State of our Gulf

Tikapa Moana – Hauraki Gulf
State of the Environment Report 2011

Hauraki Gulf
Marine Park
Ko te Pataka kai
o Tikapa Moana

Hauraki Gulf Forum
Tikapa Moana

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Tikapa Moana

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The Hauraki Gulf Forum is a statutory body, established under the Hauraki Gulf Marine Park Act 2000, responsible for the promotion and facilitation of integrated management and the protection and enhancement of the Hauraki Gulf. The Forum has representation on behalf of the Ministers of Conservation, Fisheries and Māori Affairs, elected representatives from Auckland Council (including the Great Barrier and Waiheke local boards), Waikato Regional Council, and the Waikato, Hauraki, Thames-Coromandel and Matamata-Piako district councils, plus six representatives of the tāngata whenua of the Hauraki Gulf and its islands.

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Hauraki Gulf Forum
Tikapa Moana

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Chairman's Foreword

I am pleased to introduce the Hauraki Gulf Forum's third State of the Environment Report.

We have made much progress over the past three years in building understanding of the requirements of the Hauraki Gulf Marine Park Act 2000, since the appointment of a full-time manager. We have published four guides on implementation of the Act through policies and plans (Hauraki Gulf Forum 2009), and the use of non-regulatory tools, under the Resource Management Act (Hauraki Gulf Forum 2010a); through the Fisheries Act (Hauraki Gulf Forum 2010b); and via the process of spatial planning (Hauraki Gulf Forum 2011).

The Act seeks integrated management aimed at sustaining the life-supporting capacity of the Gulf. It recognises that it is the interrelationships between water, islands and catchments that provide this capacity and is a matter of national significance.

Management agencies are required to protect and, where appropriate, enhance this capacity for the social, economic, recreational and cultural well-being of people and communities.

This is our most ambitious report in that it attempts to respond faithfully to the Act's requirement for the Forum to produce every three years "a report on the state of the environment in the Hauraki Gulf, including information on progress towards integrated management and responses to [prioritised, strategic issues]."

As a basis for the report a core set of indicators drawn from biophysical monitoring programmes available from agencies was used. Because the available indicator sets are limited in their scope and longevity, the report also contextualises the state of the Hauraki Gulf against historical information and knowledge about how marine systems function ecologically.

This enables us to recognise the transformation which has occurred in the Gulf over two human lifespans and the incremental change which continues. The report concludes that most environmental indicators either show negative trends or remain at levels which are indicative of poor environmental condition.

The report also assesses the responses of agencies to the important issues facing the Gulf, according to their scale and potential impact, and the degree of integrated management.

It concludes that there has been a collective failure to halt or reverse decline in the Gulf's natural resources. This makes for challenging reading and calls into question some of the fundamental assumptions we use when undertaking business as usual.

I am pleased with the contribution by Professor John Montgomery and Dr Simon Thrush, which points out that the Hauraki Gulf is probably the best studied and known ecosystem in New Zealand, and such knowledge provides a platform for world-leading, ecosystem-based management. They suggest areas for research focus also, noting this must be rigorous and of a high quality if we are to move to effective action.

In adopting this assessment for publication the Forum asked for feed back on options to address the adverse environmental impacts it identifies.

I expect that this will include an expanded set of indicators which enables us to track progress towards clear targets and carefully planned interventions aimed at protection and enhancement. This is needed to ensure a rich diversity and abundance of fish and marine life in the Hauraki Gulf in the future.

Mayor John Tregidga
Chair Hauraki Gulf Forum

1.

Executive Summary

This report measures progress toward achieving the vision of the Hauraki Gulf Forum, and considers whether the life-supporting capacity and resources of the Tīkapa Moana – Hauraki Gulf are being protected or, where necessary, enhanced in accordance with the objectives of the Hauraki Gulf Marine Park Act 2000. The Forum's vision aims for a future where environmental quality is maintained, and the Hauraki Gulf is rich in diversity, with thriving fish and shellfish (kaimoana). It also seeks to ensure that resources are used wisely to grow a vibrant economy, and to protect our cultural heritage.

Humans have lived in New Zealand for only a relatively short time, but their impacts on the natural environment have been profound. The degradation of the environment began with the arrival of Māori, and was accelerated once European settlement occurred. Within the last two human lifespans we have seen the extinction of a number of native terrestrial species, native forests and vast wetlands being replaced by pastoral land use, rapid sedimentation of the coastal zone, the destruction of ecologically important marine habitats (e.g. extensive subtidal mussel beds in the Firth of Thames and Tamaki Strait), large reductions in the populations of fished species, and continuing growth in urbanisation leading to the loss, modification and contamination of the coast.

New Zealand has ground-breaking environmental regulations, which should have reduced environmental degradation and habitat loss in the Gulf and allowed the recovery of depleted species, ecological communities and habitats over the past 20 to 30 years.

This State of the Environment Report evaluates the current state of the environment and fisheries within the Hauraki Gulf Marine Park against historical information and an assessment of what the state of the Gulf would likely have been prior to human presence impacts. This historical baseline provides a useful reference point to evaluate the extent of change which has occurred in the Gulf, but the reference point cannot be interpreted as a target and the changes indicated cannot automatically be interpreted as failures in management. It is inevitable, and contemplated by the relevant legislation, that some change will occur as a result of people using and enjoying the natural resources of the Gulf, but it is important that these changes are kept within levels which maintain the overall healthy functioning of the Gulf as a natural system.

Encouraging signs are apparent for a few indicators, such as improving trends in total suspended solids concentrations along the Auckland coast, which appears to be a response to the former Auckland Regional Council's (ARC) efforts at reducing sediment run-off through regulatory and non-regulatory initiatives. Nutrient concentrations have displayed declining trends also in most of Auckland's rivers, but this may be due to a decrease in dairy farming rather than response-specific management initiatives, and opposite trends are apparent in the Waikato. Kahawai catch limits have also been set at levels that will allow the north-eastern stock (KAH1) to rebuild to about 52% of unfished levels by 2028.

However, most of the indicators examined in this report suggest that the Gulf is experiencing ongoing environmental degradation, and resources are continuing to be lost or suppressed at environmentally low levels.[1] For instance:

– An empirical estimate of actual snapper biomass obtained in 1995 indicated that at that time snapper biomass had been reduced to 10.4% to 12.6% of the "virgin", or unfished, biomass. Modelling predicted that limiting the total allowable catch to current levels would allow the stock to increase above the biomass required to produce the maximum sustainable yield within 20 years, with a 100% probability. An empirical estimate of snapper biomass has not been made since 1995, so the model predictions have yet to be verified. However, a stock assessment is scheduled for 2012. The maximum sustainable yield is the default fisheries target, which is produced at c. 23% of virgin snapper biomass in the Hauraki Gulf-Bay of Plenty substock. This means that, under the current management criteria, 77% of the potential snapper biomass will remain missing from the Hauraki Gulf-Bay of Plenty ecosystem.
– The "vulnerable biomass" of crayfish, in the CRA2 fishery area[2], was estimated to be around 20% of 1945 levels in 2002. Biomass was expected to remain at that level through to 2007. Best available information suggests the CRA 2 fishery is still above the statutory target level, and therefore, the total allowable catch has not been altered since 1997.

1. In this report, fisheries data is interpreted from an environmental management perspective, rather than from one of sustainability and utilisation.
2. Vulnerable biomass is the biomass of individuals above the minimum legal size after size-related differences in catch rates, protection of berried females and seasonal vulnerability are taken into account. The CRA2 fishery area runs from just south of Whangarei Harbour entrance to East Cape.

- The size characteristics of the fished and unfished snapper and crayfish populations differ substantially. Fished populations tend to be comprised of few, mainly young individuals that are below or near the legal size limit, while protected populations tend to have large numbers of older, large individuals above the legal size. This has implications for reproduction and population resilience during prolonged periods of poor recruitment.
- Trawl survey data from the Hauraki Gulf indicates that rare and threatened fish species, fish diversity, and fish size and productivity displayed negative trends in the Firth of Thames between 1965 and 2000.
- Significant, local reductions in shellfish populations have been recorded at three beaches, apparently due to harvesting, environmental stress, disease, or a combination of these conditions. A 36% reduction in cockle abundance occurred in Whangateau Harbour between 2004 and 2010. Cockle abundance also declined at Umupuia between 1998 and 2007, but subsequently increased due to an influx of small cockles. These locations have a low proportion of large cockles too, with only 1% to 2% of the population being of harvestable size. Similar declines and changes in population size structure have also been reported at Cheltenham Beach. Cockle numbers at other beaches monitored by the Ministry of Fisheries (MFish) have been relatively stable.
- Toxic metal and organic contaminants are causing localised effects in Auckland estuaries. A number of metal contaminants exceed sediment guideline values in the southern Firth of Thames as well. Threshold effects level (TEL) guideline values are exceeded at 21 of the 50 sites that are regularly monitored by Auckland Council. Probable effects level (PEL) guidelines are only exceeded at the lower tidal banks of Meola Creek and Motions Creek in the Waitematā Harbour. Management actions are not expected to remediate areas affected by urban and legacy contamination, but may slow accumulation and prevent the degradation of areas with clean sediments.
- Riverine inputs of nitrogen to the Firth of Thames now exceed loads from oceanic sources. Waihou and Piako rivers dominate nutrient loads to the Gulf, contributing around 90% of nutrients entering from the Waikato Region and exceeding river and wastewater loads from the Auckland Region. The mass load of nitrogen from Hauraki rivers is estimated to have increased by about 1% per year between 2000 and 2009, while phosphorus decreased by about 5% per year during the same period. The long-term implications of increasing nitrogen loads are poorly understood.
- Fourteen or more of the 42 beaches monitored in the Auckland Region between January 2006 and April 2009 exceeded the “action”-level guideline for marine bathing each year. Exceedance of this guideline indicates that swimming, or other forms of contact recreation, may pose a health risk. In the Waikato Region, eight of the 16 sites monitored exceeded the action threshold at least once in January-February 2006, while two sites exceeded the action threshold in January-February 2008.
- A number of studies carried out over the past decade or so have confirmed that sediment is a serious environmental contaminant that degrades coastal habitats and is toxic to most marine organisms.
- Modern sediment accumulation rates are typically greater than those for natural sedimentation rates. However, as mentioned earlier, there are signs that management initiatives in the Auckland Region are reducing suspended solids concentrations on the Auckland coast.
- Sediment accumulation has contributed to the expansion of mangroves in many, if not all, estuaries in the Gulf.
- Changes in the composition of benthic communities that are consistent with increased sediment-mud content have been detected at sites in Puhoi, Wairewa, Orewa, Turanga and Waikopua estuaries, and in Mahurangi Harbour. The proportions of mud and fine sand increased significantly between 2001 and 2006 at monitoring sites in the Firth of Thames, but these changes were not matched by negative trends in species sensitive to fine sediments.
- A total of 139 non-indigenous marine species have been recorded in the Hauraki Gulf. Four arrivals in the past 10 years are notable for their potential to cause significant ecological and/or economic effects: the Mediterranean fanworm (*Sabella spallanzanii*); the clubbed sea squirt (*Styela clava*), the Asian kelp (*Undaria pinnatifida*); and the Japanese mud crab (*Charybdis japonica*). Three of these are formally classified as unwanted species.
- Large amounts of litter continue to enter the coastal environment. Plastics are particularly problematic owing to their environmental persistence and effects on wildlife and aesthetics.

- Between 1960 and 2005 seven of the 15 most common waders displayed declining trends in the Firth of Thames' Ramsar site. By comparison, four wader species increased in number, and four species maintained relatively stable populations. Mangrove expansion and other habitat changes were implicated in the decline of at least four species.
- Between 1989 and 2008 two endangered Bryde's whales were killed in the Hauraki Gulf from entanglement in mussel farm spat lines, and 11 Bryde's whales were killed by lethal injuries that were consistent with vessel strike.
- Forty-seven per cent of the Gulf's mainland bays and beaches (named on topographical maps) are fully urbanised, intensively developed or moderately developed, while the land surrounding 38% of bays and beaches was either undeveloped or contained only scattered buildings. The Waikato Region has more undeveloped bays and beaches than the Auckland Region, with 36% undeveloped in Waikato cf. 5% in Auckland.
- Large-scale development of new or "greenfield" coastal land has occurred around the margins of the Auckland urban isthmus in the past 10 to 15 years. Smaller-scale developments have also taken place around the outlying towns of Warkworth, Snells Beach, Omaha, Matakana and Beachlands.
- There was a steady increase in the number of dwellings in east-coast settlements on Coromandel Peninsula between the 1991 and 2006 censuses, with holiday homes responsible for a large proportion of development. In 2006, 48% of dwellings in the Thames-Coromandel District were unoccupied, with most of these consisting of holiday homes and/or baches (however, vacant properties for sale, properties completed but not yet occupied and other properties such as "abandoned" dwellings are also included in this figure).
- A third of the commercial holiday parks on Coromandel Peninsula closed between 1996 and 2006.

Not enough information was available to adequately characterise the impact that some activities are having, but local and international studies suggest that the magnitude and scale of their effects are likely to be among the most significant in the Gulf. For instance:
- Bottom trawling is one of the most commonly used methods of catching fish in the Hauraki Gulf, accounting for around 30 to 40% of the total commercial catch and occurring in most areas north of a line running from Kawau Island to Colville Bay. Virtually nothing is known about seabed ecology in trawled areas, but they are likely to contain (or have once contained) ecologically important habitats and features that are sensitive to bottom disturbance. Local and international research suggests that trawling causes substantial reductions in species and habitat diversity.
- Commercial scallop fishing has occurred in an area of 350 to 450 km^2 for most of its history, but dropped to 200 km^2 in 2001, and 100 km^2 in 2005, with effort shifting from the central Gulf and Aotea (Great Barrier Island) to Mercury Bay and Bay of Plenty. The areas targeted by commercial and recreational fishers contain a variety of benthic habitats. Habitat-forming or ecologically important species are commonly collected in scallop dredges, including horse mussels, dog cockles, starfish, sponges, kelp and turfing algae. Very little information is available on the current or historical ecology of scallop fishing areas, or the impacts of dredging on them.
- Of the top 15 fish species caught commercially:
  - the current status of nine species is not known;
  - overfishing of two species is about as likely as not to be occurring, but can't be confirmed either way (tarakihi and trevally);
  - three species (pilchard, baracoutta and grey mullet) are not considered to be at risk of collapse, but not enough is known about the stocks to assess whether they are at or above target levels or depleted;
  - two species (snapper and kahawai) are considered to be at or above target levels, and are not depleted or at risk of collapse.

In addition, harmful algae and pathogens have had a major ecological and economic impact on the Hauraki Gulf over the past 30 years. The causes, historical incidence and implications of mass mortalities are poorly understood, but their impact has been significant. Mass mortalities have included: the loss of around 80% of juvenile oysters on oyster farms; the loss of 60 to 80% of cockles in Whangateau Harbour; the largest recorded fish kill in the world (pilchards); the die-off of the main canopy-forming kelp on northern reefs (*Ecklonia radiata*); a major loss of scallops; the death of tens of thousands of fish in the central-inner Gulf; and the loss of around 8,500 paua at a farm in Kennedy Bay.

While many activities are causing unfavourable environmental effects, island and marine conservation efforts are clearly producing positive outcomes:

– Many islands in the outer Gulf have a high proportion of native forest cover. Hauturu (Little Barrier Island) is almost fully forested, while 86% or more of Aotea (Great Barrier Island) and Kawau Island are covered by indigenous forest, broadleaved indigenous hardwoods, or manuka and kanuka. Most of the islands around Coromandel Peninsula are also covered in native vegetation, the notable exceptions being Great Mercury and Slipper islands. Rangitoto Island is covered with native forest, while volunteers have planted around 206,000 trees on Motuora and 280,000 trees on Tiritiri Matangi. Motutapu and Motuihe have been partially revegetated, and the Rotoroa Island Trust is replanting on Rotoroa Island.
– Forty-three per cent of islands in the Gulf that are larger than 10 ha are currently free of mammalian herbivorous and predatory pests. Pests have been eradicated also from Rangitoto and Motutapu islands, but their pest-free status is yet to be confirmed. The elimination of mammalian pests has allowed one nationally critical (takahe) and four nationally endangered (hihi, kokako, North Island weka and brown teal) bird species to be translocated to, or among, islands in the Gulf. In addition, one nationally critical (Mercury Island tusked weta) and two nationally endangered (Mahoenui giant weta and wetapunga) insects, and one nationally vulnerable (Whitaker's skink) reptile have been translocated. A number of other less-threatened species have also been translocated among islands.
– Finally, at least two of the Gulf's marine reserves and the only marine park (i.e. Tawharanui, which is awaiting formal gazzetting as a Marine Reserve) have allowed the local recovery of heavily fished species such as snapper and crayfish, which has led to corresponding changes in reef ecology and productivity.

This report highlights the incredible transformation the Gulf has undergone over two human lifespans. That transformation is continuing in the sea and around the coast, with most environmental indicators either showing negative trends or remaining at levels which are indicative of poor environmental condition. It is inevitable that further loss of the Gulf's natural assets will occur unless bold, sustained and innovative steps are taken to better-manage the utilisation of its resources and halt progressive environmental degradation. The regulatory tools appear to be available to do this, but to date they have either not been implemented or the manner of implementation has not been effective. The challenge facing today's managers and kaitiaki (guardians)who seek to achieve the Hauraki Gulf Forum's vision for the Gulf is to find solutions to the progressive decline in the Gulf's resources and ecosystem, and to protect opportunities for future generations.

2.

Background

2.1 The Park

The Hauraki Gulf Marine Park was established under the Hauraki Gulf Marine Park Act (2000). It currently includes the foreshore, seabed (excluding defence areas) and seawater on the east coast of the Auckland and Waikato regions (i.e. the Gulf), as well as Hauturu (Little Barrier Island), the Mokohinau Islands, more than half of Aotea (Great Barrier Island), Cuvier Island, Rangitoto Island, Motutapu Island, Mount Moehau, Mansion House on Kawau Island, North Head Historic Reserve, other small islands administered by the Department of Conservation (DOC), four marine reserves and the internationally recognised Ramsar wetland at the Firth of Thames. It also includes a number of reserves owned by, or previously owned by, Forest and Bird, Waitakere City Council and Rob Fenwick. Although the Hauraki Gulf Marine Park does not include the entire catchment of the Gulf (Figure 1), the Act does recognise the interrelationship between the Gulf, its islands and catchments and therefore contains objectives related to catchment management. Tāngata whenua (original inhabitants) have no single name for the Gulf, but Tīkapa Moana and Te Moananui a Toi are often used.

The marine environment in the Hauraki Gulf Marine Park extends from the deep ocean to bays, inlets and harbours off the coastline and the shallow sea and broad intertidal flats of the Firth of Thames. The complexity and nature of the physical environment is reflected in a diverse and highly productive marine ecosystem. The islands of the Gulf are also a critical refuge for rare plants and animals. Some of the species on the islands, which were once common, no longer naturally occur anywhere else in the world.

The Gulf has a rich history of human settlement and use. It is one of the earliest places of human settlement in New Zealand, and has sustained tāngata whenua for many generations. The history of the Gulf can be traced through places like the pā (fort), kainga (village) and garden sites of antiquity on most islands, while European settlement and development is recorded in driving dams, copper and gold mines, whaling stations, timber mills, industrial sites, and grand and ordinary homes.

The Gulf is economically important and most of its catchments are intensively developed and settled. Its shores contain New Zealand’s largest metropolitan area and extensive tracts of productive farmland. Its coastal waters are of great importance to commerce in this country: containing the Port of Auckland, together with many smaller ports and marinas. It is lived in and worked in, and used for marine commerce, commercial fishing and transport.

People also use the Gulf for recreation and the sustenance of human health, well-being and spirit. The natural amenity of the Gulf provides a sense of belonging for many New Zealanders and for them it is an essential touchstone with nature, the natural world and the marine environment.

The Gulf, its islands and catchments have complex interrelationships that need to be understood and managed, to ensure that their values are to be maintained, protected or enhanced in perpetuity. The Gulf crosses territorial and departmental jurisdictions, land and water boundaries and cultures. It is therefore essential that the objectives and approaches of management organisations are integrated in a way which provides for conservation, sustainable utilisation, development and enhancement.

The purpose of establishing the Hauraki Gulf Marine Park was therefore to:

a. recognise and protect in perpetuity the international and national significance of the land and the natural and historical resources within the Park;
b. protect in perpetuity and for the benefit, use and enjoyment of the people and communities of the Gulf and New Zealand, the natural and historical resources of the Park including scenery, ecological systems or natural features that are so beautiful, unique or scientifically important to be of national significance, for their intrinsic worth;
c. recognise and have particular regard to the historical, traditional, cultural and spiritual relationship of tāngata whenua with the Hauraki Gulf, its islands and coastal areas, and the natural and historical resources of the Park; and
d. sustain the life-supporting capacity of the soil, air, water and ecosystems of the Gulf in the Park.

2.2 The Hauraki Gulf Forum and the State of the Environment Report

The Hauraki Gulf Forum (subsequently referred to as the Forum) is made up of representatives from local and regional councils, central government departments (Māori Affairs, MFish and DOC) and tāngata whenua. It was established under the Act to facilitate communication, co-operation and co-ordination among the member organisations.

Functions that the Forum must perform are: to obtain, share and monitor information on the state of the natural and physical resources of the Gulf; identify strategic issues; and to prepare and publish a report on the state of the environment in the Hauraki Gulf every three years. Previous State of the Environment reports produced in 2004 and 2008 (Hauraki Gulf Forum 2004, 2008a) identified a wide range of activities that affect the natural and physical resources of the Gulf. The impacts of these activities vary widely in their scale and magnitude, with some causing minor, localised effects and others having major consequences for the whole Gulf.

In this report, there is a deliberate focus on the most pressing environmental issues, and, where possible, the current state of the environment is put into context by considering historical information. The issues considered here are linked to the high-level strategic issues previously identified by the Forum (Table 1, Hauraki Gulf Forum 2008b), but there is a deliberate focus on indicators related to the natural environment. These indicators are contained within the headings:

1. fishing;
2. sediment;
3. toxic chemicals;
4. nutrients;
5. microbial pollution of bathing beaches;
6. introduced marine species;
7. harmful algae, pathogens and mass mortalities;
8. litter;
9. maintenance and recovery of biodiversity; and
10. coastal development.

At least one of these issues appears to be relatively new, yet its historical occurrence and causes are poorly understood. Toxic algae and pathogens have recently demonstrated their capacity to cause rapid, large-scale and serious impacts on the Gulf and well beyond. In recent years, mass mortalities caused by toxic algae, pathogens and other unknown causes have been reported for a growing list of fish, plants and invertebrates. Biotoxins have also caused poisonings in the human population. We do not know what influence human activities have on the occurrence or spread of harmful algae and pathogens, but it is possible that their impact could increase if human activities reduce the resilience of the marine ecosystem. Available information on this issue is therefore included in this report.

In order to put information on the state of the environment into context it is crucial for an appropriate baseline to be defined. Furthermore, to avoid the potential of a “sliding baseline” this reference point should be founded on a natural benchmark. Failure to use a natural reference point will almost invariably result in a sequential worsening of environmental quality over successive generations. It would also lead to a failure to detect the creeping disappearance of environmental values and resources, and the use of inappropriate reference points for evaluating impacts (Pauly 1995).

Routine and robust state-of-the-environment monitoring data from the Hauraki Gulf has been collected for only a relatively short period (starting with water quality monitoring in the Auckland Region in the late 1980s). However, scientific studies and historical records are available, which allow the major changes that have occurred in the Gulf to be described and in many cases quantified. Historical background information is therefore provided from a range of published and unpublished scientific papers, reports and theses. Where possible, this is used to put the current state of the environment into context and to provide a benchmark for comparison. This has been achieved by including a section with information on the natural setting for the Gulf and a general summary of human impacts. When available, long-term data and model projections are also presented in the sections on environmental indicators.

However, the knowledge base is still incomplete and fundamental gaps remain in our understanding of what the Gulf contains, how the Gulf functions and the impacts that humans have had. The lack of information was recently highlighted in the discovery that Omaha Bay contained up to 4 million worm-eels (*Scolecenchelys australis*) that are rarely encountered by humans. If such abundances were typical, it would make this unusual and infrequently encountered species one of the more abundant fish in coastal New Zealand (Taylor and Morrison 2008). The fact that this type of discovery is still being made in such an accessible and heavily utilised area clearly illustrates that our current level of understanding is inadequate. The report therefore includes a section that considers key knowledge gaps and makes recommendations on the research required to fill them.

Table 1: Links between strategic issues identified by the Hauraki Gulf Forum (Hauraki Gulf Forum 2008b) and environmental indicators considered in this report.

Strategic Issue	Related Indicators
Maintaining and enhancing Tikapa Moana – Hauraki Gulf as a pataka (storehouse of food and knowledge)	Fisheries, sediment, toxic chemicals, nutrients, microbial pollution, introduced marine species, harmful algae, pathogens and mass mortalities, and maintenance and recovery of biodiversity.
Water quality	Sediment, toxic chemicals, nutrients, microbial pollution, and possibly harmful algae, pathogens and mass mortalities.
Biological diversity	Fisheries, introduced marine species, harmful algae, pathogens and mass mortalities, and maintenance and recovery of biodiversity.
Natural character and landscape	Coastal development.
Climate change	No direct indicators, but climate change potentially influences the maintenance and recovery of biodiversity, introduced marine species, and possibly, harmful algae, pathogens and mass mortalities.
Cultural heritage	Coastal development.
Integrated management	All indicators.
Raising awareness, understanding and recognition of the national significance of Tikapa Moana – Hauraki Gulf	All indicators.
Access to Tikapa Moana – Hauraki Gulf	Coastal development.
Coastal hazards	Coastal development.

Progress on recognising the historical, traditional, cultural and spiritual relationship of tāngata whenua with the Hauraki Gulf is also considered by reviewing how tāngata whenua values and practices are recognised in the Hauraki Gulf Marine Park Act, the roles of agencies and iwi planning documents, the effects of treaty settlements and options for agencies to respond to tāngata whenua's interests. Tāngata whenua case studies are also presented for Tāmaki River and Whangamatā.

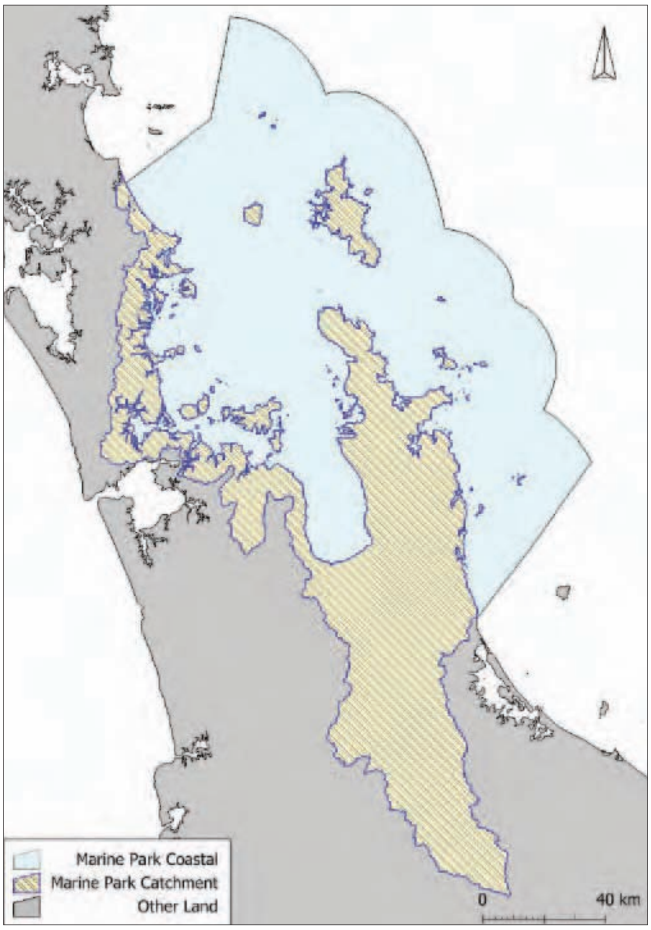
Finally, the State of the Environment Report is required to include information on progress being made towards integrated management and responses to strategic issues identified by the Forum. This is achieved by reviewing the policy framework and recognising management gaps and opportunities. The focus of this assessment is on examining the level of integration occurring at a strategic level, and in particular at co-ordinating programmes that will deliver the vision for Tikapa Moana – Hauraki Gulf.

Vision for Tikapa Moana – Hauraki Gulf

Tikapa Moana – Hauraki Gulf is celebrated and treasured because

- Kaitiaki sustain the mauri of the Gulf and its taonga. Communities care for the land and sea. Together they protect our natural and cultural heritage.
- Tikapa Moana is thriving with fish and shellfish, kaimoana.
- Rahui Tapu is being systematically instituted by communities conscious of maintaining the integrity of Tikapa Moana as a food cupboard, pataka kai.
- Individuals, groups and communities are conscious of, and undertake their responsibilities to maintain optimum quality standards of the waters, air, and land in their catchments.
- There is rich diversity of life in the coastal waters, estuaries, islands, streams, wetlands and forests, linking the land to the sea.
- People are familiar with the rich history, cultural and physical heritage and spirituality of Tikapa Moana – Hauraki Gulf, gain a sense of place, connection and identity from these and behave in ways that respect and protect them.
- People enjoy a variety of experiences at different places that are easy to get to.
- People live, work and play in the catchment and waters of Tikapa Moana – Hauraki Gulf and use its resources wisely to grow a vibrant economy.
- The community is aware of and respects the values of Tikapa Moana – Hauraki Gulf and is inspired to enhance and protect this great place.

Figure 1: Extent of the Hauraki Gulf Marine Park and its associated catchment.



3.

The Gulf

3.1 Natural setting

3.1.1 Geology

The origins of the oldest, greywacke, rocks in the Hauraki Gulf can be traced back to sand and mud deposits, which accumulated off the coast of the ancient southern continent, Gondwanaland, around 140 to 250 million years ago. Since those rocks were laid down, the geology of the Gulf and its catchments have been slowly shaped over millions of years through uplifting, marine subsidence, erosion, sediment transport and deposition, sea-level change and volcanism. Time and geological processes have therefore formed the natural landscape of coastal and underwater features that make up the Gulf.

Coromandel Peninsula and Aotea (Great Barrier Island) largely consist of rocks derived from magma, volcanic flows and volcanic deposits, which cover a basement of ancient greywacke. These rocks have been locally altered in many places by pockets of hydrothermal activity. Small exposures of greywacke still occur on the northern half of Coromandel Peninsula and Aotea (Great Barrier Island), with the largest outcrops found at their tips. The islands to the east of Coromandel Peninsula, Little Barrier Island, Mokohinau Islands, Rangitoto Island and Browns Island also have volcanic origins, but rock types differ among the islands. Rangitoto Island is a very young "shield" volcano whose iconic cone shape was created around 600 years ago through the build-up of overlapping lava flows that poured out in all directions and solidified into hard, fine-grained basalt rock.[3] Its steep sided scoria cones were produced by fountains of frothy lava (Cameron *et al.* 2008). Hautarui (Little Barrier Island) is the emergent part of a large "stratovolcano" that has been built up by many layers (strata) of hardened lava, tephra, pumice and ash (Edbrooke 2001). Stratovolcanoes tend to have steeper profiles than shield volcanoes and are characterised by periodic, explosive eruptions. Islands to the east of Coromandel Peninsula were mainly created by a mix of andesite, rhyolyte and basalt flows and deposits. Cuvier Island has a slightly different geology, being composed of magma-based rocks that were formed in the earth's crust and later exposed.

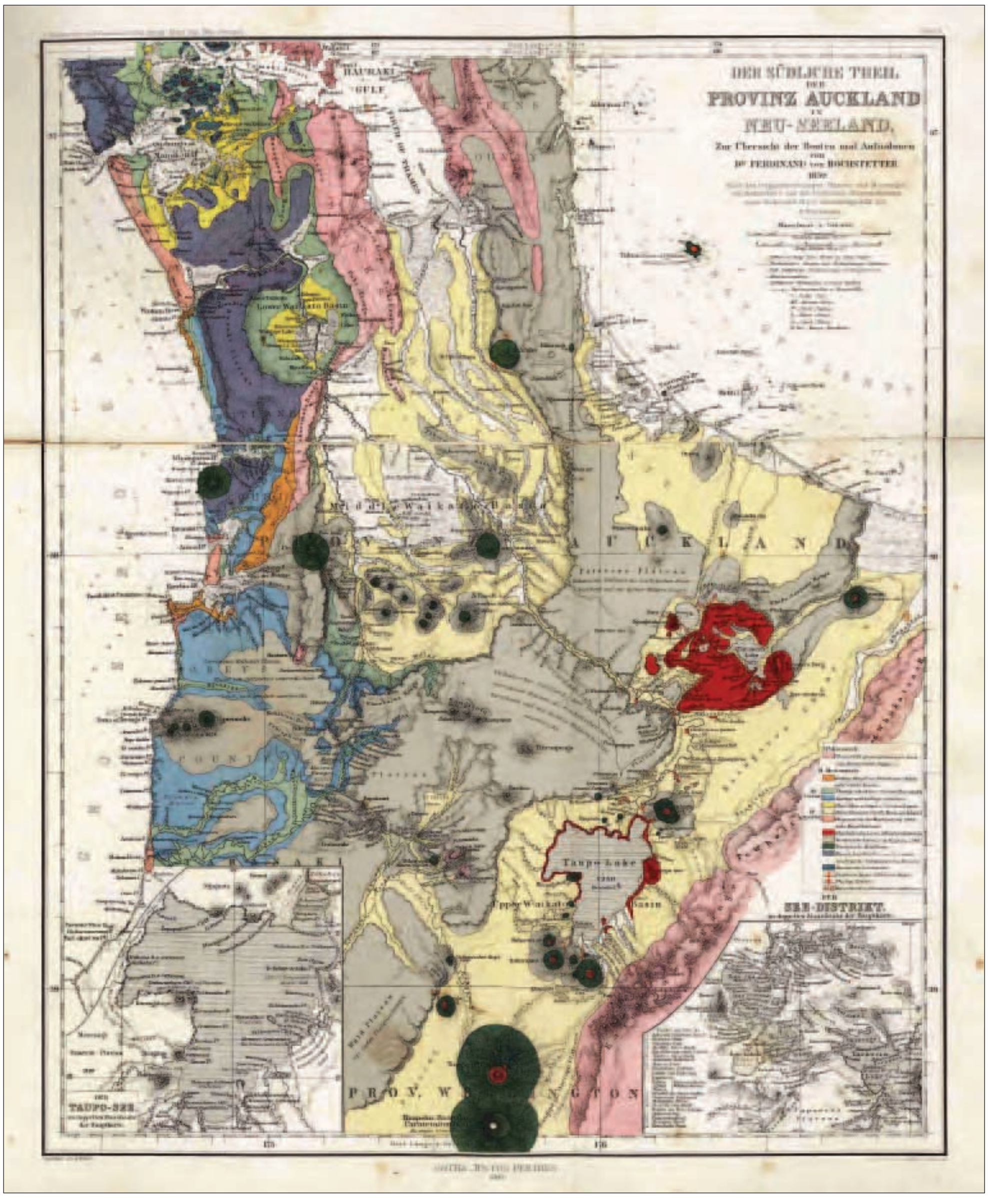
In stark contrast, the western catchment of the Gulf from Maraetai Beach north is largely comprised of soft, erodible Waitematā sand and mudstones that were formed in a deep marine basin when the area subsided beneath the sea around 20 to 25 million years ago (Grant-Mackie 1983, Edbrooke 2001). These are interrupted by the basalt lava flows and volcano deposits of the Auckland volcanic field, and by small pockets of volcanic rock around Leigh. Stony Batter on Waiheke Island is also a small, remnant volcano. The Hunua Ranges, Waiheke Island and Kawau Island are predominantly composed of greywacke which was once covered by a thick layer of Waitematā sand and mudstones. Uplifting and erosion have weathered away softer rock to re-expose the hard, underlying basement. Smaller outcrops of greywacke have been re-exposed is a similar fashion on Tawharanui Peninsula and around Leigh too.

The Hauraki Plains and Firth of Thames were formed by an active rift between the Firth of Thames Fault along the eastern side of the Hunua/Hapuakohe Ranges and the Hauraki Fault that runs along the western side of the Coromandel/Kaimai Ranges (Edbrooke 2001). This area was historically part of an extensive alluvial plain in the lower reaches of the Waikato River, which diverted its course from the east to the west coast around 20,000 years ago. It is currently drained by two large river systems: the Waihou and Piako rivers. The Hauraki Plains, Firth of Thames and broader Hauraki Gulf have a geologically recent history of marine inundation and emergence due to sea-level fluctuations and infilling by river sediments. During the peak of the last glacial period, around 18,000 years ago, the sea level is estimated to have been over 100 m below present levels. Most of the Gulf would have consisted of exposed lowlands dominated by the volcanoes of Hauturu (Little Barrier) and Aotea (Great Barrier) islands. Inundation by the sea began around 15,000 years ago and approximately half of the outer Gulf was submerged within 3,000 years, producing a north-facing bay with tidal inlets in the main channels. It took another 2,500 years for the sea level to rise to approximately 28 m below present levels, producing an outer Gulf with a shape similar to today's coastline, but the innermost Gulf remained a terrestrial plain or estuary. Modern sea-level position was achieved by about 6,500 years ago (Manighetti and Carter 1999), when the southern shoreline of the Firth of Thames was

3. One Tree Hill is an older "shield" volcano that was formed through a similar process.

around 13 km inland of its current position. The build-up of volcanic sediment brought down the Waihou and Piako rivers shifted the Firth of Thames' shoreline north at a rate of around 2 km every thousand years, and formed an extensive mud wedge which extends seaward of the current shoreline. Following the last glacial period, extensive peat bogs also formed on the Hauraki Plains. These initially developed as a series of small mires of podocarp-angiosperm swamp forest during mild climatic conditions. Over the past 10,000 years or so, the peat bogs have expanded and retracted in response to climatic conditions and changes in the shoreline.

Figure 2: Map of Ferdinand von Hochstetter (1859), showing the braided river fan and swampy peat bog that once covered the Hauraki Plains. This feature was largely created by the Waikato River, prior to its course shifting to the west coast around 20,000 years ago (map reproduced courtesy of Early New Zealand Books Collection, University of Auckland Library, www.enzb.auckland.ac.nz/).



3.1.2 Rivers

River catchments[4] of the Hauraki Plains make the largest contribution to the catchment of the Hauraki Gulf, comprising around 47% of the total river-catchment area (Figure 3). River catchments on the eastern side of Coromandel Peninsula are also relatively large, contributing to 18% of the total river-catchment area. The remaining 35% of the Gulf's river catchments are made up of:

- the western Coromandel, Tamaki Strait and the western Gulf north of Waitematā Harbour, which each contribute around 8% to the total area;
- the Waitematā catchment, which contributes 5% to the total area; and
- the western Firth of Thames and Barrier Islands, which each contribute around 3% to the total area.

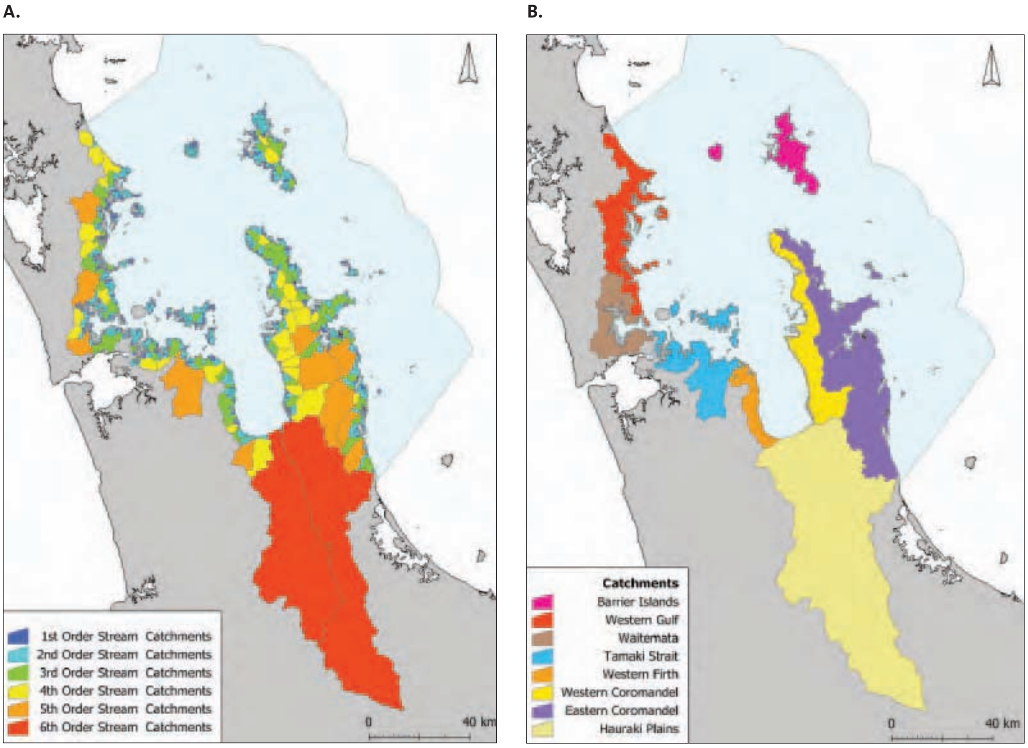
3.1.3 Currents and circulation

Water circulation and currents in the Hauraki Gulf are largely driven by the combined influences of ocean currents, wind, tides, bathymetry and the shape of the coast. The East Auckland Current is a key oceanographic feature of the outer Gulf, which flows southwards along the margin of the continental shelf and effectively defines the boundary between coastal and oceanic waters. The continental shelf bulges out in the northern Gulf, where the 200 m depth contour is situated around 80 km from the mainland. Further south, the continental shelf curves towards the shore and in the southern-eastern section of Coromandel Peninsula the 200 m depth contour is only 23 km out from the coast. Depths increase sharply out from the Alderman Islands to exceed 500 m at the Park boundary.

The central Gulf is relatively flat with seabed slopes as low as 1:2000. This area gradually shoals from water depths of 40 to 50 m to the shores of the inner Gulf and Coromandel Peninsula. A very gentle slope of around 1:1500 leads from the central Gulf to sand and mudflats at the southern end of the Firth of Thames. Seabed gradients are steeper north of Tawharanui Peninsula and on the eastern side of Coromandel Peninsula. They also increase offshore, with slopes of 1:400 towards the shelf break (Manighetti and Carter 1999).

4. As defined using National Institute of Water & Atmospheric Research Ltd's (NIWA) river environment classification.

Figure 3: Individual (a) and combined (b) river catchments of the Hauraki Gulf. Individual catchments are coloured according to the complexity of their river systems, with first-order streams branching once between the ocean and their headwaters and sixth-order streams branching six times.



Coastal incursions of clear oceanic water regularly occur in summer, when south-easterly winds drive warm oceanic surface waters onshore, and occasionally into the inner Gulf through Jellicoe Channel (Sharples 1997). In contrast, flows through Cradock Channel appear to bypass the inner Gulf, and be deflected out through Colville Channel (Greig 1990). Incursions of oceanic surface waters have a major influence on the inshore ecosystem. Plankton species, such as salps, are commonly carried inshore with the oceanic water, leading to changes in the composition and dynamics of the water column community (Zieldis *et al.* 1995). These incursions are also thought to be responsible for the occasional blooms of toxic algae such as *Gymnodinium* sp., which pose a risk to humans and marine species (Chang *et al.* 1995).

An important consequence of south-easterly winds driving warm oceanic water inshore is downwelling. This takes nutrient-rich water away from the coast, so fewer nutrients are available to support algae growth. Conversely, northwest winds drive coastal waters offshore, leading to the upwelling of cool, nutrient-rich water that fertilises the continental shelf and promotes algae growth. Predominant wind directions typically cause seasonal upwelling in winter and spring, and downwelling in summer (Broekhuizen *et al.* 2002). However, weather patterns also vary with El Niño and La Niña conditions. During El Niño, winds tend to blow from the west, causing upwelling, whereas easterlies prevail during La Niña conditions, causing downwelling. The shape of the coast has a major influence on water mixing as well, with headlands and islands causing upwelling in tidal eddies (Black *et al.* 2000).

The Gulf tide has a vertical tidal range of 1.9 to 2.9 m. Tidal currents tend to be greater on the eastern (Coromandel) half of the inner Gulf, and in the narrow gaps between islands and headlands (Black *et al.* 2000). The eastern side of Coromandel Peninsula generally has weak tidal flows off the coast, but currents are stronger in the north, where the Mercury Islands constrict and accelerate flows (Bradshaw 1991). Wind also defects tidal currents, so circulation patterns in the inner Gulf vary depending on both tide and weather conditions.

3.1.4 Sediments

The seabed in the Hauraki Gulf consists mainly of subtidal sediment, with intertidal sand and mudflats, a relatively narrow band of intertidal and subtidal reefs, and sandy, pebbly and cobbly beaches around the coastal margin. Sediment characteristics are influenced by geology, geomorphology (i.e. the shape of the coast), land erosion, currents, depth, exposure and biological features. Local variation in these characteristics has created a diverse mosaic of sediment types throughout the Gulf. Estuaries act as active sediment traps that accumulate sediments from both the land and the sea. Their sheltered nature and intimate connection with the land makes them sensitive to changes in sediment run-off patterns. However, some types of estuary are more prone to accumulating land-derived sediment than others. The vulnerability of estuaries to sediment accumulation depends on the geology and land cover of the surrounding catchment, and how the estuary processes sediment. Five types of estuary have been identified in the Hauraki Gulf (Hume *et al.* 2007, Figure 4), with the most common being types "D" (coastal embayments such as Mercury Bay), "E" (tidal or barrier-enclosed lagoons such as Whangapoua Harbour) and "F" (barrier-enclosed lagoons or drowned valleys such as Waitematā Harbour).

Type D estuaries, such as Mercury Bay and Tryphena Harbour, do not tend to accumulate terrigenous sediments because hydrodynamic and sediment processes are dominated by the ocean. Mixing and sedimentation within these estuaries is driven by wind and waves, and as a result their substrates are mostly sandy. Type E estuaries, such as Coromandel Harbour, are shallow, oval basins with simple shorelines and extensive intertidal zones. These estuaries are less susceptible to terrigenous sediment accumulation because they are well flushed with small river flows and large tidal volumes, so most of the water leaves the estuary on the outgoing tide. Wave-generated resuspension of the substrate and strong flushing causes these estuaries to maintain sandy beds. Type F estuaries, such as the Whitianga and Waitematā harbours, have complex shorelines and numerous arms leading off a main basin. The main bodies of Type F estuaries have sandy substrates, but sheltered side branches tend to accumulate muddy terrigenous sediments because wind and wave-driven resuspension of the substrate is limited in these parts of the estuary. The two remaining types of estuary (Types B and C) are associated with tidal river mouths in the southern Firth of Thames and at Pakiri Beach (Type B), and at Waikawai Beach and Awana Bay (Type C). Type B estuaries tend to be muddy except in areas of high tidal flows, while Type C estuaries have lagoons with coarser substrates at their mouths.

Hydrodynamics control sediment patterns beyond estuarine and sheltered near-shore environments of the Gulf (Figure 5a). The input of new sediment into the central and outer Gulf is minimal and consists of fine sediment loads coming from local rivers. Most sediments on the continental shelf are therefore relict sands which accumulated over thousands of years, and are continually redistributed by near-bottom currents driven by tides, winds, waves and oceanic incursions. Storms are probably the major agent for redistributing these sediments and are potentially capable of mobilising bed sediments in 100 m of water (Manighetti and Carter 1999). Modelling suggests that the prevailing direction of sediment transport is southwards across the shelf and through Jellicoe and Cradock channels, with sand mobile for up to 33% of the time (Manighetti and Carter 1999).

Local variations in hydrodynamic patterns cause sediment characteristics to vary widely around the central and outer Gulf. The amount of mud on the seabed increases toward the centre of the inner Gulf, peaking halfway between Whangaparaoa and Coromandel peninsulas (Figure 5b). Acoustic surveys also indicate that there is a progressive change in the characteristics of the seabed from the southern Firth of Thames and Tamaki Strait, to the mid-Gulf area south of Mahurangi Harbour and Cape Colville (Morrison *et al.* 2003). This is consistent with the gradual fining of sediment toward the inner Gulf. Sediments coarsen from sandy-mud to muddy-sand towards Colville Channel, with both sediment types also containing sand to gravel-sized shell debris. Colville Channel has a distinctive mosaic of sediments that range from almost pure shell-gravel to shelly-gravelly-sand and muddy-gravelly-sand.

Sediments progressively become finer east of Colville Channel, with sandy mud becoming prevalent as the sea deepens across the continental shelf. A deep area of sediment accumulation is also located around Mokohinau Islands, with a pocket of fine sediment east of the islands (Figure 5). Another significant feature is a large body of sand that extends out from Pakiri Beach. In water depths of 40 to 60 m this sand is mounded into 5 m high asymmetric dunes, which are spaced 500 to 1,000 m apart and aligned perpendicular to the prevailing alongshore currents.

Coastal sediments on the eastern side of Coromandel Peninsula can be broadly grouped into older sediments formed by shore erosion as sea level rose following the last glacial period, and more recent sediments derived from new material that has passed through infilled estuary systems. The older sediments were primarily eroded from steep, rocky headlands and deposited in adjacent embayments, where they created thick sheets of sand and sand barriers. Over the last 6,500 years, waves and currents have reworked, sorted and redistributed these sediments, while the infrequent but intense storms have formed large dunes in water depths of 20 to 80 m. Recent sediments tend to be comprised of fine and very (often muddy) fine sands and are particularly abundant across the upper shoreface and mid-shelf surfaces, and in Mercury Bay, these sediments completely blanket the older sediments (Bradshaw *et al*. 1994).

Figure 4: Distribution of estuary types in the Hauraki Gulf according to the categories provided in Hume *et al*. (2007).

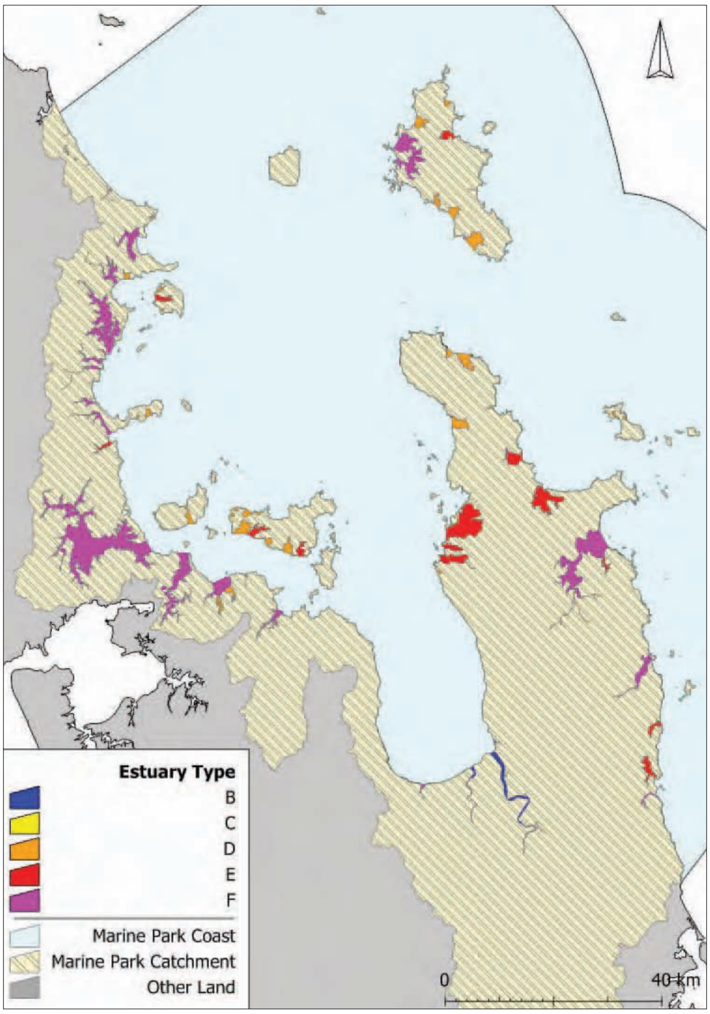
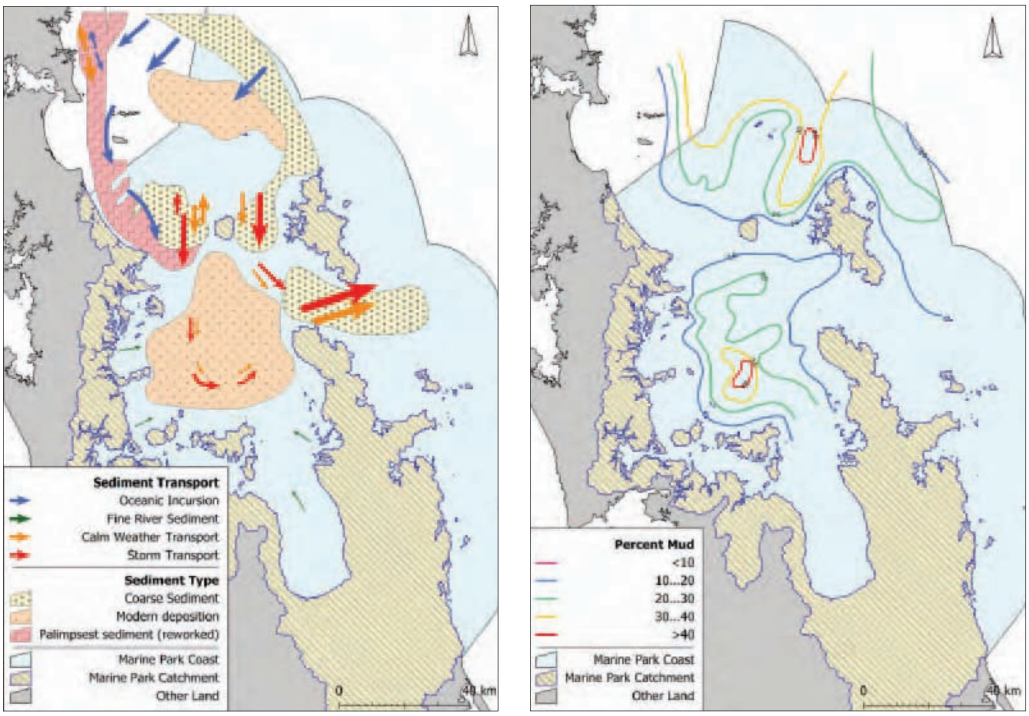


Figure 5: Patterns in the distribution of (a) sediment pools and (b) fine sediment (percentage of mud) in the Hauraki Gulf (adapted from Manighetti and Carter 1999). Arrows provide a qualitative indication of the magnitude and direction of sediment transport in relation to various sediment sources and hydrodynamic forces.



3.1.5 Reefs

Reefs provide a fringe of structurally complex habitat along the margin of the shore and in isolated patches throughout the Gulf. They are situated across a range of exposures, which vary from high-energy environments on rocks and islands of the outer Gulf to benign conditions within estuaries. Similarly, they occur along a continuum of terrestrial influence, with some reefs arising in areas that experience high sediment loads and salinity fluctuations due to freshwater run-off, while others are found in near-oceanic conditions. The depth range of reefs also changes from the inner to outer Gulf, with outer Gulf reefs covering a much greater depth range than reefs in the inner Gulf, and in harbours and estuaries.

Reefs on Coromandel Peninsula, Aotea (Great Barrier Island) and on islands of the eastern Coromandel coast are largely of volcanic origin. Volcanic formations on Coromandel Peninsula and Aotea (Great Barrier Island) overlay ancient basement rocks (greywacke), which were formed on the seabed around 140 to 250 million years ago. Pockets of greywacke reef occur in the northern half of Coromandel Peninsula and Aotea (Great Barrier Island), with the largest pockets found at their tips. Reefs from the western Firth of Thames to Maraetai and from Ponui to Mototapu islands have a similar origin but are part of the Hunua formation. These rocks also occur on Kawau Island, Tawharanui Peninsula and around Leigh. Mainland reefs on the western side of the Gulf from Maraetai north are mainly comprised of softer, more erodible sand and mudstones that were formed around 20 to 25 million years ago (Grant-Mackie 1983, Edbrooke 2001). These reefs are occasionally interrupted by small reefs formed by volcanic flows. Examples of these occur at Meola Reef, North Head, Milford Beach and Ti Point. Reefs around Rangitoto Island and Hauturu (Little Barrier Island) are of volcanic origin as well.

Coastal exposures of basement greywacke tend to form hard rocky shores with prominent headlands and bouldery to pebbly beaches. Volcanic shores on Coromandel Peninsula form hard rocky shores with bouldery beaches also, but these shores often have large amounts of mud associated with them, particularly in the southern Firth of Thames. Recent basalt reefs, such as those around Rangitoto Island and Meola Reef in the Waitematā Harbour, are jagged, irregular and extremely rocky. In contrast, Waitematā sediments are easily eroded by mechanical and chemical processes and tend to form steep, soft cliff faces, with distinct, relatively flat shore platforms and shelly, medium-fine sandy beaches (Greig 1982).

3.1.6 The Gulf's ecosystem

Marine life in the Gulf is sustained by energy from the sun (i.e. light), carbon and nutrients being captured by seaweeds (macroalgae), microscopic plants (microalgae including phytoplankton) and other plants (such as seagrass, mangroves and other coastal vegetation), and by being passed up the food chain. Carbon is freely available, so plant growth is generally limited by the availability of light and nutrients. The main nutrients are nitrogen and phosphorus, with nitrogen being the most important for plant growth in the Hauraki Gulf because its supply is highly variable, whereas phosphorus tends to be more readily available (Broekhuizen *et al*. 2002).

Productivity varies seasonally, due to the balance between light and nutrient availability. Pulses of nitrogen-rich water from the outer Gulf, together with the mixing of the water column and seasonal variation in light, play pivotal roles in phytoplankton growth. Intrusions of nitrogen-rich bottom water from the outer Gulf and the remobilisation of deposited nitrogen cause nitrate concentrations to be greatest near the seabed of the inner Gulf. The flow of nutrients between relatively dark bottom waters, where algae growth is limited by low light levels, to bright surface waters, where growth is limited by the supply of nutrients, has a significant influence on primary production. However, seasonal stratification of the water column creates a barrier in the water column, which obstructs nutrient mixing and affects primary production.

Stratification is caused by:
– freshwater inputs which produce a buoyant, low-salinity layer that “floats” on heavier, high-salinity bottom waters; and
– high summer temperatures, which warm the upper part of the water column causing water in it to rise and form a distinct surface layer that “floats” on the cool bottom waters.

In the Firth of Thames, freshwater run-off from the Waihou and Piako rivers causes a moderate amount of salinity-driven stratification in winter and early spring. Short winter days and the trapping of nutrients in dark bottom waters limit algae growth over this period. During late spring and early summer the water column becomes alternately mixed and stratified, as the influence of freshwater inputs decrease and the influence of temperature increases. Productivity rises dramatically in summer, when surface waters warm up and sustained temperature-driven stratification traps nutrients in bright surface waters. In late summer, nutrients become depleted in the surface layer and, consequently, productivity decreases again (Chang *et al*. 1995, Broekhuizen *et al*. 2002).

In reality, this simplistic description of microalgae productivity is complicated by climatic conditions (and their effect on upwelling, mixing and nutrient supply) at the scales of days, weeks and years (Broekhuizen *et al*. 2002, Zeldis *et al*. 2005). As a result, large variations in microalgae concentrations occur from year to year and microalgae are not uniformly spread around the Gulf.

Microalgae are consumed by planktonic invertebrates that live in the water column. These grazers are subsequently eaten by other invertebrates and fish which, in turn, are consumed by a series of other animals. The zooplankton community is composed of fish and invertebrates that either:
– spend their whole lives in the water column;
– have a dispersive larval phase that is spent in the water column, but at later stages settle on the seabed where they develop into adults and remain; or
– regularly move between the seabed and the water column.

Most sessile (i.e. relatively immobile) species rely on a planktonic dispersal phase to spread and colonise new space.

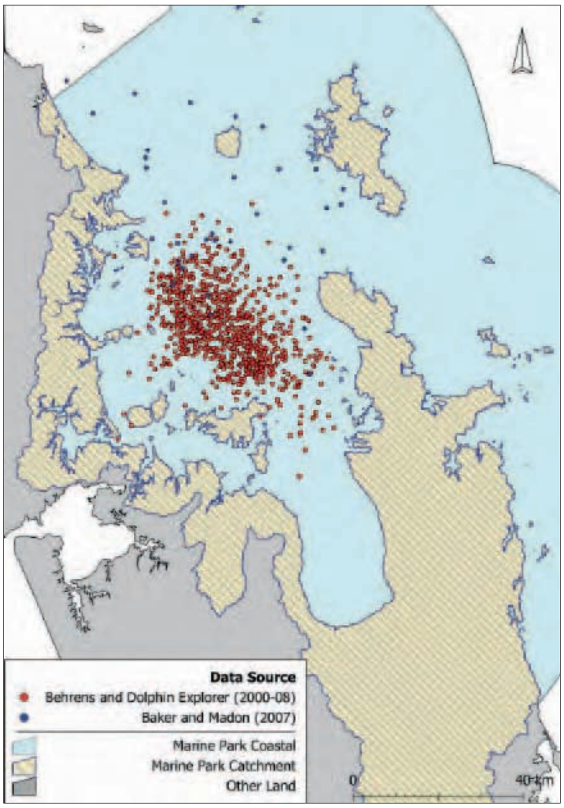
Schools of crustaceans (such as krill, *Euphausia superba*) and plankton-feeding fish such as anchovies (*Engraulis australis*), pilchards (*Sardinops sagax*) and saury (*Scomberesox saurus*) occur throughout the Gulf. Tight concentrations of these small animals commonly lead to “feeding frenzies”, with a variety of predators attacking from the sea and air. Swarms of kahawai, jack mackerel, snapper and kingfish attack from the sides and below, while gannets (*Morus serrator*), shearwaters, petrels (*Procellariidae*) and terns (*Laridae*) strike from the air. Larger mammalian predators such as short-beaked common dolphins (*Delphinus delphis*), common bottlenose dolphins (*Tursiops truncates*) and Bryde’s whales also feed on the small fish and crustaceans involved in such “boil-ups”. Bryde’s whales are present in the Gulf year-round and are frequently seen feeding in, or moving through, central to outer parts (Baker and Madon 2007, Behrens 2009) (Figure 6). In New Zealand their prey is likely to include krill (*Euphausia superba*), saury (*Scomberesox saurus*), anchovy (*Engraulis australis*), garfish

(*Hyporhamphus ihi*), jack mackerel (*Trachurus declivis*), pilchard (*Sarninops sagax*) and sprat (*Sprattus antipodum*) (Behrens 2009). Schools of these fish and crustaceans are therefore considered to be critical for the continued survival of Bryde's whales in the Gulf (pers. comm. Rochelle Constantine, University of Auckland).

Figure 6: Bryde's whale (a) emerging at the surface while feeding on a school of fish (photo courtesy of Stephanie Behrens), and (b) sightings recorded by Stephanie Behrens and Dolphin Explorer from 2000 to 2008 (red dots), and presented in Baker and Madon (2007) (blue dots).

A.

B.



Sediments are the most extensive seabed habitat in the Gulf. Their characteristics vary widely due to differences in grain size, organic matter and the relative amounts of shell and mineral material. Sediments are formed into sand and mudflats, channels, spits, dunes and corrugations. They vary along texture gradients and are moulded into a patchwork of composition and relief by waves, eddies and currents. This habitat complexity is further enhanced by interactions between sediments, currents, depth, water conditions and biology.

Sediment-based ecosystems have been extensively studied in a number of the Gulf's estuaries. The sheltered coastal margins of estuaries commonly contain a band of coastal saltmarsh, with dense plant patches which provide habitat for secretive native birds, such as the fernbird and the banded rail. Saltmarsh habitats usually have a discrete margin that adjoins open sediment flats, shell banks or mangrove forest. Historically, the extent of mangrove forests has been relatively limited, but in recent years mangroves have expanded in many places (Morrisey *et al.* 2007a). Seagrass meadows occur beyond the mangrove zone in many of the Gulf's estuaries. Seagrass can form extensive beds, which extend from the intertidal to shallow subtidal zone, but it also occurs in much smaller patches.

Estuaries are highly productive ecosystems that support large numbers of shellfish and other animals. The animal communities living in estuary sand and mudflats are maintained through the energy they derive from microalgae, which is filtered from the water column (by filter feeders) or collected from the seabed (by deposit feeders). In turn, filter and deposit feeders are consumed by predatory invertebrates (such as whelks), fish and birds. Animal distributions within estuaries are driven by physical, chemical and biological processes that operate on a range of different scales. On the estuary-wide scale, ecological processes reflect the response of individual species to broad-scale variation in factors like sediment texture, sediment inputs, tidal inundation, currents and freshwater inputs. On smaller scales, the characteristics and behaviour of individual species and interactions between species become increasingly important (e.g. Thrush 1989).

Open-coast sediment systems are made up of a patchwork of benthic species, whose broad-scale distributions frequently overlap. Within this mosaic, populations of individual species often occur in very discrete, high-density beds with clearly defined margins. Well-known examples include green-lipped mussels and horse mussels, scallops and sand dollars, but many other species are also distributed in this manner. Densities and absolute numbers of individual species can be extremely high within these beds. For example, Taylor and Morrison (2008) estimated that an approximate 1.5 km^2 patch of clams (i.e. the morning star shell, *Tawera spissa*) in Omaha Bay contained around 1.4 billion individuals. Depth, sediment, waves and currents appear to influence species distribution in near-shore coastal areas (Thrush *et al.* 2001, Taylor and Morrison 2008, Chiaroni *et al.* 2008), but there is little information on benthic systems further from shore.

Diversity can be very high in open-coast sediment systems. For instance, 204 taxa were recorded in the suction and grab samples collected from Omaha Bay (Taylor and Morrison 2008). Species that protrude above the seabed, such as horse mussels, increase diversity by providing hard substrates that are colonised by a variety of other sessile species (Thrush *et al.* 2001), and refuges for fish (Usmar 2009) and mobile invertebrates such as lobsters (Kelly *et al.* 1999). These habitats tend to be sensitive to physical disturbance and can be very slow to recover (if at all). Historically, extensive and dense beds of green-lipped mussels covered large parts of the seabed in Tamaki Strait and the Firth of Thames (Reid 1968, Greenway 1969).

The interface between reefs and sediments is an important zone for a number of species which use the reefs as a refuge and forage out on the surrounding sandflats. Probably the most impressive species to display this behaviour is the crayfish (actually spiny lobsters, *Jasus edwardsii*), which gather on the reef margin to replenish themselves after not eating for weeks to months during the mating and moulting seasons. In protected areas where populations have recovered, hundreds of crayfish pile up on the reef margin during the day before moving out on to the sandflats to forage at night (Figure 7).

Figure 7: Crayfish gathering on the reef margin in Tawharanui Marine Park prior to moving out on to the surrounding sandflats to forage.

Trawl surveys conducted by the survey vessel Kaharoa in the 1990s indicate that the biomass of fish living near the seabed (i.e. demersal fish) in the Hauraki Gulf is dominated by snapper (*Pagrus auratus*). Total fish biomass and snapper biomass tend to be highest in southern parts of the inner Gulf and the Firth of Thames (Figure 9), even though snapper utilise many habitats and can occur in most parts of the Gulf. Although fish biomass is dominated by snapper, this species may not be the most abundant fish in the Gulf. For instance, it is estimated that Omaha Bay alone could contain up to 4 million worm-eels (*Scolecenchelys australis*), which are small snake-like fish that are rarely seen owing to their burrowing behaviour (Taylor and Morrison 2008).

The distribution and abundance of other fishes varies in relation to species-specific adaptations. Many have evolved to occupy very specialised niches. For instance, kelp-eating butterfish are mainly found within a narrow depth band on reefs that are exposed to surge and with extensive kelp cover.

They are most common in water depths of less than 10 m, where, in northern waters, they browse almost exclusively on the brown seaweeds, flapjack (*Carpophyllum maschalocarpum*) and paddle weed (*Ecklonia radiata*). Marblefish are also herbivorous and commonly live in the same areas as butterfish, but they prefer to graze on leafy red and green seaweeds (Clements 2003). In contrast, many other fish species have much broader distributions and inhabit large, and relatively diffuse, areas in the Gulf. However, the distribution of fish is invariably patchy with individual species tending to be more abundant in some parts of the Gulf than others (Kendrick and Francis 2002).

Some habitat features appear to be particularly valuable in terms of sustaining fish diversity and abundance. Physical or biological features that add structural complexity in otherwise featureless habitats are especially important for juvenile fish. For example, small sandstone reefs with adjoining beds of Neptune's necklace (*Hormosira banksii*) and mangrove forest act as nursery habitat for juvenile parore (*Girella tricuspidata*) in Whangateau Harbour, and are thought to be the main source of adult parore on coastal reefs in the Leigh area (Morrison 1990). Subtidal seagrass is an important nursery habitat for a variety of fish species including snapper, trevally, parore, garfish/piper, spotties and triplefins. Horse mussel (*Atrina pectinata zelandica*) beds act as nursery habitat for snapper (Usmar 2009), while mangroves provide nursery habitat for short-finned eels (*Anguilla australis*). Sponge, maerl and kelp beds may perform similar functions also (Morrison *et al.* 2009).

In general, fish diversity and abundance are more concentrated on reef or physically complex habitat than they are in two-dimensional habitats such as sand or mudflats. Similarly, reefs provide a stable surface for the attachment of seaweeds, sponges and a variety of other organisms. Seaweeds are important habitat-formers that support diverse and productive assemblages of small mobile invertebrates. These small animals contribute about 80% of energy flow and materials through rocky-reef animal communities (Taylor 1998). The lower limits of seaweed distributions are set by light availability. The depth range of individual seaweed species is therefore narrower in the inner Gulf where light levels are reduced by high water turbidity (Grace 1983).

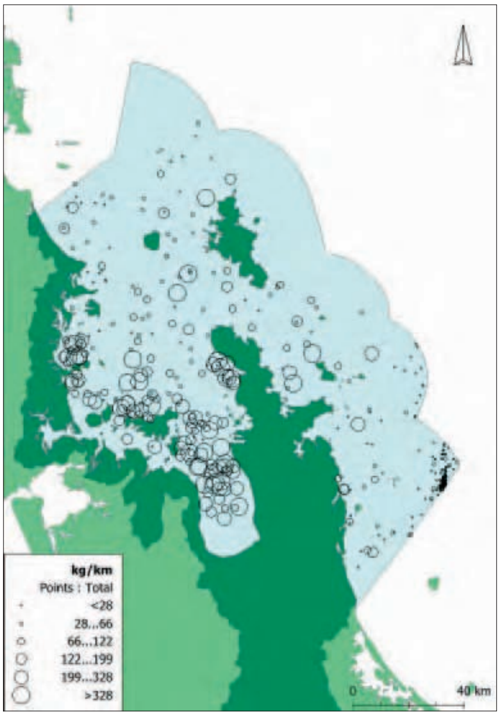
Figure 8: Fish schooling around reefs in Tawharanui Marine Park.

3.1.7 Terrestrial ecology

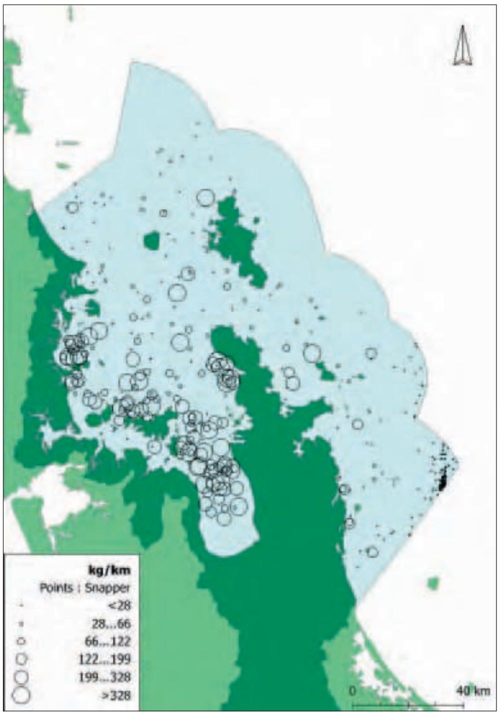
For thousands of years prior to the arrival of humans the Gulf's catchments were completely covered by forest or wetlands, apart from small flood-prone river terraces, steep cliffs, active sand dunes and areas that were recently disturbed by volcanism, slips from other natural events (McGlone 1989). Most terrestrial plants and animals had evolved over millions of years in isolation from the rest of the world, but occasionally invertebrate, reptile, bird and plant species managed to find their ways to New Zealand by the westerly wind drift and island hopping. Other than bats, no land mammals existed. Native birds, reptiles and insects therefore filled the niches occupied by mammals elsewhere. Birds took on the roles of large grazing herbivores (such as moa), fearsome predators (such as Forbes' harrier) and tiny ground-dwelling insect feeders (such as flightless wrens). Some insects, such as weta, also filled the niches of small rodents in other parts of the world, which play a similar role to mice in New Zealand's forests (Flemming 1977). Weta and mice have similar sizes, nocturnal foraging habits and diet. They both use diurnal shelters, display polygamy and even have similar droppings. Seabirds were abundant also and comprised a large proportion (30%) of the total bird fauna (Craig *et al.* 2000).

The lack of ground-dwelling predators led to the evolution of flightlessness and gigantism in birds and insects, with many species using concealment rather than flight to elude airborne attackers (Trewick *et al.* 2005, Tennyson and Martinson 2006). New Zealand birds, reptiles and insects also tended to be long-lived and have slow breeding rates. These characteristics are typical of species that evolved of oceanic islands without predatory mammals, but they ultimately doomed New Zealand's native fauna when exotic mammals were introduced by humans (Daugherty *et al.* 1993, Tennyson and Martinson 2006).

Figure 9: Spatial variation in (a) total fish biomass and (b) the biomass of snapper (dot size). Data was obtained from MFish trawl surveys conducted by the research vessel Kaharoa in the 1990s and was standardised to 1 km trawl lengths.



A.



B.

3.2 Human impacts

Humans have had a major, and predominantly unidirectional, impact on the Gulf ever since the arrival of Māori around 1200 to 1300 AD and Europeans in the early 1800s. The effects of Māori settlement in New Zealand are well documented. Ogden *et al.* (2006) summarises these as:

- extinctions or drastic reductions of many small bird, vertebrate and invertebrate species, largely due to the rapid spread of kiore (Rattus exulans);
- extinction of the large birds by hunting (especially moa);
- direct and indirect impacts on coastal marine mammals, fish and shellfish;
- destruction of forest vegetation by fire; and
- consequential effects of increased erosion and sedimentation.

Māori used fire to clear forests from large parts of the country (McGlone 1983, Ogden *et al.* 1998). For instance, the Tāmaki Makau Rau, Auckland isthmus, had been cleared of larger trees by the time Europeans arrived, apart from the remnants of bush that still remained in steep gullies (Stone 2001). Fire had also cleared forests in areas such as Aotea (Great Barrier Island) and Kauaeranga Valley on Coromandel Peninsula (Byrami *et al.* 2002, Ogden *et al.* 2006), which led to associated increases in estuary sedimentation (Ogden *et al.* 2006). Across New Zealand, Māori hunting eliminated 26 species (30%) of land bird and 4 (18%) species of the seabird, while ecosystem loss and companion animals eradicated a further 8 land birds (Craig *et al.* 2000). Māori hunting also removed fur seals from the Gulf (Smith 1989) and annual harvests of thousands of tons of snapper were potentially caught in pre-European New Zealand (Leach 2006, Parsons *et al.* 2009). Tuatara, some lizards and some invertebrates were also displaced from the mainland, and became restricted to relatively small offshore islands (Craig *et al.* 2000).

However, the rate of environmental degradation increased rapidly after 1840, as European settlers harvested or cleared forest for timber, towns and agriculture, and introduced a new wave of exotic mammals. This modified or replaced natural habitats, caused widespread erosion and led to a new series of extinctions (Craig *et al.* 2000, Swales *et al.* 2002, Hatvany 2008). Nationally, a further 16 land birds were driven to extinction, together with a bat, a fish and a number of invertebrates and plants. Most of the remaining terrestrial fauna declined and many are continuing to do so. The majority of native birds, bats, lizards, frogs and invertebrates are now characterised by low population densities or local extinction, range contraction and severe population fragmentation. Offshore islands provide the sole refuge for both species of tuatara, 37% of lizard species and many birds (Craig *et al.* 2000).

The history of the Hauraki Plains and Firth of Thames probably provides one of the most poignant examples of environmental degradation and habitat loss in the Gulf and its adjoining catchment. These changes have an ongoing legacy in terms of their cumulative, long-term and large-scale impacts on the Gulf.

Polynesian forest burning around Thames occurred as a series of discrete fires starting around 630 to 810 years ago[5], which initially did not devastate the forests but did have an adverse cumulative effect over time (Byrami *et al.* 2002). New Zealand tree species are generally killed by fire and neither re-sprout nor re-establish from buried or shed seeds. Therefore, when fire occurs the original vegetation is destroyed and a prolonged succession begins, taking centuries for the original forest structure and composition to re-establish (Ogden *et al.* 1998). However, the Hauraki Plains wetland, which was the largest in New Zealand, was largely intact when Europeans first arrived. This wetland had developed over thousands of years (Newnham *et al.* 1995) and, for Māori, was an important food basket that provided waterfowl, fish and edible plants (Hunt 2007).

From 1875 to 1920 the landscape of the Hauraki Plains was completely transformed, through the logging of kahikatea (white pine), diking and canalising of rivers, and drainage of the land. Forests of giant kahikatea, which thrived in the wetlands, were felled and used for butter boxes, rabbit crates and packing cases to support trade between New Zealand, Australia and Britain. Wet and low-lying land was then drained for dairy farming. This industry took off in the late 1880s thanks to the advent of refrigeration, which made bulk dairy sales to British markets a lucrative New Zealand trade. By 1910, fewer and fewer kahikatea were being milled, and cross-cutters were being sent out into swamps to clean up by stumping and burning, as well as scattering grass seed, turning "useless swamp into rich farmland" and building stopbanks "to prevent the tide backing up over the flats" and "the rivers from spreading where they chose". Most of the Hauraki flood plain was eventually logged, drained and transformed into a geometric grid of dairy farms and embanked rivers (Hatvany 2008). The exception is the 7,000 ha Kopuatai peat dome which was too low-lying to be developed into farmland.

The conversion of wetlands on the Hauraki Plains to intensive dairy farms provided employment and made a substantial, and ongoing, contribution to the local (and national) economy. However, it also led to the loss of an important taonga for Māori and the destruction of an extremely valuable terrestrial ecosystem. It exacerbated sediment and nutrient loads, and at the same time compromised the ability of the natural drainage system to filter water and strip these contaminants prior to them flowing to the Gulf. Kauri logging and mining on Coromandel Peninsula increased erosion and sediment run-off as well, while mining also produced a legacy of heavy-metal contamination (Kim 2007, Harding and Boothroyd 2004, Napier *et al.* 2009).

The impacts of these, and other, activities on the Firth of Thames have been dramatic. On average, over the past 6,500 years the southern coastal margin of the Firth of Thames has shifted seawards at a rate of around 2 km every thousand years (i.e. 2 m per year). However, the rate of sedimentation and seaward expansion appears to have increased significantly during the past 50 years or so. These changes are closely linked to historical increases in sediment loads following catchment deforestation and river works.

Until the mid-1940s, tidal flats in the southern Firth of Thames were composed of gently-sloping muddy-sand flats that were largely free of mangroves. From the 1940s onwards, there was a marked shift in sediment texture from sand to mud, and by the mid-1960s the former muddy-sand flat had been replaced by mudflat (Swales *et al.* 2008). Mangroves began to colonise the upper mudflat in the mid-1950s, and rapidly expanded seawards (Figure 10). Mangroves have a preference for soft, muddy, waterlogged sediments, and readily colonise areas where gradual sediment accretion creates habitat with suitable sediment characteristics and elevation. The level of the substratum must be sufficient to expose seedlings to the air for part of the tidal cycle, because very young seedlings are intolerant of continuous submersion (Morrisey *et al.* 2007a). The expansion of mangroves is therefore a natural response to the increase in land erosion and sediment run-off caused by human activities, which led to coastal infilling in the southern Firth of Thames (Figure 11).

5. Based on pollen data collected from Kauaeranga Valley.

By the mid-1970s, surface elevations within the forest were one metre above the adjacent mudflat. Consequently, the supply of sediment to this area declined and the forest became progressively isolated from the mudflat. However, large quantities of sediment were still being trapped and deposited along its seaward margin (average accumulation rate of 100 mm per year-1). Sedimentation rates in this area increased two to ten-fold, and by the mid-1980s, a wide mud platform of several hundred metres had formed along the margin of the old mangrove forest. This platform was raised 0.8 to 0.9 m above mean sea level and gradually became colonised by mangroves until the early 1990s, when a period of rapid mangrove expansion and infilling occurred. Overall, mangroves have expanded by about 900 to 1,000 m into the southern Firth of Thames since this process began (Swales *et al*. 2008).

There is little doubt that the expansion of mangroves led to the loss of ecologically diverse and productive open intertidal sand and mudflats. Although empirical data is not available, it is inevitable that the extent and abundance of mud-sensitive benthic species (such as cockles and wedge shells) would have been reduced. The spread of mangroves has also altered the distributions of roosting shorebirds, with areas that formerly held substantial quantities being abandoned and some species declining in number (Battley and Brownell 2007). Displacement has been particularly noticeable for wrybills (*Anarhynchus frontalis*), golden plovers (*Pluvialis fulva*), red knots (*Calidris canutus*) and whimbrels (*Numenius phaeopus*). However, mangrove expansion has increased available habitat for birds that feed, roost or breed within them.

Similar patterns of land development and associated sediment run-off were repeated throughout the Gulf, albeit at smaller scales. In most of the estuaries studied, sediment accumulation rates increased after 1840, and again after 1950 (see Section 4.5). Mangrove expansion has frequently followed (Morrisey *et al*. 2007a, Section 4.5), and has also been potentially encouraged by other factors such as warmer temperatures, elevated nutrient levels and hydrological obstructions (e.g. causeways) (Morrisey *et al*. 2007a).

Figure 10: Expansion and infilling of mangroves in the southern Firth of Thames between (a) 1952, (b) 1977 and (c) 2006. Imagery provided by Waikato Regional Council and Terralink International Ltd. Copyright reserved.

A.

B.

C.

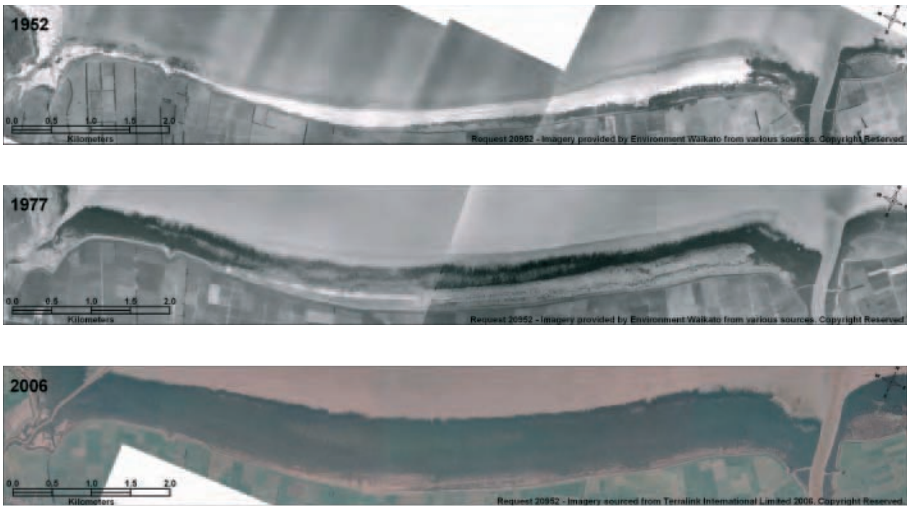
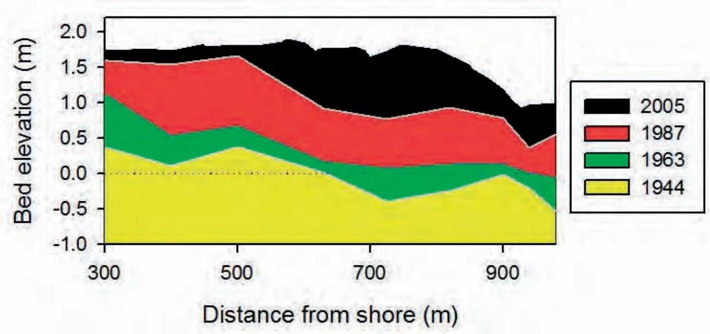


Figure 11: Changes in bed elevation along a shore profile in the southern Firth of Thames between 1944 and 2005 (see Swales *et al*. 2008).



The conversion of a wetland ecosystem to farmland not only led to elevated sediment run-off but also increased nutrient loads to the Firth of Thames (Judge and Ledgard 2009). Historically, the Firth is thought to have been oligotrophic (i.e. to be low in nutrients and algal growth). However, it is now nutrient enriched with nitrogen loads dominated by catchment (mainly from the Waihou and Piako rivers) rather than oceanic sources, as they were in the past (Zeldis 2008). As a consequence, the Firth is probably more productive today than it was in previous times, but water quality (in terms of nutrient levels, colour and clarity) is likely to have diminished.

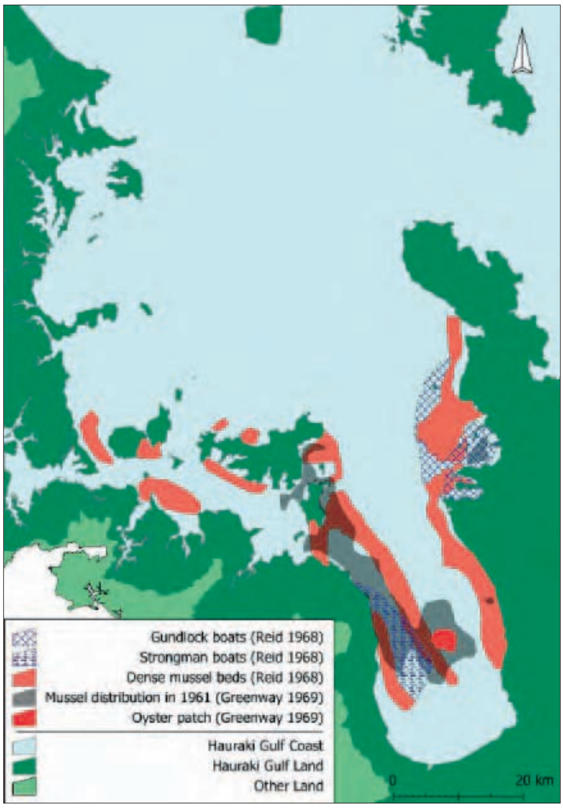
Although direct habitat destruction initially occurred on land, it did not stop there. During the 20th century, fishing directly led to the destruction of what was nominally one of the most valuable marine habitats in the Gulf: extensive subtidal mussel beds in the inner Gulf and the Firth of Thames (Figure 12). Researchers have only recently begun to appreciate the critical role that large and structurally complex, habitat-forming biota such as green-lipped mussels, horse mussels and sponges play in ecosystem processes. Such species are regarded as "ecosystem engineers", because they have a strong influence on other species and the local ecosystem. For instance, large species that grow on the seabed, such as green-lipped mussels, increase local biodiversity by providing complex, three-dimensional habitat in an otherwise flat environment. They provide attachment surfaces for algae and immobile invertebrates, refuge for small mobile vertebrates, foraging areas for adult fish and probably act as important nursery habitats for juvenile fish. High-density populations of mussels can filter vast amounts of water, which increases exchange between the sea floor and the water column (bentho-pelagic coupling) and may exert strong controls on phytoplankton populations and eutrophication effects (Morrison *et al*. 2009).

These beds once supported a commercial dredge fishery which operated from the 1920s to the 1960s, when the fishery finally collapsed due to very low mussel densities (Reid 1968, Greenway 1969). Surveys of the inner Gulf and Firth of Thames carried out in 2002/03 found that the mussel beds had not recovered, even though fishing had ceased 40 years earlier. Only small clumps of mussels were found at two sites, the biggest being about 1 m^2 in extent (Morrison *et al*. 2002, 2003). A more recent study of remnant mussel beds in the Hauraki Gulf documented a larger bed off Waimangu Point on the north-western side of the Firth, which was spread across an area of approximately 64 ha (McLeod 2009). That study found also that:

- mussel beds in the Gulf have the highest animal (secondary) productivity rates of any marine habitat yet recorded in New Zealand, with most productivity coming from the mussels and small mobile invertebrates;
- mussel harvesting is estimated to have reduced secondary production by small mobile invertebrates by 390 to 33,000 tonnes per year (dry weight), which could have supported 200 to 16,000 tonnes of small predatory fish (wet weight) per year;
- average fish density on mussel beds was 10 times higher than in adjacent sandy areas; and
- based on upper estimates of mussel density, historical mussel beds could have filtered the entire volume of the Firth of Thames in less than a day, whereas remnant beds would take nearly two years.

Populations of individual fish and invertebrate (e.g. crayfish) species became increasingly affected by industrial fishing also, which depleted their biomass, changed the age and size structure of their populations (by removing old and large individuals) and eliminated the display of some intrinsically special and ecologically important behaviours, such as snapper spawning aggregations (Leach and Davidson 2000, Parsons *et al.* 2009, Ministry of Fisheries Science 2010).

Figure 12: Historical distribution of green-lipped mussel in the inner Hauraki Gulf and Firth of Thames (from Morrison *et al.* 2009 and based on original maps in Reid 1968 and Greenway 1969). Reid (1968) used interviews with the two families that dominated the mussel fishery to draw maps of where the dense mussel beds once were, as well as additional areas fished by either Strongman or Gundlock boats (which used various types of dredge, and boats with different towing power). Greenway (1969) drew a map of mussel distribution based on his 1961 survey (206 stations), as well as identifying small areas of dredge oysters in the centre of the Firth of Thames.



Urban development has had a major impact in the Auckland Region too, particularly on the Waitematā Harbour and Tāmaki Inlet. The complex shorelines and numerous tidal inlets of these estuaries provided easy access to seafood resources, sheltered anchorages and tauranga waka (canoe-landing sites), and formed coastal "highways" that connected Māori and European settlements. However, the indented nature of the shoreline also impeded catchment, and road and rail development, which became increasingly important in the 20th century. In addition, tidal inlets accumulated sediments and urban contaminants that were washed into the sea with stormwater run-off (Mills and Williamson 2008). As Auckland grew from a small settlement in the 1840s to the largest city in New Zealand, it progressively sprawled across the catchment of Waitematā Harbour and beyond (Figure 13). Consequently, over the past 100 years or so, most tidal inlets in Waitematā Harbour and Tāmaki Inlet have been progressively modified by: reclamation; bridge, causeway, weir and dam construction (Figure 14); and contaminated sediments. These effects are compounded by modifications to the foreshore and seabed for port and boating activities. For instance, an assessment carried out in 1983 estimated that 45% of the shoreline between North Head and the Auckland Harbour Bridge had been modified by reclamation, and 24% of the harbour had been claimed by wharves, breakwaters, embankments, causeways and other uses (Dromgoole and Foster 1983). Further encroachment into the harbour has occurred since that assessment was carried out.

Figure 13: Auckland urban sprawl between 1870 and 2001.

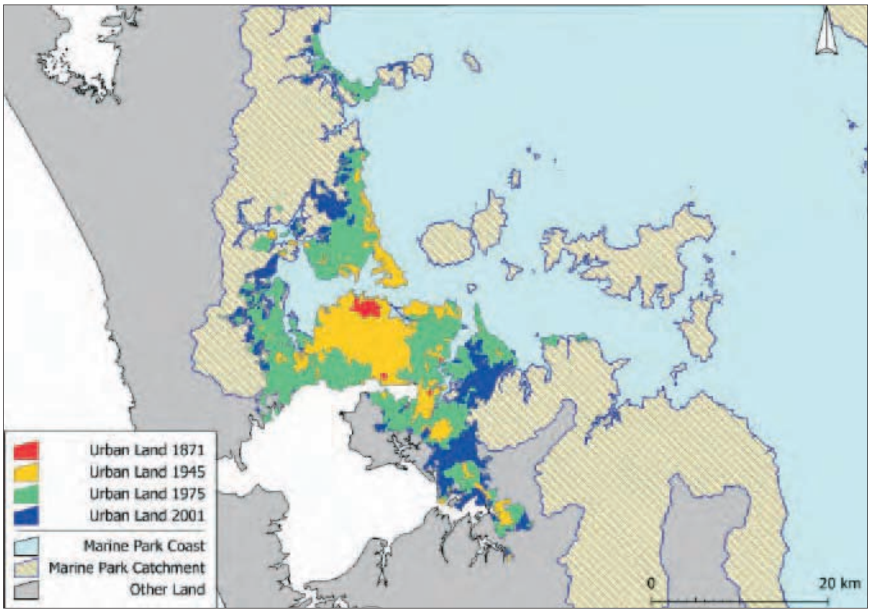


Figure 14: Segmentation of Okahu and Hobson bays by rail and road causeways, reclamation, breakwaters and pipelines. (Photo courtesy of the former Auckland Regional Council.)

Sewage disposal has also been a major issue for Auckland. Night-soil was originally collected in the developing settlement of Auckland. However, large amounts of sewage and horse droppings still ended up in a foul open channel, Ligar Canal, which ran down Queen Street and into the Waitematā Harbour. Construction of a sewer to address the problem commenced in 1854, but the appalling condition of the canal persisted for many years, such that in 1870 the NZ Herald ran an article which described the canal as: "That abomination, the Ligar Canal, is still a pestiferous ditch, the receptacle of every imaginable filth, bubbling in the noonday sun". Mounting intolerance of night-soil collection saw the eventual construction of a reticulated sewer system with an outfall at Okahu Bay, which began operation in 1914. Sewage was held in tanks (which now house Kelly Tarlton's aquarium) and discharged on the upper half of the tide, after being screened to remove larger solid material. The discharge of crude sewage on to shellfish beds directly opposite the ancestral village of Ngāti Whātua was a grievous insult to the tribe. The disposal of human waste to water, especially in such great volumes, offends all sensibilities of Māori people, particularly in proximity to the main habitation place, profaning that which is sacred.

By 1920, it was apparent that the waters around the Orakei outfall and adjacent shores were polluted and the discharge of effluent there a menace to health (Fitzmaurice 2009). In 1933 raw sewage was also discharged from two outfalls at both Devonport and Takapuna, and septic tank effluent was released through a single outfall at Northcote as well (Hounsell 1935). The discharge from Orakei continued until 1960, when sewage from there was finally diverted to the Mangere Wastewater Treatment Plant (Fitzmaurice 2009). The diversion of wastewater to Mangere and other metropolitan treatment plants undoubtedly improved water quality in Waitematā Harbour and the inner Gulf. However, large parts of Auckland are still serviced by the old sewer network, which causes ongoing issues in terms of network capacity and overflows after rainfall events (Figure 15).

Figure 15: Combined wastewater and stormwater overflowing from a constructed discharge point following a heavy rainfall event.

The diversion of sewage to the Mangere Wastewater Treatment Plant is probably the most significant engineering projects to be carried out, in terms of its positive effect on water quality in the Gulf. However, smaller-scale wastewater projects have been undertaken in many other areas too, in order to protect or improve water quality and meet the wastewater demands of a growing population. These schemes have provided centralised treatment, improved the performance of wastewater networks and treatment plants, and reduced the effects of discharges on the Gulf. Over the past 10 to 20 years, a variety of programmes have also been initiated to minimise the scale and magnitude of stormwater contamination and coastal sedimentation. These programmes are using a combination of regulation, technological development, infrastructure and community initiatives.

Perhaps the greatest environmental achievements in the Gulf are related to the protection and restoration of its islands, and the protection of marine areas through the establishment of five marine reserves and the Tawharanui Marine Park. These initiatives provide small, but critical, refuges for threatened bird, reptile and invertebrate species, and marine communities. Introduced mammalian predators and herbivores have been eradicated from eight islands in the Gulf, and another 20 islands have been kept free of these pests. Tiritiri Matangi has been replanted with native trees, and similar restoration is now occurring on Motuihe, Motutapu and Moturoa islands. A variety of threatened birds and reptiles have also been reintroduced to pest-free islands of the Gulf, where populations are now increasing. In addition, populations of heavily exploited species such as lobster and snapper have rebuilt to more natural levels in protected marine areas (Kelly *et al.* 2000, Willis *et al.* 2003). This has caused surprising changes in the broader functioning and productivity of the protected ecosystems (Babcock *et al.* 1999, Shears and Babcock 2002), and once again illustrates how the effects of humns have led to unanticipated environmental consequences.

3.3 Strategic considerations

1. The Hauraki Gulf and its ecosystem developed in isolation over millions of years. The history of human occupation of the Gulf and surrounding land is relatively short, but the effects of human activities have been profound, particularly over the past 150 years or so. In all but a few instances environmental changes have been negative and unidirectional, such that nearly every part of the Hauraki Gulf has been modified by human activities. Key components of the natural ecosystem, such as subtidal mussel beds and fish populations, have effectively been lost or significantly reduced.
2. The highly successful protection and ecological restoration of islands in the Gulf has provided a “lifeline” for native flora and fauna. These refuges are essential for the ongoing survival of threatened species which can no longer live on the mainland. Similarly, marine reserves and the Tawharanui Marine Park have allowed populations of heavily fished species such as snapper and crayfish to rebuild within them.
3. Indicators used to assess the current state of the environment should be considered relative to natural, baseline conditions in the Gulf. Failure to use a natural reference point will almost invariably lead to a sliding baseline, which will result in a sequential worsening of environmental quality over successive generations.

4.

Environmental Indicators

4.1 Fisheries

The purpose of the Fisheries Act (1996) is to provide for sustainable utilisation of fisheries resources. New Zealand's fisheries are managed with a quota management system, which was introduced in 1986 to address a concerning decline in some fish stocks. Under this system, New Zealand's coast is divided into quota management areas (Lock and Leslie 2007). The Minister of Fisheries must set the total allowable catch (TAC) in tonnes for quota species within each quota management area. The Minister must allocate the TAC between the customary, recreational and commercial fishing sectors. Allowance is also made for incidental mortality that is caused by fishing. Priority is given to ensuring that there is sufficient allowance for customary harvest, with the remaining catch being allocated between the commercial and recreational fishing sectors (Lock and Leslie 2007). The Minister is required to set a total allowable catch that will maintain each the stock at, or above, a level that can produce the maximum sustainable yield (or work towards doing so). The legislation also requires all sustainability decisions to take into account: effects on associated and dependent species; the maintenance of biological diversity; and, protection of habitat with particular significance for fisheries management.

The Fisheries Act specifies that the baseline for sustainable fishery stock management is the concept of maximising sustainable production or achieving the maximum sustainable yield (MSY) from stocks. The MSY is the greatest yield (catch) that can be achieved over time while maintaining the stock's ability to keep producing. The MSY for a given stock will depend on its biology and environmental influences on its population dynamics. Typically, the MSY is produced by a stock at a biomass level (BMSY) well below its unfished state, because the principle relies on achieving productivity benefits from more younger, faster-growing fish and less competition for food and space. Fish stocks are typically most productive when they are between 20%-40% of unfished levels. The Fisheries Act provides for stocks to be managed at biomass levels greater than the BMSY where various factors indicate the purpose of the Act would be better achieved by a higher target biomass. These factors can include to manage specific environmental risks, or to achieve particular social, cultural, or economic objectives.

The total allowable commercial catch for each species is shared among commercial fishery participants that own individual transferable quota (ITQ) for that species. The proportion of the total quota shares they possess is equal to the proportion of the total allowable commercial catch they are allowed to take in any fishing year. The amount of fish able to be commercially harvested is therefore tightly regulated. Owing to the reporting required for the commercial sector, it is usually relatively simple to obtain information on commercial catch levels (Lock and Leslie 2007). The Maori customary fisheries regulations ('Kaimoana' regulations) also require reporting to the Ministry of Fisheries. However, these Regulations have not been fully adopted within the boundaries of the Hauraki Gulf Marine Park and reliable records of customary fishing are not yet available for the Hauraki Gulf (Shannon Tyler, MFish Auckland, pers comm.).

In contrast, recreational harvesting is managed using measures such as seasonal closures, bag limits, size limits, restrictions on fishing equipment and locations. Reporting of recreational catch is not required, therefore recreational harvest quantities are determined through surveys and are more uncertain. Consequently, the recreational catch can change in an unknown fashion as the size of the fishing population changes, the biomass of stocks changes, patterns of fishing change, and or access to sophisticated fishing technology improves.

The quota management system arrested historical declines in key fish stocks such as crayfish and snapper (Ministry of Fisheries, Science 2010), but subsequently maintains most stocks in a reduced state, with lower biomasses and fewer old and large individuals than could be achieved if an alternative to the MSY was used as the management target. The Minister can adopt a TAC that will produce a biomass above that which will produce the MSY, and has done this for kahawai. In 2010 the kahawai KAH1 area TAC (that includes the Hauraki Gulf, but is a much larger area) was set at a level which would allow biomass to increase from the current level to 52% of the unfished biomass by 2028 (cf. 35% of the unfished biomass which would be the biomass that would produce the MSY). This was done to increase the non-commercial benefits derived from the kahawai stock.

The Fisheries Act (1996) provides for the utilisation of fisheries resources while, among other things, avoiding, remedying or mitigating any adverse effects of fishing on the aquatic environment. However, the incidental effects of fishing on most species that are not directly targeted by fishers, and on marine habitats in the Gulf, are currently not well understood and, in general, not actively managed. For instance, the ecological effects of trawling and dredging on benthic habitats have not been directly assessed in the Gulf (although a desktop assessment has been carried out for scallop harvesting – see Tuck *et al.* 2006), monitoring of benthic impacts is not being undertaken, and controls have not been developed that specifically focus on avoiding, remedying or mitigating any adverse benthic impacts. Note that there are spatial controls on activities such as trawling and dredging, but these were not implemented to specifically manage benthic impacts and, therefore, may or may not, address this issue.

A key tool for improving the management of the adverse environmental effects of fishing is Fisheries Plans. MFish has identified their development as a priority in Ministerial Briefings since at least 1999, and currently has two approved plans that are relevant to the Hauraki Gulf Marine Park:
– National Fisheries Plan for Highly Migratory Species; and
– National Fisheries Plan for Deepwater and Middle-depths Fisheries.

In addition, draft national plans for inshore finfish, shellfish and freshwater fisheries became operational as from 1 July 2011.

It is important to emphasise that, within the context of this report, the primary indicators are considered in terms of the state of the environment, not the state of the fishery. However, sustainability indicators for the fisheries have been developed by MFish and are therefore provided in Section 4.2.1 below. These are complemented by more detailed information on:
– the spatial distribution of fishing in the Gulf;
– the state of three ecologically, economically and culturally important species: snapper, crayfish and cockles for example;
– fisheries ecosystem indicators derived from trawl survey data; and
– bottom disturbance.

4.1.1 Fishing in the Hauraki Gulf

Fishing occurs in most parts of the Gulf, but regulations govern how, where and when fishing can occur. For example, regulations limit where trawling can occur, the size of vessels that can be used for trawling and/or the time when trawling can occur (Figure 16). Consequently, in recent years trawling has been confined to central and outer parts of the Gulf, whereas commercial long-lining is more widespread (Figures 17a and b). Recreational fishing is mainly concentrated along the coast, with the heaviest concentrations of effort in Kawau Bay, Rangitoto Channel, Motuihe Channel, Wilsons Bay, around Pakatoa and Tiritiri Matangi islands, and in the Motukahaua and Motuoruhi island groups north of Coromandel Harbour (Figure 17c).

The commercial catch of finfish is mainly obtained through bottom trawling, Danish seining and bottom long-lining, which together provided between 85% to 90% of the combined catch of snapper, gurnard, tarakihi, kahawai, rig, trevally and John Dory in the 2007/08 to 2009/10 fishing seasons. A smaller proportion of the fish catch is obtained by set netting, which is mainly used to target parore, flatfish and mullet.

Fish stocks in New Zealand are managed in areas called Quota Management Areas (QMAs) that are broken down into smaller units called statistical areas, which are used for reporting purposes. The Hauraki Gulf Marine Park covers fisheries' statistical areas 005, 006, 007 and parts of 003, 004, 008 and 009. This report uses data provided by MFish from the inshore statistical areas of 005, 006 and 007 to establish the main commercial inshore species within the Hauraki Gulf Marine Park. Statistical area 008 covers the inshore waters to the east of Aotea (Great Barrier Island) and Coromandel Peninsula, but it includes much deeper waters also and therefore deepwater fisheries.

Overall, around 75 different finfish species are commercially caught in the Gulf. Of these, snapper is the main commercial species in terms of the weight of the reported catch, and it is the most targeted species for commercial vessels too. In terms of their landed weight, the other important species caught within the Gulf include jack mackerel, pilchard, John Dory, gurnard, kahawai, flatfish, tarakihi, trevally, yellow-bellied flounder and leatherjackets (Figure 18 - note that deepwater species caught within statistical area 008 were not included in this figure).

Key commercially-fished invertebrates include crayfish, kina and scallops, with annual catches of crayfish varying from c. 100 to 116 tonnes between the 2007/08 and 2009/10 fishing seasons, kina varying from c. 105 to 111 tonnes, and scallops varying from c. 33.3 to 71.4 tonnes (meat weight) (data provided by MFish).

Figure 16: Areas where trawling and Danish seining is either prohibited or limits apply to the size of vessel, or times when trawling and Danish seining can occur.

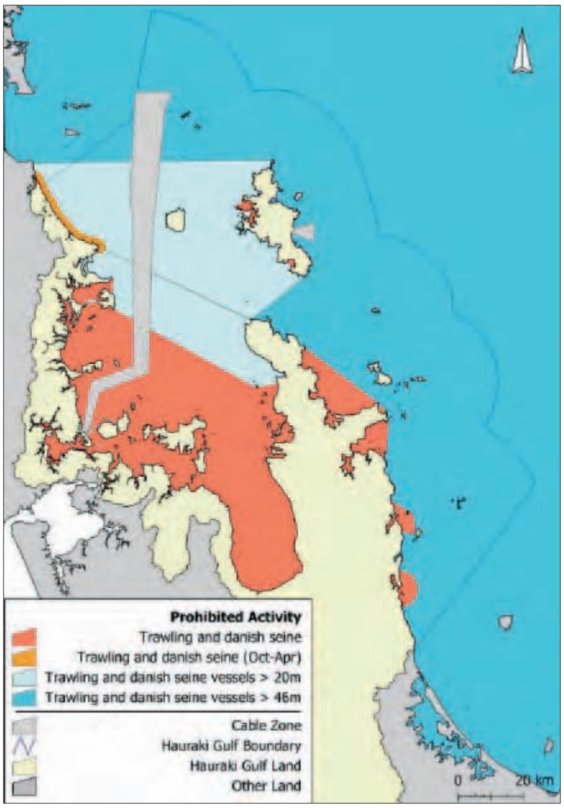
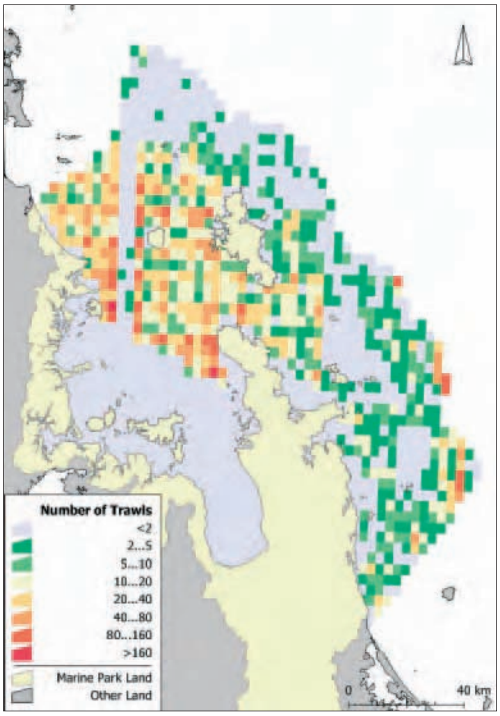
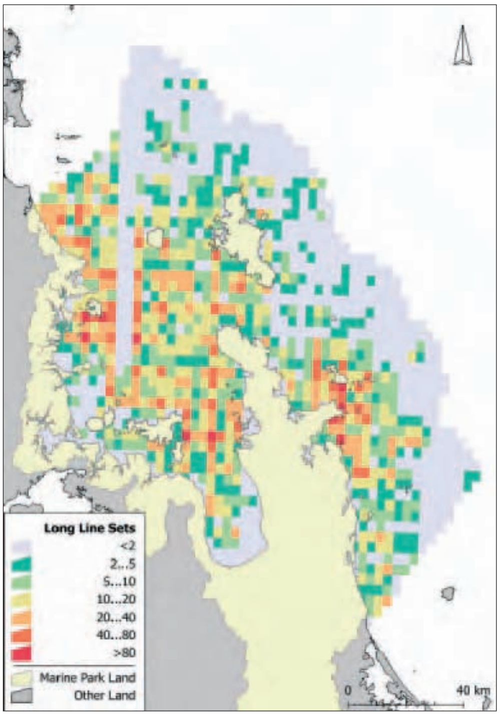


Figure 17: Spatial distribution of: (a) trawl (combined number of bottom and mid-water trawls between January 2008 and 31 December 2010); (b) bottom long-line (number of sets between January 2008 and 31 December 2010); and (c) recreational (vessels per km) fishing effort in the Hauraki Gulf. Data obtained from MFish based on reported fishing returns data and aerial survey of recreational fishing (see Hartill *et al.* (2007) and Hartill et al. (2007b)).



A.



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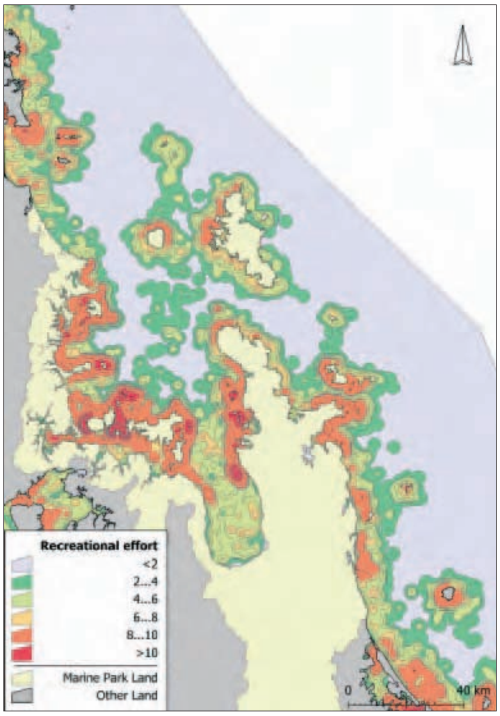


c.

4.1.2 Indicators of fisheries' sustainability

Sustainability indicators for the top 15 inshore finfish species caught in the Hauraki Gulf (by catch weight) are presented in Table 2 (below). Depending on the species, these indicators are assessed in relation to:

1. quota management areas, which are much larger than the Hauraki Gulf; or
2. for north-eastern New Zealand, Hauraki Gulf and Bay of Plenty substocks, which are contained within or include parts of the Hauraki Gulf.

The status of fisheries and stocks is characterised by MFish in the following way:

- **Overfishing:** If average fishing mortality is higher than the rate that will produce the MSY (or another appropriate target), overfishing is deemed to be occurring. Such stocks will ultimately be depleted below the biomass that produces the MSY.
- **Depleted:** If stock levels reach less than 50% of the biomass that will produce the MSY, or 20% of unfished stock levels (whichever is higher), they are depleted (or overfished) and in need of rebuilding.
- **Collapsed:** If stock levels reach less than 25% of the biomass that will produce the MSY, or 10% of unfished stock levels (whichever is higher), they have collapsed.

Of the 15 key species listed:

– Two (snapper and kahawai) are at or above target levels and not considered to be depleted or at risk of collapse.
– Another three species (pilchard, baracoutta and grey mullet) are not considered to be at risk of collapse, but not enough is known about the stocks to assess whether they are at or above target levels, or depleted.
– Overfishing of two species (tarakihi and trevally) is about as likely as not to be occurring, but can't be confirmed either way. Not enough is known about these stocks to assess whether they are at or above target levels, or depleted. The tarakihi stock is not considered to be at risk of collapse.
– For the remaining eight species the status of the stocks is unknown, because an appropriate quantitative analysis has not been undertaken or because the analyses that have been carried out have not been definitive enough to assess their status (jack mackerel, John Dory, gurnard, flatfish, yellow-bellied flounder, leatherjacket, rig and parore).

Figure 18: Total commercial catch of the key inshore finfish species caught in the fisheries' statistical reporting areas 005, 006, 007 and 008 (i.e. the shaded areas shown on the map).

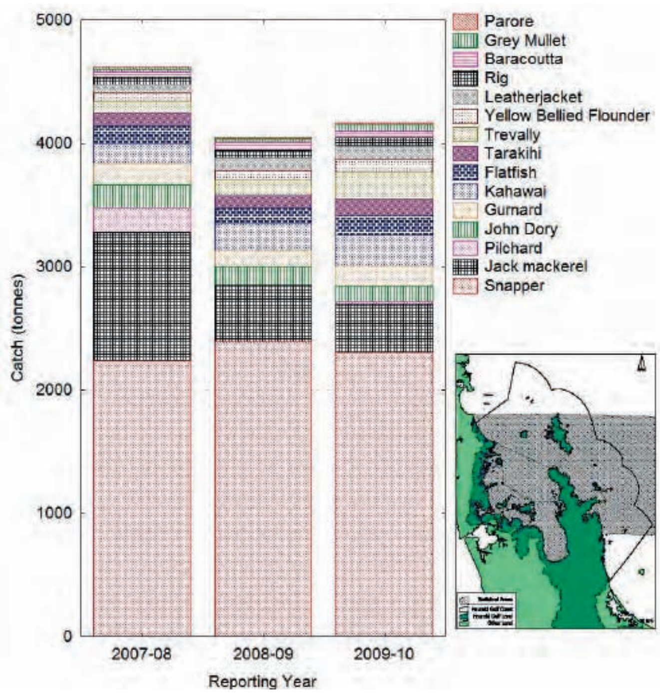


Table 2: Status of finfish stocks reported MFish 2010 Stock Status Table (17 December 2010), with comments obtained from the 2010 Plenary Report (MFish 2010). Ticks indicate a favourable status, while crosses indicate an unfavourable status. The number of ticks or crosses indicates the degree to which the status is favourable or unfavourable. Question marks indicate that the stock status is unknown, because an appropriate quantitative analysis has not been undertaken or analyses were not definitive. Note that the extent of quota management areas vary between species, but are generally larger than the Hauraki Gulf.

Species name	Last assessed	Quota management areas or substocks	At or above target levels?	Overfishing?	Depleted?	Collapsed?	Comments
Snapper	2000	SNA1	✓	?	✓✓	✓✓	Modelling carried out at the last assessment indicated that the recruited biomass of the Hauraki Gulf/Bay of Plenty stock was less than that required to produce the maximum sustainable yield (MSY), but it was expected to exceed the BMSY by the end of a 20-year projection period.
Jack mackerel	None	JMA1	?	?	?	?	It is not known whether catches at the level of the current TACCs or recent catch levels are sustainable in the long term.
Pilchard	None	PIL1	?	✓✓	?	✓✓	There have been no stock assessments of New Zealand pilchard and no estimates of current biomass are available. It is not known if the current catches or TACCs are sustainable.
John Dory	2010	JDO1E and JDOBoP	?	?	?	?	Recent catch levels and the current TACC are likely to be sustainable at least in the short term, but it is not known if they are sustainable in the long term. The north-eastern substock appears to have cyclical variations in catch rates, probably in response to recruitment variation, and the current trend is downward. Catch rates in the Bay of Plenty substock have displayed a declining trend since 1989 and are likely to continue to decline.
Gurnard	2010	GUR1E and GURBoP	?	?	?	?	Catch rates cycle in a manner that is consistent with a short-lived species with variable recruitment. In recent years, catch per unit effort (CPUE) in the north-east substock increased over six consecutive years, to peak in 2004/05 and subsequently declined. It is not possible to predict how the stocks are going to respond in the next few years, but modellers believe that current catches are unlikely to affect the long-term viability of the stock.
Kahawai	2009	KAH1	✓✓	✓✓	✓✓	✓✓✓	Assessments carried out in 2008 predicted that biomass in KAH1 fisheries management area (including the Hauraki Gulf substock) would increase over the next five years. It is unlikely that the stock will decline below the biomass that produces the MSY at currently assumed catch levels.
Flatfish	2008	Hauraki Gulf	?	?	?	?	Flatfish is a combined grouping of eight species. The Hauraki Gulf is an important fishing ground for two of these: yellow-bellied flounder and sand flounder. Fishers often report these species under the generic flatfish code, even though they also have their own species-specific codes. See below for further comments on yellow-bellied flounder.
Tarakihi	2009	TAR1 East	?	x	?	✓✓	CPUE indices for the three substocks within TAR 1 were calculated using data through to the end of the 2006-07 fishing year. The indices remain stable suggesting that current catches and the TACC for TAR 1 are sustainable. In 2002 the Inshore WG concluded that TAR 1 was likely to be above BMSY. There is no evidence from the CPUE analyses to suggest any major changes in abundance since this time.

Species name	Last assessed	Quota management areas or substocks	At or above target levels?	Overfishing?	Depleted?	Collapsed?	Comments
Trevally	2006	TRE1	?	x	?	?	Recent catches reported for TRE1 fisheries The assessment for TRE 1 undertaken in 2006 was not accepted by the Pelagic Working Group due to the lack of a reliable abundance index. Recent catches reported for TRE 1 are less than the estimated maximum constant yield (MCY) levels and below the TACC. Reduced proportions of older age classes in the single bottom trawl catch between 1999-00 and 2006-07 combined with the strong drops in landings in 2006-07 and 2007-08 may indicate that stock abundance is declining at current catch levels.
Yellow-bellied flounder	2008	Hauraki Gulf	?	?	?	?	Catch rates have been increasing in the Hauraki Gulf from a low in 2001/02 to a level well above the long-term mean in 2007/08.
Leatherjacket	None	LEA1	?	?	?	?	There are no estimates of reference or current biomass. It is not known whether the leatherjacket stocks are at, above or below a level that can produce the MSY.
Rig	None	SPO1	?	?	?	?	Since 1989/90, catch rates have increased at Thames and decreased in other east-coast areas within SPO1. Patterns in relative abundance suggest that recent catch levels are probably sustainable in the short term, but it is unknown whether the current TACC is sustainable.
Baracoutta	None	BAR1	?	?	?	✓✓	Estimates of current and reference biomass are not available for any baracoutta stocks and therefore it is not known if current TACCs and recent catches are sustainable or whether they are at levels which will allow the stocks to move towards a size that will support the MSY. However, in the last seven years, catches have been below the estimated maximum constant yield in BAR1, which suggests that the current catch levels in that stock are sustainable.
Grey mullet	2007	GMU1	?	?	?	✓✓	The Hauraki Gulf substock makes a relatively minor contribution to catches in the GMU1 fisheries management area. Catch rates have fluctuated in this substock since 1990, but have not displayed consistent trends. Harbours and embayments appear to contain relatively distinct sub-populations of grey mullet.
Parore	None	PAR1	?	?	?	?	Estimates of current and reference biomass are not available. It is not known if recent catch levels or TACs are sustainable.

4.1.3 Snapper

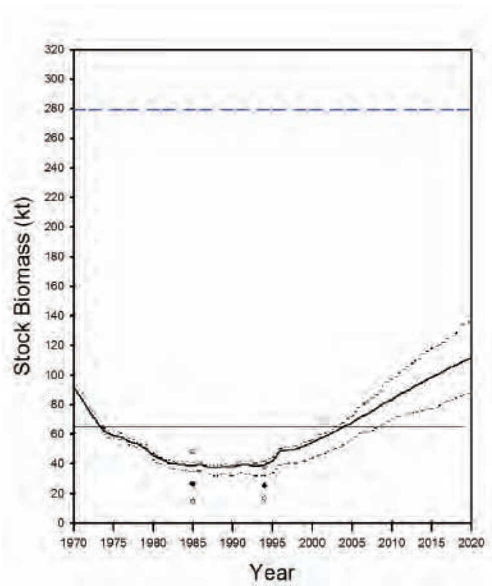
Snapper are the dominant fish in northern New Zealand and inshore communities and occupy a wide range of habitats including rocky reefs and areas of sand and mud bottom. They are most abundant in 15 to 60 m water depth, but can also be found in depths of about 200 m (Ministry of Fisheries *Science* 2010). Snapper are generalist predators that primarily feed on small, soft-bodied invertebrate prey, but larger and harder-shelled animals (fish, molluscs, crabs and hermit crabs) are eaten in increasing quantities as snapper expand in size. Feeding does not appear to be highly selective: rather, snapper appear to feed on whatever is available (Coleman 1972). Research carried out in the Hauraki Gulf suggests that snapper (and crayfish) may influence primary productivity on reef habitats through the consumption of sea urchins (*Evechinus chloroticus*), whose grazing prevents kelp from becoming established and growing (Babcock *et al.* 1999, Shears and Babcock 2002). Consequently, kelp-free zones called reef or urchin barrens tend to be more prevalent in areas where fishing is allowed, and less prevalent in protected areas such as marine reserves (Babcock *et al.* 1999, Shears and Babcock 2002). Scientific information on the broader ecological role of snapper in other habitats is limited.

The Hauraki Gulf is a nationally significant area in terms of high snapper abundance. Snapper is the most targeted commercial species and produces the greatest yield (by weight) of any species in the Gulf. Between June 2007 and June 2010 annual national export earnings from snapper are estimated to have ranged from $29.7M to $36.4M (Ministry of Fisheries 2010). Snapper are also New Zealand's most sought-after recreational, saltwater fish (Bradford 1999). Consequently, fishing has had a major adverse effect on snapper populations.

Fish were a major component of the Māori diet and annual harvests of thousands of tons of snapper were potentially caught in pre-European New Zealand (Leach 2006, Parsons *et al.* 2009). After the arrival of Europeans, a commercial snapper fishery was initially developed using hand-lining and netting from small sailboats, and progressed to more efficient fishing methods, with beam trawling from c. 1899, long-lines from c. 1912, steam trawlers from c. 1915, Danish seiners from c. 1923 and pair trawling throughout the 1970s and 1980s, when annual catches peaked (Parsons *et al.* 2009). The Hauraki Gulf/Bay of Plenty substock declined through to the mid-1980s, until the quota management system was introduced. In 1995, snapper biomass estimates from a fisheries' tagging programme indicated that the Hauraki Gulf/Bay of Plenty substock contained 29,115 to 35,249 tonnes of snapper (depending on assumptions used to obtain the estimates), which suggested that the substock had been reduced to 10.4% to 12.6% of the "virgin"[7] snapper biomass of 279.2 kilotonnes (kt) (Ministry of Fisheries *Science* 2010).

Limiting catch levels through the quota management system finally halted the decline of snapper. Modelling carried out in 1999 indicated that the current TACs would allow the Hauraki Gulf/Bay of Plenty snapper substock to rebuild to levels above the biomass required to produce the MSY over a 20-year period, with a 100% probability. In the base-case model, the biomass required to produce the MSY was estimated to be c. 23% of the virgin snapper biomass, and the biomass predicted for 2020 was around 40% of the virgin biomass (Ministry of Fisheries, *Science* 2010). The accuracy of those predictions has not been verified by a subsequent stock assessment, with the last empirical estimate of biomass being obtained in 1995. The next stock assessment is scheduled for 2012.

Figure 19: Predicted change in the Hauraki Gulf/Bay of Plenty snapper stock biomass (+ 90% confidence intervals) over time. The biomass estimated to produce the maximum sustainable yield (64 kt) is indicated by the black horizontal line, and biomass estimates from the two tagging programmes are plotted (solid diamonds) with their assumed 90% confidence intervals (hollow diamonds). The dotted blue line indicates the virgin biomass (adapted from Ministry of Fisheries, Science 2010).



7. Theoretical biomass that would occur if all harvesting ceased.

Information obtained from marine reserves in the Hauraki Gulf is generally consistent with the predictions obtained from the fisheries assessments, except that localised depletion around marine reserves tends to be higher than fisheries models predict for the whole Hauraki Gulf/Bay of Plenty snapper stock. Willis *et al.* (2003) found that average densities of harvestable snapper were 14 times higher in the Cape Rodney to Okakari Point and Te Whanganui-a-Hei (Hahei) marine reserves, as well as in the Tawharanui Marine Park, than in surrounding fished areas (i.e. densities of unprotected populations were 93% lower than protected populations). Between 1997 and 2002, seasonal (November to May) fishing-related mortality of legally harvestable snapper around these reserves exceeded 70%, of the population and reached as high as 96% (Willis and Millar 2005).

Between 2000 and 2007 the mean densities of legally harvestable snapper around the Cape Rodney to Okakari Point Marine Reserve have varied from 1% to 14% of densities inside the reserve (Sivaguru 2007). Similarly, between 2000 and 2010 the mean density of legally harvestable snapper around the Te Whanganui-a-Hei (Hahei) Marine Reserve varied from 0% to 28% of mean densities within the reserve (Haggitt *et al.* 2010). In contrast, densities of undersized snapper outside these reserves frequently exceeded mean densities inside the reserves.

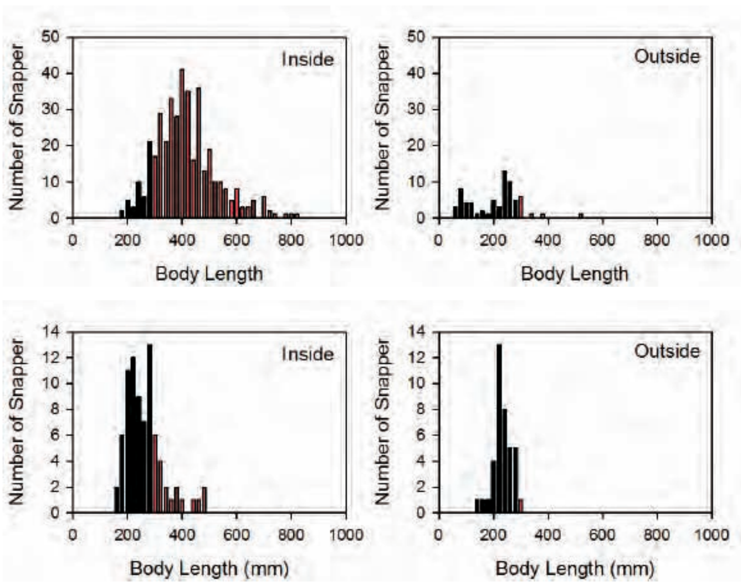
Consequently, the characteristics of the fished and unfished populations in the Gulf differ substantially, with the fished populations being comprised of few, mainly young snapper that are below or near the legal size limit, and protected populations containing large numbers of older snapper with a high proportion of large fish above the legal size (e.g. see Figure 20, Sivaguru 2007, Haggitt *et al.* 2010). This is reflected in the larger mean size of snapper in protected areas. Mean snapper size ranged from 289 mm to 404 mm in the Cape Rodney to Okakari Point Marine Reserve (cf. 148 mm to 242 mm outside) between spring 2000 and autumn 2007, and 233 mm to 323 mm in the Hahei Marine Reserve (cf. 144 mm to 290 mm outside) between spring 2000 and autumn 2010.

Overall, fisheries and marine reserves' monitoring data suggests that fishing has depleted snapper populations by more than 80% in the Hauraki Gulf and Bay of Plenty, and that the greatest impact has been on older, larger fish. Populations are expected to rebuild with current catch levels and catch limits, to reach the biomass targets set under the Fisheries Act 1996. Management at those target levels would produce the MSY, but set standing stock levels at about 77% below the unfished biomass, using the current default targets.

Figure 20: Comparison of snapper size and abundance: (a) inside and outside the Cape Rodney to Okakari Point Marine Reserve in 2007 (data from Sivaguru 2007); and (b) inside and outside the Te Whanganui-a-Hei (Hahei) Marine Reserve in 2010 (data from Haggitt *et al.* 2010).

A.

B.



4.1.4 Crayfish

The common New Zealand crayfish, *Jasus edwardsii*, is actually a relatively slow-growing and long-lived spiny lobster. *Jasus edwardsii* are one of the largest and most conspicuous mobile invertebrates on reefs in the central and outer Hauraki Gulf. In protected areas they can occur in very high densities (Haggitt *et al.* 2010), particularly when they cluster into seasonal aggregations that may contain hundreds of individuals (Kelly *et al.* 1999, Figure 7). They are generalist feeders that prey on a wide range of invertebrates, as well as consuming fish and algae (Kelly and McKoy, unpublished data). Feeding rates vary throughout the year in relation to moulting and reproductive cycles, with prolonged periods of non-feeding during the mating and moulting seasons, being punctuated by periods of extremely high consumption (Kelly *et al.* 1999). *Jasus edwardsii* and predatory fish such as snapper have a positive effect on kelp forest cover and primary productivity in reef habitats by consuming sea urchins (*Evechinus chloroticus*). Sea urchin grazing prevents kelp from becoming established and growing, leading to the formation of reef or urchin barrens. These are open areas of pink, coralline algae-covered reef, which are devoid of large brown seaweeds. Consequently, kelp-free urchin barrens tend to be more prevalent in areas where fishing is allowed and less prevalent in protected areas such as marine reserves (Babcock *et al.* 1999, Shears and Babcock 2002). Crayfish forage also beyond the reef, where they prey on shellfish and other animals living in sandy habitats. Experiments suggest that they play an important role in the survivorship of adult bivalve populations on the sandflats adjacent to reef systems (Langlois *et al.* 2006).

Crayfish are a highly prized and high value species. Consequently, fishing has had a major effect on crayfish populations. In 2002, the "vulnerable biomass" of crayfish, in the CRA2 fishery area was estimated to be around 20% of 1945 levels, and was expected to remain at roughly that level through to 2007. However, there was a considerable amount of uncertainty associated with this prediction (Ministry of Fisheries, Science 2010), and biomass has since declined (Alicia McKinnon, pers. comm.). Best available information suggests the CRA 2 fishery is still above the statutory target level, and therefore, the total allowable catch has not been altered since 1997.

Density estimates have also been obtained from marine reserve surveys. Between 2000 and 2009, the mean density of lobsters in fished areas outside the Cape Rodney to Okakari Point Marine Reserve has fluctuated between 6% and 28% within the reserve, while mean densities outside the Te Whanganui-a-Hei Marine Reserve have fluctuated between 5% and 15% of those inside.

Marine reserve monitoring from the Gulf and elsewhere (Kelly *et al.* 2000) indicates also that the composition of lobster populations has been substantially altered by fishing (Figure 22). Reserve populations are dominated by lobsters above the legal size limit, with relatively high numbers of old and large animals. In contrast, fished populations are dominated by sub-legal animals. Large male and female lobsters have been shown to make a disproportionate contribution to reproduction by producing more sperm and eggs, mating more frequently and defending access to favourable mates (MacDiarmid 1989, MacDiarmid and Butler 1999). Large lobsters also display different behaviours to small-sized ones. For instance, large lobsters frequently forage for extended periods on offshore sandflats, where they form defensive aggregations for mutual protection during the daytime (Kelly *et al.* 1999). In contrast, most sub-legal lobsters in the Hauraki Gulf appear to remain within reef habitat.

Overall, fisheries and marine reserves' monitoring data suggests that fishing has reduced lobster populations by 80% or more in the Hauraki Gulf and Bay of Plenty, and that fishing has had the greatest impact on old, large crayfish. Populations are not expected to increase with current catch levels.

Figure 21: Predictions of the vulnerable biomass of crayfish, for the autumn-winter (top) and spring-summer (bottom) seasons, in the CRA2 fishery area. For each year, the horizontal line represents the median, the box spans the 25th and 75th percentiles and the dashed whiskers span the 5th and 95th percentiles.

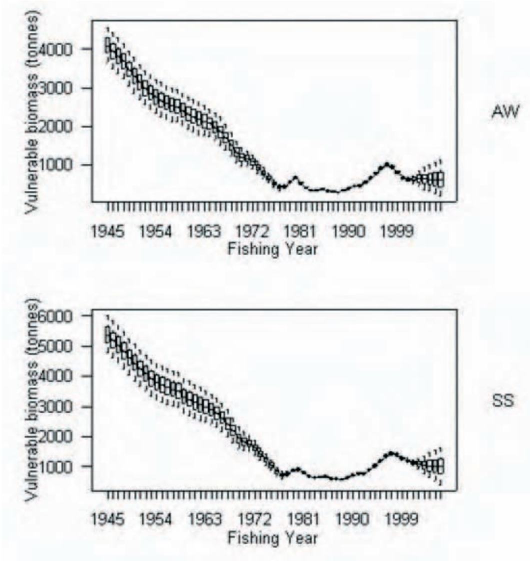
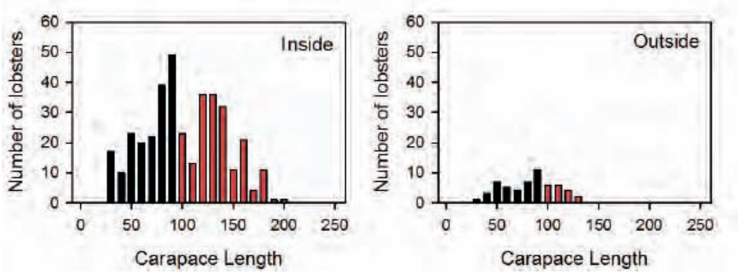
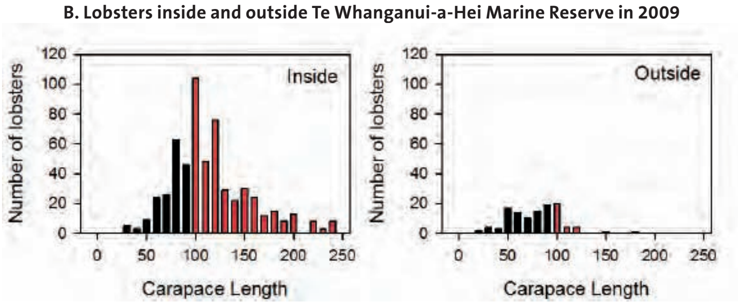


Figure 22: Comparison of lobster size and abundance between protected and non-protected areas. Data is presented from: (a) Cape Rodney to Okakari Point Marine Reserve in 2009[1]; (b) Te Whanganui-a-Hei Marine Reserve in 2009[2]; and (c) Tawharanui Marine Park in 2009[1]. Note that the patterns in the Cape Rodney to Okakari Point Marine Reserve in 2009 and Te Whanganui-a-Hei Marine Reserve are also consistent with those reported from other years.

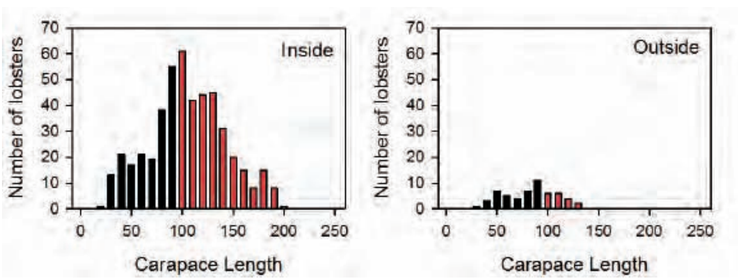
A. Lobsters inside and outside Cape Rodney to Okakari Point Marine Reserve in 2009



B. Lobsters inside and outside Te Whanganui-a-Hei Marine Reserve in 2009



C. Lobsters inside and outside the Tawharanui Marine Park in 2009



1 Data from Haggitt and Mead (2009a)
2 Data from Haggitt and Mead (2009b)

Figure 23: Daytime aggregation of large male lobsters in a sandy area that is remote from reef cover. (Photo courtesy of Dr Shane Kelly, Coast and Catchment Ltd.)

4.1.5 Cockles

Cockles (*Austrovenus stutchburyi*) are filter-feeding bivalves which are among the most numerous of shellfish in the sheltered shores of harbours and estuaries, with densities as high as 4,500 per m^2 having been reported in some areas (MFish, *Science* 2010). Cockles burrow to 25 mm or so, and flourish between low and mid-tide where sediments contain less than 50% mud (Stephenson 1981). Maturity appears to mainly be a function of size rather than age, and occurs at c. 18 mm shell length (MFish, *Science* 2010). However, cockles may live for up to 20 years (Owen 1992). Cockles are a major part of the diet for a range of different animals, including mud whelks (*Cominella glandiformis*), sand flounder (*Rhombolsolea plebeia*) and pied oystercatchers (*Haematopus finschii*) (Jones and Marsden 2005). They are regarded as “ecosystem engineers” that play an important role in the exchange of energy and nutrients, between the seabed and within the water column, and in the composition of seabed communities (Thrush *et al.* 2006). Cockles have a major influence on productivity and nutrient dynamics in estuaries due to their size, wide spread and high abundance, and their role in mixing the upper 2 to 3 cm of the sediment (Sandwell *et al.* 2009).

Cockles are not commercially harvested in the Hauraki Gulf, but they do support recreational and customary fisheries. Consequently, MFish has intermittently monitored cockle abundance and size at 14 sites in the Hauraki Gulf since 1998 (Figure 24a). At most sites the overall abundance of cockles has fluctuated over time, without showing obvious increasing or decreasing trends (Figure 25). However, clear trends in overall abundance are apparent at two sites:

– a 36% reduction in overall cockle abundance in Whangateau Harbour occurred between 2004 and 2010; and
– overall cockle populations declined at Umupuia between 1998 and 2007, and subsequently increased between 2007 and 2010 due to an influx of small cockles.

Three Gulf sites were included in the most recent survey in 2009. Statistically significant declines in the number of harvestable cockles (> 30 mm) were detected at the Whangateau Harbour and Umupuia sites between 2006 and 2009, but no change occurred at Okoromai Bay on Whangapoua Peninsula. High levels of cockle harvesting has previously been reported in Whangateau Harbour (Kearney 1999), but mass mortalities of cockles have also contributed to recent declines (see Section 4.7). A low proportion of harvestable cockles in both Whangateau Harbour and at Umupuia was also concerning, with only 1% to 2% of the population consisting of cockles with > 30 mm shell width.

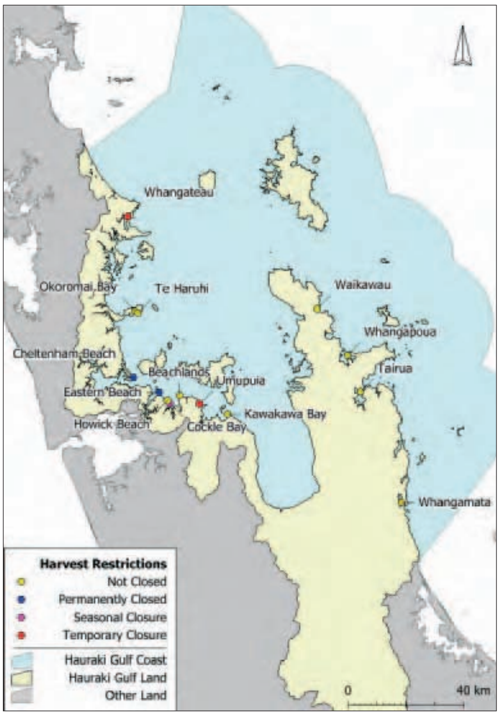
Community shellfish monitoring is carried out also by a variety of schools, iwi, training organisations and care groups at 19 sites in the Hauraki Gulf (Figure 24b). In most cases monitoring has not been occurring for long enough to obtain reliable information on trends. The exceptions are:

– Whangateau Harbour, where 2009 and 2010 cockle densities at the Lews Bay site were around 50% lower than those recorded in 2004. In contrast, densities have remained relatively stable at the Omaha causeway site.
– Cheltenham Beach, where cockle densities displayed a continuous decline between 1995 and 2003, then stabilised at low levels.

MFish has responded to local community concerns about over-harvesting and mass mortalities of cockles (in the case of Whangateau Harbour), by banning shellfish gathering at five sites in the Hauraki Gulf. These include permanent bans on harvesting at Eastern Beach and Cheltenham Beach, temporary bans at Umupuia and Whangateau Harbour, and a seasonal ban at Cockle Bay (see Figure 24a).

Overall, this data suggests that, in recent years, cockle abundance has been relative stable at most of the sites in the Hauraki Gulf which are (or were) susceptible to harvesting and also monitored by MFish or community groups. The exceptions are Umupuia and Whangateau Harbour where relatively large declines in cockle abundance have occurred, and there is a very low proportion of cockles of harvestable size. Similar declines have been reported at Cheltenham Beach too

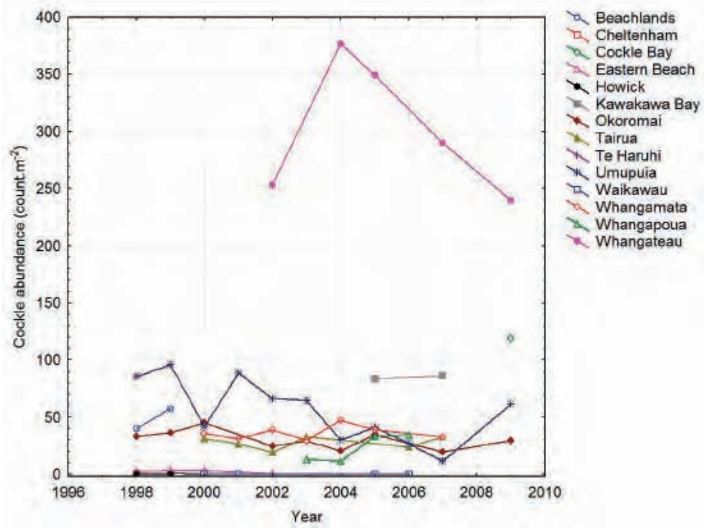
Figure 24: Sites that have been: (a) intermittently monitored by MFish and (b) community groups in the Hauraki Gulf. Beaches where shellfish harvesting has been banned are also indicated in (a).



A.

B.

Figure 25: Temporal variation in the relative abundance of cockles at MFish's monitoring sites. Note that shellfish harvesting is temporarily or permanently banned at Cheltenham Beach, Umupuia, Whangateau Harbour and Cockle Bay.



4.1.6 Ecosystem indicators

A variety of indicators of ecosystem effects has been tested in relation to MFish's trawl survey data collected from the Hauraki Gulf between 1965 and 2000 (Tuck *et al*. 2009). The indicators can be broadly divided into different five categories:

1. rare and threatened species;
2. species diversity;
3. taxonomic diversity;
4. habits and food chains; and
5. size and productivity.

Trends in each indicator were assessed for 11 areas in the Gulf (Figure 26). Statistically significant trends were most frequently detected in the Firth of Thames, and these tended to suggest that adverse changes were occurring in relation to indicators of rare and threatened species, species' diversity, and size and productivity (see Table 3). Statistically significant trends in the indicators of size and productivity also tended to be negative in central parts of the Gulf (eight negative responses), although two positive trends were detected as well. Indicators in the other areas were mostly stable with relatively few significant trends revealed. Tuck *et al*. (2009) concluded that species-based measures of diversity (Pielou's evenness, Shannon-Weiner index, species' richness, and Hill's N1 and N2) were the most useful fisheries indicators because they tended to be correlated with fishing intensity. However, it is important to note that causality has not been verified and that the ecological significance of these changes is unknown.

Overall, fisheries ecosystem indicators suggest that the abundance of rare and threatened species, species diversity, and the size and productivity of fish declined in the Firth of Thames between 1964 and 2000. Negative trends in indicators of fish size and productivity were also detected in the central Gulf and in inshore strata between Kawau and Waiheke islands over the same period.

Figure 26: Areas used to examine trends in ecosystem indicators for fisheries, using MFish's trawl survey data collected between 1965 and 2000

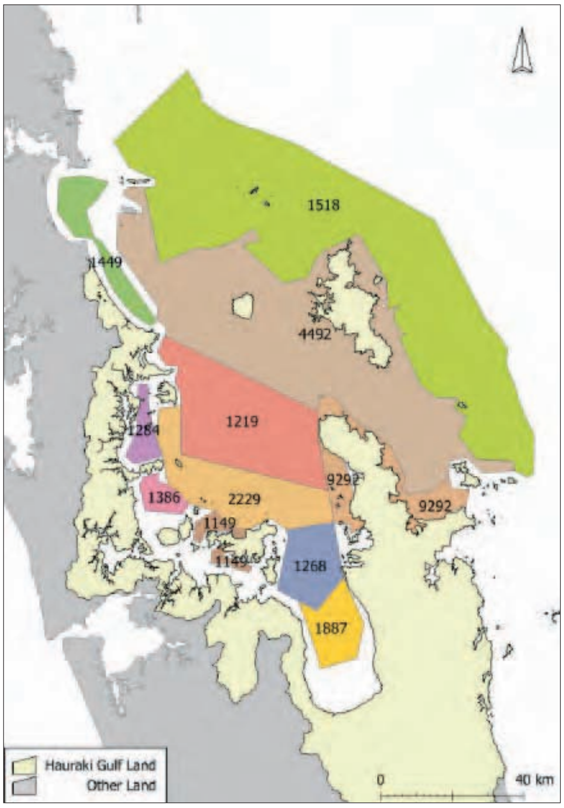


Table 3: Statistically significant trends in ecosystem indicators for fisheries, based on MFish's trawl survey data collected between 1965 and 2000. Negative trends are highlighted in red and positive trends are highlight in green.

		Inshore Kawau to Waiheke islands			**Firth of Thames**		**Central Gulf**			**Deep Shelf**	**Inshore Northern Coromandel**	**Pakiri**
	Sub-Areas	**1284**	**1386**	**1149**	**1268**	**1887**	**2229**	**1219**	**4492**	**1518**	**9292**	**1449**
Rare and threatened species	Proportion of threatened species (IUCN Red List Species)				–	–						
	Low-resilience species				–	–		–				
	Hill's N1 diversity				–	–						
	Hill's N2 diversity				–	–						
Species' diversity	Species' richness											
	Margarlef's diversity											
	Shannon-Weiner's diversity				–	–		–				
	Pielou's diversity				–	–						
Taxonomic diversity	Average taxonomic distinctness						+	+				
	Variation in taxonomic distinctness						+	+				
Fish habits and food chains	Demersal:Total fish ratio		+	+	+	+			–		+	
	Pisciverous:Total fish ratio											
	W statistic		+									
	Mean trophic level											
Size and productivity	Median length							–				
	95th percentile of length				–	–		–	–			
	Proportion > 30 cm					–		–	–			
	Biomass spectra curvature	–			–	–	+				–	+
	Biomass spectra x vertex		–			–		–				
	Biomass spectra y vertex				+			+				
	Size spectra intercept				–							
	Size spectra slope	–			–	–	–	–				

4.1.7 Benthic disturbance

Bottom trawling and dredging are relatively indiscriminate methods of fishing that capture, disturb and injure both target and non-target species. They also affect habitat quality by removing emergent biota and other physical features, and evening out seabed sediments. Such disturbance has important consequences for sea-floor biodiversity. Studies carried out in the Hauraki Gulf, and elsewhere, indicate that diversity is strongly related to local variation in sediment characteristics and the presence of emergent features (see Thrush *et al.* 2001 and references within). Trawling and dredging therefore have both direct and indirect effects on target and non-target species.

Bottom trawling is one of the most commonly used methods of catching fish in the Hauraki Gulf, accounting for around 30 to 40 % of the total catch (Ministry of Fisheries 2009, Hauraki Gulf Forum 2010b) and occurring over a wide area (Figure 17a). All trawling and Danish seining is prohibited south of a line running approximately between Kawau Island and Colville Bay, and from a number of inshore zones on the eastern side of Coromandel Peninsula. Trawling is also prohibited in a number of cable zones in the Hauraki Gulf (see Figure 16).

Virtually nothing is known about seabed ecology in the areas subject to trawling in the Gulf, or how they are affected. However, the areas targeted by commercial trawlers contain a variety of different substrates and are likely to also contain (or to have, once contained) diverse seabed communities, which are probably sensitive to trawling disturbance.

The commercial scallop fishery in the Coromandel area started in the 1970s and was introduced into the quota management system in 2002. Dredges are used for all of the commercial scallop harvesting carried out in the Gulf. Since 1992, controls have been in place which limit dredge size, the fishing season, the minimum size of scallops, total catch, hours of fishing and fishing days. Until 1994 the minimum legal size of scallops for the commercial fishery was 100 mm shell width, but this was reduced to 90 mm shell width in a package of measures that were primarily designed to reduce incidental mortality (pers. comm. Martin Cryer, MFish). The package of measures also included the implementation of voluntary closed areas and a reduction in catch limits (Tuck *et al.* 2006).

The total area fished by the commercial scallop industry has ranged from 350 to 450 km^2 for most of its history, but dropped to 200 km^2 in 2001 due to low scallop abundance and a downturn in the industry, and subsequently decreased again in 2005 (to 100 km^2) due to very high scallop abundance. Catch and effort landing return (CELR) data and information provided by the industry indicates that there has been a change in the spatial pattern of fishing over time, with effort shifting from the central Gulf and Aotea (Great Barrier Island) to Mercury Bay and Bay of Plenty areas (Tuck *et al.* 2006, Figure 27). The shift in fishing patterns is largely due to the implementation of voluntary closed areas which have reduced conflict between the commercial and amateur fisheries. Amateur harvesters dive and dredge for scallops. Telephone surveys indicate that around 10% of the scallops collected by amateurs are obtained by dredge (Tuck *et al.* 2006).

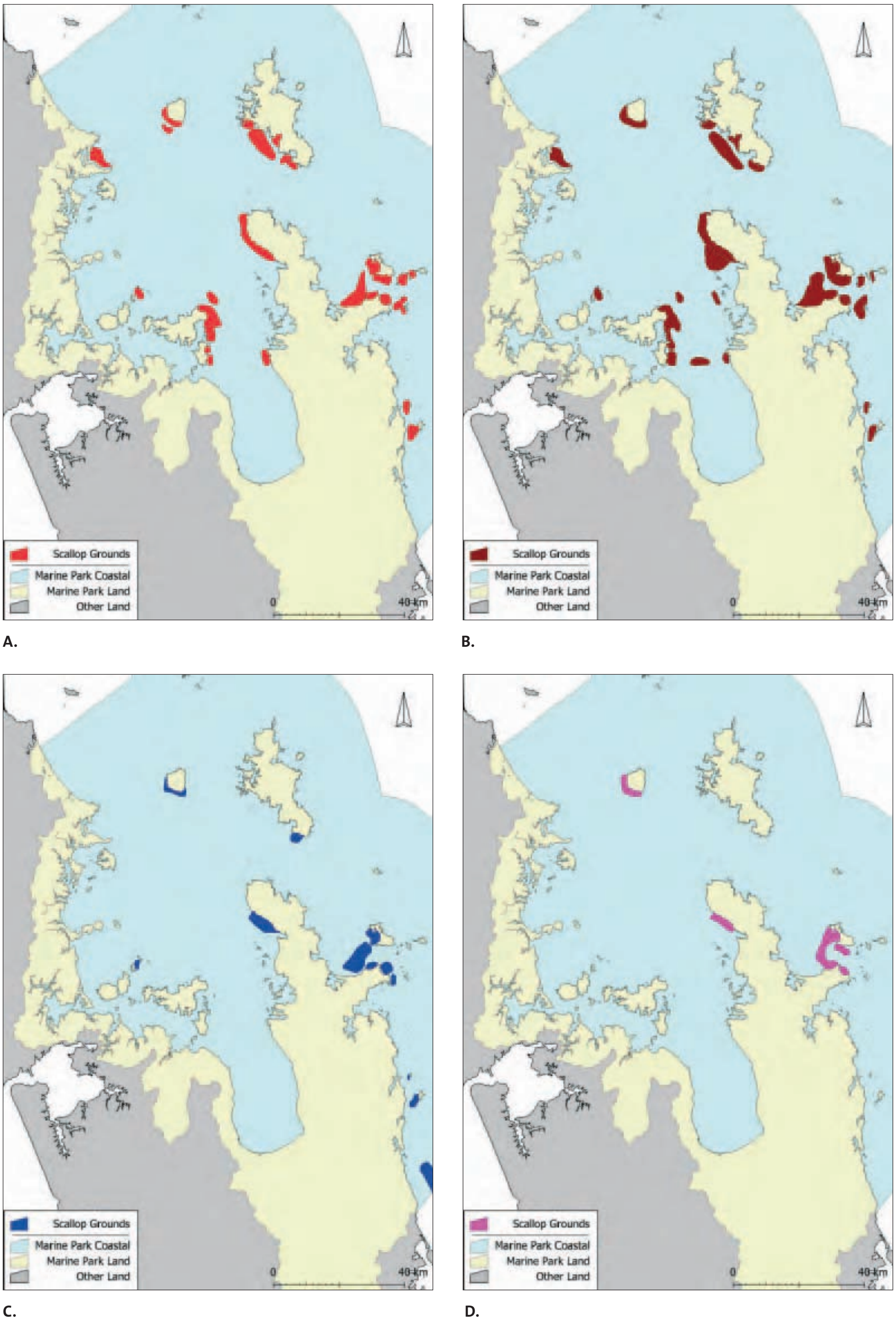
The areas targeted by recreational and commercial fishers contain a variety of benthic habitats, but there appears to be very little information on the current or historical ecology of these areas, or the actual impacts of scallop dredging in the Gulf (but see Tuck *et al.* 2006). However, a range of non-target species is commonly collected in scallop dredges, including horse mussels, dog cockles, starfish, sponges, kelp and turfing algae. As discussed above, large, emergent species like sponges, horse mussels and kelp are particularly important because they provide structural complexity in otherwise featureless habitats and have a positive influence on biodiversity.

4.1.8 Strategic considerations for fishing

1. Fishing impacts affect most, if not all, of the Hauraki Gulf and have a large influence on the marine ecosystem.
2. Stock assessments have been carried for few commercially fished species. Consequently, the status of the majority of commercial fish stocks in relation to target levels is not known.
3. In the mid 1990s fishing had depleted snapper biomass by more than 87%[9] in the Hauraki Gulf and Bay of Plenty, with the greatest impact on old, large fish. Modelling suggests that the current TAC will allow the Hauraki Gulf snapper stock to rebuild and exceed the biomass[10] estimated to produce the MSY by 2020, with a 100% probability. However, harvesting is expected to hold the stock at a level that is 77% below the virgin biomass , if the MSY is used as the target for managing this species. The actual biomass of snapper has not been verified since 1995, but a stock assessment is scheduled for 2012.
4. Fishing has reduced lobster biomass by 80% or more in the Hauraki Gulf and Bay of Plenty, with the greatest impact on old, large crayfish. Populations are not expected to increase with current catch levels.
5. In recent years, cockle abundance has been relatively stable at most of the sites that MFish monitors in the Hauraki Gulf. The exceptions are Umupuia and Whangateau Harbour where relatively large declines in cockle abundance have occurred, and there is a very low proportion of cockles of harvestable size. Similar declines have been observed also in the community monitoring programme for Cheltenham Beach.
6. Ecosystem indicators suggest that the abundance of rare and threatened fish, fish diversity, and the size and productivity of fish declined in the Firth of Thames between 1964 and 2000. Negative trends in indicators of fish size and productivity were detected also in the central Gulf and in inshore strata between Kawau and Waiheke islands over the same period. However, a causal link with fishing has not been verified and the ecological significance of these changes is unknown.
7. Large areas of the Gulf are subject to trawler and scallop dredge disturbance, but the ecological values, and historical and current state of seabed habitats in the areas affected are largely unknown. Research carried out in the Hauraki Gulf, and elsewhere, indicates that seabed disturbance by trawlers and dredges can have a significant effect on benthic habitats and communities.
8. Historical mussel dredging eliminated most subtidal mussel beds in the Firth of Thames and Tamaki Strait. Their removal has almost certainly led to a major loss of ecological and biophysical function in the Gulf. This loss may be partially offset by farmed mussels, but it is not known if, or how, the delivery of functions and services differs between natural beds and farmed systems.

9. Relative to the virgin, or unfished, biomass.
10. The virgin, or unfished, biomass is the theoretical biomass that would occur if all harvesting ceased.

Figure 27: Indicative areas fished for scallops in: (a) the 1980s, (b) 1990s, (c) 2000 and (d) 2005. Data was digitised from hand-drawn maps in Tuck *et al.* (2006), as provided by fishers working in the Coromandel scallop fishery.



4.2 Sediment contamination

Human activities generate a variety of toxic heavy metals and organic compounds that are used in the coastal environment (e.g. sacrificial zinc anodes and anti-fouling paints) or enter coastal waters through spills, run-off and discharges. Contaminants originate from ongoing activities and historical activities that can have continuing, long-term environmental consequences. Major spills sometimes have immediate and catastrophic effects, but many contaminants slowly accumulate to toxic levels over time (typically decades). Many of these contaminants bind to sediments and other particulate matter, which settles out and accumulates on the seabed. Elevated contaminant sediment concentrations can therefore affect the survival, reproduction and/or behaviour of benthic organisms.

Monitoring and investigations carried out by the former Auckland Regional Council (ARC), Waikato Regional Council and DOC indicate that the main causes of sediment contamination in the Gulf are urbanisation (Mills and Williamson 2008, 2009) and historical mine activity (Kim 2007). "Hotspots" of sediment contamination are also associated with port activities, marina developments, landfills, agrichemicals and industrial discharges. In some cases, contaminant concentrations within hotspots are particularly high, but the extent of the affected areas tends to be fairly localised.

In urban areas the main contaminants that are most elevated (relative to sediment quality guidelines) are zinc, copper, lead and polycyclic aromatic hydrocarbons (PAHs). However, a variety of other metal and organic contaminants co-occur with these pollutants and potentially compounds their effects. New contaminants are constantly emerging and, consequently, researchers are struggling to keep pace with the rapidly increasing list. Emerging contaminants, such as endocrine-disrupting compounds, are particularly problematic because: biological effects occur at extremely low concentrations (which are often below the detection limits of most analytical instruments); guidelines are not available; and there is no standard or common method of analysis and monitoring (Bolong *et al.* 2009).

In the Auckland Region, contaminant concentrations are most elevated in the sheltered estuaries and tidal creeks associated with old urban catchments (Figure 28 and Figure 29a, Kelly 2007). In these locations, lower threshold effects level (TEL) sediment quality guideline values are frequently exceeded for zinc, copper and lead, and less frequently for PAHs (see Table 4 for a description of sediment quality guidelines). Of the 50 sites in the Hauraki Gulf that are regularly monitored by Auckland Council, 21 exceed TEL guideline values for at least one of these contaminants. All of these sites are in tidal creeks and estuaries associated with urban catchments. However, higher probable effects level (PEL) guidelines are exceeded at only two of Auckland Council's monitoring sites i.e. the lower tidal banks of Meola Creek and Motions Creek.

Concentrations of copper, lead, mercury and zinc exceed TEL sediment quality guidelines also in the south-eastern Firth of Thames, and in particular around the Thames and Waihou River mouth due to historical mining (Figure 28 and Figure 29b, Kim 2007).

The former ARC assessed the response of seabed communities to stormwater contamination with a benthic community health model, which is able to link community composition to the concentrations of the heavy metals copper, lead and zinc (Anderson *et al.* 2006, Thrush et al. 2008, Hewitt *et al.* 2009). Originally, 85 sites were included in the model and a subset of these has been monitored on a rotational basis since 2002. The ecological health of each site is ranked on a five point scale from 1 "Good" to 5 "Degraded". Degraded sites tend to have fewer rare and large taxa. Rare species dominate the community structure and make a substantial contribution to overall biodiversity. They are also important in maintaining the stability and resilience of ecosystems, especially in changing environments. Large taxa can make a disproportionately high contribution to ecosystem functions such as the deep mixing of sediments, modification of water flows along the seabed and providing sizeable packages of food for fish and other larger consumers. They are also likely to affect oxygen, carbon and nutrient exchanges between the water column and the sea floor, leading to effects that are beyond simple changes in composition (Hewitt *et al.* 2009). Importantly, the benthic health model indicates that benthic community responses become apparent at sediment concentrations below existing sediment quality guideline values.

The most recent rankings for each site are provided in Figure 30. Of the 85 sites monitored:
- 10 sites were ranked 1 (i.e. had good health);
- 8 sites were ranked 2;
- 22 sites were ranked 3;
- 32 sites were ranked 4; and
- 13 sites were ranked 5 (i.e. had degraded health).

Spatial patterns of benthic health generally mirror patterns of stormwater contamination, i.e. ecological health is worst in tidal creeks and estuaries which are associated with older, fully developed urban catchments. Comparable analyses have not been carried out in the Waikato Region.

4.2.1 Strategic considerations for sediment contamination

1. Sediment contamination affects a relatively small area on the Gulf-wide scale (although the actual area affected is still likely to be > 60 km^2). However, the affected areas are locally important and the functions and services they provide increase their area of influence (e.g. filtration and trapping of sediments and contaminants close to source).
2. Contaminant levels are moderately elevated in some places and have a measurable impact on the ecological health of seabed communities.
3. Significant effort is being directed at addressing sediment contamination, including:
   a. containing the spread of activities that generate contaminants by setting spatial limits on urban development;
   b. requiring stormwater treatment for high-risk industrial sites and new urban developments;
   c. developing and implementing integrated catchment management plans, which identify options for stormwater management;
   d. where appropriate and practicable, retrofitting stormwater treatment in developed urban areas;
   e. implementing community education on stormwater issues; and
   f. ensuring case-by-case management of legacy contaminant issues.
4. The above responses are not expected to remediate areas affected by urban and legacy contamination but may slow accumulation and prevent the degradation of areas with clean sediments.

Figure 28: Extent of the coastal marine area where low-level (TEL) and high-level (PEL) sediment quality guideline values are known to be exceeded by one or more metal contaminants (excluding arsenic which tends to be naturally elevated). Locations of the two main sources of metal contaminants in the Hauraki Gulf, i.e. urban activities and mines, are indicated.

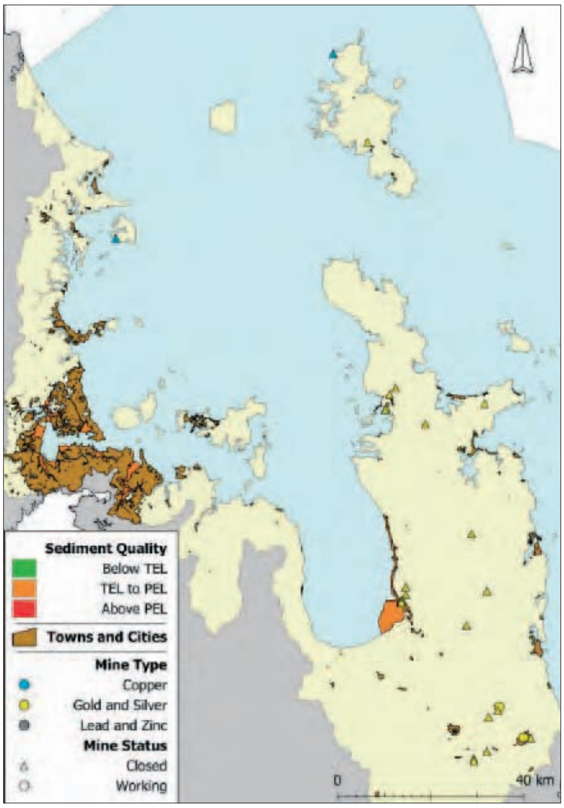
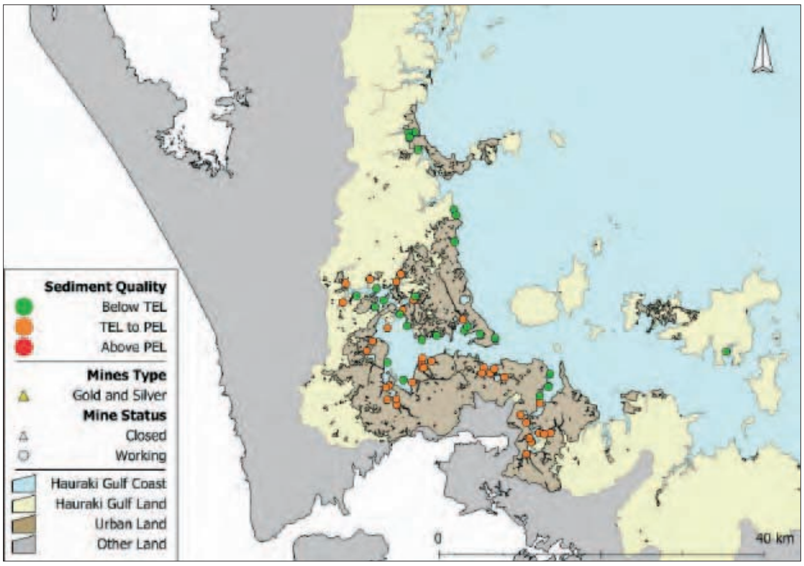


Figure 29: Monitoring or investigation sites where low-level (TEL) and high-level (PEL) sediment quality guideline values are known to be exceeded by one or more metal contaminants (excluding arsenic which tends to be naturally elevated). Operational and disused mines are also indicated on Coromandel Peninsula.

A.



B.

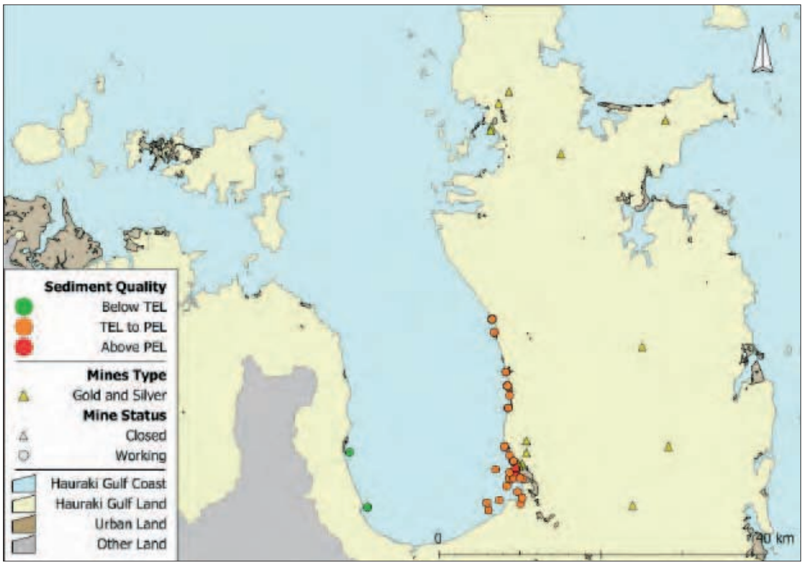


Table 4: Sediment quality guidelines and background concentrations

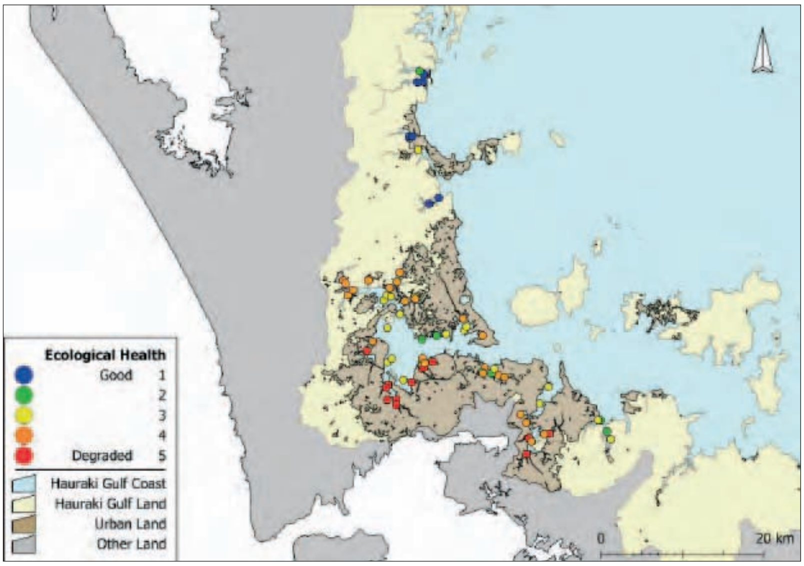
Sediment and water quality guidelines are commonly used to assess the potential for contaminant-related ecological effects. These are usually provided as a set of low and high values.

- **TEL (Threshold Effect Levels, MacDonald *et al.* 1996)** guideline values provide an early warning of contamination, which allows timely management intervention to prevent or minimise adverse environmental effects. TEL guidelines are low-level limits that are indicative of contaminant concentrations where biological effects are "rarely" expected to occur. O'Connor (2004) defines "rarely" as having an observed frequency of 5 to 8%, leading to a rule of thumb that low-level guideline concentrations correspond to a 10% probability of toxicity.
- **PEL (Probable Effect Levels, MacDonald *et al.* 1996)** guideline values indicate that adverse environmental effects have a high probability of occurring and management intervention may be required to remediate the problem. They are indicative of contaminant concentrations where biological effects are frequently expected to occur.

Parameter	Nominal background concentration in the Auckland Region	TEL Guideline Value	PEL Guideline Value
Copper	c. 5 mg/kg[1]	18.7 mg/kg	108.2 mg/kg
Lead	c. 5 mg/kg[1]	30.2 mg/kg	112.2 mg/kg
Mercury	Undetermined	0.13	0.70
Zinc	c. 35 mg/kg[1]	124 mg/kg	271 mg/kg
PAH (high molecular weight)	Undetermined	655 ug/kg	6676 ug/kg

1. Diffuse Sources Ltd (2004)

Figure 30: Ecological health of benthic communities in relation to stormwater contamination. Health is ranked from 1 "Good" (blue) to 5 "Degraded" (red).



4.3 Nutrients

Nutrients are necessary to sustain plant (algae) growth that forms the foundation of the food chain. Slight increases in nutrient levels can therefore increase ecosystem productivity, but high nutrient levels are detrimental: potentially leading to nuisance phytoplankton and seaweed blooms; reduced water clarity; and toxic effects. The Hauraki Gulf is naturally maintained by nutrients that regularly upwell from deep offshore waters, are recycled on the seabed and wash off the land. Humans increase nutrient inputs from the land mainly through wastewater discharges, fertiliser application and the farming of livestock.

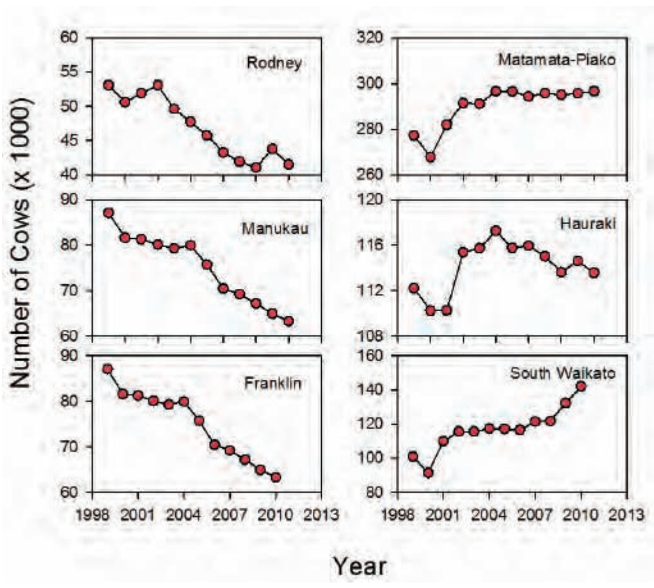
4.3.1 River-loads of nutrients

The largest riverine contributions of nutrients to the Gulf are likely to come from the Waikato Region, which has large catchments with a high degree of intensive, agricultural land use (particularly dairy farming). Around 90% of nutrient loads originating from the Waikato Region are discharged into the Firth of Thames via the Waihou and Piako rivers (pers. comm. Bill Vant, Water Quality Scientist, Waikato Regional Council). Waihou River is the largest river and is conservatively estimated to contribute in excess of 1,900 tonnes of nitrogen and 138 tonnes of phosphorus to the Firth of Thames each year. Note that the total loads are underestimated because they do not include inputs from a relatively large proportion of the catchment. Loads of both nitrogen and phosphorus in the main stem of the Waihou River (i.e. above the point where the Ohinemuri River enters the Waihou) increased by a modest amount (c. 1% per year) between 2000 and 2009. In contrast, phosphorus loads in the Ohinemuri River stem were significantly reduced by the upgrade of the Waihi Wastewater Treatment Plant (a reduction of 5.8% per annum over the last decade), although it should be noted that this stem makes a relatively minor contribution to the overall phosphorus load from Waihou (7.8%) (Vant 2011). Flows from the Ohinemuri stem enter Waihou River near Paeroa and the combined flows enter the south-eastern corner of the Firth of Thames, near Thames.

Piako River's flow rate (including the Waitoa stem) is around 22.5% of Waihou River's, but it contributes the equivalent of approximately 68% of the Waihou River's total nitrogen and 82% of it's phosphorus loads. Nitrogen loads in the upper stem of Piako River (at Paeroa-Tahuna Road Bridge) increased at a rate of 3.4% per annum between 2000 and 2009, but total phosphorus concentrations did not display any significant trend. In contrast, annual reductions of 22% for phosphorus and 1.8% for nitrogen were recorded in the Waitoa stem of the Piako River, due to the upgrade of the Waitoa dairy factory. Piako River enters the Firth of Thames near the mouth of the Waihou River. Overall, the combined mass flow of nitrogen from Hauraki rivers is estimated to have increased by about 1% per year between 2000 and 2009, while phosphorus decreased by about 5% per year during the same period (Vant 2011).

The increase in nitrogen concentrations in rivers of the Hauraki Plains is generally consistent with increasing trends in dairy cow numbers (see figures for Matamata-Piako, South Waikato and Hauraki in Figure 31, and Cameron *et al.* 2009) and associated changes in farm management practices, such as increasing uses of fertiliser and supplementary feeds (Judge and Ledgard 2009). Around 70% of the combined mass flow of nitrogen to the southern Firth of Thames is estimated to have come from diffused agricultural sources. Point-source discharges are estimated to have contributed around 8% of the total mass flow of nitrogen, while "natural" background flows are estimated to contribute around 23% of the nitrogen load (Vant 2011).

Figure 31: Trends in dairy cow numbers in six districts that are partially or wholly within the Hauraki Gulf Marine Park. Districts in the Auckland Region are shown on the left and those in the Waikato Region are shown on the left. Data obtained from the Livestock Improvement Corporation (LIC) (www.lic.co.nz/lic_Publications.cfm).

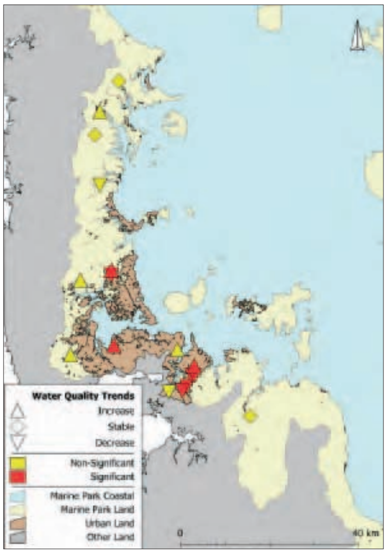


The contribution of nutrients from rivers and streams in the Auckland Region is likely to be minor relative to inputs from the Hauraki Plains. However, an analysis of water quality data collected from 17 streams in the Auckland Region from 1986-1993 to 2005 shows that water quality has generally improved since the late 1980s/early 1990s (Scarsbrook 2007). Of the 17 sites monitored:

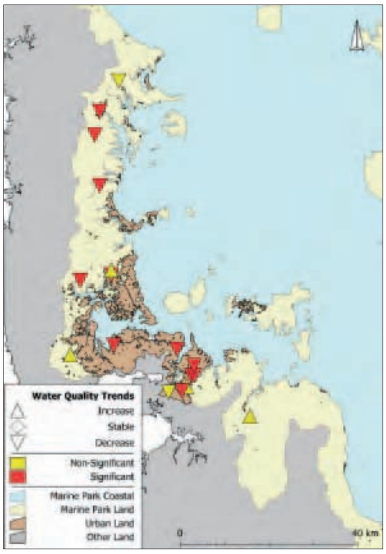
- 10 sites had stable (n=3) or declining (n=7) ammonia-nitrogen concentrations over the full monitoring period. The declining trends were statistically significant at five sites (Figure 32a).
- 13 sites had declining nitrate-nitrite-nitrogen trends, and these trends were statistically significant at 11 sites (Figure 32b).
- 16 sites had stable (n=7) or declining (n=9) trends in soluble reactive phosphorus. The declining trends were statistically significant at all nine sites (Figure 32c).
- All 17 sites had stable (n=2) or declining (n=15) trends in soluble reactive phosphorus. The declining trends were statistically significant at all 15 sites (Figure 32d).

These trends are consistent with the decline in dairy cow numbers in the Auckland Region (see figures for Rodney, Manukau and Franklin in Figure 31).

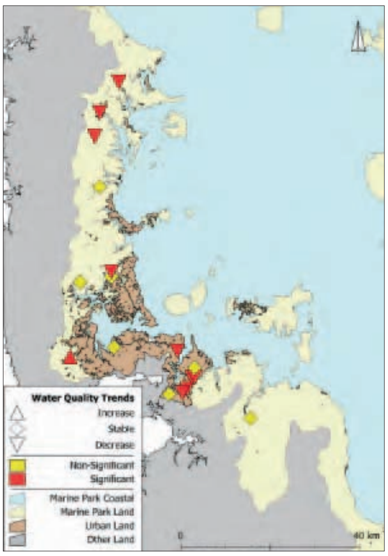
Figure 32: Trends in (a) ammonia-N, (b) nitrate-N, (c) soluble reactive phosphorus and (d) total phosphorus concentrations at Auckland Council's stream water quality monitoring sites that were sampled at monthly intervals from 1986-1995 (depending on the site) to 2005 (Scarsbrook 2008).



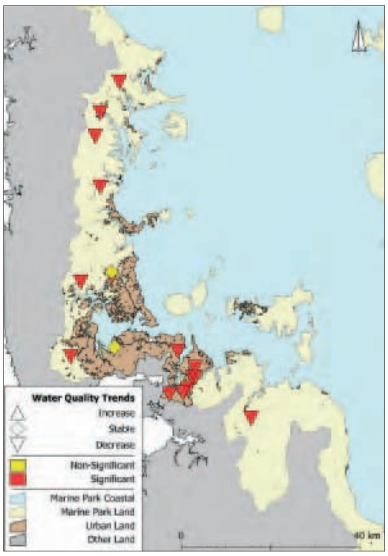
A. Ammonia-N



B. Nitrate-N



C. Soluble Reactive Phosphorus

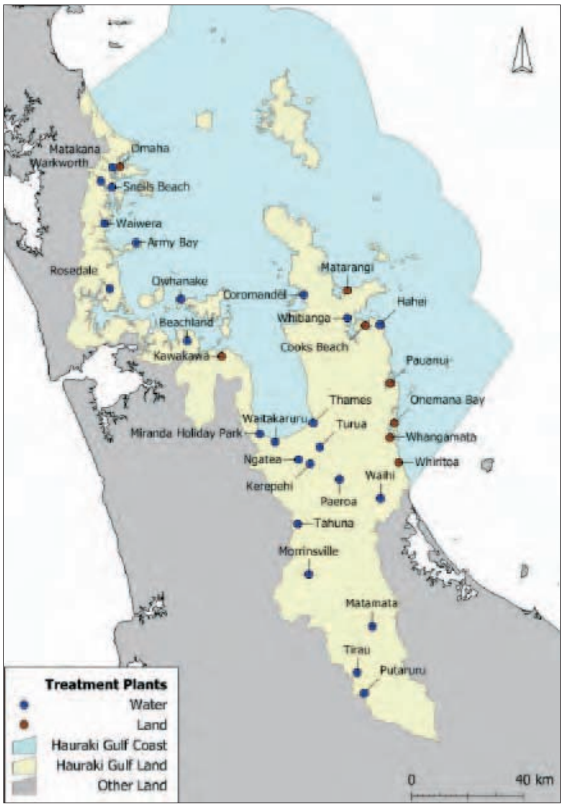


D. Total Phosphorus

4.3.2 Wastewater inputs

The total nitrogen load from the two largest wastewater treatment plants to discharge into the Hauraki Gulf (i.e. Rosedale and Army Bay) was estimated to be around 198 and 39 tonnes respectively in 2010 (i.e. equivalent to 7.4% of the nitrogen load coming from the upper half of the Hauraki Plains). Total nitrogen loads are not measured at the other wastewater treatment plants in the Auckland or Waikato regions (Figure 33) but, given the sizes of the populations they service, additional loads are likely to be relatively minor. Furthermore, on the eastern side of Coromandel Peninsula, nutrient loads from wastewater plants are minimised by using land disposal at six of the eight treatment plants. Land disposal is also used at Kawakawa Bay and Omaha within the Auckland Region.

Figure 33: Wastewater treatment plants in the Hauraki Gulf showing whether the discharge is to land or water.



4.3.3 Coastal nutrients

Auckland Council (and its predecessor, ARC) has consistently collected coastal water quality data from 20 sites in the Hauraki Gulf over a 17 to 23-year period from 1987-1993 to the present day. An analysis of that data carried out in 2008 ranked water quality for each monitoring site (excluding Goat Island) based on six indicators of sediment, nutrients and wastewater contamination: total suspended solids, nitrate-nitrogen, ammonia-nitrogen, total phosphorus, soluble reactive phosphorus and faecal coliforms (Scarsbrook 2008). That data indicated that water quality was very good in coastal areas, but quality tends to decline within harbours and estuaries, as concentrations of suspended solids, nutrients and indicators of faecal contamination increase.

Of the 20 sites monitored by Auckland Council:

– 18 sites had stable nitrate-nitrogen and ammonia-nitrogen concentrations over the full monitoring period, or displayed improving trends. However, few (n=5) of the declining trends were statistically significant. The Goat Island site displayed a slight but statistically significant upward trend in nitrate-nitrogen concentrations, and Warkworth town basin displayed a slight but non-significant upward trend in ammonia-nitrogen concentrations.

– All 20 sites displayed improving trends in soluble reactive phosphorus and/or total phosphorus concentrations. All of these trends were statistically significant for soluble reactive phosphorus, while declining trends in total phosphorus were statistically significant at 14 sites. However, the Mahurangi Heads, Ti Point, Goat Island and Orewa sites displayed slight but statistically significant upward trends in total phosphorus concentrations.

Comparable long-term data is not available from the Waikato Region, but monthly monitoring was carried out at three sites in the southern Firth of Thames between November 2006 and December 2007. Median concentrations of total phosphorus were in the range of 40 to 60 mg/m^3 and of total nitrogen were 200 to 400 mg/m^3. Concentrations of total phosphorus changed little over the year, but total inorganic nitrogen concentrations were more variable. Based on this monitoring, Vant (2011) concluded that water quality in the southern Firth of Thames was reasonably good, with no obvious grounds for concern.

Figure 34: Water quality rankings of Auckland Council's water quality monitoring sites that were sampled at monthly intervals from 1987-1993 to 2007 (Scarsbrook 2008).

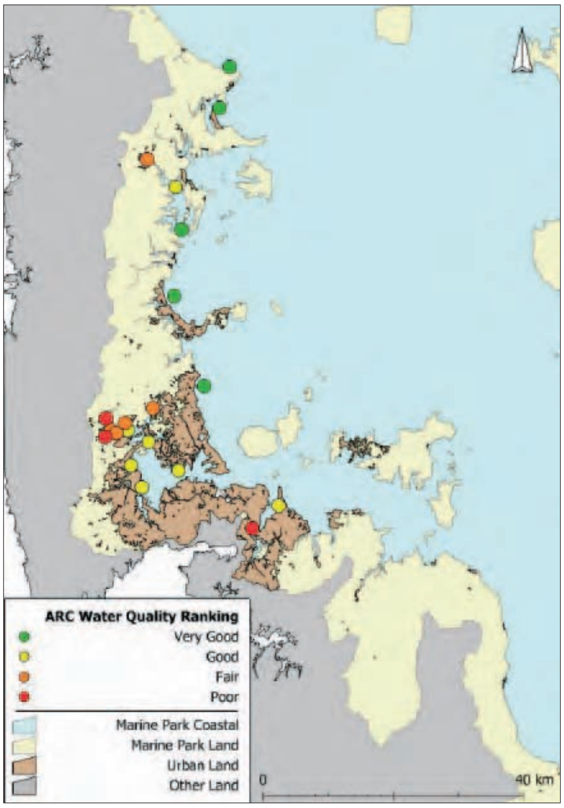
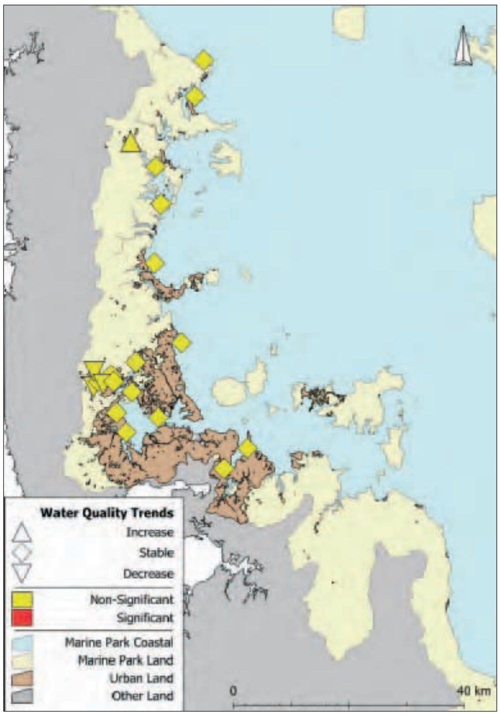
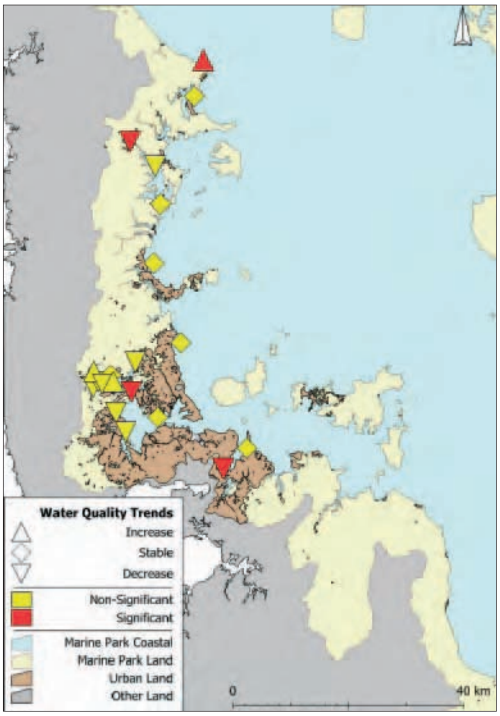


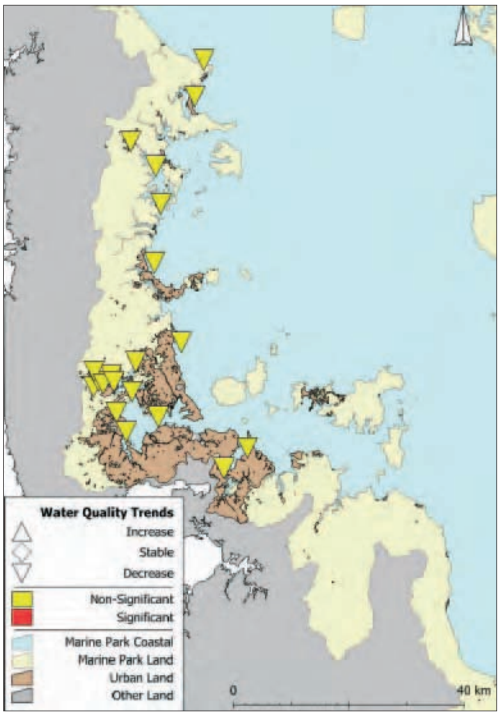
Figure 35: Trends in (a) ammonia-N, (b) nitrate-N, (c) soluble reactive phosphorus and (d) total phosphorus concentrations at Auckland Council's coastal water quality monitoring sites that were sampled at monthly intervals from 1987-1993 to 2007 (Scarsbrook 2008).



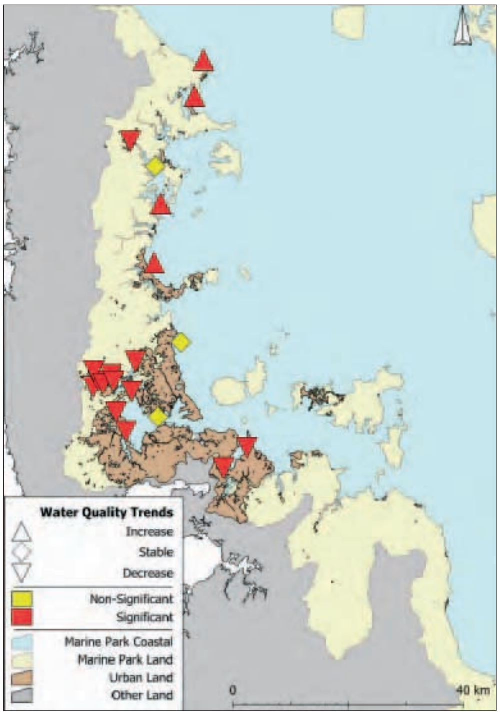
A. Ammonia-N



B. Nitrate-N



B. Soluble Reactive Phosphorus



C. Total Phosphorus

4.3.4 Strategic considerations for nutrients

1. The Firth of Thames is enriched with nitrogen relative to historical levels.
2. Historically, oceanic sources of nitrogen are likely to have been the dominant input to the Firth of Thames. However, riverine inputs now surpass oceanic ones.
3. Nutrient loads from the Waikato Region dominate inputs to the Gulf and around 90% of these originate from the Waihou and Piako rivers.
4. The two largest wastewater treatment plants in the Gulf (Rosedale and Army Bay) contribute less than 7.4% of the nitrogen loads coming from the Waihou and Piako rivers.
5. Inputs from other rivers in the Auckland Region are likely to be insignificant at the Gulf scale.
6. The mass load of nitrogen from Hauraki rivers is estimated to have increased by about 1% per year between 2000 and 2009.
7. The increased nitrogen loads from Waihou and Piako rivers is consistent with an increase in dairy cows in the Matamata-Piako and South Waikato districts over a similar period.
8. Nutrient levels in Auckland rivers displayed stable or declining trends between 1986-1993 and 2005, which is in line with a decline in the number of dairy cows.
9. Nutrient levels in coastal waters of the Auckland Region have also displayed stable or declining trends.
10. Trends in coastal nutrient levels are not available for the Waikato Region.

4.4 Beach water quality

Wastewater pathogens (disease-causing organisms) primarily enter the coastal environment through leakage from septic tanks, overflows and discharges from wastewater networks, contaminated stormwater, discharges from wastewater treatment plants, and animal droppings. These organisms pose a health hazard when water is used for contact recreation, such as swimming and other high-contact water sports. In most cases ill-health effects are minor and short lived, but there is potential for contracting more serious diseases, such as hepatitis A, giardiasis, cryptosporidiosis, campylobacteriosis and salmonellosis (Ministry for the Environment, Ministry of Health 2002). Contamination of swimming beaches is assessed using *Enterococci* bacteria as an indicator of the harmful pathogens that can cause illness.

A variety of beaches in the Auckland and Waikato regions are monitored during summer (November to March/April), in general accordance with the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (Ministry for the Environment, Ministry of Health 2002). Monitoring is generally carried out once per week during the summer period but, in the Auckland Region, occurs more frequently if high *Enterococci* counts are detected. The guidelines provide three status zones in terms of monitoring and management actions:

Status	**Enterococci count per 100 ml**	**Management action**
Surveillance	< 140	Continue weekly monitoring
Alert	140-280	Monitor daily
Action	Two consecutive samples > 280	Monitor daily, erect warning signs and inform the community that a public health problem exists

Enterococci counts of 280 per 100 ml were therefore used as an indicator for the state of the Gulf's beaches.[11] Between January 2006 and April 2009 the number of beaches monitored in the Auckland Region has varied, mainly due to Rodney District Council ceasing beach monitoring in 2007. However, monitoring carried out during that period shows that *Enterococci* levels regularly exceeded counts of 280 per 100 ml between 2006 and 2009 (Figure 37). Exceedances occurred mainly on North Shore beaches, in Waitematā Harbour and on eastern beaches. Occasional exceedances also occurred at Orere Point and in Tryphena Harbour on Aotea (Great Barrier Island). In contrast, *Enterococci* levels on beaches from Whangaparaoa north never exceeded 280 per 100 ml.

11. Data provided by Auckland Council and included weekly samples as well as subsequent re-samples that were carried out when alert and action thresholds were exceeded. Environment Waikato data is from weekly samples collected in January and February 2006 and 2008.

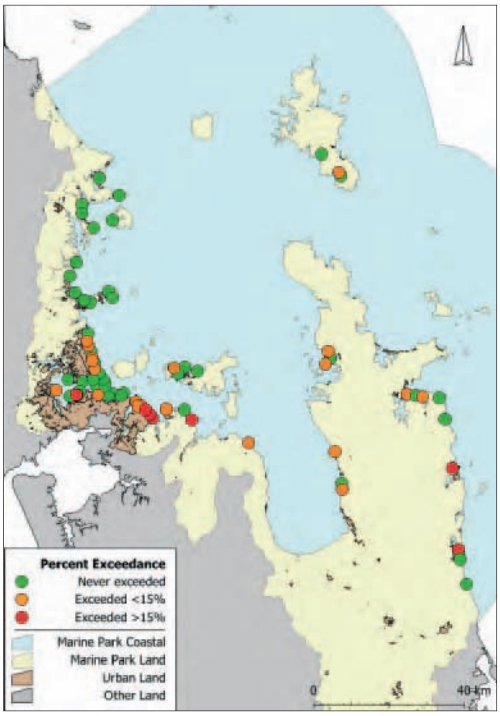
Bathing beach water quality has remained stable at the 42 Auckland sites that were monitored every year between January 2006 and April 2009, with little change in the number of sites exceeding *Enterococci* counts of 280 per 100 ml during each year (14 to 16 sites annually), and no change in the proportion of samples exceeding 280 per 100 ml among those sites.

In the Waikato Region, eight of the 16 sites monitored exceeded the action threshold at least once in January-February 2006, with two sites (in Whangamatā and Tairua harbours) exceeding it two to three times. In January-February 2008, only two sites (Cooks Bay and Tairua Harbour) exceeded the action threshold, both on a single occasion.

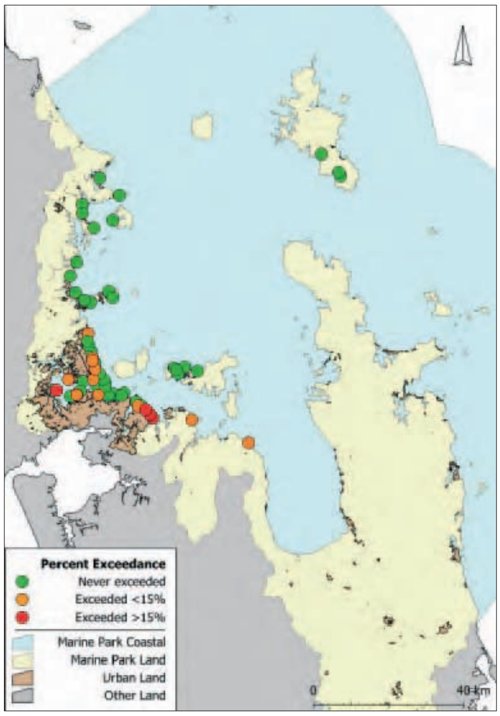
4.4.1 Strategic considerations for bathing beach quality

1. Exceedances of the "action"-level guideline for contact recreation frequently occur in the Gulf.
2. Exceedances occur mainly on urban Auckland and Coromandel Peninsula beaches.
3. Microbiological contamination poses a risk to human health, but is not a significant ecological issue.

Figure 36: Bathing beach sites that had water samples which exceeded the Ministry for the Environment and Ministry of Health's "action"-level guideline for Enterococci levels between 2006 and 2009. Dot colours show: green = no samples exceeded "action" levels; orange = less the 15% of samples exceeded "action" levels; and red = more than 15% of samples exceeded "action" levels.

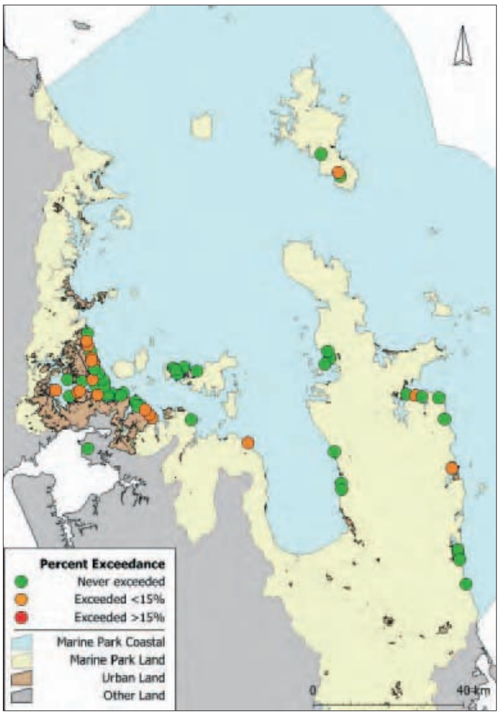


A. 2006

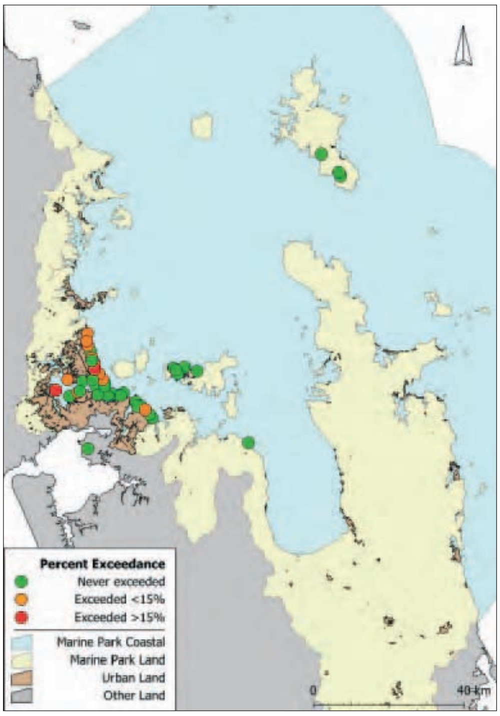


B. 2007

Figure 36: Bathing beach sites that had water samples which exceeded the Ministry for the Environment and Ministry of Health's "action"-level guideline for Enterococci levels between 2006 and 2009. Dot colours show: green = no samples exceeded "action" levels; orange = less the 15% of samples exceeded "action" levels; and red = more than 15% of samples exceeded "action" levels.

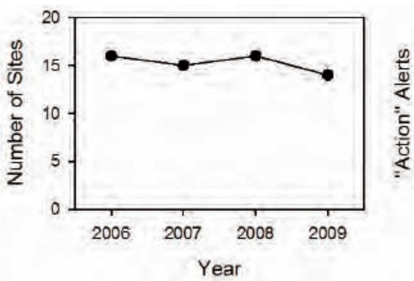


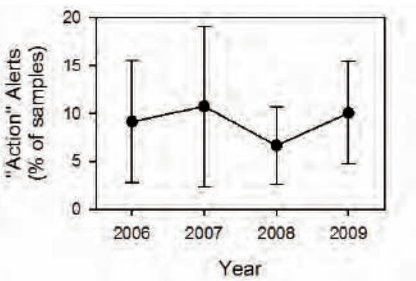
C. 2008



D. 2009 (Jan-April)

Figure 37: The (a) number of sites that were monitored every year between 2006 and 2009 and exceeded the Ministry for the Environment and Ministry of Health's "action"-level bathing guidelines for Enterococci levels, and (b) mean (+ S.D.) proportion of samples from those sites which exceeded "action" levels.





4.5 Sediment

Sediment is a serious environmental contaminant that degrades coastal habitats and is toxic to many marine organisms (Airoldi 2003, Thrush *et al.* 2004). Deposited sediment accumulates in sheltered estuaries or deep coastal areas, where the energy from waves and currents is too weak to remobilise sediments once they settle. In estuaries, thick (> 2 cm deep) deposits of terrigenous sediment (i.e. sediment eroded from the land) rapidly kill most animals buried beneath them (Norkko *et al.* 2002). Thin deposits (1 to 7 mm) also lead to a reduction in species' diversity and abundance, even in muddy areas where species are expected to have adapted to high sediment loads (Berkenbusch *et al.* 2001). Recovery tends to occur slowly after depositional events and can take in excess of a year (Norkko et al. 2002). Suspended sediments also affect marine plants and animals by reducing water clarity and light levels, as well as reducing food quality and feeding efficiency. Consequently, the condition and survival rates of marine species frequently decline as suspended sediment concentrations increase (e.g. Hewitt *et al.* 2001, Nichlolls *et al.* 2003, Ellis *et al.* 2002, Morrison *et al.* 2009).

4.5.1 Coastal sedimentation

The most obvious long-term impacts of sedimentation in the coastal environment are the infilling of estuaries and the associated expansion of mangroves. Sheltered upper estuary areas are particularly susceptible, but these processes can also occur in large, exposed waterways such as southern parts of the Firth of Thames (see Section 3.2, Swales *et al.* 2008). A number of studies have been carried out over the past decade that have improved our understanding of sediment generation and accumulation in the coastal environment. These studies have shown that:

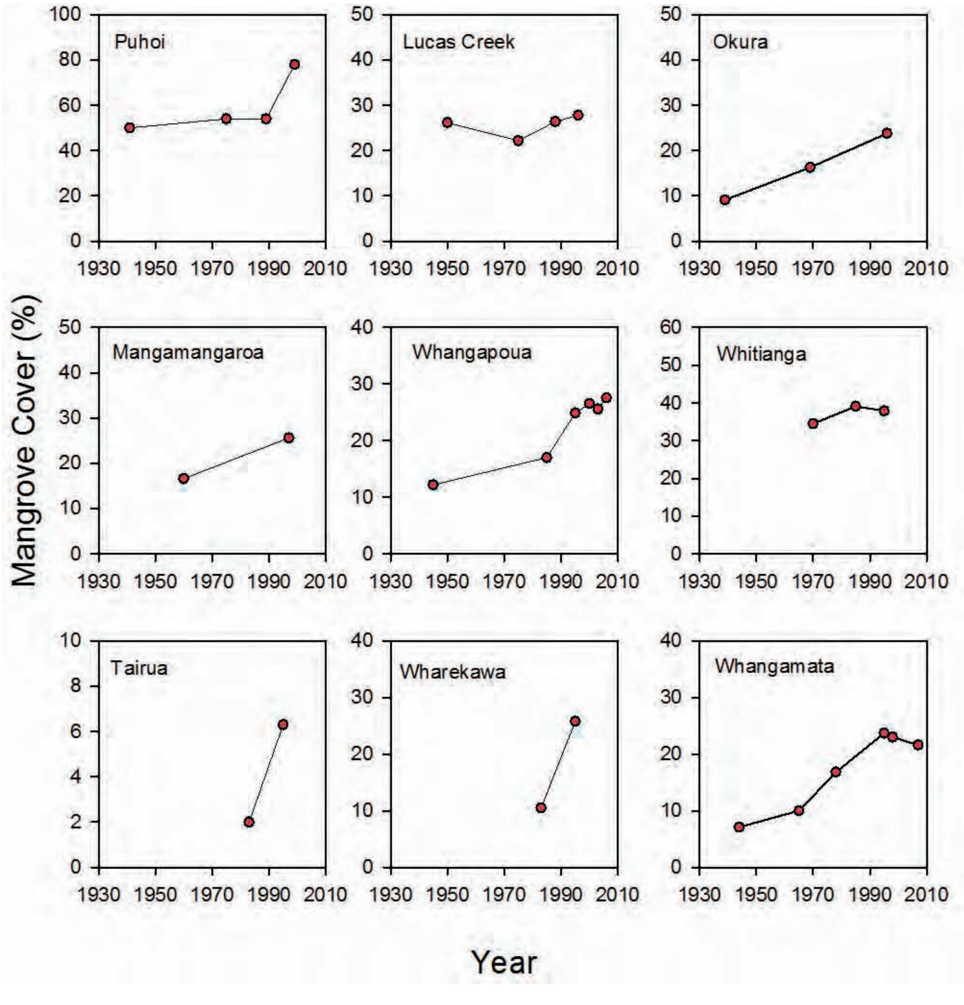
1. Sedimentation rates vary among harbours and estuaries and also among locations within harbours and estuaries (Swales *et al.* 2002).
2. Modern sediment accumulation rates on the coast are frequently much greater than natural sedimentation rates, particularly following large-scale changes in land-use and land-isturbance activities, such as forest clearance and urbanisation (Swales *et al.* 2002, Jones 2008).
3. After correcting for the effects of rainfall and hill slope, sediment yields from forested and developed urban areas are estimated to be 33% and 75% lower than those from pasture, respectively (Hicks *et al.* 2009).
4. Run-off from rural land and forest harvesting can make a significant contribution toward the overall amount of sediment deposited in estuaries (Gibbs 2006).
5. Intertidal sedimentation rates (and hence trapping rates) decrease as infilling raises seabed levels, which decreases tidal inundation (Swales *et al.* 2008). Consequently, sediments are likely to be dispersed more broadly in infilled estuaries.

4.5.2 Mangroves

Over the past 50 or so years, mangrove cover has increased substantially in many parts of the Hauraki Gulf (see Figure 38 for changes in mangrove cover within nine estuaries). This expansion has largely been attributed to sedimentation. Mangroves have a preference for soft, muddy, waterlogged sediments, and readily colonise areas where gradual sediment accretion creates habitats with suitable sediment characteristics and tidal elevation. The level of the substratum must be sufficient to expose seedlings to the air for part of the tidal cycle, because very young seedlings are intolerant of continuous submersion (Morrisey *et al.* 2007a). The expansion of mangroves is therefore a natural response to the increase in land erosion and sediment run-off caused by human activities. However, other factors, such as warmer temperatures, elevated nutrient levels and in some cases, hydrological obstructions (e.g. causeways), may also enhance mangrove growth and survival (Morrisey *et al.* 2007a).

Estimates obtained from the Ministry for the Environment's land classification database (LCDB2) indicate that in the summer of 2001/02 mangroves covered 2,641 ha in the Auckland Region and 2,422 ha in the Waikato Region.[12] These areas appeared to have remained unchanged from the previous assessment in the summer of 1996/97, although the spatial resolution of this data was relatively coarse. However, the spread of mangroves continues to cause serious concern among many local communities. For example, in Whangamatā, local frustration about the spread of mangroves (Figure 39) led to their illegal removal in October 2005 and January 2007. A resource consent was subsequently granted by the Environment Court, which allowed the limited removal of mangrove seedlings. Waikato Regional Council is currently working with the community to improve the environmental management of Whangamatā Harbour, and further options for mangrove management are considered in the Whangamatā Harbour and Catchment Management plans, which have now been completed.

Figure 38: Changes in the percentage of area covered by mangrove forest in nine Hauraki Gulf estuaries. Data was collated from Jones (2008) and Morrisey et al. (2007a).



12. These estimates are based on spectral analysis of satellite images using a minimum mapping unit of 1 ha.

Figure 39: Historical mangrove distribution in Whangamatā Harbour showing the increase in cover (green areas) from (a) 1944 to (b) 1965, (c) 1978 and (d) 2002. The red outline indicates mangrove extent in 2002.

A. 1944

B. 1965

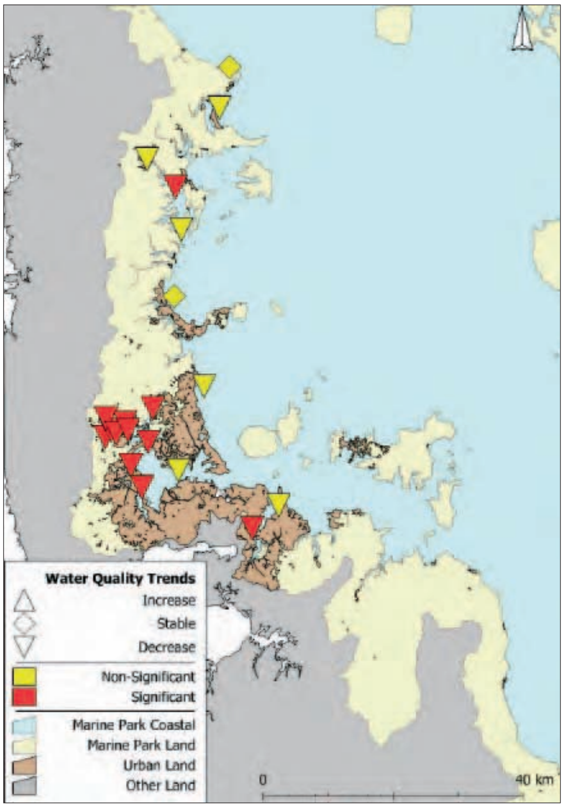
C. 1978

D. 2002

4.5.3 Total suspended solids

Auckland Council (and its predecessor, ARC) has collected coastal water quality data from 20 sites in the Hauraki Gulf over a 17 to 23-year period from 1987-1993 (depending on the site) to the present day. Of the 20 water quality sites monitored by Auckland Council, 18 sites displayed improving trends in total suspended solids concentrations, with 12 of these trends being statistically significant. Total suspended solids concentrations at the two remaining sites (Goat Island and Orewa) were low and stable over the full monitoring period. This suggests that efforts by ARC to control sediment generation over the past 20 or so years are leading to improved environmental outcomes. However, it should be noted that while suspended solids includes sediments, they can also include other biological and non-biological material.

Figure 40: Trends in the concentrations of total suspended solids at Auckland Council's water quality monitoring sites that were sampled at monthly intervals from 1987-1993 to 2007 (Scarsbrook 2008).



4.5.4 Sediment characteristics and effects on seabed communities

Auckland Council (and its processor, ARC) and Waikato Regional Council monitor sediment characteristics and seabed communities in a number of harbours and estuaries in the Hauraki Gulf (Figure 41). In 2000, ARC initiated a monitoring programme that was specifically designed to detect sediment-related changes in the composition of intertidal communities in Okura Estuary. Between 2002 and 2004, this programme was expanded to include Puhoi, Wairewa, Orewa, Mangemangeroa, Turanga and Waikopua estuaries, which were all facing an increase in development pressure and an associated risk of increasing sedimentation. Whangateau Harbour was subsequently added in 2009, due to specific concerns about ecological degradation in that estuary.

Trends in community composition, which are consistent with increased sediment-mud content, were detected at two sites in Turanga, Puhoi and Orewa estuaries and one site in each of the other estuaries, with the exception of Mangemangeroa. Changes in diversity or in the abundance of specific taxa, which are consistent with ecological responses to increased terrestrial sedimentation or mud content, were also observed at one site in each of Orewa, Puhoi, Waikopua and Waiwera, and at four sites in Okura.

Sediment characteristics at four state-of-the-environment monitoring sites in the central Waitematā Harbour were relatively stable between October 2000 and February 2008, apart from a slight decrease in the proportion of medium sand in Shoal Bay. Over that period, changes have occurred in species' abundances, but these cannot be attributed to sedimentation or contamination effects. Rather, they may reflect natural long-term cycles in species' abundances (Townsend *et al.* 2008b).

However, long-term monitoring of the state of the environment by ARC has detected a marked change in the sediment characteristics of Mahurangi Harbour, which occurred between April 1996 and April 1997, and involved an increase in the proportion of fine sand. This was followed by stepwise declines in the populations of five taxa at the muddiest intertidal site (Hamilton Landing) in 2000. These populations had not recovered by 2009. Three of the taxa (the wedge shell *Macomona liliana*, cockle *Austrovenus stutchburyi* and polychaete *Scoloplos cylindrifer*) are known to be sensitive to increased suspended sediment concentrations. Furthermore, cockles and wedge shells are each declining at one other site within the harbour (Halliday and Cummings 2009).

Similarly, Waikato Regional Council found that the proportions of mud and fine sand increased significantly between 2001 and 2006 at monitoring sites in the Firth of Thames (Figure 42). However, the proportion of mud remained relatively low (< 6%). The source of the fine sediments is likely to have been run-off from the catchment, but it is not easy to determine whether it was due to recent run-off events or the redistribution of historically deposited fines. Although clear trends of increasing fine sediments and decreasing coarse sand were observed, these changes were not matched by negative trends in species that are sensitive to fine sediments. Diverse macrofaunal communities remained at the five sites, which included species that cannot tolerate a high proportion of fine sediments. This suggested that despite that the increase in sediment-mud levels, they remained low enough to maintain populations of sensitive species (Felsing and Singleton 2008).

4.5.5 Strategic considerations for sediment

1. Terrigenous sediment is a serious contaminant that is responsible for relatively large-scale impacts on the coastal margin.
2. Sediment impacts are the result of ongoing and historical changes in land-use and land-disturbance activities.
3. Sediment accumulation has caused coastal infilling in the southern Firth of Thames and elsewhere, and has contributed to widespread mangrove expansion.
4. Estuaries affected by sedimentation have experienced reductions in the abundance of species that are sensitive suspended and deposited sediments, and changes in the composition of their benthic communities.
5. Suspended solids concentrations have been declining in coastal water from the Auckland Region. However, the interpretation of this trend is complicated because suspended solids include sediment as well as other particulate material.

Figure 41: Estuaries, harbours and sites where benthic ecology and sediment characteristics are monitored by the former ARC (Auckland Council's predecessor) and Waikato Regional Council. Colours indicate the year that monitoring began at each location.

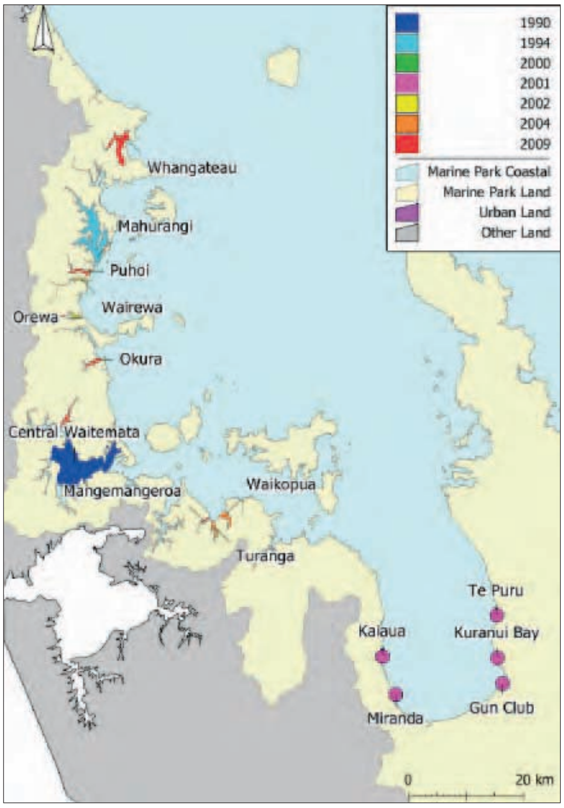
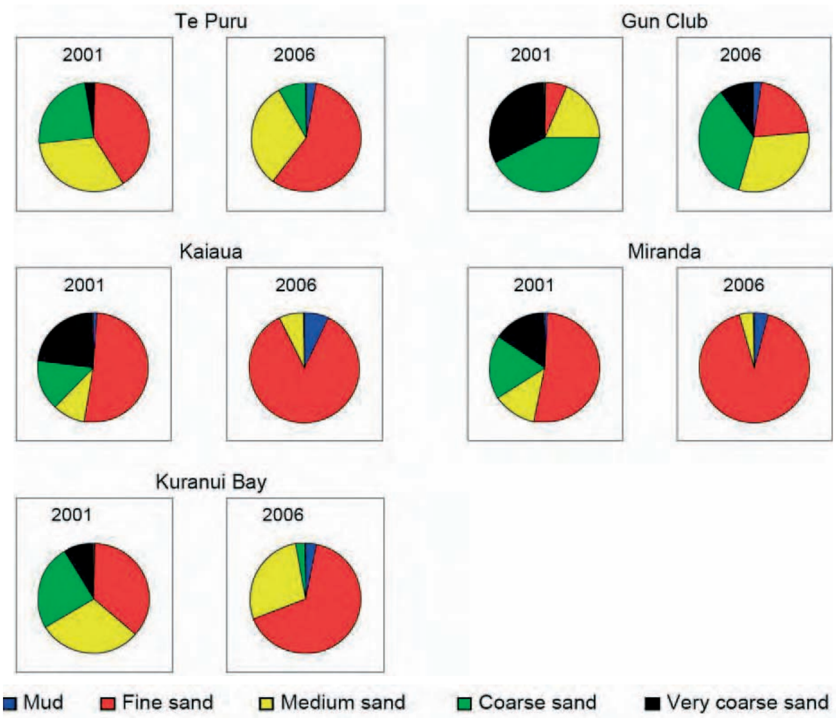


Figure 42: Average grain size characteristics of sediments from monitoring sites in the southern Firth of Thames in April 2001 and April 2006 (Felsing and Singleton 2008). Grain sizes: mud = < 63 µm; fine sand = 63-250 µm; medium sand = 250-500 µm; coarse sand = 500-1000 µm; very coarse sand = > 1000 µm.



4.6 Introduced (non-indigenous) marine species

Introduced plants and animals pose a serious threat to the natural ecology, native biodiversity, aesthetics, commercial activity and human health by:
– competing with native species for food, space and other resources;
– consuming native and aquaculture species;
– spreading disease;
– exerting toxic effects; and
– fouling natural and artificial surfaces.

Exotic marine species are accidentally introduced and spread through the movement of vessels, structures and equipment. Common transportation vectors include ships' ballast water and sea-chests, fouled vessel hulls and fouled marine equipment. They can also be unintentionally or intentionally introduced and spread through activities such as aquaculture, fisheries and the aquarium trade (Hewitt *et al.* 2004).

Owing to the amount of international, national and regional shipping and boating activity, ports are recognised as high-risk areas in terms of their capacity to facilitate the introduction, establishment and spread of introduced species. Consequently, Biosecurity New Zealand (Biosecurity NZ) has conducted baseline surveys to document the occurrence of non-indigenous species in New Zealand's major port and associated harbours, including Auckland (*Inglis et al.* 2005, Inglis et al. 2006). In addition, routine surveillance is carried out to detect the presence of a group of non-indigenous species that present a significant risk of arriving and establishing in New Zealand. That monitoring is also used to detect changes in the distribution of established non-indigenous or pest species (Morrisey *et al.* 2010). As with the baseline surveys, sampling in this programme is focused on harbours that have high-volume commercial ports and marinas, which are entry points for international vessels (Morrisey *et al.* 2007b). Biosecurity NZ supports passive surveillance too, through the identification and recording of unusual specimens provided by members of the public.

A total of 139 non-indigenous marine species in the Hauraki Gulf have been recorded by Biosecurity NZ (Figure 43). Many of these appear to be well established in the Port of Auckland and have widespread distributions in other ports and marinas nationwide. However, a number of recent arrivals are notable for their potential to cause adverse effects. Among them were three species listed on the New Zealand Unwanted Organisms register (which only contains eight marine species):

1. The Mediterranean fanworm *Sabella spallanzanii* is a large (up to 70 cm in length) tube-building polychaete that is native to the Mediterranean and Atlantic coasts of Europe. *Sabella spallanzanii* can form dense mats that could affect native species by competing for food and space. They could also affect nutrient-cycling processes due to their high filtering capacity. *Sabella spallanzanii* prefer growing on hard vertical surfaces and, in other countries, have been observed growing on mussel ropes. They are not considered to be a significant nuisance by marine farmers. However, dense beds could become a hazard to recreational and commercial fishers through the clogging of dredges and fouling of other fishing gear.
2. The clubbed sea squirt *Styela clava* (Figure 44), which is native to the coastal waters of Japan, Korea, northern China and Siberia. *Styela clava* was first identified in New Zealand in the Viaduct Basin, Waitematā Harbour, in August 2005, and was subsequently found to be relatively widespread. This species poses a potential threat to the marine environment and its resources, particularly to mussel farming. In its native range it is known to foul hanging baskets of oysters and fish cages, and in Canada it has caused a decline in the production of cultivated mussels (see Gust *et al.* 2009).
3. The Asian kelp *Undaria pinnatifida* (Figure 44) was detected in the Auckland port area in September 2004, but was first discovered in Wellington Harbour in 1987. It is an invasive seaweed originating from temperate regions of Japan, China and Korea, where it is farmed as a food crop (commonly known as Wakame). *Undaria pinnatifida* rapidly colonises bare space following environmental disturbances, and forms a dense canopy which prevents other seaweeds from gaining a foothold. It out-competes native species through rapid growth, early maturity and large reproductive output. It is easily spread by human activities and has a hardy microscopic stage which is difficult to eradicate.

Another arrival of note is the Japanese mud crab *Charybdis japonica*, which is a large and aggressive (maximum carapace width ~ 10 cm) paddle crab that is native to the north-west Pacific, including coastal regions of China, Malaysia, Korea, Taiwan and Japan. It was probably introduced to New Zealand in the late 1990s by international shipping, and was first discovered in Waitematā Harbour by a commercial fisher in September 2000. By April 2002 it was widely distributed in the harbour and in September 2002 it was found also in Weiti and Tamaki estuaries. *Charybdis japonica* could be a significant predator of small bivalves with populations such as cockles (*Austrovenus stutchburyi*), pipi (*Paphies australis*), scallops (*Pecten novaezelandiae*) and mussels (*Perna canaliculus*) being particularly vulnerable. There is no native crab equivalent to *C. japonica* in New Zealand estuaries (Gust and Inglis 2006).

Once established, the eradication of non-indigenous marine species is extremely difficult to attain. Management is therefore focused on preventing the introduction and spread of species to locations where they do not presently occur.

4.6.1 Strategic considerations for introduced marine species

1. The Port of Auckland is a high-risk area in terms of its capacity to facilitate the introduction, establishment and spread of introduced species.
2. The large amount of boating and other marine-based activities in the Gulf increases the risk that introduced species will be spread.
3. At least four unwanted or high-isk species have arrived in the Gulf over the past 10 years or so.
4. Once established, the eradication of non-indigenous marine species is extremely difficult and often in practice impossible

Figure 43: Number of non-indigenous marine species recorded in the Hauraki Gulf through Biosecurity New Zealand's baseline and surveillance surveys, and specimens obtained through passive surveillance.

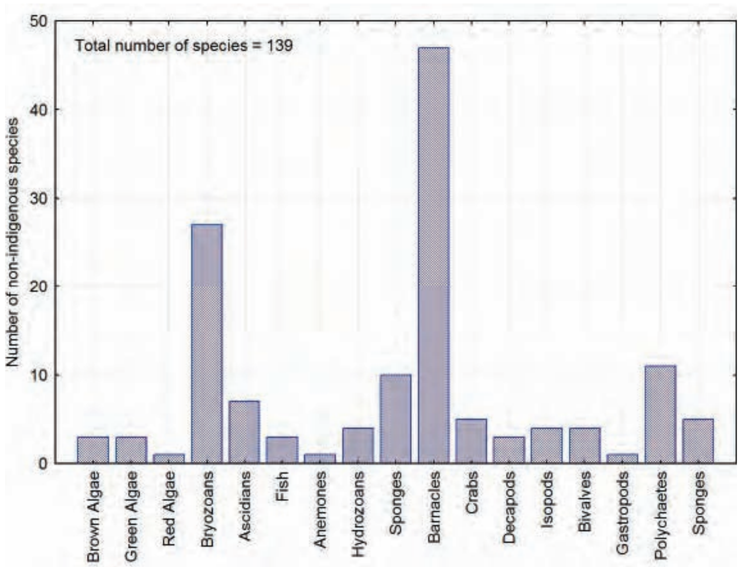


Figure 44: Images of (a) the clubbed sea squirt *Styela* clava growing on shallow-reef habitat in Long Bay Marine Reserve in 2007, and (b) the Asian kelp *Undaria pinnatifida* fouling mussel lines in Fitzroy Harbour in 2006. (Photos courtesy of Dr Shane Kelly, Coach and Catchment Ltd.)

A.

B.

4.7 Harmful algae, pathogens and mass mortalities

Harmful algae and pathogens are commonly linked to mass mortalities of individual or multiple marine plant and animal species. Harmful algae also pose a serious health risk for humans who consume affected seafood or who live in coastal areas. Little is known about the historical occurrence and ecology of harmful algae and pathogens in New Zealand, so it is not possible to determine whether human activities have exacerbated their occurrence. Outbreaks could possibly be promoted by creating favourable environmental conditions for the survival and growth of harmful species, or by facilitating their spread among locations. The susceptibility of marine plants and animals to the effects of harmful algae and pathogens could be increased as well, if ecological resilience is already compromised by human activities such as fishing or pollution (Hsieh *et al.* 2010, Österblom et *al.* 2008).

A routinely collected record of harmful algal blooms and pathogens is not maintained by any particular organisation. The scientific literature, records from the Ministry of Agriculture and Fisheries' (MAF) Investigation and Diagnostic Centre and personal communication with scientific experts was therefore used to produce a list showing the first records of harmful algae and pathogens, and their subsequent frequency of occurrence (Table 5). Given the limitations of the dataset, this list is likely to be incomplete. However, it suggests that the prevalence of harmful algae blooms and pathogens has increased since the 1980s, and that outbreaks of these organisms have had rapid and highly visible impacts on humans, susceptible species and associated industries.

Notable events caused by harmful algae and pathogens include:
- blooms of a previously unknown toxic algae, *Karenia concordia*, in 1992/93 and 2002 which resulted in significant human health issues and the deaths of fish, other algae and farmed paua;
- the occurrence of a herpes virus in 1995, which caused what is considered to be the largest mass mortality of a fish species ever recorded (the Australasian pilchard *Sardinops sagax neopilchardus*);
- mortality of up to 60 to 80% of cockles in Whangateau Harbour in 2009, linked to a bacterial infection which was potentially exacerbated by high temperatures causing heat stress; and
- mass mortalities of juvenile Pacific oysters in 2010 linked to a herpes virus, which killed up to 80% of spat.

Year	**Harmful algae or pathogen**	**Type of harmful organism**	**Notes**
1983	*Cerataulina pelagica* and *Prymnesium calathiferum*	Algae	Marine life was killed through oxygen depletion caused by the seemingly harmless diatom *Cerataulina pelagic*. A bloom of a previously unknown toxic algae, *Prymnesium calathiferum*, was also recorded in Bream Bay and its occurrence was linked to fish and shellfish kills (Chang and Ryan 1985, Chang *et al.* 2008).
1992/93	Unidentified virus?	Virus	Significant die-offs of the canopy-forming kelp Ecklonia radiata were recorded in many parts of the Gulf. Virus-like particles were identified in diseased plants (Easton *et al.* 1997), but amphipod grazing of injured plants has also been implicated in *E. radiata* die-offs (Haggitt and Babcock 2003).
1993	*Karenia concordia* (originally identified as *Gymnodinium cf. breve*) and possibly *K. mikimotoi* and *K. brevisulcata*	Algae	First reported cases of shellfish poisoning of humans in New Zealand, caused by a newly discovered species. More than 180 people were notified as developing neurological symptoms, and there were numerous reports of respiratory irritation from an airborne toxin in sea spray (Chang *et al.* 1995, Chang and Ryan 2004, Chang *et al.* 2008, Chang 2011). Although not specifically linked to toxic algae, mass mortalities of scallops in the Omaha Bay and Kawau Island areas were also recorded (Morrison 1999).
1995	Herpesvirus	Virus	Extraordinarily large-scale mortalities of Australasian pilchard *Sardinops sagax neopilchardus* that spread rapidly between March and September 1995 and covered more than 5,000 km of the Australian coastline and 500 km of the New Zealand coastline. This event is thought to be the largest mass mortality ever recorded, both in terms of the number of fish and the geographic range affected. The rate of spread suggested that a vector was involved in the transport of the virus. Possible vectors include birds, marine mammals, ships and contaminated bait (Hyatt *et al.* 1997, Jones et al. 1997, Whittington *et al.* 1997).
1998/99	Unknown cause of scallop mortality.	Unknown	High mortality in scallops with a "black gill" condition observed in relation to the die-off. This condition was not considered to be indicative of a causative disease agent (although Rickettsiales-like organisms were found in animals with the condition) (Cryer 2001). A massive increase in the distribution and density of the filter-feeding tube worm *Chaetopterus* occurred around the same time too, suggesting that broad-scale environmental conditions could also have contributed to scallop mortality (Cryer 2001, Tuck *et al.* 2006).

Approx. 1998 onwards	*Ostreopsis siamensis*	Algae	Blooms of the toxic algae Ostreopsis siamensis appear to be a new phenomenon on shallow reefs in New Zealand. Ostreopsis siamensis grows as a distinctive rusty-brown-coloured mucilaginous film on reefs and blooms in the Gulf and have been linked to spine loss, and an associated increase in predation on grazing urchins Evechinus chloroticus (commonly known as kina). This phenomenon had not been reported prior to 1998 (Shears and Ross 2009, 2010).
2002	*Karenia concordia* and possibly *K. mikimotoi* and *K. brevisulcata*	Algae	Blooms of the toxic algae *Karenia concordia* occurred in mid-October and caused mass mortalities of another conspicuous bloom-forming algae *Noctiluca scintillans*, tens of thousands of fish in the central-inner Gulf (including spotties, yellow-eyed mullet, flounder, eels, parore and goby/blennies) and around 8,500 paua at a farm in Kennedy Bay were also killed (Chang *et al*. 2003, Chang *et al.* 2008).
2009	Coccidian and *Mycobacterium* infection	Bacterial pathogens	Mass mortalities of up to 60 to 80% of cockles in Whangateau Harbour were linked to bacterial infection. Cockles were possibly weakened by heat stress, which left them more susceptible to infection (MAF Investigation and Diagnostic Centre 2009c).
2009	Unknown	Unknown	Large numbers of dead pilchards (*Sardinops neopilchardus*) were recorded on beaches north of Auckland (Martins Bay, Orewa Beach, Red Beach, Stanmore Bay, Army Bay and Long Bay) from 3 to 31 July 2009, and deaths of jack mackerel (*Trachurus spp.*) were reported on Aotea (Great Barrier Island) on 5 August 2009. Internal parasitic infections were detected in the pilchards, but these were not considered to have caused the deaths. No other evidence of an infectious agent was detected in the pilchards of mackerel (MAF Investigation and Diagnostic Centre 2009a and 2009b).
2010	Ostreid herpesvirus OsHV-1	Virus	Mass mortality of juvenile Pacific oysters occurred on oyster farms from Parengarenga Harbour in Northland to Ohiwa in the eastern Bay of Plenty were linked to a herpesvirus. On some farms, up to 80% of juvenile oysters died, compared with 5 to 10% in a normal year. The die-off is expected to have a significant impact on production in the near term.

Occasional mass mortalities of other species, such as little blue penguins (Taylor 1976) and common dolphins, have also been recorded. Little blue penguins appear to be sensitive to a food limitation and have a relatively long history of reported mortality. For instance, in March-April 1975, 20 to 30 dead penguins were found per kilometre along Pakiri Beach. They bore no signs of disease, but all examined had empty stomachs. It is thought that these, and other, blue penguin deaths were caused by limited food supplies, possibly associated with high sea temperatures (Taylor 1976).

4.7.1 Strategic considerations for harmful algae, pathogens and mass mortalities

1. Impacts from harmful algae, pathogens and mass mortalities of unknown cause typically occur very rapidly, have covered very large areas and have had severe consequences for humans, affected species and associated industries.
2. Records of these events are scattered among a variety of sources, making it difficult to access information and assess trends in occurrence and severity.
3. The role that human activities have in exacerbating the occurrence or spread of harmful algae and pathogens is not known.
4. The effects of mass mortalities could worsen, if human activities reduce the resilience of the marine ecosystem.

4.8 Litter

Man-made litter is a ubiquitous and ongoing issue for the Hauraki Gulf. The volume of plastics and their persistence in the marine environment makes them particularly problematic, but a variety of other material also enters and accumulates in the coastal environment.

Marine pollution by plastics is a global concern due to their environmental persistence, the large volumes involved and their wide dispersal by ocean currents (Gregory 2009). Plastic litter:
- fouls beaches;
- entangles marine life and kills by drowning, strangulation, creating drag and reducing feeding efficiency;
- is often ingested by marine and bird life;
- is the source and sink for xenoestrogens and persistent organic pollutants (POPs) in marine and aquatic environments;
- acts as a vector for the dispersal of invasive species;
- can degrade nursery habitats; and
- fouls vessel intake ports, keels and propellers, putting crews at risk.

Once in the ocean, floating debris is either forced back to the shore by onshore winds, or offshore winds carry debris toward major ocean currents. In the deep ocean, high pressure gyres tend to concentrate the debris, while low-pressure systems tend to disperse it. Over 260 species, including invertebrates, fish, seabirds and mammals, have been reported to ingest or become entangled in plastic debris, resulting in impaired movement and feeding, reduced reproductive output, lacerations, ulcers and death (Gregory 2009). Plastics weaken and may kill seabirds through starvation and false feelings of satiation, irritation of the stomach lining, and failure to put on fat stores necessary for migration and reproduction. For example, prions (seabirds) retrieve very small prey from the sea's surface, and can mistakenly collect plastic pellets floating on the water. In New Zealand, Harper and Fowler (1987) found that there was an increasing trend in the number of plastic pellets in the gizzards of five prion species washed up dead on Wellington beaches between 1958 and 1977. There was also an inverse relationship between the number of pellets found and the body weight of birds.

Plastics become brittle when exposed to UVB radiation in sunlight, the oxidative properties of the atmosphere and the hydrolytic properties of seawater, and subsequently fragment into smaller and smaller pieces. Consequently, plastic fragments are widespread in the oceanic and sedimentary habitats. The wide distribution of plastic pellets on New Zealand beaches was first reported by Gregory (1977). Pellet abundance was highly variable, but tended to be greatest close to major urban centres.

Plastics provide a direct and indirect pathway for the uptake of toxic organic contaminants by wildlife. In seawater, plastics sorb and concentrate contaminants such as polychlorinated biphenyls (PCBs), dichlorodiphenyldichloroethylene (DDE), nonylphenol and phenanthrene. These can become several orders of magnitude more concentrated on the surface of plastic debris than in the surrounding seawater (Barnes *et al.* 2009, also see Rios 2007). Microscopic plastic fragments are likely to pose a greater risk than large plastic items because of their greater ratio of surface area to volume which increases sorption capacity. A range of chemicals is also usedas additives in the manufacture of plastics. Some of these, such as phthalate plasticisers and brominated flame retardants, are potentially harmful and have been associated with carcinogenic and endocrine-disrupting effects (Teuten *et al.* 2009).

4.8.1 Trends and characteristics of litter

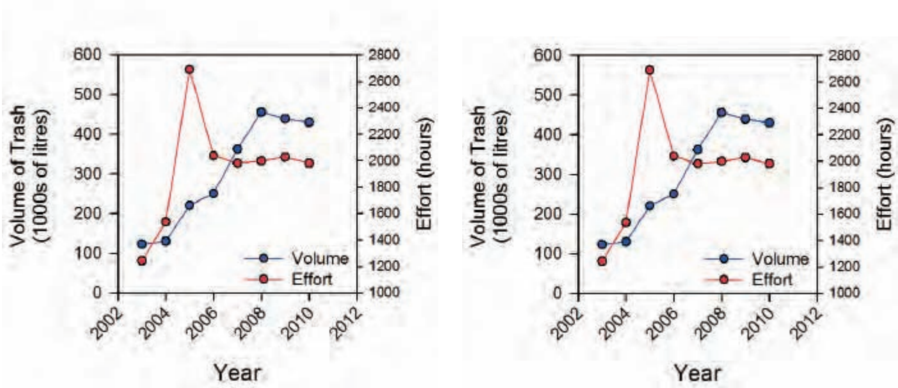
Data on litter volumes and characteristics in the Hauraki Gulf was obtained from the Waitematā Harbour Clean-up Trust and the Sustainable Coastlines organisation. The Waitematā Harbour Clean-up Trust operates a 6.5 m boat, the *Phil Warren*, which works in conjunction with kayaks and a flat-bottomed punt, to clean the shoreline, beaches, estuaries and mangrove areas of the Waitematā Harbour, Tāmaki Estuary and islands in the Auckland Region. The volume of litter collected by staff of the Trust increased steadily between 2004 and 2008 (Figure 45). Since 2008 the amount of litter collected has stabilised at around 420,000 to 450,000 litres per annum. Clean-up efforts by the Trust's staff peaked in 2005, and have since been relatively steady at around 2,000 hours per annum. Similarly, the amount of litter collected per hour increased between 2005 and 2008, and has since stabilised. Note that stabilisation in the volume and yield of litter does not mean that the amount of trash entering the coastal environment has evened out. Rather, this may reflect the maximum amount of litter that can be collected with the resources available.

Sustainable Coastlines co-ordinate community-based clean-ups at locations throughout the Gulf, and collect detailed data on the amount and characteristics of litter collected. Their data demonstrates that litter entering the Hauraki Gulf comes from a variety of sources. Information obtained during recent clean-ups of North Shore beaches and Rangitoto Island indicates that in those areas the bulk of litter came from food packaging, household and personal items, and uncategorised sources.[13] In contrast, fishing-related material dominated the litter collected from Coromandel beaches (Figure 46). At all locations, plastic materials were the dominant form of litter, and the relative contribution of plastics tended to increase at more remote locations.

4.8.2 Strategic considerations for litter

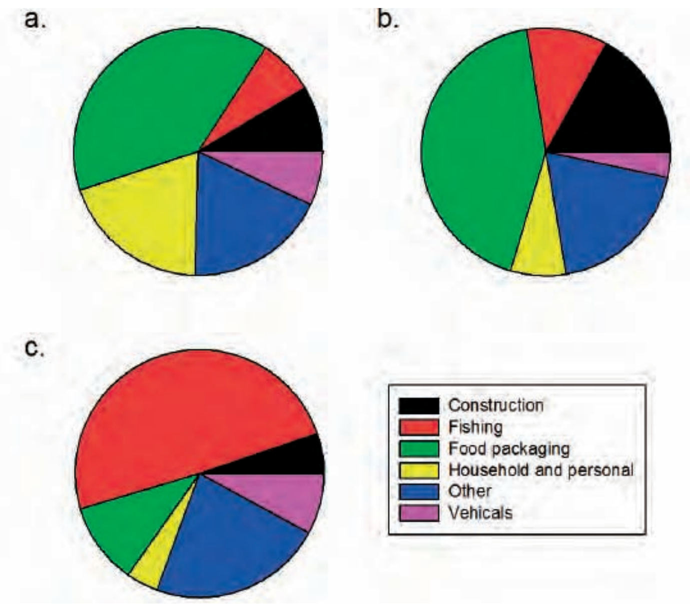
1. Litter is a ubiquitous, highly visible and ongoing issue for the Hauraki Gulf and beyond.
2. Plastics are particularly problematic owing to their environmental persistence and their effects on aesthetics and wildlife.

Figure 45: Litter collected by the Waitematā Harbour Clean-up Trust between 2003 and 2010, showing (a) estimated volume collected and effort exerted, and (b) the yield of trash per unit effort. Trash collected by volunteers has been excluded from the plot (data provided by Ben Harris, skipper of the Phil Warren).



A. **B.**

Figure 46: General sources (percentage by volume) of litter obtained from clean-ups carried out by Sustainable Coastlines on (a) the North Shore in April 2011, (b) Rangitoto Island in December 2010 and (c) Coromandel Peninsula in April 2011.



13. Includes plastic bags, cardboard boxes and packaging, glass bottle pieces, organic waste, plastic resin pellets, plastic of unknown origin and polystyrene/foam.

4.9 Maintenance and recovery of biodiversity

Many native species that were once widespread in the Gulf and its catchments have either been lost or severely reduced in number and distribution, and an alarmingly large number of native species can only survive on small offshore islands that are free of mammalian herbivores and predators. Other species, such as seabirds, shorebirds and Bryde's whales, have specific habitat or resource requirements and compete with humans for resources and space. Their survival or continued presence in the Gulf is threatened by the loss or modification of habitats and resources, or interactions between them and human activities. This section therefore uses the state of islands, seabirds, shorebirds and Bryde's whales in the Gulf as key indicators for maintenance and recovery of biodiversity. These indicators are considered to be particularly important because of their national and international significance, the severity of threats and their high sensitivity to human activities. Note that benthic marine and fish biodiversity issues are covered in Sections 4.1 to 4.7 and are not considered further in this section.

4.9.1 Islands of the Gulf

The islands of the Gulf provide vital sanctuaries for New Zealand's terrestrial biodiversity. It is estimated to contain 425 "islands", including reefs, stacks and sandbars, with islets of between 0.1 and 1.0 ha being the most numerous feature (Lee 1999). All have been modified by human activities, with many of the larger islands being almost totally cleared of indigenous vegetation at some stage of their history. Probably the least modified island is Hauturu (Little Barrier Island), which contains the largest remaining area of relatively unmodified northern New Zealand forest that is protected from alien mammals. The island is sufficient large and high enough to provide a diverse mix of forest types, and forests at various stages of maturity. It is therefore capable of supporting species with very specific habitat requirements such as hihi (stitchbirds).

Hauturu's mountainous landscape is dominated by broadleaf forests near the coast, with northern rata (*Metrosideros robusta*) and tawa (*Beilschmiedia tawa*) occurring on the slopes. Mixed kauri (*Agathis australis*) forest occurs extensively on ridges from 50 to 500 m, with forests of towai (*Weinmannia silvicola*) and tawa further up. These give way to summit vegetation dominated by quintinea (*Quintinea acutifolia*), tawari (*Ixerbia brexioides*) and southern rata (*Metrosideros umbellata*). Although much of the island's original forest cover remains intact at higher altitudes, lowland forest was cleared for timber and farming and is now dominated by dense pioneer growth of manuka (Leptospermum scoparium) and kanuka (*Kunzea ericoides*) in varying stages of transition to broadleaf and kauri forest communities (Rayner *et al.* 2007b).

Kiore (the Polynesian rat, *Rattus exulans*) were present on the island for hundreds of years, and cats and pigs were released after the arrival of Europeans. The lower sections of the island were also temporarily grazed by cattle and sheep. Pigs were removed in the early 1900s, but cats and kiore remained until successful eradications in 1980 and 2004 respectively (Rayner *et al.* 2007b).

Hauturu (Little Barrier Island) is one of New Zealand's first offshore sanctuaries and was originally established as a nature reserve in 1895. It has played a critical role in species conservation in New Zealand. By the 1880s it was home to the only surviving population of the nationally endangered hihi (Taylor *et al.* 2005), and it was among the first islands to be used for bird translocations, with brown and great spotted kiwi being moved to the island between c. 1903 and c. 1919 (Bellingham *et al.* 2010). Hauturu is one of only two breeding grounds for black petrel (the other being on Aotea (Great Barrier Island)), and is the most important breeding location for Cook's Petrel in the world (Rayner *et al.* 2007a). It is one of the few places with thriving populations of nationally endangered North Island saddleback and kokako. North Island saddleback had been reduced to a single population of about 500 individuals on Hen Island by 1910 and were transferred (via Cuvier Island) to Hauturu between 1984 and 1988 (Parker 2008). Thirty-two kokako were transferred to the island between 1980 and 1988, and the island is now home to one of the largest populations in the country (Innes and Flux 1999). In addition, Hauturu is one of only two locations on which the nationally endangered chevron skink is known to occur (the other being Aotea (Great Barrier Island), Towns *et al.* 2002), and it is an important sanctuary for tuatara, which are only found in the wild on offshore islands in Cook Strait and to the east of the North Island (Gaze 2001). Prior to recent translocations to the islands of Tiritiri Matangi and Motuora, Hauturu also supported the only remaining population of New Zealand's largest insect, the wetapunga (*Deinacrida heteracantha*).

Many other islands in the outer Gulf have a high proportion of native forest cover too (Figure 47). For instance, the land cover database (LCDB2) indicates that around 90% of Aotea (Great Barrier Island) has a cover of indigenous forest, broadleaved indigenous hardwoods, or manuka and kanuka. Eighty-six per cent of Kawau Island is covered by indigenous forest (including manuka or kanuka), and most of the islands around Coromandel Peninsula are covered in native vegetation, the notable exceptions being Great Mercury and Slipper islands.

Motuora and Tiritiri Matangi have a long history of grazing, but they have recently been revegetated with community assistance, producing extensive areas of regenerating coastal shrubland. Between 1990 and 2006, around 206,000 plants including 21 early successional species and some tall forest species were planted on 35 ha of retired pasture on Motuora (Towns *et al.* 2009). Similarly, between 1984 and 1994, volunteers planted around 280,000 trees into rank pasture on Tiritiri Matangi (Towns *et al.* 2009).

Rangitoto Island is the youngest cone in the Auckland volcanic field, having erupted only about 600 years ago, and is one of the least modified. It is an iconic landscape feature in the Hauraki Gulf, dominating the local seascape. Rangitoto's bare lava fields, lava caves, pillars and tunnels are all obvious features of the island's volcanic landscape. Its lava rocks host nearly 170 species of native trees and flowering plants, including many species of orchid and more than 50 kinds of fern. The vegetation on Rangitoto Island is internationally significant as an area of forest naturally colonising young basaltic lava flows. The island contains the largest area of pōhutukawa (and pōhutukawa-rata hybrid) forest in New Zealand. Its unique indigenous ecosystem and vegetation have been recognised by its status as a separate and entire ecological district.

However, most islands in the inner Gulf have lower proportions of native forest cover (Table 6). Motutapu and Motuihe have also been partially revegetated. Motutapu still consists of mostly pasture with a coastal fringe of remnant indigenous vegetation that is often heavily infested with weed species (Lindsay *et al.* 2009), but the revegetation of Motuihe is more advanced. The Rotoroa Island Trust is replanting areas of Rotoroa Island. Approximately 17% of native vegetation on the inner Gulf islands is in protected areas, with cover largely consisting of land on islands administered by DOC as recreation, scenic or scientific reserves (Lindsay *et al.* 2009).

Figure 47: Extent of native forest on islands of the Hauraki Gulf in 2001/02 (based on GIS information in the land cover database two (LCDB2)).

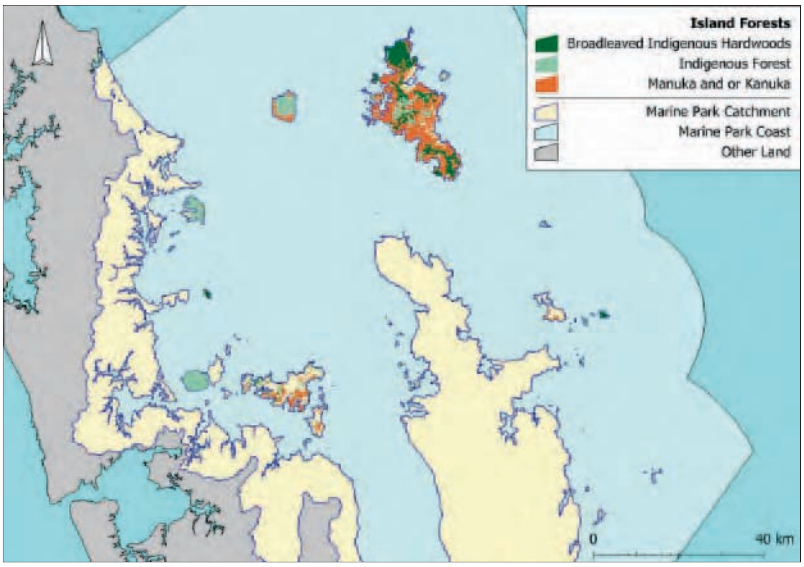


Table 6: Native forest cover on islands of the inner Gulf. Area estimates were obtained using GIS and the land cover database (LCDB2), with indigenous forest, broadleaved indigenous hardwoods, or manuka and kanuka vegetation classes from 2001-02.

Island	**Total Island Area (ha)**	**Forest Area (ha)**	**Percent Forested**
Tiritiri Matangi	192	140	73%
Noises	25	23	91%
Rakino	154	16	11%
Rangitoto	2326	2307	99%
Motutapu	1560	79	5%
Motuihe	181	24	13%
Browns	*60*	0	0%
Waiheke	9274	3876	42%
Pakatoa	31	7	24%
Pakihi	116	26	22%
Rotoroa	92	16	17%
Ponui	1806	713	39%
Tarakihi	6	6	100%

Islands are particularly important for conservation because they can be kept free of mammalian herbivorous and predatory pests. Twenty-seven of the 62 (43%) islands in the Gulf that are larger than 10 ha are currently free of mammalian herbivorous and predatory pests (Figure 48). Pest eradication has been occurring also on Rangitoto and Motutapu islands, but their pest-free status is yet to be confirmed. Beehive Island is pest free too, but this island is less than 10 ha in size. Predator fences have also been, or are being, used to establish predator-free sanctuaries at Tawharanui Regional Park and Shakespeare Regional Park, and Glenfern Sanctuary on Aotea (Great Barrier Island), although these are not within the Hauraki Gulf Marine Park.

The establishment and maintenance of pest-free sanctuaries has allowed threatened bird, reptile and insect species to be transferred among locations (Table 7 to Table 9). Translocation reduces the risk of populations being destroyed by a catastrophic event such as volcanism, tsunami, fire or disease. It can also be used to add genetic diversity to island populations, and contribute to ecosystem restoration.

One nationally critical (takahe: threat status 1) and four nationally endangered (hihi, kokako, North Island weka and brown teal: threat status 2) bird species have been translocated to, or among, islands in the Gulf. Four of these species, including hihi, have involved translocations to Tiritiri Matangi Island. However, supplementary feeding is required to maintain translocated hihi (Ewen and Armstrong 2007). In addition, one nationally critical (Mercury Island tusked weta) and two nationally endangered (Mahoenui giant weta and wetapunga) insects, and one nationally vulnerable (Whitaker's skink) reptile have been translocated. Motutapu is one of the few islands in the Auckland Conservancy that has significant wetlands, which will provide a rare opportunity for the translocation of wetland species once mammalian pests have been eradicated.

A comprehensive State of the Environment Report for Aotea (Great Barrier Island) was produced by the Great Barrier Island Trust and launched in February 2010 (Great Barrier Island Charitable Trust 2010). That report highlighted the special features of Aotea's (Great Barrier Island) environment, including: its low human population with extensive areas of natural or semi-natural vegetation, much of which is under some form of protection; the absence of some (but not all) of the predators which have ravaged the native New Zealand fauna elsewhere; and the consequent survival of several otherwise-endangered species. However, ongoing pressures (especially the presence of rodents) still threaten species such as brown teal and chevron skink, which could be lost from the island.

Aotea's (Great Barrier Island) residents and rate-payers, and the management agencies involved with the island, place considerable value and emphasis on the island's environment. This is reflected in legislation, planning documents, volunteer involvement and social research. However, community and management responses have, generally, not matched the nature and scale of threats to native flora and fauna. A process for identifying, prioritising and agreeing on action was therefore an anticipated outcome from the State of the Environment Report for Aotea (Great Barrier Island). The Hauraki Gulf Forum has endorsed the report's recommendation that a technical feasibility study be initiated which explores the methods, issues and costs/benefits of island-wide eradication of rats and feral cats. This recognised community interest in the issues raised in the State of the Environment Report for Aotea (Great Barrier Island), the ecological significance of the island to the future of the Hauraki Gulf Marine Park and the potential benefits of a successful eradication programme.

Figure 48: Locations in the Gulf that are free of mammalian herbivorous and predatory pests, and where translocations of endangered birds, reptiles and/or insects have occurred. Red labels indicate sites that are free of mammalian herbivorous and predatory pests, green labels indicate sites that have received translocated species, and blue labels indicate sites that are free of mammalian herbivorous and predatory pests and have received translocated species.

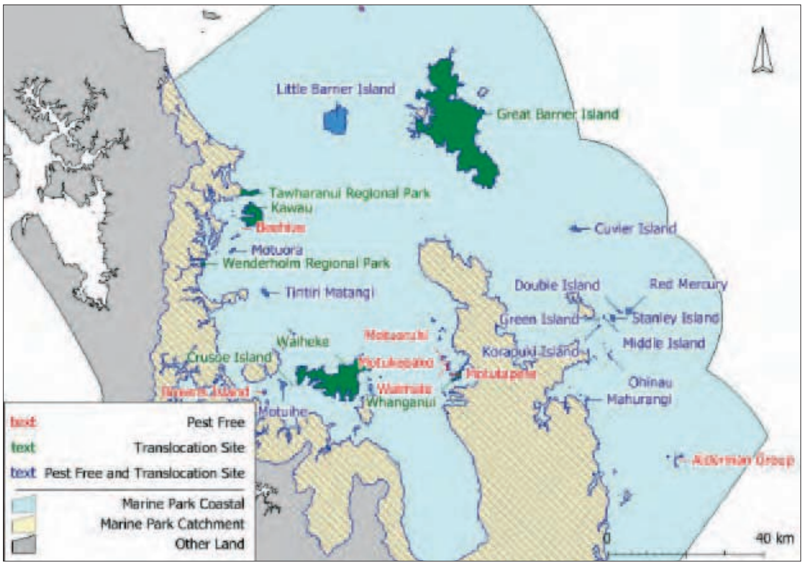


Table 7: Reintroduced and translocated bird species on islands in the Gulf and adjoining mainland sanctuaries.

Location	Bellbird (nt)	Black Petrel (rr)l	Common Diving Petrel (nt)	Hihi (ne)	Kokako (ne)	Little Spotted Kiwi (rr)	North Island Brown Kiwi (sd)	North Island Fernbird (s)	North Island Robin (nt)	North Island Saddleback (rr)	North Island Tomtit (nt)	North Island Weka (ne)	Pateke (Brown Teal) (ne)	Pycroft's Petrel (rr)	Red-crowned Kariki (nt)	Rifleman (gd)	Takahe (nc)	Whitehead (nt)
Little Barrier Island		•			•		•			•								
Aotea (Great Barrier Island)									•									
Tawharanui Marine Park							•		•				•		•			•
Kawau Island							•					•						
Motuora Island			•				•							•				•
Wenderholm Regional Park									•									
Tiritiri Matangi Island				•	•	•		•	•	•	•		•		•	•	•	•
Motuihe Island	•					•				•					•			
Crusoe Island																		
Waiheke Island	•																	
Whanganui Island												•						
Cuvier Island										•				•	•			
Red Mercury Island (Mercury Group)						•				•								
Stanley Island (Mercury Group)										•								

Threat Codes:

Nationally critical **Nationally endangered** **Nationally vulnerable** **Serious decline**

Gradual decline **Range restricted** **Sparse** **Not threatened**

Table 8: Reintroduced and translocated insect species on islands in the Gulf.

Location	Auckland Tree Weta	Large Darkling Beetle	Mahoenui Giant Weta	Mercury Island Tusked Weta	Wetapunga
Tiritiri Matangi					• (Nationally endangered)
Cuvier Island				• (Nationally critical)	
Motuora Island					• (Nationally endangered)
Red Mercury (Mercury Group)				• (Nationally critical)	
Stanley Island (Mercury Group)				• (Nationally critical)	
Double Island (Mercury Group)				• (Nationally critical)	
Korapuki Island (Mercury Group)	• (Not threatened)	• (Not threatened)		• (Nationally critical)	
Ohinau				• (Nationally critical)	
Mahurangi			• (Nationally endangered)		

Threat Codes:
- Nationally critical
- Nationally endangered
- Nationally vulnerable
- Serious decline
- Gradual decline
- Range restricted
- Sparse
- Not threatened

Table 9: Reintroduced and translocated reptile species on islands in the Gulf.

Location	Auckland Green Gecko	Duvaucel's Gecko	Egg-laying Skink	Forest Gecko	Marbled Skink	Northern Tuatara	Robust Skink	Shore skink	Whitaker's Skink
Little Barrier Island						• (Sparse)			
Tawharanui Marine Park	• (Gradual decline)			• (Not threatened)					
Motuora		• (Sparse)						• (Not threatened)	
Tiritiri Matangi		• (Sparse)						• (Not threatened)	
Motuihe								• (Not threatened)	
Crusoe Island								• (Not threatened)	
Red Mercury (Mercury Group)							• (Range restricted)		• (Nationally vulnerable)
Stanley Island (Mercury Group)							• (Range restricted)		
Korapuki Island (Mercury Group)			• (Range restricted)		• (Range restricted)		• (Range restricted)		• (Nationally vulnerable)

Threat Codes:
- Nationally critical
- Nationally endangered
- Nationally vulnerable
- Serious decline
- Gradual decline
- Range restricted
- Sparse
- Not threatened

4.9.2 Shorebirds

The Firth of Thames is an internationally important feeding area for waders, and is recognised through its designation as a wetland of international importance (commonly called a Ramsar site) under the Convention on Wetlands of International Importance Especially as Waterfowl Habitat.[14] Migratory shorebirds utilise a number of sites over the course of a year, including winter feeding grounds, breeding grounds and, often, refuelling sites during long migrations. The Firth of Thames and Manukau Harbour are terminal points for the East Asian-Australasian flyway, which is used by shorebirds that migrate from winter in Siberia and Alaska to summer in the southern hemisphere, and later return between March and June to their northern breeding grounds (Battley and Brownell 2007). A total of 132 species of birds has been recorded in the Firth of Thames with approximately 35,000 waders utilising the area each year. This includes about 11,000 Arctic breeders from Siberia and Alaska which come to forage on the extensive and highly productive intertidal sand and mud-flats of the Firth of Thames (Battley and Brownell 2007).

The New Zealand Ornithological Society has been routinely counting birds at a number of sites in the Firth of Thames since 1960. Between 1960 and 2005 four of the most common wader species increased in number, four species maintained relatively stable numbers, and seven species displayed declining trends. A summary of the long-term trends displayed by each of these species is provided below (Battley and Brownell 2007):

Increasing Trends		
Species	**Seasonal patterns**	**Long-term patterns**
Pied oystercatcher	Higher counts in winter	Numbers increased from 1960s to late 1990s then declined through to 2005.
Variable oystercatcher	Slightly higher counts in summer	Low numbers from 1960s to mid-1980s, then a sharp increase.
Spur-winged plover	Slightly higher counts in winter	Single birds or pairs first recorded in 1977. Numbers increased sharply from mid-1980s to late 1990s then declined slightly.
Whimbrel	Higher counts in summer	Numbers generally low, but increased in late 1970s and remained relatively stable through to 2005. Roosting area changed possibly due to mangrove expansion.

Declining Trends		
Species	**Seasonal patterns**	**Long-term patterns**
Banded dotterel	Slightly higher counts in winter	Declining summer numbers and fluctuating winter numbers since 1960. Older records indicate that large numbers used to occur at sites which are no longer utilised. Habitat changes appear to have reduced the attractiveness of the southern Firth of Thames to banded dotterels.
Wrybill	Higher counts in winter	Numbers have declined since the early 1970s and spatial patterns have changed, probably due to mangrove expansion.
Pacific golden plover	Higher counts in summer	Numbers dropped sharply after 1987 and very few were recorded from 1988 to 2004. Relatively high numbers were recorded in 2005, which was a good year for golden plovers nationally. Areas that were once used by golden plover have now been colonised by mangroves.

14. The Convention on Wetlands of International Importance Especially as Waterfowl Habitat was adopted on 2 February 1971 in the Iranian city of Ramsar, and is commonly known as the Ramsar Convention.

Turnstone	Higher counts in summer	Numbers increased from the 1960s to the late 1970s, and subsequently declined. Winter numbers were low between 1989 and 2005 (none recorded in nine years, < 5 in three years and 15 birds in one year), and were consistently low in summer between 1994 and 2005.
Curlew sandpiper	Higher counts in summer	Fluctuating numbers with three peaks between the 1960s and 1995. However, numbers dropped sharply after 1995 and curlew sandpiper were virtually absent through to 2005.
Red-necked stint	Higher counts in summer	Numbers declined since the 1960s, possibly due to mangrove expansion.
Eastern curlew	Higher counts in summer	Summer numbers declined strongly between the 1960s and 2000. Only occasional visitors were recorded in summer or winter between 2000 and 2005.

Stable		
Species	**Seasonal patterns**	**Long-term patterns**
New Zealand dotterel	Slightly higher counts in winter	Fluctuating numbers around a long-term mean since the 1960s.
Bar-tailed godwit	Higher counts in summer	Numbers fluctuated between the 1960s and 2005.
Sharp-tailed sandpiper	Higher counts in summer	Numbers fluctuated between the 1960s and 2005, with a large peak in the late 1980s and lows in the mid-1970s and late 1990s.
Red knot	Higher counts in summer	Numbers fluctuated between the 1960s and 2005, with peaks in the late 1960s to early 1970s and early 2000s, and a low in the early 1990s.

In addition to adequate food supplies, wading birds also require safe, undisturbed and otherwise suitable roosting areas. Habitat changes at individual roosting sites have led to major shifts in the distribution of many species in the Firth of Thames. The Karito, Waitakaruru and Piako sections of the southern Firth were important roosting sites for many species from the 1960s to the 1980s, but owing to mangrove growth they are now only irregularly used by a low number of birds. Conversely, a sandbar began to develop near the Waihou River mouth in the mid-1990s, which has seen large increases in the number of red knots, whimbrels and bar-tailed godwits utilising this area. The southwards growth of a shellbank opposite the Miranda Naturalists' Trust Shorebird Centre, and subsequent infilling with mangroves behind it, has also caused local changes in the use of that area by knots and bar-tailed godwits over the past 45 to 50 years.

In many cases the reasons for trends in shorebird numbers cannot be determined with certainty, due to the birds' highly mobile nature. Counts are affected by changes in breeding productivity, immigration, emigration and survival, as well as in sampling and observer biases. Survival and breeding success is affected by factors in both the Hauraki Gulf and the other areas used by the birds. The degree of site-faithfulness can also affect bird numbers over time. Unfortunately, information on these factors is lacking, even for common shorebird species in New Zealand (Battley and Brownell 2007).

4.9.3 Seabirds

The Hauraki Gulf Marine Park is an internationally recognised region of high biodiversity value, and seabirds, as top predators, are key components of this ecosystem. The region boasts one of the highest diversities of seabirds in the world (over 80 species).

The Hauraki Gulf islands, like many offshore islands throughout this country, provide a "lifeboat" for precious terrestrial fauna, which have been subject to human-induced ecosystem destruction and species' extinctions on mainland New Zealand. Similarly, these islands are also vitally important refugia for seabirds, with 23 species confirmed to breed in the region (Table 10).

Seabirds extend island ecosystems by feeding exclusively within the marine environment and in a range of different marine habitats. Short-ranging species (such as terns, shags and blue penguin) forage within coastal habitats less than 10 km from their breeding sites, whereas species favouring the wider continental shelf habitat (including smaller shearwaters, prions, storm petrels, diving petrels and gannets) may travel considerable distances from their breeding colony on a single trip (< 100 km). For the larger shearwaters and pelagic petrels, foraging areas may extend to hundreds, and in some cases thousands, of kilometres away on highly productive shelf-break areas, eddies and upwellings. As a result, the Hauraki Gulf's influence as a breeding "home-base" from a seabird perspective extends well beyond its boundaries.

Equally, the health of these critically important seabird populations is dependent on the wider oceanic environment. Seabirds are affected by tidal movements, spatial and temporal changes in sea temperature, salinity and plankton occurrence, and cross-shelf intrusions of subtropical water from the East Auckland current. Fisheries and other activities that reduce water quality or cause the loss of marine habitats can also affect seabirds. Thus the Hauraki Gulf is a dynamic environment in which seabirds rely on food that is patchy in distribution and ephemeral by nature. Consequently, there is a strong need to understand spatial and temporal patterns within the Gulf environment in relation to management decisions that could affect seabirds.

The 2008 Hauraki Gulf State of the Environment Report identified the need for systematic seabird and island surveys throughout the Gulf. The last major surveying was undertaken in the late 1980s/early 1990s, but there has been very little data gathered following island eradications of mammalian pests. To date, comprehensive studies have been carried out on only four of the 23 species that breed in the Gulf. These are the critically endangered New Zealand fairy tern and the vulnerable ranked black petrel, Cook's petrel and flesh-footed shearwater.

The New Zealand fairy tern is this country's most endangered species, with only 43 individuals estimated to remain prior to the 2010/11 breeding season, with a further six chicks fledging over that period. The total population contains only 10 breeding pairs, of which eight are fertile. Fledging success has been ensured through intensive management by DOC, with the help of the New Zealand Fairy Tern Trust and community volunteers. However, recruitment into the breeding population has remained low (Hansen 2006). Only one pair breed within the boundaries of the Hauraki Gulf Marine Park (at Pakiri, where two chicks were produced in the 2009/10 season), although the largest concentration of breeding fairy terns is located at Mangawhai Harbour, which directly adjoins the northern boundary of the park (Ismar and Baird unpublished; Department of Conservation unpublished information).

Black petrel breed at only two sites: Mount Hobson (Hirakimata) on Aotea (Great Barrier Island) and Hauturu (Little Barrier Island). Protection of these two areas is critical to the survival of this species. The most recent population estimate from a 35 ha study area at Mount Hobson was 3,342 to 4,130 birds (including c. 1,360 breeding pairs) (Bell et al. 2011). Black petrel breeding success at Mount Hobson ranges from 67 to 84% (chicks fledged from eggs laid; mean 75%), and out of 1,668 chicks banded during the study, 66 have been recaptured at the colony (Bell et al. 2011). The youngest age of return is three years old, but the mean is 5.1 ± 0.2. The age of first breeding ranges from four to nine years (mean 6 ± 0.2). A minimum of 46% of chicks departing the colonies survive to age three. After three years of age c. 89% survive, for an estimated adult survival rate of 87% (Bell et al. 2011). This survival rate is extremely low for a procellariiforme and of great conservation concern. Geolocator light-loggers fitted to 11 birds during breeding season have provided preliminary foraging and at-sea distribution data. Initial data indicates that black petrel forage west and east of northern New Zealand, as far as the Kermadecs, East Cape, Eastern Australia and towards Fiji. A further 80 devices have been deployed and data from them is expected to be published during 2011.

Population estimates of Cook's petrel on Hauturu (Little Barrier Island) were upgraded in 2005 from a previous estimate of 50,000 plus breeding pairs to 286,000 (95% confidence interval: 213,000 to 413,000) pairs (Rayner *et al.* 2007a). Similarly the species conservation status (IUCN red list) of this species was downgraded from Endangered to Vulnerable following the population revision and the eradication of kiore (Pacific rat) from Hauturu in 2004. Prior to the removal of kiore, the breeding success of Cook's petrel was 0.09 + 0.04 chicks per burrow. After kiore were removed in 2004, breeding success increased to 0.59 + 0.03 chicks per burrow (Rayner *et al*. 2007b).

Flesh-footed shearwaters principally breed on nine islands in New Zealand, although smaller colonies (generally < 10 pairs) occur at up to 10 other sites (Taylor unpublished data). These include three islands in the Hauraki Gulf Marine Park: Green and Middle Islands of the Mercury Island Group and Ohinau Island (Ohena Sub-group of Mercury Group). Taylor (unpublished data) estimated that New Zealand's total population of flesh-footed shearwaters consisted of 25,000 to 50,000 pairs. However, a more recent population estimate from eight of the nine main breeding islands by Baker *et al*. (2010) is 8,614 occupied burrows (95% confidence interval: 6,689 to 10,540), which is equivalent to annual breeding pairs. This would indicate that the New Zealand population of flesh-footed shearwaters is considerably less than the estimate Taylor suggests. Note that Middle Island in the Mercury Group, for which Taylor (unpublished data) estimated 3,000 pairs, was not included in the Baker *et al*. (2010) survey.

4.9.3.1 Ongoing seabird research projects

Although many gaps remain in our understanding of seabird populations and ecology, significant progress is being made in some areas. For instance, current or recent research projects have been examining:

1. Cook's petrel census and tracking: This research has examined the sizes of the Cook's petrel populations on Little Barrier and Codfish islands and is now investigating the role of the inter-annual movements of Cook's petrel within the Pacific Ocean in mediating divergent population genetics among the species (Rayner *et al*. 2007a; Rayner *et al*. 2007b; Rayner *et al*. 2007c; Rayner *et al*. 2008; Rayner *et al*. 2010; Rayner *et al*. in press-a).
2. Black petrel census and tracking: This long-term research (since the 1995/96 breeding season) has examined the size of the black petrel population on Aotea (Great Barrier Island), population trends (adult and juvenile survival, recruitment, fidelity and annual breeding success) at the Mount Hobson (Hirakimata) colony and at-sea foraging and distribution (using global positioning system (GPS) and geolocator light logger technology) of breeding birds within New Zealand and migration through international waters to the wintering ground in South America (Bell *et al*. 2011).
3. Grey-faced petrel tracking from Ruamaahua (Alderman) Islands: This research used satellite telemetry to determine the at-sea distribution of 32 adult grey-faced petrels during July to October in 2006 and 2007 (MacLeod *et al*. 2008).
4. Flesh-footed shearwater and Pycroft's petrel on Chickens Islands (Booth and Pierce unpublished)
   a. Research on population dynamics and population changes following rodent eradications in early 1990s
   b. Data-loggers attached to flesh-footed shearwaters in December 2010.
5. Flesh-footed shearwater population assessment (2010): Data collection of demographic, distributional and trophic information on the flesh-footed shearwater to allow estimation of effects of fishing on population viability: 2009/10 field season (Baker *et al*. 2010).
6. Grey-faced petrel surveys
   a. Motuora Island (Gardner-Gee *et al*. 2008)
   b. Little Barrier Island (Rayner *et al*. 2009)
   c. Goat Island (Hawere) (Russell unpublished).
7. Pterodroma project (from 2009): This research is using miniaturised tracking technology to investigate the seasonal movements of Pycroft's and black-winged petrel within and beyond the Hauraki Gulf (Rayner unpublished).
8. Fairy tern foraging study (2010): This work focused on the feeding ecology of the tern at Mangawhai Harbour and the distribution of non-breeding birds in Kaipara Harbour during the breeding season (Ismar and Baird unpublished).
9. Acoustic survey programme (from 2009): Developing biological (nocturnal) inventories to assess seabird distribution on islands, allowing also for the study of vocalisations (Gaskin unpublished)
   a. Mokohinau Group (2009 to 2011)
   b. Little Barrier Island/Hauturu (2009)
   c. Tawharanui (2009 to 2011)

   d. Also, Hen/Taranga, Hen and Chickens Group (2010); Aorangi Island, Poor Knights Group (2010/11) (although outside the Hauraki Gulf Marine Park, seabirds breeding on these islands are a major feature of the Gulf marine environment).
10. GPS tracking on Australasian gannets from Mahuki Island (Broken Islands, Aotea/Great Barrier Island) (from 2010): Gannets are ubiquitous top predators within the Hauraki Gulf and offer the potential to act as sentinels for changes in the marine environment that impact their prey and subsequent breeding success. This exploratory research is seeking to develop a capacity to use gannets as marine indicators within the Gulf through understanding of factors that predict the distribution of foraging birds tracked with high-resolution GPS tracking devices (Dennis and Rayner ongoing research started in 2010).
11. Hauraki Gulf Seabird Spatial Ecology project (Taylor, Ismar, Rayner and Gaskin ongoing research started in 2010 (Stage 1 – Mokohinau Group 2010 to 2012)), involving:
    a. black-winged petrel tracking (data-loggers);
    b. isotope analysis and molecular sexing on seven species (little, fluttering and sooty shearwaters, grey-faced and black-winged petrels, common diving petrel and white-faced storm-petrel);
    c. grey-faced petrel and sooty and fluttering shearwaters to be fitted with data-loggers in 2011.
12. Burgess Island (Mokohinau Group) vegetation and seabird survey (Gaskin and Heiss-Dunlop paper in preparation).
13. Seabird restoration projects
    a. Translocation of Pycroft's petrels to Cuvier Island (Taylor between 2001 and 2003);
    b. Translocation of diving petrels to Motuora Island (Gardner-Gee and Gummer in 2008 and 2009);
    c. Restoring burrowing seabirds to Motuihe Island (a seabird restoration plan) (Gaskin and Heiss-Dunlop in 2011);
    d. Acoustic attraction projects:
       i. Motuora Island (in conjunction with translocations) – installed;
       ii. Tawharanui Marine Park (Tawharanui Open Sanctuary) – installed May 2011;
       iii. Motuihe Island – install September 2011. Possibly other inner Gulf islands (e.g. Motutapu).

4.9.3.2 Future research priorities for seabirds

Ongoing research priorities for seabirds include:
1. Assessment and monitoring of population numbers and trends for a greater range of seabird species is urgently required to accurately assess their conservation status.
2. Monitoring for biosecurity risks (e.g. introduction of animal and plant pest species to breeding sites) is needed to cover all breeding locations.
3. Locating the breeding sites of New Zealand storm petrel to identify critical breeding areas and determine population size, seasonal activity and conservation status (currently "data deficient" (NZ Bird Rankings), "critically endangered" (Birdlife International 2009).
4. Using top predators as indicators of key oceanographic sites within the Hauraki Gulf Marine Park (HGMP) (two parts):
   a. There is a strong need to understand spatial and temporal patterns of marine hotspots within the Gulf region by which to base management decisions. Top predators such as seabirds present ideal indicators for understanding the locations of marine hotspots and this research seeks to investigate the inter-seasonal dynamics of key seabird species within the HGMP ecosystem. The research has two non-exclusive aims, being:
      1) to investigate the spatial and temporal ecology of seabirds within the HGMP; and
      2) to combine this geo-distributional data with oceanographic attributes into a model of key productivity areas within the HGMP.
   b. Spatio-temporal ecology of seabirds in the HGMP. This research proposes to combine high-resolution ecological studies of HGMP resident seabirds and remote sensor-based surveys of marine productivity within the HGMP at an inter-annual scale. For Australasian gannet and fluttering shearwater, the HGMP is an integral part of their home range and essential for completion of their life cycle. The spatial and behavioural ecology of these species will be investigated with deployments of high-resolution GPS tracking devices in combination with dive-depth logging devices on individuals. This data will reveal where and when animals forage within the HGMP, and this information will be combined with studies of stable isotopes and dietary analyses of birds returning to their colonies to reveal what prey are being consumed.

5. Movement and dispersal of petrels (at sea and between colonies).
6. Comparative study of seabird species in the Hauraki Gulf and Auckland west coast marine zones.
7. Continue long-term research projects (e.g. black petrels on Aotea (Great Barrier Island), Cook's petrel on Little Barrier Island) to monitor population changes and at-sea risks.
8. Investigate restoration of seabird species on islands and headlands cleared of mammalian pests using new translocation techniques.
9. Develop tertiary-level student research projects.

Table 10: Seabirds breeding in the wider Hauraki Gulf area.

PROCELLARIIFORMES	**Seabird species in Hauraki Gulf**	**Breeding Locations**	**IUCN Rank**	**Threat Status**	**Threat Codes**	**Explanation (qualifiers in brackets)**
	Cook's Petrel (Pterodroma cookii) **	98% of total population breeds on Hauturu/Little Barrier (2% on Codfish/Whenua Hou). Aotea/Great Barrier colony believed extirpated	V	At Risk – Relict	B (Inc RR)	> 20,000 mature individuals, stable or increasing, occupy < 10% of their original range (Increasing, Range Restricted)
	Pycroft's Petrel (P. pycrofti) * **	Poor Knights; Hen/Taranga and Chickens/Marotere; Cuvier; Mercury	V	At Risk – Recovering	B (Inc RR)	5,000-20,000 mature individuals, population increase > 10% (Increasing, Range Restricted)
	Black-winged Petrel (P. nigripennis)	Breeding not confirmed although they have been found on Burgess Island (Dec 2004, Jan 2006, Dec 2007); records for Poor Knights, Cuvier	LC	Not Threatened	(SO)	(Secure Overseas)
	Grey-faced Petrel (P. [macroptera] gouldi)	Breeds on majority of offshore islands (more than 2 km of the mainland) in the Hauraki Gulf; also Sentinel Rock, Goat/Hawere; Tawharanui Marine Park	LC	Not Threatened	(De Inc RR)	(Designated, Increasing, Range Restricted)
	Buller's Shearwater (Puffinus bulleri) * **	Poor Knights only	V	Naturally Uncommon	(OL St)	(One Location, Stable)
	Flesh-footed Shearwater	Hen/Taranga and Chickens/Marotere, Mercury, Ohinau	NT	At Risk – Declining	B(1/1) (RR TO)	20,000-100,000 mature individuals, 10-50% population decline (Range Restricted TO)
	Fluttering Shearwater	Poor Knights; Hen/Taranga and Chickens/Marotere; Mokohinau; Tiritiri Matangi and Wooded Island; Channel; Mercury, Alderman	LC	At Risk – Relict	B (RR)	> 20,000 mature individuals, stable or increasing, occupy < 10% of their original range (Range Restricted)
	North Island Little Shearwater	Poor Knights, Chickens/Marotere; Mokohinau; Mercury, Alderman	V	At Risk – Recovering	B (Inc RR)	5,000-20,000 mature individuals, population increase > 10% (Increasing, Range Restricted)
	Sooty Shearwater (P. griseus)	Mokohinau, Mercury	LC	At Risk – Declining	B(1/1) (SO)	20,000-100,000 mature individuals, 10-50% population decline (Range Restricted)
	Black (Parkinson's) Petrel (Procellaria parkinsoni) * **	Aotea/Great Barrier; Hauturu/Little Barrier	V	Nationally Vulnerable	B(1/1) (RR)	1,000-5,000 mature individuals (unnatural), stable (Range Restricted)

1. Species in bold are those breeding within the Hauraki Gulf Marine Park.
2. * Hauraki Gulf endemics
3. ** New Zealand endemics
4. IUCN Rank: C = Critical; E = Endangered; V = Vulnerable; NT = Near Threatened; LC = Least Concern.
5. Threat rankings for New Zealand birds – refer Townsend et al. (2008a), Miskelly et al. (2008) for more details and definitions

PROCELLARIIFORMES	Fairy Prion (Pachyptila turtur)	Poor Knights	LC	At Risk - Relict	B (RR SO)	> 20,000 mature individuals, stable or increasing, occupy < 10% of their original range (Range Restricted, Secure Overseas)
	Common Diving Petrel (Pelecanoides urinatrix)	Poor Knights; Hen/Taranga and Chickens/Marotere; Mokohinau; Hauturu/ Little Barrier (Lot's Wife); Tiritiri Matangi; Motuora; Channel; Cuvier; Mercury	LC	At Risk - Relict	B (Inc RR SO)	> 20,000 mature individuals, stable or increasing, occupy < 10% of their original range (Increasing, Range Restricted, Secure Overseas)
	NZ White-faced Storm Petrel (Pelagodroma marina maoriana) **	Poor Knights; Mokohinau; The Noises; also Ohinau, Hongiora (Alderman)	LC	At Risk - Relict	B (RR)	> 20,000 mature individuals, stable or increasing, occupy < 10% of their original range (Range Restricted)
	New Zealand Storm Petrel (Pealeornis maoriana) * **	Breeding not confirmed, but likely for Hauraki Gulf	C	Nationally Vulnerable - Data deficient	(DP)	(Data poor)
SPENISCI-FORMES	**Northern Blue Penguin (Eudyptula minor iredalei)**	Poor Knights; Hen/Taranga and Chickens/Marotere; Mokohinau; Hauturu/Little Barrier; Tiritiri Matangi; Motuora; Te Haupa; Kawau; Goat/Hawere; Aotea/Great Barrier (incl. offshore islands); Channel; Cuvier; Mercury; and some mainland sites	NT	At Risk - Declining	DP EF (DP EF)	5,000-20,000 mature individuals, 10-30% population decline (Data Poor, Extreme Fluctuations)
PELECANIFORMES	**Australasian Gannet (Morus serrator)**	Poor Knights (High Peak and Sugar Loaf Rocks); Māori Rocks (Mokohinau); Mahuki (Broken Islands, Aotea/Great Barrier); Horuhoru Rock; some Coromandel/Thames islands	LC	Not Threatened	(DE Inc SO)	(Designated, Increasing, Secure Overseas)
	Pied Shag (Phalacrocorax varius) **	Breeds coastally through the Hauraki Gulf including inshore and offshore islands				
	Little Shag (Phalacrocorax melanoleucos brevirostris)	Some inner Gulf islands and estuaries	LC	At Risk – Naturally Uncommon	(Inc)	(Increasing)
	Spotted Shag (Stictocarbo punctatus punctatus) **	Ponui; Waiheke; and some Coromandel islands	LC	Not Threatened		
CHARADRIIFORMES	**Black-backed Gull (Larus dominicanus)**	Breeds on some inshore and offshore islands (e.g. Mokohinau, Tiritiri Matangi); also coastal sites e.g. Miranda	LC	Not Threatened	(SO)	(Secure Overseas)
	Red-billed Gull (L. scopulinus) **	Breeds on some inshore and offshore islands (e.g. Mokohinau, Tiritiri Matangi); also coastal sites	LC	Threatened – Nationally Vulnerable	E(1/1)	20,000-100,000 mature individuals, 50-70% population decline
	White-fronted Tern (Sterna striata) **	Breeds on some inshore and offshore islands (e.g. Mokohinau, Tiritiri Matangi); also coastal sites e.g. Miranda	V	Threatened – Nationally Vulnerable	B(1/1) (DP)	1,000-5,000 mature individuals (unnatural), stable (Data Poor)
	Caspian Tern (Hydroprogne caspia)	Breeds in coastal locations (e.g. Mangawhai)	NT	Threatened – Nationally Vulnerable	B(1/1) (SO)	1,000-5,000 mature individuals (unnatural), stable (Secure Overseas)
	NZ Fairy Tern (Sternula nereis davisae) **	Pakiri Beach; Mangawhai Heads; and Waipu Estuary (all mainland sites)	C	Threatened – Nationally Critical	A (CD RR)	< 250 mature individuals (natural or unnatural) (Conservation Dependent, Range Restricted)

4.9.4 Bryde's whales

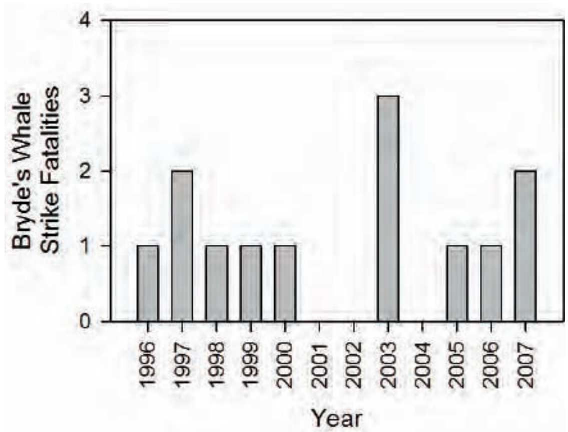
Bryde's whales are listed as a nationally critical species (i.e. threat status 1) in New Zealand because of their small population size in this country. The total New Zealand population is estimated to have fewer than 250 mature individuals, with many of these feeding, breeding and raising their calves in the Hauraki Gulf. This large, slow-moving whale spends considerable time near the surface in one of the busiest waterways in New Zealand. Consequently, collisions between the whales and vessels, and interactions between the whales and other human activities are a serious concern. From 1989 to 2008, there were 38 recorded mortalities of Bryde's whales in New Zealand, of which:

- 23 (61%) died of unknown causes (although data was not collected from most of these carcasses);
- two (5%) died from entanglement in mussel farm spat lines; and
- 13 (34%) were "probably or possibly" killed by vessel strike (Behrens and Constantine 2008).

The bodies of 11 of the whales thought to be killed by vessel strike were obtained from the Hauraki Gulf (Behrens 2009).

Bryde's whales have very specific feeding patterns and requirements: targeting tightly packed schools of small bait fish. Competition between Bryde's whales and humans for this resource could have serious consequences for this species also (pers. comm. Rochelle Constantine, University of Auckland).

Figure 49: Number of known and probable fatalities of Bryde's whales.



4.9.5 Strategic considerations for the maintenance and recovery of biodiversity

1. Islands of the Gulf have a highly critical role in preventing the extinction of native fauna.
2. Pest-free islands must be continuously monitored to prevent invasions of exotic flora and fauna.
3. Catastrophic events such as volcanism, tsunami, fire or outbreaks of disease could have severe consequences for island populations of threatened species.
4. Risks are greater for species that have self-sustaining populations on only a single island (e.g. hihi).
5. Efforts to replant islands, remove exotic mammalian predators and herbivores, and re-establish populations of threatened species have generally been successful, but some species such as hihi are less responsive to translocation due to their specific habitat requirements.
6. Nearly half (seven) of the 15 most common wader species in the Firth of Thames have displayed declining trends in their numbers since 1960.
7. Habitat change, and in particular the expansion of mangroves, appears to have contributed to declines in at least four of the above species.
8. A high proportion of the New Zealand Bryde's whale population is resident in the Hauraki Gulf.
9. Bryde's whales are highly threatened in New Zealand, being classified as a nationally critical species (i.e. threat status 1).
10. Eleven Bryde's whales appear to have been killed by vessel strike and two by mussel line entanglement in the Hauraki Gulf between 1989 and 2008.

4.10 Coastal development

Coastal development is a growing issue in terms of its environmental cost. The environmental impacts of coastal development tend to be unidirectional and cumulative (Kelly 2009). Among other factors, these impacts can include:

- the degradation of natural landscapes and wilderness features;
- modification of the natural coastline through reclamation and the construction of marinas, seawalls, wharves, boat ramps and other coastal structures;
- habitat loss through direct or indirect physical disturbance during land development and the construction and maintenance of coastal structures;
- the release of stormwater, wastewater, anti-foulants and other contaminants into the environment;
- increased biosecurity risks for marine biota and coastal vegetation;
- growing threats to coastal birds through direct disturbance, habitat loss and increased numbers of mammalian predators (including cats and dogs); and
- increased pressure of fish and shellfish resources.

In addition, coastal development can destroy or degrade sites that have important historical or cultural values and reduce visitor access to the Gulf by decreasing the number of camping grounds. Several indicators are therefore used to examine patterns and trends in coastal development, including: the extent of development around bays and beaches; trends and patterns of new coastal development; loss of camping grounds; and overlap between coastal development and outstanding natural landscapes.

4.10.1 Development around bays and beaches

Bays and beaches have traditionally been focal points for coastal development. A qualitative assessment[15] of the land surrounding 232 mainland bays and beaches in the Gulf was therefore used to quantify the extent of development associated with these important coastal features. The bays and beaches used in the analysis were either named on 1:50000 topographical maps, or had adjoining coastal settlements. Forty-seven per cent of these bays and beaches have been fully urbanised, intensively developed, or moderately developed (Figure 50 and Figure 51). Conversely, the land surrounding 38% of bays and beaches was either undeveloped or contained only scattered buildings. The remaining bays and beaches had small settlements.

The Waikato Region had more undeveloped bays and beaches than the Auckland Region (36% in the Waikato Region cf. 5% in the Auckland Region), but the two regions had a similar proportion with scattered buildings (17% cf. 19%).

15. The degree of development was subjectively ranked into six categories using the latest satellite image on Google Earth™.
The categories were: fully urban; intensively developed; moderately developed; small settlement; scattered buildings; and undeveloped.

Figure 50: The degree of development in relation to the bays and beaches that were either named on 1:50000 topographical maps or had adjoining coastal settlements. The degree of development was subjectively ranked into six categories using the latest satellite image on Google Maps™.

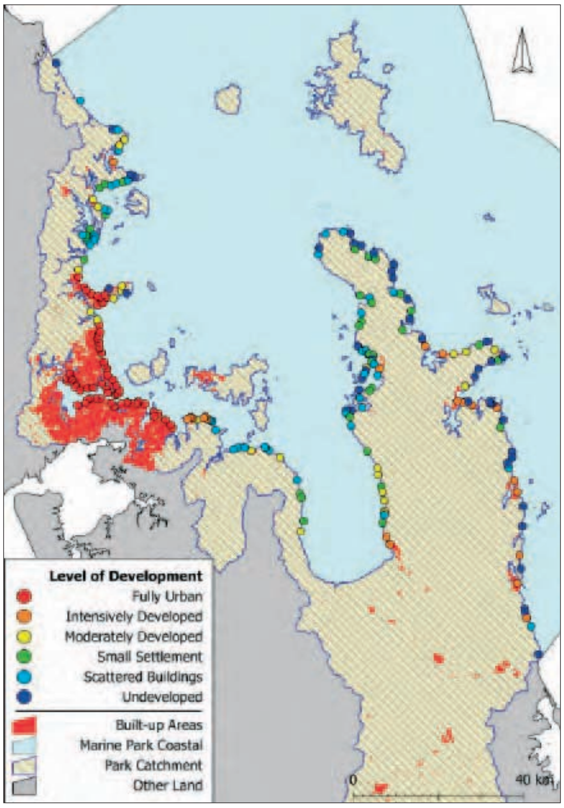
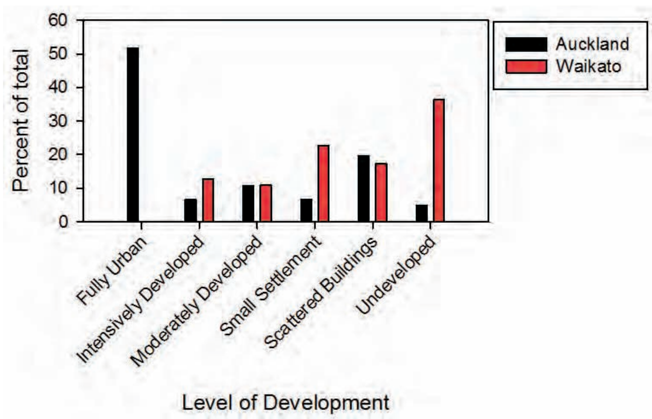


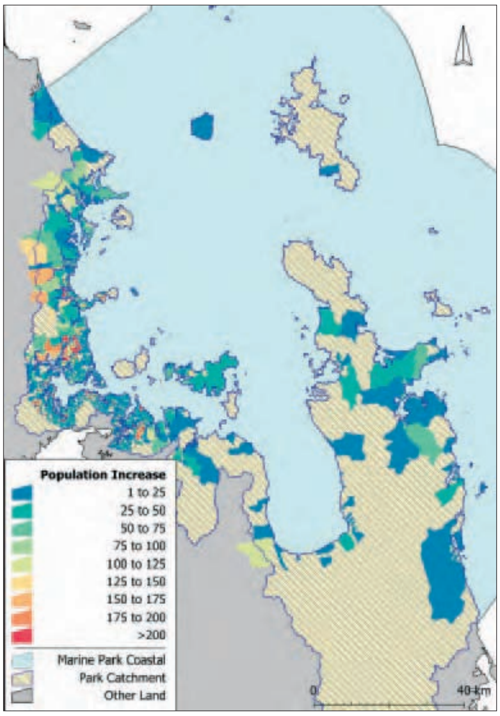
Figure 51: The proportion of bays and beaches from the Auckland and Waikato regions that were either named on 1:50000 topographical maps or had adjoining coastal settlements, and whose surrounding land use was categorised as: fully urban; intensively developed; moderately developed; small settlement; scattered buildings; and undeveloped. The degree of development was subjectively ranked using the latest satellite image on Google Maps™.



4.10.2 Trends and patterns in new development

Over the past 15 years, the greatest increase in coastal development has occurred in central to northern parts of the Auckland Region (Figure 52 and Figure 53). This includes the relatively large-scale development of new or "greenfield" sites around the margins of the Auckland urban isthmus at Orewa, Albany, Silverdale, Long Bay, Hobsonville, Gulf Harbour, Botany and Flatbush. Smaller-scale developments have also occurred around the outlying towns of Warkworth, Snells Beach, Omaha, Matakana and Beachlands. As a consequence, intensive coastal development extends almost contiguously from Maraetai Beach in the south, to Hatfields Beach in the north, with only three small breaks of less-intensive development around Whitford Peninsula, Long Bay-Okura and parts of the upper Waitematā Harbour (Figure 54). Urban development has modified a relatively large proportion of the western end of Waiheke Island too.

Figure 52: Changes in coastal populations between 1996 and 2006 with (a) areas where the population increased, and (b) areas where the population remained stable or declined.



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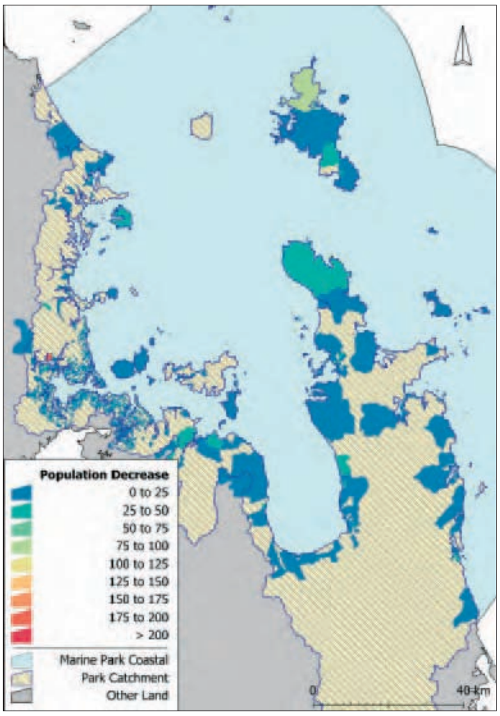
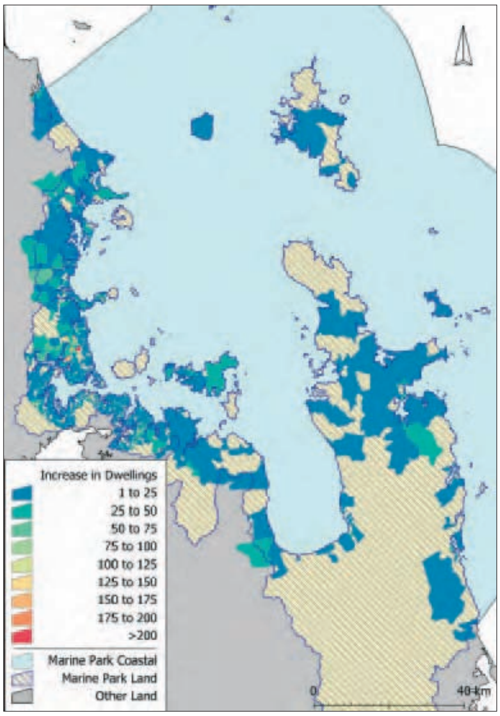


B.

Figure 53: Changes in coastal dwellings between 1996 and 2006 with (a) areas where the number of dwellings increased, and (b) areas where the number of dwellings remained stable or declined.



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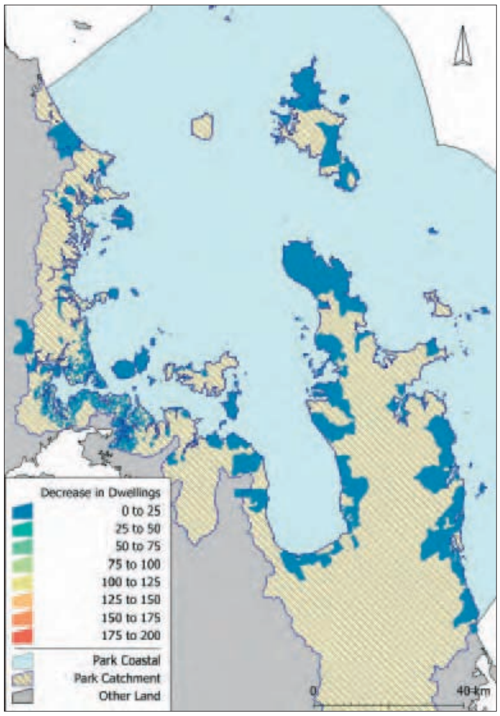
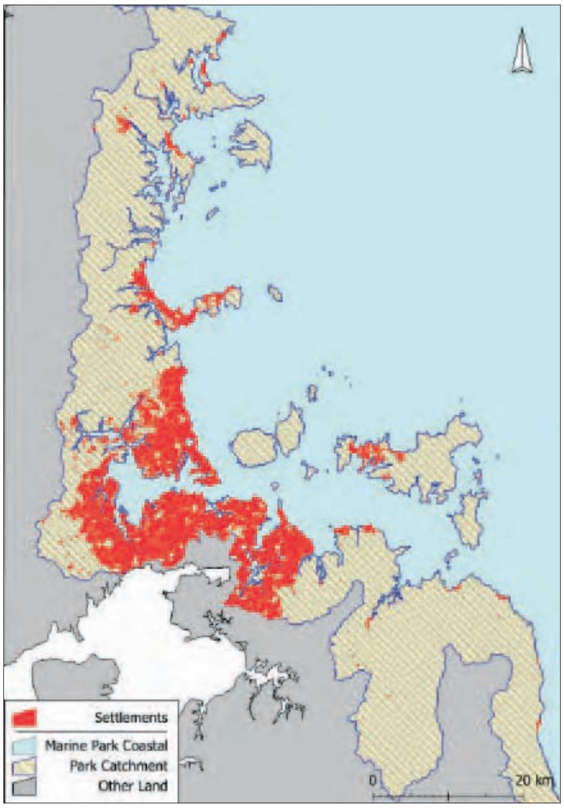


B.

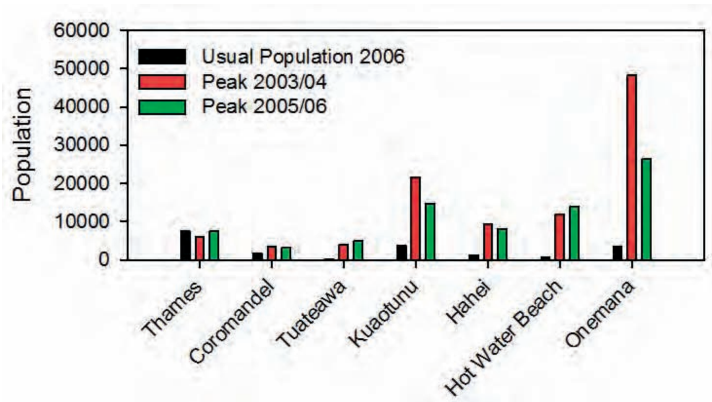
Figure 54: Developed coastal areas (excluding Aotea (Great Barrier Island) in the Auckland Region in 2001. Data was obtained from built-up areas in the land classification database two (LCDB2).



Holiday homes are likely to make a relatively minor contribution to coastal development in the Auckland Region, but residential development in holiday areas such as Omaha have still caused significant localised effects (Kelly 2009). In contrast, the construction of holiday homes is responsible for a large proportion of coastal development on Coromandel Peninsula. The Thames Coromandel District experiences extreme holiday peaks in its population, particularly from 26 December to 4 January. Hotspots for holidaymakers include Opito Bay and Otama, which grew 51 times their normal population size during surveys conducted over the peak summer period in 2005/06 (Beca Carter Hollings & Ferner Ltd 2007b). Whangapoua experiences the next largest proportional increase, growing 27 times its usual resident population over summer, followed by Matarangi with 24 times and Cooks Beach, Hahei and Pauanui growing 18 times (see Figure 55 for data from a subset of settlements).

During the latest 2006 census, 10,920 dwellings in the Thames-Coromandel District were unoccupied, which constituted 48% of the 22,700 dwellings in the district. Most of these were holiday homes and/or baches, but vacant properties for sale, properties completed but not yet occupied and other properties such as "abandoned" dwellings are also included in this figure (Beca Carter Hollings & Ferner Ltd 2007b).

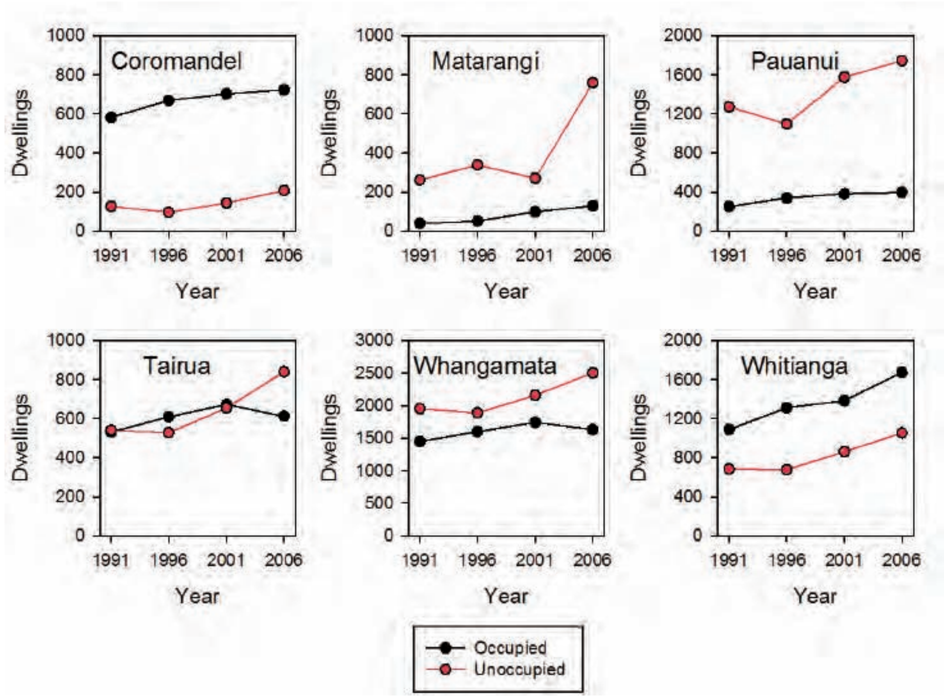
Figure 55: Usual population numbers in settlements on Coromandel Peninsula and population numbers during the peak summer holiday periods of 2003/04 and 2005/06 (data from Beca Carter Hollings & Ferner Ltd 2007b).



Historically, the west coast of Coromandel Peninsula contained more settlements with a permanently resident population whereas the east coast was characterised by non-resident "holiday home" settlements. However, between 1996 and 2006, most growth in the resident population and number of dwellings occurred on the eastern side of Coromandel Peninsula, with the western side declining slightly (Figure 52 and Figure 53). During the 1990s the northern sub-catchment of the Peninsula and Whangamatā were key destinations, followed by the Pauanui-Mercury Bay area and to a lesser degree Thames. Growth in the resident population has now shifted to the area behind Coromandel township, small pockets of Matarangi Beach, Whitianga Harbour, Tairua and Pauanui and Thames south. To a lesser extent, growth in the resident populations has also occurred in inland areas of Whitianga Harbour to Tairua, Pauanui to Opoutere and inland behind Whangamatā (Beca Carter Hollings & Ferner Ltd 2007b, Figure 52).

The strong demand for coastal properties has led to the linear sprawl in residential development along the coast, with steady increases in the number of dwellings (Figure 56 and Figure 54). Limited development is also occurring in areas that were previously untouched due to their isolation and steep topography such as Sailors Grave (Beca Carter Hollings & Ferner Ltd 2007b). The Thames-Coromandel District Plan has a settlement and amenity policy, which aims to keep development and growth within the serviced settlements of Thames, Coromandel, Matarangi, Whitianga, Tairua, Pauanui and Whangamatā. However, the 2006 census shows that the eastern settlements of Cooks Beach, Hahei and Kuaotunu are hotspots for growth in new dwellings (Beca Carter Hollings & Ferner Ltd 2007a).

Figure 56: Change in the number of dwellings in Coromandel settlements between the 1991 and 2006 censuses (data from Beca Carter Hollings & Ferner Ltd 2007a).



4.10.3 Loss of camping grounds

Camping grounds in the Gulf have been affected by high land prices, the demand for residential properties and limited commercial viability. Between 1996 and 2006, 20 camping areas were closed in the Auckland and Coromandel regions (which was the greatest loss on a national basis), resulting in one third of the total commercial camping capacity of Coromandel Peninsula being lost (DOC Heritage Appreciation Unit 2006).

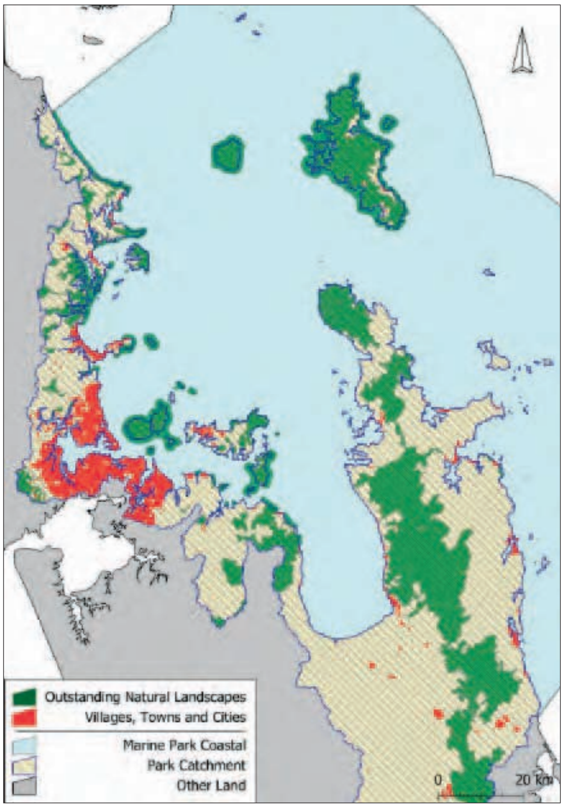
4.10.4 Overlap between development and outstanding natural landscapes

There is relatively little overlap between coastal development and areas with outstanding natural features and/or landscape values, identified by Auckland Council and Waikato Regional Council (Figure 57). Auckland Council has identified most undeveloped parts of its coastline as having outstanding natural landscape values, whereas the massive volcanic landform of Coromandel Peninsula is the most extensive feature identified by Waikato Regional Council. This forms the distinctive backbone of the peninsula and is characterised by its bush-clad peaks, pinnacles and rocks. The area is highly significant to tāngata whenua and has historical values related to goldmining and logging as well. However, Waikato Regional Council also recognises the outstanding natural features and landscapes of Cathedral Cove, Shakespeare Cliff and coastline south of Hahei. These areas have white silica beaches with dramatic cliffs rising to 100 m in places, together with pinnacles, arches, blowholes and islands off the coast. The northern tip of Coromandel Peninsula has a combination of pasture and bush running out to cliffs and bays. This area has dramatic and vivid coastal features, such as pōhutukawa-lined coastal fringe and steep slopes with native forest above and coastal edge below. The wild and remote character of this area contributes to its outstanding status too. The coastal margin around Tuateawa, on the east coast of Coromandel Peninsula between Waikawau Bay and Kennedy Bay, is also recognised for its combination of having a dramatic coastal edge, stony beaches and rock reefs, backed by steep slopes with large numbers of pōhutukawa. In addition, this area has many historical pā sites (Buckland et al. 2010).

4.10.5 Strategic considerations for coastal development

1. Coastal development causes significant and cumulative impacts on the ecology and landscapes of the coastal environment.
2. Intensive coastal development is a unidirectional change, which reduces opportunities for future generations.
3. There are very few mainland bays and beaches in the Auckland Region that do not have any form of building development on the surrounding land, whereas around a third of Waikato bays and beaches are undeveloped.
4. Coastal development has increased in many areas since 1996.
5. Coastal development has contributed to the loss of camping opportunities in the Gulf.
6. Pressure to develop coastal areas is likely to increase, particularly for high value and iconic beaches such as New Chums (Wainuiototo) and Pakiri which are currently “untouched” or minimally developed.

Figure 57: The location of villages, towns and cities relative to outstanding natural landscapes (and also incorporating outstanding natural features in the Waikato Region) identified by Auckland Council and Waikato Regional Council.



5.

Research Gaps and Opportunities

Invited contribution by Dr Simon Thrush[16] and Professor John Montgomery[17]

16. Principal Scientist and Science Leader, Coastal Ecosystems, NIWA.
17. Director, Leigh Marine Laboratory, University of Auckland

The Hauraki Gulf is an iconic coastal marine ecosystem with high biodiversity that supports a wide range of benefits across our society. Considering the research gaps and opportunities, the Hauraki Gulf provides an opportunity to envision the future of this ecosystem against a background of current and future trends in environmental stressors and the potential to develop a 21st-century capacity for resource management and conservation. Importantly, capturing the intellectual capital of the Gulf's catchment should bring modern techniques of science, engineering and organisation to the management of its ecosystems. These developments can provide a unique opportunity to make a major advance. By leading the way in nurturing and connecting trans-disciplinary science to ecosystem-based management of the Hauraki Gulf, the Forum could provide a model for New Zealand, and in fact for the world, of the implementation of ecological sustainability that fosters economic, cultural and environmental restoration. We see enhanced education, valuation and understanding of the interconnections within the Hauraki Gulf's ecosystems and social-ecological system as beneficial for sustainability. Given the growing recognition of human dependence on ecosystems and increased attention on the value of ecosystem services, we see it as critical to better describe, quantify and value (ecologically, culturally and economically) the importance and benefits of the goods and services provided by the Gulf's ecosystems and biodiversity.

5.1 Do we know what the issues are?

Any consideration of the threats to the Hauraki Gulf must bear in mind both the legacy of previous activities and current stressors as well as look forward to future challenges. The spatial scale, frequency, duration and cumulative effects of impacts are important factors, but any risk assessment, resource allocation or remediation needs to be balanced against spatial variation in the value and use of the Gulf's ecosystems and catchments. Sections 3 and 4 of this report identify key environmental issues and important emerging concerns in order to frame a number of key scientific challenges.

Many issues are identified in this report and while researchers and managers have made progress in addressing key concerns, our brief is to focus on current gaps and opportunities. The list of priority issues will expand in the near future with the reality of climate change impacts, the potential for finfish aquaculture, power generation, mineral extraction and emerging contaminants. While management should consider each issue in terms of the extent of the threat and potential to change the Gulf's ecosystems, from a scientific perspective we focus on trying to identify strategic issues where new knowledge and technology informs management across multiple matters to improve conservation and sustainability goals.

At a workshop involving researchers (NIWA and University of Auckland) and resource managers (Auckland Council, Waikato Regional Council, MFish, DOC) held at NIWA's Auckland office (3 March 2011) a range of threats that face the Gulf was discussed and from this we identified the following critical issues:

- The Gulf functions as a connected whole with links to the land and human activities. Managing this interrelated system is an ongoing process requiring understanding, information and modelling.
- The ecosystem goods and services provided by the Gulf and catchment are under pressure. The underpinning bases of these goods and services need to be identified, managed and improved.
- There has been a decline in the quality of some habitats, and declines in the abundance of fish, crayfish and shellfish. Restoration of habitats and populations to increase abundance and ecosystem resilience needs to be investigated.

Some specific concerns are:
– pressure on commercially, culturally and recreationally important exploited species and the ecosystem consequences of changes in size and age structure of these populations;
– loss of biogenic (living) habitats and changes in habitat diversity as a result of bottom disturbance by commercial and recreational fishing, and reduced water quality;
– sediment impacts as a result of both current and historical land use;
– nutrient loads particularly in the Firth of Thames, but not excluding other more localised issues;
– non-point source urban contaminants;
– invasive species; and
– human pathogens.

To some extent, we understand how to link these threats to ecosystem responses. However, examples exist of ecosystem-wide responses where we are unable to specify the underlying mechanism driving that response. For example:
– Toxic algae blooms were first recorded in the 1980s.
– A series of mass mortalities has also been recorded including the largest mass mortality ever documented, both in terms of the number of fish and the geographic range affected (pilchards in 1995). Other mass die-offs have been reported for scallops, cockles (Ecklonia) and kina.
– Toxic sea slugs on our beaches have been reported in the news media in recent years.

In some cases, these ecosystem responses may appear to have increased because they are now being monitored or reported by the general public.

The key issues for the Gulf are well known. The State of the Environment reports produced in 2004 and 2008 highlighted significant gaps in our knowledge and ability to assess the state of the Gulf environment (Hauraki Gulf Forum 2004, 2008a). In 2009, the Hauraki Gulf Forum published *Governing the Gulf: Giving effect to the Hauraki Gulf Marine Park Act through Policies and Plans* (Hauraki Gulf Forum 2009), which summarised the findings of State of the Environment reports produced in 2004 and 2008, noting:

"Human activities have had a profound impact on the natural environment of the Gulf. This is described in detail in the two recent Hauraki Gulf State of the Environment reports prepared by the Hauraki Gulf Forum (Hauraki Gulf Forum 2004 and 2008a). Some of the more significant impacts on the coastal marine area have resulted from contaminants from land ending up in rivers and groundwater and ultimately in the sea. Sedimentation is one of the most pervasive problems in the Gulf impacting on many estuaries and harbours. Earthworks, forestry and farming all contribute to the problem. Heavy-metal contamination, nitrogen enrichment and microbial pollution also negatively impact on the coastal marine area, but occur at a more localised scale.

Urban and rural-residential development is having a major impact on the natural character and landscapes of the Gulf by replacing natural features with built structures. It is also resulting in the loss of cultural heritage, through the destruction of archaeological sites. The main pressures are on the coastline of the Auckland Region but also along the east coast of Coromandel Peninsula.

Within the coastal marine area, the harvesting of fish and shellfish has reduced many stocks to a small proportion of their original quantity. More insidious is the degradation of ecosystems and marine habitats which has resulted from the cumulative effects of fishing activity, land-sourced sedimentation and pollution and physical changes to the seabed from dredging and trawling activities, reclamation and other construction works. This is of particular concern as it is the health of these habitats and ecosystems which underpin the productivity of the Gulf's coastal marine area and support the wildlife and people that depend on it.

The effects of climate change are likely to place further stress on marine systems. Warmer temperatures will provide more viable habitats for subtropical and tropical organisms, some of which could become invasive. Increased rainfall and storminess may result in greater levels of sedimentation. Increasing acidity of seawater caused by rising levels of CO_2 may negatively affect shellfish. And rising sea-levels will increase 'coastal squeeze' as the natural foreshore moves landwards and comes up against a wall of artificial coastal structures."

From the above, it is clear that defining the current threats facing the Gulf is not an information gap, at least in broad terms. What we are missing is a framework for understanding how the Gulf's ecosystems respond to these and future threats and translating this understanding to inform effective management and societal responses. Governing the Gulf (Hauraki Gulf Forum 2009) analysed the purposes and management objectives of the Hauraki Gulf Marine Park Act, highlighting some special attributes that should foster a more proactive and integrative management framework:

- It is the interrelationships between the Gulf's coastal area, its catchments and islands which create its nationally significant qualities.
- The nature of the marine environment is dynamic, where individual elements are linked within complex webs.
- There is a very strong marine focus to the legislation.
- Sustaining the life-supporting capacity of the Gulf should be the focus for management efforts, rather than how to allocate the Gulf's resources between competing users.

It is also worth noting that the Hauraki Gulf is an important test case for the Government's vision for fisheries, as articulated in Fisheries 2030. This document seeks to see fisheries resources used in a manner that provides greatest overall economic, social and cultural benefit whilst preserving the capacity and integrity of the aquatic environment, habitats and species, including that:

- Biodiversity and the function of ecological systems, including trophic linkages, are conserved.
- Habitats of special significance to fisheries are protected.
- Adverse effects on protected species are reduced or avoided.
- Impacts, including cumulative impacts, of activities on land, air or water are restricted.
- Ecosystems are addressed.

In light of this, we propose an ecosystem-based management approach to foster and focus research and to put existing and new knowledge to work to fulfil the goals of the Hauraki Gulf Marine Park Act. We also identify that, in the medium term, predictive process-based models have a contribution to make in capturing our state of knowledge, identifying knowledge gaps and providing an effective interface between science and management. Environmental research is undertaken in the Gulf for a variety of different purposes and is supported by a range of agencies. A focus on ecosystem-based management, including modelling, would place the Hauraki Gulf Forum in a strategic role for closing key gaps, and integrating and synthesising knowledge. The key objective is to build on an understanding of the critical elements, linkages and dynamics of the Gulf system, and develop a predictive ability to detect changes in the capacity of the system to support life and deliver societal benefits.

5.2 Ecosystem-based management as an organising principle

Sustainability means different things to different people, and this can cause confusion and misdirection of management actions. From the perspective of ecosystems' science, sustainability and sustainable management require a broad view integrating historical, current and future ecosystem responses to human and natural changes. To achieve this, it is necessary to implement ecosystem-based approaches to management. Ecosystem-based management should seek to balance the needs and values of different sectors of society in an inclusive fashion, rather than focus on the delivery of benefit to specific resource users. Explicitly it focuses on the sustainability of ecosystem structures and processes necessary to deliver goods and services.

From the perspective of ecological science, sustainable ecosystem management should include:

- long-term ecological sustainability as a fundamental value;
- clear operational goals;
- sound models providing an understanding of complexity and interconnectedness;
- recognition of the dynamic character of ecosystems;
- attention to context and scale;
- acknowledgment of humans as ecosystem components; and
- a commitment to adaptability and accountability.

These issues have important implications across the scientific process, from framing questions, gathering and interpreting data, developing models, recognising the value of understanding and ultimately to forecasting ecosystem responses. Particularly within an ecosystem-based management context, it is important to consider the following:

a. adaptive management;
b. the potential for interaction between stressors increases as we move from the detection of immediate stressor effects to broader consequences on ecosystem function and changes in ecosystem services;
c. whether current and historical stressors and future changes will lead to slow degradative change in a specific ecosystem, which is potentially easy to restore, or to drastic "regime shifts" that markedly change the potential of ecosystems to deliver a diversity of services from which restoration of services will be very difficult.

5.3 Why should we care? The bridging role of ecosystem services

It is all too easy to stop an assessment of research gaps at an assessment of threats, but from an ecosystem perspective, it is imperative we also consider how the ecosystem may respond to change, and how the management options may favourably shift the benefits and values we derive, either actively or passively, from the Hauraki Gulf.

Ecosystem services derived from the coastal ecosystems can be broadly categorised to include:

- production and quality of food resources;
- shoreline protection;
- climate change mitigation;
- nutrient cycling;
- contaminant processing;
- sediment stability and creation;
- resilience and biodiversity;
- mitigation of harmful algal blooms;
- supporting science and education;
- underpinning natural aesthetic values;
- boosting tourism;
- strengthening amenity values;
- energy;
- transport and navigation;
- leisure and recreation;
- fostering cultural values.

These services are generated by a diverse array of ecosystem functions. The recognition of the value of these functions involves linking ecosystem function to service and societal values. Recent research conducted by Auckland Council, in partnership with NIWA's Coasts and Oceans outcome-based investment programme, reveals the potential for complex and indirect interactions between natural and human-induced drivers, and the feedbacks between ecosystem pressures and responses. A key science challenge is addressing the complexity of mechanisms that connect ecosystem function to service, the limits of our current understanding of these processes and of how they are affected by different external drivers. Progress in this area is possible and essential, as many of the directives to which resource managers must respond are clearly linked to the maintenance of ecosystem function and the concomitant services. In effect, this expanding area of ecosystem service research should be developed into a tool for contrasting how scenarios of different management actions could affect the ecosystem and the multifaceted benefits derived from it by society.

5.4 Key research themes

In this section, we identify key integrative questions and offer advice on how it would be possible to move forward with defining environmental status and targets and the more holistic issues of ecosystem-based management and sustainability. Perhaps more than any other coastal ecosystem in New Zealand, there is an extensive multidisciplinary research and monitoring base for components of the Hauraki Gulf. The region's universities, NIWA and other research providers provide fundamental and strategic environmental research to support applied work by regional councils, MFish and DOC. Our analysis of gaps and opportunities builds on this knowledge and technology platform, seeking to maximise benefit and minimise duplication. Within a framework of conducting and interpreting credible science to underpin management, conservation and stewardship of the Hauraki Gulf, we have identified eight key interdependent research themes and key questions that we must address to fill major gaps.

As previously noted, the key issues are well known and there is a substantive body of scientific expertise and relevant scientific information generated specifically from the Gulf or available in the international scientific literature to inform management. We are already putting our current knowledge to good use. For example, the effects of habitat disturbance by trawl and dredge fisheries in the Gulf have been described and the marine reserve at Leigh had highlighted important ecological changes associated with the loss of large predatory organisms, like snapper and crayfish. Sophisticated risk assessment models have been used to link changes in land use to the threat of sediment deposition in different estuarine and coastal habitats and to forecasting the immediate ecological consequences of that disturbance. We have resource inventories and habitat maps of some of the Gulf's estuaries and harbours and extensive survey of shallow-water coastal reefs. We also have numerical models of water, nutrient and phytoplankton dynamics to inform our understanding of land and ocean-forcing of primary production in the Gulf's waters and to help better plan spatial allocation for aquaculture.

In building on the substantive body of knowledge and the good working relationships between researchers and managers, it is important to remember that the Hauraki Gulf Marine Park Act has some special attributes. The intention of the Act is to foster a more proactive and integrative management framework, with a focus on interrelationships between places and process to sustain the life-supporting capacity of the Gulf, rather than on how to allocate the Gulf's resources between competing users. Sustaining the "life-supporting capacity" requires that we understand resilience and ecosystem functioning and are able to link environmental change to ecosystem futures. These are the major challenges we must address.

Ecosystem functions and services

Key questions:

– What are the key ecosystem services that support the values of the Hauraki Gulf?
– What ecosystem functions are critical in supporting those services?
– How is the functional performance of these Gulf ecosystems changed by major stressors?
– How can we effectively map the potential for service delivery around the Hauraki Gulf to prioritise areas/habitats and management actions?
– What mechanisms are appropriate to link ecosystem services to societal values and improve recognition of the benefits we derive from the Hauraki Gulf?

Resource mapping

Key questions:

– Can we map key biogenic habitats that potentially play important roles in ecosystem function or resource sustainability (e.g. in the outer Gulf subtidal environments, > 10 m soft-sediment and > 30 m rocky reef)?
– What are key pathways for connectivity within the Hauraki Gulf ecosystem and across its boundaries, in terms of the movement of organisms, fluxes of energy and matter?
– How is the proportion of key biogenic habitats changing over time?
– Can we develop a robust habitat classification scheme for the Gulf that defines and classifies habitats in an ecologically meaningful and robust way?

Indicators of change
Key questions:
- What are the most important indicators to assess the status and trends of the Gulf against appropriate baselines?
- What are the biologically important levels for threshold effects of nutrients, sediments and pollutants?
- How do we integrate different indicators associated with biological, physico-chemical and hydrodynamic measures of environmental quality with societal values?
- What new technologies can be developed to improve monitoring of the Gulf?
- Is the frequency of Harmful Algal Blooms increasing and if so, how do blooms relate to environmental drivers such as nutrient loading or sea-floor sediment characteristics?
- What is the Harmful Algal Bloom risk to specific use (e.g. swimming, sailing or aquaculture)?
- What are the ecological threats posed by invasive species and what are the management options that allow a fast response to limit their spread?
- Can veterinary forensics be combined with environmental monitoring data to explain mass mortality events?

Ecosystem resilience
Key questions:
- Can we identify potential tipping points in resource use or ecosystem response to stress?
- Can we improve our ability to demonstrate the risk of cumulative effects and identify multiple stressors that deplete resources and restrict ecosystem performance?
- Once status is assessed, how do we prioritise areas for restoration and rehabilitation?
- How do we effectively restore degraded marine habitats?
- What management actions are needed to increase the adaptive capacity of the Gulf's ecosystems (e.g. to change in nutrient inputs, climate change)?

Conservation
Key questions:
- What are the ecosystem services of marine-protected areas (MPAs) that add to our understanding and management of the life-sustaining capacity of the Gulf?
- Is the current network of MPAs effective at conserving the Gulf's biodiversity?
- How are broad-scale changes in the Gulf's ecosystem affecting endangered species and sites (e.g. Ramsar site in the Firth of Thames; shark nursery grounds and teleost fish spawning grounds, key habitats and migrations pathways)?
- How do we maximise the social and economic benefits from conservation?
- How are terrestrial conservation areas (e.g. mainland and island reserves) linked to the adjacent marine environment?

Resource sustainability
Key questions:
- What are the consequences of exploitation on the resilience of the stock and the broader ecosystem?
- What are the consequences for exploited resources of natural or anthropogenic perturbations?
- What role do exploited species play in ecosystem functioning and how has exploitation modified functional performance (e.g. the population dynamics of harvested animals, their prey and competitors)?
- What management options are there to allow exploitation but maintain ecosystem functions?
- How does aquaculture influence ecosystem process (e.g. sources and sinks for nutrients, suspended sediment) or the movement of organisms (e.g. pelagic larvae, microbes, parasites, megafaunal migrations)?
- How do the costs of ecosystem services and functions compare to the cost-benefits from the use of ecosystem resources, including commercial and recreational take?
- How does the connectivity of exploited species across the Gulf (e.g. larval and post-larval transport/movement) and associated sources and sinks affect population stability/resilience/productivity, in the face of human disturbance?

Modelling

While models are tools rather than thematic issues, we recognise their value in heuristics, communication, prediction and forecasting. Many models are already available and others are "in progress". We acknowledge that any model must be fit-for-purpose. From the Hauraki Gulf Forum perspective, these are potentially essential tools for integration and consideration of the environmental future options for the Gulf's ecosystems.

Key requirements:

– Hydrodynamic models to address questions at a range of spatial and temporal scales and assess the connectedness of areas based on water flow.
– Models of the sources, sinks and dynamics of contaminants, nutrients and sediments (particularly suspended sediments).
– Geomorphological models resolving the physical variability and dynamics of the seabed, including the coastal fringe, to examine habitat stability and linkages to ecological transitions.
– Coastal hazards risk and mitigation models.
– Ecological connectivity models based on the dispersal of specific species or relationships between regional and local species' pools.
– Morphological models that capture the linkages between oceanographic, ecological and substrate dynamics at a range of temporal scales relevant to management.
– Ecosystem modelling of trophic relationships, community dynamics and exploited populations.
– Model testing and validation is seen as an essential component of all model building.

Social science

Key questions:

– Is society getting the best environmental, social and economic return on the resources of the Gulf?
– How do we create effective institutional structures and connections to assimilate knowledge and translate it into management action?
– How do we balance short-term and more certain benefits with long-term and less-certain benefits?
– How do we develop adaptive frameworks to feed information on status and trends back to the efficacy of management actions and policy?
– How do we provide opportunities for community based research, which integrates marine and freshwater linkages (e.g. through community programmes to track the status and trajectory of native fish populations)?
– Can we define acceptable and unacceptable environmental futures for the Gulf that can help define the key processes and ecosystem functions that need wise management?
– How do we raise/heighten public understanding of the importance of the Hauraki Gulf and the integrated nature of the ecosystem?

5.5 Synthesis and integration

We consider this aspect to be a major focus for the Hauraki Gulf Forum. Individual research and monitoring agendas within the Hauraki Gulf area are set by a variety of needs and interests. Synthesis and integration of new knowledge and technologies to expand on the wise management of the Hauraki Gulf within an ecosystem-based management framework is a critical task.

This process will require definition of different systems and their connections; an analysis of sources and sinks, flows and stocks. For example, science makes assumptions to advance our understanding and represent the biogeophysical/chemical/ecological/social processes in models. Many of these processes are complex and poorly understood. As a result, placing bounds on uncertainties is extremely difficult, particularly in a context when the inputs are not quantified exactly. One way to address this issue is to run multiple models so that inter-comparison of model results linked to critical assessment by field measurements provides information on the spread of possible predictions. Such parallel model developments are a useful foundation for adaptive management under uncertainty and for future sustainability assessments, and are a mechanism for ensuring that a diversity of models continues to be developed. In addition, we propose a data management strategy to ensure that the benefit of the legacy of the research is maximised. Such a management strategy will quantify what is known, highlight data gaps and make data publicly available online. This would include maps of resources (e.g. fish stocks), habitats, management areas (e.g. marine reserves, cable zones), shipping lanes, marinas, harbours, freshwater inputs, contaminant distributions, water quality, scientific literature, species inventory, human population distribution, recreational activities (types, locations, pressures) and trends in this data over time. The database can then be used as a platform to promote collaboration amongst researchers and minimise disconnected research activities. A key aim is to ensure that, once new research findings or management actions emerge, the public can see the evidence behind these on the database website. Models of such databases already exist in NIWA, Auckland Council, DOC and Land Information New Zealand (Oceans 2020). A key issue will be ensuring the quality of information stored on the database. However, this data management strategy should also support public dissemination of fact and knowledge and be a visible product of the research supporting the Hauraki Gulf Forum.

To support these actions we recommend the following specific practical steps:

1. The development of a technical working group of key resource managers and scientific experts to assist with the translation of scientific knowledge and encourage relevant and rigorous science. An essential feature of the group will to provide feedback to the Hauraki Gulf Forum on ecosystem-based management and assess, improve and update the modelling/monitoring/mapping and environmental understanding as research advances. Such a working group should be empowered to commission reviews on, for example, the current research programmes related to the Gulf or analysis of knowledge management practices to ensure information is shared between agencies to support integrated management.
2. Use the technical advisory group to fill the gaps and recommend specific research topics for support by the Hauraki Gulf Forum.
3. Identify key synergies in current research initiatives and build on these, particularly in terms of integration.
4. Recognise educational opportunities that foster better understanding in society of the value of the Gulf and credible scientific research to manage and restore it.
5. Improve research networks to allow trans-disciplinary research on the Gulf's socio-ecological systems to develop.
6. Build a comprehensive and quality-controlled database to provide public transparency regarding the underlying research and the state of the environment and the Gulf's resources.

5.6 Summary recommendations of core knowledge needs

Because of its political visibility and economic importance, there is tremendous opportunity for the Hauraki Gulf to be a flagship for ecological sustainability. Although sustainability is a common policy and management goal, the application of ecosystem-based approaches to management are still in their infancy. Much is known about the Hauraki Gulf ecosystem; this provides a good platform for further research and the development of management strategies focused on aspirations of the Hauraki Gulf Marine Park Act. Although there remain knowledge gaps and uncertainties, management actions that ensure the resilience of these ecosystems are imperative. Further, we see enhanced education, valuation and understanding of the interconnections within the Hauraki Gulf's social-ecological system as beneficial for sustainability.

Core knowledge needs for sustaining the life-supporting capacity of the Gulf's resources and ecosystems

As recognised by the Hauraki Gulf Marine Park Act, management of the Gulf requires a focus on systems rather than discrete elements. The Gulf is interconnected, so too should be the science. Here we present five core knowledge needs to act as both focus and nexus for research. The research needed for the Gulf must be rigorous and of a high quality if it is to help in moving from policy and planning to effective action.

Core knowledge 1:
Mapping and classifying the Hauraki Gulf's ecosystems and defining its status We have good information on some of the estuarine and shallow-reef habitats, but the broader gulf is poorly described in terms of biogenic (living) environments. This information is needed to underpin stewardship and assess trends in relation to human activity (both impact and restoration). This lack of knowledge fundamentally constrains our ability to implement spatially explicit management. We have a number of indicators of ecosystem health and integrity for some habitats in the Gulf, but these need to be extended to define the status and trends of the Gulf in a way that is both scientifically defensible and suitable for public dissemination.

Core knowledge 2:
Defining the ecological infrastructure of the Hauraki Gulf At the foundation of the Hauraki Gulf Marine Park Act is "sustaining the capacity of the system". This requires that we determine the major ecosystem functions, their relationship to specific habitats and the connectivity between habitats. Ecosystem functions define how the system works and responds to change. Many key functions ultimately underpin the broad range of benefits we derive from the Gulf. We think the focus here should be on maintaining biodiversity, nutrient and carbon recycling, sediment stability, nursery habitats for exploited species and productivity through the food webs. Developing new knowledge of ecological functions is essential if we are to maintain the adaptive capacity and define the limits to the resilience of the Gulf's ecosystems.

Core knowledge 3:
Getting the best return on resource exploitation The exploitation of resources has been an important element in the Gulf, but now our growing knowledge of coastal ecosystems and how they are changed by fishing should be used to test new approaches to managing fisheries that addresses the unintended consequences on the Gulf's ecosystems. A case study for adaptive management, with a strong focus on spatial management, would provide a much-needed broad-scale test of how we move forward in placing fisheries into an ecosystem context. This would build on previous research and the precedent of spatially explicit fisheries regulations for the Gulf.

Core knowledge 4:
Defining the interrelationships between land and sea The Hauraki Gulf Marine Park Act focuses on connectivity. How the land affects the coast is of major importance, historically, now and into the future. Key issues are soil loss and the run-off of contaminants particularly from our increasingly urbanised landscape. We know much of the localised and immediate impacts of sediment deposition associated with changes in land used but we must address the much broader effects of changes in suspended sediment concentrations on organisms living on the seabed and within the water column. We must gain a better understanding of multiple stressor effects associated with land-derived sediments. For example, as the sediments in our estuaries and coasts become muddier, this shifts the distribution patterns of important species and amplifies the stresses associated with urban run-off. As the sediments in the Gulf become muddier and waters more turbid this will change how organic matter is recycled and processed by the seabed and potentially predisposing the ecosystem to the effects of eutrophication. Understanding such multiple stressor effects is critical for setting limits to contaminant loads. Not all the interaction between stressors is bad; the recovery of parts of the Manukau from high contaminant concentrations is in part mediated by the burial of dirty sediments, and the eutrophication threat in the Firth of Thames is mitigated by high turbidity.

Core knowledge 5:
Adapting to the future What will the Gulf look like in 50 years' time? There are many uncertainties, but climate change will be an important influence. While eutrophication is not a major threat to the Gulf as a whole, future activities may change or reprioritise threats. In particular, we need to consider how the broad systemic changes observed in the Gulf such as Harmful Algal Blooms, mass mortalities and invasive species could be facilitated by climate-induced changes in oceanographic and land run-off. Key to adapting to the future is the ability to define realistic alternatives and for this we need to develop a range of models to inform learning and decision-making.

6.

Tāngata Whenua

This chapter discusses:
- how tāngata whenua's values and practices are recognised in the Hauraki Gulf Marine Park Act;
- agency roles, and the statutes they implement;
- the effects of Treaty settlements;
- the role of iwi planning documents;
- options for agency responses; and
- further development

Two case studies are provided to illustrate the issues raised.

6.1 The Hauraki Gulf – Tikapa Moana context

The Hauraki Gulf Marine Park Act provides direction within its jurisdiction for public agencies acting under of a number of statutes. During the last three years, publications of the Forum have clarified the nature of how those obligations under the Act should be implemented (Hauraki Gulf Forum 2009, 2010a, 2010b).

Governing the Gulf (Hauraki Gulf Forum 2009) lists examples of the nature of provision for tāngata whenua under the Act. These can be summarised as:
- Historical associations can be provided for by: interpreting landscapes in terms of pre-European history; ensuring correct place names are used; appropriately managing Māori archaeological landscapes; and providing for tāngata whenua-specific uses.
- Traditional associations can be provided for by protecting traditional resources (e.g. for weaving and medicinal purposes); identifying and protecting traditional walking routes, moorings etc; identifying and protecting traditional landmarks; supporting and enforcing rāhui (bans); and enabling pāpa kāinga (ancestral settlement) development.
- Cultural associations can be provided for recognising the whakapapa (geneology) of people within the natural world and appropriately implementing cultural practices and values such as whanaungatanga (relationship) and kaitiakitanga (guardianship).
- Spiritual associations can be provided for by: acknowledging Māori's spiritual dimensions of the natural world, and ensuring environmental management is sensitive to those values; and seeking means of ensuring concepts such as mauri (life principle) are appropriately included in policies and practices.

The centrality of integrated management in the role of the Forum and the purpose of the Hauraki Gulf Marine Park Act is consistent in principle with kaitiakitanga (Volkerling 2007[18]). Provisions for the four types of tāngata whenua associations above, which are derived from the statutory objectives in Section 8 of the Act, can contribute to integrated management and exercising of kaitiakitanga.

6.2 Implementation

The objectives of the Hauraki Gulf Marine Park Act are achieved through actions of those public agencies with responsibilities under this Act. These agencies can all contribute to provision of the tāngata whenua associations. The principal agencies and statutes are:
- DOC is responsible for conservation management under the Conservation Act, and has statutory roles in the Coastal Marine Area under the Resource Management Act (RMA).
- Councils have responsibilities principally under the RMA and the Local Government Act.
- MFish has responsibilities under the Fisheries Act. The Ministry also has responsibilities for the fisheries and aquaculture Treaty settlements.

18 The research paper *Kaitiakitanga and Integrated Management* was received by the Hauraki Gulf Forum on 30 March 2007, and adopted for use "to inform future Forum projects, activities and actions". See www.arc.govt.nz/albany/index.cfm?2137E2E7-145E-173C-9818-94058B87C940

All these agencies and statutes have importance in implementation of the Hauraki Gulf Marine Park Act, but the role of the councils under the RMA is the most significant.

6.3 Treaty settlements

Treaty settlements for iwi in the Auckland and Waikato regions are at various stages. Some settlements have been concluded, such as Ngāti Whātua ki Orakei. Others have been through a Waitangi Tribunal process and are now in a negotiation stage. Others are in direct negotiation without having gone to the Tribunal.

The settlement process and its results have several aspects:
– The research, mandating and negotiating processes can lead to greater understanding of identity.
– Land can be transferred as a settlement asset.
– The financial settlement leads to an increased asset base and income stream. This can be used to develop capacity to exercise kaitiakitanga.
– Formal relationships with statutory agencies can be determined through the settlement legislation. These can include Memoranda of Understanding and co-management over land or resources.
– Statutory acknowledgments in settlement legislation requirements for public agencies, such as for consultation.
– Cultural redress provisions can be negotiated to address a range of issues, including some of those above. Cultural redress provisions have varied in effectiveness in settlements. The Waikato River provisions represent a high benchmark for cultural redress in future settlements.[19]

As settlements progress to finality and the entities which receive settlement assets increase their capacity for response, greater effectiveness in exercising kaitiakitanga can be anticipated.

6.4 Iwi planning documents

"One way in which tāngata whenua can proactively encourage the implementation of the spirit of the Hauraki Gulf Marine Park Act is through the preparation of iwi planning documents which address the above issues. These documents can serve to influence the content of RMA policies and plans through the requirement in sections 61(2A), 66(2A) and 74(2A) of the RMA that councils 'take into account' any relevant planning document recognised by an iwi authority and lodged with the council."[20]

Iwi planning documents can address a wide range of environmental issues from a tāngata whenua perspective, such as the Hauraki Māori Trust Board's comprehensive plan; or they can be focused on specific issues, such as the Ngātiwai Aquaculture Management Plan. Future development in iwi planning documents can be expected. They can address issues such as reviews of regional planning statements. Development of spatial planning could also be informed by future iwi planning documents.[21]

19. For instance, the settlement provides a co-management arrangement. Elements of the settlement have the status of a Regional Policy Statement, and must be given effect in RMA planning instruments.
20. Governing the Gulf (Hauraki Gulf Forum 2009) page 71
21. Iwi planning documents currently lodged with councils in the Gulf catchment include:
– 1991 Ngāti Te Ata Tribal Policy Statement;
– 1995 Ngātiwai Policy Statement on kiore management
– 1995 Te Kawerau a Maki Resource Management Statement;
– 1996 Ngāti Paoa Resource Management Plan;
– 2003 Hauraki Customary Fisheries Strategy;
– 2004 Hauraki Māori Trust Board Environmental Plan;
– 2007 Ngātiwai Iwi Environmental Policy; and
– 2007 Waikato Iwi Management Plan.

6.5 Agency responsiveness

Agencies can contribute to the ways in which support for the maintenance and enhancement of the types of associations identified in Governing the Gulf (Hauraki Gulf Forum 2009) can be provided for. Some examples of the type of need for support include the following.

Historic

- Landscape planning methodologies should recognise pre-European and tāngata whenua values and references.
  - Landscape planning guidelines produced by the Environmental Defence Society have addressed these issues, but there has been limited subsequent implementation.
- Historic occupancies should be recognised by signage and other means.
  - For example, the Omaha Beach area is now developed as residential subdivision. The area was an important meeting place for hapū from all of Ngātiwai. No Māori land remains in this area, but the historic occupation is of traditional importance.
- Appropriate traditional place names should be in all official usages.
  - Names of islands such as Aotea (Great Barrier) and Hauturu (Little Barrier) should be recognised. Both DOC and local government are increasingly including these traditional names in their documentation.
  - Traditional names of all maunga (mountains) should be recognised, such as Takarunga for Mount Victoria.
- Effective management of impacts on Māori archaeological sites and landscapes needs to be developed.
  - The Auckland City Cultural Heritage Index needs to maintained, and a similar initiative should be developed for the Waikato Region.
  - Planning instruments need to include provisions which are effective for heritage management of Māori sites and landscapes.

Traditional

- The distinctive nature of traditional resources needs to be identified, and appropriate management provided in planning instruments.
  - For instance korari (flax), as the species *Phormium tenax*, has no protected status. However, within the species there are important categories of flax which are not biologically recognised and can be locally scarce. Important for weaving use is muka, a flax with strong fibres. If this is not protected and recognised at localities, an important weaving resource can be lost.
  - Manu oi (mutton birds) are of importance to tāngata whenua. The current programme to re-establish manu oi at locations is of importance in this context.
  - The Ngātiwai protocol with DOC enables the recovery of whale bone from stranded whales.
- Traditional communication linkages can be identified.
  - Traditional walking tracks and waka moorings can be recognised on DOC maps, and in planning instrument maps.
  - Signage can be provided to identify these locations.
- Rāhui can be recognised and supported.
  - MFish can establish formal protocols with iwi (tribes) and hapū (subtribes) for support and enforcement of rāhui.

- Allocation processes can be informed by traditional methods. Allocation of resources to competing users is a complex issue which is not easily addressed under the RMA. An increasing number of resources, including fresh water and aquaculture space, need to be allocated between competing users.
  - Tohatoha is a traditional process for sharing and distributing resources. This kaupapa (subject) can be investigated as to how it can inform allocation processes in a culturally appropriate way.
- Pāpa kainga development can be supported. In remnant Māori land, or on land returned through settlement processes, there is a need for RMA planning specific to its needs.
  - While some councils have mechanisms to support pāpakainga development, specific planning provision is rare.
  - RMA Section 33 transfers of power in terms of planning on pāpa kainga could be structured to meet both the tāngata whenua and council needs.

Cultural
- Kaitiakitanga (guardianship) and mātauranga (knowledge) can effectively inform environmental management.
  - While there is frequently reference to kaitiakitanga, and to an extent to mātauranga, actual programmes to implement their consequences are infrequent.
  - The Forum has adopted in principle that integrated management should include the methodology of kaitiakitanga, but this has not often been followed through by the Forum's constituents in their actions.
- Acknowledgment of the Māori view of the natural world, with people included in that world through whakapapa.
  - Much environmental management considers people and the natural world, rather than people in the natural world.
  - Many policies, and some statutes, maintain this separation. An example is the Marine Reserves Act in which permanent prohibitions on any harvest is established. This is contrary to the concept of a rāhui, which is open to reconsideration when conditions change.

Spiritual
- Environmental management needs to provide for the values and concepts of kaitiakitanga which are based on spiritual dimensions of the natural world.
  - Planning instruments often refer to mauri, but then provide for it only in terms of high environmental standards. For instance, the mauri of fresh water is provided for by addressing contaminants, sedimentation and other impacts. While those factors are necessary for maintenance of mauri, they are not sufficient, and mauri itself requires further responses.

6.6 Further development

The analysis above of the response to the types of associations included in the Hauraki Gulf Marine Park Act is informal, as no indicators of the extent to which there has been effective delivery by public agencies is yet to be developed. The analysis can provide a basis for how those indicators can be developed, and also a basis for a range of possible programmes and projects to ensure appropriate response.

Development of a set of response indicators will need to address a range of issues:
- Agreement on the nature of the indicators will require further discussion and development. This is both on the nature of the indicators and the relative priority within the indicator set.
- Development of a means of collating data to inform the indicators will need to reflect the priorities established, and the resourcing constraints involved.

6.7 Strategic considerations for responding to tāngata whenua values

1. Providing for the historical, traditional, cultural and spiritual associations of tāngata whenua, as required by the Hauraki Gulf Marine Park Act, will require agencies to develop new programmes with new approaches which are based on the appropriate tikanga (custom) and kawa (protocol).
2. If agencies are to develop a management approach which integrates kaitiakitanga effectively, changes in methodologies used and increasing capacity to respond to tāngata whenua appropriately are essential.
3. Indicators which measure the response of agencies to the provision for the tāngata whenua associations, as required by the Hauraki Gulf Marine Park Act, need to be developed.

6.8 Case Study 1: Tāmaki River (invited contribution by Moana Tamaariki-Pohe)

A traditional name for the Tāmaki River is Waimokoia, which refers to "a place of assembly for mutual protection". Auckland is traditionally known as Tāmaki Makaurau, meaning "Tāmaki, desired by many". Tāmaki has been highly sought after and occupied by many, just as it is in contemporary times.

At the time of the Great Migration, Taikehu of the ancestral Tainui waka was the first to sight the Tāmaki River while standing on the summit of Takarunga (now known as Mount Victoria). Just beyond the river he saw the expansive Manukau Harbour, and thereby discovered the shortest portage between the east and west coast of Te-Ika-a-Māui (the North Island). The waka sailed the Waitematā and into the southern reaches of the Tāmaki River. The great Tainui waka was then beached and dragged two kilometres overland, across the Otahuhu Portage, to be launched into the Manukau Harbour before sailing along the west coast to its final landing place at Kawhia.

The traditions of many other ancestral arrival waka also pass through Tāmaki River, including Matahorua, Aotea, Mataatua, Te Arawa, Takitimu and Tokomaru. The overland crossing provided access to west coast destinations such as Kawhia, Raglan or Taranaki, without the arduous journey around the North Cape. It was of immense strategic importance to Māori, as well as later European travellers. The Tāmaki River marked the boundary between tribal lands, and several notable pā were built along it. Fierce battles for supremacy, of legendary proportions, were fought on and along the river. Many warriors were captured, slain or drowned in the river during the fighting.

In more peaceful times, the river served as a major thoroughfare for travel by waka. It was an abundant source of seafood, including fish, cockles, pipi, oysters, scallops and mussels. The surrounding land was filled with kainga (villages) and gardens.

The river itself is actually an estuary, with bright-green seagrass meadows, large exposed sandflats and sandstone reef, mudflats and rock platforms, and even an exposure of volcanic ash from the Taupo volcanic zone. It includes extensive shellfish beds and a long sand-shell spit used by hundreds of native wading birds, some of which are endangered. DOC has designated it as an "Area of Significant Conservation Value".

What will it take to return the Tāmaki River to its former glory? Would knowing the history make a difference? Would knowing its original state and status help people to see the extent of modern abuse and degradation? What will it take to revitalise the once majestic river?

Fortunately or unfortunately, whichever way you choose to look at it, most of the published information available today pertains to the level of pollution, toxins and other contaminants in the Tāmaki River.

In January 2007 the ARC released a media statement "Aquatic Life Affected in Tāmaki", noting from the 2005 survey that the Tāmaki River is amongst the worst in the region, with particularly high levels of zinc. Zinc enters the estuary from sources such as galvanised roofing, killing off small invertebrates such as cockles. As these creatures are at the bottom of the food chain, they in turn affect larger species such as fish and seabirds.

Formerly common species of shellfish have been poisoned by an anti-fouling paint used on marine vessels. The paint has now been banned; nonetheless, its detrimental effects on the ecosystem continue: many species of shelled molluscs are smaller in both size and number. Exotic species introduced by international shipping have caused further problems. The introduced Asian date mussel, for example, creates vast carpet-like beds that exacerbate the build-up of mud and siltation.

The area surrounding the estuary has become heavily urbanised: it includes densely populated residential areas, motorways, factories and an abattoir. Building developments have caused freshwater run-off, silt and sewage overflows to enter the estuary; most of the land in the area discharges untreated stormwater into the estuary. Formerly sandy beaches have been buried in mud. Salinity levels have dropped, decreasing biodiversity and straining native species that thrive in salty water. From the banks of the estuary, the pollution is obvious. There is broken glass, debris, factory rubbish and run-off, and household refuse floating in the bad-smelling water (Figure 58).

Figure 58: Abandoned shopping carts and other refuse accumulating on the shore in the upper parts of Tāmaki River.

Nonetheless, people still fish from the banks, and local waka ama teams continue to train here. Paddlers complain of infected wounds after being cut on hidden debris in the murky, silty water. Bouts of conjunctivitis are common after being splashed in the eyes. Some paddlers are careful to wash exposed skin with clean water and disinfectant immediately after sports training, to minimise the health risks caused by contact with the polluted water.

Restoring the Tāmaki River will not be easy, and will require deeper understanding and collaboration from all parties. But as the American environmentalist Aldo Leopold said, “We grieve only for what we know.” In order to attain support for clean-up efforts, we must strengthen our knowledge of the ecological importance and cultural significance of the estuary. A deeper understanding of its history, and appreciation for its great potential, will certainly strengthen the urgency to work collaboratively to establish rāhui and return the river to a clean, thriving state.

6.9 Case Study 2: Whangamatā (invited contribution by Nathan Kennedy, Ngāti Whanaunga)

The Whangamatā catchment holds an ancient continuous Māori cultural landscape from the harbour into the adjacent steep forest valleys. The tribal whakapapa of Whangamatā is long and complex, having been occupied from earliest times. The catchment represents a mosaic of iwi and whānau (family) ancestral relationships, from earliest to more recent centuries of occupation and use. Regarding archaic sites at Whangamatā, archaeologist Warren Gumbley wrote:

"It is axiomatic among archaeologists in New Zealand that sites including archaeological deposits relating to the Archaic Phase of New Zealand Eastern Polynesian Culture are valuable. They relate to the earliest period of New Zealand history and can be inferred to have been relatively few in the first instance, and to have become less common through natural and human processes over time.

The archaeological record confirms a long Māori occupation of Whangamatā but provides only a partial view of the cultural landscape. The township conceals some of the earliest human occupation sites in Aotearoa. Like residential development, forestry and farming in the catchment have destroyed numerous ancestral places, leaving no record except the traditions and memories held by tāngata whenua."

Under the management of Thames-Coromandel District and Waikato Regional councils, there is a range of statutory and non-statutory planning instruments operating at Whangamatā. These include:

- Coromandel Blueprint Project – non-statutory inter-agency long-term planning project; positions Whangamatā as one of three growth nodes for the peninsula;
- Whangamatā Community Plan – Thames-Coromandel District Council; heralded by Parliamentary Commissioner for the Environment (PCE) as a model for community planning (PCE 2005);
- District Plan;
- Regional plans and policy statement; and
- DOC's draft Conservancy Plan and Fisheries plans.

Most, if not all, of these appear to include adequate Māori-specific provisions, bringing with them an expectation that tāngata whenua's values and interests will be provided for and protected in environmental planning processes and decisions. However, as has been observed regarding council planning nationally (Day, Mason et al. 2009), there is a gap between planning provisions and their implementation at Whangamatā. Despite Māori planning provisions and protests from tāngata whenua, wāhi tapu (sacred places) and wāhi taonga (treasured ancestral places) have been modified and destroyed as a result of numerous developments, often as a result of council's own activities, and continue to be destroyed at Whangamatā.

A number of significant developments that have impacted on tāngata whenua are considered below.

6.9.1 Managing Whangamatā's cultural landscape

6.9.1.1 Mana Whenua – Mana Moana

The Whangamatā Marina was recently granted consent after legal opposition by tāngata whenua and the wider community lasting more than 10 years. The resulting marina, and the cultural and environmental destruction caused, rank it as one of the most significant place-specific grievances of Gulf Māori of the last decade and it is the subject of an outstanding contemporary Treaty of Waitangi claim.

The marina was finally constructed, bringing the loss of Te Matatuhi – an ancient wetland and tribal taonga, the destruction of the traditional home of one of few known mainland populations of moko skink, dredging and removal of the tribal rohe (area) of the mata (obsidian, dark glassy volcanic rock). The new all-tide channel dissected the harbour's main pipi and tuangi (cockle) beds, and ongoing dredging prevents recolonisation (Figure 59).

Ironically the removed moko have bred with unpredicted success in captivity, and tāngata whenua and DOC have, several times in the last two years, released populations to selected locations around their harbour. Similarly, the access barrier to the kaimoana beds caused by the new channel as well as shellfish flesh discoloration during the marina construction and the rāhui resulting from algae, had the combined effect that recent 2011 surveys of the kaimoana beds found plentiful and mature populations of pipi and tuangi. Results of other tests for shellfish quality have not yet been received.

Figure 59: The Marina Society's plan (red) with the car park overlaying Te Matatuhi, the dredged channel bisecting the pipi bed (yellow).

While allowed under RMA processes, the marina was given practical effect when both the local council and DOC granted long-term leases of land. On this basis, the now-repealed Foreshore and Seabed Act was invoked by counsel for tāngata whenua, but dismissed by the Chief Environment Court judge as not being a matter before the court. The Minister of Conservation first declined the coastal occupation permit applications, largely because of tāngata whenua's concerns, but the decision was overturned by the High Court, and the then Environment Minister granted them. Despite continued opposition from tāngata whenua, resulting in a month-long occupation of the land, the marina was finally constructed.

6.9.1.2 Mauri, Manawa, Kaimoana

Whangamatā remains an important pātaka kai (food store) of Hauraki iwi but has suffered from decades of pollution, including occasionally semi and untreated human waste. One consequence of this is a proliferation of manawa (mangroves). Manawa are significant to Whangamatā tāngata whenua, as a kōhanga – a haven for juvenile kaimoana, and for their role as a buffer and filter of run-off from adjacent land. Illegal removal of several hectares of mangroves has taken place in recent years, but despite long-standing opposition by tāngata whenua, the regional council has lodged applications for consent to remove large areas of Whangamatā mangroves. The current draft Whangamatā Harbour Management plan is largely concerned with mangroves, and anticipates their large-scale removal (Waikato Regional Council 2007a). Waikato Regional Council is currently preparing consent applications for large-scale removal.

A stretch of coastline north and south of Whangamatā has been closed for kaimoana gathering for 15 months due to toxic algae. Otawhiwhi pipi beds to the south were previously closed by the Ministry of Health because of the presence of effluent-related bacteria and other nutrients. This closure increased pressure on Whangamatā kaimoana, but this was relieved by the wider area algal closure.

During recent decades the regional council reported pollutants in the harbour (Vant 2001), identifying potential health issues arising from this pollution (Vant 2000). Monitoring observations have included periphyton growth downstream of irrigation areas, and the absence of taonga fish species (Kessels 2005), and excessive levels of various pollutants within the harbour.

Environmental balance and its achievement are matters of utu (concerning the maintenance of balance). The extent to which people can extract resources and other benefits from an environment needs to be tempered by the ability of that place to absorb the effects of activities without significant detriment. In various tribal tikanga (custom), long-term local environmental balance must be maintained or environmental consequences will ensue. Central to such tikanga is the position that man-made effects of activities such as residential subdivision and commercial forestry are yielding significant environmental effects and that mitigation measures imposed are providing little relief.

The mauri of Whangamatā has been repeatedly impacted by human activity. Shadow areas created by two causeways, constructed despite engineering advice to the contrary, have created sediment sinks which have been colonised by manawa. Material removed for regional council stream maintenance has been left piled within the harbour, despite tāngata whenua identifying inadequate energy for dispersal.

On the positive side, management agencies have provided for tāngata whenua (and wider community) input to consent and other planning processes, and some public/iwi concessions have been granted, but largely only after legal action; few have been offered as part of initial applications lodged and heard by local and regional councils. Furthermore, over 90% of consent applications have been granted on a non-notified basis (Ministry for the Environment 2009); tāngata whenua have little faith therefore that Māori values are being properly considered.

Thames-Coromandel District Council supported and applied for wastewater plant and disposal consents including irrigation to land, largely in recognition of the offensiveness to tāngata whenua of disposal directly to water. Council has commissioned Māori values assessments for recent significant projects, Waikato Regional Council staff have endeavoured to rationalise and reduce the area of mangrove removal sought by vocal Whangamatā community removal advocates, and forestry operators of Crown licences now (sometimes) take measures to identify and protect Māori historic sites.

However, there are currently few or no iwi-agency formalised relationships at Whangamatā, and interaction that does occur does so when it suits the agencies. As elsewhere in the country, there is little or no participation in reserves land management or that of other significant Māori resources. Furthermore, participation in planning processes costs iwi dearly, both financially and as a drain on human resources. Despite plan provisions for resourcing iwi participation (Thames-Coromandel District Council 1999; Waikato Regional Council 2000; Waikato Regional Council 2007b), this seldom occurs.

6.9.2 Māori environmental evaluation

There has been some evaluation of environmental results at Whangamatā, mainly resulting from monitoring requirements in consent conditions. As a result, evaluation has been undertaken sporadically, and results cannot be easily compared over time. Accordingly, how do agencies substantiate any claims to environmental success, from either a Māori or wider-community perspective?

The Hauraki Gulf Forum has previously recognised a need for the development or recognition and formalisation of tāngata whenua's environmental indicators for Tīkapa Moana, and its members have made limited efforts toward exploring these (Kennedy and Jefferies 2008; Hauraki Gulf Forum 2009).

To date, few environmental evaluation frameworks based on Māori perspectives and knowledge have been applied to the management and evaluation of Tīkapa Moana. But these do exist and are being used and adapted within Tīkapa and elsewhere by tāngata whenua and other agencies (Aranovus Research 2007; King, Goff *et al.* 2007).

6.9.2.1 The PUCM Māori Outcome Evaluation (MOE) Methodology

One Māori-focused evaluative framework is that developed within the Foundation for Research, Science and Technology – funded Planning Under Co-operative Mandates (PUCM) programme (Bachurst, Day *et al*. 2002)[22]. The PUCM MOE incorporates physical environmental indicators work such as that of Gail Tipa and associates with Ngāi Tahu (Tipa and Teirney 2006), and Garth Harmsworth with Ngāti Porou (Harmsworth 2004). The research considered the significant but short-lived Māori input into the national indicators development programme run by the Ministry for the Environment in the late 1990s, and similar work since.

From these sources and widespread input by Māori practitioners and experts, environmental objectives and outcomes are assessed in terms of relevant tikanga. It includes indicators aimed at evaluating performance against Māori provisions in legislation. The PUCM MOE was trialled by iwi and councils, including the Gulf Forum's Ngāti Maru Runanga and Matamata-Piako District Council, receiving favourable feedback.

PUCM's Māori Outcome Evaluation Methodology helps to fill a void in outcomes and indicators reporting, by linking kaupapa (foundation principles), associated environmentally important tikanga (fundamental rules governing Māori relationships) with the natural environment, and Māori aspirations (in the form of outcomes), to environmental indicators.

It thereby provides a means by which councils can interpret the effectiveness of statutory plans and their implementation using Māori values as a foundation.

22 www.waikato.ac.nz/igci/pucm/Publications-Phase3.htm

7.

Responses to Strategic Issues

The previous chapters have described a range of environmental indicators and have identified a number of strategic considerations in relation to each. The information presented demonstrates that historical and ongoing activities have had a major impact on the Gulf, and that most indicators are continuing to show negative trends or have stabilised at environmentally low levels.

This chapter considers how local, regional and central government organisations have responded to the strategic environmental issues identified in this report, and presents an alternative trajectory which will require a significant shift from business as usual. Management responses to strategic issues are discussed below and summarised in Table 11.

7.1 Human impacts on the Gulf

Chapter 3 gave an overview of human impacts on the Gulf and concluded that key components of the natural ecosystem, such as benthic habitats and fish populations, have been lost or significantly reduced. This means that the life-supporting capacity of the Gulf has been diminished. It also means that resilience, which is the ability of natural systems on the Gulf to withstand and recover from disturbances, has also been compromised.

The Hauraki Gulf Marine Park Act emphasises the need to protect and, where appropriate, enhance the resources of the Gulf. Where those resources are significantly degraded, management approaches could be expected to focus on restoration, rather than on slowing deterioration or maintaining the status quo.

Many marine ecosystems retain the ability to restore themselves if the pressure of human activities is significantly reduced. This is demonstrated by the marked rebounding of snapper and crayfish populations, and reduction in sea urchin barrens, in marine reserves within the Gulf after fishing pressure was removed.

There are currently five marine reserves within the Hauraki Gulf, covering a total of 3,538 ha. A further marine reserve of 400 ha in the location of the Tawharanui Marine Park has been approved but has yet to be gazetted. These cover only a very small proportion of the Gulf's marine area (0.3%) and are collectively not large enough to make a significant contribution to the ecological health and productivity of the Gulf as a whole.

In 2006, the Government released the *Marine protected areas policy statement and implementation plan*. The purpose of the policy is to "protect marine biodiversity by establishing a network of MPAs [marine protected areas] that is comprehensive and representative of New Zealand's marine habitats and ecosystems". MFish and DOC are jointly responsible for implementing the policy.

The implementation plan identifies 14 biogeographic regions which collectively cover the entire New Zealand marine area out to the 200 m depth contour. Under the plan, each of these regions is to be the focus of a planning process undertaken by community-based marine protection planning fora consisting of stakeholders and supported by staff from MFish and DOC.

The Hauraki Gulf falls within the north-east biogeographic region which extends from Ahipara on the north-west coast, around North Cape, and down the east coast as far as East Cape. No forum has yet been established to progress the identification of MPAs in this region. The further implementation of the MPA policy statement is currently on hold, pending the results of an internal review.

Achieving restoration on land usually requires active weed and pest control and the replanting of indigenous species. Despite this, restoration approaches have been applied very successfully to many of the Gulf's islands, with these now providing important refuges for threatened species. Introduced mammalian predators and herbivores have been eradicated from eight islands in the Gulf, and another 20 islands have been kept free of these pests. A variety of threatened birds and reptiles has also been reintroduced to pest-free islands of the Gulf, where populations are now increasing.

Tiritiri Matangi has been replanted with native trees, and similar restoration is now occurring on Motuihe, Motutapu and Moturoa islands. DOC has embarked on an ambitious project to make Rangitoto and Motutapu islands (which total 3,800 ha) pest free, and when this is achieved it will comprise the largest animal pest-free habitat in the Gulf.

7.2 Fishing impacts

The fisheries environmental indicators highlighted the large influence which fishing activity has had on the Gulf's natural systems. Fisheries ecosystem indicators show declines in the Firth of Thames and central Gulf. Impacts of trawling and dredging on the seabed are occurring in the outer Gulf and are likely to be significant.

A variety of sustainability decisions made by MFish, under the Fisheries Act 1996, has a significant impact on the health and productivity of the Gulf's marine environment. A key decision is setting the total allowable catch (TAC) for each stock. The TAC affects the size of targeted fish stocks, and this in turn can have an impact on the stock's productivity, size, age structure and genetic diversity. The TAC can also impact on the broader marine ecosystem through inter-linkages and trophic cascades flowing through food webs.

Under the Fisheries Act, the Minister is required to set a TAC for each fish stock that maintains its biomass "at or above" a level that can produce the maximum sustainable yield" (MSY). The biomass that will produce the MSY is typically between 20 and 30% of the virgin (unfished) stock size. Snapper and kahawai stocks in the Gulf are thought to be at or above this level.

The setting of TACs to achieve the maximum sustainable yield is aimed at extracting the maximum biomass of fish over time while maintaining the stock's productive capacity. It is designed to ensure that an individual stock is fished "sustainably" but does not generally consider the environmental consequences of extracting the fish.

Current fisheries management is thought to be resulting in a slow rebuild of the snapper stock and stable cockle populations (although with declines in some areas). Lobster stocks are being maintained at around 20% of 1945 levels, and tarakihi and trevally stocks are as likely as not being fished at levels which will cause them to either fall below, or remain below, the biomass required to produce the MSY. MFish has not obtained sufficient information to ascertain the status of other stocks. Permanent bans have been placed on cockle harvesting at Eastern Beach and Cheltenham Beach, temporary bans have been imposed at Umupuia and Whangateau Harbour and there is a seasonal ban at Cockle Bay. There are no other current management responses to these issues.

Fisheries management decision-making affecting the Gulf is largely single stock-focused and does not generally consider the wider impacts of fishing on the Gulf's marine ecosystems. Addressing these wider effects may require management decisions which allow stocks to rebuild to levels higher than MSY.

A large amount of the commercial catch taken within the Gulf is being harvested by bottom trawling in the outer Gulf, the environmental impacts of which are unknown but potentially significant. Although bottom trawling is currently excluded from the inner Gulf, there is currently no management response to the potential impacts of this activity in the outer Gulf.

The Fisheries Act provides for the Minister to approve fisheries plans which can relate to fish stocks, fishing years or areas such as the Hauraki Gulf. The plans are intended to enable a more strategic and objectives-based approach to be applied to fisheries management. The plans must be taken into account when the Minister applies fisheries sustainability measures and councils must have regard to them when preparing RMA policies and plans. These have been identified as a priority since at least 1999. Draft national plans for inshore finfish, shellfish and freshwater stocks have been operational from 1 July 2011.

7.3 Sediment contamination

Sediment contamination affects relatively localised areas, but in the areas where it is occurring, the ecological health of the seabed communities is significantly affected.

Considerable effort is being directed at addressing sediment contamination, including:
- containing the spread of activities that generate contaminants by setting spatial limits on urban development;
- requiring stormwater treatment for high-risk industrial sites and new urban developments;
- developing and implementing integrated catchment management plans, which identify options for stormwater management;
- where appropriate and practicable, retrofitting stormwater treatment in developed urban areas;
- implementing community education on stormwater issues; and
- ensuring case-by-case management of legacy contaminant issues.

The above responses are not expected to remediate areas affected by urban and legacy contamination but may slow accumulation and prevent the degradation of areas with clean sediments.

7.4 Nutrients

The nutrient environmental indicators have identified the Firth of Thames as being enriched with nitrogen. High levels of nitrogen can result in blooms of phytoplankton and seaweed, reduced water quality and can have toxic effects on marine life. The major source of the nutrients is thought to be from the Waihou and Piako rivers, likely resultant from an increase in dairy cows within the catchment. Nitrogen can enter waterways as a result of the application of nitrogen-based fertiliser on pasture and discharge of effluent from grazing stock.

The management response to this issue so far has been weak. Under the Waikato Regional Plan, stock are now excluded from "priority 1" waterways which include the stretch of the Waihou River two kilometres upstream of saltwater intrusion. This is intended to address stream-bed erosion and water quality issues arising from stock urinating or defecating in waterways.

However, the grazing of dairy cows is a permitted activity within the catchments of the Waihou and Piako rivers under the Waikato Regional Plan. The application of fertiliser is also a permitted activity so long as it complies with a series of standards including the development of a nutrient management plan. No maximum application rate is prescribed in the plan.

In the proposed Hauraki District Plan (notified 24 August 2010) farming is a permitted activity within the rural zone of the Hauraki District with no performance standards applied to address non-point discharges. Farming is similarly a permitted activity in rural areas of the Matamata-Piako District.

7.5 Bathing beach quality

There are frequent exceedances of guidelines for contact recreation on urban Auckland and Coromandel Peninsula beaches. These are a result of overflows from wastewater infrastructure and poorly-performing septic tanks.

The contamination poses a risk to human health but is not a significant ecological issue. Addressing it requires investment in upgrading wastewater infrastructure. This is gradually occurring through:
- the adoption of a catchment management approach under the Auckland Regional Plan: Air, Land and Water and requirement that operators of waste and stormwater networks apply for consent;
- separation of combined wastewater and stormwater networks within the Auckland isthmus;

– long-term investment in increasing the capacity of the wastewater network and reducing overflows throughout the Auckland region;
– construction of a new wastewater treatment plant to service Kawakawa Bay and replace polluting septic tanks; and
– investment in the upgrading of wastewater plants on Coromandel Peninsula.

7.6 Sediment

Accelerated sediment release from land is having large-scale impacts on the coastal margins, especially in estuaries. Sources of sediment include earthworks as well as grazed pasture and forestry operations.

In the Auckland region, there has been a continuing and progressive effort to control sediment release through regional and local planning processes, consenting, education, and proactive intervention. Suspended sediment concentrations appear to be declining in Auckland's coastal water suggesting that this effort is leading to improved environmental outcomes. *The Auckland Regional Plan: Sediment Control* is currently under review and it is anticipated that further improvements will be made.

Greatest improvements have been made in controlling sediment discharges from large earthworks through provisions in the *Auckland Regional Plan: Sediment Control*. However, monitoring in the Mahurangi Harbour and other estuaries, which have largely rural catchments, has shown significant negative impacts on benthic communities as a result of sedimentation. There are currently much weaker regulatory controls within the Auckland Region over the generation of sediment from rural activities. Forestry harvesting is a permitted activity so long as it complies with the standards in the plan. There are no controls on sediment produced from grazing activities.

Auckland Council is using non-regulatory approaches to address this problem in a number of catchments, based on the model developed from the *Mahurangi Action Plan*. The first phase of the *Mahurangi Action* Plan ran from 2004 to 2009 and focused on support for riparian fencing and planting. The second phase is focusing on the development of a Mahurangi Strategic Catchment Plan which will determine priority actions going forward. This plan is still under development. A similar action plan has been under development for the Whangateau Harbour under the council's Sustainable Catchments Programme.

Within the Waikato Region there are stronger regulatory controls on vegetation clearance associated with forestry and these are designed to protect riparian areas and control harvesting on steep slopes including those draining into estuaries on Coromandel Peninsula. However, there are much weaker controls on sediment generated by grazing activities in the Waikato Region. Farming is a permitted activity outside stock-exclusion water bodies provided environmental standards are met.

Sedimentation issues are also being addressed by the *Peninsula Project*, which is a collaborative initiative between Waikato Regional Council, the Thames-Coromandel District Council, DOC and the Hauraki Māori Trust Board. The project is focused on flood protection, river and catchment management and animal pest control. It consists of a range of individual projects such as river bank stabilisation, tree planting and possum control undertaken by relevant agencies and landowners with financial assistance. It has also included the development of a management plan for the Wharekawa River catchment and a draft plan for the Whangamatā Harbour catchment.

The New Zealand Coastal Policy Statement 2010 includes new national policy on sediment management in the coastal environment. Under Policy 22, councils now must:

1. Assess and monitor sedimentation levels and impacts on the coastal environment;
2. Require that subdivision, use, or development will not result in a significant increase in sedimentation in the coastal marine area, or other coastal water;
3. Control the impacts of vegetation removal on sedimentation including the impacts of harvesting plantation forestry; and
4. Reduce sediment loadings in run-off and in stormwater systems through controls on land-use activities.

7.7 Introduced marine species

The Port of Auckland is a high-risk area for the introduction of invasive species given the large number of overseas vessels which visit. In addition, the large boating community in the Gulf can rapidly spread problem species. Maintaining a healthy marine environment which is resilient to biological invasions is very important, as is prevention and early detection, as once a species is established it is very difficult to eradicate it.

Biosecurity NZ currently controls the discharge of ballast waters on international vessels through an Import Health Standard and this requires ballast water to be exchanged at sea (200 nautical miles from land) before it can be discharged in New Zealand waters.

The other main vector for new organisms to be brought into the area is through attachment to the hull of vessels and underwater structures. There are currently no rules addressing this issue but Biosecurity New Zealand is in the process of developing an Import Health Standard on vessel biofouling.

In early 2008 Biosecurity NZ initiated a programme of targeted marine pest surveillance which looks out for six specific unwanted marine pests. Surveillance is being undertaken twice yearly in winter and summer at several locations within the Gulf.

7.8 Harmful algae, pathogens and mass mortalities

The role of human activities in the occurrence of these incidents is unknown, but the effects could potentially worsen if other activities serve to further reduce the resilience of the Gulf's marine ecosystems. There has been no direct response to this issue other than investigations to determine the direct cause of individual incidents. There have also been no management responses aimed directly at resilience issues.

7.9 Maintenance and recovery of biodiversity

The islands of the Gulf have a critical role to play in preventing the extinction of native fauna and require continual vigilance to ensure that invasions of weeds and pests do not occur. The restoration and ongoing maintenance of the islands is achieved through a partnership between DOC, Auckland Council, Waikato Regional Council and community groups, including:

- the implementation of the regional pest management strategies which control the movement of listed species into or between islands;
- Auckland Council pest eradication and control programmes on Rakino and the Noises islands and on key mainland sites;
- Department of Conservation weed control work on Hauturu (Little Barrier Island) and pest control work on Rangitoto and Motutapu islands;
- joint Auckland Council and DOC programme on Aotea (Great Barrier Island); and
- partnerships between DOC and community-led trusts to protect and restore Hauturu (Little Barrier), Motuihe, Motukaikoura, Motuora, Motutapu and Tiritiri Matangi islands.

Nearly half of the 15 most common wader species in the Firth of Thames have displayed declining trends in their numbers since 1960. "Muddy Feet", a collaborative project between Waikato Regional Council, Auckland Council, Thames-Coromandel District Council, Hauraki District Council, DOC, MFish, local iwi and the Miranda Naturalists' Trust, has focused on identifying and addressing threats to wading birds in the Firth of Thames.

Phase III of the project involves the implementation of a restoration action plan and the promotion of an ecotourism development vision. Actions are currently focused on undertaking baseline surveys, control programmes for weeds, predators and mangroves, community education and restoration of swamp habitats.

Bryde's whales are highly threatened and a significant number have been killed by vessel strike with others killed by mussel line entanglement. The habitat of the Bryde's whales coincides with the major shipping channel entering the Port of Auckland. These threats could be reduced significantly if the speed of large vessels entering the harbour were reduced. Commercial fishing of the relatively narrow range of species that Bryde's whales consume could also have a serious impact on the whale population. No action is currently being taken to address these issues.

7.10 Coastal development

Coastal development is having significant cumulative impacts on the ecology and landscapes of the Gulf's coastal environment. There are few mainland bays and beaches in the Auckland Region without building development on the surrounding land. Around a third of bays within the Waikato Region are undeveloped. The pressure to upgrade these undeveloped areas is likely to increase in the future.

Within the Auckland Region, urban development has been governed by the *Auckland Regional Growth Strategy*, which is given effect through the regional policy statement and district plans. This implements a policy of containment and intensification of development within nodes and corridors among established urban areas with limited provision for greenfield development. It includes the demarcation of a metropolitan urban limit which is designed to contain rural and coastal sprawl.

Auckland Council is in the process of developing a new Auckland spatial plan. The purpose of the spatial plan is to set a strategic direction for Auckland's growth and development over a 20 to 30-year timeframe which integrates social, economic, environmental and cultural objectives. The direction given by this plan is likely to have a significant impact on the location of coastal development.

In the Waikato Region, a collaborative project between Thames-Coromandel District Council, Waikato Regional Council, Hauraki Whanui and DOC, the Coromandel Peninsula Blueprint Project, commenced in 2006 and has resulted in an agreed strategic direction for future growth and development of Coromandel Peninsula over the next 50 years. The next stage of the project involves the development of seven Local Area Blueprints. The Thames-Coromandel District Council is embarking on a process to review its district plan and to incorporate the direction set out in the Blueprint document.

Auckland Council has had an active programme of purchasing coastal regional parks to protect sensitive areas of the coast from development and to make them available for public use and enjoyment. Sixteen regional parks are located within the coastal environment of the Hauraki Gulf. Recent activity includes purchases in 2005 of the 178 ha Pakiri Regional Park, in 2008 of the 50 ha Te Arai Regional Park, and in 2010 of a 13.7 ha addition to the Duder Regional Park.

There is no similar regional park programme within the Waikato Region and consequently there are no regional parks within this portion of the Gulf.

Thanks to the generosity of philanthropists Neal and Annette Plowman, a 100-year lease has been granted over Rotoroa Island to the Rotoroa Island Trust. The Trust is in the process of restoring the island and it is now publicly accessible.

Table 11: Summary of strategic issues for the Hauraki Gulf and current management responses.

Issue	Strategic considerations	Response
Human impacts	– Key components of natural ecosystem lost or significantly reduced.	– Weed and pest control and/or restoration on 28 Gulf islands. – 5 marine reserves (but covering only 0.3% of the Gulf). – Approval of new marine reserve at Tawharanui. – No progress on identifying representative network of MPAs.
Fishing	– Fishing impacts affect most of the Gulf's marine ecosystems. – The status of the majority of commercial fish stocks is unknown. – Snapper stock is reduced but rebuilding. – Lobster stock is reduced and being maintained at about 20% of 1945 levels with current the statutory target. Model projections of stock biomass contain a considerable amount of uncertainty. – Cockle abundance is relatively stable with large declines in some areas. – Negative trends in abundance of rare and threatened fish and fish diversity in the Firth of Thames. – Negative trends in fish size and productivity in Firth of Thames, central Gulf and inshore between Kawau and Waiheke islands. – Large areas of Gulf subject to trawler and scallop dredge disturbance with impacts unknown but likely to be significant.	– Setting of TAC resulting in slow rebuild of snapper stock and maintenance of kahawai above the MSY. – Lobster CRA2 fishery is still above the statutory target level, and therefore; the total allowable catch has not been altered since 1997. – Insufficient information obtained to fully ascertain the status of other fish stocks. – Fisheries decision-making single-stock focused and does not address wider ecosystem impacts. – No action to address potential environmental impacts of trawling in the outer Gulf.
Sediment contamination	– Affects a relatively small area of the Gulf but locally important. – In some areas contaminant levels moderately elevated with measurable impact on ecological health of seabed communities.	– Concerted management efforts to address issue through combination of control at source and treatment of wastewater discharges but not sufficient to prevent further contamination.
Nutrients	– Firth of Thames enriched with nitrogen with 90% originating from the Waihou and Piako rivers and consistent with increase in dairy cows. – Nutrient levels in coastal waters of Auckland region stable or declining. – Trends in coastal nutrient levels not available for the Waikato Region.	– Stock excluded from lower reaches of Waihou River – Little additional management response with grazing and fertiliser application-permitted activities in relevant regional and district plans.
Bathing beach quality	– Exceedances of the "action"-level guideline for contact recreation frequently occur in the Gulf, mainly on urban Auckland and Coromandel beaches.	– Ongoing investment in upgrade of wastewater treatment infrastructure.
Sediment	– Land-sourced sediment resulting from ongoing and historical land-use and land-disturbance activities responsible for relatively large-scale impacts on the coastal margin including infilling, mangrove expansion and changes in the composition of benthic communities. – Suspended sediment concentrations declining in coastal water in the Auckland Region.	– Strong controls on large earthworks in Auckland region. – Few controls on forestry harvesting in the Auckland region. – Stronger controls on forestry harvesting on Coromandel Peninsula. – No controls on grazing activities. – Ongoing catchment-based collaborative projects.

Issue	Strategic considerations	Response
Introduced marine species	– Port of Auckland a high-risk area for introduction, establishment and spread of introduced species. – Large amount of boating and other marine-based activities in Gulf increase risk of their spread. – Once established, eradication extremely difficult.	– Import health standard for discharge of ballast water. – No current controls on hull fouling but import health standard under development. – Ongoing marine surveillance programme. – No action focused on increasing resilience of the marine environment.
Harmful algae, pathogens and mass mortalities	– Impacts typically occur very rapidly, cover large areas and have severe consequences for humans, affected species and associated industries. – Information difficult to access.	– No management response other than to ascertain cause of individual incidents.
Maintenance and recovery of biodiversity	– Islands of the Gulf have a highly critical role in preventing extinction of native fauna and must be continually guarded to prevent invasions of exotic flora and fauna. – Nearly half of the 15 most common wader species in the Firth of Thames have displayed declining trends in their numbers since 1960. – Bryde's whales are highly threatened and 11 have been killed by vessel strike and two by mussel line entanglement in the Hauraki Gulf between 1989 and 2008.	– Collaborative initiatives to protect and restore Gulf islands. – Collaborative initiative to protect wading birds in Firth of Thames. – No direct action to reduce threats to the Bryde's whale
Coastal development	– Coastal development causes significant and cumulative impacts on the ecology and landscapes of the coastal environment. – There are few mainland bays and beaches in the Auckland region without building development on the surrounding land whereas around a third of Waikato bays and beaches are undeveloped. – Pressure to develop coastal areas likely to increase.	– Auckland regional growth strategy. – Auckland spatial plan. – Coromandel Peninsula Blueprint. – Auckland regional park acquisition. – No coastal reserve acquisition programme in the Waikato Region.
Tāngata whenua values	– Programmes and approaches based on appropriate tikanga and kawa poorly developed. – Limited organisational capacity to respond to tāngata whenua and adopt kaitiakitanga-based methodologies. – Development of response indicators required.	– Settlement and negotiation of Treaty settlements – Some new iwi management plans – Emergence of collaborative governance models. – Limited application of kaitiakitanga and matauranga.

7.11 Integrated management

A key purpose of the Hauraki Gulf Marine Park Act is to "integrate the management of the natural, historical and physical resources of the Hauraki Gulf, its islands, and its catchments" (Section 3(a)). The State of the Environment Report for the Hauraki Gulf is required to include information on progress towards integrated management (Section 17(1)(g)).

Integrated management includes integration across biophysical boundaries such as the land and the sea, between different management agencies such as DOC, MFish and the various councils, and between government and community efforts. Integrated management is designed to enable the cumulative impacts of activities on the Gulf to be addressed.

The above description of management responses to strategic considerations has identified a number of areas where integrated management approaches are being applied. These include:

- restoration of the Gulf islands (with the involvement of DOC, councils and community trusts);
- management of coastal development (Auckland regional growth strategy, Auckland spatial plan, and Coromandel Peninsula Blueprint);
- protection of wading birds in the Firth of Thames (Muddy Feet project);
- restoration of the Mahurangi Harbour (Mahurangi Action Plan);
- catchment management on Coromandel Peninsula to achieve multiple objectives (Peninsula Project); and
- catchment management approaches to reducing wastewater discharges (Auckland Regional Plan: Air, Land and Water).

However, despite these initiatives, the environmental indicators show that management initiatives have collectively failed to halt or reverse the decline in the Gulf's natural resources. There appear to be a number of reasons for this:

- Intervention is not of sufficient scale or intensity: Many of the initiatives are not of a sufficient scale or intensity to successfully address the targeted environmental issues and/or to make a measurable difference to the environmental quality of the Gulf as a whole.
- Lack of clear environmental goals: Many of the initiatives lack clear goals in terms of measurable improvement in the environmental quality of the Gulf's marine area. A focus on mitigation of the effects of individual activities has in many cases failed to effectively address cumulative effects. This is particularly the case with the management of sediment and nutrient discharges.
- Key gaps in management response: In some key areas there has been a lack of management response including non-point discharges from many rural activities and the broader environmental impacts of fishing activity.
- Implementation gaps: There are often difficulties in translating policy or the outcome of strategic planning exercises into actions which affect activities on the ground, such as through the introduction of stronger rules into regional and district plans.
- Fragmentation: In some key areas management is fragmented between different management agencies. For example, there is currently particularly poor integration between fisheries management and management under the RMA. There is also fragmentation between planning and management efforts in the Auckland and Waikato regions.
- Roadblocks: In many cases technical, political, social or economic roadblocks prevent the implementation of solutions.

7.11.1 A new management response?

The vision for Tīkapa Moana Hauraki Gulf established by the Hauraki Gulf Forum refers to a place which is “celebrated and treasured”, which is “thriving with fish and shellfish, kaimoana”, which has a “rich diversity of life” and which supports a “sense of place, connection and identity” and a “vibrant economy”. So what might a management response look like if the Forum’s vision is to be achieved?

It is likely to include at least the following five elements:

Tāngata whenua relationships are acknowledged and reflected in resource management practice: There is growing appreciation of the Māori world view of connectedness between humans and the natural world, strengthened roles for tāngata whenua in decision-making backed by settlements of historical Treaty claims, and traditional knowledge and tikanga find application in the way resources are managed, with resulting protection and enhancement of culturally important environmental resources and values.

A flourishing “green-blue network”: The Gulf has a network of restored island sanctuaries and protected, regenerating areas within the marine area. The network will provide places where biodiversity thrives, where the ecological health and productivity of the marine area is enhanced and where the resilience of these natural systems is strengthened. The network will be the focus of community engagement in caring for the Gulf and will support diverse recreational opportunities and thriving low-impact business opportunities.

Enhancement of fisheries: Fishing activity is carefully managed to ensure that important marine species, habitats and ecological processes are not damaged. Alternatives to the maximum sustainable yield are more widely implemented to improve ecosystem outcomes, while also providing thriving fish stocks that support a prosperous local fishing industry, and generously provide for cultural, subsistence and recreational harvests.

Sediment and contaminants kept on the land: Effective catchment management will ensure that the input of sediment, nutrients and other contaminants to the Gulf is minimised, and levels do not exceed ecological limits. The Gulf’s harbours and estuaries will be healthy and teeming with life. They will support thriving shellfish beds and a rich fauna of bird life. They will also provide safe nursery areas for juvenile fish thereby contributing to fisheries productivity. Mangroves will no longer be expanding into new intertidal areas.

Knowledge generation occurs within an ecosystem-based management framework: Only intact, healthy ecosystems can provide the complete range of benefits that humans want and need over a long period of time. Research therefore focuses on ways of preventing the environmental costs of current activities being passed to future generations. Economic opportunities are identified, which provide for sustainable growth while halting the serial depletion of natural resources. Ways for protecting and restoring marine ecosystems, and the services they provide, are developed and implemented.

8.

Discussion

The Hauraki Gulf Forum has set an aspirational vision (see Section 2.2), which seeks to protect and care for the Gulf. The vision aims for a future where environmental quality is maintained, and the Gulf is rich in diversity, with thriving fish and shellfish (kaimoana). It also seeks to ensure that resources are used wisely to grow a vibrant economy, and that our cultural heritage is protected. This report measures progress toward achieving that vision, and also considers whether the life-supporting capacity and resources of the Gulf are being protected or, where necessary, enhanced, in accordance with the management objectives of the Hauraki Gulf Marine Park Act (2000).

Note that this is a State of the Environment Report. Its focus is therefore clearly on the environment, rather than on the state of fisheries, or any other exploited resources. Fisheries assessments seek to maximise the yield, while maintaining the stock's productive capacity. This is achieved by deliberately fishing down stocks to levels where productivity is maximised. Models indicate that this usually occurs somewhere between 30 and 60% of unexploited levels (Mace 2001), but it can be lower. For instance, the maximum sustainable yield (MSY) for snapper in the Hauraki Gulf and Bay of Plenty substock is theoretically achieved when the stock is fished down to 23% of the unexploited biomass. As a result, fishing is a major environmental stressor that affects the whole of the Gulf. In this report fisheries data is therefore interpreted from an environmental management perspective, rather than from a fisheries' sustainability or productivity one.

In order to assess progress toward achieving the vision and achievement of management objectives, it is necessary to put contemporary information into a context. Humans have lived in New Zealand for only a relatively short time, but their impacts on the natural system have been profound. The past 150 years (i.e. two human lifespans) have seen the extinction of a number of native terrestrial species, native forests and vast wetlands being replaced by pastoral land use, rapid sedimentation of the coastal zone, the destruction of ecologically important marine habitats (e.g. mussel beds), large reductions in the populations of fished species, and continuing growth in urbanisation leading to the loss, modification and contamination of the coast (Section 3.2). The natural resources of the Hauraki Gulf and its catchments have therefore had a relatively short but unenviable history of unsustainable utilisation.

Concern about environmental issues has led to ground-breaking changes in New Zealand's environmental regulations over the past 20 to 30 years, including the introduction of the quota management system for fisheries, and the creation of the RMA. It is reasonable to expect these regulations should have reduced environmental degradation and habitat loss in the Gulf, and allowed the recovery of depleted species and communities. There are encouraging signs for some indicators. For instance, the former ARC spent considerable effort in reducing sediment run-off through regulatory and non-regulatory initiatives. It is therefore pleasing that 18 of the council's 20 coastal water-quality monitoring sites displayed improving trends in total suspended solids concentrations since 1987-1993, with 12 of these trends being statistically significant. Similarly, nutrient concentrations have displayed declining trends in most of Auckland's rivers, although this may be due to a declining trend in dairy farming rather than a response to specific management initiatives.

However, most of the indicators examined in this report suggest that environmental degradation is continuing, or that natural resources are being suppressed at environmentally low levels. For instance, in 1995, snapper biomass had been reduced to around 10.4% to 12.6% of the "virgin", or unfished, snapper biomass. Modelling carried out in 1999 predicted that the current total allowable catch (TAC) will allow the substock to rebuild and exceed the MSY over a 20-year period, with a 100% probability. The MSY is the default fisheries target, which is produced at c. 23% of virgin snapper biomass. This means that under the current management criteria, 77% of the potential snapper biomass will remain missing from Gulf's ecosystem. Furthermore, empirical estimates of snapper biomass have not been obtained since 1995, so predictions of a rebuild cannot be verified (Section 4.1.2). The next stock assessment is scheduled for 2012.

Similarly, the "vulnerable biomass" of crayfish, in the CRA2 fishery area[22], was estimated to be around 20% of 1945 levels in 2002. Crayfish biomass was expected to remain at that level through to 2007, but this prediction was not considered to be very reliable. Conditions which would trigger a reduction in the TAC for crayfish have not been met since 1991/92, but an increase in the total allowable catch occurred in 1997/98. The catch level has not been altered since that time (Section 4.1.3).

22. Vulnerable biomass is the biomass of individuals above the minimum legal size after size-related differences in catch rates, protection of berried females and seasonal vulnerability are taken into account. The CRA2 fishery area runs from just south of Whangarei Harbour entrance to East Cape.

The size characteristics of the fished and unfished snapper and crayfish populations differ substantially also. Fished populations tend to be comprised of few, mainly young individuals that are below or near the legal size limit, while protected populations tend to have large numbers of older, large individuals above the legal size. Importantly, while the quota management system halted the decline in both of these species, it now maintains them at ecologically low levels, and with highly modified population structures. This has direct consequences for each species, but it also affects the broader marine ecosystem. For instance, both of these species are high-level predators, which influence overall reef productivity through predation on urchins that, if left unchecked, suppress the growth of kelp forests through intensive grazing (Babcock et al. 1999, Shears and Babcock 2002).

MFish trawl survey data also indicates that indicators of rare and threatened fish species, fish diversity, and fish size and productivity displayed negative trends in the Firth of Thames between 1965 and 2000. Statistically significant trends in the indicators of size and productivity also tended to be negative in central parts of the Gulf, although two positive trends were detected. Indicators of fish diversity, size and productivity were mostly stable in the other areas with relatively few significant trends.

Reductions in shellfish populations have also occurred at some beaches in the Gulf, apparently due to harvesting, environmental stress, disease, or a combination of these conditions. MFish's monitoring of 14 sites in the Hauraki Gulf since 1998 indicates that the abundance of cockles have fluctuated through time at most sites, without showing obvious increasing or decreasing trends. However, a 36% reduction in overall cockle abundance in Whangateau Harbour occurred between 2004 and 2010. Overall cockle abundance also declined at Umupuia between 1998 and 2007, but subsequently increased due to an influx of small cockles. A low proportion of large cockles in Whangateau Harbour and at Umupuia is concerning, with only 1% to 2% of the population being of harvestable size. Similar declines have also been reported at Cheltenham Beach (Section 4.1.4).

Toxic metal and organic contaminants are causing localised effects in Auckland's estuaries, and concentrations are also elevated in sediments of the southern Firth of Thames. Concentrations of zinc, copper and lead have been linked to adverse changes in benthic communities in Auckland, with contaminated sites tending to have fewer rare and large taxa. Threshold effects level (TEL) sediment quality guideline values are exceeded at 21 of the 50 sites that are regularly monitored by Auckland Council. Probable effects level (PEL) guidelines are only exceeded in tidal areas of Meola Creek and Motions Creek in the Waitematā Harbour. Concentrations of copper, lead, mercury and zinc also exceed TEL sediment quality guidelines in the south-eastern Firth of Thames, and in particular around Thames, where large-scale mining historically occurred (Section 4.2). Management actions are not expected to remediate areas affected by urban and legacy contamination, but may slow accumulation and prevent the degradation of areas with clean sediments. The metropolitan urban limit is an important regulatory tool for constraining the area affected by urban stormwater contaminants, but considerable pressure is being applied to have the limit extended or removed.

Historically, oceanic inputs are likely to have been the dominant source of nitrogen to the Firth of Thames, but riverine inputs now exceed oceanic sources. Waihou and Piako rivers dominate nutrient loads to the Gulf, contributing to around 90% of nutrients entering from the Waikato Region and exceeding river and wastewater loads from the Auckland Region. Loads of both nitrogen and phosphorus in the main stem of the Waihou River have increased by a around 1% per year over the past decade, while nitrogen loads in Piako River have increased at a rate of 3.4% per annum over the past decade. Piako River's flow rate is around 27% of Waihou River's, but it contributes the equivalent of approximately 68% of the Waihou River's total nitrogen load. The long-term implications of increasing nutrient loads are poorly understood (Section 4.3).

Fourteen to sixteen of the 42 beaches monitored in the Auckland Region between January 2006 and April 2009 exceeded the "action"-level bathing beach guideline value each year, and there has been no change in the annual proportion of samples exceeding action levels. Exceedance of this guideline indicates that swimming, or other forms of contact recreation, may pose a human health risk. In the Waikato Region, eight of the 16 sites monitored exceeded the action threshold at least once in January-February 2006, with two sites (in Whangamatā and Tairua harbours) exceeding it two to three times. In January-February 2008, only two sites (Cooks Bay and Tairua Harbour) exceeded the action threshold, both on a single occasion (Section 4.4).

A number of studies have been carried out over the past decade, which have shown that sediment is a serious environmental contaminant that degrades coastal habitats and is toxic to many marine organisms. Sedimentation rates vary among harbours and estuaries, but modern sediment accumulation rates are frequently much greater than natural sedimentation rates. However, as mentioned earlier, there are signs that management initiatives in the Auckland Region are reducing suspended sediments on the coast.

Over the past 50 years or so, sediment accumulation has also contributed to the expansion of mangroves in many parts of the Gulf. For instance, sediment accumulation has allowed an approximately 1 km band of mangroves to develop along the southern shore of the Firth of Thames since the 1940s. Maps of vegetation cover produced from the land classification database (LCDB2) indicate that there was little change in the cover of mangroves between the summers of 1996/97 and 2001/02, although the spatial resolution of these data is relatively poor (Section 4.5).

Changes in benthic community composition consistent with increased sediment-mud content have been detected at sites in Puhoi, Wairewa, Orewa, Turanga and Waikopua estuaries, and in Mahurangi Harbour. Changes in community composition have also occurred in the Waitematā Harbour, but these appear to be unrelated to sediment. The proportions of mud and fine sand increased significantly between 2001 and 2006 at Waikato Regional Council's monitoring sites in the Firth of Thames, but these changes were not matched by negative trends in species sensitive to fine sediments (Section 4.5.4).

A total of 139 non-indigenous marine species have been recorded in the Hauraki Gulf with many of these well established in the Port of Auckland. Four arrivals in the past 10 years or so are notable for their potential to cause significant ecological and/or economic effects: the Mediterranean fanworm (*Sabella spallanzanii*); the clubbed sea squirt (*Styela clava*), the Asian kelp (*Undaria pinnatifida*); and the Japanese mud crab (*Charybdis japonica*). The introduction of other new species is a particular concern, because the eradication of exotic marine organisms is extremely difficult, if not impossible (Section 4.6).

Harmful algae and pathogens have had a major ecological and economic impact on the Hauraki Gulf over the past 30 years. Mass mortalities have included: the loss of around 80% of juvenile oysters on oyster farms; the loss of 60 to 80% of cockles in Whangateau Harbour; the largest recorded fish kill in the world (pilchards); the die-off of the main canopy-forming kelp on northern reefs (*Ecklonia radiata*); a major loss of scallops; the death of tens of thousands of fish in the central-inner Gulf; and the loss of around 8,500 paua at a farm in Kennedy Bay. The causes, historical incidence and implications of mass mortalities are poorly understood (Section 4.7).

The Ramsar site in the southern Firth of Thames is internationally significant as a shorebird sanctuary. Between 1960 and 2005, seven of the 15 commonest species displayed declining trends, four wader species increased in number, and four species maintained relatively stable numbers. Mangrove expansion and other habitat changes within the Firth of Thames were implicated in the decline of at least four species. The reasons for changes in other species are poorly understood, but are likely to include responses to environmental variation at the other locations in New Zealand and the northern hemisphere (Section 4.9.3).

Bryde's whales are listed as a nationally critical species, with a total New Zealand population of fewer than 250 mature individuals. Many of these feed, breed and raise their calves in the Hauraki Gulf. Bryde's whales compete with humans for space and resources. As a result, between 1989 and 2008 two Bryde's whales were killed in the Hauraki Gulf from entanglement in mussel farm spat lines, and 11 whales are thought to have been killed by vessel strike (Section 4.9.4).

Significant areas of coastal land have been developed in the past 10 to 15 years, particularly in the Auckland Region where relatively large-scale development of new or "greenfield" sites has occurred around the margins of the Auckland urban isthmus. Smaller-scale developments have also occurred around the outlying towns of Warkworth, Snells Beach, Omaha, Matakana and Beachlands. Steady increases also occurred in the number of dwellings at east-coast settlements on Coromandel Peninsula between 1991 and 2006. Holiday homes were responsible for a large proportion of that development. In 2006, 48% of dwellings in the Thames-Coromandel District were unoccupied, with most of these consisting of holiday homes and/or baches (but vacant properties for sale, properties completed but not yet occupied and other properties such as "abandoned" dwellings are also included in this figure). At the same time, there has been a corresponding decline in the number of commercial holiday parks on Coromandel Peninsula, with a third of them closing between 1996 and 2006.

Coastal development has led to the land surrounding 47% of the Gulf's mainland bays and beaches (as named on 1:50,000 topomaps) being fully urbanised, intensively developed or moderately developed, while the land surrounding 38% of bays and beaches was either undeveloped, or contained only scattered buildings. The Waikato Region had more undeveloped bays and beaches than the Auckland Region, with 36% undeveloped in Waikato cf. 5% in Auckland.

In some cases, not enough information was available to adequately characterise the impact that particular activities are having or to examine trends through time, but their magnitude and scale of effects are likely to be significant. Fishing occurs throughout the Gulf, and probably has the largest and most widespread impact on the Gulf's ecosystem. However, characterising that impact is hampered by a lack of fundamental information.

Bottom trawling and dredging have a major influence on sea-floor habitats and biodiversity (Kaiser *et al.* 2000, Thrush *et al.* 2001, Thrush and Dayton 2002). Bottom trawling is one of the most commonly used methods of catching fish in the Hauraki Gulf, accounting for around 30 to 40 % of the total commercial catch. The areas targeted by commercial trawlers contain a variety of different substrates and are also likely to contain (or to have once contained) diverse seabed communities, which are sensitive to trawling disturbance. However, virtually nothing is known about seabed ecology in those areas. The total area dredged by the commercial scallop industry has ranged from 350 to 450 km^2 for most of it history, but dropped to 200 km^2 in 2001, and 100 km^2 in 2005, with effort shifting from the central Gulf and Aotea (Great Barrier Island) to Mercury Bay and Bay of Plenty. The areas targeted by commercial and recreational fishers contain a variety of benthic habitats, and a range of non-target species are commonly collected in scallop dredges, including horse mussels, dog cockles, starfish, sponges, kelp and turfing algae. There is very little information on the current or historical ecology of these areas, or the actual impacts of scallop dredging. Large, emergent species like sponges, horse mussels and kelp are particularly important because they tend to increase biodiversity (Section 4.1.6).

It is common for insufficient information being available in order to assess the status of fish stocks. The current status of nine of the top 15 fish species caught in the Gulf is not known, overfishing of two species is thought to be occurring (tarakihi and trevally), while three species (pilchard, baracoutta and grey mullet) are not considered to be at risk of collapse, but not enough is known about the stocks to assess whether they are at or above target levels or depleted. Only two species (snapper and kahawai) are thought to be at or above target levels and not considered to be depleted or at risk of collapse. However, snapper biomass was last measured over 15 years ago (Section 4.1.1).

While many activities are causing unfavourable environmental outcomes, island restoration and protection initiatives have clearly produced positive conservation results. The greatest conservation achievements have occurred through community, DOC and regional council-led initiatives. The islands of the Gulf provide vital sanctuaries for New Zealand’s terrestrial biodiversity. Many islands in the outer Gulf have a high proportion of native forest cover. Ninety per cent of Aotea (Great Barrier Island) and 86% of Kawau Island have a cover of indigenous forest, broadleaved indigenous hardwoods, or manuka and kanuka. Most of the islands around Coromandel Peninsula are also covered in native vegetation, the notable exceptions being Great Mercury and Slipper islands. Motuora and Tiritiri Matangi islands have been revegetated, with volunteers planting around 206,000 trees on Motuora and 280,000 trees on Tiritiri Matangi. Motutapu and Motuihe islands have been partially revegetated, but still consist of mostly pasture, and the Rotoroa Island Trust is replanting on Rotoroa Island.

Twenty-seven of the 62 (43%) islands in the Gulf that are larger than 10 ha are currently free of mammalian herbivorous and predatory pests. Pest eradication has also been occurring on Rangitoto and Motutapu islands, but their pest-free status is yet to be confirmed. The elimination of mammalian pests has allowed one nationally critical (takahe) and four nationally endangered (hihi, kokako, North Island weka and brown teal) bird species to be translocated to, or among, islands in the Gulf. In addition, one nationally critical (Mercury Island tusked weta) and two nationally endangered (Mahoenui giant weta and wetapunga) insects, and one nationally vulnerable (Whitaker's skink) reptile have been translocated. A number of other less-threatened species have also been translocated among islands.

The Gulf’s marine reserves have also allowed the recovery of heavily fished species such as snapper and crayfish, which has led to corresponding changes in reef ecology and productivity (Babcock *et al.* 1999, Shears and Babcock 2002).

9.

Conclusions

New Zealanders have an intimate connection with the coast which, for many, is strongly linked to their sense of place and belonging. On any given day thousands of people look out upon the Hauraki Gulf and appreciate its natural beauty. On calm, summer days its waters shimmer and sparkle, enticing families to the beach to swim and play. On wild days the Gulf demonstrates its raw power, which can inspire fear, awe or inspiration. People visit and inhabit its picturesque islands, beaches and bays. They spend their spare time on the water and around it shores. Many make their living off the sea.

The natural beauty of the Gulf is one of its greatest assets, but it has many others. Most of these are hidden from view or are infrequently seen, but all have been affected by humans. Human utilisation of the Gulf has been occurring for only a relatively short time, but our impact has been immense. Many of the Gulf's natural assets have been seriously impacted. Some are just clinging on to existence. Too many have been lost.

This report highlights the incredible transformation the Gulf has undergone over two human lifespans. That transformation is continuing in the sea and around the coast, with many environmental indicators either showing negative trends or remaining at levels which are indicative of poor environmental condition. Key exceptions are the critical island restoration work that is being carried out to help the survival of endangered birds, reptiles and insects, and marine reserves, which have allowed the recovery of populations and ecosystem functions. However, it is inevitable that further loss of the Gulf's natural assets will occur unless bold, sustained and innovative steps are taken to reduce the utilisation of its resources and halt progressive environmental degradation. The regulatory tools appear to be available to do this, but to date they have either not been implemented or the manner of implementation has not been effective. The challenge facing today's managers and kaitiaki is to find solutions to the progressive decline in the Gulf's resources and ecosystem to protect opportunities for future generations.

"The focus must be on finding solutions for regenerating and sustaining the mauri (life-energy force) and integrity of Tikapa Moana's domain for Tikapa Moana's own sake. Future generations benefit when the mauri and integrity of Tikapa Moana is sustained." *Betty Williams, tāngata whenua representative*

10.

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It draws upon relevant biophysical indicators available from agency monitoring programmes, and a core set of indicators defined and approved by the Hauraki Gulf Forum in May 2010.

The report was peer-reviewed by the Hauraki Gulf Forum's Technical Officers Group and approved for publication by the Hauraki Gulf Forum at its meeting on 27 June 2011.

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11.

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