Photo: Rangitoto Island, Hauraki Gulf. (Source: ARC).

4.4

State of the environment and biodiversity – Marine

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4.4

Marine

Introduction

The spectacular twin coastlines with their beaches and estuaries, three large harbours and the islands of the Hauraki Gulf provide a huge variety of different marine environments that help to define the Auckland region.

The marine environment is important, not only for its cultural significance and the recreational and tourism opportunities it offers, but also because it provides many different habitats that support a diverse number of species. A range of marine mammals use the waters surrounding the region, including the critically endangered Maui's dolphin (the worlds smallest dolphin) that is found only on the west coast of the North Island. More than 195 fish species have been recorded, including the snapper that is important for both commercial and recreational fishing. Estuaries and river mouths provide important spawning habitats for fish species. Many areas, such as the Kaipara and Manukau Harbours, also provide important feeding and breeding grounds for coastal and migratory birds. In addition, the marine environment supports a rich diversity of other plants and animals that all play an equally important role in marine ecosystems.

The marine environment also provides a range of ecosystem services and functions that are of great value to the Auckland region, such as food resources, shoreline protection, climate change mitigation, nutrient recycling, contaminant processing and sediment stability.

However, it is subject to high, and often conflicting, uses and its health is under increasing pressure from direct use as well as activities that generate discharges to the marine environment. Examples of direct use include coastal reclamation, coastal structures such as sea walls, dredging and mining (see Chapter 3: Seabed use, pg 49). All of these uses can remove or change the natural habitat and alter water flows. Aquaculture uses space and can affect habitats by altering fod web dynamics and habitat structure. There is an ever-present risk of oil and chemical spills from boating and shipping (see Chapter 3: Marine discharges, pg 68) and an emerging use of the coastal environment is power generation.

Land-based activities can generate discharges of sediment, chemical contaminants, nutrients and sewage into the marine environment (see Wastewater and stormwater in Part 3). These can have adverse effects on water quality, and on the overall health and diversity of marine ecosystems.

Global environmental pressures from climate change are likely to result in a rise in sea temperature and may also disrupt or modify weather patterns such as rainfall and wave climate, which may influence and intensify other pressures on the marine environment (see Climate change, Box1, pg 12). For example, more intense rainfall may deliver more sediment to the marine environment. In addition, carbon dioxide adsorbed by the oceans makes the seawater more acidic, with potential effects on the productivity of many marine systems.

The impact of multiple environmental stressors on an ecosystem also needs to be considered, e.g. the effects of chemical contaminants on an ecosystem that is already impacted by increasing levels of sediment.

ARC's marine monitoring programmes are regionally representative and provide a large amount of data that is used to shape our marine management decisions and policies and enable the ARC to detect whether things are getting better or worse. The ARC monitors three key areas; coastal water quality, contaminants in sediment and shellfish, and ecological quality. Together, these programmes provide comprehensive information on the overall quality of Auckland's marine environment. This increased knowledge enables the ARC to work more effectively to protect the marine biodiversity and the valuable resources provided by the region's marine environment.

Coastal water quality

Key findings

- A crucial part of many coastal activities is the quality of the water. Open coast sites had the best coastal water quality in the Auckland region.
- Overall, coastal water around the Auckland region showed significant improving trends in water quality, with reduced levels of faecal bacteria, suspended solids, total phosphorus, soluble reactive phosphorus and nitrate.
- Trends (particularly for nutrients and suspended sediments) indicated that some sites with good or excellent coastal water quality were experiencing a decline in water quality.
- There were declines in suspended sediment concentrations but elevated levels of sediment remain a major concern in the marine environment.
- Inner harbour sites tended to have the poorest water quality, which reflects their proximity to freshwater inputs carrying contaminants from urbanised land.
- High levels of contaminants within stormwater and wastewater (that enter the marine environment as a result of overflow events) were the main factor in beach closures.
- The number of bathing beach water samples that exceeded the 'action' threshold was low for most areas. Bathing beach water quality north of Whangaparaoa and on the northern side of Waiheke rarely, if ever, exceeded the 'alert' thresholds.
- The proportion of both 'alert' and 'action' threshold exceedences is highest at beaches in Waitakere and Manukau cities.
- Some beaches within the metropolitan urban limit (MUL) more regularly experienced levels of microbiological contaminants that are potentially harmful to human health.

Marine

Box 1 The Maui's dolphin

The critically endangered Maui's dolphin is one of a range of marine mammals found in the waters surrounding the Auckland region. Around 22 species of whales and dolphins have been recorded in the Hauraki Gulf. Common and bottlenose dolphins, Bryde's and pilot whales are among the most commonly sighted.

The Maui's dolphin is found only on the west coast of the North Island of New Zealand and it is estimated that only 111 remain in existence. Females produce a single calf every 2-3 years from age 7-9 and only live for 20 years; the loss of just one dolphin can therefore have a big impact on this small Maui's population.

DOC administers the Marine Mammals Protection Act 1978, which provides for the conservation, protection and management of all marine mammals including Maui's dolphin. The ARC supports marine mammal management, conservation and research by submitting on proposed management plans, through advocacy and funding research.

The ARC's Parks and Heritage Committee passed a resolution that Council works with other relevant agencies, regional councils, territorial authorities and interested groups to develop the scope, and advocate for, the establishment of a marine mammal sanctuary and other initiatives such as the extension of a set net ban. In addition, a submission was made in support of the DoC and MFish's Hector's and Maui's Dolphin Threat Management Plan.

The ARC's Coastal Fund has supported World Wildlife Fund work in the production of displays and other material promoting conservation of the Maui's. Funding has also been provided for community-based marine litter collection for Manukau and west coast beaches, and information has been distributed to other councils, community and volunteer groups and to park notice boards and information kiosks in the region. In the 2008/09 year the ARC's Coastal Enhancement Fund provided funding to a University of Auckland research project on the Bryde's whale investigating its distribution in the main shipping and boating areas of the Hauraki Gulf and their vulnerability to shipping strike.

(Source: Royal Forest & Bird Protection Society of New Zealand).

Introduction

The quality of the coastal water is crucial to many coastal activities such as food gathering, recreation and tourism around the region. Marine plants and animals also need good water quality to survive and be healthy. Poor coastal water quality can adversely affect enjoyment of the marine environment, and ecosystem productivity and functions.

Land use activities in the surrounding catchments can discharge contaminants such as sediments, nutrients and biological wastes (organic and faecal material) into coastal waters (see Chapter 3, Indicator 27, pg 62 and Chapter 4.2, pg 134, Sediment). These contaminants can degrade the coastal water quality and influence the types of organisms that can survive there, along with water temperature, salinity and natural variations in nutrient content.

Coastal water quality monitoring programme

The ARC monitors contaminants associated with erosion, nutrients and biological wastes in the coastal water, as well as physical conditions such as temperature and salinity. The ARC has produced New Zealand's most comprehensive long-term dataset for coastal water quality.

ARC collect water samples on a monthly basis from 27 sites at some harbours and estuaries and in the wider coastal zone of the region (Table 1). It began sampling six sites in the Manukau Harbour in 1987 and sampling began at the other 21 sites between 1991 and 1993. This regular sampling allows long-term trends in coastal water quality to be detected, but is not designed to detect the influence of individual storm events; these can potentially deliver large volumes of sediment, nutrients and contaminants to the marine environment over a very short time.

Up to 23 water quality parameters are monitored. Seven key water quality parameters were used to assess the health and quality of coastal water and its ability to support coastal ecosystem services at the monitored sites (Table 1). These parameters are:

- → dissolved oxygen (per cent saturation)
- → pH
- → total suspended sediment
- → ammonia
- → total phosphorous
- → nitrate
- → Chlorophyll a.

The results were used to rank the sites from the healthiest to the most degraded, and then to produce a Water Quality Index (WQI), see Box 3, Chapter 4.3 pg 146. The levels of these parameters at each monitoring site were also assessed for long-term trends.

Marine

TABLE 1 Coastal water quality classes at each monitoring site in 2007. (Source ARC).

Site name	Location/harbour	Scope	Frequency	Magnitude	WQI	Water quality class
Goat Island	Open coast	0.0	0.0	0.0	100.0	Excellent
Browns Bay	Open coast	14.3	1.3	0.3	91.7	Excellent
Ti Point	Open coast	14.3	1.3	0.4	91.7	Excellent
Orewa	Open coast	14.3	2.7	0.9	91.6	Excellent
Chelsea Wharf	Waitemata	28.6	2.7	0.5	83.4	Good
Mahurangi Heads	Mahurangi	28.6	3.6	1.8	83.3	Good
Hobsonville Jetty	Waitemata	28.6	3.9	2.2	83.3	Good
Waimarie Rd	Waitemata	28.6	5.2	5.9	82.9	Good
Grahams Beach	Manukau	28.6	9.8	7.8	82.0	Good
Whau Creek	Waitemata	42.9	6.7	3.5	74.9	Good
Dawson's Creek	Mahurangi	42.9	7.1	2.7	74.9	Good
Henderson Creek	Waitemata	42.9	9.3	1.7	74.7	Good
Lucas Creek	Waitemata	42.9	9.1	6.5	74.4	Good
Rarawaru Creek	Waitemata	42.9	9.1	10.5	74.0	Good
Paremoremo Ski Club	Waitemata	66.7	10.4	3.9	61.0	Good
Tamaki	Tamaki	57.1	6.0	1.9	66.8	Fair
Confluence	Waitemata	57.1	15.6	10.5	65.3	Fair
Panmure	Tamaki	57.1	19.0	6.3	65.0	Fair
Clarks Beach	Manukau	57.1	20.7	18.6	63.3	Fair
Rangitopuni Creek	Waitemata	71.4	15.8	27.1	55.0	Fair
Shelly Beach	Kaipara	71.4	26.2	24.8	53.8	Fair
Shag Point	Manukau	71.4	31.7	49.2	46.7	Poor
Brighams Creek	Waitemata	85.7	15.8	30.8	46.6	Poor
Weymouth	Manukau	85.7	28.0	24.9	46.0	Poor
Town Basin	Mahurangi	85.7	40.3	31.0	42.5	Poor
Puketutu Point	Manukau	85.7	45.1	57.4	35.0	Poor
Mangere Bridge	Manukau	85.7	54.3	48.9	35.0	Poor

Indicator 1: Coastal water quality

Water Quality Index (state)

Monitoring data for the seven water quality parameters were used to produce the WQI for each of the 27 sites.

The results also show that, across the whole of the region, most of the sites with the poorest water quality were in the Manukau Harbour. The worst sites were Mangere Bridge and Puketutu Point; these are influenced by inputs from urbanised and industrialised catchments and water discharging from the Mangere Wastewater Treatment Plant. Consequently, at the Mangere Bridge and Puketutu Point sites, 85.7 per cent of the seven water quality parameters regularly failed to meet the compliance thresholds (45.1 and 54.3 per cent of the time respectively) and when they failed the exceedences were generally high.

Long-term trends

The long-term trends for coastal water quality were assessed using the data for the same seven water quality parameters that were used in the WQI. Regional trends for each parameter between 1993 and 2007 were assessed. Decreasing trends indicate improving coastal water quality while increasing trends indicate deteriorating water quality.

The majority of coastal water quality parameters were either improving or showed no change at most sites across the Auckland region (Table 2). The majority of trends were consistent with improving water quality. Improvements in water quality were especially evident in the 11 Waitemata Harbour sites.

TABLE 2 Long-term trends in coastal water quality parameters at 27 sites within the Auckland region, 1993-2007. (Source: ARC).

Water quality class	Percentage of sites improving	Percentage of sites not changing	Percentage of sites declining
Excellent sites	10	65	25
Good sites	57	37	6
Fair sites	55	40	5
Poor sites	80	3	17

However, some individual sites had trends that indicated a decline in water quality, particularly due to increasing nutrient and sediment levels. For example, while there was a significant long-term decline in suspended sediment levels at the worst sites (a positive trend), the trend of increasing levels of suspended sediment at some of the most pristine open coastal and outer harbour sites is of concern.

Long-term trends indicative of deteriorating coastal water quality were detected at Mahurangi Heads where turbidity, chlorophyll a and total phosphorous increased significantly, Ti Point which had increased levels of chlorophyll a and total phosphorous, and Goat Island which had increased levels of nitrate and total phosphorous. All of these sites were considered to have good and excellent water quality (Table 1).

In contrast, the water in Manukau Harbour, particularly at Mangere Bridge, Puketutu Point and Shag Point, has shown dramatic improvements in coastal water quality since the Mangere oxidation ponds decommissioning work was completed in 2002. These sites were heavily enriched in nitrogen (particularly nitrate and ammoniacal nitrogen which are indicators of wastewater discharges) but have shown significant declines in the levels of ammoniacal nitrogen, total phosphorus and suspended sediments between 1987 and 2007, with notable decreases in the last five years. However, other trends have indicated increases in dissolved nutrients (nitrate and dissolved reactve phosphorous) at Puketutu Point since 2001 and increasing nitrate at the Weymouth site.

Bathing beach water quality

The Auckland region's beaches are highly valued and popular places in summer. There are times when stormwater and/or wastewater containing microbiological contaminants is flushed directly into the coastal water and sometimes the beaches have to be closed for swimming or shellfish gathering bans put in place. The New Zealand Food Safety Authority monitors whether shellfish are safe eating.

Bathing beach water quality monitoring programme

Bathing beach water quality testing for microbial contamination is carried out by local councils and this information gets collated by the ARC.

Five local councils in the Auckland region regularly monitor water quality of the region's beaches to make sure they are suitable for recreational pursuits such as swimming. In total the councils monitor 76 beaches during the summer season (November to March/April):

- → North Shore City monitors 26 beaches
- → Auckland City monitors 15 beaches
- → Manukau City monitors 15 beaches
- → Franklin District monitors 5 beaches
- → Waitakere City monitors 15 beaches.

Marine

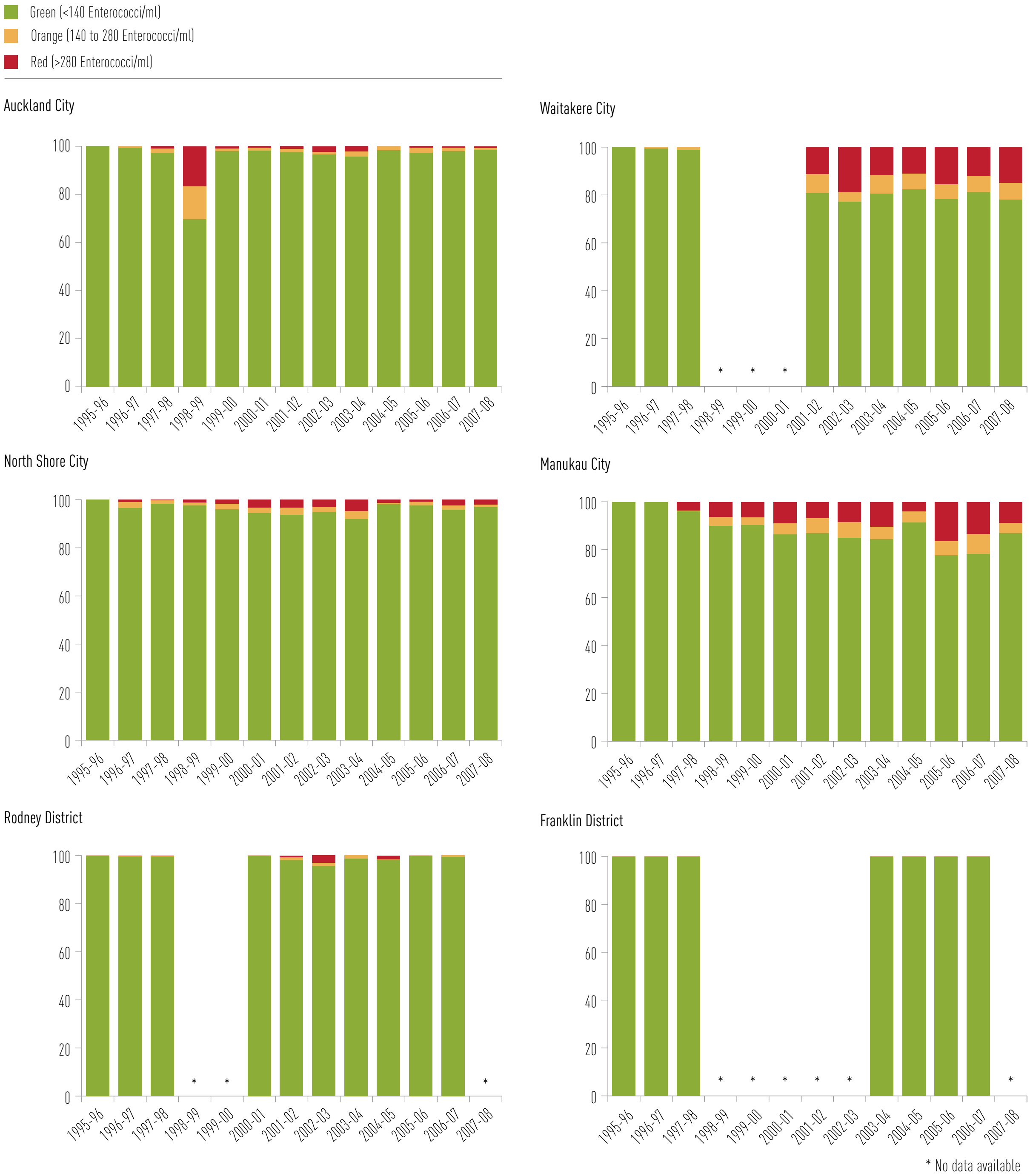

FIGURE 1 Percentage of bathing beach water quality samples collected from monitored beaches within Green, Amber and Red modes, within each council district. (Source: ARC).

The Rodney District, North Shore City and Auckland City Councils established a 'Safe Swim' programme in 1998 which provides consistent data on microbiological contaminant levels at central and northern beaches within the region. Rodney District Council (RDC) terminated its 'Safe Swim' programme in 2007 and no longer monitors any beaches.

The level of microbiological contamination is assessed by the level of *Enterococci* bacteria in a water sample. These bacteria indicate the presence of faecal contaminants which can result in gastro-enteritis and respiratory illness.

The level of *Enterococci* in a water sample determines whether or not a beach should be closed. The Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas formulated by the MfE recommend the use of two thresholds: 'alert' and 'action' (Table 3).

TABLE 3 Microbiological water quality guidelines for beaches in New Zealand. (Source: MfE).

Threshold	Action	Number of Enterococci bacteria per 100ml water
Acceptable (green mode)	No action required	Less than 140
Alert (amber mode)	Daily monitoring of the beach water is required.	Between 140 and 280
Action (red mode)	The beach should be closed if this level is exceeded on two consecutive days.	More than 280

Differences in how the bathing beach water quality monitoring programme is carried out by each council makes it very difficult to compare bathing beach water quality across the Auckland region. Therefore, Figure 1 summarises the results to show the bathing beach quality for each local council, rather than for the region.

The results of re-tests were not always available when compiling the data for this report, and some results were interpreted using an earlier (and now outdated) 'action' threshold of one exceedence of 277 *Enterococci* per 100ml.

It is also important to note that routine monitoring is performed only once a week during the summer, meaning that unsafe bathing beach water may occur on a greater number of occasions than those detected by routine monitoring. In addition, since routine monitoring is only carried out in summer, it will not detect occurrences of unsafe bathing beach water in other seasons.

Indicator 2: Bathing beach water quality

The number of bathing beach water samples that exceeded the 'action' threshold (as a percentage of the number of samples taken) was low for most areas.

Figure 1 shows that the proportion of both 'alert' and 'action' threshold exceedences was highest at beaches in the Waitakere and Manukau cities.

A closer examination of the data shows that exceedences of the 'action' threshold tended to be greater on beaches that are close to highly urbanised catchments. Bathing beach water quality north of Whangaparaoa and on the northern side of Waiheke rarely, if ever, exceeded the 'alert' thresholds. In contrast, beaches within the MUL (Figure 2, pg 9) regularly experienced levels of microbiological contaminants that are potentially harmful to human health.

Implications of coastal water quality

Although there were some very positive improvements in coastal water quality, the trends indicated a decline in water quality at some of the best sites. This decline highlights that there is a need to focus on land management practices and discharges from rural land in the Auckland region. Although there were declines in the levels of suspended sediment across the region, elevated levels of sediment remain a major concern in the marine environment due to its effects on coastal water quality (e.g. increased turbidity) and marine ecosystems (e.g. smothering organisms that live on the seabed).

Elevated levels of microbial contaminants in water can adversely impact human health and affect safe enjoyment of the marine environment. High levels of contaminants in stormwater and wastewater that get into the marine environment as a result of overflow events, are the main cause of degraded water quality at the beaches and that is the main reason why beaches have to be closed. There is a need for continued monitoring of bathing beach water quality. There is also a need for a consistent sampling method across the region so people can be reliably informed when a beach is unsafe and also to ensure that data from different areas can be accurately compared.

4.4

Marine

Sediment and shellfish contamination

Key findings

- A huge variety of chemical contaminants that are produced by land-based activities can be washed down into the marine environment through the stormwater network and directly off the land.
- Contaminant levels in marine sediments around the Auckland region were generally low, although some sites were found to be contaminant hotspots. These hotspots had elevated levels of contaminants that may be affecting the ecological health of that area. They tend to be muddy estuarine sites and tidal creeks that receive runoff from older urban catchments.
- There was a long-term trend for increasing concentrations of zinc in marine sediments, particularly at sites that are already contaminated.
- New organic contaminants are emerging as potential concerns but it is too early to know whether their levels are increasing or if they pose an environmental risk.

Introduction

The seabed of the harbours, estuaries and coasts provide vital habitats and feeding grounds for many species, but a huge variety of chemical contaminants that are produced as a result of land-based activities can be washed down into the marine environment through the stormwater network and directly off the land.

When any of these chemical contaminants enter the marine environment they can adversely impact the health of marine organisms and degrade water quality. The main sources of chemical contaminants are vehicle emissions, runoff from roads, roofs and buildings, and soils that contain chemical residues associated with applications of pesticides and fertilisers. Chemical contaminants can also be discharged directly from shipping.

Examples of chemical contaminants that are of concern in the marine environment are:

- Heavy metals. Some metals such as copper, lead and zinc are essential for life in very small (trace) quantities but can be toxic at higher levels (Box 1 in Chapter 4.2). Common sources include building materials, car parts and motor vehicle emissions.
- Polycyclic aromatic hydrocarbons (PAHs). There are thousands of different PAH compounds: some are toxic while others cause cancers and genetic mutations. Although there are some natural sources of PAHs, most result from human activities such as the incomplete combustion of fossil fuels in vehicle emissions.
- Organochlorines. These chemical contaminants have been synthesised from petrochemicals and chlorines and are commonly used as pesticides. They are now causing concern because their potential toxicity to humans (and other organisms) has been recognised and also because they persist in the environment for many years. Some organochlorines (such as DDT and Dieldrin) are now banned in New Zealand.
- Emerging organic contaminants. A wide range of chemical contaminants found in everyday use, but of potential environmental concern include flame retardants, estrogens, antifoulants and pesticides. Results from a preliminary survey suggest that residues of some emerging organic contaminants can be found at widely varying concentrations in estuarine sediments within the region. However, it is too early to assess their full environmental significance.

We monitor contaminant accumulation in both sediments and some types of shellfish.

Sediment contaminant monitoring programme

This monitors the levels of chemical contaminants in coastal sediments and compares them to the sediment quality guidelines in ANZECC and the Environmental Response Criteria (ERC) in ARC Technical Publication 168.

There are two complimentary sediment contaminant monitoring programmes: the State of the Environment (SoE) programme monitors regionally-representative sites including harbours, estuaries and beaches, while the Regional Discharge Programme (RDP) focuses on sites subjected to stormwater discharges. For the purposes of this report, results from both programmes have been combined to provide sediment quality results from 72 sites around the Auckland region.

Indicator 3: Heavy metals (copper, lead and zinc) in sediment

Concentrations of copper, lead and zinc are monitored every two years in the SoE programme, and every two to five years in the RDP programme depending on the level of contamination.

Figure 2 shows the numbers and proportion of monitoring sites with measurable concentrations of copper, lead and zinc, based on the most recent monitoring results for each site between 2002 and 2007. Results are classified according to our ERC. The ERCs were developed as a conservative early warning system.

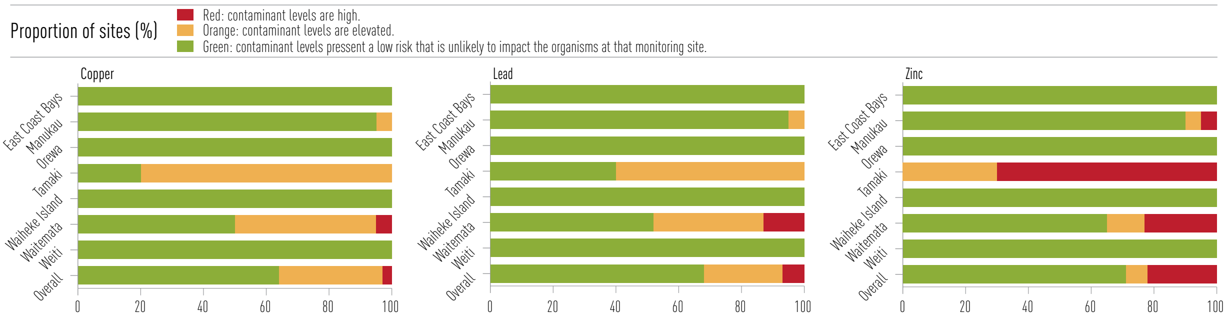

FIGURE 2 Number of monitored sites with heavy metal concentrations in the red, amber (orange), and green ERC categories. Sites are grouped by location type (e.g. harbour). 'Overall' shows all sites monitored. (Source: ARC).

Results show that:

- More than 60 per cent of the monitoring sites were in the 'green' category indicating that organisms in many marine environments were at low risk from heavy metals.
- The highest concentrations of heavy metals were found in muddy estuarine sites and tidal creeks that receive runoff from older urban catchments, particularly in the middle Waitemata Harbour and the upper Tamaki Estuary, where heavy metal concentrations commonly fell into the 'amber' or 'red' categories.
- Zinc concentrations fell into the 'amber' or 'red' categories more often than copper or lead.

The middle Waitemata Harbour is widely contaminated. Although concentrations of heavy metals in the upper Waitemata Harbour were below ERC thresholds (in the 'green' category) they are higher than would be expected, given the predominantly rural land use in the surrounding catchments. The reasons for this are currently unknown.

Concentrations of heavy metals were generally low in the Manukau Harbour (apart from the Mangere Inlet where the elevated levels may be partially related to historical industrial pollution). This is due to the large size of the harbour and its relatively small catchment areas that have a low proportion of urban land use and little recent urbanisation.

In contrast, the Tamaki Estuary is relatively highly contaminated in its older, densely urbanised headwater areas. However, the levels of heavy metals reduce as the distance from these areas increases, so the estuary mouth is relatively uncontaminated.

Estuaries to the north of Auckland have relatively low levels of contamination although zinc levels were slightly elevated.

Catchments that drain the East Coast Bays area discharge to the open coastline where wave energy tends to disperse fine sediments and any associated contaminants. Consequently, contaminant concentrations were low on these coastal beaches.

The long-term regional trend for all monitoring sites between 1998 and 2007 showed an increase in zinc levels and a decrease in lead levels. Changes in copper were variable. The highest accumulation rates for heavy metals were found at muddy, upper harbour urban sites.

Indicator 4: Other heavy metals, PAHs and organochlorines in sediment

As part of the SoE programme, a range of other metals are monitored every two years, and PAHs and organochlorines are monitored every four years.

Arsenic was low at all 27 sites, below the ANZECC Interim Sediment Quality Guidelines (ISQG). Mercury was present at or just above ANZECC ISQG (low) at seven of the sites but below detection limits everywhere else.

The levels of PAHs in 2005 showed a correlation with the levels of heavy metals, particularly lead, suggesting common sources and common delivery paths into the marine environment. More positively, the concentrations of PAHs were generally low compared with the ERC, with elevated concentrations found in relatively few locations.

Concentrations of organochlorines in 2003 were also generally low. The organochlorines detected most often were DDTs and Dieldrin. The highest levels of DDTs were found at Meola Creek and Henderson Creek, and the highest levels of Dieldrin were found at Ann's Creek, Mangere Cemetery and Motions Creek.

Endosulfans were also found at relatively low and variable concentrations at five sites, particularly Weiti and Paremoremo.

Shellfish contaminant monitoring programme

In addition to measuring contaminants in sediment to assess which contaminants are in the marine environment, the ARC also look at the levels of contaminants in various organisms. Oysters and mussels are filter-feeding shellfish and, over time, accumulate chemical contaminants in their tissues, even when ambient levels in the water are relatively low. This means that the tissues of oysters and mussels can provide a biologically relevant indication of the levels of chemical contaminants in the coastal environment.

Contaminants have been monitored annually in natural populations of oysters collected from Manukau Harbour since 1987. Monitoring of deployed mussels placed in the Waitemata Harbour and Tamaki estuary was introduced in 1999 and in the Manukau Harbour in 2000 (Figure 3). Shellfish tissues are analysed for concentrations of heavy metals, organochlorine pesticides, PAHs and PCBs.

Currently there are no established guidelines to assess the ecological effects of chemical contaminants in shellfish, so the concentrations are compared to overseas values taken from international literature and analysed for long-term trends.

Chemical contaminants are not monitored in relation to human health standards because this is the role of the New Zealand Food Safety Authority.

Indicator 5: Metals in shellfish

In 2007 metal concentrations in deployed mussels were relatively low. However, mussels placed by the ARC in the Tamaki estuary (on the east coast) and Mangere Inlet (on the west coast) tended to have higher concentrations of copper when compared to all other sites.

In contrast, the oysters showed strong differences in the concentrations of copper and zinc among sites within the Manukau Harbour. Copper concentrations tended to be highest at Grannys Bay and lowest at Cornwallis. Median concentrations of copper in oysters were generally higher than those from international databases for all sites except Cornwallis, where concentrations were similar to those in international databases. Oysters from Cornwallis also had consistently lower concentrations of zinc than those from other sites. Concentrations of zinc at other Manukau Harbour sites were equal to or exceeded median values from international databases.

Concentrations of arsenic in oyster tissues from all sites in the Manukau Harbour were high in comparison to international levels, particularly at Cornwallis. Concentrations of cadmium were low and concentrations of chromium were comparable with international levels. Concentrations of lead in oysters were variable over time.

Marine

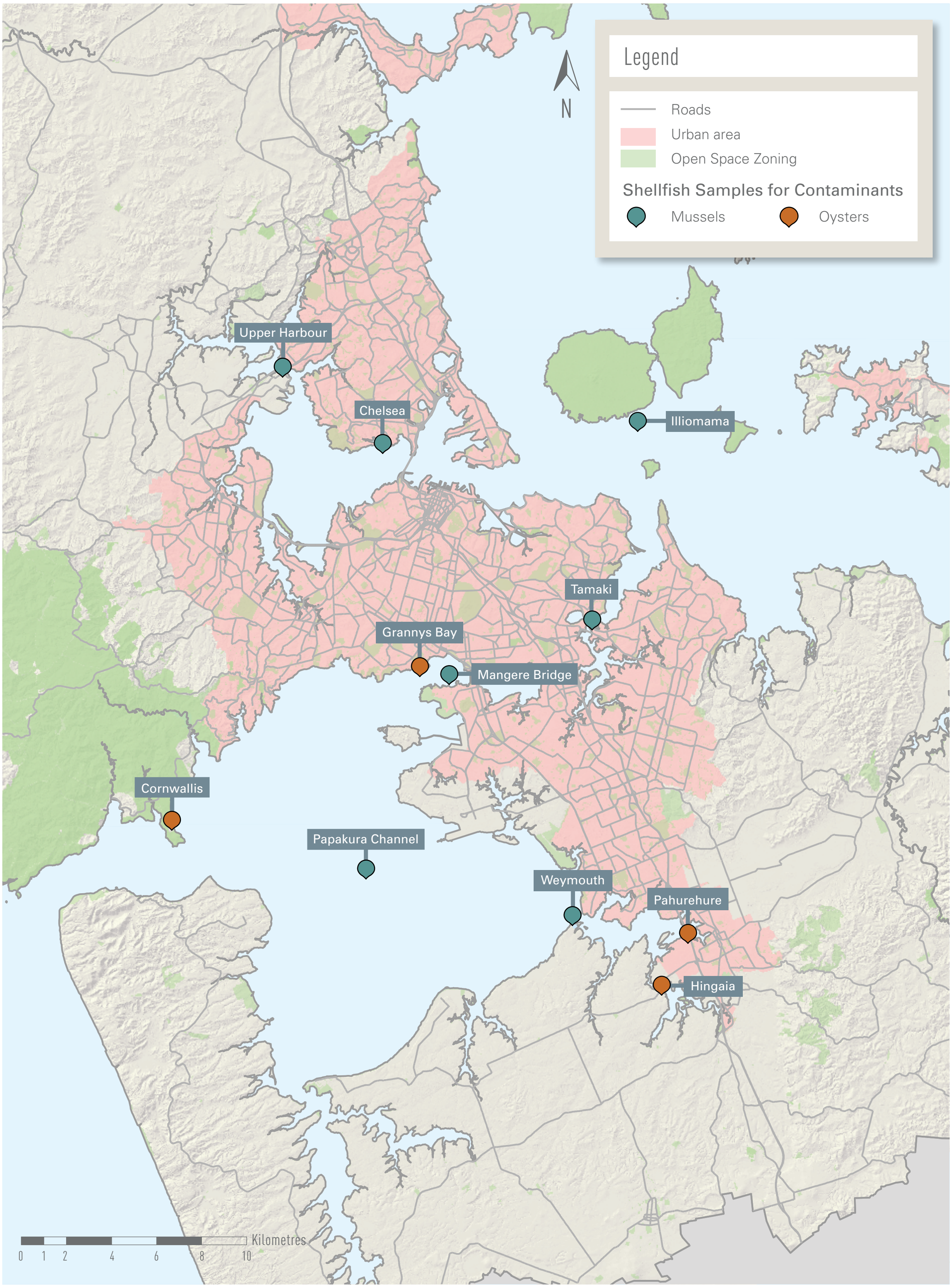

FIGURE 3 Location of monitoring sites for contaminants in shellfish.

Indicator 6: PAHs and organochlorines in shellfish

In general, levels of PAHs and organochlorines in shellfish tissues in the Auckland region were low in 2007 in comparison to international values. However, there were clear variations between monitoring sites.

The highest levels were generally detected in the Mangere Inlet and Tamaki estuary. Shellfish from the Waitemata Harbour had intermediate levels of PAHs and organochlorines and those from the outer Manukau Harbour had low to slightly elevated levels.

Long-term trends in the concentrations of PAHs and organochlorines were observed between 1987 and 2007, with a significant decline in the levels of lindane, chlordane and dieldrin in oysters from the Manukau Harbour following a ban on the use of these contaminants. Recent pulses (increases) in DDT, chlordane and PCB concentrations were observed in oysters from Mangere Inlet; which coincided with the decommissioning of the treatment ponds at the Mangere Wastewater Treatment Plant.

Implications of sediment and shellfish contamination

Some sites are contaminant hotspots because they have elevated levels of contaminants that are likely to be affecting the ecological health of that area. These areas tend to be muddy estuarine sites and tidal creeks that receive runoff from older urban catchments, particularly in the middle Waitemata Harbour and the upper Tamaki estuary. Generally contaminants are low or comparable to overseas examples.

There is a long-term trend which indicates increased concentrations of zinc in marine sediment, particularly at sites that are already contaminated. The highest accumulation rates for heavy metals were found at muddy, upper harbour urban sites. It is concerning that some sites have elevated levels of chemical contaminants. While many of the contaminant issues result from historic activities, there is still a need to slow the input and consequent accumulation of these contaminants in the marine sediments.

Many of the contaminant issues are the result of historical land use changes in older catchments (see History of environmental change in the Auckland region in the Introduction, pg 13). However, new contaminants are emerging as potential concerns although it is too early to know whether their levels are increasing or if they pose an environmental risk.

Ecological quality

Key findings

→ In general, our ecology monitoring programmes showed a clear pattern: the most degraded sites were found in sheltered coastal areas close to the oldest urban areas and the healthiest sites were found at the greatest distance from Auckland City centre.

→ Most sediment-dwelling communities close to urban areas (not just those at the known contaminant hotspots) were in relatively poor condition.

→ At present, the majority of monitored sites are not showing any significant changes. Their current state is more reflective of past impacts from historical land-based activities that delivered increased levels of sediment and contaminants to the marine environment.

Introduction

The varied marine environments around the Auckland region support a rich diversity of species. Any type of disturbance to the marine environment (such as a decline in the water quality or an increase in the amount of sediment deposition) can degrade the environment and act as a stressor, leading to changes in the types and numbers of organisms present.

In addition to the environmental impact resulting from one type of disturbance, it is important to note that marine organisms may be affected by more than one type of disturbance simultaneously (these may be the result of natural changes, changes resulting from human activities, or a combination of both). These multiple stressors can combine to produce an overall environmental impact that is much greater than that produced by simply adding up their individual impacts.

Marine ecology monitoring programmes

Effective management of marine ecosystems requires an understanding of the natural composition and abundance of communities, and information about whether these communities are stable, increasing or decreasing over time.

Given the importance of the marine environment and its ecosystems, it is vital to understand as much as possible about this complex natural resource. It is important to try and understand how these ecosystems are structured (e.g. the distribution of habitats) and how they work in relation to physical processes such as tides and waves, and their biological processes such as competition and predation. This is why the ARC undertakes or commissions research, and why it is important that the ARC works co-operatively with Crown funding agencies and other research providers.

We monitor marine ecology in different environments and in relation to different potential environmental pressures but it is not possible to monitor the full range of biodiversity within the Auckland region. Instead, the abundance and types of seabed dwelling (benthic) organisms found in coastal ecosystems provides a sensitive measure of ecosystem condition

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or health. Organisms in these communities form a significant component of the region's biodiversity and also provide an important food source for birds, fish and people. The ARC runs two monitoring programmes:

- The Benthic Health Model. This uses an established relationship between chemical indicators of environmental quality (using stormwater associated heavy metals) and the marine biological community.
- The Benthic Ecology Monitoring Programme. This monitors changes over time in the numbers and types of organisms that live in and on the muddy, sandy and rocky seabeds of regionally-representative harbours, estuaries and coastal areas.

The marine environment is extremely variable and, in order to determine whether changes in species or habitats are due to human-induced activities, natural processes or climatic variation, the ARC needs to understand this natural variability. Therefore, it is important to use consistent, long-term monitoring methods so that natural biological and climatic variations can be filtered out.

Benthic Health Model

The Benthic Health Model produces an index which defines the health of an ecological community at any one site, based on the range of ecological communities found along a gradient created by the concentration of metals in sediments.

The current focus of this monitoring programme is to detect the impacts of stormwater on ecological communities at coastal sites around the Auckland region.

Indicator 7: Benthic health in relation to stormwater

When developing the Benthic Health Model, the ecological community at 85 sites was sampled in 2002 and the model was used to assign an overall rank to each site. Since 2002, sites with higher contaminant levels were monitored on rotational basis. Sampling has not been going on long enough to analyse trends.

The results for all 85 sites are presented to provide an overview of benthic health in relation to stormwater contaminants (Figure 4). When sites have been sampled more than once, the most recent rank is shown. Each site is ranked on a five point scale, where 1 is healthy and 5 is degraded. Of the 85 monitoring sites:

- 10 sites were rank 1
- 8 sites were rank 2
- 22 sites were rank 3
- 32 sites were rank 4
- 13 sites were rank 5.

The ecological condition at the majority of sites was ranked as 3 or 4, indicating some level of environmental degradation. This contrasts with the results for sediment quality (where the majority of sites were ranked as 'green') because the sediment quality grades were for single contaminants and, in reality, organisms are exposed to multiple contaminants and stressors.

The location of sites and their relative ranking is shown in Figure 4. In general, sites that were the farthest from the city centre had the healthiest ecological condition although some sites in the Manukau Harbour such as Cape Horn, Clarkes Beach and Auckland Airport were also ranked as 1.

As was seen for sediment, sites in sheltered locations near the Auckland City centre had the poorest ecological condition with rankings of 5. Most of these sites are next to catchments that drain into the southern Waitemata Harbour and the Tamaki Inlet. Other sites with relatively poor ecological health (rankings of 4) were located in the upper Waitemata Harbour, Mangere Inlet and parts of Hobson Bay.

As expected, there was a strong relationship between the level of chemical contamination at a site and its ecological condition. In general, sites with low concentrations of metals in the sediment had ecological communities that were in good health while sites with high concentrations of metals in the sediment had ecological communities that were in poor health.

Benthic ecology monitoring programme

This monitors changes over time in the numbers and types of organisms that live in soft sediments and on intertidal and subtidal reefs, and was designed to be representative of the harbours, estuaries and reefs in the Auckland region. However, as each location is unique in terms of size, types of habitat, species composition and physical variables such as tidal flow and prevailing wind direction, it is difficult to make direct comparisons; consequently this programme focuses on changes at specific monitored locations.

Changes in the composition of the ecological communities can result from improving or declining environmental conditions. These changes may be related to natural variables such as cyclical patterns in recruitment (the addition of new individuals to a population) or a change in water temperature. However, other types of change (such as a loss of sensitive species due to chemical contaminants) may result from human activities.

Some species are known to be more sensitive to sediment and chemical contaminants than others, so a change in their abundance at a site can act as an useful indicator of the quality of the benthic environment at that site. For example, filter-feeding shellfish are sensitive to suspended sediment.

The ARC monitors:

- intertidal sandflats in the Mahurangi, central and upper Waitemata and Manukau Harbours,
- six subtidal reefs along the east coast of Auckland, as well as intertidal and subtidal sites at Meola Reef in the Waitemata Harbour,
- intertidal flats in seven estuaries along the east coast of the region (Puhoi, Waiwera, Orewa, Okura, and three arms of the Whitford embayment at Mangemangeroa, Turanga and Waikopua).

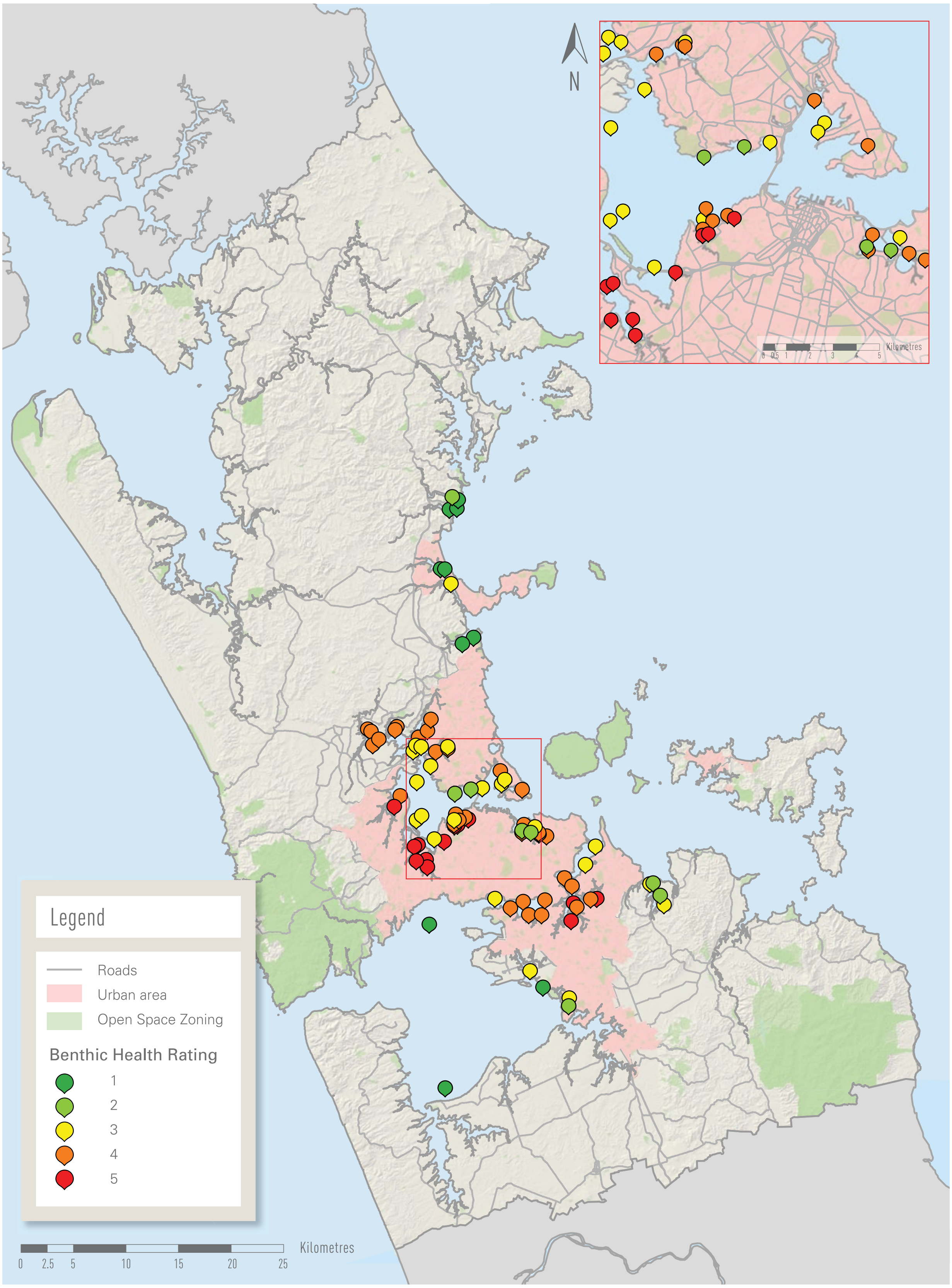

FIGURE 4 The rank of each site based on the results of the Benthic Health Model. Where sites have been sampled on more than one occasion, the results shown here are from the most recent sampling time. (Source: ARC).

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Indicator 8: changes in soft sediment communities

Central Waitemata Harbour (2000 to February 2008).
All sites showed minimal changes in sediment grain size since monitoring began but much larger changes occurred in the composition of the ecological communities. This suggests that the changes in sediment grain size were not contributing to the ecological changes in the central Waitemata Harbour.

A number of species showed both increasing and decreasing trends but monitoring has not been going long enough to suggest the causes. However, based on our knowledge of the sensitivities of the species that are showing trends, the changes in their numbers are unlikely to be caused by chemical contamination.

Upper Waitemata Harbour (2005 to February 2008).
Few consistent, seasonal patterns in changing abundances across the monitoring sites were observed. Similarly, few continuous changes in the numbers of species was observed, although the species composition at two sites was changing slightly. Monitoring has not been going long enough to identify longer term trends.

Mahurangi Harbour (1994 to January 2009).
Changes in the ecology of the harbour were noted in the first six years of monitoring with many of those changes being consistent with elevated levels of sedimentation or organic enrichment. Monitoring has continued and three species that are sensitive to increased suspended sediment concentrations are declining in abundance (Table 4).

Two ecologically important bivalve species – the wedge shell (*Macomona liliana*) and cockle (*Austrovenus stutchburyi*) – and a polychaete worm (*Scoloplos cylindrifer*) continued to decline in abundance at Hamilton Landing, the muddiest site. Decreasing trends in abundance were also detected for cockles and the nut shell (*Nucula hartvigiana*) at Te Kapa Inlet, and for the wedge shell at Mid Harbour. These declines may be related to continuing sedimentation or to a time lag between past sedimentation and ecological effect. Continued expansion of the muddy portion of the Te Kapa Inlet site has been noted.

More positively, the decline in abundance of wedge shell populations at some sites in previous years was no longer apparent, due to significant recruitment. Although this was encouraging, much of this apparent recovery was due to a couple of large recruitment events. The high number of juveniles did not survive and there were very few adult-sized individuals.

Numbers of horse mussels (*Atrina zelandica*) were still low and their sizes had not increased much over the past two years: it is possible that the growth of these populations was slowing as individuals aged and reached their maximum size.

Manukau Harbour (1987 to February 2009).
Although changes in the abundances of species have occurred at the monitoring sites in the harbour, long-term data reveal that many of these changes were part of long-term cycles related to cyclic climate patterns. There was no evidence to suggest any detrimental effects on the health of the ecosystem within the extensive intertidal flats that make up the main body of the Manukau Harbour, although impacts on some tidal creeks are evident.

TABLE 4 Summary of monitored organisms showing trends in abundance at Mahurangi monitoring sites and their sediment preferences. Sites are arranged in order with the least sediment mud content on the left, and the muddiest on the right of the Table. S = prefers sand, ⇩ = decreasing trend, ⇧ = increasing trend, * = no trend. (Source: ARC).

Sed pref	Taxa currently showing trends	Jamieson Bay (least muddy)	Mid Harbour	Te Kapa Inlet	Cowans Bay	Hamilton Landing (most muddy)
S	Austrovenus stutchburyi	*	*	⇩	*	⇩
S	Macomona liliana	*	⇩	*	*	⇩
S	Nucula hartvigiana	*	⇧	⇩	*	*
S	Scoloplos cylindrifer	*	*	*	*	⇩
I	Aricidea sp.	*	*	*	*	⇧
I	Arthritica bifurca	*	⇧	*	*	*
I	Cossura consimilis	*	*	⇧	⇩	⇧
I	Heteromastus filiformis	*	*	*	*	⇧
I	Nemerteans	*	*	*	⇩	*
I	Polydorids	⇩ (S)	*	⇩	*	⇩
I	Prionospio aucklandica	*	*	⇩	*	*

The most significant changes observed over the monitoring period occurred at Cape Horn. Changes at this site between 2001 and 2005 were, largely, those that had been predicted to occur as a result of improved wastewater treatment (a reduction in the abundance of suspension feeders, reduced silt levels and reduced chlorophyll a concentrations). However, at least some of the changes appear to have been influenced by the strong El Niño Southern Oscillation (ENSO) event that New Zealand had experienced at this period. This finding illustrates the importance of long-term datasets, which enable changes related to anthropogenic activities to be identified against a background of natural climatic variation.

East coast estuaries (2000 to Apr 2007).
Communities at individual sites and individual estuaries remained stable over the monitoring period. The overall diversity, abundances and sizes of individual bivalve species such as cockles, wedge shells and pipi all remained stable. Variation in the structure of the benthic communities was greater for monitoring sites within estuaries than among estuaries.

Indicator 9: Changes in subtidal reef communities

Since 1999, the ARC has monitored subtidal rocky reefs annually along the east coast of the Hauraki Gulf (including those at Waiwera, Stanmore Bay, Little Manly, Long Bay, Torbay and Campbells Bay) in order to detect any changes in ecological communities, particularly in relation to potential development pressure along this coast. Meola Reef within the Waitemata Harbour is also monitored. The west coast of the Auckland region has very limited subtidal rocky reef and little is known about these particular habitats because the wild, exposed nature of this coastline makes it very difficult to study.

On a regional scale, the east coast sites are all comparatively sheltered from wind and waves due to the influence of the Coromandel and Whangaparaoa peninsulas, as well as Great Barrier Island and the inner Hauraki Gulf islands. Subtidal rocky reefs in the mid Hauraki Gulf differ from the more exposed rocky reefs in the outer Hauraki Gulf at Leigh and Tawharanui, mainly due to the changes in wave exposure and presence of sedimentation that influence the composition of the ecological communities. When there is less wave action, sediment has more influence on the composition (and therefore the physical structure) of reef communities.

The two most wave exposed monitoring sites; Waiwera and Stanmore Bay, contained the most distinctive community assemblages. The remaining sites have similar exposure levels and showed considerable overlap in their community assemblages.

The structure of these ecological communities has remained relatively stable over time although some patterns are emerging around changes in species and the coverage of sediment. However, these require further investigation before any conclusions can be drawn.

Implications of ecological quality

The ARC's ecological monitoring programmes showed a clear pattern: the most degraded sites were found in sheltered coastal areas close to the oldest urban areas and the healthiest sites were found at the greatest distance from Auckland's city centre.

At present, the majority of monitored sites are not showing any significant trends of concern, and their current environmental state is more reflective of the impacts from historical land-based activities that delivered increased levels of sediment and chemical contaminants to the marine environment. However, trends in Mahurangi Harbour are of concern as they continue to show changes in ecology that are associated with increased levels of sediment. These declines may be because sediment is still being generated, or there may be a time lag between existing sediment supply and ecological impact. More positively, the recruitment of some species that has occurred highlights the potential for recovery in some areas of the harbour if sediment supply is reduced.

Multi-year cycles (that span more than one year) were identified for several benthic species in the Manukau Harbour at sites where monitoring has occurred for the past 20 years. This has allowed the source of natural variability to be distinguished from changes that are caused by human activity. This finding illustrates the real value of long-term datasets. Weather patterns in the Auckland region can be affected by multi-year factors such as the ENSO and temperature trends from climate variability. Gradual impacts from human activities cannot be distinguished from natural multi-year cycles without continuous long-term datasets. Ongoing monitoring is, therefore, crucial in order to gain an understanding of potential cumulative impacts and long-term natural patterns in the region.

Exotic marine species

Exotic species are non-native species that are known, or suspected, to have been deliberately or accidentally introduced to the marine environment. These can include organisms such as fish and plants, as well as diseases. The introduction of new species has the potential to impact the existing ecology, and commercial and social activities.

In the marine environment, there are two main sources of new exotic species:

- → ships' ballast water (the water carried within a ship and used as a weight to stabilise it)
- → bio-fouling (organisms attached to ships' hulls).

Bio-fouling can potentially introduce new organisms into New Zealand and can also help to spread exotic species around the country. This spread may be helped by the transport of equipment associated with coastal structures and aquaculture.

New Zealand's largest commercial port, the Ports of Auckland, is established in the Waitemata Harbour in Auckland. This harbour is also a popular destination for national and international yachts and cruise liners and is, therefore, at risk from the potential arrival and establishment of new marine species.

MAF Biosecurity New Zealand (MAF BNZ) holds responsibility for co-ordinating efforts against the introduction of unwanted pests and diseases through border control, surveillance and response.

The arrival of exotic species is not a new phenomenon and a number of exotic marine species are already established nationally. In 1998, 159 exotic marine species were recorded around New Zealand. Of these, 148 were introduced

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accidentally, mostly through ballast water and bio-fouling, and about 90 per cent had established permanent populations. Comprehensive data on the number and extent of marine pests within the Auckland region is not available. However, in 2003, MAF BNZ found 13 exotic species in the Auckland port area, 24 species whose geographic origins were uncertain and 22 species that could not be identified.

Within the Waitemata Harbour, more than 66 introduced species have been recorded, with many well-established and widespread. A number of more recent incursions have occurred, including species listed by MAF BNZ as unwanted organisms.

Although any exotic species entering the marine waters of the region poses a risk, MAF BNZ's main focus is on the following six specific unwanted marine species:

→ Chinese mitten crab (*Eriocheir sinensis*)

→ Mediterranean fanworm (*Sabella spallanzanii*)

→ Northern Pacific seastar (*Asterias amurensis*)

→ European shorecrab (*Carcinus maenas*)

→ Asian clam (*Potamocurbula amurensis*)

→ Caulerpa taxifolia (a seaweed).

Conclusions on the state of the marine environment

The Auckland region's marine environment is highly diverse and consequently there is a large variation in both the physical conditions and the biological diversity.

Overall, the coastal water around the region showed significant, improving trends in water quality, with reduced levels of faecal indicator bacteria, suspended solids, total phosphorus, soluble reactive phosphorus and nitrate. Most of these improvements were consistent with decreased anthropogenic pressures. However, it is of concern that water quality was declining at some sites rated Good and Excellent for coastal water quality (particularly for nutrients and suspended sediments). It is too early to tell if these changes are strongly linked to land management practices.

The quality of the coastal water is poorest at inner harbour monitoring sites but is relatively good in outer harbour or open coastal locations. Open coast sites had the best coastal water quality, primarily due to strong tidal flushing, their distance from freshwater inputs and isolation from contaminants resulting from urban land uses. Inner harbour sites tended to have the poorest water quality because of their proximity to freshwater inputs that carry contaminants from land and less flushing.

When the results of the three main monitoring programmes are considered together, the pattern that emerges reflects past inputs of sediment and contaminants from historical urbanisation and industrial activities. There is a trend for sites close to more rural catchments to show declining water quality and declining ecological heath, possibly reflecting the continued input of sediments and nutrients from associated land management practices in these areas.

Marine ecosystems are clearly affected by any type of land-based activity that generates material that is discharged into the coastal environment through the stormwater or wastewater networks or by direct overland runoff. Therefore, in order to successfully manage the marine environment it is essential to monitor and manage land based activities in the contributing catchments.

Although some nearshore coastal areas are showing signs of degradation associated with land use activities, the majority of the marine environment in the region still retains its biological diversity and functioning ecosystems. It is important to recognise their value and continue to invest in the management of these ecosystems, in order to maintain this valuable resource and broad spectrum of values they underpin or provide directly.

Heavy metal contaminant levels are highest in estuaries and tidal creeks within the oldest and most urbanised catchments, particularly those with industrial land use activities. Chemical contaminants are also increasing most rapidly in the most contaminated areas. There are some hotspots where the chemical contaminant levels in the sediment are likely to be having negative effects on the health of the ecological communities in those areas.

The Benthic Health Model Index shows that most of the benthic ecological communities close to urban areas (not just those at the known hotspots) are in relatively poor condition. There is strong evidence that their health is being affected by the cumalitive impact of chemical contaminants at levels lower than those predicted by available guidelines. This is causing concern as chemical contaminant levels are predicted to increase in the future, suggesting that the impact on ecological communities close to urban catchments may become even more intense.

Sedimentation is a concern in the region and is an issue that may increase in importance in more rural areas in the future, as shown by the increasing levels of sediment or nutrient loads at some sites that presently have the best water quality. Some locations in the Mahurangi Harbour show a continuing decline in species that are sensitive to sediment.

Case Study: The quality of freshwater and marine environments

The ARC undertakes region-wide monitoring of water quality in both freshwater and marine environments as part of its state of the region monitoring (see Sections 4.3 and 4.4).

What happens on land, flows down streams and subsequently ends up in the sea. For example, contaminants used on land (for, agriculture, forestry or industry) enter rivers and eventually discharge into harbours and estuaries.

Eight water quality parameters are common across the freshwater and marine water quality monitoring programmes. Unsurprisingly, the marine water quality monitoring programme results closely mirror those observed in the freshwater programme.

Across the region, from the early 1990s until the mid 2000s results show:

- → Concentrations of some sediment-related variables, such as suspended sediment and total phosphorous decreased at most monitored freshwater and marine sites (Table 1).
- → Concentrations of bacteria (faecal coliforms), nitrate, soluble reactive phosphorous decreased in both environments.
- → Trends in ammonicial nitrogen were more variable with some sites decreasing and some sites increasing.
- → Varied turbidity (water clarity) results with decreases in freshwater environments and no consistent trend identifiable for marine sites.
- → A region-wide increase in water temperature at both marine and freshwater sites.

TABLE 1 Trends in water quality parameters recorded in both freshwater and marine monitoring programmes. Green arrows indicate improvements (or parameters decreasing), red arrows indicate deteriorating conditions (or parameters increasing) and white arrows indicate no change.

Parameter	Freshwater sites	Marine sites
Faecal coliforms	⇩	⇩
Ammonicial nitrogen	⇔	⇔
Nitrate	⇩	⇩
Soluble reactive phosphorous	⇩	⇩
Temperature	⇧	⇧
Total phosphorous	⇩	⇩
Suspended sediment	⇩	⇩
Turbidity	⇩	⇔

Rangitopuni Creek is a test site located in the upper Waitemata Harbour. Here, freshwater and marine water quality parameters are sampled at different sites in the creek and results showed improving water quality from the early 1990s to the mid 2000s. We have observed a reduction in the concentrations of five of the eight parameters listed in Table 1 (faecal coliforms, the two phosphorous species (total and soluble), suspended sediment and turbidity). The complexity of the relationship between water quality, climate and human activities makes it difficult to determine the exact causes of water quality changes; however, the observed improvements are likely to result, in part, from improvements in land and waste management.

Data from the water quality monitoring programmes have enabled us to demonstrate regional improvements in the condition of freshwater and marine environments both regionally and on a smaller scale at individual sites. Although there have been improvements there is still much work to do to ensure the continued recovery and sustainable use of our streams, rivers and marine waters.

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