Auckland Regional Council

09

State of the Auckland Region

OUR REGION, OUR FUTURE

Auckland Regional Council
TE RAUHĪTANGA TAIAO

4.0

State of the environment and biodiversity

Part 3 discussed the pressures that are put on the environment in the Auckland region and what the ARC is doing to respond to those pressures.

This part discusses how those pressures are impacting different aspects of the natural environment and the present state of the air, land, freshwater and marine environments in the Auckland region, as well as terrestrial biodiversity.

It also discusses the ARC's responses to the pressures.

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State of the environment and biodiversity – Air

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4.1

Air

Introduction

Clean air is a precious, natural resource that is essential to life. New Zealand's isolated position in the South Pacific means that air arriving at the coastline is relatively pure and fresh (Figure 1). However, it is rapidly degraded by many daily activities that release chemicals and particulates into the air as pollutants. These air pollutants can damage human health, cause unpleasant smells and produce hazy days that reduce air clarity.

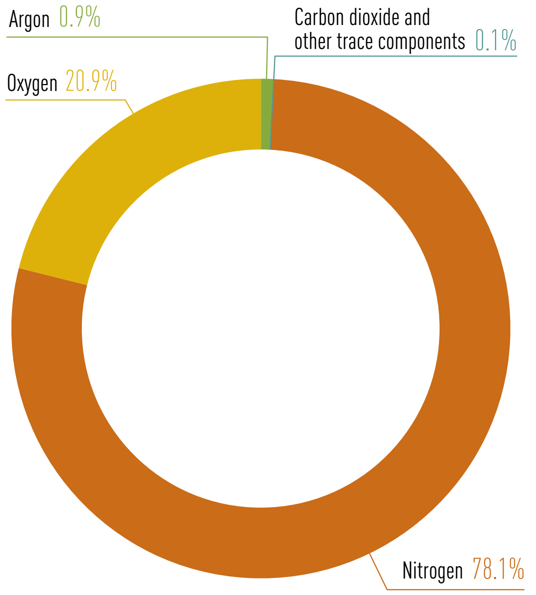

FIGURE 1 Composition of clean air arriving at New Zealand. (Source: NIWA).

Urban areas tend to experience a higher level of air pollution because many air pollutants originate from concentrated sources such as motor vehicles, urban, and industrial activities. The major sources of air pollution in the Auckland region include the combustion of fuels such as wood, gas, oil; diesel and petrol in vehicles, domestic fires and industrial processes.

The cleanliness of the air is measured by the ambient air quality, which depends on:

- the amount of pollution released into the air by human and natural activities,
- the amount of dispersion due to wind and weather,
- complex chemical reactions that can occur between pollutants.

On average, everyone in the Auckland region breathes 11,000 litres of air each day (based on a typical resting breathing rate of 7.5 litres per minute); a huge volume when compared to the two to three litres of water that each person drinks. The breathing rate rises to about 30 litres per minute when walking, and can reach 80 litres per minute during strenuous exercise, so an active person may require more than 14,000 litres of air each day.

Key findings

- The transport sector is the predominant contributor to air pollution but domestic fires are also a significant source of air pollutants during winter.
- The PM_{10} and $PM_{2.5}$ particulate concentrations exceed air quality standards and guidelines. Annual PM_{10} particulate concentrations showed a generally decreasing trend but this has levelled off in recent years. The trend for $PM_{2.5}$ particulates is not so clear.
- NO_2 concentrations at peak traffic sites exceed air quality standards and guidelines.
- Levels of CO, SO_2, ozone, benzene and lead currently comply with air quality standards and guidelines.
- Air pollution costs at least $547 million each year in health costs. The levels of PM_{10} particulates are of the most concern and cause the worst health problems, particularly those from diesel combustion.
- Emissions of PM_{10} and $PM_{2.5}$ particulates and NO_2 all need to be reduced substantially.

Air quality monitoring programme

The ARC is responsible for ensuring that the outdoor air in the Auckland region is clean and healthy to breathe. Therefore, it needs to have a sound scientific understanding of the current pollutant levels, any long-term trends and the sources of the pollutants so that the ARC can manage the air quality effectively and help reduce the level of pollutants in our air.

The ARC monitors the main air pollutants, which are PM_{10} and $PM_{2.5}$ particulates, nitrogen dioxide (NO_2), carbon monoxide (CO) and ozone (O_3).

Air quality monitoring has been undertaken for many years within the Auckland region. This means that the ARC can use the annual averages, seasonal trends and spatial trends to indicate how concentrations of different pollutants are changing over time and to detect any long-term trends.

There are some limitations to our monitoring programme – the ARC cannot monitor every air pollutant. A range of different pollutants are released into the air and the main pollutants monitored are only a subset of this range.

Other limitations include:

- pollutants may undergo chemical reactions in the air, producing other types of pollutants that may be more harmful to human health,
- any synergistic effects on human health from two or more pollutants are not considered,
- monitoring is carried out only at 'typical' locations that are chosen to best represent the whole Auckland region and therefore may not cover other locations where people are exposed to relatively high levels of air pollution.

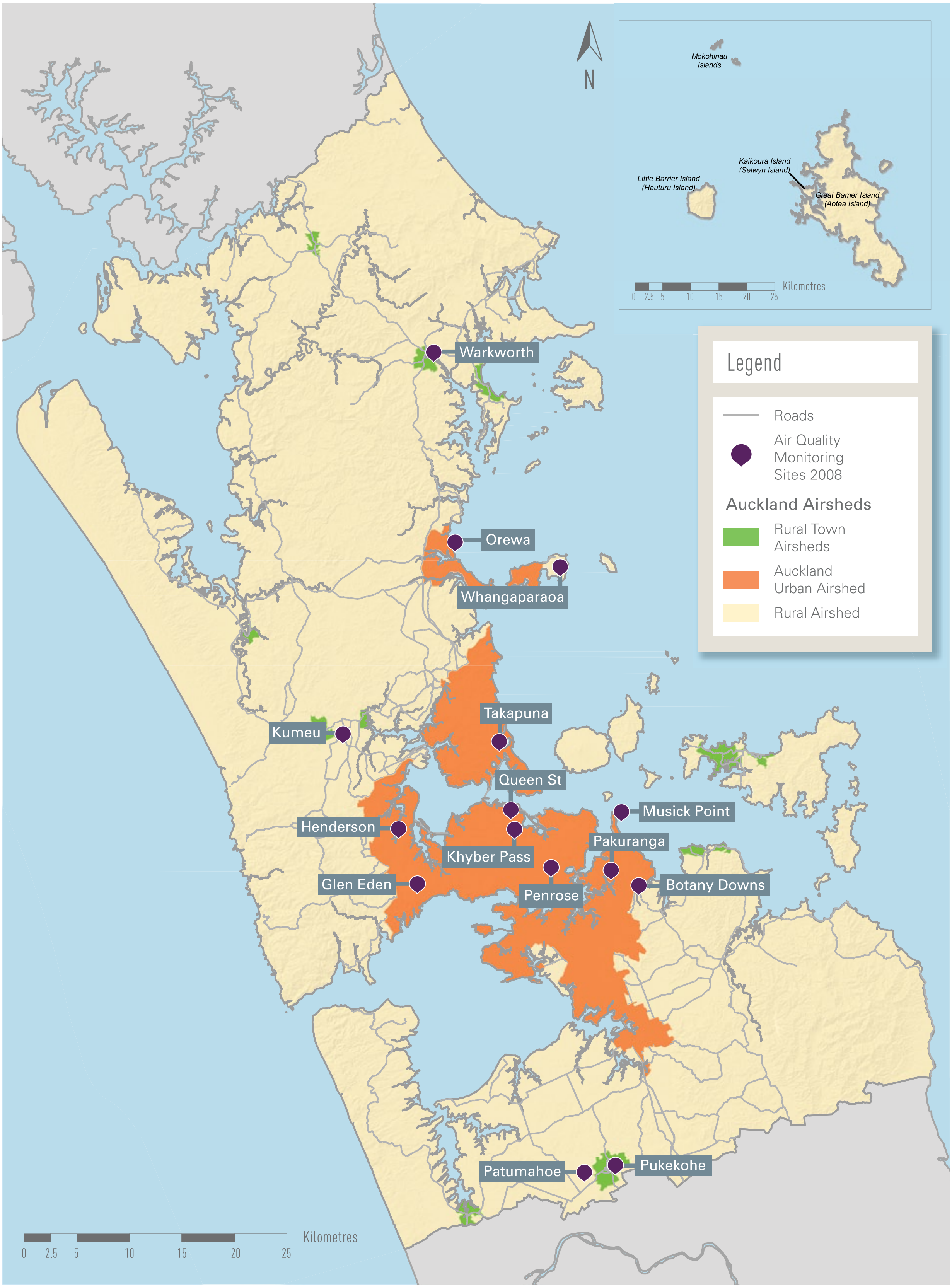

FIGURE 2 Location of the ARC air quality monitoring sites, and airsheds, in the Auckland region in 2008. (Source: ARC).

4.1

Air

Monitoring sites

The ARC continuously monitors several air pollutants at 15 sites spread across the Auckland region, ranging from Pukekohe to Warkworth, and Henderson to Botany Downs (Figure 2). MfE shares funding at two sites. These sites are selected to represent a variety of pollutant sources and exposures.

Peak traffic monitoring sites are located 2 to 3m from the roadside. These monitoring sites provide the ARC with an indication of the level of pollution that pedestrians and people who work close to busy roads are exposed to.

Urban or suburban residential area monitoring sites are located at least 10m from the roadside to represent areas where people live, work, study or play.

Industrial monitoring sites are located in industrial areas.

Rural areas are also monitored because they can be affected by air pollution from urban areas and because some rural activities can lead to air pollution.

The ARC also undertakes passive sampling of some particular air pollutants from time to time. This involves exposing passive samplers, e.g. an activated filter paper, to the air for a period of time and analysing them later to see how much of the pollutant was in the air. The pollutants measured this way nitrogen dioxide (NO_2), sulphur dioxide (SO_2), benzene, toluene, ethylbenzene and xylene.

Passive sampling is a useful survey method that can be used to show spatial distributions and long-term trends, but the results are not measured against the air quality standards and guidelines.

Air quality guidelines and standards

The Ministry for the Environment (MfE) has published air quality guidelines under the RMA. These identified the maximum acceptable concentrations for specified air pollutants in order to protect both human health and the environment, and were based on recommended guidelines from the World Health Organisation (WHO).

These guidelines were updated in 2002 and include the following air pollutants:

- → nitrogen dioxide (NO_2)*
- → PM_{10} and $PM_{2.5}$ particulates*
- → carbon monoxide (CO)*
- → sulphur dioxide (SO_2)*
- → hydrogen sulphide (H_2S)
- → ozone (O_3)*
- → benzene*
- → 1-3 butadiene*
- → benzo(a)pyrene
- → formaldehyde
- → acetaldehyde
- → lead*
- → chromium (VI, III and Cr metal)
- → mercury (organic and inorganic)
- → arsenic (inorganic)
- → arsine.

Target levels for all of these air pollutants are included in the Proposed Auckland Regional Plan: Air, Land and Water and those marked* are monitored in the Auckland region.

Box 1 National Environmental Standards (NES) for air quality

The National Environmental Standards (NES) for air quality were introduced by the Government in 2004 and then amended in 2005. They contain 14 individual standards or regulations that apply to all of New Zealand.

Seven of these standards ban activities that discharge unacceptable levels of dioxins and other toxic substances into the air. Prohibited activities include open burning of tyres, coated wire, oil, bitumen (for road maintenance) and waste at any landfill, as well as new school or healthcare incinerators (unless a resource consent is obtained) or any new high-temperature incinerators for hazardous waste.

Five of the standards impose ambient air quality standards for:

- → carbon monoxide (CO)
- → PM_{10} particulates
- → nitrogen dioxide (NO_2)
- → sulphur dioxide (SO_2)
- → ozone (O_3).

The NES ambient standards define the permissible concentrations of contaminants in the air over a specified time and the number of annual allowable exceedences. There are also NES for new small-scale domestic wood burners and MfE has since identified a list of compliant appliances. MfE prohibits discharges from non-compliant wood burners from sections of two hectares or less (although discharges from open fires and other forms of burners are not prohibited).

Another standard prohibits the release of gas from large landfills unless the landfill has a system that can collect this gas and has been designed to meet specified requirements.

In 2004, MfE also introduced National Environmental Standards (NES) to improve air quality and protect the health of the general population (Box 1). These standards are regulations issued under sections 43 and 44 of the RMA and were effective from 1 September 2005. They apply to ambient (outside) air everywhere.

The NES use only one averaging period for each of the five specified air pollutants and include a number of exceedences that are allowed per year.

An exceedence occurs when the concentration of an air pollutant exceeds the permitted level in the standard or guideline. When the number of exceedences in a year is more than that allowed by the standard, this is known as a breach of the standard.

Airsheds

The ARC has also identified areas where the air quality is already known to exceed – or is likely to exceed – the air quality standards, either now or in future. These areas are designated as separate airsheds (by notice in the New Zealand Gazette, the official newspaper of the Government of New Zealand) and are the focus of our air quality management programmes.

The Auckland region has 12 gazetted airsheds (Figure 2):

- → The urban airshed covers most of urban Auckland and was formalised on 1 September 2005.
- → Eleven rural town airsheds cover the urban areas of the larger rural and coastal settlements in the Auckland region and were formalised on 1 July 2007.

The remainder of the Auckland region forms the Auckland rural airshed.

Air quality

The following pollutants have been chosen to indicate the quality of the air in the Auckland region and to identify long-term trends:

- → PM_{10} and $PM_{2.5}$ particulates
- → nitrogen dioxide (NO_2)
- → carbon monoxide (CO)
- → ozone (O_3)
- → sulphur dioxide (SO_2).

Benzene, lead and 1-3 butadiene are also measured on a long-term basis at one or more sites in Auckland.

All of these air pollutants are monitored because they are known to endanger human health and well-being and their levels can be compared to the air quality standards and guidelines.

Visibility can also be used as a subjective indicator of air quality.

Daily trends also reveal how concentrations of some air pollutants vary during the day, depending on the weather and the sources of pollution.

Fine particulates (PM_{10} and $PM_{2.5}$)

PM_{10} and $PM_{2.5}$ particulates are tiny solid and liquid particles that are suspended in the air but are invisible to the human eye.

They can be produced from natural sources such as pollen, bushfires, sea spray, windblown dust and secondary particulates, which are formed in the air by chemical reactions. They are also produced by human sources such as domestic fires, industrial activities, motor vehicle emissions, tyre and brake wear and from re-suspended road dust.

PM_{10} particulates are less than 10 micrometres (10^{-6}m or µm) in diameter, about one fifth the width of a human hair. PM_{10} particulates can stay suspended in the air for over a month and can affect visibility by creating a haze over large areas. They can also contribute towards the soiling and corrosion of buildings.

PM_{10} particulates can be inhaled easily. They lodge in the lungs and can adversely affect human health, especially for people who are asthmatic or have heart or lung disease. They can contribute towards heart attacks, strokes, respiratory diseases and can reduce lung function leading to premature deaths, hospitalisation, increased medication and days off work or school. PM_{10} particulates can also carry carcinogenic materials into the lungs.

$PM_{2.5}$ particulates are a smaller fraction of the larger PM_{10} particulates, with a diameter under 2.5 micrometres. They have the same effects as PM_{10} particulates but, because they are much smaller, can penetrate more deeply into the tiny air sacs in the lungs so their adverse health effects are greater.

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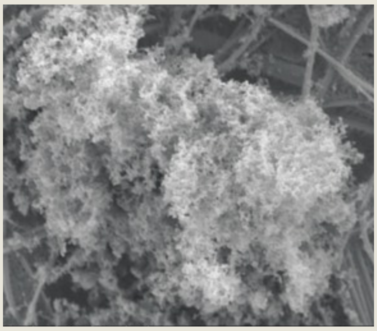
Box 2 What do the particulates look like?

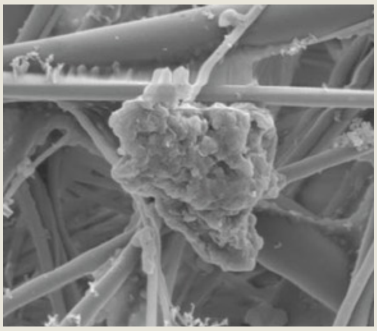
PM_{10} particulates (less than 10 micrometres) and $PM_{2.5}$ particulates (less than 2.5 micrometres) are mixtures of different particulates that have many shapes and sizes. The particulates also have different compositions depending on their origin. The types of particulates that the ARC has found on our filters included:

- combustion particulates
- salt crystals (sodium chloride)
- mineral material (e.g. soil, silt, clay dust)
- other crystals – possibly calcium sulphate (gypsum)
- seeds, spores and pollen (mainly basidiospores from fungi).

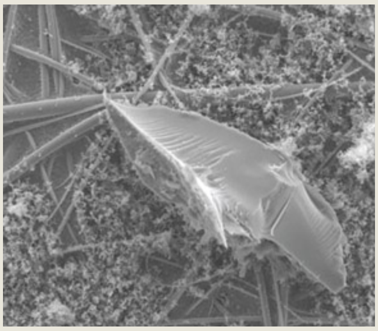
PM_{10} and $PM_{2.5}$ particulates are so small that they are invisible to the human eye. Some magnified examples are shown here:



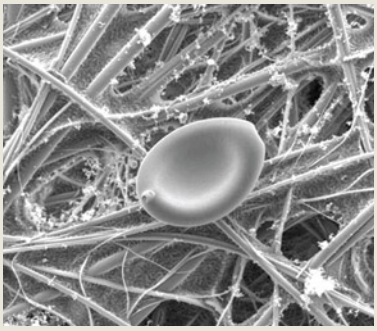
Combustion particle at Takapuna



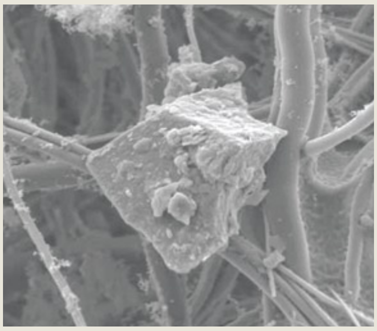
Mineral material at Kingsland



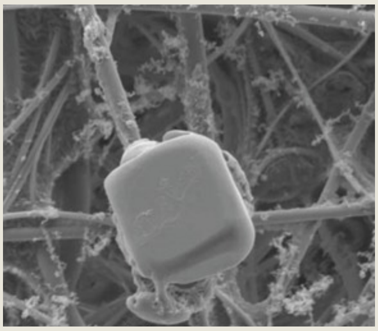
Glass fragment at Khyber Pass Road



Fungal spore at Khyber Pass Road



Mineral material at Takapuna



Salt crystal at Khyber Pass Road

The PM_{10} standard for the 24-hour average is 50 µg/m^3 with one allowable exceedence per year.

The PM_{10} guideline for the annual average is 20 µg/m^3.

The $PM_{2.5}$ monitoring guideline for the 24-hour average is 25 µg/m^3.

Safe levels of PM_{10} or $PM_{2.5}$ particulates have not been identified but adverse effects can occur at only 25 per cent of the levels given in the standards and guidelines, therefore people may be affected at much lower concentrations.

Diesel particulates are carcinogenic. They are the most toxic of all the PM_{10} and $PM_{2.5}$ particulates.

Sources of fine particulates

As discussed earlier, fine particulates can come from both natural and anthropogenic sources. The air emissions inventory (see Sources of air pollution in Part 3) can give the ARC information on the amount of particulates in the air generated by human activities (anthropogenic emissions) but does not give the ARC information on the amount of natural particulates. The ARC needs to understand this so that it can establish the reductions required to protect human health. Therefore, an extensive study has been undertaken on the composition of particulates in order to provide further information on both natural and anthropogenic sources, including their origin, variability and proportion of total particulate concentrations.

Figure 3 shows the average contributions overall from natural and anthropogenic sources to PM_{10} and $PM_{2.5}$ during summer and winter. Wood burning, motor vehicle emissions and sea salt were the most common sources of $PM_{2.5}$ particulates and PM_{10} particulates. Natural sources typically form a greater proportion of PM_{10} particulates than of $PM_{2.5}$ particulates. During winter, concentrations are usually higher and anthropogenic sources such as domestic heating and vehicle emissions contribute to a far greater proportion of the PM_{10} and $PM_{2.5}$ particulates.

The total sulphate contribution to PM_{10} particulates was similar to $PM_{2.5}$ particulates at around 10 per cent.

Dust was also present as a minor source at all monitoring sites, except at Penrose, where the dust included contributions from nearby industrial activities. Industry sources contributed minor quantities to PM_{10} and $PM_{2.5}$ particulates at Penrose and Takapuna (around 4-6 per cent of the total PM_{10}.)

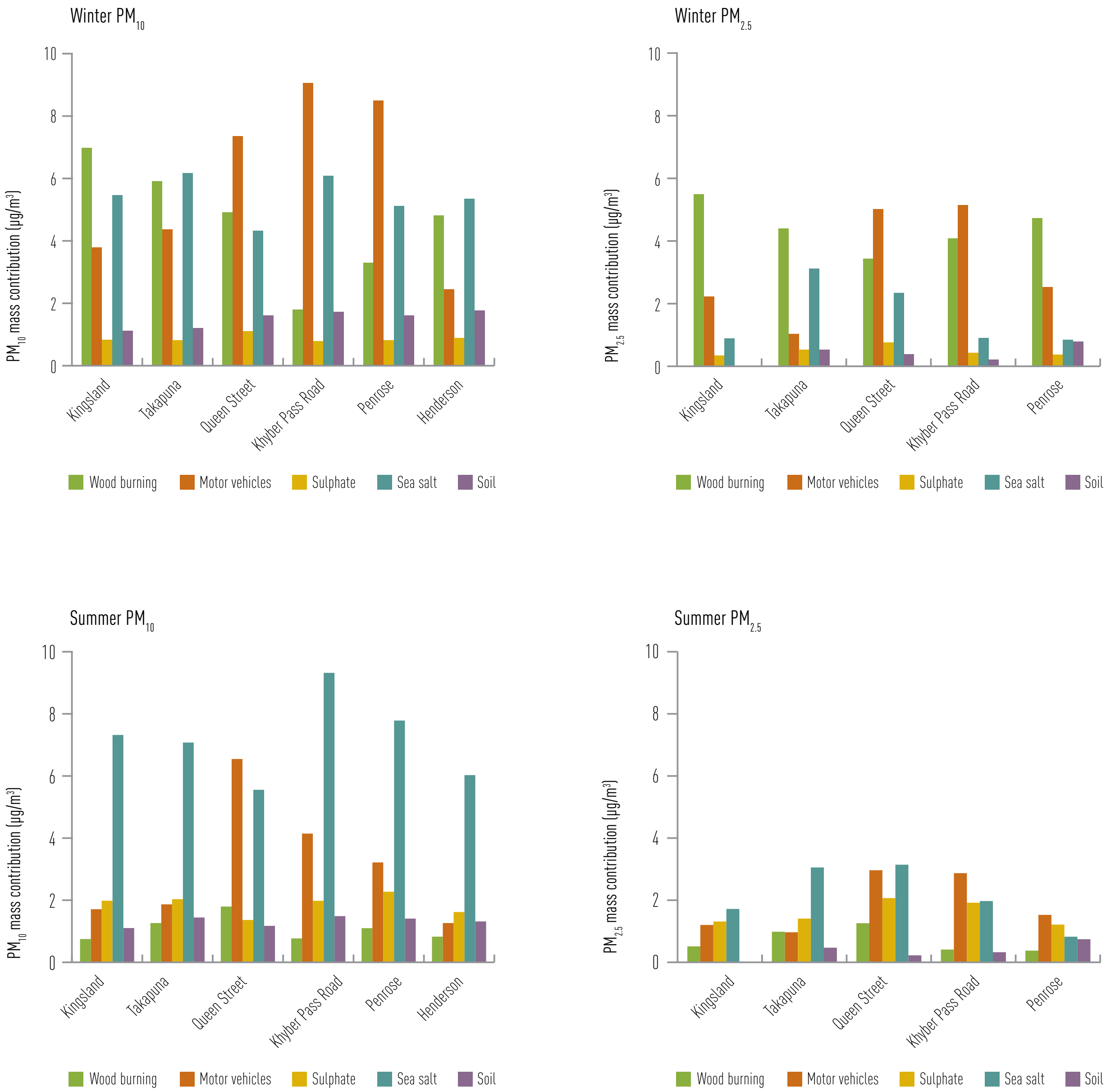


FIGURE 3 Average winter and summer contributions to PM_{10} and $PM_{2.5}$ at air quality sites in Auckland (excludes minor industry sources).

Air

Indicator 1: Concentrations of fine particulates

The PM_{10} and $PM_{2.5}$ particulate concentrations measured in the Auckland region exceed the air quality standards and guidelines.

Annual averages of fine particulates

Annual PM_{10} particulate concentrations at the Khyber Pass and Queen Street monitoring sites showed a generally decreasing trend but this has levelled off in recent years. Other sites have remained relatively static over the ten year period to 2008 (Figure 4).

Vehicle emissions and domestic fires are known to be the main sources of fine particulates in the Auckland region and, over recent years, significant improvements in both vehicle and fuel technology have been achieved. In addition, both new and used vehicles entering New Zealand now have to conform to minimum emissions standards that are becoming progressively tighter over time. This combination of factors will result in a gradual reduction of fine particulate emissions per motor vehicle in the near future. Unfortunately this reduction has been offset over the last few years (and will continue to be offset) by the growth in vehicle numbers, an increased number of kilometres driven and increasing age of the vehicle fleet (see Pressures: Transport, pg 75).

The use of solid fuels (wood and coal) for domestic fires in winter has been declining slowly but, due to the large number of residential domestic fires, solid fuels remain a significant source of particulate emissions.

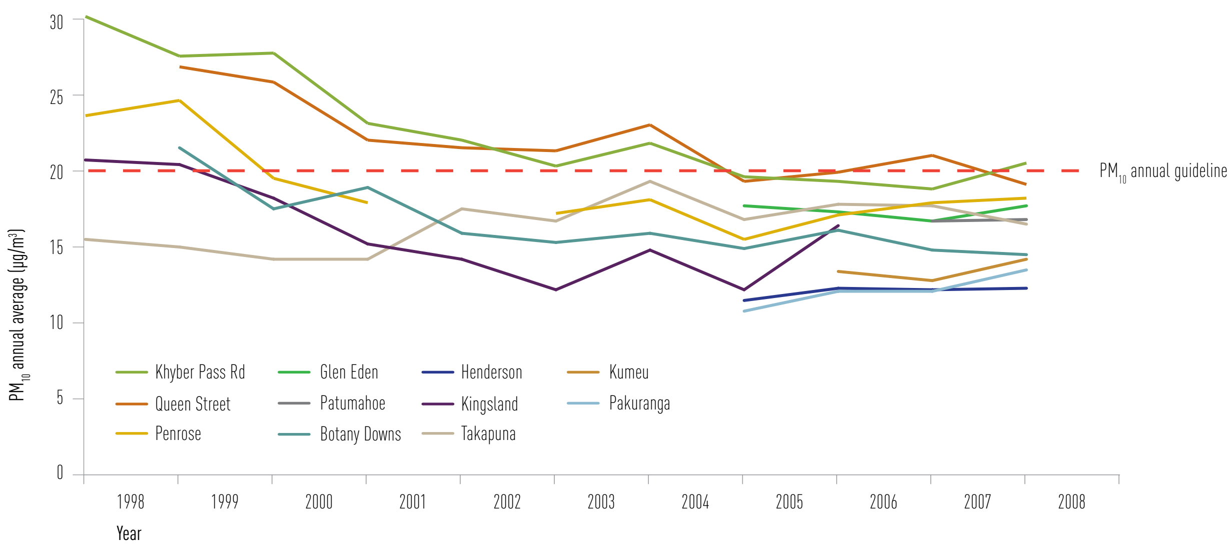


FIGURE 4 Annual averages of PM_{10} particulates in air, 1998-2008. The Kumeu site is in a rural town airshed, Patumahoe is in the rural airshed and the remaining sites are in the Auckland urban airshed. (Source: ARC).

Seasonal trends of fine particulates

PM_{10} and $PM_{2.5}$ particulate concentrations can be higher at some sites during winter, depending on the local sources of the particulates. However, it is also possible to get high PM_{10} particulate concentrations during summer and exceedences of the 24-hour standard can occur in any season.

In winter, wood burning and motor vehicle emissions were the primary sources of PM_{10} particulates at all the monitoring sites. Motor vehicle emissions dominated the roadside monitoring locations at Queen Street and Khyber Pass Road and wood burning was the primary source at the residential monitoring location in Takapuna.

During the other seasons, dust and sea salt were more likely to be found in the larger size fraction of PM_{10} particulates, particularly sea salt which is the dominant source at times.

Figure 5 shows the seasonal variations in natural and anthropogenic sources of PM_{10} particulates at the monitoring sites. Figure 6 shows the seasonal variations in natural and anthropogenic sources of $PM_{2.5}$ particulates in the monitoring sites.

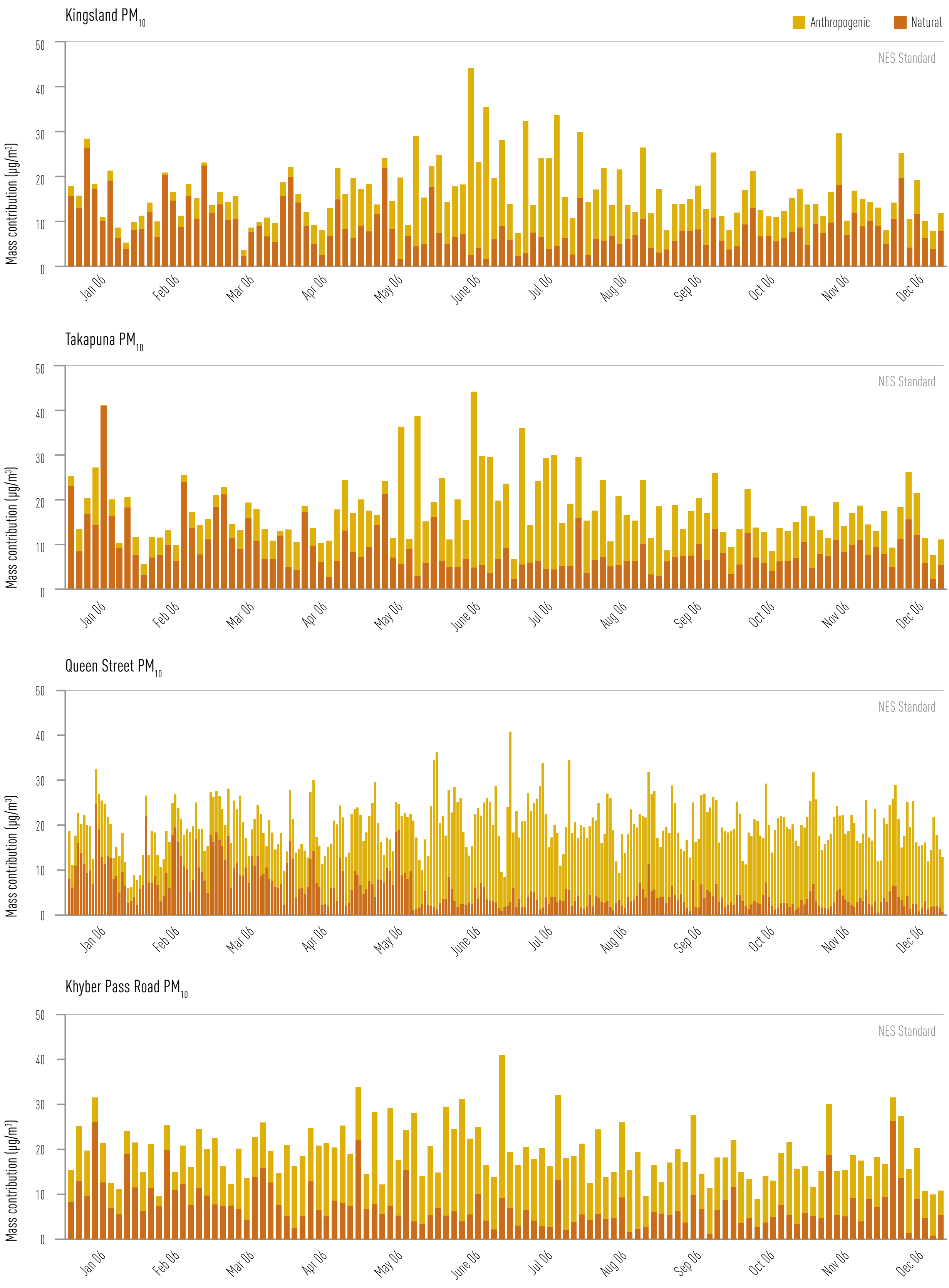


FIGURE 5 Seasonal variations in natural and anthropogenic sources of PM_{10} particulates at monitoring sites in 2006. (Source: ARC).

FIGURE 6 Seasonal variations in natural and anthropogenic sources of $PM_{2.5}$ particulates at monitoring sites in 2006. (Source: ARC).

Overall, domestic heating was shown to be the main contributor to both PM_{10} and $PM_{2.5}$ particulates at residential sites during winter.

Transport is the main contributor to both PM_{10} and $PM_{2.5}$ particulates at Queen Street and Khyber Pass Road in winter. In other seasons, transport is the main source of $PM_{2.5}$ particulates at Queen Street and Khyber Pass Road but not of PM_{10} particulates.

Motor vehicle emissions were the main source of $PM_{2.5}$ particulates during all the other seasons at all monitoring sites.

Sulphate and sea salt concentrations were highest during the summer at all monitoring sites.

The combination of a range of contributing sources results in less obvious seasonal trends for fine particulates in the Auckland region. This means that if particulate concentrations are to be reduced, measures that will reduce emissions from all sources (motor vehicles, domestic fires and industrial activities) need to be considered.

Nitrogen dioxide (NO_2)

Nitrogen dioxide is a brown, pungent, acidic gas which is mainly formed from the reaction of nitric oxide (NO) with ozone (O_3) in the air. These compounds may also react in the air for several days to form nitric acid as well as nitrate and nitrite particulates that form part of the $PM_{2.5}$ particulates.

NO and NO_2 are together referred to as nitrogen oxides (NO_x). Nitrogen oxides are formed by the combustion of fossil fuels (coal, oil and gas). Motor vehicles are a large source of NO_x in urban areas, mostly emitted as NO with some NO_2.

NO_2 can irritate the lungs and increase susceptibility to, and severity of, asthma and lower resistance to infections such as influenza. Long-term exposure to low levels of NO_2 can affect lung function growth in children and cause damage to some plants.

High levels of NO_2 can significantly affect visibility by contributing to the formation of haze and smog.

The NO_2 standard for the 1-hour average is 200 μg/m^3 with nine allowable exceedences per year.

The NO_2 guideline for the 24-hour average is 100 μg/m^3. The annual average guideline for protecting vegetation is 30 μg/m^3.

Indicator 2: Concentrations of nitrogen dioxide

Vehicle emissions are the main source of nitrogen oxides (NO and NO_2). NO then reacts with ozone and some volatile organic compounds (VOCs) (together referred to as oxidants) to form NO_2. Consequently, measured NO_2 concentrations at peak traffic sites exceed the standards and guidelines.

Annual averages of nitrogen dioxide

Annual average NO_2 concentrations have decreased at some sites but increased at others (Figure7). The annual average NO_2 concentrations are largely controlled by the oxidant (O_3) concentrations which have changed little over the years.

As a result, the average NO_2 concentrations have not shown significant changes within the Auckland region although reductions at the peak traffic sites reflect local changes in traffic patterns and profiles.

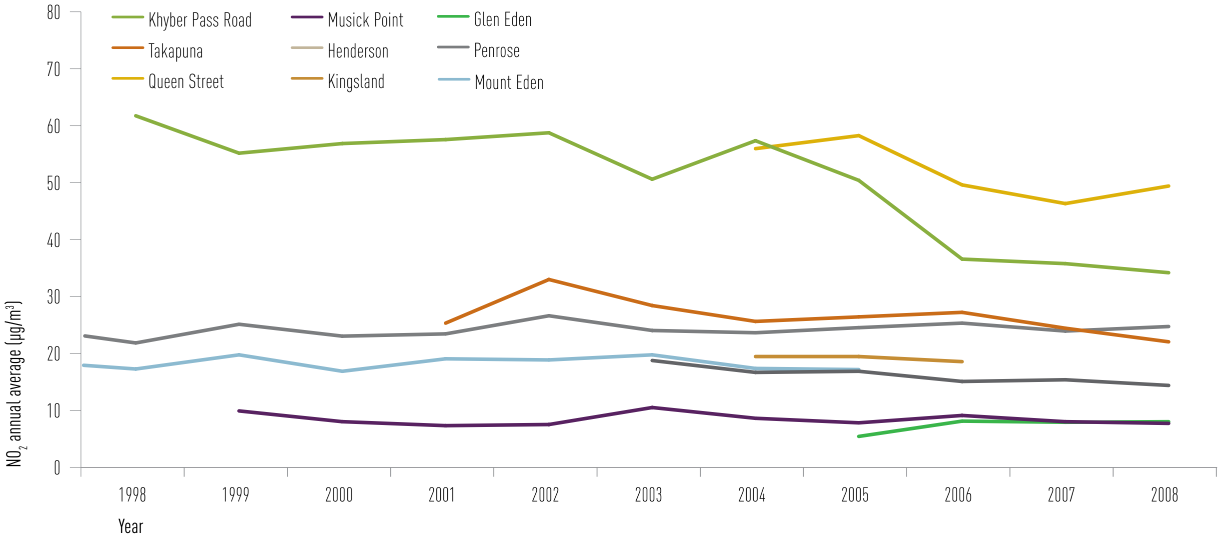


FIGURE 7 Annual averages of nitrogen dioxide in air, 1998-2008. Note, the Warkworth and Pukekohe sites are in rural town airsheds, Patumahoe is in the rural airshed and the remaining sites are in the Auckland urban airshed. (Source: ARC, MfE).

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Factors that influence the annual averages are the rapid growth in both the number and frequency of use of light and heavy duty diesel vehicles. These two factors have offset the benefits of reduced NO_2 emissions from vehicles with improved engine technology because diesel vehicles produce more NO_2 than petrol vehicles.

Seasonal trends of nitrogen dioxide

Concentrations of NO_2 are usually higher in winter than in summer. NO_2 is formed mainly from the reaction of NO with oxidants so the higher NO_2 levels in winter are due to increased oxidant levels and poor dispersion conditions, rather than due to an increase in NO_2 emissions during that season.

Figure 8 shows the seasonal trends of NO_2 concentrations in the Auckland region. Concentrations in winter are about twice as high as those in summer.

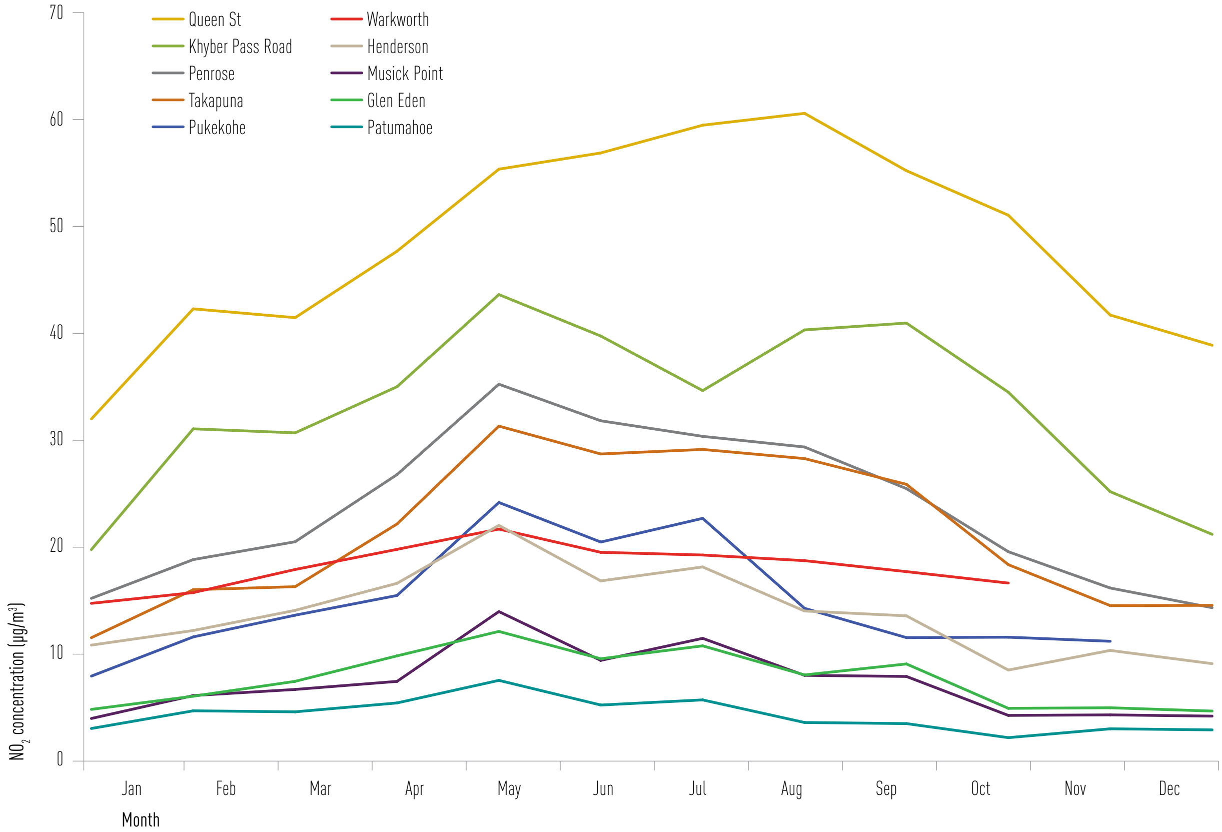

FIGURE 8 Monthly NO_2 concentrations in air, 2008. The Warkworth and Pukekohe sites are in rural town airsheds, Patumahoe is in the rural airshed and the remaining sites are in the Auckland urban airshed. (Source: ARC).

Carbon monoxide (CO)

Carbon monoxide is a colourless, odourless, tasteless and relatively inert gas which slowly converts to carbon dioxide (CO_2) in about a month. It is formed by natural processes such as volcanic activity and by human activities, primarily motor vehicle emissions.

CO is produced from the partial combustion of carbon-based fuels in air. If there is sufficient oxygen for complete combustion, CO is transformed into CO_2. Concentrations of CO are usually higher in winter than in summer. Emissions from domestic heating and poor dispersion conditions are the reasons for higher CO levels in winter.

CO interferes with the blood's ability to absorb and circulate oxygen. Low CO levels can adversely affect people with heart conditions such as angina and clogged arteries. High CO levels can cause dizziness, nausea, drowsiness and impair co-ordination and attention. Extremely high CO levels can cause death.

The CO standard for the 8-hour running average is 10mg/m^3 with one allowable exceedence per year.

The CO guideline for the 1-hour average is 30mg/m^3.

Indicator 3: Concentrations of carbon monoxide

Vehicle emissions, particularly those from petrol vehicles, are the most significant source of CO in the Auckland region. Improving vehicle technology and the increasing proportion of vehicles that are fitted with catalytic converters have reduced CO levels significantly over the past ten years, particularly at the peak traffic sites. Consequently, CO levels in the Auckland region now usually comply with air quality standards and guidelines (Figure 9).

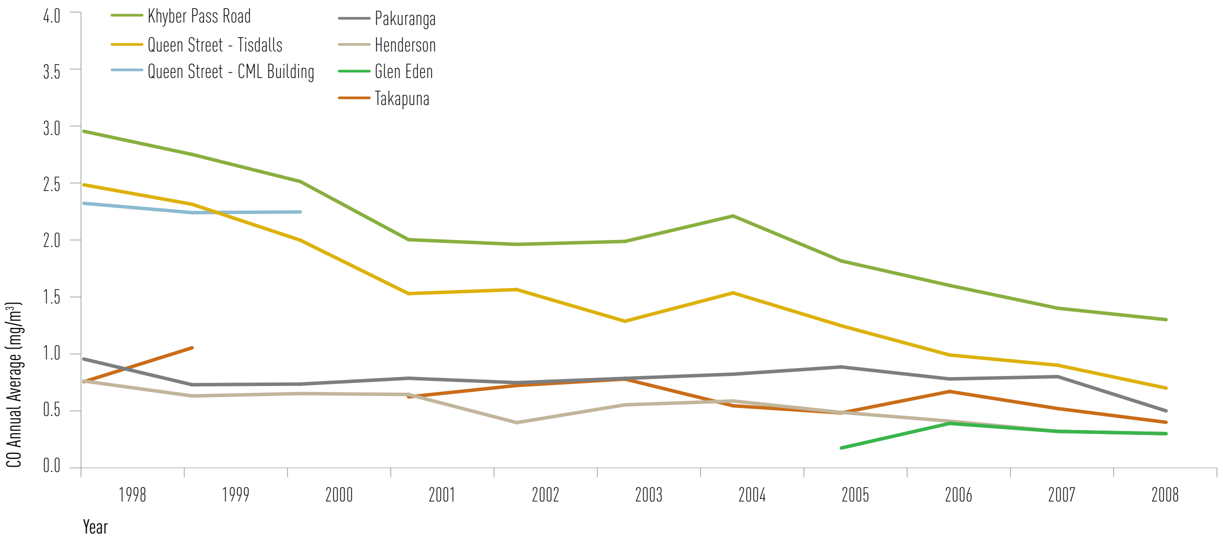

FIGURE 9 Annual averages of carbon monoxide in air, 1998-2008. (Source: ARC).

Sulphur dioxide (SO_2)

Sulphur dioxide is a colourless, pungent, acidic gas which readily reacts in the air to form sulphuric acid and other compounds. SO_2 is usually oxidised in the air within a few days.

SO_2 is mainly produced by the combustion of fossil fuels that contain sulphur (such as coal and diesel) and by industrial processes. It also comes from natural emissions such as volcanic eruptions or emissions from phytoplankton in the sea. SO_2 reacts to form sulphate particulates (part of the $PM_{2.5}$ particulates) and also forms acid rain. Although acid rain is a problem in the northern hemisphere, it is not usually a problem in New Zealand.

Exposure to SO_2 irritates the lungs causing coughing, wheezing or breathlessness. Asthmatics are particularly sensitive and may suffer breathing problems. Long-term exposure to high SO_2 levels and particulates can aggravate heart disease and cause respiratory illness.

SO_2 is toxic to some plants and is corrosive to some building surfaces and metals in moist conditions.

The SO_2 standard for the 1-hour average is 350 μg/m³ with nine allowable exceedences per year. The standard is 570 μg/m³ for the 1-hour average with no allowable exceedences per year.

The SO_2 guideline for the 24-hour average is 120 μg/m³. The guideline also includes levels for protecting agricultural crops, forest and natural vegetation, and lichen.

In 2006 the WHO updated the SO_2 guideline for the 24-hour average from 125 μg/m³ to 20 μg/m³ because the previous guidelines were considered insufficient, due to new evidence about health effects. This change is not yet reflected in New Zealand's guidelines and standards. The WHO SO_2 guideline for the 10-minute average remains at 125 μg/m³.

Indicator 4: Concentrations of sulphur dioxide

SO_2 levels decreased in the 1970s and 1980s due to reduced use of coal in industrial areas, but rose again between 1995 and 1999 due to the import of used diesel vehicles (Figure 10). However, the levels of sulphur in diesel fuel have fallen dramatically in recent years, producing another reduction in SO_2 levels.

Measured SO_2 concentrations typically meet air quality standards and guidelines. However, the introduction of the new SO_2 guideline by the WHO (that reduces the 24-hour average from 125 to 20 μg/m³) means that it is necessary to continue monitoring SO_2 levels.

It is possible that some parts of the Auckland region will not comply with this new guideline.

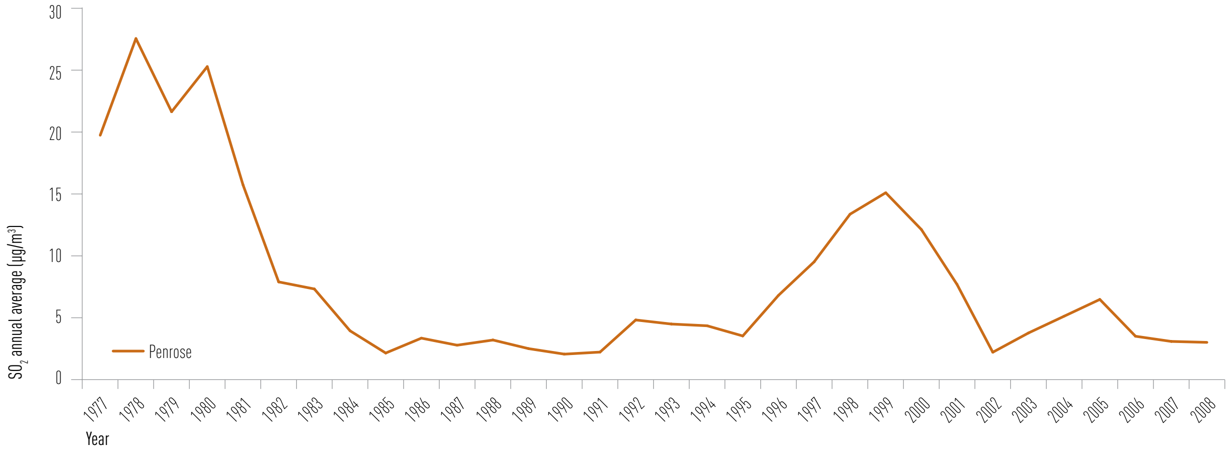

FIGURE 10 Annual averages of sulphur dioxide in air at Penrose, 1977-2008. (Source: Ministry for the Environment).

Benzene

Benzene is a colourless, flammable gas with a sweet petrol-like odour. It is a volatile organic compound (VOC) and is emitted from a range of sources including motor vehicle emissions, evaporation of petrol, petrol lawn mowers, cigarette smoke and domestic fires.

Short-term inhalation of benzene may cause drowsiness, dizziness and headaches as well as irritation to the eyes, skin and respiratory tract. At high levels it can cause unconsciousness. Long-term exposures have caused blood disorders and reproductive effects have been reported at high levels.

Benzene is classified as a human carcinogen and is associated with an increased incidence of human leukemia and adverse foetal development in animals.

The benzene guideline is 10 µg/m³ for the annual average until 2010. This drops to 3.6 µg/m³ from 2010 onwards.

Benzene and 1-3 butadiene are the two VOCs that are considered to be most hazardous to human health.

Indicator 5: Annual averages of benzene and 1-3 butadiene

Figure 11 shows the monthly benzene concentrations at Khyber Pass Road, obtained by passive sampling. Government specifications that required the level of benzene in petrol to be reduced in stages (from 4 to 3 per cent in 2004, then down to a maximum of 1 per cent in January 2006) are indicated by vertical dotted lines.

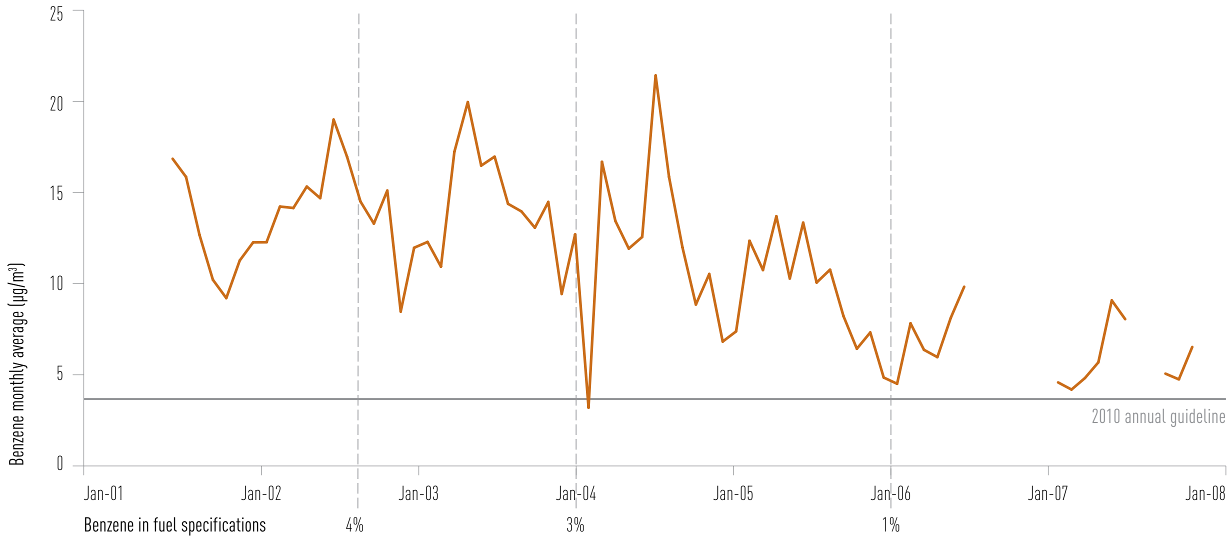

FIGURE 11 Monthly average benzene in air at Khyber Pass Road. (Source: ARC). Note: gaps indicate periods where no sampling took place.

As a result of these mandatory requirements, benzene concentrations have shown a long-term decline and have reduced significantly over recent years.

Benzene concentrations in the Auckland region now comply with current air quality guidelines. However, the guideline value will be reduced in 2010 and exceedences of this new guideline may occur at busy roadsides in the future.

1-3 butadiene concentrations in the Auckland region comply with the guideline but could increase as a result of an increase in traffic.

Lead

Lead is a heavy metal which can be absorbed by humans through the air, water and soil. High lead exposure can affect the nervous system, brain, kidneys, metabolic processes and reproductive systems.

The major source of lead in the air used to be the combustion of petrol containing lead which was added to boost the octane rating and to prevent engine knock. However, lead levels in petrol in New Zealand began to be reduced in 1986 and lead additives were completely removed in 1996.

Lead in contaminated road dust can re-enter the air due to vehicle movements and wind. Another source of airborne lead is the restoration of old houses coated with lead-based paints, particularly if dry sanding is used to remove the paint. Industrial sources include battery manufacture and small secondary smelting operations such as solder and sinker manufacture.

The lead guideline for a 3-month moving average is 0.2 μg/m³.

Indicator 6: Concentrations of lead

In 1996 lead was eliminated from petrol. Consequently, there has been a significant long-term decline in the amount of lead in the air (Figure 12) and lead levels in the Auckland region are now well below the air quality guideline.

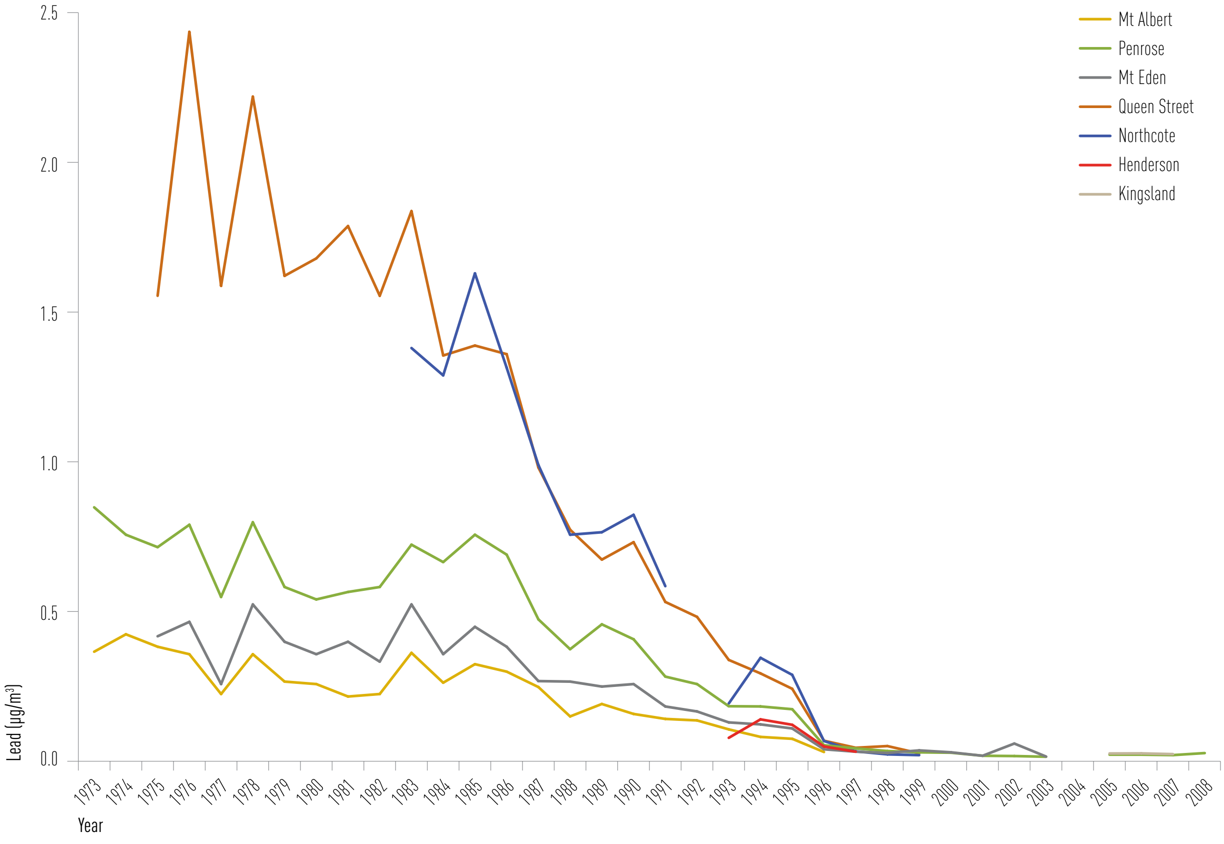

FIGURE 12 Annual average lead in air, 1973-2008. (Source: Ministry for the Environment).

Air

Ozone (O_3)

Ozone (O_3) is a colourless, highly reactive gas with a distinctive odour. It forms naturally in the air and is a vital component of the upper atmosphere where it protects the earth from ultraviolet (UV) radiation from the sun.

However, ozone at ground level is one of the main components of photochemical smog that can seriously reduce visibility, e.g. photochemical smogs in California mean that it is often almost impossible for tourists to see the Grand Canyon. It also causes deterioration of materials such as rubber and paints, and damages sensitive plants.

At ground level, ozone can form under certain conditions when nitrogen oxides and VOCs from motor vehicle emissions and industrial activities react in the presence of sunlight.

Ozone causes runny eyes, irritation of the nose and throat and breathing difficulties, especially in asthmatics. It can also cause lung damage that reduces lung capacity and lowers resistance to respiratory illnesses, particularly in infants and the elderly.

The ozone standard is 150 µg/m³ for the 1-hour average with no allowable exceedences per year.

The ozone guideline is 100 µg/m³ for the 8-hour average. The guideline also includes levels for protecting forests, semi-natural vegetation and crops.

Indicator 7: Concentrations of ozone

Ozone levels in the Auckland region are determined by two factors:

→ the natural background concentration

→ ozone that is produced locally as a result of photochemical reactions.

Measured ozone levels generally meet the air quality standards and guidelines.

Annual averages of ozone

The natural background concentration is the main factor that influences the annual average levels. Consequently, there has been little change in these levels over the past ten years (Figure 13).

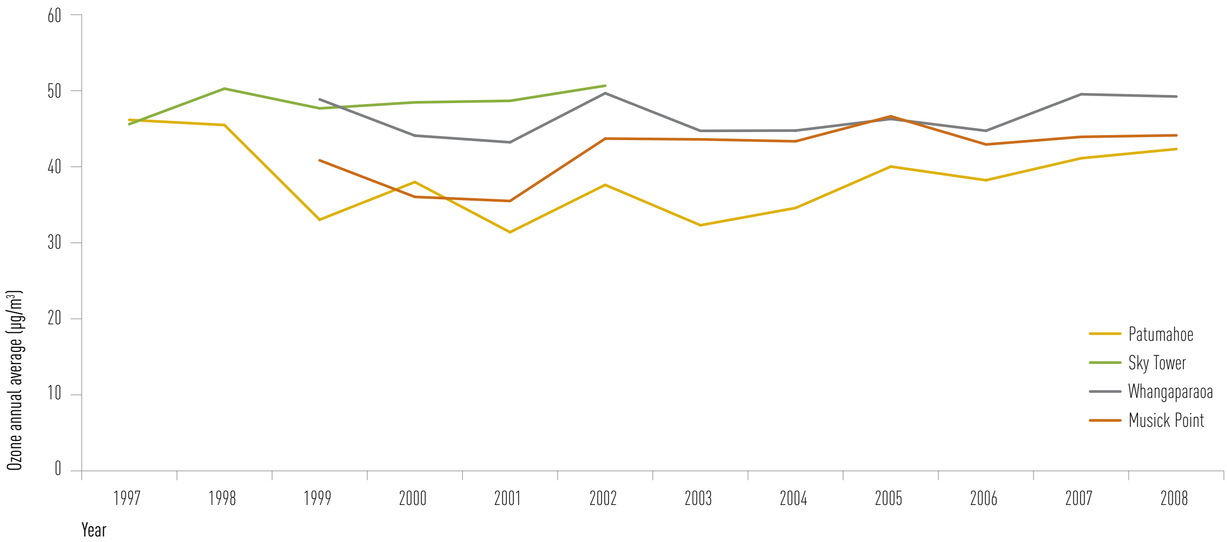

FIGURE 13 Annual averages of ozone in air, 1997-2008. (Source: ARC).

Seasonal trends of ozone

The natural background level of ozone is higher in winter than in summer in New Zealand but high, short-term, concentrations of ozone can occur in summer when sunlight and warm temperatures lead to photochemical reactions in the polluted air. This may result in photochemical smog.

Figure 14 shows an example of elevated ozone concentrations typical of photochemical reactions in summer. The high ozone concentrations at both Musick Point and Whangaparaoa occurred on 13 February 2008 – a warm and sunny day. The temperature reached 24.2°C at 3pm on that particular day at Musick Point.

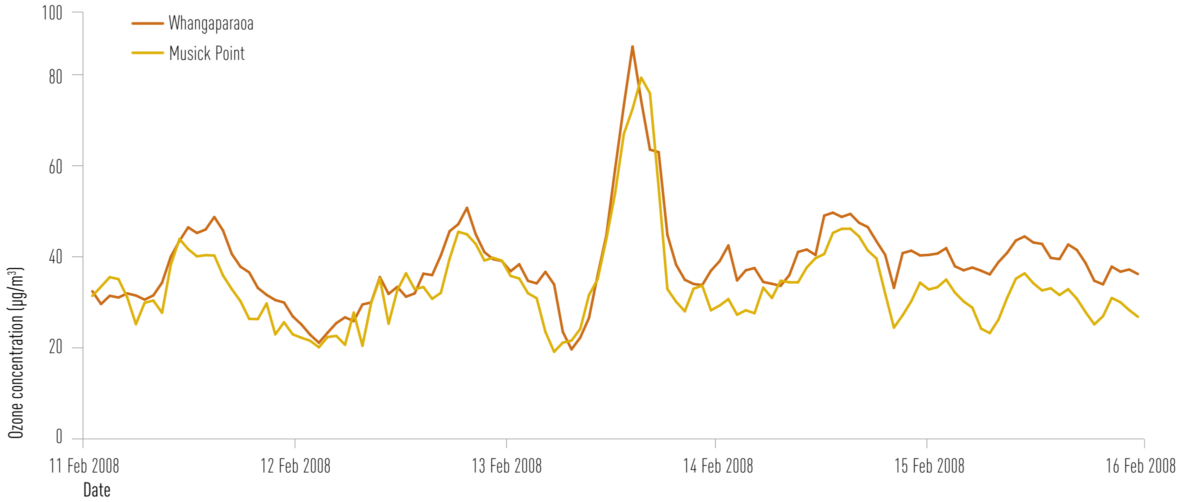

FIGURE 14 The 1-hour average ozone concentrations in the Auckland region, with high concentrations at Musick Point and Whangaparaoa 11-16 February 2008. (Source: ARC).

Exceedences of standards and guidelines

Exceedences of the PM_{10} and $PM_{2.5}$ particulate standards and guidelines have occurred in the Auckland region due to:

- → vehicle emissions
- → domestic fires
- → road works
- → special events (e.g. Guy Fawkes, Christmas in the Park, rural burning of onion skins)
- → natural sources.

Exceedences at the peak traffic monitoring sites located at Khyber Pass Road and Queen Street are due usually to vehicle emissions, while exceedences at other sites may be due mostly to domestic fires (or a combination of both). Domestic fires are the usual cause of PM_{10} and $PM_{2.5}$ particulate exceedences during winter.

NO_2 exceedences at monitoring sites located close to busy roadsides are due to motor vehicle emissions. The number of exceedences of air quality standards and guidelines has decreased at Khyber Pass Road and Queen Street in recent years, probably due to localised changes in traffic flows and fleet composition.

Emissions of PM_{10} and $PM_{2.5}$ particulates and NO_2 all need to be substantially reduced, particularly those from motor vehicles and domestic fires, in order to meet the air quality standards and guidelines.

Guidelines for other contaminants have also been exceeded occasionally in the Auckland region. For example, two exceedences of the air quality guideline were recorded at Musick Point in 2002 and all of the air quality monitoring sites have recorded ozone peaks that are close to exceedence levels.

Benzene levels have exceeded the annual guideline in the past but are lower at present due to improved fuel quality as a result of government regulations.

Over the past ten years there has been a significant trend showing a reduction in the number of CO exceedences, largely as a result of improvements in vehicle technology. Trends for other pollutants are less apparent and are likely to mirror the weather conditions of the Auckland region, rather than any changes in emissions.

The number of exceedences in any one year depends on the pollutant sources and the weather. When there is a lot of wind or rain, pollution levels are frequently lower compared to it is calm and fine weather.

Indicator 8: Number of exceedences of standards and guidelines

Air in the Auckland region frequently exceeds the standards and guidelines for PM_{10} and $PM_{2.5}$ particulates and NO_2 (Figure 15 and Table 1).

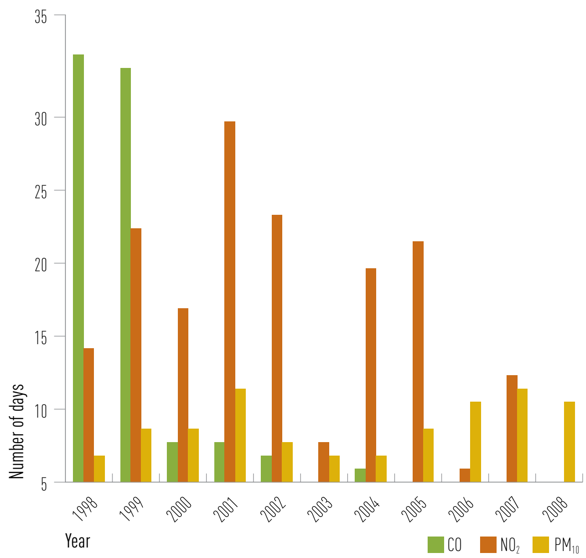

FIGURE 15 The number of days on which the air quality standards have been exceeded 1998-2008. (Source: ARC).

4.1

Air

TABLE 1 The number of days on which the air quality standards and guidelines have been exceeded* 1998-2008. (Source: ARC).

Year	Carbon monoxide		Nitrogen dioxide		PM_{10} **	$PM_{2.5}$ **	Total ***
	1 hour	8 hour	1 hour	24 hour	24 hour	24 hour	
1998	0	32	10	18	2	6	53
1999	1	31	19	15	4	3	57
2000	0	3	13	21	4	3	33
2001	0	3	27	18	7	4	46
2002	0	2	20	21	3	1	36
2003	0	0	3	6	2	6	15
2004	0	1	16	20	2	5	37
2005	0	0	18	16	4	2	31
2006	0	0	1	0	6	5	8
2007	0	0	8	0	7	9	21
2008	0	0	0	0	6	5	8

* An exceedence day of the ozone guideline was recorded in 2002.
** PM_{10} or $PM_{2.5}$ at some sites were sampled on every third day, therefore, the actual number of their exceedence days could be up to three times higher.
*** Total may not be the sum of individual pollutants as the exceedence days may overlap.

Visibility

Visibility is a measure of how far the human eye can see through the air.

Air pollution can lead to poor visibility, therefore visibility is widely used to indicate the air quality and amenity value.

Photographs of the Auckland skyline provide a useful indication of the amount of discolouration of the air and a rough indication of air clarity. The following photographs compare the Auckland skyline on a clear and a polluted day.

Figure 16 The Auckland skyline on a clear day, 22 December 2006. (Source: ARC).

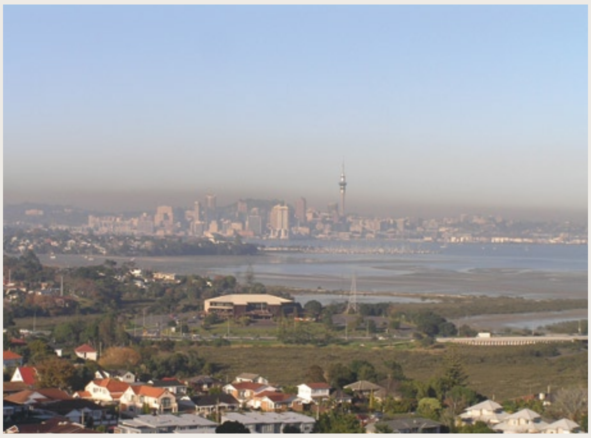

Figure 17 The Auckland skyline on a hazy day, 3 June 2009. (Source: ARC).

During the winter months, usually between May and October, a brown haze caused by air pollution can form over Auckland and reduce visibility. It usually disappears by about 1pm but occasionally lasts all day. The frequency of these brown hazes depends on pollutant sources and weather conditions.

Indicator 9: Annual number of brown haze days

Auckland experiences degraded visibility from air pollution for roughly 30 days per year. Between 2001 and 2006, the number of brown haze days ranged from 16 days in 2006 to 47 days in 2001.

Daily trends

Higher levels of air pollutants such as CO and NO_2 occur during rush hour because their main source is vehicle emissions (Figure 18).

Concentrations of fine particulates can be high in the winter evenings when people light domestic fires (Figure 19).

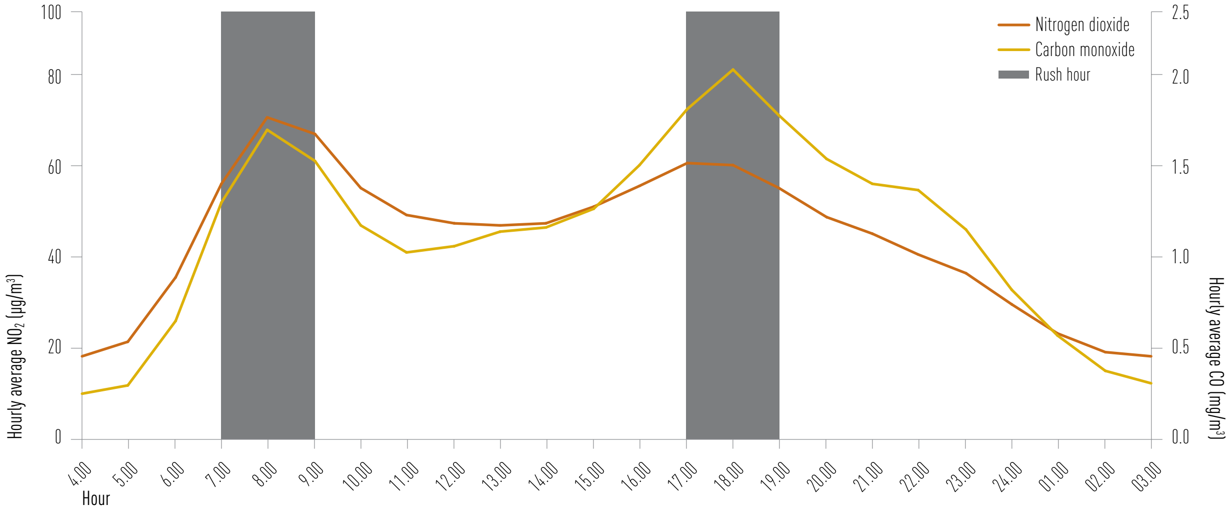

FIGURE 18 Average daily variation of CO and NO_2 concentrations at Khyber Pass Road, 2008. (Source: ARC).

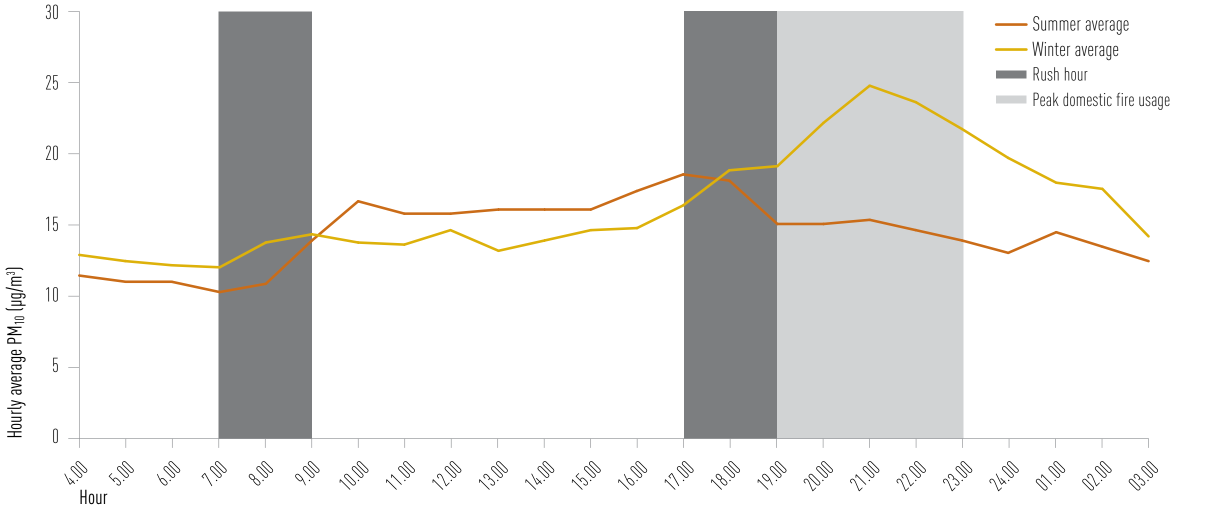

FIGURE 19 Average daily variation of PM_{10} concentrations at Khyber Pass Road, 2008. (Source: ARC).

4.1

Air

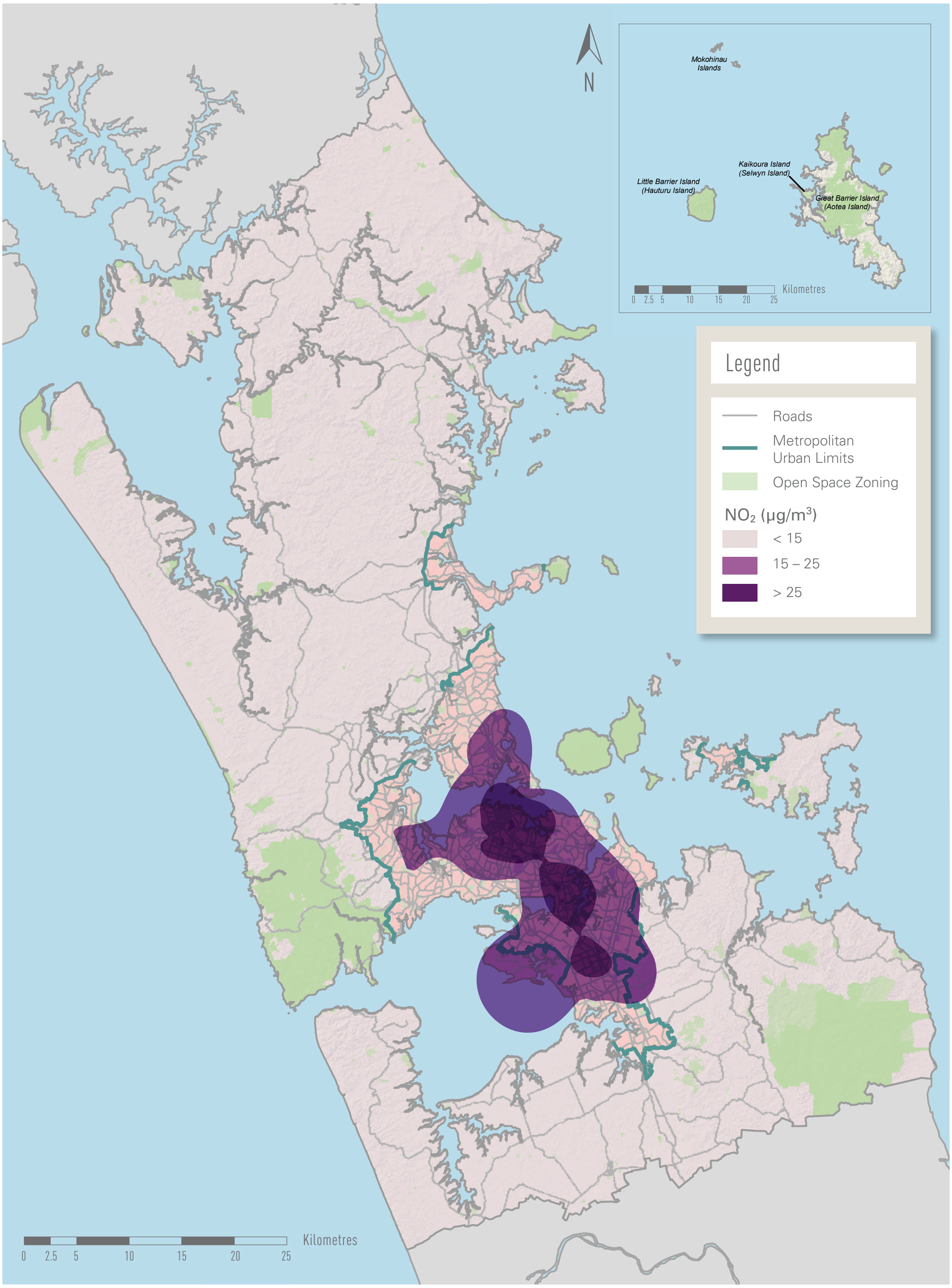

FIGURE 20 Spatial distribution of NO_2 concentrations in Auckland (three-month means) July-September 2006. (Source: ARC)

Stable weather conditions and low wind speeds can limit dispersal of air pollutants and contribute to high CO and NO_2 levels in the morning and high particulate levels at night.

Some sites, such as Khyber Pass Road, have similar traffic levels and pollutant emission levels through the day, although concentrations are usually lower at midday because there is more wind.

Spatial trends

Fine particulate (both PM_{10} and $PM_{2.5}$) levels at busy roadsides are higher on average than those at urban and residential sites due to emissions from motor vehicles, particularly diesel vehicles. However, because fine particulates stay suspended in the air for up to 30 days, their distribution is relatively uniform, with all the residential sites having an annual average within the range of 12 to 18 µg/m³.

NO_2 and CO levels are highest at roadside sites because motor vehicle emissions are the major source of these air pollutants.

Benzene levels close to busy roadsides are significantly higher than levels in urban or industrial areas due to emissions from petrol vehicles and evaporation of petrol.

A comprehensive passive sampling programme was carried out at 78 locations around the Auckland region during the winter of 2006 to investigate where higher levels of NO_2 occur. The results showed that relatively high concentrations of NO_2 were broadly aligned along the south-east to north-west route of State Highway 1. The highest concentrations occurred in the CBD and Newmarket areas (Figure 20).

The high NO_2 concentrations found close to motorways generally decline as distance from the motorway increases, although the concentrations can remain elevated at distances of 300m from the motorway.

A passive sampling programme was carried out at 17 locations around the Auckland region during the winter of 2007 to investigate where higher levels of SO_2 occur.

The results showed elevated concentrations around the port of Auckland and the Penrose site compared with all the other sampling locations. This is due to the environmental impact of shipping and industrial activities. Ships use high sulphur fuels which emit SO_2 during combustion. An analysis of the composition of airborne particulates in the Auckland region also suggests that SO_2 emissions around the port of Auckland and Penrose contribute to the measured secondary sulphate (a fine particulate formed from chemical reactions in the air that involve SO_2).

Ozone concentrations tend to be the highest at sites away from the city because, in the time taken for the NO_2 emissions to react and form the ozone, these two pollutants have been shifted by the prevailing winds. Compared to other air pollutants, concentrations of ozone across the Auckland region tend to be more uniformly distributed because of the mixing and reaction times needed.

Implications of poor air quality

In the Auckland region, the levels of PM_{10} particulates are of the most concern and cause the worst health problems, particularly when they originate from diesel combustion. About 6000 tonnes of PM_{10} are emitted each year in the Auckland region. Annually about 50 per cent of the emissions in the region come from motor vehicle emissions, 40 per cent from domestic fires and 10 per cent from industry. This changes in winter when domestic fires account for 65 per cent, motor vehicles for 25 per cent and industry for 10 per cent of the overall PM_{10}

Estimates based on updates to the 2007 study on health and air pollution in New Zealand suggest that fine particulates contribute to more than 600 premature deaths each year in the Auckland region.

However, the overall health impact is much greater. One in six adult New Zealanders and 27 per cent of six to seven year olds suffer from asthma. Fine particulates and NO_2 are not a proven cause of asthma but are known to be an irritant for people with asthma, which leads to an increased likelihood and severity of asthma attacks.

Children are very sensitive to air pollution because their lungs are not fully developed until they are about six years old. They breathe 50 per cent more air than adults (by body weight), their immune system is immature and they have a higher exposure to air pollutants as they spend more time outside and exercising.

Table 2 shows that the estimated 'restricted activity days' per year include 1.1 million days when asthmatics or those with heart or lung disease cannot function normally.

TABLE 2 Impacts of air pollution in the Auckland region. (Source: ARC, based on Fisher et al. (2007) but updated with Statistics New Zealand 2006 census data).

Indicator	Auckland region	New Zealand
Premature fatalities	> 600	> 1,400
Restricted activity days	> 1,100,000	> 2,400,000
Health costs	> $547 million	> $1.14 billion

The figures in Table 2 are based on effects on New Zealanders over 30 years of age and do not account for the effects of air pollution on children's mortality and morbidity, such as impaired lung development and asthma.

The total economic cost of air pollution in New Zealand, including health costs from both premature deaths and adverse health impacts, is estimated to be $1.3 billion per year.

Although most of the health problems are associated with fine particulates, other pollutants such as NO_2, CO and VOCs also cause problems.

4.1

Air

Conclusions on the state of the air

Air quality in the Auckland region is generally good in comparison to many cities in the world.

Motor vehicles are the main cause of the air pollution problem in the Auckland region. The second highest source of air pollution is domestic fires, which in winter produce 65 per cent of the PM_{10}.

Policies and regulations for cleaner fuel have significantly improved the air quality in the Auckland region. Lead levels in petrol were reduced after 1986 and were eliminated in 1996. As a result, lead levels in the air have decreased dramatically, particularly at roadside sites, and are now well below the air quality guideline. Sulphur dioxide (SO_2) concentrations have also fallen substantially in response to the dramatic reduction in permitted sulphur levels in diesel and petrol since early 2000. The reduced benzene levels that are permitted in petrol have also resulted in lower benzene concentrations in the air since early 2000, although it is not yet clear whether this reduction will be enough to meet the new 2010 guideline.

Vehicle technology has improved significantly over the years. Exhaust emissions standards have been introduced recently for new and used vehicles entering New Zealand and these standards get progressively tighter over time. As a result, there has been a gradual reduction in the concentrations of carbon monoxide (CO) and fine particulates emitted from motor vehicles.

However, the improvements in air pollution that have resulted from better fuel, new vehicle technology and tighter emissions standards have been offset by the growth in vehicle numbers, kilometres travelled and the ageing vehicle fleet.

Although the use of solid fuels for domestic fires is declining slowly, the population is growing. Consequently, the levels of PM_{10} and $PM_{2.5}$ particulates have levelled off in recent years but are still at levels that can cause significant adverse health effects. Concentrations of fine particulates and nitrogen dioxide (NO_2) in the region currently exceed air quality standards and guidelines. Emissions of fine particulates and nitrogen oxides (NO_x) from motor vehicles and domestic fires need to be reduced in order to meet the standards and guidelines and to protect human health.

Annual average ozone levels in the region are mainly determined by the natural background levels. As a result, annual average ozone levels have changed little over the past ten years. However, there is continuing evidence of photochemical reactions occurring in the region and elevated levels of ozone could occur during summer, leading to exceedences of the standards and guidelines.

The average NO_2 concentrations are strongly affected by the availability of oxidants, which have changed little over the years. Subsequently, average NO_2 concentrations have not shown significant changes within the region, although they are increasing slowly at some sites and have decreased at the peak traffic sites. These trends are probably due to changes in local traffic emissions, with lower traffic volumes and fewer heavy-duty vehicles at the peak sites.

Air pollution costs the region at least $547m each year in health costs, therefore the potential benefit of reducing the levels of pollutant emissions from the Auckland vehicle fleet and domestic fires would be significant for the region, both in terms of improved health and in the associated reduced costs.

The ARC is close to meeting the ambient standard values, but these do not ensure protection of human health. The stated health effects and costs are based on current long-term exposure of the population.

The World Health Organisation Guideline: Global Update 2005 (pages 7 and 9) states,

"... as research has not identified thresholds below which adverse effects do not occur, it must be stressed that the guideline values provided here cannot fully protect human health.

Rather than standard-setting, process needs to aim at achieving the lowest concentrations possible in the context of local constraints ..."

Case Study: On-road vehicle emissions – monitoring to support policy

Vehicle emissions are a major contributor to air pollution in Auckland's urban area. Fortunately, improvements have been made to vehicle emission technologies and fuel quality in recent years. This means that, in theory, as old vehicles leave the fleet and are replaced by new ones, the amount of pollution from vehicles overall should be reducing – but are we seeing this in practice? Understanding how emissions are changing over time highlights whether additional strategies and policies might be required to meet reduction targets.

This case study describes how our measurement campaigns for real-world emissions have been used both to influence the development of policy and to see whether that policy is having an effect.

How did we measure on-road vehicle emissions?

To date, three on-road studies have investigated emissions from the Auckland fleet – initially in 2003, then later in 2005 and 2009[1]. Using a technique known as remote sensing (Figure 1) tailpipe emissions were sampled for carbon monoxide (CO), nitric oxide (NO), unburned hydrocarbons (HC) and opacity (smokiness) as an indicator of fine particulates. To find out which factors influenced emissions most, particularly for those vehicles known as 'gross emitters' (the most polluting vehicles in the fleet), the measurements were matched to vehicle characteristics such as mileage, fuel type and year of manufacture.

FIGURE 1 On road monitoring equipment and smart sign in the background (Source: NIWA). Emissions are calculated by measuring the changes in (UV and IR) light as it passes through the emissions from a vehicle's tailpipe.

A smart sign was also erected in 2003 and 2005 (Figure 2) to raise driver awareness and give motorists an immediate indication of their vehicle's emissions – good, fair or poor.

In 2005, remote sensing was combined with a broader education initiative known as the 'Big Clean Up – Tune Your Car' campaign, which used billboards and radio advertising to encourage drivers to get their vehicles checked and regularly serviced. Drivers were offered discounts at certain garages.

FIGURE 2 Smart sign display when a vehicle passes by with high emissions (Source: NIWA).

[1] The ARC funded on-road testing in April 2003 and was involved in jointly-funded programmes with NIWA and NZTA in May/June 2005 and May 2009.

Air

What have the measurements told us?

- Most vehicles (83 per cent) have good emissions
- 10 per cent of vehicles create 50 per cent of the air pollution
- New vehicles generally emit less pollution than old vehicles
- Older vehicles that are well-maintained produce less pollution than poorly maintained new vehicles
- Diesel vehicles produce higher emissions of smoke, but petrol vehicles are worse for NO and CO emissions
- Japanese used imports generally discharge less pollution than New Zealand new vehicles of the same age.

TABLE 1 Emissions from vehicles for 2003, 2005 and 2009 (Source: ARC/NIWA).

Pollutant	Average concentration in exhaust plume					
	Petrol vehicles			Diesel vehicles		
	2003	2005	2009	2003	2005	2009
Carbon monoxide (%)	0.84	0.65	0.46	0.12	0.05	0.03
Nitric oxide (ppm)	703	649	494	415	519	476
Hydrocarbons (ppm)	354	245	149	162	108	97
Smoke (uV)	0.41	0.07	0.05	1.00	0.20	0.16

Looking at the trends in Table 1, vehicle emissions have shown the following improvements since 2003:

- Average emissions of CO, NO, HC and smoke from petrol vehicles have decreased
- Average emissions of CO, HC and smoke from diesel vehicles have decreased
- The trends for average emissions of NO from diesel vehicles are inconclusive.

Has this work helped to reduce vehicle emissions?

The results provide valuable information on the state of Auckland's fleet, and has been used by the ARC to encourage the government to take further action on addressing vehicle emissions. Recent legislative milestones include on-going fuel quality improvements, banning the tampering or removal of emissions control technologies and requiring both used and new vehicles entering the fleet to meet minimum emissions standards (discussed in more detail in Chapter 4). In addition, minimum emissions standards for buses used in public transport have been developed for Auckland and the rest of New Zealand.

Public awareness and education campaigns undertaken by the ARC and the Ministry of Transport have increased understanding of the harmful effects of vehicle emissions and have encouraged more drivers to correctly maintain their vehicles.

Data from remote sensing campaigns and information from the ARC air quality monitoring sites confirm that emissions from the vehicle fleet have indeed been reduced. We are currently trying to establish whether those reductions will be sufficient to meet air quality standards in future.

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Photo: Market gardens, Auckland. (Source: ARC).

4.2

State of the environment and biodiversity – Land

Contents 4.2

4.2

Land

Introduction

The land resource includes landforms, parent material and soil types. All of these vary in the Auckland region.

The west coast is dominated by huge dunes that form the peninsulas at Awhitu and South Kaipara Head: much of this sandy land contains brown soils, and is unstable and prone to erosion. In the north, the land consists of layers of sandstone and mudstone (the Waitemata formation). This area is dominated by highly weathered clay soils on rolling and hilly slopes, with some steeper slopes that are unstable and prone to erosion. The Waitakere Ranges in the west were formed by lava from volcanic eruptions and are covered mostly in native forest. The low undulating land of the Auckland isthmus is scattered with numerous small volcanic cones consisting of volcanic ash and lava (see Volcanic eruptions in Chapter 5.1). The volcanic eruptions covered a wide area and resulted in well-structured and productive granular soils in the west and south. Alluvium (older volcanic material re-deposited by water) is found south of the Manukau Harbour. To the east the soils are a mixture of brown soils from alluvium, and clayey soils from Waitemata formation. The Hunua Ranges in the south-east are characterised by steep slopes formed by greywacke and argillite. The central Franklin District is covered by airfall volcanic ash from local basaltic volcanoes and from much older rhyolitic eruptions from the central North Island volcanoes, producing well-structured and productive granular soils.

The land in the Auckland region is an important and valuable resource. It supports the growing population by providing food, a place to live and work, recreational and tourism opportunities, and it also has cultural significance.

Use of the land, changes in land use and intensification have a wide range of short and long-term implications for the environment. The conflict between continued agricultural production and urban expansion resulting from the increasing population in the Auckland region is putting the soil resource under pressure, and the productive potential of the soil is being lost or reduced by the increased development and non-economic rural residential blocks at the urban fringes (see Pressure: Land use, pg 37).

Inappropriate land use practices can lead to:

- → accelerated erosion
- → loss of soil structure
- → nutrient loss
- → reduction in organic matter
- → loss of soil biology
- → elevated levels of trace elements.

It takes thousands of years for soil to form, so for all practical purposes it is a non-renewable resource that must be well managed. Therefore it is vital to understand the condition of the land resources in the Auckland region, monitor changes, understand any long-term trends and develop policies to prevent further degradation of the soil resource. Our land monitoring programmes are predominantly concerned with the rural land in the Auckland region. Different rural land uses have different characteristics and different resource requirements. Other monitoring programmes look at the effects of urban land use.

Land stability, soil disturbance and bare soil

Key findings

- → Stable surfaces cover 30.1 per cent of the Auckland region. Unstable surfaces cover 51.2 per cent and include erosion-prone (35.7 per cent), eroded but re-vegetated (8.0 per cent) and eroding surfaces (7.4 per cent). The remainder of the Auckland region is extensively modified (17.8 per cent) or was not covered in the photographic survey (0.9 per cent).
- → Between 1999 and 2007 there was no change in the amount of stable surfaces. The amount of erosion-prone surfaces decreased and eroded surfaces increased. The amount of active erosion also increased, as shown by an increase in eroding surfaces (1.9 per cent).
- → The soil was intact at 53.9 per cent of the 2007 sample areas and showed no soil disturbance. Of the 45.2 per cent of soil that was disturbed:
  - → 7.4 per cent was caused by natural erosion
  - → 34 per cent was disturbed due to land use activities
  - → 3.8 per cent consists of natural features that are extensively disturbed.
- → Bare soil accounts for 3.29 per cent (16,524 hectares) of the Auckland region. The 2007 survey indicated a relatively low level of natural erosion that produced bare soil on only 1.18 per cent of the land, although land use activities added another 2.11 per cent of bare soil.
- → The amount of bare soil exposed by natural processes remained constant (at 0.55 per cent of the Auckland region) between 1999 to 2007. There was an increase in the amount of soil disturbance in rural areas as a result of land use activities, from 0.72 per cent in 1999 to 1.07 per cent in 2007. This equates to 0.35 per cent or 1758 hectares.

Introduction

It is important to understand how well the land resource is remaining in place so that it continues to be available for urban use, farming, forestry and conservation across the Auckland region. Measuring the stability of the land gives the ARC an understanding of how much land is stable, unstable and affected by natural erosion processes.

Soil disturbance can occur through natural erosion processes (e.g. streambank erosion and landslides) and also through human-induced processes related to land use activities that disturb the land (e.g. creating tracks and cultivation).

The amount of bare soil that is associated with soil disturbance is important. When soil is lost, the productive capacity of land is reduced. Although vegetation returns within a few years on an eroded site, this new growth is generally less productive because the underlying soil is thinner and holds fewer nutrients. When bare soil is exposed, the potential generation and discharge of sediment is increased. Increased levels of sediment have adverse effects on both the freshwater and marine environments.

Changes over time in the land stability, amount of soil disturbance and bare soil indicate whether these are improving or getting worse. Understanding what types of natural and human land use result in soil disturbance can help to improve land management decisions and shape land management policies.

Land stability, soil disturbance and the bare soil monitoring programme

In order to monitor the land stability, and amounts of soil disturbance and bare soil, the ARC takes point samples from 5277 different one hectare sample areas. These point sample areas are spaced at one km intervals across the Auckland region. They are visually inspected using aerial photographs by someone who has landform and erosion knowledge and skills in photographic interpretation. Although the one km grid is not spatially random, it does provide a random sample because the underlying landforms, soils and land uses are distributed irregularly across the region. In addition, the 1 by 1km spacing provides sufficient sample areas to represent the whole of the region.

Within each sample area, the land stability and any soil disturbance as a result of land use or natural processes, are recorded. Soil disturbance is measured by interpreting the one hectare sample area and recording any sign of disturbance. Wherever soil disturbance was recorded within a sample area, a cluster analysis is used to record the percentage of bare ground within each of those sample areas. This determines the percentage of soil bare in the one hectare sample area and provides information on the proportion of soil within the Auckland region that is bare at the time of the survey.

This type of survey was completed for the first time in 1999. It captures the land stability status, and the amount of soil disturbance and bare soil, and is repeated every time there is new aerial photographic coverage of the Auckland region. New aerial photography was taken over the summer of 2006/07 so the survey was repeated in 2007. This also examined the extent of changes that had occurred since the 1999 survey.

Indicator 1: Land stability

It is important to understand how much land in the Auckland region is stable. Stable land can be used for a wide range of production purposes. Stable surfaces show no signs of past natural erosion, have a smooth appearance and are completely vegetated (unless the topsoil is disturbed by land use). Stable land surfaces make up 30.1 per cent of the Auckland region (Figure 1).

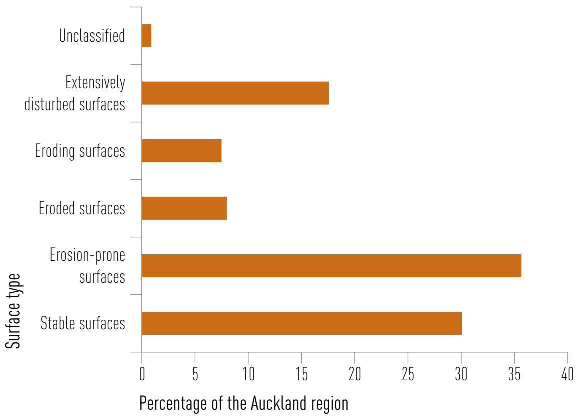


FIGURE 1 Land stability by surface type. (Source: ARC).

Unstable land is prone to natural erosion due to topography and geology, and needs to be managed carefully if used for production purposes so that erosion is not accelerated. Unstable surfaces may not always have active erosion but have been subject to natural erosion in the past. Unstable surfaces make up 51.2 percent of the Auckland region and are split into three categories:

- Erosion-prone surfaces: these show signs of past erosion but are not eroding at present, erosion scars have healed and are well vegetated. Past erosion usually occurred at least a decade prior to the aerial photography. More than one third (35.7 per cent) of the land is erosion-prone and has already undergone some form of erosion.

Land

- Eroded surfaces: these are erosion scars that are partially vegetated but still rough. Erosion has usually occurred within the decade before the aerial photography. 8 per cent of the Auckland region is naturally eroded, meaning that it has been disturbed in recent years but is now revegetating.
- Eroding surfaces: these are active erosion scars with no vegetation. Erosion has usually occurred in the year before the aerial photography and 7.4 per cent of the land in the Auckland region is currently eroding through natural processes.

Extensively disturbed surfaces are those where the soil has been partly or completely removed, re-contoured, or covered by buildings and pavements. They cover 17.8 per cent of the Auckland region, with 3.0 per cent partly covered by rural buildings, yards and major rural roads, another 11.0 per cent covered by urban land use (residential buildings and gardens, commercial buildings and yards, urban roads, railways and airfields, and open spaces with vegetation) and 3.8 per cent consisting of rock platforms, beaches, tidal creeks, and estuarine sandflats or mudflats.

Unclassifiable surfaces account for 0.9 per cent of the Auckland region. These are areas that had no aerial photographic coverage at the time of the survey.

Changes in land stability

The Auckland region has a large proportion of unstable surfaces that have eroded in the past or are currently eroding. It is important to monitor the percentages of different surface types to determine if these are changing, and whether land management practices are working and if more resources are required to help manage soil erosion.

There was no overall change in the amount of stable surfaces between 1999 and 2007. Erosion-prone but inactive land surfaces declined from 37.6 per cent in 1999 to 33.8 per cent in 2007, indicating that there was some active erosion on these surfaces. This can be seen by the increase in both eroded surfaces that were active in 1999 but have now been re-vegetated (up by 2.2 per cent from 1999), and eroding surfaces (up by 1.9 per cent from 1999).

Indicator 2: Soil disturbance

Natural erosion and land use activities can disturb the soil. The soil can be removed by water or wind as part of natural erosion processes and then deposited elsewhere, e.g. streambank erosion, landslides and sandblows (Table 1). Soil can also be disturbed by humans for land use activities, e.g. cutting a track for stock movement, cultivating a paddock for vegetable growing, and roading and urban development (Table 2).

In 2007, the soil was intact at 53.9 per cent of the sample areas. Of the 45.2 per cent of soil that was disturbed:

- 7.4 per cent was caused by natural erosion processes
- 3.8 per cent consisted of natural features that were extensively disturbed (rock platforms, beaches, tidal creeks, and estuarine sandflats or mudflats)
- 34 per cent was disturbed due to land use activities.

Note that 0.9 per cent of the Auckland region had no aerial photography coverage and was excluded from the analysis.

TABLE 1 Percentages of soil disturbance by natural processes. (Source: ARC).

Natural process	Percentage
Landslide	1.8
Debris avalanche	0.2
Slump or earthflow	0.7
Tunnel gully	0.2
Gully	0.4
Streambank scour	0.9
Streambank deposit	1.2
Sandblow	0.7
Sheetwash	0.3
Rockfall or bare rock	1.0
Total disturbance by natural processes	**7.4**

Soil disturbance by natural erosion

The assessment of soil disturbance by natural erosion that was undertaken in 2007 indicated that landslides generated the most soil disturbance (see Natural Hazzards: Landslides, pg 263); followed by streambank erosion (scour) and deposition (Table 1). When combined, scour and deposition accounted for most of the soil disturbance.

TABLE 2 Percentages of soil disturbance by land use activities. (Source: ARC).

Land use activity	Percentage
Grazing pressure	3.9
Cultivation	1.6
Harvest	1.5
Spraying	0.6
Drains	0.9
Tracks	8.6
Earthworks	1.5
Roads	1.3
Rural buildings	3.1
Urban areas	11
Total disturbance by land use activities	**34**

Soil disturbance by land use activity

Table 2 shows the type of land use activities that cause soil disturbance. Urban land use placed the most pressure on the soil, accounting for almost one third of the total land use disturbance in the Auckland region. Tracks on land that is used for production contributed a substantial amount of soil disturbance. Grazing pressure was another major land use activity causing soil disturbance.

Soil disturbance by land use type

To assess the effects of land use on soil disturbance, the survey assigned each sample area to a land use type, based on the predominant land use at that sample area.

Figure 2 shows that within the extensively disturbed category (rural buildings, major rural roads, residential buildings and gardens, commercial buildings, urban roads, railways, airfields, rock platforms, beaches, tidal creeks) most land use disturbance was human induced. This contrasts with sample areas covered by native vegetation, which had the lowest amount of human induced disturbance (this was often associated with access tracks). On land that is used for production, sheep-beef farming resulted in most of the human-induced disturbance and natural disturbance.

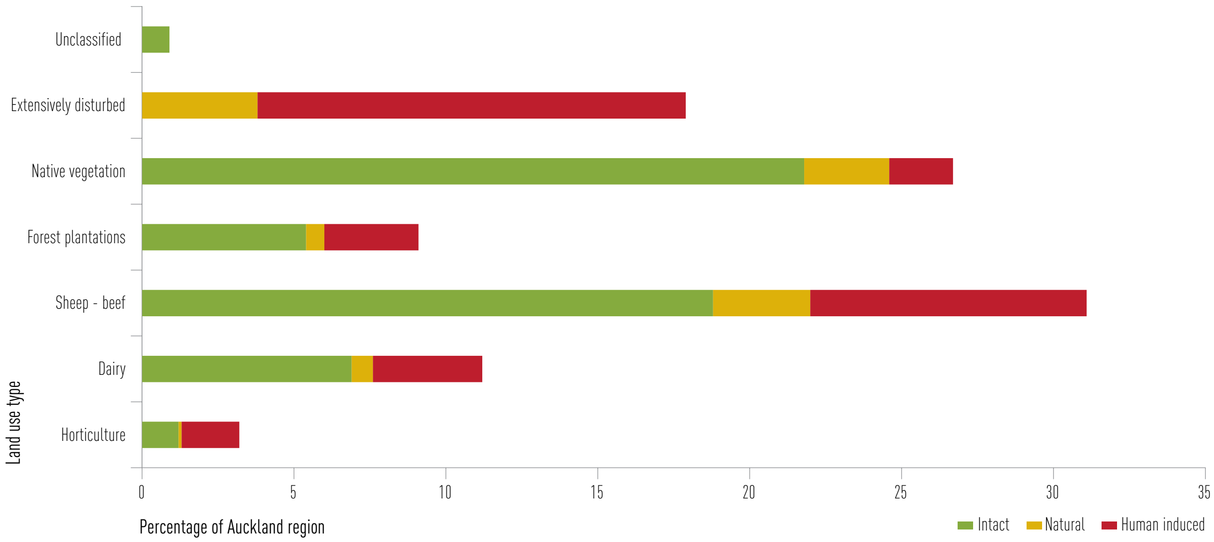


FIGURE 2 Soil disturbance, by land use type. (Source: ARC).

4.2

Land

Indicator 3: Bare soil

Natural erosion and land use activities both disturb the soil and have the potential to generate sediment.

If a sample area is recorded as disturbed, this does not necessarily mean that the entire sample area is bare soil, e.g. a farm track might be partially covered by vegetation with only some bare soil.

The 2007 survey showed that 3.29 per cent of the land within the Auckland region was bare through natural processes or human-induced land use disturbance. This equates to 16,525 hectares (equivalent to about twelve Rangitoto Islands in area).

Bare soil from natural processes

Bare soil exposed through disturbance from natural processes covers 1.18 per cent (5927 hectares) of the region. Figure 3 identifies the main types of erosion that are occurring in the region and their contribution to the total amount of bare soil.

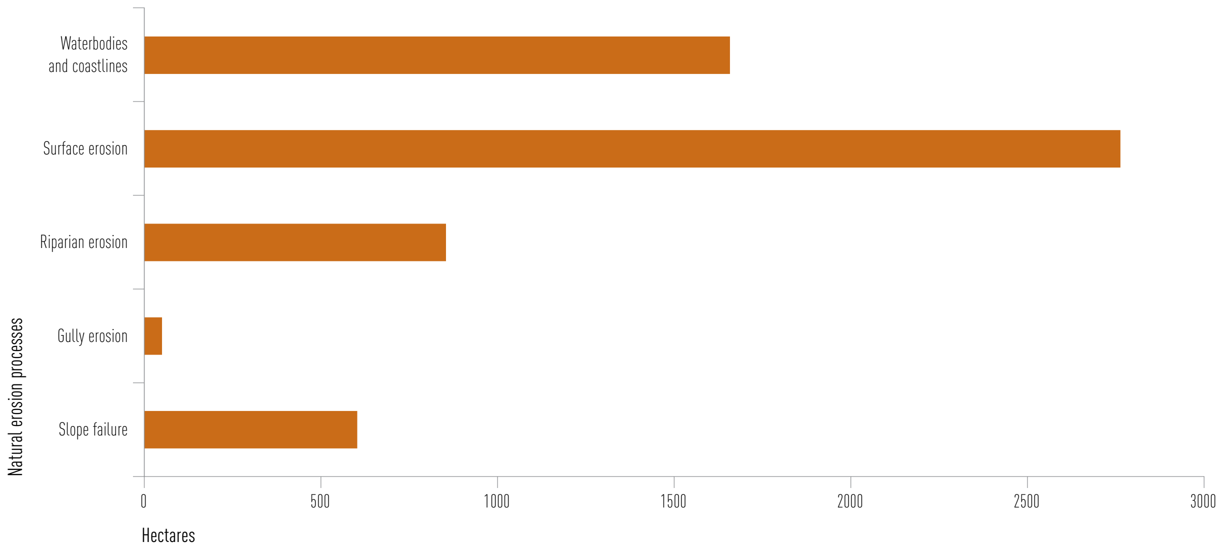


FIGURE 3 Hectares of soil bared by natural erosion processes. (Source: ARC).

Surface erosion produced the most bare soil in total, as a result of sheetwash, rock outcrops and sandblows. Deposits of sand, silt and gravel along the edges of rivers, together with streambank scour and collapse produced smaller amounts of bare soil, followed by slope failures (e.g. landslides and slips) with even smaller amounts resulting from gully erosion, tunnel gullies (under-runners) and open gullies. Other natural erosion processes around the coastline exposed bare soil, sediment, rock, estuarine flats, beaches and rock platforms.

Changes in the amount of bare soil from natural erosion processes

Some bare and eroding surfaces that were visible in 1999 were now revegetating, while some vegetated but inactive surfaces had been eroded since 1999 and now had bare soil. However, there was no overall change in the amount of bare soil from natural erosion processes in the Auckland region.

There were some changes in the types of erosion occurring between 1999 and 2007:

- → slope failures (landslides, debris avalanches, slumps and earthflows), under-runners and gullies decreased
- → sheetwash and sandblows showed little change
- → streambank scour and deposits increased.

Bare soil by land use activities

Land use disturbance exposed 2.11 per cent (10,598 hectares) of the bare soil in the Auckland region. Figure 4 shows the types of land use activities that were exposing bare soil in 2007.

Cultivation was responsible for the most widespread soil disturbance that resulted in bare soil although this is to be expected, given the nature of this land use activity. Farm and forest tracks accounted for a substantial amount of bare soil, while rural yards and urban areas (including earthworks in urban areas) were also major contributors.

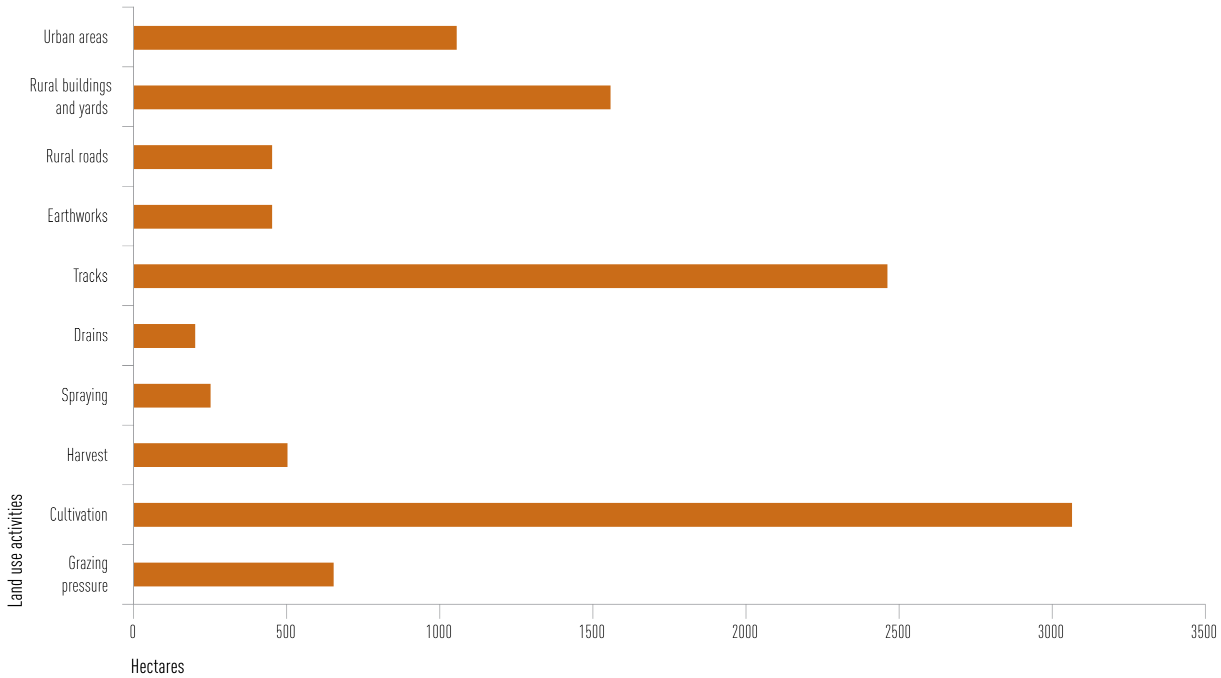


FIGURE 4 Hectares of soil bared by land use disturbance from human activities, 2007. (Source: ARC).

Changes in the amount of bare soil from rural land use activities

A comparison of sample areas measured at both dates showed an increase in the land use related disturbance of soils in rural areas of the Auckland region, from 0.72 per cent in 1999 to 1.07 per cent in 2007. This 0.35 per cent increase equates to 1758 hectares.

There has been a slight increase in the amount of bare soil generated from all rural land use activities (grazing pressure, cultivation, harvesting, spraying, drains, tracks and earthworks).

Bare soil by land use type

This measure looks at the amount of bare soil (hectares) that is associated with each broad land use type in the Auckland region. It indicates the level of pressure placed on the soil resource. Figure 5 shows the proportions of bare soil (from disturbances by natural processes and/or land use activities) by land use type.

In 2007, the greatest area of bare soil was associated with horticultural land use (as would be expected). This is often a temporary state before crops are grown but, as the survey is only snapshot in time, it cannot give a full picture of the amount of bare soil over a complete season or year.

Substantial areas of bare soil were measured in sheep-beef and dairy pasture as a result of grazing pressure. Rural buildings and yards, and urban areas also exposed sizeable areas of bare soil. Lower but measurable areas of bare soil were found in forest plantations due to topsoil exposure from logging and associated tracking. There was only a slight amount of bare soil under native vegetation and that was often due to tracks.

Natural processes often disturb subsoil as well as topsoil. In 2007, disturbance from natural processes was slight on land under dairy pasture and forest plantations. Most disturbance occurred in sheep-beef pasture and, predominantly, under native vegetation (native forest, natural scrub and coastal grasses). These land use activities and land cover types are more prone to erosion as they are often found on land that is steep and unstable. Natural erosion processes along waterbodies and coastlines tend to result in both erosion and deposition.

Land

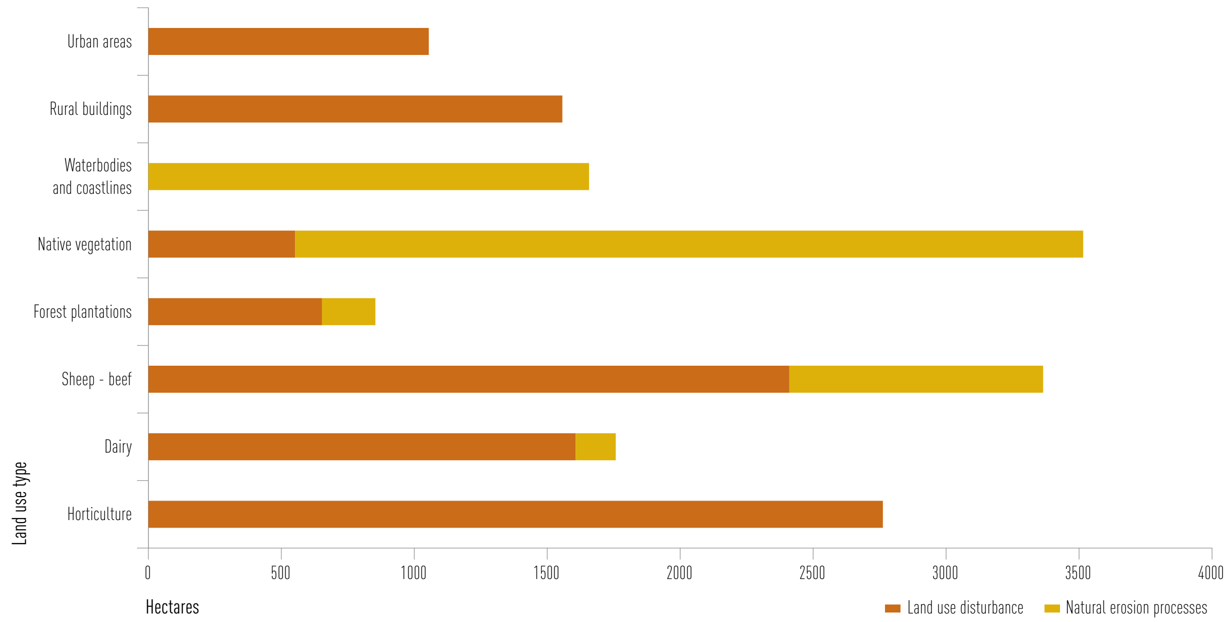


FIGURE 5 Hectares of bare soil and the proportions contributed by natural erosion and land use disturbance, by land use type. (Source: ARC).

Changes in the amount of bare soil by land use type

Between 1999 and 2007 there was:

- no change in the amount of bare soil on land under horticulture; none was noted on either date.
- an increase (from 0.19 to 0.31 per cent) in the amount of bare soil under dairy pasture, due to land use disturbance. There was also an increase (from 0.36 to 0.48 per cent) in the amount of bare soil under sheep-beef pasture and an increase (from 0.06 to 0.13 per cent) in the amount of bare soil due to land use disturbance in forest plantations.
- little or no change in the amount of bare soil under native vegetation due to land use disturbance.
- little or no change due to natural disturbance under all other rural land uses (dairy, sheep-beef, forestry and native vegetation).

No land use disturbance under waterbodies and coastline, including coastal grass and scrub was recorded on either date. Although it does occur (e.g. from grazing pressure) it is swiftly transformed into moving sandblows which are recorded as natural disturbance.

Implications of soil disturbance and bare soil

Although natural erosion processes can expose bare soil and generate sediment, human activities have altered the natural land cover and changed the original land use by disturbing the land through the removal of vegetation, cultivation, intensive grazing and earthworks.

As a result of land use activities and associated disturbances the amount of bare soil has increased and erosion has accelerated. Both natural and accelerated erosion can lead to:

- increased instability of the surrounding surfaces
- loss of the soil's productive capability, resulting in reduced production
- more sediment being generated and potentially washed into the freshwater and marine environments
- adverse effects on surface and subsurface drainage
- damage to infrastructure, fences, farm tracks, roads and houses
- destruction or damage to native plant or animal habitats
- adverse effects on the aesthetic and cultural values associated with land.

It is hard to quantify the economic effects of erosion but one study suggests that surface erosion of bare topsoil can reduce crop yield and pasture growth by at least 20 per cent and, in extreme cases, more than 60 per cent.

Mass movements of subsoil by slumps, earthflows, earth slips and soil slips can initially reduce pasture growth by 40 to 80 per cent. After the surfaces have re-vegetated, production often remains depressed by 10 to 40 per cent, with a subsequent economic cost to the land owner. Table 3 shows the estimated costs in dollars.

TABLE 3 Estimated economic costs of lost productivity due to soil erosion. (Source: Landcare Research 2001).

Erosion type	Cost ($/hectare)
Mass movement	1,385.00
Surface erosion – arable cropping	750.00
Surface erosion – pasture	2.10

Table 4 shows the variable costs of farm repairs resulting from the cumulative impact of mass movement, gully creation and streambank erosion.

TABLE 4 Damage repair costs, 1988-92, averaged over farm area. (Source: Environment Waikato).

Type of repair	Minimum cost ($/hectare)	Maximum cost ($/hectare)
Fences	6	44
Tracks	1	26
Buildings	1	11
Pasture re-sowing	1	13
General clean-up	3	4

Soil quality

Key findings

→ The data from 88 sites that were assessed by seven soil quality parameters for rural land use categories (dairy, sheep-beef, horticulture, forestry and native vegetation) indicated that 38 per cent of the monitored land area met all the soil quality targets and was classified as excellent, 55 per cent was fair and 7 per cent was poor.

→ Dairy and horticulture had the lowest number of sites that met all seven soil quality parameters, and native vegetation had the highest number.

→ The two soil quality parameters that are of most concern for rural land in the Auckland region are low macroporosity indicating widespread soil compaction, and high Olsen P levels indicating high chemical fertility.

Introduction

Soil quality is often defined as the capacity of a soil to sustain biological production, maintain environmental quality, and promote plant and animal health. It is assessed using seven soil quality parameters that measure physical, chemical and biological functions of the soil. Changes in soil quality can be both positive and negative.

Soil quality monitoring programme

Soil quality monitoring is used to monitor status and trends, and to identify the long-term effects of production land uses on soil quality. The objective is to make sure that soil productivity is retained and that soils are protected from permanent loss and degradation, as current land management practices may not be sustainable for some combinations of soil and land use.

Soil quality monitoring helps to identify which soil parameters are of greatest concern and enables an appropriate management response to be determined, e.g. targeted education on the effects of soil compaction and the economic benefits of managing soil quality. In the longer term, trends can be identified and it is possible to see whether land management practices are improving or whether soil quality is deteriorating.

The ARC was involved in two programmes: one ran from 1995 to 1998 to identify 'preferred soil quality parameters' with Landcare Research, the second was the 500 Soils Project that ran from 1999 to 2000 and was developed by the Ministry for the Environment (MfE) and Landcare Research.

The initial programme measured a range of chemical, biological and physical soil quality parameters at sites throughout New Zealand. The results enabled these parameters to be reduced to seven soil quality parameters (see Table 5) that help to identify whether current land use practices are having a beneficial, or an adverse, effect on the soil.

Land

TABLE 5 The seven chemical, biological and physical soil parameters used to assess soil quality. (Source: ARC).

Indicator type	Soil parameter	Soil management issue
Chemical	Total carbon	Carbon depletion
Chemical	Total nitrogen	Nutrient depletion/saturation
Chemical	pH	pH changes (acidity)
Chemical	Olsen P	Nutrient depletion/saturation (fertility) – the amount of phosphate readily available to plants
Biological	Mineralisable nitrogen	Measure of soil organic matter
Physical	Bulk density	Measure of structural decline
Physical	Macroporosity	Measure of the amount of large pore spaces which allow oxygen and water to move through the soil

The target range levels for each soil quality parameter were assigned for various land use types and soil classes at a series of workshops in 1999. These target range levels represent critical levels where deterioration of soil function occurs.

Between 1995 and 2000, a total of 88 sites were sampled across rural land in the Auckland region. These sites were considered to be a representative cross-section of the major soil and land use types, as it is not possible to measure all combinations of land use and soil classes within the Auckland region. The five broad types of land use were: dairying, sheep-beef pasture (also known as drystock), forest plantations, horticulture and native vegetation.

The ARC re-sampled the horticultural sites in 2008 when the ARC re-established its soil quality monitoring programme. The ARC will re-sample the other land use types over the next three years. After then, the horticultural sites will be sampled every three years, dairy and sheep-beef sites will be sampled every five years, and forestry sites every ten years. Native vegetation will be re-sampled every 20 years.

Infrequently the ARC analyses soil quality samples for a range of trace elements (Box 1 page 133).

Indicator 4: Soil quality

Soil quality by site

Table 5 shows the seven parameters that were used to assess the soil quality of a site. The results were analysed for each site, in order to identify the number of sites that met the target range levels for all of the seven parameters. The results for the 88 sites sampled (Figure 6) showed that:

- 29 sites (33 per cent) met all targets for the seven soil quality parameters
- 38 sites (43 per cent) did not meet the targets for one parameter
- 14 sites (16 per cent) did not meet the targets for two parameters
- four sites (five per cent) did not meet the targets for three parameters
- three sites (three per cent) did not meet the targets for four parameters.

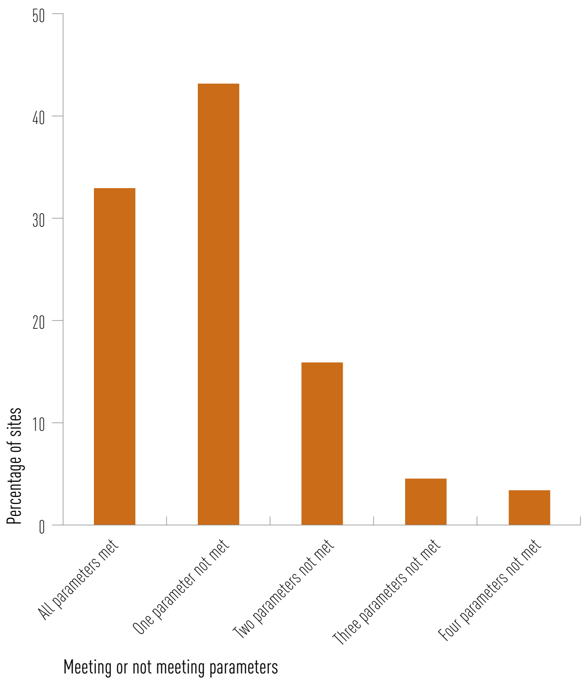


FIGURE 6 Percentage of sites meeting or not meeting the target range levels for soil quality parameters. (Source: ARC).

Soil quality by land use

To assess the effects of land use on soil quality, the 88 sites were split into broad land use types and assessed against the target range levels for all of the seven soil quality parameters. Of the 88 sites analysed, 21 were dairy pasture, 18 were sheep-beef pasture, 20 were horticulture, nine were forestry and 20 were native vegetation.

To get a better understanding of the soil quality data and how this related to the different types of rural land use, the data were categorised into the three groups and shown in hectares. Data from the land cover database (2002) which covers the period when samples were taken, and land use data from the Soil Intactness Survey (1999) were used to determine the area in hectares each land use type, excluding the categories of urban and other.

The data were classified into the following three categories:

- → Excellent: all soil quality parameter target levels were met
- → Fair: one or two parameters did not meet the target levels
- → Poor: three or four parameters did not meet the target levels.

Figure 7 shows the percentage of sites in each category. Native vegetation had the greatest number of sites classified as Excellent and no sites in the Poor category. Dairy and horticulture had the lowest number of sites in the Excellent category. Conversely, forestry recorded the highest proportion of sites categorised as Poor.

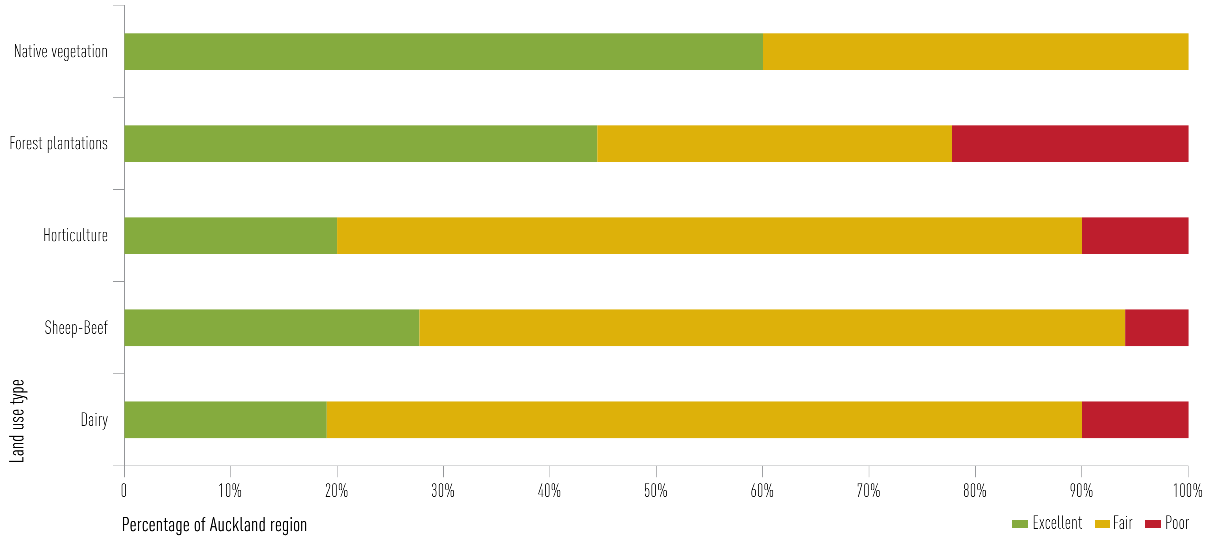


FIGURE 7 Percentage of sites categorised as Excellent, Fair or Poor soil quality according to five land use types. (Source: ARC).

Table 6 indicates that 38 per cent of the land area has Excellent soil quality, while 55 per cent has Fair soil quality and seven per cent has Poor soil quality. The three non-forested land uses (dairy, sheep-beef and horticulture) all have similar percentages in each of the Excellent, Fair and Poor soil quality categories.

Forestry has the highest percentage of Poor soil quality (22 per cent) covering an area of just under 12,000 hectares. Sheep-beef has the smallest amount of Poor soil quality by percentage but is substantial by area (just behind forestry).

TABLE 6 Rural land area (hectares) according to the three soil quality categories. (Source: ARC).

Land use	Area	Excellent (%)	Land area excellent	Fair (%)	Land area fair	Poor (%)	Land area poor
Dairy	63,811	19	12,124	71	45,306	10	6381
Sheep-beef	185,257	28	51,872	67	124,122	6	11,115
Horticulture	9281	20	1856	70	6497	10	928
Forest/Plantations	54,371	44	23,923	33	17,942	22	11,962
Native vegetation	135,856	60	81,513	40	54,342	0	0
Total	**448,576**		**171,289**		**248,210**		**30,386**
Percentage	**100**		**38**		**55**		**7**

Soil quality parameters by site

The percentage of sites not meeting targets for specific soil quality parameters identifies which of the seven soil quality parameters is of greater concern. Results from all 88 sites (Figure 8) show that the two major soil quality issues are:

- low macroporosity, which indicates widespread soil compaction (43 per cent of sites)
- high Olsen P levels, which indicates high chemical fertility (32 per cent of sites).

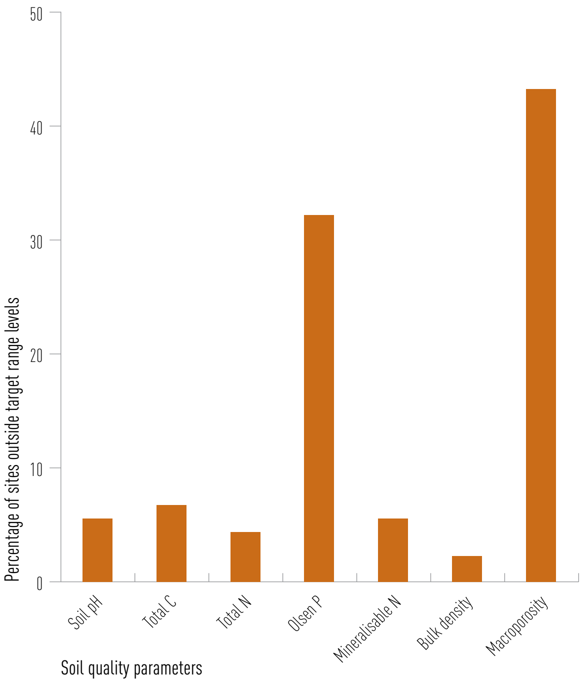


FIGURE 8 Percentage of sites not meeting soil quality targets for specific parameters. (Source: ARC).

Horticultural soil quality in 2008

Twenty horticultural sites (market gardens, vegetable producers, orchards and vineyards) that were sampled between 1995 and 2000 were sampled again in 2008. The soil quality parameters and target levels specific to soil type and land use were used to assess the soil quality at these horticultural sites. The ARC was unable to take samples from two of the original sites because they had since been built on).

In 2008:

- Four sites (22 per cent) met all the targets for the seven soil quality parameters
- Six sites (33 per cent) did not meet the targets for one parameter
- six sites (33 per cent) did not meet the targets for two parameters
- two sites (11 per cent) did not meet the targets for three parameters.

When the 20 horticultural sites were originally sampled between 1995 and 2000, only two sites met all the target levels for all soil quality parameters. The number of sites that met all the soil quality parameter target range levels has doubled but further monitoring is required to establish if this is a trend.

The status of each site in 2008 was compared with data from previous samples collected between 1995 and 2000. No consistent changes in soil quality were detected between the specific horticultural activity or soil class. The sites showed both positive and negative changes.

The percentage of horticultural sites not meeting targets for specific soil quality parameters identified which of the seven soil quality parameters are the biggest issues in 2008. The results from the horticultural sites (Figure 9) show that the soil quality parameters of greatest concern remain those identified between 1995 and 2000 for the Auckland region.

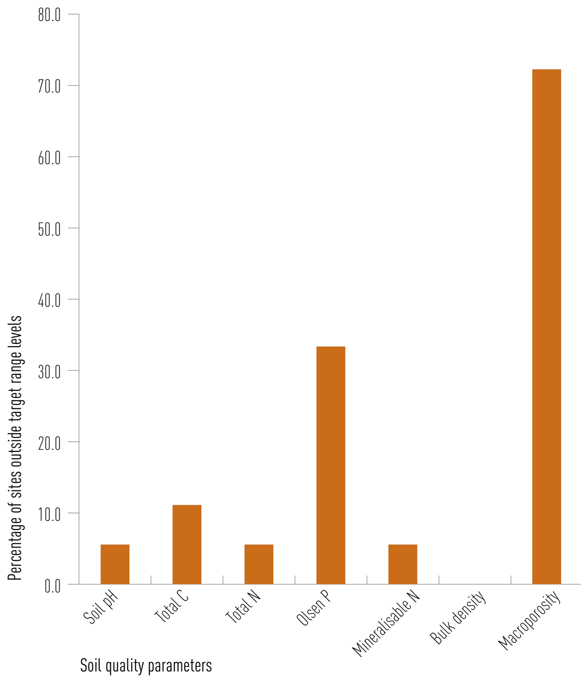


FIGURE 9 Percentage of horticultural sites not meeting soil quality targets for specific parameters. (Source: ARC).

Box 1 Trace elements in rural soil

Trace elements occur naturally in soils, mainly as a result of the natural weathering of rocks and minerals. These natural levels are often referred to as 'background concentrations' and can vary depending on the soil type, geology and climate. Trace elements can also be added to the soil as the result of agricultural and horticultural land use activities. Soils on land used for production can have different trace element profiles than soils with natural background levels.

In pastoral areas, the use of superphosphate fertiliser results in the gradual accumulation of several trace elements such as cadmium, fluorine and uranium. Arsenic based dips have also been used for sheep and beef cattle. Facial eczema remedies containing zinc sulphate are likely to account for zinc. Horticultural soils can receive high loads of pesticides and fungicides, some of which break down slowly.

Trace element concentrations that are higher than the background concentrations are usually referred to as 'elevated'. At present, there are no set national standards to assess trace elements for environmental or population health in soil, although guidelines exist that allow some comparison. For instance, the Guidelines for the Safe Application of Biosolids to Land in New Zealand (2003) have been used to assess the trace element results for arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc.

Monitoring for trace elements in the Auckland region is part of the soil quality monitoring programme. Fifty-two archived soil quality samples from 1999 and 2000 were analysed for 39 trace elements. Across horticulture, dairying, sheep-beef, planted forestry and native vegetation land use types guidelines for chromium, lead, mercury, nickel and zinc were met. For cadmium, horticulture, dairying and drystock all had higher average concentrations in the soil compared to the background concentration for native vegetation. Dairying sites had the highest average concentration. For copper, dairying and horticulture concentrations were above native vegetation but within the range of concentrations for soils in the Auckland region.

Continued monitoring will give a better understanding of the accumulation of trace elements under various land uses in the Auckland region and help to identify emerging issues.

Implications of poor soil quality

Compaction

Large numbers of stock (high stocking rates) can cause immediate direct damage to pasture as stems, leaves and roots are crushed and plants are smothered under sediment. In the short-term, there is a drop in pasture productivity and in the amount of available feed for stock. In the long-term, high stocking rates can lead to structural breakdown of the soil as pore spaces are lost or reduced by compaction. Heavy machinery and repeat cultivation using heavy machinery, can also lead to compaction in soils under intensive cultivation. Wet conditions can exacerbate the effects of these land management practices. The structural decline of the soil from compaction limits subsequent pasture growth. Annual yield losses ranging between 15 and 30 per cent have been reported from severely compacted soils in the Manawatu, coastal Otago and Southland, Northland and the Waikato.

The implications of increased structural breakdown of soils under cultivation include:

- → increased fertiliser and irrigation requirements
- → poor seed germination and emergence
- → poor plant growth and vigour
- → delays in sowing and in harvesting
- → re-sowing of poorly performing paddocks and subsequent uneven ripening of crops
- → increased susceptibility to root diseases and pest attack
- → reduced crop yields and grain quality.

Soil compaction is also an issue for farmers when water drainage deteriorates due to the loss of pore spaces in the soil, as this can lead to ponding of water and surface runoff. Ponding can create anaerobic conditions that can restrict plant root growth. Surface runoff can lead to valuable nutrients and topsoil being lost and this, in turn, reduces pastoral or horticultural growth.

Increasing phosphate levels

The phosphate levels on land under intensive use often exceed the plant uptake level and the excess may be lost through leaching and/or surface erosion. This loss has a direct economic cost to the farmer and the potential to degrade water quality (see River water quality programme and Lake water quality programme in Chapter 4.3). For example, a study in 2002 estimated that the value of nutrients in Pukekohe vegetable-growing topsoils was between $8000 and $26,000 per hectare. Assuming a net rate of soil loss between seven and 30 tonnes per hectare per year, the loss of excess nutrients would be worth $35 to $570 per hectare per year.

4.2

Land

Phosphate fertilisers also contain cadmium (Box 1). The Cadmium Working Group has reported a steady increase in the amount of phosphate fertiliser used in New Zealand, to a high of over two million tonnes in 2002/03. Cadmium levels will be investigated as part of the soil quality monitoring programme, as there are possible future implications if cadmium levels continue to rise:

- → Toxicity of soil to organisms, plants and animals may occur.
- → Cadmium in soil may rise to levels that could restrict the growth of certain types of produce if these levels exceed New Zealand and international food standards.
- → The ability to subdivide land for residential purposes could be restricted if cadmium accumulates to a level where the land is classified as contaminated.
- → The flexibility to change land use might be limited, as crops or vegetables sensitive to the uptake of trace elements would be restricted.

Sediment

Key findings

- → The variation in specific sediment yield was mainly due to catchment rainfall, mean slope and land use.
- → A regression model indicated that for a given rainfall and slope, the yields from forested areas were 66 per cent lower than pasture, while the yields from urban areas were 25 per cent lower than pasture.

Introduction

Sediment is any solid material mineral and organic that is in suspension, is being transported or has been moved from its site of origin by air, water, gravity or ice and has been deposited on the Earth's surface above or below water.' (Auckland Regional Council Technical Publication 90.)

The generation of sediment is a natural process driven by rainfall, geology, topography and land cover. It has been accelerated by human-induced land use change and intensification. Studies indicate that native forest catchments yield less sediment than pasture and exotic forest catchments. Changes in land use, e.g. forest harvesting and urban development, can cause major increases in sediment yields but these are often temporary.

Not all of the sediment generated in a catchment area will be flushed into the rivers, as some will be trapped near its source. However, some suspended sediment will drop out of suspension and be deposited on the riverbeds, and some will be carried out into the marine environment (see Pressures: Indicator 27, pg 62). Sediment can have many adverse impacts on the habitats and health of freshwater and marine ecological communities. Therefore, some freshwater and marine monitoring programmes measure the amount of sediment in the water (see river and lake monitoring programmes in Chapter 4.3, pages 143 and 161, coastal water quality monitoring programme and benthic ecology monitoring in Chapter 4.4, pages 183 and 189).

Sediment yield monitoring

Sediment yields in the Auckland region are monitored on a project basis as there is no regionally representative programme in place. It is impractical to continuously monitor sediment yields in every catchment across the region so, by developing an understanding of how sediment yields vary (according to land use and the hydrological and physical characteristics of catchments), sediment yields across the region can be estimated.

The information provided in Indicator 5 (below) is a measure of sediment yield from different land uses. The ARC will be developing this further to strengthen its regional application and address current limitations.

Indicator 5: Sediment yield

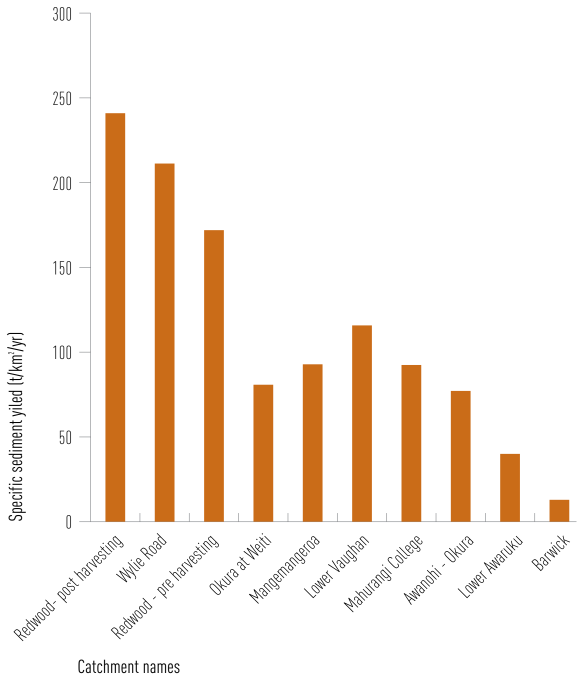
Sediment yields during storms at nine catchment areas within Waitemata Formation were analysed. The sediment yields from storm events and the mean annual sediment yields were determined. The catchment areas were under various land uses and ranged in size from 0.2 to 48.8km^2. The mean annual sediment yields from specific catchments were investigated using three approaches to compensate for the limited flow record for most of the study sites (Table 7).

The relationships between sediment yield and catchment characteristics were examined by comparing plots of sediment yield against land use. Figure 10 shows that the highest sediment yields are linked with forest harvesting (Redwood Forest) and the lowest occur in urban catchments (Lower Awaruku and Barwick). Between these extremes, there appears to be a trend for sediment yield to increase as the percentage of pasture increases and forest decreases. The exceptions are Redwood Forest during the pre-harvesting phase, and the Okura catchment, which both show higher than expected sediment yields. However, the high sediment yield at Redwood Forest may be due to its steep slopes and relatively high rainfall. The figures for the largely-forested Okura catchment may be higher than the long-term average due to the short recording period.

TABLE 7 Catchment-specific annual average sediment yields (t/km²/yr). (Source: ARC)

Catchment and area (km²)	Land use	Sediment yield	Years of flow data
Redwood Forest (0.6)	Exotic forest post-logging	241 +/- 35	11 months
Wylie Road (1.05)	Pastoral	200 +/- 2	1 year, 4 months
Redwood Forest (0.6)	Exotic forest pre-logging	172 +/- 19	2 years, 8 months
Lower Vaughan (2.17)	Pastoral	98 +/- 18	6 years, 1 month
Mangemangeroa (4.44)	Pastoral	89 +/- 7	8 years, 1 month
Mahurangi College (48.83)	Pastoral	88 +/- 19	26 years, 4 months
Okura at Weiti* (1.70)	Exotic vegetation	82 +/- 13	6 months
Awanohi – Okura (5.27)	Native vegetation	74 +/- 12	6 years, 4 months
Lower Awaruku (2.66)	Urban	40 +/- 11	3 years, 4 months
Barwick* (0.24)	Urban	13	6 months

*Results for Barwick and Okura at Weiti should be viewed with caution due to the short (six month) recording period, but all the remaining sediment yields are within the range of previous estimates for the Auckland region.



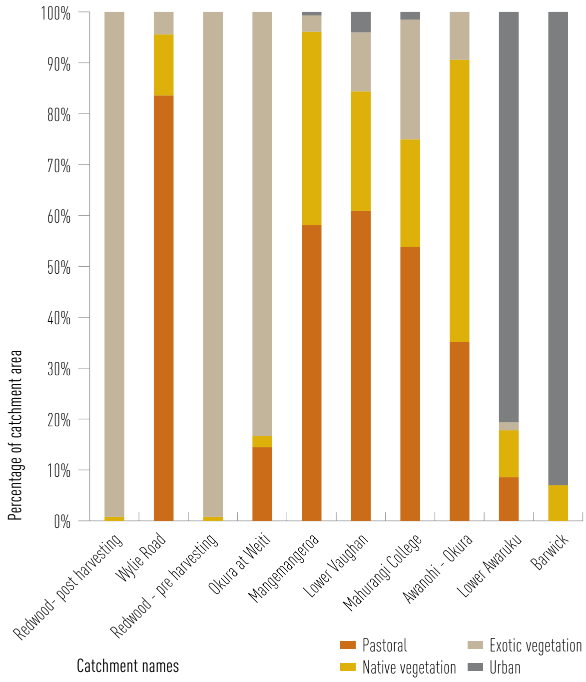


FIGURE 10 Specific sediment yield and land use type for each catchment. (Source: ARC).

Land

Sediment yields among the Lower Vaughan, Mangemangeroa, Mahurangi College, Okura-Weiti and Awanohi-Okura catchments range from 74 to 98 t/km^2/yr and, even allowing for the estimated uncertainty, there is little difference between them. Therefore, among these catchments at least, any influence from the type of land use does not appear to be strong.

The relationship between sediment yields and catchment characteristics was developed through another analysis. It indicated that variations in the annual average sediment yields are due mainly to catchment rainfall, the mean angle of the slope and the type of land use. For a given rainfall x slope product, sediment yields from forested areas are two thirds of those from pasture areas, while sediment yields from urbanised areas are one quarter of those from pasture areas.

Further monitoring of sediment yields at key sites is required to validate the relationship developed above. The programme will also need to monitor the other broad geologies to develop the picture for sediment yields across the Auckland region. In the long-term the ARC needs to understand the trends and evaluate the effectiveness of land management measures.

Implications of sediment

Sediment that is deposited on the land can smother pasture and crops, decreasing the productive capability of the land and reducing individual profit margins. It can also adversely affect other types of land cover and result in habitat loss. In the rivers and marine environment, suspended sediment can degrade the water quality by reducing the water clarity. Sediment can also silt up channels and accumulate in receiving environments such as lakes and harbours, adversely affecting natural habitats and ecosystems and leading to physical changes such as increasing the area of tidal flats.

Sediment also has a direct economic cost to the community when it damages infrastructure, e.g. siltation of reservoirs, and blocked roadside drains and stormwater networks. Excessive levels of sediment (and other debris such as sand, rocks and trees) that are washed into the rivers can cause further erosion, instability and ecological damage. Erosion control measures on the banks of unstable rivers can be very expensive and are often beyond the resources of individual landowners.

Conclusions on the state of the land

The ARC measures the effects that different land use types have on the land and soil. It does this by measuring soil stability, soil disturbance, bare soil, soil quality and sediment generation. Results show that the land and soil across the Auckland region are losing their ability to sustain their maximum productivity levels, because of soil degradation caused by land use activities.

In 2007, just under one third of the land in the region had stable land surfaces. Most land has been disturbed at some time in the past but has been re-vegetated. Natural processes have disturbed 7.4 per cent of the land and 17.8 per cent was extensively modified, largely due to urbanisation. Between the two surveys in 1999 and 2007 (and allowing for changes in survey methods) there was no change in the amount of stable surfaces but there was an increase in eroding surfaces due to the pressure of human-induced land disturbance, shown by an increased 0.35 per cent (1,758 hectares) of bare soil. Land use disturbance can be somewhat controlled, in comparison to natural erosion, through the use of best management practices and regulatory processes. Findings from these surveys will help to form policy decisions and target education within the region.

There were 16,525 hectares of bare soil (3.29 per cent of the region) with the potential to generate sediment. Bare soil and some land use activities including logging, pastoral land use and earthworks generate a greater proportion of bare soil than under natural land cover. Although sediment can impact the land, it is of greater concern when it enters freshwater and marine receiving environments because it can degrade the water quality and adversely effect existing ecosystems.

The most significant pressures leading to soil loss are agricultural practices that increase the exposure and vulnerability of soils. These include the removal of protective vegetation through the cultivation of soil for intensive uses, and the creation of farm and forestry tracks. At the time of the survey, natural processes had less impact than land use practices.

Of the 88 sites assessed by the seven soil quality parameters for rural land use categories (dairy, sheep-beef, horticulture, forestry and native vegetation), 38 per cent of the monitored land area met all the suggested soil quality targets.

The physical condition of the soil had decreased when land was under horticultural, dairy and sheep-beef pasture, as represented by low macroporosity indicating soil compaction. Repeat cultivation or the use of heavy machinery at certain times of the year when soil moisture conditions are not optimal are likely to be causing compaction in soils under horticultural use.

There was also a decrease in the chemical condition of the soil resulting from the addition of excessive nutrients (phosphate fertiliser) on land under horticultural use. The high use of chemical fertiliser on market gardens is of concern, as shown by the number of horticultural sites that had high Olsen P levels that exceeded the target range levels. The same concerns (low macroporosity and increased Olsen P levels) identified in the first sample of horticultural soils were identified again in the repeat sampling in 2008. Further sampling is required to determine if this is a real long-term trend.

Deterioration of one soil quality indicator may not necessarily cause an immediate loss of soil quality, but may have a synergistic effect that leads to a gradual reduction in soil quality.

Degradation or depletion of the land and soil resource has major economic, environmental and aesthetic implications for the region that can impact both the individual and the community. Soil quality can degrade quickly, but restoring the quality of a degraded soil tends to be a slow and costly process. Therefore, maintaining the soil quality is essential for sustainable land use that will continue to benefit the region's economy and maintain its water quality.

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Photo: Lake Ototoa, Auckland. (Source: ARC).

4.3

State of the environment and biodiversity – Freshwater

Contents 4.3

4.3

Freshwater

Introduction

The plentiful rainfall across the Auckland region sustains a wide variety of freshwater environments including all the rivers, lakes and wetlands on the surface as well as the hidden store of groundwater. These freshwater environments support numerous ecosystems, providing habitats for birds, plants, insects, invertebrates, fish and amphibians. The quality and quantity of freshwater required to support these ecosystems is of high importance.

Freshwater is a vital, but limited, resource that is essential to life. Without sufficient, clean freshwater, human health, cultural health, the economy and agricultural output would all decline. Freshwater features such as rivers and lakes also enhance the landscape, as well as providing an important resource for recreational activities such as swimming, freshwater fishing, and kayaking.

Water is a fundamental taonga (treasure) to Māori, who have cultural, historical and spiritual links with many of the rivers, lakes and wetlands in the Auckland region.

Under the provisions of the RMA, water is taken from surface waters (rivers and lakes), abstracted from groundwater through boreholes or collected from rainwater. However, as the population of the Auckland region continues to grow and land use practices intensify, managing the freshwater resources in order to ensure a reliable supply of freshwater while maintaining the health of the freshwater ecosystems, becomes even more critical. Therefore, the ARC needs to understand the quantity and quality of the freshwater resources and identify changes and long-term trends in order to manage it effectively and make informed decisions.

ARC's freshwater monitoring programmes help the ARC to characterise the environmental and ecological characteristics of the freshwater resource and to understand the effects of environmental stressers upon it. However, the ARC programme monitoring does have limitations. It is impossible to comprehensively monitor the entire region therefore, the ARC monitors a selection of sites using measures that are selected for their relevance to environmental pressures. The sites are selected to be representative of the whole freshwater resource in the Auckland region; this means that the ARC monitors all sizes and types of freshwater and cover the range of land cover types found in catchment across the Auckland region.

Note: The RMA defines a 'river' as a continually or intermittently flowing body of freshwater, including streams and modified watercourses. The term 'river' is used in this chapter consistent with this definition.

Rivers

Key findings

- → The Auckland region has around 16,500km of permanent rivers and most are relatively small (less than a few metres wide). Most (63 per cent) flow through non-forested rural land and 21 per cent flow through native forest.
- → River water quality is strongly related to the type of land cover in the surrounding catchment area. Native forest sites have the best water quality and urban sites have the worst. However, trends indicate that urban river water quality improved between 1995 and 2005.
- → The ARC ecological monitoring programme showed a similar pattern in relation to the catchment land cover. Native forest rivers had healthy biological communities but urban streams had an impoverished fauna.

Introduction to rivers

The Auckland region has thousands of kilometres of rivers, ranging from tiny headwaters to the largest, the Hoteo River (Box 1). The water in any river comes from all the seeps, springs and surface runoff in its catchment area. As these flow downhill they merge, forming a permanent river that eventually flows to sea.

The Strahler order system allows the ARC to classify permanent rivers based on the size and number of their tributaries (Figure 1). A river with no tributaries is classified as first order. When two first order rivers merge, they form a second order river. When two second order rivers merge, they form a third order river. Rivers only increase in order when two tributaries of the same order merge, e.g. if a second order river merges with a third order river, the river remains as third order. Therefore, a third order river becomes a fourth order river only when it merges with another third order river.

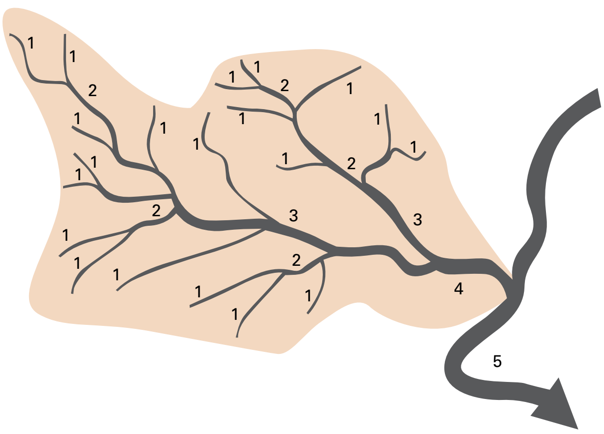


FIGURE 1 The Strahler order system. (Source: U.S Army Corps of Engineers).

Freshwater

As no mainland location in the Auckland region is more than 20km from the coast, the catchment areas of each river are relatively small. This means that most of the rivers reach the sea before they merge with others to form large rivers. Consequently, most rivers are first and second order (Table 1), meaning that they are relatively small and usually less than a few metres wide. These small catchments are characteristic of the Auckland region and mean that only 3 per cent of the rivers are fifth order and greater.

The relatively low elevation of the Auckland region and the underlying geology of the land also have a profound influence on the nature of the rivers, usually resulting in slow flowing, low gradient rivers with soft bottomed beds. Fast flowing, high gradient rivers with stony, hard bottoms are mostly restricted to catchments that drain the higher areas in the Waitakere Ranges and the Hunua Ranges.

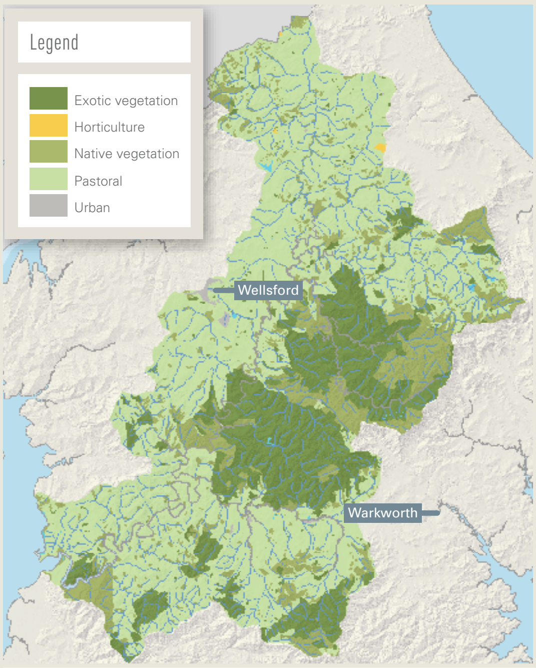
TABLE 1 Permanent rivers in the Auckland region classified by the Strahler order system. (Source: ARC).

Strahler order	Length (km)	% in order	Cumulative %
1	8753	52.7	52.7
2	4262	25.6	78.3
3	2121	12.7	91.0
4	1003	6.0	97.0
5	372	2.2	99.2
6	122	0.7	99.9
7	16	0.1	100
Total	**16,650**	**100**	

Box 1 The Hoteo River – the biggest in the Auckland region

The Hoteo River area drains nearly 8 per cent of the Auckland region. It is the biggest river in the Auckland region, by both flow and catchment area. Its headwaters are around Wellsford and it drains into the Kaipara Harbour near Mangakura. The Hoteo is seventh order at its mouth and has a catchment area of 405km^2. The catchment area is mainly rural (78 per cent) with areas of native forest (9 per cent) and exotic forest (13 per cent).

The Hoteo discharges 175 gigalitres every year on average (1 gigalitre is 1,000,000,000 litres). Although it is the biggest river in the Auckland region, it is relatively small on a national scale, e.g. the Waikato River discharges over 12,000 gigalitres each year.



Land cover by type in the Hoteo River catchment.

4.3

Freshwater

Box 2 Examples of permanent, intermittent and ephemeral rivers in the Auckland region

Permanent

The Wekatahi River in the Waitakere Ranges. This type of river flows all year round.

Intermittent

An unnamed tributary of the Okura River. This type of river flows for most of the year, but dries up in prolonged dry periods; it usually has a clear channel within defined banks.

Ephemeral

An unnamed tributary of the Mahurangi River. This type of river is dry most of the time and flows only after rainfall, it does not usually have a clear channel or defined banks.

It is difficult to determine the exact total length of rivers in the Auckland region for a variety of reasons. Our current best estimate, based on remote sensing and GIS analysis is 28,240km consisting of:

- 16,650km of permanent rivers
- 4480km of intermittent rivers
- 7110km of ephemeral rivers.

See Box 2 for descriptions and examples of these river types.

The River Environment Classification (REC) scheme has classified each river in New Zealand by the type of land cover in its surrounding catchment. Land cover affects the quality and quantity of water, the types of ecological habitats in the river and its flow patterns. The REC is based on the following types of land cover:

- native forest (including natural alpine environments)
- exotic forest
- rural (includes all non-forested rural land)
- urban.

The majority (63 per cent) of rivers within the Auckland region drain non-forested rural catchments (pastoral farming, horticulture and rural residential), followed by native forest catchments (21 per cent), with exotic forest and urban catchments accounting for 8 per cent each (Table 2). This shows that the proportions of catchment land cover types for rivers within the Auckland region are quite different from the rest of New Zealand.

These differences reflect the high population density in the Auckland region and the environmental pressures associated with this. For example, 8 per cent of rivers in the Auckland region have urban catchments compared with only 1 per cent nationwide. The Auckland region also has fewer rivers with native forest catchments (21 per cent) compared to the country as a whole (51 per cent).

In addition to the differences in catchment land cover types, all rivers show natural variation between their source and the sea as they increase in size, decline in gradient and accumulate increasing amounts of nutrients and sediment. This natural variation, together with the effects from different types of catchment land cover, produces a wide range of environmental conditions that, in turn, provide a wide range of ecological habitats.

TABLE 2 Proportions of catchment land cover types for rivers in the Auckland region compared to the whole of New Zealand (2005). (Source: ARC, MfE).

Type of land cover	Percentage of rivers	
	Auckland region	New Zealand
Rural	63	43
Native forest	21	51*
Exotic forest	8	5
Urban	8	1

*Includes Alpine environments which are not found in the Auckland region.

River monitoring programmes

The ARC operates three river monitoring programmes:

- → **Water Quantity Programme.** This monitors river level and flow at 32 sites across the Auckland region. The hydrological data is collected automatically through a range of sensors and sent to the ARC by a telemetry network. The hydrological data is also complemented by a network of 37 rainfall stations. Collectively, the data enable the ARC to determine long-term trends in the hydrology, more accurately predict the extent of flooding and impacts of droughts, and support our water quality and ecological monitoring programmes (described below).
- → **Water Quality Programme.** This monitors some of the physical, chemical and microbiological properties of rivers at 27 sites (Figure 4) around the Auckland region once each month. It provides information on the water temperature and amount of nutrients, oxygen, sediment and other pollutants in the rivers. The results enable the ARC to assess the life-supporting capacity of the river (how suitable it is for supporting plant and animal life) and the microbiological quality of the river (how suitable it is for recreational use and for stock to drink).
- → **The Ecological Quality Programme.** This monitors the type and number of invertebrates (such as insects, crustaceans, worms and snails) found at up to 64 sites (Figure 6) around the Auckland region once a year. The type and number of invertebrates found at a site are used to indicate the ecological quality of the river.

The three monitoring programmes are regionally representative. This means that they monitor all sizes and types of rivers, and also cover the range of different catchment land cover types found across the Auckland region. The overall aim is to characterise the environmental and ecological characteristics of the rivers and to understand the effects of different land cover types upon them.

Surface water quantity programme

The rainfall, river levels and river flows in the Auckland region have been monitored continuously since 1975. This lengthy dataset is extremely useful as it enables the ARC to build up a picture of the hydrological systems in the Auckland region, including studies on climate and weather patterns, the probabilities of river flooding and the effects of the aftermath of droughts such as that in 1993/94.

Understanding and predicting effects of land use, development, urbanisation and other human activities on water resources is an important hydrological issue in Auckland.

Indicator 1: Regional rainfall

The Auckland region on average received 14 per cent more rainfall in 2008/09 than 2007/08, with increased rainfall recorded at all hydrological sites over this period (Figure 2).

During the latter half of 2008 the Auckland region experienced average rainfall, except for September which was exceptionally dry (up to 42 per cent below average). Although 2009 began with a drier than normal January, this was easily countered by a very wet February with double the amount of rainfall normally expected (Figure 3).

Indicator 2: Regional river flows

The Auckland region experienced one large flood event between June 2008 and May 2009 (see Floods in Chapter 5.1 page 262 for information on other flood events).

This event occurred on 30 July 2008 when flow at the Mangawheau River, Hunua was recorded at a 1 in 22 year annual return period (Table 3). (An annual return period is a statistical estimate of the likelihood of a given discharge occurring in any single year).

The higher than average rainfall across the Auckland region that was identified in Indicator 1 is reflected in higher than average discharges at all of the hydrology sites the ARC monitors (Table 3). For example, between June 2008 and May 2009 the Kaipara and North Shore rivers that the ARC monitors had discharges up to 34 per cent higher than the long-term annual average discharge.

Freshwater

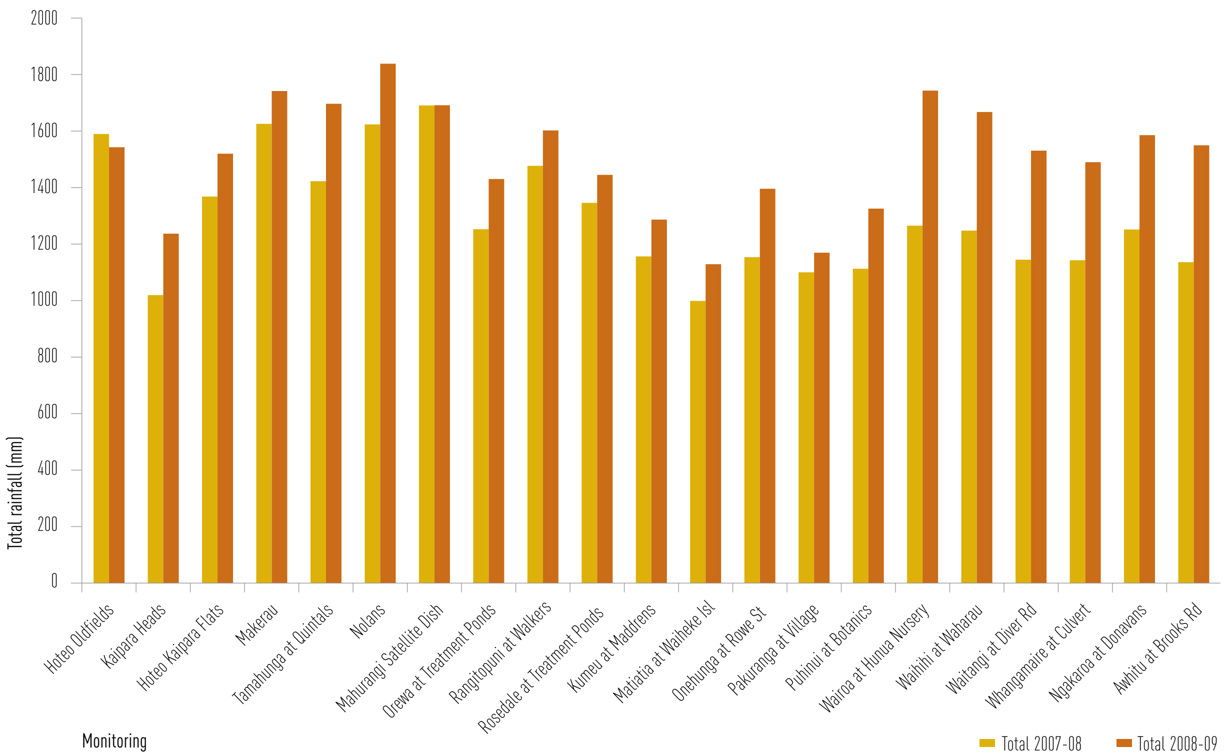


FIGURE 2 Comparison of 2007/08 and 2008/09 rainfall totals at selected monitoring sites across the Auckland region. (Source: ARC).

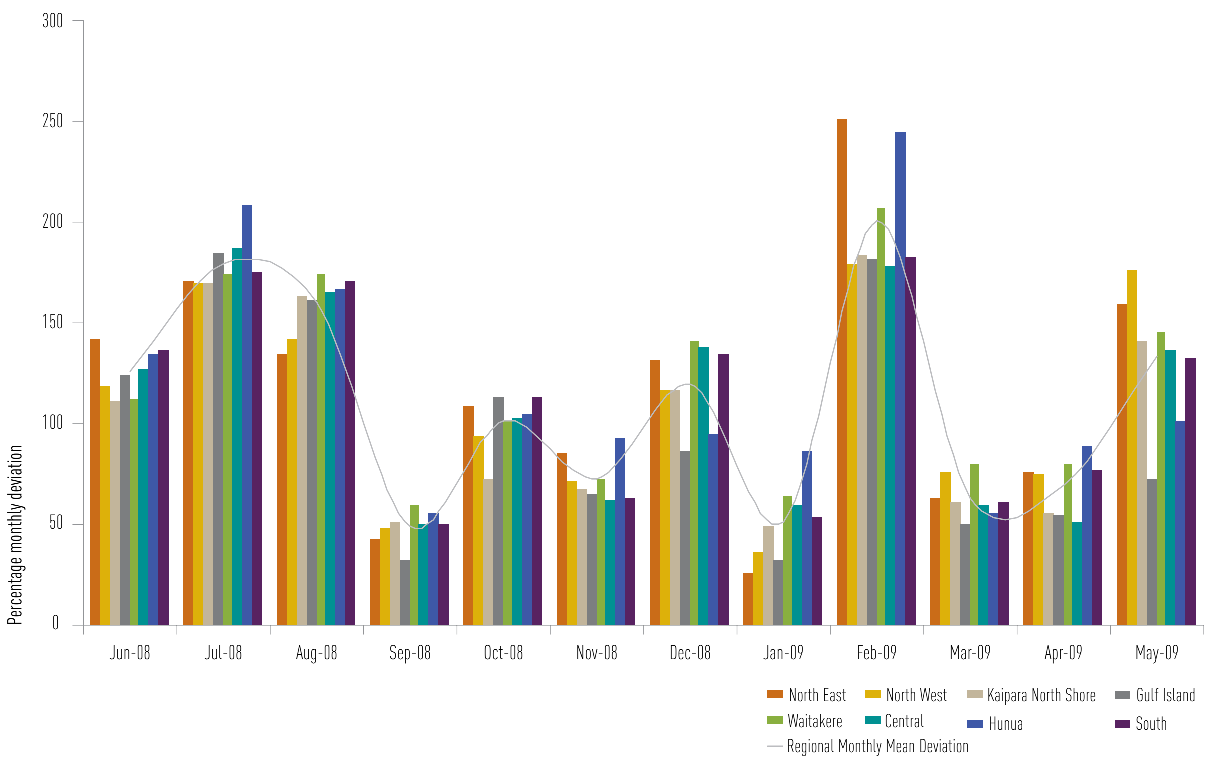


FIGURE 3 Percentage deviation of the 2008/09 regional monthly rainfall against the long-term monthly average at selected monitoring sites across the Auckland Region. (Source: ARC).

TABLE 3 Comparison of river flows (m^3/s) at ARC hydrological sites between June 2008 and May 2009, with the long-term data record. (Source: ARC).

Water resource region	River	Long-term annual average discharge	Annual average discharge (June 2008 to May 2009)	% difference annual average discharge	Largest recorded discharge (on 30 July 2008 unless shown otherwise)	Annual return period
Auckland Central	Mangemangeroa	0.048	0.053	10.9	6.43	1.9
	Meola	0.154	0.185	20.0	4.02	1.2
	Puhinui	0.194	0.235	21.0	12.0	1.6
	Papakura	0.847	1.011	19.4	48.2	5.9
	Otara	0.299	0.365	22.1	24.9	1.8
Hunua	Mangawheau	0.692	0.837	21.1	69.3	22.7
	Wairoa	2.714	3.191	17.6	171	9.2
Kaipara – North Shore	Oteha	0.211	0.267	26.6	17.5	1.4
	Kumeu	0.945	1.079	14.1	42.9 at 24 Aug 2008	4.7
	Rangitopuni	1.473	1.633	10.9	110	2.7
	Oratia	0.657	0.720	9.6	43.3 at 24 Aug 2008	1.2
	Swanson	0.529	0.595	12.6	63.4 at 24 Aug 2008	2.2
	Opanuku	0.655	0.756	15.4	58.4 at 24 Aug 2008	1.9
	Kaipara	2.944	3.948	34.1	96.9 at 24 Aug 2008	4.3
	Ararimu	1.116	1.459	30.7	44.5 at 24 Aug 2008	3.5
North East	Tamahunga	0.190	0.238	25.3	18.4	1.6
	Mahurangi	1.164	1.448	24.4	112	5.2
	Orewa	0.174	0.231	32.5	40.4	3.5
North West	Kaukapakapa	1.215	1.335	9.9	111	9.7
	Waiteitei	1.839	2.259	22.8	104	2.3
	Hoteo	5.892	7.317	24.2	162	3.5
South Auckland	Ngakaroa	0.092	0.112	22.4	4.39	5.4
	Whangamaire	0.138	0.149	7.5	1.19	4.9
	Waitangi	0.236	0.283	19.9	18.9	6.1
Waitakere	Robinsons	0.008	0.010	22.6	0.22 at 24 Aug 2008	N/A

4.3

Freshwater

Water quality monitoring programme

Seven water quality parameters were used to assess the life supporting capacity of river water at each of the 27 monitoring sites (Figure 4). These parameters are:

- dissolved oxygen
- pH
- turbidity
- ammonia
- temperature
- total phosphorus
- total nitrogen.

The levels of these parameters at each monitoring site were evaluated for compliance with the target levels (thresholds) for life supporting capacity that are derived from national guidelines (Box 3). Some of the national guidelines were refined to better reflect the natural range found at monitoring sites within the Auckland region. For example, the temperature of rivers in the region are naturally higher than that of rivers in the South Island so the target level has been adjusted to account for this.

Box 3 Calculation of Water Quality Index (WQI)

The results were used to produce four water quality indices that enables the ARC to assign a water quality class to each monitoring site. This methodology was developed and described by the Canadian Council of Ministers of the Environment (2001). The four indices that are used to assess the water quality – for both freshwater and marine water – are:

- Scope. This represents the percentage of parameters that failed to meet the compliance thresholds at least once (the lower this index, the better).
- Frequency. This represents the percentage of all individual tests that failed to meet the compliance thresholds (the lower this index, the better).
- Magnitude. This represents the amount by which failed tests exceeded the compliance thresholds (the lower this index, the better).
- WQI. This represents an overall Water Quality Index for ecological health based on a combination of the three indices described above (the higher this index, the better).

This Water Quality Index (WQI) enables the ARC to assign an overall water quality class using the following ranges:

- Greater than 90 = Excellent water quality
- Between 70 and 90 = Good water quality
- Between 50 and 70 = Fair water quality
- Lower than 50 = Poor water quality.

Indicator 3: Water quality

Site based

Monitoring data for the seven water quality parameters were used to produce the four water quality indices for each of the 27 sites (Table 4) and the overall WQI index was calculated to determine a water quality class for each site. The location and quality class of each site is shown in Figure 4).

Two native forest sites, Cascades and West Hoe, met all the target levels. The other site with Excellent water quality, Mahurangi Forest, drains a catchment that contains exotic forest. These three sites are the only ones in the monitoring programme that have catchments covered entirely or predominantly in forest, and clearly show the benefits of this type of land cover with regard to the water quality.

The value of forest land cover is also demonstrated by the four sites that have Good water quality; although the predominant land use in these four catchments is rural, all have more than 40 per cent of the catchment covered by either native or exotic forest.

All of the sites with Poor water quality were located in predominantly urban catchments and these sites typically exceeded the compliance thresholds for all variables (with the exception of pH) on multiple occasions during the year. All of these sites also failed more than 20 per cent of the individual tests and the magnitude of the exceedences was generally high.

TABLE 4 The river water quality monitoring network and water quality class. (Source: ARC).

Rank	Site name	Scope	Frequency	Magnitude	WQI	Water quality class
1	Cascades	0	0	0	100	Excellent
2	West Hoe	0	0	0	100	Excellent
3	Mahurangi Forest	14.3	1.3	0.8	91.7	Excellent
4	Mahurangi W.T.P.	42.9	8.3	2.4	74.8	Good
5	Mahurangi Town Centre	42.9	9.5	3.4	74.6	Good
6	Matakana	42.9	8.4	6.7	74.5	Good
7	Waiwera	42.9	10.8	2.9	74.4	Good
8	Opanuku	57.1	6.0	1.6	66.8	Fair
9	Hoteo	57.1	12.0	2.2	66.3	Fair
10	Kumeu	57.1	20.0	15.9	63.9	Fair
11	Vaughans	57.1	23.2	13.1	63.6	Fair
12	Rangitopuni	71.4	20.5	8.0	56.8	Fair
13	Wairoa	71.4	20.2	10.3	56.7	Fair
14	Oteha	71.4	19.5	13.3	56.6	Fair
15	Oakley	71.4	20.2	13.0	56.5	Fair
16	Lucas	71.4	22.9	18.4	55.4	Fair
17	Okura	71.4	28.4	8.6	55.3	Fair
18	Pakuranga @ Greenmount	71.4	29.8	12.6	54.7	Fair
19	Papakura	71.4	31.3	13.9	54.3	Fair
20	Ngakaroa	71.4	20.2	30.0	53.8	Fair
21	Otara @ East Tamaki	71.4	31.0	27.7	52.3	Fair
22	Otara @ Kennel Hill	85.7	23.8	9.3	48.4	Poor
23	Pakuranga @ Guys Road	85.7	22.6	20.2	47.5	Poor
24	Pakuranga @ Botany	85.7	31.0	9.1	47.1	Poor
25	Puhinui	85.7	33.3	12.8	46.4	Poor
26	Omaru	85.7	44.0	27.8	42.1	Poor
27	Otaki	85.7	46.4	61.4	33.5	Poor

4.3

Freshwater

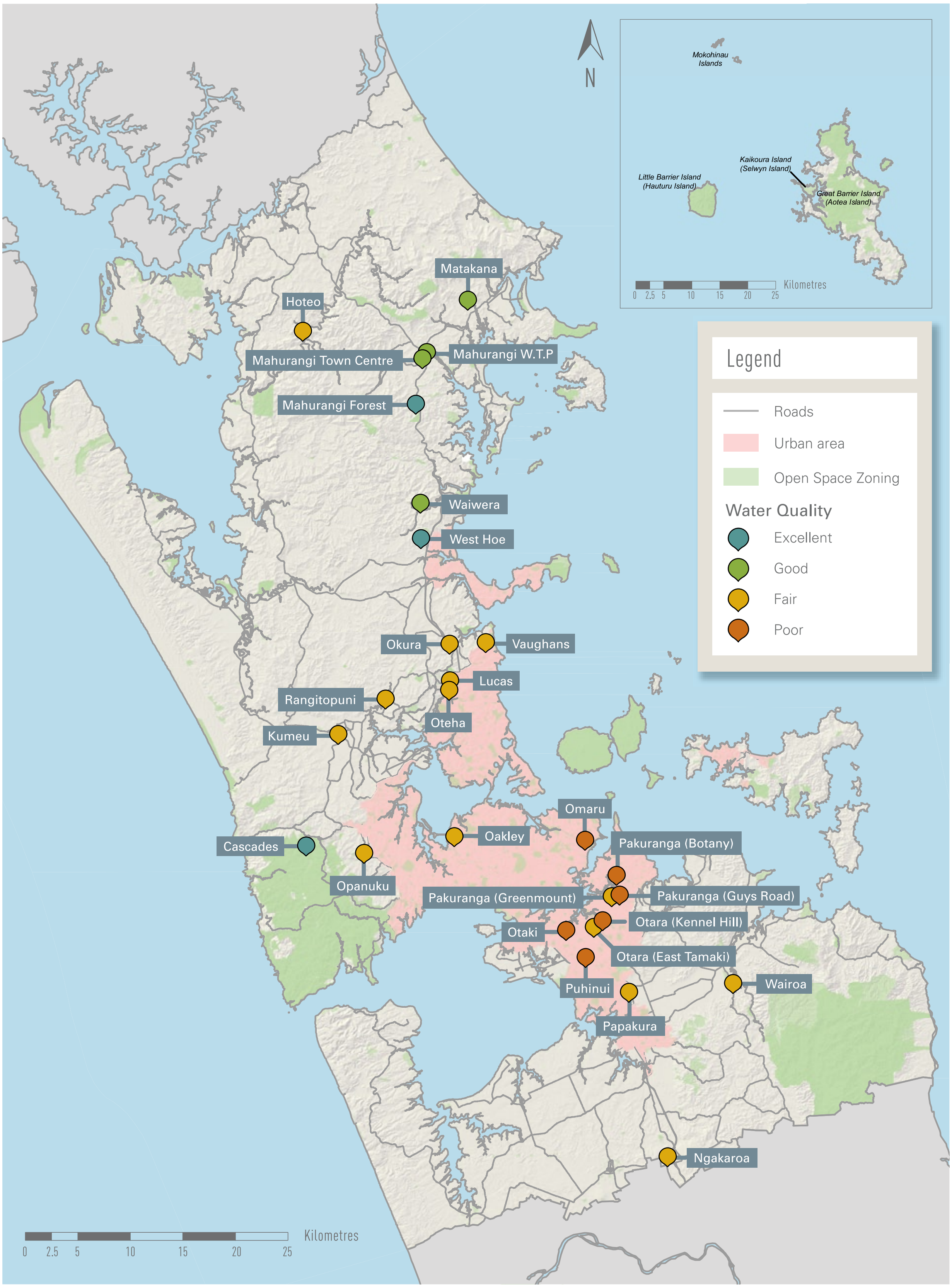


FIGURE 4 The river water quality monitoring network and water quality class. (Source: ARC).

Land cover based

To assess the effect of land cover on water quality for ecological health, the 27 sites in the monitoring programme were assigned to one of three land cover types (forested, rural or urban) on the basis of the predominant land cover in their catchments. (Native and exotic forest sites were combined into the same class because of the low number of sites).

The average values for each of the water quality indices shown on page 146 were then calculated for each land cover type.

Table 5 shows that forested sites, with an average WQI score of 97.2, clearly produce the best water quality scores. In contrast, urban sites clearly have the worst water quality with an average WQI score of 49.1. The rural sites, with a average WQI score of 64.3, were between the forested and urban land use types.

TABLE 5 Average WQI scores for all sites within a land use type. (Source: ARC).

Land use type	Scope	Frequency	Amplitude	Average WQI
Forested	4.8	0.4	0.3	97.2 (Excellent)
Rural	58.2	16.8	9.2	64.3 (Fair)
Urban	79.2	29.5	20.5	49.1 (Poor)

This result is reinforced when the percentage of sites in each water quality class are stratified by land cover within the catchment. Table 6 shows that all of the forested sites were classified as having Excellent water quality, rural sites had either Good (31 per cent) or Fair water quality (69 per cent), and urban sites had Fair (45 per cent) or Poor (55 per cent) water quality.

TABLE 6 Percentage of sites in each WQI class, by land use type. (Source: ARC).

Land use type	Excellent	Good	Fair	Poor
Forested	100	0	0	0
Rural	0	31	69	0
Urban	0	0	45	55

Trends by land cover type

The 2007 River Water Quality – State and Trends report analysed trends in water quality parameters between 1995 and 2005. This analysis was used to identify trends in the six water quality parameters that are used to assess the life supporting capacity of the water (pH was not included).

For both forested and rural sites, the majority of sites showed no change between 1995 and 2005. A small percentage of sites showed improvements; the most notable being decreasing nitrogen levels at several rural sites (Table 7).

The strongest trends were in urban rivers, where half of the trends indicated improvements in water quality. Improving trends were identified across all the urban sites and were particularly noticeable for:

- → ammoniacal nitrogen (declining levels at five sites)
- → nutrients (decreasing nitrogen at eight sites and decreasing phosphorus at eight sites)
- → turbidity (declining levels at seven sites).

There was little significant change in the level of dissolved oxygen or water temperature.

When the trend analysis was summed for all sites, most parameters at most sites showed either no change or an improvement in the water quality for ecological health. The small number of declining trends showed no consistent pattern but one site (Wairoa), showed declining trends in three parameters (dissolved oxygen, ammoniacal nitrogen and turbidity).

TABLE 7 Percentage of parameters at all sites that are improving, showing no change or declining, stratified by land cover. (Source: ARC).

Land use type	Percent improving	Percent not changing	Percent declining
Forested	16	83	0
Rural	15	76	8
Urban	50	47	3
All sites	31	63	5

Freshwater

Microbiological water quality

The suitability of water for recreational activities (such as swimming) is typically assessed by the level of *Escherichia coli* bacteria in a water sample. Although most *E. coli* are harmless, elevated levels are used to indicate the presence of faecal pollution, which may pose a threat to human health because it contains other pathogenic organisms.

The ARC monitors *E. coli* levels at each of the 27 sites in the water quality monitoring programme. These levels are compared with the red mode of the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (produced by the MfE and MOH in 2003 and shown in Table 8) and the frequency and magnitude of any exceedences are assessed.

TABLE 8 Recreational water quality thresholds based on the levels of *E. coli* bacteria. (Source: MfE and MOH).

Mode	Number of *E. coli* bacteria per 100ml water
Green mode (Acceptable)	Less than 260
Amber mode (Alert)	260 to 550
Red mode (Action)	More than 550

The suitability of water for stock drinking is assessed in a similar way. The ARC uses the same indicator bacteria but a different threshold (1000 *E. coli* per 100ml water) as described by ANZECC (1992). This measure is calculated only for the rivers with rural catchments within the monitoring programme, as these are the catchments that are likely to provide drinking water for stock. The observed levels of *E. coli* at these 13 sites are compared with the ANZECC guideline, and the frequency and magnitude of exceedences are assessed in the same way.

Indicator 4: Water quality for recreation

Site based

The Cascades and Mahurangi W.T.P sites had the best microbiological water quality of the monitored sites in 2007. Although all of the 27 monitoring sites had *E. coli* levels that exceeded the Green mode guideline at least once during 2007, the Cascades and Mahurangi W.T.P. sites exceeded the guideline on only one occasion.

All of the sites (except Cascades and Mahurangi W.T.P.) recorded at least one exceedence of the Red mode guideline during 2007 (Table 9).

In contrast, the Omaru, Otaki and Papakura sites failed to meet the Red mode guideline on every sampling occasion in 2007. The worst individual sample was from the Otara – East Tamaki site, when a level of 510,000 *E. coli* per 100ml was recorded in February 2007.

TABLE 9 Ordersites by frequency first and then magnitude, 2007. (Source: ARC).

Rank	Site name	Frequency	Magnitude
1	Cascades	0.0	0.0
2	Mahurangi W.T.P.	0.0	0.0
3	West Hoe	8.3	5.0
4	Mahurangi T. C.	8.3	5.3
5	Mahurangi Forest	8.3	65.2
6	Hoteo	25.0	17.4
7	Rangitopuni	25.0	48.4
8	Matakana	25.0	49.0
9	Pakuranga @ Guys Rd	33.3	43.4
10	Ngakaroa	41.7	65.8
11	Oteha	41.7	71.3
12	Okura	50.0	69.1
13	Kumeu	50.0	71.3
14	Pakuranga @ Greenmount	58.3	46.9
15	Waiwera	58.3	66.0
16	Lucas	58.3	69.6
17	Opanuku	66.7	65.7
18	Puhinui	75.0	60.0
19	Wairoa	75.0	63.5
20	Pakuranga @ Botany	75.0	85.1
21	Otara @ Kennel Hill	83.3	77.8
22	Oakley	83.3	79.3
23	Vaughans	83.3	86.2
24	Otara @ East Tamaki	83.3	99.3
25	Omaru	100.0	84.7
26	Papakura	100.0	96.4
27	Otaki	100.0	98.3

Land cover based

To assess the effect of the type of land cover on recreational water quality, the 27 sites in the monitoring programme were assigned to one of three land use types, based on the predominant land use type in their catchments (native and exotic forest sites were combined into the same class because of the low number of sites).

The average values for the frequency and magnitude of the exceedences of the recreational water quality guidelines were then calculated for each land use type (Table 10).

The forested sites clearly produced the best recreational water quality scores with a lower average frequency and magnitude of exceedences of the Red mode threshold. At the other end of the scale, the urban sites clearly had the greatest frequency and magnitude of exceedences while the rural sites were intermediate between the forested and urban land use categories.

TABLE 10 Frequency and magnitude of recreational water quality exceedences for all sites within a land use type. (Source: ARC).

Land cover type and number of sites	Frequency	Magnitude
Forested	5.6	23.4
Rural	46.8	54.2
Urban	72.0	74.2

Indicator 5: Drinking water quality for stock

The majority of the 13 rural sites failed to meet the ANZECC stock drinking guideline at least once during 2007. However, the two Mahurangi sites met the stock watering guideline throughout 2007 and the Hoteo site failed to meet the guideline only once.

In contrast, the Papakura site exceeded the guideline on every sampling occasion and the magnitude of the exceedences was very high (Table 11).

TABLE 11 Frequency and magnitude of exceedences of the ANZECC stock watering guideline. (Source: ARC).

Rank	Site name	Frequency	Magnitude
1	Mahurangi W.T.P	0.0	0.0
2	Mahurangi T.C.	0.0	0.0
3	Hoteo	8.3	4.8
4	Rangitopuni	16.7	30.4
5	Matakana	16.7	30.6
6	Waiwera	33.3	46.2
7	Ngakaroa	33.3	46.9
8	Kumeu	40.0	53.8
9	Wairoa	41.7	41.0
10	Okura	41.7	50.8
11	Opanuku	50.0	43.6
12	Vaughans	83.3	75.4
13	Papakura	100.0	93.5

4.3

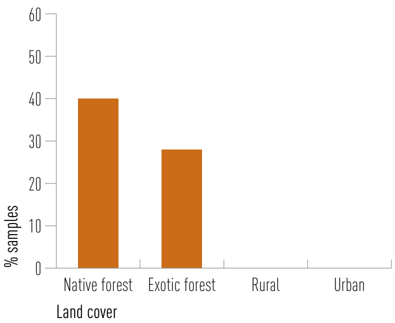
Freshwater

Ecological quality programme

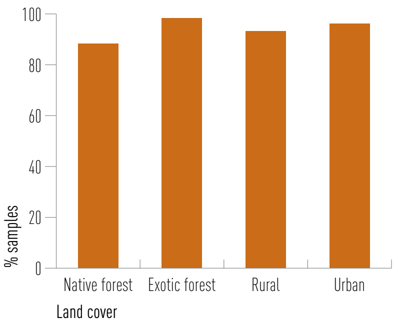
Invertebrate community monitoring programme

Many species of invertebrates (also known as macroinvertebrates), such as aquatic insects, crustaceans, snails and worms live in rivers and have been used to indicate the ecological quality of rivers since the early 1900s.

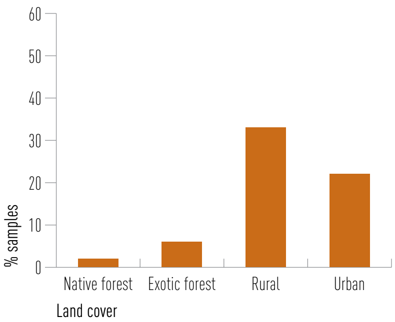
Invertebrates are suited to this role primarily because of their high abundance and diversity. Many different types of invertebrates live in the rivers and they react differently to various environmental pressures. For example, some species, such as the *Helicopsyche* caddisfly (Figure 5a) are extremely sensitive and are found only in high quality rivers while others, such as the *Potamopyrgus* snail (Figure 5b), are tolerant and can survive in a wide range of rivers. Some species, such as the *Glossiphonia* leech (Figure 5c), are found mainly in degraded rivers with rural or urban land cover.



5a
Helicopsyche caddisfly



5b
Potamopyrgus snail



5c
Glossiphonia leech

FIGURE 5 The different distribution patterns of three freshwater invertebrates, reflecting their environmental sensitivity. (Source: ARC).

This differing sensitivity means that the ARC can use the types and numbers of invertebrates found at a river as biological indicators to show the ecological quality of the river. The information generated from invertebrate sampling is often complex so it is typically summarised into an index. In New Zealand, the Macroinvertebrate Community Index (MCI) is used.

Essentially, the MCI assigns a score to each invertebrate found at a sampling site, based on its sensitivity to environmental conditions. Scores range between one (least sensitive) and 10 (most sensitive). The MCI score for a site is calculated based on the average score for all the invertebrates found at that site.

The MCI score is then interpreted into ecological quality classes using the following ranges:

→ Greater than 120 = Excellent quality

→ Between 100 and 120 = Good quality

→ Between 80 and 100 = Fair quality

→ Lower than 80 = Poor quality.

Although the ARC began an invertebrate community monitoring programme in 1999, there have been methodological developments and programme changes since then. More recently, the programme has been stable; consequently the ARC used data only from 2006, 2007 and 2008 and included only those sites that were sampled in each of these years.

This produced a dataset for 52 sites across the Auckland region (Figure 6).

Indicator 6: Ecological quality (MCI)

Site based

There was a wide range in average MCI scores (from 44.4 to 141) across the 52 sites, indicating a large variation in ecological quality at the monitoring sites (Table 12).

Sixteen sites (31 per cent) were classified as excellent on the basis of their average MCI score, 13 (25 per cent) sites as Good, 14 (27 per cent) as Fair and 9 (17 per cent) as Poor.

Most of the 16 Excellent sites were in rivers that drained from forested catchments (nine native forest and four exotic forest catchments) whereas only three were from catchments with more intensive land use types (two rural and one urban catchment).

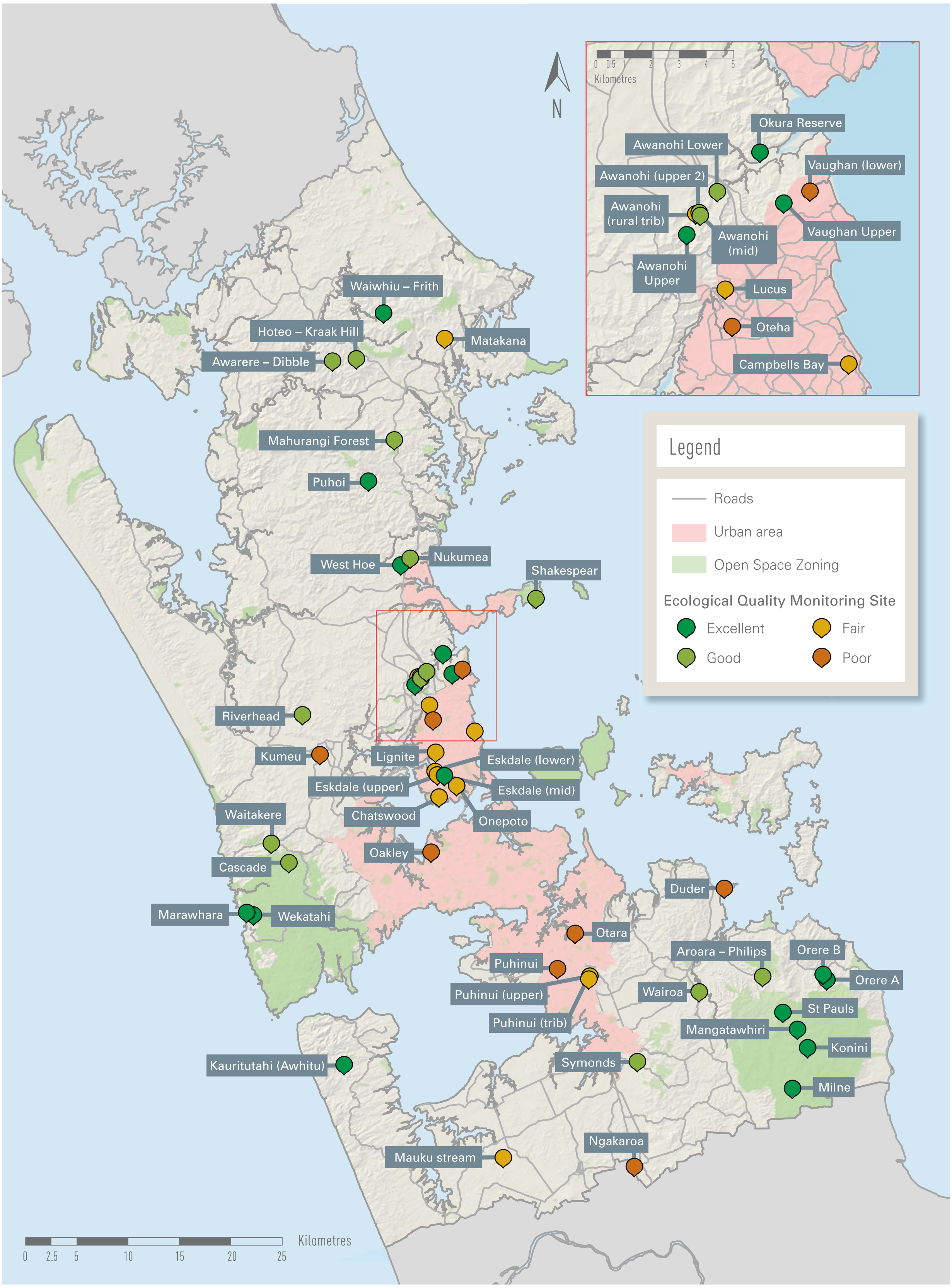


FIGURE 6 The ecological quality monitoring network and quality class. (Source: ARC).

Freshwater

TABLE 12 Individual and average MCI scores for each monitoring site sampled in 2006, 2007 and 2008 and ecological quality class based on the average MCI score. (Source: ARC).

Site	MCI score for year			Average MCI score	Ecological quality class
	2006	2007	2008		
Orere B	147.0	144.3	131.7	141.0	Excellent
Konini	137.9	140.0	132.3	136.7	Excellent
Milne	130.8	136.4	130.8	132.6	Excellent
Orere A	134.1	138.9	124.3	132.4	Excellent
Wekatahi	132.8	133.9	126.8	131.2	Excellent
Awanohi Upper	139.3	124.0	127.5	130.2	Excellent
St Pauls	133.0	132.8	123.4	129.7	Excellent
Puhoi	126.9	134.2	127.8	129.6	Excellent
Kauritutahi (Awhitu)	126.2	134.8	127.7	129.5	Excellent
Marawhara	127.3	136.8	121.0	128.4	Excellent
Mangatawhiri	130.4	121.2	127.6	126.4	Excellent
West Hoe	129.4	124.8	125.0	126.4	Excellent
Vaughan Upper	130.4	121.6	122.4	124.8	Excellent
Waiwhiu @ Frith	134.7	141.6	97.1	124.4	Excellent
Okura (reserve)	124.1	116.4	124.2	121.6	Excellent
Eskdale (upper)	132.0	119.1	109.1	120.1	Excellent
Awanohi (mid)	120.1	100.0	117.7	112.6	Good
Mahurangi Forest	117.0	114.7	105.5	112.4	Good
Riverhead	108.0	116.1	104.5	109.5	Good
Waitakere	122.1	103.1	101.8	109.0	Good
Awanohi (upper 2)	103.0	111.4	111.8	108.7	Good
Awarere @ Dibble	104.9	111.5	106.6	107.7	Good
Cascades	103.3	105.6	105.4	104.8	Good
Wairoa	107.5	106.2	98.2	104.0	Good
Aroara	92.7	112.8	104.1	103.2	Good

Contd...

TABLE 12 continued Individual and average MCI scores for each monitoring site sampled in 2006, 2007 and 2008 and ecological quality class based on the average MCI score. (Source: ARC).

Site	MCI score for year			Average MCI score	Ecological quality class
	2006	2007	2008		
Shakespear	86.6	115.5	103.9	102.0	Good
Symonds	95.2	100.7	108.4	101.4	Good
Hoteo @ Kraak Hill	106.3	92.5	104.1	101.0	Good
Awanohi Lower	94.3	112.5	95.5	100.7	Good
Puhinui (upper)	97.5	94.4	96.7	96.2	Fair
Matakana	95.5	94.3	92.6	94.1	Fair
Onepoto	92.7	95.3	89.3	92.4	Fair
Opanuku	83.3	104.8	84.0	90.7	Fair
Eskdale (mid)	89.8	90.0	85.6	88.5	Fair
Awanohi (rural tributary)	92.9	84.7	87.8	88.5	Fair
Lignite	84.6	91.3	86.4	87.4	Fair
Lucus	93.4	76.4	88.0	85.9	Fair
Mauku stream	71.2	97.1	86.0	84.8	Fair
Campbells Bay	71.3	84.0	89.5	81.6	Fair
Eskdale (lower)	82.9	73.6	87.6	81.4	Fair
Chatswood	78.0	86.2	78.6	80.9	Fair
Duder	75.2	74.5	84.4	78.0	Poor
Ngakaroa	83.8	53.3	67.9	68.3	Poor
Kumeu	70.8	64.7	62.4	65.9	Poor
Oakley	54.3	58.9	64.5	59.2	Poor
Oteha	54.4	63.9	55.9	58.1	Poor
Papakura	59.1	52.9	60.1	57.4	Poor
Vaughan (lower)	51.2	50.0	65.7	55.6	Poor
Otara	47.3	47.5	59.2	51.3	Poor
Puhinui	51.6	32.7	48.9	44.4	Poor

Freshwater

Land cover based

To assess the effect of land cover on the ecological quality of the river, each of the 52 sites in the invertebrate monitoring programme were assigned to one of the four catchment land cover types (native forest, exotic forest, rural and urban) on the basis of the predominant land cover in their catchments. The average MCI score was then calculated for all sites in each land cover type (Table 13).

The native forest sites clearly produced the best average MCI score indicating Excellent ecological quality, followed by the exotic forest sites which produced an average score indicating Good ecological quality. In contrast, the urban sites produced the lowest average MCI scores indicating Poor ecological quality at these sites. The rural sites were intermediate between the urban and exotic forest sites.

TABLE 13 Average MCI score for all sites within a land cover type with indicative MCI quality class. (Source: ARC).

Land cover type and number of sites	Average MCI	MCI quality class
Native forest (11)	124.5	Excellent
Exotic forest (8)	119.8	Good
Rural (19)	95.2	Fair
Urban (14)	77.6	Poor

This finding was reinforced when the percentage of sites in each MCI quality class were stratified by land cover type within the catchment (Table 14). All of the sites draining forested catchments (native and exotic forest) produced average MCI scores indicating excellent or good ecological quality while all but one of the urban sites produced average MCI scores indicating either fair or poor ecological quality.

However, the average MCI scores indicated a wide range of ecological quality at rural sites, with scores ranging from 55.6 to 130.2. The wide range of average MCI scores at rural sites, in comparison with the other land cover types, can be seen in Figure 7.

TABLE 14 Percentage of sites in each MCI quality class by land cover type. (Source: ARC).

Land cover type and number of sites	Excellent	Good	Fair	Poor
Native forest (11)	82	18	0	0
Exotic forest (8)	50	50	0	0
Rural (19)	11	42	26	21
Urban (14)	7	0	57	36

There was a strong relationship between the ecological quality of a river measured using invertebrates and the type of land cover in the surrounding catchment. Rivers with intensive (urban and rural) land cover were associated with lower ecological quality (as measured with MCI scores) than those with forested catchments. Overall, urban rivers had the lowest ecological quality.

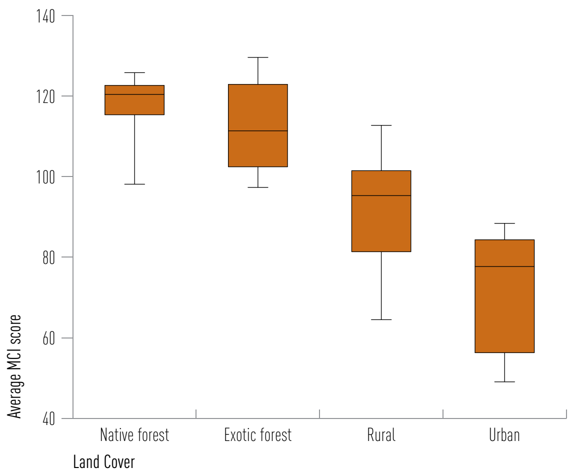


FIGURE 7 Box plots showing the variation of MCI scores for each land use type (line = average, box = 25th to 75th percentiles, whiskers = 5th and 95th percentiles). (Source: ARC).

Native fish programme

The rivers of the Auckland region are home to seventeen species of native fish (Table 15). These include common species that are familiar to many people, such as longfin and shortfin eels, as well as rare and threatened species such as the black mudfish and dwarf inanga. Most native fish are small, well camouflaged and nocturnal, with the result that they are seldom seen and therefore unfamiliar to many people.

TABLE 15 Native fish species in the Auckland region. (Source: NZFFD).

Common name	Scientific name	Frequency of occurrence (% of sites)	Distribution
Banded kokopu	*Galaxias fasciatus*	39	Widespread
Shortfin eel	*Anguilla australis*	37	Widespread
Longfin eel	*Anguilla dieffenbachii*	33	Widespread
Common bully	*Gobiomorphus cotidianus*	20	Frequent
Inanga	*Galaxias maculatus*	17	Frequent
Redfin bully	*Gobiomorphus huttoni*	13	Frequent
Cran's bully	*Gobiomorphus basalis*	10	Frequent
Giant bully	*Gobiomorphus gobioides*	3	Sparse
Common smelt	*Retropinna retropinna*	2	Sparse
Torrentfish	*Cheimarrichthys fosteri*	2	Sparse
Koaro	*Galaxias brevipinnis*	1	Rare
Giant kokopu	*Galaxias argenteus*	1	Rare
Dwarf inanga	*Galaxias gracilis*	<1	Rare
Black mudfish	*Neochanna diversus*	<1	Rare
Bluegill bully	*Gobiomorphus hubbsi*	<1	Rare
Shortjaw kokopu	*Galaxias postvectis*	<1	Rare
Lamprey	*Geotria australis*	<1	Rare

Five fish species collectively make up the whitebait fishery: these are the giant kokopu, banded kokopu, shortjaw kokopu, koaro and inanga. These all belong to the *Galaxiidae* family.

Most native fish species are diadromous, meaning that they need to migrate between freshwater systems and the sea to complete their life cycle. This requirement can increase their vulnerability to human-induced environmental pressures, particularly barriers to migration such as weirs, dams and culverts. If these are poorly designed, they can exclude native fish from large areas of freshwater habitat (Figure 8).

FIGURE 8 Example of a perched culvert, a common barrier to fish passage. Native fish are unable to leap the vertical distance required to enter the culvert and continue migrating upstream. (Source: ARC).

Freshwater

Although the ARC does not currently operate a comprehensive fish monitoring programme across the Auckland region, a large amount of information is available from the New Zealand Freshwater Fish Database (NZFFD). This national repository, administered by NIWA, contains more than 28,000 site records nationwide, with over 2000 individual records from the Auckland region. By analysing these records the ARC can gain an understanding of the frequency of occurrence and distribution of native fish species within the Auckland region.

Due to the need to migrate between the marine and freshwater environments, the two overriding natural environmental factors that influence the distribution of most native fish populations are elevation and the distance from the coast. This means that a greater number of native fish species are expected at sites close to the coast and at low elevations, when compared to sites that are found further inland and at higher altitudes.

The Quantile Index of Biotic Integrity (QIBI) is a tool that enables the ARC to assign a score to a site based upon the fish species found there. The QIBI predicts which fish species should be present at a site – based on its elevation and distance from the coast – and compares this prediction with the fish species actually found there. QIBI scores range from 0 (no native fish found) to 60 (the full range of species predicted for that site were present).

The QIBI score can be interpreted into ecological quality classes associated with the following ranges:

- 49 to 60 = Excellent quality
- 37 to 48 = Good quality
- 25 to 36 = Fair quality
- 1 to 24 = Poor quality
- 0 = No native fish present.

The QIBI is a powerful tool for comparing the effects of factors such as the type of land cover on fish populations. It allows comparisons to be made between sites and provides a basis for management decisions aimed at conserving and enhancing the native fish populations.

A limitation of the QIBI is its inability to specifically identify the influence of fish passage barriers (both natural and man-made) from other factors that may influence the distribution of fish species at some sites. For example, a site might have a low QIBI score due to a weir or large waterfall downstream, despite having high habitat and water quality values. Therefore, site-specific factors have to be taken into account when interpreting individual scores.

Indicator 7: Ecological quality for native fish

To investigate the effects of land cover on native fish populations within the Auckland region the QIBI model was used to analyse data from Auckland sites in the NZFFD. The sites were stratified into four land cover types (urban, pasture, exotic forest and native forest) using the REC scheme described in the Introduction to rivers. The average QIBI score was then calculated for all sites in each land cover type.

The native forest sites had the highest average QIBI score, indicating Good habitat quality, while the urban sites had the lowest, indicating Fair habitat quality (Table 16).

TABLE 16 Average QIBI score for all sites within a land cover type with indicative quality class. (Source: ARC).

Land cover type and number of sites	Average QIBI score	Quality class
Native (362)	39.1	Good
Exotic forest (78)	33.7	Fair
Pasture (955)	30.9	Fair
Urban (669)	28.6	Fair

Figure 9 shows that the urban sites had significantly lower QIBI scores than all other categories, while native sites scored significantly higher than the other types of land cover. There was no significant difference between the pasture and exotic forest land cover types, but their scores were significantly lower than native and higher than urban. This indicates that the native sites (which are subject to less human pressures) have fish communities that are less impacted than those at other types of site.

This finding is supported when the percentage of sites in each QIBI quality class are compared across the REC land cover categories (Table 17). Sites in catchments covered by native vegetation have a higher percentage of Excellent scores and a lower percentage of Poor and No native fish scores than sites in the other three categories. In contrast, urban sites have the lowest percentage of scores indicating Excellent habitat quality and the highest percentage of sites containing no native fish.

TABLE 17 Percentage of sites in each QIBI quality class, by land cover type. (Source: ARC).

Land cover type and number of sites	Excellent	Good	Fair	Poor	No native fish
Native (362)	23	36	27	6	7
Exotic forest (78)	8	38	32	8	14
Pasture (955)	7	28	34	18	13
Urban (669)	4	25	35	20	15

The low QIBI scores for the pasture and urban sites may be partially attributable to the higher numbers of man-made barriers to fish passage such as culverts, weirs and dams that are likely to be present in these catchments.

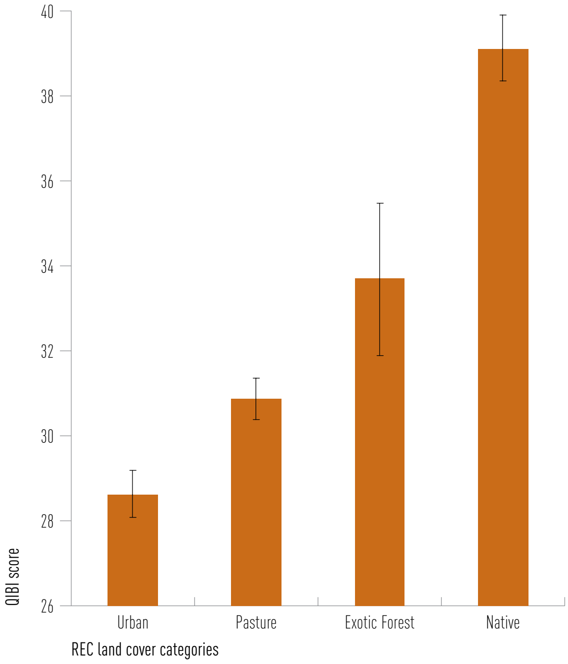


FIGURE 9 Average QIBI scores (± 1 standard error) for 2064 sites in the Auckland region, stratified by land cover type in the surrounding catchment. (Source: ARC).

Implications of river quality

The results from the ARC's freshwater monitoring programmes consistently emphasise the importance of the land cover type in the surrounding catchment on both the water quality and ecological quality of the river.

Rivers draining forested catchments (particularly native forest) have Excellent water quality and Excellent ecological quality. In contrast, rivers draining urban catchments typically have Poor water quality and Poor ecological quality. These findings indicate that the life supporting capacity of urban and rural rivers is impaired. These river systems are impacted by the type of land cover in their catchments and typically do not support diverse populations of native invertebrates and fish.

There was a statistically significant correlation between the ecological quality and the water quality at the 16 sites that were common to both monitoring programmes. This correlation shows that sites with poor water quality also have poor ecological quality, while good water quality is linked with good ecological quality (Figure 10). However, this does not necessarily demonstrate a causal relationship between water quality and ecological quality, since both could be responding to the same environmental pressure, such as land use type.

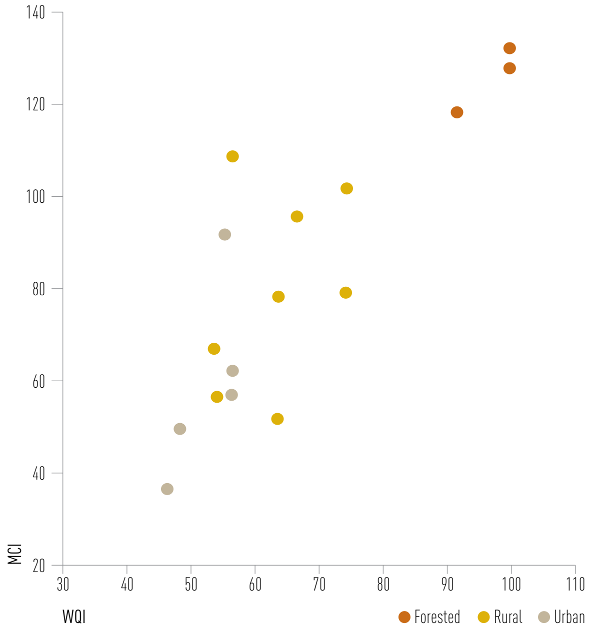


FIGURE 10 The relationship between ecological quality and water quality at the 16 sites common to both monitoring programmes. (Source: ARC).

Overall, the monitoring sites in urban catchments had the lowest water quality. This finding is similar to the results from the national river water quality monitoring network, which concluded that urban rivers had lower water quality than rivers with rural or forested catchments for almost all of the water quality parameters.

However, an analysis of trends for the Auckland region between 1995 and 2005 indicated that, for most parameters at most sites, the water quality was either stable or improving. These findings are a very positive development for the rivers in the Auckland region, which had some of the worst water quality in the country. It is clear that there has been a considerable improvement in water quality, particularly in the urban streams. The causes of these improving trends are difficult to identify, but it is likely that improvements in water management within the urban areas have helped.

Although only a few of the rivers within the Auckland region are used for recreation, our microbiological water quality monitoring programme showed elevated levels of *E. coli* bacteria in many of the rivers, indicating the presence of faecal pollution. Again, there was a strong relationship between the type of land cover in the surrounding catchment and the microbiological water quality. Intensive (urban and rural) land cover types were associated with higher levels of *E. coli* than forested catchments. Overall, sites in urban catchments exceeded the guidelines the most frequently, and by greater magnitudes. In addition, the assessment of rural rivers against the ANZECC stock drinking guideline showed that most rural rivers exceeded this guideline at least once during 2007. This means that some rural rivers may not be suitable sources of drinking water for stock because of elevated levels of faecal pollution.

4.3

Freshwater

Another notable finding was the large variation in the water quality and ecological quality at different rural sites. This raises questions around the land management of rural catchments. For example, rural sites in our monitoring programmes ranged from unfenced rivers with degraded riparian vegetation (the trees and shrubs that grow alongside a river) to rivers with riparian fencing and riparian buffers of native woody vegetation (Box 12, Chapter 4.6, pg 239).

Lakes

Key findings

- The Auckland region has 72 lakes, most of which are small in a national context.
- The water quality of the monitored lakes was generally degraded, due principally to nutrient enrichment, but the microbiological lake water quality was good when compared with national guidelines for recreation. There was no clear trend for changes in lake water quality (some lakes had improved, some had got worse and some had not changed).
- The ARC's ecological monitoring programmes showed that the ecology of the lakes was impaired, with exotic species considered to be the main cause of environmental stressor.

Introduction

There are 72 natural and artificial lakes that are larger than one hectare in the Auckland region. These range in size from small farm ponds to the largest water supply reservoir behind the Mangatangi Dam in the Hunua Ranges. On a national scale, the lakes are small and shallow; there are no large deep lakes in the Auckland region.

Lakes can be classified according to how they were formed. Natural lakes in the Auckland region are usually dune lakes although one, Lake Pupuke, has a volcanic origin (Box 4). Dune lakes have one common feature – a barrier of sand that blocked the stream valleys to form a dammed valley lake, e.g. Lakes Ototoa and Wainamu. The water supply reservoirs are usually found in flooded valleys behind artificial dams in the Waitakere Ranges and the Hunua Ranges.

The ARC routinely monitor the water quality, ecological quality, and microbiological quality of seven natural lakes within the Auckland region. The surrounding catchments have different types of land cover and this can affect the water quality, habitat quality and the water level of the lake. Two of the lakes (Ototoa and Wainamu) have predominantly forested catchments, four of the lakes (Kereta, Kuwakatai, Spectacle and Tomorata) are in predominantly rural catchments and one lake (Pupuke) is in an urban catchment.

Note: The RMA defines a 'lake' as a body of freshwater which is entirely or nearly surrounded by land. The term 'lake' is used in this chapter consistent with this definition.

Box 4 Lake Pupuke – an explosive beginning

Lake Pupuke is located between Takapuna and Milford on the North Shore. It is Auckland's only freshwater volcanic lake.

It formed about 150,000 years ago after volcanic activity left a crater that later filled with freshwater. It covers 110 hectares and has a maximum depth of about 60 metres.

Lake was used as a source of drinking water for much of the North Shore between 1894 and 1944, until a new drinking water supply was sourced from the Waitakere Ranges.

Lake Pupuke is now used extensively for recreation, with a wide range of water sport activities occurring on the lake.

The water quality of the lake is usually good, although the ecology is affected by the numerous exotic fish and plant species found in the lake.

Lake monitoring programmes

The ARC operates two lake monitoring programmes in the Auckland region (see in Figure 11). These monitoring programmes are:

The Water Quality Programme. This monitors some of the physical, chemical and microbiological properties of seven lakes around the Auckland region, six times each year. This provides information on the water temperature and the amount of nutrients, oxygen, sediment and other pollutants in the lakes. The results enable the ARC to assess the life supporting capacity of the lake (how suitable it is for supporting life) and the microbiological quality of the lake (how suitable it is for recreational use).

The **Ecological Quality Programme** monitors the biological community of up to 29 lakes. This programme operates two sub-programmes:

→ **Rotifers**. These are part of the lake zooplankton community and are sampled at the seven lakes in the lake water quality monitoring programme (at the same time as the water quality samples are taken). The type and number of rotifers are used to provide an indication of the ecological health of the lake.

→ **Macrophytes** (aquatic submerged plants). These are surveyed at 29 lakes within the Auckland region. The type and amount of macrophytes are used to provide an indication of the ecological health of the lake.

The ARC's lake water quality and ecological quality monitoring programmes aim to characterise the environmental and biological conditions of these lakes and to understand the effects of environmental stressors upon them.

Lake water quality programme

Four water quality parameters are used to assess the life supporting capacity of lake water at each of the seven lakes:

→ chlorophyll a

→ secchi depth

→ total phosphorus

→ total nitrogen.

The levels of these parameters at each monitoring site are evaluated for compliance with thresholds for life supporting capacity that are derived from national guidelines.

The results are used to produce a lake water quality index called the Trophic Level Index (TLI) that allows the ARC to assign a quality class to each of our lake monitoring sites (Box 5).

Box 5 The Trophic Level Index (TLI)

The TLI is an indicator of lake water quality and a combination of four parameters: nutrient levels (phosphorus and nitrogen), water clarity, and algae abundance (measured using chlorophyll a). The measurements of these parameters are combined in an equation to produce the TLI. It ranges from 0 to 7 and can be used to assign a quality class, also known as a trophic level, to each lake. The lower the TLI, the better the water quality of the lake.

TLI	Trophic level	Description	Water Quality
< 2	Microtrophic	Very low nutrients and algae, with very high water clarity. These lakes are usually high altitude lakes, fed by water inputs from snow melt or glaciers.	Excellent
2 – 3	Oligotrophic	Low levels of nutrients and algae, with high water clarity.	↓
3 – 4	Mesotrophic	Moderate levels of nutrients and algae.	↓
4 – 5	Eutrophic	Elevated levels of nutrients and algae, with low water clarity.	↓
5 – 6	Supertrophic	Saturated with nutrients, high algae growth with blooms possible during summer. Very low water clarity.	↓
> 6	Hypertrophic	Super-saturated with nutrients, very high algae growth with blooms common in summer. Very low water clarity.	Very poor

Freshwater

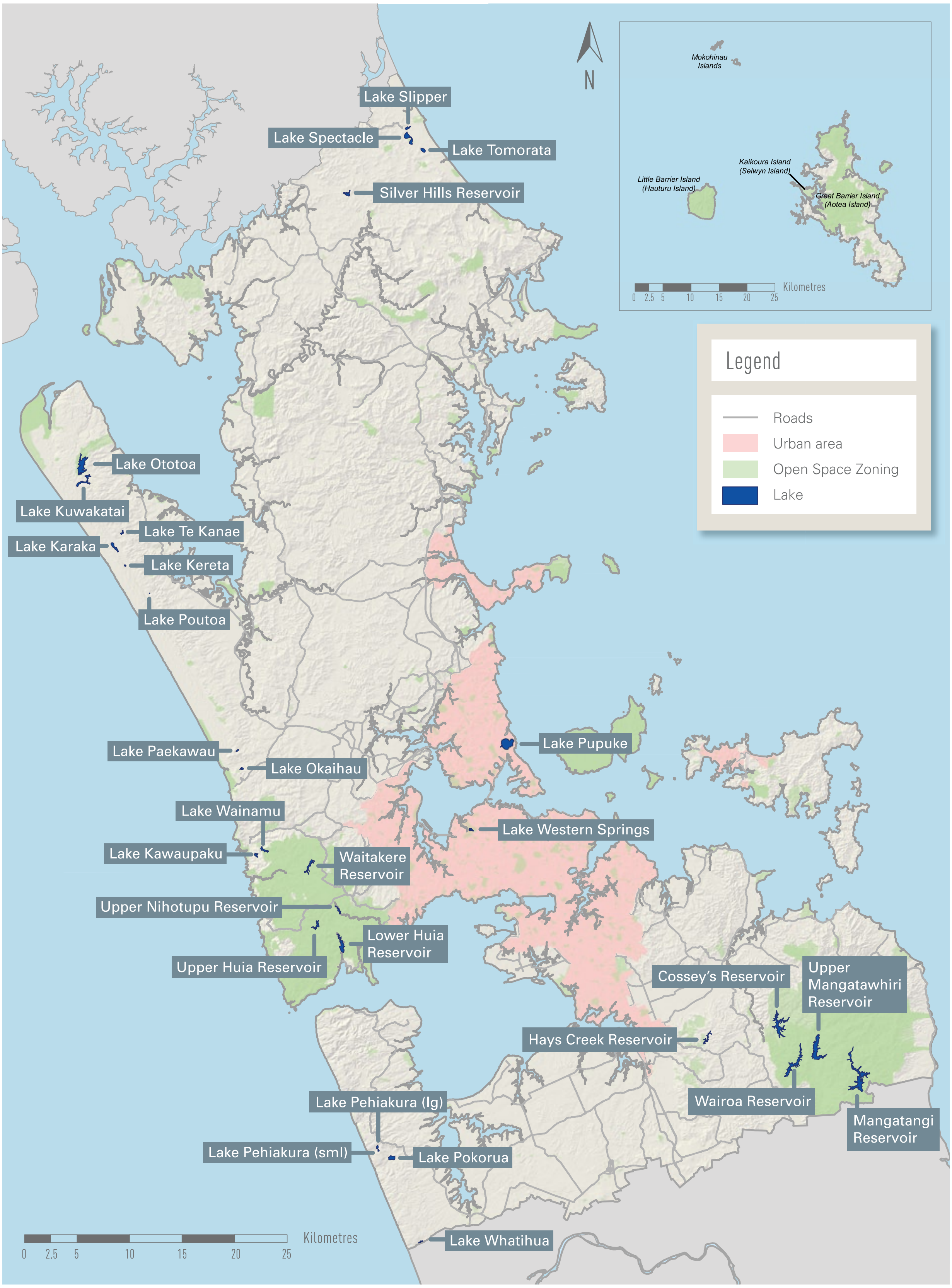


FIGURE 11 Locations of the lakes that the ARC monitors in the Auckland region. (Source: ARC).

Indicator 8: Lake water quality

Site based

Monitoring data for the four water quality parameters were used to produce the TLI lake water quality index for each of the seven lakes in the monitoring programme. The TLI was used to determine a quality class for each of the lakes. Table 18 shows the results for the 2007 lake sampling year (July 2007 to June 2008).

TABLE 18 Lake TLI index and biological productivity class (2007 sampling year). (Source: ARC).

Lake	Catchment	TLI	Quality class
Ototoa	Forested	3.9	Mesotrophic
Pupuke	Urban	4.0	Eutrophic
Tomorata	Rural	4.4	Eutrophic
Wainamu	Forested	4.4	Eutrophic
Kuwakatai	Rural	5.2	Supertrophic
Kereta	Rural	5.8	Supertrophic
Spectacle	Rural	6.2	Hypertrophic

All of the lakes had quality classes that indicated some degree of nutrient enrichment. None of the lakes were classified as microtrophic or oligotrophic.

Lake Ototoa had the lowest TLI and therefore considered to have the best water quality of the seven lakes monitored in the Auckland region. In contrast, Lake Spectacle had the highest TLI and is considered to have the worst water quality.

Although not enough lakes were sampled to identify reliable relationships between the type of land cover in the surrounding catchment and the water quality of the lake, the results shown in Table 18 suggest a far more complex relationship than the one that was clearly identified for rivers.

Trends

The 2005 Water Quality of Selected Lakes in the Auckland Region report examined trends in lake water quality between 1992 and 2005. This analysis was used to identify trends in the four water quality parameters that are used to assess the life supporting capacity of the water for each of the seven monitored lakes and the overall TLI.

The change in the overall TLI indicated that the water quality of Lakes Kereta and Tomorata improved between 1992 and 2005. Improving trends in chlorophyll a were seen at both lakes, with improving trends in total phosphorus at Lake Kereta and secchi depth at Lake Tomorata.

The change in the overall TLI indicated that the water quality of Lakes Ototoa and Spectacle declined between 1992 and 2005. All four parameters showed declining trends at Lake Ototoa, with three of the four parameters showing declines at Lake Spectacle.

TABLE 19 Trends* in individual parameters and lake TLI between 1992 and 2005. (Source: ARC).

Lake	Parameter				
	Chlorophyll a	Secchi depth	Total phosphorus	Total Nitrogen	Overall TLI
Ototoa	⇩	⇩	⇩	⇩	⇩
Pupuke	⇩	⇩	⬄	⬄	⬄
Tomorata	⇧	⇧	⬄	⬄	⇧
Wainamu	⬄	⬄	⇧	⬄	⬄
Kuwakatai	⬄	⬄	⬄	⇧	⬄
Kerata	⇧	⬄	⇧	⬄	⇧
Spectacle	⇧	⇩	⇩	⇩	⇩

*Trends are shown by ⇩ for declining, ⇧ for improving, and ⬄ for no detectable change.

Microbiological lake water quality

In lakes, the suitability of the water for recreational activities is typically assessed by the levels of two indicator organisms, blue-green algae and *E. coli*. The ARC monitors the levels of these indicator organisms at each of the seven sites in the lake water quality monitoring programme.

Indicator 9: Lake water quality for recreation (blue-green algae)

Blue-green algae (cyanobacteria) are commonly found in lakes all over the world. However, some species of blue-green algae, under certain conditions, produce chemicals that are highly toxic to mammals. Consequently, health authorities recommend avoiding contact with water containing high levels of blue-green algae because of potential adverse reactions to the toxins.

The ARC monitors the levels of blue-green algae in the seven lakes as part of the lake water quality monitoring programme, but it is important to note that the ARC's monitoring measures the levels of (potentially toxin producing) blue-green algae, not the presence or levels of any toxins.

Freshwater

The levels of blue-green algae at the lakes were compared with threshold derived from existing international guidelines (15,000 cells/ml). Levels above this threshold are indicative of an increased health risk. The frequency and magnitude of exceedences of this threshold were also measured (Table 20).

TABLE 20 Frequency and magnitude of exceedences of the blue-green algae threshold (2007 sampling year). (Source: ARC).

Lake	Frequency	Magnitude
Ototoa	0.0	0.0
Pupuke	0.0	0.0
Tomorata	0.0	0.0
Wainamu	14.3	1.7
Kuwakatai	14.3	7.1
Kereta	14.3	18.5
Spectacle	57.1	48.4

Lakes Ototoa, Pupuke and Wainamu had low levels of blue-green algae throughout the 2007 sampling year (July 2007 to June 2008) and, therefore, complied with the threshold. At the other end of the scale, Lake Spectacle exceeded the threshold frequently and by the biggest magnitude.

Lakes Kuwakatai, Kereta and Tomorata exceeded the threshold only once during the summer (in either December 2007 or January 2008). Lake Spectacle had the greatest magnitude of exceedences.

Indicator 10: Lake water quality for recreation (bacteria)

As with rivers, the suitability of lake water for recreation activities is also assessed by the level of *Escherichia coli* bacteria in a water sample. Although most *E. coli* are harmless, elevated levels are used to indicate the presence of faecal pollution, which may pose a threat to human health because it contains other pathogenic organisms.

The ARC monitors *E. coli* levels at each of the seven lakes in the lake water quality monitoring programme. These levels are compared with the Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas (produced by the MfE and MOH in 2003, see Table 8). The frequency and magnitude of any exceedences are also assessed.

All samples from all the lakes met all of the guidelines. The highest single sample (200 *E. coli* per 100ml from Lake Spectacle in May 2008) was within the Green mode guideline (260 *E. coli* per 100ml). Every other sample collected during 2007 produced results below 100 *E. coli* per 100ml.

Ecological quality programme

Rotifer monitoring programme

Rotifers are part of the natural zooplankton community of lakes and, as with invertebrates in rivers, they are useful biological indicators because of their high abundance and diversity, and their sensitivity to environmental impacts.

The rotifer community was sampled at the seven lakes in the water quality monitoring programme, at the same time as the water quality samples were collected. The information generated from these samples is often complex, so it is summarised into a rotifer index for ease of interpretation and communication.

The rotifer index can be used to infer the ecological quality of the lakes and allow comparison with the results from the lake water quality class. As with the TLI, the lower the rotifer index, the better the lake quality.

Indicator 11: Ecological quality (based on rotifer index)

Lake Ototoa had the lowest rotifer index and inferred quality class (Table 21), and was therefore considered to have the best ecological quality (based on rotifers) of the seven monitored lakes. At the other end of the scale, Lake Spectacle had the highest rotifer index and was considered to have the worst ecological quality of the monitored lakes.

Again, there are not enough lakes sampled in each type of catchment land cover to identify reliable relationships between catchment land cover and lake water quality. However, it is interesting to note that the two lakes in predominantly forested catchments had the best ecological quality, based on their rotifer index results.

TABLE 21 Rotifer index results for 2008. (Source: ARC).

Lake	Catchment	Rotifer index	Inferred quality class
Ototoa	Forested	3.0	Mesotrophic
Wainamu	Forested	3.7	Mesotrophic
Tomorata	Rural	4.0	Eutrophic
Pupuke	Urban	4.2	Eutrophic
Kuwakatai	Rural	4.2	Eutrophic
Kereta	Rural	4.9	Eutrophic
Spectacle	Rural	5.8	Supertrophic

Macrophyte monitoring programme

In a pristine state, lakes within the Auckland region would contain a diverse range of native macrophytes (submerged plant species) growing from the lake edge towards the centre of the lake. Their extent is determined by the water clarity or the maximum depth of the lake. In shallow lakes, the macrophytes would have probably grown across the entire lake. Today, relatively few lakes remain in a pristine condition because invasive species and reduced water clarity has limited the quality and extent of the macrophytes in most lakes.

To assess the ecological condition of lakes based on their macrophyte communities, surveys were undertaken at 29 lakes during 2008. Key features of the macrophyte community structure and composition were used to produce a series of indices using the LakeSPI (Submerged Plant Indicators) tool. Macrophytes are useful indicators of ecological condition because of their size, ease of identification and perennial nature.

Results from the macrophyte survey and subsequent LakeSPI analysis produced three indices:

→ LakeSPI index. This is an overall index of the plant community (the higher this score, the better).

→ Native condition index. This index is based on the diversity and quality of native submerged plants (the higher this score, the better).

→ Invasive condition index. This index is based on the degree of impact by invasive weed species (the lower this score, the better).

The LakeSPI index enables the ARC to assign an overall quality class using the following ranges:

→ Greater than 75 = Excellent quality

→ Between 50 and 75 = Good quality

→ Between 20 and 50 = Fair quality

→ Between 1 and 20 = Poor quality

→ 0 = Non-vegetated.

Indicator 12: Ecological quality (based on macrophytes)

A wide range in LakeSPI index scores (from 0 to 90) was observed from surveys of the 29 lakes, indicating a large variation in the ecological quality of these lakes. Of the 29 sites:

→ four lakes (14 per cent) were classified as Excellent,

→ three lakes (10 per cent) as Good,

→ seven lakes (24 per cent) as Fair,

→ seven lakes (24 per cent) as Poor,

→ eight lakes (28 per cent) were non-vegetated.

The environmental pressure having the biggest effect on the LakeSPI index was identified for those lakes that produced scores lower than 50 (Table 22). As expected, water level changes had the biggest effect in the water supply reservoirs.

Of more interest were the many natural lakes that had lower than Good LakeSPI scores: the main limiting factor for these lakes was considered to be invasive weeds. The number of lakes within the Auckland region that have invasive weeds is high compared to the national average.

Implications of lake quality

The lake water quality programme indicated that all seven monitored lakes were enriched to some extent, although there was no clear relationship with land cover in the surrounding catchment. This may be due to the relatively small number of sites in the monitoring programme, although our ecological monitoring programme (using macrophytes) indicated that invasive weeds may be the most important stressor in the lakes.

The trend analysis of the lake water quality produced mixed results. The best and worst lakes (Ototoa and Spectacle) both showed signs of a decline in water quality between 1992 and 2005 but two others (Tomorata and Kereta) showed signs of an improvement in water quality. The ARC is researching the nature and impact of these trends.

As with the lake water quality monitoring, the rotifer index indicated that all of the seven routinely monitored lakes were enriched to some extent. As with most of the lake indicators, the relationship with land cover is not obvious, although the two lakes with forested catchments did produce the lowest rotifer index and hence best quality class.

The assessment of the submerged plant community, using the LakeSPI indices, indicated that the ecological quality of most of the lakes was degraded. The main impact on the natural degraded lakes was considered to be the presence of aquatic plant pests.

Unlike the rivers, several of the lakes are used for recreational activities. Our lake water quality programme showed that the recreational water quality of these seven lakes was generally good with little, if any, indication of faecal pollution. The low level of *E. coli* at all seven lakes was a welcome result and indicated an absence of faecal pollution. The levels observed were all below the most conservative (green mode) national recreational guidelines and, therefore, also met the stock watering guideline.

Lake Spectacle exceeded the blue-green algae threshold frequently. This lake is located within a catchment where intensive agriculture dominates land use. As a result nutrient levels were very high, water clarity was very low and algal blooms were common.

Whilst there was some agreement between the water quality and ecological monitoring, the correlation between the results of the two programmes was not statistically significant.

Freshwater

TABLE 22 LakeSPI results derived from the submerged plant surveys at 29 lakes. (Source: ARC).

Lake	LakeSPI index	Native condition index	Invasive condition index	LakeSPI class	Main limiting factor
Poutoa	90	82	5.6	Excellent	
Tomorata	78	56	0	Excellent	
Mangatawhiri*	76	61	0	Excellent	
Pokorua	76	82	23	Excellent	
Ototoa	72	60	8.1	Good	
Wairoa*	66	47	0	Good	
Waitakere*	51	46	39	Good	
Cossey's*	49	28	20	Fair	Water level change
Upper Huia*	36	22	53	Fair	Water level change
Whatihua	33	43	81	Fair	Invasive weeds
Lower Huia*	31	23	33	Fair	Water level change
Pupuke	30	35	79	Fair	Invasive weeds
Silver Hills*	30	22	59	Fair	Water quality
Pehiakura (small)	25	25	85	Fair	Invasive weeds
Okaihau	18	16	80	Poor	Invasive weeds
Wainamu	16	16	85	Poor	Invasive weeds
Pehiakura (large)	15	5	89	Poor	Invasive weeds
Kuwakatai	11	5	99	Poor	Invasive weeds
Te Kanae	10	4	96	Poor	Invasive weeds
Kawaupaku	10	3.3	89	Poor	Invasive weeds
Kereta	8	3	94	Poor	Invasive weeds
Mangatangi*	0	0	0	Non vegetated	Water level change
Hays Creek*	0	0	0	Non vegetated	Water quality
Karaka	0	0	0	Non vegetated	Water quality
Paekawau	0	0	0	Non vegetated	Water quality
Slipper	0	0	0	Non vegetated	Water quality
Spectacle	0	0	0	Non vegetated	Water quality
Nihotupu*	0	0	0	Non vegetated	Water level change
Western Springs	0	0	0	Non vegetated	Grass carp

* Water supply reservoirs

Groundwater

Key findings

→ The Auckland region has six major aquifer types, two are typically unconfined and four are typically confined.

→ Natural groundwater quality is controlled principally by the aquifer's geology, confinement and rate of groundwater flow.

→ The potential for groundwater contamination is primarily controlled by the aquifer confinement, depth and ground water age.

→ Deep, confined aquifers are not usually contaminated.

→ Contamination of unconfined aquifers is strongly related to the overlying and upgradient land use activities.

Introduction

The Auckland region has many aquifers, typically of sedimentary or volcanic origin (Figure 13). Stored in these aquifers is groundwater used for municipal water supply, irrigation, geothermal energy, domestic and stock water supplies; they also contribute to the water in the rivers and other surface water bodies such as lakes and wetlands.

Aquifers are defined as 'saturated rocks or sediments with sufficient permeability to yield economic quantities of water.'

The principal aquifer systems of the Auckland region are related to rock types (Figure 13):

→ volcanics (basalt and andesite lava flows, and pyroclastics)

→ alluvial sands and gravels

→ coastal dune sands

→ shelly marine sandstones

→ marine sandstones and mudstones

→ marine greywackes.

Each of these rock types contains many aquifer systems which, in turn, consist of numerous, individual aquifers that each store and transport quantities of groundwater.

The quality of the groundwater is related to the geology of the aquifer (through the water interacting with the rock), how long the water is in the aquifer and the degree of confinement and depth of the aquifer.

Figure 12 shows the different aquifer types. A confined aquifer occurs where the rocks above and below the aquifer are relatively impermeable. This restricts the vertical flow of groundwater and restricts the rise of the water table, pressurising the aquifer.

An unconfined aquifer is where the rocks above the aquifer are permeable. This allows the vertical flow of groundwater, movement of contaminants from the surface and permits the water table to rise and fall.

The impermeable layers that overlie a confined aquifer tend to protect the aquifer from contaminants migrating vertically downwards, particularly those from overlying land use activities (anthropogenic contamination). However, the groundwater quality can be affected by land-use activities within the groundwater recharge zone that can be located a large distance away. Generally, the deeper the aquifer the greater possibility of a confining layer existing between the aquifer and the surface.

Other important factors that control the effect of land use activities on groundwater quality are the rate of flow of groundwater through the aquifer and the volume of water stored within the aquifer. The length of time that the water has been in the ground is also important. When the groundwater is old, historic land uses that are no longer present can still have a significant impact today.

Groundwater quality monitoring programme

The quality of the High Use and Sensitive aquifers in the Auckland region is monitored routinely. The ARC's groundwater quality monitoring programme monitors the physical, chemical and microbiological properties of the groundwater at 24 boreholes. Bores are sampled quarterly, twice a year or annually, depending on the rate of groundwater flow and the rate of change in groundwater quality.

The physical parameters monitored include field measurements of the water temperature, pH, electrical conductivity, dissolved oxygen and redox potential. Laboratory measurements of pH, turbidity, suspended solids and total dissolved solids are also conducted.

The chemical parameters monitored include alkalinity, hardness, nutrients, pesticides, major and minor cations and anions, and silicate. Levels of faecal coliforms and *E-coli* bacteria are also monitored.

The groundwater quality monitoring enables the ARC to assess the:

→ natural physical and chemical characteristics of the groundwater within each aquifer type,

→ nature and degree of contamination within each aquifer system,

→ suitability of the groundwater for supporting plant and animal life upon discharge into the rivers (as baseflow) and the coastal environment,

→ suitability of the groundwater for drinking and irrigation.

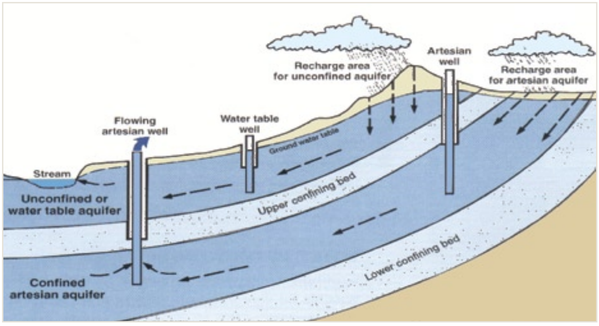


FIGURE 12 Groundwater Concepts (Source: ARC).

Freshwater

The groundwater quality of the aquifers in the Auckland region was summarised into three specific groundwater quality indicators based on the relevant environmental, recreational or drinking water guideline or standard. The indices is used to assess groundwater quality are described earlier in Box 3: Water Quality Index (page 146).

The WQI enables the ARC to assign an overall groundwater quality class. This can be used to evaluate the groundwater in each of the aquifer systems for its suitability for discharge to rivers and the coastal environment, and for use as drinking water (Table 23).

Groundwater data from 1998 to 2009 was used to calculate the drinking water quality indices and data from 2004 to 2009 was used for the river and coastal discharge indices.

TABLE 23 Threshold for assigning quality classes to rivers and coastal environments and for drinking water. (Source: ARC).

Class	Groundwater quality for discharge to rivers and coastal environments	Groundwater quality for use as drinking water
Excellent	Greater than 90	Greater than 90
Good	75-90	70-90
Fair	60-75	50-70
Poor	Less than 60	Less than 50

Groundwater quality for discharge to river and marine environments

Indicator 13: Groundwater quality for discharge to rivers

The suitability of the groundwater quality in each of the monitored aquifer systems to support plant and animal life when discharged as baseflow into rivers was calculated using 15 dissolved parameters. The parameters used comprised forms of nitrogen, aluminium, arsenic, boron, chromium, copper, iron, manganese, nickel, lead, zinc and *E. coli* bacteria. Table 24 shows the results.

Indicator 14: Groundwater quality for coastal discharge to marine environments

The suitability of the groundwater quality in each of the monitored aquifer systems to support plant and animal life when discharged into the coastal environment was calculated using the same parameters for Indicator 13, except for iron. Table 25 shows the results.

Sedimentary aquifers

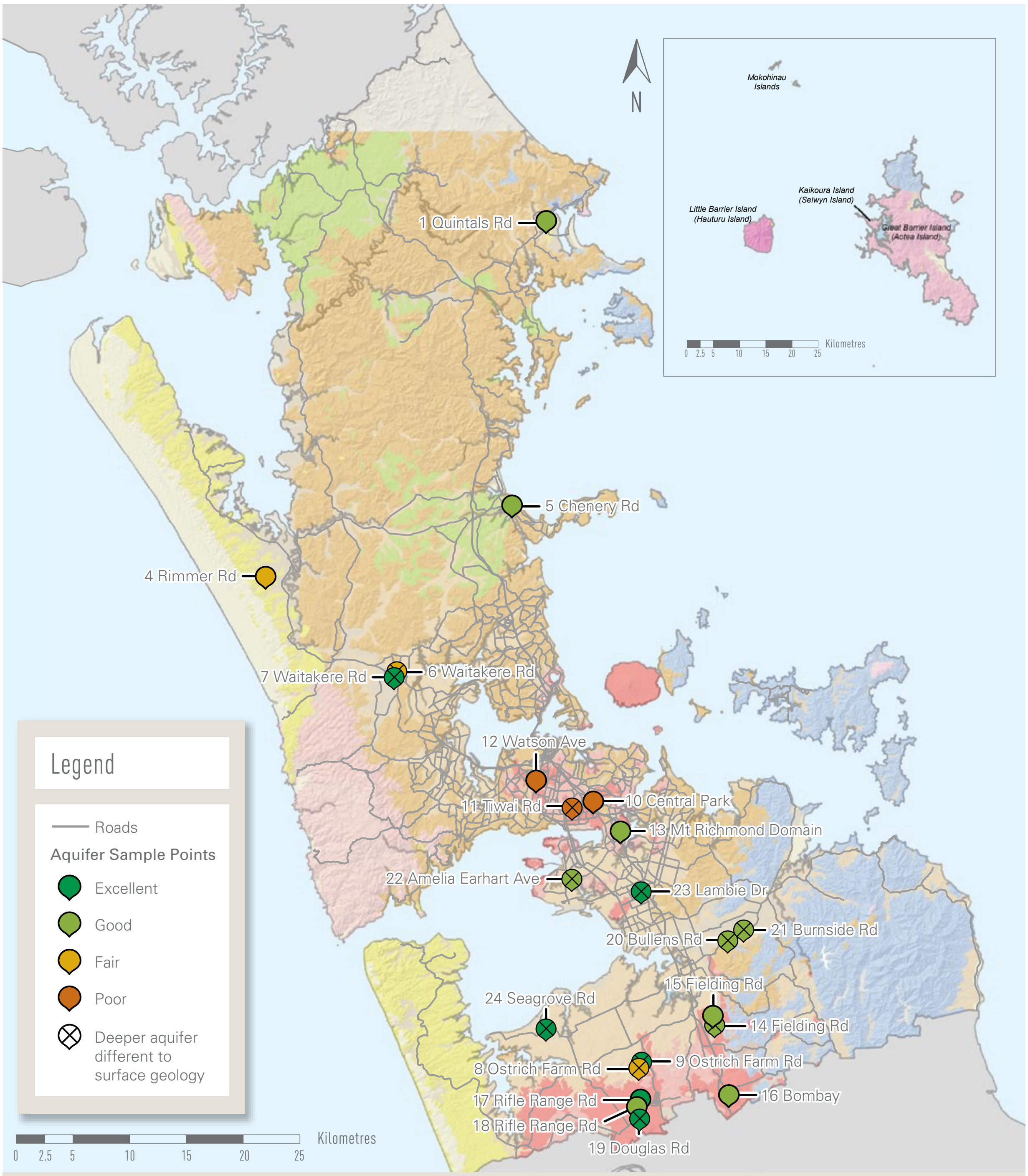
The groundwater quality for discharge to rivers from deep, confined sedimentary aquifer systems of the Waitemata Group and Pleistocene Alluvial Sediments was classed as Good or Excellent. This was primarily due to their relatively good flow rates, good protection from overlying land use activities and groundwater aged typically more than 100 years.

However, the groundwater in these confined sedimentary aquifers tends to have naturally elevated levels of ammoniacal nitrogen, iron, boron, manganese and zinc (depending on the geology and degree of confinement of the particular aquifer). When the iron levels are elevated, the groundwater quality often exceeds (up to 10 times) the environmental guideline for protection of freshwater ecosystems. Occasionally, zinc can marginally exceed the freshwater guidelines, (typically around 1-2 times). Boron, in the very deep (typically 100-200m) southern Waitemata Group aquifers can be at, or marginally exceed, the freshwater guidelines. Levels of ammoniacal nitrogen and manganese, although naturally elevated, remain below the freshwater guidelines.

Whether the groundwater quality for discharge to rivers for these confined aquifer systems is classified as Good or Excellent depends mainly on the amount of iron that has dissolved naturally within the groundwater, as a result of complex chemical reactions between the rocks and the groundwater. These reactions are controlled mainly by the redox potential, pH and temperature of the groundwater within the aquifer.

Most of the deep, confined sedimentary aquifer systems with low iron concentrations have excellent groundwater quality due to their strongly anoxic conditions.

The groundwater quality for discharge to rivers from the deep, confined Pliocene Dune Sands aquifer is classified as Fair due to naturally high iron concentration and anoxic conditions. The semi-confined shallow aquifer in the northern Waitemata Group at Waitakere Road is also classified as Fair due to the high iron concentrations from strong weathering on the top of this rock. The groundwater quality for discharge to the marine environment from all deep, confined sedimentary aquifers is classified as Excellent.



Geology

Holocene Sediments
- Alluvial Sediments
- Dune Sands

Pliocene and Pliocene Sediments
- Alluvial Sediments
- Dune Sands
- Kaawa – Shelly, Calcareous Sandstones

Waitemata Group
- Sandstones, Mudstones

Te Kuiti Group
- Sandstones, Mudstones, Coal measures

Northland Allochthon
- Mudstones, Limestones and Minor Volcanics

Jurassic Basement
- Greywackes

Great Barrier Island Volcanics
- Volcanics

Waiheke Island
- Volcanics

Little Barrier Island Volcanics
- Volcanics

South Auckland and Auckland Volcanics
- Basalt
- Scoria
- Tuff

Waitakere Group Volcanics
- Volcanics
- Volcaniclastic

FIGURE 13 Aquifers and quality scores. (Source: ARC).

Freshwater

TABLE 24 Groundwater quality class for discharges to rivers for monitored aquifers in the Auckland region. (Source: ARC).

Aquifer system and borehole name	Type of aquifer confinement	Aquifer depth (m)	Scope (%)	Freq. (%)	Mag. (%)	WQI (%)	Class
Central Auckland Volcanics							
10 – Central Park	Unconfined	13-22	40.0	10.4	18.5	73.8	Fair
12 – Watson Ave	Unconfined	32.5-38.5	40.0	3.5	19.0	74.4	Fair
11 – Tiwai Rd	Unconfined	46.5-58.5	40.0	2.9	1.5	76.8	Good
13 – Mt. Richmond Domain	Unconfined	29.0-36.5	26.7	5.2	15.5	82.0	Good
South Auckland Volcanics							
17 – Rifle Range Rd	Unconfined	30-42	20.0	7.0	2.3	87.7	Good
16 – Bombay	Unconfined	62-79.5	13.3	9.6	6.4	89.8	Good
15 – Fielding Rd	Semi-confined	16.3-46.7	6.7	0.6	0.9	96.1	Excellent
18 – Rifle Range Rd	Confined	78-90	6.7	0.3	0.0	96.1	Excellent
Pleistocene Alluvial Sediments							
14 – Fielding Rd	Confined	57-64	20.0	5.6	1.7	88.0	Good
Pliocene Dune Sands							
4 – Rimmer Rd	Confined	49.5-61.5	13.3	7.3	53.5	67.9	Fair
Waitemata Group							
6 – Waitakere Rd	Semiconfined	10-15.0	13.3	6.7	51.8	68.9	Fair
1 – Quintals Rd	Confined	94-129.6	3.7	6.1	23.0	85.7	Good
5 – Chenery Rd	Confined	151-500	13.3	5.0	12.2	89.2	Good
7 – Waitakere Rd	Confined	78-150	13.3	5.7	10.8	89.6	Good
20 – Bullens Rd	Confined	38.9-75	20.0	6.1	5.7	87.5	Good
21 – Burnside Rd	Confined	154.2-169	13.3	7.0	12.5	88.7	Good
23 – Lambie Dr, Puhinui	Confined	60-200	13.3	5.3	3.0	91.5	Excellent
24 – Seagrove Rd	Confined	97.8-201	0.0	0.0	0.0	100.0	Excellent

TABLE 25 Groundwater quality class for discharges to the coastal environment for monitored aquifers in the Auckland region (Source: ARC).

Aquifer system and borehole name	Type of aquifer confinement	Aquifer depth (m)	Scope (%)	Freq. (%)	Mag. (%)	WQI (%)	Class
Central Auckland Volcanics							
10 – Central Park	Unconfined	13-22	28.6	8.7	13.1	81.2	Good
12 – Watson Ave	Unconfined	32.5-38.5	28.6	2.5	14.6	81.4	Good
11 – Tiwai Rd	Unconfined	46.5-58.5	28.6	2.2	1	83.4	Good
13 – Mt. Richmond Domain	Unconfined	29.0-36.5	14.3	4.2	13.6	88.4	Good
South Auckland Volcanics							
17 – Rifle Range Rd	Unconfined	30-42	21.4	7.1	2.1	86.9	Good
16 – Bombay	Unconfined	62-79.5	14.3	9.6	3.5	89.8	Good
15 – Fielding Rd	Semi-confined	16.3-46.7	0	0	0	100	Excellent
18 – Rifle Range Rd	Confined	78-90	7.1	0.3	0.1	95.9	Excellent
Pleistocene Alluvial Sediments							
14 – Fielding Rd	Confined	57-64	7.1	0.6	0	95.9	Excellent
Pliocene Dune Sands							
4 – Rimmer Rd	Confined	49.5-61.5	0	0	0	100	Excellent
Kaawa Formation							
8 – Ostrich Farm Rd #1	Confined	68-84	7.1	1.6	0.6	95.8	Excellent
8 – Ostrich Farm Rd #2	Confined	46-47	7.1	0.6	1.7	95.7	Excellent
22 – Amelia Earhart Ave	Confined	42.6-48.6	0	0	0	100	Excellent
19 – Douglas Rd	Confined	254-268	0	0	0	100	Excellent
Waitemata Group							
6 – Waitakere Rd	Semiconfined	10-15.0	13.3	6.7	51.8	68.9	Fair
1 – Quintals Rd	Confined	94-129.6	3.7	6.1	23.0	85.7	Good
5 – Chenery Rd	Confined	151-500	13.3	5.0	12.2	89.2	Good
7 – Waitakere Rd	Confined	78-150	13.3	5.7	10.8	89.6	Good
20 – Bullens Rd	Confined	38.9-75	20.0	6.1	5.7	87.5	Good
21 – Burnside Rd	Confined	154.2-169	13.3	7.0	12.5	88.7	Good
23 – Lambie Dr, Puhinui	Confined	60-200	13.3	5.3	3.0	91.5	Excellent
24 – Seagrove Rd	Confined	97.8-201	0.0	0.0	0.0	100.0	Excellent

Volcanic aquifers

The groundwater quality for discharge from the confined and semi-confined aquifer systems in the South Auckland Volcanics is classified as Excellent. These aquifer systems have very high groundwater flow rates and some protection from vertical migration of contaminants from overlying land use activities by less permeable layers above. However, this groundwater tends to be over 100 years old, meaning that any contamination may not have yet reached this part of the aquifer.

The groundwater quality for discharge from the shallow unconfined aquifer systems of the South Auckland Volcanics is classified as Good. These are more vulnerable to contamination from the overlying intensive horticultural and market garden land use activities. Nitrates, principally from fertiliser application, consistently exceed guideline values. Pesticide and herbicide residues have also been occasionally detected, albeit at low levels.

Although the shallow, unconfined Central Auckland Volcanic aquifer system is classified Good or Fair it is highly vulnerable and at risk of pollution from overlying urban land use activities. At the volcanic cones, where the aquifer system is overlain by parkland, the groundwater quality is Good because contaminant levels in the surface water or stormwater that migrates into the groundwater are relatively low. However, where the overlying land use is residential or commercial, the groundwater quality is variable as contaminants migrate easily into these unconfined aquifers. Microbial contamination is often ten times above guideline values mostly due to sewerage overflows and leaky pipes. Zinc and copper are also elevated due to stormwater contamination. Fortunately, the very high groundwater flow and recharge rates in these unconfined aquifer systems dilutes the contamination and, as a result, the groundwater quality is not as bad as it would otherwise be.

Groundwater quality for drinking water

Indicator 15: Groundwater quality for drinking water

The suitability of the groundwater quality for drinking was also assessed using 23 different parameters.

The results were compared to both the maximum acceptable values for human health and the guideline values for aesthetics following the New Zealand Drinking Water Standard. This assessment does not take into account any water supply treatment process. The results are shown in Table 26 and illustrated in Figure 13.

Sedimentary aquifers

The groundwater quality for drinking from the deep confined sedimentary aquifer systems of the Waitemata Group, Kaawa Formation and Pleistocene Alluvial Sediments was generally classified as Good or Excellent. This was primarily due to their relatively good flow rates, good protection from overlying land use activities and groundwater more than 100 years old.

The aquifers with excellent groundwater quality for drinking tend to have naturally higher pH (more than pH 8.5) and low iron levels, whereas those with good groundwater quality for drinking tend to have naturally elevated levels of iron, ammoniacal nitrogen, turbidity, total hardness, boron and manganese (depending on the geology and degree of confinement of the aquifer). Iron typically exceeded the aesthetic drinking water standard up to 16 times.

Volcanic aquifers

The groundwater quality for drinking from the confined aquifer systems in the South Auckland Volcanics is classified as Excellent. The semi-confined aquifer system is classified as Good due to naturally elevated levels of iron and turbidity. However, the shallow, unconfined aquifer systems, although classified Good, are impacted by high nitrate levels due to overlying intensive horticultural and market garden land use activities. Pesticides and herbicides (including Bentazone, Alachlor and Metolachlor) have also been detected within these aquifer systems, although not above the guidelines for drinking water.

The groundwater quality for drinking from the shallow, unconfined Central Auckland Volcanic aquifer system covered by parkland is classified as Good. However, where the overlying land use is residential or commercial, the groundwater quality for drinking is Poor due to the impact of stormwater contamination, overflows from sewers and leaky pipes.

Overall groundwater quality

When the results of the indicators are considered together, they show that land use effects on groundwater quality are strongly affected by the degree of confinement of the aquifer and the age of the groundwater (Figure 13).

Little or no land-use impacts were found in the deep confined sedimentary or volcanic aquifers with groundwater in excess of 100 years. However, the impacts of land use activities were apparent in the vulnerable unconfined, younger volcanic aquifer systems and, to a lesser degree, in the semi-confined aquifers.

E-coli and nitrate contamination from sewerage overflows and leaking pipes is an important issue for the unconfined aquifer systems of the Central Auckland Volcanics. Similarly, nitrates are also cause for concern in the South Auckland Volcanics unconfined aquifer system.

TABLE 26 Groundwater quality class for drinking water for monitored aquifers in the Auckland region. (Source: ARC).

Aquifer system and borehole name	Type of aquifer confinement	Aquifer depth (m)	Scope (%)	Freq. (%)	Mag. (%)	WQI (%)	Class
Central Auckland Volcanics							
10 – Central Park	Unconfined	13-22	28.6	8.7	13.1	81.2	Good
12 – Watson Ave	Unconfined	32.5-38.5	28.6	2.5	14.6	81.4	Good
11 – Tiwai Rd	Unconfined	46.5-58.5	28.6	2.2	1.0	83.4	Good
13 – Mt. Richmond Domain	Unconfined	29.0-36.5	14.3	4.2	13.6	88.4	Good
South Auckland Volcanics							
17 – Rifle Range Rd	Unconfined	30-42	21.4	7.1	2.1	86.9	Good
16 – Bombay	Unconfined	62-79.5	14.3	9.6	3.5	89.8	Good
15 – Fielding Rd	Semi-confined	16.3-46.7	0.0	0.0	0.0	100.0	Excellent
18 – Rifle Range Rd	Confined	78-90	13	2.4	0.2	92.3	Excellent
Pleistocene Alluvial Sediments							
14 – Fielding Rd	Confined	57-64	7.1	0.6	0.0	95.9	Excellent
Pliocene Dune Sands							
4 – Rimmer Rd	Confined	49.5-61.5	0.0	0.0	0.0	100.0	Excellent
Kaawa Formation							
8 – Ostrich Farm Rd #1	Confined	68-84	7.1	1.6	0.6	95.8	Excellent
22 – Amelia Earhart Ave	Confined	42.6-48.6	0.0	0.0	0.0	100.0	Excellent
19 – Douglas Rd	Confined	254-268	0.0	0.0	0.0	100.0	Excellent
Waitemata Group							
6 – Waitakere Rd	Semi-confined	10-15.0	0.0	0.0	0.0	100.0	Excellent
1 – Quintals Rd	Confined	94-129.6	0.0	0.0	0.0	100.0	Excellent
5 – Chenery Rd	Confined	151-500	7.1	0.9	2.3	95.6	Excellent
7 – Waitakere Rd	Confined	78-150	0.0	0.0	0.0	100.0	Excellent
20 – Bullens Rd	Confined	38.9-75	7.1	0.6	1.0	95.8	Excellent
21 – Burnside Rd	Confined	154.2-169	0.0	0.0	0.0	100.0	Excellent
23 – Lambie Dr, Puhinui	Confined	60-200	14.3	1.4	1.3	91.7	Excellent
24 – Seagrove Rd	Confined	97.8-201	0.0	0.0	0.0	100.0	Excellent

Freshwater

Copper and zinc contamination from stormwater soakholes and leaky pipes occurs in the unconfined Central Auckland Volcanic aquifers and, to a lesser degree, in the unconfined South Auckland Volcanic aquifers. Zinc, and to a lesser degree, copper, may also originate from elevated natural background concentrations within these volcanic rocks. Occasionally, levels of nickel, iron, chromium and lead are of concern in the unconfined Central Auckland Volcanic aquifers, although natural background levels could account for these concentrations, particularly nickel and iron. However, the elevated levels of lead are indicative of anthropogenic contamination.

Groundwater quality is generally worse in the more vulnerable shallow, unconfined aquifers in both urban and rural areas where the groundwater is not older than any land use.

Implications of groundwater quality

Groundwater quality of the aquifers in the Auckland region was mostly Good or Excellent although some aquifers had Fair or Poor groundwater quality.

The level of groundwater contamination is predominantly controlled by the rate of groundwater flow and by the amount of protection from the overlying land uses determined by the overlying geology. Knowledge of the age of the groundwater is important when determining the potential for future impact or any ongoing impact on the groudwater quality of an aquifer.

The deeper confined aquifers (the Waitemata Group, Kaawa Formation and Pleistocene Alluvial Sediments) all had Good or Excellent groundwater quality. Any variations in water quality (particularly iron, ammonia, manganese and boron) tend to be natural and are related to the aquifer's geology, depth, confinement and the groundwater's pH, temperature and redox potential.

Natural variations in iron levels have the largest effect on the groundwater quality of the sedimentary aquifers. The higher the iron levels, the lower the groundwater quality. The Fair groundwater quality of the shallow semi-confined Waitemata Group aquifer and the Pliocene Dune Sands aquifers is due to their naturally high iron levels.

Unconfined aquifers are highly vulnerable to contamination from overlying land uses. The unconfined South Auckland Volcanic aquifers are affected by the overlying rural land uses with very high levels of nitrate from prolonged horticultural and market garden land use and the associated application of fertilizers. The unconfined Central Auckland Volcanic aquifers were also significantly affected by the overlying urban land uses, with very high *E. coli* levels and elevated levels of copper, zinc and nitrate from urban stormwater contamination, sewerage overflows and leaky pipes.

Our groundwater monitoring programme does not specifically monitor the groundwater quality from contaminated land. Consequently, there are areas of very poor groundwater quality within the Auckland region that are not included in this assessment.

Exotic freshwater species

Exotic freshwater plant pests

Many exotic freshwater plants are found in New Zealand but, fortunately, the two worst pest plant species (*Hydrilla verticulate* and *Phragmites australis*) are not found in the Auckland region. However, many other exotic freshwater plants are found in the Auckland region and Table 27 indicates their relative distribution and potential environmental risk.

If un-managed, exotic freshwater plants can form dense, unsightly and hazardous weed beds. These growths can displace native plant communities and degrade the habitat for freshwater animals; block stream channels, drains and irrigation systems; reduce oxygen levels in the water and create drowning hazards for people and animals.

The five exotic freshwater plants the ARC considers to be the worst in the Auckland region because of their environmental effects are *Egeria*, Hornwort, Alligator weed, Lagarosiphon and Manchurian wild rice. These five species can all produce dense growths that reduce biodiversity by excluding native species and can be associated with declines in water quality and ecological quality. Extremely dense growth can affect the water flow and interfere with irrigation and water supply, restrict water traffic and recreational activities, and pose a drowning risk because of entanglement.

Egeria (Egeria densa)

Originally from South America, *Egeria* was first discovered at Western Springs in Auckland in 1963 and is now widespread throughout the North Island. It is the most common of the high environmental risk exotic plants, and has been found in at least eight lakes in the Auckland region.

It is a submerged, bottom-rooted perennial freshwater plant that inhabits standing and slow flowing water bodies. It can form dense weed beds up to 8m deep in clear lakes, and displaces both native and other introduced species. *Egeria* can spread only by distribution of vegetative fragments because there are only male plants in New Zealand, meaning that it cannot set viable seed.

Hornwort *(Ceratophyllum demersum)*

Hornwort has a wide global distribution, ranging from North America to Australia. It was first recorded in Auckland at Glendowie in 1975 and is widespread throughout the North Island. Because of its environmental effects it is considered to be the worst submerged freshwater exotic plant in New Zealand and has been found in at least five lakes in the Auckland region.

It is a submerged, perennial freshwater plant that inhabits standing and slow flowing waterbodies. Unlike *Egeria*, it does not produce true roots and anchors only lightly to the substrate using buried stems and leaves. It forms dense weed beds up to 10m deep in clear lakes and displaces both native and other introduced species. Hornwort is a relatively brittle plant so fragments break off readily and form new growths elsewhere. Like *Egeria*, this is the only mechanism of spread. Although the plants produce both male and female flowers, this species has not yet been observed to produce viable seed in New Zealand.

Alligator weed *(Alternanthera philoxeroides)*

Originally from South America, Alligator weed was first recorded in Auckland at Piha in 1945 and it is widespread throughout the upper North Island. Temperature is thought to limit its distribution.

It is an emergent, perennial freshwater plant that inhabits a wide range of freshwater and terrestrial environments, and can even tolerate salt water. It is a rooted plant that can produce dense beds up to 1m deep. It is typically found in slow flowing rivers, drains and wetlands and can form marginal mats in lakes although it cannot set root in water deeper than 3m. It is a relatively brittle plant and fragments break off easily and form new growths elsewhere. This is the only mechanism of spread as this species has not yet been observed to produce viable seed in New Zealand.

Lagarosiphon *(Lagarosiphon major)*

Originally from South Africa, this species of oxygen weed was first recorded in Auckland at Western Springs in 1953 and is widespread throughout New Zealand.

It is a submerged, bottom-rooted perennial freshwater plant that inhabits standing and slow flowing waterbodies. It can form dense weed beds up to 7m deep in clear lakes and displaces both native and other introduced species. This species can only spread by distribution of vegetative fragments because there are only female plants in New Zealand and, therefore, it cannot set viable seed.

Manchurian wild rice *(Zizania latifolia)*

Originally from China, Manchurian wild rice was first recorded in Auckland at Lake Kereta in 1950. It is limited to a small number of sites in the Auckland region and nationally is restricted to the upper North Island (Northland, Auckland and Waikato) with the exception of one isolated site in Wellington.

It is a very tall perennial grass that inhabits the margins of waterbodies and can tolerate brackish water. It is a strongly rooted plant that can form dense stands up to 4m in height. It spreads aggressively through rhizomes up to 10m from the parent plant. It also produces viable seeds and can regenerate from fragments.

Freshwater

TABLE 27 Exotic freshwater plants known in the Auckland region. (Source: ARC).

Common name	Scientific name	Distribution	Environmental risk
Egeria	*Egeria densa*	Widespread	High
Hornwort	*Ceratophyllum demersum*	Widespread	High
Alligator weed	*Alternanthera philoxeroides*	Widespread	High
Lagarosiphon	*Lagarosiphon major*	Frequent	High
Manchurian wild rice	*Zizania latifolia*	Sparse	High
Bladderwort	*Utricularia gibba*	Frequent	Moderate
Sagittaria	*all Sagittaria p. except S. teres*	Sparse	Moderate
Senegal tea	*Gymnocoronis spilanthoides*	Sparse	Moderate
Water poppy	*Hydrocleys nymphoides*	Sparse	Moderate
Eelsgrass	*Valisneria* sp.	Sparse	Moderate
Water lily	*Nymphaea* sp.	Frequent	Moderate
Great reedmace	*Typha latifolia*	Sparse	Moderate
Marshwort	*Nymphoides* sp.	Sparse	Moderate
Curled pondweed	*Potamogeton crispus*	Frequent	Moderate
Water buttercup	*Ranunculus trichophyllus*	Sparse	Moderate
Canadian pondweed	*Elodea canadensis*	Frequent	Moderate
Cape pondweed	*Aponogeton distachyus*	Sparse	Moderate
Yellow flag iris	*Iris pseudocorus*	Sparse	Moderate
Purple duckweed	*Landoltia punctata*	Frequent	Moderate
Spearwort	*Ranunculus flammula*	Sparse	Low
Water celery	*Apium nodiflorum*	Sparse	Low
Water primrose	*Ludwigia peploides*	Frequent	Low
Water purslane	*Ludwigia palustris*	Widespread	Low
Ferny azolla	*Azolla pinnata*	Frequent	Low
Lotus	*Lotus pedunculatus*	Sparse	Low
Marsh bedstraw	*Galium paustre*	Frequent	Low
Nardoo	*Marsilea mutica*	Sparse	Low
Jointed rush	*Juncus articulatus*	Sparse	Low
Bulbous rush	*Juncus bulbosus*	Frequent	Low
Lizard's tail	*Saururus cernuus*	Sparse	Low
Watercress	*Nasturtium officianle*	Widespread	Low
Swamp lily	*Otellia ovalifolia*	Frequent	Low

TABLE 28 Exotic freshwater fauna known in the Auckland region. (Source: ARC).

Common name	Scientific name	Distribution	Environmental risk
Perch	*Perca fluviatilis*	Widespread	High
Mosquitofish	*Gambusia affinis*	Widespread	High
Rudd	*Scardinius erythrophthalmus*	Widespread	Moderate
Koi carp	*Cyprinus carpio*	Frequent	Moderate
Goldfish	*Carassius auratus*	Frequent	Moderate
Golden orfe	*Leuciscus idus*	Sparse	Moderate
Tench	*Tinca tinca*	Sparse	Low
Brown trout	*Salmo trutta*	Sparse	Low
Rainbow trout	*Oncorhynchus mykiss*	Sparse	Low
Brown bullhead catfish	*Ameiurus nebulosus*	Sparse	Low
Grass carp	*Ctenopharyngodon idella*	Sparse	Low
Silver carp	*Hypophthalmichthys molitrix*	Sparse	Low
Gudgeon	*Gobio gobio*	These species were present in the Auckland region but all populations are now believed to have been eradicated.	
Marron	*Cherax* sp.		

Exotic freshwater fauna

There are many freshwater ecosystems within the Auckland region that contain established populations of exotic freshwater fish; indeed, some have more than five species present. Some exotic freshwater fauna (Table 28) have been in the Auckland region for over a century (e.g. rainbow trout, brown trout and brown bullhead catfish) while others were introduced in the mid to late twentieth century (e.g. rudd and orfe).

Some exotic fish species have bought benefits to the Auckland region. For example, trout are an important sport fish, while grass carp are used as biological agents to control plant and algae growths. However, several of the exotic species have adverse environmental effects.

These can include:

- competition or predation on native species, reducing native biodiversity
- changes to the community structure of submerged aquatic plants
- hybridisation
- the introduction or transmission of parasites and diseases
- food web impacts through changes to the composition of the plankton community
- water quality impacts and habitat degradation from devegetation or bio-perturbation.

4.3

Freshwater

Conclusions on the state of freshwater

The majority of the trends for water quality showed no change between 1995 and 2005 for forested and rural rivers but a small percentage of trends did show some improvement; particularly the decreasing nitrogen levels at several rural sites. Urban streams also showed several improving trends, particularly for decreasing levels of ammoniacal nitrogen, nutrients and turbidity.

Our freshwater and lake monitoring programmes suggest that different environmental stressors are impacting the rivers and lakes within the Auckland region.

The freshwater monitoring programmes consistently reveal the importance of land cover in the surrounding catchment on both the water quality and the ecological quality of the river. The main stressor on the rivers therefore appears to be intensive land use in the surrounding catchment.

Rivers that drain forested catchments (particularly native forest) have excellent water quality and excellent ecological quality while rivers that drain urban catchments typically have poor water quality and poor ecological quality.

There is a large variation in the water quality and ecological quality of the rivers that drain catchments. More than 60 per cent of the rivers in the Auckland region flow through rural catchments so there is scope to make dramatic and lasting improvements in the rural rivers that currently have poor water quality and ecological quality.

Many rivers also had elevated levels of *E. coli* bacteria, indicating the presence of faecal pollution. This makes them unsuitable for recreational activities. There appears to be a strong relationship between the type of land cover in the surrounding catchment and the microbiological water quality, with intensive land uses (both urban and rural) associated with higher levels of *E. coli* than forested catchments. These elevated levels of faecal pollution mean that some rural rivers are not suitable for stock to drink from.

The lake water quality programme indicated that all seven monitored lakes are enriched by nutrients to some extent, although there was no clear relationship with land use in the surrounding catchment. Invasive weeds appear to be the main threat to the ecological qualiy of the lakes.

Management of pest species is a complicated and difficult issue; this suggests that the ecological quality of the lakes and rivers is likely to remain degraded for some time. Although the presence of pest fish can impact the native fish populations, physical modifications to the rivers (such as weirs, dams and culverts) can also have a significant effect on native fish populations, because these structures prevent fish from migrating between the sea and the rivers.

The deep, confined aquifers in the region generally contain old groundwater and are relatively well protected from surface contamination and generally had good or excellent water quality. However, the shallow, unconfined groundwater systems containing younger groundwater are vulnerable to impacts from the overlying land use activities and water quality was particularly degraded in the central and southern volcanic aquifer systems. Reducing the discharge of contaminants to the ground is likely to improve the groundwater quality of vulnerable aquifers in the long-term.

In summary, our freshwater monitoring programmes show that most of the rivers, lakes and shallow unconfined aquifers in the Auckland region are degraded to some extent although the recreational water quality in the lakes is generally good with no faecal pollution. There have been welcome improvements in some aspects of the water quality of the rivers (particularly the urban streams) and many of the rural streams have the potential for dramatic improvement and recovery with suitable management.

References and further reading

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

4.4

State of the environment and biodiversity – Marine

Contents

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

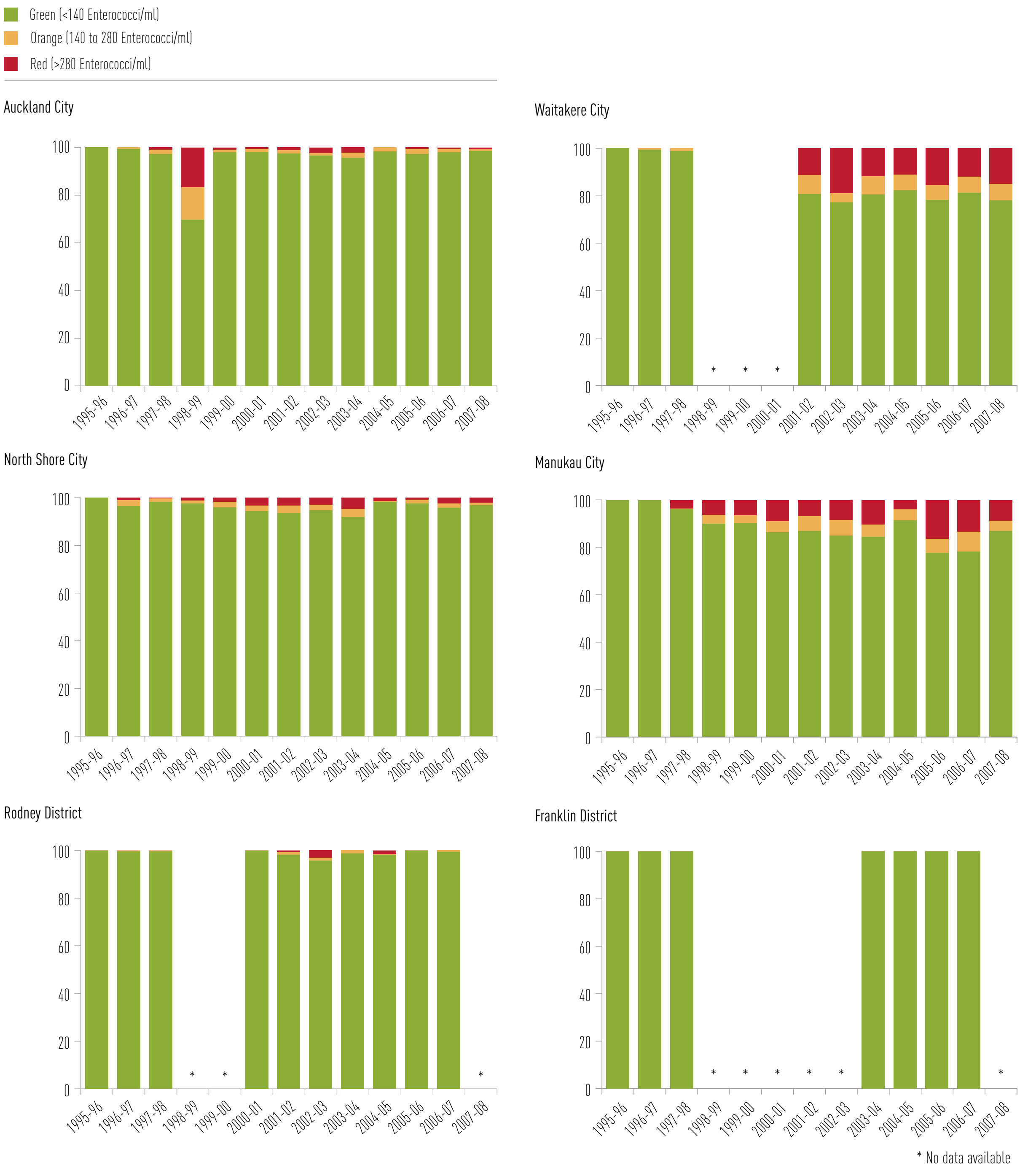

FIGURE 1 Percentage of bathing beach water quality samples collected from monitored beaches within Green, Amber and Red modes, within each council district. (Source: ARC).

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.

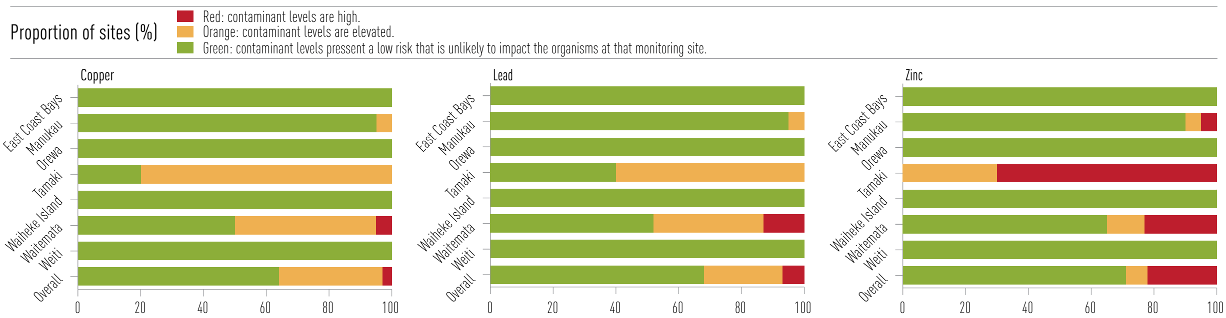

FIGURE 2 Number of monitored sites with heavy metal concentrations in the red, amber (orange), and green ERC categories. Sites are grouped by location type (e.g. harbour). 'Overall' shows all sites monitored. (Source: ARC).

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

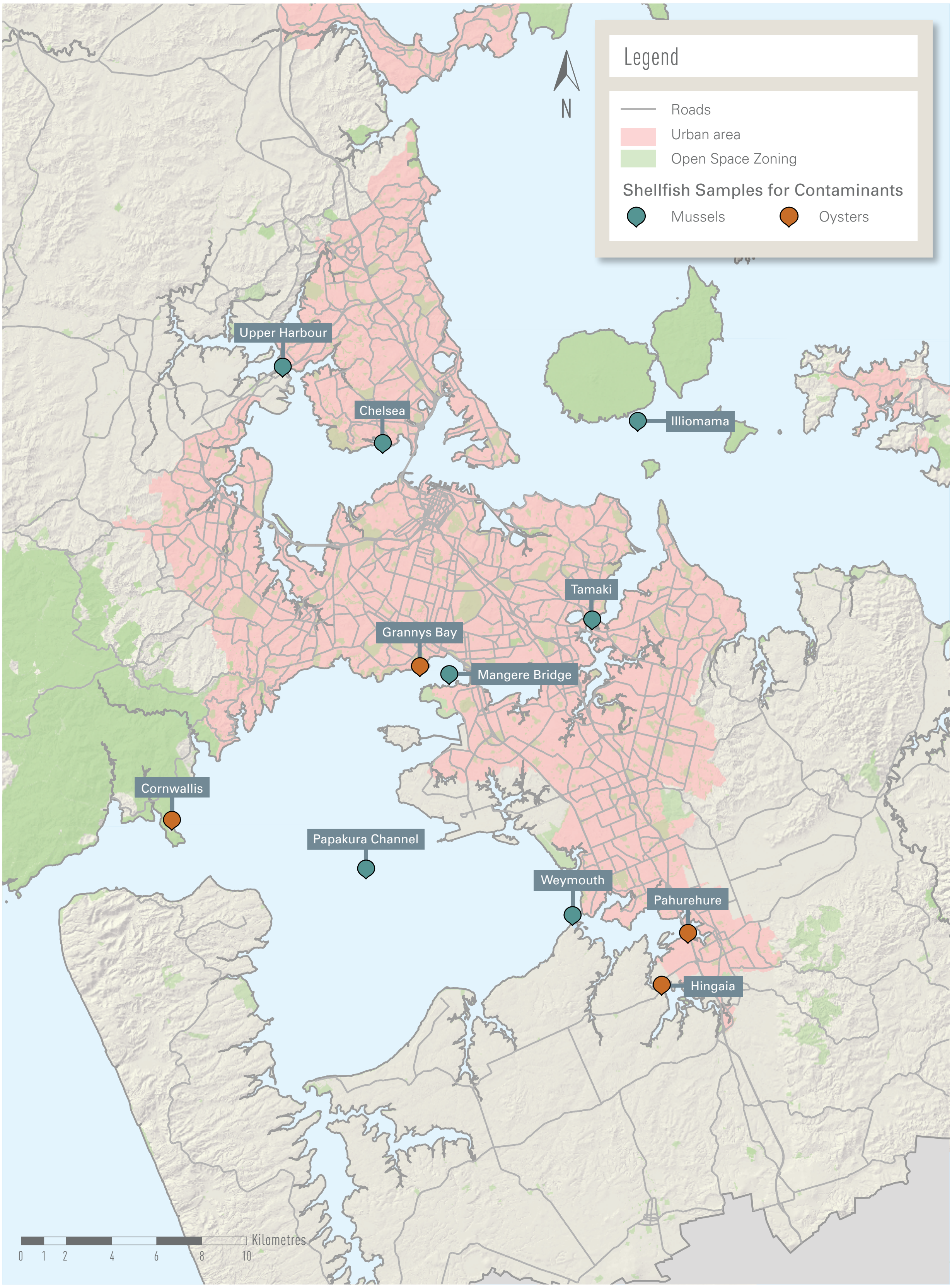

FIGURE 3 Location of monitoring sites for contaminants in shellfish.

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).

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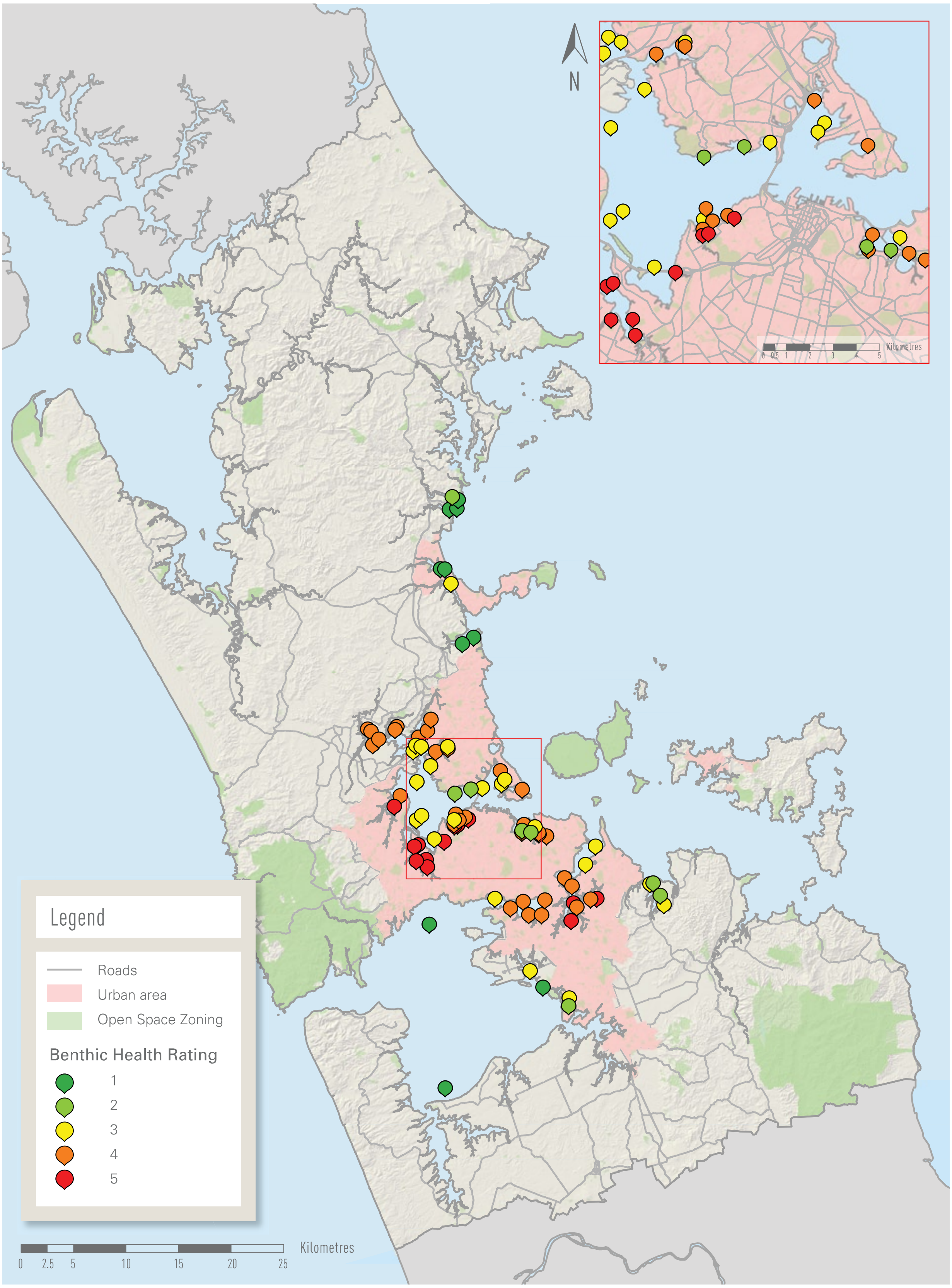

FIGURE 4 The rank of each site based on the results of the Benthic Health Model. Where sites have been sampled on more than one occasion, the results shown here are from the most recent sampling time. (Source: ARC).

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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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Photo: Tui sitting on a branch of flax plant. (Source: Shutterstock).

4.5

State of the environment and biodiversity – Terrestrial biodiversity

Contents

4.5

Terrestrial biodiversity

Introduction

Biodiversity (biological diversity) is commonly defined as the variety of all life. It includes genetic, species and ecosystem diversity and all the interactions between them.

Biodiversity is important because it contributes to environmental, economic, cultural and social well-being by providing valuable ecosystem services such as pollination, carbon storage by forests, biofiltration of water, nutrient cycling, soil formation, erosion control, sediment retention and recreation opportunities.

Although, the Auckland region makes up only 2 per cent of New Zealand's total land mass it is an important reservoir of New Zealand's total biodiversity. However, since human settlement there has been a marked decline in the region's terrestrial biodiversity.

This decline has occurred through the loss and fragmentation of native ecosystems due to human settlement and consequent land use changes, combined with the introduction of various invasive species, overharvesting and pollution. In addition, climate change is now emerging as a significant potential threat (see History of environmental change in the Auckland region and Climate change in the Introduction, pages 12 and 13).

Key findings

- The Auckland region contains a wide range of terrestrial biodiversity, but a considerable number of ecosystem types and species are under threat from the loss and fragmentation of native habitats, and the impacts of invasive species (particularly mammals and weeds).
- Only 27 per cent of indigenous land cover now remains in the Auckland region, with several ecosystem types (mainland lava forest, wetlands, coastal broadleaf forest and kauri forest), and several ecological districts (e.g. Tamaki, Awhitu, and Manukau) severely depleted.
- Despite its small size, the Auckland region contains a large proportion of New Zealand's threatened species, including 20 per cent of its terrestrial vertebrate fauna and 19 per cent of its threatened plant species, such as the pateke and Auckland green gecko.
- It also includes several endemic species that are found only in the region, such as the black petrel and chevron skink.
- An ecological assessment of the region found that many of the important ecological sites were in very good (13 per cent) or good (43 per cent) condition, although there were similar numbers of sites in very poor (10 per cent) or poor (34 per cent) condition. The impacts of ungulates (deer, pigs, goats and livestock) and weeds were identified as the main threats.

Terrestrial biodiversity monitoring

The ARC is responsible for environmental monitoring in the Auckland region, which informs the ARC about biodiversity status and trends. The ARC has information on native land cover, native birds, pests and weeds. In addition, a number of monitoring programmes have been established to assess the effects of pest management (e.g. kokako monitoring in the Hunua Ranges and vegetation, bird, and invertebrate monitoring at Tawharanui Regional Park).

A network of High Conservation Value (HCV) sites has been identified through occasional ecological surveys such as the Protected Natural Areas Programme (PNAP) and the Special Sites of Wildlife Importance (SSWI) programme.

Monitoring habitat condition in HCV sites allows the ARC to assess the effectiveness of pest control programmes. This type of periodic reassessment of HCV sites is currently our only method of tracking changes in habitat condition and identifying key issues within the Auckland region.

Assessment of the HCV sites provides useful information about the current health of the HCVs; however it does have some limitations, in particular poor representation of some ecologically significant sites across the Auckland region, under-representation of non-forested sites and data collection issues, inconsistencies and gaps.

However, the ARC is building on this by developing a comprehensive regional monitoring programme that will provide quantitative information on terrestrial ecosystems, including the abundance and diversity of species and significant threats. This knowledge will enable the ARC to measure the efficiency and effectiveness of related policy and management initiatives in a more systematic manner

Native land cover

Before human settlement, the natural land cover in the Auckland region is estimated to have been 93 per cent native forest (largely podocarp-broadleaf forest with localised kauri and coastal broadleaf) with open water, wetlands, dunelands and shrublands covering the remainder. However, much of the original native land cover has been lost or altered, now only 27 per cent of native land cover remains. Consequently, this has led to an overall decline in biodiversity, and a corresponding increase in the number of threatened ecosystems and species.

Habitat loss, fragmentation and degradation

Ecosystems are impacted in various ways when native habitats are lost or substantially modified. Plants and any other organisms that cannot move are usually destroyed, while the survival of other native species is reduced.

The process of habitat fragmentation is known to have an adverse impact on native biodiversity because it reduces the size of habitat area, increases the proportion of edge habitat and increases isolation from resources. Generally, larger habitat fragments are able to support species that require a large area, enabling them to maintain robust and healthy populations.

Habitat isolation can reduce the ability of species to disperse successfully across the landscape. Dispersal is essential for the long-term survival of many animal and plant species, particularly those that need a large area of habitat or specific resources. The degree of isolation is determined by the distance between the habitats, the characteristics of the surrounding landscapes and the dispersal patterns of different species.

Smaller fragments also have a higher proportion of edge area or 'edge habitat' that is influenced by adjacent land uses (e.g. agricultural or urban). Human-induced edge effects are known to have a direct effect on biodiversity in habitat fragments through changes in the amount of light, temperature, wind and moisture, and by improving access for unwanted organisms and other materials such as pollutants and invasive weeds. In turn, these factors typically result in indirect edge effects such as changes in plant densities, the amount of understorey cover (the plants between the tree canopy and the forest floor), shrub heights and species composition. Nevertheless, the importance of small habitat fragments can be high, particularly if they contain threatened ecosystems or threatened species.

Indicator 1: Habitat loss

The proportion of land cover types in the Auckland region is assessed using the Land Cover Database (LCDB). The first land cover database, LCDBI, was developed in 1996/97 and was followed by LCDBII in 2001/02. LCDBII was intended to assess the changes in land cover over the intervening five years but its limited accuracy has restricted our assessment of the extent of native land cover and ecosystem types.

Some native ecosystem types in Auckland are critically depleted and now cover less than 10 per cent of their original extent. These are:

- kauri forests (9 per cent)
- freshwater wetlands, including wetland forest (4 per cent)
- coastal forests (3 per cent)
- mainland lava forests (0.5 per cent).

Areas that have similar ecological characteristics have been defined as Ecological Districts (ED). There are 12 in the Auckland region (Figure 1). The amount of habitat loss varies considerably amongst these EDs. For example, Waitakere ED (which includes the Waitakere Ranges Regional Park) retains a large proportion of its native ecosystems:

- 73 per cent of its podocarp-broadleaf and kauri forest
- 36 per cent of its dune vegetation
- 51 per cent of its freshwater wetland and wetland forest.

In contrast, the native ecosystems and specific ecosystem types in other EDs such as Kaipara, Tamaki, Awhitu, Rodney and Manukau are severely depleted. For example:

- only 7 per cent of the native cover, one per cent of freshwater wetlands and wetland forests, and 0.5 per cent of lava forest remain in the Tamaki ED
- only 1 per cent of native coastal forest remains in the Kaipara ED and the Hunua ED
- only 1 per cent of freshwater wetlands and wetland forest remain in Hunua ED
- in Manukau ED only 1.6 per cent of the land area remains in native vegetation with 85 per cent of sites left, less than five hectares in size.

Indicator 2: Habitat fragmentation

To compare the amount of fragmentation in the Auckland region with the rest of New Zealand, the ARC used the LCDBII to determine the average size of habitat fragments and the proportion of edge-to-interior habitat.

Table 1 shows that the average habitat fragment size in the region is only 18 hectares – the smallest of all the regions. This compares unfavourably with the national average of 110 hectares.

In addition, the mean habitat fragment size within the region differs considerably among each district, e.g. only five hectares in Auckland City but 114 hectares in Waitakere City. This is not surprising as Auckland City (excluding the Hauraki Gulf Islands) is almost completely urbanised, while large areas of intact native forest remain in Waitakere City.

The proportion of edge habitat in the Auckland region is relatively high (1.30km per km^2) compared to the national average of 0.81km per km^2. Within the region, North Shore City has a particularly high ratio of edge: forest area, presumably due to the high proportion of forest fragments remaining in gullies.

Terrestrial biodiversity

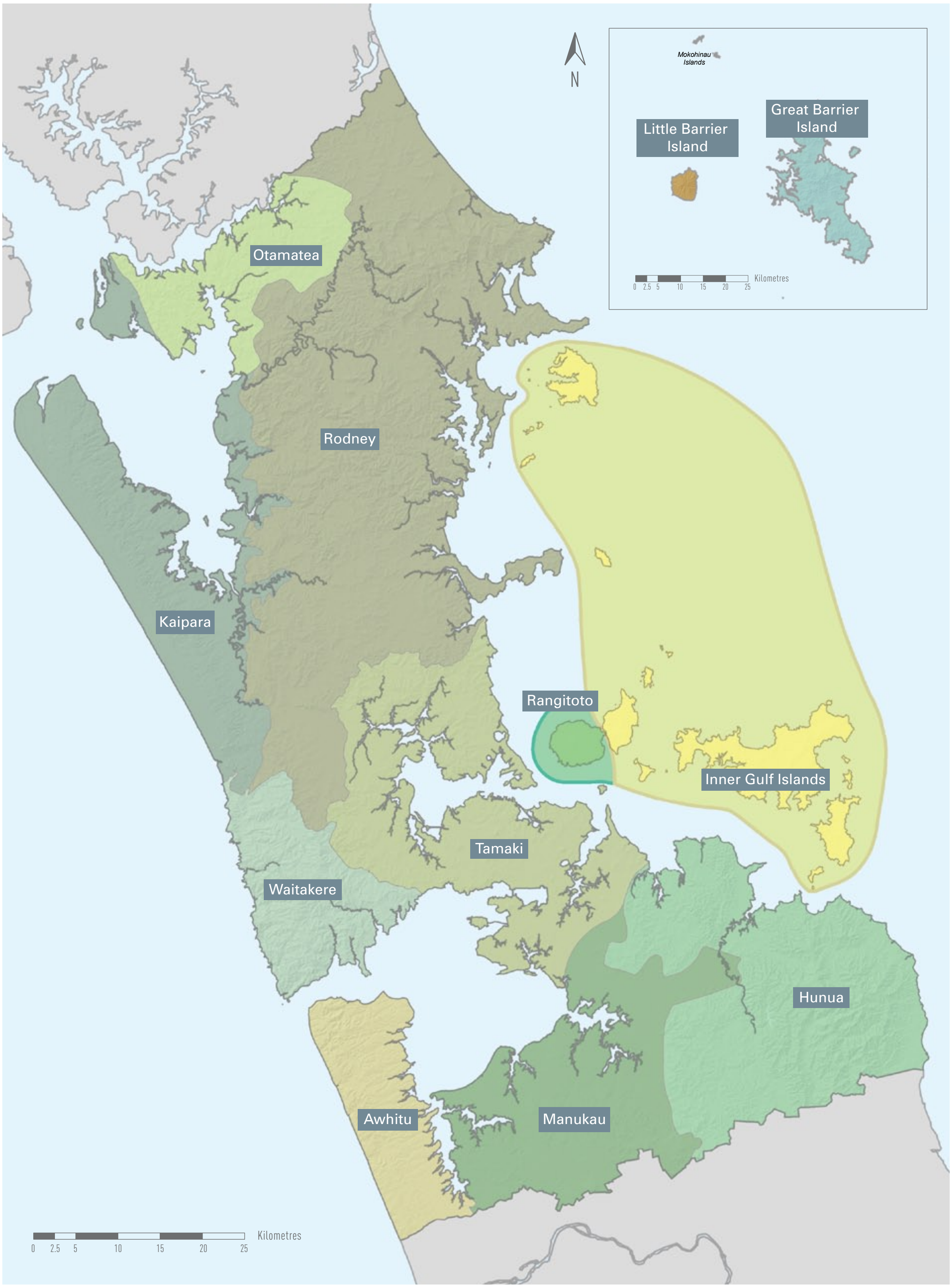

FIGURE 1 Location of the 12 Ecological Districts in the Auckland region. (Source: ARC).

TABLE 1 Regional and district assessment of native forest fragmentation. (Source: Modified from Ewers 2006).

Area	District (hectares)	Forest fragments (hectares)	Average edge fragment area (hectares)	Proportion of edge habitat (km per km^2)
New Zealand	**26,426,398**	**57,231**	**110**	**0.81**
North Island	11,401890	41,927	61	0.93
Auckland Region	**591,161**	**4552**	**18**	**1.30**
Auckland City	15,794*	78	5*	0.57
Franklin District	219,205**	1423	18	0.95
Manukau City	55,581	443	42	1.25
North Shore City	13,044	136	9	2.08
Papakura District	11,972	69	14	1.03
Rodney District	238,154	2270	9	1.49
Waitakere City	37,411	133	114	1.59

*Hauraki Gulf Islands are excluded from the analyses.
** Includes portion of Franklin district outside the Auckland region.

Indicator 3: Habitat condition

Over 200 HCV sites were assessed between 2004 and 2009 using the Forest Monitoring and Assessment Kit (FORMAK) method, which uses a four point scale to score sites according to 12 measures of forest condition. These measures were summed to provide an overall condition score ranging from 12 (lowest) to 48 (highest).

Each site was subjectively assigned to a forest condition category based on its score:

- → very poor (less than 31)
- → poor (31 to 36)
- → good (37 to 42)
- → very good (43 to 48).

A number of site characteristics such as the size of the HCV, the dominant surrounding land use type (agricultural, residential, forest reserve or exotic forest) and pest management history were also recorded, based on existing databases or conversations with landowners or land managers.

Figure 2 shows that just over half of the HCV sites were in very good (13 per cent) or good (43 per cent) condition, with the remainder in very poor (10 per cent) or poor (34 per cent) condition. In addition, two sites had been completely cleared.

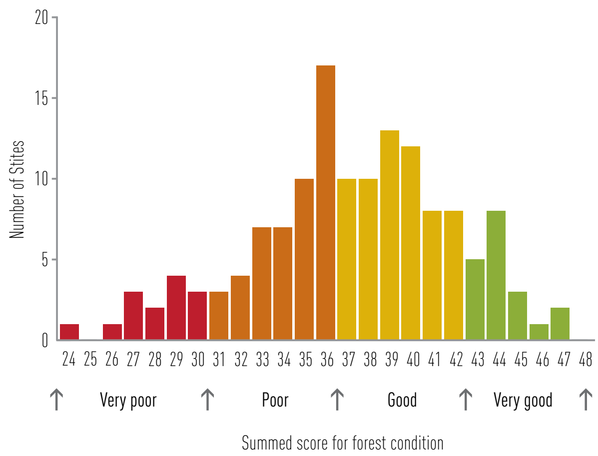

FIGURE 2 Summed scores for forest condition for HCV sites in the Auckland region, 2004-09. (Source: ARC)

There was also considerable variability in the scores for each of the 12 measures of forest condition (Figure 3). Most notably, a relatively large proportion of sites suffered from weed infestations at the forest edge, poor regeneration of native plants and understorey browsing by mammals.

More positively, weed infestation of forest interiors and browsing of forest canopies by possums were not shown as major issues, the latter presumably reflects the scale and effectiveness of possum control operations across the Auckland region. Although ungulates (pigs, goats, deer and livestock) were not as widely distributed as possums, they were generally abundant wherever they were found and, therefore, had a significant impact in these locations, as shown by the levels of browsing damage and lack of understorey regeneration.

Terrestrial biodiversity

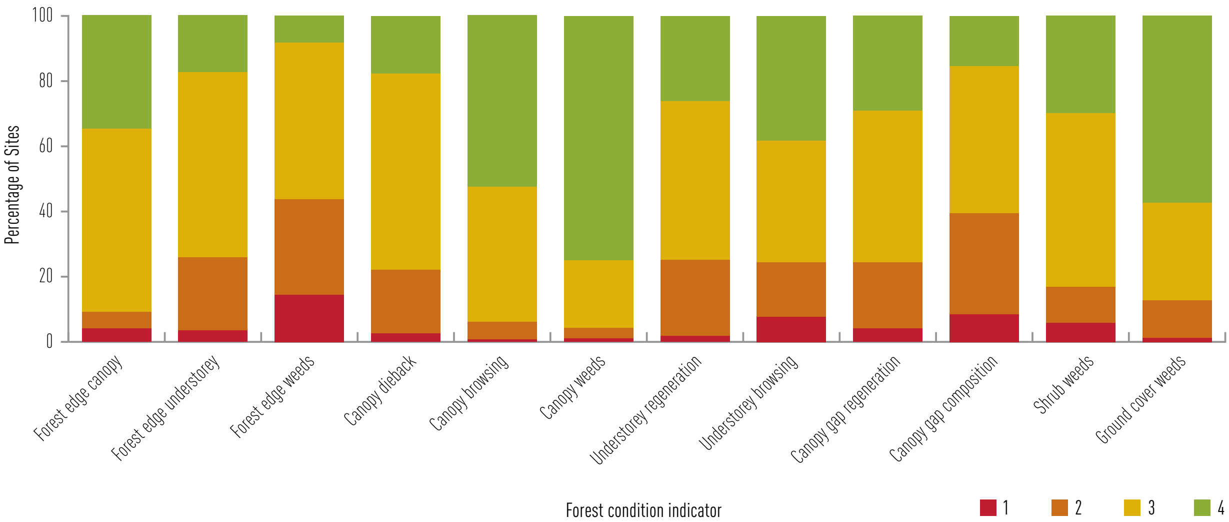

FIGURE 3 Relative percentages of scores (1 = lowest, 4 = highest) for each of the 12 forest condition measures used to assess the overall condition of HCV sites. (Source: ARC).

The type of land use around the HCV sites influenced the forest condition (Figure 4). Sites next to exotic forestry typically had problems with both weeds and pest mammals. These sites were generally unmanaged.

Sites next to farmland had relatively few weeds but were affected by browsing mammals, including livestock. Only 31 per cent of the HCV sites next to farmland had effective fencing.

Sites in residential areas tended to have substantial weed invasions. The increased occurrence of weeds at these sites was a direct result of their proximity to gardens or unmanaged open areas.

Sites surrounded by reserves were generally in the best condition, with relatively low levels of weed infestations and little sign of ungulate damage. Despite this, signs of feral pigs were most commonly encountered in reserve areas. Unlike other ungulates, pigs can directly affect native fauna through predation, and these impacts can be significant.

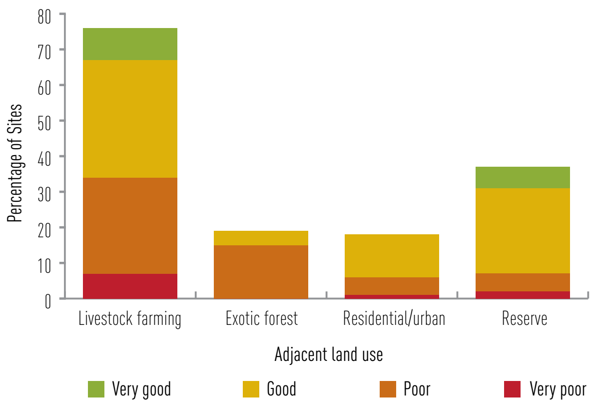

FIGURE 4 Percentages of HCV sites in each forest condition category in relation to adjacent land use type. (Source: ARC)

In general, the amount of habitat loss and the associated impact on terrestrial biodiversity in some ecological districts within the Auckland region has been extreme. This indicates the importance of retaining native land cover, the continued (or increased) need for weed and animal pest control, and ongoing support for private land owners and community groups who want to maintain or restore native habitats.

Threatened species

The Department of Conservation (DoC) has recently re-classified native plants and birds into categories which describe how vulnerable they are to extinction. Three broad threat categories are sub-divided into a further seven categories. In descending order of threat, these are:

→ threatened (nationally critical, nationally endangered)

→ nationally vulnerable

→ at risk (declining, recovering, relict, naturally uncommon).

Reptiles, amphibians and bats have not yet been re-classified, so the vulnerability of threatened species is described using the previous classification system.

Indicator 4: Number of threatened species

Of the native terrestrial fauna found in the Auckland region, 48 per cent of the birds, 71 per cent of the reptiles and both native mammals (bats) are nationally threatened.

The region contains 49 (20 per cent) of New Zealand's threatened terrestrial vertebrate fauna and is a stronghold for a number of nationally threatened species such as the pateke, banded rail, New Zealand dotterel, Auckland green gecko, Hochstetter's frog and Northern New Zealand dotterel. It also contains several species that are found only in the Auckland region such as the Great Barrier Island kanuka, chevron skink, black petrel and possibly the recently discovered New Zealand storm petrel. These species are, therefore, endemic to the region. At least 80 native plants are known to have their northern or southern distribution limit in the

TABLE 2 Threatened terrestrial vertebrates in the Auckland region. (Source: DoC).

Taxa	Scientific name	Threat classification
Bats		
Northern short-tailed bat	*Mystacina tuberculata aupourica*	Nationally endangered
North Island long-tailed bat	*Chalinolobus tuberculata (N.I)*	Nationally vulnerable
Birds		
New Zealand storm petrel	*Oceanites maorianus*	Data deficient
white heron (kotuku)	*Egretta alba modesta*	Nationally critical
takahe*	*Porphyrio mantelli*	Nationally critical
grey duck (parera)	*Anas superciliosa superciliosa*	Nationally critical
fairy tern (tara-iti)	*Sterna nereis davisae*	Nationally critical
Australasian bittern (matuku)	*Botaurus poiciloptilus*	Nationally endangered
North Island weka	*Gallirallus australis greyi*	Nationally endangered
black-billed gull (tarapunga)	*Larus bulleri*	Nationally endangered
North Island kaka	*Nestor meridionalis septentrionalis*	Nationally endangered
stitchbird (hihi)	*Notiomystis cincta*	Nationally endangered
North Island brown kiwi*	*Apteryx mantelli*	Nationally vulnerable
New Zealand dabchick (weweia)	*Poliocephalus rufopectus*	Nationally vulnerable
black petrel (taiko)	*Procellaria parkinsoni*	Nationally vulnerable
pied shag (karuhiruhi)	*Phalacrocorax varius*	Nationally vulnerable
reef heron (matuku moana)	*Egretta sacra sacra*	Nationally vulnerable
Northern New Zealand dotterel (tuturi whatu)	*Charadrius obscurus aquilonius*	Nationally vulnerable
banded dotterel (tuturi whatu)	*Charadrius bicinctus bicinctus*	Nationally vulnerable
wrybill (ngutu-pare)	*Anarhynchus frontalis*	Nationally vulnerable
red-billed gull (tarapunga)	*Larus novaehollandiae scopulinus*	Nationally vulnerable
Caspian tern (taranui)	*Sterna caspia*	Nationally vulnerable
North Island kokako	*Callaeas cinerea wilsoni*	Nationally vulnerable
northern little blue penguin (korora)	*Eudyptula minor iredalei*	Declining
flesh-footed shearwater (taonui)	*Puffinus carneipes*	Declining
sooty shearwater (titi)	*Puffinus griseus*	Declining
white-fronted tern (tara)	*Sterna striata striata*	Declining
pied oystercatcher (torea)	*Haematopus finschi*	Declining
pied stilt (poaka)	*Himantopus himantopus leucocephalus*	Declining
North Island rifleman (titipounamu)	*Acanthisitta chloris granti*	Declining

* denotes species that have been reintroduced to the region.

Contd...

Terrestrial biodiversity

TABLE 2 continued Threatened terrestrial vertebrates in the Auckland region. (Source: DoC).

Taxa	Scientific name	Threat classification
New Zealand pipit (pihoihoi)	*Anthus novaeseelandiae novaeseelandiae*	Declining
North Island fernbird (matata)	*Bowdleria punctata vealeae*	Declining
black shag (kawau)	*Phalacrocorax carbo novaehollandiae*	Naturally uncommon
little shag (kawau-paka)	*Phalacrocorax melanoleucos brevirostris*	Naturally uncommon
little black shag (kawau-tui)	*Phalacrocorax sulcirostris*	Naturally uncommon
royal spoonbill (kotuku-ngutupapa)	*Platalea regia*	Naturally uncommon
banded rail (moho-pereru)	*Gallirallus philippensis assimilis*	Naturally uncommon
long-tailed cuckoo (koekoea)	*Eudynamys taitensis*	Naturally uncommon
fluttering sheawater (pakaha)	*Puffinus gavia*	Relict distribution
Cook's petrel (titi)	*Pterodroma cookii*	Relict distribution
spotless crake (puwheto)	*Porzana tabuensis plumbea*	Relict distribution
marsh crake (koitareke)	*Porzana pusilla affinis*	Relict distribution
red-crowned parakeet (kakariki)	*Cyanoramphus novaezelandiae novaezelandiae*	Relict distribution
little spotted kiwi*	*Apteryx owenii*	Recovering
brown teal (pateke)	*Anas chlorotis "North Island"*	Recovering
variable oystercatcher (toreapango)	*Haematopus unicolor*	Recovering
North Island saddleback (tieke)*	*Philesturnus carunculatus rufusater*	Recovering
Reptiles		
chevron skink	*Oligosoma homalonotum*	Nationally endangered
Pacific gecko	*Hoplodactylus pacificus*	Declining
Auckland green gecko	*Naultinus elegans elegans*	Declining
ornate skink	*Cyclodina ornata*	Declining
Duvaucel's gecko	*Hoplodactylus duvaucelii*	Sparse
moko skink	*Oligosoma moco*	Sparse
Northern tuatara	*Sphenodon punctatus punctatus*	Sparse
egg-laying skink	*Oligosoma suteri*	Range restricted
Towns' skink	*Cyclodina oliveri townsi*	Range restricted
Amphibians		
Hochstetter's frog	*Leiopelma hochstetteri*	Sparse

* denotes species that have been reintroduced to the region.

Auckland region. The region also has:

- 35 plant species that are now considered to be extinct
- 169 species of plants that are nationally threatened (19 per cent of the national total). This is the fourth highest number of plants for any regional area in New Zealand, despite Auckland being one of the smallest regions
- 326 plant species that are regionally threatened (43 per cent of the total number of plant species in the Auckland region)
- seven endemic plants
- an unknown number of invertebrates.

Terrestrial biodiversity

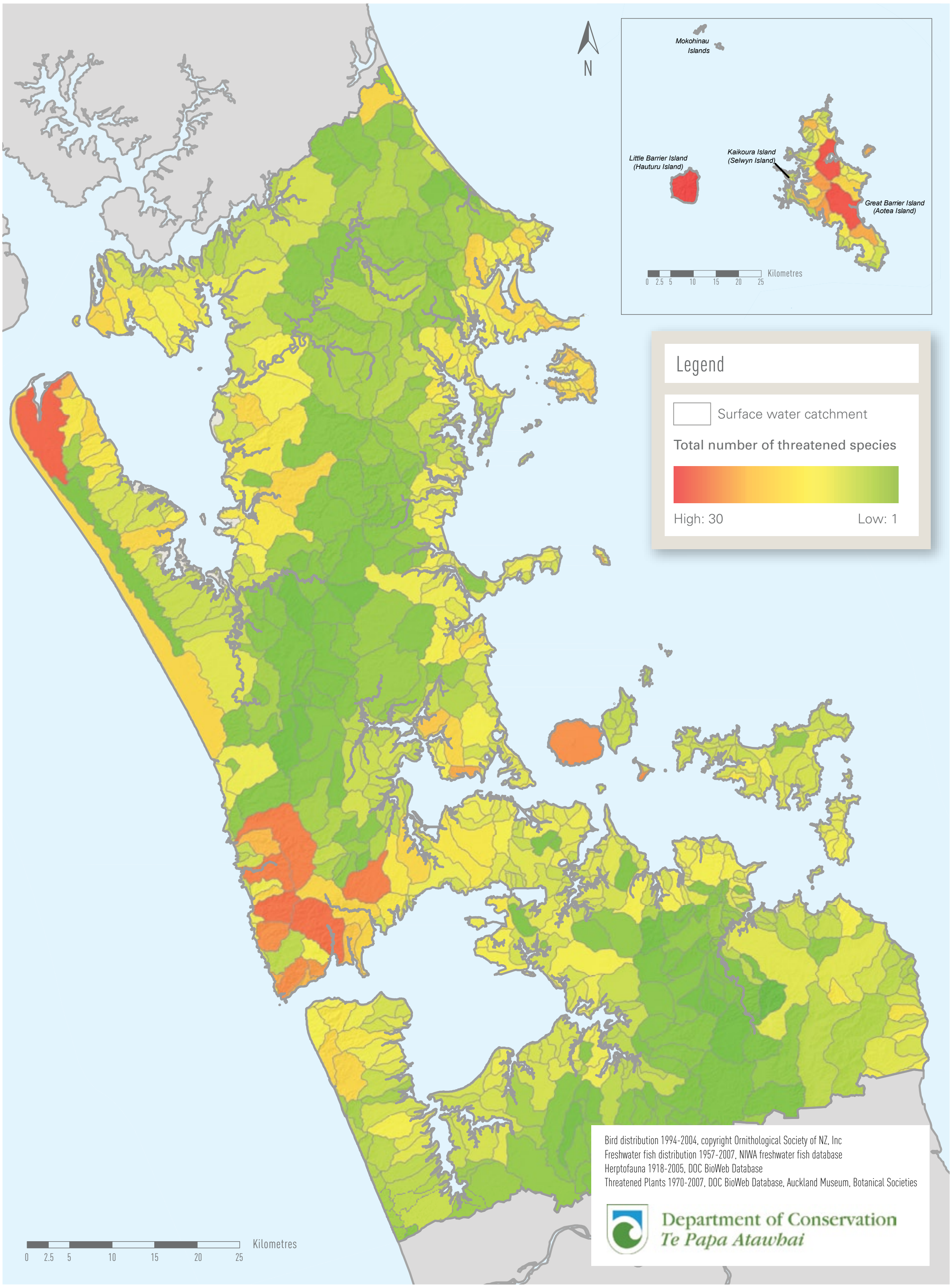

FIGURE 5 Distribution of selected and threatened species in the Auckland region. (Source: DoC).

Terrestrial biodiversity

Indicator 5: Spatial distribution of threatened species

The distribution of threatened birds, reptiles, amphibians, fish and plant species varies considerably across the Auckland region.

Many threatened species in the region now survive only on some offshore islands in the Hauraki Gulf. Such islands are relatively pristine and free of all or some introduced mammalian predators and competitors and invasive plant species. Islands which harbour significant numbers of threatened species include: Great Barrier Island, Little Barrier Island, Tiritiri Matangi, Motuora and Motuihe Islands.

High numbers of threatened species also occur in the Waitakere and Hunua Ranges and South Kaipara Head (Figure 5). The Kaipara and Manukau harbours contain enormous areas of mudflats and sandflats that are of international significance as feeding grounds for thousands of migratory and locally breeding shorebirds including the nationally vulnerable New Zealand dotterel and the wrybill plover.

The large number of threatened species in the Waitakere and Hunua Ranges reflect the quality and extent of intact native forest, wetlands and dunelands.

Indicator 6: Distribution of threatened species by ecosystem type

Some ecosystem types have more threatened species than others (Figure 6). For example, many threatened plants are low-growing species that are amongst the first to colonise a particular type of habitat. These species include the shrubs, herbs and grasses that are commonly associated with shrublands, volcanic substrates, wetlands, dunelands and riparian sites areas.

Some of the region's threatened fauna are also associated with these ecosystem types, particularly wetlands and dunelands. Others such as the Chevron skink, kaka and kokako mainly occur in mature native forest.

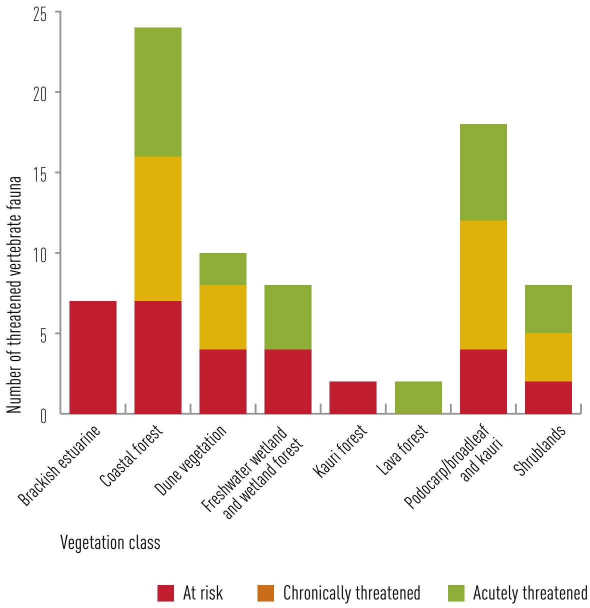

FIGURE 6 Number of threatened vertebrate fauna in the Auckland region, by threat category and ecosystem type. (Source: DoC).

Terrestrial biodiversity

Terrestrial pests

An exotic species is any non-native organism that has been introduced to a new location by human action or by natural means. Not all of these introduced species threaten the native biodiversity. About 10 per cent of any accidentally or deliberately introduced species will appear in the wild, 10 per cent of those will become established and 10 per cent of those will become invasive.

Species become 'invasive' when they spread rapidly and have an adverse impact on their new environment. Invasive species pose an ongoing threat to native terrestrial biodiversity because they may compete with, or consume, native plants and animals.

The Auckland region is a major international gateway. Ships, aircraft and their cargoes present potential biosecurity risks as they provide a potential mechanism for the accidental introduction of unwanted species. Several examples of deliberate introductions of exotic species to the Auckland are also known, e.g. most exotic plants were introduced as ornamental garden plants and possums were introduced for the fur trade.

Invasive animals, plants and other organisms such as pathogens have played a major role in the decline of native biodiversity. The effects of pest mammals, for example, have been as profound in the decline of native birds, reptiles, amphibians and invertebrates as the loss of habitat.

Mammalian pests

Native vegetation has been significantly altered by introduced mammalian herbivores and omnivores, which have radically changed the structure and composition of native forest ecosystems. In particular, possums cause extensive and catastrophic forest canopy collapse while deer and goats browse the understorey and, together with rodents, inhibit forest regeneration.

Mammalian predators have also had an adverse impact on native biodiversity. Rats and mice, in particular, are responsible for many extinctions and ecosystem changes as their generalist feeding habits mean that they eat plants, invertebrates, reptiles, mammals and birds. Possums, cats, mustelids (weasels, stoats and ferrets) and dogs also threaten native biodiversity. For example, feral cats eradicated the saddleback from Little Barrier Island and threatened colonies of black and Cook's petrels.

Predatory mammals can also have an indirect adverse impact on ecological processes through predation of native species. Some avian seed dispersers such as moa are now extinct, while others such as the hihi and saddleback are now confined to predator-free offshore islands. Kokako and weka have severely restricted mainland distributions. The New Zealand pigeon (kereru) is widespread but reduced in numbers and the bellbird and whitehead are absent from most parts of Auckland. Consequently, the distribution of some plant species that rely on birds for pollination are limited. Species with large fruits (more than 1.4 cm diameter) such as tawa and taraire, now depend solely on the kereru for dispersal.

Invertebrate pests

Some introduced invertebrates can have adverse impacts on terrestrial ecosystems. Many social insects such as ants, wasps, bees and termites fit into this category because they can feed on a variety of foods and their reproductive and dispersal characteristics make them very effective invaders.

It is estimated that about 2200 species of introduced invertebrates are now established New Zealand, with the majority established in Auckland.

Two species of introduced *Vespulia* wasp are established in the Auckland region. Wasps can reach very high numbers and prey on some native invertebrate species. Wasps have been recorded attacking and killing reptiles and nesting birds, although the level of threat from wasp predation is not known. Wasps may also compete with native reptiles, birds and bats.

Wasps and other invertebrate predators are highly sensitive to climate. Wet winters reduce populations while warm dry conditions are ideal for explosive population growth. This warrants concern in view of projected climate changes for the Auckland region.

Plant pests

Terrestrial pest plants are invasive exotic plant species that invade natural ecosystems and cause major modifications to native biodiversity and ecosystem functions.

Pest plant species can have major effects on ecosystem processes by altering structure, function and biodiversity. In the Auckland region, wild ginger invades native forest and shrublands fragments altering the forest structure by decreasing the number and variety of native seedlings and improving the relative survival rate of species with larger seeds, such as kohekohe. Moreover pest plants have been implicated in the decline of numerous threatened species due to competition. For example, kikuyu and marram grasses have contributed to the decline of shore spurge (*Euphorpia glaua*) which has disappeared from the Auckland mainland.

The Auckland region has 750 native vascular plant species, 642 exotic naturalised plant species and thousands of exotic plant species used in horticulture. In 2004, about 10 per cent of the naturalised exotic plant species were recognised as pest plants by DoC. Three-quarters of these were originally introduced legitimately for ornamental use. Only 14 per cent were introduced for agriculture, horticulture or forestry and only 10 per cent naturalised through unintentional release. Consequently, there is a huge pool of potential pest plant species already in the country. A number of exotic naturalised species are likely to be 'sleeper pest plant species'. These arrive in an area, then naturalise and remain localised for some time before they suddenly increase and become classified as a pest plant species.

4.5

Terrestrial biodiversity

Conclusions on the state of terrestrial biodiversity

Terrestrial biodiversity in the Auckland region is under threat from various environmental factors. These include habitat alteration as a result of the loss and fragmentation of native land cover, and the adverse impacts of introduced species, grazing, overharvesting and pollution.

Of these factors, habitat alteration and introduced species are considered to be the main threats. Overharvesting and various types of pollution, however, can be the dominant threat on a local scale, or for a particular type of ecosystem. It is often difficult to attribute declines in terrestrial biodiversity to specific threats and it is also increasingly clear that the adverse impact from one threat can be exacerbated by the effects of other threats acting together (e.g. habitat fragmentation combined with invasive species).

As with other lowland areas of New Zealand, the Auckland region has lost a large proportion of the biodiversity of its terrestrial ecosystems. This loss has been disproportionately large with only 27 per cent of our native land cover remaining. Some ecosystems have less than 10 per cent of their original extent or have been lost altogether.

The Auckland region has 326 plants that are classified as nationally or regionally threatened, including 35 now considered regionally extinct and seven that are only found in the Auckland region. It also contains 49 threatened vertebrate fauna, and several of these are found only in the Auckland region.

The Auckland region is a hotspot for threatened ecosystems and species and the future of these ecosystems and species is heavily dependent on effective biodiversity management. While biodiversity decline in the Auckland region has been dramatic, there are still large and ecologically significant ecosystems and habitats such as the Kaipara and Manukau harbours, Waitakere and Hunua Ranges, as well as a number of nationally important offshore islands that lack some (or all) mammalian pests.

Case Study: Loss of wetlands in the Auckland region

Wetlands – permanently or temporarily wet areas – are possibly our most valuable freshwater and terrestrial ecosystem. They provide a variety of essential services such as biofiltration, flood control and carbon sequestration. The swamps, bogs, fens, salt marshes, and estuaries that make up the wetlands are also home to 22 per cent of our plant species and 30 per cent of our native fish.

New Zealand has one of the worst records for protecting wetlands, and more than 90 per cent have been destroyed; mostly drained for agriculture. Many of the remaining wetlands are degraded through changes to the water, pollution from nutrients and sedimentation, and invasive species. New Zealand's wetlands now contain a greater proportion of threatened native species than any other terrestrial ecosystem.

The region's record for wetland protection is worse than that for New Zealand as a whole, with remaining wetlands covering only 4 per cent of their original extent. Regionally it is estimated that almost one third of the nationally threatened plants in the Auckland region survive in wetlands, along with a number of threatened wetland birds (e.g. the New Zealand bittern), and fish (e.g. the black mudfish).

Notable remaining Auckland wetlands include:

- the Waitemata, Kaipara and Manukau harbours and their associated estuaries
- the Firth of Thames (internationally recognised wetland site)
- Kaitoke swamp and Whangapoua estuary Great Barrier Island
- Te Matuku, Rocky Bay and Awaawaroa wetlands on Waiheke Island
- Te Henga wetland, Waitakere
- the dune lakes at Kaipara (South Head), Pakiri and Awhitu peninsula
- freshwater and saline wetlands in association with dune systems at Kaipara and Whatipu
- urban wetland remnants at Western Springs
- Omaha kahikatea swamp forest.

The Wetlands of Representative and Ecological Importance (WERI) database was used to assess recent wetland losses. Wetlands in this database were identified in the 1980s and while the database only includes ecologically significant wetlands of more than 1 ha, it serves as a means to measure change. We compared aerial photographs taken in 2006/07 with those taken in the 1980s to discover which WERI sites were still present, and to measure any changes in their size and shape.

Despite limitations related to dataset accuracy, at least 94 per cent of the WERI sites appeared to be unchanged in terms of spatial extent. Ten wetlands could not be assessed because the relevant area was not covered by the WERI aerial photographs. Two wetlands (1 per cent) appeared to have been completely or substantially drained and cleared.

These findings suggest that the continued loss of larger wetlands (over 1 ha) within the Auckland region is relatively minor. However, the number of smaller wetlands (less than 1 ha) that have been lost was not assessed and anecdotal evidence suggests that these wetlands are the most vulnerable and continue to be lost. In rural areas many of these smaller wetlands are impacted by grazing.

Many of these smaller wetlands are only temporarily inundated with surface water (i.e. seasonal or ephemeral wetlands). Plant and invertebrate communities are therefore specifically adapted to these conditions and can be quite distinct from wetland communities found in larger permanent wetlands. For example, many aquatic invertebrates in temporary wetlands do not occur in permanent wetlands due to the presence of predatory fish.

Crucially, this study did not assess wetland quality or condition, and although there appears to have been little change in area for most of the WERI sites, their condition may have changed. Regional wetlands continue to be impacted by drainage, grazing, nutrients and pollution, and by invasive species. For example, Te Henga wetland has been impacted by the spread of grey and crack willow and a control programme is in place.

In 2007, in recognition of their value and current lack of protection, DoC and MfE declared the protection of biodiversity on wetlands (and dunelands) on private land to be a national priority. Only 38 per cent of the remaining 4 per cent of remaining regional wetlands are protected, so legal protection through land acquisitions and covenanting, as well as ecological restoration initiatives are considered paramount.

On a positive note, several wetlands have been substantially restored. The former oxidation ponds at the Mangere Wastewater Treatment Plant have been decommissioned and returned to harbour, the Tawharanui wetlands (in a pest-free area on the peninsula), and those in the Awhitu Regional Park have been greatly expanded, the Waiataura wetland in Auckland City has been restored and the Te Henga wetland is subject to a willow control programme. The trend to restore the region's wetlands looks set to continue through efforts from a variety of organisations and conservation groups.

Photo: Wetlands at Whatipu on Auckland's west coast. (Source: ARC).

Terrestrial biodiversity

Case Study: Vegetation clearance on the North Shore

North Shore City contains a large proportion of urban Auckland's remaining native terrestrial habitats. These include ecologically significant remnants of kauri forest, broadleaved/podocarp forest, coastal forest, lava forest, shrubland, and wetlands.

The ARC and North Shore City Council have classified a number of these habitats as Significant Natural Areas (SNAs) with three levels of significance: Level 1 (high priority habitats); Level 2 (younger and more common habitat types), and Level 3 (ecological linkage areas). Level 3 areas tend to be impacted more by exotic species such as pines or wattles, but still provide important habitats and movement corridors for indigenous flora and fauna. Some significant habitats will not be included in the current SNA network because they have not been formally assessed.

To determine the extent of recent habitat loss and fragmentation in North Shore City's SNAs, the ARC compared aerial photographs taken in 2001 and 2006. All habitat loss, both consented and non-consented, was measured and mapped. The reason for the loss was also identified.

In 2001 indigenous habitat classified as SNAs totalled approximately 2,234 hectares. By 2006, this had been reduced to 2,152 hectares, indicating that 59 hectares (about 3 per cent) of classified ecologically significant habitat were cleared between 2001 and 2006. It is also likely that unclassified ecologically significant habitats have been lost, though this is not been measured.

Most of the vegetation was cleared from the Level 3 ecological linkage areas rather than from the priority vegetation sites or Level 2 areas (Table 1). Nevertheless, it is alarming that between 2001 and 2006, more than 12 per cent of the North Shore's ecological linkage areas were cleared (Table 1).

TABLE 1 Amount of vegetation cleared in each of the three categories of significance.

Significance level	Vegetation cleared	Total area in each significance level	% of significance level cleared
Priority vegetation sites	8.8 ha	1,202 ha	0.7
Level 2 significance	11.1 ha	714 ha	1.6
Ecological linkage areas	39.0 ha	319 ha	12.2

Cleared areas tended to include pines in the canopy or vegetation types that were dominated by manuka or kanuka. The least impacted were wetland habitats (saline and freshwater) (Table 2).

TABLE 2 Type of vegetation cleared within designated Significant Natural Area (SNA) sites.

Vegetation classes	Hectares cleared	Area of vegetation class in city	% of vegetation class cleared
Vegetation with some pines	37.8 ha	345 ha	11.0
Manuka-kanuka dominated vegetation	12.6 ha	487 ha	2.6
Bush with some kanuka-manuka	1.5 ha	156 ha	1.0
Mature forest types	6.0 ha	818 ha	0.7
Wetlands	1.0 ha	427 ha	0.4

Terrestrial biodiversity

The main reasons for vegetation clearance were subdivisions, new roads, and the incremental expansion of residential grounds (Table 3).

TABLE 3 Purpose of vegetation clearance and contribution of each to the overall amount of clearance from 2001 to 2006.

Purpose of clearance	Hectares cleared	% of 2001 vegetation	Percentage of total clearance
Total clearance	37.8 ha	345 ha	11.0
New subdivisions	35.6 ha	1.59	60.5
New roads	18.3 ha	0.82	31.1
Residential expansion on existing property	6.8 ha	0.30	11.5
Agricultural expansion	3.9 ha	0.18	6.7
Expansion of recreational reserves	0.6 ha	0.03	1.1
Other	0.4 ha	0.02	0.7

As well as a reduction in the total amount of habitat, native habitats in North Shore City have been increasingly broken up into smaller pieces. In several instances, habitat loss has divided a single larger fragment into two or more smaller fragments. In 2001, a total of 309 habitat fragments were identified as being significant. By 2006, many of these had been cut into smaller fragments, resulting in 349 habitat fragments. Correspondingly, the average size of each habitat fragment had fallen from 7.23 ha to 6.23 ha.

At least 50 metres of the outer edge of native habitat experience what is termed as 'edge effects' and native habitat here is exposed to altered conditions such as increased light, wind, and temperature fluctuations, and reduced moisture levels. Many species of weeds prefer these conditions, but some indigenous species that prefer shady and damp environments are unable to persist. On the North Shore, as the size of habitat fragments has shrunk, the ratio of edge to interior habitat and the total amount of edge habitat have increased between 2001 and 2006 (Table 4), and this is likely to have had an overall negative impact on native biodiversity.

TABLE 4 Changes in the number of habitat fragments and proportion and amount of edge within North Shore City from 2001 to 2006.

	2001	2006
Fragment Number	309	349
Total edge (habitat within 50m)	524km	538km
Mean area	7.23 ha	6.23 ha
Mean ratio perimeter to area	0.078	0.090

Terrestrial biodiversity

References and further reading

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Terrestrial biodiversity

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Responses

Introduction

Managing the diverse range of land, freshwater and marine environments that are found in the Auckland region and protecting the air quality and native biodiversity is a complex task, especially when this environmental perspective has to be balanced against the environmental pressures generated by the needs of a growing population and the agricultural, industrial and commercial activities that underpin the economy.

The strategic response discussed in Part 2 is important in setting the general direction for long-term positive change. However, on a day-to-day basis the ARC has to manage all manner of immediate risks and, in that respect, a crucial part of our response is the suite of regional plans that have been prepared under the Resource Management Act (RMA). These regional plans provide the basis to control and work alongside various activities in order to get the best possible outcomes for the Auckland region. However, regulation through these regional plans is not the only way that the ARC responds. The ARC also deploys a wide range of other responses to environmental issues including advocacy, incentives and community education.

The responses discussed in this chapter focus around our regional plans and the rules and non-regulatory methods the ARC uses to respond to the actual and potential impacts on our land, water, air, coast and biodiversity on a day-to-day basis.

Many of the responses address more than one of the risks and impacts discussed in the previous chapters. When the ARC can achieve multiple benefits from what it does, it contributes to an effective and efficient integrated management approach. One of the major objectives is to promote and deliver integrated management in order to make positive change across the Auckland region.

Developing targets for reducing PM_{10} emissions

The concentrations of PM_{10} particulates in the Auckland region are known to exceed the National Environmental Standards for air quality, therefore the council has set policy objectives to reduce the 2005 levels of PM_{10} emissions by 53 per cent to ensure compliance with this standard by 2013.

In order to achieve this, the ARC has set net reduction targets for each of the following sectors in the Auckland urban airshed:

- industrial sector – 0 per cent reduction,
- domestic sector – 58 per cent reduction,
- vehicle (transport) sector – 58 per cent reduction.

Our ARC's primary statutory response to air quality is contained in the Proposed Auckland Regional Plan: Air, Land and Water. This sets out the objectives, policies and rules that apply to discharges to air within the Auckland region. It does not contain the PM_{10} emissions reduction targets defined above because the need for specific sector reductions was not apparent when the proposed plan was developed.

While the rules and associated resource consent requirements in the proposed plan continue to play an important role in managing discharges to air (particularly those from the industrial sector), some sources of PM_{10} emissions and other pollutants cannot – or cannot easily – be controlled under the RMA. Consequently, a range of responses and management policies are required and these are discussed in the following sections.

It is important to note that, although the primary aim is to reduce PM_{10} emissions, reductions in the levels of $PM_{2.5}$ particulates and NO_2 are also needed to meet national and international guidelines. These can also be achieved by reducing emissions from the transport (vehicle) and domestic sectors. Levels of other air pollutants that originate from these sectors are also expected to be reduced.

Reducing vehicle emissions

To achieve the desired 58 per cent reduction in vehicle emissions within the Auckland region by 2013 the ARC needs to influence:

- traffic and demand management
- fuel quality and content
- vehicle technology
- vehicle maintenance.

Traffic and demand management

Traffic and demand management is achieved largely through strategic responses such as integrating land use and transport through the Auckland Regional Growth Strategy (ARGS), the Regional Land Transport Strategy (RLTS) and various sub-strategies such as those detailed in Box 1, and also through the provision and co-ordination of public transport (see Transport planning and public transport delivery in Part 3). However, the ARC realises that the bulk of reduced emissions will have to be achieved through more direct interventions.

Fuel quality, vehicle technology and maintenance

Fuel quality, vehicle technology and vehicle maintenance are difficult for the ARC to address because they are controlled by regulation at national level. Nevertheless, the ARC has taken a strong advocacy position on these issues and has liaised closely with central government agencies to help bring about a number of changes. These include:

Clean Fuels[1]

- Lead was banned in petrol in 1996 enabling catalytic converter technology to be used.
- Sulphur was progressively reduced in diesel (from 3000 ppm in 2002 to 50 ppm in January 2006) allowing Euro IV[2] diesel technology. By 1 January 2009 the sulphur content was reduced to a maximum of 10 ppm ('zero sulphur diesel') in New Zealand. This is a significant fuel improvement milestone as it allows Euro V diesel technology to be safely imported and operated in New Zealand, and will reduce fine particulate emissions from new diesel vehicles to equal that from new petrol vehicles.
- Benzene in petrol was progressively reduced to 1 per cent by 2006.

Responses

Box 1 Freight strategy and the management of arterial corridors

In addition to the land use and transport strategies and plans discussed in Part 3, the ARC has prepared an Auckland Regional Freight Strategy (2006) and a Draft Regional Arterial Road Plan (2008).

The Auckland Regional Freight Strategy acknowledges the need for better integration of freight and land use planning, and the potential for future population growth and increasing infill of the urban area. It recognises that these will impose environmental pressures and result in increasing conflict between residential and business activities. Consequently, it contains a range of objectives including a goal of improving, protecting and promoting public health and ensuring environmental sustainability. A number of specific policies and actions are proposed in response to these objectives including:

- reducing the environmental impacts of freight routes and traffic, and reducing the impact of freight on adjacent land use by designation of a strategic freight network and development of Local Area Freight Management Plans,
- encouraging low emission freight vehicles and clean fuels through advocacy for enhanced central government regulation and the possible use of incentives such as parking/loading concessions for low emission vehicles.

The Draft Regional Arterial Road Plan defines the role and function of the arterial road network, provides for the integrated management of the arterial network and surrounding land use, and provides a basis for project prioritisation and development of a rationale for more appropriate funding for arterial roads in the Auckland region.

It sets out a range of objectives, and strategic and operational policies to guide the management of the arterial road network. It stresses the importance of arterial roads and the need to recognise them in district plans, and the need to make the most efficient use of road space (including giving priority to bus lanes and the needs of cyclists and pedestrians) as well as supporting land use intensification that is consistent with the ARGS. A range of specific actions are proposed for implementation of the Draft Regional Arterial Road Plan including the preparation of Corridor Management Plans.

Since the mid-1990s, when New Zealand lagged behind the rest of the developed world in terms of fuel and emissions standards, the gap between New Zealand and the rest of the world has shrunk considerably. Levels of sulphur in diesel and benzene in petrol have fallen dramatically since 2002 (Figure 1).

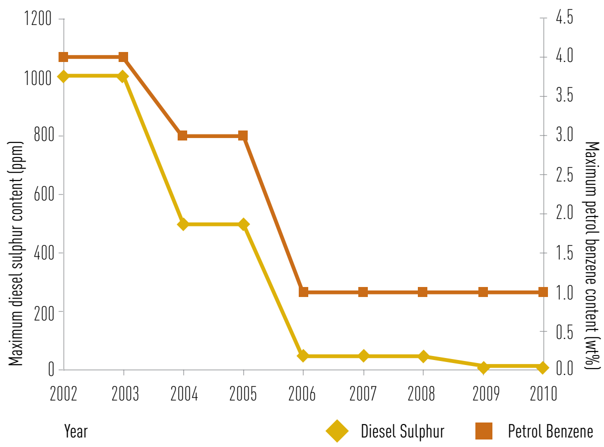

FIGURE 1 Changes in fuel specifications regulations for New Zealand petrol and diesel. (Source: Ministry of Economic Development).

Clean vehicle technology[3]

In 2004 the Land Transport Rule: Vehicle Exhaust Emissions was introduced. Both used and new vehicles are required to meet a schedule of progressively tighter emissions standards over time, with used vehicles generally one standard below the new requirement. From 1 January 2009 the emissions standards are:

- new diesel and petrol vehicles (light and heavy duty) to meet Euro IV or equivalent
- used diesel vehicles (light and heavy duty) to meet Euro IV or equivalent
- used petrol vehicles (light and heavy duty) to meet Euro III or equivalent.

In addition, used vehicles entering the New Zealand fleet must now undertake a metered emissions test to ensure they continue to meet the emission standard to which they were manufactured.

In 2008, a Land Transport New Zealand rule was introduced that banned the tampering or removal of emissions control technologies from vehicles.

1 Mostly initiatives taken by the Ministry of Economic Development (MED).

2 European or "Euro" emissions standards are defined by a series of European Union directives staging the progressive introduction of increasingly stringent vehicle emission standards. Currently, emissions of nitrogen oxide (NO), hydrocarbons (HC), carbon monoxide (CO) and particulates (PM) are regulated for most vehicle types, and different standards apply to each vehicle type. Compliance is determined by running the engine at a standardised test cycle.

3 Mostly initiatives undertaken by the former Ministry of Transport and Land Transport New Zealand.

Responses

Vehicle maintenance

The ARC ran the 0800 Smokey campaign in 2000 to raise community awareness of vehicle emissions and motivate action. The campaign allowed people to report smokey vehicles and the owners were sent vouchers to tune their vehicle.

In 2001, the ten second rule for excessive smoke was introduced, targeting on-road ‘gross emitting’ smokey vehicles (mainly diesels).

The ARC conducted the first on-road testing campaign in 2003 to highlight the fact that 10 per cent of vehicles produced up to 50 per cent of emissions. The ARC conducted another on-road testing campaign in 2005 with Transit New Zealand. This signalled to motorists their vehicle emissions and encouraged maintenance.

A 5 Second Visible Smoke check was introduced to the Warrant of Fitness requirements in 2006 to target in-service smokey vehicles (mainly diesels). The Ministry of Transport also ran a Choke the Smoke campaign in 2006 promoting the new visible smoke check, and the use of car-pooling and public transport.

Although the ARC was not involved in all of these initiatives we encouraged them through strong advocacy. In 2006 the ARC, the Ministry of Transport and other central government agencies established a Joint Air Quality Task Force. This has been a useful mechanism for extending and enhancing similar initiatives.

Minimum emissions standards for buses on ARTA-funded services

The ARC and the Auckland Regional Transport Authority (ARTA) worked together to set minimum emissions standards for bus service contracts in the Auckland region. This means that any bus services operating under contract to ARTA have to ensure that their vehicles meet these minimum emissions standards.

National minimum standard for urban buses

The ARC recently made a submission on the proposed National Minimum Standard for Urban Buses that is being developed by the NZ Transport Agency (NZTA). The proposed standard would address a range of matters relating to the quality of urban buses, including compliance with vehicle emission rules.

The final version of this standard will form part of the Procurement Support Guide that is being developed by the NZTA. It will become a condition that must be met in order to receive NZTA funding for contracted public transport services.

Our submission was that buses less than five years old should have to meet the Euro III emission standard, while buses older than five years should have to meet Euro II emission standard and also be required to fit filters to capture the fine particulates created from diesel fuel combustion.

We also advocated for ‘in-service’ emission testing for buses in view of the fact that diesel vehicles in Auckland are estimated to be responsible for 73 per cent of the PM_{10} fine particulate emissions from motor vehicles, despite making up only 17 per cent of the vehicle fleet based on mileage. Half of these emissions can be attributed to buses and trucks.

Reducing vehicle emissions: is it working?

Levels of benzene, lead and SO_2 in the air have all decreased in recent years and there is a clear relationship with the removal of those pollutants from motor vehicle fuels. This shows that changes in the national regulations governing fuel specifications have been very effective. Although these changes were not (and could not) be made directly by the ARC, it has been a strong advocate.

Levels of CO are decreasing, although this is related to improvements in vehicle technology and catalytic converters rather than to any policy that the ARC introduced.

The introduction of minimum emission standards has also resulted in a gradual reduction of fine particulates from vehicle emissions. However, these gains have been offset by the growth in vehicle numbers, the increasing number of kilometres driven (see Indicator 35 in Part 3) and the increasing age of the vehicle fleet over the past few years (Figure 2).

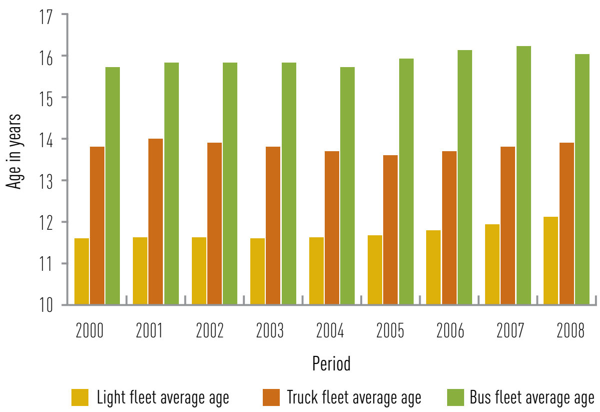

FIGURE 2 Average age of the national fleet, 2001-08. (Source: Ministry of Transport).

Reducing emissions from domestic fires

To achieve the desired 58 per cent reduction in emissions from domestic fires within the Auckland region by 2013, the ARC needs to adopt a range of measures to reduce emissions from domestic fires.

National regulation of wood burners

The NES for air quality (Box 1, Chapter 4.1, pg 98) impose an emission standard for wood burners of 1.5 grams of fine particulates for each kilogram of dry wood burnt and a thermal efficiency standard (measured as the ratio of usable heat energy output to energy input) of not less than 65 per cent.

The emission standard means that it is illegal to use any wood burner that was installed after 1 September 2005 (on a site less than two hectares) that does not comply with this standard. The RMA allows regional councils to impose more stringent rules in their regional plans but less stringent rules are over-ridden by the NES. However, this emission standard relates only to wood burners. Other types of domestic fires are not regulated, neither are wood burners that were installed before this date.

Controlling other types of domestic fires

The ARC Proposed Auckland Regional Plan: Air, Land and Water also regulates domestic fires and, in some respects, extends the scope of the regulations within the NES on air quality. The proposed plan bans any type of domestic solid fuel fire (not just wood burners) that was installed after 1 September 2005 in urban areas, unless it can achieve emissions of not more than 4 g/kg of fuel burned (for appliances without catalytic combustors) or 2.25 g/kg of fuel burned (for appliances with catalytic combustors).

Other regulations also apply to ensure best practice in the design, installation and use of these appliances. They are intended to prevent the installation of most types of pot-bellied stoves, coal ranges and open fireplaces in urban areas within the Auckland region.

Domestic heating appliances (including open fires) that were installed before 1 September 2005, and those in rural areas, are allowed to continue but need to ensure that their emissions do not pose an unacceptable risk to human health beyond the site boundary. To achieve this, the ARC promotes best practice including the use of dry, well-seasoned wood. The Proposed Auckland Regional Plan: Air, Land and Water also prohibits burning waste in domestic fires; this includes wood that is painted or tanalised, green waste, plastic, rubber, oils, solvents and similar materials.

Reducing emissions from domestic fires: is it working?

Although the NES and Proposed Auckland Regional Plan: Air, Land and Water can regulate the number and design quality of domestic heating appliances in use, they cannot easily control any other factors that also contribute to air pollutant emissions (such as the quality of the fuel and the way the appliance is operated). There are also difficulties associated with enforcement of the NES and with the actual performance of authorised domestic heating appliances.

Neither the NES or the Proposed Auckland Regional Plan: Air, Land and Water address the use of appliances installed before 1 September 2005: these pose a significant problem as they generally emit the highest levels of air pollutants.

Despite these challenges, research indicates that the use of solid fuels (wood and coal) in domestic fires is declining. Census data indicates that between 1996 and 2006 the number of homes burning wood in domestic fires decreased by approximately 16,000. Our home heating survey in 2007 found that only 29 per cent of households burn solid fuel, although 42 per cent could potentially do so as the properties were equipped with domestic heating appliances such as open fires and wood burners.

It is difficult to assess the effectiveness of our initiatives in contributing to this decline. Survey results indicate that environmental consciousness is not a major driver of change in home heating. Instead, the majority of people who burn wood appear to be influenced primarily by financial factors, with 52 per cent saying they burn wood because they have access to wood that is cheap or free. Only 8 per cent said they would change their domestic heating for environmental reasons, with about two thirds of those saying they would need a financial incentive as well. A further 35 per cent said they would not change under any circumstances.

Although solid fuel use has decreased it remains a significant source of air pollutant emissions, and the survey results indicate that our current strategies will not achieve the significant reductions required from domestic fires by 2013. The ARC is investigating additional ways to achieve the desired reductions in emissions from this source.

Controlling industrial emissions

All industrial emissions are controlled by rules in the Proposed Auckland Regional Plan: Air, Land and Water. These rules categorise emissions and require resource consents to be obtained when it is likely that the effects will extend beyond the site boundary.

The resource consent process provides an opportunity for the ARC to require use of the Best Practical Option (BPO) to avoid or minimise significant adverse effects arising from the discharge of pollutants to the air. Compliance with these practices is ensured by imposing conditions on the resource consents granted.

The proposed reduction target for PM_{10} particulates from industrial emissions is zero per cent. However, in order to allow new businesses within this sector to establish and operate, the ARC has set a provisional target of a 15 per cent reduction in discharges for all existing industrial emitters. This reduction from existing industrial emitters will allow new industrial emitters to operate while keeping all industrial emissions within the zero per cent overall cap.

This is being achieved through the resource consent process (discussed above) and by applying the policies of the Auckland Regional Policy Statement (ARPS) and the Proposed Auckland Regional Plan: Air, Land and Water that require industries to use the BPO and minimise emissions.

Controlling industrial emissions: is it working?

The resource consent process for industrial emissions is limiting the discharge of various hazardous and objectionable emissions to the air within the Auckland region.

The reduction target for PM_{10} particulates that needs o be met by existing emitters is in the early stages of implementation and is not yet reflected in ARC plans. At present it is too early to assess its success.

Responses

Reducing exposure risk to air pollution

Although the resource consent process is designed to minimise the effects of discharges to the air, it is seldom possible to contain all effects within a site boundary. Consequently, our approach to air quality management recognises the need for effective land use planning, in order to separate activities associated with discharges to air from sensitive activities (such as residential use and early childhood education centres). This separation protects both the health and amenity values of residents and the rights of industry to continue established activities. This concern for 'reverse sensitivity' is reflected in both the ARPS and the Proposed Auckland Regional Plan: Air, Land and Water.

Implementation of this approach relies largely on territorial authorities applying the policies sensibly, as part of their control of land use. The ARC is also trying to achieve this type of separation by participating in the inter-agency Air Quality Advisory Panel that was set up to investigate developing location criteria for early childhood education centres in Auckland. This panel will provide recommendations on the location of early childhood education centres in order to prevent exposure to air pollution. The results are likely be factored into our planning processes.

Reducing exposure risk: is it working?

There is little quantified data on the extent of incompatible land use although there is significant anecdotal evidence of some poor land use decisions which are likely to expose occupants to air pollution that could have been avoided by better planning.

We are monitoring this issue carefully, particularly in light of the urban growth strategy that emphasises intensification of residential development in nodes and along transport corridors (see Chapter 3, Box 7, Evaliation of the Auckland Regional Growth Strategy in Pressures, pg 80).

Controlling sediment from land disturbance

Although natural erosion processes can generate sediment and expose bare soil, human activities have disturbed the land through the removal of vegetation, cultivation, intensive grazing and earthworks. These types of land use activities can generate large amounts of sediment if not properly managed.

The adverse environmental impacts on the rivers and coastal areas in the Auckland region that are caused by elevated levels of sediment discharged from land development activities have long been recognised as a major issue (Chapter 4.2 pg 134 and 4.4 pg 188).

Controlling sediment from land disturbance can have flow on benefits for fresh water and marine ecosystems.

Box 2 Regulating sediment generation in the Auckland region

The Auckland Regional Authority (the ARC predecessor) first addressed the problem of sediment generation in 1979. Initially, a voluntary control system was developed in conjunction with the distribution of an Urban Earthworks Guideline to encourage land developers to undertake sediment control measures. However, this was only partially effective with a large number of sites, in our view, having inadequate sediment control measures.

In June 1988, the ARA introduced direct controls on urban land disturbance activities in the Auckland region. An Urban Earthworks Notice was issued under Section 34(2) of the Soil Conservation and Rivers Control Amendment Act (1959). This Act provided for a public notice requiring prior consent for activities 'likely to cause soil erosion, floods or deposits in watercourses, lakes or the sea' and it became a statutory requirement for anyone carrying out major urban earthworks to seek approval from the ARA. Consents required a satisfactory erosion and sediment control plan that complied with predetermined minimum standards, and monitoring of sediment control was carried out to ensure compliance with the plan. Associated activities involved public education programmes, extensive liaison with the earthworks industry and, latterly, research.

In 1990, a further Section 34 Notice was introduced, requiring forestry operations in areas greater than two hectares to apply to the ARC for consent. An erosion and sediment control plan was also required.

After the introduction of the Resource Management Act (1991) the existing Section 34 Notices were carried over into a Transitional Regional Plan. These notices expired on 30 September 1993 and were replaced by the Auckland Regional Plan: Sediment Control. This was one of the first regional plans that the ARC prepared and it effectively continued the previous measures that were used to control sediment discharge. It is now recognised as having limitations compared to more recent regional plans; in particular, it does not provide for archaeological, contaminant or geotechnical issues to be considered and addressed through sediment control resource consents. In addition, the performance standards specified for permitted activities are not well-defined, making effective monitoring and enforcement difficult. The Auckland Regional Plan: Sediment Control is currently being reviewed.

Responses

The principal regulatory approach to controlling sediment is contained in the Auckland Regional Plan: Sediment Control. This plan controls specific soil disturbance events related to land development activities including earthworks, forestry (vegetation clearance) and quarries.

It permits small-scale land disturbance in areas that are not high risk, subject to performance standards, but requires resource consent for larger scale land disturbance. The type of resource consent that is required is determined by the scale and location of the land disturbance. The ARC currently receives between 150 and 220 applications for earthworks each year and up to ten applications relating to quarries. At any one time there can be 400 to 500 active earthwork and quarry sites in the Auckland region.

The basic requirements for earthworks resource consent applications are to ensure that water is kept off bare soil sites (through bunds or similar techniques) and that any flow generated by rainfall is treated before it runs off the site as stormwater. The ARC aims to achieve a 75 per cent sediment removal rate from stormwater through this approach.

Box 3 Auckland Regional Council Technical Publications that cover erosion control and sediment generation

We have produced two important Technical Publications on the management of erosion and sediment:

- Technical Publication 90 (TP90) was introduced in 1999 to replace an earlier guide and was updated in 2007. TP90 provides comprehensive guidelines for anyone engaged in land use activities that result in soil disturbance on how to best manage erosion and sediment. It explains the principles and also provides detailed technical advice on the range of erosion and sediment control practices and techniques that can be used to help meet our regulatory requirements. TP90 also provides a guide to the rules of the Auckland Regional Plan: Sediment Control and is a key input into resource consent application processes made under that plan. TP90 provides a clear indication of the likely requirements (in terms of the content of erosion and sediment control plans) for projects, compliance with conditions of consent and performance standards for activities permitted by the Auckland Regional Plan: Sediment Control.
- Technical Publication 223 (TP223) builds upon TP90 but focuses specifically on forestry operations and therefore contains some control measures that are not required in TP90. TP223 provides guidance on regulatory requirements and how forestry operators can meet those requirements by using the sediment control practices and techniques detailed within it.

This goal is achieved through compliance with Auckland Regional Council Technical Publication 90 (Box 3) and, in particular, the use of appropriately sized stormwater retention (sediment) ponds. In many cases the ARC also requires chemical treatment (the addition of a coagulant to the water in sediment ponds) to change the ionic charge of the sediment grains so that they drop out of suspension and settle quickly to the bottom of the pond. This technique enables up to 95 per cent of the sediment to be removed.

We also apply various other controls to reduce the risk of sediment being released into stormwater. For example, bulk earthworks are not generally permitted during the winter months and resource consents include a condition that requires bare soil sites to be closed down (covered with straw to reduce sediment generation) after 14 days if they are not being worked.

Forest harvesting (or vegetation clearance) is a permitted activity but moving the felled trees to loading sites and associated activities can, potentially, result in significant land disturbance and sediment generation. For this reason, the ARC requires at least two weeks notification of vegetation clearance before the work is undertaken. Foresters must use effective erosion and sediment control measures such as contour drains and retention ponds as well as covering bare ground. The range of measures can be constrained on steep forestry land due to the terrain. The ARC manages the risks through frequent inspections during harvesting: this activity is made possible by a $40 per hectare per year monitoring charge made under the Auckland Regional Plan: Sediment Control that applies to forest owners in the Auckland region.

In new urban developments, runoff from hard surfaces (other than roofs) must be treated using a technique suitable for the risk posed. This may mean installation of sand filters and rain gardens, or perhaps swale and pond systems for larger volumes of runoff.

Controlling sediment from land disturbance: is it working?

Our compliance monitoring programme involves a weekly visit to every active bulk earthworks site (potentially over 400 sites), two to three visits to every quarry each year, and six-monthly visits to forestry operations.

The inspections result in the degree of compliance being scored (using the scoring system described in Dairy farm discharges). A key performance indicator for assessing the level of compliance by earthworks sites is calculated as the percentage of Grade 1 and 2 scores throughout the earthworks season. Figure 3 shows a summary of the scores for key performance indicators for earthworks since 2003 that demonstrates a positive general trend towards a greater level of compliance over time.

Responses

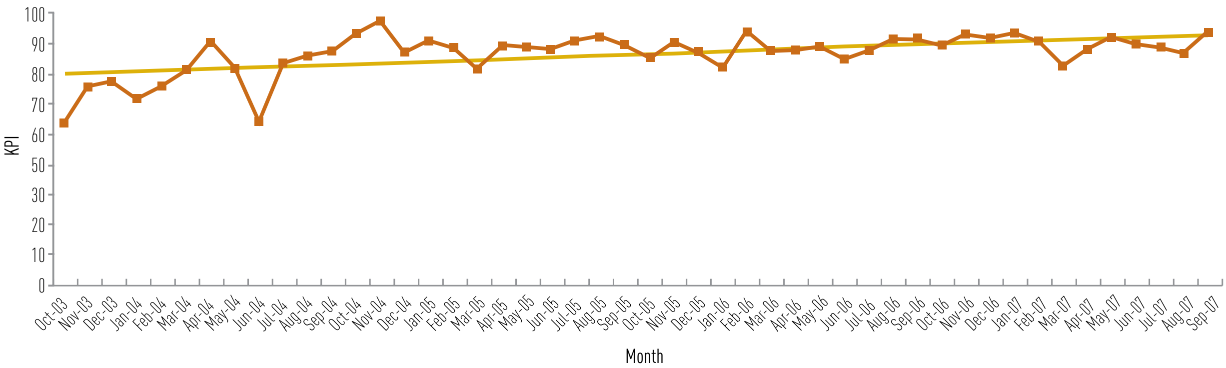

FIGURE 3 Compliance with earthworks rules and consent conditions, 2003-07. (Source: ARC).

The compliance monitoring process also results in the major earthworks contractors being ranked on their performance. Contractors that perform well are recognised by the ARC and can receive concessions regarding certain requirements. This also creates an incentive for good performance.

Controlling sediment runoff from cultivated land

Land cultivation and the associated discharge of sediment is managed under the Proposed Auckland Regional Plan: Air, Land and Water. This permits cultivation and discharge of sediment (except to the immediate margins of significant coastal areas, wetlands or lakes) provided the land is not steeper than 15 degrees and provided that appropriate stormwater management measures are implemented and maintained in accordance with best management practices. This can be achieved by compliance with an erosion and sediment control guideline derived from the Doing It Right – Guide to Sustainable Land Management (Box 4).

Cultivation of land with slopes greater than 15 degrees (27 per cent) and associated discharge of sediment is not permitted by the Proposed Auckland Regional Plan: Air, Land and Water and a resource consent is required by anyone wanting to undertake such cultivation.

Box 4 Doing It Right – Guide to Sustainable Land Management (Franklin Sustainability Project)

In 1997, the Franklin Sustainability Project was set up to test a range of sustainable land management techniques and involve growers in planning and monitoring these techniques.

This followed severe floods during the mid to late 1990s, when large volumes of sediment were generated from land used for market gardening in the Auckland region. The project was intended as a partnership between the growers, regulatory authorities and MfE.

The Pukekohe Vegetable Growers Association (PVGA) and Agriculture New Zealand led the development of the Doing it Right – Guide to Sustainable Land Management (2000) based on field-testing of various land management techniques.

Erosion management options were developed, related to the development and use of paddock plans, erosion co-ordination, raised access ways, wheel track ripping, silt traps, cover crops, headlands, hedges, cultivation techniques and contour drains. The project also covered integrated pest management and other land management research relating to nitrate leaching, hygiene, irrigation and soil quality monitoring.

All growers subsequently received a copy of Doing it Right – Guide to Sustainable Land Management and workshops and field days were held. The initiative was acknowledged at the time by a Ministry for the Environment Green Ribbon Award. The PVGA subsequently received funding from MAF to employ a person to promote the guide.

The best management principles in the guide are included as an appendix to the Proposed Auckland Regional Plan: Air, Land and Water. These require the diversion of sediment laden stormwater into silt traps (excavated pond-like areas) or long-bunded areas. The appendix specifies the design requirements for silt traps, including the size and depth according to the size of catchment, slope and length of cultivated rows.

Controlling sediment from cultivated land: is it working?

Many of the traditional measures that were used to control soil erosion were not capable of managing 'at risk' areas under cultivation. Between 2001 and 2006 the ARC visited sites in Bombay, Pukekohe Hill and Patamahoe that were identified as 'at risk' for soil erosion and sediment discharge. The aim was to continue support for, and provide advice on, implementation of sediment control measures explained in the Doing It Right guide.

Our experience has found limited, localised progress since the Doing It Right guide was launched. Although most growers are aware of sediment issues, there has been no consistent effort within the growing region to address ongoing sediment loss. Growers are often reluctant to remove land from production and use it for non-productive sediment controls. Existing control devices tend to be significantly undersized, poorly designed or not maintained. Consequently, sediment continues to be discharged during rainfall events.

A benchmarking survey in 2004 found that the growers' use of best management practices declined between 2002 and 2004. For example, the use of cutoff drains seemed to decrease by 20 per cent, contour drains by 23 per cent, vegetated strips by 15 per cent, silt traps by 5 per cent and raised accessways by 2 per cent.

In 2009, a study was conducted in the Whangamaire catchment, near Pukukohe. This study found that 52 per cent of the sites surveyed in August 2009 had no sediment or erosion management problems identified. Problems found on remaining sites were attributed to either an absence of control measures, or to undersized, poorly designed, or poorly maintained controls. The management features with the least uptake were the use of cutoff or contour drains and headlands followed by sediment traps. These can be the most difficult to implement and maintain. Positively, the use of vegetative buffer strips and hedges to control discharges is apparent at over half of the sites (Figure 4).

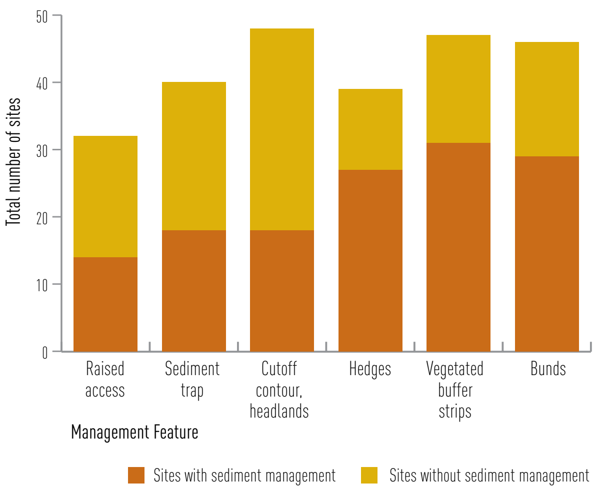

FIGURE 4 Types of sediment management features in the Whangamaire catchment, 2009. (Source: ARC).

The ARC is continuing to work with growers to encourage implementation of the measures detailed in the Doing it Right guide by taking a catchment based approach to sediment management on cultivated land.

Catchment management: Mahurangi Action Plan

Catchment management of non-point source (diffuse) rural discharges and soil degradation issues focuses on the scale of the catchment rather than its individual properties, because the ARC recognises that meaningful improvements rely on collective action.

Where environmental monitoring suggests that concentrated effort is required at the catchment scale, the ARC has initiated catchment management projects. The most significant of these projects recently is for the catchment surrounding the Mahurangi Harbour.

In 2004, monitoring of the Mahurangi Harbour showed high rates of sediment accumulation and a decline in abundance of species known to be sensitive to sediment. In response, the ARC established the Mahurangi Action Plan (MAP) in conjunction with Rodney District Council. The MAP involves a range of land use management, regulatory, research and community education initiatives. The aim is to halt, slow, or reverse the adverse effects of sedimentation on the ecological health of the Mahurangi Harbour. Emphasis was placed on direct engagement with land owners in the surrounding catchments, and on work to revegetate riparian margins and exclude stock from particularly vulnerable catchments.

The MAP was implemented in 2004 and since then the ARC has committed approximately $1.37 million to it. Since 2004, the following has been achieved within the surrounding catchments:

- 80km of stream and coastal edge fencing on private land
- 870 hectares of vulnerable land
- 150,000 native seedlings have been planted.

This has been achieved through ARC grants, planting days and around 9500 hours of volunteer effort. The ARC has also held education workshops, organised field trips, prepared farm plans, started a Catchment Management Plan and commissioned further research.

Following this experience at Mahurangi Harbour, the ARC identified that a similar plan was needed for Whangateau Harbour. Work is currently underway to scope this plan, engage with the community and to assess the surrounding catchment and the issues and threats to it.

Experience in the Mahurangi Harbour catchments has highlighted the benefits of intensive catchment management. Consequently, the ARC has developed a broader sustainable catchment management programme that applies the lessons learnt in Mahurangi to other harbour catchments, prioritised according to their current state, environmental value and significance of threats.

Responses

Controlling agricultural discharges

A significant environmental stressor on freshwater and marine environments are discharges from intensive land uses, in particular agricultural and horticultural activities in the surrounding catchments. Examples include:

- nutrient-rich point source discharges from dairy farms and intensive farming operations such as piggeries, poultry farms and glasshouse-based horticulture,
- sediment-laden discharges from market gardening activities (discussed earlier),
- diffuse discharges of nutrients, sediment and faecal material associated with stock farming (particularly from excessive fertiliser application and stock in waterways).

We seek to manage these point and non-point source discharges using a mix of regulatory and non-regulatory methods.

Most agricultural discharges are permitted by the Proposed Auckland Regional Plan: Air, Land and Water provided they can meet the prescribed levels of performance.

This places a responsibility on the ARC to monitor and inspect sites to ensure that discharges (or land uses that may give rise to discharges) are occurring in accordance with the rules, and to respond to complaints received from any individuals or community groups who are concerned about discharges that they see occurring.

Dairy shed wastes and dairy sludge

Dairy farms use large volumes of water for washing down dairy sheds, machinery and yards after milking to clear away effluent. The resulting untreated wastewater (known as 'wash water') has a high biochemical oxygen demand, elevated levels of nitrogen and phosphorous, and contains microbial contaminants and suspended solids.

Many dairy farms also generate large volumes of dairy sludge (accumulated organic solids from dairy oxidation ponds, barrier ditches, storage ponds, wintering barns or hard stand areas). Dairy sludge needs to be disposed of but, like wash water, contains high level of nutrients and microbial contaminants that can have significant adverse effects if it enters freshwater.

We have prepared the Auckland Regional Plan: Dairy Farm Discharges specifically to manage the dairy shed waste and dairy sludge (Box 5) in the Auckland region. The plan contains rules that permit the discharge of wash water and dairy sludge onto or into land, subject to a range of conditions. These limit the amount of nitrogen that may be applied on a per hectare basis over a given period, effectively limiting the cumulative application rate of wash water, dairy sludge and nitrogen fertiliser. The conditions also state that wash water and dairy sludge may not be applied in such a manner that enables it to enter the water. Around 250 dairy farms in the Auckland region currently dispose of wash water to land.

Dairy farmers that cannot meet the conditions for land-based discharge, or those operating a two-pond treatment system and wanting to discharge treated waste to freshwater, require a resource consent. No discharge may be made to natural wetlands, freshwater lakes or waterways draining into specified lake catchments. Two-pond systems and subsequent disposal to water is not encouraged and no consents for such discharges have been issued in recent years. Currently, about 70 farms in the Auckland region operate under resource consents that authorise disposal of treated wash water to freshwater. Discharges of untreated wash water or dairy sludge to freshwater are prohibited under the Auckland Regional Plan: Dairy Farm Discharges.

Box 5 The Auckland Regional Plan: Dairy Farm Discharges

The Auckland Regional Plan: Farm Dairy Discharges became operative in 1999. It was one of the first regional plans that the ARC prepared under the RMA. It was given priority because the ARC recognised the threat that dairy waste from the (then) 600-odd dairy farms with about 100,000 dairy cows posed for the small rural streams in the Auckland region.

The plan recognises the potential of dairy farm waste, if inappropriately disposed of, to:

- decrease dissolved oxygen in water leading to the suffocation of aquatic life
- be toxic to aquatic life due to high levels of ammonia,
- increase nutrient levels in the water resulting in nuisance growths of aquatic weeds and algae
- increase bacteria levels, making the water unsuitable for swimming, food gathering or stock drinking
- increase siltation of rivers and the amount of suspended solids in the water, with adverse aesthetic and ecological consequences
- elevate nitrate levels in potable water giving rise to human health risks.

The objective of the plan is to maintain water quality in water bodies and coastal waters that already have good water quality and to enhance water quality that is currently degraded. The main approach is to encourage disposal of dairy farm waste to land.

The Auckland Regional Plan: Dairy Farm Discharges is currently due for review.

Dairy farm discharges

Compliance monitoring

We inspect dairy farms annually for compliance but do not regularly monitor other types of farming. Our compliance monitoring role focuses mainly on dairy farms as these probably pose the greatest risk to rivers in the Auckland region. The results of our compliance monitoring provide an indication of the effectiveness of this approach. For compliance monitoring purposes dairy farms are graded as follows:

- Grade 1: Full compliance with permitted activity or resource consent requirements.
- Grade 2: Minor non-compliance, minor in nature and potential environmental impact, caused by poor system construction, operation or maintenance.
- Grade 3: Moderate non-compliance, with potential to have, or had, adverse effects on the environment.
- Grade 4: Major non-compliance, with significant adverse environmental effects.

Unfortunately, previous data from compliance monitoring is not considered reliable so an analysis of longer-term trends is not possible. Compliance monitoring was outsourced for a period but is now conducted by the ARC again and the data is considered to be more reliable. With about half of all the dairy farms inspected for the 2008/09 year, the most recent data show only 46 per cent of farms as Grade 1, 35 per cent as Grade 2, 11 per cent as Grade 3, and 8 per cent as Grade 4.

This means that, of the 325 farms inspected in the 2008/09 dairy season, 8 per cent had major non-compliance problems and a further 15 per cent presented an actual or potential risk of adverse environmental effects. 45 per cent of dairy farms inspected were fully compliant.

It is difficult to draw firm conclusions from the data about the overall effectiveness of our response to dairy farm discharges but this regime has now been in place for ten years and a significant level of non-compliance still remains. This suggests that there is cause for concern.

Enforcement

When the conditions for permitted activities such as wash water disposal, land cultivation and fertiliser application cannot be met a resource consent is, in theory, required. In practice, however, the ARC works with land owners to bring their activities into compliance or take enforcement action where necessary. Between 1 July 2005 and 28 February 2009, 40 abatement notices and 35 infringement notices were issued. Over half of these were issued in the 2008/09 year.

Other farm discharges

Agricultural and horticultural activities produce a variety of discharges. Stock farming can be associated with discharges from feedlots and hard stand areas, silage pits, offal holes and wintering barns. As already noted, most dairy farms spray wash water onto pasture while greenhouses can be associated with discharges of nutrient-rich solutions. Pastoral and arable farming involves the application of nitrogenous fertiliser.

The ARC manages these types of farm discharge through the Proposed Auckland Regional Plan: Air, Land and Water (Box 6). The general approach is to permit these discharges subject to conditions (performance standards). The conditions vary according to the type of discharge but typically control the scale and location of the discharge. There is an additional requirement for no discharge into any surface water body and no contamination of groundwater.

The plan also limits the application rate of nitrogen (including nitrogen in wastes and also in nitrogenous fertiliser) to grazing land. The standard is 150kgN per hectare per year and 30kgN per hectare in any 31 day period in areas underlain by aeolian sand or volcanic basalt, and 200kgN per hectare per year and 50kgN per hectare in any 31 day period on all other soil types.

Conditions also apply to the application of fertiliser that, essentially, require compliance with the relevant codes of practice.

Responses

Box 6 The Proposed Auckland Regional Plan: Air, Land and Water

The Proposed Regional Plan: Air, Land and Water was notified by the ARC in 2001. (It is referred to as 'proposed' because there are appeals against specific provisions that remain to be resolved). The proposed plan contains objectives, policies, rules and other methods relating to the use of air, land and water including the soil, rivers, streams, lakes, groundwater, wetlands and geothermal water.

The land and water provisions apply to that part of the Auckland region not covered by the Auckland Regional Plan: Coastal. The air discharge provisions apply to the entire Auckland region, including the coastal marine area.

The proposed plan is the largest and most comprehensive of our regional plans and its provisions cover:

- → discharges to air (including domestic fires, mobile sources, outdoor burning, dust, emissions from industrial processes and the application of agrichemicals),
- → discharges to land and water (including stormwater and wastewater, runoff from cultivation, fertiliser use, contaminated land and landfills),
- → the taking, damming and diversion of water (including surface and groundwater),
- → structures on, or disturbance of, the beds of lakes and rivers.

The proposed plan does not address every land and water issue in the Auckland region, as some land and water issues outside this plan are addressed by regional plans prepared in the 1990s. However, it does control the use of most major resources within the Auckland region and responds to most major environmental issues and risks in a (largely) comprehensive manner. The proposed plan therefore provides integrated management of our resources, ensuring that our efforts are both effective and efficient.

The proposed plan forms a crucial part in environmental management within the Auckland region because the RMA states that, unless permitted by a rule in a regional plan or a resource consent, people may not discharge to the environment, take water or disturb the beds of rivers and lakes. Consequently, the proposed plan is extremely important, not only because it regulates activities that may harm the environment, but also because it provides access to resources without the need for people to seek individual resource consents. This means that many everyday activities carried out across the Auckland region that are necessary for people's well-being and prosperity are lawful.

Managing contaminated sites

Discharges from contaminated sites are regulated by the Proposed Auckland Regional Plan: Air, Land and Water (Box 6) and managed by the ARC's Contaminated Sites Team.

The total number of contaminated sites within the Auckland region is not known. The ARC does know of many contaminated sites, but it also knows that there are many other contaminated sites, both urban and rural, for which it has no information.

The ARC takes a largely reactive role in contaminated sites issues. When a land owner or occupier, or prospective land owner or occupier, becomes aware that the land may be contaminated, they will often investigate the state of soil and any discharges.

In general, there is a strong incentive for the owners of land that is potentially contaminated due to past land uses to ensure that any discharges are consented and that contamination is appropriately managed. The appropriateness of the management depends on the intended future land use. Change in the land use (and associated territorial authority consent requirements), or the sale and purchase of land often trigger a site investigation. Land use change or sale and purchase agreements often cannot be concluded until any contamination issues or risks have been resolved.

The Proposed Auckland Regional Plan: Air, Land and Water sets out standards (with reference to a range of national and international guidelines for contaminated sites) that define the permitted level of contaminants in discharges and, correspondingly, the types of discharge that require resource consent. Resource consent is required only if a discharge is occurring. Some industries, such as the oil industry, are proactive in seeking certificates of compliance from the ARC and verifying that sites comply with permitted activity standards. In the 12 months to June 2009 the ARC granted 41 resource consents for discharges from contaminated sites and seven for landfills.

Managing sites through resource consent conditions may involve a range of approaches, from leaving the soil intact and simply covering the site with an impervious surface, to minimising the discharge risk through the removal of soil offsite and subsequent site monitoring. Soil that is removed from a contaminated site can be disposed of only at a facility or site authorised to accept such material.

The work done by the Contaminated Sites Team revolves around assessment to determine if resource consent is required, consenting including imposing appropriate conditions, monitoring to ensure that resource consents are being complied with and to oversee the situation at about 60 closed landfills in the Auckland region, and follow-up (including major pollution incidents) to assess whether remedial action is required.

Managing contaminated sites: is it working?

The main difficulty with contaminated sites within the Auckland region is a general lack of information. It is not known how many sites there are, how contaminated they are, or the level of risk they pose. The ARC is currently compiling a Register of Land Quality.

The ARC is also aware of sites that do not have resource consent but are likely to be contaminated to such an extent that a resource consent is required. Similarly, although the ARC monitors resource consents for about 60 closed landfills in the Auckland region, it is likely that there are an equal number (at least) that do not have resource consent.

Therefore, while the ARC is confident that the sites it has assessed and consented are being appropriately managed, there is an on-going risk from sites that have yet to be assessed or that are not known. Some level of risk from contaminated sites will remain unless the ARC actively seeks out and monitors them.

Managing urban pollution

We maintain a pollution response team and operate a 24-hour pollution hotline. The ARC staff, or an external contractor in the case of backyard burning complaints, are available 24 hours a day, seven days a week, to respond to pollution incidents or complaints. Members of the public, industry, territorial authorities or other ARC staff can alert the pollution response team to incidents. The ARC may also be called to pollution incidents by the Fire Service.

When a pollution incident occurs, an ARC staff member will visit the site and assess the clean-up needs, and will also try to identify who is responsible for the pollution incident and direct the responsible party to clean-up according to ARC requirements. If the cause of a spill cannot be determined the ARC will generally take responsibility for the clean-up. Large incidents may require the assistance of external contractors.

The types of pollution incidents addressed in this way include a broad range of deliberate or accidental discharges to land, water and air. The most common spills to land and water include hydrocarbons (petrol and diesel), concrete, sewage, sediment and paints. Air pollution incidents include industrial emissions, backyard burning and odour. Figure 5 shows the number and type of pollution incidents (excluding air pollution incidents).

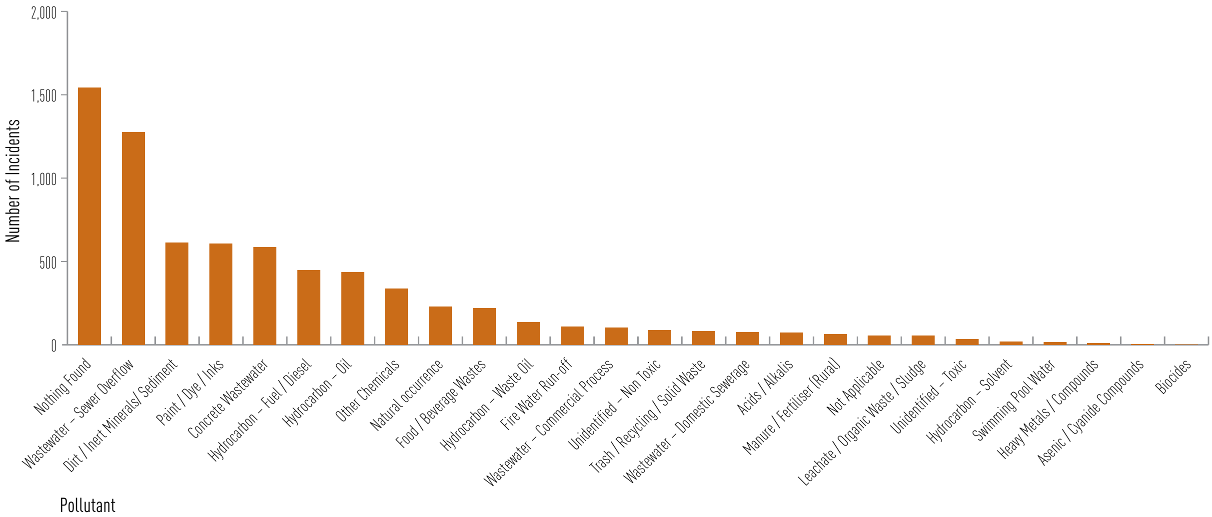

FIGURE 5 Total numbers of land and water pollution incidents, 2004-09. (Source: ARC).

In recent years the ARC has typically responded to between 1000 and 1200 land or water pollution incidents each year and up to 330 air pollution incidents.

In addition to arranging clean-ups, the pollution response team also takes enforcement action by issuing abatement and infringement notices, and prosecuting under the RMA (Table 1) when necessary.

The ARC also has an industrial and trade processes team who undertake proactive pollution prevention and compliance assessments on a wide range of industries. The aim of the assessments is to identify pollution issues and whether resource consents are required. If pollution issues are identified, the team works with the company to prevent land and water contamination. The team has previously worked with the metal finishing industry (i.e. electro platers, galvanisers, and anodisers) and is currently working with scrap metal and automotive dismantlers, timber treatment and concrete batching industries, amongst others.

4.6

Responses

TABLE 1 Enforcement action resulting from pollution incidents. (Source: ARC).

Enforcement action	2008 to 30 March 09	2007/08	2006/07	2005/06	2004/05	2003/04
Warnings	22	Not available	Not available	Not available	Not available	Not available
Infringement notices	84	87	92	187	141	192
Abatement notices	80	79	60	50	54	114
Prosecutions	3	6	2	3	3	Not available

The ARC's pollution response team also undertakes pollution awareness exercises. These involve visiting specific business areas to highlight pollution issues, advising on pollution risk and educating businesses about their environmental responsibilities. Geographic areas are selected for these pollution awareness exercises on the basis of the potential pollution risk according to the types of businesses present, history of pollution incidents and sensitivity of the receiving environments. These pollution awareness exercises are generally done with only limited prior notice.

Litter collection in the Waitemata Harbour

The ARC, the city councils, Watercare Services Ltd and initially the Ports of Auckland financially support the Waitemata Harbour Clean Up Trust. The trust works with community groups to remove litter from the Waitemata Harbour, using a boat donated by the Ports of Auckland. Rubbish is scooped up from the harbour and taken to shore for appropriate disposal. The trust has removed 1786 m^3 of rubbish from the sea (the equivalent of about 46 standard shipping containers) since it began in 2002. The trust also works with schools to show people how easily rubbish can end up in the sea if not appropriately disposed of on land.

Controlling the taking, damming and diverting of water

Water is taken from surface waters (rivers and lakes), abstracted from groundwater through boreholes or collected from rainwater under the provisions of the RMA.

The ARC control the taking, damming and diversion of water through the Proposed Auckland Regional Plan: Air, Land and Water (Box 6). This plan identifies High Use Stream and High Use Aquifer management areas: these are waterbodies subject to high levels of demand for water abstraction. These areas, and other specified areas, receive a higher level of protection and management than those that experience less demand.

This regulatory approach to water allocation also recognises the vulnerability of the generally small, short rivers within the Auckland region. It favours water takes from groundwater rather than surface water, and new off-stream rather than on-stream dams. Most aquifers have groundwater availability limits that are defined in the Proposed Auckland Regional Plan: Air, Land and Water.

While there are no restrictions on the taking of water for domestic purposes and stock drinking, most other water takes require resource consent. In High Use Aquifer management areas only 5m^3 of water may be taken each day without resource consent, and in High Use Aquifer management areas that are already fully allocated (such as Omaha and Kumeu) a resource consent is required for all water takes.

When considering whether or not to grant a resource consent for water taking, the ARC considers a wide range of matters that are set out in the Proposed Auckland Regional Plan: Air, Land and Water. Applicants are required to:

→ justify the quantity of water sought

→ show that the quantity of water sought is available at the location of the proposed water take

→ show that the water take will not significantly effect the environment or other users of the same water body.

The proposed plan also stresses the need for water conservation and water efficiency. When assessing the need for water the ARC compares the volume sought with guidelines (and historical water metering records for similar activities) for water consumption by land use type. If there are discrepancies, the ARC works with the applicant to verify the demand estimates. This might involve, for example, industries undertaking water audits (either in association with an application or as a condition of resource consent).

Applications to take water for municipal supply must include a:

→ demand management plan, to maintain a reasonable per person consumption

→ network efficiency and conservation plan that specifies the measures that will be put in place to minimise unaccounted for water loss

→ drought management plan.

Resource consent conditions ensure that limits are reported against quarterly.

When managing water body takes the ARC aims to ensure that, for each waterbody, the metered water use is less than water allocated, and that consented allocation is less than that available. These measures are specified as performance indicators for the water allocation team and the ARC reports against these in an annual water quantity statement. This reports the data collected from the eight High Use Aquifer management areas, as these are under the greatest pressure from the demands of water abstraction.

When water allocation is nearing the available limits, and if resource consent conditions allow, the ARC reviews the resource consents and redistributes water from those with unused allocations to other users that have a demonstrated need. This approach has been used in the Omaha and Kumeu High Use Aquifer management areas and in one of the zones within the Kaawa High Use Aquifer management area.

Resource consents are usually issued for about 15 years. The expiry dates vary by catchment or aquifer as there is a policy of synchronising the review and expiry of resource consents in each catchment or aquifer. This allows for integrated and effective management of any cumulative effects as well as any changes in demand. Resource consents are issued with conditions, allowing for the review of conditions at concurrent five-year intervals if necessary.

In addition to regulating water takes, the water allocation team also monitor compliance, send out a quarterly newsletter to all consent holders, and develop and publish educational material and factsheets.

Water take monitoring relies on self-reporting by the water users, who send the ARC quarterly records of their water meter readings or directly update our electronic database. This knowledge is critical as it enables the ARC to assess whether water use is being kept within allocation limits. It is also used for the annual water quantity statements. The ARC follows up instances of non-reporting and recovers the follow up cost from consent holders. Auditing meter readings is also undertaken with the frequency related to the risk posed by the particular take. Larger, complex resource consents and those that take water from particularly sensitive rivers or aquifers are audited annually.

Controlling water takes: is it working?

The annual water quantity statements show that water takes of groundwater are within allocations, and that the allocations are within the availability limits set by the Proposed Auckland Regional Plan Air, Land and Water. On that basis, the approach is working.

However, it is getting more and more difficult to meet the demand for water in several High Use Aquifer management areas. Managing the water to meet demand in these areas has often been achieved only because of the removal of a major water user (such as a dairy farm), where a major user has been able to make significant water savings (as at the Glenbrook Steel Mill), or where new abstractions could be directed to other less pressured aquifers. Fully allocated aquifers have no capacity for takes by new users.

While surface water takes are managed within allocation limits, it is uncertain whether those allocation limits are appropriate as the ARC is yet to define minimum flows for most of the rivers in the Auckland region. The ARC's current management approach for maintaining minmum flows, protecting water quality and requiring mitigation is through resource consent conditions.

Water use monitoring by self-reporting has been consistently high, with 80 to 90 per cent of the water users returning information over the past five years. This has given the ARC a robust information base.

Stream enhancement and compensatory works

Whenever possible, the ARC tries to stop rivers from being damaged or degraded. However, in order to achieve a diverse and healthy freshwater environment the ARC also tries to improve and enhance rivers that are already degraded. It does this in a number of ways.

Stormwater projects funded by Infrastructure Auckland:

- The (now disestablished) Infrastructure Auckland (IA) funded a number of stormwater projects (Box 7) to enhance urban streams. These included projects that focused on riparian planting and streambank stabilisation.
- The most significant is the Twin Streams Project that began in 2004. It covers the stream catchments that drain into Henderson Creek and Huruhuru Creek. These include the Lower Oratia and Lower Opanuku streams and the Waikumete, Swanson and Pixie streams.
- The Twin Streams Project aims to improve both the water quality and ecological health of these waterways largely through weed and rubbish removal, geotechnical work such as bank stabilisation and revegetation of 56km of streambanks. It also aims to develop wetlands to help manage stormwater and flood risk. This involves the purchase of 75 residential properties located in and around natural drainage channels (although it should be noted that only the stormwater aspects were funded through IA). By the end of 2008, the project had planted 373,000 native plants.
- The Twin Streams Project received funding approval as six separate projects totalling $39.5 million (almost half of the funds committed to stormwater projects). From mid 2004 to February 2008 the ARC paid out almost $25.5 million on behalf of the former IA, with a further $14 million still to be paid.

Responses

Box 7 Funding from Infrastructure Auckland

Infrastructure Auckland (IA) was established in 1998 as the custodian of a fund of regional investments worth approximately $1.3 billion that had been inherited from the former Auckland Regional Services Trust. IA was tasked with managing those investments to provide tangible benefits for the community through grants made to transport and stormwater projects. Around $150 million of the available cash reserves were notionally allocated to stormwater projects with about $550 million notionally allocated to transport projects.

IA was disestablished by a change to the Local Government Act in 2004 that involved reorganisation of Auckland's regional assets and the creation of ARTA (to manage regional transport) and Auckland Regional Holdings Ltd (ARH). Under the new legislation, the ARC was tasked with the responsibility for ongoing stormwater grants and ARTA with the responsibility for transport grants.

When IA was disestablished it had already approved $103 million for stormwater projects but the majority of this had not yet been paid out. A wide range of stormwater projects had been funded including new public stormwater pipes, separation of older combined sewers, installation of catch-pit filter systems, litter booms, treatment ponds, artificial wetlands and stream improvement projects. Funding decisions were made on the basis of a rigorous assessment process at the time but without the benefit of integrated catchment management plans, as these were then largely non-existent. Recipients were mainly local authorities (as network operators) but a small amount of funding was allocated to community groups.

By March 2009, $36.5 million had been paid out to regional stormwater projects with a further $34.5 million committed but not yet paid. The allocation of funds to IA-approved stormwater projects is likely to be completed by about 2014 although the exact date will depend on the start and completion dates of these projects.

The remaining $47 million (of the $150 million notional allocation) was retained for stormwater purposes but is no longer available for physical works. Instead, it was allocated to the ARC with the major portion going towards the development of integrated catchment management plans (ICMPs) by stormwater network operators (local councils). This fund is now administered by the stormwater action team.

Projects funded by the Environmental Initiatives Fund

In 2007, the Environmental Initiatives Fund (EIF) allocated $500,310 to 212 applicants in the region (Box 8). The projects included waste reduction, sustainable gardening, an educational nature trail, environmental awareness workshops and newsletters, restoration of dunes, native forest and historic buildings, native plant propagation, animal plant pest control, erosion control, and riparian and wetland fencing and planting.

137 applicants received a total of $362,236 for biodiversity related projects (native planting, fencing and/or an animal and plant pest control). A total of 28,415m of fencing was installed, 4,850m of stream edges were fenced and 77,262 native plants were planted in 2008.

Box 8 The Environmental Initiatives Fund

The ARC established the Environmental Initiatives Fund (EIF) in 1999 to support individuals and groups who wanted to improve and care for the natural, cultural and physical environments within the Auckland region. The EIF is an umbrella for other funds including the Honda Tree Fund.

About $500,000 is available annually to support projects and about 200 applications are received each year. To be eligible, projects must be consistent with the EIF vision and purpose and fit at least one of the funding outcomes.

Since the first funding round in February 2000, 1,235 grants worth $3 million were provided to community projects. These projects focused on biodiversity, cultural heritage, and education projects such as organic gardens and worm farms for schools and communities.

Compensation for lost stream values

Freshwater habitats and native fish populations are at risk from activities undertaken in rivers, such as excavation ('cleaning') and the placement of structures such as bridges, pipes and culverts.

The ARC controls these activities through the Proposed Auckland Regional Plan: Air, Land and Water. This proposed plan includes rules that control the disturbance of rivers by distinguishing between rivers (and stretches of rivers) that are in a relatively unmodified state with high natural values, and those that are more modified and therefore have lower natural values.

Piping, culvert installation and excavation of the more modified rivers is permitted, subject to conditions that are designed to minimise both temporary and long-term adverse environmental effects such as flood risk, sediment generation and restricted fish passage. The scale of disturbance is also controlled (e.g. a 30 metre limit is imposed on any culvert, piping or channelling and a 100 metre limit is applied to excavation work).

Disturbance of a river bed that is in a more natural state, or disturbance that cannot meet the performance standards requires a resource consent.

When there are significant and unavoidable adverse environmental effects (e.g. when an urban river has to be piped) the ARC requires compensation for the lost environmental values. Until recently this was done through a financial contribution (calculated at $330 per metre and payable by the resource consent holder) to restore or enhance the environmental values of other rivers within the catchment (or elsewhere if necessary). Recently this approach has been modified to ensure that the compensation more accurately reflects the lost environmental values. The new approach uses the ecological stream valuation methodology developed for the ARC. The approach calculates the recommended length of riparian restoration by taking into account the ecological value of the river that is being lost and the existing ecological value of the river to be enhanced.

Box 9 The Dairying and Clean Streams Accord

The Dairying and Clean Streams Accord is an industry self-management initiative that aims to improve the environmental performance of dairy farming. It was signed by Fonterra Ltd., regional councils, the Ministry for the Environment and the Ministry of Agricultural and Forestry in 2003. Fonterra Ltd. and the regional councils developed regional action plans for the main dairying regions to implement this Accord by June 2004. The principal priorities and performance targets of the Accord are outlined here:

- Dairy cattle are excluded from streams, waterways, lakes and their banks. Streams are defined as permanently flowing waterways that are deeper than a 'Red Band' (ankle depth) and 'wider than a stride'. However, fencing may not be required where natural barriers already prevent stock access, and the type of fencing erected will depend on factors such as terrain, stock type and costs. Performance target: dairy cattle excluded from 50 per cent of streams, waterways, lakes and their banks by 2007, 90 per cent by 2012.
- Farm races include bridges or culverts where stock regularly (more than twice a week) cross a watercourse. Performance target: 50 per cent of regular crossing points have bridges or culverts by 2007, 90 per cent by 2012.
- Farm dairy effluent is appropriately treated and discharged. Performance target: 100 per cent of farm dairy effluent discharges to comply with resource consents and regional plans immediately.
- Nutrients are managed effectively to minimise losses to ground and surface waters. Performance target: 100 per cent of dairy farms have systems in place to manage nutrient inputs and outputs by 2007.
- Existing regionally significant or important wetlands (as defined by regional councils) are fenced and their natural water regimes are protected. Performance target: 50 per cent of regionally significant wetlands to be fenced by 2005, 90 per cent by 2007.

Restricting stock access to waterways

Stock in waterways can have a range of adverse environmental impacts. These include increased nutrient levels, damage to freshwater and marine ecosystems, increased sedimentation and turbidity as a result of discharge of animal waste directly into the water, disturbance of the river bed, and vegetation loss and erosion along the riverbanks.

Currently, the ARC does not control stock access to waterways. However, the Proposed Auckland Regional Plan: Air, Land and Water does contain a commitment to introduce an appropriate response in the future. Our current strategy relies largely on education and advocacy and dairy farmers' compliance with the Fonterra Accord (Box 9).

The ARC and Fonterra have agreed on an Auckland Regional Action Plan that reflects the performance targets of the Fonterra Accord. Under the terms of this plan, the ARC has committed to a range of programmes such as guidance material for land owners to assist with compliance, and Fonterra has agreed to 'report publicly on progress annually'.

We also provide some public funding for fencing private land through our Environmental Initiatives Fund (Box 8).

Stock access to waterways: are the strategies working?

There is no historical record of the rate at which rivers in the Auckland region have been fenced to exclude stock. This makes it almost impossible to compare the effectiveness of this provision in the Dairying and Clean Streams Accord (Box 9) against the time before it was introduced.

Fonterra commissioned an assessment of compliance with the performance targets, as part of its requirement to report progress made towards its performance targets and found that the targets set in the Fonterra Accord were being met.

The ARC performed a comprehensive study of stock access to rivers in 2008 and aimed to provide a benchmark against which the effectiveness of our future responses to the issues around stock access to rivers could be assessed. Using 60 sample units (each a 500 metre length of river that was randomly selected from identified units spanning all major rural land uses), researchers undertook field survey work and recorded the fencing status. The research was designed to yield statistically robust results that would reflect the situation (within confidence levels) within the Auckland region as a whole.

Using that methodology, the ARC determined that the proportion of rivers fenced along both sides was 24.8 per cent overall. Rivers through dairy farms, with 26 per cent fenced, were better protected from stock access than the regional average. Rivers through drystock farms were less protected, with 60.7 per cent of rivers unfenced and a further 18.3 per cent fenced one side only. Rivers through dairy farms had 38 per cent with no fence and a further 36.8 per cent fenced on one side only. Rivers through rural residential properties showed similar results to those through dairy farms.

There is a difference between the ARC research findings and the Accord figures. Different data collection and interpretation account for some of this.

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Responses

Improving urban stormwater discharges

A large variety of chemical contaminants, representative of a range of activities from various land uses, enter fresh water and marine environments through the stormwater network.

Network discharges

The vast majority of local stormwater and wastewater networks within the Auckland region are owned by the territorial (city and district) councils and by council-owned enterprises such as Metrowater Ltd. The bulk wastewater network is operated by Watercare Services Ltd.

Although the stormwater and wastewater networks are constantly being expanded as a result of urban growth and redevelopment, most were designed and built before the RMA and before the ARC developed a good understanding of their impact on the coastal environment. Consequently, although they represent acceptable practice for their age, they have many design limitations compared to current environmental expectations (see Chapter 3: Wastewater and Stormwater, pg 61).

The RMA required all operators of stormwater and wastewater networks to apply to the ARC for new resource consents by 2001. This provided an opportunity to take a comprehensive look at the performance of the existing networks and to improve that performance over time. It had long been recognised that interactions between the wastewater and stormwater networks produced adverse environmental effects resulting from events such as wet weather and dry weather overflows (see Indicator 26, Chapter 3: Pressures, pg 61).

The Proposed Auckland Regional Plan: Air, Land and Water established a regulatory framework of objectives, policies and rules to control both stormwater and wastewater network discharges.

Resource consents for stormwater network discharges cover the discharge of stormwater from any point in the network, including the final discharge point into the receiving environment as well as overflows and leakages.

Resource consents for wastewater network discharges cover the discharge of wastewater that occurs as a result of overflows at designated relief overflow points (as well as elsewhere) and as a result of leakages that may occur before the wastewater arrives at a wastewater treatment plant.

This regulatory approach encourages the network operators to prepare an Integrated Catchment Management Plan (ICMP), see Box 10. In theory, applications by network operators for discharges from the networks would be considered after the relevant ICMP has been prepared. As part of this consenting process, network operators are required to adopt the Best Practical Option (BPO). This means that the ARC considers, on a case-by-case basis, the most appropriate means of improving performance given the issues with that network and its receiving environment, the particular catchment and the options available to address those issues, as well as the financial implications in terms of available funding and priorities relative to other catchments.

Although resource consent applications were first lodged in 2001, most have been on hold pending the collection of better information through the ICMP and resource consent process. However, in recent years the ARC has started to issue network resource consents.

Box 10 Integrated Catchment Management Plans (ICMPs)

ICMPs are plans for the management of stormwater and wastewater discharges, diversions and associated activities within the catchment or district. This is a ten year programme that began in 2004. These plans identify:

- the stormwater or wastewater issues facing the catchment and the range of effects from those discharges, diversions and associated activities,
- strategic objectives for the management of stormwater and wastewater discharges, diversions and associated activities within the catchment or district,
- a range of management options and the preferred management approach for avoiding, remedying or mitigating environmental effects and risks,
- roles and responsibilities for implementation of the management approach,
- tools to support implementation of the management approach,
- a process for review.

Importantly, ICMPs should take into account all types of discharge within the catchment (both network and non-network). They aim to address the full range of actual or potential flood events, water quality and ecosystem health issues.

Integrated catchment management planning can be a lengthy process that requires a detailed understanding of the current performance of the network and its effects and risks on the receiving environment. It also requires an understanding of likely future inflows, based on projected increased development within the catchment and the implications of this on the network performance.

These requirements usually mean that modelling and other technical work is needed to assemble the necessary data and devise an appropriate management approach. In recognition of the costs involved in preparing an ICMP (and the regional benefit that is derived from that work) Auckland Regional Holdings Ltd (ARH) provides funding to network operators through us, to assist with timely preparation of ICMPs.

As at June 2008, $6,150,562 was available from ARH (through us) for the development of ICMPs. Coverage of these plans is shown in the map.

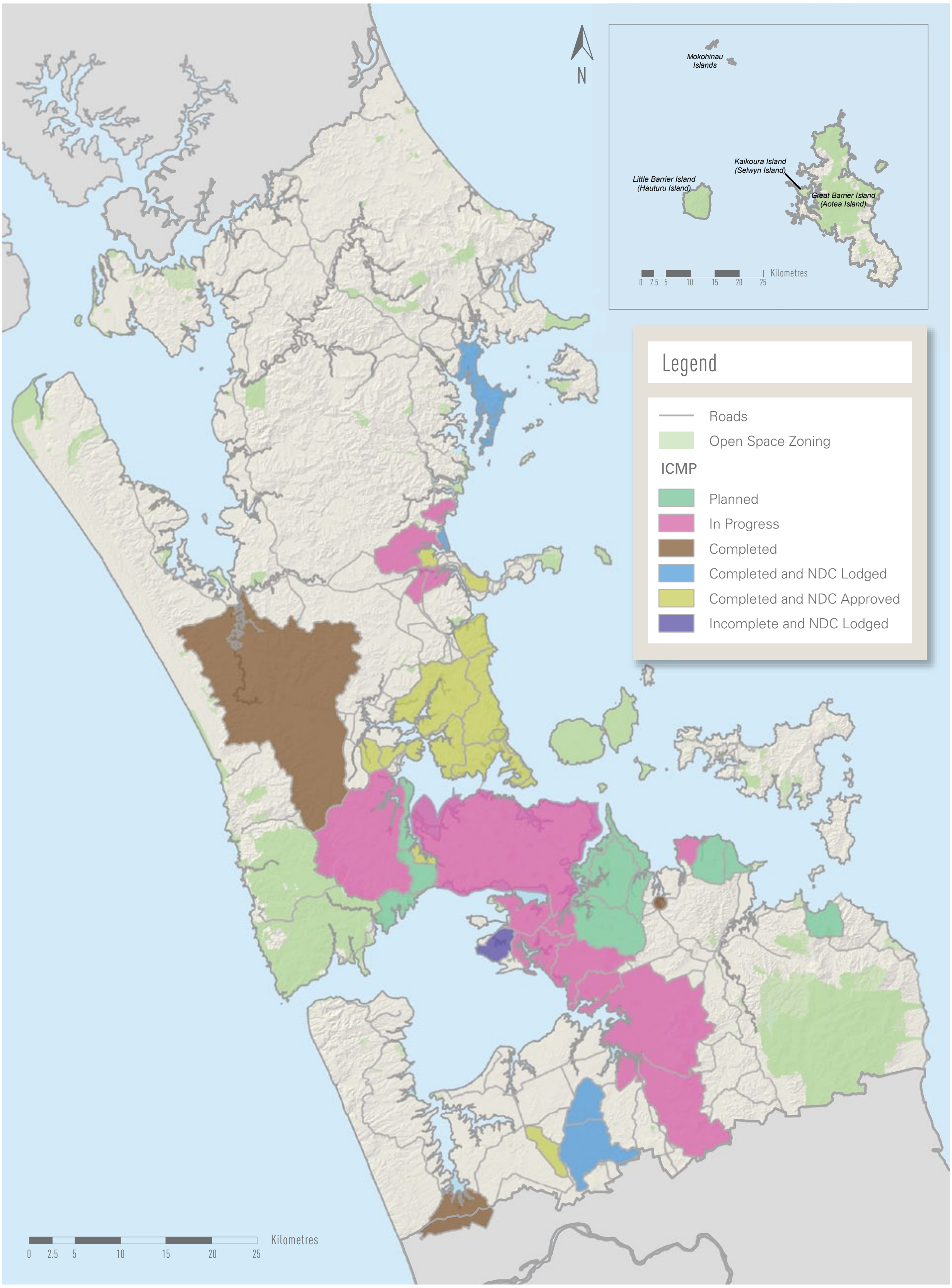

FIGURE 6 Progress of ICMPs in the Auckland Region (2008). (Source: ARC).

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Reporting the overall progress is difficult because each network operator has elected to seek resource consents in different ways. E.g. NSCC sought single (global) resource consent for entire networks while WCC submitted multiple applications on a catchment basis. Watercare Services Ltd. has submitted 76 applications, one for each pumping station (potential overflow points), 49 have been granted and the remaining 27 are being processed.

Applications for network resource consents can be made for existing networks or for future development areas (as part of a single application or as separate applications, depending on the applicant).

While there will often be significant limitations around the potential to improve stormwater management in some areas, a wide range of stormwater management techniques is available for others, particularly future development areas.

Since the network resource consent applications were lodged and the Proposed Auckland Regional Plan: Air, Land and Water introduced, much has been done to refine and develop a high quality stormwater management regime. A major review in 2004 identified five areas that needed improvement in order to deliver better stormwater outcomes. These were:

- improving the quality and timeliness of ICMPs,
- improving the range of measures and solutions, with particular emphasis on controlling the sources of contaminants rather than treatment of contaminated stormwater,
- improving and co-ordinating education and awareness of stormwater issues,
- improving organisational capacity and leadership,
- improving and securing sufficient funding for stormwater responses.

We responded to the review by preparing the Auckland Regional Stormwater Action Plan (SWAP) which explained how the ARC would meet these five challenges. The ARC also established a stormwater action team to deliver the commitments set out in the SWAP.

Non-network discharges

The ARC also regulates stormwater discharges from sites that are not connected to stormwater networks. The Auckland Regional Plan: Air, Land and Water requires that discharges of stormwater from sites with more than 1000m^2 of impervious surface need resource consent, unless otherwise permitted. This requirement is designed to control the discharges from a range of industrial and commercial activities, both inside and outside the MUL (Figure 1, Introdution, pg 9).

When considering whether to grant a resource consent, ARC considers the management of three issues in particular:

- Contamination (mostly from hydrocarbons and heavy metals). The ARC requires some form of treatment to be applied in accordance with the guidelines in Auckland Regional Council Technical Publication 10 (Box 11). Contaminant particles adhere to sediment in the water column so removing the sediment is the principal means of stormwater treatment. The Auckland Regional Plan: Air, Land and Water requires of 75 per cent of the total suspended solids to be removed from stormwater.
- The physical effect on aquatic habitats through, for example, riverbank erosion. The ARC requires stormwater retention devices that can cope with a 34.5mm rainfall event and release the retained water over a 24-hour period.
- The potential for flooding. The ARC imposes conditions on resource consents that are designed to ensure overload flood paths have the capacity to cope with two, ten or (in some cases) 100 year flood events, depending on the particular risk profile of the site and wider environment.

Box 11 ARC Technical Publications on stormwater discharges

- Auckland Regional Council Technical Publication 10 (TP10) was developed in 1992 and updated in 2003 to assist in compliance with ARC stormwater management requirements. It sets out an accepted design approach for structural stormwater devices that provides benefits for both water quantity and water quality. More specifically, it provides design guidance for ponds, wetlands, filtration practices such as sand filters and rain gardens, infiltration practices such as trenches and dry wells that divert runoff to groundwater rather than into streams, biofiltration practices such as swales and filter strips, and other preferred stormwater management. TP10 has had a significant influence on the type and nature of stormwater management across the Auckland region. Other technical publications that assist with stormwater management are:
- TP108 provides guidance on rainfall runoff modelling to be used for stormwater management design within the Auckland region.
- TP124. This presents an alternative approach to site design and development from a stormwater management perspective, and is primarily applicable for residential land development. The low impact design advocated is another stormwater management tool aimed at reducing the adverse impacts of stormwater runoff. This is becoming recognised as an important element of good urban form.

Other stormwater initiatives

In addition to the regulatory approaches to stormwater management, the ARC seeks to improve knowledge and skills within the Auckland region through a range of non-regulatory initiatives. These include running training courses and seminars, sponsoring a Low Impact Design competition at the University of Auckland, operating a Low Impact Design Innovative Grant programme, supporting demonstrations of low impact design at the Regional Botanic Gardens and similar educational programmes. The Infrastructure Auckland (IA) grant scheme is another significant non-regulatory initiative aimed at improving stormwater outcomes (Box 7 page 234).

Improving urban network discharges: is it working?

The new regulatory regime should result in new investment (in networks and the use of techniques to control the quality of stormwater entering the network) that would otherwise not have occurred, as well as improvements to the aquatic receiving environment. However, it will be difficult to determine the extent of both outcomes.

There has been a considerable investment in upgrading the older networks within the Auckland region over recent years. Much of this was driven by the asset management planning process combined with a generally recognised need to improve environmental performance, rather than as a result of our new regulatory framework. However, this investment was made in the knowledge that our regulatory framework was being tightened.

The extent to which the various non-regulatory activities of the Stormwater Action Plan (SWAP) are influencing change is difficult to gauge. An independent review of the SWAP in 2008 found that the ARC was successfully performing an important task and facilitating implementation of ICMPs in the Auckland region. Progress was also being made in delivering on the specific actions set out in the SWAP.

At present, it is too early to say whether our regulatory and non-regulatory activities are delivering improvements in the aquatic receiving environments.

Improving riparian management

Effective riparian management has many beneficial effects on the river and evidence suggests that the monitoring sites with riparian vegetation and fencing have higher water quality and higher ecological quality than those without. This suggests that there is an opportunity to improve both the water quality and ecological quality of degraded rural streams through improvements in riparian management (Box 12), particularly as over 60 per cent of the rivers in the Auckland region flow through rural catchments. Additional benefits to marine environments are also acknowledged, evident in the Mahurangi Action Plan.

Box 12 Riparian management (looking after the trees and shrubs that grow alongside a river)

Effective management of riparian margins can greatly influence the water quality and ecological quality of river systems. The presence of established woody vegetation on riverbanks can have numerous benefits to the river, including:

- shading, which prevents high water temperatures
- stabilisation, which prevents riverbank erosion
- food provision, from leaves and wood falling into the river
- habitat for the terrestrial phases of aquatic insects.

These benefits of riparian management can be achieved without compromising the productivity of rural land and within a relatively short timeframe. The photographs below show an example of the difference made by good riparian management along a river at the Awhitu peninsula. The upper photograph was taken in 1993 and the lower in 2003.

Responses

Lake restoration

Lake Wainamu

See case study on page 254.

Lake Ototoa

Lake Ototoa is Auckland's most pristine lake, with very high water quality and extensive beds of native aquatic plants. In early 2007 a highly invasive aquatic pest plant, hornwort (*Ceratophyllum demersum*), was identified in the north-west arm of the lake. This caused great concern due to its potential impact on the lake's ecology.

The ARC officers immediately carried out surveys to determine the extent of the spread. The ARC also installed two large barrier nets in an attempt to contain the hornwort within the north-west arm of the lake. The aquatic herbicides Diquat and Endothall were also applied to kill the hornwort infestation and these appeared to work successfully.

Unfortunately, further infestations of hornwort outside the contained area were discovered in March 2009. These appear to be too widespread to allow for eradication, leaving no easy options for future management of the lake.

Controlling the use of coastal space

The ARC controls activities within the CMA around the Auckland region through the Auckland Regional Plan: Coastal. This plan sets out the objectives, policies and rules about what people can do in the CMA and also applies to the wider coastal environment that includes an area landward of Mean High Water Springs.

Everyday passive recreational use of the CMA is permitted by the Auckland Regional Plan: Coastal but any activities that permanently or exclusively occupy coastal space (such as moorings, aquaculture and marinas) or that have potentially significant adverse environmental impacts (such as dredging or reclamation) are regulated.

A specified number of swing moorings are permitted in defined Mooring Management Areas, although consent must be obtained from the Harbour Master under bylaws prepared under the Local Government Act (1974). Moorings outside these defined areas or that exceed the permitted number require resource consent. A similar approach is taken to marinas.

Structures and buildings in the CMA such as seawalls, wharves, jetties and boatsheds are categorised as permitted, discretionary or non-complying activities, depending on the scale and location of the activity. The ARC considers applications on the basis of whether they are appropriate for the proposed location, and take account of any effects on public access and the coastal environment.

Over recent years, the ARC has been assessing and legitimising existing structures in addition to considering applications for new structures. Many of the existing structures had no prior approval as they were built well before the introduction of the RMA.

Although few applications are declined through the consenting process, any larger projects that the ARC approves are typically required to provide some level of mitigation, such as planting, provision of public access or other amenities.

A compliance monitoring programme ensures that the resource consent requirements are met. This programme involves inspections during the construction stages and subsequent visits to check that activities continue to comply and that structures are kept in good order. The frequency of these inspections is determined by the level of risk posed by the activity.

Integrated planning for coastal areas

In 2004 the ARC recognised the need for a strategic approach to coastal planning that would span the land/water interface and provide a framework to assist making regulatory decisions. Therefore, the ARC began to prepare non-statutory Coastal Compartment Management Plans (CCMPs) in conjunction with relevant territorial authorities.

These plans cover discrete parts of the coast that have an identifiable physical and/or social character. At the time of writing this report, three plans have been prepared for Pahurehure Inlet, Algies Bay and Waiuku Estuary. Although the breadth of issues that may be addressed in a CCMP is wide, the plans prepared so far have tended to focus on access, erosion control and mangrove management.

Implementation of CCMPs may be done through regulation (the incorporation of key provisions into plans prepared under the RMA) or through non-regulatory means including, in particular, council-funded works and services. Initially the ARC expected to prepare five CCMPs each year but progress has been much slower than expected.

Supporting community initiatives in the coastal environment

The ARC operates a Coastal Enhancement Fund (CEF) that provides grants to support individuals, organisations and community groups who want to enhance, restore or protect the coastal environment.

For the 2009/10 financial year, total funds of $336,000 were available from the CEF. The funds are distributed evenly between three categories of projects:

- environmental enhancement activities such as dune restoration, coastal wetland enhancement, beach clean-up, removal of derelict coastal structures and beach re-nourishment
- safety and navigation improvements such as the provision of training courses, education campaigns, signs and navigation lights.
- public works in the coastal zone such as building boat ramps and walkways, and wharf restoration.

The largest grant of $54,000 in the 2009/10 financial year was made to the University of Auckland to continue research into Brydes Whale's in the Hauraki Gulf. In general, individual grants are relatively small with most projects producing localised benefits.

Our EIF also supports projects that respond to coastal issues (Box 8 page 234). Most of the coastal projects supported by the EIF over the past few years have been related to fencing and restoration of coastal and estuarine margins although some dune restoration, biodiversity protection and clean-up projects have also been funded.

Vehicles on beaches

The use of vehicles on Auckland's beaches has grown substantially in the last couple of decades. This has developed into a form of recreation that – at certain locations – has resulted in risks to public safety, alienation of non-vehicle users, damage to Auckland's coastal environment and significant ongoing infrastructure costs for the agencies involved. This has been a long-standing issue for the ARC but more recently has been brought to prominence due to a number of serious incidents at Muriwai Beach and Te Oneone Rangatira.

In 2008, the ARC confirmed its desire for greater control of vehicles on beaches to ensure necessary access is identified and protected, while damaging and dangerous use is stopped. The ARC has identified a multi-pronged, staged approach to achieve this. This approach encompasses joint agency bylaw reviews and development, education, enforcement and monitoring.

Protecting and enhancing terrestrial biodiversity

Improving land use planning

The way in which land is used and developed poses many threats to the terrestrial biodiversity of the Auckland region although, conversely, management by regulatory authorities present opportunities for biodiversity protection and enhancement.

We seek to minimise threats and maximise opportunities for biodiversity through the policies in the Auckland Regional Policy Statement (ARPS) that are designed to guide land use management by the territorial authorities within the Auckland region (Box 13). The ARC promotes these policies through our regional advocacy role, by ensuring that the policies are reflected in the plans and resource consents issued by territorial authorities.

Box 13 Biodiversity policies in the Auckland Regional Policy Statement (ARPS)

The ARPS includes a chapter that addresses natural, geological and historic heritage and landscape. Natural heritage relates essentially to native biodiversity within the Auckland region. The policies contained in the ARPS:

- establish criteria for assessing the significance of natural heritage (this is important because the degree of protection offered is related to the assessed significance of places and habitats),
- require the control of subdivision, use and development so that heritage resources of significance are preserved or protected from significant adverse effects. If this is not possible, the policy requires any significant adverse effects to be remedied or mitigated,
- define significant adverse effects (in the context of heritage),
- promote natural heritage restoration, mainly through use of incentives and provision of information.

The ARPS requires regional and district plans to include provisions that implement policies and set out the range of mechanisms that should be considered to achieve protection. It also directs regional and district plans to consider a range of statutory and non-statutory provisions that enable financial contributions to be taken in order to offset unavoidable effects on natural heritage.

The ARPS also includes a schedule of Sites of Ecological Significance in Appendix B. The schedule includes areas of 'regional significance' but is not considered to be a complete record of all significant natural heritage resources in the Auckland region.

Responses

Bonus subdivision rights and conservation covenants

One of the ways that local authorities seek to meet their obligations to protect biodiversity under the RMA and the ARPS is to allow subdivision in return for permanent legal protection of native vegetation.

Protection is usually secured through the use of covenants. Rodney District Council (RDC) and Franklin District Council (FDC) have good databases that provide statistical information on bush lots and covenanted areas. Other councils have not yet extracted this data from their property files to create an accessible database of their covenants.

To promote protection of Significant Natural Areas (SNAs), RDC has provided subdivision rights through its district plan in return for the creation of conservation covenants. When significant areas of native bush, wetlands and other habitat types are permanently protected, land owners are given the opportunity to subdivide. Further incentives have also been provided; these allow native vegetation to be replanted, or weeds and pests to be managed, in exchange for subdivision rights.

The covenants established under the RMA include several specific conditions that seek to preserve the health and integrity of the biodiversity values of the area. These conditions are enforceable under the RMA.

Conservation covenants: are they working?

At present, there are 3543 conservation covenants in Rodney District. Together, these protect 8641 hectares of wetlands, native forest fragments and revegetation areas that have an average size of 2.5 hectares.

However, a pilot exercise showed that current land owners were often unaware of the location of the conservation covenant, the reasons for its existence, and its conditions and legal requirements. As a result, compliance with the conditions of conservation covenants was often low. Consequently, RDC intends to implement a bush lot monitoring programme and an associated communications plan to raise awareness and compliance amongst land owners.

Rules controlling vegetation clearance

Another common way in which territorial authorities seek to implement regional policy is through rules that limit the amount of vegetation clearance allowed and protect identified SNAs.

However, there is considerable variation in the scope and nature of rules in place at territorial level and little monitoring information available to assess their effectiveness. In addition, the effectiveness of such rules in protecting native vegetation can be undermined by both discretionary and non-complying resource consents (see case study: vegetation clearance on the North Shore, pg 214).

Managing plant and animal pests

One of the greatest threats to terrestrial biodiversity in the Auckland region comes from introduced plant and animal pest species.

While MAF Biosecurity New Zealand is responsible for keeping potential pest species out of New Zealand, responsibility for managing the pest species that are already in the country rests largely with the regional councils.

The ARC plays a major role in pest control within the Auckland region using the powers available to the ARC under the Biosecurity Act (1993) and the Auckland Regional Pest Management Strategy that the ARC prepared in accordance with that Act.

The Auckland Regional Pest Management Strategy

Recently the ARC prepared a new Auckland Regional Pest Management Strategy (RPMS) under the Biosecurity Act (1993) in order to implement our preferred approach to pest management across the Auckland region. The new RPMS covers the period from 2007 to 2012 and replaces the previous RPMS that covered 2002 to 2007.

The new RPMS continues the general strategy of the previous RMPS. It sets out a programme for addressing major pest threats using a mix of regulations, ARC-funded pest control operations, public education programmes and surveillance.

Under the RPMS, land owners and occupants are responsible for most pest control operations. However, the ARC controls a range of low-incidence but high-threat pest plants, as well as pest mammals such as possums, feral goats, feral deer, feral pigs and mustelids (weasels, stoats, and ferrets) that damage areas of high ecological or conservation value.

Pest plants are controlled in strategic locations in order to protect the regional park network and also undertake eradication work against key terrestrial pests in high value areas (e.g. Argentine ants on Great Barrier Island). The ARC also ensures that land owners or occupants are aware of, and comply with, a number of rules relating to pest plants and animals, such as the requirement to keep boundaries clear of ragwort in rural areas.

The ARC implements the RPMS through a team of biosecurity officers who ensure that the RPMS is applied consistently throughout the Auckland region by:

- managing pest control work (often through contracts to private sector operators)
- investigating complaints
- monitoring and releasing biological control agents
- advising on best practice pest control methods
- publicising pest issues in the community
- inspecting and controlling Total Control pest plants (for which the ARC has assumed management responsibility)
- general surveillance inspections
- nursery and retail shop inspections.

Individual biosecurity officers are also responsible for a range of regionwide projects such as liaison with landcare groups and management of the pest plant control programme within regional parkland.

The ARC currently spends approximately $6.3 million annually on implementing the RPMS and associated biosecurity measures.

Terrestrial pest plants

The pest plant control work that the ARC performs can be divided into the following:

- Species-led work. This focuses on a single species within an area or across the Auckland region because of the particular threat posed by that species.
- Site-led work. This focuses on managing the values of a particular site by targeting a broad range of pest plant species on that site.
- The RPMS classifies pest plants as Total Control plants, Containment plants or Surveillance plants, and our role differs according to the classification.
- Total Control. These pest plants have a low incidence but pose a high threat. The ARC carries out or arranges all the control work for these types of pest plant at no expense to the land owner. Total Control pest plants are banned from sale, propagation, distribution and exhibition within the Auckland region. The objective for Total Control pest plants in the RPMS is to eradicate all currently known sites within five or ten years, depending on the species.
- Containment. These pest plants are abundant in certain habitats or areas within the Auckland region. Land owners or occupants are required to remove these plants or to perform boundary control (depending on the particular species) whenever these plants appear on their land. ARC's role is to enforce these rules.
- Surveillance. These plants have significant adverse impacts on the biodiversity values of the Auckland region. The ARC tries to prevent these plant species from becoming established or spreading further by prohibiting their sale, propagation, distribution and exhibition. ARC staff regularly monitor establishments such as plant nurseries and other places where plants are grown or offered for sale.

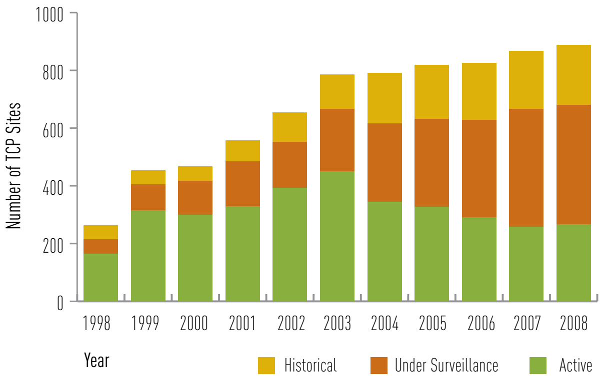

FIGURE 7 Annual trends in the number of Total Control pest plant sites and the relative proportion of their status categories across the Auckland Region. (Source: ARC).

Figure 7 shows the numbers and status of known Total Control plant sites in the Auckland region; including sites where control is underway, sites where control has been completed but frequent checks are carried out to monitor reoccurrence and, finally, historical sites where the pest plant has been eradicated.

Mammalian pests

Management of terrestrial pest mammals is performed by government agencies, community groups and private land owners using a variety of control methods (Figure 8 and Table 2). These include eradication, large-scale single species control of possums or ungulates (deer, goats, and pigs) and intensive small-scale multi-pest control of mammalian predators such as stoats, rodents, feral cats and hedgehogs.

The particular approach taken depends on a number of factors such as the level of knowledge about the relative impacts of different pest mammals on native biodiversity, their distribution, ecological requirements and behaviour patterns, and the technological challenges and resource constraints associated with their management.

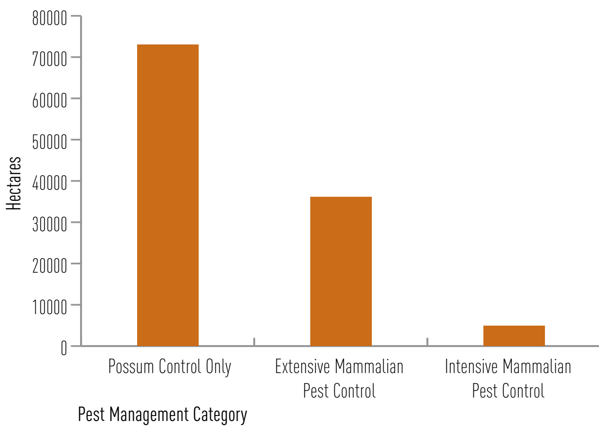

FIGURE 8 Amount of land (hectares) under management for terrestrial pest mammals in the Auckland region, 2008. (Source: ARC).

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TABLE 2 Summary of animal pest control programmes in the Auckland region. (Source: ARC).

Pest	Location	Agency/group	Timing/frequency
Possums	Auckland region	ARC led, DoC contribution, community groups	3 to 7 year rotation depending on rate of re-invasion
Feral goats	Hunua Ranges	ARC	Annual
Feral pigs	Waitakere Ranges	ARC	Twice a year
Mustelids	As part of site-led integrated management programmes, e.g. Ark in the Park	ARC, DoC, community groups	Variable
Feral cats	As part of site-led integrated management programmes, e.g. Tawharanui regional park	ARC, DoC	Variable
Feral deer	Auckland region, outside of South Kaipara peninsula	Combined ARC & DoC programmes	As and when reported
Rabbits	As site-led projects on ARC parkland and community projects on private and public land, e.g. Bethells beach	ARC, DoC, community groups	Variable
Rodents	As part of site-led integrated management programmes, e.g. Tawharanui regional park	ARC, DoC, community groups	Variable
Reptiles	Auckland region	ARC	Collection of red-eared sliders from the wild as and when reported.
Rooks	Auckland region	ARC	As and when reported
Argentine ants	Great Barrier Island, Tiritiri Matangi Island	ARC, DoC, community	Annually, over summer months
Wallabies	Kawau Island	ARC, some private land owners	During the RPMS period (2007-2012)

Pest fish

Twelve lakes within the Auckland region and their surrounding catchments have been assessed as High Conservation Value (HCV) water bodies due to their high natural values. These are listed and mapped in the RMPS. All fishing activities are prohibited in these lakes apart from trout fishing in Lakes Ototoa, Whatihua and Tomorata.

It is important to note that perch, rudd and tench are designated as pest fish only within these HCV lakes, and are designated as sport fish elsewhere in the Auckland region.

Pest management: is it working?

Pest plants in the Auckland region are managed by a number of agencies and groups including us, the DoC, territorial authorities, community groups and individuals. In 2008, approximately 6260 hectares across the region were controlled for invasive plant species by private land owners and community groups.

Since 1999, the number and total area of offshore islands that have been declared free of pest mammals has increased considerably (Figure 9). This positive trend looks set to continue with initiatives to remove pest mammals from the 500 hectare Kaikoura Island (off Great Barrier Island) and the Rangitoto/Motutapu Island complex of 3500 hectares.

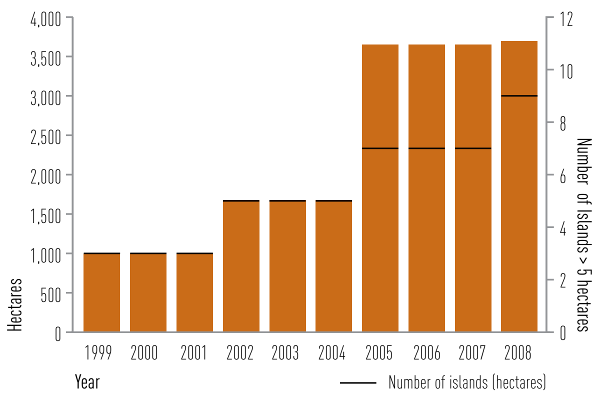

FIGURE 9 Changes in the number of islands and hectares in the Hauraki Gulf that are free of pest mammals, 1999-2008. (Source: ARC).

Pest control on both the mainland and the larger offshore islands is occurring on an increasingly larger scale and is reducing the numbers of target pest species to extremely low levels. For example, between 2004 and 2007, possum control on 42,803 hectares of HCV land achieved a residual trap catch of less than 3 per cent.

Although control and eradication of pest mammals is generally improving, it is increasingly recognised that the ecological consequences of pest control are not always clear. This is because the direct and indirect interactions between different pest species are not easy to predict. For example, in the podocarp-broadleaf forests of the central North Island, the numbers of ship rats increased five-fold following possum control operations. This increase was attributed to the greater availability of, and reduced competition for, seeds and fruit.

To address these difficulties, improvements are being made to pest control operations through a more integrated approach. This will help to ensure that the relative advantages and disadvantages of different pest control operations can be determined.

Working with land owners and communities

Community groups and private land owners play an important role protecting and restorating native biodiversity on public and private land. For example, over 300 community groups exist in the Auckland region with more than 4000 people actively involved in the restoration of biodiversity.

Biodiversity-focused groups operating within the Auckland region range from longstanding, organised and registered community groups and landcare groups, to smaller, less formalised groups, schools and individuals. Examples of community based support for conservation on regional parkland and DoC estate include Tawharanui Open Sanctuary Society, Shakespear Open Sanctuary Society, Ark in the Park, and Supporters of Tiritiri Matangi.

The ARC recognises the value and importance of this voluntary work and fund these groups and individuals to ensure they can continue to undertake projects that contribute significantly to local and regional biodiversity.

Funding for community groups and private land owners

Approximately half of the native land cover in the Auckland region is on private land which contains many rare and threatened native species. Consequently, private land owners play a critical and increasing role in the protection and restoration of native biodiversity. Community groups are hugely important in biodiversity management on many public land areas (e.g. Shakespear Regional Park).

Both national and local government agencies fund biodiversity-focused community groups (Figure 10). Some of the major biodiversity funding available in the Auckland region include:

- Environmental Initiatives Fund (EIF) administered by the ARC
- Biodiversity Condition and Advice Fund administered by DoC and MfE
- Natural Heritage Funds administered by local councils, e.g. ACC and RDC
- ASB Community Trust.

The ARC established the EIF in 1999 (Box 8). About $500,000 is available each year to support projects. This is at the upper end of funding compared to other regional councils but relatively low on a per capita basis (Table 3 page 246). Biodiversity projects funded by EIF can be separated into education, planting, fencing, and animal and plant pest control activities. At least one of these activities is usually the main focus of the funding applicants.

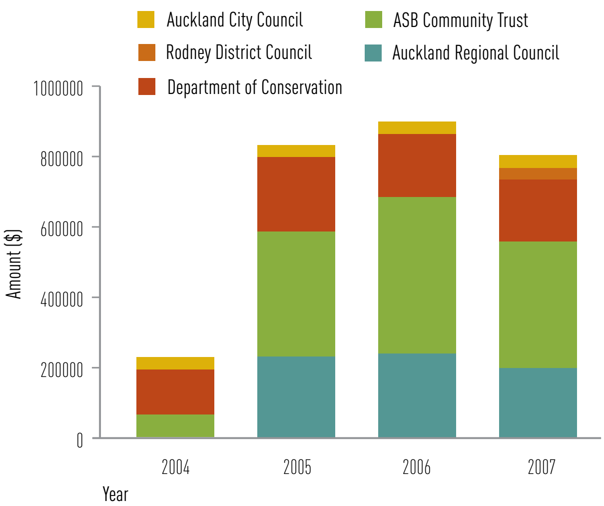

FIGURE 10 Total amount and relative proportions of community funding allocated to biodiversity projects by regional agencies, 2004-07. (Source: ARC).

Table 3 compares the total annual funds that are available from eight of the 16 regional authorities in New Zealand. This funding is specifically to support members of the community who are carrying out conservation and restoration of biodiversity on private or public land. The total amounts vary greatly between the regional authorities as a result of different funding and eligibility criteria.

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TABLE 3 Comparison of annual biodiversity funding available from eight regional authorities. (Source: ARC).

Regional Authority	Annual funding amount	Eligible projects
Northland Regional Council	$520,000	Environmental
Auckland Regional Council	$500,000	General: Biodiversity, sustainability and cultural heritage
Environment Bay Of Plenty	$450,000	Environmental
Taranaki Regional Council	$112,000	Biodiversity
Horizons Manawatu Regional Council	$369,000	$324,000 for bush and wetland sites and remainder for general biodiversity
Greater Wellington Regional Council	$170,000	Biodiversity
Environment Canterbury	$220,000	Environmental enhancement and the Honda Tree Fund
Otago Regional Council	$200,000	Environmental enhancement

Contributions from community groups and private land owners

Community groups and individuals carry out a variety of valuable biodiversity-related activities including:

- propagating and planting native vegetation
- pest control operations for terrestrial pest plants and pest mammals
- environmental monitoring
- species translocations
- increasing public awareness through advocacy and education.

The amount of time and resources that are provided voluntarily by members of the community in order to carry out these activities contribute significantly to the restoration and protection of native biodiversity in the Auckland region, on both private and public land. For example, members of the community planted over 45,000 native plants in 2007 with assistance from our EIF. In 2008, community groups and private land owners worked together to conduct pest control operations on more than 56,300 hectares, an enormous increase on the 100 hectares in 1998 (Figure 11).

QEII covenants in the Auckland region

The ARC is not the only agency working with land owners to help protect terrestrial biodiversity within the Auckland region. The QEII National Trust has been active for many years and works closely with us, DoC and the district councils (Box 14).

We actively promote QEII covenants through liaison activities with land owners and biodiversity protection work, and the ARC provides technical support to QEII representatives.

The first QEII covenant within the Auckland region was registered in 1981. Since then, 2795 hectares have been protected under 216 covenants (Figure 12). These include areas of podocarp-broadleaf forest, coastal forest, coastal wetlands, lowland forest, scrublands, wetlands and archeological sites.

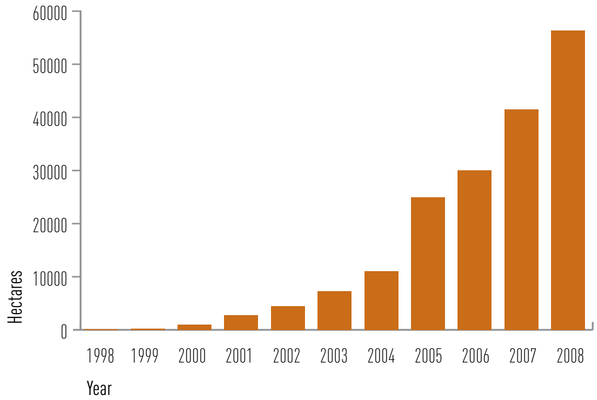

FIGURE 11 Number of hectares under pest control by community groups or private land owners in the Auckland region, 1998-2008. (Source: ARC).

Box 14 The Queen Elizabeth II National Trust

The Queen Elizabeth II National Trust (QEII) is an independent statutory organisation that was set up in 1977 to encourage and promote (for the benefit of New Zealand), the provision, protection, preservation and enhancement of open space.

It helps private land owners to protect significant natural and cultural features on their land through open space covenants, and acts as a perpetual trustee to ensure that these values remain protected forever. Features that can be protected include landscapes, forest remnants, wetlands, grasslands, threatened species habitats, and cultural and archaeological sites.

A QEII open space covenant is a legally binding protection agreement registered on the land title. It is voluntary but, once in place, binds the current and all subsequent land owners. Each covenant is unique, with varying applicable conditions.

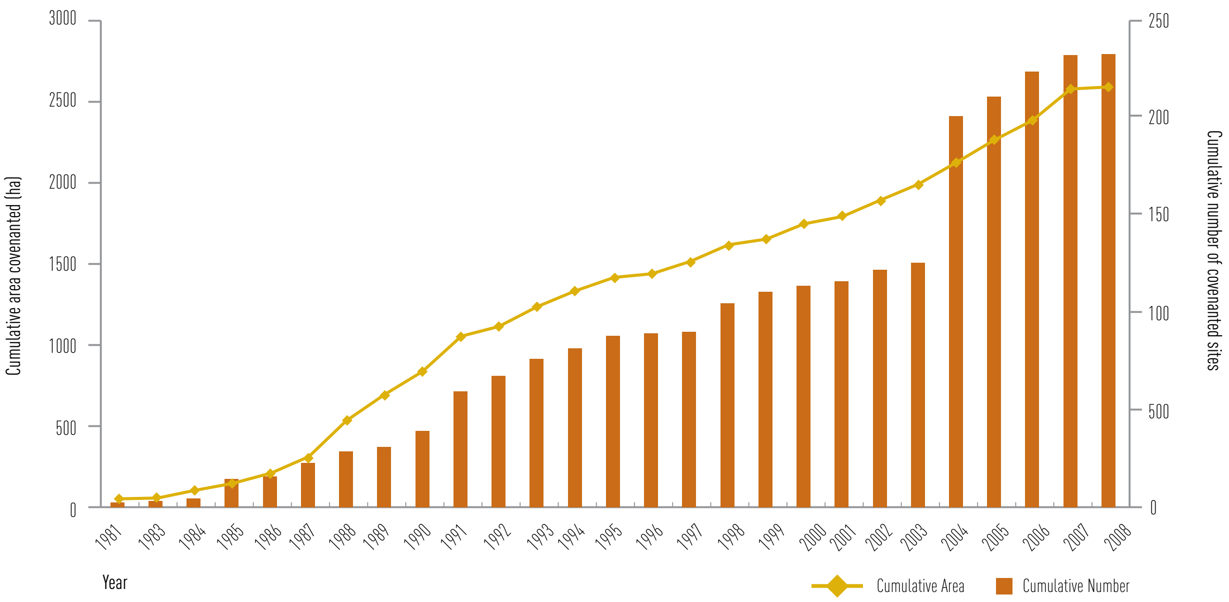

FIGURE 12 Cumulative area (hectares) and number of QEII covenants in the Auckland region, 1981-2008. (Source: ARC).

QEII covenants: are they working?

The number of QEII covenants on private land continues to grow in the Auckland region, reflecting the commitment and support from private land owners for biodiversity protection.

QEII national monitoring shows that the majority of covenants not only meet the terms and conditions of their covenants but exceed them. This is partly because a QEII covenant is a voluntary partnership normally requested by the land owner, and partly due to the ongoing support and involvement provided by QEII.

The QEII model of protection has proven to be a robust, simple and cost-effective tool for resource management and biodiversity protection.

Acquisition and management of regional parks

The most significant and direct impact that the ARC has made towards protecting and enhancing terrestrial biodiversity across the Auckland region results from the management and expansion of our regional park network.

Regional parks are managed according to the Regional Parks Management Plan (RPMP). This plan sets out the overall management policies and principles, including guidance on how the regional parks will be used, developed and restored. The RPMP also includes specific policies and actions for each regional park.

Although the aims and purposes of the regional park network are much broader than the protection of our terrestrial biodiversity, their management and planning framework favours the protection of existing valuable and sensitive ecological features. Therefore, the regional park network provides a haven for remaining native vegetation and habitat types that might otherwise be lost or degraded through development.

Policies in the RPMP promote biodiversity protection by restorating, expanding and enhancing different habitat types and engaging in species recovery programmes. Other major benefits to the ARC's regional park network include the protection of coastal values (Box 15).

Box 15 Coastal protection resulting from the acquisition of regional parkland

Our 1999 Parks Acquisition Plan includes a parklands acquisition policy that identifies, as a priority, the future acquisition of prime coastal locations that have high recreational potential associated with the beaches.

The Regional Open Space Strategy produced by the Regional Growth Forum also identifies the preservation and protection of the natural character of the coastal environment as a desired outcome.

The effect of these policies is evident in the recent additions to our regional park network, as all recent acquisitions including Pakiri (2005), Atiu Creek (gifted to the Auckland region in 2005), Te Rau Puriri (2006) and Te Arai Point (2008) were coastal properties.

Another benefit resulting from these additions to the regional park network is the protection of these coastal areas from development.

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Extent of the regional park network and habitat types

The regional park network presently covers about 40,700 hectares (8.1 per cent of the total land area within the Auckland region) and includes a number of native ecosystems of ecological significance.

Collectively, the regional parks protect a number of nationally and regionally important ecosystem and habitat types such as broadleaf/podocarp/kauri forest, shrublands, freshwater wetlands, dune systems and estuarine areas (Figure 13).Even though the regional park network covers less than one tenth of the land area within the Auckland region, it contains almost one quarter (24 per cent) of the native ecosystems found within the Auckland region.

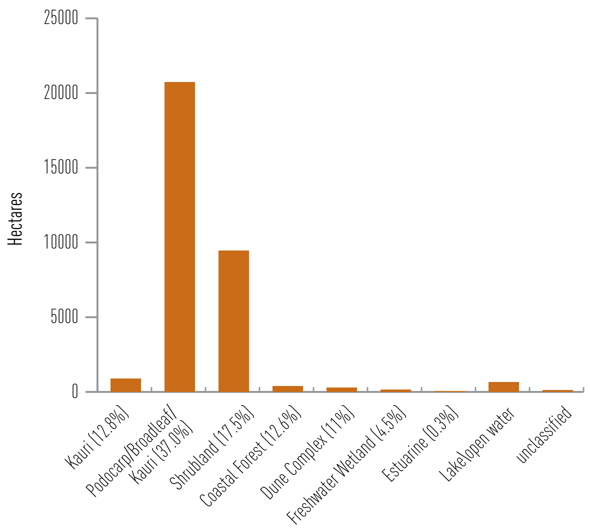

FIGURE 13 Size (ha) and relative proportion of each ecosystem type in the Auckland region that exist within the regional parks. (Source: ARC).

Podocarp/broadleaf/kauri forest is well-represented, largely due to dominance of this ecosystem type within the regional parks in the Hunua and Waitakere Ranges. The regional parks network also provides protection for threatened ecosystem types such as wetlands, dune systems and coastal forest. Many of the remnant ecosystems are the best examples of their type in an ecological district. Examples include, coastal forest at Wenderholm, Tawharanui, Scandrett and Duder regional parks, dune systems at Pakiri, Whatipu and Muriwai, and protected and restored wetland at Awhitu, Whatipu and Tawharanui. Te Arai protects nationally rare dune lake ecosystems.

The regional park network supports a large proportion of the native terrestrial biodiversity found in the Auckland region including 49 per cent of birds, 54 per cent of reptiles, one of the two native bat species, the single amphibian and (at least) 13 of the 17 species of native freshwater fish.

Threatened species in regional parks

Non-threatened native ecosystem types make up the majority of ecosystem types in the regional park network, but the importance of the regional parks in maintaining native terrestrial biodiversity is clearly shown by the number and proportion of threatened species within them.

In total, almost 100 nationally threatened plants and vertebrates are known to exist in the regional parks. These represent 46 per cent of the threatened plants and vertebrates that are known to occur in the Auckland region and reflect the quality and quantity of habitat types found within the park network. Threatened invertebrates are also known to occur within the regional parks but detailed information on these has not been collated.

Several regional parks act as national or regional strongholds for some threatened species, e.g. the only population of North Island kokako on the mainland in the Auckland region exists in the Hunua Ranges regional park. The regional parks in the Waitakere Ranges and Hunua Ranges act as national strongholds for populations of Hochstetter's frog.

In some cases, regional parks are the only known remaining locations for some threatened plant species, e.g. the Waitakere Ranges regional park supports the only known location of *Hebe bishopiana* in New Zealand. This species is endemic to the Waitakere Ranges.

Although a list of regionally threatened fauna has not yet been developed, there is a list of 300 regionally threatened plants. At present, only 13 of the 26 regional parks have been surveyed closely but already two thirds (200) of these regionally threatened plants have been found within them. This suggests that much of the native flora is protected within regional parkland, and that a range of protected habitat types provide opportunities for a diverse range of plant species to persist.

Few surveys of threatened plants and secretive, rare or cryptic fauna have been completed on private land. Consequently, it is possible that more threatened species may yet be found within the Auckland region. This possibility also applies to the regional parks that have not yet been surveyed.

Parkland acquisition and conservation management: is it working?

Regional parks provide critical protection for terrestrial biodiversity in the Auckland region, as shown by the range of habitat types and number of threatened species within them. However, when viewed purely from a terrestrial biodiversity protection perspective, the existing parkland acquisition strategy is, by itself, not sufficient to achieve the regional biodiversity protection objectives.

About half of the remaining native land cover in the Auckland region is protected, as district or regional council parks or DoC estate, but the proportion of protected native land cover varies across different ecosystem types and ecological districts (Table 4). On the positive side, 73 per cent of the remaining kauri forest and 70 per cent of the remaining dunelands are protected. On the negative side, only a tiny amount (0.5 per cent) of lava forest remains and of this, only 17 per cent is protected. Similarly, only 38 per cent of the remaining 4 per cent of freshwater wetlands or wetland forest is protected.

TABLE 4 Extent (hectares) of native ecosystems and areas under protection. (Source: DoC).

Vegetation Class	Remaining hectares	% remaining	Protected hectares	% protected
Brackish estuarine	14093	Unknown	2289	16
Coastal forest	3160	3	1356	42
Dune vegetation	2577	15	1806	70
Freshwater wetland and wetland forest	3731	4	1427	38
Kauri forest**	6972	9	5119	73
Lava forest*	29	0.5	5	17
Podocarp/broadleaf/kauri	56030	20	31736	56
Shrublands	54096	Unknown	20201	37
Unclassified	6362	Unknown	732	11
Total	132957	24	66476	49

* This excludes Rangitoto Island which is considered to be early successional lava forest.
** Accuracy of data is uncertain.

Consequently, there is a strong case for future efforts to protect native terrestrial biodiversity in the Auckland region through habitat protection that will focus on lava forest, freshwater wetlands and wetland forest, and coastal forest.

Conservation management: species recovery

Many ecosystems in the Auckland region have lost significant components of their fauna so efforts to reinstate these components in order to restore important ecological functions such as pollination, seed dispersal and recycling of nutrients is supported by conservation agencies.

Recent advances in pest management and habitat restoration efforts on both public and private land have enabled a number of species to be transferred to sites where they were known (or were likely to have been) present in the past. Such transfers are known as 'translocations' and are often necessary to help the recovery of threatened species or to restore the ecological integrity of degraded ecosystems.

We instigate and project manage (in collaboration with DoC) translocations to our regional parks and, in some instances, assist with translocations on private land.

Translocations

Given the increasing number of offshore islands and ecosystem types that are now free of pest mammals, there are growing opportunities to translocate native species. Correspondingly, there is an overall trend of increasing numbers of translocations and an increased variety of species are being translocated (Figure 14).

The proportional increase in non-bird translocations (including lizards, invertebrates and plants) is due partly to an increasing recognition that these species also form important components of ecosystems, and partly to improved translocation techniques (e.g. for reptiles).

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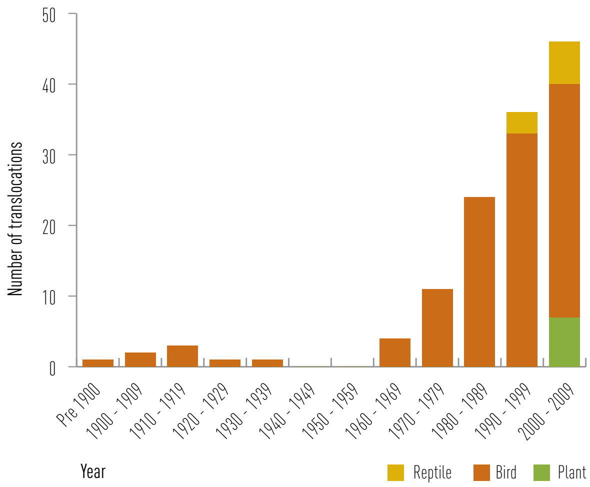

FIGURE 14 Number of translocations in the Auckland region per decade, pre-1900 to 2009. (Source: ARC).

The high proportion of bird translocations is expected to remain, partly because compared to more secretive species (e.g. reptiles), it is usually very clear if a bird species is absent from a chosen release site. Also the risk of failure is too high for some other species (particularly plants and invertebrates) due to insufficient knowledge about their habitat requirements, key threats or the most suitable translocation procedures. Bird translocations are also very popular with the public.

Translocations: are they working?

Currently there is no database that records whether a translocation has succeeded or failed, and in some cases the level of monitoring performed after the release is inadequate to determine the outcome.

In some instances, the size of the founder population is small and this may compromise the genetic diversity of the population in the long-term. However, translocations have contributed very positively to threatened species recovery and ecosystem health in the Auckland region, with a total of 22 translocated species known to persist at ten sites (Table 5).

TABLE 5 Translocations where the translocated species are known to persist. The term ‘persist’ includes species that are well established and breeding in the absence of conservation management, species that have been recently translocated, and species that persist in low numbers an require active management. (Source: ARC).

Species	Translocation date	Release location
Little spotted kiwi	1993/96	Tiritiri Matangi Island
North Island brown kiwi	1863/64	Kawau Island
	1903/19	Little Barrier Island
	1964	Ponui Island
	1999	Motuora Island
	2006/08	Tawharanui Open Sanctuary
Black petrel	1986/90	Little Barrier Island
Brown teal (Pateke)	1987-2002	Tiritiri Matangi Island
	2008	Tawharanui Open Sanctuary
Takahe	1991/95	Tiritiri Matangi Island
Red-crowned parakeet (Kakariki)	1974/76	Tiritiri Matangi Island
	2008	Motuihe Island
North Island robin	1992/93	Tiritiri Matangi Island
	1999	Wenderholm Regional Park
	2004/05	Great Barrier Island
	2005	Waitakere Ranges (Ark in the Park)
	2007	Tawharanui Open Sanctuary

Contd...

TABLE 5 Translocations where the translocated species are known to persist. (Source: ARC). (Contd)

Species	Translocation date	Release location
Whitehead	1989/90	Tiritiri Matangi Island
	2004, 2008	Waitakere Ranges (Ark in the Park)
	2007	Tawharanui Open Sanctuary
New Zealand fernbird	2001/02	Tiritiri Matangi Island
North Island kokako	1997-2000	Tiritiri Matangi Island
North Island saddleback (Tieke)	1984/88	Little Barrier Island
	1984/90	Tiritiri Matangi Island
	2005	Motuihe Island
Stitchbird (Hihi)	1995/96	Tiritiri Matangi Island.
		Waitakere Ranges (Ark in the Park)
Common diving petrel	2007/08	Motuora Island
Rifleman	2009	Tiritiri Matangi Island
Weka	1863 (approx.)	Kawau Island
Northern tuatara	2003	Tiritiri Matangi Island
Duvaucel's gecko	2005	Tiritiri Matangi Island
	2006	Motuora Island
Forest gecko	2005	Tawharanui Open Sanctuary
Auckland green gecko	2006	Tawharanui Open Sanctuary
Shore skinks	2006	Tiritiri Matangi Island, Motuora Island
	2008	Motuihe Island
Flax snails	Unknown	Noises Island
Kauri snails	Unknown	Waitakere Ranges
	Unknown	Awhitu Peninsula
Clianthus puniceus var. puniceus (Kakabeak)	1997	Moturemu Island (Kaipara harbour)
Dactylanthus taylorii	1998	Tiritiri Matangi Island
Ileostylus micranthus (Green mistletoe)	1996	Whakatiwai
	2005	Waitakere Ranges (Ark in the Park)
Euphorbia glauca	2002	Brown's Island (Crater Bay)
	2003	Brown's Island
Lepidium flexicaule (Shore cress)	2000	Rangitoto Island

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Case Study: Tawharanui Open Sanctuary

Tawharanui (588 ha) is one of Auckland's best loved coastal regional parks. It lies at the tip of Takatu Peninsula, a long finger of land, which reaches out into the Hauraki Gulf towards Little Barrier Island.

The landscape is an attractive mix of sandy ocean beaches backed by extensive dunelands, rocky coves and headlands, saltmarshes, freshwater wetlands, coastal broadleaf forest, scrublands and open pastureland.

Tawharanui has one of the best swimming beaches on Auckland's east coast and there are numerous shady picnic sites, a spacious campground and many well marked walking trails. A no-take marine park extending several kilometres along the northern coast holds good populations of various reef fishes, rock lobsters and other marine life characteristic of the sandy and rocky shores of Auckland's east coast.

Since the park was acquired in 1973, about 400 ha of natural habitats and steep gullies have been progressively retired from grazing, with about 150 ha retained as a working sheep and cattle farm. Some retired areas have been left to regenerate naturally, and other areas, including some wetlands, have been actively revegetated with thousands of ecosourced plants and trees. This revegetation is restoring lost habitats and rebuilding linkages through the landscape.

In the 2002 Regional Parks Management Plan, Tawharanui was identified for development as an open sanctuary to be protected by a pest-proof fence along the park's western boundary. In the mid-1990s, intensive pest control was established in the Hunua Ranges to protect a relict kokako population and at Wenderholm Regional Park to protect nesting kereru. With the experience the ARC gained at Hunua, and in particular at Wenderholm, it was clear that Tawharanui would benefit from so-called mainland island management to protect its natural values, and that this management would enhance the public's enjoyment of an already popular regional park. Elsewhere in New Zealand, DoC and various community groups were also establishing successful mainland islands following big improvements in pest-proof fencing technology and aerial poisoning to remove predatory mammals.

A working group comprising ARC staff and contractors, representatives of the local community and iwi was created to co-ordinate the development of the sanctuary. A specialist open sanctuary co-ordinator was also appointed. A supporters' group, the Tawharanui Open Sanctuary Society Inc. (TOSSI), was also established to assist the ARC to raise funds for the pest-proof fence, and to support and help generally with management of the open sanctuary. Fundraising and volunteer support by TOSSI has been essential to the success of the project. The society has also raised the profile of the sanctuary through its website and newsletters, and its biennial 'Art in the Woolshed' has become a very well attended fundraising event in the local arts calendar.

A 2.5km Xcluder pest-proof fence costing $650,000 was installed across the inner boundary of the park in July 2004, and two aerial poison drops to eradicate pest mammals were carried out in September and October of that year. Although there have been some pest incursions around the coastal fence-ends, the sanctuary remains largely free of the most important predatory mammals such as possums, rats, feral cats and mustelids.

Low pest numbers in the sanctuary quickly resulted in significant recoveries of existing fauna in the park such as shore skinks, tui and kereru. Several locally-extinct species have recolonised, and a number of reintroductions of other missing species have been carried out. Bellbirds, formerly absent from most parts of the Auckland mainland, colonised the park en masse from nearby Little Barrier in early 2005 and are now the second most abundant forest bird, while kaka and grey-faced petrels are also now breeding at Tawharanui after a long absence. Since 2005, green and forest geckos, brown kiwi, pateke, red-crowned kakariki, whiteheads and North Island robins have also been reintroduced. Several species are now so abundant that Tawharanui is being used as a source of fauna for translocations to other sites. Shore skinks have been transferred to Motuora, Motuihe and Tiritiri Matangi, while bellbirds will be transferred from Tawharanui to Motuihe and Waiheke in 2010. Plans are afoot to apply the successful Tawharanui open sanctuary model to Shakespear Regional Park, where Auckland's second predator-fenced open sanctuary will be established.

Photo: Bringing back pateke to Tawharanui. (Source: ARC).

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Photo: The Tawharanui Peninsula. (Source: ARC).

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Case Study: Lake Wainamu

Wainamu is a 14 hectare dune lake located near Bethells Beach on Auckland's west coast. It was formed by a large sand dune that dammed three streams (Plum Pudding, Houghton and Wainamu) and which is now the lake's dominant feature.

Most of the surrounding land is regenerating bush administered by the Queen Elizabeth II National Trust but managed by the ARC. Some pastoral farming is still carried out on the lake's north-eastern perimeter. In summer the lake is a popular spot for swimming and sightseeing, and it is regularly used as a location by film crews.

Unfortunately the lake has been compromised by the introduction of a suite of unwanted fish and aquatic weeds that threaten its recreational and ecological values.

From the mid-1970s the exotic fish rudd, tench and perch were illegally introduced to the lake. Other exotic species introduced include brown bullhead catfish, goldfish and gambusia. Together these fish have caused considerable damage to the lake's ecology, they hunt and compete for food with native fish species and disturb the lakebed through their feeding habits.

It is possible that the invasive aquatic weed *Egeria densa* (oxygen weed) was also introduced to the lake with these illegal fish introductions. Although *Egeria*, which is designated a Surveillance Pest Plant under the Regional Pest Management Strategy, was not recorded in Lake Wainamu prior to 1990 it was likely present at very low levels. By 1995 however, it had become so established that it had colonised the entire available habitat in the lake to 4m depth. Extensive meadows of native charophytes were smothered and reduced to small pockets around the lake, while large surface-reaching swards of *Egeria* extended around much of the lake's shoreline, raising local community concerns about the possibility of swimmers becoming entangled.

By 1996 the lake could no longer support the amount of *Egeria* and the vegetation collapsed, leading to a drastic decline in water clarity. This catastrophic change further heightened community concern for the lake and investigations undertaken in 2001-2003 implicated exotic fish as a contributor to the *Egeria* collapse, while confirming the negative role these fish had on the re-establishment of native aquatic plants.

In order to address the threat of introduced fish to the lake, the ARC instituted a fishing programme in 2004. Since then, over 10,000 fish have been removed from the lake and the water quality has shown a corresponding improvement. The amount and size of exotic fish caught using gill nets has also decreased over this time, indicating that the ongoing fishing pressure is effecting the populations of exotic fish in the lake.

Photo: Lake Wainamu showing dune feature. (Source: ARC).

Photo: NIWA scientists gather weed from Wainamu. (Source: ARC).

As a result of the increase in water clarity, *Egeria* began to re-establish in the lake and its density is now reaching levels seen prior to its collapse in 1996.

To prevent this same boom/bust cycle from repeating itself, ARC staff investigated options to manage *Egeria* within the lake. Mechanical control methods (suction dredging, hand removal by divers or mechanical harvesting) were all discounted as being expensive, logistically difficult and unable to deliver a long-term solution to the problem.

Likewise, chemical control using herbicides was rejected as offering only temporary control, likely to be opposed by the local community and tangata whenua.

The most cost-effective and environmentally-friendly option was the use of biological control, namely the introduction of herbivorous grass carp (*Ctenopharyngodon idella*). It was also the only option that could completely eradicate *Egeria* from the lake, thereby eliminating the need for an ongoing long-term control programme.

Grass carp are native to Asia and have been successfully used to eradicate *Egeria* from a number of water bodies in New Zealand. They are a different species from the pest fish koi carp and are unable to breed in New Zealand, making them suitable for weed control.

In March 2009 we released 270 grass carp into the lake with the approval of DoC, Fish & Game, local community and iwi. Each fish is radio-tagged so their numbers and growth rates can be tracked.

The ARC expects that these fish will completely eradicate *Egeria* from Lake Wainamu within five years, at which point they may be removed. The native vegetation that once dominated will naturally regenerate from the seed bank still present in the lake's sediment, resulting in a more stable and natural ecosystem than has existed recently.

Yearly monitoring of the grass carp and six-monthly weed surveys allow us to track the progress of the lake restoration and assess the effectiveness of the grass carp over time.

This case-study illustrates the complex nature of ecosystems that have been affected by the introduction of exotic pest species, and highlights the need for a range of management solutions to deal with their impacts.

Photo: Grass carp release. (Source: ARC).