Tauranga Harbour Science Gap Analysis

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Executive summary

Tauranga Harbour is a significant asset and an iconic area in the Bay of Plenty region, providing economic, ecological, cultural, amenity and recreational value. The Bay of Plenty Regional Council (BOPRC) is responsible for managing Tauranga Harbour and the natural resources of surrounding catchments. Scientific data and knowledge are fundamental to understanding, enhancement and effective management of these resources. This report describes the key environmental issues in Tauranga Harbour, identifies gaps in our scientific knowledge and understanding of these issues, and recommends research projects to address these gaps.

Water quality, sediment dynamics, habitat degradation, and decline in kaimoana were identified as key environmental issues for Tauranga Harbour. An overview of the monitoring work undertaken in Tauranga Harbour related to these issues and of the scientific data available to BOPRC was provided. A total of 35 gaps in our scientific knowledge and understanding were identified across all key issues and research projects were recommended to address these gaps.

Research recommendations were assigned to the following gap themes:

(a) obtain new data

(b) improvements to methods and reporting

(c) modelling, and

(d) review state of knowledge.

The greatest number of gaps were identified for the key issues habitat degradation and water quality (12 gaps each). The least number of gaps were identified for the key issue decline in kaimoana (five gaps). The greatest number of gaps (18 gaps) across all key issues was assigned to the gap theme obtain new data.

This analysis highlighted gaps in our knowledge and understanding of key environmental issues for Tauranga Harbour. The challenge is how to best fill these gaps given the reality of constrained resources and time. The next step is to prioritise and rank these gaps. In undertaking such a ranking process, it is important to consider a number of key issues, including that:

- there is a need for better integration of different science programmes
- there is a need to consider which gaps will need to be filled to enable implementation of the NPS-FM, and
- there is a need to consider the data and information needed to support computer models.

By considering these issues as part of the gap analysis and prioritisation process, it is expected that more informed decisions can be made about gaps which need to be addressed as a matter of urgency and those which can be regarded as optional.

Contents

Part 1:

Introduction

Harbour overview

Tauranga Harbour is a significant asset and an iconic area in the Bay of Plenty region, providing economic, ecological, cultural, amenity and recreational value. There is an increasing need for sound science to play an important role in achieving the aspirations of the Tauranga Harbour Programme. In place since 2012, the key focus for this programme is to coordinate and deliver on community expectations for the harbour and surrounding catchments through Council's various work streams.

Tauranga Harbour (or Te Awanui) is a large estuary of approximately 200 km^2 located on the western edge of the Bay of Plenty region. The harbour is protected by a barrier island (Matakana) and defined by two volcanic headlands (tombolos) at either end. The harbour is separated into two basins (North and South) by large intertidal sandflats in the centre, with little water movement between. The harbour has a number of sub-estuaries and freshwater riverine inputs with the largest being the Wairoa River. The harbour catchment has an area of 1,300 km^2 and has a significant influence on the health of the harbour due to a range of land use activities.

Tauranga Harbour is identified under the Bay of Plenty Regional Coastal Environment Plan in its entirety as an outstanding natural feature and landscape, and nearly the entire harbour (except the port area) is identified as an area of significant conservation value. The harbour has also been identified by the Department of Conservation (DOC) as an area of outstanding natural features and a landscape supporting high biodiversity[1]. However, there is community concern that the values of the harbour are being degraded, particularly those that relate to ecological health, cultural wellbeing, sustainable land use and economic importance. BOPRC is responsible for managing Tauranga Harbour and the natural resources of surrounding catchments. Scientific data and knowledge are fundamental to understanding, enhancement and effective management of these resources.

Purpose

This report describes the key environmental issues in Tauranga Harbour, identifies gaps in our scientific knowledge and understanding of these issues, and recommends research projects to address these gaps.

The specific aims of this report are to:

- describe key environmental issues in Tauranga Harbour
- provide an overview of the monitoring work undertaken in Tauranga Harbour and of the scientific data available to BOPRC which is related to these issues and needed for the environmental management of the harbour by BOPRC
- identify gaps in our scientific knowledge and understanding of these issues, and
- recommend research projects to address these gaps.

It is intended that the gaps identified in this document will direct the BOPRCs future scientific work program for Tauranga Harbour and will also identify priority areas for research collaborations with the University of Waikato and other researchers.

[1] Van Meeuwen-Diijkgraaf A., Shaw, W.B. Mazzieri F. (2009). Ecosystem services of protected areas and ecological corridors within the Kaimai-Tauranga catchments. Technical Report Series 2 Department of Conservation.

Scope

The scope of this report is limited to the physical and ecological characteristics of Tauranga Harbour. This includes the topics of water quality, sediment dynamics, habitat degradation and decline in kaimoana. The Tauranga Harbour Catchment (also referred to as the Tauranga Harbour Water Management Area) is outside the scope of this report and will be addressed in a separate gaps analysis related to the implementation of the National Policy Statement for Freshwater Management (NPS-FM)[2]. It is intended that this gaps analysis be undertaken closer to the time of implementation. Marine mammals and birds are also outside the scope of this report as they are managed the (DOC).

The overview of monitoring work in Tauranga Harbour and scientific data available to BOPRC was limited to research undertaken by BOPRC, consultants contracted by BOPRC, or research partners funded by BOPRC (e.g. PhD students at the University of Waikato). Monitoring in the harbour is also undertaken by some consent holders as a condition of their consents. This type of monitoring was only documented for major consents with large potential impacts on the harbour (e.g. stormwater discharges, wastewater treatment discharges). A full search of the published scientific literature was not undertaken. However, if an extensive body of published scientific literature on topics relevant to this report was known to exist then it is noted in the relevant section.

Report structure

This report is structured into 8 parts. **Part 2** outlines the key environmental issues for Tauranga Harbour. **Parts 3 – 6** then outline the relevant scientific data BOPRC has for these issues and identify gaps in our scientific knowledge and understanding of these issues. Each key environmental issue is dealt with in a separate chapter. The report concludes in **Part 7** with a summary of the gaps identified throughout the report and recommended research projects to address these gaps. Key references and reports are provided for each key environmental issue in Table format at the end of each of **Parts 3 – 6.** A full list of references and reports referred to throughout this document is also provided in **Part 8**.

[2] New Zealand Government (2014). The National Policy Statement for Freshwater Management. Ministry for the Environment.

Part 2:

Key environmental issues

Introduction

This section describes the key environmental issues that have been identified for Tauranga Harbour. These issues have been collated from a number of recent documents published by BOPRC on Tauranga Harbour. As noted above, these issues are limited to those that are relevant only to the harbour/estuary area. Environmental issues related to the Tauranga Harbour catchment will be covered in a separate gaps analysis (see Part 1: Scope)

Water quality

Water quality is one of the key determinants of the health of Tauranga Harbour. Nutrients, sediments and contaminants that originate in the catchment as a result of urbanisation, agricultural activities, vegetation clearing and industry, eventually end up in the harbour, with potential impacts on water quality and harbour ecosystem. Excessive nutrient inputs to the harbour can lead to macroalgal (e.g. sea lettuce) and/or phytoplankton blooms, which can be toxic to some organisms. Excessive nutrients can also reduce dissolved oxygen in the water, lower biodiversity and lead to anoxic sediments. Excessive pathogen inputs (e.g. as indicated by *E. coli*) can increase the disease risk from bathing, wading or eating shellfish to unacceptable levels. The impacts of excessive sediment and contaminant inputs are discussed below (Part 2: Sediment Dynamics).

An understanding of water quality in Tauranga Harbour and the capacity of estuaries to assimilate physical, biological, and chemical stressors will be vitally important for the implementation of the NPS-FM in the Tauranga Harbour Water Management Area (WMA). The NPS-FM directs councils to manage fresh water in an integrated and sustainable way. This includes requirements to implement a National Objectives Framework which sets compulsory values for freshwater to protect human health for recreation and ecosystem health. However, we currently do not know if limits for water quality set in freshwater environments are sufficient to protect estuarine environments.

Sediment dynamics

Sedimentation rates in Tauranga Harbour have increased due to land development in the catchments surrounding the harbour. Much of the harbour’s catchments were previously forested with native bush, which has been cleared for agriculture, horticulture and urban development. Combined with the harbour’s topography, removal of wetlands, and the building of causeways and bridges, this has increased sediment delivery to the harbour and altered the hydrology (currents) within the harbour enabling greater sedimentation.

Impacts from high sedimentation rates in the harbour are caused mainly by high loads of fine clay and silt fractions which settle in more sheltered sub-estuaries. Sedimentation of estuaries generally replaces clean sand with nutrient rich, muddier substrates. Cleaner sand supports a diverse assemblage of biota including seagrass beds, shellfish, invertebrates and macroalgae. In contrast, muddy substrates support a less diverse community comprised mainly of marine worms and are less productive than the sandier habitats. Muddier, nutrient rich substrates also encourage the proliferation of mangroves (see Part 2: Habitat degradation below) and macroalgal blooms, which also reduce human values and uses.

Estuaries are natural collection points and toxic contaminants can accumulate in sediments and impact the harbour. These contaminants include heavy metals from road and roofing runoff, pesticide residues from farm runoff, industrial discharges and wastewater. If potentially toxic contaminant inputs are excessive then estuary biodiversity may be threatened and shellfish and finfish may be unsuitable for eating. Often the levels of toxic contaminants are not high enough to kill estuarine organisms immediately, but they accumulate over time by moving up the food chain where they present a greater risk of chronic poisoning to estuarine organisms at the top of the food chain.

Habitat degradation

Degradation of estuarine habitats, in particular wetlands and seagrass, proliferation of mangroves and sea lettuce blooms, and invasive marine species are key issues for BOPRC and were also identified as issues of concern in public perception surveys.

Human modification of Tauranga Harbour's wetland and saltmarsh habitats through reclamation, dredging or building of causeways and seawalls has removed and modified harbour margins and river mouths. The extent of wetlands in the harbour is estimated to have reduced from 3,002 ha in 1840 to 469 ha in 1991, which is an 84% loss. Up to 1991 it is estimated that over 693 ha of saltmarsh was destroyed by reclamation. Similarly, there have been significant declines in the extent of seagrass beds in Tauranga Harbour. Since the 1950's seagrass cover has decreased from around 40,437 ha to 2,735 ha in 2011. Over 61% of historic seagrass beds in the harbour have been lost, with the greatest decrease observed in the southern harbour. Both saltmarsh and seagrass provide valuable habitat for many species and are very productive ecosystems. Saltmarsh areas also provide a buffer between terrestrial land and the estuary, by slowing and filtering contaminants that may be harmful to the estuarine environment.

The proliferation of mangroves has been an issue of focus from residents surrounding the harbour. Total canopy cover of mangroves throughout all of Tauranga Harbour has increased from 240 ha in 1943 to 811 ha in 2011 and the greatest increases in canopy cover have been observed in recent times, with an almost 200 ha increase documented between 2003 and 2011. Sedimentation and climate warming are the two key factors driving mangrove expansion. Mangroves trap finer sediment and exacerbate the degradation caused by sedimentation.

Sea lettuce blooms are also an issue for residents surrounding the harbour. Sea lettuce accumulating on beaches when it decomposes creates an odour issue affecting residents and recreational users of the harbour. Large sea lettuce blooms can also have adverse effects on the estuary ecosystem. These include extensive loss of seagrass, shellfish beds and all benthic macrofauna due to sea lettuce smothering causing reductions in light, prevention of all shellfish and macrofauna recruitment, loss of oxygen and increases in toxic levels of ammonium nitrogen and hydrogen sulphide.

Invasive marine species, hereafter referred to as marine pests, can have adverse effects on Tauranga Harbour. There are more than 170 exotic species present in New Zealand's coastal environments, some of which are significant marine pests that have the potential to cause harm to valued marine species, ecosystems or environments. Marine pests also present a significant risk to our region's economic, social and cultural values. As new invasive species can be easily introduced from commercial shipping, aquaculture equipment and recreational vessels, there is a high risk of marine pest incursion to Tauranga Harbour. The management of these pests is difficult as they are not often detected early enough to enable successful eradication. Marine pests that have been identified to date in Tauranga Harbour include the Japanese kelp (*Undaria pinnatifida*), Asian date mussel, *Didemnum* sea squirt, Mediterranean fan worm (*Sabella spallanzanii*) and clubbed tunicate sea squirt (*Styella clava*).

Decline in kaimoana

Kaimoana (finfish, shellfish and macroinvertebrates) provides cultural, spiritual and physical sustenance and identity for coastal Māori. Kaimoana not only sustains the way of life of the individual, but also maintains tribal mana and standing. Kaimoana has long been part of the diet of coastal Māori, providing essential vitamins and minerals. It has also been an important resource for trading with inland tribes for goods. However, coastal kaimoana resources are under intense pressure from over-harvesting and from the effects of increasing development in coastal areas. Surveys of shellfish distribution and abundance have shown a decline in Tauranga Harbour's upper estuaries. Additionally, anecdotal reports note that horse mussels near Otumoetai have disappeared, shellfish gathered from particular beds are unsuitable to eat, and cockles are getting smaller and are being depleted by spreading silt layers. Overfishing, and increased sediment and nutrient inputs to the harbour are thought to be responsible.

Part 3:

Water quality

Introduction

Estuaries are the transitional environment between rivers and the sea and because of this they have complex hydrology and water quality. Rivers and streams transport various contaminants, including sediment and nutrients, and these can build up over time in estuaries, often with ecological consequences. The harbour catchment covers an area of approximately 1,300 km^2 and is well developed with extensive horticultural and agricultural use. At the southern end of the harbour, the city of Tauranga and surrounding area supports a large residential population (around 120,000). Near the southern entrance, the Mount Maunganui – Sulphur Point region of the harbour has been progressively developed for port facilities. All of these land-uses impact on estuarine water quality.

This section provides an overview of the monitoring work undertaken in Tauranga Harbour and scientific data available to BOPRC related to water quality. This includes bathing water quality, stormwater, wastewater and industrial discharge. Gaps in our knowledge and understanding of water quality are identified and discussed. Sedimentation and contaminants are discussed in Part 4: Sediment Dynamics. Shellfish contamination is discussed in Part 4: Sedimentation. Identifying drivers and causes of poor water quality is outside the scope of this report and is not discussed here. Consequences of poor water quality (e.g. high nutrient loads, high sediment loads) is addressed under specific topics in Part 5: Habitat degradation where relevant (e.g. mangroves, sea lettuce). More general discussion of the consequences of poor water quality is outside the scope of this report and not discussed here.

Estuarine water quality

Estuarine water quality has been monitored under the Natural Environment Regional Monitoring Network (NERMN) since 1990. Until recently, 14 sites were sampled every two months, 11 of these over the high tide period and three of these over the low tide period. However, a review of the NERMN monitoring programme in 2014 recommended that sampling frequency be increased to monthly at all sites. Additional consideration of the estuarine water quality monitoring programme recommended changing all sampling times to sample at mid-tide on the outgoing (ebb) tide to capture water that better represents the dominant conditions and the influence of upstream catchments rather than the influence of incoming oceanic water. Removal and replacement of some sites with other more representative sites was also recommended. Consequently, six sites were removed from the monitoring programme and an additional three sites were added. A total of eight sites have been monitored from mid-2015 and sampling now occurs monthly on the mid ebb tide (Table 3.1). These sites have been selected to target potentially impacted areas of the catchment (e.g. Tauranga city urban areas) and downstream regions of the harbour that would capture the influence of multiple upstream catchments. There are no sampling sites on Matakana Island or in the middle region of the harbour between Ōmokoroa and Kauri Point. However, the water quality in these regions should be encapsulated by sampling sites downstream of this region such as Kauri Point.

Additionally, water quality data is collected for most major rivers and streams flowing into Tauranga Harbour. This data can provide important information on the likely water quality of sub catchments in the harbour which are not sampled as part of the estuarine water quality program. An analysis of this data is outside the scope of this report and will be addressed in a separate gaps analysis related to the implementation of the National Policy Statement for Freshwater Management in Tauranga Harbour. This analysis will include an investigation of whether the distribution of stream and river water quality monitoring sites is sufficient to allow the potential impacts of freshwater inflows to the harbour to be assessed. The revised estuarine water quality sampling program has now been running for over 12 months but has not yet been reviewed. This is a gap and a review needs to be undertaken to compare data collected before and after changes were made to the sampling program and to provide an up to date summary of water quality trends for the harbour.

Table 3.1 Estuarine sites sampled for water quality under the NERMN programme before and after changes were made to the sampling programme in mid-2015.

Site	Pre mid-2015 sampling	Post mid-2015 sampling
Kulim Ave, Otumoetai	Low tide, bi-monthly	-
Grace Street	Low tide, bi-monthly	-
Pilot Bay Wharf	High tide, bi-monthly	-
Maungatapu Bridge	High tide, bi-monthly	Mid ebb tide, monthly
Waipu Bay (Boat Ramp)	High tide, bi-monthly	-
Whareroa (Toll Bridge Marina)	High tide, bi-monthly	Mid ebb tide, monthly
Otumoetai, Beach Road	High tide, bi-monthly	-
Te Puna, Pitua Road	High tide, bi-monthly	-
Omokoroa, Wharf	High tide, bi-monthly	Mid ebb tide, monthly
Pahoia Beach Road	High tide, bi-monthly	-
Kauri Point Jetty	High tide, bi-monthly	Mid ebb tide, monthly
Ongare Point	Low tide, bi-monthly	-
Tanners Point Jetty	High tide, bi-monthly	Mid ebb tide, monthly
Bowentown Boat Ramp	High tide, bi-monthly	-
Mt Maunganui*	-	Mid ebb tide, monthly
Waikareao Estuary*	-	Mid ebb tide, monthly
Tilby Point**	-	Mid ebb tide, monthly

* Sampled fortnightly from 2013 – 2014 by Alex Port, University of Waikato.
** Sampled bi-monthly from 2013 – 2014 by Alex Port, University of Waikato.

Dissolved oxygen (near the surface), temperature and salinity are measured in the field and water samples are collected for laboratory analysis of turbidity, suspended solids, conductivity, salinity, pH, chlorophyll a, nitrate-nitrogen, ammonium-nitrogen, dissolved reactive phosphorus, total phosphorus, faecal coliforms, and the indicator bacteria E. coli and Enterococci (Table 3.2).

Table 3.2 NERMN estuary water quality monitoring regime.

Number of sites	• Eight currently monitored sites. • Nine historically monitored sites.
Sampling frequency	• Monthly.
Measured parameters	• Dissolved oxygen, temperature, pH, water clarity, conductivity, salinity, NH4-H, NOx-N, TN, DRP, TP, turbidity, suspended solids, *E.coli*, Faecal Coliforms, Enterococci, chlorophyll-a.
Length of data record	• 1990 to present for five sites. • 2015 to present for three sites. • 1990 to 2015 for nine sites.

Targeted nutrient water quality monitoring has also been undertaken to better understand nutrient dynamics in the harbour and more specifically the influence of El Nino weather patterns on these. Water sampling initially occurred fortnightly and then weekly on the mid outgoing and mid-incoming tide over the 2015/2016 summer period at the southern harbour entrance (Mt Maunganui site in the NERMN estuarine water quality monitoring program). This project has been continued this year and will run from the start of December 2016 to the end of February 2017. The data collected in this project will provide some baseline data to help understand the degree of oceanic nutrient upwelling that occurs under El Nino weather conditions, however we still have a very limited understanding of this topic and this is an information gap in our overall understanding and knowledge of nutrient dynamics and water quality in Tauranga Harbour. This issue is discussed in relation to sea lettuce in Part 5: Mangroves.

BOPRC are also sampling partners in the New Zealand Ocean Acidification Observing Network (NZOA-ON) project jointly run by NIWA and the University of Otago. Water samples are collected each fortnight from the Whareroa (Toll Bridge Marina) site for analysis of acidity parameters (alkalinity and total dissolved inorganic carbon) to develop a long-term data series. pH_T, pCO_2, carbonate ion concentration, and saturation states are also calculated. Sampling has been ongoing since February 2015.

In addition to the water quality monitoring undertaken as described above, BOPRC have also supported a number of student projects which have investigated nutrient dynamics to some extent in Tauranga Harbour. PhD student Alex Port (University of Waikato) investigated nutrient and *Ulva* (sea lettuce) dynamics in Tauranga Harbour[3]. As part of this work, two sites (main harbour entrance and Waikareao Estuary) were sampled fortnightly for two years (2013 – 2014) and a further six sites were sampled every two months for one year. Sampling was done at mid-tide on both the outgoing and incoming tide and the same water quality parameters outlined above were monitored. Both of the sites which were sampled fortnightly and one of the sites that was sampled bimonthly were added to the NERMN monitoring programme when it was revised in 2015 (Table 1).

Ben Stewart is currently investigating dissolved inorganic nitrogen (DIN) fluxes within Tauranga Harbour for his PhD (University of Waikato). The overall aim of this project is to determine the relative magnitude of sources of DIN within the harbour, the exchange of nutrients between harbour sub-regions and the exchange to the surrounding shelf. Ben has recently completed the first chapter of his thesis which investigated submarine groundwater discharge and the associated fluxes of nutrients into Tauranga Harbour. Key findings from this research are that the amount of submarine groundwater discharge into the harbour is around one to three times greater than the input from all the major rivers and creeks discharging into the harbour and when scaled up, the submarine groundwater discharge inputs for to the harbour are around five times greater for nitrogen inputs and around eight times greater for phosphorus inputs than the input from surrounding rivers and streams. This is the first investigation of groundwater discharges into the harbour and these preliminary findings highlight a number of significant gaps in our understanding of the influence on submarine groundwater discharge of nutrient dynamics in the harbour. Key gaps are an understanding of the location and stability of groundwater seeps in the harbour and an estimate of the age of the groundwater.

A key gap in our understanding of nutrient dynamics in the harbour is that all monitoring work is based on the collection of discrete samples. However, nutrient concentrations can be highly variable and this variability may not be reflected in the data collected under the current monitoring program. Continuous monitoring of physical water parameters and nutrients needs to be conducted to better define the range and variability of parameters. This data can then be fed into comprehensive harbour wide hydrodynamic models (see Part 3: Information gaps). A further gap is that we don’t have a clear understanding of the contribution of sediment nutrient recycling to nutrients loads in estuarine water. Nutrients recycled from the sediments may be a significant input to the nutrient budget of the harbour. However at present we do not know the relative importance of this source compared to other inputs such as rivers and streams and submarine groundwater discharge. Some information on sediment nutrient recycling is available in the peer reviewed literature (e.g. Tay et al 2013; Santos et al 2014), however to date, it has not been reviewed and compiled into a report assessing its relevance in Tauranga Harbour.

[3] Port, A. (2016). Measuring and modelling estuarine macroalgae blooms and water column nutrients. University of Waikato PhD thesis.

BOPRC does not conduct any monitoring of heavy metals, agrichemicals (e.g. herbicides, pesticides) or other contaminants in the water within the harbour itself. Some data on this has been collected for river and stream inflows. Some of these compounds are also monitored as part of wastewater, stormwater and industrial discharge contents (see Parts 3.3, 3.4 and 3.5), however, concentrations of compounds are typically monitored in the discharge itself rather than in the receiving environment. This gap is partially filled by some research undertaken by Julien Huteau as part of his PhD (University of Waikato)[4]. Julien determined the concentrations of aluminium (Al), phosphorus (P), arsenic (As), chromium (Cr), manganese (Mn), barium (Ba), cadmium (Cd), copper (Cu), nickel (Ni), lead (Pb) and uranium (U) in water collected from six locations within and outside Tauranga Harbour. Discrete water samples were collected at least eight times in spring/summer 2014 and DGT (diffusive gradients in thin film) samplers were also deployed over the same time. While this research has provided some data on heavy metal/trace element concentrations in receiving environments, sampling was only undertaken in the southern harbour and data is not available for the northern harbour.

BOPRC regularly monitors the concentration of heavy metals and periodically monitors the concentration of agrichemicals and other contaminants in estuary sediments (See Part 4.2). Contaminant loads in shellfish have also been monitored (See Part 4: Sedimentation). Data from these studies suggests that the likely levels of these compounds are low in estuarine water across the harbour, with the exception of a few “hotspots” of higher concentrations for specific compounds (e.g. mercury at the Matahui site). However, a comprehensive one-off survey of heavy metals, agrichemicals (e.g. herbicides, pesticides) and any other contaminants of concern in estuary water would provide baseline data which could be used to ground truth expected levels of these compounds based on sediment contaminant surveys. Due to the expected low loads of these contaminants passive sampling devices such as diffusive gradients in thin films (DGT) or polar organic chemical integrative samplers (POCIS) could be used as an alternative to analysing water samples.

Recreational water quality

Water quality surveys occur at popular bathing sites to identify the risk to public health from faecal contamination. Approximately 18 water quality sites are monitored weekly during the summer bathing season (March to October), although the exact number can vary from year to year (Table 3.3). When bacteria (enterococci) are detected above alert levels monitoring is increased to daily and further sampling in the catchment may also occur. Sampling has occurred annually since the 1989/1990 summer. Five of the sites sampled for bathing water quality are also regarded by communities as desirable shellfish gathering locations (Table 3.3). Accordingly, water samples from these sites are additionally analysed for faecal coliforms, which are suitable microbiological indicators for sanitary safety with regards to public shellfish consumption.

The current bathing water quality monitoring regime provides adequate coverage of popular marine and estuarine recreational sites and is sufficient to provide assessment in terms of the national protocols for bathing water quality. However, there are some issues and key gaps around the frequency of monitoring. There is a considerable risk that bacterial levels may increase and the water may become unsafe for swimming several days before a site is sampled again as part of the weekly monitoring program. A more accurate real time indication of bathing water quality is needed. The development of a microbial water quality model would enable real time predictions of bathing water quality to be made based on a hydrodynamic model of the harbour and up to date measurement of rain and river and stream flow into the harbour. This model could be linked to a public website, allowing a far more robust assessment of bathing risk for the public than the current protocol. Such an approach is currently being trialled by Greater Wellington Regional Council, with plans to make the tool publically accessible in the 2017/2018 summer.

[4] Huteau, J. (2017) The fate and effects of contaminants in estuarine environments. University of Waikato, PhD thesis.

Table 3.3 Recreational water quality monitoring regime.

Number of sites	• ~18 bathing water quality sites. • Five shellfish water quality sites.
Sampling frequency	• Weekly from October to March.
Measured parameters	• Enterococci, faecal coliforms.
Length of data record	• 1989 to present.

Stormwater discharge

Stormwater discharges to the harbour are managed under comprehensive consents issued to Tauranga City Council (consent numbers 66823, 63636 and 65714) and Western Bay of Plenty District Council (consent numbers 61768, 65065 and 61181).

A condition of the consents issued to Tauranga City Council is that stormwater discharges to freshwater and marine receiving environments must be monitored and results of this monitoring are reported annually. The quality of stormwater discharged as baseline flow and during/following a less than 1 in 10 year rainfall event is self-monitored by Tauranga City Council at 42 locations across Tauranga City, four locations across Pāpāmoa and five locations across Maranui/Mangatawa Catchments. Baseline sampling is undertaken quarterly following at least three days of no rain and storm sampling is undertaken annually between February and April inclusive, within 24 hours following a rainfall event that is greater than 10 mm. Temperature, dissolved oxygen, pH, conductivity and salinity are measured in the field, and a range of parameters are analysed in collected samples in the laboratory (Table 3.4). Monitoring of the marine receiving environment takes place every two to five years for 15 priority and 34 non-priority sites respectively. Weather conditions, site habitat values, macroinvertebrate fauna, sediment contaminants, sediment grain size and physico-chemical parameters are sampled for this monitoring. BOPRC does not conduct any specific monitoring of stormwater discharges in addition to that conducted by Tauranga City Council.

The three Western Bay of Plenty District Council consents comprise the urbanised parts of the district within the Tauranga Harbour Catchment. These are consent number 61768 (Ōmokoroa Peninsula), 61181 (Katikati – Waihī Beach including communities at Tanners Point, Tuapiro Point, Kauri Point and Ongare Point) and 65065 (Central catchments including Te Puna and Minden). Note that at time of writing, applications for consents 65065 and 61181 were still in process so conditions were not finalised however it is likely that the consents when granted will include a comprehensive programme of monitoring for key contaminants for urbanised stormwater catchments and trigger levels and specified responses for marine receiving waters where relevant.

Table 3.4 Parameters monitored in stormwater discharges at Tauranga City, Pāpāmoa, Maranui/Mangatawa and in freshwater and marine receiving environments by Tauranga City Council.

Parameter	Tauranga City	Papamoa	Maranui/ Mangatawa	Receiving environments
pH	√	√	√[1]	√
Total suspended solids	√	√	√	√
Total petroleum hydrocarbons	√		√	√
Chemical oxygen demand	√			√
Total nitrogen		√		
Total ammonia	√	√		√
Nitrate	√	√	√	√

Parameter	Tauranga City	Papamoa	Maranui/ Mangatawa	Receiving environments
Total phosphorus		√		
Dissolved reactive phosphorus		√		
Arsenic	√			√
Copper	√	√	√	√
Lead	√	√	√	√
Zinc	√	√	√	√
Nickel	√		√	√
Mercury	√			√
Cadmium	√			√
Chromium	√		√	√
E. coli	√	√		
Naphthalene				√
Aqueous hardness		√		
Chlorophyll A		√		

[1] Total ammonia is measured at pH 8.

Wastewater discharge

Similar to stormwater discharges, wastewater discharges to the harbour from wastewater treatment plants are managed under consents issued to Tauranga City Council and Western Bay of Plenty District Council which require the consent holders to monitor the outfalls and receiving environments. Tauranga City has two wastewater treatment plants, one at Chapel Street and the other at Te Maunga. Treated wastewater from both plants is discharged into the Te Maunga wetlands and then pumped out to sea 950 m off the coast of Ōmanu (consent number 62878). A range of parameters, including nutrients, metals and bacterial contaminants are monitored at varying frequencies in the effluent discharged to the ocean (Table 3.5). Ocean monitoring of the receiving environment is also performed at nine sampling points located approximately 400 m offshore and at 500 m intervals along the coast on 2 km either side of the sewage outfall. Five water samples are collected at each sampling point per month during December, January, February and March, to give a total of 20 samples per sampling location per year. All monitoring is conducted by Tauranga City Council.

There is also a wastewater treatment plant in Katikati, with the outfall discharging to on the eastern (seaward) side of Matakana Island (consent number 24895). A range of parameters including nutrients, metals and bacterial contaminants are monitored at varying frequencies in the effluent discharged to the ocean (Table 3.5). In addition, water samples are monitored quarterly for enterococci and faecal coliform bacteria at four sites near the marine outfall (two sites up-current and three sites at intervals down-current of the outfall). All monitoring is conducted by Western Bay of Plenty District Council.

Table 3.5 Parameters monitored in tertiary treated wastewater effluent discharged to the ocean by Western Bay of Plenty District Council (WBOPDC) and Tauranga City Council (TCC).

Parameter	Statistic	Monitoring frequency	
		WBOPDC	TCC
Five-day carbonaceous biochemical oxygen demand	Mass daily discharge, concentration	At least 1 day per week	Twice weekly
Suspended solids	Mass daily discharge, concentration	At least 1 day per week	Twice weekly
pH	pH	-	Monthly
Conductivity	mS/m	-	Monthly
Total nitrogen	Mass daily discharge, concentration	At least 1 day per week	-
Ammonia nitrogen	Concentration	-	Monthly
Nitrate nitrogen	Concentration	At least 1 day per month	Monthly
Nitrite nitrogen	Concentration	At least 1 day per month	-
Kjeldahl nitrogen	Concentration	At least 1 day per month	Monthly
Total phosphorus	Concentration	-	Monthly
Dissolved reactive phosphorus	Concentration	-	Monthly
Faecal coliform bacteria	Concentration	Monthly monitoring of 4 samples of the effluent taken no less than 6 days apart within a month	-
Enterococci	Concentration	Monthly monitoring of 4 samples of the effluent taken no less than 6 days apart within a month	Twice weekly
E. coli	Concentration	-	Twice weekly
Arsenic	Concentration	Quarterly	Quarterly
Cadmium	Concentration	Quarterly	Quarterly
Chromium	Concentration	Quarterly	Quarterly
Copper	Concentration	Quarterly	Quarterly
Lead	Concentration	Quarterly	Quarterly
Mercury	Concentration	Quarterly	Quarterly
Nickel	Concentration	Quarterly	Quarterly
Zinc	Concentration	Quarterly	Quarterly
VOC	Concentration	-	Annually
SVOCC	Concentration	-	Annually

Wastewater is treated through on-site treatment systems (e.g. septic tanks and on site ground disposal) in all other areas of the Tauranga Harbour WMA that do not have access to sewage reticulation. These systems generally function effectively with little environmental impact. However, in some cases they can contribute to nutrient enrichment of the waterways and harbour through surface water contamination and seepages and impacts on groundwater. As part of the on-site effluent monitoring programme, BOPRC monitors stormwater discharges, seepages and groundwater for contamination in Tanners Point, Ongare Point and Te Puna. Monitoring began in 1996 and is conducted every three months. Six sites are monitored at Tanners Point, six sites are monitored at Ongare Point and 10 sites are monitored at Te Puna. Water samples are analysed for faecal coliforms, *E. coli*, enterocci, total oxidised nitrogen, total Kjeldahl nitrogen, ammonium nitrogen, total phosphorus, dissolved reactive phosphorus, pH, temperature, conductivity and suspended solids. Six sites have also been monitored at Ōmokoroa as part of this programme. Dwellings in Ōmokoroa originally had on-site treatment systems; however, since mid-2007 sewage has been reticulated to the Tauranga City Council wastewater treatment plant. Targeted monitoring of drains and seepages on the Ōmokoroa foreshore has been carried out since reticulation to determine whether contamination of waterways has reduced.

The monitoring data collected as part of the on-site effluent monitoring programme allows assessment of whether on-site wastewater treatment systems are functioning effectively, with little environmental impact. However, the Tauranga region has rapidly developed in recent times with a concomitant increase in population size. Consequently, there may be some communities with on-site treatment systems situated close to the harbour which have recently increased in size that are not included in this monitoring programme, despite their potential to impact on surrounding waterways and the harbour. An assessment of the number of dwellings with on-site treatment systems in communities bordering the harbour is required to determine whether any additional communities need to be monitored as part of the on-site effluent monitoring programme.

Industrial discharges

The other major discharges to Tauranga Harbour occur from industrial sites in the vicinity of the Port of Tauranga. BOPRC monitors the impacts of these discharges to the harbour through monthly monitoring of a site (Whareroa) within the port area as part of the NERMN estuarine water quality monitoring programme. This site gets monitored for a range of parameters as described above (see Part 3: Estuarine water quality). As with stormwater and wastewater discharge, all individual industrial discharges to the harbour are managed through consents which include a requirement for the consent holder to self-monitor the discharge effluent. Activities around the port comprise a variety of industries, one of the biggest being fertiliser production from Ballance Agri-Nutrients Limited. Under consent number 60987, seawater is taken from the harbour and used in the fertiliser plant and then cooling water, industrial wastewater and anti-fouling agent are discharged to the harbour. A weekly composite wastewater discharge sample and a weekly grab wastewater discharge sample are analysed for pH, suspended solids, dissolved reactive phosphorus, ammoniacal nitrogen and fluoride. Additionally, in January and July of each year a weekly composite wastewater discharge sample is analysed for arsenic, cadmium, chromium VI, copper, mercury, uranium, vanadium, and zinc. Every four years Ballance Agri-Nutrients is also required to undertake a sediment quality sampling program at four sub-tidal stations and six inter-tidal stations within Waipu Bay. Sediment samples are analysed for total fluoride, total phosphorus, cadmium, and zinc. As the processing of fertilisers at this site introduces a risk of nutrient and heavy metal contamination to the harbour in discharged industrial site treated stormwater, Ballance Agri-Nutrients Limited is required to self-monitor the treated industrial site stormwater during at least six storm events annually (consent number 61063). Discharged stormwater is analysed for pH, suspended solids, dissolved reactive phosphorus, ammonia nitrogen and fluoride.

A key knowledge gap around discharges to the harbour is an understanding of the distribution, magnitude and combined effects of discharges managed under multiple consents and their potential cumulative effects on the estuarine environment. Aside from the on-site effluent treatment monitoring conducted by BOPRC as described above, all other discharges to the harbour are self-monitored by consent holders and, in general, the monitoring data remains associated with the individual consent file. Impacts on the environment from discharges are assessed on a case by case basis for each consent and the combined or cumulative impacts of these discharges are difficult to consider without detail of all the other smaller inputs and changes to water quality in the harbour. However, the combined and cumulative effects of multiple discharges on the harbour receiving environment may be considerable. Associated with this is the infrequent collation and reporting of monitoring data provided by consent holders by BOPRC - the last report on the impacts of effluent discharges on receiving water was published in 2008.

Summary of data availability

A summary of the monitoring data available for water quality described in this chapter is provided in Table 3.6. The spatial distribution of this data across Tauranga Harbour is illustrated in Figures 3.1 and 3.2. It is evident from these maps that there is a lack of water quality data available for the harbour in the region spanning from Ōmokoroa to Kauri Point. While sampling at sites downstream of this region (e.g. Tanners Point, Bowentown Heads) will provide some information of likely water quality in this region, it is a gap in our understanding of water quality for the harbour. The addition of an extra sampling site at Matahui Point or somewhere similar as part of the NERMN estuary water quality monitoring programme would address this gap.

Table 3.6 Summary of monitoring data available for water quality described in this chapter. Parameters measured are categorised as physical, chemical, biological, and other toxicant. Specific detail of parameters measured is provided in the main body of the report. For datasets where the start date varies between monitoring sites, the earliest start date that data is available for across all sites is given. BOPRC – Bay of Plenty Regional Council; UoW – University of Waikato; TCC – Tauranga City Council; WBOPDC – Western Bay of Plenty District Council. Note that other sources of data on water quality which are not included in this table may have been outlined in the main body of this chapter.

Parameters measured				Source	Data start time	Data end time
Phys.	Chem.	Biol.	Other			
√	√	√		BOPRC, NERMN estuary water quality monitoring	1990	Present*
		√		BOPRC, NERMN recreational water quality monitoring	1989	Present*
√		√		BOPRC, El Nino water quality monitoring	2015	Present*
√	√			Alex Port UoW, PhD thesis	2013	2014
			√	Julien Huteau UoW, PhD thesis	2014	2014
√	√	√	√	TCC, stormwater discharge consent monitoring	Unknown	Present*
√	√	√	√	TCC, wastewater discharge consent monitoring	Unknown	Present*
√	√	√	√	WBOPDC, wastewater discharge consent monitoring	Unknown	Present*
√	√	√		BOPRC, On site effluent monitoring program	1997	Present*
√	√	√	√	Balance Agri-Nutrient Ltd, industrial discharge consent monitoring	Unknown	Present*

* Program is ongoing; data will continue to be collected.

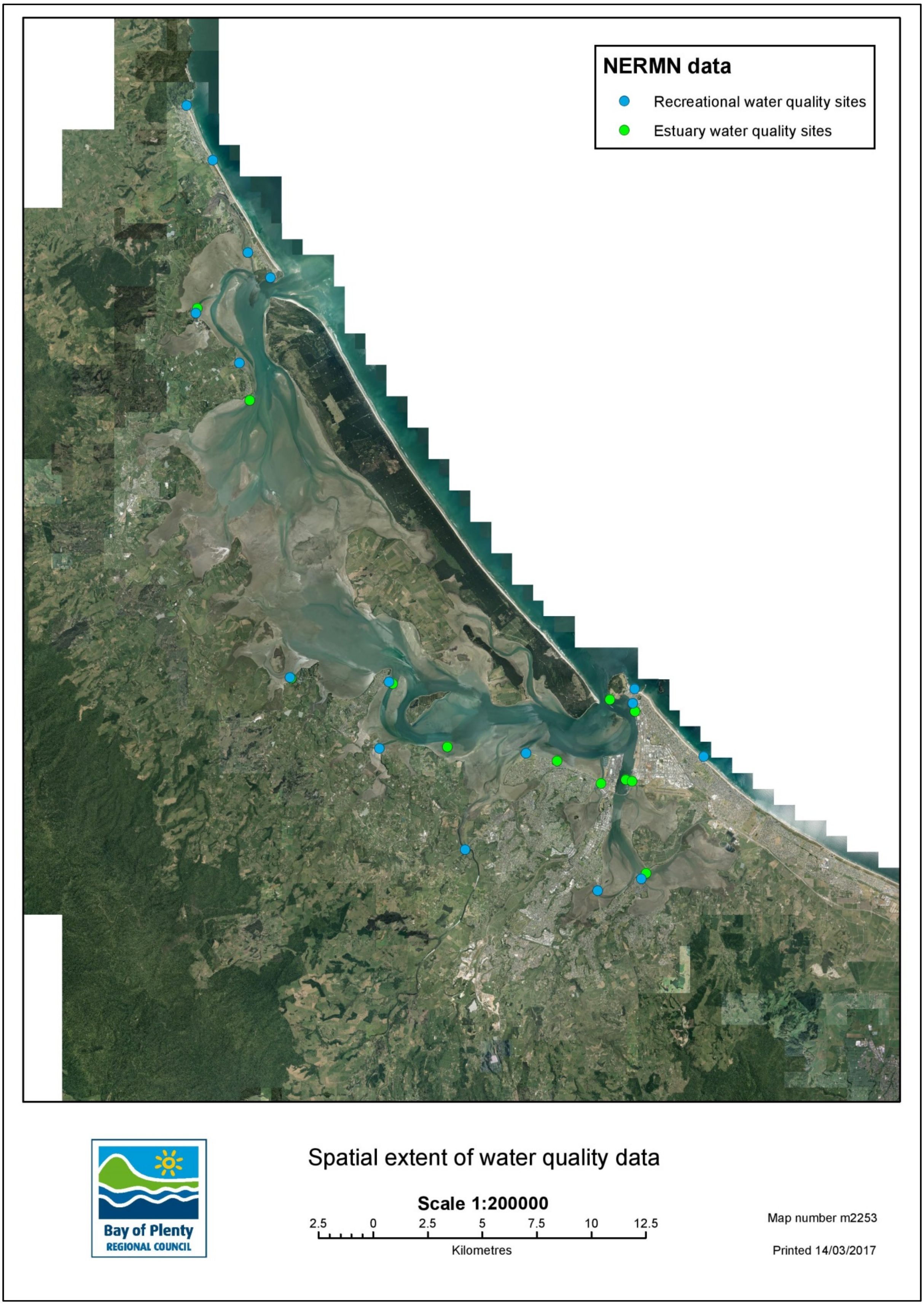

Figure 3.1 *Spatial distribution of water quality data for Tauranga Harbour collected as part of the NERMN programme. See Table 3.6 for further information about data sources. Note that only current monitoring sites are displayed.*

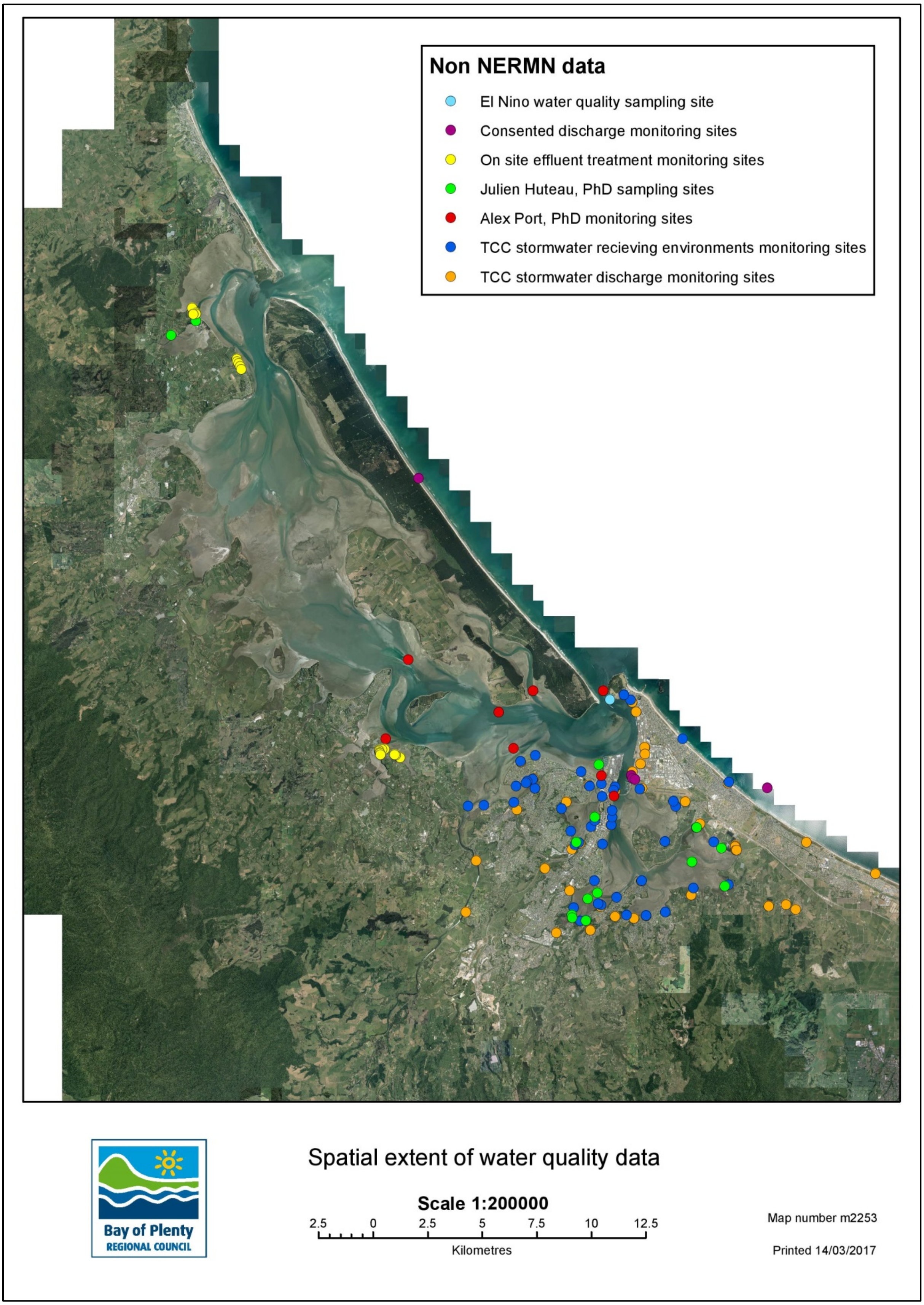

Figure 3.2 *Spatial distribution of water quality data for Tauranga Harbour collected outside of the NERMN programme. See Table 3.6 for further information about data sources.*

Relevant reports

Table 3.7 Reference details for the most recent and/or most relevant key reports for each subject covered in this chapter. Only the most recent report is included for regular monitoring programs where sampling sites and parameters monitored remain the same in each consecutive report. Note that other reports are available for this topic which are not included in this table.

Subject	Report
Estuarine water quality	• Scholes, P. (2015) NERMN Estuary Water Quality Report 2014. Bay of Plenty Regional Council Environment Publication 2015/01.
Bathing water quality	• Scholes, P and McKelvey, T. (2015) Recreational Waters Surveillance Report 2014/2015. Bay of Plenty Regional Council Environment Publication 2015/06.
Stormwater discharge	• Tauranga City Council (2016) Tauranga City, Pāpāmoa & Maranui/Mangatawa Comprehensive Stormwater Catchment Consents (No. 66823, 63636 & 65714). Annual Monitoring Report – 2015.
Wastewater discharge	• Scholes, P. (2011) Monitoring impacts of on-site wastewater treatment systems – Bay of Plenty. Bay of Plenty Regional Council Environment Publication 2011/05. • Scholes, P. (2008) Effluent discharge receiving water impact report 2008. Bay of Plenty Regional Council Environment Publication 2008/10.
Industrial discharge	• No specific reports available for this topic. Data is presented in reports associated with individual resource consents.

Information gaps

The following table identifies gaps in our current scientific knowledge of water quality for the Tauranga Harbour and explains why knowledge of these gaps is important. A reference number (Ref. No.) for each gap is provided to allow easy cross referencing with the research recommendations provided for each gap in Part 8 (Table 8.2). This is an un-prioritised list of all identified gaps, large or small. Further assessment of need, urgency, and resourcing required will be carried out to determine which gaps will be filled, when and how.

A key gap not identified in the main body of this chapter is an integrated assessment of the different types of estuarine water quality data described above. Each type of data is currently assessed in separate reports, with few linkages made between each type of data. Additionally, little context is given for the data presented. For example in the NERMN Estuary Water Quality Report the ANZECC water quality guidelines are used to provide a clearer picture as to the relevance of concentrations of a given parameter (Scholes 2015). However, this report notes that these values may not represent a reliable or realistic measure for Bay of Plenty waters and recommends that water quality managers develop their own indicators better suited to their respective regions. A framework or set of guidelines relevant to Bay of Plenty waters needs to be applied or developed to provide some context to the data available and an overall assessment of the state of water quality in Tauranga Harbour needs to be undertaken. The recently developed NZ Estuary Trophic Index[5] may be one such appropriate approach. Ideally, water quality data could be combined with estuarine plant, animal and macroalgal abundance and distribution data, and cover of seagrass meadows, mangroves and saltmarsh to provide an overall rating of estuarine health. Depending on the spatial availability of data, ratings of estuarine health could be provided at the sub-estuary level as well as for the entire harbour.

[5] Robertson, B.M., Stevens, L., Robertson, B., Green, M., Madarasz.Smith, A., Plew, D., Storey, R., Oliver, M. (2016) NZ Estuary Trophic Index Screening Tool 2. Determining Monitoring Indicators and Assessing Estuary Trophic State. Prepared for Envirolink Tools Project: Estuarine Trophic Index, MBIE/NIWA Contract No: CO1X1420.

A second overall gap is the lack of a comprehensive hydrodynamic model for the entire harbour which incorporates nutrient, sediment and potentially contaminant input to the harbour. Importantly, the contributions of various sources of nutrients, such as coastal upwelling, streams and rivers, submarine groundwater and sediment nutrient recycling, to the entire nutrient budget of the harbour are hard to estimate at present. Development of a model would provide valuable information on this which could be used to assess for example the potential effects of discharges to the harbour and provide context to diffuse nutrient and contaminant loading in streams and rivers. Additionally, a model would allow scenario testing to predict and describe likely consequences of different management options that could be applied in the catchment, such as limits for particular variables such as nitrogen or sediment loads set under the NPS-FM. Scenario testing would also allow the cumulative effects of multiple stressors on the harbour to be considered at multiple spatial and temporal scales. Linked to the development of a harbour-wide model is the need for a continuous monitoring logger or buoy to be deployed in the harbour which records physical water quality data and nutrient concentrations and several smaller loggers of different parameters to be deployed across the harbour to better define what the range and variability of parameters are.

Table 3.8 Information gaps for water quality.

Ref no.	Topic	Gap	Relevance
1	Estuarine water quality	The revised estuarine water quality sampling program has now been running for over 12 months but has not yet been reviewed.	A review of the new sampling program needs to be undertaken to compare data collected before and after changes were made to the sampling program to check that it is providing adequate coverage and informative data and to provide an up to date summary of water quality trends for the harbour as the last report of estuarine water quality only covered data collected up to 2013.
2	Estuarine water quality	We have a limited understanding of the influence of El Nino weather patterns on nutrient dynamics in Tauranga Harbour.	El Nino weather patterns are thought to increase nutrient concentrations in the harbour as a result of upwelling of nutrient rich deep oceanic water that typically occurs in El Nino years. These increased nutrient concentrations are thought to be a key driver of sea lettuce blooms in the harbour (see Part 4: Habitat degradation).
3	Estuarine water quality	We have a limited understanding of the influence of submarine groundwater discharge of nutrient dynamics in the harbour. Key gaps are an understanding of the location and stability of groundwater seeps in the harbour and an estimate of the age of the groundwater entering the harbour.	Preliminary investigations have shown that submarine groundwater discharge results in significant input of nutrients to the harbour (approximately 5 – 8 times the nutrient input of freshwater streams and rivers). A greater understanding of this input is vital to enable an overall understanding of nutrient dynamics in the harbour.
4	Estuarine water quality	We don't have a clear understanding of the contribution of sediment nutrient recycling to nutrients loads in estuarine water.	Nutrients recycled from the sediments may be a significant input to the nutrient budget of the harbour. However at present we do not know the relative importance of this source compared to other inputs such as rivers and streams and submarine groundwater discharge.
5	Estuarine water quality	BOPRC does not conduct any monitoring of heavy metals, agrichemicals (e.g. herbicides, pesticides) or other contaminants in the water and only limited data on this is available from self-monitoring conducted by consent holders and Julien Huteau's PhD research project.	The concentrations of compounds are typically self-monitored by consent holders in the discharge itself rather than in the receiving environment and Julien Huteau's PhD data only covers locations in the southern harbour. Sediment contaminant monitoring suggests that concentrations of these compounds in estuarine water are likely to be low, however we only have limited data available to confirm this prediction. A comprehensive one-off survey of heavy metals, agrichemicals (e.g. herbicides, pesticides) and any other contaminants of concern in estuary water would provide baseline data which could be used to ground truth expected levels of these compounds based on sediment contaminant surveys.

Ref no.	Topic	Gap	Relevance
6	Bathing water quality	Bathing water quality is currently only sampled weekly. A more accurate real time indication of bathing water quality, such as a microbial water quality model, is needed.	There is a considerable risk that bacterial levels may increase and the water may become unsafe for swimming several days before a site is sampled again as part of the weekly monitoring program. The development of a microbial water quality model would enable real time predictions of bathing water quality to be made based on hydrodynamic model of the harbour and up to date measurement of rain and river and stream flow into the harbour. This model could be linked to a public website, allowing a far more robust assessment of bathing risk for the public than the current protocol.
7	Wastewater discharge	The on-site effluent monitoring programme was established in 1996 and the communities monitored as part of this programme have not been updated since this time. An assessment of the number of dwellings with on-site treatment systems in communities bordering the harbour is required to determine whether any additional communities need to be monitored.	On-site effluent treatment systems with poor treatment and disposal can have adverse environmental impacts, however without monitoring these impacts would go unnoticed and therefore unmitigated. The Tauranga region has rapidly developed over recent times with a concomitant increase in population size. Consequently, there may now be some communities or areas of more concentrated dwellings bordering the harbour which are not monitored as part of the on-site effluent monitoring programme but should be.
8	Stormwater, wastewater and industrial discharge	Limited understanding of the distribution, magnitude and combined effects of discharges managed under multiple consents and their potential cumulative effects on the estuarine environment. Monitoring data collected by consent holders is collated and reported infrequently by BOPRC. The last report on the impacts of effluent discharges on receiving water was published in 2008.	Because all of the data on discharges into the harbour are associated with individual consent holder files it is difficult to get an overall understanding of the combined impacts and effects of these discharges on estuarine water quality. While each individual discharge may be have little or no obvious impact on the receiving environment, the combined and cumulative effects of multiple discharges may be considerable.
9	Estuarine water quality	There is a lack of water quality data available for the harbour in the region spanning from Ōmokoroa to Kauri Point.	This region accounts for a significant portion of the harbour where we do not have a good understanding of the current state of water quality and trends in water quality over time.

Ref no.	Topic	Gap	Relevance
10	Estuarine water quality	There is no overall assessment of estuarine water quality data, each type of data is currently assessed in separate reports and, with the exception of recreational water quality, all other water quality data has not been assessed against a relevant framework/set of guidelines to provide some context to the results. There is no overall rating for estuarine health (e.g. integrated assessment of estuarine water quality data, plant, animal and macroalgal abundance and seagrass, mangrove and saltmarsh cover).	An integrated assessment is necessary to enable conclusions to be drawn about the overall health of the harbour. This cannot be done if data is continued to be analysed in separate reports with few linkages made between reports for each individual topic.
11	Estuarine water quality	There is no comprehensive hydrodynamic model for the entire harbour which incorporates nutrient, sediment and potentially contaminant input to the harbour.	The contributions of various sources of nutrients, such as coastal upwelling, streams and rivers, submarine groundwater and sediment nutrient recycling, to the entire nutrient budget of the harbour are hard to estimate at present. Development of a model would provide valuable information on this which could be used to assess for example the potential effects of discharges to the harbour and provide context to diffuse nutrient and contaminant loading in streams and rivers. Additionally, a model would allow scenario testing to predict and describe likely consequences of different management options that could be applied in the catchment. Scenario testing would also allow the cumulative effects of multiple stressors on the harbour to be considered at multiple spatial and temporal scales.
12	Estuarine water quality	There is not a continuous monitoring logger or buoy in the harbour which records physical water quality data and nutrient concentrations.	A continuous monitoring logger or buoy that records physical water quality data and nutrient concentrations and several smaller loggers of different parameters deployed across the harbour would enable the range and variability of parameters to be better defined. This information is vital to enable to development of an accurate and useful harbour-wide hydrodynamic model as described above.

Part 4:

Sediment dynamics

Introduction

Sedimentation and the impacts of increased sediment loads on estuarine communities is one of the biggest threats to Tauranga Harbour. This section provides an overview of the monitoring work undertaken in Tauranga Harbour and the scientific data available to BOPRC related to sediment dynamics. This includes sedimentation, sediment nutrient recycling and contaminants. Gaps in our knowledge and understanding of sediment dynamics are identified and discussed. Considerable research on this topic has been undertaken both globally and by Conrad Pilditch and colleagues at the University of Waikato and many studies on this topic are available in the academic literature.

Sedimentation

Sediment accumulation rates in the harbour are monitored using buried sediment plates. 59 sediment plates were installed at 18 locations around the harbour in December 2013 - January 2014 (Table 4.1). Plates in the Tuapiro, Waimapu and Waikareao estuaries are monitored quarterly (14 plates); all other plates are monitored annually. Due to the dynamic nature of sediment deposition and the relatively small changes in sediment depth that are recorded using the plates (mm per year) it can take at least five years after installation for sedimentation trends and patterns to become evident. Therefore, in the short-term, data from these plates will not be very informative. However, after the initial establishment period has passed the sediment plates will provide an accurate assessment of longer term sedimentation rates for each site (plate) in the harbour. At this time the location and distribution of sites across the harbour can also be assessed to determine whether there are any gaps.

Sedimentation in the harbour has also been investigated using sediment accumulation transects (profiles). Transects were surveyed at 25 sites across the harbour in 2003 to provide baseline data (Table 4.1). Two transects in Waikareao estuary were resurveyed in 2007 and a subset of transects were resurveyed in 2010. It has now been a minimum of 10 years since any transects were surveyed. Therefore it is time for all transects to be resurveyed and for data to be analysed. Until this happens it will not be possible to calculate sedimentation rates along these transects and this is an information gap. Resurveying sediment transects across the harbour will provide detailed data on sedimentation rates at each transect across the shore at a range of depths, not just in a single discrete point as per sedimentation rates calculated from sediment plate data. However the accuracy of the methodology (plus or minus 1 - 2 centimetres) means that changes in bed height will only be reliably detected after lengthy periods of time (5 - 10 years) where sedimentation rates are relatively low (1 – 3 mm per year).

BOPRC also conducts continuous monitoring of water flow and turbidity in the Waimapu stream, Kopurererua Stream and Tuapiro Stream which provides data on the potential for sedimentation by looking at sediment loads in streams. An analysis of this data has recently been completed (Carter, 2017).

Information about the impacts of sedimentation on the quality of the sediments can be provided by looking at sediment grain size and the percentage composition of gravel, sand and mud (silt and clay) in sediments. A comparison of sediment composition at a site through time can provide an indication of whether the sediments are getting muddier, sandier or remaining the same and can help identify areas where fine sediment is settling. Sediment grain size has been sampled in a number of studies since 1991. Sediment grain size was measured at 73 sites around the harbour between January and May 1991 (McIntosh 1994, Park & Donald 1994), and 373 sites between 2001 and 2003 (Park 2003). Since 2003, sediment grain size has been monitored at 31 sites at three-yearly intervals as part of a regular monitoring programme investigating sediment contaminants (see below). These 31 sites correspond with sites previously sampled in 2003 (Park 2003). Sediment grain size is also monitored at sites sampled as part of the Coastal and Estuarine Ecology programme, which monitors benthic macrofauna. Annual monitoring occurs at seven sites for this programme, but historically 21 sites have been monitored in

Tauranga Harbour over various periods of time (see Table 5.3 for more detail). Sediment grain size has also been sampled at 75 sites across the harbour as part of a one-off broad scale ecological survey for the Manaaki Taha Moana project (Ellis et al 2013). In each study, sediment samples were analysed for grain size, providing information on the percentage composition of gravel, sand and mud (silt and clay) in sediments at each site. In combination, these studies provide adequate monitoring of sediment grain size through time and across the harbour.

Table 4.1 Sediment monitoring regime. SC programme - Sediment Contaminant monitoring programme; CEE programme – Coastal and Estuarine Ecology programme.

Number of sites	• Sediment plates: 59 sites within 18 locations. • SC programme: 31 sites. CEE programme: 7 sites.
Sampling frequency	• Sediment plates: quarterly for 14 plates, annually for all others. • SC programme: every three years. • CEE programme: annually.
Measured parameters	• Sediment plates: sediment accumulation rate, sediment grain size. • SC programme: sediment grain size. • CEE programme: sediment grain size.
Length of data record	• Sediment plates: summer 2013/2014 to present. • SC programme: 1990 to present. • CEE programme: variable depending on site. Sites first monitored in 1990. See Table 5.3 for more detail.

In addition to this regular monitoring, there have been a number of discrete studies on sedimentation in the Harbour. In 2007, BOPRC contracted NIWA to investigate sedimentation patterns in a study called the Tauranga Harbour Sediment Study, although coverage was only for the southern half of the harbour. The objectives of this study were to 1) assess the relative contributions of catchment sediment sources surrounding Tauranga Harbour, 2) assess the characteristics of significant sediment sources from the catchment and 3) investigate the fate (dispersal and deposition) of catchment sediments throughout Tauranga Harbour. These objectives were achieved through the development of models which were then used to make predictions about sedimentation in the harbour based on different catchment development scenarios. The time frame for predictions was from 2001 to 2050. As part of this project sediment grain size and composition data were extracted from previous studies and collated to provide information on these parameters for 26 sub-estuaries in the southern harbour (Hancock et al 2009) and sediment accumulation rates were measured in 10 sub-estuaries using radioisotopic dating of sediment cores (Hancock et al 2009). The Tauranga Harbour Sediment Study project provided a comprehensive assessment of sedimentation in the southern harbour south of Matahui Point. There is no comparable assessment of sedimentation for the northern harbour regions. However, this information gap should be addressed through Peter de Ruiter's PhD project (see below).

PhD student Peter de Ruiter (University of Waikato) is supported by BOPRC and is currently investigating hydrodynamic controls on sedimentation within Tauranga Harbour, with the overall objective of determining the critical processes controlling the movement and deposition of sediment within the harbour. Peter is still in the early stages of his PhD, however planned outputs of the project are a calibrated coupled hydrodynamic and morphological model of sedimentation for the entire harbour; calculations of sediment flux between different regions of the harbour under different conditions; and identification of sources, sinks and storage pools of sediment with particular emphasis on the relatively less studied northern basin of the harbour.

A key information gap is that we don't have any estimates of historical (pre-human) sedimentation rates in the various estuaries around the harbour. We do not know how rates have varied over the past 100 years for example compared to present times. This data could be provided using sediment cores. While it may be difficult to do this in every estuary across the harbour, it should at least be done for the three estuaries that are being continuously monitored for sediment inflows (Waimapu, Waikareao and Tuapiro). A further gap that was evident during the compilation of this section is that the data on sedimentation is spread amongst a number of different sources and there is no single report that summarises all available data in a concise format. This can make it difficult to identify trends and patterns and make linkages between different types of data (e.g. sediment grain size, suspended sediment loads, sediment accumulation rates) to provide an overall understanding of sedimentation processes occurring around the harbour.

Contaminants

The level of contaminants in the harbour can be assessed by measuring concentrations of contaminants in sediments. Sediment contaminants are regularly monitored by BOPRC through two separate programmes (Table 4.2). 31 sites are sampled in Tauranga Harbour as part of a three-yearly NERMN sediment contaminant programme started in 2003. Samples are analysed for sediment grain size, total organic carbon (TOC), total polycyclic aromatic hydrocarbons, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Sediment contaminant data is also collected during summer as part of the coastal and estuarine ecological programme. Samples are analysed for TOC, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Annual monitoring occurs at seven sites for this programme, but historically 21 sites have been monitored in Tauranga Harbour over various periods of time (see Table 5.3 for more detail).

In addition to this regular monitoring, targeted one-off sampling for different types of sediment contamination has occurred. An extensive sediment survey covering the whole of Tauranga Harbour was undertaken from 2001-2003 to provide information on sediment particle size (392 sites), nutrients and TOC (135 sites), metals (32 sites), total petroleum hydrocarbons (29 sites), pesticides (18 sites), polycyclic aromatic hydrocarbons (PAH's) (19 sites) and polychlorinated biphenyls (PCB's) (eight sites) (Park 2003). The sampling of sites was weighted towards the sheltered sub-estuaries around the harbour, particularly for the contaminant sampling which targeted settlement areas.

A one-off survey of sediment contaminants in freshwater and marine sites associated with stormwater outfalls and industrial areas around Tauranga City was conducted in 2008 (Park 2009). Six freshwater sites and 10 marine sites were surveyed and samples were analysed for TOC, total PAH's, total polychlorinated biphenyls (PCBs), arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.

In 2011/2012, a survey of organic compounds focusing on herbicide and pesticide contaminants in sheltered sub-estuaries of Tauranga Harbour was undertaken (Park 2012). Nine sites were surveyed for around 300 organic compounds including pesticides, herbicides, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, phenols, plasticisers, haloethers and various other halogenated, semi-volatile and nitrogen containing organic compounds. This study also linked into a broadscale ecological survey conducted as part of the Manaaki Taha Moana project, which included sampling of sediment contaminants at 75 sites across the harbour (Ellis et al 2013). Samples were analysed for ash-free dry weight (AFDW, a measure that provides similar information to TOC), total nitrogen, total phosphorus, lead, zinc, copper and chlorophyll-α.

Table 4.2 Sediment contaminant monitoring regime. SC programme - Sediment Contaminant monitoring programme; CEE programme – Coastal and Estuarine Ecology programme.

Number of sites	• SC programme: 31 sites. • CEE programme: 7 sites.
Sampling frequency	• SC programme: every three years. • CEE programme: annually.
Measured parameters	• SC programme: total organic carbon (TOC), total polycyclic aromatic hydrocarbons, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. • CEE programme: TOC, arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc.
Length of data record	• SC programme: 2003 to present. • CEE programme: variable depending on site. Sites first monitored in 1990. See Table 5.3 for more detail.

Sediment contaminant sampling around Tauranga Harbour has also been undertaken as part of student research projects supported by BOPRC. Sediment sampling was undertaken at 30 sites in Rangataua Bay in 2014 by MSc student Vanessa Taikato (University of Waikato)[6]. Sediment samples were analysed for organic matter (AFDW), arsenic, copper, lead, mercury, zinc, total nitrogen, total phosphorus, and chlorophyll-α. PhD student Julien Huteau (University of Waikato) surveyed trace metal concentrations in sediments at three sites within each of Waimapu, Rangataua, Waikareao and Tuapiro estuaries in 2013. Samples were analysed for a range of heavy metals (K, B, Al, V, Cr, Fe, Cd, Ni, Cu, Zn, As, U and Pb).

The bioavailable concentrations of contaminants in the water column can be estimated by measuring the concentration of these compounds in filter feeding shellfish such as mussels and oysters while sediment feeding animals including shellfish can indicate what is available in the sediments. Shellfish monitoring for contaminants has been undertaken in several studies in Tauranga Harbour. Organic pollutants were analysed in wild oysters collected from four locations around Tauranga Harbour in 1990 (Trower and Holland 1991). Samples were collected from Waihī (four individuals), northern harbour (six samples), southern harbour (five samples) and the port (five samples) and analysed for polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), chlordanes, total DDT, dieldrin and chlorophenols. A range of wild shellfish including pipi, mussel, scallops, tuatua, cockle, oyster and mactra were collected from 26 sites around Tauranga Harbour between December 1998 and March 1999 and analysed for heavy metals (As, Cd, Cu, Cr, Fe, Hg, Pb, Zn) and organic contaminants (tributyltin, PAHs and pesticides) (McIntosh 1999). Two studies have used sentinel shellfish to investigate contaminants in Tauranga Harbour. In the first study oysters were deployed at 20 sites around the harbour for a two month period and then collected and analysed for various trace metals (silver, arsenic, cadmium, chromium, copper, iron, lead, mercury, and zinc) and organic compounds (Power 1994). In the second study, oysters were deployed for a two to six month period at 10 sites, predominantly located in the southern area of the harbour, and then collected and analysed for heavy metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc) and organic contaminants (Park 2016). Wild shellfish collections were also made at a further five sites. Ten of the sites sampled in the earlier study were included as sites in the 2016 study. Organic contaminant classes analysed in both studies included PAHs, PCBs, tributyltin, triphenyltin and organochlorine pesticides.

[6] Taikato, V. (2015) Estuarine condition and macro-benthic communities in Te Tahuna o Rangataua, Te Awanui, Tauranga Harbour. University of Waikato, MSc thesis.

The three programs which monitor sediment contaminants provide adequate spatial coverage across Tauranga Harbour and sufficient frequency of sampling. In contrast, the coverage provided by the shellfish monitoring is not as spatially extensive and has only been sampled twice over an approximately 25 year period. More frequent sampling of the bioavailable component of contaminants in Tauranga Harbour is required. This could be achieved by repeating shellfish contaminant sampling more frequently (e.g. every 5 – 10 years) and/or through the use passive sampling devices such as diffusive gradients in thin films (DGT) or polar organic chemical integrative samplers (POCIS). Recent research indicates that passive sampling devices can complement shellfish environmental monitoring[7]. However, an important difference between passive sampling devices and biota monitoring is that passive sampling devices do not incorporate particulate associated concentrations and so potentially do not represent the whole bioavailable component, where particulate matter is taken up by the biota. This is especially important for hydrophobic contaminants such as PAHs, which generally associate with particulate matter. Therefore, an integrated program which combined shellfish monitoring at 5 – 10 yearly intervals and passive sampling devices at 3 – 5 yearly intervals distributed across the harbour would provide an indication of the potential threat of contaminants to ecosystem health.

A knowledge gap for contaminants is our understanding of the effects of emerging contaminants. These are chemicals that are not commonly monitored but have the potential to cause adverse ecological and/or human health effects. They are predominantly organic chemicals (referred to as emerging organic contaminants or EOCs) and include industrial chemicals (flame retardants, plasticisers), surfactants, pesticides, preservatives and pharmaceuticals and personal care products. A major concern is that EOCs are not regulated and environmental concentrations and effects are largely unknown. Sources of EOCs include sewage, stormwater, landfill leachate, recreational activity, antifouling paint, horticulture and agriculture. Current regular sediment contaminant monitoring programs include organic pollutants, such as polycyclic aromatic hydrocarbons (PAHs) and heavy metals, and there was a one-off survey of herbicides and pesticides in 2011/12, but we do not have any data on most other EOCs. A review of international studies and data is required to determine which EOCs are likely to be present in the harbour and are likely to be impacting on ecological communities. Based on the findings of this review baseline monitoring can then be conducted to determine which sites within the harbour and which EOCs are of most concern.

Summary of data availability

A summary of the monitoring data available for sediment dynamics described in this chapter is provided in Table 4.3. The spatial distribution of this data across Tauranga Harbour is illustrated in Figures 4.1 and 4.2. These maps indicate that sampling sites are well spaced throughout the harbour and information on sediment dynamics is available at most locations from both the NERMN programme, and through non-NERMN sources.

Table 4.3 Summary of monitoring data available for sediment dynamics described in this chapter. Parameters measured are categorised as sedimentation and contaminants. Specific detail of parameters measured is provided in the main body of the report. For datasets where the start date varies between monitoring sites, the earliest start date that data is available for across all sites is given. BOPRC – Bay of Plenty Regional Council; MTM – Manaaki Taha Moana; UoW – University of Waikato, NIWA – National Institute of Water and Atmospheric Research. Note that other sources of data on sediment dynamics which are not included in this table may have been outlined in the main body of this chapter.

Parameters measured		Source	Data start time	Data end time
Sediment.	Contam.			
√		BOPRC, NERMN sediment plate monitoring	2013	Present*
√	√	BOPRC, NERMN sediment contaminant monitoring	2003	Present*

[7] Stewart, M., Cameron, M., McMurtry, M., Sander, S., Benedict, B., Graham, L., Hosie M. & Green, T. (2016) Development of passive sampling devices for bioavailable contaminants of current and emerging concern: Waitemata Harbour case study, New Zealand Journal of Marine and Freshwater Research, 50:4, 526-548.

Parameters measured		Source	Data start time	Data end time
Sediment.	Contam.			
√	√	BOPRC, NERMN coastal and estuarine ecology monitoring	1990	Present*
√		BOPRC, sediment accumulation transects**	2003	2010
√	√	MTM, Broadscale intertidal ecological survey	2012	2012
√		NIWA, Tauranga Harbour sediment study	2007	2008
	√	Vanessa Taikato UoW, MSc thesis	2014	2014
	√	Julien Huteau UoW, PhD thesis	2013	2013
	√	BOPRC, shellfish contaminant monitoring	2016	2016

* Program is ongoing; data will continue to be collected; ** sediment transect locations not displayed in Fig 4.2.

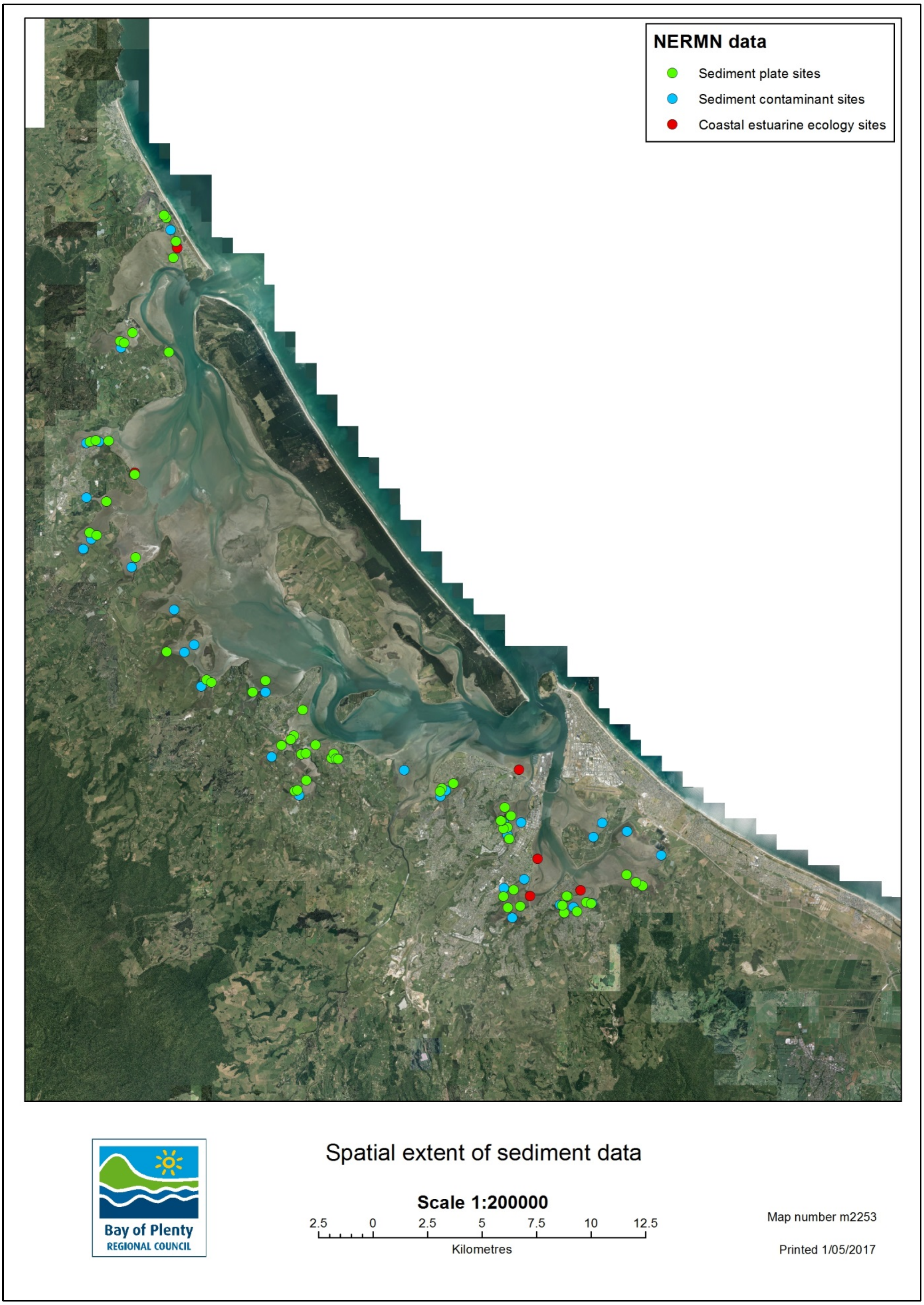

Figure 4.1 Spatial distribution of sediment dynamics data for Tauranga Harbour collected as part of the NERMN programme. See Table 4.3 for further information about data sources. Note that only current monitoring sites are displayed.

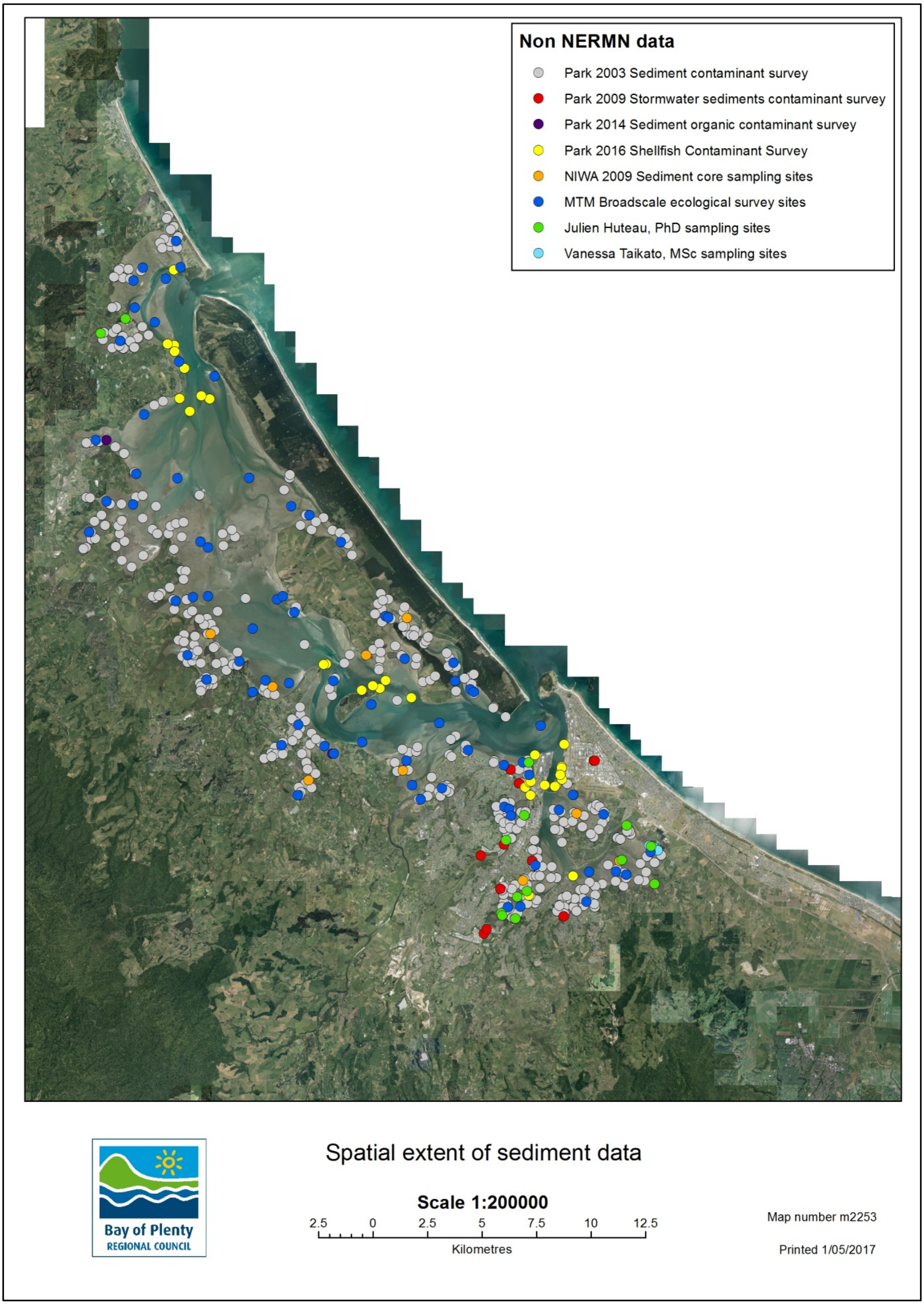

Figure 4.2 Spatial distribution of sediment dynamics data for Tauranga Harbour collected outside of the NERMN programme. See Table 4.3 for further information about data sources.

Relevant reports

Table 4.4 Reference details for the most recent and/or most key relevant reports for each subject covered in this chapter. Only the most recent report is included for regular monitoring programs where sampling sites and parameters monitored remain the same in each consecutive report. Note that other reports are available for this topic which are not included in this table.

Subject	Report
Sedimentation	• Elliot, S., Parshotam, A., and Wadhwa, S. (2009). Tauranga Harbour Sediment Study, Catchment Model Results, NIWA Client Report HAM2009-046, prepared for Environment Bay of Plenty, April 2009 (amended May 2010). • Hancock, N., Hume, T., and Swales, A. (2009). Tauranga Harbour sediment study: harbour bed sediments. NIWA Client Report: HAM2008-123, prepared for Environment Bay of Plenty. • MacGibbon, R., Hamill, K. and Muirhead, A. (2011). Tauranga Harbour Sediment Management Review. Prepared for Bay of Plenty Regional Council by Opus International Consultants Ltd.
Contaminants	• Park, S. (2014) Bay of Plenty Marine Sediment Contaminants Survey 2012. Bay of Plenty Regional Council Environmental Publication 2014/03. • Park, S. (2009) Bay of Plenty Marine Sediment Contaminants Survey 2008. Environment Bay of Plenty Environmental Publication 2009/01. • Park, S. (2003) Marine Sediment and Contaminants Survey (2001-03) of Tauranga Harbour. Environment Bay of Plenty Environmental Report 2003/20. • Park, S. (2016) Comparison of contaminant levels in oysters from Tauranga Harbour in 1990 and 2016. Bay of Plenty Regional Council Environmental Publication 2016/09. • Power, F. (1994) Environment BOP Tauranga Harbour Regional Plan Environmental Investigations – Sentinel Shellfish. Environment Bay of Plenty, Environmental Report 94/9. • Ellis, J., Clark, D., Hewitt, J., Sinner, J., Patterson, M. Hardy, D., Park, S., Gardner B., Morrison, A., Culliford, D., Battershill, C., Hancock, N., Hale, L., Asher, R., Gower, F., Brown, E., McCallion, A. (2013). Ecological Survey of Tauranga Harbour. Prepared for Manaaki Taha Moana, Manaaki Taha Moana Research Report No. 13. Cawthron Report No. 2321. 56 p. plus appendices.

Information gaps

The following table identifies gaps in our current scientific knowledge of sediment dynamics for the Tauranga Harbour and explains why knowledge of these gaps is important. A reference number (Ref no.) for each gap is provided to allow easy cross referencing with the research recommendations provided for each gap in Part 8 (Table 8.2). This is an un-prioritised list of all identified gaps, large or small. Further assessment of need, urgency, and resourcing required will be carried out to determine which gaps will be filled, when and how.

Table 4.5 Information gaps for sediment dynamics.

Ref no.	Topic	Gap	Relevance
13	Sedimentation	It has been at least 10 years since sediment transects were resurveyed.	Resurveying sediment transects across the harbour and analysing this data will provide detailed data on sedimentation rates at each site across a range of depths, not just in a single discrete point as per sedimentation rates calculated from sediment plate data.
14	Sedimentation	Understanding the current sources and causes of sediment inputs to waterways, including an understanding of what proportion of the sediment load is natural as opposed to human induced.	Understanding which sediment sources are primary contributors to suspended sediment loads in streams will enable the development of management strategies to reduce sediment loads. An understanding of the proportion of sediment loads that are human induced will enable realistic sediment reduction targets to be set.
15	Sedimentation	We don't have any estimates of historical (pre human) sedimentation rates in the various estuaries around the harbour. We do not know how rates have varied over the past 100 years for example compared to present times.	Knowledge of historic sedimentation rates in estuaries across the harbour will provide context to current sedimentation rates. While it may be difficult to do this in every estuary across the harbour, it should at least be done for the three estuaries that are being continuously monitored for sediment inflows (Waimapu, Waikareao and Tuapiro). This will contribute towards our overall understanding of sedimentation in the harbour.
16	Sedimentation	No single report summarising and linking all sedimentation data together in a concise format.	As sedimentation data is dispersed amongst a number of different sources and reports it is difficult to identify patterns and trends and get an overall understanding of sedimentation processes in the harbour. The Tauranga Sediment study conducted by NIWA addressed this issue to some degree, but only focused on the southern harbour and contained multiple output reports.

Ref no.	Topic	Gap	Relevance
17	Contaminants	Sampling of bioavailable component of contaminants in harbour through shellfish monitoring is only conducted infrequently and does not cover all areas of the harbour.	Sediment contaminant sampling provides an estimate of total concentrations of contaminants in the estuary. However, the bioavailable component of total contaminant concentrations is important as this is the component that directly affects ecosystem health. More frequent sampling of the bioavailable component of contaminants in the harbour would provide an indication of the potential threat of contaminants to ecosystem health.
18	Contaminants	No baseline data or monitoring of emerging organic contaminants (EOCs) in the harbour.	Mounting evidence suggests that some EOCs may cause deleterious environmental effects. A major concern is that EOCs are not regulated and environmental concentrations and effects are largely unknown. A review of international studies and data is required to determine which EOCs are likely to be present in Tauranga harbour and which are likely to be impacting on ecological communities. Based on the findings of this review, baseline monitoring can then be conducted to determine which sites within the harbour and which EOCs are of most concern.

Part 5:

Habitat degradation

Introduction

Habitat degradation or loss can be monitored directly by measuring changes in the abundance of different habitat types (e.g. seagrass, saltmarsh, mangroves) and sea lettuce blooms. The impacts of habitat degradation can also be investigated by tracking changes in the abundance and composition of benthic macrofauna communities, while the impacts of marine pests can be investigated through regular monitoring of high risk areas. This section provides an overview of the monitoring work undertaken in Tauranga Harbour and the scientific data available to BOPRC related to habitat degradation. This includes seagrass, saltmarsh, mangroves, sea lettuce, benthic macrofauna and marine pests. Gaps in our knowledge and understanding of habitat degradation are identified and discussed. Shellfish of commercial/recreational interest are discussed in Part 6: Decline in kaimoana.

Seagrass

The distribution and extent of seagrass in Tauranga Harbour is monitored under the NERMN program using high resolution aerial photography and, where necessary, field surveys to ground truth the photography information. The photography is used to map seagrass extents throughout the harbour and assess trends and changes in seagrass extent over time. Mapping has been carried out at irregular intervals, most recently in 1996 and 2011, dependent on when suitable harbour wide photography was available (Table 5.1, Park 1999a; 1999b; 2016). In addition to current regular five yearly mapping of seagrass distribution, the influence of sediment mud content, nutrient loads and suspended sediment loads (1991 data) on seagrass extent in 1996 have been investigated (Park 1999a).

In addition to this regular monitoring, a number of one-off studies have been carried out. An extensive survey of the intertidal abundance and distribution of seagrass was conducted in 1990/1991 by BOPRC along 91 transects at locations across the harbour (Park and Donald 1994). During the 2007/2008 summer, seagrass meadow size was estimated at five sites within Tauranga Harbour by PhD student Virginie dos Santos (University of Waikato)[8]. Seagrass biomass was also determined monthly from February 2009 to February 2010 at four of the sites using percentage cover data estimated from six 0.25 m^2 plots at each site and an established relationship between percentage sea grass cover and biomass. Viriginie dos Santos also investigated the links between seagrass condition and environmental parameters (nutrients, light availability, sedimentation, contaminants) at five sites in Tauranga Harbour, and evaluated how black swan grazing and environmental stressors can affect seagrass meadow condition and resilience at four sites in Tauranga Harbour.

A key information gap around seagrass is an understanding of the degree of connectivity between seagrass beds in different parts of the harbour and an understanding of the level of genetic diversity both within and among populations. When combined with the findings of Virginie dos Santos's PhD research around seagrass resilience and condition, this information would enable predictions to be made about the likely recovery potential and resilience of seagrass populations to stressors, such as increased sedimentation and nutrient loading. Information on connectivity, health and condition could also be used to help prioritise catchments for management action (e.g. reduction in sediment loads), and to identify potential donor sites and transplant sites for seagrass restoration. A further information gap is an understanding of the factors driving seagrass decline, and in particular whether these are the same in subtidal and intertidal areas. This information could be used to help develop management strategies to mitigate the loss of seagrass.

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[8] Dos Santos, V. (2011) Impact of black swan grazing and anthropogenic contaminants on New Zealand seagrass meadows. University of Waikato, PhD thesis.

Table 5.1 NERMN monitoring regime for seagrass, mangrove and saltmarsh distribution and sea lettuce abundance.

Seagrass	• Distribution and extent across the entire harbour. • Mapping data available for 1959, 1996 and 2011.
Saltmarsh	• Not regularly monitored through NERMN. • Distribution and extent across the entire harbour mapped in 1959, 2008. • Extent at four sites in the southern Harbour mapped in 2003.
Mangroves	• Distribution and extent across the entire harbour. • Mapping data available for 1943, 1959, 1964, 1969, 1974, 1975, 1986, 1991, 1993, 1996, 1999, 2003, 2011. Harbour wide data only available for some of these years.
Sea lettuce	• Three sites monitored every two months for abundance, water quality and sea lettuce tissue nutrient content. • Data available from 1991 to present.

Salt marsh

Saltmarsh distribution is not regularly monitored or mapped as part of the NERMN program (Table 5.1). However, the distribution of saltmarshes across the entire harbour in 1959 was mapped from aerial photos to determine whether mangrove expansion is displacing saltmarsh (Park 2004). Mapping of saltmarsh from aerial photos was repeated in 2013, but only for four sites in the southern harbour for the purpose of tracking whether mangroves are displacing saltmarsh (Park 2015). Saltmarsh areas in Tauranga Harbour have also been mapped as part of a larger study undertaken by Wildland Consultants to identify natural areas in Tauranga Harbour and assess the values associated with those areas (Beadel et al. 2008). Mapping of saltmarsh areas in this study was based on high resolution aerial photography and site visits to ground truth information where necessary. Further information on saltmarsh areas in Tauranga Harbour is provided in a comprehensive review of wetlands in the Bay of Plenty region (Cromarty and Scott 1995). This review does not provide any mapping data, but includes information on state and management. Further information is also provided in a report by Park (2000) on the Bay of Plenty Maritime Wetlands database, which draws on information collected from wetland vegetation surveys, digital mapping, database design and data capture. This report presents an initial analysis of the information contained in the database to display its usefulness for environmental management. But the report does provide an estimate of the amount of estuarine saltmarsh lost by land reclamation between 1840 and 1991/1992.

Mangroves

The distribution and extent of mangroves in Tauranga Harbour is monitored under the NERMN program using high resolution aerial photography. The frequency of mapping has varied since 1943, depending on when suitable harbour wide photography was available (Table 5.1). It recent times, mapping has occurred every three to 10 years and going forward it is planned for every five years. Photography is available for 2015 but is yet to be analysed. In addition to regular mapping of mangrove distribution, the influence of sediment mud content and tidal height on mangrove extent were investigated in 2003 (Park 2004). The displacement of seagrass and saltmarsh habitat has also been investigated using high resolution aerial photography and overlaying the distribution of mangroves in 2011 with the distribution of saltmarsh in 2003 and seagrass in 1959 (Park 2015). Mangrove displacement of saltmarsh has been investigated at four sites in southern Tauranga Harbour and mangrove displacement of seagrass has been investigated across the entire harbour.

Mangrove extent in Tauranga Harbour has more than doubled over the last forty years (Park 2015) and since 2009 BOPRC has been involved in the management of mangroves in support of community groups. Management actions include the removal of mature mangroves in some areas and the control of seedlings in others, with the primary goal to restore open estuary sandflat conditions in areas that have been colonised by mangroves since the 1970s. Several studies have investigated the impacts of mangrove removal on estuary communities. Lundquist et al. (2012) surveyed trends in sediment characteristics and benthic communities after mechanical removal of mangroves and *in situ* mulch deposition in at five sites in Tauranga Harbour. Similarly, Park (2012) monitored sediment characteristics and benthic macrofauna composition and abundance at two sites following mechanical removal of mangroves and *in situ* mulch deposition. This project is ongoing. White (2015) monitored the effects of mulching of mangrove stumps that had remained after previous mangrove cutting operations on sediment compaction, organic debris, sediment quality and benthic macrofauna communities at two estuaries. These studies have provided good data on the effects of mangrove removal on benthic macrofauna communities in Tauranga Harbour.

Rapid mangrove expansion in Tauranga Harbour is generally accepted to be caused by a combination of climate warming, particularly the significant reduction in frosts, and increasing sedimentation of the harbour providing shallow muddy areas where mangroves can grow (Win, Park and Quinn, 2015). Therefore, many of the knowledge gaps around mangroves are related to a greater understanding of sedimentation in the harbour. These include an understanding of how much sediment is entering the harbour from each catchment, the sediment accumulation rates in each sub-estuary, changes in sediment particle size and nutrient content, knowledge of depositional areas for sediment within the harbour and identification of areas where sediment is flushed from the harbour. All of these gaps relating to a general lack of knowledge about sedimentation processes in the harbour are discussed in the Sedimentation section of the Estuary Water Quality chapter above. Information gaps around sedimentation specifically related to mangroves are data on sediment profiles and characteristics in all sub-estuaries (e.g. measurement of depth of mud and underlying sandy substrate). This information would provide an indication of the possibility of successful restoration of estuaries back to sandier mudflats after mangrove removal. A further gap is knowledge of levels of sediment contamination within mangroves. This information would provide greater understanding of the ecosystem services of mangroves for removal of contaminants and would identify areas where mangroves should not be removed if sediments are contaminated. A final knowledge gap is that we do not know how fast below ground biomass of mangroves decomposes once the above ground biomass has been removed. This is important as mangrove roots can continue to bind sediments after the above ground biomass is removed. Knowledge of below ground biomass decomposition rates will provide an indication of timeframes that increased erosion of muddy sediments in mangrove removal areas are likely to occur over following mangrove removal.

Sea lettuce

Sea lettuce abundance and water and sea lettuce tissue nutrient content have been measured every second month since 1991 at three intertidal sites in Tauranga Harbour as part of the NERMN program (Table 5.1). To provide an understanding of the factors that trigger sea lettuce blooms, the relationships between freshwater nutrient inputs from the Kopurererua Stream and the Wairoa River, nutrient concentrations at marine monitoring sites around the harbour, climatic variables, sea lettuce abundance and sea lettuce tissue nutrient concentrations have been explored (Park 2011). In addition, a one-off study was conducted in 2010 to identify relative sources of nutrients in sea lettuce (Park 2011). Samples of sea lettuce were collected from 18 sites (including the three sites sampled during regular NERMN monitoring) and water samples were collected from eleven marine sites and nine river and stream sites and were analysed for nitrogen stable isotope content. Sea lettuce tissue samples collected between 1991 and 2010 as part of regular bi-monthly monitoring were also analysed for nitrogen stable isotope content.

A number of one-off studies have investigated sea lettuce abundance and distribution in Tauranga Harbour and ecological drivers of sea lettuce blooms. An extensive survey of the intertidal abundance and distribution of sea lettuce was conducted in 1990/1991 by BOPRC along 91 transects at locations across the harbour (Park and Donald 1994). A systematic survey of the distribution and abundance of subtidal sea lettuce in Tauranga Harbour was undertaken in 1995/1996 in conjunction with laboratory experiments to determine the effects of light and nutrients on sea lettuce growth (de Winton et al, 1996). 34 sites across the harbour were surveyed on a single occasion in 1995 and eleven of these sites were resurveyed on a single occasion in 1996. In a further study, sea lettuce abundance was monitored at an adjacent subtidal and intertidal site in the Otumoetai region of Tauranga Harbour from 1994 to 1998
(de Winton et al., 1998). Monitoring was conducted fortnightly over summer (December – February) and at monthly to three monthly intervals during the remainder of the year.

This study also included an investigation of the probable role of the physical harbour environment in influencing patterns of sea lettuce abundance, a physiological investigation into sea lettuce growth responses to light, nutrient availability and temperature, and determination of the genetic and morphological variation within the sea lettuce population of Tauranga Harbour.

A number of gaps in our knowledge of sea lettuce in Tauranga Harbour were identified by Park (2011). A key gap was the lack of a fully integrated hydrodynamic based growth model of sea lettuce in Tauranga Harbour. This is needed because of the complexity of interacting variables that ultimately drive sea lettuce abundance. This gap has been partially addressed through research undertaken by PhD student Alex Port (University of Waikato). Alex examined the dynamics of estuarine sea lettuce blooms in the Southern Harbour and the environmental factors controlling them using mathematical models and observational data. The relationship between the concentration of nitrogen in the water column and the concentration of nitrogen in sea lettuce tissue was modelled. Seasonal and long term population dynamics of sea lettuce and the influence of water nutrient concentrations, temperature, light and salinity were investigated.

Further gaps identified by Park (2011) were that the bathymetry of the subtidal areas throughout Tauranga Harbour needs to be updated. This is needed to improve the accuracy of hydrodynamic models and habitat mapping. There is a need to improve spatial assessment of sea lettuce abundance across the whole harbour, including both intertidal and subtidal habitats, as abundance is currently only monitored at three intertidal sites. Improved spatial assessment of sea lettuce will help to identify production areas and rates, accumulation/loss and nutrient recycling zones and ultimately more accurately identify growth drivers including climatic influences. The dynamics of sediment nutrient recycling in the harbour needs to be mapped (see Part 4: Sedimentation). This is required to quantify contributions to algal production, particularly sea lettuce blooms. Finally, the frequency of nutrient measurements within the harbour needs to be improved. Ideally, a nutrient logger with associated sensors (e.g. chlorophyll, turbidity, temperature) should be set up in the southern harbour basin to help understand environmental drivers of sea lettuce abundance. Data obtained from such a logger could be used to inform the development of harbour-wide hydrodynamic model as described under Part 3: Relevant reports.

Park (2011) showed that sea lettuce abundance in Tauranga Harbour is strongly correlated with El Nino weather patterns. Abundance is higher in El Nino years and it is thought that this is due to increased availability of nutrients in these years as a result of upwelling of nutrient rich deep oceanic water. Nutrient concentrations in water are regularly measured around the harbour, including at sites where sea lettuce abundance is monitored, as part of the NERMN program (see Part 3: Estuarine water quality). However there has been little targeted sampling to identify the influence of El Nino weather patterns on nutrient concentrations in water around the harbour and this is a gap in our knowledge and understanding. Comparing nutrient water quality data collected in both El Nino and neutral/La Nina years to sea lettuce abundance measured over the same time period will help to elucidate the influence of El Nino related nutrient enrichment on sea lettuce population dynamics.

A final key information gap is that we don’t quantitatively know where the sea lettuce biomass that forms large, free floating blooms in the harbour originates from. Genetic studies of sea lettuce populations in Tauranga Harbour were conducted in 1998 (de Winton et al., 1998) but only provided limited insights into the relatedness of samples from different locations. Further sampling in Tauranga Harbour was conducted in 2006 by Biosecurity New Zealand as part of a study investigating genetic diversity and possible origins of New Zealand populations of *Ulva* (the algal genus commonly called sea lettuce) (Heesch et al., 2007). This study only focused on species identification and finer scale investigations of the relatedness of samples from different sites was not investigated. However, genetic techniques now have the potential to differentiate between individual samples and could be used to identify source populations at very fine spatial scales.

Benthic macrofauna

Changes in the abundance and composition of benthic macrofauna communities can provide an indicator of whether estuarine habitats are becoming degraded. Benthic macrofauna in Tauranga Harbour have been monitored annually under the NERMN program since 1990 (Table 5.2). The diversity, density and size of benthic organisms such as crustaceans, worms, snails and shellfish in sediment cores are recorded. In total, there have been 21 sites monitored in Tauranga Harbour over various periods of time (Table 5.3). Descriptive parameters of the sediments, including sediment grain size, sorting, skewness and total organic carbon (TOC), and more recently TN, TP and metals are monitored at these sites. A number of the monitoring sites are also in close vicinity to water quality sites monitored as part of the NERMN program. Seven sites are currently monitored (Table 5.3). These represent a core set of stable and sensitive sites that best reflect potential impacts and future changes from development pressure. A review of the location and number of these monitoring sites and sampling frequency is outlined in Part 4.2 of Park (2012). The current monitoring program and the historical baseline data from sites not currently monitored provide adequate spatial and temporal coverage to detect changes in benthic macrofauna community abundance and distribution across the mid harbour areas.

Table 5.2 NERMN benthic macrofauna monitoring regime.

Number of sites	• 7 currently monitored sites. • 14 historically monitored sites.
Sampling frequency	• Annually.
Measured parameters	• Diversity, density and size of benthic organisms.
Length of data record	• Variable depending on site. Sites first monitored in 1990. See Table 5.3 for more detail.

Table 5.3 Current and historical benthic macrofauna NERMN monitoring sites.

Site	Habitat type	Length of data period
Island View Beach	Open coastal	Annually monitored from 1991 to 1995.
Ōmanu Beach	Open coastal	Annually monitored from 1991 to 1998.
Pāpāmoa Beach*	Open coastal	Annually monitored in all years from 1991 to 2012 except 2002, 2006, 2011.
Pio's Beach*	Estuarine	Annually monitored in all years from 1991 to 2016 except 2012.
Tuapiro Estuary	Estuarine	Annually monitored from 1991 to 1998.
Matakana Island North	Estuarine	Annually monitored from 1991 to 1997.
Katikati Estuary*	Estuarine	Annually monitored in all years from 1991 to 2016 except 1992, 1993 and 2012.
Blue Gum Bay South	Estuarine	Annually monitored in all years from 1991 to 1995 except 1992.
Blue Gum Bay North	Estuarine	Annually monitored in all years from 1991 to 1997 except 1992.
Hunters Creek	Estuarine	Annually monitored from 1991 to 1998.
Duck Bay	Estuarine	Annually monitored from 1991 to 1998.
Te Puna Estuary*	Estuarine	Annually monitored in all years from 1991 to 2016 except 2012.
Tilby Point	Estuarine	Annually monitored from 1991 to 1998.
Otumoetai South	Estuarine	Annually monitored from 1991 to 2012.

Site	Habitat type	Length of data period
Waikareao Estuary	Estuarine	Annually monitored from 1991 to 1998.
Grace Road*	Estuarine	Annually monitored in all years from 1991 to 2016 except 2012.
Waimapu Estuary	Estuarine	Annually monitored from 1991 to 1997.
Welcome Bay	Estuarine	Annually monitored from 1991 to 2000.
Mid Harbour	Estuarine	Only monitored in 1996.
Waimapu Estuary*	Estuarine	Annually monitored in all years from 1998 to 2016 except 2002.
Welcome Bay*	Estuarine	Annually monitored from 2001 to 2016.

* Current monitoring site.

In addition to annual monitoring, a comprehensive survey of intertidal and subtidal soft shore benthic communities of Tauranga Harbour was carried out in 1990/91 (Park and Donald, 1994). Benthic macrofauna in sediment cores from 16 subtidal sites and 160 intertidal sites were sampled. More recently, a comprehensive survey of intertidal benthic communities was conducted in 2011/2012 as part of the Manaaki Taha Moana program (Ellis et al. 2013). This study sampled benthic macrofauna in sediment cores at 75 sites across the harbour in a range of habitats including intertidal sand flats, shellfish beds, seagrass meadows and areas likely to be impacted by pesticides. Data on epifauna (animals living on the surface of the sediment, e.g. anemones, crabs, sea stars) was also collected at each site as part of this study, but is yet to be analysed or reported. A comprehensive survey of subtidal benthic communities was also conducted in 2015/2016 as part of the Manaaki Te Awanui program. This study sampled macrofauna in sediment cores at taken from the subtidal zone at the same 45 locations across the harbour, some of which were sampled in the BOPRC subtidal survey conducted in 1990/1991. The results of this subtidal survey are due to be reported in 2017.

There have also been numerous one-off studies of benthic macrofauna in Tauranga Harbour, however these tend to be limited to small geographic areas and are focused on assessing the effects of specific stressors on estuarine communities. A range of studies carried out by the Port of Tauranga or through graduate student research projects have assessed the impacts of dredging and spoil dumping on benthic macrofauna (see Sinner et al., 2011, pg 53 for a list of references). PhD student Vanessa Taikato (University of Waikato) sampled benthic macrofauna in sediment cores from 30 sites in Rangataua Bay to investigate the effects of the Te Maunga wastewater treatment plant on estuarine communities. Cole et al. (2000) surveyed infaunal bivalve molluscs in December 1994 and May 1995 on Centre Bank, the flood tidal delta adjacent to the Port of Tauranga. Ellis et al. (2000) sampled the benthic macrofauna in Wairoa Estuary as part of an assessment of the potential environmental impacts from the proposed construction of the Te Tawa Quays marina. Stevens et al. (2002) sampled amphipods in Waimapu Estuary at monthly intervals from October 1999 to October 2000. As described above, several studies have assessed the effects of mangrove removal on benthic macrofauna (see Part 5: Mangroves for details).

In combination, these studies provide extensive but not comprehensive information on the distribution, abundance and composition of benthic macrofauna in soft shore habitats around Tauranga Harbour over a roughly 20 year time period. We also have a reasonable understanding of the effects of stressors such as suspended sediment on soft shore estuarine communities and there are many general studies in academic journals on this topic. In contrast, few surveys of rocky communities in Tauranga Harbour have been conducted, most likely due to the small area of habitat they cover in the harbour (<0.1% of the total area and perimeter of Tauranga Harbour). Most research into rocky reefs in Tauranga Harbour is related to the activities of the Port and potential impacts on the coastal environment.

Marine pests

Eleven species are declared to be marine pests under the Biosecurity Act 1993. These species have the potential to establish in the Bay of Plenty and are capable of causing adverse effects. Among these, the Asian paddle crab (*Charybdis japonica*) and the Australian tunicate (*Eudistoma elongatum*) have been found in New Zealand, but not in the Bay of Plenty. The Styela sea squirt (*Styela clava*) and the Mediterranean fan worm (*Sabella spallanzanii*) have been detected in Tauranga harbour since 2013. The Asian date mussel, Japanese kelp (*Undaria pinnatifida*) and the didemnum sea squirt (*Didemnum vexillum*) were detected in Tauranga Harbour prior to 2013 and it is believed that their current distribution is beyond what can be effectively controlled with current technologies.

Management and monitoring of marine pests in Tauranga Harbour is a joint responsibility of BOPRC and the Ministry for Primary Industries. Responsibilities are dependent on circumstances and are outlined in the Bay of Plenty Marine Biosecurity Management Plan[9]. In general, BOPRC is the lead agency and works together with the Ministry for Primary Industries to manage marine pests that are well established and for which eradication is not deemed to be a viable option.

BOPRC undertakes extensive surveillance of Tauranga Harbour to check for the presence of marine pests. Sulphur Point Marina and Bridge Marina are designated as high risk areas of the harbour and are surveyed every three months. All hard structures, including boats and rock walls, and any other surfaces in the marina are checked. All swing moorings in the harbour and their associated boats are surveyed two times per year. All bridge piles and the rockwall area stretching from the Tauranga CBD to the Sandfords Wharf are also surveyed two times per year. The Port of Tauranga has only been surveyed intermittently to date, due to the high risks associated with conducting diving in this area. Additionally, NIWA undertake their own surveillance in this area for marine pests on behalf of the Ministry for Primary Industries (MPI). However, from 2017 onwards the entire port area will be surveyed once per year by BOPRC. Surveys are undertaken by scuba divers and consist of divers conducting visual searches for non-indigenous organisms. The abundance and distribution of non-pest species are not recorded during these surveys.

Summary of data availability

A summary of the monitoring data available for habitat degradation described in this chapter is provided in Table 5.4. The spatial distribution of this data across Tauranga Harbour is illustrated in Figures 5.1 and 5.2. These maps indicate that there is good spread of data available on habitat degradation across the harbour, particularly for non-NERMN data.

Table 5.4 Summary of data available for habitat degradation described in this chapter. Parameters measured are categorised as habitat extent; organism ecology; organism abundance and distribution. Specific detail of parameters measured is provided in the main body of the report. For datasets where the start date varies between monitoring sites, the earliest start date that data is available for across all sites is given. BOPRC – Bay of Plenty Regional Council; UoW – University of Waikato; MTM – Manaaki Taha Moana. Note that other sources of data on habitat degradation which are not included in this table may have been outlined in the main body of this chapter.

Parameters measured			Source	Data start time	Data end time
Habitat	Ecol.	Abun/ dist.			
√			BOPRC, NERMN seagrass mapping	1959	Present*
√			BOPRC, NERMN mangrove mapping	1943	Present*
		√	BOPRC, NERMN sea lettuce monitoring	1991	Present*

9 Lass, H. (2015) Bay of Plenty Marine Biosecurity Management Plan. Bay of Plenty Regional Council Environmental Publication 2015/05.

Parameters measured			Source	Data start time	Data end time
Habitat	Ecol.	Abun/ dist.			
	√	√	BOPRC, NERMN coastal and estuarine ecology monitoring	1990	Present*
		√	BOPRC, seagrass and sea lettuce abundance, one-off study (Park and Donald 1994)	1990	1991
	√		BOPRC, sea lettuce ecology one-off study (Park 2011)	2010	2010
√	√		Virginie dos Santos UoW; PhD thesis	2007	2008
	√	√	de Winton et al; sea lettuce ecology, consultant research undertaken for BOPRC	1994	1998
	√		Lundquist et al; mangrove mulch monitoring, consultant research	2010	2011
	√		White et al; mangrove mulch compliance monitoring, undertaken for BOPRC	2013	2014
	√	√	MTM, Broadscale intertidal ecological survey	2012	2012
		√	Vanessa Taikato UoW, MSc thesis	2014	2014
	√	√	BOPRC, benthic macrofauna one off study (Park and Donald 1994)	1994	1994

* Program is ongoing; data will continue to be collected.

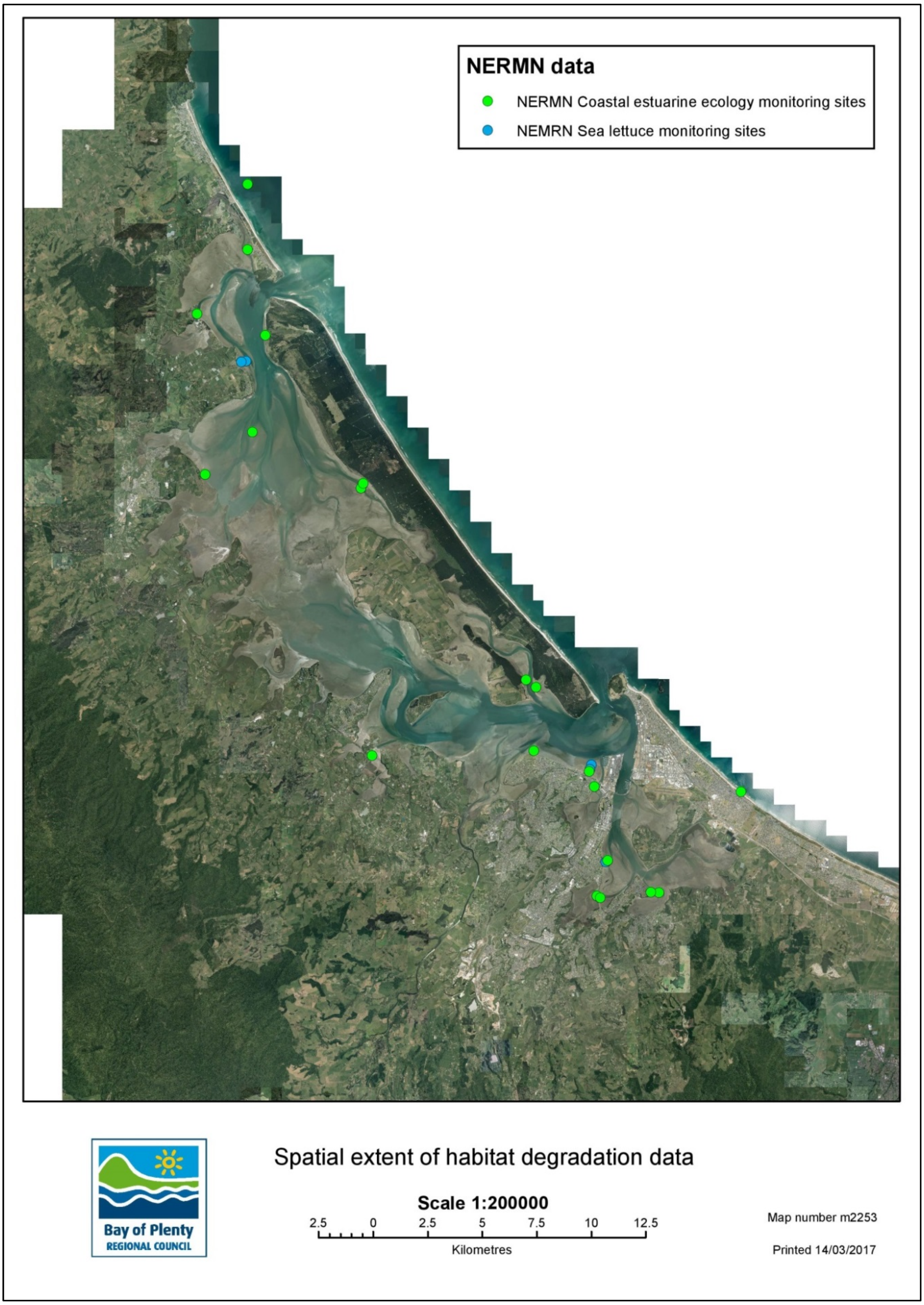

Figure 5.1 Spatial distribution of habitat degradation data for Tauranga Harbour collected as part of the NERMN programme. See Table 5.4 for further information about data sources. Note that seagrass mapping and mangrove mapping are not included are they cover the entire harbour area; only current monitoring sites are displayed.

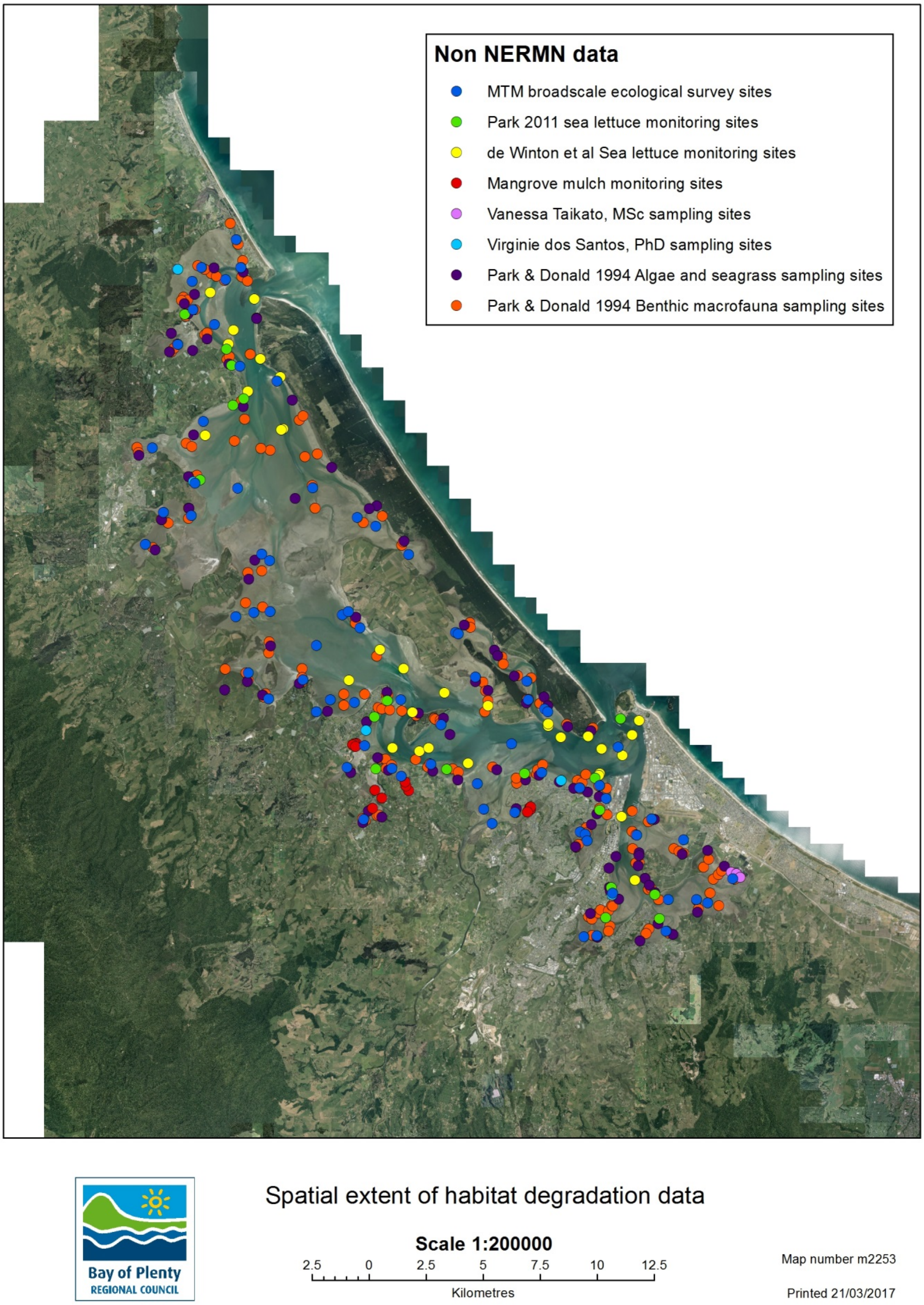

Figure 5.2 Spatial distribution of habitat degradation data for Tauranga Harbour collected outside of the NERMN programme. See Table 5.4 for further information about data sources.

Relevant reports

Table 5.5 Reference details for the most recent and/or most relevant key reports for each subject covered in this chapter. Only the most recent report is included for regular monitoring programs where sampling sites and parameters monitored remain the same in each consecutive report. Note that other reports are available for this topic which are not included in this table.

Subject	Report
Seagrass	• Park, S. (2016) Extent of seagrass in the Bay of Plenty in 2011. Bay of Plenty Regional Council Environment Publication 2016/03. • Park, S. (1999a). Changes in abundance of seagrass (*Zostera spp.*) in Tauranga Harbour from 1959-96. Environment Bay of Plenty Environmental Report 1999/30. • Park, S. (1999b). Changes in abundance of seagrass (*Zostera spp.*) in Southern Tauranga Harbour. Environment Bay of Plenty Environmental Report 1999/12. • Park, S. and Donald, R. (1994). Environment Bay of Plenty Tauranga Harbour Regional Plan environmental investigations: ecology of Tauranga Harbour. Environment Bay of Plenty Environmental Report 1994/08.
Mangroves	• Park, S. (2015). 2011 Mangrove abundance in the Bay of Plenty. Bay of Plenty Regional Council Environment Publication 2015/08. • Park, S. (2004). Aspects of mangrove distribution and abundance in Tauranga Harbour. Environment Bay of Plenty Environmental Publication 2004/16. • Win. R, Park, S. and Quinn, A. (2015) Tauranga Harbour Mangrove Management Literature Review. Bay of Plenty Regional Council Environment Publication 2015/10. • Park, S. (2012) Benthic macrofauna habitat and diversity associated with mangrove removal sites in Tauranga Harbour - year 2 of monitoring. Bay of Plenty Regional Council internal memorandum, File Ref: 4.00198, dated 9 March 2012. • Lundquist, C., Hailes, S., Cartner, K., Carter, K. and Gibbs, M. (2012). Physical and ecological impacts associated with mangrove removals using i*n situ* mechanical mulching in Tauranga Harbour. NIWA Technical report 137. • White, S. (2015) Tauranga mangrove stump mulching ecological monitoring. Technical report for Bay of Plenty Regional Council. Pacific Coastal Ecology.
Saltmarsh	• Park, S. (2015). 2011 Mangrove abundance in the Bay of Plenty. Bay of Plenty Regional Council Environment Publication 2015/08. • Park, S. (2004). Aspects of mangrove distribution and abundance in Tauranga Harbour. Environment Bay of Plenty Environmental Publication 2004/16. • Beadel, S., Renner, M., Stephen, M., Bawden, R., Collins, L., and Honey, M. (2008). Natural areas in Tauranga ecological district. Prepared for Environment Bay of Plenty by Wildland Consultants Ltd. Contract report no. 1914.

Subject	Report
Sea lettuce	• Park, S. and Donald, R. (1994). Environment Bay of Plenty Tauranga Harbour Regional Plan environmental investigations: ecology of Tauranga Harbour. Environment Bay of Plenty Environmental Report 1994/08. • Park, S. (2011). Sea lettuce and nutrient monitoring in Tauranga Harbour 1991 - 2010. Bay of Plenty Regional Council Environment Publication 2011/06. • de Winton, M., Clayton, J. and Hawes, I. (1996). Subtidal Ulva within Tauranga Harbour: 1995/96. NIWA Report BPR70205/1 prepared for Environment Bay of Plenty. • de Winton, M., Clayton, J. and Hawes, I. (1998). Sea lettuce dynamics and ecophysiology in Tauranga Harbour, Bay of Plenty. NIWA Report BPR802 prepared for Environment Bay of Plenty.
Benthic macrofauna	• Park, S. (2012). Coastal and estuarine benthic macrofauna monitoring report 2010. Bay of Plenty Regional Council Environment Publication 2012/03. • Park, S. and Donald, R. (1994). Environment Bay of Plenty Tauranga Harbour Regional Plan environmental investigations: ecology of Tauranga Harbour. Environment Bay of Plenty Environmental Report 1994/08. • Ellis, J., Clark, D., Hewitt, J., Sinner, J., Patterson, M. Hardy, D., Park, S., Gardner B., Morrison, A., Culliford, D., Battershill, C., Hancock, N., Hale, L., Asher, R., Gower, F., Brown, E., McCallion, A. (2013). Ecological Survey of Tauranga Harbour. Prepared for Manaaki Taha Moana, Manaaki Taha Moana Research Report No. 13. Cawthron Report No. 2321.
Marine pests	• Lass, H. (2015) Bay of Plenty Marine Biosecurity Management Plan. Bay of Plenty Regional Council Environmental Publication 2015/05.

Information gaps

The following table identifies gaps in our current scientific knowledge of habitat degradation for Tauranga Harbour and explains why knowledge of these gaps is important. A reference number (Ref no.) for each gap is provided to allow easy cross referencing with the research recommendations provided for each gap in Part 8 (Table 8.2). This is an un-prioritised list of all identified gaps, large or small. Further assessment of need, urgency, and resourcing required will be carried out to determine which gaps will be filled, when and how.

One information gap that is relevant across a number of topics covered in this chapter is an understanding of how light availability in the harbour affects primary productivity. Measures of photosynthetically active radiation (PAR – the amount of light available for photosynthesis) could be integrated with existing water quality monitoring networks to enhance the biological relevance of water quality monitoring. This data could also be used to develop biologically relevant thresholds for critical primary producers (e.g. seagrass, microphytobenthos) which could be fed back into environmental water quality monitoring networks and used to actively manage and monitor coastal stressors. By using these light thresholds, activities such as dredging or land developments could be managed to avoid or minimise light limitation impacts on critical benthic habitats.

A further overall gap related to habitat degradation is that different subtidal habitat types within the harbour such as shellfish beds, worm fields and biogenic reefs have not been fully mapped. Without accurate maps of these habitat types, areas of significance and high biodiversity value cannot be identified and managed to prevent degradation.

Table 5.6 Information gaps for habitat degradation.

Ref no.	Topic	Gap	Relevance
19	Seagrass	The degree of connectivity between seagrass beds in different parts of the harbour and the levels of genetic diversity both within and among populations is unknown.	When combined with the findings of Virginie dos Santos's PhD research around seagrass resilience and condition, this information would enable predictions to be made about the likely recovery potential and resilience of seagrass populations to stressors, such as increased sedimentation and nutrient loading. Information on connectivity, health and condition could also be used to help prioritise catchments for management action (e.g. reduction in sediment loads) and to identify potential donor sites and transplant sites for seagrass restoration.
20	Seagrass	An understanding of the factors driving seagrass decline, and in particular, whether these are the same in subtidal and intertidal areas.	Without clear understanding on the factors driving seagrass decline we cannot develop effective management strategies which will help to mitigate that decline.
21	Mangroves	Lack of data on sediment profiles and characteristics in all sub-estuaries (e.g. measurement of depth of mud and underlying sandy substrate).	This information would provide an indication of the possibility of successful restoration of estuaries back to sandier mudflats after mangrove removal.

Ref no.	Topic	Gap	Relevance
22	Mangroves	Knowledge of levels of sediment contamination within mangroves.	This information would provide greater understanding of the ecosystem services of mangroves for removal of contaminants and would identify areas where mangrove should not be removed if sediments are contaminated.
23	Mangroves	Lack of data on mangrove below ground decomposition rates.	Mangrove roots can continue to bind sediments after the above ground biomass is removed. Knowledge of below ground biomass decomposition rates will provide an indication of timeframes that increased erosion of muddy sediments in mangrove removal areas are likely to occur over following mangrove removal.
24	Sea lettuce	Bathymetry of subtidal areas throughout Tauranga Harbour needs updating.	This is needed to improve the accuracy of hydrodynamic models used to model sea lettuce abundance. If these models have low accuracy then confidence around predictions of sea lettuce growth, abundance and distribution from the models will be low.
25	Sea lettuce	Spatial assessment of intertidal sea lettuce abundance across the whole harbour needs to be improved as abundance is currently only monitored at three intertidal sites and there is no monitoring of subtidal sites.	Improved spatial assessment of sea lettuce will help to identify production areas and rates, accumulation/loss and nutrient recycling zones and ultimately more accurately identify growth drivers including climatic influences. Monitoring of subtidal sites in addition to intertidal sites will help to determine the importance of subtidal regions as a source of biomass for sea lettuce blooms.
26	Sea lettuce	The contributions of sediment nutrient recycling to sea lettuce growth are currently unknown.	Without knowing the contributions of sediment nutrient recycling to sea lettuce growth it will not be possible to predict the likely effect of nutrient reduction in freshwater inputs to the harbour on sea lettuce growth. If the contribution of sediment nutrient recycling to sea lettuce growth is high, then it is possible that reducing nutrient loads in streams entering the harbour will not result in a reduction in sea lettuce abundance.
27	Sea lettuce	The frequency of nutrient measurements within the harbour needs to be improved. Ideally, a nutrient logger with associated sensors (e.g. chlorophyll, turbidity, temperature) should be set up in the southern harbour basin.	More frequent measurement of nutrients and associated physical water parameters within the harbour will help to understand how they vary with tidal cycles and seasons. This information can then be linked to data on sea lettuce abundance and distribution to understand the influence of environmental drivers on sea lettuce blooms.

Ref no.	Topic	Gap	Relevance
28	Sea lettuce	The influence of El Nino weather patterns on nutrient concentrations in water around the harbour is unknown.	Sea lettuce abundance is higher in El Nino years and it is thought that this is due to increased availability of nutrients in these years as a result of upwelling of nutrient rich deep oceanic water. However, there has little targeted sampling to identify the influence of El Nino weather patterns on nutrient concentrations in water around the harbour. Therefore we don't actually know if El Nino weather patterns result in increased nutrient concentrations in water inside the harbour. Comparing nutrient water quality data collected in both El Nino and neutral/La Nina years to sea lettuce abundance measured over the same time period will help to elucidate the influence of El Nino related nutrient enrichment on sea lettuce population dynamics.
29	Seagrass, sea lettuce	We have a very limited understanding of how light availability in the harbour affects primary productivity.	Measures of photosynthetically active radiation could be integrated with existing water quality monitoring networks to enhance the biological relevance of water quality monitoring. This data could also be used to develop biologically relevant thresholds for critical primary producers (e.g. seagrass, microphytobenthos) which could be fed back into environmental water quality monitoring networks and used to actively manage and monitor coastal stressors. By using these light thresholds activities such as dredging or land developments could be managed to avoid or minimise light limitation impacts on critical benthic habitats.
30	General habitat degradation	Different subtidal habitat types within the harbour such as shellfish beds, worm fields and biogenic reefs have not been fully mapped.	Without accurate maps of these habitat types, areas of significance and high biodiversity value cannot be identified and managed to prevent degradation.

Part 6:

Decline in kaimoana

Introduction

Management of kaimoana, including fish, shellfish and other macroinvertebrates, is complex. BOPRC manages activities on the land and in the harbour which can have direct impacts on kaimoana, for example through changes to water quality, but BOPRC does not directly manage harvesting of kaimoana. Commercial, recreational and customary harvesting of kaimoana in Tauranga Harbour is managed by the Ministry for Primary Industries. Formal assessments of stock status for managed species are published each year in the Fishery Assessment Plenary Report[10]. However, reporting by the Ministry for Primary Industries generally occurs at a scale that reveals little about the health of stocks in Tauranga Harbour. Given the importance of kaimoana to local iwi and communities, a greater understanding of the distribution and status of kaimoana stocks in Tauranga Harbour and the potential effects of poor water quality, increased sedimentation and habitat degradation on kaimoana is required. This section provides an overview of the monitoring work undertaken in Tauranga Harbour and the scientific data available to BOPRC related to kaimoana. This includes shellfish, macroinvertebrates and finfish (hereafter fish). Gaps in our knowledge and understanding of kaimoana are identified and discussed. Gaps related to quantifying harvests, stock status and basic biology of target species are not addressed here as they are the responsibility of the Ministry for Primary Industries and therefore are considered out of scope of this report.

Shellfish and other macroinvertebrates

Species of shellfish and other macroinvertebrates in Tauranga Harbour that are managed by the Ministry for Primary Industries under the Quota Management system are outlined in Table 6.1. Commercial catch landings for all of these species are very low or non-existent, customary catches are unknown and data that exists for recreational catches is unreliable[12]. Data is presented at the scale of fishstocks and specific data for Tauranga Harbour is only available for pipis and cockles. The Ministry for Primary Industries has conducted intermittent assessments of cockle and pipi abundance and population structure at Bowentown Heads and Otumoetai since 2000 (Berkenbusch & Neubauer, 2015; 2016). Sediment grain size and organic content has also been sampled at these sites as part of these studies since 2013 and the relationship between these variables and cockle abundance has been investigated (Berkenbusch & Neubauer, 2016).

Table 6.1 Shellfish and macroinvertebrates of commercial, recreational or customary interest managed by the Ministry for Primary Industries under the Quota Management System (QMS). The year that the species was introduced to the QMS, the relevant fishstock (Quota Management Area) for Tauranga Harbour and whether the species is important for customary harvest and recreational harvest are presented.

Common name	Species	Year added to QMS	Fishstock	Customary species	Recreational species
Cockle	*Austrovenus stutchburyi*	Not specified	COC1C	Yes	Yes
Green lipped mussel	*Perna canaliculus*	2004	GLM1	Yes	Yes
Horse mussel	*Atrina zelandica*	2004	HOR1	Yes	Yes

[10] Ministry for Primary Industries (2016). Fisheries Assessment Plenary May 2016: Stock Assessments and Stock Status.

Common name	Species	Year added to QMS	Fishstock	Customary species	Recreational species
Kina	*Evechinus chloroticus*	2002	SUR1B	Yes	Yes
Pāua	*Haliotis iris,* *Haliotis australis*	1986	PAU1	Yes	Yes
Pipi	*Paphies australis*	2005	PPI1C	Yes	Yes
Scallops	*Pecten novaezelandiae*	2002	SCA CA	Yes	Yes
Tuatua	*Paphies subtriangulata*	2005	TUA1B	Yes	Yes
Deepwater tuatua	*Paphies donacina*	2004	PDO1	Yes	Yes

BOPRC indirectly monitor the abundance of some shellfish in Tauranga Harbour as part the NERMN benthic macrofauna monitoring program described in Part 5: Benthic macrofauna. Abundance of cockles, pipi, wedge shells and nut shells are recorded and shell length data is collected for cockles as part of this program. In total, there have been 18 sites monitored in Tauranga Harbour over various periods of time (Table 5.3). However, it should be noted that this monitoring program is not designed to specifically monitor shellfish and macroinvertebrate stocks utilised as kaimoana.

In addition to the research conducted by Ministry for Primary Industries and the BOPRC benthic macrofauna monitoring program, a number of other studies have collected data on shellfish in Tauranga Harbour. Bioresearches sampled sites at Rereatukahia Inlet, Wairoa Estuary, Waikareao Estuary, Waimapu Estuary and Welcome Bay Estuary in 1974 as part of a series of studies on edible shellfish in Tauranga Harbour and recorded the abundance of benthic fauna including mud snails, pipi, cockles, green-lipped mussels and scallops (Bioresearches 1974). The level of sampling replication in this study was insufficient to allow a robust analysis of the results. However, the data provides an indication of the abundance and distribution of key species at the time of sampling.

A comprehensive survey of intertidal and subtidal soft shore benthic communities of Tauranga Harbour was carried out in 1990/91 (Park and Donald, 1994). Benthic macrofauna in sediment cores from 16 subtidal sites and 160 intertidal sites were sampled. Length frequency data for cockles, wedge shells and pipis was collected from all the intertidal sites. This study provides an indication of shellfish stocks in the harbour at the time of sampling. However, not all beds of edible shellfish were sampled and the location of sampling sites was not targeted to areas where the largest shellfish were likely to be found.

A survey of customary and traditional fishing practices within Tauranga Harbour was carried out in 2006 by the Tauranga Moana Iwi Customary Fisheries Management Committee (Tata and Ellis, 2006[11]). Important customary species and fishing grounds in Tauranga Harbour were documented.

More recently, a comprehensive survey of intertidal benthic communities was conducted in 2011/2012 as part of the Manaaki Taha Moana program (Ellis et al. 2013). This study sampled benthic macrofauna in sediment cores at 75 sites across the harbour in a range of habitats including shellfish beds. Shell length was recorded for all cockles and pipis found within the core samples. A comprehensive survey of subtidal benthic communities was also conducted in 2015/2016 as part of the Manaaki Te Awanui program. This study sampled macrofauna in sediment cores at taken from the subtidal zone at the same 75 sites across the harbour that were sampled for the intertidal survey (Ellis et al. 2013). The results of this subtidal survey are due to be reported in 2017.

[11] Cited in Sinner, J., Ellis, J., Roberts, B., Jiang, W., Goodwin, E., Hale, L., Rolleston, S., Patterson, M., Hardy, D., Prouse, E. and Brown, S. (2011). Health of Te Awanui Tauranga Harbour. Prepared for Manaaki Taha Moana, Manaaki Taha Moana Research Report No. 1. Cawthron Report No. 1969.

In combination, these studies provide a considerable amount of information on the distribution, abundance and population structure of cockles and pipis in Tauranga Harbour. However, it is difficult to gain an overall picture of the status of these shellfish and trends in their abundance and distribution over time without synthesis of their findings in a single report. A literature review of information about key kaimoana species in Tauranga Harbour would fill this gap. Such a report would provide important background information which could be used to inform the upcoming limit setting process that will occur when the NPS-FM is implemented in the Tauranga Harbour WMA.

A further gap in our knowledge of shellfish is information on the location of important shellfish gathering beds for both iwi and local communities. Some information is available in the Tauranga Moana Iwi report noted above, however this report is specific to iwi and does not include other community groups. Additionally, the findings of this survey are now 10 years out of date. Information on the location of important shellfish gathering beds will enable activities in the harbour and catchment to be managed to prevent degradation of habitats and water in the vicinity of shellfish beds. Finally, we do not have a good understanding of the degree of connectivity between populations of shellfish within different regions of the harbour and the surrounding area. An understanding of population connectivity will enable predictions to be made about the likely recovery potential of declining populations, could identify target locations for restoration activities and could help to focus management actions to improve water quality and prevent habitat degradation on areas with high recovery potential.

Shellfish contamination can result from pathogenic bacteria and viruses being present at harmful levels in shellfish or when toxic producing phytoplankton species accumulate in shellfish, making them unsafe to eat. Shellfish contamination in Tauranga Harbour from faecal bacteria and from algal biotoxins is assessed through two approaches. Firstly, BOPRC intermittently test pipis, cockles, horse mussels and oysters for faecal coliforms (*E. coli* and *Enterococci*) as indicators for faecal contamination (Scholes 2014). There is no set sampling frequency for this monitoring and in general, it only occurs every few years at a particular site. BOPRC also collects weekly water samples between October and March as part of the recreational water quality monitoring program (see Part 3: Recreational water quality) from five sites around Tauranga Harbour regarded by communities as desirable shellfish gathering locations and analyses these samples for faecal coliforms. These tests provide an indication of the level of bacterial contamination in shellfish. In the second approach, shellfish and seawater samples are collected from Tauranga Harbour each week and tested for contamination with biotoxins from algal blooms. This monitoring provides an indication of the risk of paralytic shellfish poisoning (PSP) from the consumption of shellfish.

BOPRC and other partner agencies undertook a targeted study in 2009 to better understand pathogenic bacterial and virus levels in shellfish stocks in Tauranga Harbour (Scholes et al 2009). Monthly shellfish and water sampling was carried out over a 12 month period to obtain information on the microbiological and viral quality of shellfish. Comprehensive sampling was also carried out after two significant pollution events. Cockles, pipis, oysters and horse mussels were sampled at six sites spread across the harbour and water was sampled at 12 sites. This research demonstrated that indicator bacteria may not be reliable indicators of viral contamination in shellfish. Therefore shellfish may not be safe to eat even when the bacterial quality is within currently accepted microbiological limits. Shellfish sampled at Tilby Point and Pilot Bay were found to be regularly contaminated with viruses during the 12 month study. However, the current monitoring program provides no reliable method to detect this contamination and issue a public health warning to prevent shellfish gathering. Consequently, a significant gap in current monitoring programs determining whether shellfish are safe to eat is monitoring of virus levels or other indicators which will provide a reliable proxy for viral contamination.

Fish

Species of fish in Tauranga Harbour that are managed by the Ministry for Primary Industries under the Quota Management system are outlined in Table 6.2. Many of these species are important for customary and recreational harvesting. In contrast to shellfish, information on commercial catch is available for all species, and recreational harvest estimates are available for some species. However, similarly to shellfish, data is only presented at the scale of fishstocks and specific data for Tauranga Harbour is not available.

Table 6.2 *Fin fish species of commercial, recreational or customary interest managed by the Ministry for Primary Industries under the Quota Management System (QMS). The year that the species was introduced to the QMS, the relevant fishstock (Quota Management Area) for Tauranga Harbour and whether the species is important for customary harvest and recreational harvest are presented. Data is based on species presented in Tables 15 and 17 in Sinner et al 2011.*

Common name	Species	Year added to QMS	Fishstock	Customary species	Recreational species
Grey mullet	*Mugil cephalus*	1986	GMU1	Yes	Yes
Jack mackerel	*Tachurus novaezelandiae*	1996	JMA1	Unknown	Low value
John Dory	*Zeus faber*	1986	JDO1	Yes	Yes
Kahawai	*Arripis trutta*	2004	KAH1	Yes	Yes
Kingfish	*Seriola lalandi*	2003	KIN1	Yes	Yes
Parore	*Girella tricuspidata*	2004	PAR1	Low value	Low value
Sand flounder	*Rhombosolea plebeia*	1986	FLA1*	Yes	Yes
Snapper	*Pagrus auratus*	1986	SNA1	Yes	Yes
Spotted stargazer	*Genyagnus monopterygius*	1997	STA1	No	Low value
Sprat	*Sprattus sprattus*	2002	SPR1	No	No
Tarakihi	*Nemadactylus macropterus*	1986	TAR1	Unknown	Yes
Trevally	*Pseudocaranx dentex*	1986	TRE1	Yes	Yes
Yellow-belly flounder	*Rhombosolea leporina*	1986	FLA1*	Yes	Yes
Yellow-eyed mullet	*Aldrichetta forsteri*	1998	YEM1	Yes	Yes

* Jointly managed with seven other species as the fishery stock "Flatfish".

BOPRC does not conduct any monitoring of fish species in Tauranga Harbour and there have been few studies conducted by other agencies or research groups. The abundance and species composition of fish in Tauranga Harbour was surveyed by Francis et al (2005) as part of a survey of 25 northern New Zealand estuaries. Seventeen species were observed in Tauranga Harbour, however specific data on the abundance and composition of individual species is not available. Fish assemblages in tidal channels through mangrove forests in Tauranga Harbour were surveyed by Morrisey et al (2007) as part of a survey of eight northern New Zealand estuaries. Individual abundance data for the 10 species that were recorded in the survey is provided, however abundance data at the six distinct sampling sites in the harbour is not reported. A survey of customary and traditional fishing practices within Tauranga Harbour was carried out in 2006 by the Tauranga Moana Iwi Customary Fisheries Management Committee (Tata and Ellis, 2006[12]) which documented important customary species and fishing grounds. However, the findings of this survey are now 10 years out of date. Additionally, there may be some species which are of recreational or commercial but not of customary importance which were therefore not included in this study. Therefore a key gap is information on the abundance and distribution of key species of recreational or customary importance in Tauranga Harbour and key fishing grounds for these species.

[12] Cited in Sinner, J., Ellis, J., Roberts, B., Jiang, W., Goodwin, E., Hale, L., Rolleston, S., Patterson, M., Hardy, D., Prouse, E. and Brown, S. (2011). Health of Te Awanui Tauranga Harbour. Prepared for Manaaki Taha Moana, Manaaki Taha Moana Research Report No. 1. Cawthron Report No. 1969.

Summary of data availability

A summary of the monitoring data available for decline in kaimoana described in this chapter is provided in Table 6.3. The spatial distribution of this data across Tauranga Harbour is illustrated in Figures 6.1 and 6.2. These maps indicate that there is good spread of data available on decline in kaimoana across the harbour, particularly for non-NERMN data.

Table 6.3 Summary of monitoring data available for decline in kaimoana described in this chapter. Parameters measured are categorised as organism abundance and distribution, and organism ecology. Specific detail of parameters measured is provided in the main body of the report. For datasets where the start date varies between monitoring sites, the earliest start date that data is available for across all sites is given. BOPRC – Bay of Plenty Regional Council; MTM – Manaaki Taha Moana MPI – Ministry of Primary Industries. Note that other sources of data on decline in kaimoana which are not included in this table may have been outlined in the main body of this chapter.

Parameters measured		Source	Data start time	Data end time
Abun/Dist.	Ecology			
√	√	BOPRC, NERMN coastal and estuarine ecology monitoring	2006	Present*
√	√	BOPRC, macrobenthic communities one off study (Park and Donald 1994)	1994	1994
√	√	MTM, Broadscale intertidal ecological survey	2012	2012
√	√	MPI, intertidal shellfish monitoring	2000	2016

* Program is ongoing; data will continue to be collected.

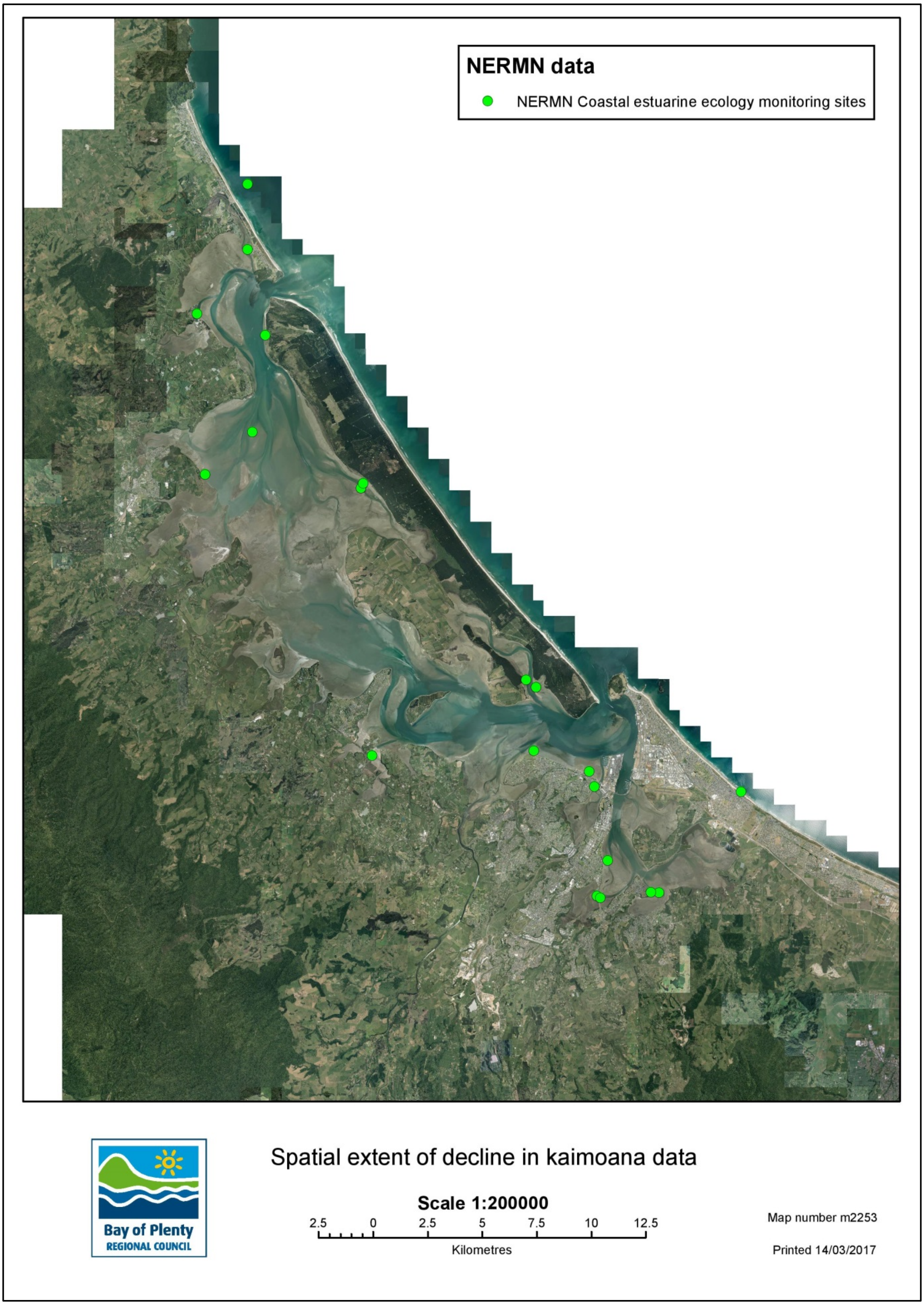

Figure 6.1 *Spatial distribution information about data sources. of decline in kaimoana data for Tauranga Harbour collected as part of the NERMN programme. See Table 6.3 for further note that only current monitoring sites are displayed.*

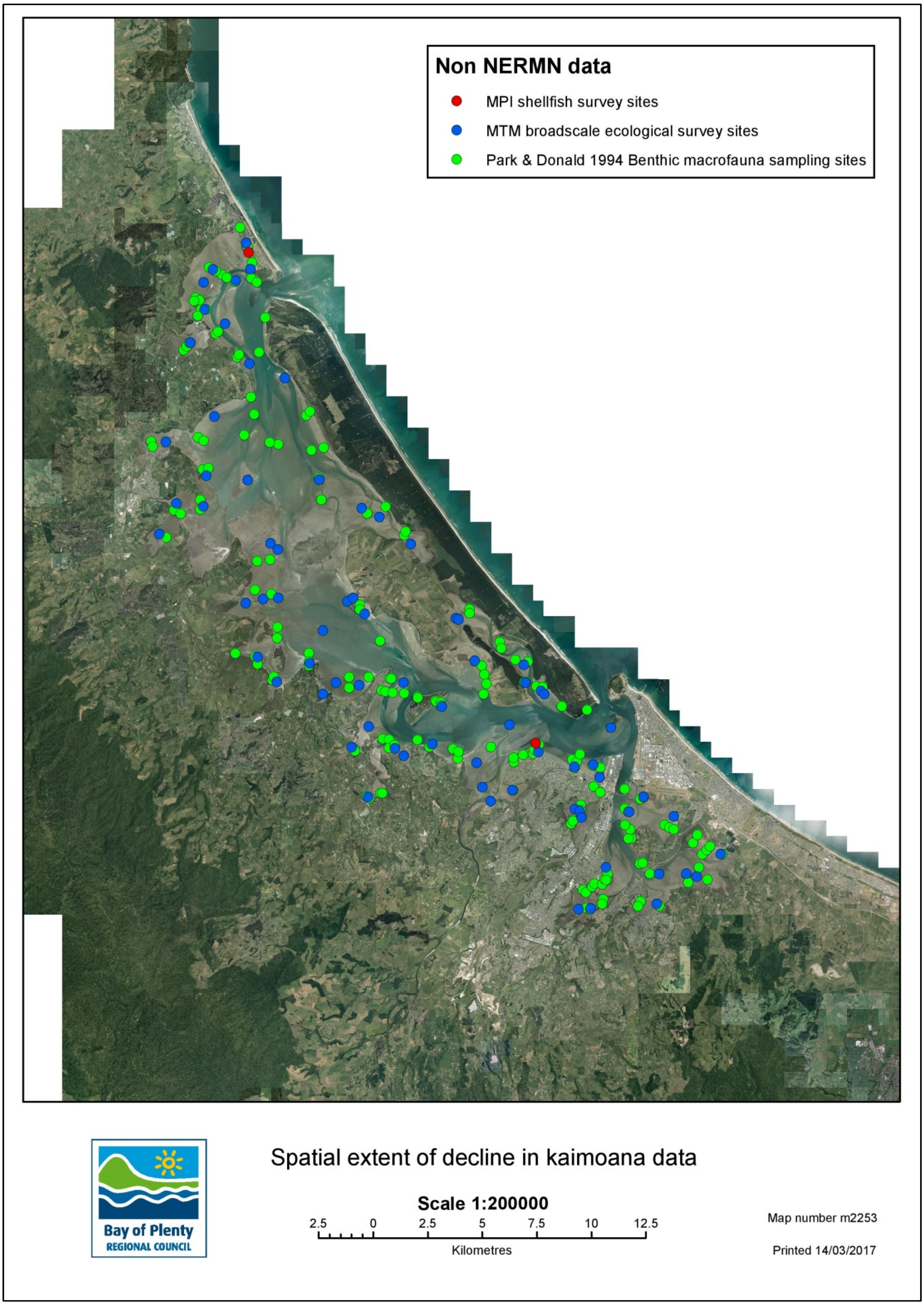

Figure 6.2 *Spatial distribution of decline in kaimoana data for Tauranga Harbour collected outside of the NERMN programme. See Table 6.3 for further information about data sources.*

Relevant reports

Table 6.4 Reference details for the most recent and/or most relevant key reports for each subject covered in this chapter. Only the most recent report is included for regular monitoring programs where sampling sites and parameters monitored remain the same in each consecutive report. Note that other reports are available for this topic which are not included in this table.

Subject	Report
Shellfish	• Berkenbusch, K.; Neubauer, P. (2016). Intertidal shellfish monitoring in the northern North Island region, 2015–16. New Zealand Fisheries Assessment Report 2016/49. 108 p. • Berkenbusch, K.; Neubauer, P. (2015). Intertidal shellfish monitoring in the northern North Island region, 2014–15. New Zealand Fisheries Assessment Report 2015/59. 110 p. • Park, S. (2012). Coastal and estuarine benthic macrofauna monitoring report 2010. Bay of Plenty Regional Council Environment Publication 2012/03. • Bioresearchers Ltd. (1974) Ecological monitoring survey of the lower reaches of the major Bay of Plenty Rivers, the Ohau Channel, and parts of Tauranga Harbour (Winter 1974), Unpublished report prepared for the Bay of Plenty Catchment Commission. • Park, S. and Donald, R. (1994). Environment Bay of Plenty Tauranga Harbour Regional Plan environmental investigations: ecology of Tauranga Harbour. Environment Bay of Plenty Environmental Report 1994/08. • Ellis, J., Clark, D., Hewitt, J., Sinner, J., Patterson, M. Hardy, D., Park, S., Gardner B., Morrison, A., Culliford, D., Battershill, C., Hancock, N., Hale, L., Asher, R., Gower, F., Brown, E., McCallion, A. (2013). Ecological Survey of Tauranga Harbour. Prepared for Manaaki Taha Moana, Manaaki Taha Moana Research Report No. 13. Cawthron Report No. 2321. • Scholes, P. (2014) Recreational Waters Surveillance Report 2013/2014. Bay of Plenty Regional Council Environment Publication 2014/09. • Scholes P., Greening G., Campbell D., Sim J., Gibbons-Davies J., Dohnt G., Hill K., Kruis I., Shoemack P., Davis A. (2009) Microbiological Quality of Shellfish in Estuarine Areas: Joint Agency Research Report, Environment Bay of Plenty, Institute of Environmental Science and Research, New Zealand Food Safety Authority, Tauranga City Council, Western Bay of Plenty District Council, Toi Te Ora Public Health Service.
Fish	• Morrisey D., Beard, C., Morrison, M., Craggs, R. & Lowe, M. (2007). The New Zealand Mangrove: Review of the Current State of Knowledge. Report prepared for the Auckland Regional Council by NIWA. Client report HAM2007-052. Auckland Regional Council Technical Publication No. 325. Hamilton.

Information gaps

The following table identifies gaps in our current scientific knowledge of decline in kaimoana for the Tauranga Harbour and explains why knowledge of these gaps is important. A reference number (Ref no.) for each gap is provided to allow easy cross referencing with the research recommendations provided for each gap in Part 8 (Table 8.2). This is an un-prioritised list of all identified gaps, large or small. Further assessment of need, urgency, and resourcing required will be carried out to determine which gaps will be filled, when and how. Gaps related to quantifying harvests, stock status and basic biology of target species are not addressed here as they are the responsibility of the Ministry for Primary Industries and therefore are considered out of scope of this report.

Table 6.5 Information gaps for decline in kaimoana.

Ref no.	Topic	Gap	Relevance
31	Shellfish	There is no literature review or report synthesising the findings of multiple discrete reports on shellfish in Tauranga Harbour.	Reporting by the Ministry for Primary Industries on shellfish stocks generally occurs at a scale that reveals little about the harbour wide health of stocks in Tauranga Harbour. Multiple studies exist which provide a considerable amount of information on the distribution, abundance and population structure of cockles and pipis in Tauranga Harbour. However, it is difficult to gain an overall picture of the status of these shellfish and trends in population abundance and distribution over time without synthesis of their findings in a single report. A literature review of information about key kaimoana species in Tauranga Harbour would fill this gap. Such a report would provide important background information which could be used to inform the upcoming limit setting process that will occur when the NPS-FM is implemented in the Tauranga Water Management Area.
32	Shellfish	Limited information on the location of important shellfish gathering beds for iwi and local communities.	Information about the location of important shellfish gathering beds will enable activities in the harbour and catchment to be managed to prevent degradation of habitats and water in the vicinity of these areas.
33	Shellfish	We do not have a good understanding of the degree of connectivity between populations of shellfish within different regions of the harbour and the surrounding area.	An understanding of population connectivity will enable predictions to be made about the likely recovery potential of declining populations and could help to focus management actions on areas with high recovery potential.

Ref no.	Topic	Gap	Relevance
34	Shellfish	Current monitoring programs determining whether shellfish are safe to eat do not monitor any parameters which provide a reliable indicator of viral contamination.	Research has demonstrated that indicator bacteria may not be reliable indicators of viral contamination in shellfish and consequently, shellfish may not be safe to eat even when the bacterial quality is within currently accepted microbiological limits. Shellfish sampled at Tilby Point and Pilot Bay were found to be regularly contaminated with viruses. However, the current monitoring program provides no reliable method to detect this contamination and issue a public health warning to prevent shellfish gathering.
35	Fish	Limited information on the abundance and distribution of key fish species of recreational or customary importance in Tauranga Harbour and key fishing grounds for these species.	A greater understanding of the distribution and status of kaimoana stocks in Tauranga Harbour and key fishing grounds for these stocks is required in order activities on the land and in the harbour to be sustainably managed to prevent adverse impacts on these stocks.

Part 7:

Recommendations

Introduction

A summary of all the gaps identified in this report and recommendations for research projects to fill these gaps are presented in Table 7.2. This is an un-prioritised list of all identified gaps, large or small. Further assessment of need, urgency, and resourcing required will be carried out to determine which gaps will be filled, when and how.

The gaps are grouped by issue:

(a) Water quality

(b) Sediment dynamics

(c) Habitat degradation

(d) Decline in kaimoana

A reference number for each gap is provided to allow easy cross referencing with the Information gaps section at the end of each chapter (Parts 3, 4, 5, 6).

Research recommendations are assigned to the following gap themes:

(a) Obtain new data

(b) Improvements to methods and reporting

(c) Modelling

(d) Review state of knowledge

A summary of the number of gaps assigned to each theme for each issue is given in Table 7.1. A total of 35 gaps were identified across all key issues. The greatest number of gaps was identified for the key issues habitat degradation and issue water quality (12 gaps each). The least number of gaps was identified for the key issue decline in kaimoana (five gaps). Differences in the number of gaps identified for each key issue may reflect the amount of effort and resourcing currently allocated to each of these issues. For example, a considerable amount of resourcing is allocated to projects contributing to the key issue of habitat degradation (the issue with the greatest number of gaps), while a smaller amount of resourcing is allocated to projects contributing to the key issue of decline in kaimoana (the issue with the least number of gaps). One potential explanation for this relationship is that gaps are more evident in areas where we have a more advanced knowledge and understanding of the issue (e.g. habitat degradation) compared to areas where knowledge and understanding is limited (e.g., decline in kaimoana).

The greatest number of gaps (18 gaps) across all key issues was assigned to the gap theme obtain new data (Table 7.1), identifying a clear need for BOPRC to direct more resources into this area. The least number of gaps were assigned to the gap theme modelling (three gaps). These trends may reflect the fact that implementation of the NPS-FM has not yet begun in the Tauranga Harbour WMA and therefore there has not yet been a strong need to develop models to inform decisions on setting values and objectives for streams and rivers.

Table 7.1 Summary of the number of information gaps for each key issue assigned to each gap theme.

	Obtain new data	Improvements to methods and reporting	Review State of Knowledge	Modelling	TOTAL
Water quality	4	5	1	2	**12**
Sediment dynamics	3	1	1	1	**6**
Habitat degradation	8	1	3	0	**12**
Decline in kaimoana	3	1	1	0	**5**
TOTAL	**18**	**8**	**6**	**3**	**35**

Conclusions

BOPRC monitors a wide range of parameters in Tauranga Harbour and has considerable data available related to the key issues of water quality, sediment dynamics, habitat degradation and decline in kaimoana. However, this analysis has highlighted key gaps in our knowledge and understanding of these issues. The challenge is how to best fill these gaps given the reality of constrained resources and time. The next step is to prioritise and rank these gaps. In undertaking such a ranking process, it is important to consider a number of key issues, including that:

- there is a need for better integration of different science programmes
- there is a need to consider which gaps will need to be filled to enable implementation of the NPS-FM, and
- there is a need to consider the data and information needed to support computer models.

By considering these issues as part of the gap analysis and prioritisation process, it is expected that more informed decisions can be made about gaps which need to be addressed as a matter of urgency and those which can be regarded as optional.

Table 7.2 Information gaps for each key issue, recommended research projects to address these gaps, and gap themes assigned to each research recommendation. A reference number (Ref no.) for each gap is provided to allow easy cross referencing with the Information gaps section at the end of each chapter.

Ref no.	Gap	Research recommendations	Gap theme
Water quality			
1	The revised estuarine water quality sampling program has now been running for over 12 months but has not yet been reviewed.	Review data collected from revised sampling program.	Improvements to methods and reporting.
2	We have a limited understanding of the influence of El Nino weather patterns on nutrient dynamics in Tauranga Harbour.	Undertake targeted water sampling program in summer in El Nino and non-El Nino years to collect baseline data. This work is currently underway. This research will also address Gap 30.	Obtain new data.
3	We have a limited understanding of the influence of submarine groundwater discharge of nutrient dynamics in the harbour. Key gaps are an understanding of the location and stability of groundwater seeps in the harbour and an estimate of the age of the groundwater entering the harbour.	These gaps are being investigated as part of Ben Stewart's PhD (University of Waikato).	Obtain new data.
4	We don't have a clear understanding of the contribution of sediment nutrient recycling to nutrients loads in estuarine water.	Conduct literature review on the contribution of sediment nutrient recycling to nutrient loads in estuarine water. Investigate opportunities for collaborative research on this topic with University of Waikato. This research will also address Gap 28.	Review state of knowledge.
5	BOPRC does not conduct any monitoring of heavy metals, agrichemicals (e.g. herbicides, pesticides) or other contaminants in the water and only limited data on this is available from self-monitoring conducted by consent holders and Julien Huteau's PhD research project.	Undertake a comprehensive one-off survey of heavy metals, agrichemicals (e.g. herbicides, pesticides) and any other contaminants of concern in estuary water to provide baseline data. This data could then be used to ground truth expected levels of these compounds based on sediment contaminant surveys. The results of this survey could be included in the next NERMN Estuary Water Quality Report.	Obtain new data.
6	Bathing water quality is currently only sampled weekly. A more accurate real time indication of bathing water quality, such as a microbial water quality model, is needed.	Develop microbial water quality model to predict bathing risk.	Modelling.

Ref no.	Gap	Research recommendations	Gap theme
7	The on-site effluent monitoring programme was established in 1996 and the communities monitored as part of this programme have not been updated since this time.	Assess the number of dwellings with on-site treatment systems in communities bordering the harbour to determine whether any additional communities need to be monitored.	Improvements to methods and reporting.
8	Limited understanding of the distribution, magnitude and combined effects of discharges managed under multiple consents and their potential cumulative effects on the estuarine environment. Monitoring data collected by consent holders is collated and reported infrequently by BOPRC. The last report on the impacts of effluent discharges on receiving water was published in 2008.	Compile updated report on stormwater, wastewater and industrial discharges into the harbour.	Improvements to methods and reporting.
9	There is a lack of water quality data available for the harbour in the region spanning from Ōmokoroa to Kauri Point.	Add an extra sampling site at Matahui Point or somewhere similar to the NERMN estuary water quality monitoring programme.	Improvements to methods and reporting.
10	There is no overall assessment of the estuarine water quality data, each type of data is currently assessed in separate reports and water quality data has not been assessed against a relevant framework/set of guidelines to provide some context to the results. There is no overall rating for estuarine health.	Review available approaches for assessment of estuarine health, select an appropriate approach and use to assess the health of Tauranga Harbour.	Improvements to methods and reporting.
11	There is no comprehensive hydrodynamic model for the entire harbour which incorporates nutrient, sediment and potentially contaminant input to the harbour.	Develop a comprehensive hydrodynamic model for Tauranga Harbour. Data collected from a continuous monitoring logger as recommended in Gap 12 could inform development of this model. A simple hydrodynamic model (e.g. physical water processes only, not incorporating other inputs to the harbour) is currently being developed as part of the coastal hazards work plan (Mark Ivamy) in collaboration with NIWA. This is expected to be completed by mid-2018. Once complete, the model could be expanded to incorporate nutrient, sediment and potentially contaminant input to the harbour.	Modelling.

Ref no.	Gap	Research recommendations	Gap theme
12	There is no a continuous monitoring logger or buoy in the harbour which records physical water quality data and nutrient concentrations.	Install a continuous monitoring logger in the southern harbour. Data from such a logger could also be used to inform development of a hydrodynamic model as recommended under Gap 10. Explore potential for BOPRC Environmental Data Services Team to undertake the fieldwork component of this work. This work will also address Gap 28.	Obtain new data.
Sediment dynamics			
13	It has been at least 10 years since sediment transects were resurveyed.	Engage BOPRC Engineering team to resurvey all remaining sediment transects across the harbour. Analyse results and compile into report. This work will also address Gap 23.	Obtain new data.
14	Understanding the current sources and causes of sediment inputs to waterways, including an understanding of what proportion of the sediment load is natural as opposed to human induced.	Undertake a study to determine sources of sediment inputs to waterways.	Modelling.
15	We don't have any estimates of historical (pre-human) sedimentation rates in the various estuaries around the harbour. We do not know how rates have varied over the past 100 years for example compared to present times.	Undertake sediment core sampling to determine historic and current sedimentation rates and investigate how they have varied over time. Sampling should occur at least in the three estuaries that are being continuously monitored for sediment inflows (Waimapu, Waikareao and Tuapiro). Explore potential to undertake this research work through a University of Waikato student project.	Obtain new data.
16	No single report summarising and linking all sedimentation data together.	Compile report reviewing and synthesising all available sedimentation data.	Review state of knowledge.
17	Sampling of bioavailable component of contaminants in harbour through shellfish monitoring is infrequent and does not cover all areas of the harbour.	Review shellfish contaminant monitoring program and design an integrated program which combines shellfish monitoring at 5 - 10 yearly intervals and monitoring using passive sampling devices at 3 - 5 yearly intervals distributed across the harbour.	Improvements to methods and reporting.

Ref no.	Gap	Research recommendations	Gap theme
18	No baseline data or monitoring of emerging organic contaminants (EOCs) in the harbour.	Undertake a review of international studies and data to determine which EOCs are likely to be present in the harbour and are likely to be impacting on ecological communities. Based on the findings of this review, conduct baseline monitoring. Results of this research could be included in the next NERMN sediment contaminant monitoring report. Results of this research could also be used to inform the review of the shellfish contaminant monitoring program recommended to fill Gap 19.	Obtain new data.
Habitat degradation			
19	The degree of connectivity between seagrass beds in different parts of the harbour and the levels of genetic diversity both within and among populations is unknown.	Undertake study on connectivity and diversity of seagrass beds in Tauranga Harbour. Explore potential to undertake this research work through a University of Waikato student project.	Obtain new data.
20	An understanding of the factors driving seagrass decline, and in particular, whether these are the same in subtidal and intertidal areas.	Conduct a literature review on the key factors driving seagrass decline.	Review state of knowledge.
21	Lack of data on sediment profiles and characteristics in all sub-estuaries (e.g. measurement of depth of mud and underlying sandy substrate).	This gap should be filled by resurveying sedimentation transects as recommended under Gap 14.	Obtain new data.
22	Knowledge of levels of sediment contamination within mangroves.	Undertake targeted study of sediment contamination within mangroves. Results of this study could be incorporated into the next NERMN sediment contaminant monitoring report.	Obtain new data.
23	Lack of data on mangrove below ground decomposition rates.	Conduct literature review of mangrove decomposition rates. Undertake an experimental study on this topic If insufficient information is found through a literature review. Explore potential to undertake this research work through a University of Waikato student project.	Review state of knowledge.

Ref no.	Gap	Research recommendations	Gap theme
24	Bathymetry of subtidal areas throughout Tauranga Harbour need updating.	Update bathymetry of subtidal areas throughout Tauranga Harbour. This work is currently underway through the coastal hazards work program at BOPRC (Mark Ivamy), in collaboration with NIWA, as part of the development of a hydrodynamic model for Tauranga Harbour (see Gap 11). It is expected that the update of the bathymetry dataset will be completed by mid-2017.	Obtain new data.
25	Spatial assessment of intertidal sea lettuce abundance across the whole harbour needs to be improved as abundance is currently only monitored at three intertidal sites and there is no monitoring of subtidal sites.	Review sea lettuce monitoring program.	Improvements to methods and reporting.
26	The contributions of sediment nutrient recycling to sea lettuce growth are currently unknown.	This gap is addressed through research recommendations for Gap 4.	Review state of knowledge.
27	The frequency of nutrient measurements within the harbour needs to be improved.	This gap is addressed through research recommendations for Gap 12.	Obtain new data.
28	The influence of El Nino weather patterns on nutrient concentrations in water around the harbour is unknown.	This gap is addressed through research recommendations for Gap 2.	Obtain new data.
29	We have a very limited understanding of how light availability in the harbour affects primary productivity.	Undertake targeted fieldwork to measure spatial and temporal variation in photosynthetically active radiation for key benthic primary production habitats in Tauranga Harbour and conduct experimental study to determine light thresholds for key primary producers. Explore potential to undertake this research work through a University of Waikato student project.	Obtain new data.
30	Different subtidal habitat types within the harbour such as shellfish beds, worm fields and biogenic reefs have not been fully mapped.	Map subtidal habitats in Tauranga Harbour. This gap may be filled through Sam McCormacks PhD (University of Waikato) which will include a component mapping biogenic habitats in Tauranga Harbour.	Obtain new data.

Ref no.	Gap	Research recommendations	Gap theme
Decline in kaimoana			
31	There is no literature review or report synthesising the findings of multiple discrete reports on shellfish in Tauranga Harbour.	Conduct literature review on the growth, distribution and ecology of shellfish of recreational and customary importance in Tauranga Harbour. Incorporate into a single report with research recommended in Gap 33.	Review state of knowledge.
32	Limited information on the location of important shellfish gathering beds for both iwi and local communities.	This information is currently being compiled for iwi by Manaaki Te Awanui as part of the OTOT study.	Obtain new data.
33	We do not have a good understanding of the degree of connectivity between populations of shellfish within different regions of the harbour and the surrounding area.	Undertake study on the connectivity of populations of shellfish of recreational and customary importance in Tauranga Harbour. Incorporate into a single report with literature review recommended in Gap 31.	Obtain new data.
34	Current monitoring programs determining whether shellfish are safe to eat do not monitor any parameters which provide a reliable indicator of viral contamination.	Investigate the feasibility of monitoring shellfish for viral contamination.	Improvements to methods and reporting.
35	Limited information on the abundance and distribution of key fish species of recreational or customary importance in Tauranga Harbour and key fishing grounds for these species.	Explore potential to undertake this research through a University of Waikato student project linked with Gap 36.	Obtain new data.

Part 8:

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