Coastal water quality and ecology in the Wellington region

State and trends

greater WELLINGTON
REGIONAL COUNCIL
Te Pane Matua Taiao

Quality for Life

Coastal water quality and ecology in the Wellington region

State and trends

MD Oliver
JR Milne

Environmental Monitoring and Investigations Department

For more information, contact Greater Wellington:

Wellington
PO Box 11646

T 04 384 5708
F 04 385 6960
www.gw.govt.nz

Masterton
PO Box 41

T 06 378 2484
F 06 378 2146
www.gw.govt.nz

GW/EMI-T-12/144
ISBN: 978-1-927217-14-6 (print)
ISBN: 978-1-927217-15-3 (online)

June 2012

www.gw.govt.nz
info@gw.govt.nz

DISCLAIMER

This report has been prepared by Environmental Monitoring and Investigations staff of Greater Wellington Regional Council (Greater Wellington) and as such does not constitute Council policy.

In preparing this report, the authors have used the best currently available data and have exercised all reasonable skill and care in presenting and interpreting these data. Nevertheless, Greater Wellington does not accept any liability, whether direct, indirect, or consequential, arising out of the provision of the data and associated information within this report. Furthermore, as Greater Wellington endeavours to continuously improve data quality, amendments to data included in, or used in the preparation of, this report may occur without notice at any time.

Greater Wellington requests that if excerpts or inferences are drawn from this report for further use, due care should be taken to ensure the appropriate context is preserved and is accurately reflected and referenced in subsequent written or verbal communications. Any use of the data and information enclosed in this report, for example, by inclusion in a subsequent report or media release, should be accompanied by an acknowledgement of the source.

The report may be cited as:

Oliver, MD and Milne, JR. 2012. *Coastal water quality and ecology in the Wellington region: State and trends*. Greater Wellington Regional Council, Publication No. GW/EMI-T-12/144, Wellington.

Main cover photo: Dr Barry Robertson (Wriggle Coastal Management) sampling in the Whareama Estuary

Executive summary

The Wellington region's near-shore coastal environment contains significant habitats for a wide variety of plants and animals, and also provides for a diverse range of human activities and values. In 2004, Greater Wellington commenced investigations and, subsequently, long-term monitoring of sediment quality and ecological health at a selection of these habitats, focussing on estuaries, harbours and sandy beaches. This report summarises the results of this monitoring, along with the results of microbiological water quality monitoring undertaken between July 2006 and June 2010.

Monitoring results indicate that most coastal environments in the Wellington region are generally in good condition. Microbiological contamination of coastal waters was low at the majority of the 77 sites monitored and shellfish flesh monitoring in early 2006 did not identify any significant microbiological or trace contaminant issues. However, there are some 'hot spots', principally coastal waters near urban areas, where faecal indicator bacteria counts are elevated at times as a result of stormwater discharges and sewage leaks/overflows.

All five estuaries monitored to date are considered to be in 'moderate' health – despite most having experienced extensive loss or modification of their intertidal habitat. While toxicant contamination is not a significant issue for any of the estuaries (localised contamination of sediments exists in some, notably at the southern end of the Onepoto Arm of Porirua Harbour), most show some 'early warning' signs of stress from either sedimentation or nutrient enrichment. Lake Onoke, and the Whareama and Waikanae estuaries in particular, have excessive sedimentation rates and a high mud content within their sediments. In Porirua Harbour, monitoring between 2008 and 2011 showed a decrease in the depth of oxygenated sediment across all four monitoring sites, coupled with an increased presence of opportunistic benthic invertebrate species tolerant of moderate levels of mud and organic enrichment. Porirua Harbour, along with the Hutt River Estuary, also has macroalgal cover present at nuisance levels in places.

The subtidal sediments in parts of both Porirua Harbour and Wellington Harbour contain several heavy metals, polycyclic aromatic hydrocarbons and Total DDT at concentrations above 'early warning' ANZECC (2000) and Auckland Regional Council (2004) sediment quality guidelines. The areas with the highest contaminant concentrations are located closest to Porirua city (ie, the Onepoto Arm) and Wellington city (eg, Evans Bay and the entrance to Lambton Basin) which receive the greatest inputs of urban stormwater, either directly or by way of urban streams. There is currently no clear evidence that any of the subtidal sediment contamination has resulted in significant adverse effects on invertebrate communities at any of the monitoring sites. However, the combination of higher heavy metal, mud and organic carbon content at some sites is linked with a less diverse community structure. Furthermore, adverse effects may eventuate in the future if contaminants continue to accumulate. This is considered highly likely if the current quality of stormwater discharges is not improved.

Generally, the condition of sandy beaches in the Wellington region is good. The intertidal sands are characterised by well oxygenated sands, low concentrations of nutrients and heavy metals, and benthic invertebrate assemblages that are typical of exposed beach environments.

Overall, alongside more global pressures – such as climate change, sea level rise and the spread of invasive species – sedimentation, eutrophication, and microbiological and toxicant contamination are significant issues for many coastal environments in the Wellington region, particularly the region's estuarine environments. With further urban development and intensification of rural land use expected in some parts of the region in the future, comprehensive integrated catchment management plans will be required that address sediment erosion and runoff, nutrient loss, and increasing pressure on sewer and stormwater infrastructure.

Contents

1. Introduction

Greater Wellington Regional Council (Greater Wellington) has a responsibility to manage and monitor the Wellington region's near-shore coastal environment; the area extending from mean high water springs to 12 nautical miles offshore. This near-shore environment contains significant habitats for a wide variety of plants and animals, and also provides for a diverse range of human activities and values. In 2004, Greater Wellington commenced monitoring water quality, sediment quality and ecological health at a selection of these habitats as part of its coastal monitoring programme.

This report summarises the results of near-shore monitoring and investigations undertaken in coastal waters in the Wellington region, focussing primarily on routine data collected over the period January 2004 to December 2011. This coastal monitoring forms part of Greater Wellington's larger programme of state of the environment monitoring, a specific requirement of regional councils under Section 35(2)(a) of the Resource Management Act (RMA) 1991.

1.1 Report purpose

This technical report is one of eight covering air, land and water resources prepared with the primary purpose of informing the review of Greater Wellington's five regional plans. These plans were established to sustainably manage the region's natural resources, including coastal waters. The review of the regional plans follows the recently completed review of the overarching Regional Policy Statement (RPS) for the Wellington region (GWRC 2010).

The focus of the eight technical reports is on providing an up-to-date analysis of monitoring information on state and trends in resource health as opposed to assessing the effectiveness of specific policies in the existing RPS (WRC 1995) or regional plans. Policy effectiveness reports were prepared in 2006 following the release of Greater Wellington's last formal State of the Environment (SoE) report, *Measuring up* (GWRC 2005).

The last technical reports supporting SoE reporting on coastal waters in the Wellington region were prepared by Milne (2005) and Sherriff (2005) and covered recreational water quality and baseline coastal investigations, respectively[1].

1.2 Report scope

The report summarises coastal water quality, sediment quality and ecological data Greater Wellington has collected across various beaches, estuaries and harbours in the Wellington region. The data available are limited to only a few surveys of most of these coastal habitats, reflecting the relatively recent introduction of much of the monitoring. As a result, this report focuses more on the state of the region's coastal habitats than temporal trends in their condition.

Note that the suitability of coastal waters for contact recreation purposes is assessed separately under Greater Wellington's recreational water quality monitoring programme (see Greenfield et al. 2012).

---

[1] Greater Wellington also prepares annual summary reports documenting the results of SoE monitoring and targeted investigations. Refer to Milne (2010a) for the most recent annual coastal monitoring report.

1.3 Report outline

The report comprises nine sections:

- Section 2 briefly outlines Greater Wellington's coastal monitoring programme, monitoring variables, and relevant indicators and guidelines.
- Section 3 provides an overview of the region's coastal environments and the key 'local' factors that influence coastal water quality and ecology.
- Section 4 presents a brief analysis of the microbiological water quality of the region's coastal waters, and summarises the results of the most recent round of shellfish flesh contaminant monitoring.
- Section 5 focuses on the region's estuaries, summarising the results of intertidal ecological monitoring undertaken at selected estuaries.
- Section 6 summarises the key findings of subtidal sediment quality and benthic ecology monitoring undertaken in Porirua and Wellington harbours.
- Section 7 provides a brief overview of sandy beach ecological monitoring in the region, focusing in particular on Greater Wellington's long-term monitoring at Castlepoint Beach.
- Section 8 revisits the main findings from Sections 4 to 7, and briefly discusses the key issues affecting the health of the region's coastal ecosystems. Monitoring limitations and knowledge gaps are also outlined.
- Section 9 presents conclusions and recommendations.

1.4 Terms and definitions

A number of environmental variables, reference documents and organisations have been abbreviated in this report. Generally, the names are mentioned in full on their first use in each section. The principal acronyms used are listed in Table 1.1.

Table 1.1: List of main abbreviations used in this report

Acronym	Definition	Acronym	Definition
ANZECC	Australia and New Zealand Environment and Conservation Council	MfE	Ministry for the Environment
ERC	Environmental Response Criteria	MoH	Ministry of Health
ISQG	Interim Sediment Quality Guideline	NIWA	National Institute of Water & Atmospheric Research
OCPs	Organochlorine pesticides	SoE	State of the Environment
PAHs	Polycyclic Aromatic Hydrocarbons	WWTP	Wastewater treatment plant

2. Overview of coastal monitoring in the Wellington region

2.1 Background

Coastal monitoring in the Wellington region began over 20 years ago, with a focus on microbiological water quality, reflecting the high use of the region for swimming, surfing and other forms of recreation. Periodic assessments of contaminants in shellfish flesh commenced around 1997, with the most recent assessment undertaken at 20 sites in 2006. In 2004 baseline monitoring was extended to coastal ecology and sediment quality, with a key focus being to monitor the effects of urban stormwater discharges on Porirua and Wellington harbours. Also in 2004, work commenced on mapping the types of substrate and vegetation of the region's river estuaries and sandy beaches. The purpose of this broad scale habitat mapping was to provide a baseline map against which changes in the size and extent of different habitats could be monitored through time. Selected sites were also chosen for fine scale sediment and ecological monitoring to assess the health of representative intertidal and shallow subtidal habitats that provide significant ecosystem services to the region and are exposed to increasing anthropogenic threats and pressures. Ecological vulnerability assessments incorporated into the broad scale surveys from 2006 helped identify priority coastal environments to be included in Greater Wellington's long-term SoE coastal monitoring programme.

2.2 Monitoring objectives

The aims of Greater Wellington's coastal monitoring programme are to:

1. Assist in the detection of spatial and temporal changes in near-shore coastal waters;

2. Contribute to our understanding of coastal biodiversity in the region;

3. Determine the suitability of coastal waters for designated uses;

4. Provide information to assist in targeted investigations where remediation or mitigation of poor water quality is desired; and

5. Provide a mechanism to determine the effectiveness of regional plans and policies.

The suitability of coastal waters for contact recreation purposes is assessed separately under Greater Wellington's recreational water quality monitoring programme (see Greenfield et al. 2012).

2.3 Monitoring sites and frequency

Details on microbiological water quality monitoring are outlined in Greenfield et al. (2012), with the location of the 77 monitoring sites discussed in this report shown in Figure 4.1 (Section 4.1) and listed in Appendix 1. In terms of coastal ecological monitoring, aside from broad scale habitat mapping which applies to the intertidal coastline region-wide and is intended to be repeated every 5–10 years, the core monitoring sites are located in Porirua and Wellington harbours, Waikanae, Hutt and Whareama estuaries, Castlepoint

Beach, and Lake Onoke (Figure 2.1, Appendix 1). There are currently two ecology-based monitoring programmes for Porirua Harbour – one focuses on the dominant intertidal habitat and the other focuses on the muddier subtidal basin habitat. Since January 2011, physico-chemical water quality has also been monitored in Porirua Harbour.

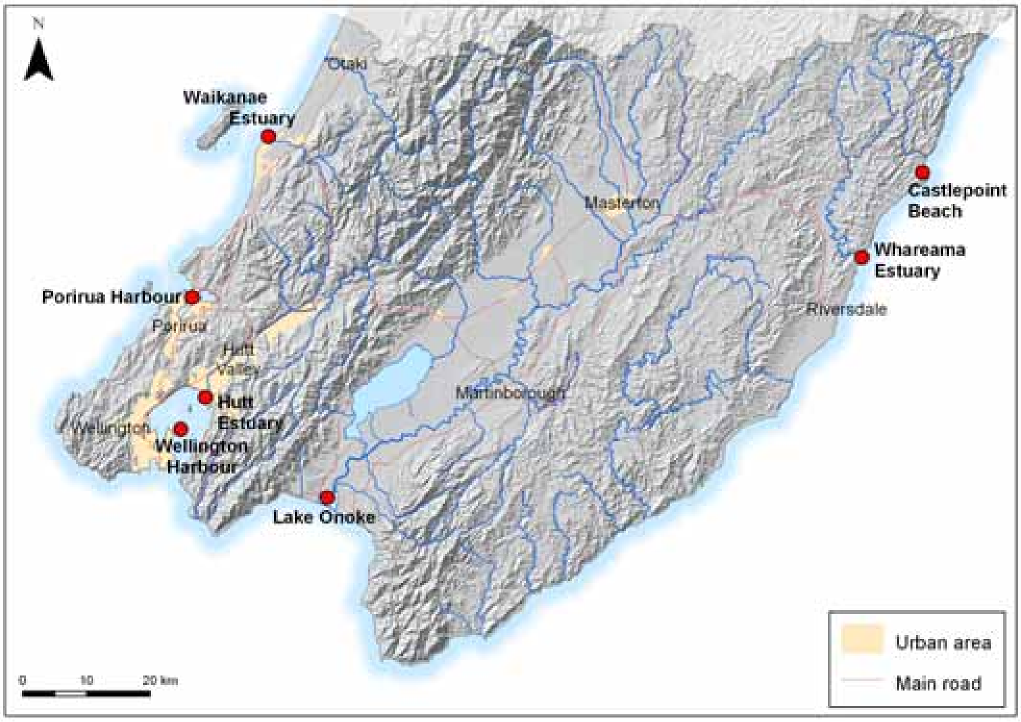


Figure 2.1: Map of the current core estuary, harbour and beach ecological monitoring sites in the Wellington region as at December 2011

Monitoring frequency varies across the sites, depending on the nature of the receiving environment, the purpose of monitoring and what the results indicate. The general approach is to monitor beach and estuary sites annually for three to four years to establish a baseline, with monitoring then reducing to five-yearly unless specific issues have been identified that warrant more frequent monitoring (eg, sedimentation in Whareama Estuary). In contrast, subtidal monitoring in Porirua Harbour and Wellington Harbour is only being undertaken two-yearly and five-yearly, respectively. This largely reflects the focus of the subtidal harbour programmes – measuring the accumulation of stormwater-related contaminants in harbour bed sediments (see Section 2.4.4).

2.4 Monitoring variables and protocol

The basic approach to monitoring coastal microbiological water quality, ecological condition of the region's estuaries and sandy beaches, and subtidal harbour sediment quality and ecology is outlined below. More detail is provided within Sections 4 to 7. Analytical methods are provided in Appendix 2.

2.4.1 Microbiological water quality

Microbiological water quality monitoring is undertaken in accordance with the 2003[2] Ministry for the Environment (MfE) and the Ministry of Health (MoH) microbiological water quality guidelines for marine and freshwater recreational areas. These guidelines (often more simply referred to as the recreational water quality guidelines) use bacteriological indicators associated with the gut of warm blooded animals to assess the risk of faecal contamination and therefore the potential presence of harmful pathogens[3]. In coastal waters, which are generally sampled weekly during the summer bathing season (November to March inclusive) and monthly during the remainder of the year, the recommended indicator is enterococci (with faecal coliforms the preferred indicator for shellfish gathering waters). Refer to Greenfield et al. (2012) for full details of Greater Wellington's microbiological water quality monitoring methods.

2.4.2 Estuaries

The broad and fine scale surveys undertaken in the region's estuaries to date have been based on the National Estuary Monitoring Protocol (Robertson et al. 2002) and recent extensions to these developed by Wriggle Coastal Management (eg, Robertson & Stevens 2008b; Stevens & Robertson 2008). The fine scale surveys, which are the main focus of Section 5 of this report, target the dominant intertidal habitat and three of the five core indicators of estuarine ecosystem health: sedimentation, eutrophication (nutrient enrichment) and toxic contamination (Table 2.1). The remaining two indicators are habitat loss and disease risk, which are assessed through periodic broad scale surveys and Greater Wellington's microbiological water quality programme (see Section 2.4.1), respectively. As outlined below, broad scale surveys also provide information relevant to assessing sedimentation and nutrient enrichment.

Broad scale monitoring involves defining the dominant habitats and features of an area and developing baseline maps with a combination of aerial photography, ground-truthing and digital mapping using GIS technology. The area boundaries are first defined at a scale appropriate for baseline monitoring, before vegetation (eg, saltmarsh, seagrass) and substrate types (eg, gravel, coarse sand, mud) are mapped (Figure 2.2) (Robertson et al. 2002). Although broad scale surveys of the Wellington region's coastline have only been undertaken once to date (between 2004 and 2007), at a more local scale, broad scale assessments of macroalgae cover have been undertaken annually across most of the estuaries in Greater Wellington's coastal monitoring programme. The data from these surveys is being used alongside information from the fine scale monitoring to assess nutrient enrichment.

Fine scale monitoring generally takes place at one or two locations (sites) within an estuary that are selected to be representative of the dominant (generally intertidal) habitat present. Each site is assessed for a suite of environmental characteristics that are indicative of estuary condition and will provide a means for detecting future change (Table 2.1) (Robertson et al. 2002). Refer to Section 5 and Table A3.2 (Appendix 2) for further detail on the specific variables and methods.

---

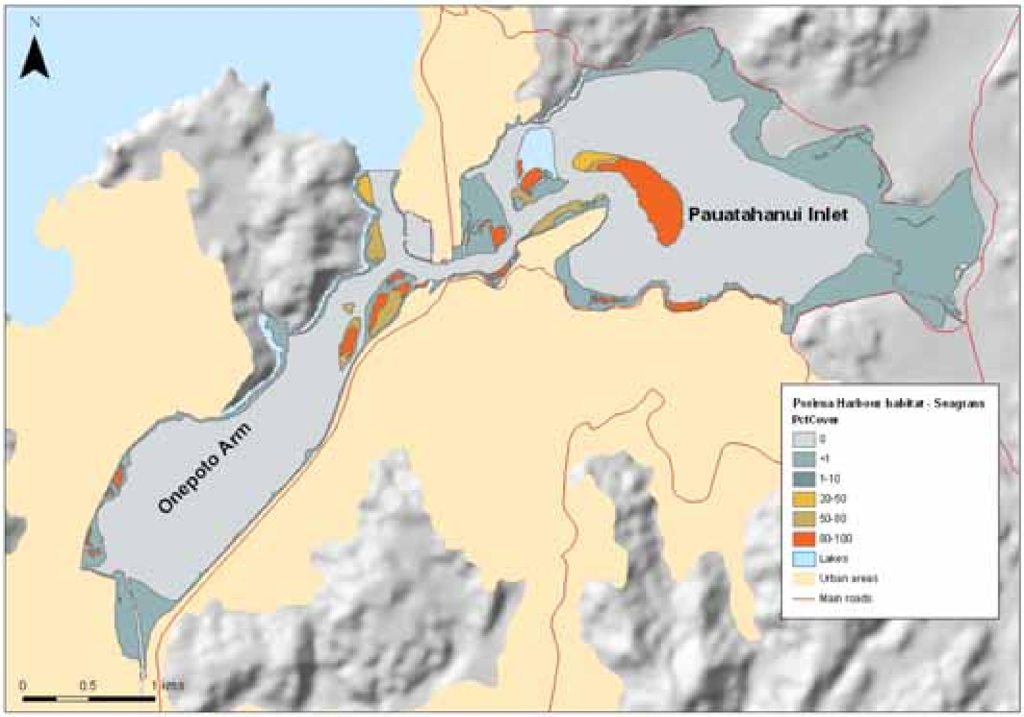
[2] The guidelines were published in June 2002 and updated in June 2003.

[3] Indicator bacteria are monitored because individual pathogenic organisms (eg, salmonella, campylobacter, cryptosporidium, and giardia) are often present in very low numbers, can be hard to detect, and the analytical tests are expensive (Milne 2005).

Table 2.1: Key broad scale (BS) and fine scale (FS) indicators used to assess estuarine condition in the Wellington region. Many of the indicators in the table are also applicable to assessing beach condition (Section 2.4.4).

(Source: Adapted from Robertson & Stevens (2008b); Stevens & Robertson (2008))

Issue	Indicator	Indicator type	Rationale
Sedimentation	Soft mud area	BS	Estuaries are a natural sink for catchment-derived sediment but if sediment inputs are excessive, estuaries infill quickly with muds, reducing biodiversity and human values and uses. In particular: - muddy sediments have a higher tendency to become anoxic and anoxic sediments contain toxic sulphides and very little aquatic life. - elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse.
	Sediment composition (% mud)	FS	
	Sedimentation rate	FS	
	Diversity of benthic fauna	FS	Soft sediment macrofauna can be used to represent benthic community health in relation to the extent of mud tolerant organisms compared with those that prefer sands.
Eutrophication (nutrient enrichment)	Nuisance macroalgae cover	BS	Mass blooms of green and red macroalgae, mainly of the genera *Enteromorpha, Cladophora, Ulva,* and *Gracilaria,* can present a significant nuisance problem, especially when loose mats accumulate and decompose. Algal blooms also have major ecological impacts on water and sediment quality, such as reduced clarity, physical smothering and lack of oxygen, and can displace estuarine animals.
	Organic content	FS	High sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients, and adverse impacts on biota.
	Sediment nutrient concentrations: • Nitrogen • Phosphorus	FS	In shallow estuaries the sediment compartment is often the largest nutrient pool in the system, and nutrient exchange between the water column and sediments can play a large role in determining trophic status and stimulating the production and abundance of fast-growing algae, such as phytoplankton and short-lived macroalgae (eg, sea lettuce).
	Sediment oxygenation (RPD depth)	FS	Surface sediments need to be well oxygenated to support healthy invertebrate communities (anoxic sediments contain toxic sulphides and very little aquatic life).
	Diversity of benthic fauna	FS	Soft sediment macrofauna can be used to represent benthic community health and classify estuary condition.
Toxic contamination	Sediment contamination – eg, concentrations of: • heavy metals • PAHs • pesticides	FS	Many chemicals discharged to estuaries via urban and rural runoff are toxic, even at very low concentrations. These chemicals can accumulate in sediments and bioaccumulate in fish and shellfish, causing health risks to people and marine life.
	Diversity of benthic fauna	FS	Soft sediment macrofauna can be used to represent benthic community health and classify estuary condition.
Habitat loss	Saltmarsh area	BS	Estuaries function best with a large area of rooted vegetation (ie, saltmarsh and seagrass), as well as a healthy vegetated terrestrial margin. Loss of this habitat reduces ecological, fishery and aesthetic values, and adversely impacts on an estuary's role in flood and erosion protection, contaminant mitigation, sediment stabilisation and nutrient cycling.
	Seagrass area	BS	
	Vegetated terrestrial buffer	BS	



(Source: Stevens & Robertson 2008, p15)

Figure 2.2: Example of broad scale habitat mapping undertaken in early 2008 to assess seagrass cover in Porirua Harbour

Along with annual estuary-scale mapping of macroalgae cover to complement the fine scale assessments of estuary condition, another extension of the tools included in the National Estuary Monitoring Protocol (Robertson et al. 2002) has been the use of sedimentation monitoring plates to measure sedimentation rates at specific locations within each estuary. Such plates have been deployed at several locations across four of the region's estuaries to date (see Section 5).

2.4.3 Harbours

Greater Wellington's harbour monitoring programme focuses on the impacts of urban-derived stormwater contaminants on subtidal sediment quality and benthic ecology. The design of the programme followed initial advice from the National Institute of Water and Atmospheric Research Limited (NIWA) and was modelled on the programme used to assess intertidal sediment contamination in harbours in the Auckland region (Ray et al. 2003). At each monitoring site sediment core samples are collected (along with 'benthos' sediment core samples) and analysed for a suite of persistent and toxic sediment contaminants associated with urban stormwater discharges, including heavy metals, polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCPs) and organotin compounds associated with anti-fouling products. Supporting sediment variables that assist with the interpretation of these contaminants and the health of the benthic fauna community are also monitored, namely particle size and total organic carbon. Refer to Section 6 for further details (and Table A2.4 of Appendix 2 for details of the analytical methods).

2.4.4 Sandy beaches

There is currently no nationally recognised protocol for ecological monitoring of sandy beaches. The monitoring methods employed at Castlepoint Beach were devised by Robertson and Stevenson (2008a) based on an approach taken by Aerts et al. (2004) for monitoring a sandy beach in Ecuador. Six stations are sampled along two transects that span from high to low tide, with the following fine scale variables measured at each station: sediment particle size, sediment oxygenation, and benthic fauna abundance and diversity (see Section 7). Other fine scale indicators relating to eutrophication and sediment contamination are not monitored at Castlepoint because this beach has no major nutrient or toxic contaminant inputs.

2.5 Guidelines and reporting protocol

With the exception of microbiological water quality, there is very little national guidance available for assessing the quality of coastal environments in New Zealand[4], particularly in terms of ecological health. For estuarine environments, Wriggle Coastal Management have developed their own set of ‘condition indices’ or ‘ratings’ (Appendix 3), based on a combination of expert opinion from extensive monitoring of estuaries across much of New Zealand and consideration of international literature (eg, the toxicity component of their ratings draws on the trigger values for toxicants outlined in the ANZECC (2000) Interim Sediment Quality Guidelines (ISQG)).

In terms of subtidal sediment quality monitoring in Porirua and Wellington harbours, sediment contaminant results to date have been compared against both the ANZECC (2000) ISQG and the Auckland Regional Council’s (2004) Environmental Response Criteria (ARC ERC). These guidelines are generally considered to be reasonably robust and conservative (ie, they err on the side of environmental protection). They are not ‘pass or fail’ numbers[5]; they are set at the concentrations which experimental and/or field evidence suggests are likely to result in impacts on aquatic life. The ANZECC (2000) guidelines, and other international sediment quality guidelines on which they are based (ie, Long & Morgon 1990), provide ‘low’ (effectively alert) and ‘high’ values:

1. ANZECC ISQG-Low trigger values – nominally indicative of the contaminant concentrations where the onset of biological effects could possibly occur. These values provide an ‘early warning’, enabling management intervention to prevent or minimise adverse environmental effects.

2. ANZECC ISQG-High trigger values – nominally indicative of the contaminant concentrations where significant biological effects are expected. Exceedance of these values therefore indicates that adverse environmental effects are probably already occurring, and management intervention may be required to remediate the problem.

---

[4] The ANZECC (2000) guidelines lack specific guidance for New Zealand’s coastal waters (see Section 8.4 for further discussion).

[5] The developers of the guidelines emphasise that they are best used as one part of a ‘weight of evidence’ approach to evaluating potential effects of contaminants on benthic biota (Stephenson & Mills 2006).

The ARC's (2004) ERC are also based on 'low' (amber) and 'high' (red) criteria, derived from the Threshold Effect Levels (TEL) and Effects Range Low (ERL) values (with rounding) of MacDonald et al. (1994) and Long and Morgan (1990), respectively (Kelly 2007). These guidelines provide a conservative, yet practical[6] early warning of environmental degradation which allows time for investigations into the causes of contamination to be carried out and the options for limiting the extent of degradation to be developed (Auckland Regional Council 2004; Kelly 2007).

---

[6] Some of the ANZECC (2000) guideline values are not practical. For example, the organochlorine pesticide dieldrin has an ISQG-Low value of 0.02 µg/kg, which is below the analytical detection limits of almost all laboratories, and probably represents a level that would be present at most rural and urban estuaries in New Zealand (Stephenson & Mills 2006).

3. Coastal waters of the Wellington region

This section provides a brief overview of the coastal environments of the Wellington region, including coastal areas of outstanding conservation value. The key pressures on the region's coast are also outlined, with the focus being on pressures that are relevant locally, such as recreational and commercial fishing, land use intensification, wastewater and stormwater discharges, erosion, dredging and power generation.

3.1 Coastline

The coastline of the Wellington region is almost 500 km long and stretches from north of Otaki on the west coast, south through Cook Strait, and north along the eastern Wairarapa coast to north of Castlepoint (Figure 3.1). The region's coastline is a high energy environment dominated by the strong tidal flows of Cook Strait (Rosier & Hastie 1992) which deliver nutrient-rich deep-ocean waters to the continental shelf.

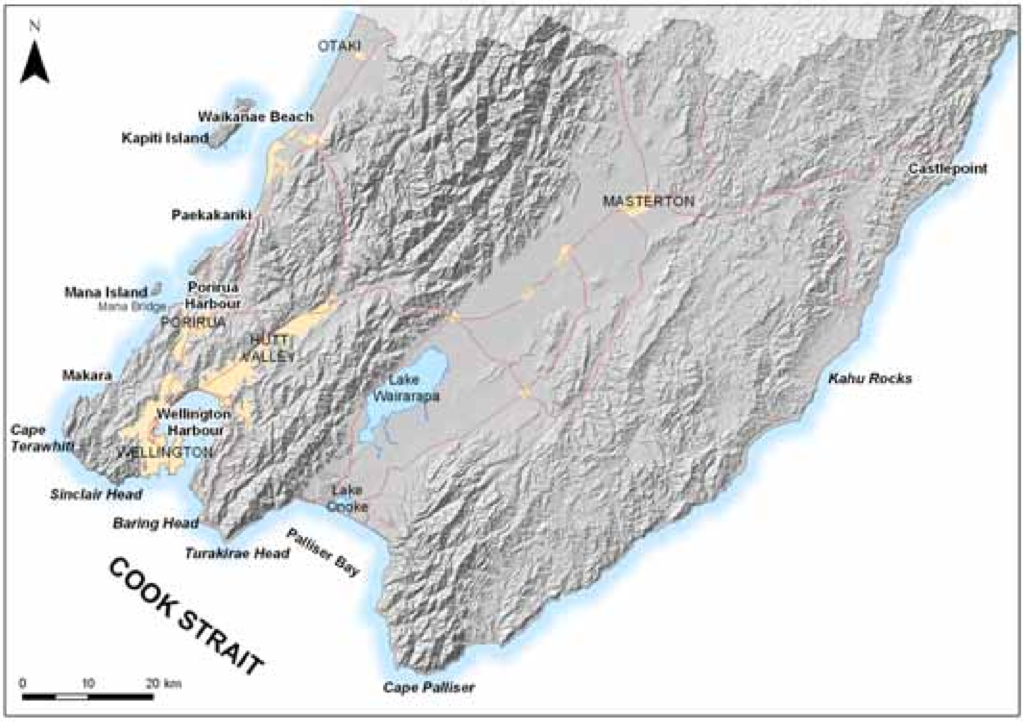


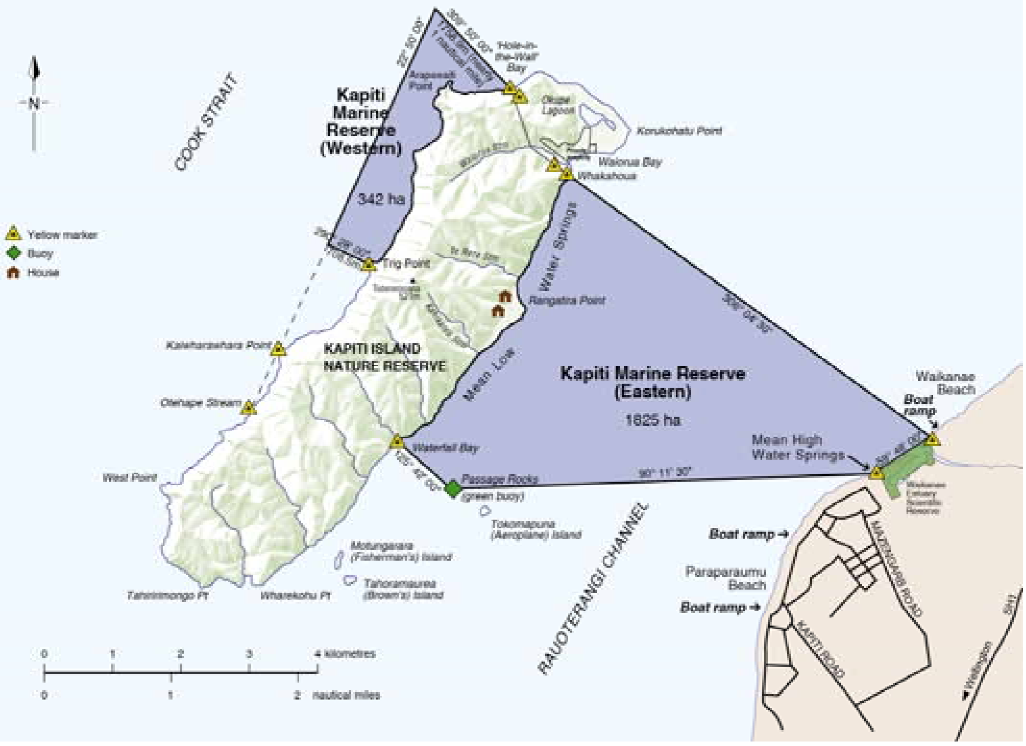
Figure 3.1: Coastal areas of the Wellington region

The near-shore coastal environment supports several coastal habitat types, including two harbours (Porirua and Wellington), more than 90 estuaries, extensive sandy beaches, dunes and rocky shores (Robertson & Stevens 2007a; 2007c). All of these habitat types sustain valuable ecosystem goods and services, such as recreation, tourism, food gathering, climate and natural hazard regulation, and collectively function as fish or bird nursery areas and hotspots of biodiversity.

The west coast from Otaki to Paekakariki is characterised by an open, flat sandy coastline backed by broad and extensive duneland (Stevens & Robertson 2006). Extending offshore from Waikanae Beach and cloaking the northern half of Kapiti Island itself, is the Kapiti Island Marine Reserve (Figure 3.2). This nationally significant reserve links the Kapiti Island Nature Reserve and the Waikanae Estuary Scientific Reserve, creating a rarely-found continuum of protected land, sea and estuary (Figure 3.3).

(Source: Matt Velde, GWRC)

Figure 3.2: Looking out to Kapiti Island from the open, flat beaches of Waikanae



(Source: DoC)

Figure 3.3: Map of Kapiti Island marine reserve

The coastline south of Paekakariki to Cape Terawhiti is exposed and rocky with pocket beaches of coarse sand and cobbles and some medium high cliffs (Figure 3.4) (Rosier & Hastie 1992). There are open rocky intertidal habitats and shore platforms dominated by encrusting invertebrates and brown algae. The currents are strong and increase in strength towards the south.

(Source: Matt Velde, GWRC)

Figure 3.4: Pukerua Bay, south of Paekakariki, is typical of the south-western coastline, being characterised by cobble beaches, rocky outcrops and moderately high cliffs

The south coast of the Wellington region, extending from Cape Terawhiti to Cape Palliser, is predominantly a continuation of the high rocky cliffs and narrow steep pebble and boulder beaches which characterise the lower west coast (Robertson & Stevens 2007a; Rosier & Hastie 1992). This exposed coast has the highest tidal currents in the region (reaching 13 km/h) and the greatest water depths, plummeting to over 1,000 m depth within kilometres of the shore. The New Zealand fur seal haulout area at Sinclair Head is of regional importance (WRC 2000) and the coast also supports breeding colonies of variable oystercatcher, southern black-backed gull and the black shag (Rosier & Hastie 1992).

On the south coast of the North Island between Sinclair Head and Baring Head lies the hub of the region’s urban activity, Wellington Harbour (Figure 3.5). The harbour is a large basin, 10–30 m deep, the main tributary of which is the Hutt River (Robertson & Stevens 2007a). The harbour is a vital shipping port in the region and provides numerous ecosystem services and functions to the cities that surround it. The harbour is highly utilised for boating, windsurfing, swimming, fishing, scientific research and diving. Wellington Harbour has a muddy central basin with rocky or gravel margins, with the exception of the sandy Petone Beach at the mouth of the Hutt River (Robertson & Stevens 2007a).

(Source: Juliet Milne)

Figure 3.5: Wellington Harbour from the suburb of Brooklyn

In contrast to the hard edged rocky habitats of the southern coastline, is Palliser Bay which lies southeast of Wellington Harbour and forms a large embayment of steep coarse sand and pebble beaches backed by low mudstone cliffs. The bay is pounded by heavy southerly swells and is too dynamic for most intertidal organisms (Rosier & Hastie 1992). Centred in Palliser Bay is Lake Onoke, a brackish intermittently open/closed coastal lake estuary fed by the Ruamahanga River (Figure 3.6). Lake Onoke is listed in Greater Wellington's Regional Coastal Plan (WRC 2000) as an area of significant conservation value for its indigenous fish, plant and animal communities (Perrie & Milne 2012).

(Source: GWRC)

Figure 3.6: Lake Onoke is a coastal lake estuary and the receiving environment for drainage from the entire Wairarapa Valley

The east coast from Cape Palliser, north to the regional boundary at Mataikona, just north of Castlepoint, is characterised by soft rock platforms or gently sloping sandy beaches dotted with estuaries and reef systems (Figure 3.7). New Zealand fur seals haulout on the Kahau Rocks, south of Riversdale, and the surrounding beaches in winter (Rosier & Hastie 1992).

(Source: Wriggle Coastal Management)

Figure 3.7: Looking south along Castlepoint Beach on the eastern Wairarapa Coast

3.2 Estuaries

The coastline of the entire Wellington region is interspersed with more than 90 estuaries that can be broadly categorised into one of four types: tidal lagoon estuaries (eg, Porirua Harbour), tidal river mouth estuaries (eg, Waikanae Estuary), tidal river estuaries (eg, Whareama River), and coastal lake estuaries (eg, Lake Onoke). The vast majority (85%) of the region’s estuaries are small river mouth or tidal lagoon estuaries with three moderate to large-sized estuaries between Kapiti and Wellington and 14 moderate-sized estuaries along the Wairarapa coastline (Robertson & Stevens 2007a; 2007c).

All of the estuaries that form part of Greater Wellington’s coastal monitoring programme have been degraded to some degree by historical loss of high value habitat. For example, the Hutt and Waikanae estuaries, along with Porirua Harbour and Lake Onoke, have been extensively modified through drainage, reclamation, diversion and ongoing loss of connectivity with neighbouring water bodies (Figure 3.8). With the exception of the Pauatahanui Arm of Porirua Harbour, high value habitats such as saltmarsh, tidal flats and seagrass beds are virtually absent; this has lowered the ability of these estuaries to function as habitats for fish, invertebrates and birds, and has reduced water and sediment quality (Robertson & Stevens 2007a; 2007c).

(Source: Wriggle Coastal Management)

Figure 3.8: The Hutt Estuary (left) and Waikanae Estuary (right) have both been modified heavily by reclamation and diversion

3.3 Conservation areas

The Wellington region has a number of coastal conservation areas (Table 3.1), including two marine reserves: the Kapiti Marine Reserve (2,167 ha) extending offshore from Waikanae and encompassing the Kapiti Island Nature Reserve and the Waikanae Estuary Scientific Reserve; and the Taputeranga Marine Reserve (854 ha) on Wellington city's south coast. There is one taiapure located in Palliser Bay; a designated area in which the local Maori community may propose regulations for the sustainable management of culturally important seafood resources. There are also four Areas of Significant Conservation Value (ASCV), including Pauatahanui Inlet, Lake Onoke, Waikanae Estuary Scientific Reserve and Castlepoint, and 20 Areas of Important Conservation Value (AICV) (see Appendix 2 and 3 of Greater Wellington's Regional Coastal Plan (WRC 2000) for details).

Table 3.1: Conservation areas of the Wellington region, sourced from the Greater Wellington Regional Coastal Plan (WRC 2000)

Name	Protection	Value
Kapiti Marine Reserve	Marine Reserve	Conservation, scenic, natural and scientific values, unique combination of habitats, flora and fauna.
Taputeranga Marine Reserve	Marine Reserve	Conservation, scenic, natural and scientific values, unique combination of habitats, flora and fauna.
Palliser Bay Taiapure	Taiapure	Contains food species that are of particular importance to local Maori.
Waikanae Estuary Scientific Reserve	Area of Significant Conservation Value	A range of important habitats for indigenous plant and animal species. A nationally significant wetland.
Pauatahanui Inlet	Area of Significant Conservation Value	Seagrass and saltmarsh habitats; nationally important for migratory shorebirds and wading birds; migratory freshwater fish, nursery area[1] and rich invertebrate fauna.
Lake Onoke	Area of Significant Conservation Value	Wildlife and conservation value, breeding ground for threatened bird and fish species.
Castlepoint	Area of Significant Conservation Value	Conservation, scenic, geological and scientific values; nesting area for numerous seabirds and visited by marine mammals.

[1] Porirua Harbour (including Pauatahanui Inlet) has recently been classified nationally as a 'high value' nursery ground for juvenile rig shark *(Mustelus lenticulatus)*, (Francis et al. 2012)

3.4 Pressures and threats

Many activities in the coastal environment cause little or no adverse effects on the habitat or plants and animals that live there. However, the cumulative effects of individual or otherwise insignificant developments or uses can place stresses on the environment. This can increase the vulnerability of that environment or habitat through degradation, and loss of habitat or ecosystem function. As the coastal environment is the ultimate receiving environment for everything that occurs on the land, many of the activities that impact on fresh waters will also, ultimately, impact on coastal waters. Harbours and estuaries in particular, often serve as ‘sinks’ for sediment, nutrient and toxic contaminants generated off the land and/or discharged to surface waters.

Aside from far reaching and global impacts such as rising sea temperatures, ocean acidification, population growth and the spread of invasive species, there are several more localised pressures on Wellington’s coastal environments. Stevens and Robertson (2006) concluded that the most significant impact along the western coastline was the loss of valuable marginal habitat associated with residential development and erosion control. They deemed this impact particularly significant because of the near irreversible nature of the changes. Other local pressures and threats include recreational and commercial fishing, land use intensification, wastewater and stormwater discharges, erosion, and dredging. Electricity generation in the form of tidal energy may be a future pressure for the region.

3.4.1 Recreational and commercial fishing

Recreational and commercial fishing are vitally important in the Wellington region and include shellfish and finfish fisheries for four of New Zealand’s largest commercial fish resources: hoki, rock lobster, paua and orange roughy. The Wellington region spans two fisheries management areas (FMA8 and FMA2) and although it is difficult to extract an exact export value for fisheries in the region, it can be estimated at more than $150 million dollars[7] per year. While there is a clear economic and resource demand for fishing, there are also environmental issues such as habitat and ecological destruction, incidental bycatch of non-target species, and overfishing. In Pukerua Bay (north of Porirua), for example, localised depletion of several valuable fisheries species, particularly paua and kina, led Ngati Toa with the support of local residents, to seek a ban on all fishing, except hand-held lines. The Ministry of Fisheries subsequently imposed the first temporary fisheries ban in 2002, followed by a series of extensions to the ban and in 2009, the implementation of a five-year fishing prohibition[8].

3.4.2 Land use intensification

Like many other areas in New Zealand, parts of the Wellington region have undergone significant land use intensification in recent decades. This is notable in both urban and rural areas, and is primarily attributed to population growth and intensification of dairying, respectively.

---

[7] Estimated from statistics provided on the Ministry for Primary Industries website, www.fish.govt.nz (accessed on 5 June 2012).

[8] See http://www.fish.govt.nz/NR/rdonlyres/CAB02298-B631-403B-9FEC-5E9A4C066DD9/0/Pukerua_Bay_closure_2010_updated.pdf

Although urban areas occupy only 2.4% of the region's land area (Sorensen 2012), these areas are concentrated mainly on the western side of the region around Wellington city, Porirua and the Hutt Valley, within which there has been considerable growth over the last decade (eg, Statistics NZ census data indicate that Wellington city's population grew 9.5% between 2001 and 2006 alone)[9]. Some of the highest population growth has occurred in the northern suburbs of Wellington city, which has resulted in significant re-zoning and clearance of low producing pasture and bushland for residential subdivision and development. Average growth in the number of new dwellings in the northern suburbs between 1996 and 2001 was 7.8% compared with 5.2% in Wellington city overall (Wellington City Council 2003). The increase in population growth in this area has placed increasing pressure on existing infrastructure, in particular wastewater and stormwater networks in neighbouring Porirua city (J Saywell[10], pers. comm. 2012).

Close to half of the 812,000 ha area of the Wellington region is in pasture, making agriculture (on a regional basis at least) an important industry. Sorensen (2012) identified that while there are still significantly more sheep than all other livestock in the region, sheep numbers have reduced consistently since 1990. In contrast, beef cattle and deer numbers remained reasonably consistent while dairy cattle increased significantly – from 62,521 in 1990 to 92,375 in 2010[11]. Although dairying is not particularly significant in terms of proportion of the Wellington region's overall land area, it is a very significant land use in some parts of the region, notably in the districts of Carterton and South Wairarapa. Continuing intensification of dairying in these areas, including agriculture in general across the wider Wairarapa Valley, has potential flow on effects for Lake Onoke (and Palliser Bay), which is the ultimate receiving environment for drainage from the entire Wairarapa Valley.

3.4.3 Wastewater and stormwater discharges

Treated sewage (wastewater) from the four main cities in the Wellington region is discharged directly to the coast. In many other populated areas, such as Paraparaumu and the five main towns in the Wairarapa, treated wastewater enters the coast indirectly, via rivers that drain to the coast (eg, the Waikanae and Ruamahanga rivers).

Wastewater from Upper Hutt and Lower Hutt cities, including the Seaview industrial area, is treated at Seaview and discharged to the coast via a short outfall at Bluff Point, Pencarrow Head. Wellington city is serviced by three wastewater treatment plants (WWTPs), although the majority of the wastewater is treated and discharged into Cook Strait via a 1.85 km long outfall at Moa Point on the city's south coast. Treated wastewater from the western suburbs (est. population of 11,000 people) is also discharged to the south coast, via a short outfall at the mouth of the Karori Stream. Wastewater from the northern suburbs of Wellington city is treated with Porirua city's wastewater at

---

[9] See http://www.stats.govt.nz/Census/2006CensusHomePage/Tables/AboutAPlace.aspx (accessed on 22 February 2012).

[10] Joanna Saywell, Senior Engineer, Porirua City Council.

[11] In addition, based on Dairy NZ (2010) data, there has been a reduction in effective farming area; collectively this has resulted in a 33% increase in average dairy herd size for the region – from 299 in 2002 to 399 in 2009. This translates to an increase in the average stocking rate from, on average, 2.54 cows per hectare of dairy farm land in 2002/03 to 2.80 cows per hectare in 2009/10 (Sorensen 2012).

Porirua City Council's WWTP and discharged to the coast off Rukutane Point, immediately southeast of Titahi Bay. The population serviced by the plant has grown in recent years and now stands at around 80,000 (J Saywell, pers. comm. 2012).

At times of very heavy or sustained rainfall, stormwater can directly infiltrate into the sewer network, resulting in high volumes of 'diluted' wastewater arriving at the treatment plants. On some occasions when storage at the WWTPs is exceeded, a portion of these 'wet weather flows' bypass treatment and are discharged directly to the coast or streams in close vicinity of the treatment plant (eg, the lower Waiwhetu Stream and Karori Stream in the cases of the Seaview and Western WWTPs, respectively). Greater Wellington's resource consent monitoring records indicate that, on average, such discharges tend to occur at least two to three times a year.

The other principal discharge to coastal waters in the Wellington region is urban stormwater. Generally defined as rainwater collected from roofs, driveways, roads, carparks and other sealed surfaces, stormwater in the Wellington region is piped directly into rivers, streams and the coast, generally without any treatment. During its travels, this stormwater picks up sediment, rubbish and a variety of other contaminants, including heavy metals, hydrocarbons, herbicides, pesticides, nutrients and pathogens.

Although general stormwater discharges are a permitted activity under Greater Wellington's existing Regional Coastal Plan (WRC 2000) and so do not require a resource consent[12], both Wellington City Council (WCC) and Kapiti Coast District Council hold 'global network' resource consents to discharge stormwater to the coast. WCC also holds consents that authorise the discharge of diluted untreated wastewater through selected stormwater outfalls during periods of heavy or sustained rainfall (eg, via the Overseas Passenger Terminal outfall to Wellington Harbour). Hutt City Council (HCC) holds similar consents, but for discharges that enter the lower reaches of the Hutt River and Waiwhetu Stream (which, from there, enter Wellington Harbour).

3.4.4 Erosion

Erosion is an issue affecting a number of coastal locations in the Wellington region. In some areas, such as Raumati South and Paekakariki, coastal erosion is occurring as a result of wave energy, threatening coastal ecosystems and residential homes (Stevens & Robertson 2006). In contrast, in the eastern Wairarapa, the erosion issues extend inland to hill country areas which are characterised by large areas of soft erosion-prone soils; here soils lost from pastoral and bare land contribute to high sediment loads in rivers draining to the coast. The result is high rates of sedimentation in estuaries such as the Whareama (discussed further in Section 5). Greater Wellington runs a soil conservation programme in the eastern hill country, a key part of which involves re-vegetating bare or erodible land.

---

[12] Stormwater discharges must meet certain criteria to be permitted, a key one being that the discharges do not adversely affect aquatic life. As discussed later in this report, monitoring and investigations by Greater Wellington in recent years have indicated that stormwater discharges in some areas may be having more than minor adverse effects on some receiving environments.

3.4.5 Dredging

With Wellington Harbour a busy operational port, dredging is an activity necessary to ensure the safe passage of increasingly larger commercial ships into and out of the harbour. This dredging is overseen by CentrePort Wellington and undertaken in conjunction with resource consents issued by Greater Wellington in 2003. These consents authorise dredging of selected berths in Wellington Harbour (21,000 m^3 of silt, sand, shell and shingle), the main navigation channel (250,000 m^3 of silt, sand, shell and shingle) and disposal of the dredged material to Fitzroy Bay. To date, this dredging has not been required. There are further consents, exercised by Greater Wellington, for the dredging of the Hutt River mouth for flood protection purposes.

3.4.6 Power generation

A potential future pressure for Wellington’s coastal waters relates to the harnessing of tidal energy to generate power. Cook Strait has some of the strongest tidal flows in the world and it is expected that this will be the site of future tide turbine farms. In 2008, resource consent was granted to Neptune Power Limited for the deployment of prototype tidal generation turbines and associated power cables in Cook Strait, but to date no turbines have been deployed. Consent was also granted in 2010 for up to three prototype wave-energy converters to be trialled near Moa Point on Wellington’s south coast. Construction and installation of the wave energy converters commenced in late May 2012. At the present time, there is limited understanding of the potential environmental impacts on coastal waters related to the installation, cabling and operation of marine energy turbines. Gill (2005) identified a number of potential environmental impacts from extensive installation of offshore tidal energy developments. These include alteration of substrates, sediment transport and deposition, emission of electromagnetic fields, alteration of habitats for benthic organisms, noise during construction and operation, toxicity of paints, lubricants and antifouling coatings, interference with animal movements and migrations, and animal strike by rotor blades or other moving parts.

4. Microbiological water quality and shellfish

Microbiological water quality in the Wellington region is primarily monitored for recreational purposes and, because state and trends in recreational water quality are the subject of a separate report (Greenfield et al. 2012), this section only presents a brief summary of the microbiological water quality of the region's coastal waters. The results of the last survey of microbiological (and trace metal) contaminants in shellfish flesh are also summarised.

4.1 Microbiological water quality

4.1.1 Approach to analysis

To align with the reporting period utilised by Greenfield et al. (2012) and enable a direct comparison with data presented in that report, this summary is limited to microbiological water quality data collected from 77 sites monitored over the five-year period ending 30 June 2010 (Figure 4.1)[13]. In contrast with the analysis presented in Greenfield et al. (2012), which focuses solely on routine weekly summer results collected over the official summer bathing season (November to March), *all available* microbiological water quality data have been considered (eg, 'follow-up' water sample test results collected in response to routine sample results exceeding the alert or action levels of the MfE/MoH (2003) recreational water quality guidelines have not been excluded), including data collected from monthly sampling between April and October.

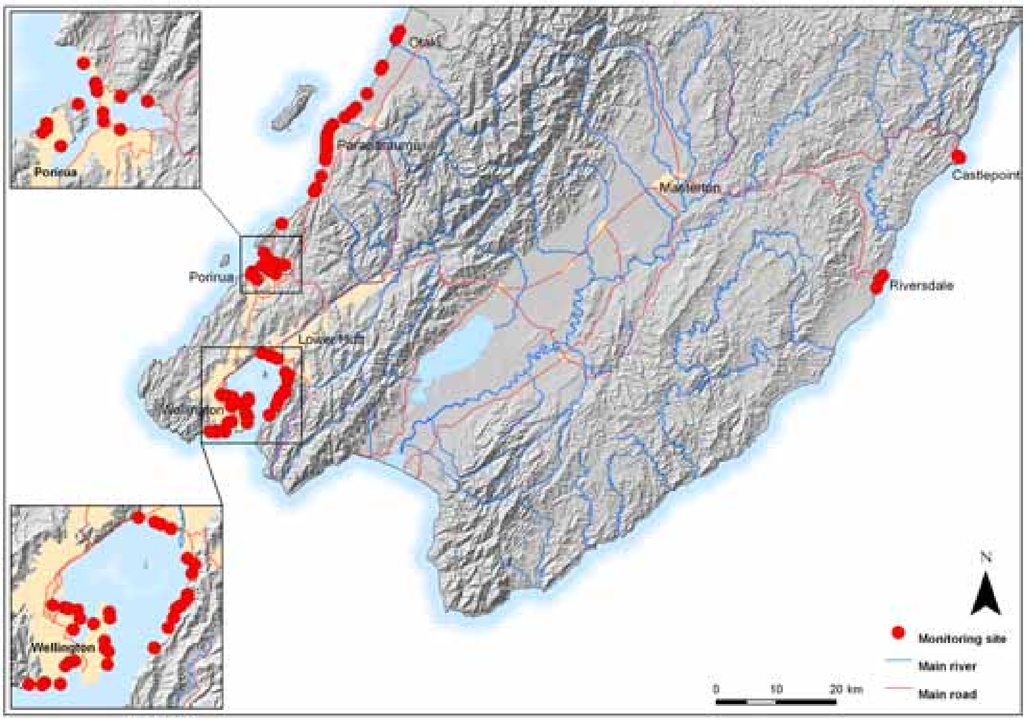


Figure 4.1: Coastal recreational water quality monitoring sites in the Wellington region sampled over 2005/06 to 2009/10

---

[13] Four sites were only monitored for part of this period – Pauatahanui Inlet at Paremata Bridge (Porirua) was only added to the programme in 2007/08 and in 2009/10, Plimmerton Beach at Queens Avenue (Porirua), Paremata Beach at Pascoe Avenue (Porirua) and Kio Bay (Wellington city) were removed from the monitoring programme as they were either in close proximity to other sites or were no longer considered to be commonly used for recreation (Greenfield et al. 2012).

The primary purpose of the analysis is to summarise microbiological water quality in the region's coastal waters between 1 July 2005 and 30 June 2010, and provide an indication of the current year-round state of water quality. No attempt is made at a formal analysis of state or temporal trends in microbiological data due to the confounding effects of other environmental variables, such as tide and weather conditions, on indicator bacteria counts. In addition, no attempt is made to duplicate the work of Greenfield et al. (2012) and assess the enterococci results against the MfE/MoH (2003) recreational water quality guidelines. However, in the case of the nine coastal sites where water quality is also monitored for recreational shellfish-gathering purposes, a general summary of all available monitoring results is followed by an assessment of routine summer and winter results against the faecal coliform thresholds identified in the MfE/MoH (2003) guidelines. These guidelines do not define a shellfish gathering season, nor do they provide any guidance on the minimum number of samples that should be used to calculate compliance with the median guideline. Therefore, while the general approach taken in Greater Wellington's reporting is to align the shellfish gathering season with the summer bathing season (ie, November to March inclusive), in assessing results gathered across the full calendar year, this report is acknowledging that shellfish gathering probably occurs year round at many coastal sites to some degree.

Prior to data analysis, enterococci and faecal coliform counts below the laboratory detection limit were halved, apart from those where the detection limit was <1 cfu/100mL (in which case a result of 1 cfu/100mL was used). With the link between rainfall and elevated indicator bacteria counts well established in the Wellington region (arising largely from urban and rural runoff to fresh and coastal waters), 95th percentile and maximum enterococci counts for selected sites were interpreted against an estimate of the daily rainfall in the catchment adjoining each site by obtaining records from the nearest rain gauge (see Greenfield et al. 2012 for rain gauge site details).

4.1.2 Enterococci counts

Table 4.1 summarises the median, 95th percentile and maximum enterococci counts recorded from all sampling conducted during the period 1 July 2005 to 30 June 2010 for each of the 77 coastal monitoring sites. A total of 53 of the 77 sites (69%) recorded a median enterococci count below 10 cfu/100mL over this period, with Riversdale Beach South (eastern Wairarapa) recording the lowest 95th percentile and maximum counts (24 and 36 cfu/100mL, respectively). Most (59) sites recorded maximum counts of over 1,000 cfu/100mL; six sites (two in Porirua and six in Wellington city) recorded maximum counts above 5,000 cfu/100mL. The two highest maximum counts (both more than two orders of magnitude above the safe recreational guideline of 140 cfu/100mL) were recorded at Seatoun Beach at Wharf (51,000 cfu/100mL on 7 August 2006) and Lyall Bay at Onepu Road (24,000 cfu/100mL on 10 August 2005). While both of these results coincided with more than 20 mm of rainfall in the 48 hours prior to sampling (much of this on the day of sampling), this degree of faecal contamination is considered exceptionally high – particularly given there is no record of any sewer faults having occurred at the time (I Idris[14], pers. comm. 2012).

---

[14] Iqbal Idris, Senior Project Manager, Wellington Water Management (Capacity) Ltd.

Table 4.1: Summary of enterococci counts recorded at 77 coastal sites monitored over 1 July 2005 to 30 June 2010 inclusive

Bathing site	Total no. of samples	Enterococci (cfu/100mL)		
		Median	95th percentile	Max
Kapiti Coast				
Otaki Beach @ Surf Club	149	5	191	1,150
Otaki Beach @ Rangiuru Rd	147	5	130	1,130
Te Horo Beach S of Mangaone Stream	158	20	424	1,480
Te Horo Beach @ Kitchener St	147	5	217	890
Peka Peka Beach @ Road End	144	5	88	310
Waikanae Beach @ William St	145	10	110	485
Waikanae Beach @ Tutere St T.C.	145	10	97	585
Waikanae Beach @ Ara Kuaka C.P.	146	10	129	650
Paraparaumu Beach @ Ngapotiki St	156	20	321	1,830
Paraparaumu Beach @ Nathan Ave	149	15	170	1,525
Paraparaumu Beach @ Maclean Pk	153	20	207	3,130
Paraparaumu Beach @ Toru Rd	150	15	213	2,340
Paraparaumu Beach @ Wharemauku Rd	149	15	180	4,400
Raumati Beach @ Tainui St	145	10	119	605
Raumati Beach @ Marine Gardens	151	15	205	2,365
Raumati Beach @ Aotea Rd	146	10	128	1,160
Raumati Beach @ Hydes Rd	148	9	149	445
Paekakariki Beach @ Whareroa Rd	141	5	75	240
Paekakariki Beach @ Surf Club	141	5	60	1,270
Paekakariki Beach @ Memorial Hall	140	3	40	140
Porirua				
Pukerua Bay	148	4	182	2,000
Karehana Bay @ Cluny Rd	152	8	234	2,400
Plimmerton Beach @ Bath St	152	12	215	2,800
Plimmerton Beach @ Queens Ave	124	12	166	1,000
South Beach @ Plimmerton	163	20	472	1,100
Paremata Beach @ Pascoe Ave	126	7	178	2,000
Pauatahanui Inlet @ Water Ski Club	151	12	300	4,000
Pauatahanui Inlet @ Motukaraka Pt	154	7	264	2,100
Pauatahanui Inlet @ Browns Bay	160	16	283	5,332
Pauatahanui Inlet @ Paremata Bridge	85	8	128	720
Porirua Harbour @ Rowing Club	172	28	1,335	9,600
Titahi Bay @ Bay Drive	159	12	265	1,600
Titahi Bay @ Toms Rd	154	10	237	1,000
Titahi Bay @ South Beach Access Rd	160	17	402	2,240
Onehunga Bay	143	4	68	310
Wellington city				
Aotea Lagoon	166	12	408	7,000
Oriental Bay @ Freyberg Beach	161	4	80	2,600
Oriental Bay @ Wishing Well	172	8	309	3,200
Oriental Bay @ Band Rotunda	166	8	205	12,000
Balaena Bay	159	2	66	1,000

Table 4.1 *cont.*: **Summary of enterococci counts recorded at 77 coastal sites monitored over 1 July 2005 to 30 June 2010 inclusive**

Bathing site	Total no. of samples	Enterococci (cfu/100mL)		
		Median	95th percentile	Max
Wellington city				
Kio Bay	136	2	138	17,000
Hataitai Beach	159	4	120	2,400
Shark Bay	156	4	60	2,400
Mahanga Bay	161	4	88	500
Scorching Bay	159	2	52	19,000
Worser Bay	158	2	102	1,600
Seatoun Beach @ Wharf	160	4	88	51,000
Seatoun Beach @ Inglis St	162	4	68	960
Breaker Bay	118	2	25	340
Lyall Bay @ Tirangi Rd	165	4	130	4,700
Lyall Bay @ Onepu Rd	162	4	76	24,000
Lyall Bay @ Queens Drive	163	4	174	1,700
Princess Bay	119	2	40	4,100
Island Bay @ Surf Club	171	8	315	1,400
Island Bay @ Reef St Recreation Ground	171	8	646	5,000
Island Bay @ Derwent St	157	4	128	2,700
Owhiro Bay	194	24	611	2,400
Hutt				
Petone Beach @ Water Ski Club	153	4	138	1,140
Petone Beach @ Sydney St	154	8	247	2,100
Petone Beach @ Settlers Museum	156	8	223	1,600
Petone Beach @ Kiosk	155	8	185	2,000
Sorrento Bay	147	4	86	1,696
Lowry Bay @ Cheviot Rd	154	4	360	2,000
York Bay	152	2	44	1,000
Days Bay @ Wellesley College	150	4	111	1,400
Days Bay @ Wharf	151	4	125	1,792
Days Bay @ Moana Rd	151	2	94	960
Rona Bay @ N end of Cliff Bishop Park	161	12	384	2,000
Rona Bay @ Wharf	156	6	215	1,300
Robinson Bay @ HW Shortt Rec Ground	161	8	400	4,240
Robinson Bay @ Nikau St	150	8	106	1,000
Camp Bay	101	2	44	520
Wairarapa				
Castlepoint Beach @ Castlepoint Stream	145	4	151	1,700
Castlepoint Beach @ Smelly Creek	143	4	119	2,000
Riversdale Beach @ Lagoon Mouth	142	2	72	1,100
Riversdale Beach Between the Flags	142	2	59	312
Riversdale Beach South	101	2	24	36

In most cases, the highest enterococci results coincided with rainfall prior to or on the day of sampling. Notable exceptions included Oriental Bay at Band

Rotunda, Kio Bay and Scorching Bay in Wellington city; all three of these sites recorded maximum enterococci counts over 10,000 cfu/100mL on 10 June 2008 in the absence of rainfall. Similarly, the maximum enterococci count recorded at Robinson Bay at HW Shortt Recreation Ground (Eastbourne) did not coincide with any significant rainfall. The reason for these high results is not known but given that three different locations in Wellington city were affected on the same day and there is no record of any sewer faults having occurred (I Idris, pers. comm. 2012), the validity of the results for these sites appears questionable – particularly given no results of this magnitude have been reported in recent years.

The highest median and 95th percentile enterococci counts were recorded at Porirua Harbour at Rowing Club (28 and 1,335 cfu/100mL, respectively) (Table 4.1). Other sites with particularly high 95th percentile values included Island Bay at Reef Street (646 cfu/100mL), Owhiro Bay (611 cfu/100mL), South Beach at Plimmerton (472 cfu/100mL), Te Horo Beach at Mangaone Stream (424 cfu/100mL), Aotea Lagoon (408 cfu/100mL), Titahi Bay at South Beach Access Road (402 cfu100mL) and Robinson Bay at HW Shortt Recreation Ground (400 cfu/100mL). Greenfield et al. (2012) note that stormwater and sewer leaks/overflows are likely to be contributing to faecal contamination at many of these sites, particularly Porirua Harbour at Rowing Club, Owhiro Bay, Titahi Bay at South Beach Access Road and Robinson's Bay at HW Short Recreation Ground. In contrast, waterfowl are possibly the primary contributor to faecal contamination at South Beach at Plimmerton while agricultural runoff entering the Mangaone Stream is thought to impact on water quality at Te Horo Beach (Greenfield et al. 2012). It is also likely that bacteria re-suspended from bottom sediment contribute to poor water quality at some coastal sites, in particular Porirua Harbour at Rowing Club. This requires further investigation, along with the influence of wastewater treatment plant discharges that enter coastal waters in several locations (refer Section 3.4.3)[15].

At some sites (eg, Owhiro Bay and Robinson Bay), the highest enterococci results were recorded during the 'winter' months (April to October), despite a much reduced sampling frequency over this period. This highlights the increased risk of microbiological contamination in winter – when rainfall (and hence urban and rural runoff) is higher – relative to the summer bathing season. The same observation was reported previously by Milne and Wyatt (2006) who demonstrated that Island Bay on Wellington city's south coast would have a poorer Suitability for Recreation Grade (SFRG) if year-round microbiological water quality monitoring results were taken into account (SFRGs are calculated using routine summer-time monitoring results – see Greenfield et al. 2012).

4.1.3 Faecal coliform counts

Table 4.2 summarises the median, 95th percentile and maximum faecal coliform counts recorded from *all* monitoring undertaken at the nine recreational shellfish

---

[15] Greenfield et al. (2012) note that the MfE/MoH (2003) microbiological guidelines cannot be applied to fresh or coastal areas in close proximity to WWTP discharges with confidence. This is because WWTPs may treat effluent to a level where the indicator bacteria concentrations are very low, but pathogens such as viruses and protozoa may still be present at substantial concentrations, effectively changing the indicator/pathogen ratio.

gathering sites between 1 July 2005 and 30 June 2010. Sites in Wellington and Hutt cities recorded the lowest faecal bacteria counts (median of 2 cfu/100mL and 95th percentiles ranging from 91 to 113 cfu/100mL). In contrast, Porirua Harbour at Rowing Club recorded the greatest faecal contamination, including a maximum faecal bacteria count of 6,400 cfu/100mL on 12 February 2008[16]. The cause of this result is not known but the site frequently records high indicator bacteria counts and a nearby 'Onepoto Stream' has been identified as a likely contributing factor (see Greenfield et al. 2012).

Table 4.2: Summary of faecal coliform counts recorded at nine coastal sites monitored over 1 July 2005 to 30 June 2010 inclusive

Site	Total no. of samples	Faecal coliforms (cfu/100mL)		
		Median	95th percentile	Max
Kapiti Coast				
Otaki Beach @ Surf Club	149	16	573	2,500
Peka Peka Beach @ Road End	144	15	341	1,200
Raumati Beach @ Hydes Rd	148	18	304	850
Porirua				
Pauatahanui Inlet @ Motukaraka Pt	92	4	175	860
Pauatahanui Inlet @ Browns Bay	96	12	518	900
Porirua Harbour @ Rowing Club	105	36	828	6,400
Wellington city				
Shark Bay	156	2	113	1,100
Mahanga Bay	157	2	112	740
Hutt				
Sorrento Bay	147	2	91	600

When the results of *routine* summer and winter monitoring were considered, only four of the nine sites consistently complied with the MfE/MoH (2003) median faecal coliform threshold (14 MPN/100mL[17]) for recreational shellfish gathering waters (Table 4.3). Of these sites, all failed the second criterion – that no more than 10% of sample results exceed 43 MPN/100mL – in two or more years. Overall, looking at the statistics for the full five-year period (July 2005 to June 2010), only Shark and Mahanga bays (Wellington city eastern bays) and Sorrento Bay (Eastbourne) complied with both MfE/MoH faecal coliform thresholds for shellfish collection. In contrast, if only routine summer sampling results are considered, a further site – Pauatahanui Inlet at Motukaraka Point – also met both thresholds (Greenfield et al. 2012). The fewer sites meeting the MfE/MoH (2003) thresholds over the full 12-month period, particularly the 'no more than 10% of samples to exceed 43 cfu/100mL' threshold, is a reflection of poorer microbiological water quality in the winter months. This arises from higher rainfall and, subsequently, increased urban and rural runoff to the coast during winter.

---

[16] It should be noted that this site, along with Pauatahanui Inlet at both Motukaraka Point and Browns Bay, are not recommended as shellfish gathering sites and are rarely used for this purpose; sampling was initiated in July 2007 in response to community interest (Greenfield et al. 2012).

[17] Note the guideline is expressed as MPN/100mL but Greater Wellington's measurements are expressed in cfu/100mL (which are considered equivalent and comparable units) – see Greenfield et al. (2012) for more details.

Table 4.3: Comparison of faecal coliform counts at selected coastal sites in Kapiti and Porirua with the MfE/MoH (2003) guidelines for recreational shellfish gathering waters, based on routine (weekly in summer and monthly in winter) monitoring over 1 July 2005 to 30 June 2010 inclusive. Routine summer results (2005/06 to 2009/10) from (Greenfield et al. 2012) are also provided for comparison. Results in bold font exceed guideline values.

	Median (cfu/100mL)	No. (and percentage) of results >43 cfu/100mL	Total no. of samples
MfE/MoH (2003) guideline	**14 MPN/100mL**	**10%**	
Otaki Beach at Surf Club			
2005/06	10	**7 (24%)**	29
2006/07	**18**	**10 (36%)**	28
2007/08	8	**6 (21%)**	28
2008/09	**18**	**7 (25%)**	28
2009/10	**34**	**12 (44%)**	27
All data	**15**	**42 (30%)**	140
All summer data	**15**	**34 (32%)**	105
Peka Peka Beach at Road End			
2005/06	**15**	**4 (14%)**	29
2006/07	**25**	**11 (39%)**	28
2007/08	6	**5 (18%)**	28
2008/09	**18**	**11 (39%)**	28
2009/10	**15**	**7 (26%)**	27
All data	**15**	**38 (27%)**	140
All summer data	**15**	**31(30%)**	105
Raumati Beach at Hydes Rd			
2005/06	**36**	**12 (41%)**	29
2006/07	5	**9 (32%)**	28
2007/08	11	**6 (21%)**	28
2008/09	**15**	**8 (29%)**	28
2009/10	**20**	**8 (30%)**	27
All data	**16**	**43 (31%)**	140
All summer data	**19**	**34 (32%)**	105
Pauatahanui Inlet at Motukaraka Point			
2007/08	2	1 (3.6%)	28
2008/09	4	**5 (18%)**	28
2009/10	4	**3 (11%)**	27
All data	4	**9 (11%)**	83
All summer data	4	5 (8%)	62
Pauatahanui Inlet at Browns Bay			
2007/08	4	**4 (14%)**	28
2008/09	8	**12 (43%)**	28
2009/10	**36**	**13 (48%)**	27
All data	8	**29 (35%)**	83
All summer data	8	**20 (32%)**	62
Porirua Harbour at Rowing Club			
2007/08	**40**	**14 (50%)**	28
2008/09	**20**	**12 (43%)**	28
2009/10	**28**	**11 (41%)**	27
All data	**32**	**37 (45%)**	83
All summer data	**30**	**26 (42%)**	62

Table 4.3 *cont.*: Comparison of faecal coliform counts at selected coastal sites in Wellington and Hutt cities with the MfE/MoH (2003) guidelines for recreational shellfish gathering waters, based on routine (weekly in summer and monthly in winter) monitoring over 1 July 2005 to 30 June 2010 inclusive. Routine summer results (2005/06 to 2009/10) from (Greenfield et al. 2012) are also provided for comparison. Results in bold font exceed guideline values.

	Median (cfu/100mL)	No. (and percentage) of results >43 cfu/100mL	Total no. of samples
MfE/MoH (2003) guideline	**14 MPN/100mL**	**10%**	
Shark Bay			
2005/06	2	**5 (14%)**	37
2006/07	2	**4 (11%)**	36
2007/08	2	2 (7.1%)	28
2008/09	2	2 (7.1%)	28
2009/10	2	2 (7.4%)	27
All data*	2	15 (9.6%)	156
All summer data	2	4 (4%)	105
Mahanga Bay			
2005/06	4	**8 (22%)**	37
2006/07	2	2 (5.6%)	36
2007/08	3	1 (3.6%)	28
2008/09	2	**4 (14%)**	28
2009/10	2	1 (3.7%)	27
All data*	2	16 (10%)	156
All summer data	2	9 (9%)	105
Sorrento Bay			
2005/06	2	2 (6.9%)	29
2006/07	2	2 (7.1%)	28
2007/08	2	2 (7.1%)	28
2008/09	3	**5 (18%)**	28
2009/10	2	**3 (11%)**	27
All data	2	14 (10%)	140
All summer data	2	10 (10%)	105

*Includes the results of extra samples taken over the 2005/06 and 2006/07 winters when these sites were sampled fortnightly.

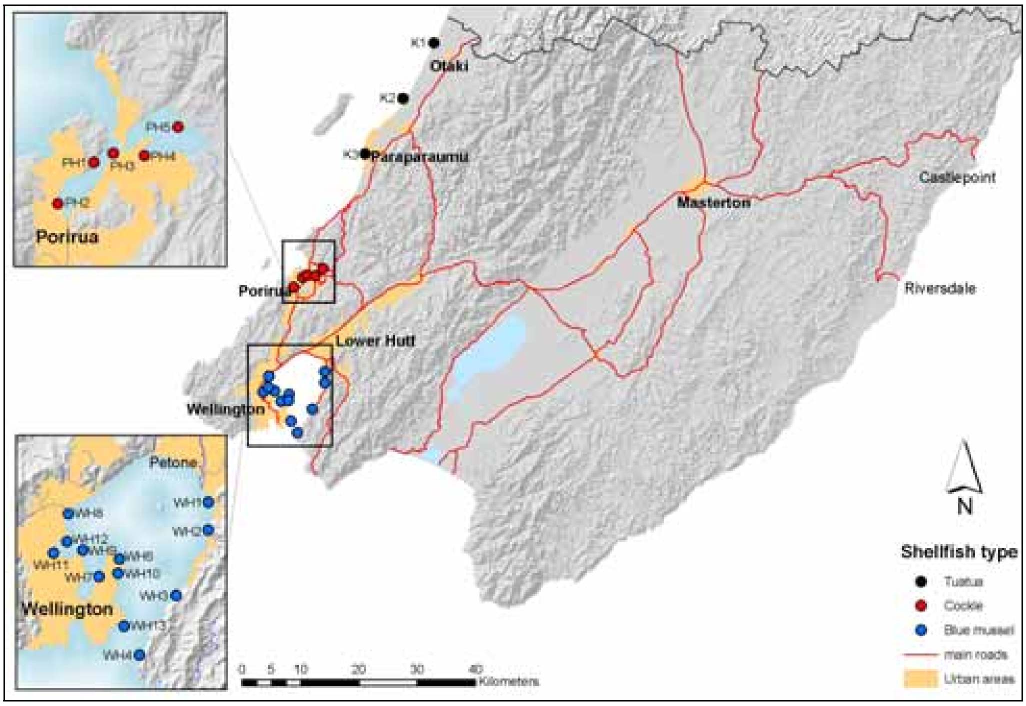
Greenfield et al. (2012) note that non-compliance with water quality guidelines for shellfish gathering is likely to be related to similar factors as non-compliance with the microbiological guidelines for swimming, including sewage contamination of stormwater and runoff from agricultural landuse. At Kapiti Coast and Porirua Harbour sites re-suspension of faecal bacteria attached to sediments may also contribute to non-compliance with water quality for shellfish gathering guidelines, particularly during strong winds when the beach waters are often turbid.

The MfE/MoH (2003) guidelines only address microbiological contamination and do not address marine biotoxins, heavy metals, or harmful organic contaminants which in certain places and locations can pose a significant risk to people gathering shellfish. For this reason, the guidelines can not be used with any certainty to determine whether shellfish are actually safe to eat. Monitoring of microbiological (and other) contaminants in *shellfish flesh* is needed to provide a direct measure of the risks associated with consuming shellfish. Greater Wellington has periodically undertaken such monitoring; the results from the most recent round of monitoring are summarised next.

4.2 Contaminants in shellfish flesh

The Wellington region has numerous coastal habitats that are popular for both traditional and recreational harvest of shellfish species. In the interest of public health and coastal water quality, Greater Wellington has complemented routine monitoring of microbiological water quality in selected recreational shellfish gathering areas (Section 4.1) with periodic surveys of microbiological and trace contaminants present in shellfish flesh. These surveys have largely focussed on filter feeding species such as cockles and mussels, which in processing large amounts of water from a fixed location, have the tendency to accumulate a wide range of contaminants in their tissues. As such, tissue contaminant levels provide an indication of ambient water quality conditions, with the added advantage that the accumulated contaminants are representative of only those forms which are biologically available to other organisms such as fish, birds and people (Milne 2006).

Only one shellfish flesh survey was undertaken during the reporting period, in February–March 2006. The results of this survey are reported in full in Milne (2006) and summarised briefly here. This survey assessed microbiological and trace metal contamination in the flesh of tuatua (*Paphies subtriangulata*), cockles (*Austrovenus stutchburyi*) and blue mussels (*Mytilus galloprovincialis*) at 20 sites in the western half of the Wellington region (Figure 4.2). Sampling sites included seven where water quality for shellfish gathering is monitored (and shellfish flesh sampling had been conducted previously), and additional sites in Porirua Harbour (eg, Browns Bay) and Wellington Harbour (eg, Frank



(Source: Milne 2006, p3)

Figure 4.2: Location of shellfish sites sampled during February–March 2006

Kitts Park). The additional sites, although not necessarily utilised by the public for shellfish collection, were selected as part of a broader investigation by Greater Wellington into the impacts of urban stormwater discharges on aquatic receiving environments.

Three replicate composite samples were collected from each sampling site, with the number of shellfish per sample varying from 40 to 100 depending on the size and availability of shellfish at each site. Samples were analysed for faecal coliforms and seven trace metals (total recoverable cadmium, chromium, copper, lead, mercury, nickel and zinc). Analyses were conducted on homogenised, composite samples of whole shucked shellfish, and samples were not depurated[18] prior to analysis.

4.2.1 Faecal coliforms

Positive faecal coliform counts were detected in only a small portion of (12%) of shellfish samples, including tuatua (1 of 7), cockles (4 of 15) and mussels (3 of 36). However, all of the positive results were very low and well below Ministry of Health (1995)[19] microbiological reference criteria for bivalve shellfish.

4.2.2 Trace metals

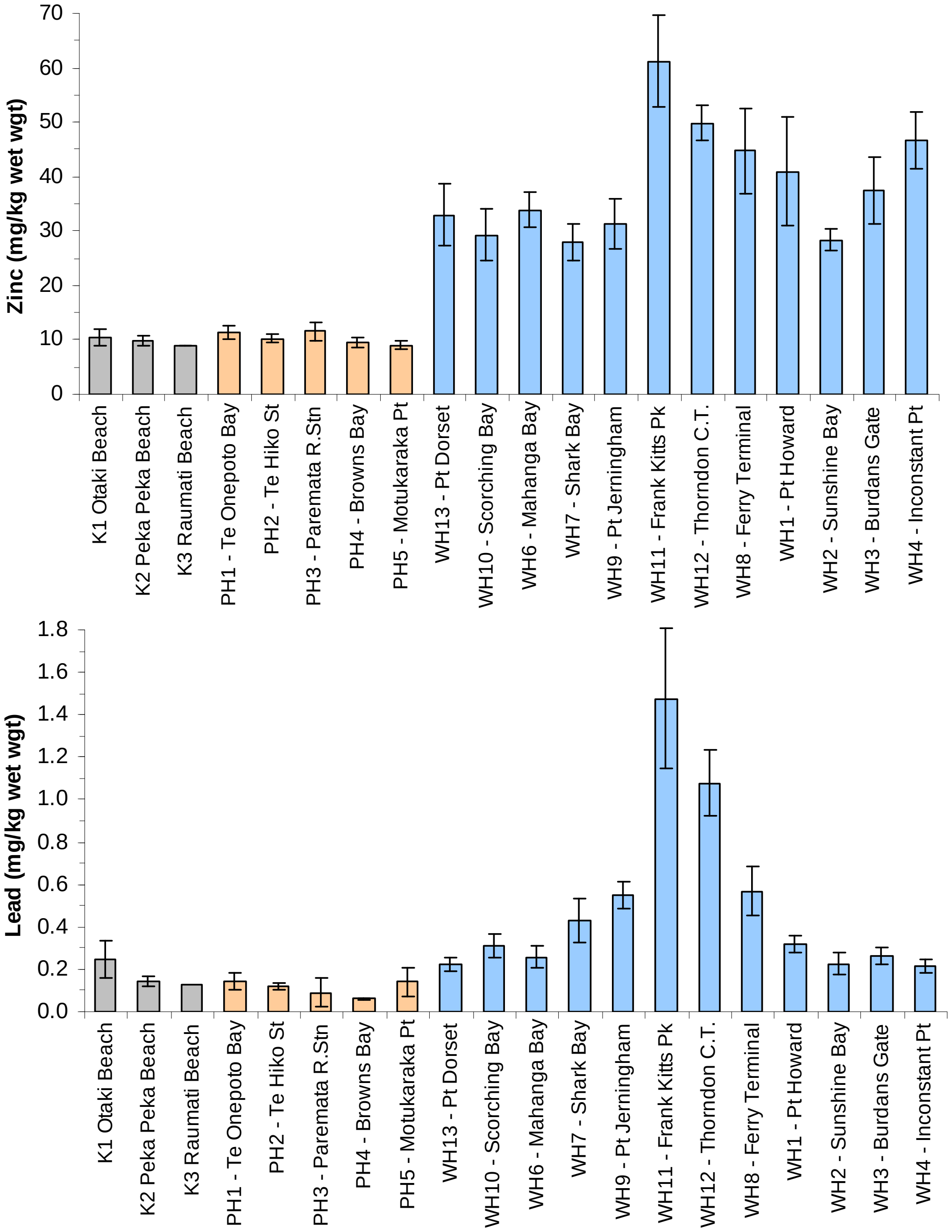
Cadmium, chromium, copper, lead, mercury, nickel and zinc were present in all tuatua, cockle and blue mussel samples. While these trace metals are naturally occurring and some are essential for normal functioning, in excessive concentrations these metals can be toxic to the organism storing them and organisms eating them. In terms of compliance with guidelines for human consumption, cadmium, lead and mercury concentrations in all samples were well below the guidelines set by the Australia New Zealand Food Standards Code (2001)[18] for edible shellfish tissue. There are no published national guidelines for concentrations of chromium, copper, nickel or zinc.

There was little spatial variation in metal concentrations of tuatua and cockle flesh, with similar mean concentrations recorded across all the sites from which they were collected. The mean concentrations of lead, zinc (Figure 4.3), copper and chromium in blue mussel tissue, however, were noticeably elevated at the Frank Kitts Park site within Wellington Harbour (Figure 4.3). Cadmium concentrations were also elevated in blue mussel flesh at the Thorndon container terminal and Frank Kitts Park sites within Wellington Harbour. These sites are located in a relatively sheltered part of the inner harbour that receives multiple stormwater inputs.

---

[18] Depuration is the term applied to the purification of shellfish, under controlled conditions. When metal bioavailability is the key monitoring objective, shellfish are often depurated to enable an accurate estimate of tissue metal (Langston & Spence 1993). However, depuration is not justified when metal contamination is being assessed for human health purposes as the gut contents of the shellfish species are not usually removed or depurated before consumption (Kennedy 1986).

[19] These guidelines were current at the time of the 2006 survey and have since been superseded (although the guideline values remain largely the same).



(Source: Milne 2006,pp9–10)

Figure 4.3: Mean zinc and lead concentrations (+/- 1 standard deviation) measured in composite tuatua (grey bars), cockle (orange bars) and blue mussel (blue bars) samples collected during February–March 2006

4.2.3 Comparison with previous surveys

Direct comparison of the 2006 survey results with those of earlier shellfish flesh investigations/surveys undertaken in 1997, 2001–2002 and 2004 are difficult due to lack of replication in the earlier surveys, differences in the contaminants measured (eg, faecal coliforms were only assessed in 1997 and 2006), and a slight variation in the trace metal analytical methods. Differences aside Milne (2006) noted:

- The low faecal coliform counts recorded in 2006 were in contrast with those recorded in the 1997 survey of cockles in Porirua Harbour (Berry et al. 1997). In the 1997 investigation, faecal coliform levels were reported to be 2.4 times the guideline value at sites at Ivey Bay (790 MPN/100g) and at the guideline value at Paremata Station and Horokiri Stream (330 MPN/100g). Subsequently it was recommended that shellfish collected from the harbour should not be consumed. Note that the 2006 survey included samples from Paremata Station but not Ivey Bay or Horokiri Stream mouth.

- The metal concentrations observed in shellfish samples from most sites in 2006 were higher than the concentrations reported in 2001–2002, but similar to those reported in 2004. The exceptions were mercury and lead, which were lower at most sites in 2006.

4.3 Synthesis

Based on the results of monitoring conducted over July 2005 to June 2010, microbiological water quality in the Wellington region is generally very good. However, there are some ‘hot spots’ within the region, particularly in Porirua, where faecal indicator bacteria counts are elevated at times. Greenfield et al. (2012) consider stormwater and sewage leaks/overflows to be the main source of microbiological contamination at these sites. Overall, microbiological water quality is most compromised during wet weather, highlighting that swimming and collecting shellfish up to 48 hours after heavy rainfall carries with it an increased (and potentially high) risk to human health. At some sites, faecal indicator bacteria counts are higher in winter than during the summer bathing season, reflecting higher rainfall and, subsequently, more frequent stormwater runoff, in these months. As Greater Wellington’s recreational water quality reporting focuses on the summer bathing season, the increased health risks associated with contact recreation activities in winter is not currently communicated. This needs to be addressed because many coastal sites are used year-round for swimming (eg, Oriental Bay and Scorching Bay in Wellington city), surfing and other forms of recreation.

Shellfish flesh monitoring in early 2006 did not identify any significant microbiological or trace contaminant issues. However, caution is required because, as discussed later in Section 8.4, there is some uncertainty as to the suitability of faecal bacteria concentrations as an indicator of pathogen presence in shellfish. In addition, as noted in Section 4.2.2, the current national food safety standards lack guidance for acceptable shellfish flesh concentrations of some metals, including those commonly associated with stormwater (ie, zinc and copper).

5. Estuarine condition

As outlined in Section 2.4.2, a combination of broad and fine scale ecological monitoring is undertaken in estuaries in the Wellington region. Only one round of broad scale habitat mapping has been undertaken to date[20], with some of these mapping results having been reported by Sherriff (2005) in the last coastal SoE technical report. Therefore this section focuses on fine scale monitoring, summarising the results of surveys undertaken at long-term monitoring sites established in the Waikanae, Hutt and Whareama estuaries, and the intertidal areas of Porirua Harbour. The results of an initial fine scale assessment of Lake Onoke are also summarised.

5.1 Background

Greater Wellington's first fine scale assessments of the condition of estuarine environments in the Wellington region were undertaken by the Cawthron Institute in 2004 (Stevens et al. 2004) and 2005 (Stevens & Robertson 2006), in conjunction with broad scale habitat mapping of river estuaries and sandy beaches along the west and south coasts of the Wellington region. Following completion of broad scale habitat mapping and ecological vulnerability assessments of the Wairarapa coast in late 2006 (Robertson & Stevens 2007c), regional estuary monitoring requirements were evaluated (Robertson & Stevens 2007a; 2007c), resulting in the identification of several priority estuaries for long-term fine scale monitoring: Waikanae, Hutt and Whareama estuaries, and the intertidal margins of Porirua Harbour (Table 5.1).[21] Lake Onoke was subsequently added to the programme following a separate synoptic survey of the lake in September 2007 (Robertson & Stevens 2007b).

Fine scale ecological monitoring involves annual surveys for three to four years to establish a baseline and determine an appropriate long-term (usually five-yearly) monitoring frequency (eg, Robertson & Stevens 2007a; 2007c). Subsequently, Greater Wellington has had to implement monitoring of the priority estuaries in a staged manner. The first annual surveys began in the Whareama Estuary and Porirua Harbour in 2008 and, in 2010, annual surveys commenced in the Waikanae and Hutt estuaries (with reduced scale surveys continuing in the Whareama Estuary and Porirua Harbour to monitor specific issues of concern identified from the first three surveys). Although an initial fine scale survey of Lake Onoke was undertaken in early 2010 (Milne 2010a), regular ecological monitoring of this shallow coastal lake has not yet been established; the focus to date has been on monitoring nutrients and other physico-chemical aspects of water quality in the lake (see Perrie & Milne 2012 for a detailed analysis of the current state of water quality in the lake).

---

[20] These surveys were undertaken between 2004 and 2007 and, as noted in Section 2.3, are only proposed to be repeated at 5–10 yearly intervals.

[21] Porirua Harbour was not included in Cawthron's initial broad scale surveys in 2004 and 2005. A separate broad scale survey of the intertidal habitats within the harbour was subsequently commissioned by Greater Wellington and Porirua City Council in late 2007 (see Stevens & Robertson 2008).

Table 5.1: Key features of the estuaries in Greater Wellington's SoE coastal monitoring programme

	Waikanae Estuary	**Porirua Harbour**		**Hutt Estuary**	**Lake Onoke**	**Whareama Estuary**
		Pauatahanui Arm	**Onepoto Arm**			
Estuary type	Tidal river mouth	Tidal lagoon	Tidal lagoon	Tidal river	Shallow, coastal lake	Tidal river
Estuary area (ha)	30–40	450–470	240–250	3 km long	650	113
Depth (m)	1–2	1–2[1]	1–3	1-3	1–3	1–2
Catchment area (km^2)	149	109	65	656	3,470	533
Catchment land uses (% cover dominant land uses)[2]	Native forest/ scrub (60%), pasture (25%), exotic forest (12%), urban (3%)	Pasture (61%), exotic forest (18%), native forest (14%), urban (6%)	Pasture (39%), urban (36%), native forest/scrub (18%)	Native forest/ scrub (69%), exotic forest (10%), pasture (12%), urban (9%)	Pastoral (64%, including (9% dairy), native forest/scrub (28%)	Pasture (65%), exotic forest (25%), native forest/scrub (10%)
Major tributaries	Waikanae River	Pauatahanui & Horokiri streams	Porirua Stream	Hutt River	Ruamahanga & Turanganui rivers	Whareama River
Degree of modification	High	Moderate	High	High	High	Moderate
Survey years	2010, 2011	2008, 2009, 2010, 2011[3]		2010, 2011	2010	2008, 2009, 2010, 2011[3]

[1] A maximum water depth of 10 m has been recorded in the main channel.

[2] Based on LUCAS, MfE (2010).

[3] Reduced in scope following completion of initial baseline in 2010.

5.2 Monitoring sites and methods

Fine scale monitoring was undertaken in late summer at one or two sites (in the order of 60 m by 20 m in area) within each estuary – four in the case of Porirua Harbour, since the harbour comprises two separate estuarine arms (Figure 5.1). The sites were selected by Coastal Wriggle Management to be representative of the dominant estuary habitat present; in most cases this habitat is intertidal but, in the case of the Hutt Estuary, the dominant habitat is subtidal.

As outlined in Section 2.4.2, the monitoring methods were based on the National Estuary Monitoring Protocol (Robertson et al. 2002), including modifications to these by Wriggle Coastal Management (eg, see Stevens & Robertson 2008). Each monitoring site was marked out into 12 equal sized plots from which a minimum of three replicate sediment samples (composites collected across 10 randomly selected plots) were collected for assessment of a suite of indicators, principally sediment grain size (texture), oxygenation (redox potential discontinuity or RPD depth), nutrient and organic content, heavy metal concentrations, and benthic fauna abundance and diversity. Refer to Table 2.1 (Section 2.4.2) and Appendix 2 for more information on these indicators and the other two key indicators assessed at a broader estuary scale: percentage macroalgae cover and sedimentation rates (assessed through the deployment of multiple sedimentation monitoring plates). There was some variation in the fine scale indicators monitored across the five estuaries, reflecting the different

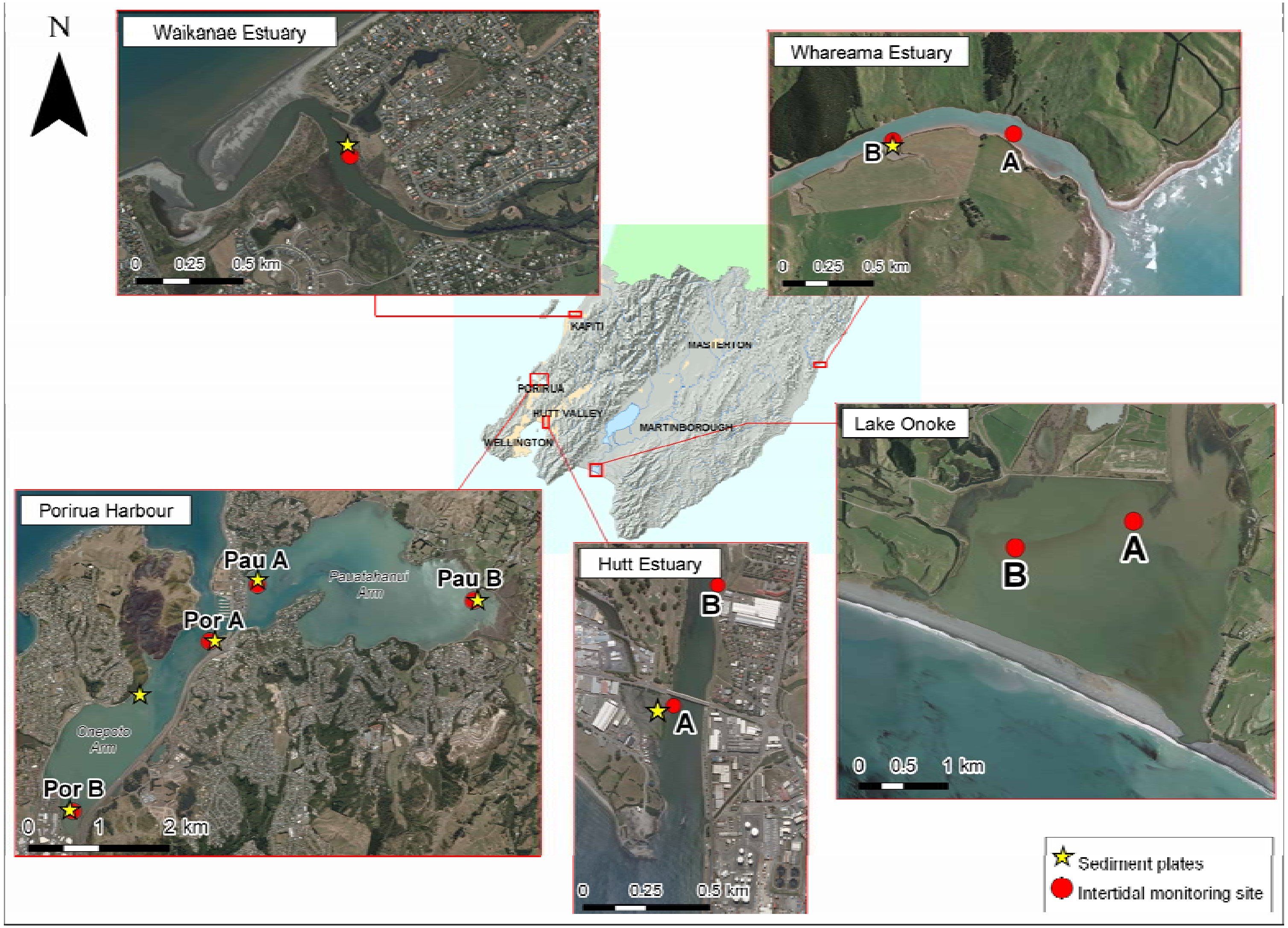


Figure 5.1: Location of existing SoE fine scale estuary monitoring sites in the Wellington region, including the location of sedimentation plates

pressures some face (eg, after two initial assessments confirmed that toxic contamination was not a significant issue, heavy metals and other toxicants were dropped from the Whareama Estuary monitoring programme).

5.3 Key condition indicators

This section focuses on the results of the key indicators monitored to assess the following estuary issues: sedimentation, eutrophication and toxic contamination. The information and photos presented are summarised from the annual fine scale ecological surveys and broad scale macroalgae surveys undertaken by Wriggle Coastal Management between 2008 and 2011 (Robertson & Stevens 2008a–c; 2009a–c; 2010a–d; 2011a–b and Stevens & Robertson 2008; 2009; 2010a–c; 2011a–e). The exception is information on Lake Onoke, which has been taken from Milne (2010a). The reader should consult the individual survey reports for full details and interpretation of the results summarised here.

5.3.1 Sedimentation

An accurate picture of sedimentation rates is still being established across the five estuaries being monitored, with the first sedimentation plates having only been installed in some estuaries in 2008. Based on the limited results to date, sedimentation is clearly an issue in the Whareama Estuary; the average rate of sedimentation between 2008 and 2011 was in the order of 6–7 mm/year (Table 5.2). A much higher rate was recorded for the Waikanae Estuary (45 mm/yr) in January 2011 but that rate was based on a measurement period of just one year and is probably attributable to two flood events in September 2010 (ie, unlikely to be representative of background sedimentation rates). Sediment plate measurements made in early 2012 indicate the average sedimentation rate between 2010 and 2012 was considerably lower, at 35.2 mm/year (Stevens & Robertson, in press).

The very high sedimentation rate in the Whareama Estuary results from high sediment loads from the upstream catchment; much of the catchment, along with much of the wider eastern Wairarapa hill country, comprises soft erosion-prone soils that are frequently removed in large volumes during heavy rain events (Figure 5.2).

As at January 2011, sedimentation rates in Porirua Harbour and Hutt Estuary were rated ‘low to moderate’ and ‘very low to low’, respectively. However, within both arms of the Porirua Harbour (Pauatahanui and Onepoto), the rate of sediment deposition has been highly variable and patchy, with mean values ranging from -1.7 to 3.2 mm/yr over the four-year monitoring period (Table 5.2). Further sedimentation plates were deployed in both intertidal and subtidal areas in 2012 to help better gauge sedimentation rates across the estuary. This follows an assessment by Gibb and Cox (2009) that estimated considerably higher average sedimentation rates of 9.1 and 5.7 mm/yr for Pauatahanui Inlet and the Onepoto Arm, respectively (derived from bathymetric survey data collected in 1974 and 2009). It is likely that during this 35-year period there were occasional years of very high sediment inputs related to large floods, and urban and rural development, interspersed with long periods of low sediment input.

Table 5.2: Estuary sedimentation, nutrient enrichment and toxic contamination condition ratings for the key estuaries in Greater Wellington's state of the environment coastal monitoring programme, based on annual fine scale assessments undertaken between 2008 and 2011 (*n*=1–4). Refer to Appendix 3 for details on the different condition ratings (note that the ratings here have been adapted for consistency and readability).

Estuary issue	Indicator	Waikanae Estuary		Porirua Harbour								Hutt Estuary		Lake Onoke[1]	Whareama Estuary			
				Pauatahanui Inlet				Onepoto Arm										
		2010	2011	2008	2009	2010	2011[2]	2008	2009	2010	2011[2]	2010	2011	2010	2008	2009	2010	2011[2]
Sedimentation	Mud content (mean % per site)	High (27)	Moderate (18)	Low (5–12)	Low (4–10)	Low (8–15)	Low (5–9)	Low (4–10)	Low (6–9)	Low (9–10)	Low (10)	High (35–43)	High (35–51)	High (23)	Very High (68–73)	Very High (43–60)	Very High (23–65)	Very High (40–80)
	Sedimentation rate (average in mm/yr)	–	Very High (45)	–	Moderate (2.3)	Very Low–Mod (0.5–3)	Very Low–Mod (-0.1–2)	–	Low–High (0.8–7)	Low–Mod (-2.5–3.8)	Very Low–Mod (-1.7–3.2)	–	Very Low–Low (-0.8)	Very High (12.5)[3]	–	Very High (14.5)	High (6.3)	Very High (11.4)
	Macrofauna (mud tolerance)	High (5.1)	High (5)	Low (1.8–3)			Not assessed	Very Low–Low (0.6-2.5)			Not assessed	High (5.5)		Not assessed	Moderate (3–4)			Not assessed
Nutrient enrichment	Nuisance macroalgae cover (% estuary area with >50% cover)	Very Low (<3%)		Very Low (<1%)	Low (10%)	Low (7%)	Low (7%)	Moderate (41%)	Moderate (34%)	Moderate (23%)	Moderate (22%)	Moderate (42%)	Moderate (42%)	Very Low (<1%)	Not assessed (nil cover)			
	Organic content (TOC)	Very Low (<1%)		Very Low (<1%)			Not tested	Very Low (<1%)			Not tested	Very Low–Low (~1%)	Very Low (<1%)	Very Low (<1%)	Low (<1.5%)	Very Low (<1%)		Not tested
	Nutrient content (N and P)	Low–Moderate		Low–Moderate			Not tested	Low–Moderate			Not tested	Moderate		Moderate	Moderate			Not tested
	RPD depth (cm)	Good (2.5–4)	Good (3–8)	Good (3–4)	Fair–Good (1–4)	Poor (1)	Poor (1)	Good (2.5–6)	Fair (2–3)	Fair (1–1.5)	Fair (1–1.4)	Good (3–5)	Good (3–3.5)	Very Good (>10)	Fair (1–3)	Fair (1.5–2.5)	Poor (1)	Poor (1)
	Macrofauna (organic enrichment)	Slightly enriched		Slightly enriched			Not assessed	Slightly enriched			Not assessed	Slightly enriched		Slightly enriched	Slightly–moderately enriched			Not assessed
Toxic contamination	Heavy metals	Very Low–Low		Very Low			Not tested	Very Low			Not tested	Low		V. Low–Low	Low			Not tested
	PAHs	Not tested		Not tested				Not tested				Very Low		Not tested	Not tested			
	Pesticides	Very Low	Not tested	Not tested		Very Low	Not tested	Not tested			Not tested	Very Low	Not tested	Very Low	Very Low	Not tested		

[1] The summary presented here is from Site A, representing the dominant intertidal habitat. See Milne (2010a) for a summary of the condition indicators for the subtidal site.

[2] 2011 surveys reduced in scope following completion of initial baseline in 2010.

[3] Inferred as an estuary-wide average from bathymetric surveying in 1994 and 2010 (see text).

(Source: Juliet Milne)

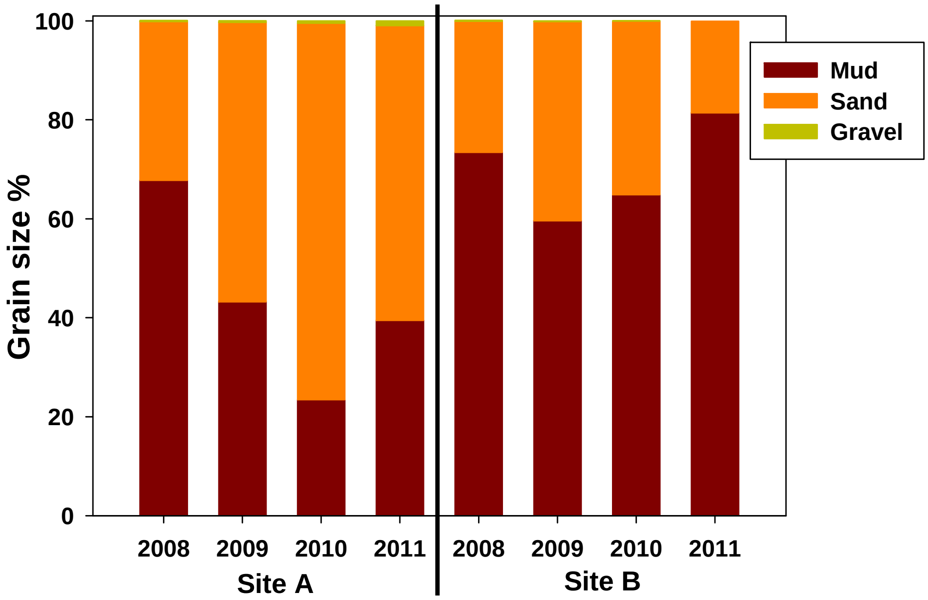
Figure 5.2: A sediment-laden Whareama River near the township of Tinui

No sedimentation plates have been installed in Lake Onoke to date but, based on bathymetric surveys undertaken of the lakebed in 1994 and 2010, average sedimentation rates across the lakebed exceed 10 mm/year[22]. The high susceptibility to sedimentation is attributed to the very large and predominantly pastoral upstream catchment, and the tendency for the lake's outlet to block on a regular basis – on average, 17 times per year (Perrie & Milne 2012). The January 2010 lake survey found muddy and anoxic sediments in western subtidal areas of the lake; the dominant intertidal habitat, however, was in 'good' condition with well oxygenated, predominantly sandy sediments (Table 5.2).

As well as high to very high sedimentation rates, the sediments of both Waikanae and Whareama estuaries, along with the subtidal sediments of the Hutt Estuary, comprise a high proportion of fine mud (Table 5.2). Such muddy habitats support less diverse benthic invertebrate communities, and are dominated by small deposit-feeding organisms that prefer moderate levels of mud and organic enrichment (eg, the bivalve *Arthritica* sp., the native tub-dwelling amphipod *Paracorophium excavatum* and the polychaete worm *Scolecolepides benhami*). The mud content of Whareama Estuary sediments appears to be increasing, especially at Site B in the upper estuary (Figure 5.3), and will likely have a negative impact on the remaining cockle populations at this site.

---

[22] It was estimated that in the 16 years between the surveys there was around a 200 mm build-up of sediment across most of the lake bed (Des Petersen, Team Leader Technical Services, Greater Wellington, pers. comm. 2012), equating to an annual sedimentation rate of 12.5 mm.



(Source: Stevens & Robertson 2011e, p3)

Figure 5.3: Sediment grain size in the Whareama Estuary, 2008–2011

5.3.2 Eutrophication (nutrient enrichment)

All five of the estuaries monitored had very low organic carbon and low to moderate stores of nitrogen and phosphorus in their sediments (Table 5.2). However, most exhibited one or more signs of slight to moderate enrichment during the monitoring period, such as a relatively shallow depth of oxygenated sediment (indicated by RPD depth), the presence of moderate macroalgae cover and/or a benthic fauna characterised by opportunistic species that are highly tolerant of organic enrichment.

Whareama Estuary consistently recorded the shallowest RPD depth (just 1 cm at both monitoring sites in 2010 and 2011), a reflection more of the very high mud content in its sediments rather than nutrient status (Figure 5.4). In 2011, the same RPD depth (1 cm) was recorded across all four sampling sites within Porirua Harbour, representing the shallowest oxygenated layer since monitoring began in 2008 (Table 5.2, Figure 5.5). While sediment nutrient concentrations were relatively low, both estuary arms support high macroalgae cover that may be contributing to organic enrichment. The Onepoto Arm in particular, has consistently recorded more than 50% cover of nuisance macroalgae, principally the green alga *Ulva* sp. and the red alga *Gracilaria* sp., over a large area of its intertidal flats (Figure 5.6), resulting in localised nuisance conditions (ie, rotting macroalgae and poorly oxygenated and sulphide-rich sediments). Despite this, the benthic communities within both arms of Porirua Harbour were considered healthy and diverse across all four surveys; the increased presence of opportunistic species that are highly tolerant of moderate levels of mud and/or organic enrichment possibly indicates that the estuary is in a transitional state with respect to eutrophication and, therefore, nutrient inputs into the harbour need managing. To assist with this, in January 2011, Greater Wellington commenced monthly water sampling at six sites in the harbour (see Table A1.8, Appendix 1) to establish a baseline of nutrient and chlorophyll *a* concentrations in the harbour (Box 1 summarises the results of the first 12 months of this monitoring).

(Source: Wriggle Coastal Management)

Figure 5.4: Sediment core samples taken from Site A in the Whareama Estuary in 2009 (left) and 2010, illustrating the shallow RPD layer and the presence of black anoxic sediments

(Source: Wriggle Coastal Management)

Figure 5.5: Sediment core samples taken from Site B in the upper Onepoto Arm of Porirua Harbour in 2008 (left) and 2010 – note the shallower RPD depth in 2010

(Source: Juliet Milne)

Figure 5.6: Dense cover of macroalgae, principally sea lettuce (*Ulva* sp.), in the Onepoto Arm of Porirua Harbour, April 2009

The Hutt Estuary recorded a relatively good RPD depth (3–5 cm across the two surveys to date) but, like Porirua Harbour, also had a moderate to high cover of macroalgae. In the 2011 survey, this cover was present over the vast majority of the intertidal area (Figure 5.7). However, nuisance conditions commonly associated with high macroalgal cover were present only in the subtidal area near the river mouth where the sediments are muddy, poorly oxygenated and sulphide rich. Although sediment stores of nitrogen and phosphorus were only rated as moderate in the 2010 and 2011 surveys, there is an indication that nitrogen concentrations have increased in the estuary. In 2004 the Cawthron Institute carried out a fine scale assessment at a site very near to Site A (refer to Figure 5.1). On this occasion nitrogen and phosphorus concentrations were reported as low and the site categorised as not enriched (Stevens et al. 2004).

(Source: Wriggle Coastal Management)

Figure 5.7: Intertidal macroalgal cover in the Hutt Estuary, January 2011

Box 1: Porirua Harbour water quality monitoring results, January to December 2011

Water samples were collected monthly on a mid-ebb tide from six sites in Porirua Harbour (Figure 1A) and analysed for temperature, pH, salinity, conductivity, dissolved oxygen, turbidity, total suspended solids (TSS), soluble and total nitrogen and phosphorus, and chlorophyll *a* (see Appendix 2 for further details).

Overall, based on the first 12 months of sampling, water quality is more variable at monitoring sites at the head of the Pauatahanui Arm (P2) and the Onepoto Arm (O2), than at the outer harbour site (E1). This reflects the influence of freshwater streams and stormwater inputs on the inner harbour areas. As expected, concentrations of phosphorus, nitrogen and chlorophyll *a* were all consistently low at site E1 compared with at other sites. Chlorophyll *a* varied seasonally at some sites, peaking in March and April 2011 at site O2.

Figure 1A: Location of Porirua Harbour water quality sampling sites

Table 1A: Median (and range)[1] of values for selected variables measured during monthly water sampling between January and December 2011

	Porirua Harbour – Entrance (E1)	Pauatahanui Arm – North (P1)	Pauatahanui Arm – East (P2)	Pauatahanui Arm – South (P3)	Onepoto Arm – North (O1)	Onepoto Arm – South (O2)
TSS (mg/L)	6.5 (2–51)	12.5 (5–83)	8.5 (4–210)	11 (3–67)	10 (5–45)	21.5 (9–230)
Turbidity (NTU)	2.35 (1.22–19.5)	6.6 (2–54)	3.8 (2.1–169)	5.45 (1.57–15.6)	5.75 (2.2-25)	9.5 (1.56–126)
Salinity (ppt)	34 (32–35)	32.5 (29–35)	31 (11–35)	32 (22–35)	32.5 (28-35)	30 (15.8–34)
Chlorophyll *a* (mg/L)	0.0015 (–)	0.0015 (0.0015–0.003)	0.0015 (0.0015–0.016)	0.0015 (0.0015–0.007)	0.0015 (0.0015–0.005)	0.0015 (0.0015–0.019)
Ammoniacal nitrogen (mg/L)	0.005 (0.005–0.026)	0.005 (0.005–0.041)	0.005 (0.005–0.074)	0.005 (0.005–0.038)	0.005 (0.005–0.051)	0.0165 (0.005–0.11)
Nitrate-N + nitrite-N (mg/L)	0.002 (0.001–0.138)	0.0035 (0.001–0.12)	0.01 (0.001–0.66)	0.001 (0.001–0.23)	0.003 (0.001–0.149)	0.1335 (0.001–0.37)
Dissolved reactive phosphorus (mg/L)	0.0055 (0.002–0.012)	0.007 (0.002–0.015)	0.008 (0.002–0.017)	0.0045 (0.002–0.014)	0.005 (0.002–0.017)	0.0035 (0.002–0.019)
Total phosphorus (mg/L)	0.0155 (0.012–0.046)	0.0265 (0.015–0.09)	0.0235 (0.015–0.24)	0.025 (0.016–0.036)	0.0275 (0.02–0.053)	0.039 (0.024–0.25)

[1] Values reported as below the laboratory detection limit have been halved.

5.3.3 Toxic contamination

Sediment contaminant concentrations were considered to be low across all of the estuaries monitored between 2008 and 2011 (Table 5.2). The organochlorine pesticide DDT and its breakdown products (DDD and DDE) were below detection limits in surface sediments from all sites and all sediment concentrations of PAHs and heavy metals were well below their respective ANZECC (2000) Interim Sediment Quality Guideline (ISQG) Low trigger values (refer to Section 2.5 for information on the guidelines referenced in this section). The exception was nickel which ranged from 17–18 mg/kg across the three replicate samples collected from Lake Onoke, approaching the ANZECC (2000) ISQG-Low trigger value of 21 mg/kg.

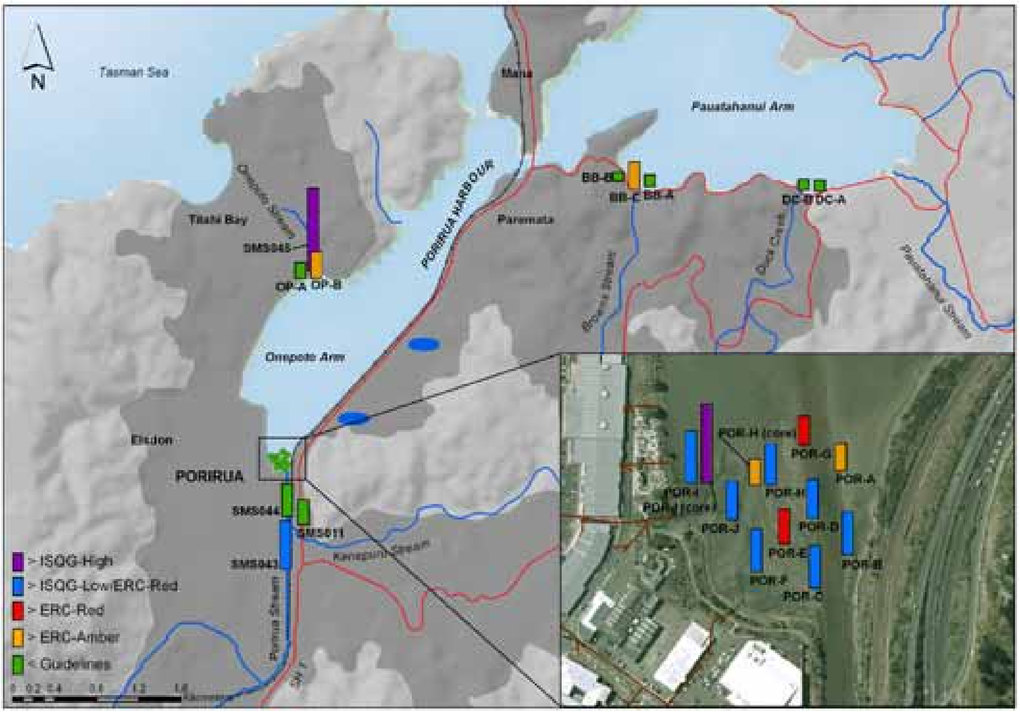
While the low levels of contaminants in the Hutt Estuary sediments indicate that there is no widespread contamination of intertidal or shallow subtidal areas, localised pockets of potentially toxic surface sediments may exist closer to stormwater outfalls and the Te Mome Stream mouth. This is certainly the case in Porirua Harbour where, as well as having elevated concentrations of contaminants in the mud-dominated subtidal basins (see Section 6), a one-off investigation of surface sediment contamination at selected intertidal 'hotspots' in Porirua Harbour in February 2009[23] identified concentrations of zinc above the ANZECC (2000) ISQG-Low trigger value spanning an area of approximately 20,000 m^2 between the Semple Street stormwater outfall and the Porirua Stream channel at the southern end of the Onepoto Arm (Sorensen & Milne 2009; Figures 5.8 and 5.9). This area is just to the south of long-term monitoring Site B in the intertidal estuary monitoring programme where sediment contaminant concentrations are well below guideline values (yet elevated compared with those recorded at the other three long-term intertidal monitoring sites in Porirua Harbour).

Sorensen and Milne's (2009) targeted 'hotspot' assessment also identified:

- Copper, lead and total high molecular weight PAH (HMW PAH) concentrations above the Auckland Regional Council (2004) Environmental Response Criteria (ARC ERC) Amber threshold in some sediment samples from the southern end of the Onepoto Arm;
- Sediments at the mouth of the 'Onepoto' Stream beside the Porirua Rowing Club with concentrations of lead, zinc (Figure 5.8) and various PAH compounds above ARC (2004) ERC-Amber and (in the case of PAHs) ANZECC (2000) ISQG-Low sediment quality guidelines;
- Sediments adjacent to the mouth of Browns Stream in Pauatahanui Inlet with lead and total HMW PAH concentrations above the ARC (2004) ERC-Amber threshold; and
- Total DDT concentrations above ARC (2004) ERC-Amber and ANZECC (2000) ISQG-Low guideline values in the sediments from all 17 sites sampled in the investigation, including the mouths of Browns Stream and Duck Creek in the Pauatahanui Inlet (Figure 5.10).

---

[23] In addition, sediment samples were collected from the lower reaches of several streams that receive urban stormwater inputs, including the Porirua Stream.

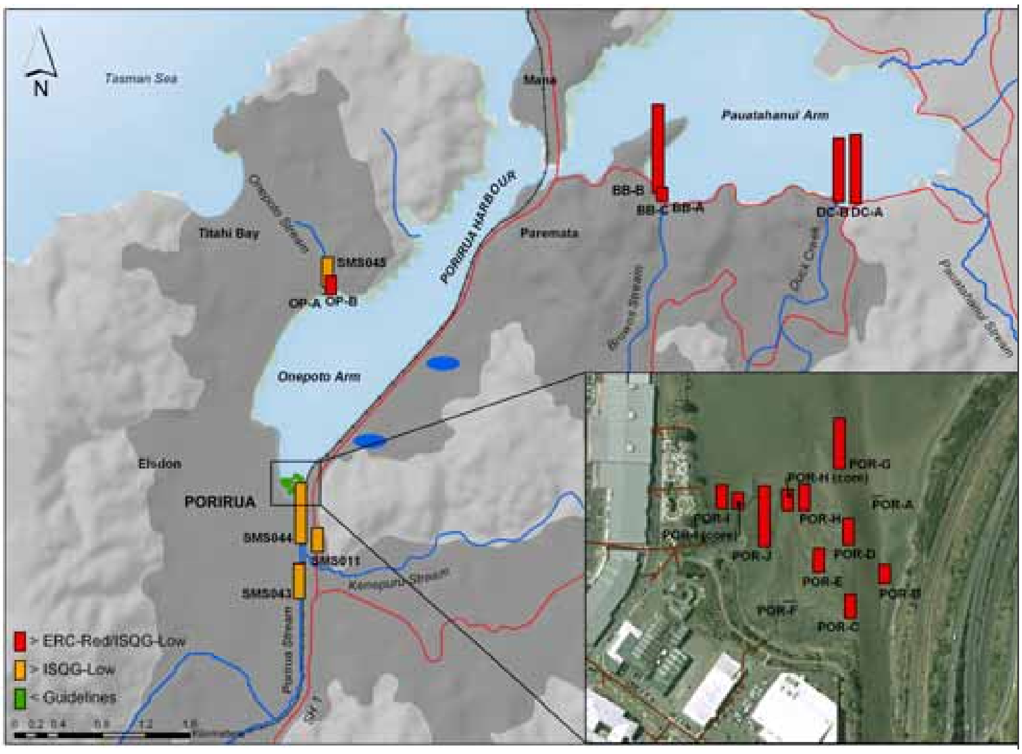


(Source: Sorensen & Milne 2009, p26)

Figure 5.8: Total zinc concentrations in surface sediments of sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment in February 2009, based on the <2 mm fraction of a single composite sample from each site. The concentrations present are coloured in accordance with sediment quality guidelines (see Section 2.5) exceeded, with the length of each bar directly proportional to the zinc concentration present.

(Source: Sorensen & Milne 2009, p1)

Figure 5.9: Outflow from the Semple Street stormwater outfall at the southern end of the Onepoto Arm of Porirua Harbour



(Source: Sorensen & Milne 2009, p31)

Figure 5.10: Total DDT concentrations in surface sediments of sites sampled as part of the Porirua Harbour targeted intertidal sediment quality assessment in February 2009, based on the <2 mm fraction of a single composite sample from each site. The concentrations present are coloured in accordance with sediment quality guidelines exceeded (see Section 2.5), with the length of each bar directly proportional to the DDT concentration present.

5.4 Synthesis

Fine scale ecological monitoring between 2008 and 2011 has enabled a baseline of estuary condition to be established for the Whareama Estuary and the intertidal arms of Porirua Harbour, against which future impacts or remediation can be measured. A further year's monitoring is needed before a robust baseline is established for Waikanae and Hutt estuaries. Similarly, further monitoring is required to establish a baseline of benthic condition in Lake Onoke.

Based on the monitoring undertaken to date, all five estuaries appear to be in a 'moderate' or 'good' condition. While sediment contamination is not an issue at any of the sites monitored, localised contamination of sediments exists at the southern end of the Onepoto Arm of Porirua Harbour and all of the estuaries exhibit some signs of 'stress' from either sedimentation or eutrophication. The Whareama Estuary in particular, has an excessive sedimentation rate and very muddy sediments, reflecting naturally high sediment inputs from the upstream catchment. Both Porirua Harbour and Hutt Estuary have macroalgal cover present at nuisance levels in places which, despite relatively low sediment nutrient concentrations, suggest a need to manage nutrient inputs from the surrounding catchment. With further urban development and future forestry harvesting planned in its catchment, sediment inputs also need to be managed in Porirua Harbour. While there is uncertainty as to the current sediment rates within the two arms of the harbour, fine scale monitoring between 2008 and 2011 showed a decrease in the depth of oxygenated sediment across all four monitoring sites, indicating the current diverse benthic invertebrate community could shift to one dominated more by opportunistic species tolerant of moderate levels of mud and organic enrichment; recent surveys have already detected an increased presence of such species.

6. Subtidal harbour sediment quality and ecology

This section summarises the results of Greater Wellington's subtidal sediment quality and benthic community surveys undertaken in Porirua and Wellington harbours between June 2004 and June 2011. Five surveys were conducted over this period, four in Porirua Harbour (in 2004, 2005, 2008 and 2010, documented in Williamson et al. (2005), Stephenson and Mills (2006), Milne et al. (2009), and Oliver et al. (in press), respectively) and one in Wellington Harbour (in 2006, documented in Stephenson et al. (2008) and Milne (2010b). A second survey of sediment quality in Wellington Harbour was undertaken in late 2011 but the results were not available at the time of preparing this report. The reader should consult the individual survey reports for full details of sampling methods and results.

6.1 Background

Like other coastal environments surrounded by densely populated urban areas, Porirua Harbour and Wellington Harbour both receive significant stormwater inputs with the potential to adversely impact on the health of their ecosystems. The most significant medium to long-term impact of urban stormwater discharges on the harbours is likely to be the accumulation of stormwater-related contaminants in the sediments, especially in muddy depositional areas. This is because the contaminants can, over time, build up to concentrations that are toxic to benthic organisms.

In response to a report documenting evidence of stormwater impacts on the sediments of Porirua and Wellington harbours (Williamson et al. 2001), long-term baseline monitoring programmes were established with the assistance of NIWA to detect trends in the concentrations of stormwater-derived contaminants in the bed sediments of both harbours (Ray et al. 2003). In Porirua Harbour, which essentially comprises two separate estuaries with significant intertidal and subtidal areas, the monitoring programme was established in the subtidal basins where the substrate comprises a high proportion of mud and fine sediment. Many contaminants tend to bind to fine sediment particles, and the low settling velocities of such particles mean that they are likely to be widely dispersed and hence representative of far-field sources of stormwater-derived contamination (Ray et al. 2003).

6.2 Monitoring sites and methods

Five sites are included in the Porirua Harbour subtidal monitoring programme, two in the Onepoto Arm and three in the Pauatahanui Arm (Figure 6.1), with each site having adjoining sediment chemistry and benthic fauna collection areas. In Wellington Harbour, 17 sites (also with adjoining sediment chemistry and benthic fauna collection areas) were sampled in the initial 2006 baseline survey from which a subset of 11 are now being used for long-term monitoring (and were sampled in the second survey in late 2011).

At each monitoring site, 25 sediment and eight 'benthos' core samples were collected from a sampling area 20 m in diameter by the use of a boat, GPS and scuba divers. The 25 sediment cores were randomly assigned into five replicate groups for chemical analysis (top 30 mm of each core only so as to

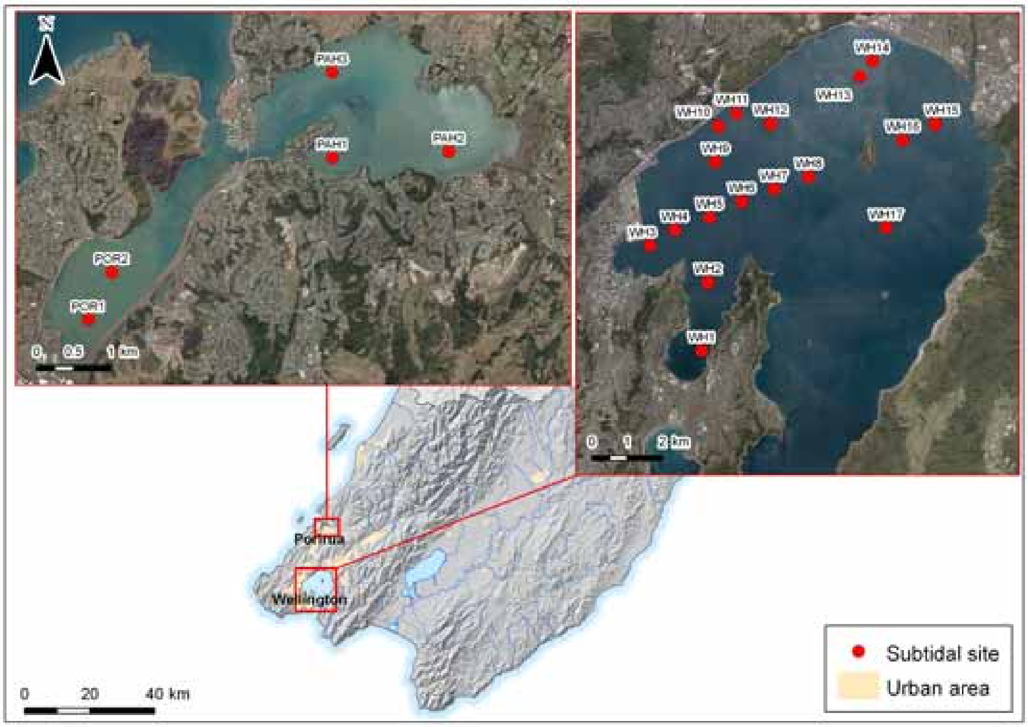


Figure 6.1: Locations of subtidal monitoring sites in Porirua and Wellington harbours sampled in sediment quality surveys between 2004 and 2010

represent ‘recent’ contamination accumulation). The suite of chemical analyses altered slightly between surveys, but included heavy metals, polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides (OCPs) and organotin compounds (refer to Table A2.4 in Appendix 2 for details of the analytical methods). Supporting sediment variables that assist with the interpretation of these contaminants and the health of the benthic fauna community were also measured, namely sediment particle (grain) size and total organic carbon (TOC). The ‘benthos’ core samples were identified to the lowest taxonomic level practicable and shell lengths of selected species measured. Refer to Oliver et al. (in press) and Stephenson et al. (2008) for further details of monitoring methods employed in Porirua and Wellington harbours, respectively.

6.3 Sediment quality

Tables 6.1 and 6.2 summarise the mean range of concentrations of heavy metals, PAHs, organochlorine pesticides and organotin compounds measured in sediment samples collected from the beds of Porirua and Wellington harbours between 2004 and 2010. The results are compared against both the ANZECC (2000) Interim Sediment Quality Guidelines (ISQG) and the Auckland Regional Council’s (ARC 2004) Environmental Response Criteria (ERC) outlined in Section 2.5, with organic contaminant concentrations normalised to 1% TOC for this purpose[24].

---

[24] TOC-normalisation gives a concentration equivalent to that which would be present in sediments with 1% TOC content, assuming the concentration of the organic contaminant is correlated with TOC content. This approach has been adopted in the ANZECC (2000) sediment quality guidelines and ARC (2004) Environmental Response Criteria to allow better comparisons of potential toxicity between sites with different sediment TOC content.

Table 6.1: Mean particle size, percentage mud (particles <63 µm) and range of concentrations of metals, dibutyltin (DBT) and tributyltin (TBT) in sediments of groups of monitoring sites in Porirua Harbour (four surveys in 2004, 2005, 2008 and 2010)[1] and Wellington Harbour (one survey in 2006). Sediment quality guidelines for comparison are ANZECC (2000) and Auckland Regional Council Environmental Response Criteria (ARC ERC; ARC 2004). Values in amber exceed the ARC ERC amber threshold and values in red exceed the ARC ERC red threshold and/or ANZECC ISQG-Low.

Analyte	**Fraction analysed**	**ANZECC (2000)**		**ARC ERC**		**Porirua Harbour**		**Wellington Harbour**				
		ISQG-Low	**ISQG-High**	**amber**	**red**	**POR 1–POR2**	**PAH1–PAH3**	**WH1–WH2**	**WH3–WH4**	**WH5–WH8**	**WH9–WH12**	**WH13–WH17**
Mean particle size (µm)	<500 µm	–	–	–	–	32.7 – 47.5	62.9 – 102.3	60.3 – 94.0	43.3 – 59.3	34.4 – 37.6	23.1 – 28.0	27.6 – 74.2
% particles <63 µm	<500 µm	–	–	–	–	73.8 – 89.9	20.4 – 50.3	25.5 –57.9	58.2 – 72.9	84.9 – 87.5	91.7 – 95.2	38.3 – 94.8
Weak acid extractable metals (mg/kg):												
Copper	<63 µm	–	–	–	–	13.2 – 16.2	7.2 – 10.0	14.2 – 20.8	14.4 – 25.0	8.8 – 9.8	10.8 – 13.2	9.8 – 15.6
Lead	<63 µm	–	–	–	–	32.0 – 39.7	15.3 – 23.1	50.5 – 69.0	44.5 – 60.4	32.0 – 34.3	40.1 – 48.8	27.7 – 40.5
Zinc	<63 µm	–	–	–	–	126.0 – 150.6	43.2 – 72.2	101.2 – 121.6	93.2 – 116.6	70.8 – 76.2	85.4 – 96.8	74.4 – 97.0
Total metals (mg/kg):												
Silver	<500 µm	1	3.7	–	–	0.11 – 0.18	0.05 – 0.07	0.5 – 0.7	0.4 – 0.6	<0.4	<0.4	<0.4
Arsenic	<500 µm	20	70	–	–	10.7 – 13	5.8 – 11	5.0 – 6.2	6.1	6.0 – 6.8	6.3 – 7.3	6.2 – 8.6
Cadmium	<500 µm	1.5	10	–	–	0.04 – 0.17	0.03 – 0.07	0.05 – 0.08	0.06	0.04 – 0.05	0.04 – 0.06	0.03 – 0.09
Chromium	<500 µm	80	370	–	–	16.3 – 26.2	13.1 – 22.4	23.7 – 24.5	24.9 – 25.6	22.8 – 24.4	25.2 – 26.1	18.3 – 25.7
Copper	<500 µm	65	270	19	34	**19.2 – 26.9**	7.7 – 18.4	**19.2 – 25.7**	**20.2 – 31.6**	13.2 – 16.9	15.7 – 18.6	11.9 – 18.4
Mercury	<500 µm	0.15	1	–	–	0.11 – 0.14	0.05 – 0.11	**0.62 – 0.79**	**0.51 – 0.77**	**0.19 – 0.32**	**0.24 – 0.36**	0.15 – **0.23**
Nickel	<500 µm	21	52	–	–	10.4 – 14	8.5 – 13.7	16.6 – 17.6	17.3 – 18.2	17.2 – 18.8	18.2 – 18.7	15.1 – 19.7
Lead	<500 µm	50	220	30	50	**38 – 42**	15.6 – 23.8	**51 – 67.1**	**50.5 – 62.5**	**30.3 – 37.9**	**40.1 – 50.5**	24.9 – **40.2**
Antimony	<500 µm	–	–	–	–	0.3 – 0.4	0.21 – 0.26	<0.4	<0.4	<0.4	<0.4	<0.4 – 0.5
Zinc	<500 µm	200	410	124	150	**127 – 203**	56.9 – 88.9	114 – **130**	117 – **132**	88.3 – 99.1	103 – 119	83.9 – 112
Organotins (µg Sn/kg):												
Dibutyltin	<500 µm	–	–	–	–	<2 – 4	3 – 6	10 – 12	17 – 22	11 – 14	12 – 16	9 – 23
Tributyltin	<500 µm	5	70	–	–	<2 – <5	<1 – 2	<3 – <5	**6 – 9**	<3	<3 – **12**	<3 – <5

[1] Values are the lowest and highest mean in each group of sites across all four surveys. Note that organotin analysis was limited to the 2004 and 2005 surveys, and antimony was only included in the total metal suite in 2005.

Table 6.2: Mean range of concentrations of total organic carbon (TOC) and selected organic contaminants in sediments of groups of monitoring sites in Porirua Harbour (averaged across four surveys in 2004, 2005, 2008 and 2010)[1] and Wellington Harbour (one survey in 2006[2]). Sediment quality guidelines for comparison are ANZECC (2000) and Auckland Regional Council Environmental Response Criteria (ARC ERC; ARC 2004). Values in amber exceed the ANZECC ISQG-Low or ARC ERC amber threshold and values in red exceed the ANZECC ISQG-Low and ARC ERC red threshold.

Analyte	Fraction analysed	ANZECC (2000)		ARC ERC		Porirua Harbour		Wellington Harbour				
		ISQG-Low	ISQG-High	amber	red	POR 1–POR2	PAH1–PAH3	WH1–WH2	WH3–WH4	WH5–WH8	WH9–WH12	WH13–WH17
TOC (%)	<500 µm	–	–	–	–	1.83 – 2.4	0.97 – 2.02	1.43 – 1.72	1.59 – 1.78	1.31 – 1.38	1.50 – 1.72	1.21 – 2.17
Organics (µg/kg):												
Fluorene	<500 µm	–	–	–	–			14.4 – 42.8	13.6 – 27.6	4.7 – 6.9	5.6 – 8.68	3.58 – 6.74
Phenanthrene	<500 µm	–	–	–	–			160 – 428	158 – 348	35.8 – 71	54 – 90	30.8 – 56.8
Benzo(a)anthracene	<500 µm	–	–	–	–			190 – 538	170 – 348	36.4 – 78.2	61 – 104.4	23.4 – 55.0
Total PAH[3,4]	<500 µm					386 – 781	91 – 224	2,452 – 6,414	2,302 – 4,588	567 – 1,097	787 – 1,354	364 – 712
Total HMW PAH[3,4]	<500 µm	–	–	–	–	198 – 428	45 – 109	1,368 – 3,585	1,279 – 2,601	289 – 593	421 – 729	186 – 381
Hexachlorobenzene	<500 µm	–	–	–	–			<0.2	<0.2 – 0.6	<0.2	<0.2	<0.2
Total DDT[4,5]	<500 µm	–	–	–	–	6.3 – 11.4	4.0 – 11.2	4.9 – 12.7	5.6 – 14.2	2.4 –3.5	2.8 – 4.0	1.8 – 5.1
Fluorene	at 1% TOC[6]	19	540	–	–			10 – 25	9 – 16	3 – 5	3 – 5	2 – 3
Phenanthrene	at 1% TOC[6]	240	1,500	–	–			112 – 248	99 – 196	26 – 51.3	34 – 53	16 – 28
Benzo(a)anthracene	at 1% TOC[6]	261	1,600	–	–			133 – 312	107 – 196	27 – 56.5	38 – 61	11 – 30
Total PAH[3,4]	at 1% TOC[6]	4,000	45,000	–	–	197 – 368	47 – 150	1,715 – 3,722	1,445 – 2,580	417 – 793	490 – 809	168 – 389
Total HMW PAH[3,4]	at 1% TOC[6]	1,700	9,600	660	1,700	101 – 211	19 – 82	957 – 2,081	803 – 1,463	213 – 429	262 – 435	86 – 208
Hexachlorobenzene	at 1% TOC[6]	–	–	–	–			<0.2	<0.2 – 0.4	<0.2	<0.2	<0.2
Total DDT[4,5]	at 1% TOC[6]	1.6	46	–	3.9	3.4 – 5.8	3.6 – 6.2	3.4 – 7.4	3.5 – 8.0	1.8 –2.5	1.7 – 2.3	1.5 – 2.4

[1] Values are the lowest and highest mean in each group of sites across all four surveys. Note that organic contaminants were not included in the 2008 Porirua Harbour survey and in 2010 survey, PAH analysis was limited to one site, POR1.

[2] For consistency with other data and Figures 6.5–6.6 presented in this section, the results taken here are the original RJ Hill Laboratory values summarised from Stephenson et al. (2008). Refer to Milne (2010b) for PAH results obtained from sediment samples re-analysed by NIWA.

[3] Polycyclic aromatic hydrocarbons have been summarised as 'Total PAH' (all the PAH compounds analysed), and as 'Total High Molecular Weight PAH', which is the sum of the concentrations of chrysene, fluoranthene, pyrene, benzo[a]anthracene, benzo[a]pyrene, and dibenzo[a,h]anthracene. This is the total used for the ANZECC (2000) sediment quality guidelines and ARC ERC (ARC 2004).

[4] For the purpose of calculating Total PAH, Total HMW PAH, and Total DDT, the concentration of any individual compound reported at 'less than detection limit' has been replaced by a value one half of the detection limit.

[5] DDT and related compounds have been summarised as 'Total DDT', which is the sum of the concentrations of 2,4'-DDE, 2,4'-DDD, 2,4'-DDT, 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT.

[6] This TOC 'normalisation' is used in the ANZECC (2000) sediment quality guidelines and ARC (2004) ERC for comparing sediments with different TOC content.

6.3.1 Heavy metals

Across all four surveys of Porirua Harbour, concentrations of total copper, lead and zinc were above ‘early warning’ sediment quality guidelines in the subtidal sediments of the Onepoto Arm of Porirua Harbour (Table 6.1, Figures 6.2 and 6.3), with total zinc concentrations exceeding both ARC (2004) ERC-Red and ANZECC (2000) ISQG-Low trigger values at the southern most site in Onepoto Arm (POR1) in three of the four surveys (Figure 6.3). Concentrations of the other metals analysed were below guideline levels in the Onepoto Arm, as were the concentrations of all metals in sediments sampled from the Pauatahanui Arm.

In Wellington Harbour, concentrations of total mercury (Figure 6.4), lead (Figure 6.5), and to a lesser extent copper (Figure 6.5) and zinc, exceeded one or more of the ANZECC (2000) ISQG-Low, ARC (2004) ERC-Amber or ARC (2004) ERC-Red threshold values in the subtidal sediments at various locations, especially in those adjacent to Wellington city.

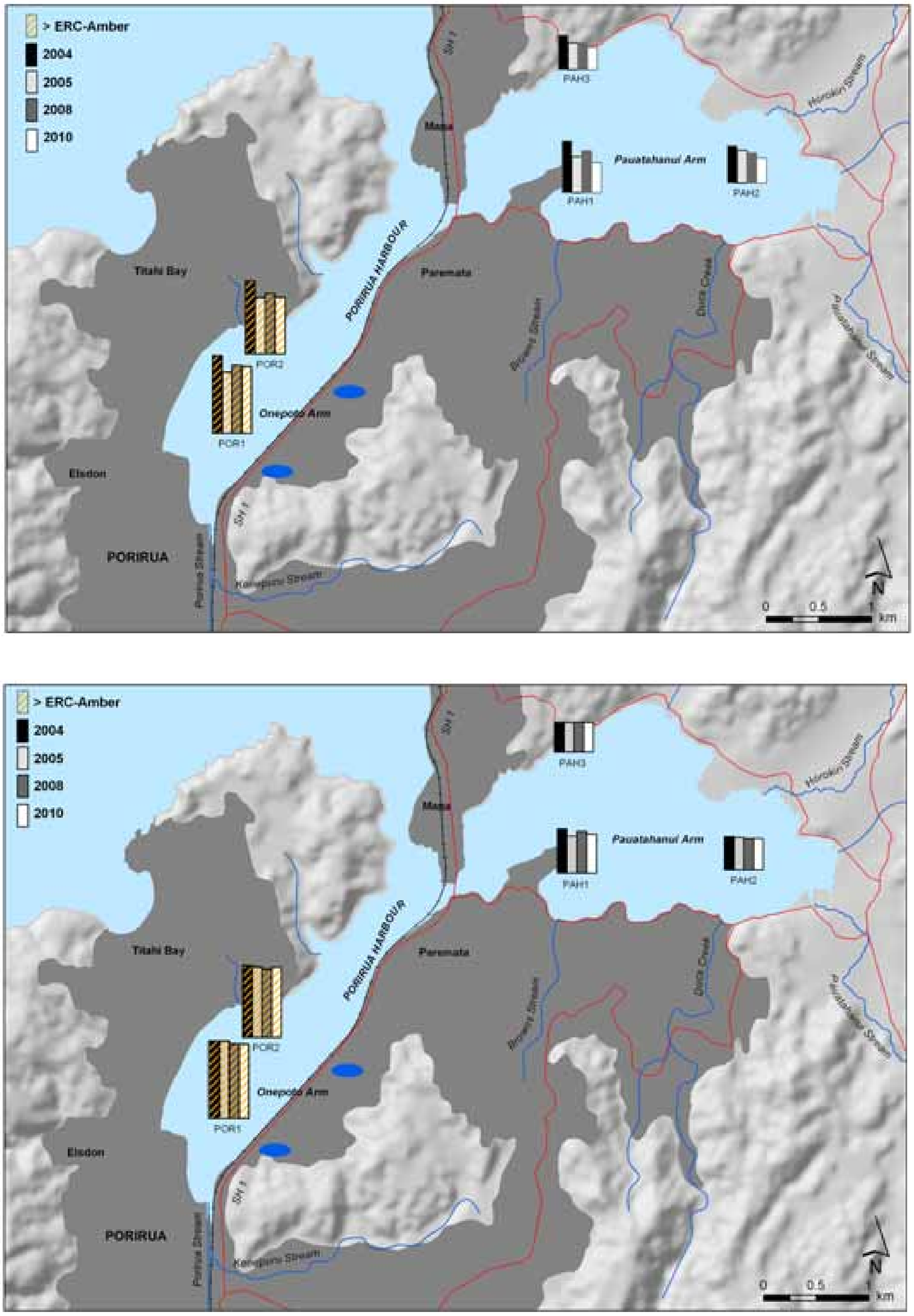
6.3.2 Organotin compounds

In both Porirua and Wellington harbours, most of the organotin compounds measured were below or close to analytical detection limits. The main exception was tributyltin (TBT) in Wellington Harbour, which was present at concentrations above the ANZECC (2000) ISQG-Low trigger value at the entrance to the Lambton Basin and off Ngauranga (Table 6.2); its less toxic breakdown product dibutyltin was found to be more widespread.

6.3.3 PAHs

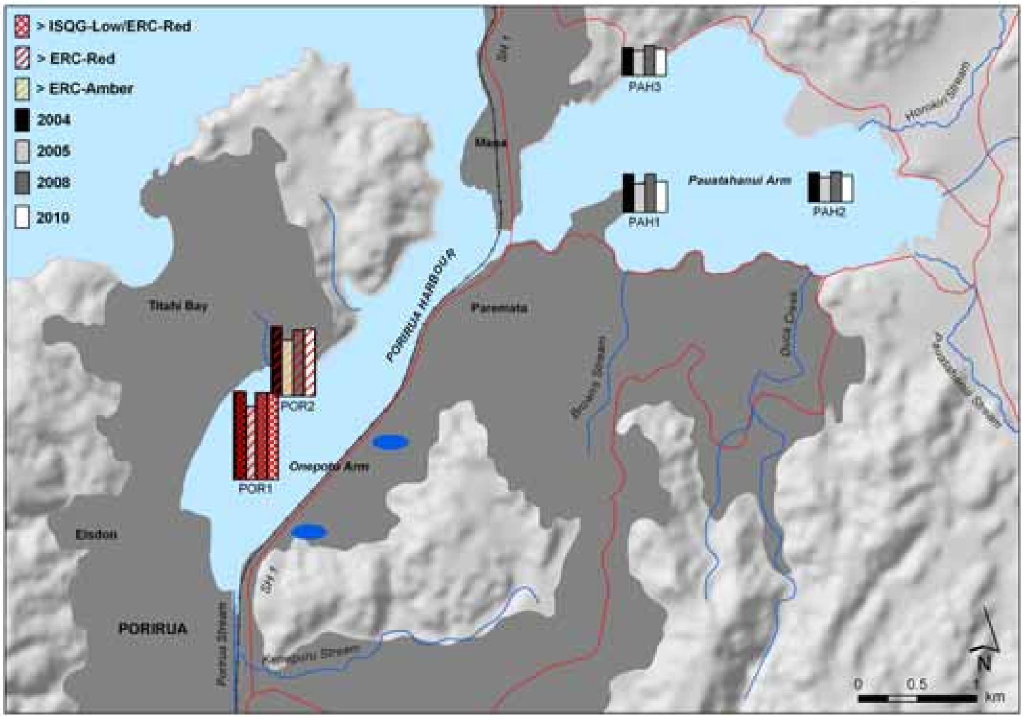
When tested in 2004 and 2005, mean Total PAH and Total High Molecular Weight PAH (Total HMW PAH) concentrations were found to be consistently higher in the sediments from sites in the Onepoto Arm of Porirua Harbour than in sediments from the Pauatahanui Arm (Table 6.2). However, mean sediment concentrations were well below both ARC (2004) ERC-Amber and ANZECC (2000) ISQG-Low thresholds at all sites.

In contrast, the 2006 baseline survey of Wellington Harbour showed Total HMW PAH compounds exceeded both the ARC (2004) ERC-Amber threshold and the ANZECC (2000) ISQG-Low trigger value in the sediments of site WH1 in southern Evans Bay (Table 6.2, Figure 6.6). Mean concentrations of three individual PAH compounds (fluorene, phenanthrene and benzo[a]anthracene) also exceeded their respective ANZECC (2000) ISQG-Low trigger values in the sediments at this site. Site WH2 in northern Evans Bay and sites WH3 and WH4 at the entrance to Lambton Basin all recorded mean Total HMW PAH concentrations above the ARC (2004) ERC-Amber threshold.



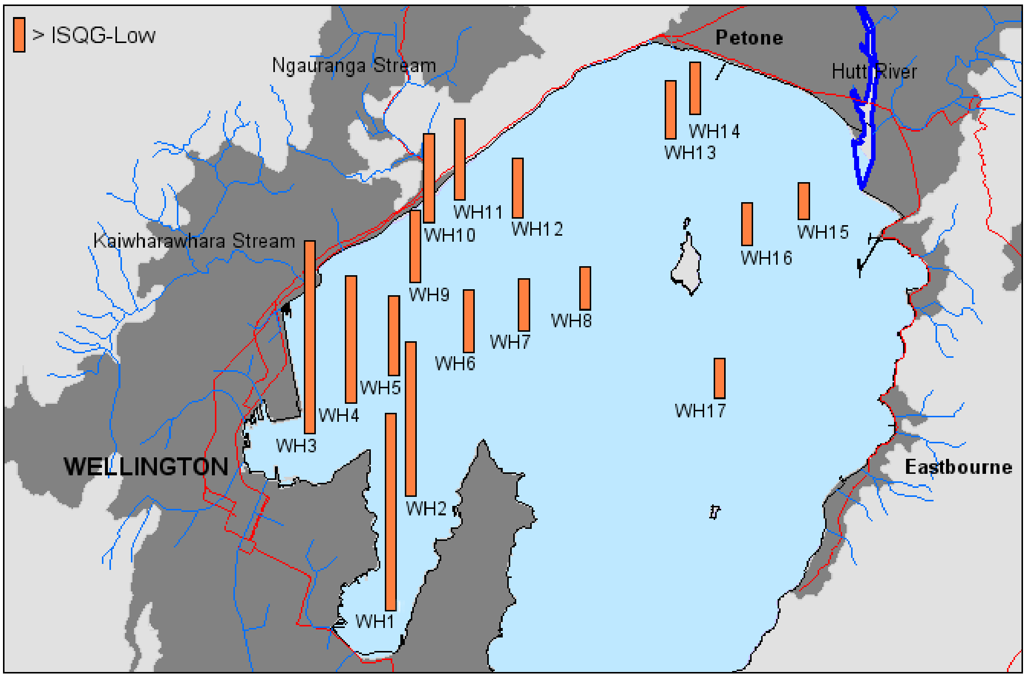
(Source: Oliver et al. in press)

Figure 6.2: Relative concentrations of total copper (top) and lead (bottom) in sediments from five sites sampled in Porirua Harbour in 2004, 2005, 2008 and 2010, based on the <500 µm fraction of a single composite sample from each site. Note that the scale used for the bars is unique to each map.



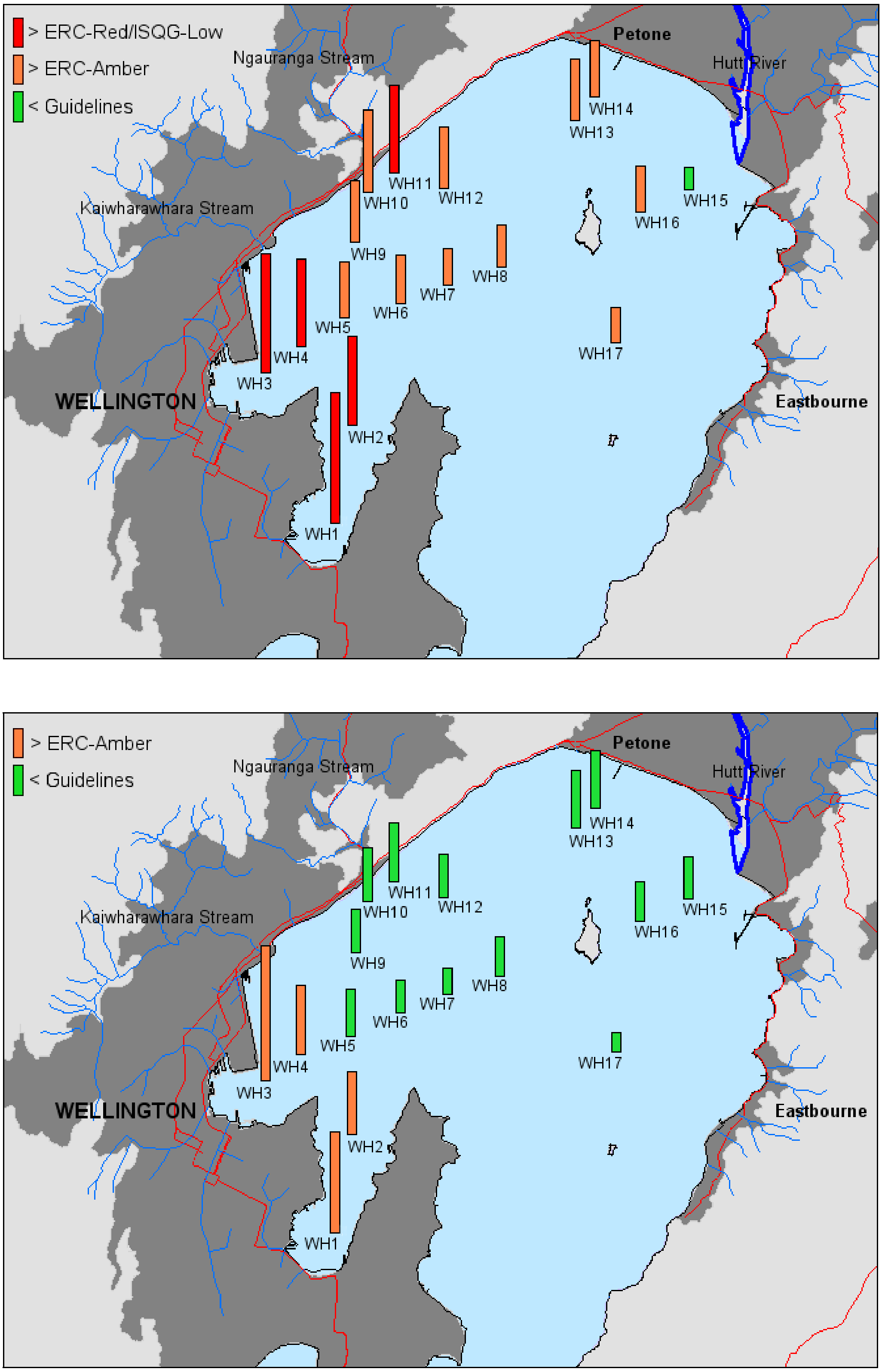
(Source: Oliver et al. in press)

Figure 6.3: Relative concentrations of total zinc in sediments from five sites sampled in Porirua Harbour in 2004, 2005, 2008 and 2010, based on the <500 µm fraction of a single composite sample from each site



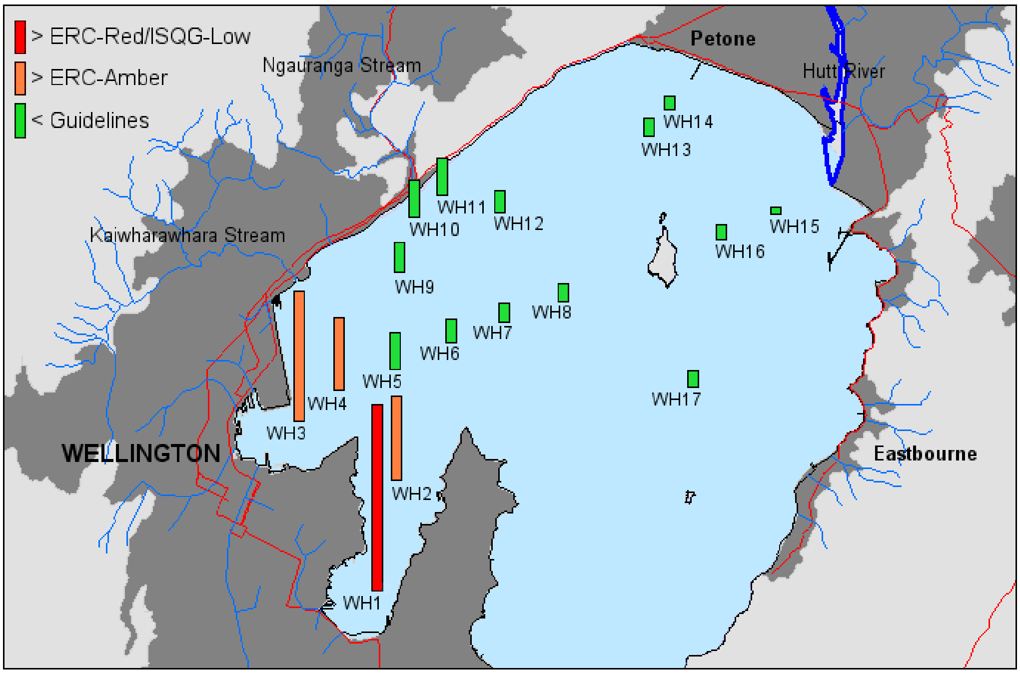
(Source: Stephenson et al. 2008, p54)

Figure 6.4: Relative concentrations of total mercury in sediments from 17 sites sampled in Wellington Harbour in 2006, based on the <500 µm fraction of a single composite sample from each site



(Source: Stephenson et al. 2008, p53)

Figure 6.5: Relative concentrations of total lead (top) and copper (bottom) in sediments from 17 sites sampled in Wellington Harbour in 2006, based on the <500 µm fraction of a single composite sample from each site. Note that the scale used for the bars is unique to each map.



(Source: Stephenson et al. 2008, p57)

Figure 6.6: Mean concentrations of Total High Molecular Weight PAHs in sediments from 17 sites sampled in Wellington Harbour in 2006, based on the <500 µm fraction of five composite samples from each site

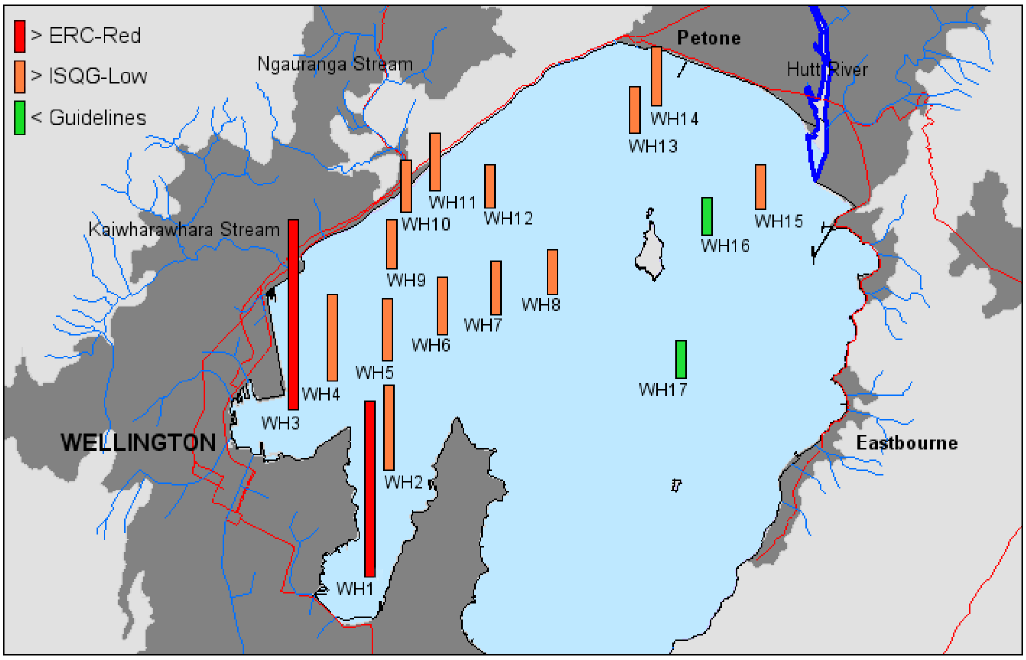
During 2009 and 2010 some further work was carried out (documented in Milne 2010b), including analysis of the 2006 sediment samples for a range of alkylated PAHs and marker compounds, to assist with identifying the potential source of the elevated levels of PAHs. The results of the PAH source analyses were inconclusive but the pyrogenic nature of the PAHs in the harbour sediments indicated that the most likely sources are soot from mobile and/or stationary combustion of fossil fuels, and coal tar from either diffuse pollution (roading) or point sources (discharge of gasworks waste) (Depree 2010). Of these, coal tar appears to be the most likely source. Although largely unknown as a diffuse pollution source, coal tar was widely used throughout New Zealand between the early 1900s and the mid-1970s as a binder for sealing roads, and would have been used in catchments that discharge into Wellington Harbour (Depree 2010).

6.3.4 Organochlorine pesticides

Of the more than 20 organochlorine pesticides Porirua and Wellington Harbour sediment samples were analysed for, only the insecticide DDT and its derivatives (DDE and DDD) were consistently measured above analytical detection limits. Four of the five sites in Porirua Harbour and sites WH1 (southern Evans Bay) and WH3 (Lambton Basin entrance) in Wellington Harbour recorded mean Total DDT[25] concentrations above both the ARC (2004) ERC-Red threshold and the ANZECC (2000) ISQG-Low trigger value (Table 6.2). At the remaining Porirua Harbour site (PAH1, refer Figure 6.1) and all other Wellington Harbour sites, except WH16 and WH17, mean DDT concentrations exceeded the ISQG-Low trigger value (Figure 6.7).

---

[25] For an explanation of the term 'Total DDT' refer to the notes under Table 6.2.



(Source: Stephenson et al. (2008), p60)

Figure 6.7: Mean concentrations of Total DDT in sediments from 17 sites sampled in Wellington Harbour in 2006, based on the <500 µm fraction of five composite samples from each site

6.4 Benthic community health

Benthic community health assessments form a critical part of the Porirua and Wellington Harbour subtidal sediment contaminant monitoring programmes. Sediment quality guidelines only serve as 'bench marks' for possible adverse ecological effects; periodic measurements of benthic community structure and richness, and comparison of these against sediment contaminant concentrations, provide a more direct means of assessing whether sediment contaminants are actually adversely impacting on benthic community health.

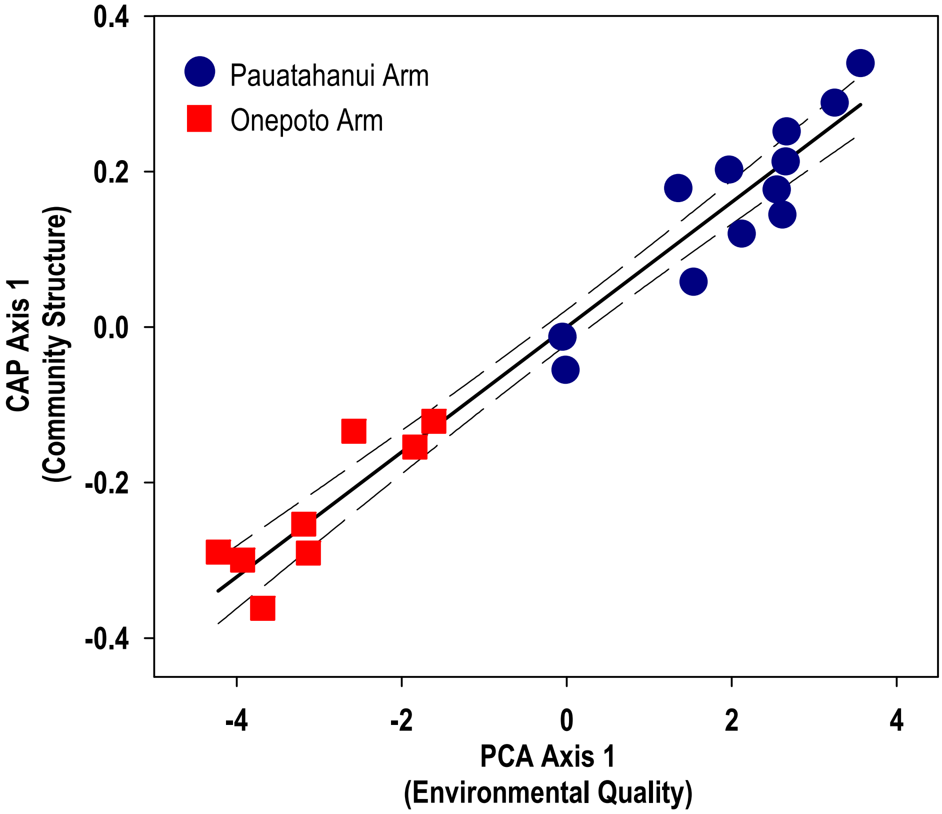
6.4.1 Taxonomic richness

The total number of species identified in the benthic fauna samples collected from Porirua Harbour between 2004 and 2010 varied between 51 (2004 survey) and 64 (2008 survey), with the benthic fauna composed predominantly of polychaetes, bivalve molluscs, and crustaceans. In each of the four surveys, taxonomic richness was significantly higher in the Pauatahanui Arm. For example, all but four of the 58 species identified in the 2010 survey were found in samples taken from sites in the Pauatahanui Arm. In contrast, only 29 of the 58 species were found in the samples taken from two sites in the Onepoto Arm (Oliver et al. in press). This is discussed further in Section 6.4.2.

A total of 101 species were found in the benthic fauna samples collected in the 2006 baseline survey of Wellington Harbour, predominantly polychaete worms, crustaceans, bivalve molluscs and nemertean worms. The fauna present at the investigation sites were considered to be variants of an inner harbour subtidal fine sediment community occurring in water depths >10 m. The heart urchin *Echinocardium cordatum*, the bivalve *Dosina zelandica*, the rag-worm *Onuphis aucklandensis*, the bamboo worm *Asychis trifilosa*, or a combination of these species, most often dominated the biomass (Stephenson et al. 2008).

6.4.2 Relationship between benthic community health and sediment quality

Multivariate statistical analyses performed on monitoring data collected across all four surveys of Porirua Harbour did not identify any clear cause and effect relationships between sediment contaminant concentrations and indices of species diversity/abundance or community composition. This is despite both monitoring sites in the Onepoto Arm clearly having higher sediment contaminant concentrations and supporting a lower diversity of benthic species than sites in the Pauatahanui Arm. However, when sediment heavy metal concentrations, and mud and TOC content were combined and treated as a sliding scale of 'environmental quality', a subtle relationship with underlying community structure was evident (Figure 6.8). From this analysis, Oliver et al. (in press) concluded that monitoring sites of higher 'environmental quality' had healthier benthic invertebrate community structure and that, generally, sites in the Pauatahanui Arm of the harbour were of higher environmental quality and thus support healthier, and more diverse, invertebrate communities than sites in the Onepoto Arm.



(Source: Oliver et al. in press)

Figure 6.8: Canonical analysis of principal coordinates (CAP) based on Bray Curtis similarities of square root transformed species counts and the PCA1 values derived from principal components analysis (PCA) of environmental variables. Note that the CAP axis can be viewed as an index of ecological community structure and the PCA axis viewed as an index of 'environmental quality'. Least squares regression and 95% confidence intervals are shown.

Like Porirua Harbour, initial multivariate analyses of Wellington Harbour monitoring data did not identify any clear relationship between elevated sediment contaminant concentrations at some sites and indices of species diversity or community composition (Stephenson et al. 2008). However, re-analysis of the data using more sophisticated multivariate techniques (including canonical analysis of principal coordinates, or CAP) indicated that the composition of the subtidal benthic communities was influenced by elevated concentrations of the stormwater-associated contaminants copper, lead and zinc (Kelly 2010). The number of individuals in the benthic samples decreased with increasing distance from major stormwater outfalls, while Pielou's evenness[26] increased with distance. Models developed to describe the succession of species after a disturbance indicate that this high abundance and low evenness at sites closer to metal contamination, is consistent with, amongst other things, an intermediately disturbed system (Kelly 2010).

6.5 Temporal trends

One of the primary aims of the Porirua and Wellington Harbour subtidal sediment contaminant monitoring programmes is to detect changes in sediment quality and benthic community health over time, thereby allowing the ongoing evaluation of urban stormwater management actions directed at maintaining or enhancing these harbour receiving environments. At the present point in time, temporal trend analysis is only possible for Porirua Harbour and, even then, caution must be exercised given the number of data points for each site is just four.

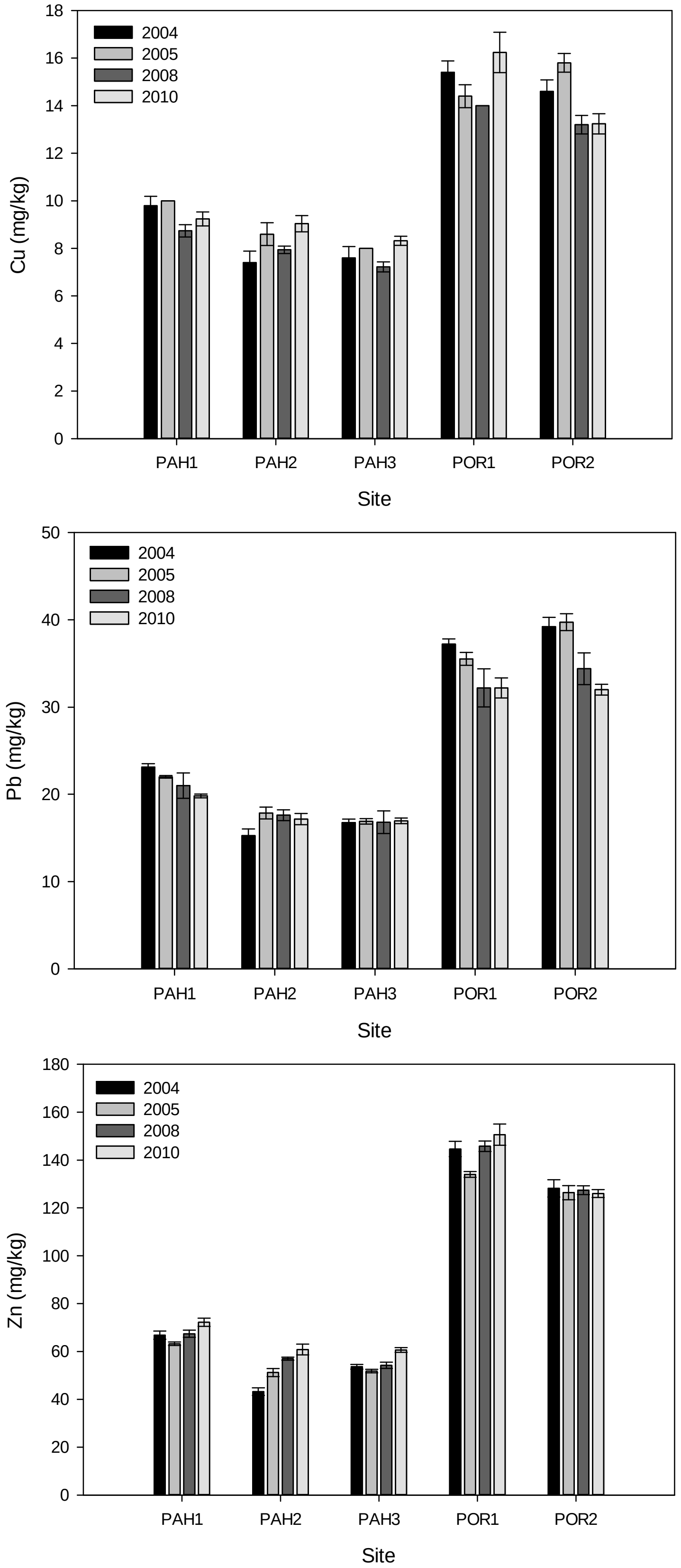
Oliver et al. (in press) recently assessed temporal trends in the concentrations of weak acid-extractable copper, lead and zinc in Porirua Harbour's subtidal sediments. Analysis of weak-acid extractable metal concentrations is both ecologically relevant and the most precise method for measuring spatial and temporal trends, allowing monitoring to detect relatively small changes in concentrations over time (Williamson et al. 2012).

Although some statistically significant trends in sediment metal concentrations were evident between 2004 and 2010, there was no consistent direction of trend (a mixture of both increasing and decreasing trends were found) and the magnitude of change in metal concentrations was small (Figure 6.9). The reliability of trend detection, and the ability to form meaningful conclusions from any detected trends, should continue to improve as more monitoring data are added and the length of the time-series increases (Oliver et al. in press).

Oliver et al. (in press) also examined changes in benthic community health across the four Porirua Harbour surveys to date. The most notable changes in species composition occurred at sites PAH1 and POR2 (refer Figure 6.1) between the 2005 and 2008 surveys; species diversity and evenness at these two sites decreased and the invertebrate communities became increasingly dominated by only one or two species. The reason for these community changes is unclear – multivariate analyses could not attribute the observed changes to any single contaminant or physical property of the sediment. It is possible that the changes may simply reflect natural population variation or may be driven by environmental variation.

---

[26] Pielou's evenness is a measure of how evenly distributed individuals are amongst species.



(Source: Oliver et al. in press)

Figure 6.9: Mean (± 95% confidence interval) concentrations of weak acid extractable copper (Cu), lead (Pb) and zinc (Zn) in sediments from five sites sampled in Porirua Harbour in 2004, 2005, 2008 and 2010, based on the <63 μm fraction of five composite samples from each site

6.6 Synthesis

The subtidal sediments in Porirua and Wellington harbours contain a range of contaminants derived from human activity in the surrounding catchments. Some of these contaminants, including several metals, PAHs and Total DDT, are present at concentrations that exceed ‘early warning’ sediment quality guidelines in areas within both harbours, particularly in areas closest to Porirua city (ie, the Onepoto Arm) and Wellington city (eg, Evans Bay and the entrance to Lambton Basin). The strong offshore gradients in sediment contaminant concentrations in Wellington Harbour and the chemical nature of some of the contaminants provide a clear indication of their land-based origin. A review of the available stormwater quality and stream monitoring data from the catchments of both harbours (Kingett Mitchell Ltd 2005; Milne & Watts 2008; Sorensen & Milne 2009; Perrie et al. 2012) indicates that urban stormwater is the principal agent in the transport of the majority of these contaminants to the harbour seabed, either directly or by way of urban streams.

There is currently no clear evidence that any of the contaminants measured in the subtidal sediments of Porirua and Wellington harbours have resulted in significant adverse effects on benthic invertebrate communities at any of the monitoring sites. However, the combination of heavy metal, and mud and organic carbon content appears to be influencing the underlying benthic community structure and adverse ecological effects may result at some sites in the future, particularly if contaminants continue to accumulate in harbour sediments. This is considered highly likely as long as stormwater discharges continue in their present form (particularly at near-shore sites such as WH1 and WH3 in Wellington Harbour and POR1 in Porirua Harbour), highlighting the need for continued periodic reassessments of both sediment quality and benthic ecology to try and ascertain when any thresholds for effects have been reached.

7. Sandy beaches ecological condition

This section summarises the results of fine scale sandy beach ecological monitoring undertaken in the Wellington region between March 2004 and January 2009. Ten beaches were surveyed over this period, including seven beaches along the western Wellington coastline, two beaches in Wellington Harbour, and one beach in the eastern Wairarapa. Only one of these beaches, Castlepoint Beach, was surveyed on more than one occasion and is currently included in Greater Wellington's coastal monitoring programme. Castlepoint Beach survey results therefore form the main focus of this section, with only a brief synopsis provided on the other beaches surveyed.

7.1 Background

Greater Wellington's first ecological assessments of sandy beaches in the Wellington region were undertaken by the Cawthron Institute in 2004 and 2005, in conjunction with broad scale habitat mapping along the west and south coasts of the Wellington region (Stevens & Robertson 2006; Stevens et al. 2004). These surveys covered seven sandy beaches between Otaki and Titahi Bay and two sandy beaches in Wellington Harbour (Figure 7.1). The surveys were a one-off, undertaken primarily as part of a general information gathering exercise on the region's coastal environments prior to formal consideration of Greater Wellington's long-term coastal monitoring requirements. It was only following completion of ecological vulnerability assessments of the region's coastal habitats in 2007 (Robertson & Stevens 2007a; 2007c) that formal sandy beach monitoring was implemented at Castlepoint Beach, a 4.5 km long exposed beach in the eastern Wairarapa.

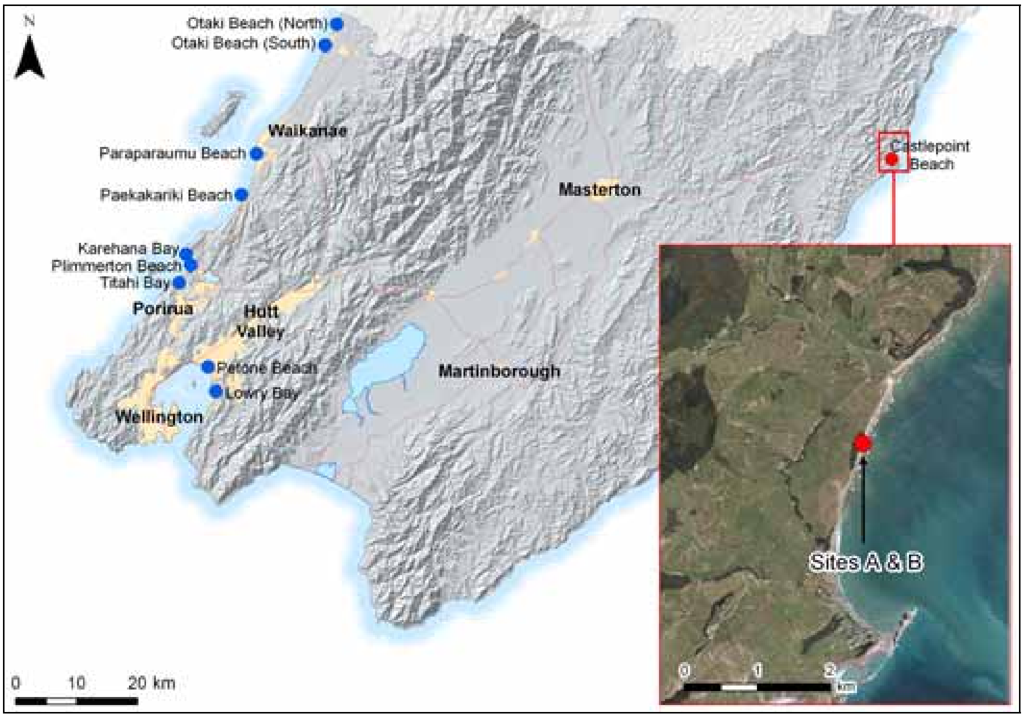


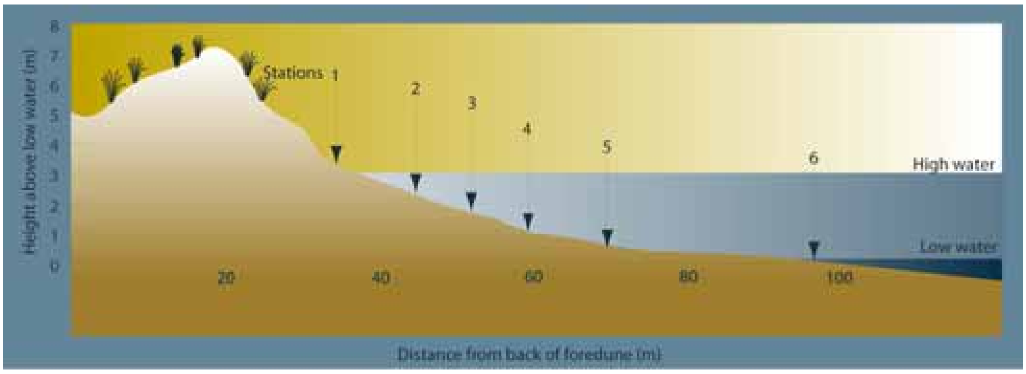
Figure 7.1: One off (blue circles) and long-term (red) sandy beach ecological monitoring sites in the Wellington region

Long-term monitoring at a dissipative[27] beach on the northern Kapiti Coast (Waikanae) is yet to be implemented.

7.2 Monitoring sites and methods

The one-off fine scale assessments carried out in 2004 and 2005 sampled random replicate locations at upper and lower intertidal beach heights at all nine beaches (at Titahi Bay and Petone Beach, control and 'impact' sites were selected to assess if there was any obvious impact from vehicle driving and beach grooming, respectively). Three replicate samples from each site were examined for a suite of indicators of beach health, including sediment particle size, organic content, sediment nutrient and heavy metal concentrations, and benthic fauna abundance and diversity. Refer to Stevens et al. (2004) and Stevens and Robertson (2006) for further details.

The 2008 and 2009 fine scale monitoring undertaken at Castlepoint Beach similarly involved collecting samples from different beach heights, but using two transects, 50 m apart). Six stations were sampled along each transect (Figure 7.2) with five stations in the intertidal zone and a sixth on dry beach. As noted in Section 2.4.4, only a limited range of fine scale variables have been assessed to date (sediment particle size, redox potential discontinuity (RPD), and benthic fauna abundance and diversity) because there are no major nutrient inputs on remote, semi-exposed beaches like Castlepoint, and the risk of toxic contamination is very low. Refer to Robertson and Stevens (Robertson & Stevens 2008a; 2009a) for full details on sampling and analytical methods.



(Source: Robertson & Stevens 2009a, p6)

Figure 7.2: Cross section of sampling transect at Castlepoint Beach

7.3 Key condition indicators

The information in this section is summarised from Stevens et al. (2004), Stevens and Robertson (2006) and Robertson and Stevens (2008a; 2009a). The reader should consult these individual survey reports for full details of the fine scale survey results.

7.3.1 Kapiti Coast, Plimmerton, Titahi Bay, Petone Beach and Lowry Bay

Overall, the 2004 and 2006 fine scale measurements of physical, chemical and biological variables found that the intertidal habitats at all sites were in a healthy condition and sediment quality was high (despite Petone and some

---

[27] A dissipative beach (eg, Castlepoint Beach) is relatively flat, fronted by a moderately wide surf zone in which waves dissipate much of their energy.

other beaches receiving multiple urban stormwater inputs). The abundance of animals living in the sandy beach environments was low, particularly in the upper tidal ranges, but this is typical of this habitat and sandy beach habitats elsewhere in New Zealand (Stevens & Robertson 2006).

At Titahi Bay, vehicle access to the northern end of the beach was suspected of having an impact on biological, physical and chemical features of the beach. Results showed that there were far fewer animals at northern sites (4 individuals) compared with southern sites (60 individuals), where vehicles are not permitted. It is unlikely that this finding is attributable to vehicle damage alone, however, as the southern area of beach has a greater variety of substrate types, than the flat northern area. Sediment chemistry results found no significant differences between the northern and southern sites and no obvious signs of contamination of the beach sediments. Amphipods and isopods were the dominant sediment-dwelling organisms at the southern end of the beach (Stevens & Robertson 2006).

At Petone Beach, the infauna was dominated by bivalve shellfish (pipi) and a range of polychaete worms, with no obvious differences between groomed and ungroomed areas of the beach. Overall, the majority of infauna were present in the wetted areas of the beach, indicating that the impact of beach grooming, if it is confined to areas above Mean High Water Springs, is unlikely to impact significantly on the most densely populated parts of the beach (Stevens et al. 2004).

7.3.2 Castlepoint Beach

The results of the 2008 and 2009 Castlepoint Beach surveys showed the dominant intertidal habitat was generally in a ‘good’ condition. The beach sediments consisted of well-oxygenated sands, with a RPD depth of at least 15 cm (Figure 7.3) and a mud content of just 1%. These sands supported benthic invertebrates typical of exposed oligotrophic (nutrient-poor) beach environments, such as isopods, amphipods, beetles and polychaete worms (Table 7.1).

(Source: Robertson & Stevens 2009a)

Figure 7.3: The RPD depth of the sediment at Castlepoint Beach in January 2009 was measured at over 15 cm, reflecting the dominance of sands (99%) in the substrate

Table 7.1: Benthic fauna identified from core samples collected along two transects at Castlepoint Beach in January 2008 and January 2009 (*n*=18 per site)

(Source: Robertson & Stevens (2008a; 2009a)

Taxa	2008		2009	
	Transect A	Transect B	Transect A	Transect B
Polychaeta				
Aglaophamus macroura	0	0	1	2
Hemipodus simplex	8	17	18	18
Lumbrineris brevicirra	0	1	0	1
Crustacea Amphipoda				
Diogodias littoralis	0	1	0	2
Patuki breviuropodus	0	5	18	18
Talorchestia quoyana	25	2	4	14
Waitangi chelatus	2	3	1	0
Crustacea Isopoda				
Actaecia euchroa	1	2	2	4
Eurylana arcuata	3	1	0	0
Macrochiridothea uncinata	0	2	1	0
Pseudaega tertia	8	34	8	42
Scyphax ornatus	18	4	6	10
Insecta Coleoptera				
Chaerodes laetus	10	4	0	0
Chaerodes trachyscelides	12	0	2	4
Coleoptera sp.#1	1	0	0	0
Coleoptera sp.#2	4	20	5	14
Coleoptera sp.#3	0	0	1	0
Coleoptera sp.#4	0	0	1	0
Pericoptus truncatus	0	1	0	0
Phycosecis atomaria	0	6	0	0
Insecta Diptera				
Diptera sp.#1	1	0	0	0
Total species in samples	**12**	**15**	**13**	**11**
Total individuals in samples	**93**	**103**	**68**	**129**

7.4 Synthesis

Fine scale ecological surveys undertaken to date indicate that sandy beaches in the Wellington region are generally in ‘good’ condition. These habitats are characterised by benthic invertebrates that are typical of exposed beaches, with well oxygenated sands and low concentrations of nutrients and toxic contaminants. At Greater Wellington’s long-term monitoring site at Castlepoint Beach, the beach condition ratings from the first two surveys suggested a third survey was not needed to establish a baseline; monitoring at this beach is now likely to be undertaken at five-yearly intervals. As noted in Section 7.1, long-term fine scale monitoring is still to be established at a beach on the northern Kapiti Coast (as recommended by Robertson & Stevens 2007a).

8. Discussion

This section revisits the main findings from coastal monitoring and investigations undertaken in the Wellington region between 2004 and 2011, drawing on material presented in Sections 4 to 7 on coastal water quality, estuaries, harbours and sandy beaches. This information is presented as a regional overview and then placed in a national context. The principal impacts on our coastal environment are also briefly considered and monitoring limitations and knowledge gaps are outlined.

8.1 Regional overview

8.1.1 State

Based on the results of a range of coastal monitoring and investigations undertaken between 2004 and 2011, most coastal environments in the Wellington region are in ‘good’ condition. Microbiological contamination of coastal waters is low at the majority of sites and shellfish flesh monitoring in early 2006 did not identify any significant microbiological or trace contaminant issues. However, there are some clear ‘hot spots’ in coastal waters in the western half of the region, where faecal indicator bacteria counts are elevated at times. Most of the problem sites are located near urban areas, where stormwater and sewage leaks/overflows appear to be the main source of microbiological contamination. This is discussed further in Section 8.3.

The intertidal habitats of all five estuaries monitored to date – Waikanae, Porirua, Hutt, Whareama and Onoke – are considered to be in ‘moderate’ health – despite most having experienced extensive loss or modification of their intertidal habitat. Toxicant contamination is not a significant issue in any of the estuaries, despite localised contamination of sediments in some areas, notably at the southern end of the Onepoto Arm of Porirua Harbour. However, there are some ‘early warning’ signs of stress from either sedimentation or nutrient enrichment for most of the estuaries. The Whareama and Waikanae estuaries in particular, have excessive sedimentation rates and a high mud content within their sediments. While there is uncertainty as to the current rates of sedimentation within the two arms of Porirua Harbour, fine scale monitoring between 2008 and 2011 showed a decrease in the depth of oxygenated sediment across all four monitoring sites. This indicates that the current diverse benthic invertebrate community could shift to one more dominated by opportunistic benthic invertebrate species tolerant of moderate levels of mud and organic enrichment; recent surveys have already detected an increased presence of such species. Porirua Harbour, along with the Hutt River Estuary, also has macroalgal cover present at nuisance levels in places, despite relatively low sediment nutrient concentrations.

Monitoring of subtidal sediment quality in Porirua Harbour (2004, 2005, 2008 and 2010) and Wellington Harbour (2006) has shown that several heavy metals, PAHs and Total DDT are present at concentrations above ‘early warning’ sediment quality guidelines in areas within both harbours. The areas with the highest contaminant concentrations are located closest to Porirua city (ie, the Onepoto Arm) and Wellington city (eg, Evans Bay and the entrance to Lambton Basin) which receive the greatest inputs of urban stormwater, either directly or by way of urban streams. While there is currently no clear evidence any of the contaminants measured in the subtidal sediments have resulted in significant adverse effects on invertebrate communities at any of the monitoring sites, the combination of heavy metal, mud and organic carbon content appears to be influencing benthic community structure. For example, sites in the Onepoto Arm of Porirua Harbour are of lower ‘environmental quality’ (higher mud, TOC and contaminant concentrations) than sites in the Pauatahanui Arm; this is reflected in the presence of less diverse benthic invertebrate communities in the Onepoto Arm.

Generally, the condition of sandy beaches in the Wellington region is good. The intertidal sands are characterised by well oxygenated sands, low concentrations of nutrients and heavy metals, and benthic invertebrates that are typical of exposed beach environments.

8.1.2 Temporal trends

As outlined earlier in this report, monitoring of the ecological condition of beaches, estuaries and harbours in the Wellington region only commenced in 2004, meaning that there are limited data with which to assess temporal trends. The exception is Porirua Harbour, where four subtidal sediment surveys have been undertaken to date. Although some statistically significant trends in sediment metal concentrations were evident between 2004 and 2010, there was no consistent direction of trend and the magnitude of changes in metal concentrations was small. Similarly, despite some changes in benthic community structure, it is not possible to determine exactly which aspects of environmental quality (eg, mud and/or organic carbon content vs contaminant concentrations) are driving the changes. The relationships between metal toxicity, environmental conditions and invertebrate abundance are complex and interrelated (Morrisey et al. 1996) and natural population variation may also be a confounding factor. Overall, it is still too early to tell whether ecologically significant changes are occurring.

8.2 National context

Placing the current state of coastal environments in the Wellington region in a national context is difficult. Despite many regions of New Zealand having long-term coastal monitoring programmes in place, national reporting of coastal environments to date (eg, Ministry for the Environment 2007) has been limited to microbiological water quality at popular recreation sites (see Greenfield et al. 2012 for a comparison of Wellington’s data) and fisheries indicators. This in part reflects a lack of national guidelines available for monitoring and reporting on the condition of coastal environments (see Section 8.4 for further discussion), as well as the lack of a national database to access coastal monitoring data.

In general terms, it is considered that the issues affecting coastal environments in the Wellington region are similar to those in many other parts of New Zealand. Where intensive urban or rural land use is present, impacts are present in the form of one or more of microbiological contamination of coastal waters and shellfish, sedimentation, eutrophication, and accumulation of heavy metals, PAHs, pesticides and other contaminants in coastal sediments. For example, there are reports of a number of estuaries and harbours across New

Zealand with elevated sediment concentrations of heavy metals, including parts of Otago Harbour (eg, Hickey 2011), the Avon-Heathcote Estuary in Christchurch (eg, Deeley 1991; Milne 1998), and Tamaki Estuary and Waitemata Harbour in Auckland (eg, ARC 2010). Sediment contaminant data from the Auckland region provide the most meaningful benchmark for comparisons with data from harbours in the Wellington region (due to similarities in monitoring design and methods – see Section 2.4.3). In the most recent state of the environment report for the Auckland region (ARC 2010), nearly 20% of the 72 monitoring sites had zinc sediment concentrations exceeding the ARC (2004) ERC-Red threshold for zinc, with a smaller percentage of sites exceeding the equivalent thresholds for copper and lead. While Porirua and Wellington Harbour sediment metal concentrations compare favourably with these results (only zinc at one site in Porirua Harbour exceeded the ERC-Red threshold), other contaminants, notably DDT, appear to be present in higher concentrations in Porirua and Wellington harbours.

Similar to metal contamination being present in a number of estuaries and harbours, many estuaries across New Zealand experience moderate to high rates of sedimentation (eg, Robertson and Stevens 2010b, Figure 8.1) and nuisance macroalgae cover (eg, the Motupipi Estuary in Golden Bay, the Avon-Heathcote Estuary in Christchurch and the Waiau Lagoon in Southland). In terms of sedimentation, the rates depicted in Figure 8.1 indicate that sedimentation in the

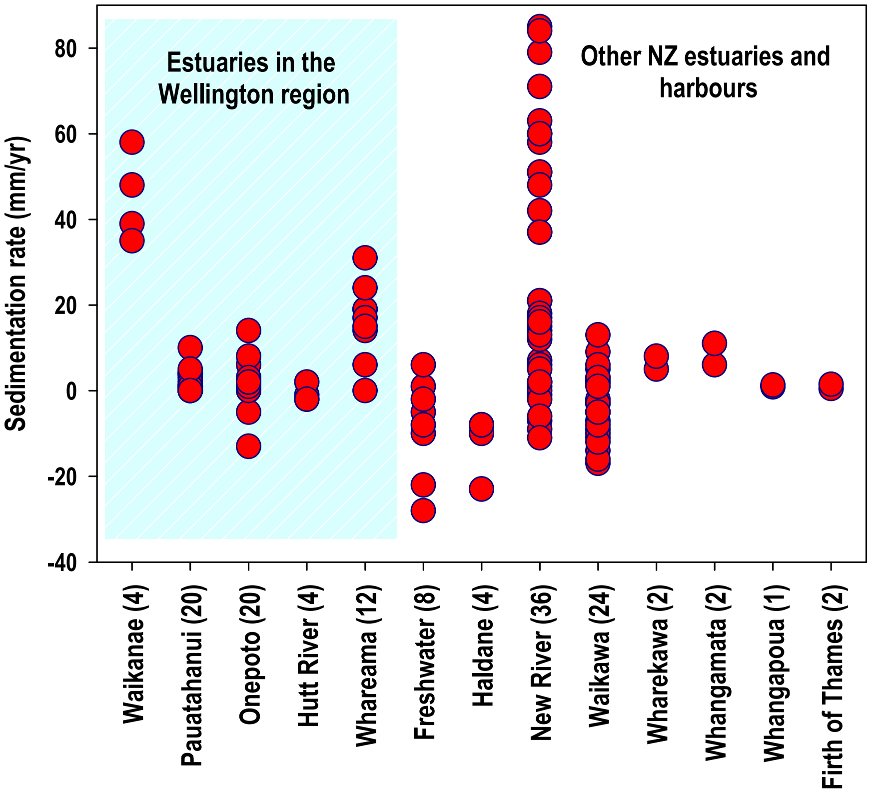


Figure 8.1: Sedimentation rates measured at various locations (numbers in brackets indicate a combination of sites and repeated measurements through time) in intertidal areas of selected estuaries in the Wellington region (shaded in blue) compared with several other regions, based on information collected and published by Wriggle Coastal Management (various reports) and Environment Waikato (2004)

Waikanae Estuary is particularly high. However, some caution is needed when interpreting this information because the Waikanae rates depicted are based on only one year of measurements.

8.3 Key issues affecting Wellington's coastal environments

While our estuaries, harbours and beaches are generally in good condition, many have been highly modified, resulting in reduced habitat quality, and localised problem areas. Some environments, such as Porirua Harbour, are coming under increasing stress from one or more of the key issues that impact on estuaries and harbours. These include sedimentation, eutrophication (nutrient enrichment), and microbiological and toxicant contamination.

8.3.1 Sedimentation

Monitoring to date has identified that sedimentation is a problem in several of the region's estuaries, notably the Whareama and Waikanae estuaries, and Lake Onoke. High sedimentation rates make the sediments increasingly muddy; muddy sediments contain less oxygen and more toxic sulphides, promote greater accumulation of contaminants, and are unable to support healthy animal communities (Robertson & Stevens 2008b).

In the Whareama Estuary, the high sedimentation rates and sediment mud content reflects high sediment inputs from erosion-prone soils in the upstream catchment. Greater Wellington (and its predecessor the Wairarapa Catchment Board) has been working with landowners in this, and other eastern Wairarapa hill country catchments for a number of decades to develop farm or sustainability plans and retire and re-vegetate erosion-prone land. In 2009 the Wellington Regional Erosion Control Initiative (WRECI) was launched, leading to the development of more comprehensive farm management plans to address soil erosion in targeted catchments. As at June 2012, such plans covered almost 30% of the Whareama catchment (15,949 ha). While this has resulted in significant soil conservation gains for landowners, sedimentation rates in the Whareama Estuary remain high, indicating that additional monitoring and management approaches are needed to identify and protect erosion 'hot spots' within the catchment. Although no work has been done to date to quantify such hot spots, it is likely that stream bank collapse and erosion are key sources of sediment entering the estuary (A. Stewart[28], pers. comm. 2012). Addressing this will require extending beyond planting on farms to the retiring, fencing and re-vegetating of riparian margins of the Whareama River and its tributaries.

The reason for the high sedimentation rate measured in the Waikanae Estuary between 2010 and 2011 is not clear, but may be linked with exotic forestry clearance; the Kaitawa Forest upstream of SH 1 was opened up for harvest around August 2010. Forestry harvest, along with agricultural land use and clearance of rural land for residential and roading developments, is also a contributor of sediment to the Pauatahanui Arm of Porirua Harbour. Perrie et al. (2012) reported a significant decline in visual clarity in the Horikiri Stream (a tributary of the Pauatahanui Arm) between July 2006 and June 2011;

---

[28] Andrew Stewart, Land Management Project Co-ordinator, Greater Wellington.

soil/stream bank erosion and sediment runoff from forestry tracking activities are possible reasons for this decline. Estimates made to date as part of the development of a ‘source to sink’ sediment transport model for Porirua Harbour (L. Stevens[29], pers. comm. 2012) indicate that the Horokiri Stream catchment contributes the largest sediment load to Porirua Harbour (in the order of 6,870 tonnes/year). Steep and unstable soils are a feature of this catchment and with an estimated 200 ha of forestry clearance likely in this catchment over the next five years (P. Handford[30], pers. comm. 2012), including 76 hectares on Greater Wellington land earmarked for harvest from 2012/13, effective sediment control measures will need to be in place to reduce sediment runoff to the Horokiri Stream. Significant forestry clearance (in the order of 300 ha over the next five years) is also expected in the neighbouring Pauatahanui and Ration Creek subcatchments (P. Handford, pers. comm. 2012). Effective sediment control measures will also be required in these areas, as well across the wider harbour catchment to manage sediment runoff from bulk earthworks associated with ongoing residential development and the construction of the Transmission Gully Highway over the next 5–10 years.

High sedimentation rates in Lake Onoke are unsurprising given the lake’s location at the bottom of the Wairarapa Valley. A significant portion of the sediment that enters the lake is likely to be sourced from drainage in the lower valley and tributaries of the Ruamahanga River that rise in the eastern Wairarapa. The Taueru River, in particular, is characterised by high concentrations of suspended sediment (Perrie et al. 2012) and drains a catchment comprising large areas of erosion-prone soils. Like the Whareama catchment, the Taueru catchment is also included in Greater Wellington’s WRECI programme.

8.3.2 Eutrophication

All of the estuaries monitored to date are slightly enriched. Although the surface sediments generally have ‘low’ to ‘moderate’ concentrations of nitrogen and phosphorus, nuisance macroalgae cover is present in both Porirua Harbour and the Hutt Estuary, and the redox potential discontinuity layer (ie, the oxygenated layer within the sediments) at monitoring sites in Porirua Harbour and the Whareama Estuary is very shallow. Over the course of four surveys of Porirua Harbour between 2008 and 2011, the oxygenated layer has reduced from an average depth of around 3–4 cm to just 1 cm. Such conditions, particularly if the sediments are also muddy, can result in diverse benthic communities being replaced by ones dominated by pollution-tolerant species (Robertson & Stevens 2008b). This is the currently occurring in the Whareama Estuary (see Section 5.3.1).

While nutrient enrichment is not a major problem in any of the five estuaries monitored to date, land use intensification that is predicted to occur in some parts of the region (eg, the Wairarapa Valley) could result in increased nutrient inputs to estuarine and coastal waters. Even moderately elevated nutrient

---

[29] Leigh Stevens, Marine Scientist, Wriggle Coastal Management. The ‘source to sink’ model is being developed for Greater Wellington, Porirua City Council and Wellington City Council to support the implementation of the Porirua Harbour and Catchment Strategy and Action Plan (PCC 2012) which identifies sedimentation as the most significant issue threatening the health of Porirua Harbour.

[30] Peter Handford, Principal Consultant, Peter Handford & Associates.

concentrations can result in increased macroalgae growth which could accelerate a shift to sediment anoxia (Robertson & Stevens 2008b), highlighting the need to manage nutrient inputs. This has been recognised in the recently released Porirua Harbour and Catchment Strategy and Action Plan (PCC 2012) which, along with emphasising the need to manage sediment inputs to the harbour, identifies nitrogen as the key nutrient to target for minimising the symptoms of enrichment in the harbour. A critical first step is determining and quantifying the major sources of nutrients to the harbour. Although this work has yet to be done, water quality results from Greater Wellington's Rivers SoE and recreational water quality monitoring programmes strongly suggest that sewer contamination may be a significant source of nutrient (and faecal) contamination to Porirua Harbour. For example, results from the Rivers SoE programme highlight that Porirua Stream (at Wall Park) frequently records elevated concentrations of nutrients (both nitrogen and phosphorus), including at base flow conditions (Ausseil 2011; Perrie et al. 2012). Further, there is a pattern of increasing median dissolved reactive phosphorus concentrations under lower flow conditions; these patterns are generally observed in situations where there are point-source discharges into the streams, or when base flow conditions are dominated by inputs from phosphorus-rich groundwater (Ausseil 2011). In wet weather, stormwater inputs and rural runoff are also expected to be a significant source of nutrients to Porirua Harbour.

8.3.3 Microbiological and toxicant contamination

Although coastal waters in the Wellington region generally experience low levels of microbiological contamination, routine monitoring across the region has highlighted some problem sites where faecal indicator bacteria counts are elevated (and, as illustrated by Greenfield et al. 2012, breach MfE/MoH (2003) recreational water quality guidelines). Most of these sites – including Porirua Harbour at the Rowing Club, Titahi Bay at South Beach Access Road, Robinson Bay at HW Shortt Recreation Ground (Eastbourne coast) and both Island Bay (at Reef Street) and Owhiro Bay on Wellington city's south coast – are located near urban areas, where stormwater and sewage leaks/overflows appear to be the main source of microbiological contamination. Poor water quality at sites such as Te Horo Beach (Kapiti) and South Beach at Plimmerton (Porirua) indicate that other sources of contamination also affect some of the region's coastal waters; these sites are both influenced by streams, one draining intensive agricultural land, and another draining a swamp supporting dense populations of waterfowl (Greenfield et al. 2012).

Overall, while there are a few exceptions (notably the sites mentioned above), microbiological contamination of coastal waters is generally confined to periods of up to 48 hours after wet weather. This highlights that swimming and collecting shellfish after rainfall carries with it an increased risk to human health. The health risk is potentially very high following heavy or during sustained wet weather when urban stormwater discharges are more likely to be contaminated with human sewage as a result of sewage pump station failures and sewer pipe overflows. Because not all territorial authorities are required to monitor and report on sewer overflows or faults it is difficult to assess the extent of sewer/stormwater infrastructure problems across the region. However, as an example, Greenfield et al. (2012) note that in the Wellington city area there were 142 alleged sewer-related pollution incidents entered onto Greater Wellington's Incidents Database between July 2005 and June 2010.

With regard to toxic contaminants, the highest concentrations of heavy metals and PAHs are present in the sediments of Porirua and Wellington harbours in areas that receive or are influenced by discharges of urban stormwater. Evidence that urban stormwater is the principal agent in the transport of the majority of these contaminants to the harbour seabed, either directly or by way of urban streams is supported by a review of the available stormwater quality and stream monitoring data from the catchments of both harbours (Kingett Mitchell Ltd 2005; Milne & Watts 2008; Sorensen & Milne 2009; Perrie et al. 2012). For example, Milne and Watts (2008) reported elevated concentrations of dissolved copper and zinc in Porirua, Kaiwharawhara, Ngauranga and Opahu streams during both 'base flow' and high (wet weather) flow conditions; wet weather stream concentrations consistently exceeded the ANZECC (2000) guidelines for aquatic toxicity and, in many cases, the USEPA (2002) acute toxicity guidelines. Milne and Watts (2008) also reported elevated concentrations of stormwater-derived contaminants in the sediments of streams that discharge into Porirua and Wellington harbours, notably zinc. In further sampling of streambed sediments in tributaries of Porirua Harbour, Sorensen and Milne (2009) reported concentrations of Total DDT, and to a lesser extent zinc, above ANZECC (2000) guidelines in Porirua, Kenepuru and 'Onepoto' streams. Sediments in the 'Onepoto' Stream also contained concentrations of several PAH compounds above guideline values.

The influence of rural land use is also evident in some of the contaminants present in the region's two harbours. For example, concentrations of Total DDT exceed the ANZECC (2000) ISQG-Low sediment quality guideline at multiple locations in both arms of Porirua Harbour, with rural soils possibly an important source of DDT to the Pauatahanui Arm (Stephenson & Mills 2006). Overall, the widespread persistence of DDT in both Porirua and Wellington harbour sediments indicates that although its use in agriculture effectively ceased in the 1970s, and its use in urban areas was banned in the late 1980s, substantial sources remain in the environment.

While there is currently no clear evidence that any of the contaminants measured in the subtidal sediments of Porirua or Wellington harbours have resulted in significant adverse effects on benthic community structure at any of the sites monitored to date, adverse effects may eventuate at some sites in the future if contaminants continue to accumulate in these harbours. This is considered highly likely if the current quality of urban stormwater discharges is not improved – and suggests that the permitted activity rules for discharges to water in Greater Wellington's existing regional plans need to be reviewed for the catchments of the region's harbours.

In the case of Wellington Harbour, stormwater discharges may already be having adverse effects closer to shore. The number of far-field sites at which sediment quality guidelines were exceeded in the 2006 baseline survey, and the offshore gradients exhibited by the contaminants involved, clearly indicates that concentrations of these contaminants will be higher as their onshore sources are approached, with a parallel increase in the likelihood of effects on the benthic ecology (Stephenson et al. 2008). Whether or not this is the case may be determined from the results of the recently completed second survey of Wellington Harbour (November 2011); this survey included sampling of an additional five sites in the inner harbour area.[31]

In most cases, contaminant concentrations in the region's two harbours only exceed 'alert level' or 'early warning' sediment quality guidelines. Therefore there is an opportunity for management intervention to limit the extent of degradation and prevent adverse environmental effects from occurring. Zinc and copper are probably the contaminants of greatest concern; both are ubiquitous (Stephenson et al. (2008) cite the primary sources as runoff from unpainted galvanised roofs and vehicle brake pad wear, respectively[32]) and, along with DDT, persist in the environment.

8.4 Monitoring limitations and knowledge gaps

A significant amount of knowledge has been gained about the region's coastal environments as a result of the monitoring and investigations documented in this report. However, there are also a number of limitations and knowledge gaps evident and a thorough review of Greater Wellington's existing coastal monitoring programme is required. The main limitations and knowledge gaps associated with monitoring and investigations to date are outlined below.

- With the exception of the recent introduction of water quality monitoring in Lake Onoke (see Perrie & Milne 2012) and Porirua Harbour (see Box 1, Section 5.3.2) monitoring of coastal waters to date has been limited to microbiological indicators, with the site selection biased towards popular recreational areas. Consequently, there is a lack of information on general coastal water quality, in particular information on water clarity and nutrient concentrations in open coastal waters.

- Interpreting the suitability of recreational waters for shellfish gathering is problematic. The MfE/MoH (2003) guidelines do not define a shellfish gathering season and the faecal coliform thresholds are based on quite dated reference material (Department of Health 1992). While monitoring of contaminants in shellfish flesh provides a more direct measure of the health risks associated with consuming shellfish, studies such as that undertaken in Tauranga Harbour which reported no distinct relationship between faecal indicator bacteria and positive Norovirus results (Environment Bay of Plenty 2009), raise questions as to whether faecal indicator bacteria can be reliable indicators of pathogen contamination. With regard to toxicants, the current national food safety standards for shellfish flesh lack guidance on acceptable concentrations of some heavy metals, including stormwater-associated metals such as zinc and copper.

- Further work is needed to identify and quantify the principal sources of sediment and nutrients entering the region's estuaries. While such work is already underway in Porirua Harbour in association with the Porirua

---

[31] This survey was undertaken in conjunction with Wellington City Council (WCC), with the additional inner harbour sites incorporated as part of sediment quality monitoring required under WCC's global resource consent for stormwater discharges into the harbour.

[32] Vehicle tyre wear and architectural uses (eg, copper spouting) are key secondary sources.

Harbour and Catchment Strategy and Action Plan (PCC 2012), similar load assessment work needs to be extended in some capacity to the Hutt (for nutrients), Whareama (sediment) and Waikanae (sediment) estuaries, as well as Lake Onoke (both sediment and nutrients). This work could be particularly important for Lake Onoke given that dairying has already intensified in South Wairarapa in recent years (Sorensen 2012) and more land use intensification is expected.

- While there is considerable information now available on the extent of heavy metal, PAH and organochlorine pesticide contamination in the sediments of selected estuaries and the region's two harbours, there is limited knowledge of the presence of 'emerging' contaminants, such as detergents, pharmaceuticals and flame retardants. Greater Wellington carried out water sampling in the vicinity of selected marinas in 2006 to contribute to a national study of anti-fouling co-biocide contamination in coastal waters (Stewart 2006) – but this was a one-off sampling event and only looked at concentrations of diuron and Iragol 1051 in surface water samples.

- The rocky shore habitats of the region – despite being significant in extent and ecological value – have not been included in coastal monitoring to date. This is principally because the initial monitoring focus was soft-substrate and low-energy environments (eg, harbours and estuaries) that are considered more susceptible to contamination and ecological degradation. However, despite being a high energy environment, research indicates that temporary sediment deposition in rocky shore habitats can disrupt the settlement and distribution of key invertebrate species such as paua and kina (Schiel et al. 2006). These animals are important components of rocky shore ecosystems, fulfilling the role of grazers in structuring their communities. Paua and kina are also important prey species for key fish and invertebrates such as lobsters, and have significant cultural and fishery value. If, as the preliminary research indicates, even small levels of sedimentation may influence paua and kina settlement success, then the structure of the rocky shore ecosystems may be profoundly altered.

- There is an overall lack of national guidelines for monitoring and reporting on coastal environments in New Zealand. Although national protocols exist for monitoring coastal recreational waters (MfE/MoH 2003) and intertidal estuarine habitats (Robertson et al. 2002), no nationally accepted protocols currently exist for monitoring sandy beaches, rocky shores or subtidal environments (eg, harbours). In addition, there is a lack of national guidance to interpret monitoring results. For example, while the ANZECC (2000) guidelines are the principal water and sediment quality guidelines for New Zealand's fresh and coastal waters, the lack of local water quality data available when they were being developed means that New Zealand users wanting to interpret coastal water quality data must refer to South-Eastern Australia guideline values which are not always appropriate. This short-coming has been recognised by the Ministry for the Environment and plans are progressing to collate New Zealand data sets held by regional councils and other organisations, with the view to developing some New Zealand-specific guidance (Ministry for the Environment 2011).

9. Conclusions

Coastal monitoring and investigations undertaken between 2004 and 2011 indicate that most coastal environments in the Wellington region are in ‘good’ condition. Microbiological contamination of coastal waters is low at the majority of sites and shellfish flesh monitoring in early 2006 did not identify any significant microbiological or trace contaminant issues. However, there are some ‘hot spots’, principally coastal water sites near urban areas, where faecal indicator bacteria counts are elevated at times as a result of stormwater discharges and sewage leaks/overflows.

All five estuaries monitored to date are considered to be in ‘moderate’ health – despite most having experienced extensive loss or modification of their intertidal habitat. While toxicant contamination is not a significant issue for any of the estuaries, localised contamination of sediments exists in some (such as at the southern end of the Onepoto Arm of Porirua Harbour) and most are showing some ‘early warning’ signs of stress from either sedimentation or nutrient enrichment. Lake Onoke, and the Whareama and Waikanae estuaries in particular, have excessive sedimentation rates and a high mud content within their sediments. In Porirua Harbour, monitoring between 2008 and 2011 showed a decrease in the depth of oxygenated sediment across all four monitoring sites, coupled with an increased presence of opportunistic benthic invertebrate species tolerant of moderate levels of mud and organic enrichment. Porirua Harbour, along with the Hutt River Estuary, also has macroalgal cover present at nuisance levels in places.

The subtidal sediments in parts of both Porirua Harbour and Wellington Harbour contain several heavy metals, PAHs and Total DDT at concentrations above ‘early warning’ sediment quality guidelines. The areas with the highest contaminant concentrations are located closest to Porirua city (ie, the Onepoto Arm) and Wellington city (eg, Evans Bay and the entrance to Lambton Basin) which receive the greatest inputs of urban stormwater, either directly or by way of urban streams. There is currently no clear evidence that any of the subtidal sediment contamination has resulted in significant adverse effects on invertebrate communities at any of the monitoring sites. However, the combination of higher heavy metal, mud and organic carbon content at some sites is linked with a less diverse community structure. Furthermore, adverse effects may eventuate in the future if contaminants continue to accumulate. This is considered highly likely if the current quality of stormwater discharges is not improved.

Generally, the condition of sandy beaches in the Wellington region is good. The intertidal sands are characterised by well oxygenated sands, low concentrations of nutrients and heavy metals, and benthic invertebrate assemblages that are typical of exposed beach environments.

Overall, alongside more global pressures – notably climate change, sea level rise and the spread of invasive species – sedimentation, eutrophication, and microbiological and toxicant contamination are significant issues for many coastal environments in the Wellington region, particularly the region’s estuarine environments. With further urban development and intensification of rural land use expected in some parts of the region in the future, comprehensive integrated catchment management plans will be required that address sediment erosion and runoff, nutrient loss, and increasing pressure on sewer and stormwater infrastructure.

9.1 Recommendations

1. Review Greater Wellington's existing coastal monitoring programme, giving priority consideration to:
    - Undertaking monitoring of nutrients and other variables in surface waters at selected coastal locations;
    - Reassessing shellfish flesh monitoring undertaken in the region, especially monitoring indicators and methods;
    - Commencing formal fine scale monitoring of Lake Onoke, including the installation of sedimentation plates on the lake bed;
    - Revising the suite of contaminants included in subtidal sediment surveys of Porirua and Wellington harbours, including consideration of analysis of some samples for emerging contaminants;
    - Commencing fine scale monitoring of a sandy beach on the northern Kapiti Coast; and
    - Establishing fine scale rocky shore monitoring at one or two representative locations.
2. Continue to communicate the increased risk to human health associated with swimming and shellfish collection in coastal waters during wet weather, especially in the winter months when water quality at some sites is particularly compromised.
3. Continue Greater Wellington's existing soil conservation programmes with landowners to reduce soil erosion across the region's erosion-prone hill country.
4. Continue with current sediment and nutrient load assessment work in the Porirua Harbour catchment and extend catchment load assessments to Lake Onoke and the Hutt, Waikanae and Whareama estuaries.
5. Take into account the findings of this report in the review of Greater Wellington's existing regional plans, particularly the need to:
    - Address the effects of microbiological and other contamination from sewer/stormwater cross connections, leaks and overflows;
    - More effectively address the effects of
        - stormwater discharges to water, and

  - sediment discharges from bulk earthworks associated with urban, forestry and roading developments,

  particularly in catchments draining to more sensitive depositional coastal environments (eg, Porirua and Wellington harbours, Waikanae Estuary);

  Mechanisms to achieve this could include improved stormwater management practices generally, stormwater education initiatives, Integrated Catchment Management Plans, the treatment of stormwater in problem catchments and/or the application of low impact urban design principles (especially in areas of new development where these principles are more readily able to be implemented)

- Address activities that contribute to excessive streambank erosion, particularly stock access to waterways and riparian margins;

- Address nutrient losses from intensive rural land uses, such as dairying and horticulture; and

- Rehabilitate degraded and protect ‘at risk’ estuary and coastal margins (eg, through increased riparian planting).

References

Aerts K, Vanagt T and Fockedey N. 2004. Macrofaunal community structure and zonation of an Ecuadorian sandy beach (bay of Valdavia). *Belgian Journal of Zoology,* 134(1): 17-24.

Auckland Regional Council. 2004. *Blueprint for monitoring urban receiving environments*. Auckland Regional Council, Technical Publication No. 168 (revised), Auckland.

Auckland Regional Council. 2010. *State of the Auckland region 2009*. Auckland Regional Council, Technical Publication No. 168 (revised), Auckland.

Ausseil O. 2011. *Nutrient status of rivers and streams in the Wellington region: An analysis of state of the environment monitoring data.* Report prepared for Greater Wellington Regional Council by Aquanet Consulting Ltd, Palmerston North.

Australian and New Zealand Environment and Conservation Council. 2000. *Australian and New Zealand guidelines for fresh and marine water quality, volume 1, the guidelines*. Agriculture and Resource Management Councils of Australia and New Zealand, Canberrra.

Australian New Zealand Food Standards Code. 2001. *Standard 1.4.1 - Contaminants and Natural Toxicants.* Australian New Zealand Food Standards Code.

Berry A, Wills J and Aitken N. 1997. *Porirua Harbour sediment and shellfish study.* Wellington Regional Council, Publication No. WRC/RINV-T-97/55, Wellington.

Deely JM. 1991. *Sediment and heavy metal distributions in the Avon Heathcote estuary, Christchurch, New Zealand.* Unpublished PhD thesis, University of Canterbury, Christchurch.

Department of Health. 1992. *Provisional microbiological water quality guidelines for recreational and shellfish-gathering waters in New Zealand.* Public Health Services, Department of Health, Wellington.

Depree C. 2010. *Potential sources of PAHs in Wellington Harbour sediments.* Report prepared for Greater Wellington Regional Council by NIWA, Report HAM2010-031.

Environment Bay of Plenty. 2009. *Microbiological quality of shellfish in estuarine areas.* Joint agency research report.

Mead S and Moores A. 2004. *Estuary sedimentation: A review of estuarine sedimentation in the Waikato region.* Report prepared for Waikato Regional Council.

Francis M, Lyon W, Jones E, Notman P, Parkinson D and Getzlaff C. 2012. *Rig nursery grounds in New Zealand: a review and survey.* New Zealand Aquatic Environment and Biodiversity Report No. 95, Ministry for Primary Industries.

Gibb JG and Cox GJ. 2009. *Patterns and rates of sedimentation within Porirua Harbour*. Report prepared for Porirua City Council, C.R.2009/1.

Gill A. 2005. Offshore renewable energy: Ecological implications of generating electricity in the coastal zone. *Journal of Applied Ecology*, 42: 605–615.

Greater Wellington Regional Council. 2005. *Measuring up: State of the environment report for the Wellington region 2005.* Greater Wellington Regional Council, Publication No. GW/ENV-G-05/278, Wellington.

Greater Wellington Regional Council. 2010. *Proposed regional policy statement for the Wellington region, May 2010.* Publication No. GW/EP-G-08/200, Wellington.

Greenfield S, Ryan A and Milne J. 2012. *Recreational water quality in the Wellington region: States and trends.* Greater Wellington Regional Council, GW/EMI-T-12/142, Wellington.

Hickey, CW. 2011. *Statement of evidence of Christopher Wayne Hickey on behalf of Port Otago Limited.* Hearing report prepared in support of an application for resource consents for Project Next Generation.

Kelly S. 2007. *Marine receiving environment stormwater contaminants: Status report 2007.* Auckland Regional Council, Technical Publication, TP333, Auckland.

Kelly S. 2010. *Further statistical analysis of Wellington Harbour sediment contaminant and benthic fauna data.* Report prepared for Greater Wellington Regional Council by Coast and Catchment Ltd.

Kingett Mitchell Ltd. 2005. *Assessment of urban stormwater quality in the greater Wellington region.* Report prepared for Greater Wellington Regional Council by Kingett Mitchell Limited.

Long ER and Morgon LG. 1990. *The potential for biological effects of sediment-sorbed contaminants tested in the national status and trends program.* National Oceanic and Atmospheric Adminstration Technical Memorandum, NOS OMA 52.

MacDonald DD, Charlish BL, Haines ML and Brydges K. 1994. *Approach to the assessment of sediment quality in Florida coastal waters.* Florida Department of Environmental Protection, Tallahassee, Florida.

Mead S and Moores A. 2004. *Estuary sedimentation: A review of estuarine sedimentation in the Waikato region.* Report prepared for Waikato Regional Council by ASR Ltd, Marine Consulting and Research, Report No. TR05/13, Waikato.

Milne JR. 1998. *Avon-Heathcote Estuary heavy metal monitoring report.* Christchurch City Council Waste Management Unit Laboratory, Christchurch.

Milne JR. 2005. *Recreational water quality monitoring technical report.* Greater Wellington Regional Council, Publication No. GW/RINV-T-05/89, Wellington.

Milne JR. 2006. *Contaminants in shellfish flesh: An investigation into microbiological and trace metal contaminants in shellfish from selected locations in the Wellington region.* Greater Wellington Regional Council, Publication No. GW/EMI-G-06/285, Wellington.

Milne JR. 2010a. *Annual coastal monitoring report for the Wellington region, 2009/10*. Greater Wellington Regional Council, Publication No. GW/EMI-G-10/164, Wellington.

Milne JR. 2010b. *Wellington Harbour marine sediment quality investigation: Supplementary report.* Greater Wellington Regional Council, Publication No. GW/EMI-T-10/76, Wellington.

Milne JR, Sorensen PG and Kelly S. 2009. *Porirua Harbour subtidal sediment quality monitoring: Results from the November 2008 survey*. Greater Wellington Regional Council, Publication No. GW/EMI-T-09/137, Wellington.

Milne JR and Watts L. 2008. *Stormwater contaminants in urban streams in the Wellington region.* Greater Wellington Regional Council, Publication No. GW/EMI-T-08/82, Wellington.

Milne JR and Wyatt K. 2006. *Will I get sick if I swim? Suitability for recreation grades for selected marine and freshwater bathing sites in the Wellington region.* Greater Wellington Regional Council, Publication No. GW/EMI-G-06/160, Wellington.

Ministry for the Environment. 2007. *Environment New Zealand 2007: Summary*. Ministry for the Environment, Publication No. ME848, Wellington.

Ministry for the Environment. 2010. *Measuring carbon emissions from land-use change and forestry: The New Zealand land-use and carbon analysis system.* Ministry for the Environment, Wellington.

Ministry for the Environment. 2011. *Australian and New Zealand guidelines for fresh and marine water quality revision: Collation of New Zealand marine water quality data.* Unpublished Draft Scope of Works. Ministry for the Environment, Wellington.

Ministry for the Environment and Ministry of Health. 2003. *Microbiological water quality guidelines for marine and freshwater recreational areas*. Ministry for the Environment, Wellington.

Ministry of Health. 1995. *Microbiological reference criteria for food*. Ministry of Health, Wellington.

Morrisey DJ, Underwood AJ and Howitt L. 1996. Effects of copper on the faunas of marine soft-sediments: An experimental field study. *Marine Biology 125: 199-213.*

Oliver MD, Conwell C and Milne JR. In press. *Porirua Harbour subtidal sediment quality monitoring: Results from the 2010 survey*. Greater Wellington Regional Council, Publication No. GW/EMI-T-12/147, Wellington.

Perrie A and Milne J. 2012. *Lake water quality and ecology in the Wellington region: States and trends.* Greater Wellington Regional Council, Publication No. GW/EMI-T-12/139, Wellington.

Perrie A, Morar S, Milne JR and Greenfield S. 2012. *River and stream water quality and ecology in the Wellington region: State and trends.* Greater Wellington Regional Council, Publication No. GW/EMI-T-12/143, Wellington.

Ray D, Timperley M and Williamson B. 2003. *Long term marine sediment monitoring programme for the Wellington and Porirua Harbours.* Report prepared for Greater Wellington Regional Council by NIWA, (NIWA project no. WRC04201).

Robertson B and Stevens L. 2006. *Southland estuaries state of the environment report 2001-2006*. Report prepared for Environment Southland by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2007a. *Kapiti, Southwest, South Coasts and Wellington Harbour: Risk assessment and monitoring recommendations.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2007b. *Lake Onoke 2007: Vulnerability assessment and monitoring recommendations.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2007c. *Wairarapa coastal habitats: Mapping, risk assessment and monitoring.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2008a. *Castlepoint Beach: Fine scale monitoring 2007/08.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2008b. *Porirua Harbour: Fine scale monitoring 2007/08.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2008c. *Whareama Estuary 2008: Fine scale monitoring.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2009a. *Castlepoint Beach: Fine scale monitoring 2008/09.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2009b. *Porirua Harbour: Intertidal fine scale monitoring 2008/09.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2009c. *Whareama Estuary: Fine scale monitoring 2008/09.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2010a. *Hutt Estuary: Fine scale monitoring 2009/10.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2010b. *Porirua Harbour: Intertidal fine scale monitoring 2009/10.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2010c. *Waikanae Estuary: Fine scale monitoring 2009/10.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2010d. *Whareama Estuary: Fine scale monitoring 2009/10.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2011a. *Hutt Estuary: Fine scale monitoring 2010/11.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. 2011b. *Waikanae Estuary: Fine scale monitoring 2010/11.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson B and Stevens L. In press. *Waikanae Estuary: Fine scale monitoring 2011/12.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Robertson BM, Gillespie PA, Asher RA, Frisk S, Keeley NB, Hopkins GA, Thompson SJ and Tuckey BJ. 2002. *Estuarine environmental assessment monitoring: A national protocol.* Cawthron Institute, Sustainable Management Fund Contract No. 5096, Nelson.

Rosier J and Hastie W. 1992. *Off the edge: A discussion document on the characteristics of the coastal marine area in the Wellington region.* Wellington Regional Council, Publication No. WRC/PP-T-92/28, Wellington.

Schiel DR, Wood SA, Dunmore RA and Taylor DI. 2006. Sediment on rocky intertidal reefs: Effects on early post-settlement stages of habitat-forming seaweeds. *Journal of Experimental Marine Biology and Ecology,* 331(2): 158-172.

Sherriff J. 2005. *Coastal investigations technical report.* Greater Wellington Regional Council, Publication No. GW/RINV-T-05/93, Wellington.

Sorensen P. 2012. *Soil quality and stability in the Wellington region: State and trends.* Greater Wellington Regional Council, Publication No. GW/EMI-T-12/138, Wellington.

Sorensen PG and Milne JR. 2009. *Porirua Harbour targeted intertidal sediment quality assessment.* Greater Wellington Regional Council, Publication No. GW/EMI-T-09-136, Wellington.

Stephenson G and Mills GN. 2006. *Porirua Harbour long-term base-line monitoring programme: Sediment chemistry and benthic ecology results from the October 2005 survey.* Report prepared for Greater Wellington Regional Council by Coastal Marine Ecology Consultants & Diffuse Sources Limited.

Stephenson G, Milne JR and Sorensen PG. 2008. *Wellington Harbour marine sediment quality investigation.* Greater Wellington Regional Council, Publication No. GW/EMI-T-08/83, Wellington.

Stevens L and Robertson B. 2006. *Broad scale habitat mapping of sandy beaches and river estuaries on the western Wellington coast.* Report prepared for Greater Wellington Regional Council by Cawthron Institute, Report No.1035, Nelson.

Stevens L and Robertson B. 2008. *Porirua Harbour: Broad scale habitat mapping 2007/08*. Report prepared for Greater Wellington Regional Council and Porirua City Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2009. *Porirua Harbour: Intertidal macroalgal monitoring 2008/09.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2010a. *Hutt Estuary: Intertidal macroalgal monitoring 2009/10.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2010b. *Porirua Harbour: Intertidal macroalgal monitoring 2009/10.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2010c. *Waikanae Estuary: Intertidal macroalgal monitoring 2009/10.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2011a. *Hutt Estuary: Intertidal macroalgal monitoring 2010/11.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2011b. *Porirua Harbour: Intertidal macroalgal monitoring 2010/11.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2011c. *Porirua Harbour: Intertidal sediment monitoring 2010/11.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2011d. *Waikanae Estuary: Intertidal macroalgal monitoring 2010/11.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L and Robertson B. 2011e. *Whareama Estuary: Intertidal sediment monitoring 2010/11.* Report prepared for Greater Wellington Regional Council by Wriggle Coastal Management, Nelson.

Stevens L, Robertson B and Robertson B. 2004. *Broad scale habitat mapping of sandy beaches and river estuaries – Wellington Harbour and South Coast.* Report prepared for Greater Wellington Regional Council by Cawthron Institute, Report No. 913, Nelson.

Stewart C. 2006. *Antifouling co-biocides in New Zealand coastal waters: 2006 resurvey*. Report prepared for the Ministry for the Environment, Wellington.

USEPA. 2002. *National recommended water quality criteria.* United States Environmental Protection Agency, 21 p. + appendices (3 p.).

Wellington City Council. 2003. *Northern growth area – A framework for growth management*. Wellington City Council, Wellington.

Wellington Regional Council. 2000. *Regional Coastal Plan for the Wellington region.* Wellington Regional Council, Publication No. WRC/RP-G-00/02 (revised April 2008), Wellington.

Williamson B, Goff J, Ray D, Mills G and Berkenbusch K. 2001. *Effects of urban stormwater in the Wellington Region: A synthesis of the existing information.* Report prepared for Greater Wellington Regional Council by NIWA, Report No. HAM2004-128, Hamilton.

Williamson B, Olsen G and Green M. 2005. *Greater Wellington Regional Council long-term baseline monitoring of marine sediments in Porirua Harbour.* Report prepared for Greater Wellington Regional Council by NIWA, Report No. HAM2004-128 (revised September 2005), Hamilton.

Acknowledgements

We would like to thank the following people who have been instrumental in shaping and implementing or reporting on Greater Wellington's coastal monitoring programme in recent years:

- Gary Stephenson (Coastal Marine Ecology Consultants)
- Dr Barry Robertson and Leigh Stevens (Wriggle Coastal Management Ltd)
- Greg Olsen (NIWA)
- Dr Shane Kelly (Coast and Catchment Ltd)

Microbiological water quality monitoring is a joint effort involving Greater Wellington and its constituent local councils, in particular the Kapiti Coast District Council, Porirua City Council, Wellington City Council and Hutt City Council.

The following Greater Wellington staff assisted us with this report:

- Shyam Morar helped compile the microbiological water quality data and prepared the report maps;
- Alice Ryan compiled many of the references;
- Summer Greenfield provided comment on the microbiological water quality and discussion sections; and
- Dr Claire Conwell peer reviewed a draft version of this report.

Appendix 1: Coastal monitoring site locations

Microbiological water quality monitoring sites

Table A1.1: Microbiological water quality monitoring sites – sampled as part of Greater Wellington's recreational water quality monitoring programme (see Greenfield et al. 2012)

Area	Site name	NZTM co-ordinates		Type
		Easting	Northing	
Kapiti	Otaki Beach @ Surf Club	1778622	5488330	Recreation & shellfish gathering
Kapiti	Otaki Beach @ Rangiuru Road	1778010	5487069	Recreation
Kapiti	Te Horo Beach S of Mangaone Stream	1775779	5482478	Recreation
Kapiti	Te Horo Beach @ Kitchener Street	1775495	5481933	Recreation
Kapiti	Peka Peka Beach @ Road End	1773215	5477905	Recreation & shellfish gathering
Kapiti	Waikanae Beach @ William Street	1771388	5475584	Recreation
Kapiti	Waikanae Beach @ Tutere St Tennis Courts	1770655	5474862	Recreation
Kapiti	Waikanae Beach @ Ara Kuaka Carpark	1769514	5473978	Recreation
Kapiti	Paraparaumu Beach @ Ngapotiki Street	1767543	5472762	Recreation
Kapiti	Paraparaumu Beach @ Nathan Avenue	1767033	5472174	Recreation
Kapiti	Paraparaumu Beach @ Maclean Park	1766694	5471267	Recreation
Kapiti	Paraparaumu Beach @ Toru Road	1766577	5470715	Recreation
Kapiti	Paraparaumu Beach @ Wharemauku Road	1766503	5470070	Recreation
Kapiti	Raumati Beach @ Tainui Street	1766531	5469229	Recreation
Kapiti	Raumati Beach @ Marine Gardens	1766516	5468441	Recreation
Kapiti	Raumati Beach @ Aotea Road	1766414	5467529	Recreation
Kapiti	Raumati Beach @ Hydes Road	1766318	5466835	Recreation & shellfish gathering
Kapiti	Paekakariki Beach @ Whareroa Road	1765598	5464128	Recreation
Kapiti	Paekakariki Beach @ Surf Club	1764791	5462273	Recreation
Porirua	Pukerua Bay	1759058[2]	5456278	Recreation
Porirua	Karehana Bay @ Cluny Road	1756093	5451360	Recreation
Porirua	Plimmerton Beach @ Bath Street	1756706	5450316	Recreation
Porirua	Plimmerton Beach @ Queens Avenue	1756758	5450177	Recreation
Porirua	South Beach @ Plimmerton	1756810	5449874	Recreation
Porirua	Paremata Beach @ Pascoe Avenue	1757116	5448733	Recreation
Porirua	Pauatahanui Inlet @ Water Ski Club	1758074	5449593	Recreation
Porirua	Pauatahanui Inlet @ Motukaraka Point	1759486	5449338	Recreation & shellfish gathering
Porirua	Pauatahanui Inlet @ Browns Bay	1758039	5447833	Recreation & shellfish gathering
Porirua	Pauatahanui Inlet @ Paremata Bridge	1757153	5448284	Recreation
Porirua	Porirua Harbour @ Rowing Club	1754891	5446947	Recreation & shellfish gathering
Porirua	Titahi Bay @ Bay Drive	1754132	5448169	Recreation
Porirua	Titahi Bay at Toms Road	1754110	5447857	Recreation
Porirua	Titahi Bay @ South Beach Access Road	1753906	5447682	Recreation
Porirua	Onehunga Bay	1755796	5449181	Recreation
Wellington	Aotea Lagoon	1748985	5427683	Recreation
Wellington	Oriental Bay @ Freyberg Beach	1749920	5427464	Recreation
Wellington	Oriental Bay @ Wishing Well	1750118	5427386	Recreation
Wellington	Oriental Bay @ Band Rotunda	1750243	5427375	Recreation
Wellington	Balaena Bay	1750958	5427267	Recreation
Wellington	Kio Bay	1751139	5426602	Recreation

Area	Site name	NZTM co-ordinates		Type
		Easting	Northing	
Wellington	Hataitai Beach	1750632	5425730	Recreation
Wellington	Shark Bay	1752211	5426197	Recreation & shellfish gathering
Wellington	Mahanga Bay	1753468	5427115	Recreation & shellfish gathering
Wellington	Scorching Bay	1753517	5426647	Recreation
Wellington	Worser Bay	1753074	5424823	Recreation
Wellington	Seatoun Beach @ Wharf	1753129	5424234	Recreation
Wellington	Seatoun Beach @ Inglis Street	1753405	5423994	Recreation
Wellington	Breaker Bay	1753312	5422970	Recreation
Wellington	Lyall Bay @ Tirangi Road	1750747	5423230	Recreation
Wellington	Lyall Bay @ Onepu Road	1750286	5423116	Recreation
Wellington	Lyall Bay @ Queens Drive	1749990	5422868	Recreation
Wellington	Princess Bay	1749586	5421504	Recreation
Wellington	Island Bay @ Surf Club	1748377	5421590	Recreation
Wellington	Island Bay @ Reef St Recreation Ground	1748229	5421542	Recreation
Wellington	Island Bay @ Derwent Street	1748155	5421415	Recreation
Hutt	Petone Beach @ Water Ski Club	1755744	5434591	Recreation
Hutt	Petone Beach @ Sydney Street	1757045	5434248	Recreation
Hutt	Petone Beach @ Settlers Museum	1757555	5434056	Recreation
Hutt	Petone Beach @ Kiosk	1758326	5433711	Recreation
Hutt	Sorrento Bay	1759632	5431384	Recreation & shellfish gathering
Hutt	Lowry Bay @ Cheviot Road	1760206	5430891	Recreation
Hutt	York Bay	1759977	5430160	Recreation
Hutt	Days Bay @ Wellesley College	1759616	5428529	Recreation
Hutt	Days Bay @ Wharf	1759654	5428313	Recreation
Hutt	Days Bay @ Moana Road	1759582	5428120	Recreation
Hutt	Rona Bay @ N end of Cliff Bishop Park	1759109	5427654	Recreation
Hutt	Rona Bay @ Wharf	1758730	5427371	Recreation
Hutt	Robinson Bay @ HW Shortt Rec Ground	1758519	5426674	Recreation
Hutt	Robinson Bay @ Nikau Street	1758131	5425856	Recreation
Hutt	Camp Bay	1756990	5424288	Recreation
Wairarapa	Castlepoint Beach @ Castlepoint Stream	1871366	5467559	Recreation
Wairarapa	Castlepoint Beach @ Smelly Creek	1871670	5467202	Recreation
Wairarapa	Riversdale Beach @ Lagoon Mouth	1858965	5447543	Recreation
Wairarapa	Riversdale Beach Between the Flags	1858435	5446948	Recreation
Wairarapa	Riversdale Beach South	1857834	5445514	Recreation

Estuary sediment and benthic fauna (fine scale) monitoring sites

Table A1.2: Waikanae Estuary intertidal sampling locations

Site	NZTM	
	Easting	Northing
Waikanae A	1769248 (Plot 01) 1769261 (Plot 10)	5473364 (Plot 01) 5473355 (Plot 10)

Table A1.3: Porirua Harbour intertidal sampling locations

Site	NZTM Easting	 Northing
Porirua A	1756457 (Plot 01) 1756494 (Plot 10)	5447774 (Plot 01) 5447811 (Plot 10)
Porirua B	1754615 (Plot 01) 1754587 (Plot 10)	5445422 (Plot 01) 5445503 (Plot 10)
Pauatahanui A	1757243 (Plot 01) 1757246 (Plot 10)	5448644 (Plot 01) 5448601 (Plot 10)
Pauatahanui B	1760358 (Plot 01) 1760378 (Plot 10)	5448343 (Plot 01) 5448341 (Plot 10)

Table A1.4: Hutt Estuary sampling locations

Site	NZTM Easting	 Northing
Hutt A	1759174.1 (Peg 1) 1759174.4 (Peg 2)	5433638.0 (Peg 1) 5433618.1 (Peg 2)
Hutt B	1759369.4 (Peg 1) 1759369.0 (Peg 2)	5434135.8 (Peg 1) 5434116.9 (Peg 2)

Table A1.5: Whareama Estuary intertidal sampling locations

Site	NZTM Easting	 Northing
Whareama A	1860703 (Plot 01) 1860684 (Plot 10)	5455343 (Plot 01) 5455338 (Plot 10)
Whareama B	1860084 (Plot 01) 1860067 (Plot 10)	5455318 (Plot 01) 5455294 (Plot 10)

Table A1.6: Lake Onoke intertidal sampling locations

Site	NZTM Easting	 Northing
Lake Onoke A	1778353 (Plot 01) 1778314 (Plot 10)	5417347 (Plot 01) 5417394 (Plot 10)

Estuary water quality monitoring sites

Table A1.7: Porirua Harbour water quality sampling locations

Site	Location	NZTM	
		Easting	Northing
PH-E1	Porirua Harbour at entrance	1756592	5448786
PH-P1	Porirua Harbour at Pauatahanui Arm East	1757999	5449405
PH-P2	Porirua Harbour at Pauatahanui Arm North	1760219	5448516
PH-P3	Porirua Harbour at Pauatahanui Arm South	1758653	5447986
PH-O1	Porirua Harbour at Onepoto Arm North	1755335	5446946
PH-O2	Porirua Harbour at Onepoto Arm South	1754535	5445707

Subtidal harbour sediment quality monitoring sites

Table A1.8: Porirua Harbour subtidal sediment quality sampling locations

Site	Location	NZTM		Depth (m)
		Easting	Northing	
PAH1	Pauatahanui Arm off Browns Bay	1758157	5448052	2.0
PAH2	Pauatahanui Arm off Duck Creek	1759727	5448139	1.7
PAH3	Pauatahanui Arm off Camborne	1758151	5449206	1.7
POR1	Onepoto Arm South	1754864	5445871	2.0
POR2	Porirua Harbour North	1755179	5446506	2.8

Table A1.9: Wellington Harbour subtidal sediment quality sampling sites

Site	Location	NZTM		Depth (m)
		Easting	Northing	
WH1	Southern Evans Bay	1751530	5425348	17
WH2	Northern Evans Bay	1751710	5427288	17
WH3	Lambton Harbour entrance	1750056	5428340	17
WH4	Lambton Harbour entrance	1750763	5428789	19
WH5	Central basin	1751748	5429138	20
WH6	Central basin	1752665	5429581	21
WH7	Central basin	1753581	5429932	21
WH8	Central basin	1754566	5430282	22
WH9	South of Ngauranga	1751921	5430708	20
WH10	South of Ngauranga	1752012	5431724	19
WH11	North of Ngauranga	1752508	5432084	19
WH12	North of Ngauranga	1753480	5431786	19
WH13	Western Petone	1756023	5433121	15
WH14	Western Petone	1756382	5433576	10
WH15	Seaview	1758160	5431778	15
WH16	Seaview	1757243	5431336	19
WH17	North of Ward Island	1756770	5428847	21

Sandy beach ecological monitoring sites

Table A1.10: Castlepoint Beach sampling locations

Site	NZTM	
	Easting	Northing
Castlepoint A	1871628 (Plot 01) 1871679 (Plot 06)	5469792 (Plot 01) 5469774 (Plot 06)
Castlepoint B	1871609 (Plot 01) 1871664 (Plot 06)	5469739 (Plot 01) 5469730 (Plot 06)

Appendix 2: Monitoring variables and analytical methods

Table A2.1: Microbiological water quality analytical methods

Determinant	Method	Detection limit
Enterococci at 41°C	US EPA Method 1600, Membrane filter on mEI agar.	1–5 cfu/100mL
Faecal coliforms at 44.5°C	APHA Standard Methods (20th Ed.) 9222D, Membrane filter on mFC agar.	1–5 cfu/100mL
Water temperature	Field meter or digital thermometer.	0.1°C
Turbidity	APHA Standard Methods (20th Ed.) 2130B.	0.1 NTU
Seaweed cover	Visual estimate within 5 m radius around sample point, including both floating and attached seaweed.	5%

Table A2.2: Estuarine (and sandy beach) sediment quality analytical methods

Determinant	Method	Detection limit
Sediment particle/grain size (2 mm, 63 µm–2mm & <63 µm fractions)	Air dried at 35°C and sieving using 2 mm and 63 µm sieves, gravimetry (calculation by difference).	0.1 g/100g dry wt
Total organic carbon (TOC)	Acid pretreatment to remove carbonates if present, Elementar Combustion Analyser.	0.05 g/100g dry wt
Total recoverable phosphorus	Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt
Total nitrogen	Catalytic Combustion (900°C, O_2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt
Total recoverable cadmium	Nitric/Hydrochloric acid digestion, <2 mm fraction, ICP-MS, trace level. US EPA 200.2.	0.01 mg/kg dry wt
Total recoverable chromium	Nitric/Hydrochloric acid digestion, <2 mm fraction, ICP-MS, trace level. US EPA 200.2.	0.2 mg/kg dry wt
Total recoverable copper	Nitric/Hydrochloric acid digestion, <2 mm fraction, ICP-MS, trace level. US EPA 200.2.	0.2 mg/kg dry wt
Total recoverable lead	Nitric/Hydrochloric acid digestion, <2 mm fraction, ICP-MS, trace level. US EPA 200.2.	0.04 mg/kg dry wt
Total recoverable nickel	Nitric/Hydrochloric acid digestion, <2 mm fraction, ICP-MS, trace level. US EPA 200.2.	0.2 mg/kg dry wt
Total recoverable zinc	Nitric/Hydrochloric acid digestion, <2 mm fraction, ICP-MS, trace level. US EPA 200.2.	0.4 mg/kg dry wt
Organochlorine pesticides	Sonication extraction, SPE cleanup, GPC cleanup (if req.), 4, 8 dual column GC-ECD analysis, trace level.	0.001 mg/kg dry wt
Polycyclic aromatic hydrocarbon (PAHs)	Sonication extraction, SPE cleanup, GC-MS SIM analysis, US EPA 8270C, trace level. Tested on as received sample.	0.001 mg/kg dry wt

Table A2.3: Porirua Harbour water quality analytical methods

Determinant	Method	Detection limit
Electrical conductivity (EC)	Saline water, Conductivity meter, 25°C. APHA 2510 B 21st Ed. 2005.	0.10 mS/m
Salinity	Meter, no temp. compensation. APHA 2520 B 21st Ed. 2005.	0.2 ppt
Turbidity	Saline sample. Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 21st ed. 2005.	0.10 NTU

Determinant	Method	Detection limit
Total suspended solids (TSS)	Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D 21st Ed. 2005.	2 mg/L
Total ammoniacal nitrogen	Saline, filtered sample. Phenol/hypochlorite colorimetry. Discrete Analyser. (NH_4-N = NH_4+-N + NH_3-N). APHA 4500-NH_3 F (modified from manual analysis) 21st Ed. 2005.	0.01 mg/L
Nitrite nitrogen (Nitrite-N)	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3-I (Proposed) 21st Ed. 2005.	0.002 mg/L
Nitrate nitrogen (Nitrate-N)	Calculation: (Nitrate-N + Nitrite-N) – NO_2N.	0.002 mg/L
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3-I (Proposed) 21st Ed. 2005.	0.002 mg/L
Total Kjeldahl nitrogen (TKN)	Total Kjeldahl digestion (sulphuric acid with copper sulphate catalyst), phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} C. (modified) 4500 NH_3 F (modified) 21st Ed. 2005.	0.1 mg/L
Total nitrogen	Calculation: TKN + Nitrate-N + Nitrite-N.	0.05 mg/L
Dissolved reactive phosphorus	Filtered sample. Molybdenum blue colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st Ed. 2005.	0.004 mg/L
Total phosphorus	Total phosphorus digestion (acid persulphate), ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P E (modified from manual analysis) 21st Ed. 2005.	0.004 mg/L
Chlorophyll *a*	Acetone extraction. Spectroscopy. APHA 10200 H 21st Ed. 2005 (modified).	0.003 mg/L

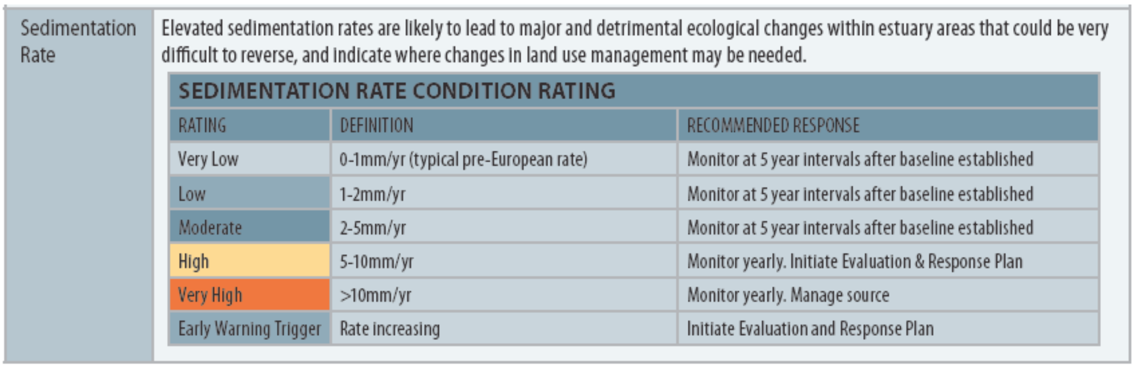
Table A2.4: Subtidal sediment quality analytical methods (see Stephenson et al. (2008) and Oliver et al. (in press) for further details of analytical test suits and detection limits, including analytical test methods for organotin compounds)

Determinant	Method	Detection limit
Sediment particle/grain size	Galai CIS-100 'time-of-transition' stream-scanning laser particle sizer or Eyetech particle size analyser, <500 µm fraction.	–
Total organic carbon	Acid pretreatment to remove carbonates if present, Elementar Combustion Analyser	0.05 g/100 g dry wt
Total recoverable Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Sb and Zn	Dried sample, <500 µm fraction, Nitric/Hydrochloric acid digestion ICP-MS, trace level. US EPA 200.2.	Various
Extractable copper	2M HCl extraction (Solid:Liquid 1:50 w/v), <63 µm fraction, ICP-MS. ARC Tech Publication No 47, 1994.	1 mg/kg dry wt
Extractable lead	2M HCl extraction (Solid:Liquid 1:50 w/v), <63 µm fraction, ICP-MS. ARC Tech Publication No 47, 1994.	0.2 mg/kg dry wt
Extractable zinc	2M HCl extraction (Solid:Liquid 1:50 w/v), <63 µm fraction, ICP-MS. ARC Tech Publication No 47, 1994.	2 mg/kg dry wt
Polycyclic aromatic hydrocarbons (PAHs)	Sonication solvent extraction and GC-MS in selected ion mode.	Various
Organochlorine pesticides (OCPs)	Sonication solvent extraction and GC-MS in selected ion mode.	Various

Appendix 3: Estuary condition ratings

The following text and tables have been reproduced from reports prepared for Greater Wellington by Wriggle Coastal Management.

A series of interim fine scale estuary 'condition ratings' (presented below) were proposed for Porirua Harbour, Waikanae, Hutt River, and Whareama estuaries (based on the ratings developed for Southland's estuaries – eg, Robertson & Stevens (2006). The ratings are based on a review of estuary monitoring data, guideline criteria and expert opinion. They are designed to be used in combination with each other (usually involving expert input) when evaluating overall estuary condition and deciding on appropriate management. The condition ratings include an 'early warning trigger' to highlight rapid or unexpected change, and each rating has a recommended monitoring and management response. In most cases, initial management is to further assess an issue and consider what response actions may be appropriate (eg, develop an Evaluation and Response Plan – ERP).

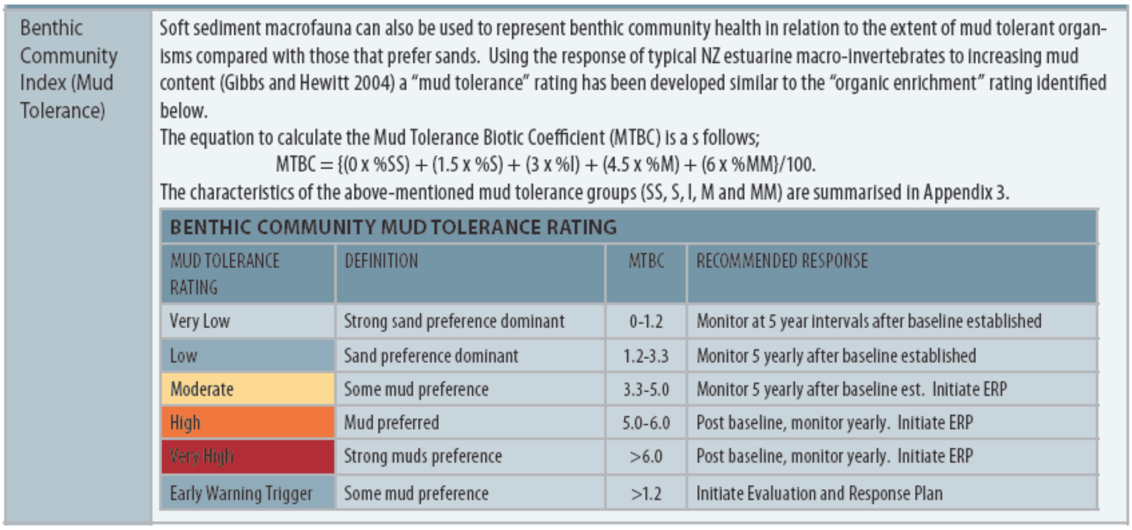


Sedimentation Rate

Elevated sedimentation rates are likely to lead to major and detrimental ecological changes within estuary areas that could be very difficult to reverse, and indicate where changes in land use management may be needed.

SEDIMENTATION RATE CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Low	0-1mm/yr (typical pre-European rate)	Monitor at 5 year intervals after baseline established
Low	1-2mm/yr	Monitor at 5 year intervals after baseline established
Moderate	2-5mm/yr	Monitor at 5 year intervals after baseline established
High	5-10mm/yr	Monitor yearly. Initiate Evaluation & Response Plan
Very High	>10mm/yr	Monitor yearly. Manage source
Early Warning Trigger	Rate increasing	Initiate Evaluation and Response Plan



Benthic Community Index (Mud Tolerance)

Soft sediment macrofauna can also be used to represent benthic community health in relation to the extent of mud tolerant organisms compared with those that prefer sands. Using the response of typical NZ estuarine macro-invertebrates to increasing mud content (Gibbs and Hewitt 2004) a "mud tolerance" rating has been developed similar to the "organic enrichment" rating identified below.

The equation to calculate the Mud Tolerance Biotic Coefficient (MTBC) is a s follows;

$$MTBC = \{(0 \times \%SS) + (1.5 \times \%S) + (3 \times \%I) + (4.5 \times \%M) + (6 \times \%MM)\}/100.$$

The characteristics of the above-mentioned mud tolerance groups (SS, S, I, M and MM) are summarised in Appendix 3.

BENTHIC COMMUNITY MUD TOLERANCE RATING

MUD TOLERANCE RATING	DEFINITION	MTBC	RECOMMENDED RESPONSE
Very Low	Strong sand preference dominant	0-1.2	Monitor at 5 year intervals after baseline established
Low	Sand preference dominant	1.2-3.3	Monitor 5 yearly after baseline established
Moderate	Some mud preference	3.3-5.0	Monitor 5 yearly after baseline est. Initiate ERP
High	Mud preferred	5.0-6.0	Post baseline, monitor yearly. Initiate ERP
Very High	Strong muds preference	>6.0	Post baseline, monitor yearly. Initiate ERP
Early Warning Trigger	Some mud preference	>1.2	Initiate Evaluation and Response Plan

Total Organic Carbon

Estuaries with high sediment organic content can result in anoxic sediments and bottom water, release of excessive nutrients and adverse impacts to biota - all symptoms of eutrophication.

TOTAL ORGANIC CARBON CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<1%	Monitor at 5 year intervals after baseline established
Good	1-2%	Monitor at 5 year intervals after baseline established
Fair	2-5%	Monitor at 2 year intervals and manage source
Poor	>5%	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Redox Potential Discontinuity

The RPD is the grey layer between the oxygenated yellow-brown sediments near the surface and the deeper anoxic black sediments. It is an effective ecological barrier for most but not all sediment-dwelling species. A rising RPD will force most macrofauna towards the sediment surface to where oxygen is available. The depth of the RPD layer is a critical estuary condition indicator in that it provides a measure of whether nutrient enrichment in the estuary exceeds levels causing nuisance anoxic conditions in the surface sediments. The majority of the other indicators (e.g. macroalgal blooms, soft muds, sediment organic carbon, TP, and TN) are less critical, in that they can be elevated, but not necessarily causing sediment anoxia and adverse impacts on aquatic life. Knowing if the surface sediments are moving towards anoxia (i.e. RPD close to the surface) is important for two main reasons:

1. As the RPD layer gets close to the surface, a "tipping point" is reached where the pool of sediment nutrients (which can be large), suddenly becomes available to fuel algal blooms and to worsen sediment conditions.
2. Anoxic sediments contain toxic sulphides and very little aquatic life.

The tendency for sediments to become anoxic is much greater if the sediments are muddy. In sandy porous sediments, the RPD layer is usually relatively deep (>3cm) and is maintained primarily by current or wave action that pumps oxygenated water into the sediments. In finer silt/clay sediments, physical diffusion limits oxygen penetration to <1cm (Jørgensen and Revsbech 1985) unless bioturbation by infauna oxygenates the sediments.

RPD CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	>10cm depth below surface	Monitor at 5 year intervals after baseline established
Good	3-10cm depth below sediment surface	Monitor at 5 year intervals after baseline established
Fair	1-3cm depth below sediment surface	Monitor at 5 year intervals. Initiate Evaluation & Response Plan
Poor	<1cm depth below sediment surface	Monitor at 2 year intervals. Initiate Evaluation & Response Plan
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Phosphorus

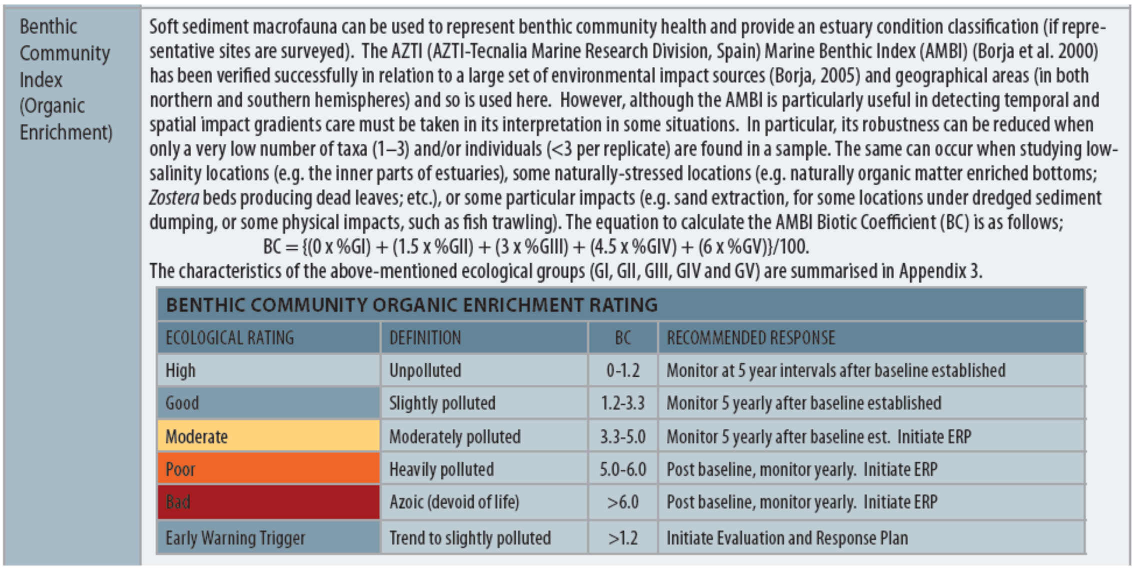
In shallow estuaries like Freshwater the sediment compartment is often the largest nutrient pool in the system, and phosphorus exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL PHOSPHORUS CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<200mg/kg	Monitor at 5 year intervals after baseline established
Good	200-500mg/kg	Monitor at 5 year intervals after baseline established
Fair	500-1000mg/kg	Monitor at 2 year intervals and manage source
Poor	>1000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Total Nitrogen

In shallow estuaries like Freshwater, the sediment compartment is often the largest nutrient pool in the system, and nitrogen exchange between the water column and sediments can play a large role in determining trophic status and the growth of algae.

TOTAL NITROGEN CONDITION RATING		
RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<500mg/kg	Monitor at 5 year intervals after baseline established
Good	500-2000mg/kg	Monitor at 5 year intervals after baseline established
Fair	2000-4000mg/kg	Monitor at 2 year intervals and manage source
Poor	>4000mg/kg	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan



Benthic Community Index (Organic Enrichment)

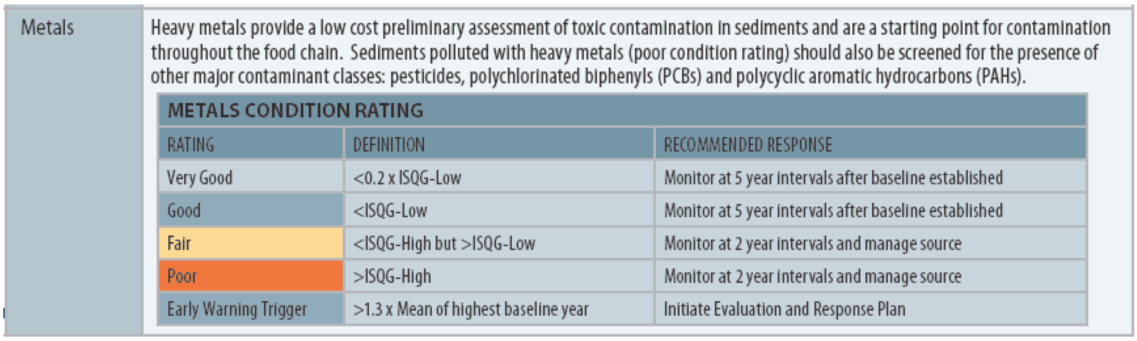
Soft sediment macrofauna can be used to represent benthic community health and provide an estuary condition classification (if representative sites are surveyed). The AZTI (AZTI-Tecnalia Marine Research Division, Spain) Marine Benthic Index (AMBI) (Borja et al. 2000) has been verified successfully in relation to a large set of environmental impact sources (Borja, 2005) and geographical areas (in both northern and southern hemispheres) and so is used here. However, although the AMBI is particularly useful in detecting temporal and spatial impact gradients care must be taken in its interpretation in some situations. In particular, its robustness can be reduced when only a very low number of taxa (1–3) and/or individuals (<3 per replicate) are found in a sample. The same can occur when studying low-salinity locations (e.g. the inner parts of estuaries), some naturally-stressed locations (e.g. naturally organic matter enriched bottoms; *Zostera* beds producing dead leaves; etc.), or some particular impacts (e.g. sand extraction, for some locations under dredged sediment dumping, or some physical impacts, such as fish trawling). The equation to calculate the AMBI Biotic Coefficient (BC) is as follows;

$$BC = \{(0 \times \%GI) + (1.5 \times \%GII) + (3 \times \%GIII) + (4.5 \times \%GIV) + (6 \times \%GV)\}/100.$$

The characteristics of the above-mentioned ecological groups (GI, GII, GIII, GIV and GV) are summarised in Appendix 3.

BENTHIC COMMUNITY ORGANIC ENRICHMENT RATING

ECOLOGICAL RATING	DEFINITION	BC	RECOMMENDED RESPONSE
High	Unpolluted	0-1.2	Monitor at 5 year intervals after baseline established
Good	Slightly polluted	1.2-3.3	Monitor 5 yearly after baseline established
Moderate	Moderately polluted	3.3-5.0	Monitor 5 yearly after baseline est. Initiate ERP
Poor	Heavily polluted	5.0-6.0	Post baseline, monitor yearly. Initiate ERP
Bad	Azoic (devoid of life)	>6.0	Post baseline, monitor yearly. Initiate ERP
Early Warning Trigger	Trend to slightly polluted	>1.2	Initiate Evaluation and Response Plan



Metals

Heavy metals provide a low cost preliminary assessment of toxic contamination in sediments and are a starting point for contamination throughout the food chain. Sediments polluted with heavy metals (poor condition rating) should also be screened for the presence of other major contaminant classes: pesticides, polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs).

METALS CONDITION RATING

RATING	DEFINITION	RECOMMENDED RESPONSE
Very Good	<0.2 x ISQG-Low	Monitor at 5 year intervals after baseline established
Good	<ISQG-Low	Monitor at 5 year intervals after baseline established
Fair	<ISQG-High but >ISQG-Low	Monitor at 2 year intervals and manage source
Poor	>ISQG-High	Monitor at 2 year intervals and manage source
Early Warning Trigger	>1.3 x Mean of highest baseline year	Initiate Evaluation and Response Plan

Water, air, earth and energy – elements in Greater Wellington's logo that combine to create and sustain life. Greater Wellington promotes **Quality for Life** by ensuring our environment is protected while meeting the economic, cultural and social needs of the community

For more information, contact Greater Wellington:

Wellington office
PO Box 11646
Manners Street
Wellington 6142
T 04 384 5708
F 04 385 6960

Masterton office
PO Box 41
Masterton 5840
T 06 378 2484
F 06 378 2146

www.gw.govt.nz

June 2012
GW/EMI-T-12/144

Please recycle
Produced sustainably