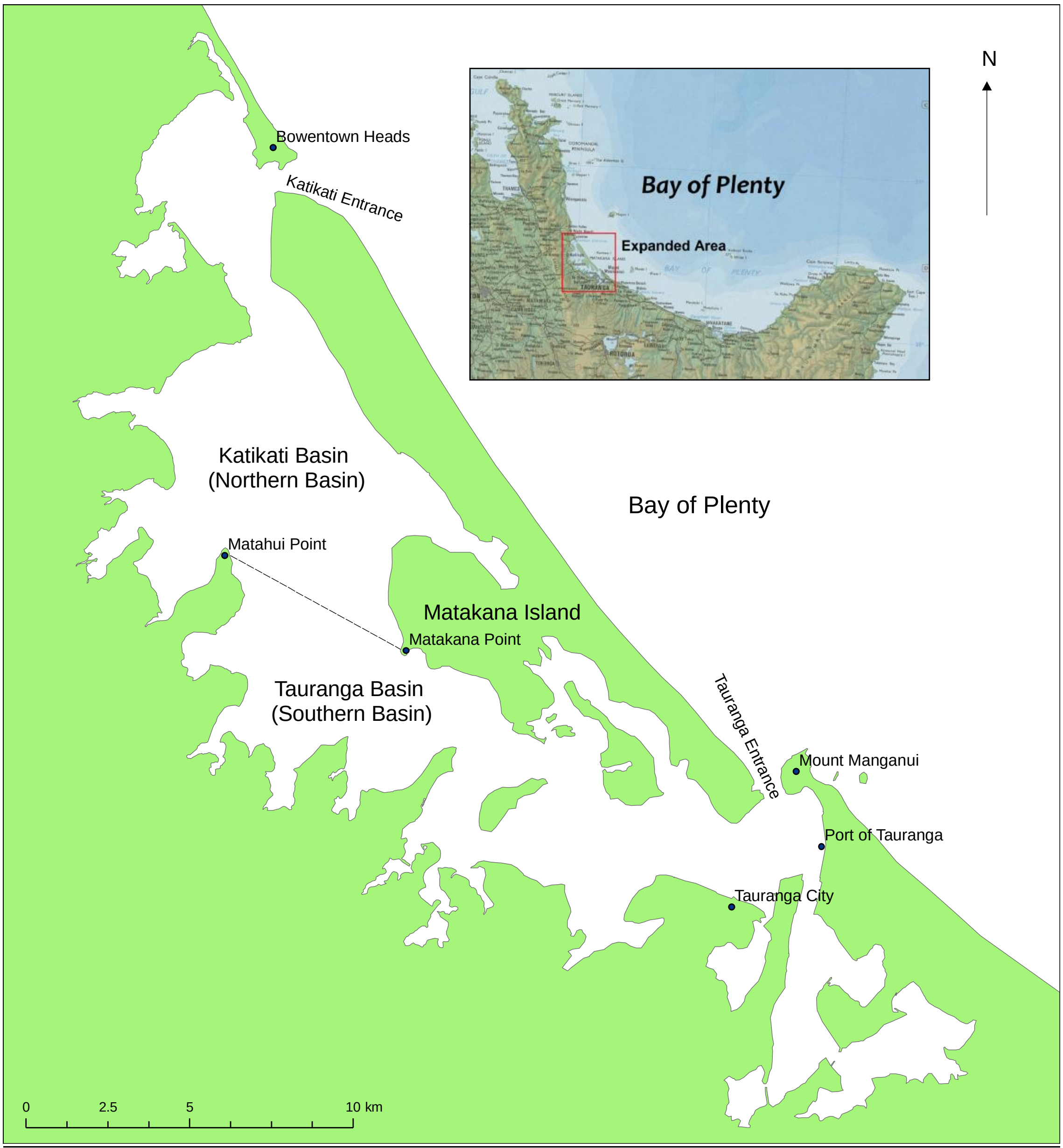

Figure 1. Tauranga Harbour showing the dividing line between the northern and southern basins. Inset shows the wider Bay of Plenty region.

2.2. The catchment area

The Tauranga Harbour catchment covers 1,300 km^2 and is home to an estimated 150,000 people as of 2010[1] (Environment Bay of Plenty, 2009b; Lawrie, 2006; Tauranga City Council, 2009a). The harbour receives discharges from many separate catchments originating in the Kaimai-Mamaku ranges (Shaw et al., 2010) (Figure 2). The northern harbour catchments cover an area of 270 km^2 with a mean freshwater inflow of 4.1 m^3s^{-1} while the southern harbour catchments cover 1,030 km^2 and have a mean freshwater inflow of 30.5 m^3s^{-1} (Park, 2009). The freshwater inflow represents only 0.1% of the harbour volume per tidal cycle in the northern basin and 0.48% in the southern basin (Park, 2003).

The Kaimai-Mamaku Ranges form the northwestern boundary to the Tauranga Harbour catchments and were formed by a series of late Pliocene rhyolite eruptions within the Coromandel Volcanic Zone (Shaw et al., 2010). In contrast, the plateau country in the south (Mamaku and Whakamarama plateaus) was formed by eruptive events originating within the Taupo Volcanic Zone, which became active during the Pliocene and remains active today (Shaw et al., 2010). The upper Tauranga Harbour catchments (eastern side of the Kaimai and Otanewainuku ranges) are typically steep, with streams having high fall rates, high stream velocities and low flow volumes (Shaw et al., 2010). Catchments in the central Tauranga area flow from ignimbrite-dominated landforms, where streams have scoured deep steep-sided gorges into land of otherwise relatively flat relief (McIntosh, 1994; Shaw et al., 2010). Between the upper catchments and Tauranga Harbour, the landscape is dominated by undulating low hills formed by siltstones, sandstones, conglomerates and fluviatile sands (Healy et al., 1974; Shaw et al., 2010). The barrier formations of the harbour were derived from sediment eroded from ash deposits (McIntosh, 1994). Figure 3 provides a geological map of the region.

[1] Statistics New Zealand subnational population estimates tables for 30 June 2010. www.stats.govt.nz. The combined population estimate for Tauranga City Council and Western Bay of Plenty District Council was 159,680; some of the WBOP district council area is outside the catchment of Tauranga Harbour.

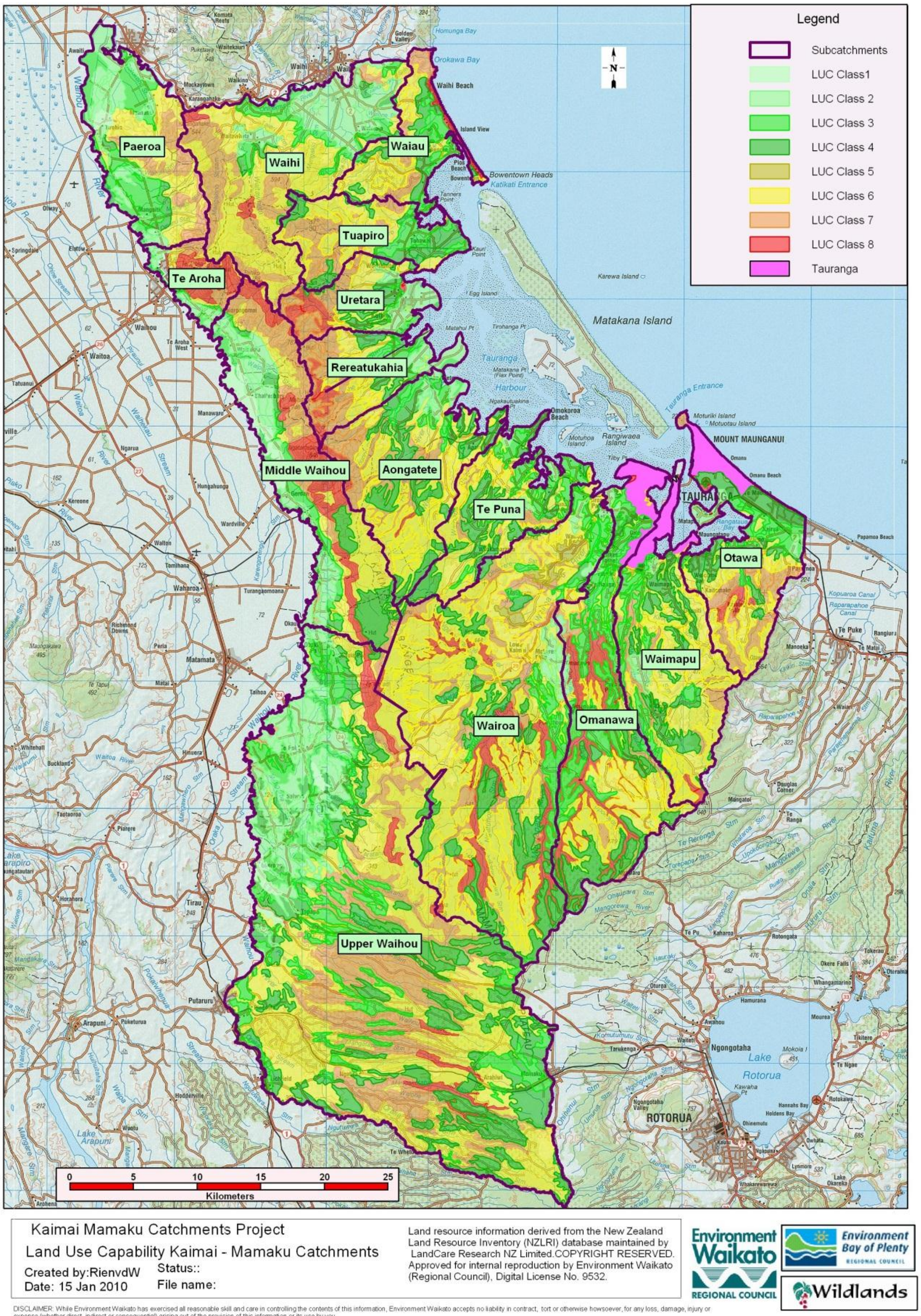

Figure 2. The catchments of the Kaimai-Mamaku Range. Catchments drain to Tauranga Harbour except Waihi, Paeroa, Te Aroha, Middle and Upper Waihou, which drain to Hauraki Gulf. LUC is Land Use Capability classification, with Class 1 the most versatile land (the least limitations for productive use) and at the other end of the scale Class 8, which is not suitable for productive use (most limitations). Source: (Shaw et al., 2010).

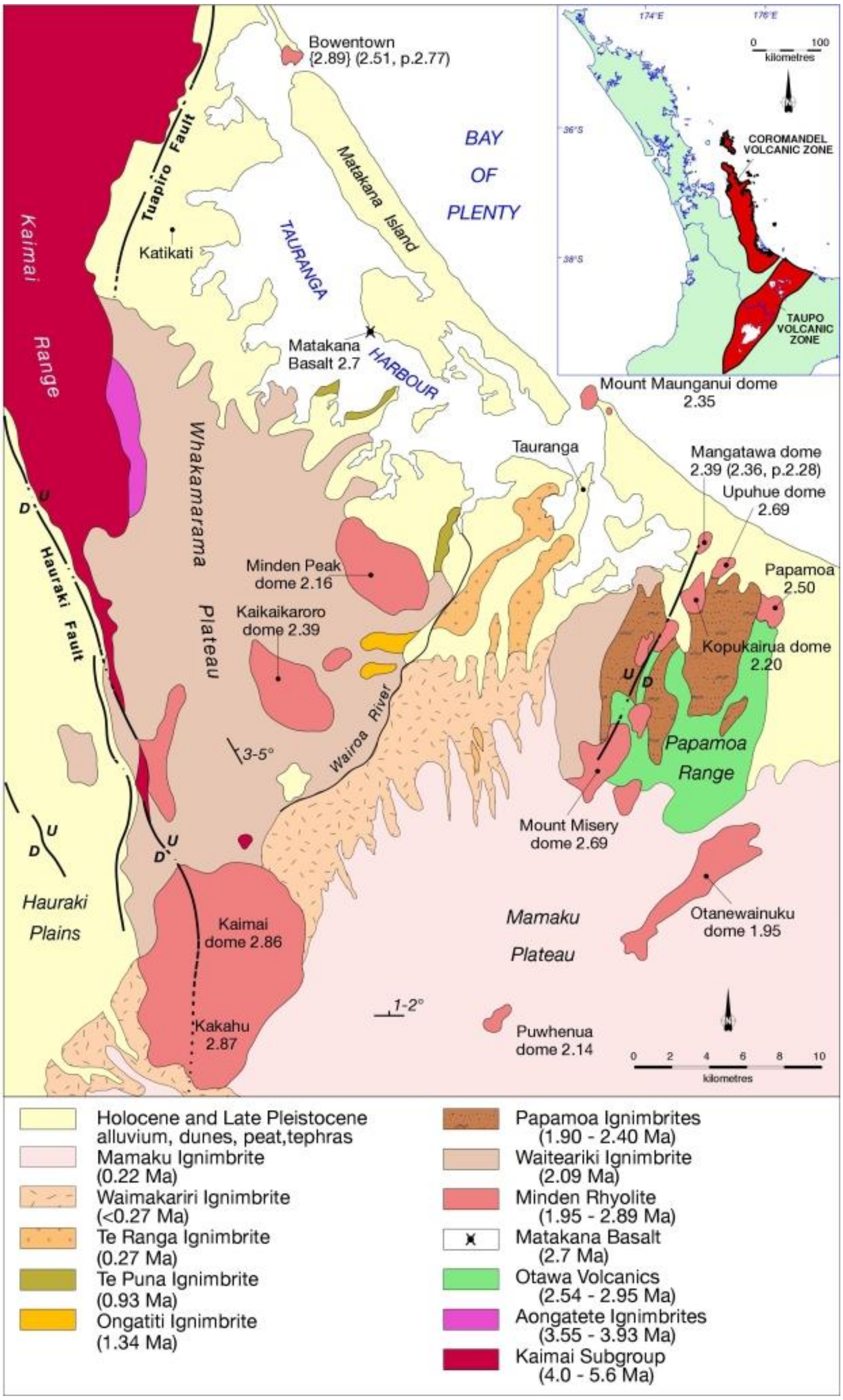

Figure 3. Geological map of Tauranga and the southern Kaimai Range. Inset shows location of Coromandel and Taupo Volcanic Zones in the North Island, New Zealand. Ma = million years ago. Source: (Briggs et al., 2005).

As of 2008, the land cover in the Tauranga Harbour catchment was predominately pasture and indigenous forest (Figure 4). Table 1 shows the breakdown by sub-catchment. The Wairoa sub-catchment has the largest area, most of which is indigenous forest (57%). Otawa and Waimapu sub-catchments show the most urbanisation (21% and 10% respectively), while the Rereatukahia, Aongatete and Tuapiro sub-catchments have almost no urban areas (0-1%). More than half of the Tauranga Harbour catchment area (64%) is land with limited productive use, primarily due to erosion risk (Shaw et al., 2010); much of this is evidently in pasture (Figure 2).

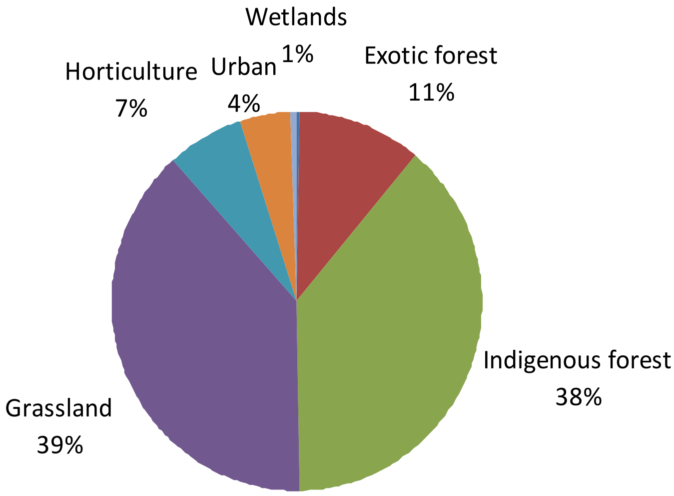

Figure 4. Land cover within the Tauranga Harbour catchment in 2008. Source: (Bay of Plenty Regional Council based on LUCAS land use database from the Ministry for the Environment.)

Table 1. Land cover in the ten sub-catchments of Tauranga Harbour

Sub-Catchment	Area (ha)	Indigenous Forest (%)	Pasture (%)	Exotic Forest (%)	Orchards & Crops (%)	Urban (%)	Other (%)
Uretara	5336.1	37	39	3	16	4	1
Waiau	5885.3	15	49	21	6	5	4
Rereatukahia	6170.9	42	37	3	16	1	1
Tuapiro	6622.4	52	29	3	15	0	1
Te Puna	8630.5	21	54	5	16	3	2
Otawa	9862.5	18	40	13	6	21	3
Aongatete	12543.4	53	37	2	7	0	1
Waimapu	13029.4	30	47	6	5	10	2
Omanawa	17330.0	39	31	16	5	9	1
Wairoa	36930.3	57	27	12	2	9	1

Source: GIS analysis undertaken by Wildland Consultants Ltd using LCDB2 data reflecting land use in 2001/02 (Shaw et al., 2010).

The Tauranga ecological district has also been surveyed to identify natural areas and assess the values associated with those areas (Beadel et al., 2008). That report identified the size and distribution of natural areas within the Tauranga Ecological District and recommended areas for protection.

Tauranga Harbour and its surrounding catchments are within the boundaries of the Bay of Plenty Regional Council (BOPRC), which has primary responsibility for resource management issues affecting the harbour. Tauranga City Council and the Western Bay of Plenty District Council also have resource management functions relevant to the harbour, as do the Department of Conservation (DOC), Ministry of Fisheries (MFish), MAF Biosecurity New Zealand, Ministry for the Environment (MfE), Maritime New Zealand, and Fish and Game New Zealand. The functions of each of these agencies are described in Appendix 1.

2.3. Climate

The lowlands surrounding Tauranga Harbour are warm and sub-humid with a median annual temperature of 15°C. Annual rainfall ranges from 1,125 mm yr^{-1} in the southeast (near Tauranga city) to 1,700 mm yr^{-1} in the northwest, around Bowentown, and up to 2,500 mm yr^{-1} in the Kaimai-Mamaku range above the harbour (Parshotam et al., 2008). Tauranga City receives around 2,200 to 2,400 sunshine hours annually (Tauranga City Council, 2009a).

Future climate projections for New Zealand include increasing prevalence of extreme events such as floods, landslides and storms (IPCC, 2007). One of the most significant influences of climate change in the Bay of Plenty is likely to be the resulting rise in sea level. Although the documented rise over the past 100 years is slightly lower in the Bay of Plenty than the national average (0.14 m compared with 0.16 m), the melting of the polar ice caps from rising temperatures will accelerate sea level rise (Bell et al., 2006). With increasing sea level, more frequent flooding of coastal margins by extreme tides, surge and waves is possible, making lowland areas vulnerable to inundation (Dahm et al., 2005).

2.4. Settlement of the harbour

Tangata whenua have occupied the Tauranga Harbour area for generations; exactly how long is not known. Tauranga’s attractive climate, abundant kai moana, kai awa, edible flora and birds provided Māori with all their nutritional needs (Ellis et al., 2008). Areas were also cultivated on a rotational basis, through a cycle of burning, then planting and cultivation for several seasons, then leaving the land to lay fallow (Shaw et al., 2010).

A map of the Tauranga District in 1840 shows the Tauranga District (i.e. what is now Tauranga City and Papamoa) was a mosaic of shrubland, fernland forest, estuarine vegetation and freshwater wetlands (Wildland Consultants Ltd., 2000) (Figure 5). European settlement on a significant scale began in Tauranga and Te Puke lowlands in the 1870s. This meant further clearance and modification for farming, logging and mining. By 1900, much of the forest in the Whakamarama, Kaimai and Oropi areas and south-west of Te Puke had been cleared (Shaw et al., 2010).

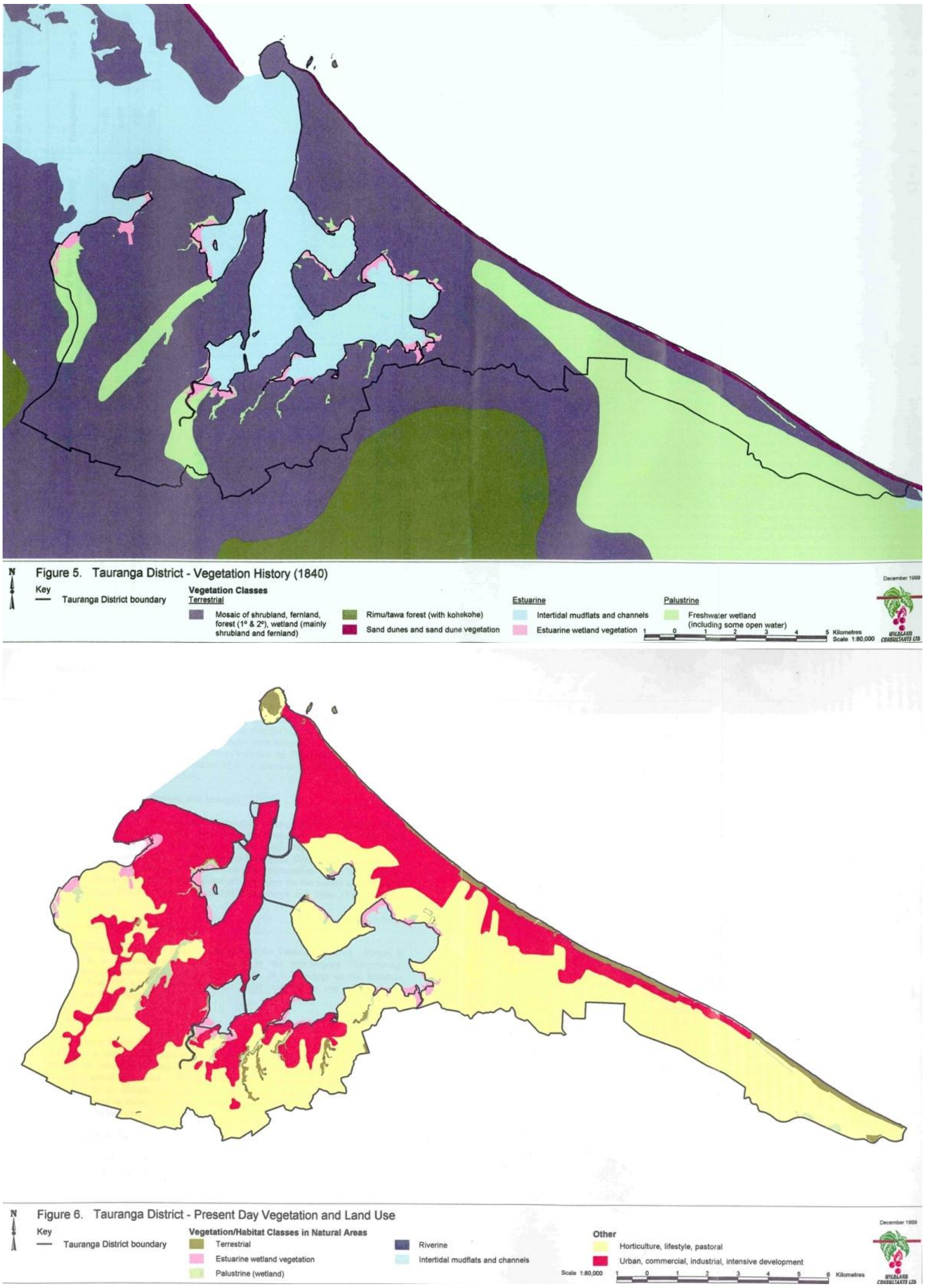

Figure 5. Land cover in Tauranga District in 1840 (top) and 2000 (bottom). Source: (Wildland Consultants Ltd., 2000).

Towns were initially established near mission stations, partly on land confiscated from Māori and redistributed after the New Zealand wars (Shaw et al., 2010). Tauranga grew rapidly in the 1950s and 1960s and in 1963 was proclaimed a city, with a population of 21,500 (Environment Bay of Plenty, 1997). This urban growth led to reclamation of harbour areas and drainage of wetlands. Additionally, there were extensive plantings of exotic forest, with the very steep, more remote areas remaining in native bush (Environment Bay of Plenty, 1997).

The establishment of the port in 1873 made Tauranga a key entry and exit point for goods in New Zealand, chiefly timber and timber products. More recently kiwifruit and avocados have been another primary export, with the conversion of a significant amount of pastoral land to horticulture (Shaw et al., 2010). The Port of Tauranga (Figure 6) is the largest port in New Zealand in terms of total cargo tonnage, and the second largest in terms of container throughput (Dacruz, 2006).

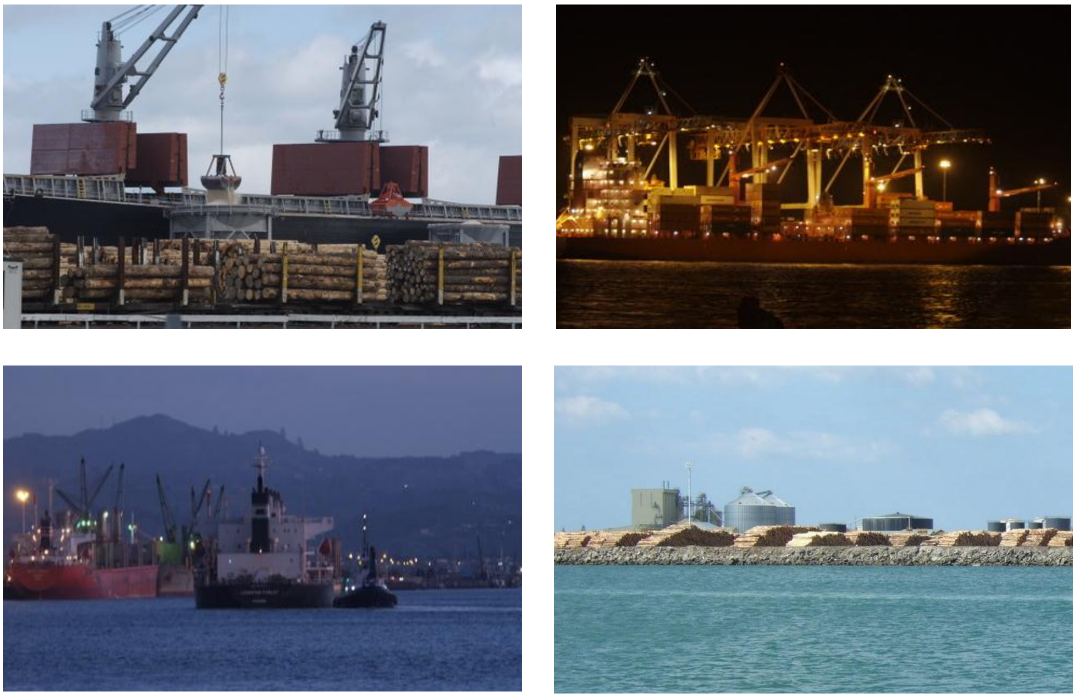

Figure 6. Activity at the Port of Tauranga (photos: Noel Peterson).

3. WETLANDS AND WATER QUALITY

3.1. Wetlands

- Wetlands are important ecosystems and have functional values in water quality, hydrology, ecology, and culture; their protection is a national priority.
- Wetlands improve coastal water quality by acting as a physical and biochemical filter to immobilize sediment and pollutants.
- In the North Island only 5% of original wetland area remains intact (1997)*.
- Between 1840 and 1991, palustrine (freshwater) wetland area around Tauranga Harbour declined by 84% while estuarine wetland area in Tauranga Harbour increased by 17%, reflecting a marked increase in mangrove vegetation (2000).
- Approximately 700 ha of saltmarsh has been lost since 1840 due to land reclamation (2000).
- Changes in area of other types of estuarine wetlands, many of which provide important habitat for birds, have not been monitored.

* Dates indicate how current the information is; full references to source documents are given in the main text.

The Ramsar Convention on Wetlands is an international treaty for the conservation and sustainable utilisation of wetlands. The Ramsar Convention defines wetlands as "*areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with 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*" (Ramsar Convention Secretariat, 2006). In a New Zealand context, the Resource Management Act 1991 (RMA) defines wetlands as "*permanently or intermittently wet areas, shallow water or land/water margins that support a natural ecosystem of plants and animals that are adapted to living in wet conditions*" (Clarkson et al., 2003).

For the purpose of this report, 'wetlands' refers to wetland ecosystems with both 'marine' and 'estuarine' hydrosystems, as well as 'palustrine' (freshwater) hydrosystems, as defined by Johnson and Gerbeaux (2004). Freshwater wetlands, although by definition not part of estuaries, are thought to contribute significantly to the quality of receiving waters in the surrounding catchment and thus can have an important influence on ecosystems in Tauranga Harbour. Estuarine wetlands are defined as per Park (2000b) and include saltmarsh, algal flats, mudflats (including mangroves) and sandflats, but not seagrass meadows, which are discussed separately in section 4.1.3.

General observations can be made regarding the ecological, cultural, and social value of New Zealand wetlands and how they are managed before considering information on wetland areas specific to Tauranga Harbour.

The wetlands of New Zealand have always been an important part of the New Zealand environment. The earliest Māori settled around coastal estuaries and lagoons and harvested the shellfish, fish and eels that abounded. It was from the flax swamps that material for weaving was collected and waterfowl snared. To the early Pakeha, wetlands brought an export product - flax fibre stronger than any fibre yet in use in the world.

Clarkson et al. (1999) notes that wetlands are among the most important ecosystems on the planet and have values for their functions in water quality, hydrology, ecology, and for culture. Wetlands improve coastal water quality by acting as a physical and biochemical filter to immobilize sediment and pollutants that pass through them. They act as buffers against flooding during storm events and release water slowly back into the ground. Some wetlands can also recharge and discharge to groundwater depending on local hydrological conditions. Ecologically, wetlands are important natural systems for supporting aquatic and terrestrial organisms. They can be highly productive systems (MfE, 1997). Wetlands have been identified as a national priority for the protection of biodiversity and are included in the proposed national policy statement on indigenous biodiversity[2] released in January 2011.

Since European settlement, New Zealand wetlands have been greatly reduced. The enormous flat swamplands yielded fertile soil when drained, sustaining farmers and supporting sheep and dairy cows. Drainage became a major cultural activity, like bush clearance, a symbol of the "great work" of turning New Zealand into an economically productive land (Commission for the Environment, 1986). Only about 10% of original wetlands remain nationally, whilst in the North Island only 5% of original wetlands are still intact (MfE, 2007). As a result, these wetlands support a disproportionately high number of New Zealand's threatened plants and animals (Clarkson et al., 2003).

Wetlands are often found associated with the margins of rivers, lakes and estuaries and form a boundary zone between land and water. They may therefore be an integral part of the water body and its aquatic ecosystem, as well as the land and its terrestrial ecosystems (MfE, 1997). It is, therefore, important that they are not drained or otherwise damaged (Environment Bay of Plenty Regional Council, 2003).

3.1.1. Bay of Plenty wetlands

Wetlands are particularly vulnerable to the adverse effects of land use and development. The Bay of Plenty Regional Water and Land Plan (Environment Bay of Plenty, 2008) covers natural and physical resources in the Bay of Plenty and includes wetlands as a water body. Issues identified in the plan include; loss of freshwater wetlands; lack of community understanding of the scarcity, value and vulnerability of wetlands; threat from adverse effects of development; and artificial maintenance of water levels. Responsibility for the management of wetlands rests with multiple agencies. BOPRC and Territorial Authorities have an advocacy role and are responsible for the control of activities in wetlands (Environment Bay of Plenty, 2008).

[2] http://www.mfe.govt.nz/publications/biodiversity/indigenous-biodiversity/proposed-national-policy-statement/statement.pdf

The loss of wetlands as a result of sea level rise is of concern to BOPRC (Lawrie, 2006), particularly in areas where there is little space between urban development and the harbour. These wetlands are likely to be “squeezed” further, resulting in loss from infilling around harbour margins and loss due to drainage. Loss from drainage includes direct drainage and drying of wetland areas, as well as loss from the interception and diversion of ground water flows. This is thought to lead to increased salinity which causes degradation/loss of wetland condition, and is often associated with weed invasion.

A report by Park (2000b) on the Bay of Plenty Maritime Wetlands Database draws on data collected from wetland vegetation surveys, digital mapping, database design, and data capture for nearly all the maritime wetland within the Bay of Plenty region. In addition, an estimation of historic wetland area has been mapped using aerial photography for Tauranga and Ohiwa Harbours. The surveys and data can provide both spatial and quality assessments for areas of special importance as well as baseline data to enable assessment, monitoring and evaluation of environmental programmes. Park (2000b) presented only an initial analysis of the information contained in the database to display its usefulness for environmental management, and noted there was a great deal more analysis possible.

BOPRC subsequently commissioned Wildland Consultants to digitise the external boundaries of freshwater wetlands in the Bay of Plenty Region. The desktop mapping exercise excludes wetlands influenced by saline water such as saltmarsh, and notes the questionable accuracy for many sites, especially those in close proximity to coastal margins where the boundary was difficult to determine.

The loss of wetland in the Bay of Plenty area has given rise to community efforts to restore and rehabilitate wetland areas. The Wetland Restoration Guide (Bay of Plenty Wetlands Forum, 2007) provides an overview of methods for creating or restoring a wetland, looking specifically at wetland types and characteristics within the Bay of Plenty.

3.1.2. Wetlands in Tauranga Harbour

According to Cromarty and Scott (1995), Tauranga Harbour is one of New Zealand's largest estuaries, with extensive, largely unmodified, intertidal seagrass beds, tidal flats, mangroves and mixed saltmarshes. Cromarty and Scott (1995) provide a comprehensive overview of Tauranga Harbour as a wetland system, including their state and management.

Natural areas within Tauranga Harbour have also been surveyed by Wildland Consultants (Beadel et al., 2008) providing information on both terrestrial and estuarine wetlands. Terrestrial natural areas were found to total 3,316 ha, 4.9% of the terrestrial area, with a heavy bias toward dune vegetation (814 ha) and wetlands (1,102 ha) within the coastal zone, particularly Matakana Island. In total 168 natural areas comprising 24,284 ha of saltmarsh, mangroves, intertidal, estuarine, subtidal and harbour habitats were identified. The largest natural areas identified were those associated with marine environments which, together with all marine and estuarine areas, comprise 24.5% of the area of the Tauranga ecological district. In contrast, terrestrial natural areas occupied 3.7% of the area of the ecological district. The Wildlands report (Beadel et al., 2008) provides an overview of the extent of natural areas within the Tauranga ecological district in each vegetation class (e.g. primary forest, secondary forest, indigenous wetland, estuarine saltmarsh, estuarine mangrove etc) for coastal and semi-costal zones.

Park (2000b) provides a useful analysis of temporal change to wetland extent in Tauranga Harbour. The analysis indicated that between 1840 and 1991, palustrine wetland area reduced by 84%, and estuarine wetland area increased by 17%. The increase in estuarine wetland is indicative of a marked (possibly exponential) increase in the area of mangroves, and is likely caused by increased sediment input. The report concludes that the most significant loss of estuarine wetland in Tauranga Harbour is through land reclamation for agricultural use. It is estimated that approximately 700 ha of saltmarsh has been lost in this way since 1840, which accounts for approximately 30% of this type of habitat across the Bay of Plenty region. According to Park, some of this area can be rehabilitated, but most cannot.

The rise of community care groups around Tauranga Harbour, especially around estuaries and waterways, highlights the community concern for degraded natural environments. Many care groups take a broad catchment approach to managing local environments, and work hard in building rapport and relationships with local landowners in an effort to improve environments. Restoration of harbour margins, esplanade reserves, and wetland systems are an integral part of care group functions.

Tangata whenua also take an active role in managing their environments, either directly by partnering with local care groups, or indirectly by developing their own resource management plans. The Te Awanui Tauranga Harbour Iwi Management Plan (Ellis et al., 2008) is a cooperative planning document prepared by the three iwi of Tauranga moana in response to the poor health of the harbour. This Plan recognizes the importance of wetland systems as specialised ecological and cultural areas. Tangata whenua consider wetlands and the associated flora, fauna and aquatic species as taonga. Wetlands are important cultural spaces, supplying traditional foods, and textiles. Spring fed wetlands were also an important water supply source. Many wetlands around the harbour margins contain sacred burial sites and are considered tapu. These areas are afforded the utmost protection by tangata whenua as the final resting place of their ancestors (Ellis et al., 2008; Fisher et al., 1997).

3.2. Sedimentation

- Land in pasture makes the largest contribution to the sediment load in the southern Tauranga Harbour (63% of total) (2010).
- 57% of sediment generated in the catchment enters the harbour (2010).
- Of this land-derived fine sediment, 42% flows out to sea (2010).
- The sub-estuaries in the southern half of the harbour receiving the most deposition are Te Puna inner, the mouth of the Waipapa River and Mangawhai Bay inner (2010).
- Sediment accumulation rates on exposed intertidal flats are low compared to other North Island estuaries (2009).
- Climate models project a 48% increase in mean annual sediment load to the southern harbour by 2051, and a 94% increase for one area (2010).
- Sedimentation affects many aspects of harbour ecology.
- The Port of Tauranga carries out dredging to maintain the channel for shipping activity.

3.2.1. Sediment inputs to the harbour

Tauranga Harbour was likely a shallow embayment when it originally formed (Hume and Swales, 2003) and has since filled in with sediment derived from the land and coast to form the extensive intertidal flats that are present today. Land derived sediments are delivered via rivers and tend to be muddy while coastal sediments enter the harbour through tidal action and tend to be sandy. Lawrie (Lawrie, 2006) estimated that almost 120,000 tonnes of sediment wash into the harbour each year, mostly from farmland and forested areas via rivers and streams. A recent study estimated the sedimentation from the southern harbour alone at 108,000 tonnes per year, suggesting the total amount entering the harbour is even higher (Elliott et al., 2010).

Sediment yield into the marine environment depends primarily on land slope, soil type, rainfall and land use with highest loss from land in pasture, steep slopes and soils that are less well-drained (Elliott et al., 2010). Elliott et al. (2010) modeled sediment loading to the southern Tauranga Harbour from the surrounding catchment (Table 2) and found that pasture (34% of the catchment) makes the largest contribution to the sediment load (63% of total), with forested areas contributing 27%. Although forest has lower sediment yields than pasture (1.2 versus 3.6 t ha^{-1} y^{-1}), it covers a larger portion of the catchment (44%) and tends to be located in steep areas with high rainfall. Orchards and cropland (5% cover) make only a small contribution to the load (0.3%) as they tend to occur on land less prone to erosion. Uncontrolled earthworks have the highest sediment yield but controlled earthworks have a much lower yield and overall earthworks contribute only 0.5% to the total sediment load.

Table 2. Sediment load and sediment yield to the southern Tauranga Harbour from various land uses. These values are before sediment deposition in the stream network. The yields in this table are averaged over the range of slopes, soils and climate that occur.

Land use	Total load ($t\ yr^{-1}$)	Fraction of total load (%)	Total area (ha)	Fraction of total area (%)	Yield ($t\ ha^{-1}\ yr^{-1}$)
Pasture	119696	62.5	33262	33.7	3.60
Bush, scrub, native forest	52291	27.3	43595	43.9	1.20
Exotic forest	9079	4.7	10098	10.2	0.90
Other bare earth	3227	3.5	121	0.1	26.66
Urban earthworks	992	0.5	186	0.2	5.33
Urban and roads	2162	1.1	6416	6.5	0.34
Orchard and cropland	579	0.3	4963	5.0	0.12

Source: (Elliott et al., 2010)

The sediment load delivered from a catchment system tends to increase with the area of the catchment (Elliott et al., 2010). The largest sub-catchment (Wairoa) produces most of the sediment to the southern harbour (46% of total load) (Table 3; Figure 7). The Apata sub-catchment has the highest yield (2.4 $t\ ha^{-1}\ y^{-1}$), due to the relatively high rainfall in conjunction with pasture land use and moderate slopes. Matakana 1 sub-catchment has the lowest yield (0.04 $t\ ha^{-1}\ y^{-1}$), as a result of land use dominated by pine forest and well-drained soils. Urban catchments had relatively low yields as a result of low sediment concentrations from impervious areas. Overall, 57% of sediment generated in the catchment reaches the estuary (Table 3).

Table 3. Sediment load to the southern Tauranga Harbour, with yield and sediment delivery ratio (SDR) for each sub-catchment. Yield is the load from the sub-catchment to the estuary divided by the sub-catchment area; SDR is the percentage of sediment generated that actually reaches the harbour (the rest remains in the stream network).

Sub-catchment name	Area (ha)	Load ($t\ y^{-1}$)	Fraction of total load (%)	Yield ($t\ ha^{-1}\ y^{-1}$)	SDR (%)
Wairoa	46534	49641	45.6	1.07	54
Waimapu	11824	16262	15	1.38	61
Kopurererua	7879	8113	7.5	1.03	60
Aongatete Bellevue	7854	4717	4.3	0.6	50
Waitao	4332	8078	7.4	1.86	64
Waipapa	3680	4722	4.3	1.28	55
Wainui	3523	4891	4.5	1.39	54
Te Puna	2799	4274	3.9	1.53	57
Kaitemako	1989	2045	1.9	1.03	66
Matakana 1	1409	62	0.1	0.04	85
Mt Maunganui	1299	393	0.4	0.3	83
Apata	1240	2955	2.7	2.38	67
Papamoa	1182	318	0.3	0.27	59
Oturu	1158	453	0.4	0.39	60
Mangawhai	957	1251	1.2	1.31	75
Bellevue	950	267	0.2	0.28	80
Matakana 2	755	316	0.3	0.42	87
Total	99366	108758	100	1.09	57

Source: (Elliott et al., 2010)

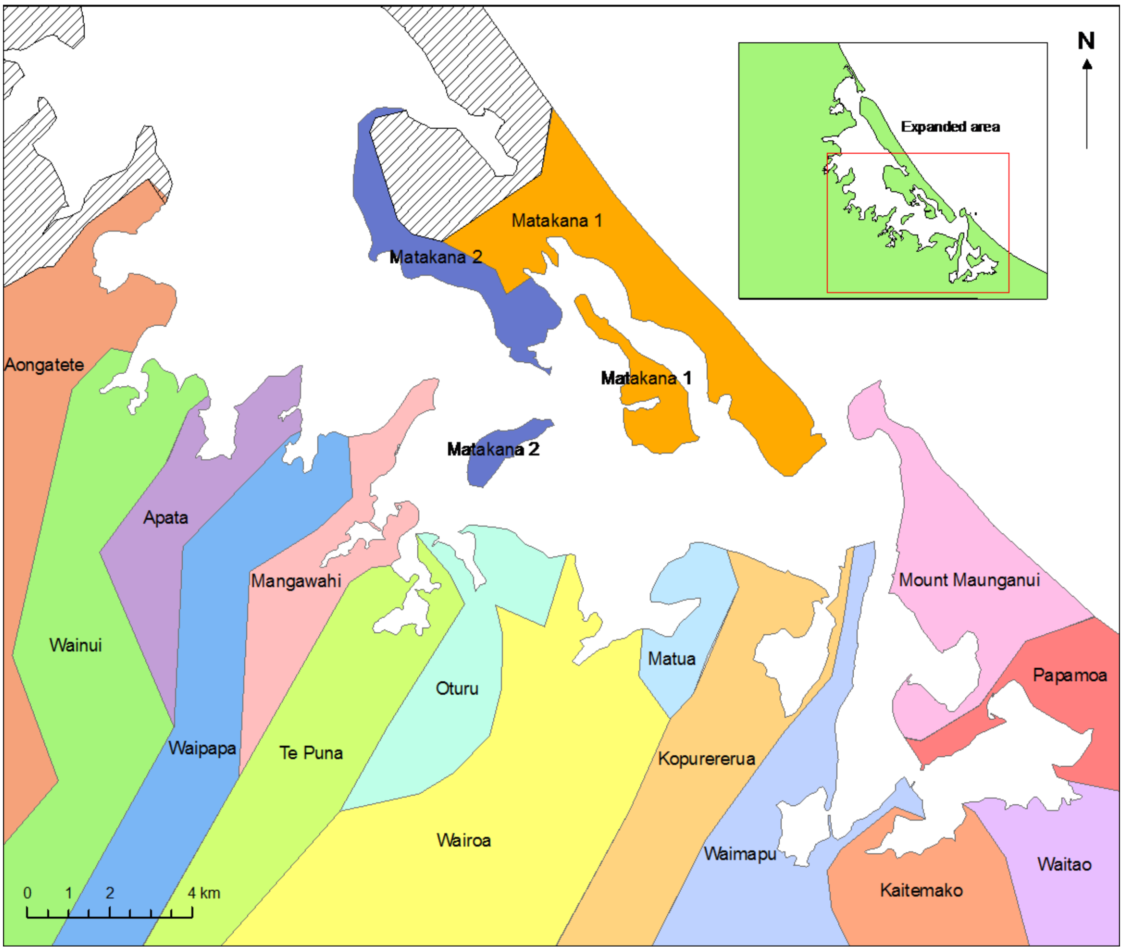

Figure 7. Approximate location of sub-catchments in the southern Tauranga Harbour as defined by Hume et al. 2010. Inset shows wider Tauranga Harbour. Note that for some sub-catchments, only part of the sub-catchment area is shown.

Coastal sediments also play a role in the harbour as sediment is transported down the coast and into the harbour by a process known as littoral drift. Approximately 22,000 m^3 yr^{-1} of sediment from littoral drift passes the harbour entrance from the north (Kruger and Healy, 2006); it is unclear how much of this sediment enters the harbour and how much is deposited versus washed out on the outgoing tide. Maintenance dredging removes an annual average of 110,500 m^3 of sediment from the harbour entrance, to maintain the channel at a navigable depth of 14 m (Kruger and Healy, 2006).

3.2.2. Dynamics

Once in the estuary, sediment is entrained and transported by wave action and tidal currents. Currently about 42% of the land-derived fine sediment into the southern harbour is lost to the ocean, with some areas of the harbour tending to be more depositional (as little as 15% net loss) than others (up to 87% net loss); see Table 4 and Figure 8 (Hume et al., 2010). Compared to fine sediments, a much higher percentage of coarse sediments remains within the harbour because they are heavier and therefore less easily re-suspended by waves and currents (Green, 2010).

Table 4. Annual mean fine sediment sedimentation rate, loss of fine sediment to the ocean, mud content of sediment and mean grain size for sub-estuaries in the southern Tauranga Harbour.

Sub-estuary	Mean fine sedimentation rate (mm y^{-1})	Loss of fine sediment to ocean (%)	Mud content (%)	Mean grain size (mm)
Speedway	1.48	15	14	0.27
Rangataua Bay	0.50	67	6.9	0.32
Welcome Bay	2.11	23	31.4	0.27
Waimapu	1.15	81	30.3	0.34
Tauranga City Foreshore	0.0	n/a	9.8	0.40
Waipu Bay	0.22	87	8.1	0.32
Waikareao	1.01	80	20.8	0.16
Mouth of Wairoa River	0.0	n/a	3.5	0.30
Waikaraka	0.77	26	35.7	0.27
Te Puna (outer)	0.71	26	22.3	0.28
Mangawhai Bay (outer)	0.25	41	23.7	0.19
Mouth of Waipapa River	2.67	53	6.3	n/a
Pahoia Beach Rd	2.38	41	48.1	0.06
Mouth of Wainui River	2.36	32	43.7	-
Aongatete	1.63	40	27.1	-
Mid Harbour Sandbanks	0.0	-	14.4	0.18
Matakana Island	0.0	-	3.4	0.40
Rangiwaea Island	0.06	42	10.8	0.32
Hunter’s Creek	0.15	42	8.5	0.32
Mangawhai Bay (inner)	2.55	41	-	-
Oikimoki Point	0.0	-	4.4	0.24
Sandbank				
- E. of Motuhoa Is	0.0	-	0.7	0.24
- W. of Omokoroa Penin	0.0	53	4.3	0.31
- E. of Omokoroa Penin	0.0	-	14.1	0.33
Matua	0.6	64	10.8	0.29
Te Puna (inner)	6.51	26	-	-

Source: (Hume et al., 2010)

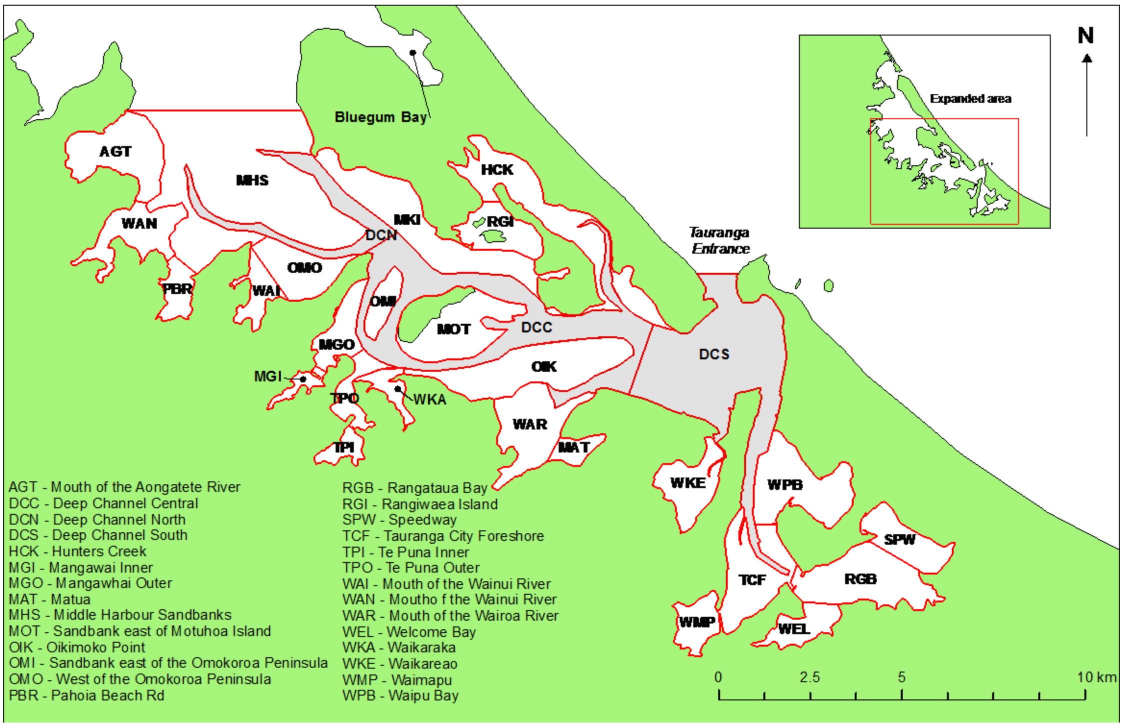

Figure 8. Approximate location of sub-estuaries in the southern Tauranga Harbour as defined by Hume et al. 2010. Grey shading shows deep channels within the harbour and inset shows the wider Tauranga Harbour. The location of Bluegum Bay is also identified.

The deposition of sediments depends on grain size and harbour morphology. In areas of higher wave energy, such as the central harbour, sediments tend to be sandy with larger grain size because only the heavier particles drop out of suspension. Finer sediments are carried to lower energy environments, such as embayments and harbour margins (Green, 2010). Park (2003) identified the Wainui/Apata estuary (Mouth of the Wainui River and Pahoia Beach Road sites) as one of the muddiest areas of the harbour (55-70% mud content) and Bluegum Bay one of the sandiest (5% mud content). A second study, focusing on the southern part of the harbour and drawing from 10 data sets ranging from 1979 to 2008, also noted the Mouth of the Wainui River and Pahoia Beach Road sites as having the muddiest sediments (43-48% mud content) (Hancock et al., 2009) (Table 4). This study did not include Bluegum Bay and instead identified the sandbank east of Motuhoa Island as the sandiest area (0.7% mud content). The mean grain size in the harbour ranges from 0.06 to 0.40 mm (Hancock et al., 2009) (Table 4).

The most depositional sub-estuaries in the southern harbour are: Te Puna inner (6.51 mm y^{-1} net accumulation, 26% sediment from the adjacent catchment is lost to the ocean); the mouth of Waipapa River (2.67 mm y^{-1}, 53% loss); Mangawhai Bay inner (2.55 mm y^{-1}, 41% loss) (Hume et al., 2010). The central reaches of the southern harbour and the intertidal flats along the Tauranga City foreshore are too exposed to accumulate fine sediments. Detailed radioisotopic dating showed sediment accumulation rates on intertidal flats in southern harbour sub-estuaries ranged from 0.75 to 1.57 mm yr^{-1} over periods of 23 to 90 years (Hancock et al., 2009). This is a relatively low rate in comparison to the rates of accumulation reported for a number of other North Island estuaries where similar methods have been applied. Auckland east coast estuaries averaged an intertidal accumulation rate of 4.7 mm yr^{-1} and the Firth of Thames averaged 25 mm yr^{-1} (Hancock et al., 2009).

The low rate of sediment accumulation and evidence of deep mixing within the surface sediments indicates a high energy environment and suggests that the large wave exposed areas of the intertidal flat in southern Tauranga Harbour are not a long term sink for fine sediment. These sediments may instead be deposited in sheltered bays, mangroves, salt marshes, tidal flats and tidal creeks (Hancock et al., 2009).

3.2.3. Future predictions

Climate models indicate that the Tauranga climate is expected to get wetter with higher mean annual rainfall (4.4% increase) and more frequent high rainfall events (Elliott et al., 2010). With higher rainfall the net amount of sediment delivered by the river catchments into the southern Tauranga Harbour is projected to increase substantially. Given the wettest predictions and a medium greenhouse gas emissions scenario (IPCC scenario A1B), a 43% increase in the mean annual sediment load delivered to the southern harbour is expected by 2051 with the majority of sediment delivery attributable to increased high rainfall events (Elliott et al., 2010). The projected increase in mean annual sedimentation load is even larger in many sheltered estuaries (e.g. Bellevue 94%, Matakana 1 48%, Waitao 47%). The resulting shallowing of estuaries would be partially offset by sea level rise which may deepen estuaries by approximately 2mm yr^{-1} and flood low lying coastal margins (Hume and Swales, 2003).

Future urbanization is predicted to reduce the total sediment load to the southern Tauranga Harbour by 0.7% by 2051 (Elliott et al., 2010), offsetting a small portion of the increase expected from climate change. This reduction in sediment load is primarily due to the conversion of pasture to urban areas, which have a lower sediment yield (Elliott et al., 2010).

A model developed by Green (2009) will enable estimation of changes in sedimentation in different parts of the southern harbour over time and the expected changes in harbour morphology. The model currently hind casts zero fine-sediment sedimentation in the central reaches of the southern harbour, including the mouth of the Wairoa River. However coarse-sediment is hind cast to accumulate in this region, which is the principal coarse-sediment depositional lobe of the Wairoa River. Fine-sediment sedimentation in the four northernmost sub-estuaries in the model is consistent with measured sedimentation.

3.2.4. Impact on flora and fauna

Morrison et al. (2009) provide a good review of the many ways that sedimentation affects harbour ecology. Sedimentation makes sheltered estuaries muddier and shallower, with associated reductions in water clarity. Direct impacts include clogging of the gills of filter feeders and decreases in the filtering efficiencies of such species (e.g. cockles, pipi, scallops), reductions in the settlement success and survival of larval and juvenile phases (e.g. paua, kina), reductions in the foraging abilities of finfish (e.g. juvenile snapper) and smothering of seagrass beds (Jones, 2008; Morrison et al., 2009). There is some evidence that bivalves (such as cockles and pipi) may be particularly sensitive to repeated exposure to high levels of suspended sediment (Norkko et al., 2006). Estuarine animals are generally adapted to changeable conditions, and tolerate some sedimentation. However, research has shown that deposition of sediment as thin as three mm can change the benthic community structure (Lohrer et al., 2004), and deposition of two cm of sediment can kill all benthic animals present due to lack of oxygen (Thrush et al., 2004).

Sedimentation can change sediment particle size, most often resulting in greater percentage mud in the sediment, affecting communities living within or upon the seabed. Many species have strict sediment particle size preferences while others are susceptible to small changes in the rate of sediment accumulation and level of turbidity (Gibberd and Carter, 2003). An increase in mud content can lead to a decrease in burrowing animals, such as marine worms, which are important in oxygenating the sediment and breaking down organic matter (Jones, 2008). A decrease in their abundance can alter sediment chemistry and decrease the productivity of the entire estuary.

Indirect effects of sedimentation include the modification of ecologically important habitats, especially those composed of habitat forming species such as seagrass beds, green-lipped and horse mussel beds, bryozoan and tubeworm mounds, kelp forests and sponge gardens (Morrison et al., 2009). Seagrass is particularly vulnerable to greater suspended sediment concentrations as it has relatively high light requirements (Turner and Riddle, 2001). Mangroves, on the other hand, respond favourably to increased sedimentation because accumulating sediment raises the intertidal flat allowing mangroves to colonise areas that were once too frequently inundated by the tide (Jones, 2008). Once established, mangroves trap more sediment creating a positive feedback as suitable area for mangrove colonisation expands (Hume et al., 2010).

An example from Northland shows that losses of important habitats, such as seagrass and horse mussel beds, can have far reaching consequences for fish populations. Recent otolith chemistry work has shown that west coast North Island snapper (*Pagrus auratus*) populations, from Cape Reinga to Wellington, primarily originate from the Kaipara Harbour where horse mussel beds and seagrass meadows provide nursery habitats (Morrison et al., 2009). The Kaipara Harbour has been impacted by land use changes over the last 100 years and these habitats continue to be affected by pressures such as sedimentation from the surrounding catchment (Morrison et al., 2009). The carrying capacity of this system, which supports the west coast snapper population, has declined substantially and any negative impacts on the production of juvenile fish in this area will cascade through into the much larger coastal ecosystem, ultimately affecting the abundance of fish several hundreds of kilometres away (Morrison et al., 2009). Seagrass meadows were once present in the Manukau Harbour, as described by (Morton and Miller, 1973). Historically this estuary most likely played a more important role in the contribution of snapper to the coastal population than the < 2% it provides at present (Morrison et al., 2009).

Changes in community structure caused by sedimentation can have cascading effects throughout the ecosystem. Benthic species are important prey for larger predators and have important roles in maintaining water quality by cycling nutrients and stabilising sediments. Plant communities are also integral to maintaining water quality and provide nursery grounds for many species. Mangrove expansion may reduce intertidal mud flats, potentially reducing wading birds' feeding habitat (Jones, 2008).

3.2.5. Dredging activity

Currents within the harbour trap sediment in the channel entrance such that the channel is infilling (Kruger and Healy, 2006). The Port of Tauranga carries out maintenance dredging approximately every two years removing around 300,000 m^3 of sediment each time (Inglis et al., 2008). Around 80,000 to 100,000 m^3 is extracted ashore and sold to concrete plants and other buyers while the remaining material is deposited at seven different sites (Inglis et al., 2008). Sand is deposited in nearshore sites to allow for renourishment of the Mt Maunganui ocean beaches while silt and other sediment unsuitable for nearshore dumping is deposited in offshore dump grounds (Inglis et al., 2008). Resource consent has recently been granted to the Port of Tauranga for further dredging (Hill et al., 2010). This consent has been appealed and was heard in the Environment Court in April 2011; a decision is pending (S. Park, pers. comm.).

3.3. Nutrients

- Many streams entering the harbour have elevated nutrient levels, with many sites at levels that support undesirable biological growth (2011).
- Levels of nutrients (N and P) within the harbour are declining (2005).
- Decreasing nutrient trends in some rivers are linked with improved rural practises, better control of surface runoff and land use changes (2009).
- Increasing nutrient trends in other rivers are associated with agriculture and increasing runoff from recently harvested forest (2009).
- Omanawa, Kopurererua, Waimapu and Rocky streams had elevated nitrogen concentrations (2009).
- Phosphorus levels were highest in the Rocky and Kopurererua streams (2009).

Under most conditions, the availability of nitrogen and phosphorus is the limiting factor for primary production (Nybakken and Bertness, 2005). Coastal waters receive nutrient inputs from adjacent land and in some cases this may lead to excessive primary production in a process known as eutrophication. Eutrophication initially increases primary productivity but when excessive it can create cascades of effects in marine ecosystems, including increases in phytoplankton blooms that reduce light levels reaching the sea floor, subsequent oxygen depletions as blooms die and increase detrital levels on the seafloor, large scale losses of benthic prey assemblages that support finfish fisheries, loss of seagrass and macrophytes, toxicity effects, changes in species composition and reductions in harvestable fish and shellfish (Morrison et al., 2009). Estuaries tend to be naturally nutrient-rich because land-derived nutrients are concentrated where run-off enters a confined channel, and are vulnerable to eutrophication especially when tidal flushing is limited by constrained openings to the sea.

BOPRC has a Natural Environmental Regional Monitoring Network (NERMN), which includes the monitoring of 16 streams and rivers flowing into Tauranga Harbour and 18 estuarine sites (13 current in 2005). Levels of nutrients (nitrogen and phosphorous) within the harbour generally declined over the monitoring period 1991-2005. However, these decreases were not always statistically significant and some individual monitoring sites displayed an increasing trend (Scholes, 2005). A majority of stream sites monitored in the Tauranga area still have elevated nutrient levels that support undesirable biological growths (Scholes et al., 2011).

Nutrient levels prior to development are not known, and threshold levels for the current ecological health of the harbour are also unknown. Nutrient levels and nutrient inputs to the harbour have been raised considerably by human induced changes in land use including run-off from fertilizers and past inputs from sewage disposal. Most point source discharges of nitrogen and phosphorus into the harbour, however, were removed in the early to mid 1990s (S. Park, pers. comm.). Dissolved inorganic nitrogen levels within the estuary are greater than Australian and New Zealand Environment and Conservation Council (ANZECC, 2000a) recommended trigger levels for estuaries (15 mg m^{-3}) (Scholes, 2005). These guidelines are based on southeast Australian ecosystems, however, and are not appropriate for Bay of Plenty waters in which oceanic water with much higher nitrogen concentrations (compared to southeastern Australia) mixes with fluvial water (ANZECC, 2000a). More relevant are trends in nutrient concentrations over time.

A report by BOPRC (Scholes and McIntosh, 2009) describes water quality trends at 12 river sites during the period 1989-2008, which helps to identify the sources of nutrients entering the harbour. No overall trend was found in nutrient (nitrogen and phosphorous) concentrations, with some rivers displaying increasing trends while others showed a decrease. Decreasing trends were linked with improved rural practices, better control of surface runoff and land use changes while increasing trends were associated with agriculture and increasing runoff from recently harvested forest. Rocky Stream had elevated nitrogen concentrations (2.3 g m^{-3}) compared to other sites due to a high plant biomass on this slow moving stream. The Omanawa, Kopurererua and Waimapu streams also had higher than average total nitrogen (1.1, 1.0 and 0.8 g m^{-3} respectively). Much of the nitrogen in the latter two streams was in the form of total oxidised nitrogen, which may indicate that livestock agriculture was the major source (Scholes and McIntosh, 2009). Phosphorus levels, like nitrogen, were highest in the Rocky and Kopurererua Streams (0.04 and 0.05 g m^{-3}). Streams with higher total phosphorus levels tended to have a larger proportion of phosphorus in the particulate form, which can be linked to suspended solids loading in these streams.

3.4. Pollutants

- There is low to moderate contamination by heavy metals in sediment surrounding industrial stormwater drains in the harbour (2009).
- Te Maire Rd industrial area is an area of high heavy metal contamination (2009).
- Zinc levels exceeded at least the low ANZECC guideline value for all sites bar one (2009).
- PAHs in sediments surrounding stormwater drains exceeded the lower ANZECC guideline value (2009).
- Copper and zinc levels were higher in shellfish from the Plumbers Point/Te Puna site than other locations in the harbour (2010).
- Heavy metals surrounding Omanu and Katikati ocean outfalls are generally within consent limits (2008).
- Levels of organochlorines in Tauranga Harbour are comparable to the Manukau Harbour and Hauraki Gulf (1994).

A number of studies have examined pollutants within Tauranga Harbour, including plastic particles (Gregory, 1978), heavy metals (McIntosh, 1994; McIntosh and Deely, 2001; Park, 2003; Park, 2009), pesticides (Burggraaf et al., 1994; Park, 2003; Scobie et al., 1999), PCBs (polychlorinated biphenyls) (Burggraaf et al., 1994; Park, 2003; Park, 2009; Scobie et al., 1999), PAHs (polycyclic aromatic hydrocarbons) (Park, 2003; Park, 2009) and resin acids (Healy et al., 1997; Tian et al., 1998). The ANZECC 2000 interim sediment quality guidelines provide both a level at which a contaminant may have sub-lethal effects on species and a higher level that indicates potential acute toxicity (ANZECC, 2000b). Despite the guideline values, it is difficult to determine safe levels as much is still unknown about the effects of these pollutants, particularly on sensitive species. Most of the substances listed above were deemed to be within ANZECC guidelines (where these exist), with the exceptions being heavy metals and PAHs at some locations.

Figure 9 shows sites that have been sampled for metals and PAH contaminants in recent years. A 2006 to 2008 survey of metal concentrations in sediments from seven coastal and estuarine sites around Tauranga Harbour found no results that exceeded ANZECC interim sediment quality guidelines (based on < 500 μm particle size) (Park, 2009). The concentration of contaminants (PAHs and metals) in sediments collected from 31 Tauranga Harbour sites in 2006 also showed no results that exceeded sediment quality guidelines (based on whole sediment analysis) (Park, 2009). When standardized to the mud fraction (< 63 μm particle size), however, some metal concentrations (arsenic, lead and zinc) from a site in the Waikareao Estuary were above guidelines. ANZECC interim sediment quality guidelines recommend standardising to the mud fraction to address the tendency for pollutants to accumulate in fine silts and clays rather than sands and coarse rock material (ANZECC, 2000b).

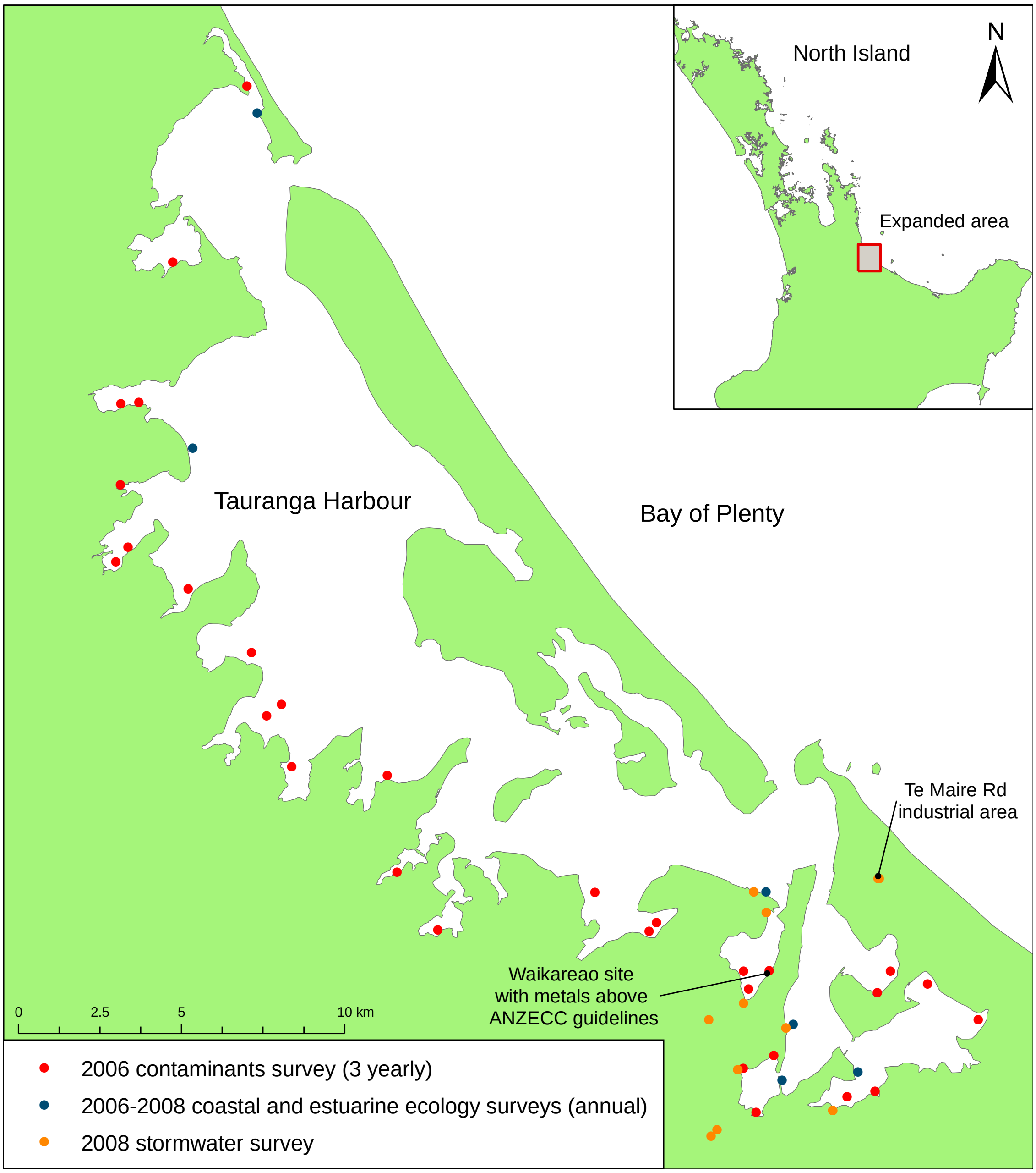

Figure 9. Monitoring sites for metals and PAH contaminants in and near Tauranga Harbour 2006-2008. Inset shows location of Tauranga Harbour within the North Island of New Zealand. Source: (Park, 2009).

Stormwater outlets that drain from industrial areas have been identified as the key source of pollutants to Tauranga Harbour (Burggraaf et al., 1994; Park, 2009). The Bay of Plenty Marine Sediment Contaminants Survey (Park, 2009) found low to moderate contamination by heavy metals in sediment samples from around industrial area stormwater drains in Tauranga Harbour. When standardised to the mud fraction, however, there were some reported high levels of contamination (Table 5). Te Maire Rd industrial area was an area of high contamination, exceeding at least the lower guideline value for every metal except mercury (Table 5). Zinc levels exceeded at least the low guideline value for all sites bar one (Table 5).

Park (2009) noted similar contamination patterns have been found for Auckland drains from industrial sites and concluded that industrial areas contribute high levels of contaminants. On-going monitoring of contaminants and strategies to reduce the contaminants have been implemented (S. Park, pers. comm.).

Table 5. Concentrations of PAHs and heavy metals (mg kg^{-1} dry wt) at stormwater impacted sites in and around Tauranga Harbour standardised to the 63 µm (mud) sediment fraction. ANZECC Interim Sediment Quality Guideline values (ISQG) for "low" (orange font; possibility of sublethal effects) and "high" (red font; possible toxicity) are provided at the bottom of the table.

Freshwater Sites	PAH	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
Waimapu River	0.3	24		26	46	**75**			**377**
Maleme St drain	0.3	14		12	20	47			
Kopurererua Tamatea Dr	0.0	15	1.0	11	21	**54**			
Kopurererua Waihi Rd	0.2	13	0.4	17	22	**53**			
Te Maire Rd below Manu	**4.6**	**54**	**9.1**	**373**	**522**	**597**		**133**	**4851**
Te Maire Rd above Manu	**4.1**	**81**	**3.2**	**154**	**368**	**261**		**43**	**3321**
Marine Sites									
Grace Rd 0-10 m	3.8					**110**	**2.2**		**635**
Grace Rd 50 m	0.3					**60**			**400**
Maxwell Rd 0-10 m	17.1	**37**		38	**72**	**152**			**646**
Maxwell Rd 50 m	**4.1**	**39**		32		44			**218**
Harbour Dr 0-10 m	**4.7**	**48**		35	34	**58**			**315**
Harbour Dr 50 m	0.6			**100**		**131**			**742**
Fraser Rd 0-10 m	2.9	24	0.5	46	**74**	**119**			**547**
Faser Rd 50 m	3.1	25	0.5	35	**214**	**129**			**525**
Welcome Bay 0-10m	**8.2**	**73**	1.4	**128**	**128**	**308**			**1179**
Welcome Bay 50 m	0.3	16	0.3	21	25	**109**	**2.6**		148
ISQG Low ≥	**4**	**20**	**1.5**	**80**	**65**	**50**	**0.15**		**200**
ISQG High ≥	**45**	**70**	**10**	**270**	**270**	**220**	**1**		**410**

Source: (Park, 2009)

PAHs are commonly derived from incomplete combustion of organic material or petroleum and coal products (Park, 2009). The Bay of Plenty Marine Sediment Contaminants Survey (Park, 2009) found that PAHs in sediments around stormwater drains exceeded the lower ANZECC sediment quality guideline value when standardized to the mud fraction (Table 5). Park (2009) suggested that coal tar, asphalt and engine exhaust were the sources of these pollutants.

Shellfish monitoring (pipi, oysters and cockles) also measures metal levels (arsenic, copper chromium, nickel, lead and zinc). Over the 2009/10 season no risk to human health was observed according to current guidelines (Scholes, 2010) but it should be noted that the Australia New Zealand Food Standards Code (2010) only has standards for arsenic (< 1 mg kg^{-1}) and lead (< 2 mg kg^{-1}). Copper and zinc levels were higher in shellfish from the Plumbers Point/Te Puna site (4.3 mg kg^{-1} Cu; 120 mg kg^{-1} Zn) than other locations within the harbour (0.62-1.6 mg kg^{-1} Cu; 4.2-4.9 mg kg^{-1} Zn) (Scholes, 2010). This is the only site that used oysters (*Tiostrea chilensis lutria*) as a test species and it has been suggested that oysters may show elevated levels of copper and zinc compared with other bivalves because they are attached to a surface above the sediment rather than living within the sediment (Scholes, 2010).

It is difficult to determine what constitutes low and high risk contamination because the effect of a pollutant on aquatic organisms depends on the habitat environment and the sensitivity of the species. Many pollutants are characteristically toxic and tend to accumulate and persist in harbours and estuaries due to restricted water circulation and the population pressures of the surrounding catchment. Areas with multiple toxins may be exposed to greater environmental risk due to compounding effects of pollutants. Sessile species are particularly at risk as they cannot move to another location to avoid contamination. There can also be problems in the food chain where higher order predators consume contaminated organisms and the toxins accumulate in their bodies (bioaccumulation). There is potential then for human health to be affected by eating contaminated seafood.

3.5. Bacterial contamination

- Despite bacterial contamination in streams and rivers in the catchment, the microbiological water quality standards for recreation are rarely exceeded in Tauranga Harbour, although shellfish contamination can occur (2011).
- Bacterial contamination in Tauranga has many possible sources: wastewater treatment plants and leaky pipes, septic tanks, livestock farming, birds, marine vessels and meat processing plants.
- Tauranga City has two wastewater treatment plants (Chapel Street and Te Maunga) and Katikati also has a wastewater treatment plant (Prospect Drive), all of which have discharges outside of the harbour and in most cases meet *Enterococci* consent limits.
- Three seepages were detected from Te Maunga oxidation ponds but it is unlikely they are impacting the ecology of the area (2006).
- A new pipeline is being built to transfer sewage from Tauriko/Greerton to the Te Maunga wastewater treatment plant (2011).
- Tanner’s Point, Ongare Point and Te Puna have been identified as areas with on-site wastewater treatment systems that pose a risk to water quality (2006).
- Open coastal sites had low levels of faecal contamination and received ‘Very Good’ ratings (2010).
- Estuarine sites had low levels of faecal contamination in most cases and received ‘Fair’ to ‘Very Good’ ratings, except Otumoetai Beach Reserve, which was given a ‘Poor’ rating (2010).
- River sites had high levels of faecal contamination and received ‘Very Poor’ to ‘Poor’ ratings, except the Tuapiro Stream, which was given a “Fair” rating (2010).
- Shellfish from most sites in the harbour (5 out of 7) met recommended safety standards for consumption (2010).
- Faecal coliform (*Escherichia coli*) levels in shellfish at the Tilby Point/Otumoetai and Plumbers Point/Te Puna sites were above guideline levels. Potential sources of contamination include rural runoff and adjacent communities with on-site wastewater treatment systems.

Bacterial contamination in estuarine environments typically originates from faecal matter, of which there are multiple sources in a catchment. These include wastewater treatment plants, on-site wastewater treatment systems (e.g. septic tanks), leaky sewage infrastructure, livestock agriculture, avian populations, marine vessels and meat processing plants (Scholes et al., 2009). Tauranga City has two wastewater treatment plants while rural households treat faecal matter through on-site treatment systems (e.g. septic tanks and on site ground dispersal). Sewage spills, overflows, leaky infrastructure and stormwater cross-contamination are constant maintenance issues (Scholes et al., 2009).

Water monitoring is carried out by councils to assess the effectiveness of the sewage treatment systems and risk to human health. Over the warmer months (Oct-Mar) recreational waters and shellfish are monitored for risks to human health from faecal and heavy metal contamination (metals are discussed in the previous section).

3.5.1. Sewage systems in the Tauranga region

Wastewater Treatment Plants

Tauranga City has two wastewater treatment plants, one at Chapel Street and the other at Te Maunga. Katikati also has a wastewater plant on Prospect Drive, with the outfall discharging on the eastern (sea-side) of Matakana Island (Western Bay of Plenty District Council, 2009).

Wastewater was discharged into the harbour until 1996. Now treated wastewater from the Te Maunga plant is discharged into oxidation ponds and wetlands before being pumped out to sea, 950 m off the coast of Omanu (Tauranga City Council, 2009b). Effluent from the Chapel Street treatment plant is disinfected with ultraviolet light and the majority is then pumped to the Te Maunga wetlands and discharged out to sea. The sludge from both sites is turned into biosolids, which are sent to landfills or can be used as a soil conditioner under controlled conditions (Tauranga City Council, 2009b).

The Tauranga City Council measures biochemical oxidation demand (BOD_5), total suspended solids and *Enterococci* levels (Table 6) in wastewater prior to discharge from the Omanu ocean outfall and these compliance conditions were met over the 2004 to 2008 period (Tauranga City Council, 2009b). *Enterococci* concentrations are also measured in water samples from the receiving environment along with *Escherichia coli,* arsenic and trace metal concentrations in shellfish from that area (Table 6). BOPRC reports that discharge has remained well within *Enterococci* consent limits over the past few years and, therefore, there is low risk of contamination reaching the beach (Scholes, 2008b). Four of the 41 shellfish samples over the 2006/2007 period detected *E. coli* concentrations just within consent limits as suitable for human consumption (Scholes, 2008b).

Water from the Katikati ocean outfall receiving environment is measured for *Enterococci* and faecal coliforms (Table 6) (Scholes, 2008b). Aside from three elevated faecal coliform results (16, 28 and 56 faecal coliforms 100 ml^{-1}) in February 2005, consent conditions were met throughout the 2004-2008 period (Scholes, 2008b).

Table 6. Compliance conditions 10.1,10.2 and 11.1 of consent 62878 for the Omanu ocean outfall and consent conditions for the Katikati ocean outfall.

Omanu Outfall	**Wastewater prior to discharge** (twice weekly sampling, 13 week period)		
	Analyte	No more than 16 values shall exceed	No more than 3 values shall exceed
	BOD_5 (mg L^{-1})	25	50
	Total suspended solids (mg L^{-1})	30	80
	Enterococci (cfu 100 ml^{-1})	3 500	n/a
	Water from the receiving environment (20 samples per year)		
	Analyte	No more than 13 values shall exceed	No more than 1 value shall exceed
	Enterococci (cfu 100 ml^{-1})	35	40
Katikati Outfall	**Water from the receiving environment**		
	Analyte	Consent conditions	
	Faecal coliforms	Median ≤ 14 n 100 ml^{-1} No more than 10% should exceed 43 n 100 ml^{-1}	
	Enterococci	Median < 35 n 100 ml^{-1} All results < 101 n 100 ml^{-1}	

Source: (Morris, 2006; Scholes, 2008b)

In addition to monitoring of wastewater discharge and the receiving environment, the Te Maunga oxidation ponds are also measured each year for seepage into Rangataua Bay. Three small seepage sites were detected in the adjacent intertidal area in both 2002 and 2006 (Morris, 2006). Two of the seepage sites noted in 2006 had low faecal coliform counts but counts were elevated at the third site. Faecal coliform counts were also high in the Mangatawa tributary, which drains the tidal marsh between the pond and a closed landfill. Due to the small scale of the seepages, it is unlikely that they are impacting the ecology of the area and the abundance of titiko in the intertidal areas adjacent to the ponds supports this assumption (Morris, 2006).

The Tauranga City Councils reports that Tauranga's wastewater network is generally in good condition, however, some of the concrete and asbestos cement truck sewers laid in the 1970s have corroded and require replacement or rehabilitation (Tauranga City Council, 2009b). Additionally, approximately 20 pumping stations no longer comply with the council's Code of Practice for Development in terms of pumping capacity and emergency storage (Tauranga City Council, 2009b). Between 2004-2008 there was an average of 12 pipe blockages per 100 km of sewer (120 blockages per year), which is below the national average of 34 (Tauranga City Council, 2009b). Over this period there was also an average of 1.5 overflows per 100 km of sewer (15 overflows per year) but this number may exclude some overflows caused by blockages (Tauranga City Council, 2009b). To cater for Tauranga's growing population the Te Maunga treatment plant is being upgraded and a new southern pipeline is being built to transfer sewage from Tauriko/Greerton to the Te Maunga wastewater treatment plant (Tauranga City Council, 2010). The southern pipeline will reduce pressure on the rest of the city's wastewater system.

On-Site Sewage Treatment Systems

Several smaller communities bordering the harbour do not have reticulated wastewater systems and instead use on-site wastewater treatment systems. Of these, Tanners Point, Ongare Point and Te Puna have been identified as having risks to water quality from their on-site wastewater systems. Omokoroa was part of the zone but has now been linked to the city's reticulation system (Western Bay of Plenty District Council, 2009).

A 2006 survey reported that all three sites showed some evidence of contamination from septic tank effluent but despite this they still had good recreational water quality (Scholes, 2007). On-site inspection of septic tanks at Tanners Point found approximately half of them failed the inspection criteria, primarily due to under size tanks, however disposal fields were generally in good condition. Tanners Point had notable contamination around the boat ramp and foreshore, with elevated levels of faecal contaminants, although on average these were below recommended contact recreation guideline values. Recently, the Western Bay of Plenty District Council has upgraded a public toilet block located a couple of hundred metres away from the boat ramp drain outlet in the hope of reducing contamination at this site (Weiss, 2010).

Monitoring at Ongare Point (1991-1992 and 1997-2005) showed two drain sample sites with consistently high nitrate-nitrogen (median 5 g m^{-3} over 1997-2005) and *Enterococci* concentrations (median 740 cfu 100 ml^{-1} over 1997-2005) over the current marine red alert level for bathing water quality guidelines (280 cfu 100 ml^{-1}) . The high nitrate-nitrogen levels indicate that some seepage from septic tank systems is occurring. Recreational water quality (2003-2010) has been relatively good, with *Enteroccoci* concentrations generally below orange alert levels (140 cfu 100 ml $^{-1}$) except during extreme events (n=10). The greatest risk to users is, therefore, contact with contaminated inflows to the harbour (Scholes, 2007).

In 2003, approximately half of the Te Puna on-site wastewater treatment systems failed to meet maintenance programme criteria and 20% of these had a soakage field/hole failure (Futter, 2003). Monitoring in 2006 showed four drains with high bacterial contamination consistent with what would be expected of poorly treated or almost raw septic tank effluent (Scholes, 2007). The main drain (Waitui) also had elevated nutrient levels, indicating contamination is coming from two or more sources. Despite the elevated bacteria and nutrient levels, recreational water quality (2003-2010) at Te Puna is relatively good, probably due to dilution and the tidal impact of the harbour, however, contamination of the foreshore remains a risk to users (Scholes, 2007).

3.5.2. Recreational bathing sites

Over the warmer months (Oct-Mar) BOPRC monitors recreational (bathing) water quality at 15 popular sites in the Tauranga Region, shown in Figure 10, to monitor and identify risks to public health from faecal contamination (Scholes, 2010). Sampling is carried out every 1-2 weeks to determine levels of faecal coliforms, *E. coli* and *Enterococci* as indicators for faecal contamination. A three tiered management framework, developed by the Ministry for the Environment (MfE) and the Ministry of Health (MoH), is used to signal when recreational waters are potentially at risk to users (MfE and MoH, 2003). Green (surveillance) indicates an acceptable risk to recreational water users, orange (alert) indicates increased risk of illness and red (action) indicates unacceptable risk to users (MfE and MoH, 2003) (Table 7). A Suitability for Recreation Grade (SFRG) rating is also used, combining a qualitative assessment of a recreational site and direct measurements of a bacteriological indicator to describe the general risk of faecal contamination at a site (MfE and MoH, 2003).

Open coastal sites (n=3; Figure 10) in the Tauranga Region (2009/10 bathing season) had very low levels of contamination as indicated by *Enterococci* bacteria (median concentration < 3 cfu 100 ml^{-1}), within the green range in all cases (Scholes, 2010). All sites received 'Very Good' SFRG ratings and no significant sources of impacts were noted.

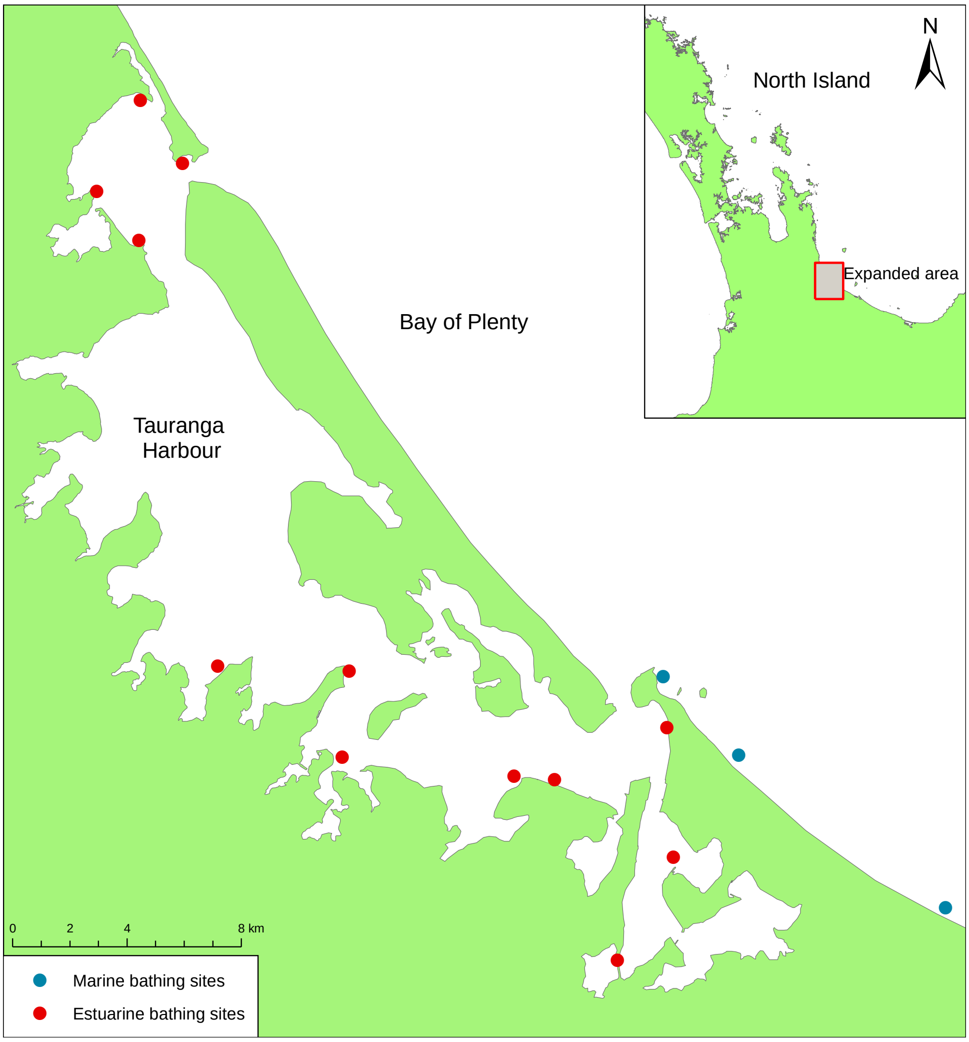

Figure 10. Bay of Plenty Regional Council monitoring sites for bathing water quality. Inset shows location of Tauranga Harbour in the North Island of New Zealand. Source: (Scholes, 2010).

Table 7. Surveillance, alert and action levels for bacterial contamination of fresh and marine waters.

Mode	**Freshwater Guideline** (*E. coli* count in colony forming units per 100 ml)	**Marine Guideline** (Enterococci count in colony forming units per 100 ml)	**Recommended Management Response**
Green (Surveillance)	Single sample ≤ 260	Single sample ≤ 140	Routine monitoring
Orange (Alert)	Single sample > 260 and ≤ 550	Single sample > 140 and ≤ 280	Increased monitoring, identify possible sources
Red (Action)	Single sample > 550	Two consecutive single samples > 280	Public warnings, increased monitoring, source investigation

Source: MfE and MoH (2003) in (Scholes, 2010)

Estuarine sites (n=12; Figure 10) were also below the orange level for most of summer, however, five sites reached extremes above the orange alert level (but less than the red alert level). The median *Enterococci* concentration for estuarine sites was below 25 cfu 100 ml^{-1}. While most sites had ‘Fair’ to ‘Very Good’ SFRG ratings, the Otumoetai Beach Reserve site had a ‘Poor’ SFRG rating, primarily due to higher *Enterococci* concentrations in previous seasons. This was a decrease from its 2008 SFRG rating of ‘Fair’ (Scholes, 2008a). The primary impacts in this area are from agricultural activities, birds and feral animals delivered via the Wairoa River, and an overflow structure for sewage reticulation located nearby (Scholes, 2008a).

It should be noted that three of the estuarine sites had ‘Follow Up’ SFRG ratings, meaning the historical bacteriological levels do not correlate with the assessed risk of faecal contamination, so cannot necessarily be considered low risk. At the Te Puna site this is due to a ‘Very High’ risk of contamination (on-site sewage disposal systems) coupled with a fairly good record in terms of faecal contamination (95 sample percentile 41-200 *Enterococci* 100 ml^{-1}). The other two ‘Follow Up’ sites had ‘Fair’ and ‘Good’ SFRG ratings in 2008 (Scholes, 2008a).

BOPRC also monitors bacterial contamination of rivers and streams within the harbour catchment. River sites have poor water quality with respect to faecal contamination as indicated by *E. coli* bacteria (Scholes, 2010). All 19 sites within the Tauranga area failed to meet standards for bacterial contamination(Scholes et al., 2011). The Kaiate Stream and Waimapu River sites showed the highest *E. coli* levels of the 27 river sites monitored in the Bay of Plenty Region (median concentration ~425 and 180 cfu 100 ml^{-1} respectively); contamination in the Kaiate Stream has been linked with stock having access to waterways (Scholes, 2008a). Exceedances usually occurred after rainfall events (Scholes, 2010). SFRG ratings for Tauranga Region rivers were ‘Poor’ to ‘Very Poor’ except the Tuapiro Stream, which was given a “Fair’ SFRG rating. The Uretara Stream had dropped from a ‘Fair’ SFRG rating 2008 to ‘Poor’ in 2010. The Uretara Stream was mainly affected by urban stormwater but the primary impact for the other rivers was runoff from agriculture (Scholes, 2008a).

The Environment Bay of Plenty Ten Year Plan 2009-2019 has a key performance indicator (KPI) for the performance of the region’s recreational bathing sites against MfE and MoH guidelines (Environment Bay of Plenty, 2009b). Of the five sites in the Bay of Plenty that did not meet the 95% compliance target for marine and lake sites, three were from the Tauranga Region. All river sites in the Tauranga Region met the 85% compliance target. BOPRC does not currently meet the recommended MfE and MoH sampling frequency for all sites (20 per season, 100 over five years).

Overall, open coastal waters around the Tauranga Harbour showed good water quality in terms of faecal contamination and received 'Very Good' SFRG ratings. Estuarine sites had low levels of faecal contamination in most cases and generally received 'Fair' to 'Very Good' SFRG ratings. River sites had high levels of faecal contamination and received 'Very Poor' to 'Poor' SFRG ratings in most cases.

3.5.3. Shellfish contamination

Over the warmer months (Oct-Mar) BOPRC monitors shellfish from open coastal and estuarine sites around Tauranga Harbour to determine if they are safe for consumption (Scholes, 2010). Species sampled are pipi (*Paphies australis*), cockle (*Austrovenus stuchburyi)* and oyster (*T. chilensis lutria*).

Shellfish are tested for faecal coliforms, *E. coli* and *Enterococci* as indicators for faecal contamination. MoH guidelines recommend faecal coliform levels in flesh less than 330 MPN (most probable number) per 100g with levels of 230-330 MPN 100 g^{-1}only marginally acceptable (MoH, 1995). New Zealand Food Safety Authority (2006) standards are used for *E. coli* and they recommend that the median MPN must not exceed 230 *E. coli* per 100 g and that not more than 10% of samples must exceed an MPN of 700 per 100 g. Over the 2009/10 season shellfish from most sites (5 out of 7) around Tauranga Harbour met recommended safety standards for consumption. *E. coli* levels at the Tilby Point/Otumoetai and Plumbers Point/Te Puna sites, however, were above standards (median 240 and 300 MPN 100 g^{-1} respectively) and faecal coliform levels were only marginally acceptable (240 and 300 MPN 100 g^{-1}). Around 50 mm of rain is likely to have influenced the elevated *E. coli* levels at Plumbers Point/Te Puna (Scholes, 2010), however, previous studies have found that oysters from Te Puna consistently show high levels of contamination (Scholes, 2008a). Potential sources of contamination include rural runoff from the stream and adjacent communities with on-site wastewater treatment systems (Scholes, 2008a).

It should be noted that Scholes et al. (2009) finds no evidence of a distinct relationship between faecal indicator bacteria (*E. coli* and *Enterococci*) and positive viral tests (norovirus and adenovirus) in shellfish. This suggests indicator bacteria may not be reliable indicators of viral contamination in shellfish, thus shellfish may not be safe to eat when the bacterial quality is within currently accepted microbiological limits, and vice versa. Sites regularly contaminated with viruses were those closest to urban areas and, therefore, most likely to be accessed by the shellfish gathering population (Scholes et al., 2009).

4. FLORA AND FAUNA OF THE HARBOUR

4.1. Marine flora

Marine flora encompasses the primary producers within the harbour including phytoplankton, macroalgae (e.g. seaweeds), marine plants (e.g. seagrass, mangroves) and wetland vegetation. They use sunlight, nutrients and carbon dioxide to grow and capture energy, forming food for animals such as zooplankton, invertebrates and fish. This section discusses the current state of marine flora in Tauranga Harbour. Sea lettuce is discussed separately from the rest of the macroalgae because considerably more research has been carried out on this group.

4.1.1. Phytoplankton

- Shellfish collection closures have regularly occurred in the harbour since 2008, as a result of toxic phytoplankton species (2011).
- Information specific to phytoplankton of the harbour is sparse (2011).
- Phytoplankton biomass is dominated by diatoms and is temporally diverse (2003).
- Pelagic phytoplankton is the dominant food source for filter feeders but in areas with strong currents benthic phytoplankton might be an important food source (2003).

Phytoplankton are tiny floating algae that are usually too small to be seen individually by the naked eye. They play an important role in ecosystems in terms of nutrient and carbon recycling. Through the process of photosynthesis, phytoplankton consume carbon dioxide on a scale equivalent to forests and other land plants (Word et al., 2010) and produce half of the world's oxygen (Ramanujan, 2005). Their growth relies on nutrients such as nitrogen and phosphorus and algal blooms may be stimulated when these nutrients are available in excess. Algal blooms may cause hypoxia (oxygen depletion in the water) due to the decomposition of dead phytoplankton.

Some phytoplankton species produce toxins, which may enter the food chain through filter-feeding animals such as shellfish. The New Zealand Food Safety Authority (NZFSA) has undertaken routine monitoring in Tauranga Harbour for toxic phytoplankton species to regulate shellfish collection closures since 2003. There were no closures in Tauranga Harbour until 2008, although biotoxin warnings were occasionally issued for some limited areas (T Ngawhika, pers. comm.). From December 2008 to March 2011, apart from a period from February to December 2009, a warning was in place advising the public not to consume shellfish collected from much of the Bay of Plenty, including Tauranga Harbour (Toi Te Ora, 2011). The phytoplankton species primarily responsible for the closures have been *Alexandrium minutum* and *A. catenella*, which can cause paralytic shellfish poisoning (PSP) (T Ngawhika, pers. comm.).

Information specific to phytoplankton of Tauranga Harbour is sparse. BOPRC reported levels of chlorophyll-a (an indicator of phytoplankton) in Bay of Plenty open waters using satellite imaging (Park and Longdill, 2006), but that study was at a coarse scale and did not encompass Tauranga Harbour. Safi (2003) examined microalgal assemblages within Tauranga Harbour in the benthos and directly above the sediment where suspension feeders feed (~10 cm). Phytoplankton biomass was dominated by diatoms and was negatively correlated with turbidity; larger phytoplankton cells were less able to cope with sediment. Pelagic phytoplankton appeared to be the dominant food source for filter feeders in the region as only 1% to 23% of the biomass near the sediment surface was benthic in origin. Strong links were observed between benthic and pelagic microalgal populations with the proportion of benthic microalgae in suspension strongly correlated with current speed and turbidity. This relationship suggests that, in areas with strong currents, benthic microalgae may also be an important source for filter feeding organisms.

Many aspects of phytoplankton dynamics (e.g. growth, mortality, the dominance and succession of species) in Tauranga Harbour are unknown. As a primary producer, phytoplankton plays a pivotal role in the food web of the harbour, so further research might be warranted to improve understanding of the temporal and spatial dynamics of the key taxonomic groups.

4.1.2. Macroalgae

- A survey adjacent to the Port found 23 species of macroaglae with red turf-like algae most common (2006).
- Sea lettuce, Neptune's necklace, *Gracilaria secundata*, pink coralline turf algae, *Gelidium caula cantheum*, and *Ceramium* species were identified as being very abundant in the soft shore areas of the harbour (1994).

Macroalgae refers to any type of seaweed that is visible to the eye. There are three distinct categories: brown, green and red seaweeds. Often these species form canopies, much like a land-based forest canopy. Other times they form 'turf-like' (< 5 cm tall) clumps on rocks. Many species form crusts over rocks and other hard surfaces and are then referred to as coralline algae. They are hard (like a coral) and are predominantly bright pink in colour. Some macroalgae provide many benefits to an ecosystem (e.g. kelp) while others are perceived as nuisance species (e.g. sea lettuce) and may have negative impacts.

Macroalgae generally dominate rocky reef communities in coastal New Zealand. Taxonomically, east coast communities resemble one another, with no one location having distinctly different species (Beaumont et al., 2008). As such, habitats can be broadly classified by dominant algal types (e.g. kelp, turf-like, bare space) and these descriptors are often used for broad-scale management (Shears et al., 2004). Mixed kelp stands dominate shallow subtidal areas in New Zealand (Cole, 1993) and form important habitats, including nursery areas for small invertebrates and finfish (Morrison et al., 2009). Mixed "turf-like" assemblages of species are common under kelp canopies or in exposed environments where large species cannot withstand conditions (refer Cole 1993). Land based stressors (e.g.

sedimentation and nutrient loading) can result in the loss of larger canopy covering macroalage, which have important links to kai moana, and replacement by prolific weedy species (Russell and Connell, 2005). For example, *Hormosira banksii* (Neptune's necklace) is an important habitat for juvenile fish (Morrison et al., 2009) and increased sedimentation can decrease attachment of *H. banksii* zygotes by over 30% (Schiel et al., 2006). Given the increasing land-based pressures on Tauranga Harbour, the cascading effects of these stressors on macroalgal assemblages need careful consideration.

Intensive research has been carried out on the macroalgae communities adjacent to the Port of Tauranga, as part of a nation-wide biosecurity monitoring programme (Inglis et al., 2006). Despite the limited extent of the survey, it provides an indication of what species might be present elsewhere in the harbour. Twenty three species of macroalgae were found across three taxonomic phyla (green, brown and red macroalgae) (Table 8). Typically, red turf-like (i.e. < 10 cm in height) species dominated. An earlier survey of Tauranga Harbour in 1994, identified sea lettuce (*Ulva* sp.), Neptune's necklace, *Gracilaria secundata*, pink coralline turf algae (*Corallina officinialis*), *Gelidium caula cantheum*, and *Ceramium* species as very abundant within soft shore areas (Park and Donald, 1994). They noted that most other algal species identified were rarely encountered.

Table 8. Macroalgae species identified in the 2006 Port of Tauranga survey. Some organisms were not able to be identified to species level.

Dictyota dichotoma var. intricate	*Codium fragile tomentosoides**
Hormosira banksii (Neptune's necklace)	*Zostera* sp. (seagrass)
Hymenena variolosa	*Ceramium* sp.
Cladhymenia lyallii	*Griffithsia* sp.
Catenella nipae	*Polysiphonia* sp.
Gigartina atropurpurea	*Hypnea* sp.
Stenogramme interrupta	*Lomentaria* sp.
Trematocarpus aciculare	*Rhodymenia* sp.
Gracilaria truncate	*Enteromorpha* sp.
Cryptonemia latissima	*Ulva* sp. (sea lettuce)
Plocamium angustum	
Codium fragile sp. *novae-zelandiae*	

* Non-indigenous species. Source: (Inglis et al., 2006)

Sea lettuce

- Sea lettuce blooms have occurred in the harbour as far back at the 1940s. Monitoring since 1991 shows the largest blooms occurred in 1991-1993, 1998 and 2003-2007 (2007).
- Sea lettuce blooms peak in spring and decline over late summer to remain low until the next spring (2007).
- The most important factor influencing blooms is nutrient availability (2000).
- Sea lettuce in Tauranga Harbour appears to be nutrient limited over summer (2007).
- Greater sea lettuce abundance was recorded during El Niño years (2007).

Sea lettuce is the collective name given to green algae (Chlorophyta) of the genus Ulva. It is distinguished by its bright green colour, thin, flat morphology, prolific growth and rapid decomposition rate (Figure 11). It is debated whether sea lettuce is native to New Zealand or introduced, however, Heesch et al. (2007) suggest that two of the five species in Tauranga Harbour are most likely native (*U. pertusa*, *Ulva spp 1*), two are introduced (*U. compressa*, *U. intestinalis*) and the origins of the other are yet to be determined (*Ulva spp 3*). In a 1994 survey, sea lettuce was listed as the second most abundant flora in Tauranga Harbour with an average total cover of 3.7% (Park and Donald, 1994). Sea lettuce blooms are common worldwide and while there is no scientific record of sea lettuce blooms prior to the 1980s, anecdotal evidence from long-term residents indicates that they have occurred in the harbour as far back as the 1940s (Park, 2007).

Figure 11. Sea lettuce (*Ulva* sp.) in Tauranga Harbour (photos: Noel Peterson)

The vigorous spread of sea lettuce in Tauranga Harbour is due to several factors. It is a notorious hull-fouling organism (Schaffelke et al., 2006), so is spread by human-mediated dispersal, and can tolerate a wide range of conditions (temperatures, salinities, nutrient concentrations), so will easily settle in new environments. The growth of sea lettuce displays similar characteristics to an invasive or 'r-selected' species in that it can grow and reproduce rapidly allowing it to quickly colonise new habitat. It has the ability to reproduce asexually via vegetative growth, which is nutrient-controlled, so it can exploit eutrophic conditions to grow rapidly to nuisance levels.

Sea lettuce is a component of the harbour ecosystem, providing food and shelter to animals such as molluscs and crustaceans. Top shell (*Micrelenchus huttoni*) and black sea slug (*Aplysia juliana*) show population increases in response to sea lettuce growth (Park, 2007). Parore (*Girella tricuspidata*) grazes on subtidal sea lettuce and orange clingfish (*Diplocrepis puniceus*), which are usually found in open rocky habitats, have also been seen amongst the sea lettuce in the harbour (Gregor, 1995; Park, 2007). Due to its large biomass over summer and high growth and decomposition rates, sea lettuce is a significant source and sink for nutrients, particulate organic matter (POM) and dissolved organic matter (DOM), helping to recycle them through the water column and sediment (Frankenstein, 2000).

Excess sea lettuce growth can, however, have a number of adverse effects on the ecology of the harbour. Large amounts of sea lettuce can lead to the fragmentation and degradation of seagrass beds, either by directly smothering the seagrass or by shading it from sunlight (Frankenstein, 2000). Sea lettuce may also smother shellfish, such as cockle (*Austrovenus stuchburyi*) and wedge shell (*Tellina liliana*) (Park, 2007), and prevent the settlement and recruitment of some larvae (Olafsson, 1988) by posing a physical barrier or exuding toxic chemicals. Dense algal mats disrupt water circulation and hence food supply to filter feeders and cause deoxygenation of the water and sediment leading to the release of sulphides from the sediments (Park, 2007). While sea lettuce has been shown to increase habitat and food for some juvenile fish (Wright, 1989) it prevents other species from foraging effectively (Isaksson et al., 1994). Shifts in communities may occur where benthic macroinvertebrates (e.g. bivalves and polychaetes) are replaced by grazers and crustaceans that utilize the algal mats for food and shelter (Frankenstein, 2000). Disruption to marine habitats and loss of their inhabiting species would in turn negatively affect population numbers of birds and fish that rely on them for food.

Prolific sea lettuce growth also poses problems to users of the harbour, with most complaints relating to visual and odour effects (Lawrie, 2006). Sea lettuce drifts accumulate along shorelines and once stranded anaerobic decomposition produces noxious odours and gases (primarily hydrogen sulfide) (Frankenstein, 2000). Dense mats of sea lettuce may prevent utilization of the beach for fishing, recreation and food gathering. Sea lettuce can clog fishing gear, block cooling water intakes of ocean vessels and weigh down mooring buoys (Park, 2007). Amongst the Tauranga community there is confusion over the causes of sea lettuce blooms and who (if anyone) is responsible for cleaning them up (Lawrie, 2006).

BOPRC has monitored sea lettuce cover and biomass at three sites within the harbour every two months since 1991 (Park, 2007). High sea lettuce abundance was seen from 1991 to 1993 (~ 40-100% cover) and in 1998 (~ 60-100% cover) while abundance over 2003 to 2007 was moderate (~ 10-60% cover) but fluctuating. Abundance in other years was generally low (usually < 20% cover). While abundance was highly variable over time, within years a strong seasonal trend was seen, peaking in spring (20% mean cover) and then declining over the late summer period (13% mean cover) to remain lower (10-11% mean cover) until the following spring (Park, 2007). Sea lettuce abundance, particularly in localized areas, is highly variable and strongly affected by tides and winds (Park, 2007). On the other hand, a commercial fisher who has operated inside the harbour for over 30 years says sea lettuce has become much worse over that time, with the first major bloom occurring in 1988 (D Kiddie, pers. comm.).

Several factors influence the formation of sea lettuce blooms, including weather conditions and hydrodynamics, but the most important is nutrient availability (Frankenstein, 2000). Nitrogen and phosphorous determine the growth of macroalgae and nitrogen in particular controls the growth of sea lettuce (Frankenstein, 2000). At sea lettuce monitoring sites in Tauranga Harbour, water column measurements of available nitrogen showed lowest concentrations in summer (0.007-0.031 NO_x mgL^{-1}) and higher levels in winter (0.027-0.147 NO_x mgL^{-1}) (Park, 2007). Nitrogen levels in sea lettuce tissue show the same trend, i.e. very low during summer (1.54% dry weight), when plants are growing fast, and higher in winter (2.56% dry weight) as growth slows and the algae can store extra nitrogen for when growth conditions improve (Park, 2007). Park (2007) concluded that sea lettuce in Tauranga Harbour is severely nitrogen limited (< 2% nitrogen dry weight) over summer.

Nitrogen levels within the harbour can be influenced by inorganic inputs (e.g. land-based runoff, outfalls) and by weather conditions, in particular the El Niño/La Niña Southern Oscillation (ENSO). In La Niña years, easterly winds dominate, while in El Niño years, westerly winds are more frequent. The westerly winds during El Niño years push water offshore, which is then replaced by nutrient-rich, deep oceanic water (upwelling). Park (2007) found a significant relationship between ENSO and sea lettuce growth, with greater sea lettuce abundance recorded during El Niño years (70-120 % higher than average) than La Niña (50-100 % lower than average). Nitrogen levels in sea lettuce tissue were also higher during El Niño years. Many other processes may also affect sea lettuce abundance, however, such as land derived nutrients, winds, tides, temperature and light intensity. For example, a pattern of increasing nutrient concentration in sea lettuce tissue was observed to match the degree to which each site is influenced by nutrient derived input form the land (Park, 2007). BOPRC is conducting further research to assess the influence of land derived versus upwelled nutrients on sea lettuce blooms. The question is also be investigated by a student at the University of Waikato using isotope analysis.

4.1.3. *Other marine plants*

Seagrass

- Seagrass beds provide a number of ecosystem functions.
- Seagrass beds have declined by 34% over 1959 to 1996, with a 90% decrease in subtidal areas (1996).
- There is some evidence of seagrass increase in Tuapiro Estuary (1996).
- Sub-estuaries with large catchments showed greater loss of seagrass (1999).
- Sedimentation and nutrient loading were implicated as the main factors in Tauranga Harbour's seagrass decline (1999).
- There are currently no proposed restoration plans but studies in Whangarei Harbour show this may be a viable option in the future (2008).

Seagrasses are native flowering plants that typically grow in subtidal and intertidal areas of estuaries and sheltered harbours. New Zealand has only one species of seagrass (Les et al., 2002), *Zostera capricorni* (Figure 12), and in 1976, the seagrass beds of Tauranga Harbour were described as more extensive than in any other New Zealand harbour (Barker and Larcombe, 1976). In 1994 seagrass was reported to be the most common plant or algae within Tauranga Harbour, covering an estimated 22.5 % of the intertidal area in a survey done during the summer of 1990/91 (Park and Donald, 1994). More recently, Tauranga Harbour has been identified as one of nine 'hotspots' for seagrass distribution in New Zealand (MFish, 2006) with a total seagrass area of 2,933 ha in 1996 (Park, 1999a).

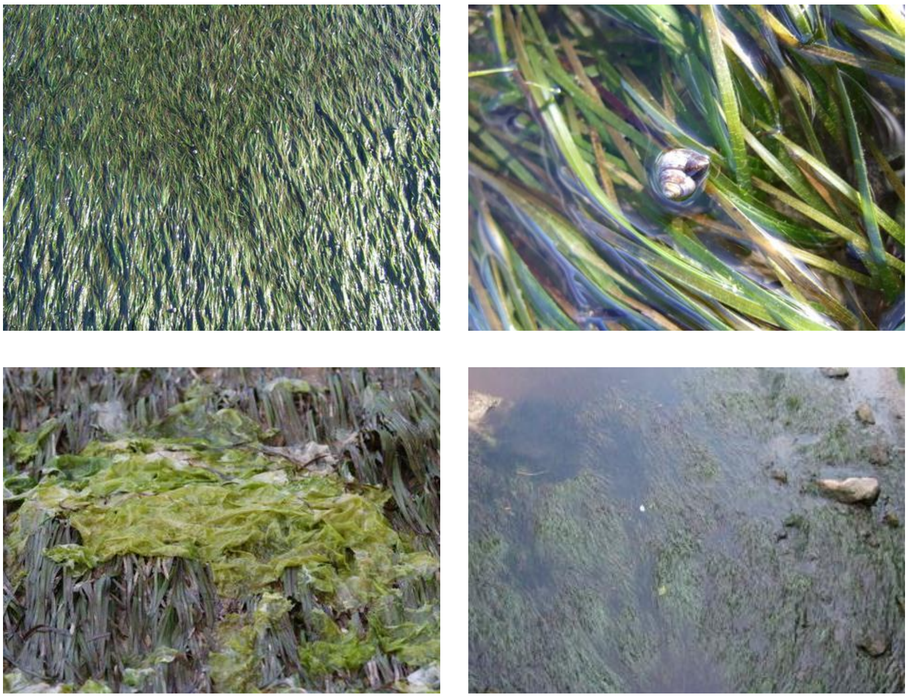

Figure 12. Seagrass (*Zostera capricorni*) in Tauranga Harbour (photos: Noel Peterson).

Seagrass meadows provide a number of ecosystem functions and are promoted by the New Zealand Ministry for the Environment as a 'national environmental performance indicator' for assessing the health of New Zealand coastal and estuarine ecosystems (MfE, 2001). Seagrass beds enhance primary production and nutrient cycling, stabilize sediment, protect the coast from erosion and support a number of animals and plants. They provide a nursery habitat for juvenile fish such as snapper, trevally, parore, spotties and triplefins (Morrison et al., 2007), protecting the small fish until they are large enough to survive in other habitats and, thereby, supporting larger fish populations on the open coast that may have cultural or economic significance.

A study of benthic macrofauna in Matapouri Estuary (Northland) found that seagrass beds are by far the habitat with the greatest diversity in the estuary, containing the largest number of species (Alfaro, 2006). Research in Tauranga Harbour also showed the highest diversity of macrofauna is found within seagrass beds (Park and Donald, 1994). Seagrasses are a key component of the estuarine environment and significant losses are likely to have negative impacts on ecosystem functioning.

Globally seagrass distribution and abundance have declined significantly (Green and Short, 2003; Orth et al., 2006). Historical aerial photos show seagrass beds in Tauranga Harbour have declined from 4,437 ha (22%) in 1959 to 2,933 ha (14%) in 1996, which is a 34% decrease in less than 40 years (Park, 1999a). Subtidal areas showed the greatest losses with a 90% decline across the whole harbour; intertidal beds declined by 27%. Seagrass beds in areas with large catchments were affected more than those near the harbour entrance or in sub-estuaries with negligible land runoff (Park, 1999a; Park, 1999b). It is unknown whether seagrass was already in decline in 1959, or whether beds have recovered or declined further since 1996, so the full impact of seagrass decline on harbour ecology may be less or greater than the above numbers suggest. In the late 1990s, regional council reports suggested that seagrass decline may be slowing and that in one area (Tuapiro Estuary), seagrass beds may be increasing (Park, 1999a; Park, 1999b). This improvement was attributed to better environmental practices, particularly the removal of point source nutrient discharge (sewage was discharged into the harbour until 1994), and reductions in the amount of land runoff and associated nutrients and sediments (Park, 1999a; Park, 1999b).

Several studies suggest that human impacts are primarily responsible for seagrass decline (Inglis, 2003; Park, 1999a; Park, 1999b; Turner and Schwarz, 2006). As seagrass is primarily found in estuarine and near-shore coastal environments in New Zealand, it is particularly vulnerable to catchment land use activities and coastal development (Turner and Schwarz, 2006). Direct human impacts include mechanical damage (*e.g.* dredging, fishing, anchor damage), eutrophication, sedimentation, pollution, introduced species, the effects of coastal constructions and food web alterations while indirect impacts include the negative effects of climate change (*e.g.* erosion by rising sea level, increased storms) (Duarte, 2002; Turner and Schwarz, 2006). Impacts can also be natural, such as storm damage, disease (*e.g.* wasting disease caused by *Labyrinthula zosterae*) and grazing by herbivores (*e.g.* black swans).

Observations of black swan feeding on seagrass beds in Tauranga Harbour showed 1-7% of plants (including rhizome) had been removed in some areas (Park and Donald, 1994).

Light is one of the primary resources limiting the growth of seagrasses (Hemminga and Duarte, 2000) and accordingly a reduction in available light has been cited as the most frequent and widespread cause of seagrass decline (Turner and Schwarz, 2006). The main factors are an increase in dissolved nutrients leading to eutrophication and an associated increase in phytoplankton, macroalgae and epiphytes and an increase in suspended sediments resulting in turbidity and, potentially, increased sedimentation. Runoff of nutrients and sediments into estuaries and coastal environments, as a result of human activities, is considered to be the greatest threat to seagrass worldwide (Green and Short, 2003; Hemminga and Duarte, 2000). Sedimentation and nutrient loading were implicated as the main factors involved in Tauranga Harbour's seagrass decline (Park, 1999a; Park, 1999b).

There is currently no restoration plan for the recovery of seagrass in Tauranga Harbour. Potential sites for restoration are those with a history of seagrass existence (Fredette et al., 1985). Conditions responsible for the loss of seagrass must have improved sufficiently and a number of key environmental parameters must be met (e.g. water depth, nutrient levels, water clarity) (Reed et al., 2005; Reed et al., 2004). This could be achieved by minimizing suspended sediments, nutrients and contaminants in runoff and discharges into the harbour using catchment management plans that incorporate the use of tools such as riparian margins, treatment wetlands and erosion protection measures (Reed et al., 2004). In Whangarei Harbour seagrass was transplanted from donor sites within the harbour to areas nearby, where formerly there were extensive seagrass beds. Seagrass cover at the transplant site had more than doubled in one year after transplanting and donor sites recovered fully within nine months (Matheson et al., 2008). Research shows that local donor sites are best for transplanting due to genetic similarity and exposure to corresponding environmental conditions (Jones et al., 2008). Tuapiro Estuary may be a potential donor site for any future restoration plans in Tauranga Harbour.

Wetland vegetation

Wetland areas within Tauranga Harbour have been surveyed and the total areas of both terrestrial and estuarine wetlands have been quantified (Beadel et al., 2008). Wetlands occur in both zones, with most in low lying coastal areas. The most extensive areas of wetland remaining in the ecological district are on the northern end of Matakana Island. Dunelands occur along the entire length of the Tauranga Ecological District coastline.

Dunelands, wetlands, saltmarsh and mangroves were found to characterize natural areas remaining in the coastal zone. Wetlands that remain free of exotic plants were rare. Of 773 ha of wetland in the coastal zone, 586 ha are invaded by exotic species to some degree, and 186 ha are dominated exclusively by willows. Wetlands in the semi-coastal zone exhibit a more severe degree of invasion by exotic species (Beadel et al., 2008). Further information including site maps and descriptions for specific areas of the Tauranga Ecological District can be found in Beadel et al. (2008).

Mangroves

- While mangroves perform many important ecological functions, there may be significant differences between the single species mangrove habitat of New Zealand and the complex mangrove forests of tropical regions (2010).
- Mangroves are declining globally but expanding in New Zealand (2007).
- Mangroves in Tauranga Harbour increased by 160% between 1943 and 2003, causing adverse effects on amenity values and possibly harbour ecology (2003).
- Mangrove expansion is likely driven by sedimentation (2010).
- 92 ha of mangroves have been removed from the harbour (2010).
- Mangrove management initiatives are becoming more catchment focused to target the source of the problem (2010).

Mangrove is the common name for a number of inshore tropical shrubs or trees that are adapted to grow in salt water (Nybakken and Bertness, 2005). New Zealand is the southern extent of mangroves' natural range and is home to only one species, *Avicennia marina* (Figure 13) (Crisp et al., 1990). Mangroves require sheltered conditions for establishment so typically occur in low-wave-energy environments with high sedimentation (Nybakken and Bertness, 2005). Overseas research shows mangroves serve a number of important ecological roles including nitrogen cycling, trapping sediment, providing nursery areas, enhancing species diversity, increasing ecological productivity and providing habitat and food for other species (Food and Agriculture Organisation of the United Nations, 2007; Miththapala, 2008; Nybakken and Bertness, 2005). In addition, by virtue of their ability to buffer shorelines from erosion, mangroves may protect the coast from the effects of future sea level rise (Jones, 2008).

Figure 13. Mangrove (*Avicennia marina*) spread and removal in Tauranga Harbour (photos: Noel Peterson)

There may be significant differences between the single species mangrove habitat of New Zealand and the complex mangrove forests (up to 30 species) of tropical regions (Morrisey et al., 2010). Overseas, a range of marine species have formed obligatory relationships with mangroves but in New Zealand there are no such examples. Mangroves in New Zealand perform a number of the same services as mangroves overseas (e.g. nutrient cycling, shoreline protection, providing habitat diversity) but the extent to which they do so may, or may not, be comparable. For example, while tropical mangroves provide critical nursery habitat for a range of marine fish, Morrisey et al. (2007) argued that it is unlikely that New Zealand mangroves are important as spawning grounds for coastal fish or as habitat for their larvae. New Zealand mangroves show low diversity in fish species, compared with other estuarine habitats, and could be considered as nursery or “effective juvenile” habitat for only three species of fish (short-finned eels, parore and grey mullet) (Morrisey et al., 2007). Care should be taken when drawing comparisons with tropical, sub-tropical and other temperate mangrove systems and further research is needed to identify the role of mangroves in a New Zealand context.

Globally mangroves are declining (Food and Agriculture Organisation of the United Nations, 2007), however, in New Zealand they are spreading at a rate that has led some communities to consider them to be a nuisance. Concerns from coastal residents of the upper North Island include reduced access, smelly mud, loss of water views, poorer fishing and shellfish gathering and decreased property values (Green et al., 2003). Mangrove expansion has the potential to reduce the area of intertidal flat in an estuary with associated changes in benthic invertebrate composition (Ellis et al., 2004). Alterations in benthic communities that are prey species for larger fauna have ecological consequences for higher trophic levels. Colonisation of intertidal flats by mangroves also has the potential to decrease feeding and roosting areas for wading birds (Auckland Regional Council, n.d).

Aerial mapping shows mangroves in Tauranga Harbour have increased in extent by 160% over the past 60 years, from 240 ha in 1943 to 623 ha in 2003 (Figure 14) (S. Park, pers. comm.; Park 2004). Much of the mangrove habitat has established within the last 25 to 40 years. Comparison of mangrove cover between sub-estuaries from 1943 to 2003 (
Table 9) shows the greatest mangrove expansion was at Tanners Point (26 ha change in canopy cover over 60 years) while Bluegum Bay and Waimapu had the smallest increases in mangrove cover (2.6 ha and 4.2 ha, respectively, over 44 years) (Park, 2004).

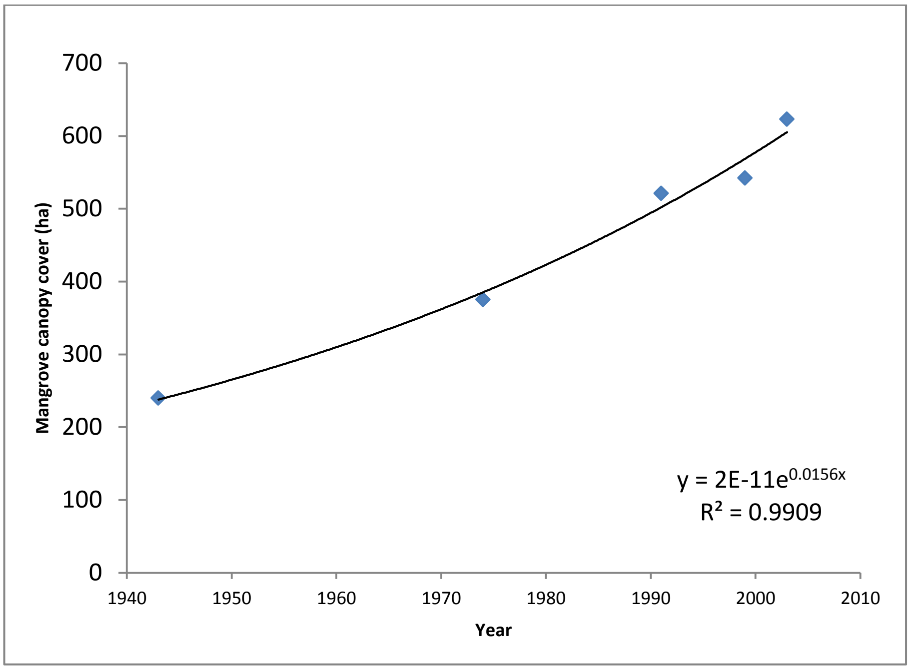

Figure 14. Mangrove cover (ha) in Tauranga Harbour 1943-2003. Data provided by S Park (pers. comm.).

Table 9. Mangrove canopy cover (ha) of sub-estuaries within Tauranga Harbour from 1943 to 2003.

Sub-estuary	**Area (ha)**	**Canopy cover of mangroves (ha)**											**Change***
		1943	**1959**	**1964**	**1969**	**1975**	**1982**	**1986**	**1993**	**1996**	**1999**	**2003**	
Welcome Bay	150	0.4	0.6	1.0	2.5	3.1				12.3	13.2	13.6	**13.2**
Tuapiro	190			0.6		1.4	2.3				13.8	17.2	**17.0**
Te Puna	160	13.2	15.5					24.1			33.2	29.0	**15.8**
Waikaraka	70	0.3	0.6					3.4			11.8	10.0	**9.7**
Tanners Point	n/a	0.2	0.9	-	-	-	-	19.3	26.1	-	29.4	26.2	**26.0**
Hunters Creek	460	0.2	0.4						7.2		7.7	10.6	**10.4**
Bluegum Bay	250		0.2						1.9		2.5	2.8	**2.6**
Waimapu	250		0.2								3.1	4.4	**4.2**

*Note: Change in cover is determined by subtracting the earliest estimate of canopy cover of mangrove for each sub-estuary from its respective 2003 estimate. Source: (Park, 2004).

Two main mechanisms likely account for the spread of mangroves, both directly driven by increased sedimentation. More sediment settling in the harbour raises the level of the intertidal seabed, allowing mangroves to colonise areas that were once too frequently inundated by the tide (Jones, 2008). An increase in sedimentation by 2 mm per year on a wide shore profile could allow mangroves to colonise an additional 1 m per year (Park, 2004). Once established, mangroves reduce water movement and wind, further enhancing fine sediment deposition and creating a positive feedback as the extent of suitable habitat for mangrove colonization concurrently increases (Hume et al., 2010). As an example, sediment accumulation in the Firth of Thames has increased from 20 mm per year to as much as 100 mm per year following mangrove colonization (Auckland Regional Council, n.d).

Fine sediments preferentially accumulate among mangrove root structures, changing the sediment composition from sandy to muddy substrate (Stokes, 2010). Muddy substrates tend to have higher nutrient levels, facilitating the growth of mangroves (Park, 2004). Within Tauranga Harbour, Park (2004) found a strong correlation between average mud content of a sub-estuary and its mangrove cover with more mangroves in muddy sediment (Table 10 and Figure 15).

This trend is not present for all sub-estuaries, for example Mangawhai and Rereatukahia are reasonably muddy (21% and 37% mud content) but have low canopy cover (2%). Thus, other factors are also likely to be important in determining rates of colonisation and overall abundance. Such factors may include global warming (*e.g.* increases in temperature and carbon dioxide enhancing production), changes in hydrodynamics (*e.g.* reduced tidal flushing) and increased nutrient inputs (Auckland Regional Council, n.d; Morrisey et al., 2007; Nicholls et al., 2004; Park, 2004).

Table 10. Canopy cover (% of sub-estuary) and mud content (% of sediment) in sub-estuaries within Tauranga Harbour in 2003.

Sub-estuary	Area (ha)	Canopy Cover (%)	Mud Content (%)
Apata	110	38	70
Wainui	380	22	55
Rereatukahia	380	2	37
Te Puna	160	18	30
Katikati	250	15	30
Welcome Bay	150	9	22
Mangawhai	140	2	21
Waimapu	250	2	21
Waikaraka	70	14	18
Tuapiro	190	9	12
Hunters Creek	460	2	9
Wairoa	540	2	7
Waipu	180	1	7
Bluegum Bay	250	1	5

Source: (Park, 2004)

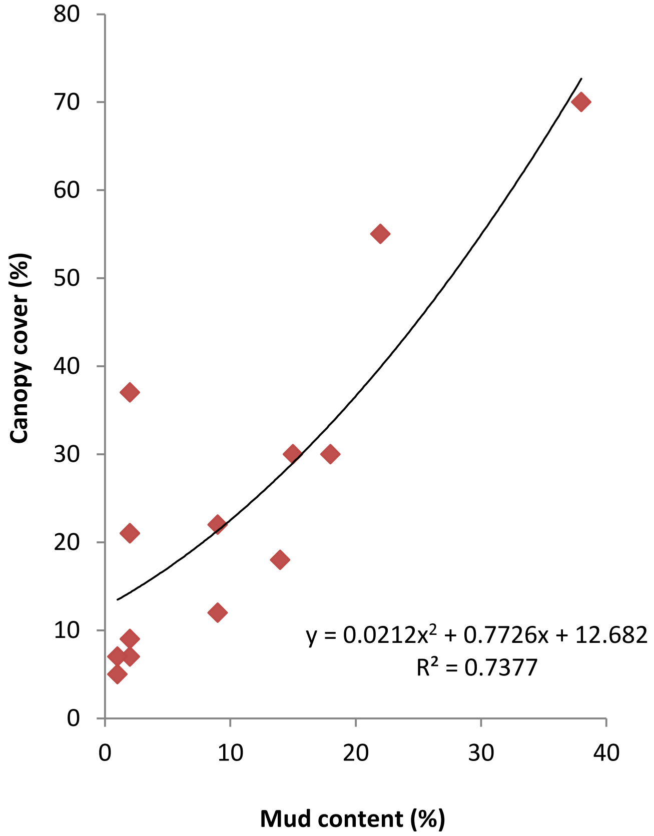

Figure 15. Relationship between mud content and mangrove canopy cover in Tauranga Harbour sub-estuaries Source: (Park, 2004).

The RMA 1991 requires a coastal permit from BOPRC for the removal of mangroves. In 2003, the Tauranga City Council was granted consent to hand remove mangroves in four estuaries (R Donald, pers. comm.). The Estuary Care Programme was set up in 2006 to support communities that wanted to become actively involved in harbour protection work, including mangrove removal, and these groups became responsible for consent application (Bay of Plenty Regional Council, 2010). There are currently 10 Estuary Care Groups and in August 2009, they were granted consent for the mechanical removal of 92 ha of mangroves from 11 sites (Bay of Plenty Regional Council, 2010). Removal began in January 2010 and was completed in early 2011. At this stage, BOPRC has no further plans for mangrove removal, however, once criteria have been developed for the assessment of potential removal, additional areas may be identified for removal (R Donald, pers. comm.).

Environmental monitoring is required as part of the mangrove removal consent conditions and includes an assessment of mulch accumulation and transportation, general observations and impacts of machinery, bird monitoring and sediment transportation (Bay of Plenty Regional Council, 2010). In June 2010, BOPRC reported that the mulch remains in situ and becomes incorporated into the mud and the impact of machinery is minor in terms of effects to benthic life. Wading birds, including the banded rail (*Rallus philippensis*) are still present in areas subject to mangrove removal (Bay of Plenty Regional Council, 2010). Sediment monitoring transects are in place and will be monitored annually by the relevant Estuary Care Group but at this stage there is deemed to be little visible sediment movement (Bay of Plenty Regional Council, 2010). Dissolved oxygen levels at two mulch sites, Waikareao and Omokoroa, were assessed six and two months, respectively, after mangrove removal (Park, 2011). A slight reduction of oxygen levels was recorded over the mulched areas but this was not below that recommended by the ANZECC aquatic life guidelines (80% saturation) and was similar to those recorded in intact mangrove areas (Park, 2011). Higher levels of dissolved oxygen depletion are likely to occur immediately after mangrove mulching and it was recommended that this be monitored further (Park, 2011). A report on monitoring of consent conditions for the mangrove removal is expected mid 2011 (R Donald, pers. comm.).

Mangrove removal at three of the 11 sub-estuaries where removals have occurred has also been assessed by Lundquist et al. (2010). Local scale impacts were compared between mangrove clearings, neighbouring unvegetated sediments and mangrove forest. Results suggested that mulch and anoxia persisted longer than predicted even at wave exposed sites. Mulch was predicted to disperse within a one month period but was present eight months after mangrove removal. Impacts on benthic communities included 100% mortality of both infaunal and epifaunal communities following mangrove removal. Sediments became anoxic with high abundances of sulphide-reducing bacteria, and abundant nuisance algae (sea lettuce*)* were recorded at mulch sites. Oxygen-depleted waters were recorded over mulch sites as compared to control sites. Water column dissolved oxygen (DO) levels at mulch sites were as low as 30% to 60% (Lundquist et al., 2010), below the ANZECC aquatic life guidelines of 80% DO saturation, leading to possible impacts on fish and other marine organisms.

While mangrove removal may temporarily restore some areas to previous conditions, the spread of mangroves is a response to sediment loading from catchment runoff and until this is addressed estuarine systems will continue to degrade. Removal of mangroves may allow some of the accumulated mud to disperse freely but mud will continue to settle in sheltered areas unless the sediment load decreases. Indeed, removing mangroves may facilitate the spread of once consolidated mud into other areas of the estuary. Mangrove management initiatives should include issues such as catchment management to address eutrophication and sedimentation generated by anthropogenic activities (Mom, 2003). BOPRC has started work on catchment management plans, which help land owners to develop better land use practises to reduce sediment runoff. The New Zealand Landcare Trust is also working on sustainable land management initiatives including riparian fencing and planting practices as part of a Kaimai/Mamaku project (Kate Akers, pers. comm.).

4.2. Marine fauna

Marine fauna encompasses the animals within the harbour including macroinvertebrates (e.g. shellfish), fish, large mammals (dolphins, whales and seals) and birds.

4.2.1. Macroinvertebrates, including shellfish

- Soft shore macrobenthic communities in Tauranga Harbour are similar to those in comparable habitats elsewhere in the northern New Zealand (1994).
- Macroinvertebrate species richness, an indicator of ecosystem health, remained stable over the 1990-2000 period (2000).
- Polychaetes were the dominant taxonomic group in subtidal areas (1994).
- Bivalves were the dominant taxonomic group in intertidal areas (1994).
- Near the Bowentown entrance to the harbour there was evidence of extensive former mussel beds (1994).
- Subtidal species diversity was limited by sediment mobility with less species in areas with low silt deposition (and therefore high currents) (1994).
- Intertidal species diversity decreased with increasing with silt content (1994).
- Macroinvertebrate diversity was higher in seagrass beds than on bare sand (1994).
- Some species showed correlations in density due to one species providing substrate for another (1994).
- Studies of the rocky communities at the harbour entrance have indicated these areas are very diverse with high densities of filter feeding species (1982-1991).
- Cockles, wedge shells and pipi all showed a trend of larger shellfish near the harbour entrance with progressively smaller sizes in the upper harbour (1994).
- Cockles showed no change in length frequencies between 1974 and 1994 (1994).
- Shellfish surveys at Otumoetai have recorded, between 2006 and 2010, a significant increase (roughly 200%) in cockle populations and a significant decline (about 50%) in pipi numbers (2010).

The term macroinvertebrate refers to animals that do not possess a backbone and are visible without the use of a microscope (generally > 0.5 mm). The group includes animals such as sponges, anemones, worms, shellfish, crabs, starfish and sea urchins but does not include fish or mammals.

Tauranga Harbour has extensive intertidal areas (subject to submergence and exposure by the tides) and shallow subtidal areas (always covered by water) supporting a diverse array of macroinvertebrates. Bioresearchers Ltd. (1976a; Bioresearchers Ltd, 1976b) reported that the harbour has exceptionally high ecological value and described it as productive, stable, rich in species and habitat, in excellent ecological condition and of importance to the ecology of the greater region. Park and Donald (1994) described large productive beds of shellfish throughout the harbour, and reported that historical impacts to the ecology of the harbour appeared to be minimal. However, pressure is now increasing due to activities such as land use changes, increasing urbanisation and greater demands for port activities.

BOPRC monitors benthic macrofauna at 17 sites within and around Tauranga Harbour to assess benthic community health and detect trends over time with respect to the integrity of ecosystems. The last published report (Park, 2000a) found that species richness, an important indicator of ecosystem health, has remained stable over the 1990-2000 monitoring period. More recent work is needed to determine whether this trend still holds true; an updated benthic monitoring report is expected to be completed in 2011 (R. Donald, pers. comm.).

Other information relating to benthic macrofauna within the harbour is limited; existing studies are either solely qualitative or limited to small geographic areas (Bioresearchers Ltd, 1974b; Bioresearchers Ltd, 1975; Bioresearchers Ltd, 1976a; Bioresearchers Ltd, 1976b; Healy et al., 1991; Healy et al., 1988; Roper, 1990). The Port of Tauranga has carried out a number of localised studies through assessments of dredging and spoil dumping and via on-going support of graduate student research projects (Blom et al., 1993; Butler, 1999; Cole et al., 1994; Cole et al., 1995; Crozier, 2001; Foster, 1992; Gouk, 2001; Grace, 1997; Grace, 1998; Grace and Blom, 1992; Graeme and Graeme, 1991; Graeme, 1995; Healy et al., 1998; Hull, 1996; Keeley and Pilditch, 1998; Putt, 1996; Ross and Pilditch, 2006; Ross and Pilditch, 2009; Teaioro, 1999). Park and Donald carried out a comprehensive survey of the intertidal and subtidal soft shore benthic communities of Tauranga Harbour, reported in 1994. While this information is somewhat out-dated, it provides a useful baseline for future reference and gives an indication of what species one might expect to find. Overall they found the communities to be similar to those of comparable habitats elsewhere in northern New Zealand. The following sections on the subtidal and intertidal areas discuss Park and Donald's findings in more detail.

Subtidal Soft Shore

Six replicate core samples from 16 subtidal sites within Tauranga Harbour were sampled and sieved through 1 mm mesh (Park and Donald, 1994). The dominant taxonomic group was the polychaetes (62% of total), followed by the bivalves (19% of total) (Table 11). The most common bivalve was the pipi (*Paphies australis*) (10.2% of total), which was common in shallow subtidal areas. The nut shell (*Nucula hartvigiana*) and cockle (*Austrovenus stutchburyi*) were also often seen (2.2% and 1.1% of total, respectively) but this was due to the shallow nature of many of the sites, as these species prefer the low intertidal. Bivalves and gastropods were less common in subtidal areas than intertidal but echinoderms (mainly starfish) and crustaceans (mainly amphipods) were more frequent. Overall, the species composition appears typical of a reasonably healthy benthic community.

Benthic communities near the entrances to the harbour are similar to Tawera-Corbula-Glycymeris bivalve communities in coarse gravels elsewhere in New Zealand. Near the northern entrance to the harbour (Bowentown) there was evidence of extensive former mussel beds (*Perna canaliculus*) but only small isolated patches of mussels remained. The loss of these mussel beds has been attributed to overharvesting (Bioresearchers Ltd, 1976a). The associated community included sea cucumber (*Stichopus mollis*), blue false crab (*Petrolisthes elongatus*) and several species of fish (*e.g.* spotties, scorpionfish). Healy et al. (1988) reported that marine life near the southern entrance to the harbour (Tauranga) is expected to be rich and diverse in the coarse sediments, but sparse on the dynamic high-energy ebb-tidal delta. They described a diverse deep channel community characterized by bivalves (*Theora lubrica, Leptomya retiaria*), polychaetes (e.g. *Pectinaria australis*), crabs (*Macrophthalmus hirtipes, Halicarcinus varius,* hermits), heart urchins (*Echinocardium australe*), brittle stars and horse mussels (*Atrina zelandica*).

Table 11. The numerically dominant macrofauna species recorded in 1994 subtidal surveys of Tauranga Harbour using 1 mm mesh sieves. Also reported is the percentage composition of the total number of individuals from the 96 (13 cm diameter) core samples collected.

Scientific name	Common name	% composition of total
Polychaetes		
Aonides oxycephala		14.0
Heteromastus filiformis		8.3
Owenia fusiformis		8.3
Aglaophamus macroura	bristle worm	4.6
Oriopsis sp.		3.2
Aquilaspio aucklandica		3.0
Magelona dakini		2.3
Lumbrinereis sphaerocephala		2.0
Macroclymenella stewartensis		1.7
Sabellidae sp.		1.7
Chaetozone platycera		1.7
Perinereis sp.	ragworm	1.5
Thelepus plagistoma		1.4
Bivalves		
Paphies australis	pipi	10.2
Felaniella zelandica		2.4
Nucula hartvigiana	nut shell	2.2
Gari stangeri	purple sunset shell	1.3
Austrovenus stutchburyi	cockle	1.1
Crustacea		
Elminius modestus	acorn barnacle	1.8
Paramoera chevreuxi	amphipod	1.6
Amphipod sp. *m*		1.6
Other		
Trochodota dendyi	burrowing sea cucumber	1.3
Urechis sp.	annelid worm	1.3
Patiriella regularis	cushion star	1.1
Other species (64)		20.4

Source: (Park and Donald, 1994)

As the sampling moved to shallower harbour waters and medium grained sand, turritellid communities dominated by turret shell (*Maoricolpus roseus*) were observed, similar to communities seen elsewhere in northern New Zealand (Morton and Miller, 1973). Further up the harbour there were extensive communities associated with scallop (*Pecten novaezelandiae*) and horse mussel. No detail was given for organisms associated with the horse mussel beds but the scallops supported red algae (*Delesseria* and *Rhodymenia leptohylla*), which in turn had associated communities of amphipods and small rissoid snails. The upper reaches of the subtidal area had low densities of juvenile scallops and species common in the lower intertidal zone.

Areas of the channel with higher silt content had moderate densities of heart urchin. Shallower subtidal areas, especially those free of silt and gravel, were dominated by olive shell (*Amalda australis*), cushion star (*Patiriella regularis*) and cake urchin (*Fellaster zelandiae*). Species observed in a 1982 subtidal soft sediment survey in Pilot Bay were similar to the domiant species found throughout the harbour (e.g. *Aglaophamus macroura, A. australis, P. regularis*) (Harrison and Grierson and Partners, 1982).

Mean species diversity (number of taxa in each sample) was 6.9. The site showing the highest species diversity (13.3) contained a large number of horse mussels, which provided additional habitat complexity and sediment stability. Species diversity in subtidal areas was limited by sediment mobility, showing a negative correlation with depth and a weak positive correlation with percentage silt content of superficial sediments. This counterintuitive trend (i.e. one might intuitively expect species diversity to be higher in areas with low silt content) most likely arises due the strong scouring action of currents in the channel. Deeper areas tend to have higher current velocities and this instability makes it difficult for species to survive. Areas with weaker currents are more conducive to colonization, and also facilitate silt deposition. The trend is not linear and if currents were to slow sufficiently to allow the deposition of higher amounts of silt, species diversity would be expected to decrease, as seen in the intertidal zone.

Healy et al. (1988) described a deep community in the Port area with high species diversity, characterized by species typical of fine or muddy offshore sediments (e.g. pink sea star, heart urchin). The presence of such species suggests currents in the deepened Port basin are not as strong as those sampled by Park and Donald (1994) and allow some stability. The Port area may be somewhat unique in this respect. The sand banks in the vicinity of the Port are characterized by clean sands with frequent beds of shellfish and quantities of loose shell derived from the local marine fauna (Healy et al., 1988).

Healy et al. (1988) reported reduced diversity in and near the offshore dredge spoil dump zones (outside harbour). Species diversity was reduced to approximately one third of that seen in control areas and remaining organisms were those which can cope with unstable seabed conditions such as bivalves (*Tawera spissa*), polychaetes (*Sigalion* sp., *Lumbriconereis sphaerocephala, A. macroura*), gastropods (*Antisolariumm egenum, A. australis*), hermit crabs and amphipods. It was suggested that physical smothering from the spoil dump was responsible for the reduction in diversity.

Intertidal Soft Shore

Four replicate core samples from each of 160 intertidal sites within Tauranga Harbour were sampled and sieved through 2 mm mesh (Park and Donald, 1994). The dominant taxonomic group was the bivalves (46% of total), followed by the polychaetes (19% of total) and gastropods (18% of total) (Table 12). The most abundant species were wedge shells and cockles, each comprising about 15% of the total number of individual animals collected. The cockle is commonly noted as a dominant intertidal species in New Zealand estuaries (Knox and Kilner, 1973). Bivalves, gastropods and coelenterates (anemones and sea cucumbers) were more common in the intertidal zone than the subtidal.

Table 12. The numerically dominant macrofauna species recorded in 1994 intertidal surveys of Tauranga Harbour using 2 mm mesh sieves. Also reported is the percentage composition of the total number of individuals from the 640 (13 cm diameter) core samples collected and the mean and maximum abundances (per m^2) of each species.

Scientific name	Common name	% composition of total	Mean abundance	Maximum abundance
Polychaetes				
Scoloplos sp.		6.7	-	-
Sclecolepides benhami		2.4	30	527
Heteromastus filiformis		1.9	24	678
Aonides oxycephala		1.0	13	829
Aquilaspio aucklandica		1.4	-	-
Macroclymenella stewartensis		1.0	12	377
Perinereis nuntia var. vallata	ragworm	2.3	30	678
Bivalves				
Tellina liliana	wedge shell	15.1	194	904
Austrovenus stutchburyi	cockle	14.9	191	2,185
Nucula hartvigiana	nut shell	11.6	149	3,918
Paphies australis	pipi	2.2	28	2,486
Felaniella zelandica		1.9	24	1,507
Crustaceans				
Callianassa filholi	ghost shrimp	<1	5	527
Macrophthalmus hirtipes	hairy mud crab	<1	13	301
Halicarcinus whitei	pill box crab	<1	10	301
Hemigrapsus crenulatus	hairy handed crab	<1	4	226
Gastropods				
Zeacumantus lutulentus	horn shell	6.6	85	979
Zeacumantus subcarinatus		3.5	46	1,808
Cominella gladiformis	mud whelk	2.8	36	2,561
Diloma subrostrata	top shell	1.8	23	678
Micrelenchus huttoni	opal shell	1.8	23	1,055
Other				
Anthopleura aureoradiata	grey anemone	11.7	150	5,048
Other species (65)		19.4	-	-

Source: (Park and Donald, 1994)

Most of Park and Donald's (1994) sample sites had relatively clean sand with low silt (8.6%), total organic carbon (0.12 g $100g^{-1}$) and nutrient content. These areas were dominated by wedge shells, cockles and seagrass. The fauna associated with the seagrass was similar to descriptions from other northern New Zealand harbours (Morton and Miller, 1973). Muddier areas were characterized by mud snail (*Amphibola avellana*) communities. Densities of the dominant species are typical of other harbours and estuaries in New Zealand. For example, the maximum density of cockles in Tauranga Harbour (2,185 m^2) is comparable to the maximum density of 2,560 m^2 recorded by Knox & Kilner (1973) in the Avon-Heathcote Estuary and by Murray (1978) in the Maketu Estuary.

Some species showed correlations in density due to one species providing substrate for another. For example, the cockle provided a hard substrate for the common shore anemone and pipi provided a hard substrate for the green shield chiton (*Chiton glaucus*). There were no highly significant negative correlations between any species that would suggest competition. There was also no correlation between bivalves and polychaetes, indicating there is little interaction with changing dominance of species amongst sites (Park and Donald, 1994).

Park and Donald (1994) reported that mean species diversity (number of taxa in each sample) was 5.3 in bare substrate and 6.2 in seagrass. It is likely a much higher diversity would have been observed in the seagrass if a smaller sieve mesh size had been used (*e.g.* 0.05 or 1 mm). The slightly higher subtidal diversity is likely due to this difference in sieve size (1 mm sieve rather than 2 mm).

Species diversity showed a strong negative correlation with silt content. The feeding structures of filter feeding species, such as cockle and nut shell, become clogged when silt levels are high. Some species, such as the hairy mud crab (*Macrophthalmus hirtipes*) and a polychaete worm (*Heteromastus filiformis*) showed a positive correlation with silt content. The importance of various parameters (e.g. silt content, total organic carbon, nutrients) varies from species to species. These results are consistent with Thrush et al. (2003) who developed models of macrofaunal species occurrence with respect to sediment mud content. Specifically they found similar responses whereby sensitive species with a preference for low mud content included the mobile suspension feeding cockle and the deposit and suspension feeding nut shell. Tolerant species with preferences for higher mud content included mud crabs and the polychaete worm (*H. filiformis*).

Rocky Shore

Rocky shores cover less than 0.1% of the total area and perimeter of Tauranga Harbour (Park and Donald, 1994). The small number of surveys carried out in the hard bottomed communities at the harbour entrance have indicated these areas are very diverse with high densities of filter feeding species (Harrison and Grierson and Partners, 1982; Healy et al., 1991; Healy et al., 1988).

Healy et al. (1988) describes the rocky communities at two dive sites near the southern entrance to the Tauranga Harbour (outside harbour, near Moturiki and Motuotau Islands). The intertidal rocks were characterized by barnacles and little black mussels (*Xenostrobus pulex*) with bands of brown seaweeds interspersed with clumps of red seaweeds below the low water mark. The rocky bottom marine life at these sites appeared typical of this type of habitat and included organisms such as sponges, ascidians, bryozoans, hydroids, sea stars and crabs (Table 13). Green-lipped mussels at one site were large while at the other there was a band of dense young green-lipped mussels (25-30 mm length) at 5 to 10 m depth, most likely the result of good settlement the previous spring. The low numbers of sea urchins and crayfish were in keeping with the rest of the coastline with its present level of fishing pressure. The report concluded that there was no obvious effect on the rocky bottom marine life from previous spoil dumping operations.

Table 13. Species observed at two rocky dive sites near the southern entrance to Tauranga Harbour in 1988. Fish are not included in this table.

Molluscs		**Sponges**	
Clown nudibranch	*Ceratosoma amoena*	Black sponge	*Ancorina alata*
Limpet	*Cellana stellifera*	Boring sponge	*Cliona celata*
Little black mussel	*Xenostrobus pulex*	Golfball sponge	*Tethya aurantium*
Green-lipped mussel	*Perna canaliculus*	Golfball sponge	*Tethya ingalli*
Crustaceans		**Echinoderms**	
Barnacle	*Chamaesipho brunnea*	Cushion star	*Patiriella regularis*
Barnacle	*Chamaesipho columna*	Eleven-armed seastar	*Coscinasterias calamaria*
Barnacle	*Epopella plicata*	Kina	*Evechinus chloroticus*
Crayfish	*Jasus edwardsii*	Reef star	*Stichaster australis*
Red rock crab	*Guinusia chabrus*	Tennis ball urchin	*Holopneustes inflatus*
Algae		**Other**	
Brown algae	*Xiphophora chondrophylla*	Hydroids	*Solanderia* sp.
Brown algae	*Carpophyllum maschalocarpum*	Anemones	*Actinothoe albocincta*
Brown algae	*Lessonia variegata*	Bryozoans	
Coralline paint	Corallinales order	Ascidians	*Hipsistozoa fasmeriana*
Kelp	*Ecklonia radiata*	Zoanthids	
Red algae	*Pterocladia lucida*		
Red algae	*Vidalia colensoi*		

Source: (Healy et al., 1988)

The rocky reefs surrounding Motuotau Island, although outside the harbour, are of interest as they are located inshore of the dump ground for dredge spoil from Port of Tauranga operations. Since 1990, biological monitoring has been carried out to determine the impact of dumped sediment on the reef biological communities using photographs of permanent transects and measurements of sediment change (Grace, 1997; Keeley and Pilditch, 1998; Ross and Pilditch, 2006; Ross and Pilditch, 2009). In concurrence with previous surveys, the most recent survey (Ross and Pilditch, 2009) showed no major changes to community composition (Appendix 2) that could be attributable to dredging activities and no significant change in height of the sediment boundary from 2006. They concluded that, in general terms, the reefs around Motuotau Island appeared to be healthy and in a state typical of reefs of similar depth, aspect and exposure found elsewhere on the neighboring coastline.

Customary, Recreational and Commercially Important Species

Gathering shellfish from Tauranga Harbour is not limited to the local population as visitors come from Auckland, Hamilton, Rotorua and as far south as Turangi to gather (Scholes et al., 2009). Shellfish beds in the harbour are easily accessible and, due to the calm conditions, shellfish are collected from here in favour of the open coast (Scholes et al., 2009). The state of shellfish beds in Tauranga Harbour has not been formally assessed recently, but local people have raised concerns over the health status of shellfish species. For example, Britton et al. (2007) reported the following concerns: horse mussels near Otumoetai have disappeared; shellfish gathered from particular beds (e.g. Tanners Point and Bowentown) are considered unsuitable to eat; shellfish beds in some areas (e.g. Waipu Bay and Matahui) are being affected by recreational activities; cockles are getting smaller and are being depleted by spreading silt layers. Although there is no consistent agreement with regard to the reasons for these changes, overfishing or other human activities are thought to be responsible.

In 2006, the Tauranga Moana Iwi Customary Fisheries Management Committee carried out a survey of customary and traditional fishing practices within Tauranga Harbour (Tata and Ellis, 2006). Macroinvertebrate species mentioned by Tauranga moana kaumatua and kuia are listed in Table 14 with cockles and titiko (*Amphibola avellana*) most frequently remarked upon. Mount Maunganui was identified as a fishing ground with high species diversity having pipi, kina, crayfish, mussels, crab, paua, catseye, oysters, cockle and tuatua. Other fishing grounds with high species diversity included Waipu, Poike, the Matakana Channel, Katikati and Tuapiro.

Table 14. Macroinvertebrate species mentioned by Tauranga moana kaumatua and kuia

Māori Name	Common Name	Māori Name	Common Name
Freshwater koura	Freshwater crayfish	Pipi	Pipi
Kina	Sea urchin	Piritoka	Limpet
Koura	Crayfish	Pupu	Catseye
Kuhara	Freshwater cockle	Tio	Oyster
Kukuroa	Horse mussel	Titiko	Mud snail
Kutae	Mussel	Tuangi	Cockle
Papaka	Crab	Tuatua	Tuatua
Paua	Black foot abalone	Tupa	Scallop

Source: (Tata and Ellis, 2006)

Early quantitative studies that focused on edible shellfish include Bioresearchers (1974a; Bioresearchers Ltd, 1977a; Bioresearchers Ltd, 1977b; Bioresearchers Ltd, 1977c; Bioresearchers Ltd, 1984; Bioresearchers Ltd, 1988) and Roan (1989). Bioresearcher's early reports (1974b, 1976a) describe edible macroinvertebrates including the mud snails (*A. crenata*), pipi (*Amphidesma australe* / *P.s australe*), cockles (*Chione stutchburyi* / *A.s stutchburyi*), green-lipped mussels (*P. canaliculus*) and scallops (*P.novazelandiae*). Pipi were recorded in a bed of exceptionally high density near the Bowentown entrance to the harbour. Otherwise this species occurred in scattered beds throughout the harbour, generally on the edges of channels (Bioresearchers 1974b). In 1976 the common pipi was recorded to occur throughout the harbour, reaching greatest densities and largest size in the beds near both of the harbour entrances. Sublittoral beds occurred in swift flowing channels. Local beds of edible pipi were recorded towards the centre of the harbour, notably at Omokoroa, and also scattered in the major channels (Bioresearchers 1976a).

Cockles occurred throughout the harbour, but over much of the area did not attain harvestable size (Bioresearchers 1974b). Very dense beds were reported in the Katikati Harbour region, particularly near low water on the edges of sand banks near the harbour entrance. Populations were of low density in seagrass beds (Bioresearchers Ltd, 1976a).

Green-lipped mussel beds were recorded in the channels of the Katikati Harbour region, however it was reported that little is known of the condition of mussel beds at present (Bioresearchers 1974b). In 1976 green-lipped mussels were reported to occur in small beds on the rocky headlands of Mount Mauganui and the northern entrance at Bowentown, as well as extensive sublittoral beds inside the northern entrance to the harbour (Bioresearchers Ltd, 1976a). The northern beds were a popular source of mussels for food, with mussels being taken by snorkel diving in shallower areas and dredging from small boats in deeper areas. It was reported that considerable damage has been done to the beds in some areas due to over exploitation and that the dense mat of living mussels and shells have been destroyed over large areas exposing a fine sand bottom unsuitable for attachment by recruiting juveniles (Bioresearches 1976a). Scallops were apparently scarce in the harbour, with beds being exploited by scuba diving in the deeper channel regions (Bioresearchers 1974b).

Healy et al. (1988) reported on edible shellfish in the vicinity of port dredging and spoil dump sites (outside harbour). Shellfish in the dredge zone consisted of moderate numbers of cockles and a few wedge shells on the shallow sandy flats and some horse mussels in previously dredged areas. The dump zone contained predominantly juvenile morning star shells (*T. spissa*) (~ 5-10 mm long; 2 years old), whereas control sites contained more adults (~ 20 mm long; 6 years old), suggesting an historical effect from spoil dumping with young morning star shells only recently recolonizing the area. No scallops were found in the dump zone but few were seen in control areas either.

As part of Park and Donald's (1994) benthic macrofauna survey, length-frequency data were collected for shellfish at the intertidal sites to give an indication of shellfish stocks in the harbour. Not all beds of edible shellfish were sampled and sampling sites were located at mean mid and low tide levels, whereas the largest cockles are usually found lower on the shore and the largest pipi in the shallow subtidal. Cockles from most of the sites were below eating size (30 mm). Park & Donald (1994) noted that there are a number of areas close to the harbour entrance with good densities of larger cockles (35 to 50 mm). Cockles, wedge shells and pipi all showed a trend of larger shellfish near the harbour entrance with progressively smaller sizes in the upper harbour. Shellfish near the harbour entrances may have better feeding conditions due to greater food availability and better water quality. Comparison of cockle length-frequency data from 1974 (Bioresearchers Ltd, 1974b) shows no apparent change over the 16 year period.

A 1996 survey of pipi on Centre Bank (near the Tauranga entrance to the harbour) found the species to be widely distributed with densities of up to 1,400 per m^2 and shell lengths of 55-65 mm (Hull, 1996). Other common bivalve species in this area were *T. spissa* and *Ruditapes largillierti.*

Since 1999, the Ministry of Fisheries (MFish) has monitored cockles and pipi at Otumoetai, near the southern entrance to Tauranga Harbour, as part of a wider survey of shellfish populations in northern New Zealand (Pawley, in press). Otumoetai was surveyed in 2001, 2003, 2006, 2007 and 2010 to monitor changes in shellfish abundance and thus to determine if management measures should be implemented, such as restrictions on harvesting at particular sites.

Pipi from Otumoetai exhibited a negative trend, with estimated total numbers down by 50% in 2010 compared to the 2006 survey. In contrast, the total number of cockles in 2007 and 2010 was significantly higher (up about 200%) compared to 2006 and earlier surveys, although the proportion of cockles of harvestable size was low, at around 1%, consistent with previous surveys (Pawley, in press).

4.2.2. Finfish

- Sand flounder, yellow-belly flounder, grey mullet and snapper are commercial fish species common within the harbour (2009).
- Snapper, trevally, kingfish and kahawai caught in Tauranga Harbour are part of larger Bay of Plenty fish stocks, and move into and out of the harbour (1998).
- The harbour is important for spawning and migration of whitebait, short-finned eel, long-finned eel and lamprey (2009).
- Of the 34 fish species recorded in northern New Zealand estuaries, 17 were observed in Tauranga Harbour (2001).
- Ten species of fish were found in the mangroves of Tauranga Harbour, predominantly small semi-pelagic schooling species, dominated by yellow-eyed mullet, smelt and short-finned eel (2007).
- Aside from grey mullet and short-finned eel, no other commercial fish species were found in Tauranga's mangroves (2007).
- Total fish and species richness in the mangroves was comparable with most other northern New Zealand estuaries (2007).
- Fish species in the mangroves varied in their response to the forest and physical environmental variables measured (2007).
- Fish species observed in rocky reef habitats are typical of this type of habitat in northeastern New Zealand (1988).
- Tangata whenua have noticed a decline in many fish species (2008).

A range of fish species are found within Tauranga Harbour (Ellis et al., 2008; Environment Bay of Plenty, 2009a); see Table 15. Amongst these, trevally, sand flounder, yellow-belly flounder, grey mullet and snapper are common commercial species (Environment Bay of Plenty, 2009a). The harbour is also important for spawning and migration of whitebait, short-finned eel, long-finned eel and lamprey (Ellis et al., 2008; Environment Bay of Plenty, 2009a).

Table 15. Common fish species within Tauranga Harbour.

Common Name	Species	Common Name	Species

Bronze whaler sharks	*Carcharhinus brachyurus*	Short-finned eel	*Anguilla australis*
Gobies	Gobiidae sp.	Short-tailed stingrays	*Dasyatis brevicaudata*
Grey mullet	*Mugil cephalus*	Smelt	*Retropinna retropinna*
Herrings	Clupeidae sp.	Snapper	*Pagrus auratus*
Jack mackerel	*Tachurus novaezelandiae*	Spotted stargazer	*Genyagnus monopterygius*
Kahawai	*Arripis trutta*	Spotties	*Notolabrus celidotus*
Kingfish	*Seriola lalandi*	Sprat	*Sprattus sprattus*
Koheru	*Decapterus koheru*	Tarakihi	*Nemadactylus macropterus*
Long-finned eel	*Anguilla dieffenbachii*	Trevally	*Pseudocaranx dentex*
Long-tailed stingrays	*Dasyatis thetidis*	Triplefins	Tripterygiidae sp.
Parore	*Girella tricuspidata*	Yellow-belly flounder	*Rhombosolea leporina*
Piper	*Hyporhamphus ihi*	Yellow-eyed mullet	*Aldrichetta forsteri*
Sand flounder	*Rhombosolea plebeia*		

Source: (Environment Bay of Plenty, 2009a; Morrisey et al., 2007)

Commercial and recreational fishing

Catch reporting by commercial fishers occurs at a scale that reveals little about the health of fish stocks in Tauranga Harbour. However, a report by a Fisheries Dispute Commissioner (Trapski, 1998) about the on-going tensions between recreational and commercial fishing in Tauranga Harbour provides a good overview of the issues related to finfish abundance in the harbour.

The Trapski report draws upon MFish (1998) and technical reports from BOPRC as well as oral submissions, but unfortunately does not provide references for specific statements or facts. Judge Trapski (1998) reported:

- Various fishing methods, and all commercial shellfish harvesting, are prohibited in the harbour at all times, and trawling and Danish seining are prohibited within 2 miles of the outer shoreline. The commercial fishing within the harbour of most concern is drag netting, which occurs mostly in tidal channels at low tide and primarily targets trevally. Snapper is also taken as a bycatch but fishers reported that they mostly return these to the sea alive.
- Over the period 1984 to 1996/97, commercial catches of trevally varied between 23 and 86 tonnes, while commercial snapper harvest fell from 27 tonnes in 1984 to 4.5 tonnes in 1996/97 (Figure 16).
- According to boat ramp surveys in 1992, the recreational catch rates in Tauranga Harbour were among the lowest in the region. Nonetheless, recreational harvest of snapper as estimated from surveys was, in 1994 and 1996, roughly ten times the commercial catch, at 46 tonnes in 1996 (Figure 16).
- Snapper, trevally, kingfish and kahawai caught in Tauranga Harbour are part of the larger Bay of Plenty fish stocks, and move into and out of the harbour "so that the extent of their exploitation in the greater Bay of Plenty waters has a major direct effect on their population within the harbour" (p.9).
- The main reason for trevally and snapper to enter the harbour is to feed. The report cites several environmental changes in and around the harbour (deforestation and siltation, black swans and loss of seagrass, an increase in recreational fishing and noise from boating) that are likely to influence the abundance of fish there, each of which has had an effect "probably far in excess of that of the operations of drag net fishers" (p.12).

- Trawlers targeting snapper concentrate much of their activity around the northern entrance to the harbour, in some cases breaching the 2 mile exclusion zone. “It is so easy to link the intensity of these trawl tows to the lack of abundance of fish at that end of the harbour and no scientific or other reasoning will shift that perception” (p.30).

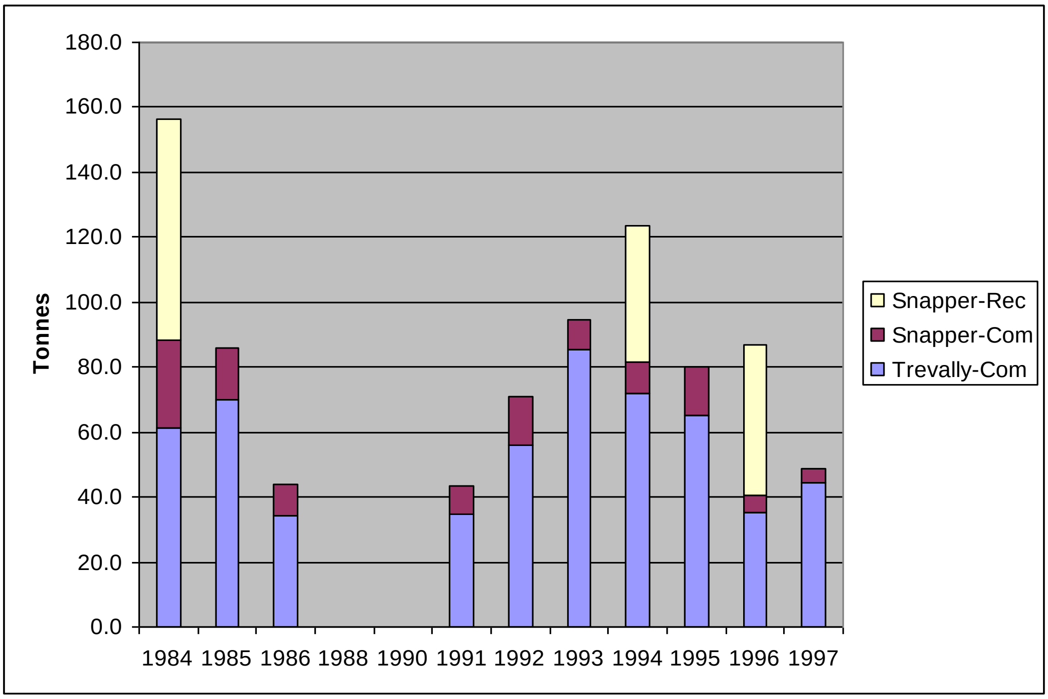

Figure 16. Commercial and recreational catch of trevally and snapper in Tauranga Harbour and Statistical Area 009. Commercial catch for 1984-86 is from Tauranga Harbour, all methods; data for 1991-1997 are from statistical area 009 for drag net only. Time series is incomplete due to changes in catch reporting systems. Recreational catch was estimated in 1984, 1994 and 1996 only, from occasional surveys of recreational fishers. Source: (MFish, 1998).

In considering various options for reducing the tensions between commercial and recreational fishers, Judge Trapski noted that banning commercial fishing or indeed all fishing was unlikely to make a large difference to fish abundance given that very little fish stock is resident in the harbour. Drag netters did, however, agree to extend voluntarily the closed period for their activity to the end of February, to provide more opportunity for recreational fishers during summer months (Trapski, 1998).

Having noted “the strength of the convictions of local people that something must be done” and “the sheer frustration of local people in seeing that their concerns appear to have been ignored” (p.24), Judge Trapski’s main recommendation was to change the way the fishery and the harbour are managed (p.28):

I therefore strongly recommend the devolution of the control of the Tauranga Harbour fishery to essentially local interests through a co-operative organisation of stakeholders with contributions from:

> *a. recreational fishing and boating interests;*
> *b. local commercial fishing interests*
> *c. local Māori; and*
> *d. the Ministry of Fisheries.*
>
> *This organisation could consider the establishment of taiapure, marine parks and marine farming in the harbour, the reseeding of lost shellfish beds, the control of adverse environmental factors, and contracting out of compliance and research, depending on funding, and take account of all matters of local and regional interest in the harbour.*
>
> *… I should report that these proposals have met with approval wherever they have been aired.*

Changes to the commercial fishing regulations were gazetted to extend the restrictions on drag netting and a mataitai for a small area has been approved (see below), but there has otherwise been no devolution of management as recommended by Judge Trapski.

Surveys of fish species and abundance

There have also been some studies that looked at fish in Tauranga Harbour more specifically.

A fish survey carried out in 25 northern New Zealand estuaries observed a total of 71,211 fish representing 34 species; 17 of these occurred in Tauranga Harbour (Francis et al., 2005). Yellow-eyed mullet (*Aldrichetta forsteri*) was the most abundant species overall, present at 90% of the sampling stations and accounting for 42% of the total catch by number.

A study of fish assemblages of temperate mangrove forests of northern New Zealand surveyed eight estuarine mangrove systems: Kaipara, Manukau, Rangaunu, Mangawhai, Mahurangi, Waitemata, Whangapoua and Tauranga (Morrisey et al., 2007). A total of 17,327 fish representing 19 species were collected during the survey; 98% were juveniles. Ten species of fish were identified in the mangroves of Tauranga Harbour and of these approximately 96% were small semi-pelagic schooling species (mullets, smelt and sprat). The dominant species was yellow-eyed mullet, followed by smelt (*Retropinna retropinna*) and short-finned eel (*Anguilla australis*). Except for short-finned eel and grey mullet (*Mugil cephalus*), no other commercial species (e.g. snapper, jack mackerel, kahawai) were found in Tauranga Harbour mangrove habitat. Total fish and species richness within Tauranga Harbour was comparable with the other estuaries, except Rangaunu and Mahurangi, which showed greater richness, and Manukau, which was higher in both total fish and richness.

The species found in the mangrove study varied in their response to the forest and physical environmental variables measured (Morrisey et al., 2007). Yellow-eyed mullet were positively associated with increasing distance from the sea, and grey mullet and yellow-belly flounder (*Rhombosolea leporina*) were strongly positively associated with total suspended sediments. Short-finned eels were positively associated with increasing mangrove habitat complexity (seedlings, saplings, and number of trees), while parore (*G. tricuspidata*) were associated with higher water clarity and intermediate sediment grain size.

Healy et al. (1988) recorded 27 species of fish at two rocky dive sites close to the southern entrance of Tauranga Harbour (outside harbour, near Moturiki and Motuotau Islands) (Table 16). These species are typical of rocky reef habitats in northeastern New Zealand and, while the authors note that the list is not comprehensive, it contains all the common species likely to be observed by diving in the area. The absence of snapper (*P. auratus*) is most likely due to the shy nature of this species and although snapper numbers were most likely down on natural stocks like other areas along the northeastern coast, they were probably present around the reefs.

Table 16. Fish species observed at two rocky dive sites near the southern entrance to Tauranga Harbour in 1988.

Common Name	Species	Common Name	Species
Banded wrasse	*Notolabrus fucicola*	Red-banded perch	*Hypoplectrodes huntii*
Bigeye	*Pempheris adspersa*	Red moki	*Goniistius spectabilis*
Blue cod	*Parapercis colias*	Red mullet	*Upeneichthys lineatus*
Blue-eyed triplefin	*Notoclinops segmentatus*	Rock cod	*Lotella rhacina*
Blue maomao	*Scorpis violacea*	Roughy	Trachichthyidae sp.
Butterfish	*Odax pullus*	Scaley-head triplefin	*Karalepis stewarti*
Conger eel	*Conger* sp.	Scorpionfish	Scorpaenidae sp.
John dory	*Zeus faber*	Spotty	*Notolabrus celidotus*
Jack mackerel	*Trachurus novaelandiae*	Sweep	*Scorpis lineolatus*
Kelpfish	*Chironemus microlepis*	Topknot blenny	*Notoclinus fenestratus*
Leather jacket	*Parika scaber*	Trevally	*Pseudocaranx dentex*
Marblefish	*Aplodactylus arctidens*	Variable triplefin	*Forsterygion varium*
Masked triplefin		Yaldywn's triplefin	*Notoclinops yaldwyni*
Parore	*Girella tricuspidata*		

Source: (Healy et al., 1988)

Tauranga Harbour is an important traditional resource supplying the nutritional needs of local people that live close by. Three forms of fishing exist within the harbour: commercial, recreational and customary. In 2007 there were approximately 6 drag netting licenses in existence but these are being phased out over time as they expire or are no longer used (Britton et al., 2007); only one commercial fisher is still operating inside the harbour in 2011 (D & B Kiddie, pers. comm.). Recreational fishing is popular within the harbour (Figure 17) but there is no obligation for recreational fishers to report their catch, so data on recreational fishing are sparse. In 2007, a survey recorded an average of 36 boats fishing in the harbour at any one time during daylight hours, on weekends and holidays (Britton et al., 2007). The Tauranga Moana Customary Fisheries Committee receives reports on fish taken from authorised customary fishers, but this information has not been compiled or published. Interviews with kaumatua and kuia of Tauranga moana identified Motiti Island (outside southern entrance to harbour), Tuapiro, Tuhua, Katikait, the Wairoa and Waimapu Rivers and Waipu as fishing grounds with high fish species diversity (Table 17) (Tata and Ellis, 2006). Snapper, flounder and kahawai were the fish species most frequently mentioned in the interviews.

Tangata whenua have noticed a decline in many fish species including flounder, shark, snapper, kingfish, trevally and mullet (Ellis et al., 2008; Tata and Ellis, 2006). Although many do not attribute the decline in fish directly to commercial fishing, they believe there is a correlation between the two. They have raised concerns over the amount of bycatch being wasted by commercial fishers and fishing methods, such as drag netting, which they believe to have adverse effects on benthic habitat comparable to scallop dredging (Ellis et al., 2008). Tangata whenua have expressed a desire for all forms of commercial fishing to be banned within the harbour to allow the replenishment of fish stocks (Ellis et al., 2008).

A commercial fisher has also noted changes in fish communities. Parore used to be so numerous that it was considered a nuisance, but now is rarely caught inside the harbour. Species such as trevally and snapper, which move into and out of the harbour, are still plentiful (D & B Kiddie, pers. comm.).

A number of commercial fishing methods are prohibited in Tauranga Harbour, including box or teichi net, purse seine net, Danish seine net, trawl net, lampara net, and set nets longer than 1000 m. In addition, no new permits are being issued for dragnetting inside the harbour (New Zealand Government, 2011).

Figure 17. Recreational fishing on Tauranga Harbour (photo: Noel Peterson).

Table 17. Fish species observed by Tauranga moana kaumatua and kuia in seven fishing grounds in and around Tauranga Harbour. 'X' indicates presence at fishing ground.

Māori Name	**Common Name**	**Motiti Island**	**Tuapiro**	**Tuhua**	**Wairoa River**	**Waipu**	**Waimpau River**	**Katikati**
Araara	Trevally		X	X				
Aua	Herring		X		X	X	X	X
Barracuda	Barracuda	X		X				
Blue Moki	Blue Moki			X				
Hake	Frost Fish	X		X	X			
Hapuka	Bass Grouper	X		X	X			
Inanga	Whitebait		X		X	X	X	
Kahawai	Kahawai		X	X	X		X	X
Kanae	Mullet		X		X	X	X	X
Kehe	Marblefish	X						
Koeaea	Butterfish	X						
Kokiri	Leatherjacket	X						
Kuparu	John Dory					X		
Maomao	Maomao	X		X				
Marlin	Marlin			X				
Paketi	Spotty				X	X		
Parore	Black snapper		X		X	X		X
Patiki	Flounder		X		X	X	X	X
Pioke	Shark	X	X	X		X	X	X
Rawaru	Blue cod	X						
Sunfish (non-target)		X						
Tamure	Snapper	X	X	X	X	X	X	X
Taraute	Trout		X		X		X	
Tuna	Eel	X	X		X	X	X	X
Wahi	Stingray	X	X	X		X	X	X
Wheke	Octopus	X						
Yellowfin Tuna	Yellowfin Tuna			X				
Total fish species		14	12	12	12	11	10	9

Source: (Tata and Ellis, 2006)

In 2008, the Te Maunga o Mauao Mataitai Reserve was established over 6 km^2 around Mt Maunganui (Figure 18). This area excludes commercial fishing and enables the Tauranga Moana Customary Fisheries Committee to advise the Minister on how best to manage fishing within the area. Within the mataitai, the recreational bag limit for mussels has been reduced from 50 per person to 25.

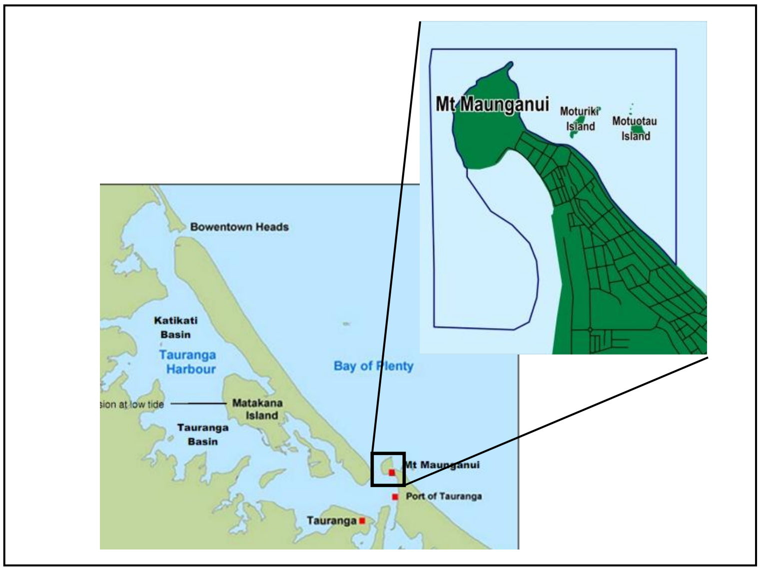

Figure 18. Area of mataitai fisheries reserve indicated by blue line around Mount Maunganui. Source: (MFish, 2008).

4.2.3. Marine mammals

- New Zealand fur seals are common visitors to the harbour and leopard and elephant seals are occasionally sighted (2011).
- More than 30 cetacean species have been observed in the Bay of Plenty and at least 8 species seen within the harbour (2011).
- Detailed information regarding seasonality and frequency of cetacean visits to Tauranga Harbour is not available (2011).

Several large marine mammals are known to frequent Tauranga Harbour, including seals, dolphins and whales (Ellis et al., 2008). The New Zealand fur seal (*Arctocephalus forsteri*) is a common visitor to the area and leopard seals (*Hydrurga leptonyx*) and elephant seals (*Mirounga leonina*) are occasionally sighted (DOC, 2009; Knill, 2009; Lodi News-Sentinel, 1987; The World, 1987). Tauranga moana kaumatua and kuia report sightings of seals at Katikati and the Waimpu River, sea lions at Tuapiro and walruses at the Waimpu River (Tata and Ellis, 2006). More than 30 cetacean species have been observed around the waters of Bay of Plenty and at least eight species have been observed within Tauranga Harbour (DOC, 2010a; DOC, 2010b). Detailed information regarding the frequency and seasonality of those cetaceans that may visit the harbour is not available. The current knowledge for a few of the more commonly sighted species is summarised below relative to their New Zealand status in order to place the Tauranga situation in context.

The common dolphin (*Delphinus delphis*), found around much of the New Zealand coastline, is often sighted within Tauranga Harbour. These dolphins are well known on the eastern side of the North Island, in the Bay of Islands (Constantine and Baker, 1997), Hauraki Gulf

(Stockin et al., 2008a) and Bay of Plenty (Neumann et al., 2002), but are also regularly sighted as far south as Kaikoura (Wursig et al., 1997). Common dolphins are often sighted in large schools of 200-400 individuals (Neumann and Orams, 2005) but reported as large as 1000 (DOC, unpublished data) in the waters of Bay of Plenty. Despite their commonality, very little is known about their population size or regular movement patterns (Dawson, 1985). They are an active species known to have a more pelagic distribution and an affinity for following warm water currents, such as the subtropical East Cape Current and thermoclines. Common dolphins are considered *not threatened* in New Zealand (Baker et al., 2010) but are known to be affected by tourism, fisheries bycatch and pollutants (Du Fresne et al., 2007; Stockin and Orams, 2009; Stockin et al., 2008b). Stranding data from the DOC database show that individual common dolphins occasionally strand within Tauranga Harbour.

Bottlenose dolphins (*Tursiops truncatus)* are also known to visit Bay of Plenty waters. In New Zealand this species inhabits the coastal waters of Northland, the Marlborough Sounds and Fiordland, with occasional sightings of animals around most other regions (Baker et al., 2010; Tezanos-Pinto et al., 2008). These three distinct regional populations show evidence of high genetic differentiation between them with very low rates of estimated migration. The Northland population is primarily found between Doubtless Bay (on the east coast of Northland) and the Coromandel Peninsula, including the Bay of Islands, but occasionally ranges from Tauranga to Manukau (Baker et al., 2010). While bottlenose dolphin populations overseas are considered to be relatively stable, this species is listed as *nationally endangered* in New Zealand due to the small region and total abundance, and evidence of local decline in two populations (Baker et al., 2010). Bottlenose dolphin populations in New Zealand are exposed to a growing eco-tourism industry throughout their range (Constantine et al., 2003) in addition to being occasionally reported as bycatch in the New Zealand trawl fishery (Du Fresne et al., 2007).

Another species that regularly visits Tauranga Harbour is the killer whale, or orca (*Orcinus orca*) (DOC unpublished information). A study by Visser (2000) suggested that the New Zealand orca population is probably comprised of three sub-populations: a North Island population, a South Island population and a population that travels between the two islands. The earliest record of orca visits to Tauranga Harbour was in 1915, where three individuals entered Tauranga Harbour and were driven ashore and killed by local whalers (Visser, 2000). More recently the Bay of Plenty Times reported observations of four orcas in the harbour (Irvine, 2010) and Tauranga moana kaumatua and kuia reported orca sightings at Katikati, Tuapiro and Tuhua (Tata and Ellis, 2006). Despite the general lack of harbour sightings, the east coast of the North Island appears to be an important region for both the North Island and the North-South Island sub-populations (Visser, 2000). They appear to be more frequent in these waters during winter and spring months and are usually found further offshore (~10-80 nautical miles) over winter months (Clement, 2010). Bay of Plenty waters may represent an important feeding habitat for these animals based on opportunistic sightings (Clement, 2010). This species is listed as one of New Zealand’s *nationally critical* marine mammal species, due to an extremely low population estimate of less than 200 animals (Clement 2010).

Other cetacean species recorded in and around Tauranga Harbour include blue whale (*Balaenoptera musculus*), sei whale (*Balaenoptera borealis*), minke whale (*Balaenoptera acutorostrata*), long-finned pilot whale (*Globicephala melaena*), southern bottlenose whale (*Hyperoodon planifrons*), pygmy sperm whale (*Kogia breviceps*), Gray's beaked whale (*Mesoplodon grayi*), Cuvier's beaked whale (*Ziphius cavirostris*) and rough-toothed dolphin (*Steno bredanensis*) (DOC, 2010a; DOC, 2010b). Tauranga moana kaumatua and kuia have reported observations of dolphins at Waipu, Maungatapu, Rereatukahia, Katikati, Tuapiro and Motiti and whale sightings at Rangataua Bay, Maungatpau, Tuhua and Motiti Island (Tata and Ellis, 2006).

4.2.4. Birds

- Birds identified around Tauranga Harbour include 20 endemic species, 28 native species, 8 migrant species and 15 introduced species (2011).
- *Nationally critical* birds that visit the harbour include black stilt, grey duck and white heron (2008).
- *Nationally endangered* birds that visit the harbour include bittern and black-billed gull (2008).
- *Nationally vulnerable* birds that visit the harbour include banded dotterel, caspian tern, New Zealand dabchick, pied shag, reef heron, wrybill, northern New Zealand dotterel and red-billed gull (2008).
- Tauranga Harbour is recognized as a wetland of international significance for the protection of migratory and indigenous wetland bird species (2003).
- Increasing coastal pressure can be detrimental to bird species that use the harbour (2006).
- Tauranga Harbour has the highest number of shorebirds in the Bay of Plenty region (2006).
- Wading bird species show mixed population trends over 1984-2010 (2010).
- During summer Matakana Island hosts the largest breeding population of northern New Zealand dotterel in the country and a large post-breeding flock of this species during the winter (2006).
- Mount Maunganui hosts one of the few remaining mainland colonies of both grey-faced petrel and blue penguin (2011).
- There was a significant increase in Canada geese over 2001-2010 (2010).

The wider Tauranga catchment is home to many birds (see Shaw et al. 2010 for a summary of historic and current avifauna in the area) but this summary focuses only on birds that use Tauranga Harbour. A number of bird surveys have been carried out around Tauranga Harbour (Beadel et al., 2003b; Ellis et al., 2008; Greenway et al., 2006; OSNZ, 2010; Owen et al., 2006). Of the bird species recorded, 20 are endemic (species that occur only in New Zealand), 28 are native (species that naturally occur in New Zealand but are also found in other countries), 8 are migrant (regular bisitors but do not breed in New Zealand) and 15 are introduced (species that are not naturally found in New Zealand and have been introduced by humans) (Appendix 3).

Nationally critical birds that visit the area include the black stilt, one of New Zealand's rarest shorebirds; the grey duck, which has experienced a greater than 70% population decline over three generations; and the white heron, for which predation and changes in land use are suggested to be the main causes for its nationwide deterioration in conservation status (Hitchmough et al., 2007; Miskelly et al., 2008) (Table 18). Other threatened birds that visit Tauranga Harbour include the Australasian bittern and the black-billed gull (both *nationally endangered*) and eight species of *nationally vulnerable* birds. Changes in ocean productivity, possibly linked to global warming, have been suggested to be the main cause for the red-billed gull's drop in status from *gradual decline* to *nationally vulnerable* (Miskelly et al., 2008).

A field survey, conducted on the Waikaraka Estuary Restoration Area (within Tauranga Harbour), identified 30 bird species of which 19 were indigenous (Beadel et al., 2003b). The *nationally vulnerable* red-billed gull was abundant, as was the New Zealand kingfisher (*Todiramphus sanctus vagans*), white-faced heron (*Ardea novaehollandiae*), and black-backed gull (*Larus dominicanus)*, while pied oystercatcher (*Haematopus finschi*, NZ conservation status *declining*), pied stilt (*Himantopus himantopus leucocephalus*, NZ conservation status *declining*) and tui (*Prosthemadera novaeseelandiae novaeseelandiae)* were less common (Beadel et al., 2003b). The only other threatened species (as per Hitchmough 2002) recorded during the survey were the North Island fernbird (*Bowdleria punctata vealeae*; 2008 conservation status *declining*), white-fronted tern (*Sterna striata striata*; 2008 conservation status *declining*) and grey duck (2008 conservation status *nationally critical*).

Tauranga Harbour meets the criteria of the Ramsar convention (Convention on Wetlands of International Importance, especially as Waterfowl Habitat) as being a wetland of international significance for the protection of migratory and indigenous wetland bird species (Beadel et al., 2003a). However, no application has yet been submitted to the Department of Conservation seeking listing and ultimate ratification by the RAMSAR Bureau of this status (Owen pers. comm.). Nevertheless, this internationally important site recognition is based on the criteria that the area regularly supports one percent or more of the population of a species or subspecies of shorebird (Owen et al., 2006). The species meeting this criteria in Tauranga Harbour include: bar-tailed godwit (*Limosa lapponica baueri;* 5% summer population), black stilt (4 to 6% winter population), northern New Zealand dotterel (2.6% summer and 1.4% winter), turnstone (*Arenaria interpres;* 2.5% summer), banded dotterel (1.7% winter), wrybill (1.7% winter), variable oystercatcher (*H. unicolour;* 2.2% summer and 1.7% winter) and pied stilt (1.5% winter) (Owen et al., 2006).

Over the last three decades increased leisure time has led to increasingly widespread recreational pressure on New Zealand's coasts and estuaries (Owen et al., 2006). These pressures, along with ever-increasing coastal development, are of major concern for safeguarding nationally and internationally important breeding, migrant and wintering shorebirds which depend upon these places as a habitat (Owen et al., 2006).

Table 18. Conservation status of threatened birds (Miskelly et al., 2008) around Tauranga Harbour. Common, Māori and scientific names. Photos top to bottom: black stilt, black-billed gull, Caspian tern, wrybill.

Nationally Critical		
Black stilt	Kaki	*Himantopus novaezelandiae*
Grey duck	Parera	*Anas superciliosa superciliosa*
White heron	Kotuku	*Ardea modesta*
Nationally Endangered		
Australasian bittern	Matuku	*Botaurus poiciloptilus*
Black-billed gull	Tarapunga	*Larus bulleri*
Nationally Vulnerable		
Banded dotterel	Tuturiwhata	*Charadruis bicinctus bicinctus*
Caspian tern	Taranui	*Hydroprogne caspia*
New Zealand dabchick	Weweia	*Poliocephalus rufopectus*
Pied shag	Karuhiruhi	*Phalacrocorax varius*
Reef heron	Matuku moana	*Egretta sacra sacra*
Wrybill	Ngutuparore	*Anarhynchus frontalis*
Northern New Zealand dotterel	Tuturiwhata	*Charadrius obscurus aquilonius*
Red-billed gull	Tarapunga	*Larus novaehollandiae scopulinus*

For example, wading birds forage over inter-tidal flats and harbours, estuaries and soft sediment beaches at low tide. At high tide – when their feeding grounds are covered by water (up to six hours, twice daily) – they gather in flocks at specific sites called ‘high tide roosts’ (Owen et al., 2006). Wading birds need the option of several high tide roosts to minimize the effects of adverse weather conditions, wind direction, timing, height of tide, overlap of habitat with non-breeding migratory birds and human and other animal disturbances (Owen et al., 2006). An increase in coastal development can result in reduction in size or complete loss of a high tide roosting site. When this happens, these birds will still attempt to use such sites, often to their detriment (Owen et al., 2006). The Sulphur Point reclamation site for port development was the principal roost site for most shorebirds on the southern half of Tauranga Harbour (Owen et al., 2006). There are currently 25 known roosting sites in Tauranga Harbour (Owen et al., 2006).

Owen et al. (Owen, 1993) surveyed marshland bird habitats and populations within Tauranga Harbour (140 sites). The birds surveyed rely heavily on marshes for their habitat requirements and included the Australasian bittern, banded rail, spotless crake (*Porzana tabuensis plumbea*), marsh crake (*P. pusilla affinis*) and North Island fernbird (Owen, 1993). Thirty-three bird species were recorded (5 endemic, 15 native, 7 migrant and 6 introduced) and the survey showed that Tauranga Harbour is nationally significant for Australasian bittern, North Island fernbird and banded rail and important for Australasian harrier (*Circus approximans*), New Zealand kingfisher and pukeko (*Porphyrio melanotus*). Reclamation (infilling), drainage, rubbish dumping, livestock grazing, residential or recreational activities, establishment of public utilities and adventives plants were considered to be the greatest threats to the future welfare of these marshland bird habitats (Owen, 1993). Owen recommended biannual monitoring on a harbour-wide scale and a follow-up survey in 2003, however, this has not occurred (Owen pers. comm.).

The Ornithological Society of New Zealand (OSNZ) has been counting wading bird species around Tauranga Harbour biannually since 1984. Of the eleven wading bird species studied, four showed an increasing population trend, five showed a decreasing trend, pied stilt showed a mixed trend and Pacific golden plover (*Pluvialis fulva*) numbers were too small to show a trend (Table 19) (Owen et al., 2006). During summer, Matakana Island (barrier island in Tauranga Harbour) hosts the largest breeding population in the country of the nationally vulnerable northern New Zealand dotterel and a large post-breeding flock of this species during the winter (Owen et al., 2006). Dotterel numbers have increased significantly over the period 1984-2003, thought to be attributable to a protection programme in place on Matakana Island (Owen et al., 2006). Numbers have decreased at all other monitored sites in the Bay of Plenty, but there were too few birds to analyse statistically (Owen et al., 2006).

Mount Maunganui, at the Tauranga entrance to the harbour, hosts one of the few remaining mainland colonies of grey-faced petrel (*Pterodoma macroptera gouldi*). Research that began in 1990 indicates that the Mount Maunganui petrel population is stable (Goodchild, 2001), although introduced predators such as rats and mustelids still pose a significant threat (Vaughton, 2001), heightened by the petrel's very low rate of intrinsic population growth (maximum of one chick per pair per year) (Miskelly et al., 2009). Chick survival rates pre and post pest control have been calculated at 20% and 70% respectively (Vaughton, 2001).

Mount Maunganui is also home to a colony of blue penguins (*Eudyptula minor*) with a relatively large population size (Jervis and Davies, 2001). A 2000-2001 mark-recapture study of 106 penguins yielded a recapture rate of just under 30% (Jervis and Davies, 2001). Jervis and Davies (2000) reported there were no indications that the Mount Maunganui population were suffering from predation (at the time), although rats, a cat and a mustelid were observed in the study area.

Fish and Game New Zealand reports on population trends for black swan (*Cygnus atratus*), Canada geese (*Branta canadensis*) and paradise shelduck (*Tadorna variegata*) (Eastern Region Fish and Game Council, 2010). Over a wide area that encompasses part of the South Waikato District as well as all of the Bay of Plenty (Fish and Game New Zealand, 2011), there was a significant increase in Canada geese for the period 2001-2010, and an insignificant decline of paradise shelduck and black swan (Eastern Region Fish and Game Council, 2010).

Table 19. Population trends (1984-2010) of eleven wading bird species in Tauranga Harbour.

Species	**Population Trend 1984-2010 for Tauranga Harbour**	**Additional Comments**
South Island pied oystercatcher  *Haematopus ostralegus finschi*	Significant **increasing** trend for both summer and winter counts	Tauranga Harbour is one of four key habitats in the Bay of Plenty.
Variable oystercatcher  *Haematopus unicolor*	General **increasing** trend for the whole harbour, but a **decreasing** trend for the winter population at the Sulphur Point roost. Significant **increasing** trend for the Matakana Island population.	Total (world) population is 4,000 (as of 1999). Protection programme operating on Matakana Island.
Pied stilt  *Himantopus himantopus leucocephalus*	General **decrease** for winter population 1984-2001, but an **increase** 2006-2010; too few bids to analyse for summer population.	New Zealand population ~30,000 (as of 1996). General **decrease** Bay of Plenty wide over study period, especially the winter populations.
Northern New Zealand dotterel  *Charadrius obscurus aquilonius*	Overall **increase**, but a **decrease** for both summer and winter populations at both the Panepane Point roost (due to coastal erosion and human disturbances) and Sulphur Point roost (due to port development).	*Nationally vulnerable* species; total population 1,700 as of 2004. Protection programme on Matakana Island. Significant **decrease** at all other Bay of Plenty sites studied.
Banded dotterel  *Charadruis bicinctus bicinctus*	**Decrease** across the harbour for both summer and winter counts, significantly so at Sulphur Point. Tauranga Airport has become an important winter feeding area for birds displaced from Sulphur Point. This is a concern because the Tauranga Airport Authority has had to 'control' the numbers of some shore birds to maintain public safety and safe aircraft movements.	*Nationally vulnerable* species. National total of 50,000 as of 1996; numbers have **declined** substantially over the past 25 years. Tauranga Harbour is a notable winter flocking site.

Wrybill  *Anarhynchus frontalis*	Summer counts too few to analyse, winter counts show a significant **decrease** 1984-2001 for the harbour as a whole, and also at the Sulphur Point roost. However, numbers recorded post 2006 have been higher than previous counts.	*Nationally vulnerable* species. National population 4,100 as at 2005.
Pacific golden plover  *Pluvialis fulva*	No winter birds; too few birds in summer to analyse. Possible that their main roost(s) is/are yet to be found.	Arctic migrant; summers throughout NZ. Bay of Plenty wide, numbers generally remain static over the summer counts.
Spur-winged plover  *Vanellus miles novaehollandiae*	Too few birds to analyse; but there has been a general **increase** in numbers.	Self-introduced from Australia in 1930s. Bay of Plenty wide has an overall significant **increase** in numbers
Turnstone  *Arenaria interpres*	Winter population too small to analyse. Summer populations have a significant **decrease** over time.	Migratory bird. NZ population between 5,000 and 7,000. Bay of Plenty wide there is also a significant **decline** in summer counts.
Knot  *Calidris canutus rogersi*	No winter birds. Summer counts were too few to analyse, but numbers have **declined** from 1984-2003.	Migrant from Siberia. Each year between 51,000 and 67,400 come to NZ.
Bar-tailed godwit  *Limosa lapponica baueri*	Winter counts too few to analyse. Summer population trends show a significant overall **decrease** 1984-2003.	An estimated 102,000 birds migrate to NZ annually. Travel 11,000 km in seven days. Tauranga Harbour hosts the largest summer population of godwit in the region.

Source: (OSNZ, 2010; Owen et al., 2006)

4.3. Invasive species

- A Port of Tauranga survey found twelve non-native marine species including three that were new to New Zealand (2002).
- Nine of the twelve non-native species recorded are likely to have been introduced via hull fouling, and the other three could have been introduced via either ballast water or hull fouling (2002).
- Four noteworthy non-native species found in Tauranga Harbour are the Asian date mussel (*Musculista senhousia*), the sea squirt *Didemnum vexillum*, Asian kelp (*Undaria pinnatifida*) and a dinoflagellate (*Alexandrium tamarense*) (2002).
- The sea squirt *Styela clava* is well established in the Hauraki Gulf and is a potential threat to Tauranga Harbour because of the amount of vessel traffic between the two areas.
- The Port of Tauranga does not have substantial numbers of invasive species, and those that are present have not yet caused significant ecological, social or economic harm (2011).
- The extent of spread beyond the port environment is unknown but there are no indications of invasive species causing significant problems in the wider harbour (2011).

Being home to an active international port, Tauranga Harbour has seen the arrival of a number of non-native species. Some non-native species appear to be relatively benign, in that infestations are localised and do not cause significant adverse impacts, while others are considered "invasive" because they can reach high levels of infestation and have the potential to be detrimental.

The Port of Tauranga was surveyed for non-native species in 2002 and 2005 for MAF Biosecurity New Zealand (Inglis et al., 2006; Inglis et al., 2008). The surveys targeted the Port of Tauranga, because that is the most likely point of introduction to the region. Additional non-native species could be present in other parts of the harbour that were not surveyed.

The 2002 survey found twelve non-native marine species, including three that were new to New Zealand. According to Inglis et al. (2006), nine of the twelve non-native species found in 2002 are likely to have been introduced via hull fouling, and the other three could have been introduced via either ballast water or hull fouling.

The more noteworthy of non-native species that have been found in Tauranga Harbour are described below, along with another species that is present in the Hauraki Gulf.

- **Asian Date Mussel**

The Asian date mussel (*Musculista senhousia*) (Figure 19) has been found in Tauranga Harbour (Environment Bay of Plenty, n.d.). Native to Japan, the mussel is a well-known fouling organism and could be dispersed in ballast water. The mussel forms large mats, which have been known to suppress the growth, richness and abundances of other species in the vicinity of the mats, in comparison to areas of substrate without mats (Creese et al., 1997). A survey of Tauranga Harbour in 2006/07 detected

Figure 19. Asian Date mussel.

mats of Asian date mussel in four locations (Environment Bay of Plenty, n.d.).

- **Didemnum**

  Didemnum vexillum (Figure 20) is a filter-feeding sea squirt, whose colonial growth form can quickly smother marine habitats. Sea squirts have a planktonic (i.e. mobile) larval life stage but then adhere to hard surfaces as adults. *Didemnum vexillum* is considered crypotogenic because it has not been firmly established whether it is native to New Zealand (Coutts and Forrest, 2007). The sea squirt has the potential to out-compete other species and to smother mussels growing on longlines.

Figure 20. *Didemnum vexillum.*

  This sea squirt is established in Tauranga Harbour (Environment Bay of Plenty, n.d.). The barge *Steel Mariner*, which was in Tauranga Harbour in May 1992 and late June 2000, was identified as the most likely vector for the spread of this sea squirt to a bay in the Marlborough Sounds from where it was spread across the top of the South Island (Coutts and Forrest, 2007).

- **Asian Kelp** *Undaria*

  The Asian kelp (*Undaria pinnatifida*) (Figure 21) has been in New Zealand since 1987 and is found in most New Zealand ports. This kelp has the potential to out-compete native species, although it tends to do better in colder climates, e.g. South Island and lower North Island, and its spread outside port environs has been limited (Sinner et al., 2000). It was first found in Tauranga Harbour in 2005 and has been found on shell banks inside the harbour entrance and on man-made structures at the southern end of the port wharves (Environment Bay of Plenty, n.d.).

Figure 21. *Undaria pinnatifida*.

- **Dinoflagellate** *Alexandrium tamarense*

  A survey undertaken in 2005 (reported in Inglis et al., 2008) found the dinoflagellate *Alexandrium tamarense*. This species produces a toxin that can cause paralytic shellfish poisoning and is listed on the Australian Ballast Water Management Advisory Council's schedule of non-indigenous pest species (Inglis et al., 2008).

- **Clubbed tunicate** *Styela clava*

  In terms of potential threats, the clubbed tunicate (*Styela clava*) (Figure 22) is a sea squirt of particular concern. It is a fouling organism with the potential to displace native species and smother aquaculture lines and other structures. *Styela clava* is well established in the Hauraki Gulf (Environment Bay of Plenty, n.d.) and is a potential threat to Tauranga Harbour because of the amount

Figure 22. *Styela clava*.

of vessel traffic between the two areas.

Based on present information, the Port of Tauranga does not have substantial numbers of invasive species, and those that are present have not yet caused significant ecological, social or economic harm. The extent of spread beyond the port environment is unknown, because the surveys have targeted the port environment only, but there are no indications of invasive species causing significant problems in the wider harbour. There is, however, the potential for new species to be introduced from overseas and also within New Zealand via commercial shipping, aquaculture equipment and recreational vessels.

5. Conclusions and research recommendations

5.1. The health of Tauranga Harbour

Based on the limited recent scientific evidence describing the overall condition of the harbour, the indications are mixed. Time series data is available only since the early 1990s and does not reveal any significant trends for nutrients and benthic communities.

Changes in the extent of seagrass beds in the harbour, however, are of particular concern. Seagrass, which covered 22% of the harbour area in 1959, had declined significantly by 1996, by which time it covered only 14%. The area of inter-tidal beds declined by 27%, and sub-tidal beds lost 90% of their area during this period; their fate since then is unknown (see section 4.1.3). Seagrass beds enhance food production and nutrient cycling, stabilize sediment, protect the coast from erosion and support a number of animals and plants. They also provide a nursery habitat for juvenile fish.

Such a significant reduction in seagrass is a cause for serious concern. Sedimentation and nutrient loading have been implicated as the main factors in Tauranga Harbour. More research is needed to confirm this, especially as there are predictions of increasing sediment loads in the coming decades due to climate change.

Sedimentation rates in Tauranga Harbour are reported to be relatively low compared to other North Island estuaries but sedimentation has nonetheless been linked to expansion of mangroves, as well as seagrass decline, and is almost certainly causing other changes to harbour ecology. Changes to fish and shellfish abundance have been noted anecdotally but there is no time series data with which to assess the extent of change.

In summarising the current knowledge about the ecological health of Tauranga Harbour from a western science perspective, a number of information gaps have become apparent. While studies have been conducted on a wide range of topics, understanding of the overall processes that drive the estuarine ecosystem is far from complete. In the remainder of this report we describe key scientific gaps and priorities for future research.

5.2. Broad scale survey

The spatial scale over which information has been collected varies greatly from one study to the next, reflecting the diverse purposes for which specific studies were undertaken. For example, sediment loading into the Tauranga Harbour has been determined from both modelling studies and a field sampling programme to record actual sediment grain size at varying sites within the estuary. In order to understand sediment within the overall harbour, that study was conducted over large spatial scales. Conversely, to determine nutrient and pollutant levels within the harbour, sampling has targeted specific sites, such as stormwater drains, to assess heavy metals. Thus, the regional council's nutrient monitoring programme has limited spatial coverage: 16 streams and 18 estuarine sites aimed at detecting elevated nutrient levels flowing into the estuary via riverine systems.

The spatial scale of sampling of flora and fauna within the harbour also varies greatly. Intensive research has been carried out on the macroalgae communities adjacent to the Port of Tauranga as part of a nation-wide biosecurity monitoring programme. Because of its limited extent, such surveys can only provide an indication of what species might be present elsewhere in the harbour. Macroinvertebrate sampling has been carried out over extensive spatial scales whereby 160 intertidal sites and 16 subtidal sites were sampled across Tauranga Harbour in 1994. While this information is useful, it is dated and the sieve size varied between the intertidal and subtidal sampling programmes. Diversity indices are therefore not comparable between the two data subsets. BOPRC now monitors benthic macrofauna at 17 sites in and around Tauranga Harbour, to assess benthic community health and detect trends over time with respect to the integrity of ecosystems. To summarize, while studies have been conducted on a wide range of topics, studies that assess biodiversity of flora and fauna at the scale of the estuary have not been conducted.

In order to understand the role of various anthropogenic stressors on biodiversity, we recommend conducting a broad scale survey of Tauranga Harbour. This would involve sampling flora and fauna over the larger spatial scale of the estuary and collecting associated sediment samples to quantify sedimentation, nutrients and pollutants at each site. Sampling could be conducted over a range of habitats from intertidal sandflats (a key habitat for shellfish) and mangrove habitats, to subtidal and seagrass areas. Macroinvertebrates would be assessed at each site using benthic core samples and quadratic information would be collected to quantify the presence of flora including macroalgae, seagrasses and sea lettuce.

A broad scale survey would provide more current and detailed information to quantify macroinvertebrate communities, biodiversity and the presence or loss of functional groups such as shellfish species across the harbour. The collection of physical data at the same sites as biological data enables changes in community composition to be linked with changes in key anthropogenic stressors such as sediments, nutrients and pollutants. Specifically the environmental variables can be used in a model to find the combination that ‘best explains’ the patterns in the macrofaunal community composition. Analyses can also be performed that identify the key environmental variables that best explain macrofaunal variance.

Hence the data can then be used to give an improved understanding of the current health of the estuary, identify key anthropogenic stressors that effect biological communities and provide baseline information for ongoing monitoring programmes. This information could then also be used by iwi and researchers to prioritise research questions for further study.

Based on what is currently known, we outline below some possible case studies for future research, focusing on shellfish and seagrass.

5.3. Possible research on shellfish populations

Tauranga Harbour has extensive intertidal and shallow subtidal areas supporting a diverse array of macroinvertebrates and shellfish beds. The harbour has been described as having exceptionally high ecological value; it is productive and rich in species and habitat of importance to the ecology of the greater region (Bioresearchers Ltd, 1976a; Bioresearchers Ltd, 1976b) with large productive beds of shellfish throughout the harbour (Park and Donald, 1994).

Extensive shellfish beds (e.g. mussel, horse mussel, scallop) are important as they can add complex physical structure to soft sediment habitats (Cummings et al., 2001) and provide predation refuges (Woodin, 1978) and substrate for settlement of epifauna (Cummings et al., 1998). Shellfish have been identified as particularly sensitive to suspended sediments (Norkko et al., 2006) and the loss of key suspension feeding bivalves can occur in estuaries experiencing high rates of sedimentation (Ellis et al., 2002), with the potential for larger-scale functional and structural impacts on benthic and estuary ecosystems. Some shellfish beds have been depleted by overharvesting (Bioresearchers 1976a).

Because of the cultural and ecological importance of shellfish, the sensitivity of these species to suspended sediments, and the disappearance of shellfish beds seen in previous surveys, we recommend shellfish as an area for further research. Determining current extent of shellfish beds and identifying the factors that affect intertidal and subtidal species distribution are primary research questions. A broad scale survey would provide current information on species distribution within the harbour, size distribution and species habitat preferences as well as information on physical variables including sedimentation, contamination and nutrients. Ordination analyses and other techniques can then be used to link shellfish populations with key anthropogenic stressors. Identification of the primary stressors on shellfish populations provides necessary information to manage associated catchment activities.

Other topics could be investigated based on the broad scale survey data, supplemented by further field experiments. These include:

1. The link between shellfish condition (measured by glycogen levels) and levels of sedimentation and contaminants within the harbour.
2. The processes that influence population dynamics such as settlement processes and larval recruitment and how these are effected by heavy metal contamination (settlement occurs in the upper reaches of the estuary where contaminant loadings are highest).
3. Whether existing levels of sedimentation or pollution limit the distribution of shellfish beds (as determined from transplant experiments) in Tauranga Harbour.
4. How the loss of shellfish beds affects the ecological functioning of benthic communities (e.g. nutrient fluxes, biodiversity, sediment stability).
5. Cumulative impacts and likely consequences of potential increases in sedimentation due to climate change.

5.4. Possible research on seagrass

The seagrass beds of Tauranga Harbour have been described as more extensive than in any other New Zealand harbour (Barker and Larcombe, 1976) and were identified as one of nine ‘hotspots’ for seagrass distribution in New Zealand (MFish, 2006). Seagrass meadows provide a number of ecosystem functions including enhancing primary production and nutrient cycling, stabilizing sediment, protecting the coast from erosion and supporting high diversity plant and animal communities e.g. by providing refuge from predators (Alfaro, 2006; Morrison et al., 2007). Seagrass beds within the harbour have already declined substantially, including a 90% decrease in subtidal areas. While sedimentation and nutrient loading have been implicated as the main factors (Park, 1999a; Park, 1999b), determining the relative impacts of various stressors on seagrass decline requires further research.

Due to the importance of seagrass habitats there are many outstanding research questions. These include:

1. Identification of the factors driving seagrass decline, and whether these are the same in subtidal and intertidal areas.
2. Assessing the role of seagrass beds in sustaining coastal fisheries.
3. Assessing how changes in subtidal and intertidal seagrass beds impact benthic communities and biodiversity.
4. Determining whether fragmentation of these beds effects their functioning.

These questions highlight current gaps in our understanding of seagrass communities and would benefit from further research. Identifying the factors that have the greatest effects on seagrass is a high priority for research. Using data from the broad scale survey, ordination analysis and species distribution modelling would provide insights into this question. It could be further addressed by field experiments across a range of seagrass habitats that are exposed to varying levels of nutrients and sediments. This should also include a selection of sites at Tuapiro estuary where there is evidence of seagrass beds expanding.

In order to assess cumulative impacts on seagrass communities, other sources of human and natural impacts besides sedimentation and nutrients need to be considered. Human impacts include mechanical damage (*e.g.* dredging, fishing, anchor damage), introduced species, the effects of coastal constructions and food web alterations, and negative effects of climate change. Natural impacts include storm damage, disease, grazing by herbivores and natural climatic variation. Further research on the stressors of seagrass, including sediment and grazing by black swans, is currently being funded by BOPRC and results are expected in 2011. As information becomes available from these studies, it can be used to develop models that assess cumulative impacts on seagrass beds of small and large scale environmental changes.

5.5. Possible research on mangrove ecosystems

In New Zealand mangroves are spreading in response to increased sediment loads into estuaries and harbours. Within Tauranga Harbour, mangroves have expanded from 240 ha in 1943 to 623 ha in 2003 (S. Park, pers. comm.) with a high percentage of expansion occurring in the last 20 to 40 years (Stokes et al., 2009). The rate of expansion has led some communities to consider them to be a nuisance and BOPRC has approved coastal permits to allow removal of mangroves in certain areas of Tauranga Harbour. However there are a number of significant data gaps on both the ecological importance of mangrove habitats and the effects of their removal. Specifically, outstanding research questions include:

1. What are the ecological consequences of the spread of mangroves into intertidal sandflats?
2. What are the functional roles of mangroves in estuaries that are not heavily impacted by sediments and how have these been modified by high rates of sediments and nutrients?
3. How does the removal of mangroves impact intertidal mudflats and adjacent sandflats? (Some work on this topic is currently being done by NIWA.)
4. What are the most effective catchment management initiatives to control sediment and nutrient loadings into estuaries?

These are complex questions and possibly beyond what can be achieved in the present research project, but it might be possible to investigate some of these questions in collaboration with other researchers.

5.6. Summary

To summarize, the spatial scale over which information has been collected varies greatly from one study to the next. Hence, while studies have been conducted on a wide range of topics, information on biodiversity of flora and fauna does not exist at harbour scale. Studies that link changes in biodiversity with varying stressors such as sediment, nutrients and pollutants have not been conducted within Tauranga Harbour, although some inferences can be drawn from research in other estuaries.

In order to generate a more comprehensive understanding of the role of varying anthropogenic stressors on biodiversity in Tauranga Harbour, we recommend starting with a broad scale survey and then using the resulting information to investigate the factors affecting populations of key species such as seagrass, mangroves and shellfish. This information could then be used by iwi and researchers to prioritise further research questions. Shellfish, seagrass beds and mangrove habitats have been identified for further research due to their cultural and ecological importance and due to documented impacts on these ecosystem components.

A number of other data gaps have also been identified. Sedimentation modeling has only been carried out in the Southern Basin. Regarding contaminants, further research may be required to develop strategies to reduce high levels of heavy metals in the upper estuary. This could also include consideration of the development of an estuary monitoring protocol. Sea lettuce blooms have become a significant source of concern, and identifying the primary factors controlling blooms including sources of nutrients is an important research area. The Intercoast research programme is currently conducting research on estuary-shelf nutrient exchange effects on interannual patterns in sea lettuce dynamics and on the effects of decomposing algal mats on benthic community structure and function. There is also limited information on the importance of seaweeds as primary producers in the harbour and limited information specific to phytoplankton including growth, mortality, dominance, succession or competition between zooplankton and shellfish for phytoplankton.

Little is known about the diet of fish in Tauranga Harbour. This information would be needed to understand the importance of specific habitats or species assemblages to higher tropic levels and the importance of the harbour as a nursery habitat for fisheries. There is also currently limited information to assess abundance estimates of dolphins and whales that use the harbour and, therefore, the extent of top down predation on food webs.

6. ACKNOWLEDGEMENTS

Many people have assisted in the preparation of this report. In addition to those listed as authors, Carlton Bidois and Tracey Ngatoko mentored and supported young research assistants based at Waka Taiao, while Aaron McCallion, Kelley Solomon and their team at Waka Digital provided an online data repository for keeping track of the many documents reviewed in compiling the information now summarised in this report.

Rob Donald and Stephen Park of BOPRC responded to numerous requests for published reports and data. The Port of Tauranga also provided reports.

We are especially grateful to Dr Chris Battershill of the University of Waikato, Lisette Collins of Wildland Consultants, Kate Akers of NZ Landcare Trust, and Stephen Park of BOPRC, each of whom reviewed a draft of this report and provided detailed comments. Thank you to Keith Owen for providing comments on the bird section of the report.

The following generougly granted permission to use previously published material:

- Waikato Regional Council and Wildland Consultants Ltd, the map of Tauranga Harbour sub-catchments and LUC (Figure 2)
- Roger Briggs, University of Waikato, the geological map of Tauranga and the southern Kaimai Range (Figure 3)
- Wildland Consultants Ltd, the map of land cover in the Tauranga District in 1840 and 2000 (Figure 5).

Noel Peterson provided a number of photographic images used in this report.

Funding for this report has been provided by the Ministry of Science and Innovation through the Manaaki Taha Moana research programme led by Massey University.

Any remaining errors and omissions remain the responsibility of the authors.

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8. APPENDICES

8.1. Appendix 1: Agencies with management functions relevant to Tauranga Harbour

Three local authorities and several central government agencies have important management functions and responsibilities that pertain to the health of Tauranga Harbour. Other agencies and entities play supporting roles. All have a responsibility to work with tangata whenua to protect Tauranga moana, an important taonga for local iwi and hapū.

8.1.1. Bay of Plenty Regional Council

Of the agencies with management responsibilities for Tauranga Harbour, the Bay of Plenty Regional Council (BOPRC) has the most wide-ranging role in promoting sustainable management. BOPRC has thirteen elected councillors of which three are elected from Māori constituencies.

Under the Resource Management Act 1991 (RMA), BOPRC has the function of setting, implementing and reviewing objectives, policies and methods to achieve integrated management of the natural and physical resources of the region. Regional councils commonly give effect to these responsibilities through their regional policy statements and regional plans, as well as through plans and activities specified in their long term council community plans and annual plans.

BOPRC's role includes the specific functions of controlling land for the purpose of the maintenance and enhancement of water quality and ecosystems in coastal waters and, within the coastal marine area, controlling any actual or potential effects of land use or development (see Box 1). BOPRC is also responsible for controlling all discharges to land, air and water within the region, including from stormwater systems operated by city and district councils.

BOPRC's regional policy statement became operative in 1999 and a new version is now being prepared. The Proposed Regional Policy Statement 2010 was open for submissions until February 2011. Once these are summarized and published, further submissions will be invited and hearings held. Decisions on submissions are expected in late 2011 or early 2012[3]. The Regional Coastal Environmental Plan, approved in 2003, provides more detailed guidance on the activities and effects that are allowed in Tauranga Harbour[4]. Some changes may follow the release of a new National Coastal Policy Statement, which came into force on 3 December 2010. Other relevant regional plans include the Proposed Regional Water and Land Plan, Regional Land Management Plan and the Onsite Effluent Treatment Regional Plan[5].

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[3] http://www.boprc.govt.nz/knowledge-centre/policies/the-next-regional-policy-statement.aspx
[4] http://www.boprc.govt.nz/knowledge-centre/plans/regional-coastal-environment-plan.aspx
[5] Copies are available at http://www.boprc.govt.nz/knowledge-centre.aspx (accessed 30 June 2011).

Box 1. RMA Functions of Bay of Plenty Regional Council

Under the Resource Management Act 1991 (section 30), Bay of Plenty Regional Council has the following functions (emphasis added to highlight functions with particular relevance to Tauranga Harbour):

(a) ***the establishment, implementation, and review of objectives, policies, and methods to achieve integrated management of the natural and physical resources of the region***:
(b) the preparation of objectives and policies in relation to any actual or potential effects of the use, development, or protection of land which are of regional significance:
(c) ***the control of the use of land*** for the purpose of—
(i) soil conservation:
(ii) ***the maintenance and enhancement of the quality of water in water bodies and coastal water***:
(iii) the maintenance of the quantity of water in water bodies and coastal water:
(iiia) ***the maintenance and enhancement of ecosystems in water bodies and coastal water***:
(iv) the avoidance or mitigation of natural hazards:
(v) the prevention or mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances:
(ca) the investigation of land for the purposes of identifying and monitoring contaminated land:
(d) ***in respect of any coastal marine area*** in the region, ***the control (in conjunction with the Minister of Conservation) of***—
(i) ***land and associated natural and physical resources***:
(ii) the occupation of space on land of the Crown or land vested in the regional council, that is foreshore or seabed, and the extraction of sand, shingle, shell, or other natural material from that land:
(iii) the taking, use, damming, and diversion of water:
(iv) ***discharges of contaminants into or onto land, air, or water and discharges of water into water***:
(iva) ***the dumping and incineration of waste or other matter and the dumping of ships, aircraft, and offshore installations***:
(v) ***any actual or potential effects of the use, development, or protection of land***, including the avoidance or mitigation of natural hazards and the prevention or mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances:
(vi) the emission of noise and the mitigation of the effects of noise:
(vii) activities in relation to the surface of water:
(e) the control of the taking, use, damming, and diversion of water, and the control of the quantity, level, and flow of water in any water body, including—
(i) the setting of any maximum or minimum levels or flows of water:
(ii) the control of the range, or rate of change, of levels or flows of water:
(iii) the control of the taking or use of geothermal energy:
(f) ***the control of discharges of contaminants into or onto land, air, or water and discharges of water into water***:
(fa) if appropriate, the establishment of rules in a regional plan to allocate any of the following:
(i) the taking or use of water (other than open coastal water):
(ii) the taking or use of heat or energy from water (other than open coastal water):
(iii) the taking or use of heat or energy from the material surrounding geothermal water:

(iv) the capacity of air or water to assimilate a discharge of a contaminant:
(fb) if appropriate, and in conjunction with the Minister of Conservation,—
(i) the establishment of rules in a regional coastal plan to allocate the taking or use of heat or energy from open coastal water:
(ii) the establishment of a rule in a regional coastal plan to allocate space in a coastal marine area under Part 7A:
(g) in relation to any bed of a water body, the control of the introduction or planting of any plant in, on, or under that land, for the purpose of—
(i) soil conservation:
(ii) the maintenance and enhancement of the quality of water in that water body:
(iii) the maintenance of the quantity of water in that water body:
(iv) the avoidance or mitigation of natural hazards:
(ga) the establishment, implementation, and review of objectives, policies, and methods for maintaining indigenous biological diversity:

Regional councils also have functions related to monitoring and reporting on the state of the environment, and typically issue "state of the environment" reports, sometimes providing a general overview of the entire region, other times focussing on particular resources. BOPRC has taken the latter approach.

Finally, BOPRC has additional functions under other legislation, e.g. for regional transport and civil emergencies, as well as the Local Government Act. Some aspects of resource management, e.g. flood control, are still carried out under the Soil Conservation and Rivers Control Act of 1941. BOPRC also administers some regional functions for Maritime New Zealand (see below).

The regional council has a Tauranga Harbour Integrated Management Strategy (Environment Bay of Plenty, 2006) that identifies sedimentation of Tauranga Harbour as the largest environmental management issue for the western part of the Bay of Plenty. BOPRC subsequently commissioned research by NIWA to identify the sources of this sediment, by catchment. The results of that study are presented in section 3.2 of this report.

8.1.2. Territorial Authorities

As territorial authorities, Tauranga City Council and Western Bay of Plenty District Council have different statutory functions than BOPRC. In particular, they provide key infrastructure services to residents, including water supply, sewerage and stormwater systems, as well as local roads and reserves. Under the RMA 1991, territorial authorities are responsible for "integrated management of the effects of the use, development, or protection of land and associated natural and physical resources of the district". Box 2 provides more detail on the RMA functions of territorial authorities.

Box 2. RMA Functions of territorial authorities (section 31)

(1) Every territorial authority shall have the following functions for the purpose of giving effect to this Act in its district:

(a) the establishment, implementation, and review of objectives, policies, and methods to achieve integrated management of the effects of the use, development, or protection of land and associated natural and physical resources of the district:

(b) the control of any actual or potential effects of the use, development, or protection of land, including for the purpose of—

(i) the avoidance or mitigation of natural hazards; and

(ii) the prevention or mitigation of any adverse effects of the storage, use, disposal, or transportation of hazardous substances; and

(iia) the prevention or mitigation of any adverse effects of the development, subdivision, or use of contaminated land:

(iii) the maintenance of indigenous biological diversity:

(c) [Repealed]

(d) the control of the emission of noise and the mitigation of the effects of noise:

(e) the control of any actual or potential effects of activities in relation to the surface of water in rivers and lakes:

(f) any other functions specified in this Act.

(2) The methods used to carry out any functions under subsection (1) may include the control of subdivision.

Territorial authorities give effect to these functions via their district plans. These plans provide detailed guidance on land use within the district, including which areas may be used for which purpose.

8.1.3. Department of Conservation

Under the RMA 1991, the Minister of Conservation has specific functions in relation to the coastal marine area. In particular, the Minister is responsible for the New Zealand Coastal Policy Statement, a new version of which came into effect on 3 December 2010, and the approval of regional coastal plans prepared by regional councils. The Minister therefore provides the overarching policy and guidance for the sustainable management of New Zealand’s coastal environment. Until a legislative amendment in 2009, the Minister also had the responsibility of deciding applications for coastal permits for activities classified as “restricted coastal activities” under the RMA 1991.

Under the provisions of the Conservation Act 1987 and the Wildlife Act 1953, the Department of Conservation (DOC) has responsibilities related to the protection of seabirds and marine mammals, and also manages whitebait fishing.

Within the catchments of Tauranga Harbour, DOC also manages large areas of land, including the Kaimai-Mamaku Forest Park. Within such areas, DOC is responsible for protecting native biodiversity, pest control, concessions, recreation, historic sites, and fire control, among other duties.

DOC also works with other agencies and local authorities to promote sustainable management of natural resources beyond the conservation estate, in support of its mission to maintain and enhance New Zealand's native biodiversity.

8.1.4. Ministry of Fisheries

The Ministry of Fisheries (MFish) is responsible for managing customary, commercial and recreational fisheries to provide for sustainable utilisation under the Fisheries Act 1996. MFish's main functions under this Act are to set and monitor total allowable catches for fisheries, recreational bag limits, and fishing gear regulations, and to otherwise manage fishing activity. MFish seeks to ensure that fish stocks do not fall below the levels that will produce maximum sustainable yield, and to protect associated and dependent species.

MFish is responsible for management of all marine fishing and for eel fishing in freshwater environments. As noted above, DOC manages whitebait, while Fish and Game New Zealand manages introduced trout and salmon.

The Ministry of Fisheries will merge with the Ministry of Agriculture and Forestry on 1 July 2011, although the two bodies will retain their separate identities until a date yet to be announced.

The Tauranga Moana Customary Fisheries Committee advises the Minister of Fisheries on how best to manage fishing within the local mataitai around Mount Maunganui – see section 4.2.2 of this report.

8.1.5. MAF Biosecurity New Zealand

MAF Biosecurity New Zealand (MAFBNZ) is the division of the Ministry of Agriculture and Forestry (MAF) charged with leadership of New Zealand's biosecurity system, i.e. which seeks to prevent the introduction of non-native species from overseas and manage those that are already established.

MAFBNZ has lead responsibility for border control (e.g. managing discharge of ballast water and arriving vessels with hull fouling), surveillance, and response to new incursions. MAFBNZ works with regional councils and other bodies on pest management for unwanted species that are well established and for which eradication is not deemed to be a viable option.

8.1.6. Maritime New Zealand

The mission of Maritime New Zealand (formerly the Maritime Safety Authority) is to lead and support the maritime community to take responsibility for ensuring New Zealand seas are safe, secure and clean.

Maritime New Zealand has overall responsibility for managing discharges of waste from vessels and for reducing the risk of accidental spills of harmful substances such as oil or chemicals, as well as responding to spills that do occur. BOPRC carries out many of these functions at a regional level.

All vessels (including recreational), gas and oil installations, and ports operating in New Zealand waters must comply with a range of environmental regulations, including rules, conventions and legislation, administered by Maritime New Zealand.

8.1.7. Ministry for the Environment

The Ministry for the Environment (MfE) is the lead agency for implementation of the RMA 1991. In addition to monitoring the performance of regional and territorial authorities under the Act, MfE and its Minister have responsibility for national policy statements and environmental standards (except for the NZ Coastal Policy Statement, which is the responsibility of the Minister of Conservation). Policies and plans developed by local authorities under the RMA must be consistent with and give effect to national policy statements.

A National Policy Statement (NPS) on Freshwater Management has been under development for several years. Following a Board of Inquiry report with recommendations in January 2010 and recommendations from the Land and Water Forum in September 2010, the Minister for the Environment released a final NPS on Freshwater Management in May 2011. Of relevance to Tauranga Harbour, the NPS requires that regional councils make or change regional plans to set freshwater objectives and water quality limits, and to provide for the integrated management of the effects of land use and development, including on the coastal environment. Councils are to implement the NPS "as promptly as is reasonable in the circumstances". Where a council is satisfied this cannot be achieved by the end of 2014, it may do this in stages so that it is completed by 2030.

MfE has several national environmental standards in development at present, including on the following topics[6]:

- ecological flows and water levels in freshwater systems
- contaminants in soil

[6] See http://www.mfe.govt.nz/laws/standards/index.html for more information.

- future sea level rise
- on-site wastewater systems (e.g. septic tanks)
- plantation forestry.

Each of these has potential implications for the health of Tauranga Harbour. Because of the influence of sediment and other contaminants that enter the coastal environment via rivers and streams, the NPS and the national standards on ecological flows and on plantation forestry could have a particularly significant effect on the objectives and policies adopted by local authorities and hence whether the health of the harbour improves or continues to decline.

8.1.8. Fish and Game New Zealand

Fish and Game New Zealand is made up of twelve Regional Fish & Game Councils and one National Council. The National Council coordinates regional activities and speaks for anglers and hunters on issues of national importance. Fish and Game Councils were established under the Conservation Act 1987 as amended by the Conservation Law Reform Act 1990. They have a statutory function to "manage, maintain, and enhance the sports fish and game bird resource in the recreational interests of anglers and hunters" (Section 26P of the Conservation Act). Fish and Game's management of waterfowl is of particular relevance to Tauranga Harbour; key species of interest are grey and mallard duck, shoveler duck, paradise shelduck, pukeko, Canada geese and black swan.

In their role as statutory managers of sports fish and game birds, Fish and Game councils set and monitor bag limits and license fees as well as other regulations. Like DOC, Fish and Game also has an advocacy role, working with central and local government agencies and with other stakeholders to promote the sustainable management of land and water resources that provide or affect habitat for game fish and birds.

Tauranga Harbour is within the Eastern Region of Fish and Game New Zealand, which has its headquarters in Rotorua.

8.2. Appendix 2: Community composition of submerged reef biota off Motuotau Island

The following table details a presence-absence record of species observed at the three Motuotau Island reef sites monitored from 1990-2009 (Ross and Pilditch, 2009). 'X' indicates the species was present at the site. This species list is in no way exhaustive and should not be interpreted as such.

Group	**Common Name**	**Species Name**	**Control Site**	**Site 1**	**Site 2**
Algae	Brown algae	*Carpomitra* sp.			X
	Brown algae	*Carpophyllum flexuosum*		X	
	Brown algae	*Carpophyllum maschalocarpum*	X		X
	Brown algae	*Cystophora*			X
	Brown algae	*Lessonia variegata*		X	X
	Brown algae	*Zonaria angustata*			X
	Brown algae	*Sargassum* sp.			X
	Coralline paint	Corallinales order	X	X	X
	Coralline turf	Corallinales order		X	X
	Kelp	*Ecklonia radiata*	X	X	X
	Red algae	*Ptericladia lucida*	X	X	X
	Red algae	*Rhodymenia* sp.	X	X	X
	Sea lettuce	*Ulva* sp.	X		
Sponges	Boring sponge	*Cliona celata*	X	X	X
	Branching sponge	*Iophon minor*		X	
	Brown football	*Polymastia fusca*	X	X	X
	Crumbly cream			X	X
	Delicate mauve			X	X
	Finger sponge	*Calyspongia ramosa*	X	X	X
	Golfball sponge	*Tethya aurantium*	X	X	X
	Golfball sponge	*Tethya ingalli*	X	X	X
	Massive grey	*Ancorina alata*	X	X	X
	Orange football	*Polymastia granulosa*	X	X	X
	Orange branching	*Raspailia* sp.			X
	Pale grey encrusting				X
	Purple encrusting		X	X	
	Purple/grey sphere		X		
	Small pink sponge			X	
	Tennis ball sponge	*Aaptos aaptos*		X	X
	Yellow fine finger		X	X	X
Molluscs	Beaded top shell	*Calliostoma punctulatum*			X
	Blue/brown nudibranch	Nudibranchia	X	X	
	Brown nudibranch	Nudibranchia	X	X	
	Butterfly chiton	*Cryptoconchus porosus*	X	X	X
	Clown nudibranch	*Ceratosoma amoena*	X	X	X
	Cook's turban	*Cookia sulcata*	X	X	X

Group	Common Name	Species Name	Control Site	Site 1	Site 2
	Gem nudibranch	*Dendrodoris deisoni*	X	X	
	Green mussel	*Perna canaliculus*			X
	Lined whelk	*Buccinulum lineum*	X	X	
	Maori octopus	*Octopus maoruam*	X	X	X
	Noble chiton	*Eudoxochiton nobilis*	X		
	Nudibranch	*Glossodoris atromarginata*			X
	Nudibranch eggs	Nudibranchia		X	X
	Smooth light nudibranch	*Aphlelodoris luctuosa*	X	X	
	Spengler's trumpet	*Cabestana spengleri*			X
	Squid eggs	Teuthida order	X		
	Tiger shell	*Calliostoma tigris*	X	X	X
	White rock shell	*Thais orbita*	X	X	X
Echinoderms	Brittle star	*Pectinura maculata*	X	X	X
	Kina	*Evechinus chloroticus*	X	X	X
	Reef star	*Stichaster australis*	X		
	Sea cucumber	*Stichopus mollis*		X	X
Crustaceans	Barnacles	Cirrpedia	X		
	Crayfish	*Jasus edwardsii*	X	X	X
	Hermit crab	*Pagurus novizealandiae*	X	X	
	Pink barnacle	*Balanus decorus*			X
	Red rock crab	*Guinusia chabrus*	X	X	X
Annelida	Tube worm	*Chaetopterous* sp.	X		X
	Web building terebellid			X	X
Ascidians	Blue sea squirt				
	Brown sea squirt	*Cnemidocarpa* sp.	X		
	Large simple ascidian		X	X	X
	Orange golfball			X	X
	Purple encrusting compound ascidian		X	X	
	Purple mushroom	*Hiptistoza* sp.		X	X
	Sea tulip	*Pyura pachydermatina*	X	X	X
	Small red simple		X	X	X
		Didemnum sp.	X	X	X
		Sigillinaria arenosa		X	X
Coelenterates	Dead man's fingers	*Alcyonium aurantium*		X	X
	White-striped anemone	*Actinothoe albocincta*		X	X
	Cup coral	*Flabellum rubrum*		X	
	Hydroids			X	X
	White zoanthid			X	
	Jewel anemone	*Corynactis hoddoni*		X	
	Mussel beard	*Sertularia* sp.			X

8.3. Appendix 3: Birds of Tauranga Harbour

The following table lists birds that have been recorded as present in or around Tauranga Harbour (Beadel et al., 2003b; Eastern Region Fish and Game Council, 2010; Ellis et al., 2008; Greenway et al., 2006; Heather and Robertson, 2005; Owen, 1993).

Endemic birds occur only in New Zealand and are protected by the Wildlife Act.
Native birds occur naturally in New Zealand, whether through self-introduction or migration. Those listed here also occur overseas, and include migratory shorebirds. Most are fully protected under the Wildlife Act.
Migrant brids are regular visitors but do not breed in New Zealand.
Introduced birds are either deliberately released cage birds or birds brought over with the early settlers from Europe and Asia. They are not protected but some are managed by Fish and Game New Zealand (see Appendix 1).

Conservation status is based on the New Zealand Threat Classification System (Miskelly et al., 2008).

Common Name	Scientific Name	Māori Name	Conservation status
Endemic birds			
Banded dotterel	*Charadrius bibinctus bicinctus*	Tuturiwhata	Nationally vulnerable
Banded rail*	*Rallus philippensis assimilis*	Moho-perehu	Naturally uncommon
Bellbird	*Anthornis melanura melanura*	Korimako	Not threatened
Black-billed gull	*Larus bulleri*	Tarapunga	Nationally endangered
Black stilt	*Himantopus novaezelandiae*	Kaki	Nationally Critical
Marsh crake*	*Porzana pusilla affinis*	Kāreke	Relict
North Island fernbird	*Bowdleria punctata vealeae*	Matata	Declining
Northern New Zealand dotterel	*Charadrius obscurus aquilonius*	Tuturiwhatu	Nationally vulnerable
New Zealand dabchick	*Poliocephalus rufopectus*	Weweia	Nationally vulnerable
New Zealand kingfisher*	*Todiramphus sanctus vagans*	Kotare	Not threatened
New Zealand pigeon	*Hemiphaga novaeseelandiae*	Kereru	Not threatened
New Zealand scaup	*Aythya novaeseelandiae*	Papango	Not threatened
New Zealand shoveler	*Anas rhynchotis variegata*	Kuruwhengi	Not threatened
Paradise shelduck	*Tadorna variegata*	Putangitangi	Not threatened
Red-billed gull*	*Larus novaehollandiae scopulinus*	Tarapunga	Nationally vulnerable

Common Name	Scientific Name	Māori Name	Conservation status
Endemic birds (cont.)			
South Island pied oystercatcher*	*Haematopus ostralegus finschi*	Torea	Declining
Southern black-backed gull*	*Larus dominicanus domincanus*	Karoro	Not threatened
Tui	*Prosthemadera novaeseelandiae novaeseelandiae*	Tui	Not threatened
Variable oystercatcher	*Haematopus unicolor*	Torea pango	Recovering
Wrybrill	*Anarhynchus frontalis*	Ngutuparore	Nationally vulnerable
Native birds			
Australasian bittern	*Botaurus poiciloptilus*	Matuku	Nationally endangered
Australasian gannet	*Morus serrator*	Takapu	Not threatened
Australasian harrier	*Circus approximans*	Kahu	Not threatened
Black shag	*Phalacrocorax carbo novaehollandiae*	Kawau	Naturally uncommon
Blue penguin	*Eudyptula minor*	Korora	Declining
Caspian tern	*Hydroprogne caspia*	Taranui	Nationally vulnerable
Fantail	*Rhipidura fuliginosa*	Piwakawaka	Not threatened
Grey duck	*Anas superciliosa superciliosa*	Parera	Nationally Critical
Grey teal	*Anas gracilis*	Tete	Not threatened
Grey warbler	*Gerygone igata*	Riroriro	Not threatened
Grey-faced petrel	*Pterodoma macroptera gouldi*	Oi	Not threatened
Little black shag	*Phalacrocorax sulcirostris*	Kawaupaka	Naturally uncommon
Little shag	*Phalacrocorax melanoleucos*	Kawaupaka	Naturally uncommon
Morepork	*Ninox novaeseelandiae novaeseelandiae*	Ruru	Not threatened
Pied shag	*Phalacrocorax varius varius*	Karuhiruhi	Nationally vulnerable
Pied stilt	*Himantopus himantopus leucocephalus*	Poaka	Declining
Pukeko	*Porphyrio melanotus*	Pukeko	Not threatened
Reef heron	*Egretta sacra sacra*	Matuku moana	Nationally vulnerable
Royal spoonbill	*Platalea regia*	Kotuku ngutupapa	Naturally uncommon
Shining cuckoo	*Chrysococcyx lucidus lucidus*	Pipiwharauroa	Not threatened
Silvereye	*Zosterops lateralis lateralis*	Tauhou	Not threatened
Spotless crake	*Porzana tabuensis plumbea*	Puweto	Relict
Spur-winged plover	*Vanellus miles novaehollandiae*		Not threatened
Sooty shearwater	*Puffinus griseus*	Titi	Declining
Welcome swallow	*Hirundo tahitica neoxena*	Warou	Not threatened
White heron	*Adrea modesta*	Kotuku	Nationally critical
White-faced heron	*Ardea novaehollandiae*	Matuku	Not threatened
White-fronted tern	*Sterna striata striata*	Tara	Declining

Common Name	Scientific Name	Māori Name	Conservation status
Migrant birds			
Asiatic black-tailed godwit	*Limosa limosa melanuroides*		Vagrant
Knot	*Calidris canutus rogersi*	Huahou	Migrant
Eastern bar-tailed godwit	*Limosa lapponica baueri*	Kuaka	Migrant
Far-eastern curlew	*Numenius madagascariensis*		Migrant
Hudsonian godwit	*Limosa haemastica*		Vagrant
Pacific golden plover	*Pluvialis fulva*		Migrant
Turnstone	*Arenaria interpres*		Migrant
Whimbrel sp.	*Numenius* sp.		Migrant/Vagrant
Introduced birds			
Australian magpie	*Gymnorhina tibicen*		
Black swan	*Cygnus atratus*		
California quail	*Callipepla californica*		
Canada goose	*Branta canadensis*		
Chaffinch	*Fringilla coelebs*		
Common myna	*Acridotheres tristis*		
Common pheasant	*Phasianus colchicus*		
Eurasian blackbird	*Turdus merula*		
European goldfinch	*Carduelis carduelis*		
Greylag goose	*Anser anser*		
House sparrow	*Passer domesticus*		
Mallard	*Anas platyrhynchos*		
Rock pigeon	*Columba livia*		
Song thrush	*Turdus philomelos*		
Starling	*Sturnus vulgaris*		

*Endemic at sub-species level