Marine Monitoring and Reporting Framework

Department of Conservation
Te Papa Atawhai

Te Kāwanatanga o Aotearoa
New Zealand Government

Cover: The nudibranch *Jason mirabilis* laying its pink eggs on *Solanderia ramosa* on the starboard side of the wreck of the *Rainbow Warrior*, Cavalli Islands. *Photo: Crispin Middleton, SeacologyNZ*

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CONTENTS

1.	Introduction	vi
2	The framework	12
3	Theme 1 – Identify the proportion of ecosystems protected	32
4	Theme 2 – Determine changes in habitat composition and condition	44
5	Theme 3 – Define and track climate change indicators	61
6	Theme 4 – Describe the abundance and demography of key species	78
7	Theme 5 – Determine the rates of compliance	102
8	Theme 6 – Evaluate environmental water quality indicators	117
9	Theme 7 – Understand human uses of and relationships with marine reserves	140
10	Theme 8 – Detect non-indigenous species	150
11	Theme 9 – Determine the effects of extreme events	161
12	Theme 10 – Understand the impact of pollution	175
13	Reviewing and auditing	187
14	References	189
	Appendix 1	200
	Network guidance process for Theme 1 – Identify the proportion of ecosystems protected	
	Appendix 2	203
	Additional data sources for Theme 3 – Define and track climate change indicators	
	Appendix 3	204
	Selection of water quality variables for Theme 6 – Evaluate environmental water quality indicators	
	Appendix 4	213
	Additional measures for Theme 7 – Understand human uses of and relationships with marine reserves	
	Appendix 5	217
	Toolbox selection for Theme 9 – Determine the effects of extreme events	
	Appendix 6	220
	Litter monitoring programmes for Theme 10 – Understand the impact of pollution	

Executive summary

Marine reserves protect the unique biodiversity of Aotearoa New Zealand by prohibiting extractive activities from occurring within them. Marine reserves are established through the Marine Reserves Act 1971, which is administered by the Department of Conservation Te Papa Atawhai (DOC). This Act stipulates that the purpose of marine reserves is for the scientific study of marine life, with these areas acting as 'scientific control sites' to understand how a particular marine ecosystem operates when left in as near to a natural state as possible.

Aotearoa New Zealand has a network of marine reserves that includes most bioregions, from the warm subtropical Kermadec Islands in the far north to the cold and wild subantarctic islands in the far south. Marine reserves are managed at place through the application of compliance, monitoring, education and advocacy. In the past, the monitoring of marine reserves in Aotearoa New Zealand has been inconsistent, with different approaches and standards being applied across the network.

This Marine Monitoring and Reporting Framework (MMRF) outlines DOC's proposed approach to monitoring marine reserves nationally, including what will be monitored at place and how this will be achieved, and will be co-designed and co-implemented with tangata whenua (whānau, hapū and iwi) and communities where there is interest to do so. Over time, a monitoring plan will be developed for each marine reserve that is based on the aspirations of tangata whenua, the community and DOC, resulting in a set of monitoring plans designed to address priorities at both the national (as outlined in the MMRF and supported by kaitiaki (guardians) and communities) and local (as identified by kaitiaki and communities) levels.

The overarching purpose of the MMRF is to provide a national marine monitoring and reporting framework that will enable the evaluation of the status and trends of marine reserve ecological integrity. The MMRF has been developed to enable DOC to work collectively towards achieving and measuring the objectives of Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy[1] and consists of 10 themes which are presented in no particular order as the objectives for monitoring marine reserves differ across the network:

- Theme 1: Ecosystem representation
- Theme 2: Habitat composition and condition
- Theme 3: Climate change
- Theme 4: Key species
- Theme 5: Compliance
- Theme 6: Water quality
- Theme 7: Human use
- Theme 8: Non-indigenous species
- Theme 9: Extreme events
- Theme 10: Pollution

The structure of the MMRF is guided by the Integrated Monitoring Framework for the Great Barrier Reef.[2] The indicators and measures were taken from DOC's Outcome Monitoring Framework. Each theme covers background information, monitoring objectives, existing monitoring programmes, sampling design, monitoring protocols, data management, data

1 www.doc.govt.nz/nature/biodiversity/aotearoa-new-zealand-biodiversity-strategy/

2 Hedge, P.; Molloy, F.; Sweatman, H.; Hayes, K.; Dambacher, J.; Chandler, J.; Gooch, M.; Chinn, A.; Bax, N.; Walshe, T. 2013: An integrated monitoring framework for the Great Barrier Reef World Heritage Area. Department of the Environment, Canberra.

analysis and reporting. The monitoring objectives for each theme were designed to be specific, measurable, achievable, realistic and time-bound (SMART). Due to logistical and financial constraints, the monitoring objectives are not always ideal, but they are functional and achievable. The MMRF is intended to be a living document and will be updated as further information and resources become available.

The MMRF has been developed for internal and external stakeholders who wish to gain an in-depth understanding of what DOC aims to monitor in marine reserves and why. These stakeholders include operational staff at place, who will be imperative in implementing the work; tangata whenua and communities who want to partner with DOC to co-design and co-implement monitoring plans for their marine reserves; and DOC's central and local government colleagues and Crown Research Institute and university partners, who are invaluable in implementing the monitoring.

1. Introduction

Aotearoa New Zealand is a maritime nation, covering vast, diverse and unique waters. It is important to protect the marine environment to provide for the needs of current and future generations, recognising that a healthy marine environment, with a diverse range of species, is important for human wellbeing, holds intrinsic values and is better able to adapt to pressures. Māori have a genealogical connection to the sea and the role of kaitiaki – an inherited responsibility to protect the natural world for future generations. Kaitiakitanga (guardianship and protection) is an essential part of the spiritual and cultural relationship of tangata whenua[3] with the marine environment.

The Department of Conservation Te Papa Atawhai (DOC) is responsible for managing various marine protected areas (MPAs) throughout Aotearoa New Zealand. MPAs are a key tool for protecting biodiversity and managing risks. Marine reserves are the only MPAs where all extractive and destructive activities can be restricted, and many have been established in Aotearoa New Zealand for the purpose of the scientific study of marine life (Marine Reserves Act 1971). Key to the management of marine reserves is the establishment of a national monitoring and reporting framework that may be implemented through different knowledge systems, as DOC needs robust, consistent and relevant data to evaluate what management actions are needed and if those management actions are effective.

DOC's Biodiversity Monitoring and Reporting System consists of three tiers, which together build a picture of ecological integrity (see Box 1.1). The Marine Monitoring and Reporting Framework (MMRF) presented in this report constitutes Tier 2 monitoring: nationally consistent monitoring of managed places and species in the ocean to report on the effectiveness of management. Specifically, the MMRF:

- Provides guidance on how to assess the status and trends of the ecological integrity of marine reserves.
- Provides the evidence for evaluating our progress towards Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020 (ANZBS; DOC 2020c).[4]
- Builds on the objectives, indicators and measures outlined in DOC's Outcome Monitoring Framework (OMF).[5]
- Is made up of 10 themes (habitat representation; habitat composition and condition; climate change; key species; compliance; water quality; human use; non-native species; extreme events; and pollution).
- Describes the types of monitoring that should be implemented in marine reserves around the country.
- Is supported by a practical suite of monitoring methods (including mātauranga Māori (traditional knowledge), DOC's biodiversity and inventory monitoring toolbox,[6] and other nationally accepted protocols for monitoring the marine environment).
- Will be implemented through monitoring plans designed specifically for individual marine reserves in partnership with iwi and local communities where possible.

3 The Māori Dictionary defines the term 'tangata whenua' as 'local people, hosts, indigenous people – people born of the whenua, i.e. of the placenta and of the land where the people's ancestors have lived and where their placenta are buried'.

4 www.doc.govt.nz/nature/biodiversity/aotearoa-new-zealand-biodiversity-strategy/

5 www.doc.govt.nz/our-work/outcome-monitoring-framework/

6 www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/marine/

Box 1.1: DOC's monitoring system

What is ecological integrity?

For DOC, ecological integrity means the degree to which ecosystems can support, maintain or enhance the full range of indigenous biodiversity both within and across ecosystems. It requires:

a) **Ecological representation** – the occurrence and extent of ecosystems and indigenous species and their habitats across the full range of environments.

b) **Composition** – the full range, natural diversity and abundance of species, habitats of species and communities within an ecosystem and across ecosystems, allowing for natural changes such as succession.

c) **Structure** – the biotic and abiotic physical features of an ecosystem.

d) **Functions** – the ecological and physical functions and processes of an ecosystem, including connectivity.

e) **Resilience** to the adverse impacts of natural or human disturbances.

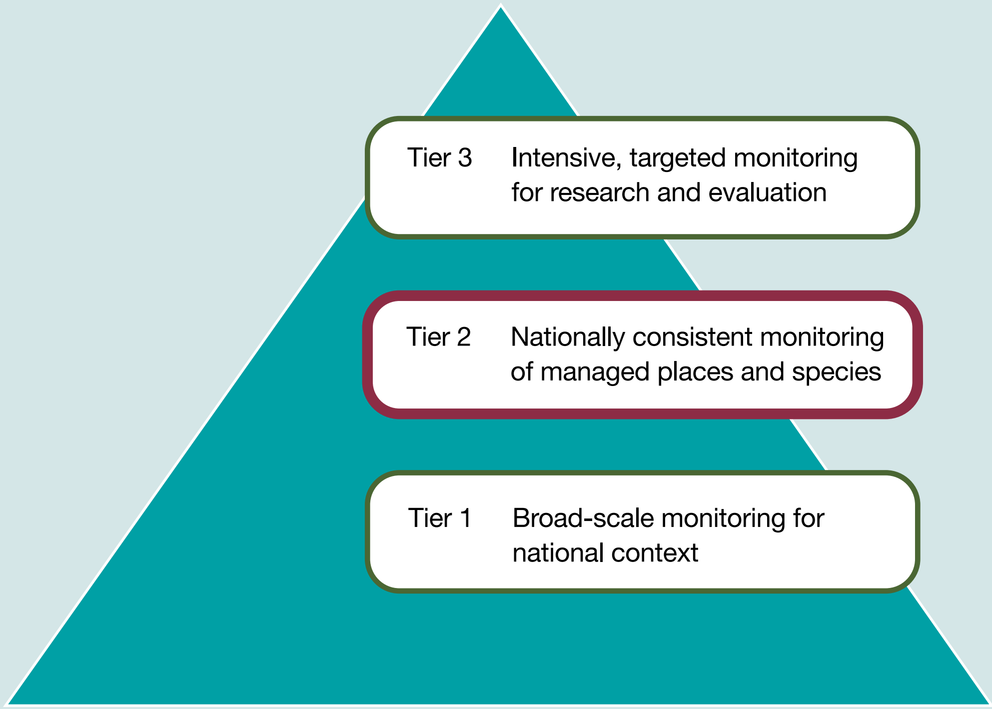

Figure 1.1. Tiers of DOC's biodiversity monitoring and reporting system.

The MMRF is a living document. What has been developed here is just the beginning of a comprehensive and robust piece of work that DOC intends to keep developing with whānau, hapū and iwi and agency and community partners. In the long term, DOC will work with others to develop the MMRF for customary protection areas (e.g. mātaitai and taiāpure) and other areas that achieve biodiversity protection.

1.1 Background

The purpose of the MMRF is:

> *To provide a national marine monitoring and reporting framework to facilitate ongoing assessment of the status and trends in the ecological integrity of marine reserves.*

The MMRF forms part of DOC's progress towards developing guidance for measuring the ecological integrity of protected marine ecosystems. It is intended to serve as the basis for long-term marine reserve monitoring that will inform marine reserve management and provide a means of measuring the extent to which objectives for marine reserves are being met. The framework will also provide a basis for reporting a national picture of the health of protected marine areas across Aotearoa New Zealand. Since the current network of marine reserves does not represent all the habitats and regions (DOC & MFish 2011), it may not always be possible to report on the trends of all indicators outlined in the MMRF. However, despite this limitation, the proposed framework maximises the value of existing methods and data and is intended to be used alongside other information.

1.1.1 Developing the MMRF in partnership with whānau, hapū and iwi

The Conservation Act 1987 applies to all conservation legislation that DOC administers, and section 4 of this Act states, 'the Act shall so be interpreted as to give effect to the principles of the Treaty of Waitangi'. DOC is committed to ensuring that Treaty rights are implemented, as reflected in Outcome 4 of the ANZBS that 'Treaty partner, whānau, hapū and iwi are exercising their full role as rangatira and kaitiaki' (DOC 2020c).

The MMRF has been designed with the flexibility to fulfil the needs of whānau, hapū and iwi (see Box 1.2). This flexibility includes the ability to expand and develop new sections that capture the aspirations of kaitiaki. The MMRF currently includes taonga species and sites of cultural and spiritual importance to Māori, and facilitates whānau, hapū and iwi, through their role as kaitiaki, to choose how, where and when monitoring will occur. This includes (but is not limited to) writing the marine reserve monitoring plan, selecting sites and species to assess, determining how to do the monitoring, and carrying out the monitoring.

Box 1.2: Cultural significance of the moana (ocean)

The moana has enormous cultural importance for Māori. As island people, the stories, traditions, world views and sustenance of Māori people are heavily based on the moana. The energy of the moana takes many forms, sometimes supporting life and sometimes bringing terrible destruction. This energy, in all its forms, is called Tangaroa.

Like all elements of the natural environment, the moana possesses a mauri (life force), of which Māori are kaitiakitanga. The moana has traditionally, and continues to be, an important source of mahinga kai (food-gathering places) for Māori. Connection to the moana is also important for many Māori to have a healthy wairua (spirit).

Future development of the MMRF will be undertaken in collaboration with whānau, hapū and iwi, other government agencies, and stakeholders. Improvements may include:

- Providing guidance on monitoring of other marine protection tools.
- Including new measures to help meet the stated aims of whānau, hapū, iwi and stakeholders.
- Providing guidance on other indicators and measures of the OMF, including additional monitoring objectives or methodologies.

1.2 Marine reserve monitoring

Monitoring is required to ensure that Aotearoa New Zealand's marine reserves are actively, effectively and efficiently managed. Monitoring allows DOC to track the state of marine reserves, support the establishment of new marine reserves, provide public education, provide data for reporting and continuously learn about the wider marine environment. To ensure implementation of an effective network of MPAs, it is important to know what is currently protected and what needs to be protected in the future.

1.2.1 Why does DOC undertake monitoring?

Biodiversity monitoring is the collection and analysis of observations or measurements to evaluate changes in the condition of biodiversity and measure progress towards meeting management objectives (Lovett et al. 2007). More specifically, the purpose of long-term monitoring of marine reserves is to provide a foundation of rigorous data to better inform effective MPA planning and policy development, which will improve accountability, confidence and support for conservation management.

DOC shares monitoring data with other agencies, such as the Ministry for the Environment (MfE), to support national environmental reporting. Data collected from the MMRF will also contribute to Aotearoa New Zealand's international reporting obligations, such as for the Convention on Biological Diversity (CBD).[7]

No monitoring programme can answer all questions, detect all possible impacts or highlight all problems. Implementation of the guidance in the MMRF will be constrained by available time and resources, as well as the specific questions being asked at place. It is important to note that monitoring has value beyond the data it generates, as it also builds capacity and fosters advocacy for environmental concerns. Long-term monitoring can also lead to better understanding of impacts such as climate change and other long-term environmental changes.

Why does DOC need to know about the state of marine reserves?

Knowledge of the state of Aotearoa New Zealand's marine reserve will help to:

- **Inform, educate and involve people –** Marine reserves can benefit and unite communities through education, shared responsibilities, connecting people to their 'big blue backyard' and creating unique attractions that boost the local economy. Marine reserves are also used for the protection of cultural values – for example, Whanganui A Hei (Cathedral Cove) Marine Reserve protects tapu (sacred) sites of Ngāti Hei.
- **Assess existing reserves –** Monitoring to date has improved our fundamental understanding of Aotearoa New Zealand's marine ecology and demonstrated the benefits of marine reserve protection (Table 1.1). The scientific value of Aotearoa New Zealand's marine reserves, including how monitoring programmes have contributed to a better understanding of the structure and function of the country's marine ecosystems, are

7 www.cbd.int/sp/targets/

Table 1.1. Summary of the commitments of the Department of Conservation Te Papa Atawhai (DOC) for marine protected areas (MPAs).

	Needed for	Benefits	Risks if absent
Fulfilment of Aotearoa New Zealand's international commitments	• Reporting on Convention on Biological Diversity Targets. • Working towards Sustainable Development Goals.*	• Aotearoa New Zealand demonstrates leadership in marine conservation. • Aotearoa New Zealand contributes to global conservation efforts. • Aotearoa New Zealand demonstrates its commitment to marine biodiversity conservation.	• Aotearoa New Zealand fails to meet its obligations from ratified conventions. • Aotearoa New Zealand's marine reserves lose their international status as protected areas.
Fulfilment of DOC's national obligations and maintaining credibility	• Informing progress towards Te Mana o te Taiao – Aotearoa New Zealand Biodiversity Strategy 2020 outcomes. • Working towards DOC's intermediate outcomes. • Reporting on the State of the Environment. • Developing conservation management strategies. • Meeting responsibilities to whānau, hapū and iwi.	• DOC's Outcome Monitoring Framework is implemented in the marine environment. • Future marine conservation goals are achievable and based on sound science. • Understanding and reporting on the health of Aotearoa New Zealand's marine environment and trends in ecological integrity are improved.	• DOC's stewardship of MPAs and reliability are considered to be poor by whānau, hapū, iwi and the public. • There is an increased reliance on anecdotal evidence and expert advice by delivering empirical evidence to inform decisions and report on progress towards outcomes.
Management of existing marine reserves	• Informing marine reserve reviews. • Responding to requests for assistance from Operations teams. • Meeting commitments to marine reserve advisory stakeholders. • Making evidence-based management decisions. • Prioritising where resources are focused. • Comparing protected areas and knowing which interventions have worked best.	• Managers, policymakers, scientists and stakeholders are better able to determine the impacts and effectiveness of DOC's management. • There is an improved efficiency of the use of resources by Operations. • Marine reserve prescription reviews are effective. • There is good communication with whānau, hapū, iwi and stakeholders. • News stories are produced for public communication. • Adverse changes are identified and responded to.	• The wellbeing of rangers is reduced. • Marine reserves are ineffectively managed. • There are poor relationships with Māori and stakeholders. • Budget is not allocated in a strategic way. • An improvement of decline in ecological integrity is not identified. • Marine reserves lose their national status as Type I MPAs.
Future MPA initiatives	• Ensuring new MPAs fill gaps in the MPA network. • Undertaking adaptive marine management. • Prioritising where protection measures are most urgently needed. • Demonstrating the contribution of MPAs to wider marine management. • Inform new research questions	• DOC is investment ready. • Data are available for decision support tools. • There is improved advocacy for support of MPA initiatives. • The protection of Aotearoa New Zealand's marine biodiversity is strengthened. • Areas where work and management interventions should be focused are identified.	• New investments in marine conservation are not well spent. • Aotearoa New Zealand is no longer seen as a world leader in conservation. • Aotearoa New Zealand's marine biodiversity is not adequately protected.

* https://sdgs.un.org/goals

summarised by Willis (2013) who also emphasises the role of marine reserves as baselines against which to assess the effects of human activities.

- **Support the establishment of an effective network of MPAs –** Evidence from marine reserve monitoring allows us to support the establishment of new MPAs (Table 1.1) to advance the goal of having an effective, representative network of MPAs around Aotearoa New Zealand.[8] Information from existing marine reserves can help with the design and prioritisation of new MPAs to maximise their effectiveness.
- **Meet domestic and international reporting requirements –** Aotearoa New Zealand is committed to making progress towards and reporting on national and international conservation targets (Table 1.1). To do so, it is necessary to evaluate the status and trends of MPAs, including marine reserves, to provide a picture of their state and health.
- **Make informed management decisions –** A lack of knowledge and understanding of marine species and ecosystems, and the absence of long-term monitoring, are making the development of strategies for conserving marine biodiversity difficult and validation of the effectiveness of such strategies almost impossible. Hence, systematic monitoring is required to inform future conservation strategies.

1.2.2 How will the MMRF improve monitoring in Aotearoa New Zealand's marine reserves?

DOC undertook a review of marine reserve monitoring in 2015, which identified several key areas where improvements could be made to ensure Aotearoa New Zealand meets its legislative, national and international commitments to biodiversity (DOC 2015). The following sections discuss how the MMRF will address these gaps.

Mahi tahi (work together)

A major gap in current marine reserve monitoring is the lack of involvement of Māori (whānau, hapū and iwi) who are kaitiaki. The ongoing development and implementation of the MMRF will allow DOC to continue to work with Māori on what they want to see monitored in their reserves and how this should be achieved.

Provide greater national oversight

Monitoring is currently haphazard and there is no long-term monitoring of most marine reserves. Even where the same species are monitored in several marine reserves, the methods used are not consistent. The MMRF will allow robust and flexible monitoring methods to be implemented at all 44 of Aotearoa New Zealand's current marine reserves and to begin monitoring in areas that are expected to have marine reserves established in the future (e.g. Otago and the Hauraki Gulf). The MMRF will also standardise the methods (to the extent possible) across marine reserves. These changes will allow the state of marine reserves to be compared and reported at a national scale.

Use smarter measures

Current monitoring largely focuses on the relative abundance and size structure of exploited species – i.e. those species that are targeted for extractive use by fishers or collectors. While response variables of these exploited species can indicate the state of their populations within marine reserves, they do not necessarily reflect the condition of the broader ecosystem or whether other values of the marine reserve's kaitiaki and stakeholders have been restored. The MMRF will monitor a comprehensive suite of indicators from the OMF developed as a set of themes, as outlined in sections 3–12.

8 www.doc.govt.nz/nature/biodiversity/aotearoa-new-zealand-biodiversity-strategy/

Strengthen the long-term integrity of the science

The MMRF outlines, coordinates and builds upon existing monitoring programmes. Where effective monitoring already exists, continuation of these valuable time series will be prioritised. Any new monitoring will follow a national standardised approach. For some programmes, new sites will be added where required to build more robust assessments.

2 The framework

The MMRF constitutes Tier 2 monitoring for marine reserves (monitoring managed places) under DOC's Biodiversity Monitoring and Reporting System[10] and will also feed into Tier 1 monitoring, which looks at national trends. The MMRF aims to systematically and concisely address the objectives, indicators (including measures and data elements), priorities, methods and requirements of monitoring informed by DOC's OMF.[11] Although the MMRF's initial focus is on marine reserves, it is designed to be flexible enough to apply to any type of MPA, in case of future changes in MPA policies or the establishment of new types of MPAs. The MMRF will be operationalised through consistent monitoring plans for each marine reserve, which will outline the resources, timeframes, protocols, sample designs and activities needed for data collection, data management, analysis, reporting and review.

2.1 Guiding principles

The 10 themes that comprise the MMRF and their associated measures and approaches have been developed under the following guiding principles.

2.1.1 Engaging tangata Māori

Effective engagement with tangata whenua enhances the conservation of natural resources and historical and cultural heritage. Māori (whānau, hapū and iwi) are tangata moana in many of our coastal places and are critical to developing and implementing the MMRF. Therefore, DOC will partner with Māori to ensure that rangatiratanga (see Box 2.1) is able to be expressed at place.

DOC has a statutory responsibility to interpret and administer the Conservation Act 1987 and all of the Acts listed in Schedule 1 of that Act to give effect to the principles of the Treaty of Waitangi (Conservation Act 1987, section 4). This will occur through the co-development and co-implementation of monitoring plans at each marine reserve. What this looks like will be different for each marine reserve, depending on the needs, aspirations and capacity of Māori at place, and exercising aspirations for rangatiratanga will encompass kaitiakitanga.

The MMRF contains suggestions for what should be monitored at place, but the final monitoring plan will be informed and agreed upon by Māori (whānau, hapū and iwi). Hence, the monitoring plans may include indicators, measures and data elements that are not outlined here. Recognition of the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, wāhi tapu (sacred sites) and other taonga will be embedded into the marine reserve monitoring plans.

10 www.doc.govt.nz/our-work/monitoring-and-reporting-system/
11 www.doc.govt.nz/our-work/outcome-monitoring-framework/

Box 2.1: What is rangatiratanga?

Rangatiratanga describes having the mana or authority to give effect to Māori culture and traditions in the management of the natural world. Recognition of the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, wāhi tapu and other taonga is embedded in the Treaty of Waitangi and thus the Conservation Act 1987.

2.1.2 Using standardised methods

A primary goal of the MMRF is to outline standard methods in the design and implementation of monitoring plans. However, where historical monitoring has occurred, there may be value in continuing with the historical methods to ensure compatibility of future data with the historical time series. Comparisons between different monitoring approaches will be made by converting the observations into response ratios and effect sizes. All statistical methods detailed in the

MMRF are simply recommendations based on common methodologies, and other methods may be used where appropriate or based on new expert recommendations.

2.1.3 Working together

Many stakeholders will benefit from broad-scale marine monitoring, and DOC is committed to engaging with these stakeholders when working to achieve its monitoring objectives. DOC will facilitate community involvement in the development of site-specific monitoring plans, which will vary depending on the local pressures on the marine environment and the values held by tangata whenua and the broader community. For example, DOC will work with regional councils to share resources to sample at a range of sites both inside and outside marine reserves.

2.1.4 Drawing on and contributing to existing monitoring programmes

Marine monitoring already occurs in many forms throughout the country, and DOC is utilising the methods developed and used by other organisations where possible. For example, NIWA, in collaboration with the University of Otago, has a national programme to monitor ocean acidification using a standardised methodology and DOC will add additional sites to the network under the MMRF. This approach enables DOC to place what is happening within marine reserves within a broader national context.

2.1.5 Involving the community and/or citizen science

DOC acknowledges the significant contributions from communities to helping it achieve conservation goals, so the MMRF has been designed to capture this enthusiasm. Several of the themes are amenable to implementation by citizen scientists and producing high-quality data – for example, Sustainable Coastlines utilises a citizen science approach to monitor beach litter. DOC will provide resources to allow this approach to be implemented in marine reserves around the country.

2.2 Development of the framework

The MMRF outlines DOC's approach to monitoring marine reserves in Aotearoa New Zealand. It has been developed from DOC's OMF[12] and addresses two of DOC's intermediate outcomes (IO1[13] and IO3[14]) directly and the remaining two (IO2 and IO4) indirectly. Since IO1 was written with a terrestrial focus, the MMRF takes the IO1[15] and IO3[16] indicators, measures and data elements and groups them into 10 themes that are relevant to the marine environment. This approach enables mātauranga Māori to be incorporated into the implementation (monitoring) plans through approaches such as (but not limited to) the selection of taonga species and sites, methods of monitoring, and the inclusion of customary protection areas (mātaitai and taiāpure; see Box 2.2) as comparative sites. The MMRF has taken DOC's standardised monitoring framework and adapted it to the marine environment as a suggestion of what should be monitored nationally. It does not make any assumptions about what is to be monitored at place. Instead, using guidance from this document, marine reserve monitoring plans will be co-developed and co-implemented with whānau, hapū, iwi and communities.

2.3 Conceptual model of the framework

Creating a framework to monitor Aotearoa New Zealand's marine reserves is complex due to the competing priorities, needs and aspirations for the different marine reserves. Therefore, the MMRF was designed to be a broad, adaptable framework that aims to capture the information needed to meet the outcomes of the ANZBS (Fig. 2.1; DOC 2020c) and to fulfil the aspirations of kaitiaki, communities and other stakeholders (see section 2.1.3).

Figure 2.1. Conceptual model of the Marine Monitoring and Reporting Framework.

12 www.doc.govt.nz/our-work/outcome-monitoring-framework/
13 www.doc.govt.nz/globalassets/documents/our-work/monitoring/omf-intemediate-outcome-1-overview.pdf
14 www.doc.govt.nz/globalassets/documents/our-work/monitoring/omf-intemediate-outcome-2-overview.pdf
15 www.doc.govt.nz/globalassets/documents/our-work/monitoring/omf-assessment-templates-intermediate-outcome-1.pdf
16 www.doc.govt.nz/globalassets/documents/our-work/monitoring/omf-assessment-templates-intermediate-outcome-2.pdf

Box 2.2: Definitions of mātaitai and taiāpure

(Adapted from www.mpi.govt.nz/fishing-aquaculture/maori-customary-fishing/managing-customary-fisheries/)

What are mātaitai reserves?

Mātaitai reserves are developed and managed by tangata whenua to recognise and provide for the special relationship between tangata whenua and their traditional fishing grounds and non-commercial customary fishing.

These reserves allow:

- Customary fishing
- Recreational fishing without needing a permit

They do not:

- Allow commercial fishing (unless reinstated by a regulation)
- Allow landing of commercial catch or holding pots
- Affect commercial fishing vessel activities such as transiting and mooring
- Affect recreational fishing rules unless there are bylaws in place
- Control whitebait fishing
- Affect access to beaches and rivers
- Change restrictions on access to private land

What are taiāpure?

Taiāpure are areas that have customarily been of special significance to iwi or hapū as a source of food or for spiritual or cultural reasons and can only be established in estuarine or coastal waters. Commercial, recreational and customary fishing are allowed in taiāpure unless the associated management committee recommends changes to the fishing rules and the Minister of Fisheries approves these.

When a taiāpure is established, the local Māori community nominates people for the management committee. The committee is appointed by the Minister of Fisheries, after consultation with the Minister for Māori Development, and can provide recommendations to the Minister of Fisheries for regulations (under the Fisheries Act) to manage taiāpure fisheries relating to:

- Species fished
- Fishing seasons
- Sizes and amounts of fish
- Fishing areas
- Fishing methods

The first outcome of the ANZBS is 'Ecosystems, from mountain tops to ocean depths, are thriving', which is captured in Objective 1 of the MMRF. Reporting on ecosystem representativeness (Theme 1) and monitoring habitat composition and condition (Theme 2) will improve our understanding of whether the current network is adequate to ensure the health and integrity of marine ecosystems. This understanding will then be built on by monitoring changes in key species (Theme 4), the presence or absence of non-indigenous species (Theme 8) and the impacts of extreme events (Theme 9).

The second outcome of the ANZBS is 'Indigenous species and their habitats across Aotearoa New Zealand and beyond are thriving', which is captured in Objective 2 of the MMRF. Working closely with whānau, hapū and iwi will allow us to identify taonga species at place and monitor them using guidance from Theme 4 (key species), while unwanted species will be monitored using Theme 8 (non-indigenous species). The MMRF also provides guidance on how to monitor the changing environment around these species, including climate change (Theme 3), water quality (Theme 6), pollution (Theme 10) and extreme events (Theme 9). This work will be supported through developing an understanding of how people use marine reserves using Theme 5 (compliance) and Theme 7 (human use).

The third outcome of the ANZBS is 'People's lives are enriched through their connection with nature', which is captured in Objective 3 of the MMRF. This will be explicitly monitored through Theme 7 (human use), but the framework aims to use monitoring tools from other themes to include whānau, hapū, iwi and communities in the ongoing monitoring of their reserves. For example, pollution could be monitored by drawing on the national litter programme that utilises citizen scientists to collect and record litter from their marine reserves.

The fourth outcome of the ANZBS is 'Treaty partners, whānau, hapū and iwi are exercising their full role as rangatira and kaitiaki', which is captured in Objective 4 of the MMRF. The criteria for meeting this objective are not explicitly outlined in the MMRF, as this can only be assessed by whānau, hapū and iwi. However, DOC will work closely with whānau, hapū and iwi at each marine reserve to ensure that they have the necessary resources and support to be rangatira (chiefs) and kaitiaki of their rohe (area).

As with the ANZBS, the MMRF implementation will be guided by three pou (pillars) that help to focus efforts to achieve the objectives: Tūāpapa, Whakahau and Tiaki me te whakahaumanu.

Tūāpapa is about getting the system right by ensuring that:

1. Governance, legislation, and funding systems are in place and enable delivery of the strategy outcomes
2. Whānau, hapū, iwi and Māori organisations are rangatira and kaitiaki
3. Biodiversity protection is at the heart of economic activity
4. Improved systems for knowledge, science, data, and innovation inform the work
5. Mātauranga Māori is an integral part of biodiversity research and management
6. Aotearoa New Zealand is making a meaningful contribution to biodiversity globally

This will be achieved by:

- Developing a flexible framework that meets the needs of DOC, whānau, hapū, iwi and the community
- Providing reliable and valid data that can be used for national and international reporting
- Engaging with whānau, hapū, iwi, the community, universities, Crown Research Institutes, and other government agencies early and often

Whakahau is about empowering action by ensuring that:

1. All New Zealanders have the skills, knowledge, and capability to be effective

2. Resourcing and support are enabling connected, active guardians of nature
3. Collaboration, co-design, and partnership are delivering better outcomes

This will be achieved by:

- Providing the resources and guidance needed for whānau, hapū, iwi and the community to undertake the monitoring at place themselves
- Spending more time telling the story of the marine reserve and the results of the monitoring

Tiaki me te whakahaumanu is about protecting and restoring by ensuring that:

1. Ecosystems and species are protected, restored, resilient and connected ki uta ki tai (from the mountain tops to the ocean depths)
2. Biological threats and pressures are reduced through management
3. Natural resources are managed sustainably
4. Biodiversity provides nature-based solutions to climate change and is resilient to its effects

This will be achieved by:

- Using the findings from the monitoring, both mātauranga and scientific, to make informed decisions about management interventions
- Ensuring that marine reserve monitoring information is included in policy decision making

2.4 Implementation of the framework

The MMRF outlines the monitoring that is required to comprehensively evaluate the condition of Aotearoa New Zealand's marine reserves. However, it will not be possible to implement monitoring to achieve the objectives of all 10 themes at all marine reserves. Therefore, representative marine reserves will be selected from each bioregion in Aotearoa New Zealand (DOC & MFish 2011), and over time all 10 themes will be implemented at these sites to provide a picture for each bioregion. All marine reserve monitoring plans will be co-developed with whānau, hapū and iwi, and it is acknowledged that additional monitoring will be needed in some areas to meet whānau, hapū and iwi needs and respond to local management issues. The processes used to design and implement the MMRF are summarised in Fig. 2.2.

2.4.1 Representative sites

The MMRF constitutes Tier 2 monitoring under DOC's biodiversity monitoring system, which focuses on delivering the detailed information needed to manage places and species effectively. This level of monitoring is more focused and intensive than Tier 1 monitoring, which constitutes a systematic sampling programme for all public conservation land that has not yet been expanded to the marine space.

Tier 2 monitoring involves consistent, rigorous monitoring of specific activities in the marine environment. A nationally consistent approach is needed to allow the data to be combined and compared across marine reserves to build an understanding of their ecological integrity.

Representative marine reserve where all themes will be implemented will be selected to ensure the following criteria are met:

- Whānau, hapū and iwi support and are involved in the monitoring
- There is at least one marine reserve from each bioregion
- The site has appropriate resources for implementing monitoring
- The reserve has a dedicated marine ranger

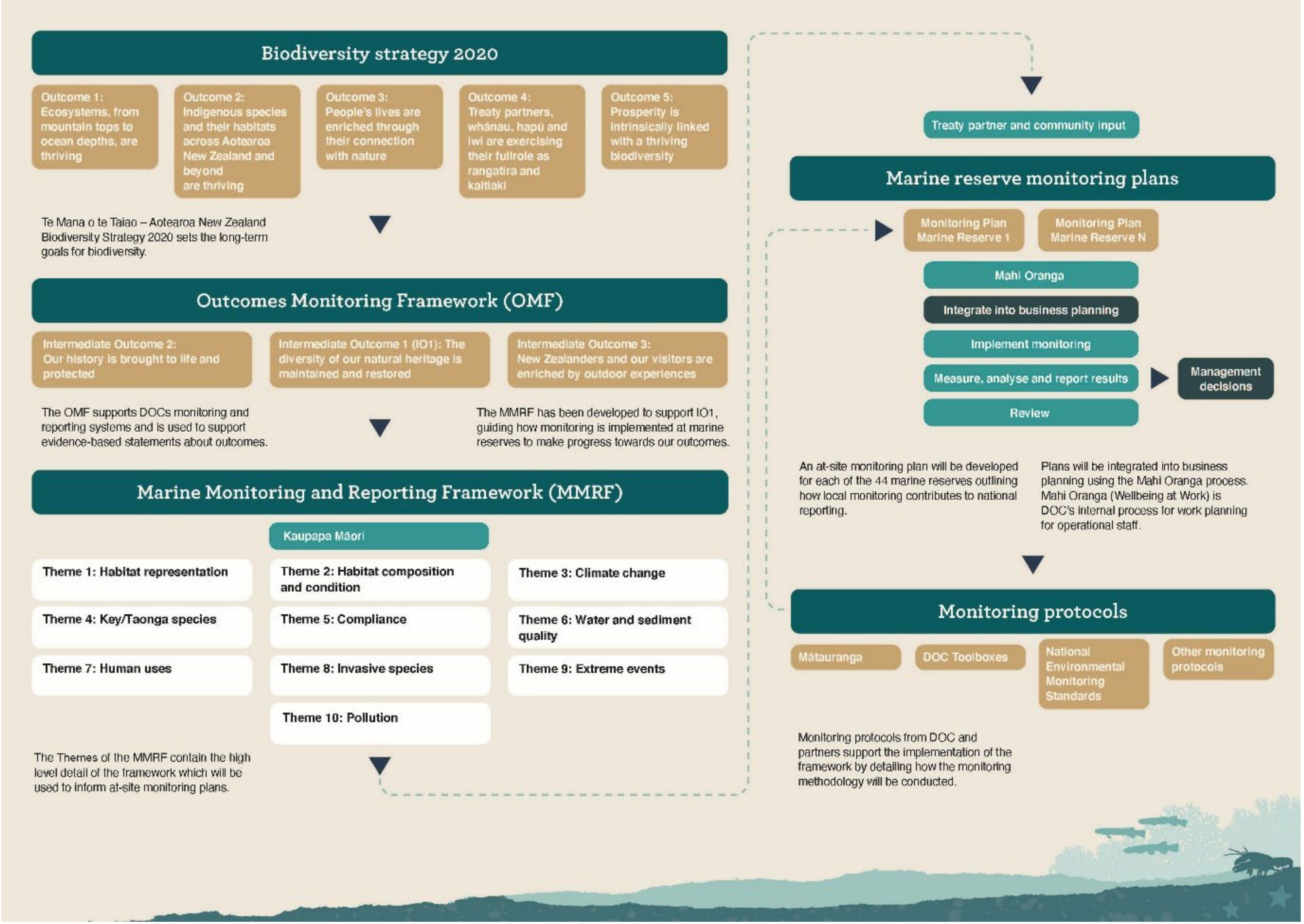

Figure 2.2. Model of the design and implementation of the Marine Monitoring and Reporting Framework.

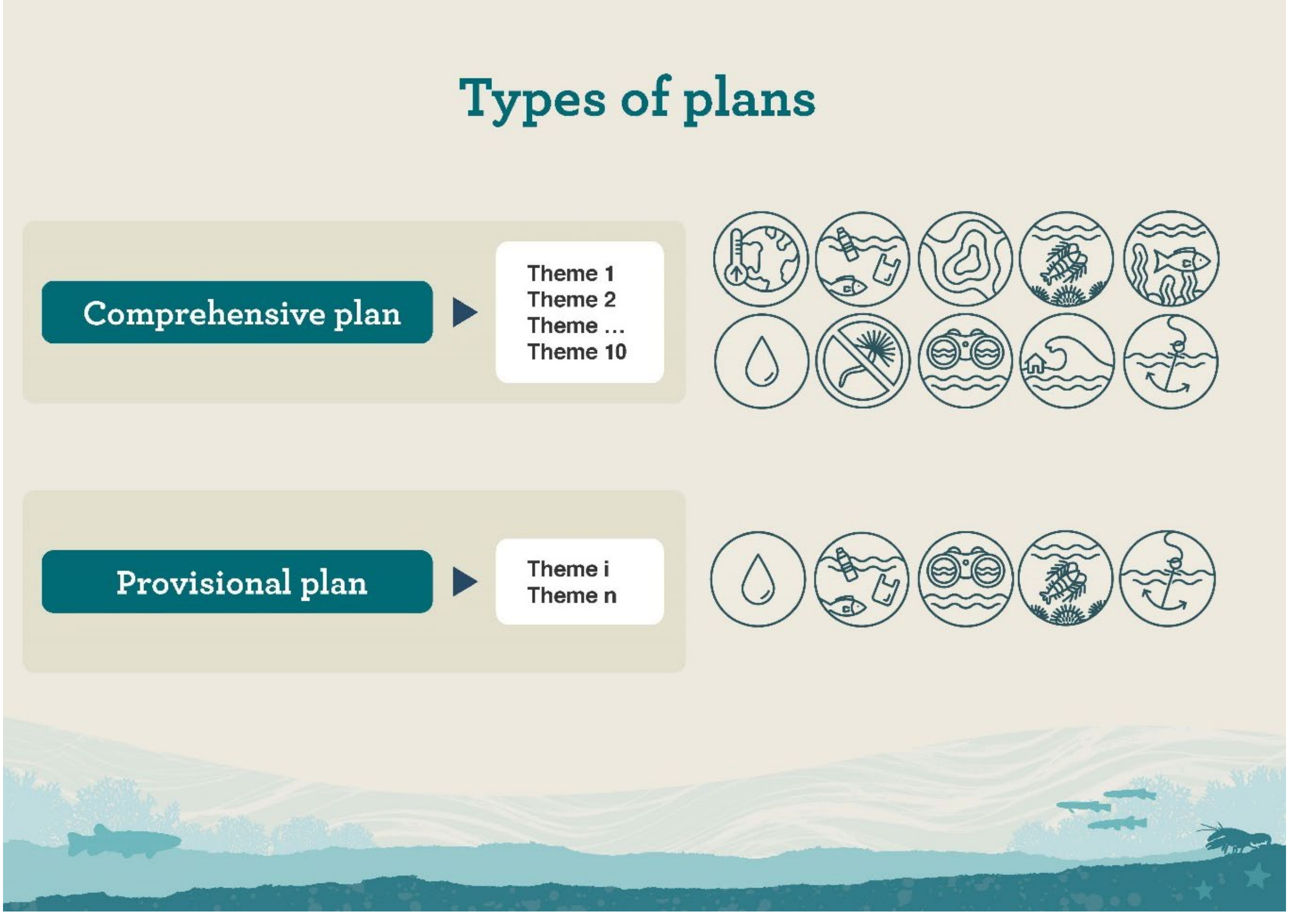

Figure 2.3. Representation of the types of plans to be developed for marine reserves under the Marine Monitoring and Reporting Framework.

A comprehensive monitoring plan will be developed and implemented for each representative site, while provisional plans will be developed for all other marine reserves.

2.4.2 Monitoring plans

A specific monitoring plan will be developed for each marine reserve or, where appropriate, group of marine reserves. Each plan will detail what is to be monitored in the marine reserve, how and how often it will be monitored, and who is responsible for ensuring that the monitoring is done. Two types of monitoring plans will be developed: (1) comprehensive plans, which will include monitoring from all themes, and (2) provisional plans, which will include a selection of the themes (Fig. 2.3). It is anticipated that all DOC-managed marine reserves will have a plan, including any newly established marine reserves.

When developing monitoring plans, DOC will:

1. Consult with local communities to identify their monitoring needs.
2. Consider how local monitoring will contribute to national-scale monitoring and reporting.
3. Develop monitoring objectives specific to the monitoring site that are relevant to local and/or national needs.
4. Select indicators and appropriate monitoring methods to address the monitoring objectives, ensuring standardisation with methods used in other monitoring programmes or at other sites where possible.
5. Include decisions around the number of sites, samples within sites and the frequency of monitoring within the plans.

2.5 Structure of each theme

Sections 3 to 12 of this document provide detailed information on the 10 themes of the MMRF. Each of these sections contains the following subsections: (1) background and objectives, (2) existing monitoring programmes, (3) sampling design, (4) monitoring protocols, (5) data management, (6) data analysis, and (7) reporting and communicating. Descriptions of each subsection are given below. There is a separate section on reviewing and auditing at the end of the report. Guidance for the presentation of the MMRF came from the Integrated Monitoring Framework (IMF) for the Great Barrier Reef (Gooch et al. 2017).[17]

2.5.1 Background and objectives

This section provides a brief literature review and links the theme to national and international objectives. The monitoring objectives are defined, providing clarity about the desired outcomes and the specific monitoring details. Monitoring objectives are SMART – specific, measurable, achievable, results-oriented and applicable over relevant timeframes (Reynolds 2012). Management objectives are captured in marine reserve monitoring plans.

2.5.2 Existing monitoring programmes

This section describes any existing monitoring programmes related to the theme that can provide guidance on how to implement the monitoring programme. For some themes, future monitoring will be integrated with existing programmes that are suitable for achieving the objectives. For other themes, no existing programmes exist and new monitoring programmes will need to be developed. It is important to capture previous monitoring programmes in this framework for continuity, pragmatism and cost-effectiveness.

2.5.3 Sampling design

Developing the sampling design for marine reserve monitoring involves three steps: selecting indicators, selecting monitoring programmes and developing a sampling design for integrated monitoring.

Selecting indicators

There are many ways to measure any particular outcome. Cost-effective monitoring requires selection of a feasible set of measures (or 'indicators') for evaluating whether the objectives for each theme are being achieved. In this case, indicators are taken from the OMF and redefined for the marine context. All relevant indicators and measures are presented for each theme, and those that are not directly addressed by this iteration of the MMRF are presented in a separate table. Each measure includes multiple data elements that are described in the context of MPAs. The selection of measures and data elements should directly address the specific monitoring objective for the reserve(s). A consistent approach to measuring outcomes will enable meaningful comparisons and data aggregation for reporting against objectives at a regional or national level.

Selecting monitoring programmes

This section identifies the relevant monitoring programmes identified in the previous section that can be implemented to achieve the monitoring objectives. Where possible, the MMRF aims to align with existing monitoring programmes that are already implemented around the country, particularly those that have proven impacts, have established data management systems, or contribute to a larger national or international programme.

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17 www.environment.gov.au/marine/gbr/publications/integrated-monitoring-framework-great-barrier-reef-world-heritage-area

Sampling design

This section describes the overall spatial and/or temporal sampling design for the theme. This will include where, when, and how often sampling will take place and will provide guidance on the appropriate level of monitoring effort that will allow for robust statistical analysis, within the capacity of the local office. A summary only of the appropriate sampling design is given and a comprehensive explanation can be found in 'Statistical considerations for monitoring and sampling' (Foster et al. 2018).

DEVELOPING A SAMPLING DESIGN

When developing a sampling design, there are three important questions that must be answered:

1. **What is an appropriate level of statistical power to inform management decisions in a timely manner?**

   The power of a statistical test (i.e. the probability of detecting a change when and where it occurs) depends on four parameters:

   - The inherent, unexplained variability in the dataset – the greater the unexplained variability, the lower the power.
   - The effect size – the larger the effect (e.g. increase in fish abundance), the greater the power.
   - The Type I error level (α) – the more relaxed the α value, the greater the power.
   - The sample size – the greater the sample size, the greater the power.

Box 2.3: Strategies to increase power and reduce variance

(Adapted from Brown et al. (2009) and Foster et al. (2018))

Increase the information content of the data

Covariates: Incorporating other variables that influence the counts of species (e.g. habitat and environmental variables) can reduce unexplained variation and thereby clarify any temporal changes.

Increase sample sizes: Increasing the number of transects can help decrease the variance and increase the power for detecting differences.

Reduce the noise from the data collection process

Pooling or stratification: Power is often limited by sample size, so pooling counts across replicates may improve the results. Otherwise, if benthic habitat maps exist or species compositions are known for the marine reserve, stratification may be used (ensuring that all known habitats or species are sampled).

Split panel design: This entails having some permanent sites and some random sites within a reserve and in appropriate control sites that are sampled each year. Permanent sites provide a stronger basis for estimating trends through time, while random sites are used to build more precise estimates of indicators (e.g. average density) as data accumulate.

Modelling with a non-normal distribution: Many traditional statistical models assume that residuals (deviation of individual data points from their mean) are normally distributed. However, this assumption may not be appropriate for many of our monitoring indicators, especially if they are counts. Therefore, alternative distributions (e.g. Poisson, negative binomial and zero-inflation) should be considered when modelling data that do not conform with the assumption of normality.

Training of observers: An increased accuracy of observers can help decrease the bias and variance of observations.

Various methods can be used to increase power and reduce variance (see Box 2.3).

2. **How will sampling sites be selected?**

   Monitoring will be implemented in all DOC-managed marine reserves where possible (see section 2.4.1 'Representative sites'). For each theme, DOC will endeavour to select marine reserves and sites within and adjacent to them to represent Aotearoa New Zealand's bioregions.

   Where possible, monitoring will follow a spatially balanced design (Foster et al. 2018). These types of designs are efficient for ecological monitoring as they:

   - Reduce the amount of spatial auto-correlation between samples (i.e. increase the independence between samples), allowing them to provide as much unique information as possible (Grafström & Tillé 2013).
   - Ensure that the influence of environmental variables (i.e. temperature, depth or habitat type) is balanced (Grafström & Lundström 2013).

Box 2.4: What is a toolbox?

Toolboxes describe DOC's standard inventory and monitoring methods for particular species, habitats, and environmental variables. Comparative tables and decision trees are provided to help choose the most appropriate methods for marine reserve monitoring.

For further information, see
www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/.

3. **How often should sampling be done?**

   The answer to this question will vary significantly depending on the theme. The sampling regime required will depend on the method being implemented to achieve the objective of the theme. It is important that any data are collected at a frequency that allows trends to be detected over time.

2.5.4 Monitoring protocols

This section summarises the data collection (field) methods that will be used. The details of the methods are predominantly captured in toolboxes (Box 2.4) or other accepted protocol documents (e.g. National Environmental Monitoring Standards), which provide explicit detail of each of the in-field steps. New toolboxes that are needed to implement the monitoring are identified for each theme and will be developed.

2.5.5 Data management

This section details how and where the data will be stored and accessed. DOC is currently working to develop national databases to hold data from marine reserve monitoring in Aotearoa New Zealand.

Quality control and quality assurance

Until the national database is established, an interim data management process will be used. Marine reserve monitoring data must be uploaded to DOC's document management system (docCM), with a standardised format for naming individual files. For example, MPA monitoring and research underwater visual census (UVC) fish data collected from Cape Rodney-Okakari Point Marine Reserve in 2021 would be uploaded with the filename 'MPAMAR data UVC Cape Rodney-Okakari Point Marine Reserve Fish 2021'. The

Table 2.1. Metadata categories for the Marine Reserve Monitoring Library.

Category	Description
DOC region	The Department of Conservation region acronym (e.g. 'AKL' for Auckland Region).
Marine protected area(s)	Name of the marine protected area (marine reserve).
Survey type	Type of survey used (e.g. monitoring programme).
Method of data collection	Methods used (e.g. potting, transects), but may also include mapping, management plan, etc.
Monitoring target	Subject of the data (e.g. the species being monitored). Surveys with more than one species or group of species (e.g. invertebrates) should use separate rows for each target species or group.
Year(s) sampled	Year the data were collected or the report was written. Multi-year data should use separate rows for each year.
Contractor, researcher or author	Names of contractors, researchers and authors.
Link to contract or organisation	Name of contractor's organisation.
Are raw data in database?	Whether raw data have been uploaded to the database (yes/no).
Monitoring reports and baseline studies	The docCM file numbers of any monitoring reports or baseline studies associated with the data, with a hyperlink to the files.
General reports, etc.	The docCM file numbers of any general reports associated with this study, with a hyperlink to the files.
Data file(s)	The docCM file numbers of the data files, with a hyperlink to the docCM files.
Type(s) of file(s)	File types (e.g. report, publication, data).
Title of project	Title of the survey, project, study or monitoring programme.
Description	Description of the survey, project, study or monitoring programme.
Comments	Any additional, relevant comments.

relevant metadata must then be recorded in the Marine Reserve Monitoring Library, with descriptions of each column as provided in Table 2.1.

The Marine Reserves Monitoring Library provides an internally searchable database of all relevant metadata, with direct links to the data in question, streamlining the MPAMAR data into a format closer to the Tier 1 library system used by DOC for terrestrial monitoring.

Future of data at DOC

DOC is developing an internal database for all quantitative monitoring data (excluding mapping data) (Fig. 2.4).[18] The general purpose of this database is to:

- Implement consistent and robust standards for the collection, grooming and archiving of data associated with marine reserve monitoring programmes.
- Provide high-quality monitoring datasets for Aotearoa New Zealand's marine reserves.

A separate, cross-government system is being developed to store and provide access to imagery (photographs and videos) and other spatial data (e.g. from multibeam or light detection and ranging (LiDAR)) through an online data portal. A Marine Geospatial Data Inventory (MGDI) has been developed specifically for DOC, which will be published publicly on www.data.govt.nz and contribute to the national marine geospatial stocktake.

18 www.doc.govt.nz/about-us/our-policies-and-plans/digital-strategy/

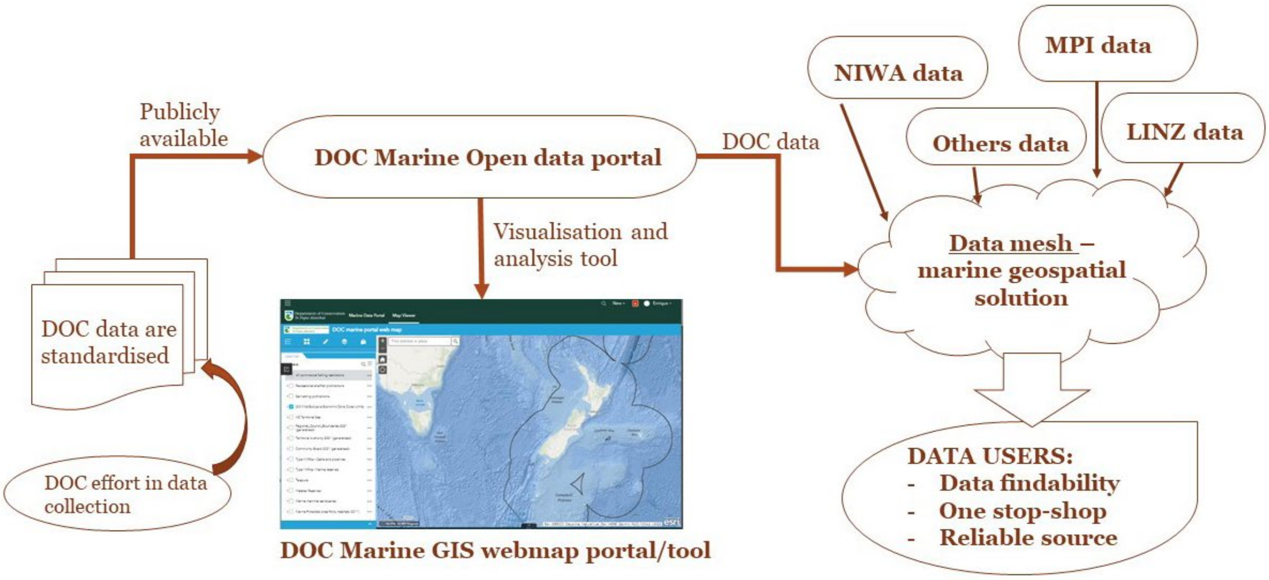

Figure 2.4. Schematic of the future of Department of Conservation Te Papa Atawhai (DOC) data. Data will be available to the public through the DOC Open Data Portal and through a joint Data mesh along with data from other agencies.

The benefits of having marine data stored in a database and publicly available is that:

- DOC's information management practices will be improved, increasing our capacity and timeliness to respond to requests and provide accurate advice;
- DOC can develop open data strategies alongside its partners making data readily available to all New Zealanders; and
- DOC can easily determine how and when datasets can be publicly released through data.govt.nz and other open data portals.

For data to be stored in the inventory or database, they must meet high metadata standards and be maintained. Several maintenance principals have been proposed for DOC that have implications for the way in which data are handled. Once these national inventories/databases are operational, the MMRF will be updated with a description of how to lodge data within them.

To be effective, the data inventory/database must meet the following key criteria:

1. **The data inventory/database aligns with DOC's data and information management principles.**

   It is important that the inventory/database and its maintenance aligns with DOC's data and information management principles to maintain consistent practices across the organisation. To achieve this:

   - Data should be described and presented in a way that is consistent with DOC's metadata and/or stylistic standards (e.g. use of acronyms, definitions, licencing rules).
   - All staff associated with maintaining marine information should be trained to use DOC's metadata standards correctly.
   - The data inventory/database and listings within it should be subject to DOC's information lifecycle management policies in relation to creation, collation, version control, etc.

2. **The data inventory/database is accessible.**

The data inventory/database should be accessible to:

- All relevant DOC staff by:
  - > Storing it on a shared drive.
  - > Including file pathways and an internal contact point or named data custodian for this internal version.
  - > Making users aware of its availability, with an explanation of the purpose and benefits of the data and how they may assist them in their work.
- The public, through data.govt.nz or similar.

3. **Listings within the data inventory/database are timely and accurate.**

Data listings should be continually updated in the internal version of the inventory/database by any staff member who is regularly collecting or managing marine data – for example, when data are:

- Collected or obtained.
- Significantly altered, updated or replaced.
- Superseded, deleted or archived.

All staff who are associated with maintaining marine information should be trained to add or update datasets in the inventory/database, and the data inventory should be reviewed regularly. A review schedule will be agreed on (e.g. annually), but there may be some circumstances where a review will take place outside this schedule – for example, when:

- A new system is implemented.
- An existing system is decommissioned.
- A significant project is initiated or there are organisational structure changes.

4. **Governance arrangements are established**

Governance arrangements should be in place to ensure accountability for maintenance of the inventory/database. To achieve this:

- There should be clearly defined roles and responsibilities.
- Existing information management governance arrangements should be used where possible.
- The inventory/database and its maintenance should be aligned with any other data and information cataloguing projects at DOC to:
  - > Avoid any duplication of effort in future discovery or maintenance activities.
  - > Ensure that the inventory/database remains the authoritative register for marine data.

2.5.6 Data analysis

There are many different approaches to analysing monitoring data to inform the objectives of each theme. The most appropriate approach depends on the objectives of the study, the methodology employed, the structure and properties of the data, and whether additional supporting information has been collected. This section describes at a high level the main analyses that are needed to produce plots for reporting on the monitoring objectives. This should be read in conjunction with the Summary Ecological Statistics toolbox,[19] and a statistician should be consulted prior to the analysis of any monitoring data.

19 www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-summary-ecological-statistics.pdf

Data analysis is typically made up of five components:

1. **Data preparation/pre-processing** – This describes the preliminary steps needed to convert the data into variables that are appropriate for analysis.
2. **Data exploration** – Before any analysis is complete and inferences can be made, the data must be plotted for visual inspection. This is a vital step in the process as it allows identification of outliers and anomalies.
3. **Assumption testing** – Where relevant, each theme will describe the assumptions required before the formal testing begins. Should any assumption be violated, then an alternative statistical test must be used.
4. **Hypothesis testing** – This component describes the statistical test (and alternative) that will be used to make formal inferences with respect to the monitoring objective (Box 2.5).
5. **Data visualisation** – This component details the steps required to produce appropriate graphs and tables to convey the results obtained from the previous steps.

Methods of data visualisation are presented under each theme in sections 3 to 12.

Box 2.5: Hypothesis testing for marine reserve monitoring data

When deciding on the best approach for analysing marine reserve monitoring data, it is important to consider the:

- Age and size of the marine reserve and its degree of isolation (Edgar et al. 2014)
- Fishing rules and level of enforcement within and near the marine reserve
- Frequency of marine reserve monitoring
- Spatial effects, including habitat types

Importantly, marine reserve monitoring must compare ocean change indicators (e.g. pH, temperature and partial pressure of carbon dioxide (pCO_2)) and water quality indicators (e.g. nutrient, chlorophyll *a* and dissolved oxygen levels) with biological indicators (e.g. species abundance and species size classes). However, biological responses to climate change may not follow the same trajectory as responses to environmental variables (Schiel & Lilley 2011). For example, while extreme weather can cause immediate mortality of some individuals, it can also cause mortality of other individuals weeks later due to limited food resources (Hallett et al. 2004). Additionally, environmental time series data are often recorded more frequently than biological data (e.g. daily temperatures versus yearly population data), and this difference in temporal scales makes understanding the influence of environmental factors on biological responses complex (Ferguson et al. 2017). To address these challenges, ecologists need to consider carefully how data are collected, formatted and analysed to estimate the influence of climate on population responses (Herrando-Pérez et al. 2014).

2.5.7 Reporting and communicating

> *There is great value in having different reporting styles such as technical reports, scientific papers and also contributions to large scale reviews, as the different levels of frequency of publication and level of scientific detail mean that both managers and scientists can benefit from the reporting of MPA monitoring results. All MPA monitoring programmes should therefore ensure that monitoring results are presented in all of these different styles.*
>
> (Addison 2011)

Reporting and interpreting the results after analysing the data are critical to the success of monitoring programmes, and there is often pressure to show the benefits and outcomes quickly. Formal monitoring and reporting systems are expensive to set up and operate, and the benefits accrue slowly over time (McGlone et al. 2020). The intention of this section is to ensure that there are clear guidelines on what, where and how often data will be reported.

Direction to carry out regular analysis, evaluation and reporting of results is integrated throughout the implementation planning of the MMRF. Marine reserves have a range of stakeholders, interest groups and Māori involved at place, so a wide range of reporting outputs are required to meet the needs of these different audiences. Regular reporting allows changes in the environment to be notified and allows management decisions to be made in a timely manner.

The reporting outcome for the MMRF will contribute to:

- Telling the wider story about the health of Aotearoa New Zealand's marine ecosystems.
- Providing more in-depth, location-specific ecological information.
- Communicating the ecological responses that may result from management activities (e.g. compliance) and decisions (e.g. extending protection measures).

Mātauranga Māori

In reporting on marine reserves, oral and written accounts of mātauranga Māori will be included as evidence of change or recovery. It is acknowledged that the recognition and integration of mātauranga Māori within mainstream conservation management needs to improve. This is being actively addressed in the MMRF through the inclusion of mātauranga Māori in both the design and implementation of monitoring plans and the reporting of monitoring outcomes. Importantly, the release of any sensitive knowledge used to make management decisions will be controlled by those to whom the information belongs (Māori).

National reporting

Aotearoa New Zealand's Official Statistics System has identified a suite of Tier 1 performance statistics for the country. Tier 1 statistics:

- Are essential to central government decision making
- Are of high public interest
- Meet public expectations of impartiality and statistical quality
- Require long-term continuity of the data
- Provide international comparability in a global environment
- Are produced by various agencies on a variety of topics

There is currently only one marine statistic included in this reporting – the area of MPAs in Aotearoa New Zealand's territorial sea.[20] However, a process is underway at DOC to increase the number of marine statistics that are reported under Tier 1.

It is anticipated that once several years of data have been collected, the information will feed into the MfE and Stats NZ 'Our marine environment'[21] reporting, which occurs every 3 years as a part of domain reporting.

Marine reserve reports and report cards

Marine reserve reports on the status and trends of the measures being monitored will be produced every 3 years. These will provide an overview of the integrity of the marine reserves and will be made available online.

20 www.doc.govt.nz/about-us/science-publications/conservation-publications/marine-and-coastal/marine-protected-areas/marine-protected-areas-tier-1-statistic/

21 www.stats.govt.nz/information-releases/new-zealands-environmental-reporting-series-our-marine-environment-2019

Marine reserve report cards[22] are designed to provide a summary of the marine reserve reports. They are available in print and online and allow the reader to quickly understand the status of a marine reserve, the pressures upon it and important species they may find there. Links and references to the associated marine reserve report and research studies are also provided for people who want more detailed information.

Marine reserve report cards focusing on key species and habitat data have already been developed for five marine reserves. Under the MMRF, the existing report cards will continue but will also include monitoring data relating to environmental and social aspects identified in the framework. The reporting schedule for specific measures will be outlined in the marine reserve monitoring plans. All report cards will be made available on the DOC website and will be disseminated to whānau, hapū, iwi, community groups and key stakeholders.

It is important to capture what is happening at place so that marine reserves can be actively managed. This requires an understanding of both the status (current condition) and trend (change in state over time) of the measure of interest (see Box 2.6), as observing either of these in isolation can lead to misunderstandings about what is happening in an ecosystem.

The scoring system describes the status and trend of a given measure. These are given for a pre-determined length of time, depending on the monitoring frequency and length of the time series of data for the measure – for example, 3–5 years is a common reporting period for many of the themes in the MMRF. During this time, any change would be captured if regular monitoring was in place. A rationale document for an explanation of the categories is available online.[23]

Box 2.6: Definitions of key reporting terms

(Adapted from 'Biodiversity in Aotearoa: an overview of state, trends and pressures' (DOC 2020a))

Status

What is known about the current situation for a specific group of animals, plants or ecosystems.

Trend

The general direction of change based on the best data and knowledge available.
In cases where there is only a short time series of data, this will not necessarily count as a 'trend' in the strictest statistical sense due to a lack of data points over time.

Target

Can be used to express how much change is acceptable whilst still considering the feature to be in a favourable condition. Targets will serve as a trigger mechanism so that when changes in the feature of interest fall outside the range of natural variability, further investigation or remedial action is taken.

22 www.doc.govt.nz/nature/habitats/marine/type-1-marine-protected-areas-marine-reserves/marine-reserve-report-cards/
23 www.doc.govt.nz/nature/habitats/marine/type-1-marine-protected-areas-marine-reserves/marine-reserve-report-cards/report-card-rationale/

For each of the themes in the MMRF, a standard structure is used for **status** and **trend** categories (Tables 2.4 and 2.5). However, the definition for each status category varies across the themes, depending on the measure being reported on.

The categories for reporting on the **status** of any particular measure are:

- Excellent
- Good
- Fair
- Poor
- Undetermined

The categories for reporting on the **trend** of that measure are:

- Improving
- Stable
- Declining
- Undetermined

Where possible, the reason for an undetermined status or trend score will be noted in the report card. An undetermined status or trend grading may be given because:

- Not enough data have been recorded
- The data are too variable
- The marine reserve was created too recently for adequate data to have been collected
- Natural levels of an indicator against which current levels are being compared are uncertain

Other reporting opportunities

There may be other opportunities to report on either the monitoring being undertaken or the ecological integrity of the reserve, the MPA network and/or the wider marine environment. These opportunities are highlighted within this section under each of the themes.

An interactive map of the marine reserves will also be developed, presenting the statuses and trends of the indicators measured. The example provided in Fig. 2.5, showing a map of the Fitzroy Basin in Australia, uses fish and turtle graphics split into parts to denote the magnitude of change in different indicators in that region. Additionally, clicking on each bioregion will produce a zoomed in map showing each reserve within that region. Specific marine reserves can appear with similar graphics as the overall bioregion (i.e. overall change in each indicator as a heat map colour with a fish graphic overlay). This type of figure will present all of the indicator data for all regions in a single graphic that is simple to understand.

2.5.8 Reviewing and auditing

Section 13 outlines when the MMRF should be reviewed.

Table 2.2. Status of a measure at the time of assessment.

Status	Example definition (Theme 1 – Identify the proportion of ecosystems protected)*
Excellent (as close to pristine as possible)	An adequate proportion of every marine habitat type of interest is under effective protection. Representation and replication of those habitats in the marine protected area (MPA) network is appropriate and meets Aotearoa New Zealand's national and international goals.
Good	At least 75% of all marine habitat types of interest are under effective protection and are adequately represented and replicated in the MPA network.
Fair	At least 50% of all marine habitat types of interest are under effective protection and adequately represented or replicated in the MPA network.
Poor	Less than 50% of the marine habitat types of interest are under effective protection and adequately represented and replicated in the MPA network.
Unknown	The status of this measure is unknown.

* www.doc.govt.nz/nature/habitats/marine/type-1-marine-protected-areas-marine-reserves/marine-reserve-report-cards/report-card-rationale/

Table 2.3. Trend of a measure at the time of assessment.

Trend	Definition
Improving	Positive trend, moving towards an improved state.
Stable	EITHER the target has been met and the state is maintained within the normal interannual range; OR there are mixed trends within the measure, which is neither improving nor declining. This would need to be defined within the normal interannual range.
Declining	Unfavourable trend, moving away from an improved state.
Undetermined	Insufficient or no comparable data.

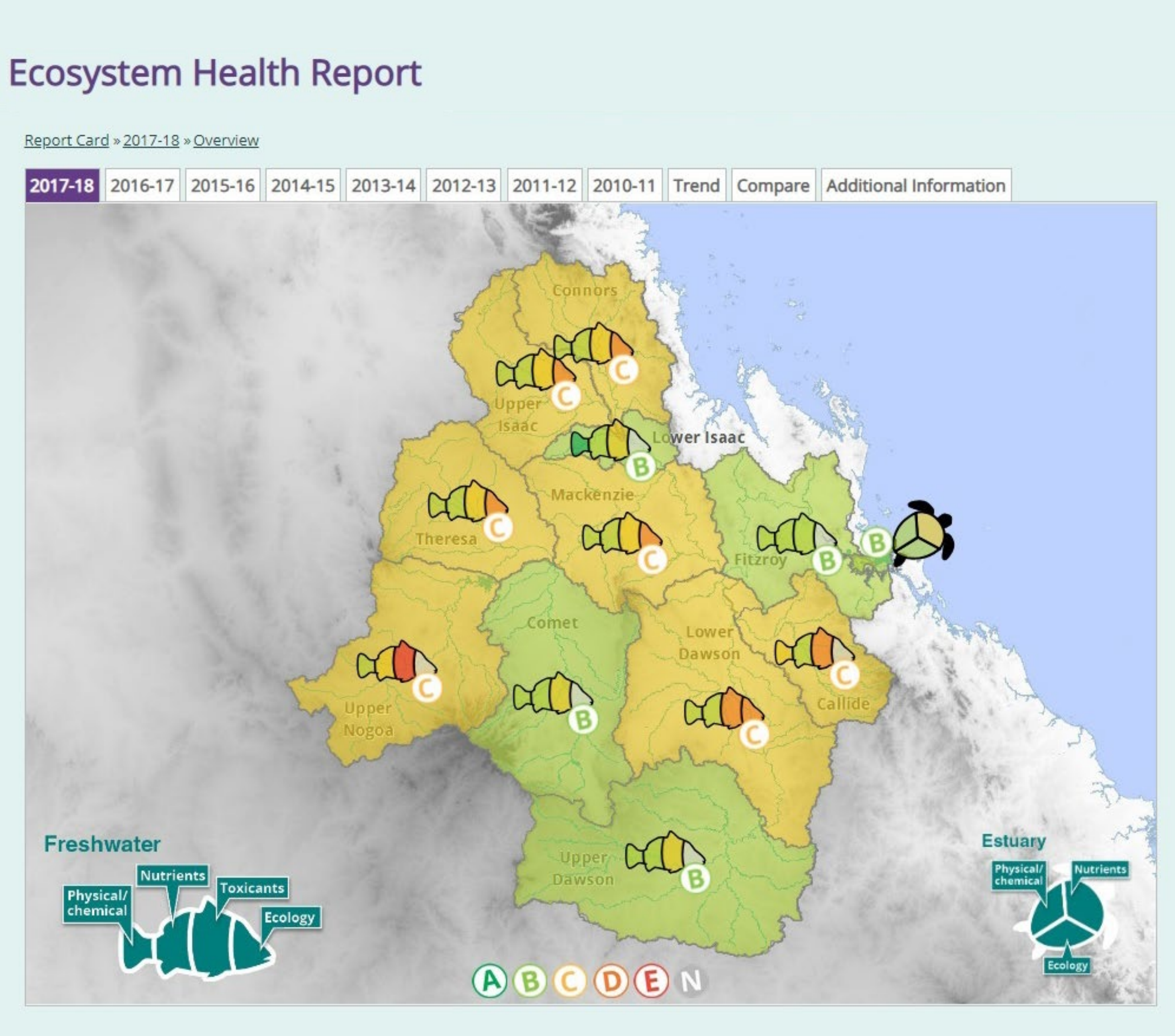

Figure 2.5. Ecological integrity report for the Fitzroy Basin in Australia for 2017–2018. Each region is given an overall grade for health, from A (excellent) to E (fail), as well as specific freshwater and estuarine indicators (see fish and turtle graphics). Source: The Fitzroy Partnership for River Health (https://riverhealth.org.au/report_card/methods/data/). Reproduced under a Creative Commons Attribution 3.0 Unported License (https://creativecommons.org/licenses/by/3.0/deed.en_GB).

3 Theme 1 – Identify the proportion of ecosystems protected

What	Proportion of ecosystem protected
Who	DOC
When	Yearly
Where	Aotearoa New Zealand
How	Computer modelling
Why	Proportion of ecosystem protected

3.1 Background and objectives

A central tenet of marine spatial planning is to try to protect the full range of ecosystems (IUCN-WCPA 2008; Roberts & Hawkins 2000; Willis 2013). Therefore, DOC aims to establish a nationwide network of MPAs that are representative of Aotearoa New Zealand's marine habitats and ecosystems.

The objective of this theme is to identify which habitats are currently protected within established marine reserves and other types of effective area-based marine protection (e.g. Type 2 MPAs) in Aotearoa New Zealand's exclusive economic zone (EEZ) (with an initial focus on the territorial sea). For a habitat to be considered protected for the purposes of representation, it must have effective protection to a level that ensures the recovery and maintenance of the associated ecosystem. The CBD's Aichi Biodiversity Target 11[24] considers a focus on representation to be crucial, as current protected area networks have gaps and some fail to offer adequate protection to many species and ecosystems. Examination of all types of effective area-based protection will ensure that the amount of protection currently in place is not under- or overestimated.

The two key features of MPA design that are relevant to this theme are 'representation' and 'replication', both of which are considered essential for developing a comprehensive and resilient MPA network at a national scale (see Box 3.1). More detailed descriptions of representation and replication and a discussion of their importance in MPA network design can be found in 'New Zealand marine protected areas: principles for network design' (DOC 2019).

3.1.1 Objectives

The monitoring objectives for this theme are focused on assessing representation and replication at a national level through computer modelling of available habitat data. These objectives will be monitored both spatially and temporally.

24 Technical rationale for the goals and Aichi Biodiversity Targets of the strategic plan for biodiversity 2011–2020: www.cbd.int/sp/targets/rationale/target-11/.

Box 3.1. Important concepts for MPA design

What is a network of MPAs?

A network is defined as 'a collection of individual MPAs or reserves operating cooperatively and synergistically, at various spatial scales, and with a range of protection levels that are designed to meet objectives that a single reserve cannot achieve' (IUCN-WCPA 2008).

What is an ecosystem?

The MPA policy and implementation plan defines an ecosystem as 'An interacting system of living and non-living parts such as sunlight, air, water, minerals and nutrients' (DOC & MFish 2005). Ecosystems can be small and short lived, such as a rock pool that is exposed during low tide, or large and long lived, such as estuaries or oceans. An ecosystem consists of all the organisms, the physical environment and their interactions, which are linked together through energy flow.

What is a habitat?

The MPA policy and implementation plan defines a habitat as 'the place or type of area in which an organism naturally occurs' (DOC & MFish 2005). Habitat relates to the resources, including physical and biotic components, that are present in a defined area and are needed to support a particular species. Thus, habitat is often considered a species-specific term, i.e. the area which a species inhabits.

What is representation?

Representation is an MPA network design principle that ensures the full suite of ecosystems and/or habitats are protected. Ecosystems are difficult to measure in practice as they are highly dependent on scale and complex interactions. Instead, when measuring representation, habitat types are used as a surrogate as they have measurable differences in key abiotic/biotic characteristics (e.g. deep reef, bryozoan reef, shallow gravel).

What is replication?

A habitat type is said to be replicated it is present in at least two MPAs. The replication of habitats in MPAs increases the probability that some habitats will survive and can support the recovery of affected areas in the face of ongoing perturbation.

Monitoring objective 1.1: To monitor the proportion of habitat types under effective protection (representativeness).

Research question: What proportion of habitats are under effective protection in Aotearoa New Zealand?

Monitoring objective 1.2: To monitor the number of instances (replication) and proportion (adequacy) of each habitat that is under effective protection.

Research question: How has the protection of effective habitats changed over time?

Caveats and assumptions

There will be several caveats associated with uncertainty and several assumptions associated with initial assessments of representativeness and replication. However, these will be addressed by running different scenarios through the modelling when data become available:

- Initially, no assessment will be made of whether the area of a habitat that occurs within an MPA is of sufficient size to ensure the ecological viability of that habitat and its associated biological assemblages. However, the analysis will incorporate this information when it becomes available.
- There is currently no agreement on what constitutes effective protection at a habitat level. An expert validation step is included to address this.
- While habitat classifications can be a proxy for patterns of biodiversity, there will remain a need to review regional patterns on a case-by-case basis as, in some cases, the same habitat types do not necessarily support the same biodiversity/communities within regions.
- This theme only relates to benthic representation. Pelagic classifications have yet to be developed, which could be incorporated into an overall assessment of representation.
- Caveat: habitats are measured as a proxy for ecosystems.

3.2 Existing monitoring programmes

In 2005, an MPA policy and implementation plan ('MPA Policy') was released for Aotearoa New Zealand, the objective of which was to 'protect marine biodiversity by establishing a network of MPAs that is comprehensive and representative of New Zealand's marine habitats and ecosystems' (DOC & MFish 2005). The MPA Policy seeks to protect representative examples of the full range of marine habitats and ecosystems, and outstanding, rare, distinctive, or internationally or nationally important marine habitats and ecosystems. The initial task scheduled by the MPA Policy was to develop the New Zealand Coastal Classification and Mapping Scheme (CCMS) (MFish & DOC 2008) as an approximate surrogate to describe broad spatial patterns in marine biodiversity where more detailed biological information was unavailable.

Progress towards establishing a comprehensive and representative network of MPAs in Aotearoa New Zealand was first reported on in a 2011 'gaps analysis' that was undertaken as part of the MPA Policy (DOC & MFish 2011). This analysis was developed by overlaying existing protection over a broad-scale habitat map and reporting on percentages of habitat types that were under existing protection. However, no consideration was given to whether MPAs were providing effective protection to specific habitats or to the size of individual habitat patches and whether they were viable.

A further gaps analysis was completed in 2019 (DOC et al. 2019) as an update of the 2011 version. However, this also did not incorporate the concepts of 'effective protection' or 'viability' in the analysis. Therefore, while these gaps analyses provide a broad picture of overall progress towards establishing an MPA network, further refinement is required to have confidence in accurately reporting on representation and replication at an ecological level.

3.3 Sampling design

3.3.1 Selecting indicators

This theme provides guidance on how to undertake monitoring for Objective 10 'Ecosystems and species are protected, restored, resilient and connected from mountain tops to ocean depths' from the ANZBS (DOC 2020c; Table 3.1).

Future updates will expand this to include measures relating to the change in extent of naturally uncommon and reduced ecosystems and the proportion of ecosystems remaining (Table 3.2).

3.3.2 Selecting monitoring programmes

This theme utilises the analyses that were conducted in the 2011 and 2019 MPA gaps analysis reports (DOC & MFish 2011; DOC et al. 2019). It formalises the process taken to produce these reports and has developed associated scripts to automate the process. Monitoring and reporting on habitat representation in effective area-based protection will benefit from progress in the following areas:

- Updated broad-scale habitat map or classification
- Mapping of key ecological areas
- Updated 'effective area-based protection' database
- Guidelines for assessing effective protection and minimum viable habitat size

Work to address these limitations is already underway through DOC's MPA science work programme, and the analysis and reporting within this theme is intended to incorporate the above steps. However, these are still in development and agreed 'targets' for minimum sizes have not yet been agreed. Nevertheless, the analysis can be undertaken using existing information, and habitat layers and minimum size metrics can be substituted in when they become available. It is important that the analysis is flexible to accommodate future advances in knowledge on MPA design.

All effective area-based protection areas will be included in this analysis to avoid under- or overestimating representation under effective protection (such an analysis was previously only performed for marine reserves and Type 2 MPAs designated under the MPA Policy). The outcomes of Theme 1 will identify gaps in the MPA network and facilitate prioritisation and future direction for establishing a network of MPAs. It will also report on progress towards achieving a network of MPAs that is comprehensive and representative of Aotearoa New Zealand's marine habitats and ecosystems.

3.3.3 Developing a sampling design

As per the 2011 and 2019 gaps analysis reports (DOC & MFish 2011; DOC et al. 2019), this theme aims to assess the extent of surrogates for habitat, such as depth, substrate, exposure and the actions of biogenic (habitat-forming) organisms, on a regular basis. It does not aim to assess outstanding, rare, distinctive, or internationally or nationally important habitats or ecosystems, or finer-scale species associations and ecosystem processes. (These important aspects do, however, need to be considered and incorporated into future MPA planning processes.) It is recommended that a gaps analysis for protected areas in Aotearoa New Zealand is conducted every 3 years.

Table 3.1. Indicators, measures and data elements relating to Theme 1 – Identify the proportion of ecosystems protected. Adapted from McGlone et al. (2020).

Indicator 1.1: Ecosystem representation and protection status	
Measure 1.1.1: Proportion of ecosystem protected	
Description	Some of Aotearoa New Zealand's ecosystems/habitats are well represented in protected areas while others are poorly represented or not represented at all. To provide assurance that biodiversity is protected and maintained in the marine environment, it is necessary to have a representation of ecosystems in effective area-based management. As ecosystems are inherently difficult to define and map in the marine environment, measures of habitat representation will be used as a proxy to ecosystems. To achieve ecological representation, the habitat must be afforded effective protection at a level that ensures the recovery and maintenance of the associated ecosystem.
Data elements	**Habitat type** Corresponds to the habitat classification used in the analysis. It could relate to a class within an environmental classification or to a thematic habitat classification habitat type (e.g. biotope). **Protection type** The type of protection that is afforded to an area of ocean. There are several protection types in Aotearoa New Zealand, including Type 1* and Type 2 marine protected areas (MPAs),† benthic protection areas, marine mammal sanctuaries, and customary management areas (mātaitai reserves and taiāpure).‡ **Key ecological area** An area of particular importance as defined using the criteria listed in table 1-1 in 'Key ecological areas' (Lundquist et al. 2020).
Links to other measures	1.1.2: Change in extent of naturally uncommon and reduced ecosystems (Theme 1 – Ecosystem representation) 1.1.3: Proportion of ecosystems remaining relative to natural extent (Theme 1 – Ecosystem representation) 2.1.3: Habitat extent (Theme 2 – Habitat changes)

* www.doc.govt.nz/nature/habitats/marine/type-1-marine-protected-areas-marine-reserves/

† www.doc.govt.nz/nature/habitats/marine/type-2-marine-protected-areas/

‡ www.doc.govt.nz/nature/habitats/marine/other-marine-protection/

Table 3.2. Indicators, measures and data elements that are to be implemented in future iterations of the Marine Monitoring and Reporting Framework.

Indicator 1.1: Ecosystem representation and protection status	
Measure 1.1.2: Change in extent of naturally uncommon and reduced ecosystems	
Description	Broad, national-scale ecosystem classifications are not well suited to dealing with naturally uncommon and critically reduced ecosystems because of their small size and often unique characteristics. In addition, these small and often fragmented ecosystems are subject to pervasive threats from accidental obliteration, pests and weeds. The International Union for Conservation of Nature (IUCN) has categories for assessing threatened ecosystems (short-term decline; historical decline; small current distribution or very few locations; very small current distribution). Therefore, special attention must be paid to the status of such systems. In Aotearoa New Zealand, there were 71 identified terrestrial rare ecosystems in 2014, 45 of which were threatened under the IUCN criteria.
Data elements	National-level classification, mapping and assessment of naturally uncommon and reduced ecosystems.
Links to other measures	2.1.3: Habitat extent (Theme 2 – Habitat changes) 1.1.1: Proportion of ecosystem protected (Theme 1 –Ecosystem representation) 1.1.3: Proportion of ecosystems remaining relative to natural extent (Theme 1 – Ecosystem representation)
Measure 1.1.3: Proportion of ecosystems remaining relative to natural extent	
Description	How to classify and map Aotearoa New Zealand's ecosystems has been a contentious issue for many years (see discussion in Singers & Rogers (2014)). The majority of systems proposed for this country have been qualitative and subjective (including the most recent outlined in Singers & Rogers (2014)), based on broad-scale mapping of combinations of dominant species in conjunction with broad environmental factors. Such classifications pose a real problem for long-term monitoring systems, as they depend on expert opinion and are therefore unstable over time and poorly defined in space (de Cáceres & Wiser 2012).
Data elements	The requirement for an acceptable element should be a quantitatively defined ecosystem and a modelled natural extent, backed up, where feasible, with historical or palaeoecological data observations. The ecosystem definition should be relatively broad and should not rely exclusively on uncommon or rare species.
Links to other measures	2.1.3: Habitat extent (Theme 2 – Habitat changes) 1.1.1: Proportion of ecosystem protected (Theme 1 – Ecosystem representation) 1.1.2: Change in extent of naturally uncommon and reduced ecosystems (Theme 1 – Ecosystem representation)

3.4 Monitoring protocols

The goal of this theme is to monitor progress towards achieving representation across the network of marine reserves in Aotearoa New Zealand. There are no specific monitoring protocols; instead, this programme of work will draw on several national processes and bring them together to meet the monitoring objective in question. This approach includes several inputs derived from other pieces of work that are collated into a Geographic Information System (GIS) analysis. Specifically, these inputs are:

- A formal, quantitative, mapped, replicable habitat classification (see Theme 2 – Determine changes in habitat composition and condition).
- Key ecological area (KEA) datasets for Aotearoa New Zealand (an evaluation of the adequacy of these datasets is currently being undertaken).
- Validation of effective area-based protection (needs to be compiled).
- Ecological guidance on adequacy and viability (partially being undertaken).

The analysis should be run every year (if new areas are designated) to inform international reporting, which is required annually.

3.5 Data management

No additional data management resources are required for this theme. Any revised habitat classification and KEA mapping that is carried out is made available through DOC's geospatial data system (NEGIS), and the database of effective area-based protection is also available within this system. The geoprocessing script for running the analysis, including the lookup tables, will be in a project folder in the DOC geospatial server.

Further details on how data management is currently approached at DOC can be found in section 2.5.5.

3.6 Data analysis

In order to automate the analysis, a geoprocessing script within ArcGIS will be used to process the four inputs described in section 3.4 ('Monitoring protocols') and output the representation and replication levels for each broad-scale habitat type and KEA (see Appendix 1). Updated habitat classifications (broad-scale and KEA) will be easily incorporated provided that a consistent habitat classification is used. Metrics relating to minimum habitat size (viability) and minimum replicate distances will be held in lookup tables to allow easy manipulation of criteria based on the best available information (e.g. an updated assessment of effective habitat patch size). Lookup tables allow for the easy creation of different scenarios based on different assessments of patch size and protection type, without needing to edit the source code. The analytical approaches that can be used for each of the data elements shown in Table 3.1 are summarised in Tables 3.3 and 3.4.

Table 3.3. Summary of analytical approaches for data relating to habitat and protection types.

<table>
<tr><th colspan="6">Data elements: Habitat type and protection type</th></tr>
<tr><th>Methods</th><th>Required data</th><th>Data preparation</th><th>Analysis</th><th>Visualisation</th><th></th></tr>
<tr><td rowspan="2">• Desktop exercise</td><td rowspan="2">• Details of all marine protected areas in Aotearoa New Zealand, including protection level.
• National-scale habitat/environmental classification.
• Qualifiers for habitats:
Viability
Minimum habitat size – the smallest patch size of a habitat that is self-sustaining and/or provides sufficient protection to maintain ecosystem functions. The home range of key species is an important component when establishing habitat viability. Viability is often a function of size and protection type.
Protection level allows for key species/habitats to be maintained or restored.
Minimum replicate distance
The distance between patches of the same habitat type that allows them to be considered replicates. The minimum distance will be a function of patch size, the scale of the threats on the habitat and the habitat type. Minimum distances will be determined on a case-by-case basis depending on the habitat type.</td><td rowspan="2">None.</td><td>Geoprocessing script overlaying protection on habitat classification (initially).
Geoprocessing utilising qualifiers when available.</td><td>Present data in a table.</td><td>Objective 1.1 – Spatial</td></tr>
<tr><td>Over time, the number of new habitat or protection types that are added to Aotearoa New Zealand's network can be reported.</td><td>Present data as a bar or line chart.</td><td>Objective 1.2 – Temporal</td></tr>
</table>

Table 3.4. Summary of analytical approaches for data relating to the key ecological area.

<table>
<tr><th colspan="6">Data element: Key ecological area</th></tr>
<tr><th>Methods</th><th>Required data</th><th>Data preparation</th><th>Analysis</th><th>Visualisation</th><th></th></tr>
<tr><td rowspan="2">• Desktop exercise</td><td rowspan="2">• Vulnerability, fragility, sensitivity or slow recovery.
• Uniqueness/rarity/endemism
• Special importance for life history stages
• Importance for threatened/declining species and habitats
• Biological primary productivity.
• Biological diversity
• Naturalness
• Ecological function
• Ecological services</td><td rowspan="2">Data must be gathered and mapped for each of the given criteria.</td><td>See Lundquist et al. (2020) for a detailed explanation.</td><td>Produce maps of the key datasets (e.g. see Fig. 3.1).</td><td>Objective 1.1 – Spatial</td></tr>
<tr><td>N/A</td><td>N/A</td><td>Objective 1.2 – Temporal</td></tr>
</table>

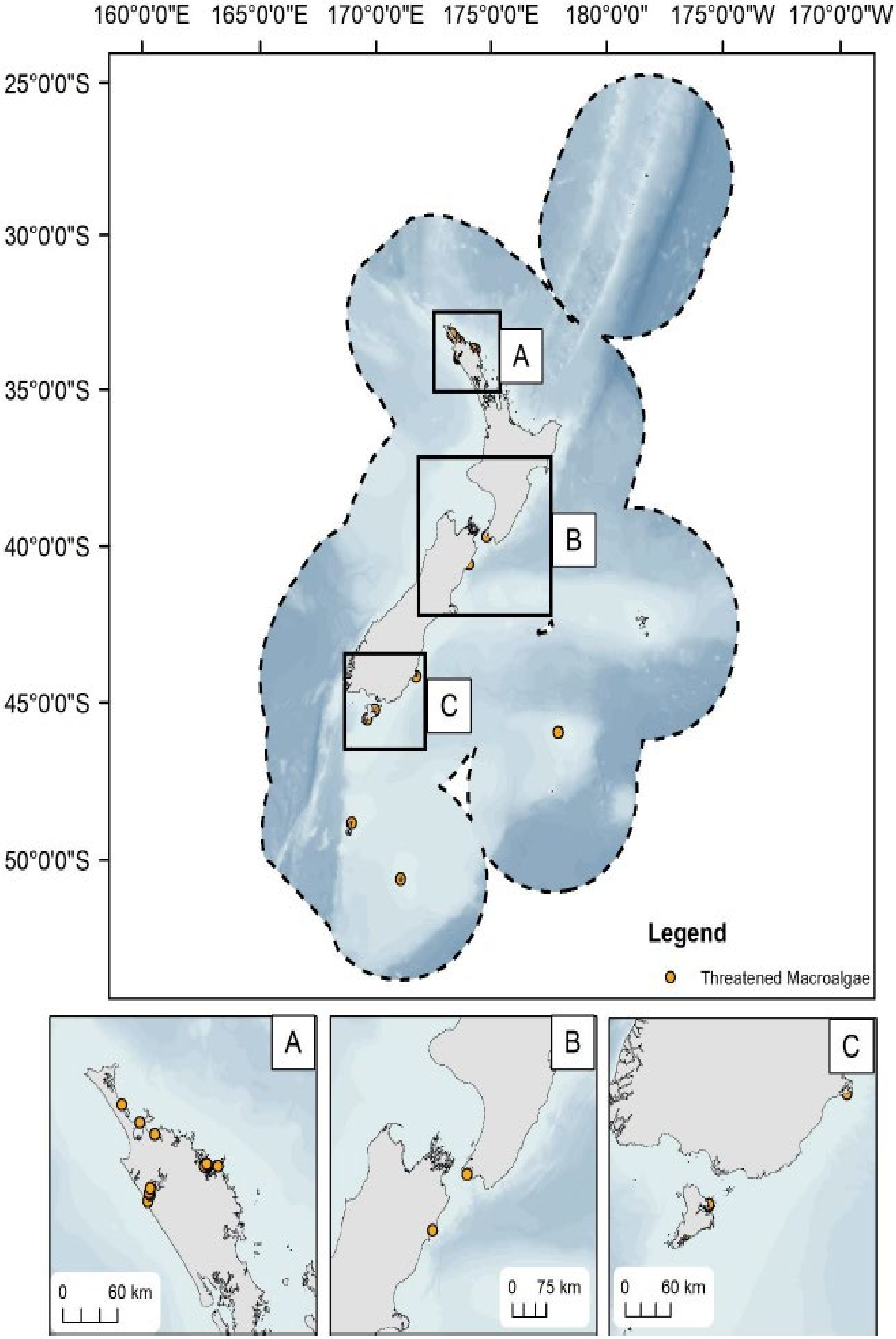

Figure 3.1. Example map for key ecological area criteria showing point records of macroalgal species assessed as threatened in Aotearoa New Zealand.

3.7 Reporting and communicating

The Marine Protected Areas: Tier 1 statistic[25] provides the current statistics relating to MPAs inshore of the outer (12 nautical mile) limit of Aotearoa New Zealand's territorial sea.

Reports at a national scale will be produced for domestic purposes (and international reporting). These will include aggregated information showing the total percentage coverage of marine reserves by bioregion and the level of representation (Table 3.5). Once criteria associated with the effectiveness of protection and viability have been developed, reports for other area-based marine protection will be included.

3.7.1 Marine reserve reports and report cards

The data elements monitored by Theme 1 that can be incorporated into individual reports and report cards are broad-scale habitats and KEAs that are protected by the reserve. The ideal state for habitat representation is that all habitat types are protected. A link to the national representation analysis could be included to allow the reserve to be considered in a national network context. The definitions for reporting on the status of the measures monitored under this theme are described in Table 3.6 (see Table 2.5 for definitions of trend).

Table 3.5. Information relating to Theme 1 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective	Ensuring ecosystem representation
Indicator	**Ecosystem representation and protection status**
Data element	**Habitat types** **Protection types**
Reporting	• Formal, quantitative, mapped, replicable habitat classification • Thematic classification maps • Key ecological areas map • Ecological guidance on adequacy and viability • Percentage coverage of habitats in protection • Level of replication for each habitat

Table 3.6. Definitions for reporting on the status of the measures for Theme 1 – Identify the proportion of ecosystems protected.

Status	Definition
Excellent	An adequate proportion of every marine habitat type of interest is under effective protection. Representation and replication of those habitats in the marine protected area (MPA) network is appropriate and meets Aotearoa New Zealand's national and international goals.
Good	At least 75% of all marine habitat types of interest are under effective protection and are adequately represented and replicated in the MPA network.
Fair	At least 50% of all marine habitat types of interest are under effective protection and adequately represented or replicated in the MPA network.
Poor	Less than 50% of the marine habitat types of interest are under effective protection and adequately represented and replicated in the MPA network.
Undetermined	The status of this measure cannot be determined.

25 www.doc.govt.nz/about-us/science-publications/conservation-publications/marine-and-coastal/marine-protected-areas/marine-protected-areas-tier-1-statistic/

3.7.2 Other reporting opportunities

The outputs from this theme will be used for annual reporting purposes and during MPA planning and design. To improve the accessibility of the data, the habitat classification utilised, KEA datasets and effective area-based protection in place will be deposited in data layers in a SeaSketch project and made publicly available.

Any national-scale reports will be accompanied by social media releases and published on a dedicated web page on the DOC website. Although no specific reporting requirements are currently in place, how habitat representation can be incorporated into reports to the CBD should be considered (given the focus on representation under the CBD's Aichi Target 11).

Gaps analysis

An analysis on how well the national network of MPAs is meeting representation targets can be undertaken at regular intervals using the methodology described above. How frequently this occurs will depend on progress in establishing MPAs nationally.

Such a gaps analysis could include summary tables by habitat type (e.g. Table 3.7), bar charts showing representation by bioregion (e.g. Fig. 3.2) and maps showing where gaps in representation occur (e.g. Fig. 3.3).

Table 3.7. Example of how habitat representation and replication could be displayed.

Bioregion	Habitat	Representation				Replication		
		Area of habitat (km^2)	% in marine reserves	% in Type 2 MPAs	Total % in MPAs	Marine reserves	Type 2 MPAs	Total MPAs
SSI	**Deep gravel**	149.6	0.0	16.2	16.2	0	1	1
SSI	**Deep mud**	3265.0	0.0	2.5	2.5	0	1	1
SSI	**Deep reef**	42.4	0.1	0.0	0.1	1	0	1
SSI	**Moderate rocky shore**	6.3	1.3	1.7	3.1	1	1	2
SSI	**Moderate shallow gravel**	39.5	0.0	0.0	0.0	0	0	0
SSI	**Moderate shallow reef**	165.9	1.7	0.8	2.6	1	1	2
	Etc.	…	…	…	…	…	…	…

Abbreviations: MPA, marine protected area; SSI, Southern South Island biogeographic region.

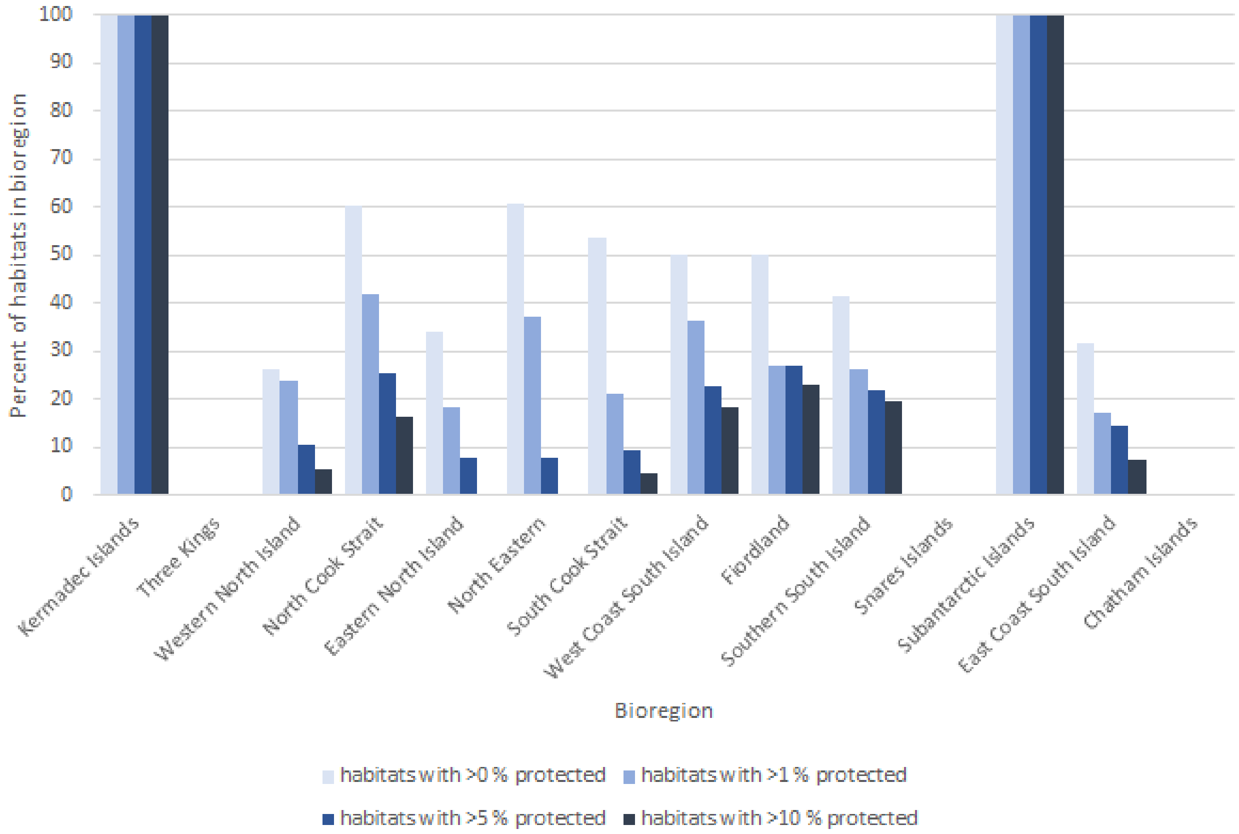

Figure 3.2. Example of how to show different levels of representation by bioregion.

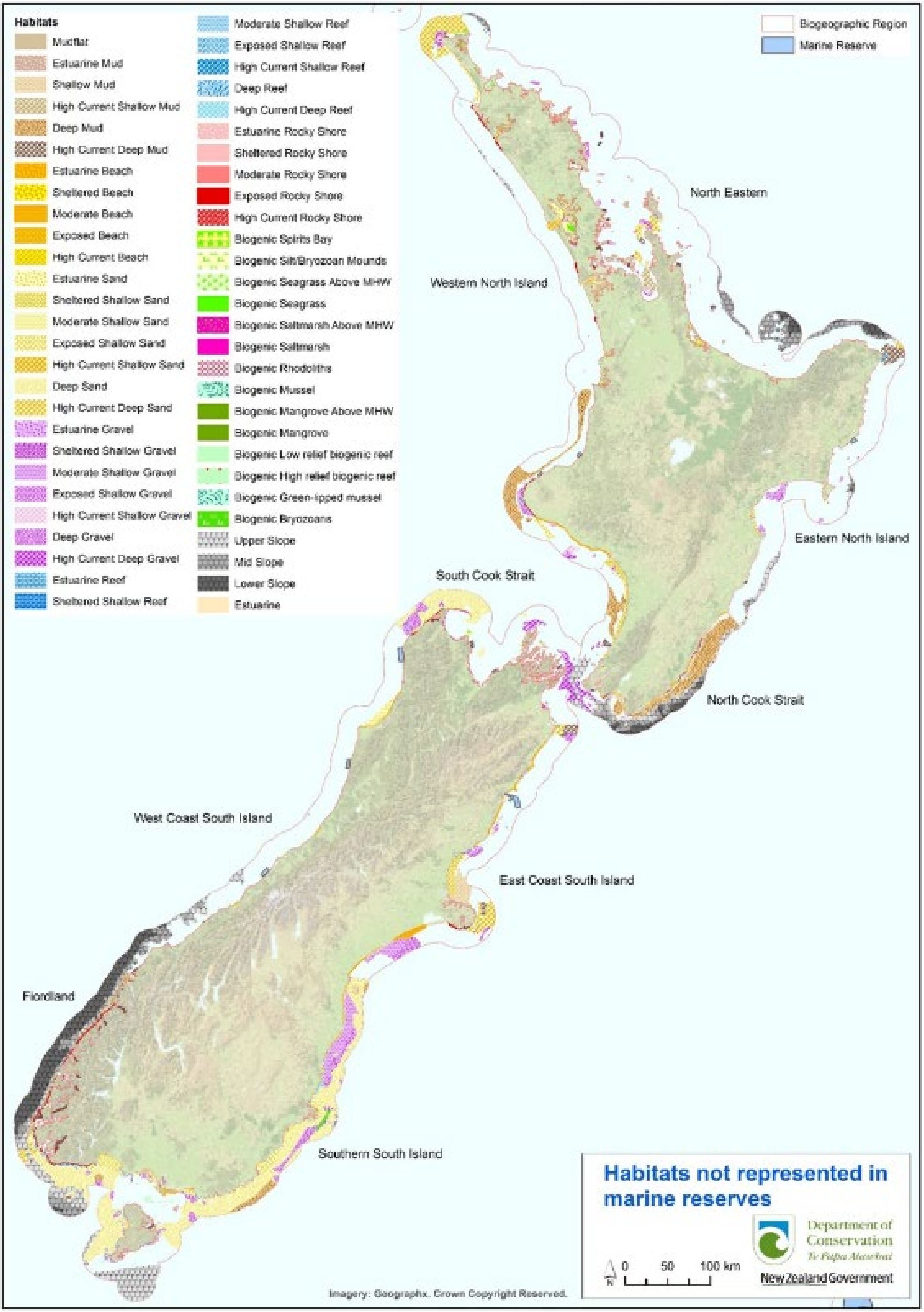

Figure 3.3. Habitats in mainland bioregions with less than 1% of their spatial extent in a marine reserve.

4 Theme 2 – Determine changes in habitat composition and condition

What	Ecosystem fragmentation, habitat availability and ecosystem extent
Who	DOC, universities, Land Information New Zealand (LINZ)
When	Once every few years, depending on the methodology and target habitat
Where	All marine reserves where possible, including comparative non-reserve sites
How	Satellite imagery, aerial photography, drones, multibeam, sidescan sonar, remote/automated vehicles, drop cameras, video sleds, diver surveys, sediment grabs
Why	To identify critical changes in ecosystem composition

4.1 Background and objectives

Aotearoa New Zealand's coastal and marine environment is home to a wide range of endemic marine flora and fauna and is one of the most diverse marine environments in the world on a per area basis (Gordon et al. 2010). Much of that diversity is supported by biophysical habitats, so changes to the structure or spatial extent of those habitats is potentially capable of disrupting ecosystem functioning, which would have consequences for entire food webs (for examples, see Thrush et al. (2017) and Schiel et al. (2019)). Thus, understanding the types of habitats that exist within the marine environment, how they change over time and what the drivers of those changes are is important for supporting management decisions (DOC et al. 2019).

Aotearoa New Zealand has committed under the CBD to ensure that the rate of habitat loss and degradation is significantly reduced (Aichi Target 5)[26] and to protect a representative range of the country's marine habitats (Aichi Target 11).[27] The Aichi Targets suggest several measures that can be used to determine if habitats are changing through time, including identifying trends in habitat extent, fragmentation, and condition.

To reflect the intent of Aichi Targets 5 and 11, 'habitat composition' is defined here as the amount and configuration of habitats within a geographical space, with a focus on biological habitats. Potential measures of habitat composition include proportional habitat abundance (the proportion of each habitat type relative to the entire area); richness (the number of different habitat types); evenness (the relative abundance of different habitat types); diversity (a composite measure of habitat richness and evenness); habitat patch size (e.g. the mean, median, maximum and variance per habitat type); habitat core area (the area unaffected by the edges of a habitat patch); and patch dispersion (the distribution of habitat patches). With regard to 'habitat condition', biological habitats that are in good condition are considered to be those that are capable of supporting the physicochemical and biological processes required to maintain their full complement of native biodiversity. Because physiological function differs between different types of biological habitats, measures of habitat condition are difficult to generalise and likely to be habitat specific.

26 www.cbd.int/aichi-targets/target/5
27 www.cbd.int/aichi-targets/target/11

Assessments of habitat composition should be underpinned by robust habitat maps. This typically requires that the entire area of interest (e.g. a marine reserve) is mapped, usually through landscape-scale mapping technologies such as high-resolution multibeam echo sounder (MBES), satellite or aerial imagery methods, which are complemented with the collection of benthic data (geology and biology). While landscape-scale mapping technologies are the ideal approaches for informing this theme, it may not be feasible to routinely employ these technologies as part of DOC's core monitoring programme for financial and logistical reasons. Consequently, monitoring programmes must weigh the need to map all habitats within the entire extent of a given marine reserve using landscape-scale technologies against mapping priority habitats within a marine reserve (such as rhodolith beds or *Macrocystis* forests) using smaller-scale mapping technologies such as drop camera and photogrammetry technologies and *in situ* observations.

4.1.1 Objectives

Monitoring objective 2.1 (spatial): To map the extent of all habitats present within a marine reserve.

Research question: What habitats are present within a given marine reserve and what is their spatial extent?

Monitoring objective 2.2 (temporal): To identify changes in the extent and condition of selected focal habitats within a marine reserve.

Research question: Are the extent and condition of focal habitats within a given marine reserves changing over time?

4.2 Existing monitoring programmes

Many of Aotearoa New Zealand's marine reserves have historical monitoring programmes. Where relevant monitoring data exist, Theme 2 will build on this information to meaningfully inform the monitoring and reporting objectives. For example, where historic habitat data are available, repeat monitoring can provide a temporal dataset that can be used to evaluate changes through time (e.g. see Leleu et al. 2012; Geange et al. 2019).

MBES-derived maps of bathymetry and physical and biological habitats have been created for several marine reserves in Aotearoa New Zealand, including Hikurangi Marine Reserve, Long Island - Kokomohua Marine Reserve (within broader Queen Charlotte Sound / Tōtaranui mapping), Taputeranga Marine Reserve (Pallentin et al. 2012), Kapiti Marine Reserve (Lamarche et al. 2020), Parininihi Marine Reserve (Sturgess 2015), Poor Knights Islands Marine Reserve (Morrison et al. 2007), Te Matuku Marine Reserve (part of the subtidal area only; Schimel et al. 2010) and Cape Rodney-Okakari Point Marine Reserve (Leleu et al. 2012), as well as various marine reserves in Fiordland (LINZ 2016). However, while the majority of MBES habitat mapping studies report on metrics such as benthic terrain, rugosity, curvature, slope, aspect, reflectivity and bathymetry, they seldom integrate the geophysical (processed backscatter) dataset with seafloor morphology and metrics of biodiversity to produce biophysical habitat layers (although the mapping project for Kapiti Marine Reserve is working towards achieving this – see Lamarche et al. (2020)). While this currently limits their utility in evaluating changes in the composition or condition of biological habitats, targeted ground truthing of historical MBES data may still be valuable in delimiting the previous extent of focal habitats in some cases. Existing MBES datasets may also be useful for informing targeted *in situ* monitoring efforts and can be integrated with biological data at a later stage to produce biophysical habitat maps.

Habitat maps within the marine environment that are derived from RGB and multispectral satellite or aerial imagery are becoming more common in Aotearoa New Zealand, particularly for intertidal and shallow subtidal areas that are difficult to sample due to their exposure to swell or difficulty of access because of the coastal topography. The diverse spectral profiles of marine macroalgae allow some macroalgal taxa to be distinguished to species level. Multispectral imagery from cameras fitted to unmanned aerial vehicles has been used to map intertidal habitats around the Kaikōura coast (Tait et al. 2019) and within marine reserves on the west coast of the South Island, and multispectral satellite imagery has been used to map shallow subtidal habitats in the Mokohinau Islands, Mimiwhangata Marine Park and Cape Rodney-Okakari Point Marine Reserve (Lawrence 2020). However, multispectral imagery has limited utility at water depths below 3 m under the turbid conditions that are characteristic of many of Aotearoa New Zealand's coastlines.

Photogrammetry is an emerging technology that has been used less frequently in Aotearoa New Zealand coastal and marine environments but, if successfully developed for deployment in the marine space, would allow high-resolution (to the cm scale), photo-realistic, three-dimensional mapping of the sea floor (Abadie et al. 2018; Marre et al. 2020). However, while this technology has been used to map features at a small spatial scale, it is still in its infancy in the context of subtidal habitat mapping. Therefore, applying this technology at the scale of thousands of square metres, which would be required to map individual habitats within a marine reserve, appears to be some time away.

In addition to MBES and multispectral imagery, a range of other mapping techniques have also been implemented to map the extent of the benthic habitats within Aotearoa New Zealand's marine reserves. The most prevalent mapping methods to date include the use of sidescan sonar, single-beam echosounder surveys, drop cameras and *in situ* diver surveys, which are often used in combination.

The use of different mapping methods in different marine reserves has resulted in large inconsistencies in the resolution and accuracy of maps between mapping projects. To start addressing these inconsistencies, Haggitt et al. (2019) developed generic guidance for combining disparate historic habitat maps with newly collected video imagery and presented a draft standardised thematic habitat classification. Therefore, until a nationally agreed thematic habitat classification is developed, DOC encourages the use of the classification presented in Haggitt et al. (2019) for the designation of habitat types.

More recently, comprehensive habitat data collection involving MBES, towed video cameras, drop cameras and diver observations has occurred within and around Kapiti Marine Reserve (Lamarche et al. 2020). This approach, which integrates geophysical and biogenic habitat datasets to produce a series of targeted habitat and habitat suitability maps for the marine reserve and adjacent non-reserve areas, with associated uncertainties, represents the preferred approach for addressing monitoring objective 2.1.

4.3 Sampling design

4.3.1 Selecting indicators

This theme provides guidance on how to measure data elements that will contribute to Objective 10 'Ecosystems and species are protected, restored, resilient and connected from mountain tops to ocean depths' from the ANZBS (DOC 2020c; Table 4.1).

Future updates will expand this to measure ecosystem extent and habitat availability (Table 4.2).

4.3.2 Selecting monitoring programmes

None of the established DOC monitoring programmes for monitoring changes in the habitat composition and condition within Aotearoa New Zealand's marine reserves can be readily implemented at new monitoring sites. Therefore, to achieve the objectives of Theme 2, standardised and consistent monitoring programmes will need to be developed from scratch.

Monitoring objective 2.1 would ideally involve the use of landscape-scale mapping techniques and associated ground-truthing to develop a comprehensive biophysical habitat map for a given marine reserve (and potentially adjacent non-reserve areas that are being used as controls in other themes). Appropriate landscape-scale technologies include MBES technologies (where the water is deep enough to accommodate vessel draft and allow mapping within the nearshore environment) and satellite or aerial imagery (where the water depth and clarity allow differentiation between different habitat types from multispectral imagery, or where intertidal areas need to be mapped). On occasion, complementary landscape-scale mapping technologies may need to be used (e.g. to map across the intertidal to depths in excess of 50 m).

Monitoring objective 2.2 could use any of several mapping techniques to quantify the composition and condition, with a focus on habitats that have been designated as:

- Sensitive marine habitats (MacDiarmid et al. 2013; Anderson et al. 2019)
- Biogenic habitats providing habitat for species (Geange et al. 2019)

Table 4.1. Indicators, measures and data elements relating to Theme 2 – Determine changes in habitat composition and condition. Adapted from McGlone et al. (2020).

Indicator 2.1: Habitat structure	
Measure 2.1.1: Habitat fragmentation	
Description	Habitat fragmentation is defined as the process whereby a large expanse of habitat is transformed into several smaller patches that are isolated from each other by a matrix of habitats unlike the original (Wilcove et al. 1986; Fahrig 2003). This definition implies that habitat fragmentation has four effects on habitat pattern: (1) a reduction in habitat amount, (2) an increase in the number of habitat patches, (3) a decrease in the sizes of habitat patches, and (4) an increase in the isolation of patches (Fahrig 2003). Empirical evidence to date suggests that the effects of fragmentation per se (independent of habitat loss) are generally much weaker than the effects of habitat loss, which can have large, consistently negative effects on biodiversity (Fahrig 2003).
Data elements	**Habitat amount** The total area of (a single or combination of different) habitat types within a given space. **Proportional habitat abundance** Abundance of a certain habitat type relative to the abundance of all habitat types in a given area. **Patch dispersion** The distribution and arrangement of habitat patches in a given area. **Number of habitat patches** The total number of patches/fragments with well-defined boundaries that differentiate them from surrounding units within a given area and that are isolated from each other by a matrix of habitats. **Habitat patch size** The size of an individual patch/fragment of a certain habitat type within a given area that is isolated by a matrix of other habitats. **Habitat patch isolation** The (mean) distance between habitat patches. **Habitat core area** The interior area of a habitat with the highest habitat quality that is not impacted by edge effects, which reduce habitat quality (e.g. lower cover, density) at the boundaries of the habitat. Core area is a compound measure of shape, area and edge depth. An increase in shape complexity and depth-of-edge effects decreases the core area.
Links to other measures	2.1.2: Habitat availability (Theme 2 – Habitat changes) 2.1.3: Habitat extent (Theme 2 – Habitat changes)

Table 4.2. Indicators, measures and data elements that are to be implemented in future iterations of the Marine Monitoring and Reporting Framework.

Indicator 2.1: Habitat structure	
Measure 2.1.2: Habitat availability	
Description	This measure quantifies the types and condition of habitats required to maintain the full complement of native biodiversity. Biodiversity is often considered to be positively associated with the complexity or heterogeneity of available habitats, including rocky reef, soft-sediment, nursery and biogenic habitats (MacArthur & Wilson 1967; Kohn & Leviten 1976).
Data elements	**Density of habitat-forming organisms** The quantity of habitat-forming organisms per given area (or volume). **Size or age of habitat-forming organisms** The size (height, area or volume) or age of individual habitat-forming organisms. **Biomass** The total quantity or weight of living biological organisms in a given area or volume. **Alpha diversity** The number and proportion of different species within a single site (or sample). A sample will have a high alpha diversity when there is a high number of species with similar abundances and a low alpha diversity when there are only a few species and one of these is numerically dominant. **Beta diversity** The turnover of species between sites (or samples) in terms of the gain or loss of species.
Links to other measures	2.1.1: Habitat fragmentation (Theme 2 – Habitat changes) 2.1.3: Habitat extent (Theme 2 – Habitat changes)
Measure 2.1.3: Habitat extent	
Description	Ecosystem extent is defined as the total area of habitat available. At the scale of local marine reserves, changes in habitat availability can result from changes in environmental conditions that impact habitats either positively (e.g. an increase in a limiting nutrient) or negatively (e.g. an increase in the frequency and magnitude of physical disturbance). Habitat loss typically results in habitats becoming unable to support species, reducing biodiversity and species abundance.
Data elements	**Habitat amount** The total area of (a single or combination of different) habitat types within a given space. **Habitat patch size** The size of an individual patch/fragment of a certain habitat type within a given area that is isolated by a matrix of other habitats. **Habitat core area** The interior area of a habitat with the highest habitat quality that is not impacted by edge effects, which reduce habitat quality (e.g. lower cover, density) at the boundaries of the habitat.
Links to other measures	2.1.1: Habitat fragmentation (Theme 2 – Habitat changes) 2.1.2: Habitat availability (Theme 2 – Habitat changes)

Appropriate monitoring techniques for monitoring objective 2.2 include (but are not limited to) landscape-scale technologies such as MBES and multispectral imagery, as well as drop cameras, *in situ* observations, remotely operated vehicle (ROV) surveys, sediment grabs and photogrammetry, depending on the habitat being monitored and the metric of condition that is of interest.

Table 4.3 provides a list of suggested habitats that monitoring objective 2.2 can focus on. Recognising that there may be insufficient resourcing to monitor the composition and condition of all focal habitats present within a marine reserve, habitats should be prioritised based on their contribution to (i) developing a national picture of habitat change; (ii) local monitoring needs (as identified during stakeholder/community/iwi engagement); and (iii) local pressures (e.g. increasing temperatures, sedimentation) acting on the local marine ecosystem. While not captured explicitly in the MMRF, pressures introduced by marine reserve users (e.g. anchoring damage) will be recorded where present.

4.3.3 Developing a sampling design

Monitoring objective 2.1: To map the extent of all habitats present within a marine reserve

Reserve-scale habitat maps should be underpinned by landscape-scale methods (primarily MBES, side-scan sonar and/or multispectral imagery) that are complemented with biophysical 'ground-truthing' data, which may include, amongst others, towed video cameras, drop cameras or *in situ* diver observations. Because this approach is expected to be resource intensive, it is unlikely that landscape-scale habitat mapping will occur as part of routine marine reserve monitoring. Instead, landscape-scale habitat maps are more likely to be one-off (or infrequent) inventories that provide a baseline of the physical characteristics of the seabed and the extent and arrangements of the habitats present. This information can then be used to inform subsequent monitoring programmes (e.g. for site selection and survey design), including to identify changes in the extent and condition of focal habitats (see monitoring objective 2.2 below) and to provide information necessary for informing more targeted field surveys under other goals within the MMRF (e.g. Theme 3 – Climate change; Theme 4 – Key species).

Table 4.3. Focal habitats for Theme 2, where focal habitats are those defined as sensitive marine environments by MacDiarmid et al. (2013) and Anderson et al. (2019); habitats for species by Geange et al. (2019); or unwanted organisms established in Aotearoa New Zealand by the Ministry for Primary Industries (Woods et al. 2015).

Functional group	Habitat	Sensitive habitat	Habitat for species	Unwanted organism
Algal beds	*Ecklonia* forest	√	√	–
	Macrocystis forest	√	√	–
	Mixed brown algae	√	√	–
	Red algae meadow	√	√	–
	Rhodolith bed	√	√	–
	Undaria bed	–	–	√
	Caulerpa taxifolia	–	–	√
Annelid beds	Tubeworm mat	√	√	–
	Tubeworm reef	√	√	–
	Sabella spallanzanii	–	–	√
Bryozoan beds	Bryozoan bed	√	√	–
Coral gardens	Black coral garden	√	√	–
Mangrove forests	Mangrove forest	√	√	
Mollusc beds	Horse mussel bed	√	√	–
	Mussel bed	√	√	–
	Oyster reef	√	√	–
	Pāua bed	√	√	–
	Scallop bed	√	√	–
	Dog cockles	–	√	–
Seagrass beds	Seagrass meadow	√	√	–
Sea pen beds	Sea pen bed	√	√	–
Sponge gardens	Sponge garden	√	√	–
Tunicate beds	*Pyura doppelgangera*	–	–	√
	Styela clava	–	–	√

MBES MAPPING

The objective of multibeam acoustic surveys is to collect sea floor data to identify, delineate and map biogenic, anthropogenic and geological features. The collected data can be used to chart water depths, creating a high-resolution bathymetric map at an appropriate resolution regarding the target habitat or feature; and differentiate boundaries between different substrate and/or habitat types.

A monitoring plan for MBES surveys should include:

1. The coverage of the area to be surveyed (bounding box), with the datum and coordinate system clearly identified.
2. Planned survey lines (direction and acquisition order).
3. System calibration survey lines (patch test).
4. Target features (e.g. focal habitat).
5. The location and frequency of the sound velocity profile (SVP).
6. The location of ground-truth reference points (e.g. locations for sediment grabs or video transects informed by the MBES survey outputs).
7. Identification of the project outputs (e.g. maps of individual surveys, raw and processed multibeam data, and derivatives such as probability of habitat occurrence spatial grids, seabed hardness grids, aspect grids, bathymetry layers and seabed interpretations such as habitat polygons).

Following data acquisition, MBES bathymetric data should be processed to characterise and classify the sea floor in a way that is relevant to the distribution of benthic habitats and to help in understanding their spatial and temporal distribution. The combination of topography (bathymetry) and textural surfaces (backscatter) provides an excellent reference dataset for research and management of marine sea floor habitats. Geomorphological analysis, which integrates the MBES dataset with ground-truth data, should be used to classify the multibeam bathymetry data and define the extents of particular habitat types, such as seagrass and rhodolith beds, rocky reef, and sediment characteristics (e.g. mud, sand, gravel, bioturbation signs). Further details on developing sampling designs for MBES surveys can be found in Buchanan et al. (2013), Edward & Martin (2015) and Lucieer et al. (2018).

MAPPING USING MULTISPECTRAL IMAGERY

The objective of multispectral image analysis is to delineate and map biogenic, anthropogenic and geological features across the intertidal and shallow subtidal area to depths of 15 m (water clarity permitting). These collected data can be used to determine the reef extent, reef type, geomorphic zonation, quantitative estimates of benthic and substrate community composition (dependent on discrimination between spectral signatures of the different types of habitats present), and three-dimensional reef structure. A monitoring plan for multispectral surveys should include:

1. The coverage of the area to be surveyed (bounding box), with the datum and coordinate system clearly identified.
2. The method of spectral image capture (e.g. satellite images, LiDAR, autonomous aerial vehicles, aerial photography).
3. Identification of target features and their spectral properties.
4. Image acquisition and analysis (including image classification, spectral indices and biophysical models).
5. A process for the collection of field calibration data, including the location of ground-truth reference points (e.g. locations for still photographs, visual surveys or video transects).

6. Error and accuracy assessment procedures.
7. Identification of the project outputs (e.g. maps of individual surveys, raw and processed data, and derivatives such as probability of habitat occurrence spatial grids and habitat interpretations such as habitat polygons).

Monitoring objective 2.2: To identify changes in the extent and condition of focal habitats at selected marine reserve sites

Where the location of focal habitats or features is known (e.g. through information collected as part of monitoring objective 2.1 or historic monitoring programmes), monitoring can be undertaken to assess changes in their composition or condition. This could include repeated landscape-scale monitoring surveys, such as MBES and multispectral image analysis at a higher resolution and with a greater degree of positional accuracy, or the use of a range of alternative monitoring methods, including divers or ROVs, *in situ* diver observations, drop or towed underwater cameras and sediment grabs. The preferred sampling method will depend on the focal habitat being monitored, the expected changes in habitat composition (e.g. whether changes in extent, patchiness or connectivity are expected) and condition (e.g. whether changes in the density or size of habitat-forming species or the diversity of habitats within an area are expected), and the resources available to undertake the monitoring.

HOW SHOULD HABITAT TYPES BE SELECTED?

The focal habitats considered under monitoring objective 2.2 include those habitats identified in Table 4.3. Determining which focal habitats should be monitored at each marine reserve will be informed by a combination of national monitoring priorities (e.g. would the monitoring of *Macrocystis* in a local marine reserve contribute towards building a national picture of changes in the composition or condition of *Macrocystis* in Aotearoa New Zealand?) and consultation with whānau, hapū, iwi, the community and (local) experts to identify local monitoring priorities (e.g. monitoring the extent of *Ulva* may be a local priority due to concerns about point-source eutrophication). Historical data on the spatial distribution of focal habitats and local pressures (e.g. sedimentation, fishing effort and invasive species) acting on the ecosystem can provide guidance to support this selection process.

HOW OFTEN SHOULD MEASUREMENTS BE TAKEN OF THE SELECTED HABITAT TYPES AND HOW SHOULD SAMPLES BE SPATIALLY ALLOCATED?

The frequency and timing of monitoring and the spatial allocation of sampling will be informed by the specific research questions being addressed, although it is also important that the frequency and timing of monitoring can disentangle natural spatial and temporal variability from long-term change. Key considerations in determining spatial and temporal sampling designs include:

- Habitat-specific growth rates – for example, in the absence of rapid environmental change or disturbance, slow-growing habitats such as rhodoliths can be monitored less frequently over longer time periods than fast-growing habitats such as seagrass or *Undaria*.
- Seasonality – for example, surveys of *Macrocystis* canopy cover should be conducted in winter/spring when the canopy is densest to avoid the confounding effects of seasonality.
- Expected spatial expansion or contraction of habitats – for example, sampling sites for *Undaria* may be focused around invasion fronts or alternatively may traverse their entire extent for habitats where fragmentation is expected.
- The frequency and duration of processes affecting the habitats – for example, if habitat monitoring aims to determine the impacts of a specific pressure, such as point-source sewage discharge, the frequency of monitoring should be informed by the frequency of

discharge and the rate of biological response to the discharge and the spatial allocation of sampling should be informed by the dispersal of the discharge.

- Natural spatial and temporal variability – for example, where the focus is impact monitoring, natural spatial variability in habitat change should be incorporated into the monitoring design so that it does not confound the results.

Additional guidance on monitoring design can be found in the study design[28] and ecological statistics[29] modules of the Biodiversity Inventory and Monitoring Toolbox and in chapter 2 of the National Environmental Science Programme's (NESP's) 'Field manuals for marine sampling to monitor Australian waters' (Przeslawski & Foster 2020).

4.4 Monitoring protocols

Ten main methodologies for mapping habitat composition and condition are identified in Table 4.4. Because each method has its own strengths and weaknesses, a combination of different methods is often required to achieve specific monitoring objectives. It is not the intention of this report to describe each of these methodologies in detail, as they are well established and described elsewhere. Instead, where DOC has developed standardised toolboxes for a particular method, a link to it is provided in Table 4.4. Where a standardised toolbox does not exist for a monitoring method that will be frequently used within the MMRF, a toolbox will be developed based on existing best practice. Toolboxes should be used in conjunction with detailed monitoring plans that include information on the location, frequency, and type of sampling to be undertaken, as well as any modifications to the standard monitoring techniques outlined in the toolboxes.

28 www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-introduction-to-marine-monitoring.pdf

29 www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-summary-ecological-statistics.pdf

Table 4.4. Summary of the methodologies to be utilised for habitat mapping and monitoring. Additional methodological aspects (e.g. replicates, sites) will be determined by the specific research questions.

	Satellite imagery	Aerial photography	Drones	Multibeam	Sidescan sonar	ROV/AUV	Drop camera	Video sled	UVC – diver surveys	Sediment grabs
Toolbox link	–	–	–	–	–	–	–	–	www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-underwater-transects-for-sampling-reef-fishes.pdf	–
Toolbox availability	Development required	Development required	Under development	Development required	Development required	Development required	Under development	Under development	Review required	Development required
Habitat information	Biophysical	Biophysical	Biophysical	Geomorphological	Geomorphological	Biophysical	Biophysical	Biophysical	Biophysical	Biophysical
Complementary data collection	Video / still image and visual census samples for ground truthing	Visual census samples for ground truthing	Visual census samples for ground truthing	Sediment, video / still image and visual census samples for ground truthing	Sediment, video / still image and visual census samples for ground truthing	Sediment and visual census samples for image verification	Sediment and visual census samples for image verification	Sediment and visual census samples for image verification	–	–
Data processing requirements	Image analysis (including multispectral analysis) and georeferencing	Image analysis (including multispectral analysis) and georeferencing	Image analysis (including multispectral analysis) and georeferencing	Bathymetric, backscatter and geomorphological analysis; integration of geomorphological and biological datasets	Bathymetric analysis and image analysis (including spectral analysis)	Video analysis and georeferencing	Image analysis and georeferencing	Video analysis and georeferencing	Video and photograph analysis where used by divers; otherwise georeferencing of diver observational data	Grain size and infauna community analysis; optionally chemical analyses
Mapping depth	< 20 m	< 20 m	< 5 m	5–100s m	5–100s m	5–100s m	5–100s m	5–50 m	1–30 m	1–100s m

Continued on next page

Table 4.4 continued

	Satellite imagery	Aerial photography	Drones	Multibeam	Sidescan sonar	ROV/AUV	Drop camera	Video sled	UVC – diver surveys	Sediment grabs
Data elements	• Habitat amount • Number of habitat patches • Habitat patch size • Habitat patch isolation • Patch dispersion • Patch connectivity	• Habitat amount • Number of habitat patches • Habitat patch size • Habitat patch isolation • Patch dispersion • Patch connectivity	• Habitat amount • Number of habitat patches • Habitat patch size • Habitat patch isolation • Patch dispersion • Patch connectivity	• Habitat amount • Number of habitat patches • Habitat patch size • Habitat patch isolation • Proportional habitat abundance • Patch dispersion • Patch connectivity	• Habitat amount • Number of habitat patches • Habitat patch size • Habitat patch isolation • Proportional habitat abundance • Patch dispersion • Patch connectivity	• perceentage cover • Density of habitat-forming organisms • Size of habitat-forming organisms • Proportional habitat abundance • Alpha diversity • Beta diversity	• Percentage cover • Density of habitat-forming organisms • Size of habitat-forming organisms • Proportional habitat abundance • Alpha diversity • Beta diversity	• Percentage cover • Density of habitat-forming organisms • Size of habitat-forming organisms • Proportional habitat abundance • Alpha diversity • Beta diversity	• Percentage cover • Density of habitat-forming organisms • Size of habitat-forming organisms • Proportional habitat abundance • Age of habitat-forming organisms • Biomass • Alpha diversity	• Sediment grain size • Sediment organic content • Sediment nutrients • Percentage cover of surface vegetation and macroalgae • Heavy metal contaminants
References for field protocols	Kachelriess et al. 2014; de Araujo Barbosa et al. 2015; Ouellette & Getinet 2016	Moore 2000	Przeslawski & Foster 2020	Micallef et al. 2012; Buchanan et al. 2013; Lurton & Lamarche 2015; Lucieer et al. 2018	McRea et al. 1999; Blondel 2009	Monk et al. 2018	Carroll et al. 2018	Carroll et al. 2018	See toolbox link above	Przeslawski et al. 2019

Abbreviations: ROV/AUV, remotely operated vehicle / autonomous underwater vehicle; UVC, underwater video census.

4.5 Data management

Details on how data management is currently approached at DOC are provided in section 2.5.5.

4.6 Data analysis

Several data elements can be analysed to obtain an understanding of how the habitat in marine reserves compares with that outside them or changes over time. The data elements presented in Tables 4.5–4.10 can be used to meet the objectives of both Themes 1 and 2. Key references for analysing changes in the spatial configuration of habitat include Gustafson (1998), Hargis et al. (1998), Fahrig (2003), Smith et al. (2009) and Edgar et al. (2017).

Table 4.5. Summary of analytical approaches for data relating to the habitat amount and proportional habitat abundance.

Data elements: Habitat amount (m^2), proportional habitat abundance					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Satellite imagery • Aerial photography • Drones • Multibeam • Sidescan sonar • Remotely operated / autonomous underwater vehicle (ROV/ AUV) • Drop camera • Video sled • Underwater visual census (UVC) – diver surveys	The total area of each habitat type within a defined area (e.g. within a marine reserve).	Sum the area of individual mapped polygons for each habitat type within a location (e.g. a marine reserve) to get an overall estimate of habitat area. For each habitat type, calculate the proportional abundance as the spatial extent of habitat *h* relative to the overall area of location *l* being mapped using the equation m^2_h / m^2_l. This would typically be performed using geospatial tools such as ArcGIS.	Compare the habitat area or proportional habitat abundance across habitat types within the same location (e.g. a marine reserve) or for a focal habitat between locations (e.g. between a marine reserve and an adjacent control site of the same spatial extent).	Include a hypothetical habitat map (which will be used for all example visualisations) showing the spatial extent of habitats, plus a chart plotting the area of each habitat type (e.g. see Fig. 4.1). Note that the plot for proportional habitat abundance will be the same, with the *y*-axis rescaled.	**Objective 2.1 – Spatial**
			Compare changes in the area or proportional abundance of a focal habitat through time.	Overlay the changing habitat types on a map (e.g. see Fig. 4.2).	**Objective 2.2 – Temporal**

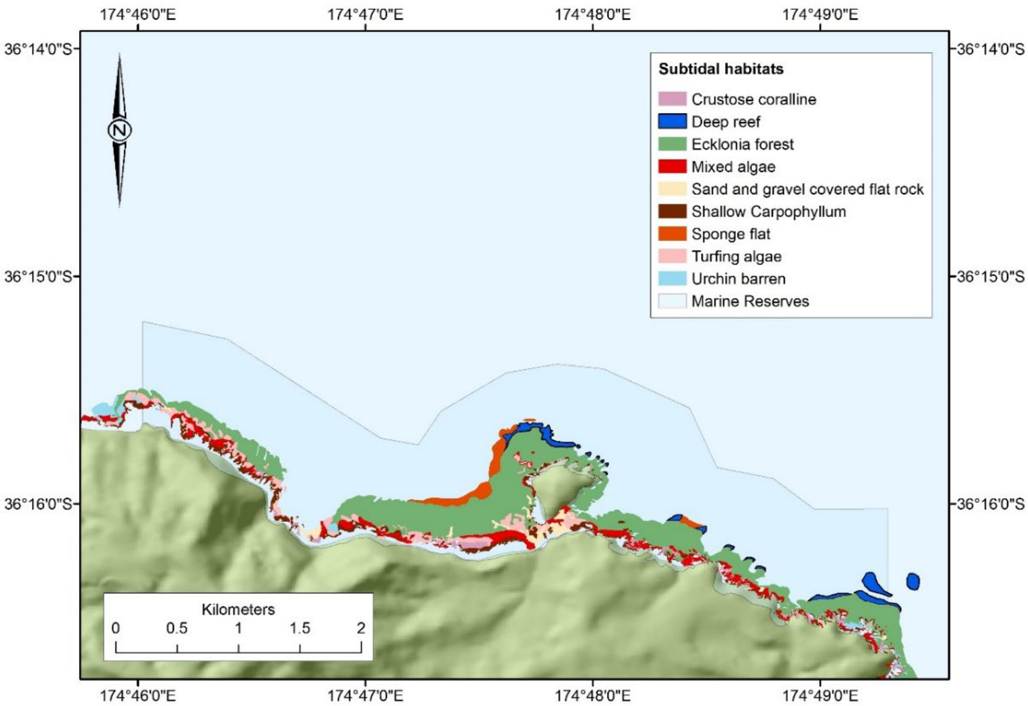

Figure 4.1. Benthic habitats (excluding sand) within Cape Rodney-Okakari Point Marine Reserve in 2006, as reported by Leleu et al. (2012). Reproduced under a CCO1.0 Universal public license from https://datadryad.org/stash/dataset/doi:10.5061/dryad.6vr28.

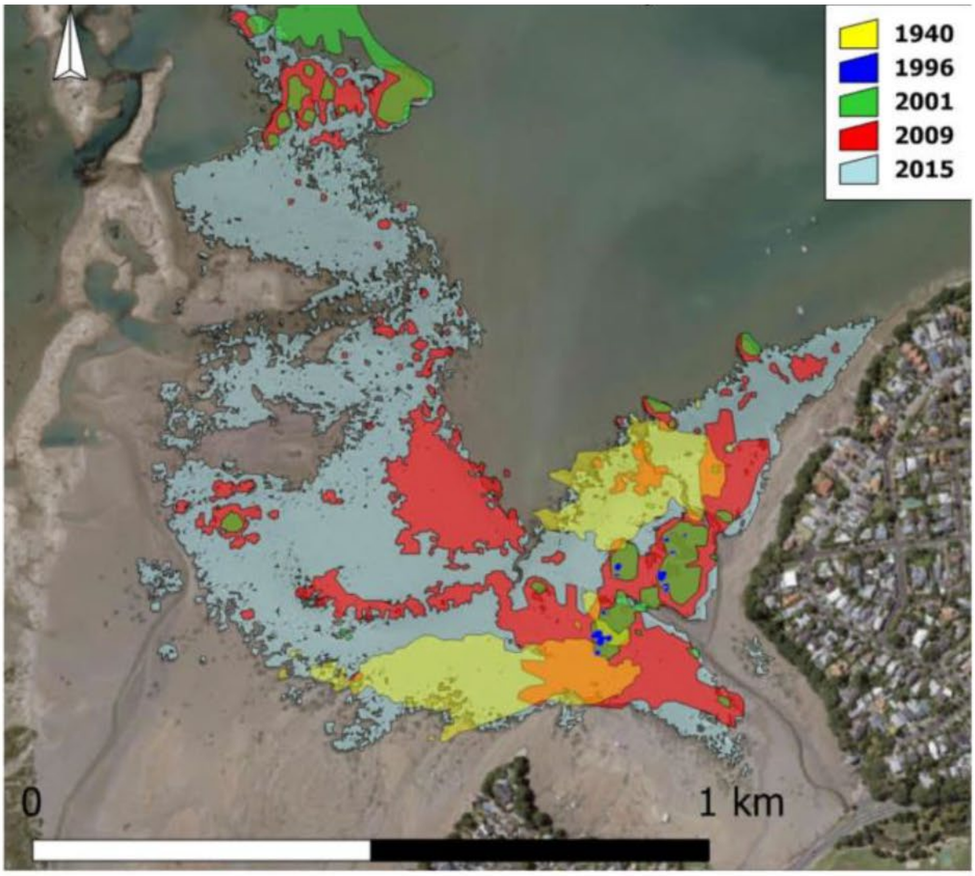

Figure 4.2. Temporal changes in seagrass cover in the Waitemata Harbour, Auckland, from 1940 to 2015. Polygons were digitised from aerial photographs and depict large changes in the extent of seagrass meadows at this location, including a significant loss by 1996 followed by a significant expansion by 2015. Source: Lundquist et al. 2018: fig. 1. Reproduced under a Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/).

Table 4.6. Summary of analytical approaches for data relating to patch dispersion (or contagion).

Data element: Patch dispersion					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Satellite imagery • Aerial photography • Drones • Multibeam • Sidescan sonar	Rasterised habitat layers from which cell adjacencies can be calculated.	Calculate the sum of two probabilities: (1) the probability that a randomly chosen cell belongs to patch type *i* (estimated by the proportional abundance of patch type *i*); and (2) the conditional probability that if a given cell is of patch type *i*, one of its neighbouring cells belongs to patch type *j* (estimated by the proportional abundance of patch type *i* adjacencies involving patch type *j*). The product equals the probability that two randomly chosen adjacent cells belong to patch types *i* and *j*. This is a measure of the extent to which patch types are aggregated or clumped; higher values will result from landscapes with a few large, contiguous patches, whereas lower values characterise landscapes with many small and dispersed patches.	Compare patch dispersion among different habitat types within a location (e.g. a marine reserve) or of a focal habitat between locations (e.g. between a marine reserve and an adjacent control site of the same spatial extent).	Include a bar plot of patch dispersion for each habitat type.	**Objective 2.1 – Spatial**
			Compare changes in patch dispersion of a focal habitat through time. See Fig. 4.3 for a demonstration of dispersal.		**Objective 2.2 – Temporal**

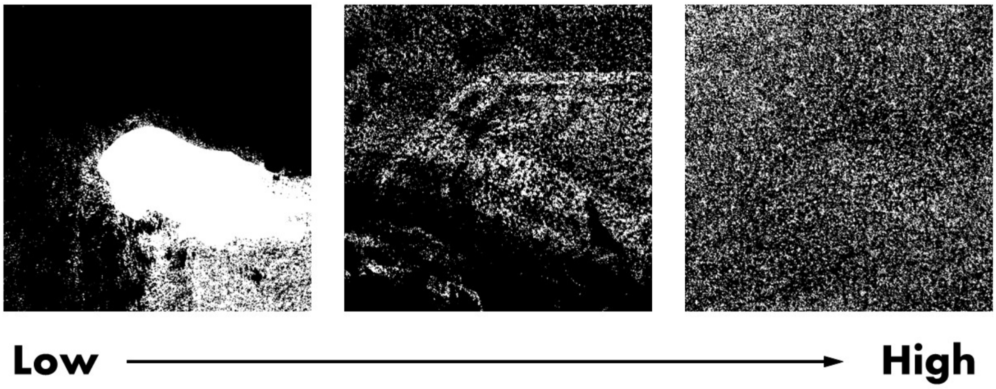

Figure 4.3. Changes in dispersion for a given patch type without any reference to any other patch types.

Table 4.7. Summary of analytical approaches for data relating to the number of habitat patches.

Data element: Number of habitat patches					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Satellite imagery • Aerial photography • Drones • Multibeam • Sidescan sonar • Remotely operated / autonomous underwater vehicle (ROV/AUV) • Drop camera • Video sled	The total number of patches/ fragments of a minimum patch size with well-defined boundaries that differentiate them from surrounding units within a given area and are isolated from each other by a matrix of habitats.	Calculate the number of individual mapped polygons for each habitat type within a location. This would typically be performed using geospatial tools such as ArcGIS.	Compare the number of patches for each habitat type within a location (e.g. a marine reserve) or the number of patches of a focal habitat between locations (e.g. between a marine reserve and an adjacent control site of the same spatial extent).	Produce a bar plot of the number of different types of habitat patches inside and outside the reserve.	**Objective 2.1 – Spatial**
			Compare changes in the number of patches of a focal habitat at a single location through time.	Produce a line plot of the number of habitat patches for one habitat type. The first point on the line shows the number of patches at time 0, with additional points indicating a change in the number of patches through time.	**Objective 2.2 – Temporal**

Table 4.8. Summary of analytical approaches for data relating to the habitat patch size.

Data element: Habitat patch size					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Satellite imagery • Aerial photography • Drones • Multibeam • Sidescan sonar	The size of an individual patch/ fragment of a certain habitat type within a given area that is isolated by a matrix of other habitats.	Calculate the area of individual mapped polygons for each habitat type within a location. This would typically be performed using geospatial tools such as ArcGIS.	Compare the mean patch size (± standard deviation (SD)) for different habitat types within a location (e.g. a marine reserve) or of a focal habitat between locations (e.g. between a marine reserve and an adjacent control site of the same spatial extent).	Produce a box and whisker plot of mean patch size for each habitat type.	Objective 2.1 – Spatial
			Compare changes in the mean patch size (± SD) of a focal habitat through time.	Produce a dot plot and layer with error bars to show changes in mean patch size over time for each habitat type.	Objective 2.2 – Temporal

Table 4.9. Summary of analytical approaches for data relating to habitat patch isolation (m).

Data element: Habitat patch isolation					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Satellite imagery • Aerial photography • Drones • Multibeam • Sidescan sonar	The (mean) distance between habitat patches.	For each habitat type, calculate the nearest neighbour distances between habitat patches. This would typically be performed using geospatial tools such as ArcGIS.	Compare mean patch isolation (± standard deviation (SD)) for different habitat types within the same location (e.g. a marine reserve) or of a focal habitat in different locations (e.g. between a marine reserve and an adjacent control site of the same spatial extent).	Produce a bar plot with error bars to show the difference in patch isolation between a marine reserve and a comparable control site.	Objective 2.1 – Spatial
			Compare changes in mean patch isolation (± SD) of a focal habitat through time.	Produce a line plot of patch isolation for one habitat type. The first point on the line shows the mean patch isolation (± SD) at time 0, with additional points indicating a change in mean patch isolation (± SD) through time.	Objective 2.2 – Temporal

Table 4.10. Summary of analytical approaches for data relating to the habitat core area.

Data element: Habitat core area					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Satellite imagery • Aerial photography • Drones • Multibeam • Sidescan sonar	The sum of the core areas across all patches.	For each habitat type, sum the core areas across all patches.	Compare the habitat core area across habitat types within the same location (e.g. a marine reserve) or for a focal habitat between different locations (e.g. between a marine reserve and an adjacent control site of the same spatial extent).		Objective 2.1 – Spatial
			Compare changes in the habitat core area of a focal habitat through time.	Produce a line plot of changes in the habitat core area of a focal habitat through time.	Objective 2.2 – Temporal

4.7 Reporting and communicating

Reporting on the changes in habitat condition and composition is critical to understanding any widespread changes in the integrity of a marine reserve (Table 4.11). Habitats provide numerous ecosystem services that keep marine environments healthy, and certain habitats are necessary for species to thrive. Reporting on these changes allows DOC to identify where key species may be negatively impacted and where the overall integrity of the reserve is in jeopardy.

Table 4.11. Information relating to Theme 2 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective	**Maintaining ecosystem processes**	
Indicator	**Ecosystem structure**	
Data elements	Habitat amount Number of habitat patches Habitat patch size Habitat patch isolation Density of habitat-forming organisms Size of habitat-forming organisms Age of habitat-forming organisms	Proportional habitat abundance Habitat core area Patch dispersion Patch connectivity Biomass Alpha diversity Beta diversity
Reporting	• Spatial extent of all habitats within a marine reserve • Changes in the extent or fragmentation of focal habitats through time • For focal habitats, changes in the densities, sizes or biomasses of habitat-forming organisms between reserve and non-reserves sites or over time	
Outcome Objective	**Ensuring ecosystem representation**	
Indicator	**Ecosystem representation and protection status**	
Data elements	Habitat amount Habitat core area Habitat patch size	
Reporting	• Proportional habitat abundance of either single or multiple habitat types within the marine reserve	

4.7.1 Marine reserve reports and report cards

The data elements monitored by Theme 2 can be included in marine reserve reports and report cards using the results of the analyses. The definitions for reporting on the status of the measures monitored under this theme are described in Table 4.12 (see Table 2.5 for definitions of trend).

4.7.2 Other reporting opportunities

To improve the accessibility of habitat data, all habitat maps will be loaded into a SeaSketch project and made publicly available. All monitoring must include as an output a comprehensive monitoring report that details the monitoring objectives, methodological approach and interpretation of the results, including inferences about the performance of the monitoring programme and the effectiveness of the marine reserve in meetings its objectives. The frequency at which these reports will be produced will be identified within the associated marine reserve monitoring plan. Monitoring results will be communicated through internal and external communication channels while data gathering is underway and once this has been completed.

Contributions to this theme may be required from whānau, hapū, iwi, regional councils, Crown Research Institutes, universities, NIWA, MPI, MfE and LINZ.

Table 4.12. Definitions for reporting on the status of the measures for Theme 2 – Determine changes in habitat composition and condition.

Status	Definition
Excellent	Habitats in the marine reserve have close to the full complement of native habitat types expected, with healthy communities of habitat-forming organisms and minimal fragmentation into isolated patches. Habitats are biodiverse and extensive.
Good	The marine reserve contains a broad range of expected native habitat types. Populations of habitat-forming species may contain younger or smaller communities, and there may be some smaller, dispersed habitat patches.
Fair	Several native habitat types are present in the marine reserve. There is some fragmentation into small habitat patches.
Poor	The marine reserve contains fewer native habitat types than expected, with low biodiversity and biogenic habitat fragmented into small, isolated patches.
Undetermined	The status of this measure cannot be determined.

5 Theme 3 – Define and track climate change indicators

What	Status and trends of physical and biological responses to climate change
Who	DOC, New Zealand Ocean Acidification Observing Network (NZOA-ON)
When	Once per month
Where	Nine marine reserves representing mainland bioregions
How	NZOA-ON monitoring programme using bottle samples of ocean water at site and temperature data supplied by data providers
Why	To understand the consequences of anthropogenic greenhouse gas emissions on the marine environment

5.1 Background and objectives

Climate change is the response of the global climate to increasing levels of greenhouse gases being released into the atmosphere since the Industrial Revolution as a result of human activities such as fossil fuel burning and land use changes (Pachauri & Meyer 2014). Since water covers 71% of the Earth's surface and has a 1000 times greater capacity to hold heat than the atmosphere, oceans play a central role in regulating the planet's climate system (Schmitt 2018). To date, oceans have absorbed more than 90% of the extra heat trapped by greenhouse gases and have taken up approximately 30% of atmospheric carbon dioxide (CO_2) released into the atmosphere from human activities (IPCC 2019), preventing the atmospheric temperature from climbing even higher. However, this absorption of emissions and heat is having profound and widespread effects on oceans and the marine biodiversity within them. Oceanic drivers, including temperature, salinity, ocean currents and oxygen (O_2), as well as other physical variables such as light, shape the physiological performance of individual cells and organisms and ultimately determine ecosystem composition, spatial structure and functioning (Pachauri & Meyer 2014).

5.1.1 Predicted effects of climate change

> *Over the 21st century, the ocean is projected to transition to unprecedented conditions with increased temperatures (virtually certain), greater upper ocean stratification (very likely), further acidification (virtually certain), oxygen decline (medium confidence), and altered net primary production (low confidence). Marine heatwaves (very high confidence) and extreme El Niño and La Niña events (medium confidence) are projected to become more frequent.*
>
> (IPCC 2019)

The following sections outline observed changes as a result of climate change to date.

Sea surface temperature (SST)

SST is a key indicator of climate change, as it describes the conditions at the boundary of the atmosphere and the oceans, where the transfer of energy takes places. As the oceans absorb more heat, SSTs are increasing, leading to more marine heatwaves[30] and modifications to large-scale circulation patterns and their associated ecosystems. SST is of direct relevance to atmospheric processes, and it is predicted that increasing global SSTs will lead to more frequent and stronger extreme events, such as storms and tropical cyclones.

Ocean heat content (OHC)

OHC is a measure of how much energy the oceans hold, from the surface down to 2000 m. The uptake of excess heat is leading to general ocean warming globally, with the greatest increases having been reported in the Southern Ocean, which accounts for 35–43% of the total heat gain in the upper 2000 m observed between 1970 and 2017 (Pachauri & Meyer 2014; Cheng et al. 2020).

Sea-level rise

The global mean sea level is rising, and the rate of increase has accelerated in recent decades due to increasing rates of ice loss from the Greenland and Antarctic ice sheets, as well as continued glacier mass loss and ocean thermal expansion[31] (IPCC 2019). Globally, the sea level increased by 1.5 mm per year between 1901 and 1990, but this increased to 3.6 mm per year between 2005 and 2015 (IPCC 2019). Further sea-level changes have been forecast through to 2100 based on different emissions scenarios (IPCC 2014).

Ocean acidification

Increasing atmospheric CO_2 concentrations not only cause ocean warming but also change the carbonate chemistry via ocean acidification. While increased CO_2 may be beneficial for photosynthesising organisms, the uptake of CO_2 from the atmosphere increases the acidity of sea water near the surface (i.e. decreases its pH) (IPCC 2019). This affects a wide variety of species, and makes it more difficult for calcifying organisms (e.g. pāua (*Haliotis* spp.), corals and some types of plankton) to produce the calcium carbonate they need to build their skeletons or shells. This lower pH also lowers sound absorption and thus increases the level of ambient noise, which has implications for animals such as marine mammals, which depend on sound transmission for communication (Hester et al. 2008) Ocean acidification can also be caused by other anthropogenic processes (e.g. through additional nutrient run-off from land) and natural processes (e.g. increased volcanic activity or long-term changes in net respiration).

5.1.2 Observed and projected impacts of climate change in Aotearoa New Zealand's waters

Aotearoa New Zealand's marine systems are not immune to climate change, with evidence having been reported for increasing SSTs, sea-level rise and changes in primary productivity (Hurst et al. 2012; Pinkerton 2016; Sutton & Bowen 2019), as well as a decreasing pH (Law et al. 2018). The regularly published reporting series 'Our marine environment' includes a variety of climate change related indicators. The sections below outline changes in the indicators that were reported on in its 2019 iteration (MfE & Stats NZ 2019).|

30 A marine heatwave is a period of extreme warm near-surface temperature that persist for days to months and can extend up to thousands of kilometres (IPCC 2019).

31 Because warmer sea water is denser, it decreases in volume.

SST

Over the last 30 years, there has been a general warming trend (0.1–0.2°C per decade) across Aotearoa New Zealand's four oceanic regions (Chatham Rise, Tasman Sea, and subtropical and subantarctic waters), with a larger increase (0.2°C) being observed in coastal waters (Fig. 5.1).[32] There was also an unprecedented heatwave in the Tasman Sea and south of the Chatham Rise in the summer of 2017/18. The 2020 National Climate Change Risk Assessment (MfE 2020) identified the risks to coastal ecosystems from an increasing incidence of heatwaves (and sea-level rise; see below) as the top risk to the natural environment in Aotearoa New Zealand.

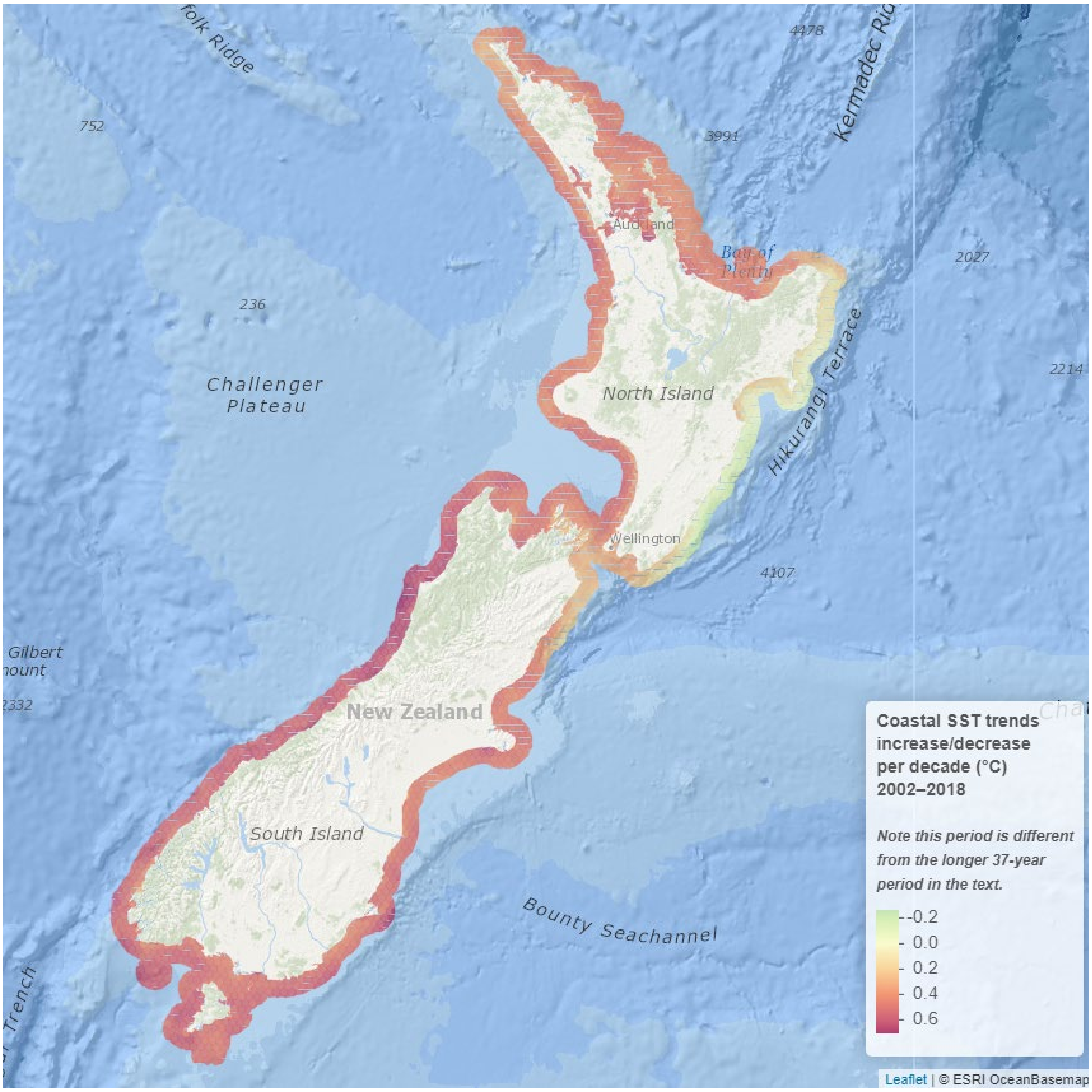

Figure 5.1. Coastal trends in sea surface temperature (SST) in Aotearoa New Zealand per decade between 1981 and 2018. This work was developed as part of the environmental reporting programme of Stats NZ and the Ministry for the Environment. Data was sourced from NIWA. Image retrieved from Stats NZ's interactive tool (https://statisticsnz.shinyapps.io/sea_surface_temperature_oct19/). Reproduced under a Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/).

32 www.stats.govt.nz/indicators/sea-surface-temperature

Coastal sea-level rise

Long-term records from tide gauges (Auckland, Wellington, Dunedin and Lyttelton) show rising sea levels of 1.81 ± 0.05 mm per year over the last decade, as well as an apparent acceleration in the rate of sea-level rise over the last six decades. The 2020 National Climate Change Risk Assessment (MfE 2020) indicated that sea-level rise will continue unabated during the 20th century, posing a serious risk to coastal ecosystems (including wetlands).

Ocean acidification

The longest time series dataset recorded in Aotearoa New Zealand, from off the Otago coast (Munida transect), indicates that acidity has increased by 7.1% over the past 20 years (MfE & Stats NZ 2019; Fig. 5.2). This places at risk carbonate-based, hard-shelled species, which play important roles in controlling ecosystem structure and function (MfE 2020).

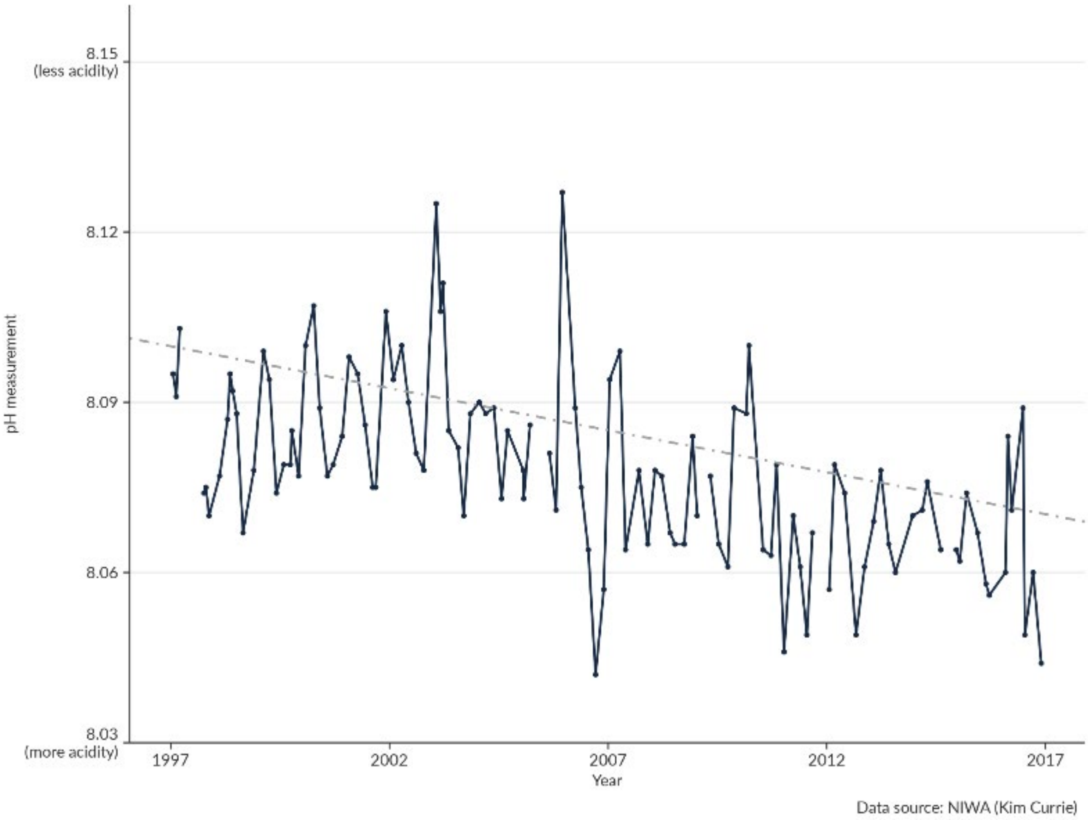

Figure 5.2. pH measurements taken in subantarctic waters (Munida transect) between 1998 and 2017.

5.1.3 Role of MPAs in a changing climate

Nature-based solutions are increasingly being seen as cost-effective investments to mitigate and adapt to climate change (IUCN 2016). Ocean ecosystems represent the largest carbon sink in the world, with blue carbon ecosystems (e.g. mangroves, salt marshes and seagrasses) accounting for approximately 50% of carbon sequestered in the oceans. Therefore, the degradation of these ecosystems affects the capacity of the oceans to maintain this important role. MPAs that are designed and managed to be climate smart provide us with a valuable tool for protecting marine biodiversity while helping to mitigate further impacts of climate change.

Part of DOC's OMF is to maintain and restore Aotearoa New Zealand's natural heritage diversity, and DOC's monitoring programmes can help fill knowledge gaps regarding species and ecosystem threats, including climate change.

5.1.4 Climate change impacts on MPAs

MPAs do not insulate species and ecosystems from experiencing the direct impacts of climate change, as ocean conditions inside MPAs are the same as those outside them (Bruno et al. 2018). However, there is international and national evidence to suggest that ecosystems in well-designed MPAs can better withstand and adapt to the impacts stemming from climate change (Micheli et al. 2012; Cornwall & Eddy 2015). Communities inside MPAs are more stable, are less impacted by disturbances and recover faster from disturbances than those outside MPAs (Mellin et al. 2016). Furthermore, as seagrass and kelp recover in MPAs, they may also ameliorate ocean acidification in surrounding waters (Rastrick et al. 2018). The effective management of MPAs can also limit other anthropogenic stressors that may compound the negative effects of climate change and can enable ecosystems to build resilience for the future (Roberts et al. 2017).

5.1.5 Marine reserve monitoring in a changing climate

Aotearoa New Zealand's marine reserves are found along a 20° latitudinal gradient that spans subtropical, subantarctic and Antarctic waters. While oceanographic variables describing the main currents, water masses, fronts, etc. in the open ocean are primarily driven by large-scale ocean processes, Aotearoa New Zealand's coastal areas – where most of the current marine reserves are located – are greatly influenced by more dynamic, shallow-water processes that result in higher natural variability. However, coastal systems are still subject to the same large-scale warming trends that are observed in the open ocean.

Determining local trends in physical variables is required to adequately disentangle both physical and associated biological responses to climate change from natural variation and other sources of anthropogenic pressures. To achieve this, long time series of measurements are necessary.

The formal attribution of a climate change impact on biodiversity values requires three criteria to be met: extreme event attribution, impact detection and impact attribution. Under each criterion, the relationship between cause and effect must be demonstrated, the detected change must be shown to be inconsistent with changes due to alternative possible drivers, and the strength of the attribution statement needs to be quantified to acknowledge the uncertainty and limitations of the available data and analysis (Harris et al. 2020).

Undertaking comprehensive and long-term monitoring of all climate change indicators in all of Aotearoa New Zealand's marine reserves is unviable and probably unnecessary. For example, the existing network of tide gauges around the country provides estimates of sea-level rise that are adequate to inform the management of marine reserves.

The climate change indicators included under the objectives below will inform the systematic collection of relevant oceanographic data. Remote sensing represents a cost-efficient approach for monitoring at suitable spatial and temporal resolutions (Baldock et al. 2014; Kachelriess et al. 2014), and the resulting data can be analysed together with indicators of biological responses. The incorporation of mātauranga Māori and other sources of local ecological knowledge will also help to develop a more complete understanding of how climate change is affecting marine ecosystems.

5.1.6 Objectives

Monitoring objective 3.1 (spatial): Determine the status of ocean climate indicators (SST and pH) across Aotearoa New Zealand's bioregions.

Research question: How is the physical environment changing in each bioregion or marine reserve as a consequence of increased CO_2 emissions?

Monitoring objective 3.2 (temporal): Determine trends in ocean climate indicators (SST and pH) within Aotearoa New Zealand's marine reserves.

Research question: Are ocean climate indicators changing over time?

5.2 Existing monitoring programmes

Aotearoa New Zealand has an existing monitoring network that gathers oceanographic data, including continuous time series, and efforts are underway to expand and improve the collection of essential data across the country's marine space (O'Callaghan et al. 2019). The current system includes long-term tide gauges that have been operating since the late 19th century, long-term temperature data collection at Cape Rodney-Okakari Point Marine Reserve, pH measurements of subantarctic waters off Otago and buoys collecting environmental data (e.g. those in the Firth of Thames). Table 5.1 provides an overview of existing long-term monitoring, which is primarily undertaken by regional councils, Crown Research Institutes and universities.

Table 5.1. Summary of past and present monitoring programmes for Theme 3 undertaken by the Department of Conservation Te Papa Atawhai (DOC) and other stakeholders, by bioregion. For additional details, see Appendix 2.

Bioregion	DOC monitoring programmes	Other monitoring programmes (inside and outside marine reserves)
Subantarctic Islands		
Southern South Island	pH – NZOA-ON (Ulva Island - Te Wharawhara Marine Reserve)	SLR – EQC and LINZ (Charleston, Dunedin) SST – NIWA (Bluff)* SST – University of Otago (Portobello) pH, SST – NZOA-ON with NIWA, University of Otago and Port of Otago (Dunedin). Munida Time Series, University of Otago.
Snares Islands		
Fiordland		SST, pH – Environment Southland; monitoring buoy (Taipari Roa (Elizabeth Island) Marine Reserve) SLR – EQC and LINZ (Puysegur Point)
West Coast South Island		pH – NZOA-ON with Fishing Industry (Jackson Bay / Okahu) SST – NIWA (Jackson Bay / Okahu)
East Coast South Island		SST – NIWA (Lyttelton) SLR – EQC and LINZ (Kaikoura, Christchurch)
South Cook Strait		SST – Tasman Council; water sampling (Long Island - Kokomohua Marine Reserve) pH – NZOA-ON with NIWA, Aquaculture New Zealand and Cawthron Institute (Marlborough Sounds, Tasman Bay, Golden Bay)
North Cook Strait	SST, SLR – WRIBO-Kapiti pH – NZOA-ON (Taputeranga and Kapiti marine reserves)	SLR – EQC and LINZ (Manakau, Wellington) pH – NZOA-ON with NIWA (Wellington Harbour (Port Nicholson)) SST – NIWA (Lyall Bay and Evans Bay) SST, SLR – Wellington Regional Council; WRIBO† buoy
Western North Island		SST – NIWA (New Plymouth)
Eastern North Island	pH – NZOA-ON (Te Angiangi Marine Reserve)	SST, pH – Hawke's Bay Regional Council; monitoring buoy (Napier) SST – NIWA (Napier) SLR – EQC and LINZ (Gisborne, East Cape)
North Eastern	pH – NZOA-ON (Tuhua (Mayor Island) Marine Reserve)	SST, pH – Auckland Council and NZOA-ON; water sampling (Motu Manawa-Pollen Island Marine Reserve, Cape Rodney-Okakari Point Marine Reserve and outside marine reserves) SST –- University of Auckland (Cape Rodney-Okakari Point Marine Reserve); data since 1967 pH – NZOA-ON with NIWA, Bay of Plenty Regional Council (Firth of Thames, Waikato Regional Council) SST – NIWA (Tauranga and Ahipara Bay) SST – Northland Regional Council (Whangārei Harbour) SLR – EQC and LINZ (Auckland, Great Barrier Island (Aotea Island), North Cape, Tauranga)
Three Kings Islands		
Kermadec Islands		SLR – EQC and LINZ (Boat Cove and Fishing Rock (Raoul Island))
Chatham Islands		SLR – EQC and LINZ pH – NZOA-ON with Paua Industry Council

Abbreviations: EQC, Earthquake Commission; LINZ, Land Information New Zealand; NIWA, National Institute for Water and Atmospheric Research; NZOA-ON, New Zealand Ocean Acidification Observing Network (marinedata.niwa.co.nz/nzoa-on/); SLR, sea-level rise; SST, sea surface temperature; WRIBO, Wellington Region Integrated Buoy Observations.

* https://environment.govt.nz/assets/Publications/Files/nz-coastal-sea-surface-temperature.PDF

† https://archive.gw.govt.nz/wellington-regional-integrated-buoy-observations-programme/#:~:text=The%20buoy%20is%20positioned%20within,based%20activities%20on%20water%20quality.Sampling design

5.3 Sampling design

5.3.1 Selecting indicators

This theme provides guidance on how to undertake monitoring for Objective 13 'Biodiversity provides nature-based solutions to climate change and is resilient to its effects' from the ANZBS (DOC 2020c; Table 5.2). Data on some related measures are also being collected as part of Theme 6 – Water quality (see section 8). Theme 3 will focus on physicochemical properties that can be routinely measured (SST and pH), which will be complemented by data from other sources.

Table 5.2. Indicators, measures and data elements relating to Theme 3 – Define and track climate change indicators. Adapted from McGlone et al. (2020).

Indicator 3.1: Basic climate series	
Measure 3.1.1: Climate averages, indices and extreme events	
Description	Aotearoa New Zealand's climate observation stations provide a broad-scale overview of changes in major climate factors. Global networks are now augmented by ocean buoys and satellite observations. However, some areas are still poorly documented and metre-scale changes that are relevant to plants and animals are not well known. The main reason for monitoring climate processes in marine protected areas (MPAs) is because the transport, growth, mortality and recruitment of a species' larvae and the productivity and availability of their prey are directly influenced by large-scale, long-term processes, such as the El Niño Southern Oscillation (ENSO), decadal shifts and regime shifts.
Data elements	**Sea surface temperature (SST)** The temperature of the ocean at the surface. **pH (seawater acidity)** The acidity or alkalinity of a solution on a logarithmic scale, where 7 is neutral, lower values are more acidic and higher values are more alkaline. pH data can be collected directly in the field and from samples in a laboratory or calculated from measurements of dissolved inorganic carbon and alkalinity.
Links to other measures	Provides a fundamental data series for most indicators 3.2.1: Ocean regime and temperature (Theme 3 – Climate change) 3.2.2: Biological responses to extreme climate events (Theme 3 – Climate change) 3.2.3: Phenological response to climatic regime change (Theme 3 – Climate change) 3.2.4: Range shifts (Theme 3 – Climate change) 6.1.1: Water physicochemical factors (Theme 6 – Water quality) 6.2.1: Ecosystem primary productivity (Theme 6 – Water quality)

Future updates will expand this to include measures relating to biological responses to extreme climate events, phenological response to climatic regime change and range shifts, as well as ocean regime and temperature, which will contribute to monitoring progress towards Objective 13.3.1 'Potential impacts from climate change have been integrated into ecosystem and species management plans and strategies, and a research and rangahau strategy has been developed to increase knowledge and understanding of climate change effects' (Table 5.3).

5.3.2 Selecting monitoring programmes

Multiple methodologies can be used to meet the objectives for Theme 3. Therefore, an evaluation of the strengths and weaknesses of different methods is required (see Table 5.4). It is important to consider how the data are collected and processed, as this varies considerably by method and will influence the overall cost and time involved, as well as the quality of the data. At this stage, DOC only undertakes consistent monitoring for ocean acidification and SST in marine reserves. Other relevant data elements (ocean heat, sea-level rise) will be added in future iterations (see Appendix 2 for a brief introduction to future methods planned).

Table 5.3. Indicators, measures and data elements that are in scope for future iterations of the Marine Monitoring and Reporting Framework.

Indicator 3.2: Responses to climate change	
Measure 3.2.1: Ocean regime and temperature	
Description	Changes in currents, wave regimes and the frequency of storm events can have major effects on the biological functioning of marine areas. This measure ensures that sufficient background data are collected for the interpretation of both short- and long-term biological changes.
Data elements	Sea surface salinity, sea-level rise, dissolved O_2 / hypoxia, mixed layer depth / stratification, currents, wave height and direction, El Niño Southern Oscillation (ENSO) state, extreme weather events, upwelling/fronts, saltwater intrusion, atmospheric properties (air temperature, alongshore wind speed).
Links to other measures	4.1.1: Exploited species production (Theme 4 – Key species) 4.2.1: Marine biological function (Theme 4 – Key species)
Measure 3.2.2: Biological responses to extreme climate events	
Description	Biological changes are expected to occur in response to an increased frequency and intensity of extreme weather and climate events, such as tropical cyclones and marine heatwaves. It is increasingly recognised that climate extremes can have greater impacts on biodiversity than more gradual and subtler changes in climate means. Biological responses can occur when, for example, the thermal tolerance of a species or tipping point for an ecosystem is reached. Coral bleaching in tropical waters is the most well-known example of impacts of warmer waters and accompanying atmospheric conditions leading to the degradation of species and the ecosystems they support (IPCC 2019). One example of this in Aotearoa New Zealand is the local extinction of bull kelp (*Durvillaea* spp.) observed at Inainatu/Pile Bay (Lyttelton Harbour) during the summer of 2017/18, when SSTs reached the highest levels recorded in 38 years (Thomsen et al. 2019). Interestingly, the area was subsequently colonised by the invasive kelp *Undaria pinnatifida* (Thomsen et al. 2019).
Data elements	Collection of biological data on indicator species (*to be determined*).
Links to other measures	3.1.1: Climate averages, indices and extreme events (Theme 3 – Climate change) 3.2.3: Phenological response to climatic regime change (Theme 3 – Climate change) 3.2.4: Range shifts (Theme 3 – Climate change)
Measure 3.2.3: Phenological response to climatic regime change	
Description	Phenology is the study of plant and animal life cycle events, which are triggered by changes in environmental conditions such as temperature and light availability. Examples include spring algal blooms, the timing of migrations and seasonal species aggregations for the purpose of mating. Phenology is a major driver in determining population dynamics, species interactions, animal movements and the evolution of life histories (Schwartz 2003). Collecting phenological data on species is crucial to assessing biological and ecological responses to long-term trends in climate variables and determining the adaptive capacity of species (i.e. their resilience) to climate change impacts (Chambers et al. 2013). Species may respond by first adjusting their phenological behaviour – for example, the timing of spawning and, with that, the timing of larval appearance in the plankton (with consequences for species that prey on plankton). Different phenological responses across species are expected to lead to temporal mismatches among trophic levels (Poloczanska et al. 2016). It is expected that biological and ecological responses to climate change will affect the capacity of marine environments to act as CO2 sinks (through the biological pump, particularly the high-carbon coastal and estuarine ecosystem – also termed 'blue carbon') and to contribute to the mitigation of climate change. Similarly, climate change may impact on the adaptive capacity of species and ecosystems and their capacity to continue providing a wide range of ecosystem services (e.g. food, stormwater protection, and wellbeing and cultural benefits).
Data elements	Collection of phenological response data of indicator species (*to be determined*).
Links to other measures	3.1.1: Climate averages, indices and extreme events (Theme 3 – Climate change) 3.2.2: Biological responses to extreme climate events (Theme 3 – Climate change) 3.2.4: Range shifts (Theme 3 – Climate change)
Measure 3.2.4: Range shifts	
Description	One of the more widely observed manifestations of a biological response to climate change is the shift of species distribution ranges, usually along latitudes as tropical waters expand or along vertical temperature gradients to deeper, colder waters (Poloczanska et al. 2016). Spatial and temporal mismatches in species migration may also lead to changes in population dynamics and species interactions. An added consequence of climate change may be that more suitable conditions for invasive species to settle, grow and propagate are created.
Data elements	Collection of distribution data of indicator species (*to be determined*).
Links to other measures	3.1.1: Climate averages, indices and extreme events (Theme 3 – Climate change) 3.2.2: Biological responses to extreme climate events (Theme 3 – Climate change) 3.2.3: Phenological response to climatic regime change (Theme 3 – Climate change)

Table 5.4. Comparison of the different methodological approaches available for monitoring physical climate change variables.

Indicator	Method	Who	Equipment/ sensors	Data frequency	Cost	Advantages	Disadvantages
pH	*In situ* – NZOA-ON	DOC Operations, whānau, hapū and iwi, and communities	Water sample	Fortnightly or monthly	$60 per sample	• Part of national network • Not overly expensive	• Not all reserves can be sampled frequently (Vance et al. 2019)
pH	Remote – satellite sensors (Land et al. 2015)	Service providers	Combines SST and salinity data to derive pH	Variable	Unknown	• Large synoptic snapshots of entire marine realm	• Resolution might not align with requirements • Needs ground truthing with in situ data
SST	*In situ* – CTD sensors	Service providers	Multiple sensors mounted on a buoy or other structure	4 scans/second (variable)	Approximately $50,000 ($20,000+ per CTD instrument and $25,000–$35,000 per buoy)	• Continuous recording of multiple parameters	• Requires servicing • Expensive
SST	*In situ* – data loggers	DOC / service providers	Loggers or sensors	Hourly to daily	$100,000–$150,000	• Can be cost-effective • In situ measurements	• Require maintenance and servicing • No long-term continuous data collection
SST	Remote – satellite sensors	NIWA	None	10–15 minutes	Free	• Cost-effective • No need to collect data	• 1-km spatial resolution*

Abbreviations: CTD, conductivity-temperature-depth; DOC, Department of Conservation Te Papa Atawhai; NIWA, National Institute of Water and Atmospheric Research; NZOA-ON, New Zealand Ocean Acidification Observing Network; SST, sea surface temperature.

* Other remote-sensing products are able to collect data at a higher spatial resolution but are not readily available (e.g. SST sensors on Landsat 8 at 30-m resolution (Kachelriess et al. 2014; Trinh et al. 2017).

Ocean acidification

Monitoring the pH of sea water is important for understanding how the absorption of atmospheric CO_2 by the ocean is affecting ocean chemistry. Ocean acidification has been shown to limit the calcification rates of calcifying organisms (e.g. coccolithophores and corals; Kroeker et al. 2010) and the survival of calcifying algal species (Cornwall et al. 2014) with mixed effects amongst other organisms and across life stages (Kroeker et al. 2010; Law et al. 2018). The coastal zone is a highly variable system when measuring ocean acidification variables (pH, temperature), with estuarine systems having up to 20 times higher variability than the open ocean. The Firth of Thames is predicted to be the most affected system in Aotearoa New Zealand and will have pH levels below the open ocean minimum regardless of changes in global emissions,[33] which will have negative consequences for calcifying animals that will be unable to lay down shells that are strong enough to protect themselves from predators (Law et al. 2018). The high nutrient and organic carbon loading from some rivers into coastal systems are exacerbating any changes in ocean acidification, making the systems less resilient and leaving less room for recovery.

The New Zealand Ocean Acidification Observing Network (NZOA-ON)[34] is a bottle sampling monitoring protocol for measuring ocean acidification variables, including pH. Measuring ocean acidification following this protocol has been selected as an indicator because:

- It is a well-established network of national and international partners with a fully developed methodology that includes quality control mechanisms and data repository capability.
- DOC will contribute data towards building a national and regional picture of ocean acidification.
- It aligns with monitoring being conducted by regional councils, the University of Otago and NIWA.
- It is a cost-efficient methodology that can be tied together with compliance visits to marine reserves.
- Its deployment is relatively easy and does not require any advanced or specialist skills.
- The frequency of sampling (minimum of once a month) can be changed to suit the needs of the local DOC office.
- Data are collected and analysed in a standardised way and on a local scale, allowing regions and marine reserves to be compared.

The need and feasibility of using novel technology for the continuous monitoring of pH and other climate change data elements in marine reserves will be evaluated in future iterations of the MMRF.

SST

SST is a key parameter to monitor as it is a direct indicator of climate change and an indirect indicator of oceanographic processes, such as changes in upwelling, water transport and currents, habitat suitability, and nutrient availability (because, for example, O_2 solubility in water is directly related to water temperature). While warming trends have been observed and are expected to continue under climate change, cooling can also occur (e.g. if the conditions for stronger upwellings are created). Specific requirements for data collection (of SST or any other required environmental variable) and guidelines to inform decision making on the frequency of data collection and deployment locations for appropriate instruments are currently under development and will be included in future iterations of the MMRF.

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33 www.forestandbird.org.nz/ocean-acidification-implications-new-zealand
34 https://nzodn.nz/portal/

5.3.3 Developing a sampling design

Ocean acidification

HOW ARE SAMPLING SITES TO BE SELECTED?

Sites will be selected to cover a geographical distribution (representing the range of Aotearoa New Zealand's bioregions), to target specific ecosystems (e.g. marine reserves with species and ecosystems that are particularly vulnerable to ocean acidification, such as corals or shellfish) and to fill gaps in the current NZOA-ON network. Marine reserves that can be accessed on a frequent basis (i.e. at least monthly) and that are supported by rangatiratanga will be the main priority. As the network of monitored sites develops, the allocation of sampling resources across sites can be reviewed. Initially, mainland marine reserves will be added to the network. However, more remote sites at the climatic limits of Aotearoa New Zealand's EEZ, such as the Kermadec Islands and Subantarctic Islands bioregions, will ideally be included in the future.

As per NZOA-ON data collection guidance, water sampling sites should be in open water as far from point source (e.g. tributaries, streams) as possible, or areas that are not well mixed (e.g. dead zones, eddies, surf zones). Sites should also be marked by the Global Positioning System (GPS) and landmarks to ensure collection from the same location over time.

HOW OFTEN SHOULD MEASUREMENTS BE TAKEN AT THESE SITES OR A SUBSET OF THESE SITES?

NZOA-ON takes samples fortnightly and monthly because coastal pH is extremely variable (Hofmann et al. 2011), influenced by a variety of drivers including the amount of photosynthesis in the system (which varies throughout the day and seasonally), watershed processes and nutrient inputs (Duarte et al. 2013). To balance cost and logistical limitations, pH will be monitored at marine reserve sites at least monthly, as less frequent sampling would decrease the likelihood of capturing the natural variability of the system. If a site is unable to be sampled monthly, it will not be sampled and ideally sites will be measured more frequently.

SST

Specific requirements for SST data collection and guidelines to inform decision making on where to deploy appropriate instruments are currently being developed. However, some general guidance on measuring SST is provided below.

HOW ARE SAMPLING SITES TO BE SELECTED?

SST data will be collected for all marine reserves.

HOW OFTEN SHOULD MEASUREMENTS BE TAKEN AT THESE SITES OR A SUBSET OF THESE SITES?

SST can have seasonal, tidal and/or daily cycles (Hofmann et al. 2011; Dudley et al. 2017). Seasonal variation is best accounted for by sampling throughout the entire year over multiple years. Ideally, each sampling event would occur during the same tide cycle, time of day and/or day of the month. However, logistical constraints (e.g. travel time between sites, bad weather) can limit the feasibility of such specific sampling regimes (Dudley et al. 2017). Therefore, this is not required provided that a regular sampling frequency (e.g. daily) is maintained.

5.4 Monitoring protocols

A brief overview of the monitoring approach is given here, with details to be included in marine reserve monitoring plans and through the service provider.

Ocean acidification

Details and a video demonstration of how water samples are collected in the field are provided on the NZOA-ON website.[35] NZOA-ON kits containing all the required equipment (bottles, crates, chemically resistant gloves, calibrated thermistors) and instructions (including health and safety information) are distributed to selected locations around the country (Fig. 5.3) and, once sampling is completed, the full crates are returned to Dunedin. Water samples are taken monthly (at least) at each selected site. For the purposes of this monitoring theme, only pH and temperature will be routinely reported on.

Figure 5.3. Sampling crates in the laboratory at the University of Otago, ready to be couriered to sampling partners. Photo: Kim Currie, NIWA

SST

Loggers may be deployed at some sites to collect higher resolution data to complement satellite-derived SST data. The precise location of these loggers will depend on the size, depth and predominant oceanographic conditions of the area. Loggers should be attached to existing underwater structures that are anchored to the bottom (e.g. using high-quality cable-ties) and have a well-known location. Loggers should also be placed close to where biological surveys are performed so that the data can be connected to potential changes in communities/habitats. Loggers should be deployed to record at 30-min intervals so that the changes in temperatures during tidal fluxes can be captured. This will allow for a running time of 28 months, so loggers should be downloaded and re-deployed every 2 years.

Specific protocols for SST data collection and guidelines to inform decision making on where to deploy appropriate instruments are to be developed.

35 https://niwa.co.nz/coasts-and-oceans/research-projects/new-zealand-ocean-acidification-observing-network-nzoa-on

5.5 Data management

Ocean acidification

Since DOC does not currently have a database for environmental variables collected from marine reserves, all NZOA-ON data will be kept at NIWA and made accessible online. NZOA-ON data are connected to the Global Ocean Acidification Observing Network (GOA-ON) data portal and consequently must adhere to specific data quality requirements. NZOA-ON data are provided by NIWA using a Creative Commons BY 4.0 licence, under the New Zealand Government Open Access and Licensing framework (NZGOAL).[36] The data are free for re-use, but any use of them should be accompanied by the statement 'NZOA-ON data sourced from NIWA'.

SST

Data management protocols are to be developed.

5.6 Data analysis

Possible approaches for analysing the data obtained under this theme are summarised in Tables 5.5–5.7. Before analysing and interpreting the collected data for a particular site (or making comparisons between sites), a statistician should be consulted to ensure that an appropriate approach is being used.

Table 5.5. Summary of analytical approaches for data relating to sea surface temperature (SST).

Data element: Sea surface temperature (SST)					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Data loggers • CTD sensors on buoys or other fixed structures • Remote sensing data	SST in °C.	Data to be prepared by service provider. All temperature data will be in °C so no unit conversion is required.	GLS regression is recommended for analysing environmental data, as this allows comparisons to be made between sites, regions, months or years. GLS models can determine the direction and magnitude of trends while also accounting for correlations between consecutive measurements (Schlegel & Smit 2016; Shears & Bowen 2017).	SST can be visualised as anomalies (e.g. see Fig. 5.4).	Objective 3.1 – Spatial
			Same analysis as above but with a focus on the impact of year.	SST can be visualised as a time series graph (e.g. see Fig. 5.4). If baseline data are available for the area, these can be used as a long-term reference (e.g. Fig. 5.5).	Objective 3.2 – Temporal

Abbreviations: CTD, conductivity-temperature-depth; GLS, generalised least squares.

36 https://creativecommons.org/licenses/by/4.0/

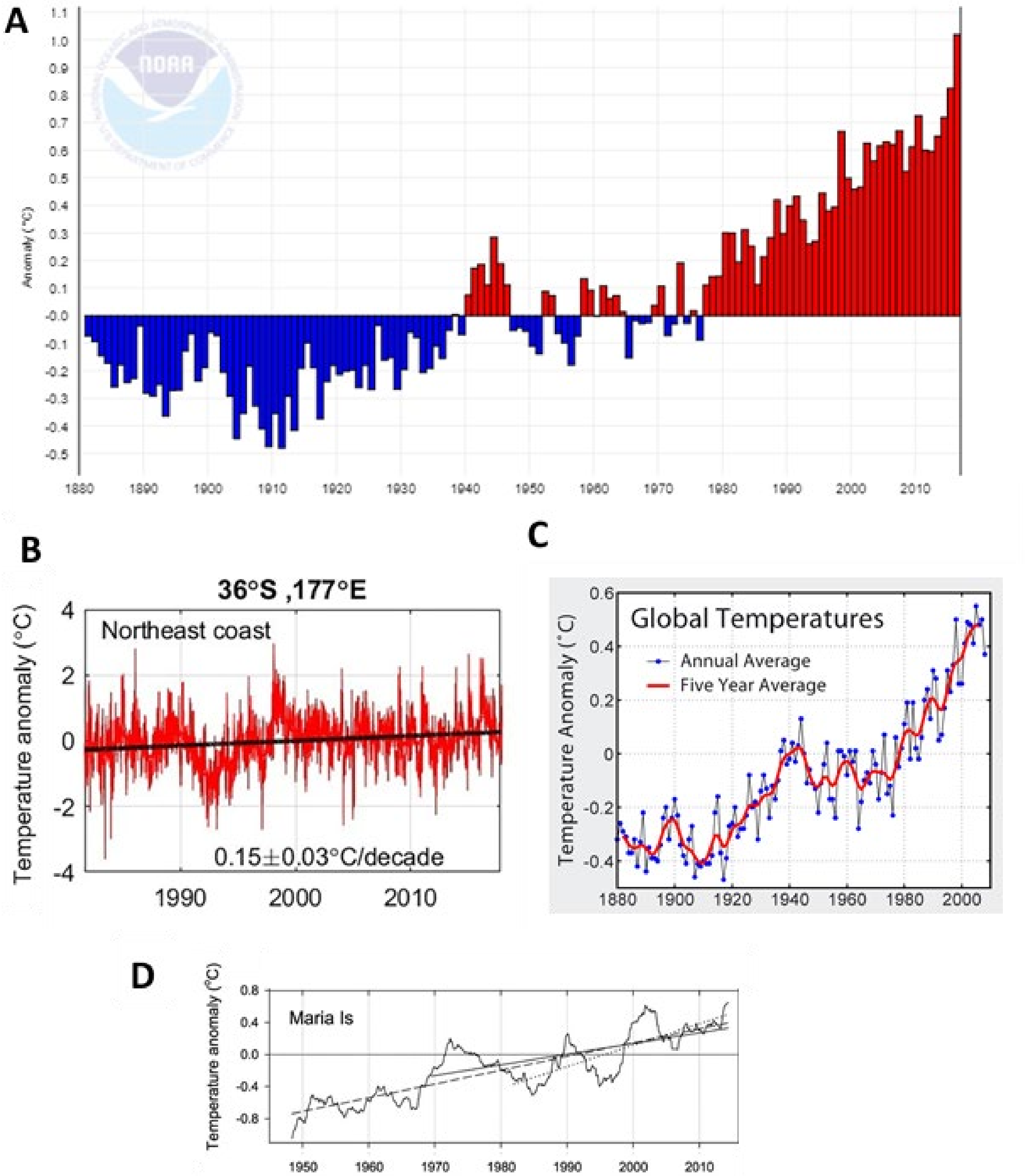


Figure 5.4. Approaches for visualising time series data. **(A)** Global land and ocean temperature anomalies, August–July. **(B)** Daily and annually smoothed temperature anomalies together with trends for two locations in the southwest Pacific. Means and seasonal cycles have been removed. **(C)** The record of global average temperatures compiled by NASA's Goddard Institute for Space Studies. The 'zero' on this graph corresponds to the mean temperature from 1961–1990, as directed by the Intergovernmental Panel on Climate Change (IPCC). Image created by Robert A. Rohde / Global Warming Art. **(D)** Long-term trends in the monthly sea surface temperature anomaly at coastal stations. Data are low-pass filtered using a 5-year running mean to highlight low-frequency variability. The solid line shows the linear trend over the last 50 years, the dotted line shows the trend over the satellite era (1982–2016), and the dashed line shows the trend for the full time series at Portobello and Maria Island. Source: MfE 2020.

Table 5.6. Summary of analytical approaches for data relating to pH.

Data element: pH					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• NZOA-ON	• pH • SST	pH is on the total scale at the *in situ* temperature and is only recorded in one set of units so no conversion is needed.	The focus should be on examining the differences between bioregions, which can be achieved using GLS (see advice for SST in Table 5.5).	Use box plots or error bars to visualise differences between bioregions.	Objective 3.1 – Spatial
			Several methods can be used to detect significant changes in time series trends. Schiel et al. (2016) used linear regression, which provides an easy-to-understand result, although natural variability is usually not linear. Linear regression of the de-seasonalised data set is suitable once the data record is long enough. Several other studies have used the adjusted standard error and adjusted degrees of freedom approach (Chiswell & Grant 2018; Sutton & Bowen 2019; Santer et al. 2000), which divides the slope of the regression by its standard error and accounts for autocorrelation using a lag; trends are significantly different from 0 if they exceed the significance level.	All parameters can be visualised as time series (e.g. see Fig. 5.4).	Objective 3.2 – Temporal

Abbreviations: GLS, generalised least squares; NZOA-ON, New Zealand Ocean Acidification Observing Network; SST, sea surface temperature.

5.7 Reporting and communicating

Reporting on the statuses and trends of ocean climate indicators across bioregions will make an important contribution to understanding the resilience of ecosystems to global and local changes (Table 5.7). Increasing CO_2 emissions pose significant threats to ocean ecosystems, so management decisions will rely on accurate and regular reporting of changes in ocean acidification (pH) and SST.

Table 5.7. Information relating to Theme 3 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective	**Adapting to climate change**
Indicator	**Basic climate series – ocean acidification**
Data elements	pH Sea surface temperature (SST)
Reporting	• Status and trends of pH and SST over time

5.7.1 Marine reserve reports and report cards

The data elements monitored by Theme 3 can be added to marine reserve reports and report cards. Currently, this theme only focuses on pH and SST, so the definitions for reporting on the status shown in Table 5.8 reflect this narrow scope (see Table 2.5 for definitions of trend). Reporting values for SST cannot be set at this time as they depend on the local conditions and interannual variation. Therefore, SST will instead be used to interpret other biological variables *in situ*. Also note that while the time required to make trend interpretations varies dependent on the amount of noise in the data, a 30-year time series is likely required. Future iterations of the MMRF will describe how to report on additional ocean climate variables.

Table 5.8. Definitions for reporting on the pH (ocean acidification) status.

Status	Definition
Excellent	pH values of 7.7–8.3.
Good	pH values of 7.5–7.7 and > 8.3–8.5.
Fair	pH values of 7–7.5.
Poor	pH values of < 7 or > 9 are unlikely, unless in a special environment (e.g. geothermal activity, pollution source, etc.).
Unknown	The status of this measure is unknown.

5.7.2 Other reporting opportunities

The data collected by DOC, whānau, hapū, iwi and community members will be added to the NZOA-ON website.[37] NZOA-ON uses a map that includes pH and temperature data collected through the network (see Fig. 5.5 for an example).

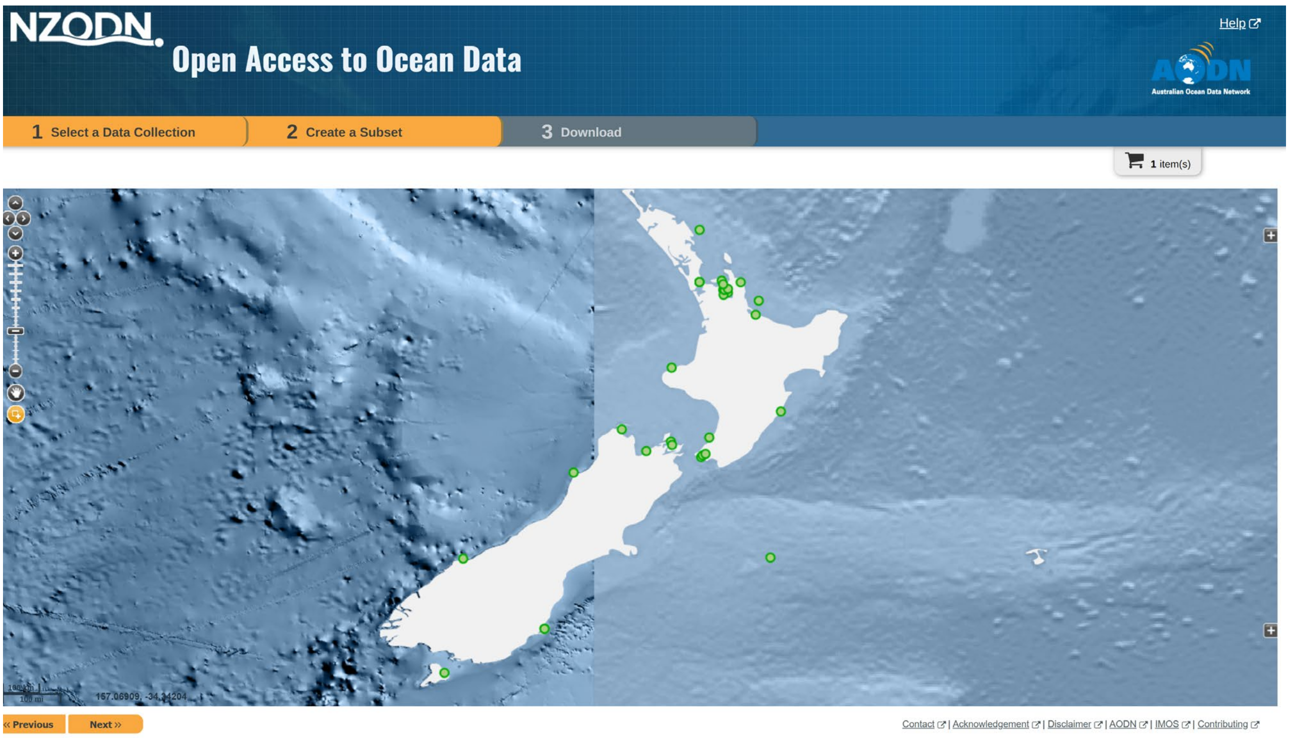


Figure 5.5. Example of site map. To view/access these data, visit https://nzodn.nz/portal/ and select 'Search ocean data' and then 'New Zealand Ocean Acificiation Observing Network (NZOA-ON)'. Data collected by NIWA, University of Otago, Department of Conservation, Cawthron Institute, Auckland Council, Bay of Plenty Regional Council, Marlborough Shellfish Quality Programme, Tuwhitu Marine Farms, Ngāti Paoa, Ngati Whatua Orake, Tuhua Trust, East Otago Taiapure and University of Auckland.

37 https://marinedata.niwa.co.nz/nzoa-on/

6 Theme 4 – Describe the abundance and demography of key species

What	Abundance and demography of common and widespread taxa
Who	DOC, kaitiaki and communities
When	Typically summer but can be all year round
Where	All marine reserves where possible
How	Observation using diver surveys, quadrats, baited underwater video (BUV) or potting
Why	To understand key species' responses to marine reserves

6.1 Background and objectives

As an island nation, Aotearoa New Zealand is strongly connected to the oceans and the species contained within them. Marine reserves have been established so that 'the marine life of the reserves shall as far as possible be protected and preserved' and 'the value of the marine reserves as the natural habitat of marine life shall as far as possible be maintained' (Marine Reserves Act 1971, sections 3(2)(b) and 3(2)(c)). These benefits are achieved in part by restricting activities that impact on biodiversity or the ability to undertake science in a robust way. Monitoring the responses of key species (see Box 6.1) to restricted activities provides a means to assess the effectiveness of MPAs (including marine reserves).

Box 6.1: What are key species?

Key species are those that either have a disproportionately large role in maintaining the structure of an ecological community (termed ecological keystone species; Paine 1969) or shape the cultural identity of a people, as reflected in the fundamental roles they have in diet, materials, medicine, recreation, economies and/or spiritual practices (termed cultural keystone species; Garibaldi & Turner 2004). In Aotearoa New Zealand, species that are of special cultural significance and importance to Māori are called taonga species.

Key species may indicate how well the whole ecosystem or specific components of the ecosystem are functioning. For instance, some species in the marine environment can be indicators of ecological integrity, with changes in their size, abundance or distribution indicating ecosystem stress or change.

Note that cryptic, migratory and nocturnal species are also important for representing the true biodiversity of marine reserves, but these are outside the scope of this initial iteration of the MMRF.

DOC has international and national obligations towards protecting key species. Internationally, Aotearoa New Zealand has committed under the CBD to protect 10% of its marine and coastal areas (Aichi Target 11)[38] and to ensure the sustainable management of living resources (Aichi Target 6).[39] The monitoring of key species allows DOC to understand both the effectiveness of MPAs (relating to Aichi Target 11) and to determine if living resources are being sustainably harvested (relating to Aichi Target 6). Domestically, DOC is working towards IO1 'The diversity of our natural heritage is maintained and restored', under which the specific Outcome Objectives 1.1 'Maintaining ecosystem processes' and 1.5 'Maintaining ecosystem composition' relate to key or taonga species.

Marine reserves reduce cumulative impacts on marine life by removing fishing pressures and preventing dumping, dredging and construction. Such protection is expected to result in an increase in the average abundance of key species, particularly in exploited size classes (Cole et al. 1990). Positive effects of marine reserves on key species such as fishes and invertebrates have been observed in both Aotearoa New Zealand and other countries (Babcock et al. 2010; Jones 2013; Edgar et al. 2017). As well as having direct effects on the abundance of previously harvested species, marine protection can have indirect effects on other components of the ecosystem. For example, trophic cascades have been described in northeastern Aotearoa New Zealand, where increases in the abundance of previously harvested tāmure / snapper (*Pagrus auratus*) and kōura / rock lobster (*Jasus edwardsii*) following marine reserve establishment resulted in declines in the abundance of herbivorous sea urchins and concomitant increases in seaweeds (Barrett et al. 2009; Babcock et al. 2010).

Māori have a special relationship with Aotearoa New Zealand's marine species, many of which are taonga. Taonga species may be valued as a source of kai (food; e.g. pāua or abalone) or spirituality (e.g. rāpoka / whakahao / New Zealand sea lion (*Phocarctos hookeri*)). Taonga species are often tohu (indicators) of a healthy moana (ocean), and the harvesting of kaimoana (seafood) is an important tikanga (protocol, ritual) passed down through generations. Having enough kaimoana to support sustainable harvest is a sign of a healthy, functioning ecosystem.

Recreational fishing is an important pastime for New Zealanders – it is the fifth most popular recreational sport, with an estimated 2 million trips being taken in 2017–18 (Wynne-Jones et al. 2019) and around $1 billion being spent each year on fishing-related equipment and activities (Holdsworth 2016). Commercial fishing is worth over $4 billion per year to the economy and employs over 13 000 people (Williams et al. 2017). Because of the importance of fishing for recreation and commerce in Aotearoa New Zealand, some fish and mobile invertebrate species are heavily exploited and are therefore likely to show change following protection (Cole et al. 1990). For example, at Te Tapuwae o Rongokako Marine Reserve (near Gisborne), the density of rock lobster increased from 20 individuals/ha to 180 individuals/ha in 5 years (Freeman et al. 2009); and in the Poor Knights Islands Marine Reserve, the population of snapper rapidly increased by 300% in 3 years (Denny et al. 2004). The rate of recovery differs across the country, and there is currently very little understanding of the most important factors that contribute to this (Willis 2013). Furthermore, the understanding of how key species recover is currently limited to a few protected areas and a small number of species. Therefore, it is important that monitoring programmes are expanded to include more key species and more MPAs across the country.

The effects of protection on key species will be assessed both spatially and temporally. Spatial differences will focus on the changes in population size inside and outside the reserve and will allow inferences about protection to be made immediately. Temporal trends will focus on the change in population sizes over time and will only be analysed after at least 5 years of data have

38 www.cbd.int/aichi-targets/target/11
39 www.cbd.int/aichi-targets/target/6

been collected, as it is unlikely that any true trends will be observed until after at least 10 years of protection (Willis 2013).

6.1.1 Objectives

Monitoring objective 4.1 (spatial): To survey key species' populations at a level that can detect differences in abundance and demographics between protected and unprotected sites.

Research question: Do marine reserves change the abundance and size of key species within the protected sites?

Monitoring objective 4.2 (temporal): To survey key species populations at a level that can detect a change in population trends over 5 years.

Research question: Do marine reserves change the number and size of key species over time?

6.2 Existing monitoring programmes

There have been several reviews of key species monitoring in marine reserves around Aotearoa New Zealand by DOC and others (e.g. Willis 2013). In total, key species have been monitored in 28 of the 44 current marine reserves in Aotearoa New Zealand since 1990. However, this monitoring has been inconsistent, with variation in both the frequency of monitoring and the species being targeted. Furthermore, while there has been reasonable consistency in the sampling methods used among marine reserves, the sampling design, size of sampling units and level of replication have varied greatly (Shears et al. 2006).

Most monitoring surveys continue to focus on examining changes in the population abundance and size structures of selected key species, particularly reef fish species, rock lobster, pāua and kina (*Evechinus chloroticus*). The longest running and most consistent monitoring of fishes has occurred at Long Island - Kokomohua Marine Reserve in the Marlborough Sounds, while reasonably long-term monitoring with some frequency has also been carried out at Cape Rodney-Okakari Point, Taputeranga, Tonga Island and Tuhua (Mayor Island) marine reserves (Table 6.1).

Table 6.1. Summary of past and present monitoring programmes for Theme 4 undertaken by the Department of Conservation Te Papa Atawhai (DOC) and other stakeholders, by bioregion.

Bioregion	DOC monitoring programmes	Other monitoring programmes
Kermadec Islands	N/A	Massey University monitoring programme
North Eastern	Whanganui A Hei (Cathedral Cove) fish and invertebrate monitoring programme, 1996–present Cape Rodney-Okakari Point and Tāwharanui fish and invertebrate monitoring programme, 2000–present Poor Knights Islands fish and invertebrate monitoring programme, 1998–present Whangarei Harbour fish and invertebrate monitoring programme, 1990–2012	Northland Regional Council community coastal monitoring Fisheries New Zealand stock assessment surveys
Eastern North Island	Te Angiangi fish and invertebrate monitoring programme, 1995–2006 Te Tapuwae o Rongokako lobster potting monitoring programme, 2001–present	Fisheries New Zealand stock assessment surveys
Western North Island	Tapuae and Paraninihi fish monitoring programme, 1995-present	Fisheries New Zealand stock assessment surveys

Table continued on next page

Table 6.1. continued

North Cook Strait	Kapiti fish and invertebrate monitoring programme, 1993–present Taputeranga fish and invertebrate monitoring programme, 1999–present	Fisheries New Zealand stock assessment surveys
South Cook Strait	Top of the South fish and invertebrate monitoring programme, 1992–present	Fisheries New Zealand stock assessment surveys Fisheries New Zealand blue cod (*Parapercis colias*) potting surveys
East Coast South Island	Akaroa and Pohatu fish monitoring programme, 2017–present Pohatu rock lobster (*Jasus edwardsii*) monitoring programme, 2010–2013 Hikurangi inter- and subtidal monitoring programme, 2016–present Hikurangi lobster potting monitoring, 2019–present	Fisheries New Zealand stock assessment surveys Fisheries New Zealand blue cod potting surveys
West Coast South Island	N/A	Fisheries New Zealand stock assessment surveys
Fiordland	Fiordland biological monitoring, 2006–present	University of Otago / NIWA surveys Fisheries New Zealand stock assessment surveys
Southern	Ulva Island monitoring programme, 1994–1999	University of Otago customary area surveys* Fisheries New Zealand blue cod potting surveys Fisheries New Zealand stock assessment surveys
Subantarctic Islands	N/A	N/A

* www.mahingakai.org.nz/

6.3 Sampling design

6.3.1 Selecting indicators

This theme provides guidance on how to undertake monitoring that is relevant to selected indicators and associated measures contained within Objective 10 'Ecosystems and species are protected, restored, resilient and connected from mountain tops to ocean depths' from the ANZBS (DOC 2020c; Table 6.2) and more specifically Objective 10.8.1 'The viability of current and future mahinga kai and cultural harvest of indigenous species has been assessed to guide future use'.

Table 6.2. Indicators, measures and data elements relating to Theme 4 – Describe the abundance and demography of key species. Adapted from McGlone et al. (2020).

Indicator 4.1: Species composition and diversity	
Measure 4.1.1: Exploited species production	
Description	The productivity of exploited species is considered by the public to be a reliable, visible indicator of ecological integrity. As the most valued species are often the first to show signs of recovery from the removal of fishing, estimating the biomass and productivity of key groups is a good indicator of marine protection effectiveness. The most commonly harvested stocks, which are often fish species (e.g. snapper (*Pagrus auratus*), blue cod (*Parapercis colias*)) but also include macroinvertebrates (e.g. lobster, oysters, mussels, squid) and, to a lesser degree, algae (e.g. giant kelp (*Macrocystis pyrifera*)), should be measured. Increasing stocks for commercial and recreational fisheries in adjacent areas are part of the public expectation for marine protected areas.
Data elements	**Biomass** The estimated mass of a given population or ecosystem. **Catch per unit effort (CPUE)** A standardised way of comparing catch over a given area. **Size structure** Used to understand the size distribution of a given population for an ecosystem. It provides information about growth rates and recruitment.
Links to other measures	4.2.1: Marine biological function (Theme 4 – Key species)
Measure 4.1.2: Abundance and demography of common and widespread taxa	
Description	A measure is needed to capture changes in widespread and abundant taxa that may also be under pressure. This is particularly important for marine reserves, in which these species are protected from pressures and so are expected to exhibit the greatest response. It is important to monitor both abundance and demographic variables, as increases in the number and size of the species of interest are commonly observed. Species richness is also a good measure for comparing marine reserves nationally, as it provides a measure of ecosystem diversity through observation of the number of species.
Data elements*	**Density** The number of individuals of a species you would expect to find in a given space. **Relative abundance** Gives an indication of how rare or abundant a species is in relation to other species in the ecosystem. **Size** [definition] **Species richness** The total count of the species found in a targeted ecosystem. **Species diversity** Calculated from the richness and abundance of a group of species in a given ecosystem. **Presence/absence** Whether a species is present or absent in areas where they are or are not expected to be found.
Links to other measures	4.1.3: Demography of functional groups (Theme 4 – Key species) 4.1.4: Representation of functional groups and guilds (Theme 4 – Key species) 4.1.5: Changes in species diversity (Theme 4 – Key species)

* Several additional data elements are outside the scope of this version of the Marine Monitoring and Reporting Framework, including recruitment, stock structure, growth rates, stock status and sex ratio.

Future updates will expand this to include measures relating to marine biological function, the demography of functional groups, the representation of functional groups and guilds, and changes in species diversity (Table 6.3).

Table 6.3. Indicators, measures and data elements that are to be implemented in future iterations of the Marine Monitoring and Reporting Framework but are not directly measured.

Indicator 4.1: Species composition and diversity	
Measure 4.1.3: Demography of functional groups	
Description	The examination of functional groups, which are defined as groups of species with similar life histories that respond to environmental fluctuations within a given habitat in similar ways, is a useful approach for building a complete understanding of an ecosystem. Functional groups may more accurately represent the true function of an ecosystem than common metrics such as richness, because multiple species can perform the same function (e.g. have the same predator specialisation), so counts of individual species may hold functional redundancy. However, while functional groups are useful for understanding ecosystems, they are also hard to define. Species can provide function to an ecosystem through their habitat use, feeding preferences or life history traits (e.g. reproduction rates). Therefore, the function(s) of interest must first be determined before that group's demography can be monitored. Demographic traits can be measured as the finite rate of growth of a population.
Data elements	**Functional traits** **Birth rate** **Mortality rate** **Immigration and emigration rates**
Links to other measures	3.2.2: Biological responses to extreme climate events (Theme 3 – Climate change) 3.2.3: Phenological response to climatic regime change (Theme 3 – Climate change) 3.2.4: Range shifts (Theme 3 – Climate change) 4.1.1: Exploited species production (Theme 4 – Key species) 4.1.2: Marine biological function (Theme 4 – Key species) 4.1.4: Representation of functional groups and guilds (Theme 4 – Key species) 4.1.5: Changes in species diversity (Theme 4 – Key species) 4.2.1: Abundance and demography of common and widespread taxa (Theme 4 – Key species)
Measure 4.1.4: Representation of functional groups and guilds	
Description	Diversity is a well-understood component of ecological integrity. Diverse ecosystems are generally more resilient, so they can cope with changing environmental conditions. Historically, diversity has been measured as species richness – the number of different species in an ecosystem. However, a better way to understand the diversity and functioning of ecosystems is to look at functional groups. Functional groups can be defined in terms of their life history, morphology, diet or habitat using different traits that represent these categories. These traits can be monitored over time to evaluate if an ecosystem is changing and is at risk of losing important functionality. Changes in functional group representation can also act as an indicator of general ecological integrity and provide a warning of environmental stress and potential ecosystem change.
Data elements	**Functional group biomass** **Functional group diversity** **Functional group richness**
Links to other measures	4.1.1: Exploited species production (Theme 4 – Key species) 4.1.2: Abundance and demography of common and widespread taxa (Theme 4 – Key species) 4.1.3: Demography of functional groups (Theme 4 – Key species) 4.1.5: Changes in species diversity (Theme 4 – Key species) 4.2.1: Marine biological function (Theme 4 – Key species)
Measure 4.1.5: Changes in species diversity	
Description	Species diversity is one of the key aspects of biodiversity that is stressed in global reporting and conservation planning at all levels. This is particularly true for 'hot spots' of biodiversity, where there is a high risk of loss through anthropogenic modification. Diversity is an important metric for predicting the resilience of ecosystems from changing environmental conditions. Species diversity concurrently considers the number of different species that are represented within a given site or sample (i.e. species richness) and how similar the relative abundances of different species are.
Data elements	**Shannon diversity index** This measures the evenness of the distribution of individuals among species – the opposite of dominance (where one or two species accounts for most of the individuals) **Alpha diversity** Species richness in a given area **Beta diversity** Turnover of species among sites within a broader location
Links to other measures	4.1.2: Abundance and demography of common and widespread taxa (Theme 4 – Key species) 4.1.3: Demography of functional groups (Theme 4 – Key species) 4.1.4: Representation of functional groups and guilds (Theme 4 – Key species)

Continued on next page

Table 6.3 continued

Indicator 4.2: Ecosystem function	
Measure 4.2.1: Marine biological function	
Description	The marine environment harbours high biodiversity, has a high variability of substrates, and is open to influences from the surrounding ocean and terrestrial environment. Direct measurement of function is time consuming and expensive, so indirect, species-based metrics are recommended to give some indication that overall biological functioning is intact.
Data elements	**Organism functional trait diversity** **Food chain length and trophic diversity** **Presence of large, old organisms**
Links to other measures	4.1.1: Exploited species production (Theme 4 – Key species) 6.2.1: Ecosystem primary productivity (Theme 6 – Water quality)

6.3.2 Selecting monitoring programmes

There are four main methodologies that can be used to meet the monitoring objectives of Theme 4:

- Underwater visual census (UVC)
- Baited underwater video (BUV)
- Potting (lobster or blue cod (*Parapercis colias*))
- Quadrat survey (intertidal or subtidal)

These methods have advantages under different environmental conditions, target different species and can be used complementarily. Several sampling techniques are often required to completely fulfil the objectives of a study (Willis et al. 2003). For example, BUV can be used in the deeper areas of a marine reserve where it is not practical to use UVC. There is no single method that can monitor all key species, so an evaluation of the strengths and weaknesses of different methods is required. It is also important to consider how the data are collected and processed, as this varies considerably by method and will influence the overall cost and time involved, as well as the quality of the data. It is not the aim of this report to describe these methodologies, as details have been provided elsewhere (for a detailed comparison of methodologies and an overview of their advantages and disadvantages, see Allum (2009)). Instead, these methods are summarised in Table 6.4.

UVC surveys

UVC is used to determine the abundance, size and species composition of reef fishes within a set volume of water, which is sampled by swimming inside it. It is an adequate method for quantitative studies that aim to answer questions relating to the distribution and abundance of fishes at different spatial and temporal scales. It is frequently used in Aotearoa New Zealand, mostly for assessments of medium to large fish species (Cole et al. 1990; Davidson 1998; Willis & Babcock 2000). UVC is a priority monitoring method because:

- It is a non-destructive method.
- With adequate replication, it allows estimates of select non-cryptic rocky reef species abundances in the area sampled to be obtained.
- The abundance and size of fishes can be acquired simultaneously.
- It can be combined with habitat characterisation and counts of invertebrates and macroalgae along the same transect, which will allow for more robust data interpretation.
- It can be used in long-term monitoring.
- It is well suited to before-after-control-impact (BACI) studies.
- A measuring tape can be used as a continuous reference point and is a useful reminder that fish sizes are magnified underwater.

Table 6.4. Comparison of the four main approaches currently used by the Department of Conservation Te Papa Atawhai (DOC) to monitor key species.

	UVC	BUV	Potting	Quadrats
Species	All non-cryptic rocky reef species	All carnivorous species	Blue cod (*Parapercis colias*) or rock lobster (Jasus edwardsii)	Invertebrate or algal species
Habitat	Rocky reef	Benthic soft sediment	Rocky reef and soft sediment	Intertidal and subtidal
No. people required	3 divers + skipper	Skipper + deckhand + recorder	Skipper + deckhand + recorder	Intertidal: 2 recorders Subtidal: 3 divers + skipper
No. days required	3–7	2–3	5–6	2–5
Time to record data	10–15 min	3 x time recorded (i.e. 1.5 h for 30 min of footage)	1–10 min per pot	1–5 min per quadrat
Transect size	Historically different at different sites and for different species	30-min recordings	Standardised commercial pots	1 x 1 m
Weather restrictions	Calm conditions with at least 10 m visibility	Calm conditions with at least 10 m visibility	Calm conditions	Intertidal: Moderate weather conditions or better Subtidal: As for UVC
Other sources of bias	Diver bias	Traps can be flooded by non-target species	Single species only	Observer bias
Indicative fieldwork costs per reserve	$25,000–$38,000	$10,000–$15,000	$9,000–$15,000 ($1,500–$3,000 per day)	$10,000–$25,000

Abbreviations: BUV, baited underwater video; UVC, underwater visual census.

In addition, if monitoring is conducted using a video system to record fishes (as in a Diver-Operated Video; DOV):

- It provides a permanent record of the area that can be re-analysed in the future.
- There is no need for divers to be competent in fish identification.
- It provides a record of fish behaviour.
- With stereo-video systems, it allows accurate size estimates of fishes to be obtained.

BUV

BUV is an unobtrusive sampling method that is effective in providing size and abundance estimates of scavenger and carnivorous reef fish species, which can be difficult to survey using divers (Willis & Babcock 2000). BUV is a priority monitoring method because:

- It gives estimates of the relative abundance of species and allows specimen sizes to be measured.
- It is a non-destructive method.
- It can be deployed in a wide range of habitats.
- Data can be acquired beyond diver-accessible depths.
- It more reliably surveys key carnivorous species, many of which actively avoid divers.
- The results are not affected by varying levels of water visibility, assuming that visibility is sufficient to view the seabed and identify the species.
- It has a high level of repeatability.
- Few personnel are needed on boat to operate it.

- Scientific divers are not required, lowering the survey cost and the need for expertise – note, however, that there are costs associated with the processing of imagery, which can be significant.
- Several self-contained units can be used at the same time.
- It provides a permanent record that can be re-analysed in the future.

Lobster potting surveys

Potting can be used to harvest commercially, recreationally and culturally important species of lobsters. Baited pots are set overnight (or over several nights) and attract lobsters into them. The design of the pots means that lobsters above a certain size remain trapped. This method is not only effective for catching lobsters for fisheries purposes, but also provides an opportunity to gather data on the relative abundance and population structure of these species. Lobster potting is a priority monitoring method because:

- Lobsters are of national and indigenous importance and a keystone species in ecosystems (Eddy et al. 2014).
- It can have less observer bias than other key species monitoring methods through the standardisation of pot sizes, selection of sites and measurement of lobsters.
- It is easier to replicate using standardised commercial size pots.
- Community stakeholders can be involved, strengthening their relationships with DOC and allowing them to observe marine monitoring in action.
- Local fishers can be involved, helping to break down some of the barriers that may exist because of the marine reserve and providing an opportunity for collaboration with other recreational and commercial fishers.
- It is relatively inexpensive.
- Marine reserve effects are easier to detect with the data collected from potting.
- The equipment is readily available, as it is usually the same as is used by the commercial and recreational fisheries.
- Surveys can be undertaken more quickly, in a broader range of sea conditions and at deeper depths than some other methodologies (e.g. diver transects), including under low or no visibility conditions, in areas with strong currents or surges, and in areas where there may be hazardous marine life.
- Data are collected from a wide range of sites in Aotearoa New Zealand's inshore environment, allowing data from particular sites to be placed in a wider context.
- It targets the species of interest and has minor ecological impacts on the environment, usually with no or limited bycatch.
- There is a low level of incidental mortality of the target species.
- The equipment does not need to be tended while in the water.
- It allows the collection of abundance and population data (e.g. size distribution data, sex ratio, reproductive status, disease prevalence).

Quadrat surveys

Quadrat sampling is a classic tool for ecological studies that allows the systematic collection of quantitative data on species or habitats. In general, a series of quadrats of a set size (and shape) are placed within a habitat of interest and the species and/or habitats within the quadrats are identified and recorded by either direct diver observations *in situ* or photographs. In surveys of Aotearoa New Zealand's marine reserves, quadrats have most commonly been used to characterise sessile invertebrate communities or to quantify the density of mobile invertebrates (e.g. sea urchins and pāua) and their associated macroalgal communities. Quadrat survey is a priority monitoring method because:

- It is usually non-destructive unless the objective of the study requires sampling the biota (e.g. for identification or measurement).
- It allows random sampling of an area, if the study is designed correctly.
- It helps to standardise search effort between individuals.
- A permanent record can be made if photographs are taken.
- No specialised equipment is needed (unless photographs are required).
- It can be used in long-term monitoring.
- It is well suited to BACI studies.
- Sampling can easily be repeated over time.
- It is amenable to the collection of covariate data regarding the physical environment, which can improve understanding of the relationship between communities or populations and their environment.
- Data can be collected from a large number of sampling units reasonably quickly and cost-effectively.
- It is amenable for use with a wide range of taxa and habitat types.

6.3.3 Developing a sampling design

Sampling designs are presented for a range of methods (UVC, BUV, potting and quadrat surveys). Species and sites will be selected through input from all interested stakeholders, including whānau, hapū, iwi, the community and DOC, and the final selection of species, methods and sites will be written into marine reserve monitoring plans.

How are species to be selected?

Species can be selected by:

- Considering which species whānau, hapū and iwi identify as taonga species for that site.
- Selecting the historically most abundant fishes or invertebrates, as these will be associated with the highest power for detecting changes.
- Seeking expert opinion, backed up with scientific literature and supported by whānau, hapū and iwi.
- Consulting the community, management committees, management staff and stakeholders.
- Searching marine reserve application records.

How are sampling sites to be selected?

Site selection will depend on the methodology that is being implemented, the ecology of the species of interest and the desires of all interested stakeholders, including whānau, hapū, iwi, the community and DOC, and it is important that the site selection method being applied is clearly stated in each monitoring plan. Where it is not possible to obtain true spatial randomisation of the sampling stations due to constraints caused by oceanographic currents, weather conditions or bottom topography (Willis et al. 2003), stratified random sampling may need to be used to select sampling locations within a site.

Stratified random sampling allows researchers to improve precision (reduce error) by dividing the population being sampled into non-overlapping groups, or 'strata', along a dimension that is expected to influence the population (e.g. fish populations are often stratified by depth to account for changes in species identity with increasing depth). Random, or haphazard, samples are then collected from within each stratum. The most efficient way to do this is to have strata that are as different from each other as possible (to maximise the variance that is being eliminated) while being as homogeneous as possible internally (to minimise the variance remaining). When planning a stratified sample, the strata should be designed so that they collectively include all members of the target population, they do not overlap, and they have precise and unambiguous boundaries. There is no rule as to how many strata should be used – this depends on the dimension being stratified and its influence on the population being sampled. Stratification can be done by dividing the area into equal-sized sections, or alternatively may be based on:

- Depth
- Habitat
- Exposure
- A combination of the above

Generally, the number of samples should be balanced, with an equal number of samples in different sampling strata, or proportional to the size of the strata, as well as inside and outside the reserve, though this will not always be the case.

How often should measurements be taken at these sites or a subset of these sites?

Babcock et al. (2010) stated that monitoring in MPAs takes, on average, 5.13 ± 1.9 years to detect direct effects on target species and 13.1 ± 2.0 years to detect indirect effects on other species. Therefore, in order to establish a baseline, monitoring for key species will be undertaken every year for the first 5 years and then every 2–3 years thereafter (Zintzen 2014). Where significant environmental change is expected, or where resources are available, monitoring will occur more frequently.

Monitoring will be carried out in summer for UVC, BUV and quadrat surveys because:

- It is the most favourable season in terms of weather for accessing sites.
- Focusing the sampling effort in one season reduces variability in the dataset. High variability in abundance between seasons has been observed for some species (Pande & Gardner 2009), and fish counts will be affected by whether there are juveniles or adults in the system.

For each method and species, there will be considerations that need to be made that are relevant to the local context. In places where monitoring plans are being co-designed with whānau, hapū and iwi, maramataka (the Māori lunar calendar) may be an important factor to consider for taonga species. In particular, the timing of lobster potting will be site dependent, as seasonal migrations have been documented throughout Aotearoa New Zealand but not on Wellington's south coast. In some places, it may also be appropriate to alternate which species are being monitored – for example, it has been advised that invertebrates and fishes at Taputeranga Marine Reserve should be surveyed in 3-yearly rolling cycles (i.e. 3 years of invertebrate surveys followed by 3 years of fish surveys). Conversations with kaitiaki, local researchers and the community will help determine what considerations are appropriate for a particular site. An example of a timetable for monitoring key species is presented in Table 6.5.

Table 6.5. Example of a timetable for key species monitoring in a marine reserve.

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Lobster potting	+	+		+		+		+		+		+		+		+
Intertidal survey	+		+		+		+		+		+		+		+	
Effort report	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Monitoring report		+			+			+			+			+		

6.4 Monitoring protocols

Monitoring protocols for the four main methods (UVC, BUC, lobster potting and quadrat surveys), including information on the timing, sites, stratification, replication and covariates, are detailed in their associated toolboxes. Prior to the implementation of toolbox methods, monitoring protocols were inconsistent between marine reserves, making it difficult to undertake comparisons. Datasets for some marine reserves span several decades, so any changes to monitoring methods need to ensure data continuity so that historic monitoring data are not devalued.

A summary of the monitoring protocol for each method is provided in Table 6.6. In addition, the functional traits[40] and soft sediment cores[41] toolboxes may also be useful for achieving the monitoring objectives of this theme.

6.5 Data management

Field data will be recorded on standardised field sheets for the methodology used, which can be found in the associated toolbox. At the end of each field sampling day, all field sheets must be photocopied, and once back in the office, all field sheets must be scanned and uploaded to docCM.

Data will be transposed from the field sheets and stored in a way that can be easily understood by a third party using standardised data entry sheets. To avoid repeating the metadata multiple times, the data will be subdivided into two sections: one that describes the metadata associated with the survey and another that comprises the species data collected. A field with unique values will link the two sections. Each data field that is recorded will be defined to remove any ambiguity in its meaning and use.

The metadata must be linked to a description of the monitoring objectives and any information that will allow someone unfamiliar with the monitoring to interpret the data and replicate the methodology. Data are arranged so that each row represents one species, with the corresponding data regarding site, replicate number, count and size arranged in separate columns. If the size has been measured for several individuals of the same species, one row must be created for each size. Ideally, all data should be located within a single database to facilitate ease of access.

This is an interim solution for data management while a database to collate and store data is being developed and implemented (see section 2.5.5).

40 www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-functional-trait-surveys-for-benthic-organisms.pdf

41 www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-soft-sediment-sampling-for-infaunal-communities.pdf

Table 6.6. Summary of the four methodologies to be utilised for key species monitoring.

	UVC	BUV	Potting	Quadrats (inter- and subtidal)
Toolbox link	Fish transects toolbox: www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-underwater-transects-for-sampling-reef-fishes.pdf Mobile invertebrates toolbox: www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-transects-for-mobile-invertebrates.pdf	BUV toolbox: www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-baited-underwater-video-surveys-for-fish.pdf	Potting toolbox: www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine/im-toolbox-marine-potting-for-lobster-populations.pdf	Quadrat toolbox: www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine-quadrats-for-invertebrate-and-macroalgal-communities.pdf
Factors to consider in site selection	Depth Habitat Exposure	Depth Turbidity Wave exposure Distance to reef Contiguity	Representativeness (of marine reserve) Availability of matched control sites	Depth Habitat Exposure
Minimum visibility	5 m	3 m	N/A	Intertidal: N/A Subtidal: 3 m
Species	Non-cryptic	Mobile carnivores	Blue cod (*Parapercis colias*), lobsters	Invertebrates, algal composition
Vessel presence	100 m away until end of survey	100 m away until end of deployment	Pots are left without boat presence	N/A
Timing	Daylight Seasonally or summer	Daylight Seasonally or summer	Deployed in daylight Same season each year Time around reproductive season	Daylight Seasonally or summer
Sites (guide only, depends on local marine reserve characteristics)	Balanced design, equal numbers of sites inside and outside marine reserve	Balanced, randomised block design	Stratified random sampling	Balanced design, equal numbers of sites inside and outside marine reserve
Stratification (guide only, depends on local site characteristics)	Fishes: 6–10 m, 10–15 m Kina (*Evechinus chloroticus*), rock lobster (*Jasus edwardsii*) and pāua (*Haliotis* spp.): 6–15 m Pāua: 1–6 m	30-min deployments for snapper (*Pagrus auratus*)	Pots are soaked for 24 h	Macroinvertebrates: 0.25 m^2 Algae: 1 m^2
Replicates (guide only – run power analysis)	Fishes: 8–12 transects per site, 4–6 per depth stratification Invertebrates: 4–8 per site	4–5 per block	Minimum 15 per site	8–12 transects per site, 4–6 per depth stratification
Distance between replicates	At least 10 m	> 100 m for a 30-min deployment > 450 m for a 60-min deployment	At least 100 m between pots	At least 1 m

Continued onto next page

Abbreviations: BUV, baited underwater video; CPUE, catch per unit effort; UVC, underwater visual census.

Table 6.6. Scontinued

	UVC	BUV	Potting		Quadrats (inter- and subtidal)
Transect/core size	Fishes: 25 m x 5 m Lobsters: 25 m x 5 m (2.5 m each side) Kina/pāua: 25 m x 2 m (1 m each side)	N/A	Standard 52-mm commercial pots		Depends on location
Covariates	Habitat (every 5 m along the transect) Temperature Wave exposure Depth Diver/observer Invertebrates: sex, size, co-habitation Fishes: behaviour, species	Predator presence (restart count 2 min after) Habitat Drift (>5 m not comparable) Noise from vessels	Season Sea conditions Bait Lunar phase Soak time Pot saturation Pot escapes Pot competition Bycatch Management regime (compliance)	Lobster covariates: Presence of injuries or deformities Unusual colouration of carapace or eggs Presence of tags Presence of a soft shell Dead/alive	Water temperature Sea state Habitat
Data elements	Length Relative abundance Biomass Presence/absence Frequency Species richness Species diversity Size structure	Maximum count Length Relative abundance Biomass Presence/absence Frequency Species richness Size structure	CPUE Sex ratio Size structure		Density Relative abundance Biomass Presence/absence Frequency Species richness Species diversity Size structure Cover

6.6 Data analysis

Spatial differences will be analysed after the first survey to look for baseline differences between the marine reserve sites and the control sites. However, several years of data must be collected before any inferences about temporal differences (i.e. trends over time) can be made. Regardless of the approach selected, the final model must include appropriate covariates (e.g. depth, habitat), including any environmental variables that may have been measured.

When analysing the data, it is important to consider:

- The age and size of the marine reserve and its degree of isolation (Edgar et al. 2014)
- Fishing rules and the level of enforcement within and near the marine reserve
- How often monitoring is occurring
- Spatial effects, including habitat types

Before conducting analyses, consult a statistician to ensure you are using an appropriate approach. Some of the analytical approaches that can be used for each of the data elements shown in Table 6.2 are summarised in Tables 6.7–6.12.

Table 6.7. Summary of analytical approaches for data relating to density.

Data element: Density					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• UVC • BUV • Quadrats	Number of individuals per transect Area of transect sampled Number of sites and transects	Convert the number of individuals observed per transect to the number per unit area (typically per m^2) by dividing the number of individuals by the area of the transect sampled. For example, if 100 individuals are counted within a 200-m^2 transect, the density of those individuals within that transect is 0.5 per m^2. Means (and associated variances) can then be calculated from these values across all measured transects.	If the assumptions are met (or a very large sample size is used), then repeated-measures ANOVA may be used. If the assumptions are not met, then PERMANOVA or GLM should be employed.	Construct bar or line plots with error bars (e.g. see Fig. 6.1).	Objective 4.1 – Spatial
		The ARR and the associated 95% confidence interval can be used to look at differences for each species over a number of years using the equation: using the equation: $ARR = \delta_{in}/\delta_{out}$ where δ is the density.	Same analysis as above but with a focus on the impact of year.	Plot the average response ratio as range bars (e.g. see Fig. 6.2).	Objective 4.2 – Temporal

Abbreviations: ANOVA, analysis of variance; ARR, average response ratio; BUV, baited underwater video; GLM, generalised linear model; PERMANOVA, permutational analysis of variance; UVC, underwater visual census.

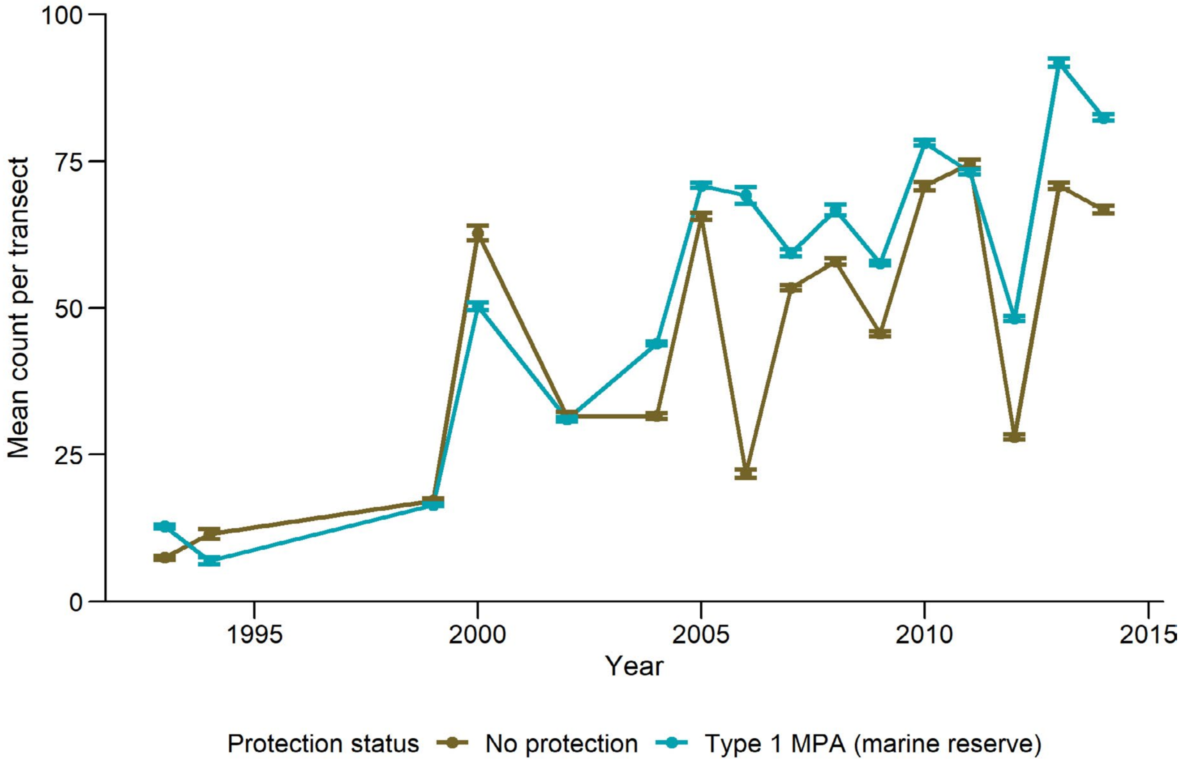


Figure 6.1. Example of how a line chart with 95% confidence intervals can be used to visualise differences inside and outside a marine reserve over time. Data obtained from surveys at Tonga Island Marine Reserve.

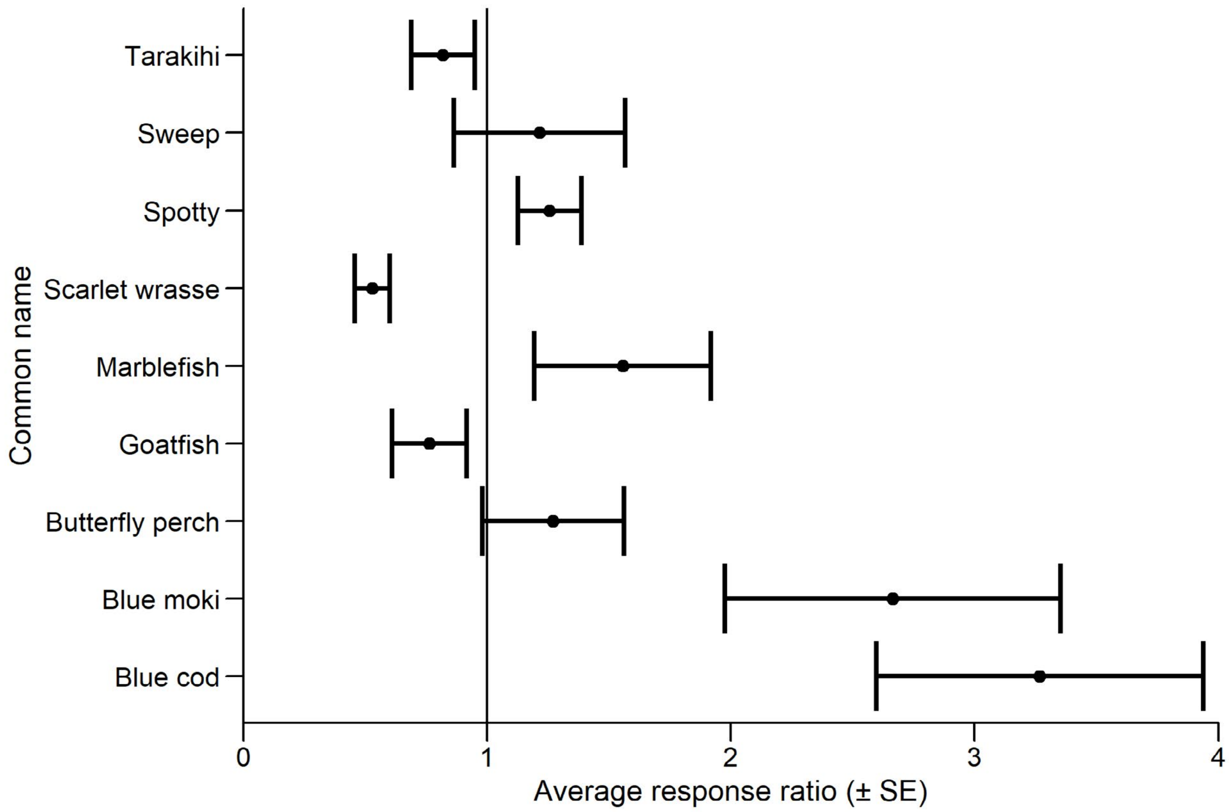


Figure 6.2. Example of an average response ratio (ARR) chart for Tonga Island Marine Reserve between 1993 and 2014. The plot shows the ARR for individual targeted and non-targeted species, where 1 is no difference, >1 is a positive effect of protection and <1 is a negative effect of protection.

Table 6.8. Summary of analytical approaches for data relating to relative abundance.

Data element: Relative abundance					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
UVC BUV Quadrats Cores	How common or rare a species is relative to other species Number of individuals of each species present	Divide the number of individuals of one species by the total number of individuals across all species.	Differences in relative abundance are not usually formally tested but instead are visualised as either rank/abundance plots or *k*-dominance curves. The rank/abundance plot ranks species in sequence from most to least abundant along the *x*-axis. Species evenness can be interpreted from the slope of the line, with a flatter slope indicating greater evenness.	Produce a 100% stacked bar chart comparing the relative abundance of selected species inside and outside a reserve for a given year (e.g. see Fig. 6.3).	**Objective 4.1 – Spatial**
			Machine learning techniques are advanced methods for analysing the abundance or relative abundance. Consult a statistician for details on how to apply these methods.	Plot the standardised residuals from a chi-square test of the relative difference in abundance inside and outside the reserve for each species (e.g. see Fig. 6.4). Values greater than 0 indicate that there is a higher frequency of occurrence of that species inside the marine reserve than outside it. Colours can be used to indicate whether the species is a fished species (targeted = yes). Use stacked bar charts to show the relative abundance of fish over time. It is important to consider how many species are appropriate for display on the graph.	**Objective 4.2 – Temporal**

Abbreviations: BUV, baited underwater video; UVC, underwater visual census.

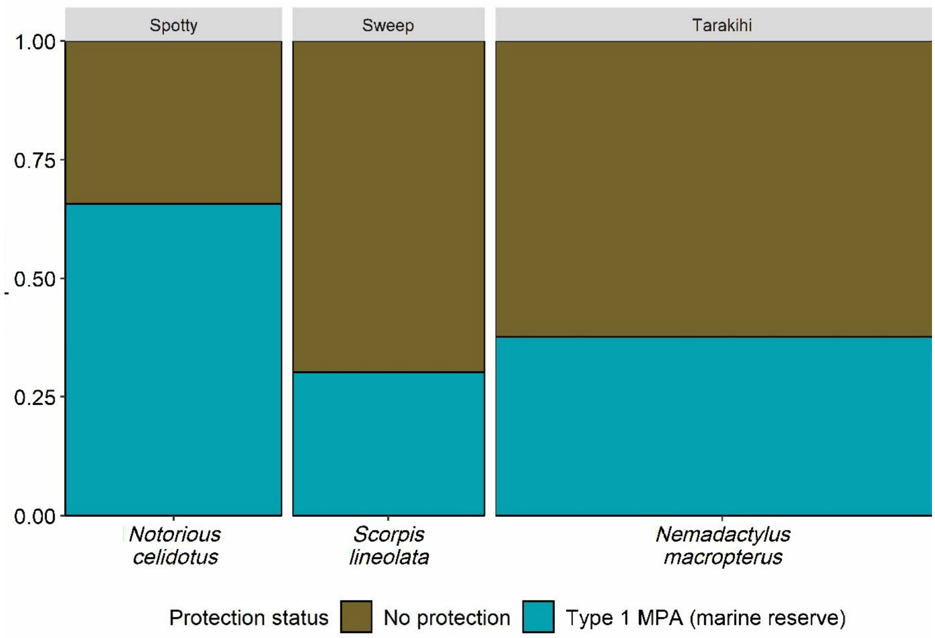


Figure 6.3. Example of a stacked bar chart showing the relative abundances of fishes from Tonga Island Marine Reserve in a single year (2000). The width of the bar represents the relative abundance of a given species compared with the other species.

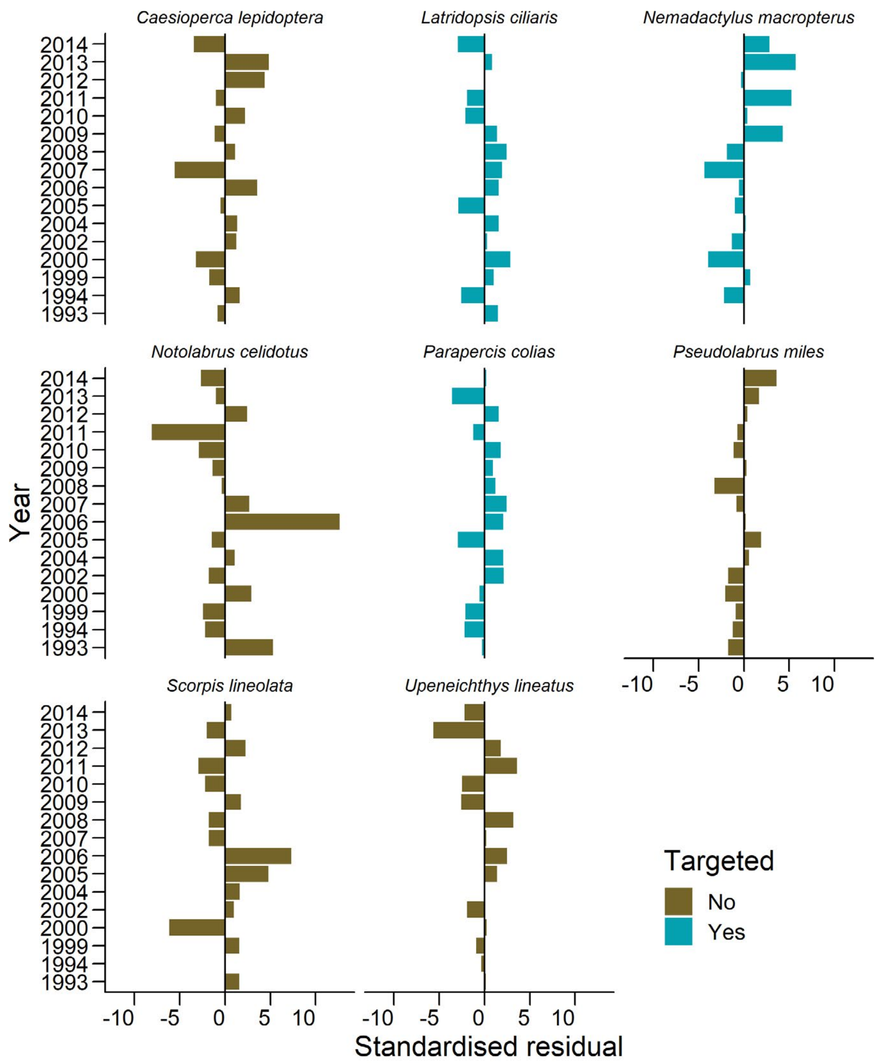


Figure 6.4. Example of standardised residual plots for the abundances of targeted and non-targeted fishes in Tonga Island Marine Reserve from 1993 to 2014.

Table 6.9. Summary of analytical approaches for data relating to species richness.

Data element: Species richness					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• UVC • BUV • Quadrats • Cores	A count of the number of species present.	Species richness is simply a count of the number of species observed. A richness estimate should be calculated for each site surveyed, and the number of unique species inside and outside the reserve over the monitoring years should be tabulated.	If the assumptions are met (or a very large sample size is used), then repeated-measures ANOVA may be used. If the assumptions are not met, then PERMANOVA or GLM should be employed.	Produce a box plot to compare reserve and non-reserve sites (e.g. see Fig. 6.5). Generate a heat map of the richness across the marine reserve and control sites or across habitat types.	**Objective 4.1 – Spatial**
			As above, ensuring that year is included in the model. If data are collected yearly, then they must be included as an integer (as years will be related).	Produce a bar chart, box plot or dot plot of species richness for a given year and/or over time.	**Objective 4.2 – Temporal**

Abbreviations: ANOVA, analysis of variance; BUV, baited underwater video; GLM, generalised linear model; PERMANOVA, permutational analysis of variance; UVC, underwater visual census.

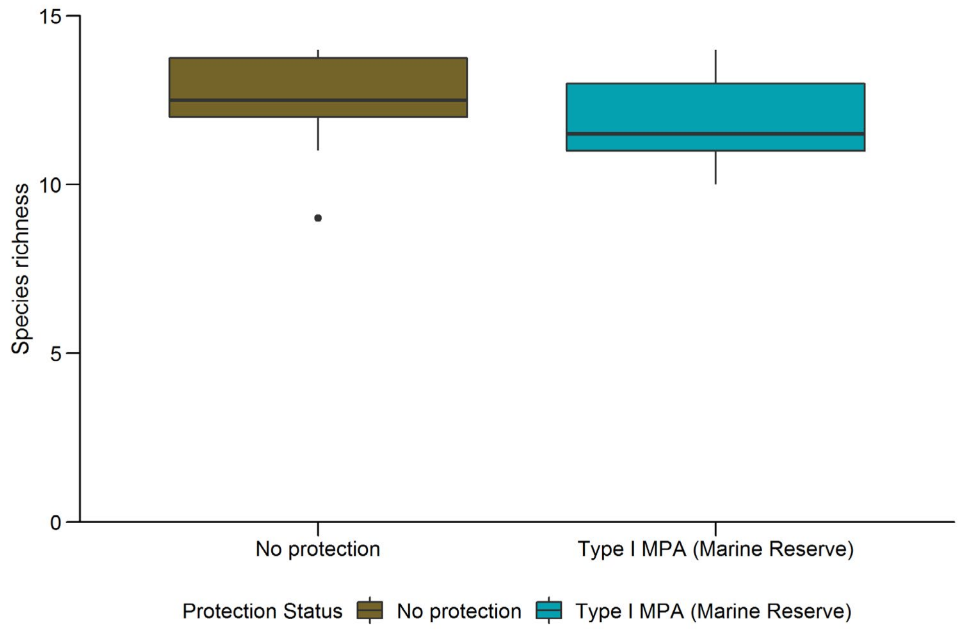


Figure 6.5. Example of a species richness box plot showing differences inside and outside Long Island - Kokomohua Marine Reserve.

Table 6.10. Summary of analytical approaches for data relating to biomass.

Data element: Biomass					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• UVC • BUV • Quadrats • Cores • Potting	• Total weight of the taxon of interest for each transect sampled, derived from length–weight estimates • Area of transect sampled	Length estimates of fishes are converted to biomass estimates using the following length–mass relationship derived for each species: $M = a(L)^b$ where M is the mass (g), a and b are species-specific constants for the allometric growth equation, and L is the length (mm). Length-fitting parameters obtained from FishBase (www.fishbase.org) can be used to convert between different types of fish length measurement.	If the assumptions are met (or a very large sample size is used), then repeated-measures ANOVA may be used. If the assumptions are not met, then PERMANOVA or GLM should be employed.	Plot bar charts with error bars showing the biomass of individual species inside and outside the reserve. Biomass should be presented as kg/m^2 (e.g. see Fig. 6.6).	Objective 4.1 – Spatial
			As above, ensuring that year is included in the model. If data are collected yearly, then they must be included as an integer (as years will be related).	Plot line charts, with points and their associated error bars representing the biomass of the species or group of species (e.g. the exploited species) for a given year. Use separate lines for inside and outside the reserve (e.g. see Fig. 6.7.)	Objective 4.2 – Temporal

Abbreviations: ANOVA, analysis of variance; BUV, baited underwater video; GLM, generalised linear model; PERMANOVA, permutational analysis of variance; UVC, underwater visual census.

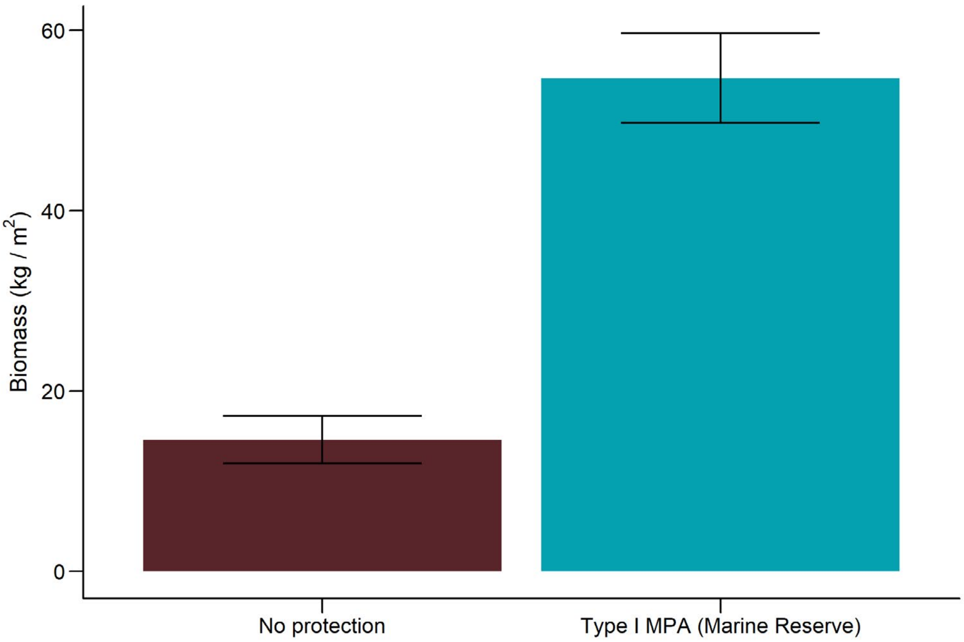


Figure 6.6. Example of a biomass plot for blue cod (*Parapercis colias*) from Long Island - Kokomohua Marine Reserve in 2015. Values are means ± SEM.

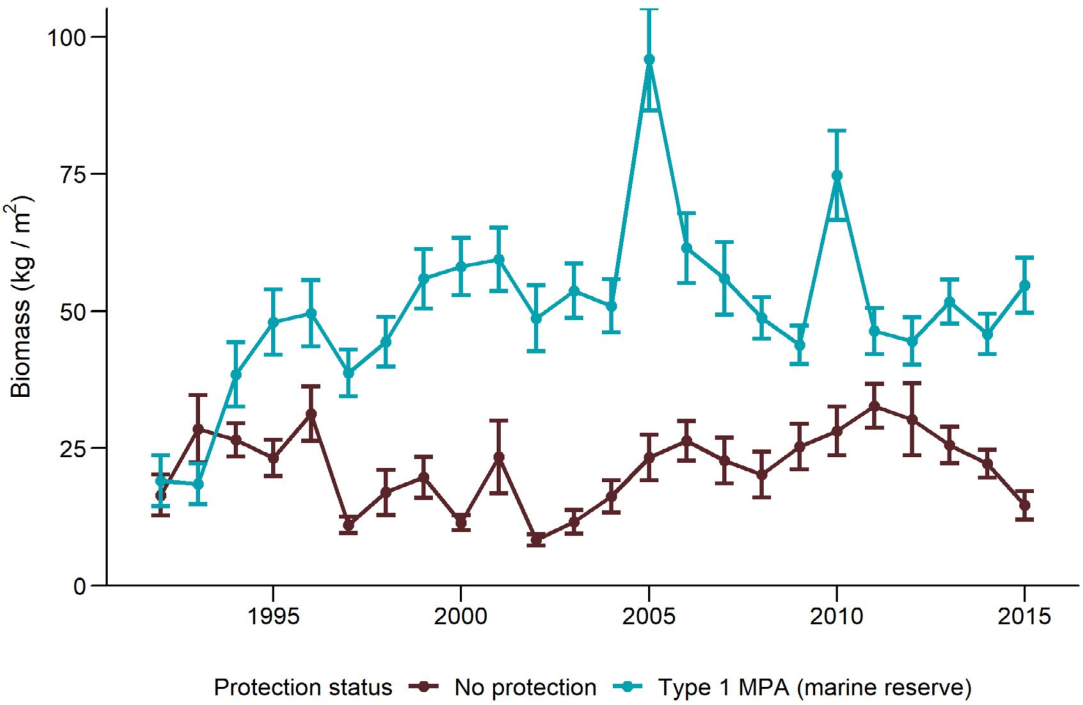


Figure 6.7. Example of a line chart for blue cod (*Parapercis colias*) from Long Island - Kokomohua Marine Reserve. Values are means ± SEM.

Table 6.11. Summary of analytical approaches for data relating to size structure.

Data element: Size structure					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• UVC • BUV • Quadrats • Cores • Potting	Size (length or mass) or size class of each individual observed.	If using an unbalanced design, then the data will need to be corrected for the area searched or the number of pots used.	Size data may be amenable to being analysed by ANOVA or *t*-test. If a balanced design was used, then use a *t*-test to examine whether the species of interest is larger inside the reserve than outside it. It is also worth looking at the differences in the shapes of the curves in terms of skewness and kurtosis, as this may indicate differences in the age structure of the population.	Population size structure may be presented simply as a mean of the parameter measured, or the full set of data may be presented as size–frequency histograms (e.g. see Fig. 6.8).	**Objective 4.1 – Spatial**
			To test if the size structure has changed over time, undertake formal statistical analysis to test the main hypotheses.	Plot the mean size of the species of interest inside and outside the reserve by year and with 95% confidence intervals.	**Objective 4.2 – Temporal**

Abbreviations: ANOVA, analysis of variance; BUV, baited underwater video; UVC, underwater visual census.

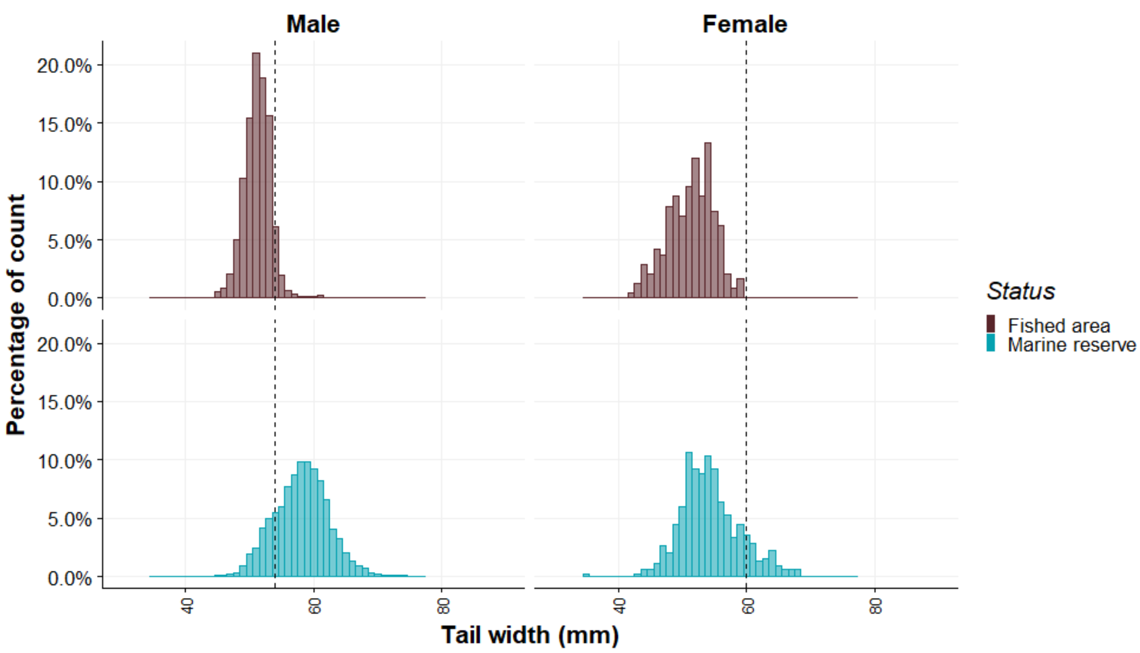


Figure 6.8. Example of size–frequency distributions of male rock lobsters (*Jasus edwardsii*) inside and outside Te Tapuwae o Rongokako Marine Reserve.

Table 6.12. Summary of analytical approaches for data relating to catch per unit effort (CPUE).

Data element: Catch per unit effort (CPUE)					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Potting	• CPUE is proportional to the abundance of lobsters at the site • Individual lobster size (tail width and/ or carapace length) • Lobster sex • Minimum legal size • Bait type • Moult cycle • Lunar cycle • Season	CPUE can be calculated in various ways but is usually presented as the wet weight (kg) of legal-sized lobsters per pot lift. CPUE can also be presented as total wet weight (both legal and sub-legal) or number of lobsters per pot (total number, or split into legal and sub-legal categories).	If the assumptions are met (or a very large sample size is used), then repeated-measures ANOVA may be used. If the assumptions are not met, then PERMANOVA or GLM should be employed.	Data should be displayed in a map to look at the variability in CPUE across the survey area. Use a heat scale to demonstrate areas of high and low catch in kg per pot lift (Fig. 6.9).	Objective 4.1 – Spatial
		CPUE will be presented as the wet weight (kg) of legal-sized lobsters per pot, as this provides a measure of fishable biomass. To calculate the weight, the tail size will be converted to wet weight using the equation: Wet weight = $a\text{TW}^b$ where *a* and *b* are sex-specific conversion factors and TW is the tail width (mm). See Fig. 6.9.	As above, ensuring that year is included in the model. If data are collected yearly, then they must be included as an integer (as years will be related).	Plot the mean for each time period surveyed with 95% confidence intervals.	Objective 4.2 – Temporal

Abbreviations: ANOVA, analysis of variance; GLM, generalised linear model; PERMANOVA, permutational analysis of variance.

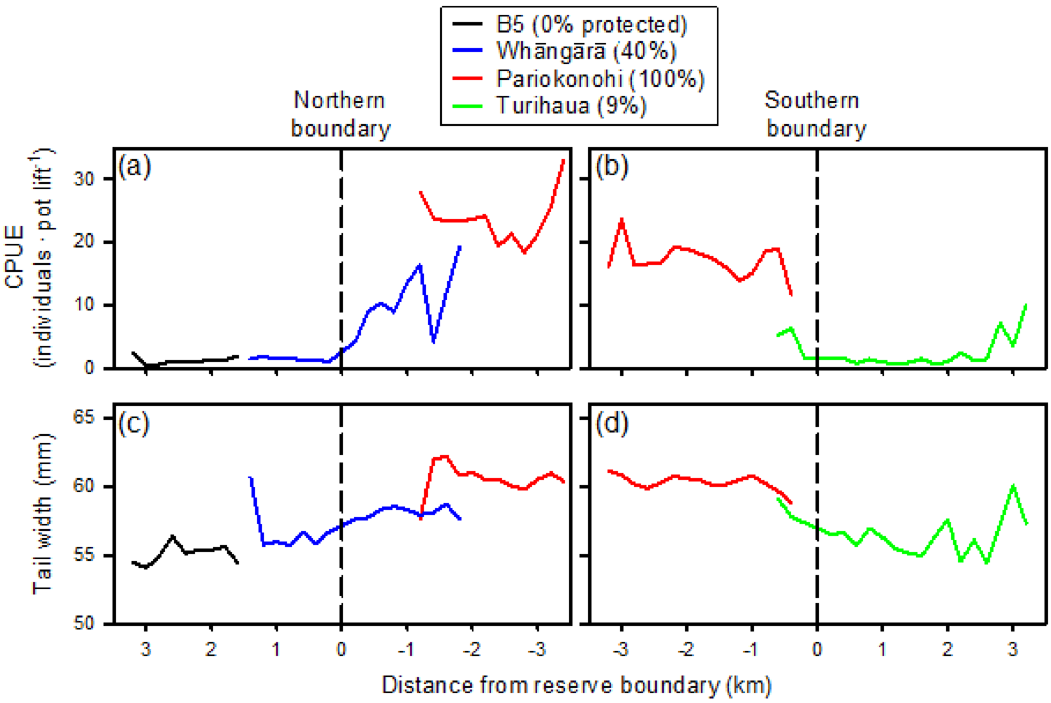


Figure 6.9. Average catch per unit effort (CPUE) and size (tail width) of legal male rock lobsters (*Jasus edwardsii*) at Te Tapuwae o Rongokako Marine Reserve in relation to the distance from the marine reserve boundary.

6.7 Reporting and communicating

Reporting on the biomass, density, size or relative abundance of key species within and near to marine reserves is an essential component of understanding the effectiveness of marine reserve protection (Table 6.13). Marine reserves in Aotearoa New Zealand exclude any extraction, so it is expected that species targeted for consumption (mahinga kai) would recover. In general, changes to species populations in these analyses are attributed to the effects of protection from fishing, but other pressures must be considered. For example, while marine reserves prohibit extractive activities, new potential pressures such as increased boat presence or SCUBA diver ecotourism can arise, which should be considered in analyses and reporting. Changes in the abundances of key species are a key indicator for understanding changes in the integrity of ecosystems and should be used to make informed management decisions.

6.7.1 Marine reserve reports and report cards

The data elements monitored by Theme 4 can be included in marine reserve reports and report cards using the analytical products. The focus of this reporting will be on the abundance, density and biomass of key species. Relative abundance is useful for understanding if the composition of the community is changing over time, but biomass may better reflect the make-up of the community – for example, if there are a lot of juveniles, then the abundance or density estimate may show a healthier community than a biomass estimate. Density is a useful measure for understanding where species occur and how that might change over time. The definitions for reporting on the status of the measures monitored under this theme are described in Table 6.14, in which the wording used considers that some of our marine reserves are in pristine or low-impacted sites (see Table 2.5 for definitions of trend).

6.7.2 Other reporting opportunities

Apps are being developed to make key species data more accessible to the public. These will include interactive maps that allow the user to drill down into each marine reserve and look at data from a high level (summarised trends) down to the raw data. An example of what this app will look like for Kapiti Marine Reserve is shown in Fig. 6.10.

Table 6.13. Information relating to Theme 4 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective	**Maintaining ecosystem processes**
Indicator	**Ecosystem function**
Data element	Biomass
Reporting	• Trends in population biomasses after at least 5 years of data have been collected
Indicator	**Species composition and diversity**
Data elements	Density Relative abundance Size
Reporting	• Difference in population density inside and outside the marine reserve • Difference in the size of species inside and outside the marine reserve • Comparison of the relative abundance of species inside and outside the marine reserve

Table 6.14. Definitions for reporting on the status of the measures for Theme 4 Describe the abundance and demography of key species.

Status	Definition
Excellent	The relative abundance, density, biomass or size of most key species is: • Greater inside the marine reserve than in an area that is impacted; or • The same or greater than what is expected in an area that is not impacted.
Good	The relative abundance, density, biomass or size of key species is: • Greater inside the marine reserve than in an area that is impacted for **some key species**; or • The same or greater than what is expected for **some key species** in an area that is not impacted.
Fair	The relative abundance, density, biomass or size of key species is: • Lower inside the marine reserve than in an area that is impacted for **a few key species**; or • Lower than what is expected for **a few key species** in an area that is not impacted.
Poor	The relative abundance, density, biomass or size of most key species is: • Lower inside the marine reserve than in an area that is impacted; or • Lower than what is expected for an area that is not impacted.
Undetermined	The status of this measure cannot be determined.

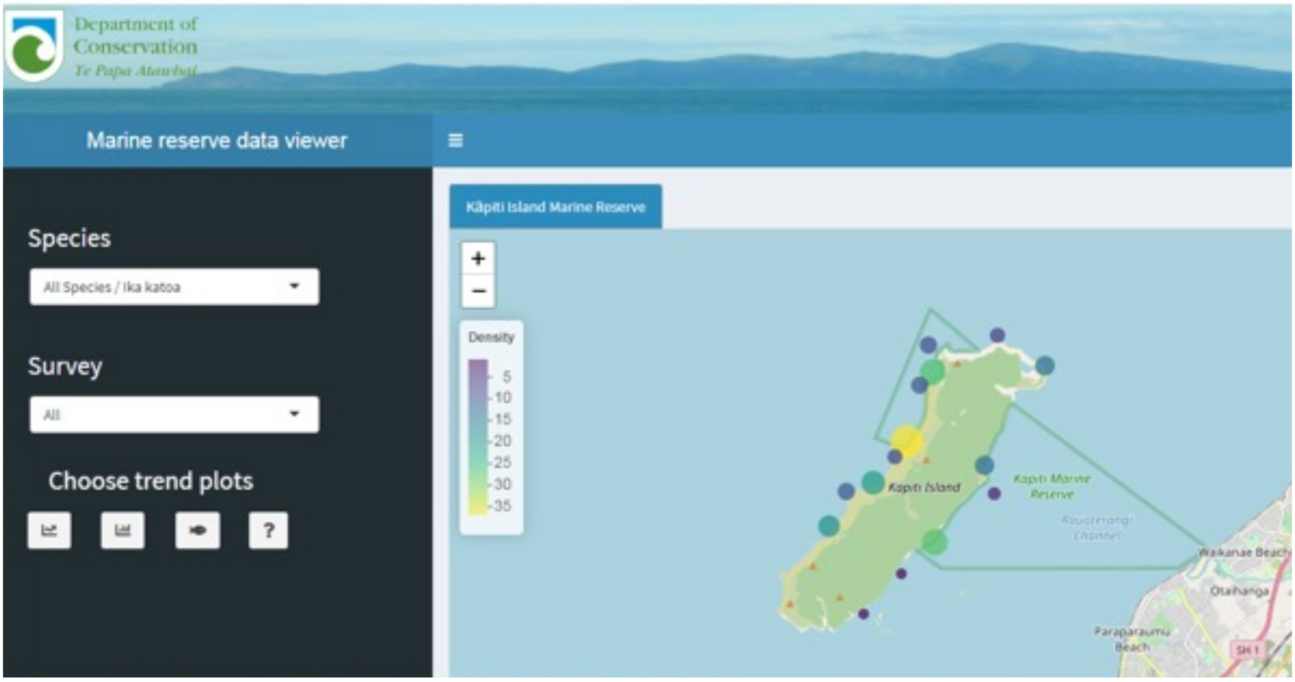


Figure 6.10. Example of the marine reserve app displaying key species data for Kapiti Marine Reserve (https://dragonfly-science.shinyapps.io/kapiti-fish-community/).

7 Theme 5 – Determine the rates of compliance

What	Spatial and temporal variation in compliance rates
Who	DOC, tangata whenua, partner enforcement agencies, stakeholders and the public
When	Year round
Where	All marine reserves where possible
How	Patrols, surveillance, digital monitoring and reports from the public, stakeholders and partner enforcement agencies
Why	To better target enforcement and education efforts and understand impacts of non-compliance on key species, habitats and values

7.1 Background and objectives

In Aotearoa New Zealand, the sustainable use of marine resources and the maintenance of species and habitats are achieved by regulating the use and take of indigenous marine and coastal species (including seaweeds, other plants, fishes and invertebrates) through a variety of Acts and regulations. However, this approach leads to a highly modified marine environment. Therefore, to better achieve the conservation goal of fully protecting a representative range of marine ecosystems, marine reserves have been established around the country. The extraction of resources and development are not permitted in these areas of the Aotearoa New Zealand territorial sea, representing the highest level of protection under New Zealand legislation. DOC administers these areas under the Marine Reserves Act 1971 and is responsible for ensuring compliance with the rules (see Box 7.1).

A key aim of marine reserves is to retain sites in their natural state (or allow them to return to their natural state) in the absence of extractive or other activities that might impact on species and habitats within their boundaries. A high level of effective compliance is important to maintain the integrity and purpose of marine reserves, as this provides confidence that they remain free from the pressures faced by other marine environments and allows them to serve as 'control' sites in scientific studies assessing the impacts of development and extractive activities. To maintain popular support for existing marine reserves and the establishment of a more complete network of MPAs, it is important that DOC can demonstrate that existing marine reserves are well managed, part of which involves ensuring that compliance work and outcomes are effective. Therefore, compliance needs to be monitored.

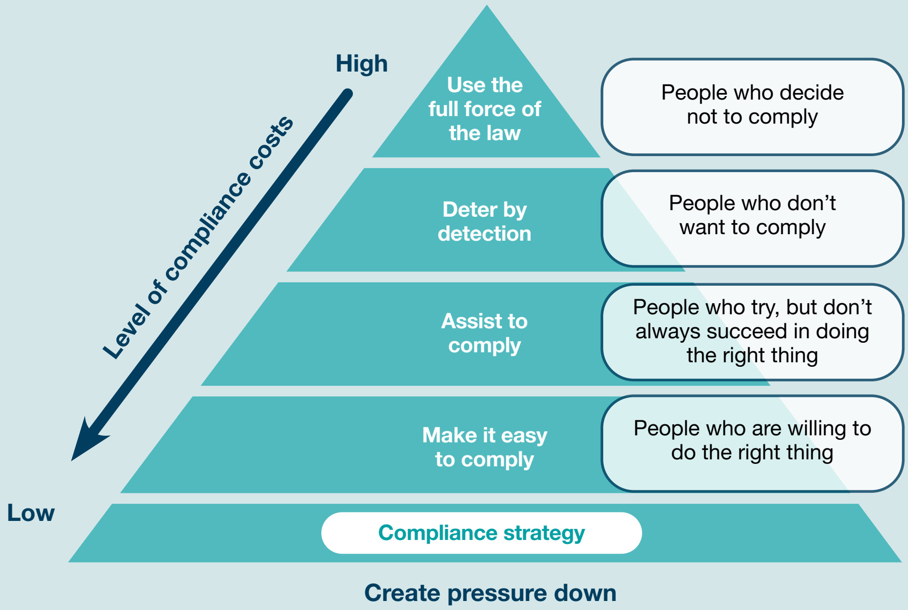
Compliance monitoring tracks DOC's effort and society's levels of compliance with the provisions of the Marine Reserves Act 1971. It needs to address the full range of compliance activity, including education, advocacy (see Theme 7 – Human use in section 9) and law enforcement. Monitoring helps to ensure that compliance work is effective in achieving the objectives of the marine reserve, including the protection of all species and habitats and the mitigation of pressures/threats. It is important to understand the reasons for both compliance (such as support for marine reserves or an awareness of and willingness to adhere to the rules) and non-compliance (such as ignorance or deliberate flouting of the rules) so that the most effective strategies can be implemented to maintain or improve adherence to the rules.

Box 7.1: What are compliance and enforcement?

Compliance means the extent to which people adhere to the law.

Enforcement means actions taken in response to people not following the law, with the aim of achieving compliance. Enforcement tools include warning letters, infringement notices, prosecutions, and active advocacy and educational outreach.

Compliance activity is directed at achieving higher levels of compliance through enforcement, advocacy and surveillance activity and should follow the National Compliance Strategy 2017–2020 (DOC 2017a). The Braithwaite Compliance Triangle can help guide where compliance effort should be spent.



The Braithwaite Compliance Triangle – see DOC's National Compliance Strategy 2017–2020 (DOC 2017a) for a full explanation of how this is used.

Monitoring may help to target educational campaigns, direct surveillance and enforcement, and allocate resources to priority sites and times to maximise the impact of compliance work.

DOC has national and international obligations to enforce the rules within the marine reserves it administers. Internationally, Aotearoa New Zealand has committed under the CBD to ensure the sustainable management of living resources (Aichi Target 6)[42] and that protected areas are managed effectively and equitably (i.e. costs and benefits must be shared fairly) (Aichi Target 11).[43] The Aichi Targets suggest several indicators that can be used to determine if these criteria are being met.

Globally, compliance monitoring in marine reserves is conducted haphazardly and very few countries explicitly monitor compliance rates, despite the potential impact of non-compliance on key species (Bergseth et al. 2015). In Aotearoa New Zealand, DOC is working towards IO1 'The diversity of our natural heritage is maintained and restored', under which Outcome Objective 1.8 '

42 www.cbd.int/aichi-targets/target/6
43 www.cbd.int/aichi-targets/target/11

Human use and interaction with natural heritage' specifically relates to compliance. Theme 5 also makes progress towards Aichi Target 6, which states that 'By 2020 all fish and invertebrate stocks and aquatic plants are managed and harvested sustainably, legally and applying ecosystem-based approaches …'.

Compliance in marine reserves is expected to vary greatly depending on a range of factors, such as the location in relation to access points and population centres, the time of day and year, the abundance of target species, the weather and sea conditions (including tides), and the perceived risk and consequences of non-compliance. These targets and expectations can give guidance on the types of compliance monitoring that is required.

7.1.1 Cultural significance

Māori have a deep connection with the natural world that is expressed through kaitiakitanga – a concept of guardianship and connection and a way of managing the environment through te ao Māori (the Māori world view). The connection between the natural world and Māori is explained through whakapapa (genealogy) and mythology. In the past, Māori followed traditional practices when they were hunting, fishing, growing or gathering food to maintain balance with the environment. However, many practices were displaced following the European colonisation of Aotearoa New Zealand. Today, tangata whenua are restoring their culture and applying traditional ideas such as te ao Māori and mātauranga Māori to the modern world.

Customary management areas and tools are already in place. Mātaitai and taiāpure provide for traditional fishery management through local restrictions and rāhui (section 186A and 186B closures under the Fisheries Act 1996). These customary tools can complement marine reserves and there is the potential for better integration through the MMRF. Whānau, hapū and iwi must also be involved in all aspects of marine reserve management, which will likely increase support and may help to increase compliance and compliance resources, including advocacy. District DOC staff hold relationships with mana whenua at place and should consult on local compliance monitoring plans, taking into account the views of tangata whenua.

7.1.2 Objectives

This section focuses on marine reserves rather than all MPAs because DOC's compliance and law enforcement duties are largely constrained to those sites.

Monitoring objective 5.1 (spatial): To determine the rates and causes of compliance/non-compliance in different marine reserves.

Research question: Where and why are people most likely to comply/not comply?

Monitoring objective 5.2 (temporal): To determine the rates of compliance in marine reserves over time.

Research question: When are people most likely to comply/not comply and what causes changes in compliance rates over time?

7.2 Existing monitoring programmes

Various government agencies have national compliance models set up around maritime activities (e.g. shipping, mining, dredging,[44] fishing,[45] and biosecurity[46]) in Aotearoa New Zealand's marine environment (see Box 7.2). Maritime New Zealand monitors accidents, incidents, near misses and breaches of the law in relation to maritime transport activities, while Biosecurity New Zealand monitors high-risk locations (such as ports) for marine pests twice per year. In addition, the Ministry for Primary Industries / Fisheries New Zealand (MPI/FNZ) monitors recreational, customary and commercial fishing to encourage sustainable fishing and compliance using methods such as shore patrols, vessel and vehicle checkpoints, patrol boats, and digital tracking methods (including satellite position monitoring and cameras onboard commercial vessels). MPI/FNZ also uses aircraft (in conjunction with the New Zealand Defence Force) and observers onboard commercial fishing vessels to assist with monitoring and to record what is caught, including the bycatch impact on seabirds and marine mammals. Monitoring programmes that are of relevance to Theme 5 are summarised in Table 7.1.

Box 7.2: Compliance monitoring in Aotearoa New Zealand

National Maritime Coordination Centre (NMCC)

The NMCC is responsible for managing Aotearoa New Zealand's maritime surveillance. It is administered by the New Zealand Customs Service but is operationally independent. DOC is a member agency of the NMCC, along with MPI/FNZ, Customs and the New Zealand Defence Force. The NMCC monitors named areas of interest, including 16 marine reserves. These are largely offshore marine reserves in remote locations that are difficult for DOC to access. DOC is notified of potential offences within marine reserves by NMCC using an alert system called MariWeb.

MariWeb

MariWeb is a system that monitors vessel satellite data using the Automatic Identification System (AIS), Geospatial Monitoring System (GMS) (fitted to commercial fishing vessels) and Forum Fisheries Agency (FFA) (fitted to commercial fishing vessels in the Pacific Islands). DOC funds two licences for MariWeb. If the NMCC detects a potential marine reserve incursion, DOC is expected to then use MariWeb to monitor the vessel and undertake an investigation.

MPI/FNZ digital GPS monitoring system

The Fisheries (Commercial Fishing) Regulations 2001 require all commercial fishing vessels in Aotearoa New Zealand's waters that are over 4 m in length to have monitoring equipment fitted. This monitoring system plots the tracks of commercial vessels every 10 min. All marine reserves are geofenced on the system, and MPI is given notification through the software Waka Haurapa when any commercial vessel enters a marine reserve.

Box 7.2 continued on next page

41 www.maritimenz.govt.nz/about/what-we-do/compliance/compliance-model.asp

42 www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/fishing-rules/

43 www.mpi.govt.nz/biosecurity/

Box 7.2 continued

Response to information received

DOC receives information about marine reserve offences from a range of external sources, including the emergency call centre (0800 DOC HOT), calls to district offices, councils and other government enforcement agencies, honorary warranted DOC officers, and direct calls to DOC rangers.

Active patrols and surveillance of marine reserves

DOC undertakes marine reserve surveillance monitoring in several ways, including foot patrols to inspect the shoreline, vessel patrols, aerial surveys and closed-circuit television (CCTV) monitoring.

Ad hoc staff visits

DOC rangers also take the opportunity to check for compliance during the course of other work activities in the locality.

Table 7.1. Summary of past and present monitoring programmes for Theme 5 undertaken by the Department of Conservation Te Papa Atawhai (DOC) and other stakeholders in Aotearoa New Zealand's marine reserves (as at June 2020).

Marine reserve (marine bioregion)	DOC-led programmes	Other programmes
Across Aotearoa New Zealand (applies to most or all marine reserves)	Responses to information received (e.g. 0800 DOC HOT, public/interagency reports)	• MPI/FNZ fisheries compliance (e.g. digital GPS and video vessel monitoring, aerial and ground surveillance • NMCC partner agencies (including Police, New Zealand Customs, MPI and NZDF)
Kermadec Islands (Kermadec Islands)	DOC staff reports (staff living on Raoul Island), ad hoc staff visits (Kermadec expeditions)	• NZDF operative tasking (will visit marine reserve if in region) • MPI/FNZ digital GPS monitoring • NMCC (MariWeb) • New Zealand Customs
Poor Knights Islands (North Eastern)	DOC boat patrols	• Maritime Police (limited) • NMCC • Independent dive companies (Dive! Tutukaka, Yukon Dive)
Whangarei Harbour (North Eastern)	DOC boat and shore patrols	• MPI/FNZ • Maritime Police (limited)
Cape Rodney-Okakari Point (North Eastern)	DOC boat and shore patrols, CCTV	• MPI/FNZ • Maritime Police • Auckland Council ranger shore patrols
Long Bay-Okura (North Eastern)	DOC boat and shore patrols	• MPI/FNZ • Maritime Police • MERC's honorary warranted DOC officers • Auckland Council ranger shore patrols • CCTV at entrance/exit to marine reserve • New Zealand Police
Te Matuku (North Eastern)	DOC boat patrols	• MPI/FNZ • Maritime Police

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Table 7.1.continued

Marine reserve (marine bioregion)	DOC-led programmes	Other programmes
Tāwharanui (North Eastern)	DOC boat and shore patrols	• MPI/FNZ • Maritime Police • Auckland Council ranger shore patrols • CCTV at entrance/exit of car park
Motu Manawa-Pollen Island (North Eastern)	DOC shore and kayak patrols	• MPI/FNZ
Whanganui A Hei (Cathedral Cove) (North Eastern)	DOC boat and shore patrols, CCTV	• Marine tourism operators • MPI/FNZ
Te Paepae o Aotea (Volkner Rocks) (North Eastern)	DOC boat patrols	• NMCC
Tuhua (Mayor Island) (North Eastern)	DOC boat patrols, CCTV (not active/working)	• NMCC
Te Tapuwae o Rongokako (Eastern North Island)	DOC boat and shore patrols, CCTV, public reports (limited by mobile coverage)	• MPI/FNZ • New Zealand Police
Te Angiangi (Eastern North Island)	DOC boat and shore patrols, public reports (limited by mobile coverage)	• MPI/FNZ • New Zealand Police
Parininihi (Western North Island)	DOC boat and shore patrols	• MPI/FNZ • New Zealand Police
Tapuae (Western North Island)	DOC boat and shore patrols	• MPI/FNZ • New Zealand Police • Port Taranaki Security
Kapiti (North Cook Strait)	DOC boat and shore patrols, CCTV	• CCTV (monitored by an NGO)
Taputeranga (North Cook Strait)	DOC boat and shore patrols	• MPI/FNZ • Maritime Police
Long Island - Kokomohua (South Cook Strait)	DOC boat and shore patrols	
Tonga Island (South Cook Strait)	DOC boat and shore patrols, CCTV	• MPI/FNZ • Harbourmaster
Horoirangi (South Cook Strait)	DOC boat and shore patrols, CCTV	• MPI/FNZ • NMCC • Harbourmaster
Westhaven (Te Tai Tapu) (South Cook Strait)	None	• MPI/FNZ • NMCC
Hikurangi (East Coast South Island)	None	• MPI/FNZ • NMCC
Pohatu (East Coast South Island)	DOC boat patrols and surveillance from land	• Regional council (harbourmaster) • MPI/FNZ • Tourism operators

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Table 7.1.continued

Marine reserve (marine bioregion)	DOC-led programmes	Other programmes
Akaroa (East Coast South Island)	DOC boat patrols and surveillance from land	• Regional council (harbourmaster, including CCTV monitoring) • MPI/FNZ • Tourism operators
Kahurangi (West Coast Stouth Island)	Ad hoc DOC staff visits by ground or air, aerial surveys/monitoring	• NMCC • NZDF (Air Force aerial monitoring) • MPI/FNZ
Punakaiki (West Coast South Island)	Ad hoc DOC staff visits by ground or air	• MPI/FNZ • NMCC
Waiau Glacier Coast (West Coast South Island)	Ad hoc DOC staff visits by ground or air	• NMCC
Tauparikākā (West Coast South Island)	Ad hoc DOC staff visits by ground or air	• NMCC
Hautai (West Coast South Island)	Ad hoc DOC staff visits by ground or air	• NMCC
Fiordland marine reserves (x10) (Fiordland)	DOC boat patrols	• MPI/FNZ (generally interagency with DOC)
Ulva Island – Te Wharawhara (Southern)	DOC boat patrols	• MPI/FNZ
Moutere Hauriri / Bounty Islands (Subantarctic Islands)	DOC boat patrols (ad hoc visits and DOC observers on cruise ships)	• NZDF operative tasking • MPI/FNZ digital GPS monitoring • NMCC
Moutere Mahue / Antipodes Island (Subantarctic Islands)	DOC patrols (ad hoc visits and DOC observers on cruise ships)	• NZDF operative tasking • MPI/FNZ digital GPS monitoring • NMCC
Auckland Islands - Motu Maha (Subantarctic Islands)	DOC patrols (ad hoc visits and DOC observers on cruise ships)	• NZDF operative tasking • MPI/FNZ digital GPS monitoring • NMCC
Moutere Ihupuku / Campbell Island (Subantarctic Islands)	DOC patrols (ad hoc visits and DOC observers on cruise ships)	• NZDF operative tasking • MPI/FNZ digital GPS monitoring • NMCC

Abbreviations: CCTV, closed-circuit television; FNZ, Fisheries New Zealand; GPS, Global Positioning System; MERC, Marine Education and Recreation Centre; MPI, Ministry for Primary Industries; NGO, non-governmental organisation; NMCC, National Maritime Coordination Centre; NZDF, New Zealand Defence Force.

7.3 Sampling design

7.3.1 Selecting indicators

This theme provides guidance on how to undertake monitoring that is relevant to selected measures contained within Objective 12 'Natural resources are managed sustainably' and more specifically Objective 12.1.3 'Marine fisheries resources are abundant, resilient and managed sustainably to preserve ecosystem integrity' from the ANZBS (DOC 2020c; Table 7.2).

7.3.2 Selecting monitoring programmes

Compliance monitoring does not measure the impacts of non-compliance on the species and ecosystems affected but may help to explain changes detected by other types of MPA monitoring (as described in other sections). For example, a high level of illegal pāua fishing (detected by compliance monitoring) might explain a decline in the pāua population within a marine reserve detected by Theme 4 – Key species monitoring (section 6). Compliance rates can be calculated by accurately monitoring and quantifying compliance effort.

Several app-based platforms are currently being developed to run on tablets or smartphones that will assist marine reserve rangers, warranted officers and other DOC staff in collecting data on marine reserve compliance effort (such as patrol and education/advocacy effort), the

Table 7.2. Indicators, measures and data elements relating to Theme 5 – Determine the rates of compliance. Adapted from McGlone et al. (2020).

Indicator 5.1: Hunting and harvesting of indigenous resources	
Measure 5.1.1: Illegal hunting and harvesting of indigenous species from marine reserves	
Description	Indigenous or strictly protected species are sometimes taken or harvested without permission. Unlawful fishing occurs within some marine reserves at places or times where perhaps the rules are not well known, the financial incentives are strong (e.g. snapper (*Pagrus auratus*) and pāua (*Haliotis* spp.)), the perceived risk of detection is low, the existence of protected areas is resented or the opportunities for significant catches are good.
Data elements	**Compliance rates** The number of offences divided by the time on patrol. **Time on active patrol hours** The time logged between leaving base, arriving at a marine reserve, conducting a marine reserve patrol and arriving back at the original base. **Number of patrols conducted (water & land)** Active-duty patrol on either the water or land of a marine reserve. **Number of offences** The number of offences against the conservation legislation that DOC administers. Note that an offender may be charged with several offences. **Number of preventions** The number of offences that are about to take place that have been actively stopped or ceased.
Links to other measures	4.1.1: Exploited species production (Theme 4 – Key species) 4.2.1: Marine biological function (Theme 4 – Key species) 7.1.1: Outdoor recreation demand being met by DOC in marine reserves – number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use) 7.2.1: Attitudes towards interaction with natural ecosystems (Theme 7 – Human use) 7.2.2: Demographic/psychographic profiles of users and non-users in marine reserves (Theme 7 – Human use)

Abbreviations: DOC, Department of Conservation Te Papa Atawhai.

type and method of offending, the target species, and outcomes. The ‘CLEWorks’ and ‘MyCLE’ apps will provide enforcement data on parameters such as what type of high-level offences were committed (i.e. ‘take’ or ‘discharge’) and the actions taken.

The work in this theme will not directly link into the monitoring programmes of other agencies, but data may be drawn from them through interagency cooperation and communication. For example, should MPI/FNZ detect offences through the digital monitoring of commercial fishing, DOC will be notified.

7.3.3 Developing a sampling design

How are sites to be selected?

Sampling sites for this theme are all DOC-managed marine reserves throughout Aotearoa New Zealand’s territorial sea. It is important that both the sea and shore are searched within each marine reserve (where applicable), as poaching can occur in both the intertidal and subtidal zones.

The monitoring of non-compliance during active surveillance and enforcement work will centre around known locations of keystone species that are vulnerable to poaching and known locations that are near fishing activity (e.g. access points, population centres, fishing areas). Greater attention may be given to the likely locations of highly valued species that are both ecologically important and known to be targeted by fishers (such as pāua, rock lobster, snapper and blue cod) or locations where the impact is expected to be greater (e.g. isolated rocky reefs). Passive surveillance, such as closed-circuit television (CCTV) and MariWeb, will not be targeted.

How often should measurements be taken at these sites or a subset of these sites?

The timing of active surveillance will generally align with standard surveillance and enforcement work, so that compliance work and monitoring can be undertaken simultaneously. Most effort will focus on times when non-compliance is considered more likely to be occurring, such as calm boating days, favourable tides, weekends and good weather, and times/seasons when key species are more vulnerable. However, to ensure the assumptions about compliance rates are correct, some monitoring might need to be carried out in places and at times where it is considered there is less likelihood of offending (e.g. when fishing conditions are less than ideal). It is possible that offenders may target marine reserves in less than ideal conditions if there is a higher prospect of a successful harvest than in areas outside marine reserves. However, to ensure the efficient use of resources (and due to limited resources in many cases), monitoring will not extend into times or locations when people are very unlikely to be there. Passive monitoring, CCTV, etc. will be ongoing.

7.4 Monitoring protocols

Compliance can be monitored in several ways, including through direct observation, indirect observation, law enforcement records, direct questioning, expert opinion and modelling (Bergseth et al. 2015). Monitoring protocols outlining data sources, site selection, timing, frequency and tools are presented in Table 7.3.

Table 7.3. Descriptions of the different monitoring protocols for Theme 5 – Determine the rates of compliance.

	DOC-led patrols	CCTV	Public report	Interagency-led reports	NMCC
Description	DOC staff are tasked with undertaking planned and proactive monitoring and surveillance of marine reserves (includes support of honorary rangers and ad hoc DOC visits).	CCTV can be used to monitor compliance proactively or retrospectively through the review of live or recorded video images.	Offences can be reported to DOC through a 24/7 emergency hotline (0800 DOC HOT), direct contact with warranted officers or calls to DOC offices.	Other enforcement or support agencies report offending to DOC (i.e. MPI/FNZ, Police, New Zealand Customs, councils/harbourmasters) or investigate/respond to offending on behalf of DOC (i.e. MPI/FNZ, Police, cross-warranted enforcement staff of other agencies).	NMCC monitors satellite data of vessels in remote marine reserves using the AIS and notifies DOC when vessels enter geo-fenced marine reserves.
Tools/ equipment	• Warranted officers • Other DOC staff • Field equipment (notebooks, warrant, camera, smartphones binoculars, etc.) • CLEWorks app • MyCLE app • Compliance/advocacy app	• Point/tilt/zoom camera (optics will vary depending on reserve) • Staff or volunteers • Digital storage	• 0800 DOC HOT • Administration/reception staff • Warranted officers • Signage, websites, pamphlets and other advocacy materials	• Waka Haurapa (MPI/FNZ commercial fishing monitoring app) • MPI/FNZ fishery officers • MPI/FNZ honorary fishery officers • MPI/FNZ analysts • Police • Cross-warranted partner agencies • DOC relationship holders (such as marine reserve rangers / warranted officers)	• MariWeb • NMCC GIS analysts • DOC GIS analysts • DOC relationship holder (National Planning Team)
Site selection	• Intertidal area • Shore • Sea, either from the platform of a vessel or with a clear field of view from a height above sea level	• Marine reserve or part of marine reserve with CCTV coverage • Shore, intertidal or sea surface of marine reserve	• All marine reserves (although some are very remote)	• All marine reserves	• 15 named marine reserves (generally remote)
Timing selection	Based on weather and ocean conditions and the time and type of day, with an increase in effort when fishing/gathering effort is more likely (e.g. offshore winds, low winds, low swell/chop, low/spring tides, after work hours, weekends, school/public holidays).	Based on weather and ocean conditions and the time and type of day, with an increase in effort when fishing/gathering effort is more likely (e.g. offshore winds, low winds, low swell/chop, low/spring tides, after work hours, weekends, school/public holidays).	As reported and investigated. Reports likely to be higher when fishing/gathering effort more likely and visitation is higher.	As reported and investigated. Reports likely to be higher when fishing/gathering effort more likely and visitation is higher.	NMCC monitoring occurs daily. Offences are reported to DOC as detected and reported.

Continued on next page

Table 7.3 continued

	DOC-led patrols	CCTV	Public report	Interagency-led reports	NMCC
Target	• Intertidal gatherers • Shore fishers • Boat fishers	• Intertidal gatherers • Shore fishers • Boat fishers	• Intertidal gatherers • Shore fishers • Boat fishers	• Recreational and commercial fishers • Commercial vessels digitally monitored	15 named remote marine reserves: • Te Paepae o Aotea (Volkner Rocks) • Poor Knights Islands • Tuhua (Mayor Island) • Hautai • Kahurangi • Tauparikaka • Waiau • Punakaiki • Westhaven (Te Tai Tapu) • Hikurangi • Moutere Mahue / Antipodes Island • Auckland Islands - Motu Maha • Moutere Hauriri / Bounty Islands • Moutere Ihupuku / Campbell Island • Kermadec Islands
Vessel length detection limit	Any	Any	Any	Any, but digital monitoring of all commercial fishing vessels > 4 m	> 20 m
Sampling effort	Depends on the location of the reserve and the resources available but can be from once per month to 3–4 times per week	3–4 times per week	As received and investigated	As received (dataset formed over financial year)	Daily
Effort	Time within or observing the reserve	Time using camera to survey	As received and investigated	As received (as above)	Daily
Responsibility	• DOC warranted officers • Other DOC staff	• DOC staff • Volunteers (in line with policy)	• 0800 DOC HOT staff • Administration staff • Warranted officers	• DOC staff who hold the relationship (marine reserve rangers, Programme Lead Marine Reserve (Compliance), warranted officers)	• DOC staff who hold the relationship (National Planning Team, National Compliance Team, GIS Team)
Covariates	• Location • Month • Tide • Time of day • Type of day • Distance to nearest population centre	• Location • Month • Tide • Time of day • Type of day	• Location • Month • Tide • Time of day • Type of day	• Location • Month • Tide • Time of day • Type of day	• Location • Month • Time of day
Data elements	• Time patrolling or surveying reserve • Number of verified offences detected	• Time surveying reserve • Number of verified offences detected	• Number of verified offences detected	• Number of verified offences detected	• Number of verified offences detected
Toolbox link	Need to develop a toolbox				

Abbreviations: AIS, automatic identification system; CCTV, closed-circuit television; DOC, Department of Conservation Te Papa Atawhai; FNZ, Fisheries New Zealand; GIS, Geographic Information System; MPI, Ministry for Primary Industries; NMCC, National Maritime Coordination Centre.

7.5 Data management

Compliance data will be managed by the National Compliance Team and held in two repositories, as detailed below.

7.5.1 CLEWorks / Pūnaha Tūtohu

This national database was established in mid-2020 and holds records of all non-compliant activity in relation to conservation legislation administered by DOC (records of offences are from September 2020 onwards). It records non-compliant activity reported by all DOC staff and from other sources, such as public and external agency reports to DOC staff, DOC offices and through the 0800 DOC HOT emergency hotline. It also tracks all investigations and prosecutions, both active and complete, as well as outcomes, including no action, warning letters and infringements. Information is held for individuals and companies, and offences are individually listed by an offence code (e.g. 6733-2 = failed to comply with section 21(1)(d) of the Marine Reserves Act 1971). Other data elements collected include the date, time and location (latitude and longitude) of where the offence occurred.

Only warranted officers and DOC staff that require this information to perform their duties have access to this database. However, all DOC staff can report non-compliant activity via the app 'MyCLE – Pūnaha Tātari' which feeds into CLEWorks. The Programme Lead, Marine Reserves (Compliance) has responsibility for periodic reporting using data extracted from the system.

7.5.2 Advocacy and compliance app

This app is being developed by the Design and Evaluation team and provides a more flexible platform for collecting and collating data elements that cannot be captured by CLEWorks. It is primarily designed to be used by rangers in the field using a tablet, although it can also be used with a smartphone. Rangers will use the app to collect data on education and advocacy interactions, patrol and surveillance effort, and the nature of offending (e.g. the method of take and species targeted).

7.6 Data analysis

CLEWorks has graph and chart capabilities within its dashboard function, although these functions are constrained and may be of limited use for the purposes of the MMRF. Data can also be exported for further analysis as required. However, these data may be insufficient to determine compliance rates. Therefore, data extracted from the advocacy and compliance app will be collated with data from CLEWorks to determine compliance rates across marine reserves and to show trends over time.

Data will be visually presented using composite bar charts to show:

- Compliance effort (time on patrol and time surveying).
- Advocacy and education efforts (target audience identified and numbers of people in an advocacy interaction).
- Number of offences and prevented offences (number of compliance actions taken, including preventions, warning letters, infringement notices and prosecutions).

The data elements will be presented alongside spatial and temporal data.

The analytical approaches that can be used for each of the data elements shown in Table 7.2 are summarised in Tables 7.4–7.6.

Table 7.4. Summary of analytical approaches for data relating to the number of offences.

Data element: Number of offences					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• DOC patrols • CCTV • NMCC • MariWeb • GPS on commercial vessels • Marine Traffic: Global Ship Tracking Intelligence • 0800 DOC HOT emergency hotline • Interagency patrols	• Offences • Infringements • Warning letters • Prosecutions • Public interactions • Preventions	Calculate the number of offences and prevented offences by adding preventions, verified offences where follow-up is not possible, warning letters, infringement notices and prosecutions.	See the guidance provided in Table 2.3 for the analysis of discrete/proportion data. Include the following covariates in the analysis: • Type of offence • Number of people • Time of day • Location	For each survey method, plot a composite bar chart showing the number of offences in marine reserves for a given year or season.	Objective 5.1 – Spatial
			As above but include time of year as a covariate.	Plot a bar chart with error bars showing the number of offences by month. Different bars should be used for different methods, but these can be compared.	Objective 5.2 – Temporal

Abbreviations: CCTV, closed-circuit television; DOC, Department of Conservation Te Papa Atawhai; GPS, Global Positioning System; NMCC, National Maritime Coordination Centre.

Table 7.5. Summary of analytical approaches for data relating to the compliance rates.

Data element: Compliance rates					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• DOC patrols • CCTV • NMCC • MariWeb • GPS on commercial vessels • Marine Traffic: Global Ship Tracking Intelligence • 0800 DOC HOT emergency hotline • Interagency patrols	• Compliance effort (time spent looking for non-compliance) • Number of offences • Type of offence • Number of people • Time of day • Time of year • Tide • Location	Calculate the rate of compliance by dividing the effort by the number of offences.	See the guidance provided in Table 2.3 for the analysis of discrete/proportion data. Include the following covariates in the analysis: • Type of offence • Number of people • Time of day • Location	Plot a bar chart showing compliance rates by marine reserve for a given season or year.	Objective 5.1 – Spatial
			As above but include time of year as a covariate.	Plot a line/point plot with error bars to show compliance rates over months or years.	Objective 5.2 – Temporal

Abbreviations: CCTV, closed-circuit television; DOC, Department of Conservation Te Papa Atawhai; GPS, Global Positioning System; NMCC, National Maritime Coordination Centre.

Table 7.6. Summary of analytical approaches for data relating to the types of offence.

Data element: Types of offences					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• DOC patrols • CCTV • NMCC • MariWeb • GPS on commercial vessels • Marine Traffic: Global Ship Tracking Intelligence • 0800 DOC HOT emergency hotline • Interagency patrols	• Type of offence	Calculate the proportion of each type of offence.	See the guidance provided in Table 2.3 for the analysis of discrete/proportion data. Investigate how the type of offence varies with type of marine reserve (urban/rural) or time of year (summer/winter).	For each type of offence, plot a composite bar chart showing the types of offences in marine reserves for a given year or season.	Objective 5.1 – Spatial
			As above, looking at how the type of offence changes over time for a given marine reserve.	Plot bar charts with error bars showing the types of offences by month.	Objective 5.2 – Temporal

Abbreviations: CCTV, closed-circuit television; DOC, Department of Conservation Te Papa Atawhai; GPS, Global Positioning System; NMCC, National Maritime Coordination Centre.

7.7 Reporting and communicating

Prior to the development of the new enforcement system and database (CLEWorks / Pūnaha Tūtohu), DOC's data on offending was limited to prosecution statistics and there was no standardised system for collecting data on either advocacy or enforcement efforts. CLEWorks and the advocacy and compliance app will give visibility to compliance efforts and rates of offending and will allow robust reporting (see Table 7.7), which may help with the identification of problem areas and times to better target resources such as educational campaigns (including signage) or patrol effort. The good reporting of data may also help to identify strategies that facilitate high rates of compliance, which can then be applied elsewhere.

The specifics of the data analysis and reporting format need to be refined and formalised. However, the data collected should be presented in a formal report at least annually.

7.7.1 Marine reserve reports and report cards

The data elements monitored by Theme 5 can be included in marine reserve reports and report cards using the analytical products. The definitions for reporting on the status of the measures monitored under this theme are described in Table 7.8 (see Table 2.5 for definitions of trend). The various compliance statuses and their associated definition thresholds will be dependent on several location-specific factors – for example, the compliance effort (number of hours/patrols) and potential for offences will be very different in subantarctic island marine reserves compared with inner Auckland marine reserves due to accessibility and the population size.

7.7.2 Other reporting opportunities

DOC's Legal team produces an annual report for internal use and for Ministry of Justice purposes, which provides a temporal view of offences by type, DOC region and district.

Table 7.7. Information relating to Theme 5 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective **Indicator**	**Human use and interaction with natural heritage** **Illegal hunting and harvesting of indigenous resources**
Data element	Rate of compliance
Reporting	• The rates of compliance over time in a marine reserve • The rates of compliance between marine reserves
Data element	Number of offences
Reporting	• The number of offences over time in a marine reserve
Data element	Number of preventions
Reporting	• The number of preventions over time in a marine reserve
Data element	Number of hours/patrols
Reporting	• The number of hours or patrols over time in a marine reserve

Table 7.8. Definitions for reporting on the status of the measures for Theme 5 – Determine the rates of non-compliance.

Status	Definition
Excellent	Rate of compliance is high, with a high number of preventions and effort.
Good	Rate of compliance is high, with a moderate number of preventions and effort.
Fair	Rate of compliance is moderate, with a moderate number of preventions and effort.
Poor	Rate of compliance is low, with a low number of preventions and effort.
Undetermined	The status of this measure cannot be determined.

8 Theme 6 – Evaluate environmental water quality indicators

What	Changes in parameters that affect environmental water quality
Who	Partnerships between regional councils, tangata whenua and DOC
When	Discrete sampling several times per year and continuous sampling
Where	All marine reserves where possible or pre-existing sampling points nearby
How	Direct collection of samples and data from buoys and continuous sampling devices, and satellite-derived data
Why	To increase understanding of the effect of water quality on the integrity of marine ecosystems

8.1 Background and objectives

Water quality is influenced by pollution, reclamation, dredging, sand and gravel extraction, mining, sedimentation, eutrophication, aquaculture, changes in freshwater input, ocean acidification, and climate change (MacDiarmid et al. 2012). The quality of the water that surrounds and is ingested by organisms influences their wellbeing, resilience and functioning, including their reproduction, feeding and survival. Poor water quality can also lead to a change in habitat quality (e.g. substrate and plant health / primary production) and the slowing down or cessation of ecosystem productivity and function. Therefore, to fully understand and conserve the wellbeing, resilience and functioning of a marine ecosystem, it is essential that a range of water quality measures are obtained (Hewitt et al. 2014; see Box 8.1).

Coastal water quality monitoring generally includes the measurement of bacterial, physical, chemical and biological parameters in marine and estuarine waters (Hewitt et al. 2014). Understanding the natural temporal trends in measures of water quality will contribute to identifying possible causes for anomalies in marine community composition and ecosystem functioning.

Aotearoa New Zealand has committed under the CBD to protect a representative range of its marine habitats (Aichi Target 11)[47] and to bring pollution (including excess nutrients) to levels that are 'not detrimental to ecosystem function and biodiversity' (Aichi Target 8).[48] Maintaining the integrity of coastal water quality is also Objective 1 in the New Zealand Coastal Policy Statement 2010 (DOC 2010). Regular monitoring of water quality measurements that are linked to ecological integrity will contribute to achieving these targets and meeting national and international commitments, and the inclusion of MPAs in the water quality monitoring programmes also helps to achieve Aichi Target 8.

Some regional councils are currently undertaking bacterial, biological and physical measurements relating to water quality as part of the State of the Environment programme (Dudley et al. 2017). Historically, water quality measures relating to human health for recreation and shellfish gathering have been prioritised by regional councils (e.g. weekly monitoring of

47 www.cbd.int/aichi-targets/target/11
48 www.cbd.int/aichi-targets/target/8

Box 8.1: What is water quality?

Water quality describes the condition of the water relative to the requirements of one or more species and can be measured using chemical, physical, radiological or biological characteristics. Water quality measurements are essential for evaluating the health of a given ecosystem. Some water quality standards for a healthy ecosystem differ between species, so it is important to understand the different thresholds for different ecosystems.

the presence of enterococci at swimming beaches between November and March; MfE 2003), but water quality measures for human health and ecosystem health may differ. While this regional council monitoring has not been specifically designed for the collection of ecosystem health related data within MPA boundaries, synergies will be explored as part of the monitoring programme.

The National Environmental Monitoring Standards (NEMS) group has developed recommendations for sampling, measuring, processing and archiving discrete coastal water quality data (Milne 2020). The information in this section has been collated using the Australian and New Zealand Environment and Conservation Council (ANZECC) water quality guidelines[49] and the DOC toolbox for water quality.[50]

The purpose of this theme is to determine the most suitable water quality parameters to measure for monitoring ecosystem health inside marine reserves. Coastal water quality can vary highly in time and space and is subject to many influences (Milne 2020). This section will summarise NEMS recommendations, providing a consistent approach to water sample collection across Aotearoa New Zealand, including *in situ* measurements, laboratory analysis and data management, to build a solid long-term record of water quality in MPAs and better understand ecosystem health.

8.1.1 Objectives

Objective 6.1 (spatial): To record environmental water quality indicators in a way that allows differences between marine reserves to be detected.

Research question: How do environmental water quality indicators differ across marine reserves?

Objective 6.2 (temporal): To record environmental water quality indicators in a way that allows differences after 5 years to be detected.

Research question: Do environmental water quality indicators change over time?

8.2 Existing monitoring programmes

In Aotearoa New Zealand, coastal water quality monitoring is undertaken by regional councils to assess environmental statuses and trends and to evaluate the effectiveness of regional policies (Fig. 8.1). The data gathered are used in the State of the Environment reporting produced each year by regional councils and are periodically presented as a part of the Environment Aotearoa reporting by MfE and Stats NZ.

Diversity in the coastal geography and hydrology around Aotearoa New Zealand is reflected in regional differences in water quality. In 2017, MfE collated and analysed water quality data

49 www.waterquality.gov.au/anz-guidelines
50 www.doc.govt.nz/globalassets/documents/science-and-technical/inventory-monitoring/im-toolbox-marine/im-toolbox-marine-sampling-of-water-and-sediment-chemistry.pdf

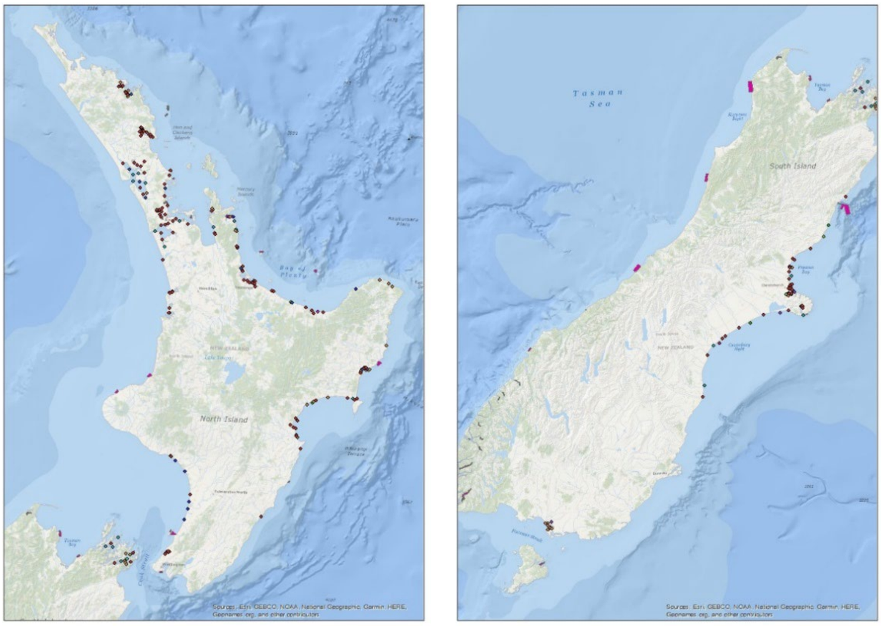

Figure 8.1. Locations of regional council water quality samples collected between 2013 and 2017 (filters applied by Dudley et al. (2017)). Marine reserves are shown as pink polygons. Data sources: www.stats.govt.nz/indicators/coastal-and-estuarine-water-quality and https://data.mfe.govt.nz/tables/category/environmental-reporting/marine/water-quality/.

that had been collected monthly or quarterly from >400 open coastal and estuarine sites by the 16 regional councils, resulting in 10- to 35-year data trends of physical, chemical and biological parameters (Dudley et al. 2017). However, the resulting report highlighted a number of inconsistencies in the regional environmental reporting requirements, such as the variables measured and the platform used to collect samples (i.e. boat, helicopter, wading), which hindered an analysis of all existing data (Dudley et al. 2017).

Current sampling sites and ongoing measurements in most regions lay the foundation for the expansion of environmental water quality monitoring into marine reserves as part of the MMRF (see Appendix 3). There are also currently approximately 15 buoys distributed around the country that collect continuous coastal water quality data (Table 8.1), some of which are close enough to existing marine reserves that their data would often be acceptable for monitoring purposes.

The buoys can also be used to 'sea truth' satellite imagery (in a similar way to ground truthing) to assist with providing both spatial and temporal data about Aotearoa New Zealand's estuarine and coastal waters. The data can then be used to extrapolate across the wider coastal environment where environmental information is deficient or absent.

Satellite data are used around the globe to measure water colour in coastal and oceanic zones and provide valuable information on both the optical water quality (e.g. water colour, light penetration and visual clarity) and the concentrations of suspended sediment, chromophoric dissolved organic matter (CDOM) and chlorophyll *a* – and therefore estimates of primary productivity.

Table 8.1. Continuous monitoring instruments and remote sensing monitoring measurements available in Aotearoa New Zealand by region.

Region	Buoy	Location	Measurements	Deployment date and links
Northland	WatchKeeper™ Met Ocean	Outer Bay of Islands	Wave (height, period, direction), wind (speed, direction, gust), dissolved oxygen, temperature, salinity, turbidity, chlorophyll *a* (surface)	Since 2019; request data from NRC
	2 x YSI EMM68 harbour buoys	Town Basin, Whangarei; Waitangi Estuary	Dissolved oxygen, temperature, salinity, turbidity, chlorophyll *a* (surface)	Since 2017; request data from NRC
	1 x fixed platform	Tikinui Wharf, Kaipara	Dissolved oxygen, temperature, salinity, turbidity, chlorophyll *a* (surface)	Since June 2019
Auckland	3 x Cawthron continuous WQ buoys	Linear array between Wairoa River mouth and Waiheke Island	Temperature, turbidity, specific conductance, dissolved oxygen (% saturation and ppm), salinity, fluorescent dissolved organic matter (relative fluorescence units and quinine sulphate units), chlorophyll *a*, blue-green algae	Since mid-March 2020; request data from ARC
	1 x Cawthron continuous WQ buoy	Mahurangi Harbour	Temperature, turbidity, specific conductance, dissolved oxygen (% saturation and ppm), salinity, fluorescent dissolved organic matter, chlorophyll *a*, blue-green algae, pH	Historic Nov 2017 – July 2019; now removed and re-deployed for the above; request data from ARC
Waikato	Wai Q Tahi	Firth of Thames	Conductivity/salinity, temperature, dissolved oxygen (at 1, 9 and 19 m depths), turbidity, chlorophyll *a*, air temperature, humidity, water level, wave (height, period, direction), wind (direction, gust, speed), current (speed, direction)	Since 2015 with interruptions; request data from WRC
	Wai QW Rua	Firth of Thames	Conductivity/salinity, temperature, dissolved oxygen, turbidity, chlorophyll *a* (at 1, 9 and 19 m depths), air temperature, humidity, water level, wave (height, period, direction), wind (direction, gust, speed), current (speed, direction)	Since 2015 with interruptions; first longer records from 2019; request data from WRC
Bay of Plenty	TRIAXYS™ Directional Wave Buoy	Pukehina Beach – 13 km off Pukehina Beach	Wave (height, period, direction), surface temperature	Deployed in 2003; http://monitoring.boprc.govt.nz/MonitoredSites/cgi-bin/hydwebserver.cgi/sites/details?site=241&treecatchment=23
	TRIAXYS™ Directional Wave Buoy	Bowentown – 7 km off Bowentown Heads	Wave (height, period, direction), surface temperature	Deployed in 2020; https://envdata.boprc.govt.nz/Data/Dashboard/102
Hawke's Bay	HAWQi	Hawke's Bay	Wave (height, period, direction), wind (speed, direction, gust), dissolved oxygen, temperature, salinity, turbidity, chlorophyll *a* (surface)	Deployed in 2012; https://data.hbrc.govt.nz/hydrotel/cgi-bin/hydwebserver.cgi/sites/details?site=2782&treecatchment=1844
Wellington	WRIBO; WatchKeeper Met Ocean	GWRC/NIWA (Wellington Harbour (Port Nicholson))	Wave (height, period, direction), current (speed, direction), wind speed, air temperature measured at the surface, water temperature, salinity, dissolved oxygen, chlorophyll a, pH, turbidity or backscatter at a range of depths through the water column	Deployed in 2017; http://graphs.gw.govt.nz/
	WRIBO-Kapiti; WatchKeeper Met Ocean	GWRC/NIWA/DOC at Kapiti Marine Reserve	Wave (height, period, direction), current (speed, direction), wind speed, air temperature (at the surface), water temperature, salinity, dissolved oxygen, chlorophyll *a*, pH, turbidity or backscatter (at a range of depths through the water column)	Deployed late 2020
	Datawell Directional Wave Buoy	Wellington Harbour (Port Nicholson) entrance	Wave (height, period, direction), surface temperature	Deployed in 1995; request data from GWRC
	TRIAXYS™ Directional Wave Buoy	Offshore south coast – Taputeranga Marine Reserve	Wave (height, period, direction), surface temperature	Deployed mid-2020
Tasman	TasCam	Tasman Bay	Temperature, salinity, turbidity, chlorophyll *a*, pH, dissolved oxygen, current, wave, wind, air temperature	Deployed around 2013; request data from Cawthron Institute; https://cawthron.org.nz/tascam/
		Golden Bay	Temperature, salinity, turbidity, current, wave, wind, air temperature	Deployed in 2007; https://niwa.co.nz/news/big-buoy-bay

Abbreviations: ARC, Auckland Regional Council; DOC, Department of Conservation Te Papa Atawhai; GWRC, Greater Wellington Regional Council; NIWA, National Institute of Water and Atmospheric Research; NRC, Northland Regional Council; WRC, Waikato Regional Council; WREBO, Wellington Region Integrated Buoy Observations.

8.3 Sampling design

8.3.1 Selecting indicators

This theme provides guidance on how to undertake monitoring that is relevant to selected measures contained within Objective 12 'Natural resources are managed sustainably' from the ANZBS (DOC 2020c; Table 8.2).

Table 8.2. Indicators, measures and data elements relating to Theme 6 – Evaluate environmental water quality indicators. Adapted from McGlone et al. (2020).

Indicator 6.1: Water quality and quantity	
Measure 6.1.1: Water physicochemical factors	
Description	Coastal and estuarine ecosystems are affected by changes in the levels of nutrients, oxygen and light. Nutrients (chemical elements and compounds that are essential for plant growth) become contaminants when they result in the degradation of natural ecosystems and the proliferation of unwanted species. Nitrogen and phosphorus are essential elements and key threats to ecological integrity, as an excess of these nutrients entering coastal waters via run-off from rural land and wastewater/stormwater infrastructure can be toxic and lead to algal blooms. Conversely, marine primary productivity depends on certain levels of nutrients and sunlight, with too little of these inhibiting plant and algal growth. Reduced oxygen caused be decaying organic material or massive pollution events has a severely negative impact on all organisms. Poor water clarity caused by suspended sediment and organic material also affects species' distributions and behaviours by limiting the available light that reaches photosynthetic structures (in the water column and on the seabed) and affecting the foraging success of visual predators.
Data elements	**Dissolved oxygen** The oxygen that is dissolved in water. Oxygen dissolves from the air–water interface and is produced through photosynthesis by phytoplankton, seagrass and macroalgae. It is usually measured as oxygen concentration (mg/L) and dissolved oxygen saturation (%). **Specific conductivity** Provides an indication of the concentration of total dissolved solids and electrolyte ions in the water. A higher conductivity will result from the presence of various ions, including nitrate, phosphate and sodium. **Salinity** The salt content of the ocean. **Visual clarity** The clarity of the water column affects species distributions and fish behaviours and condition by limiting the available light that reaches photosynthetic structures and affecting the foraging success of visual predators. Water clarity can be affected by physical properties, such as suspended sediment, and chemical properties, such as tannin staining. **Turbidity** The concentration of particulates in the water. High turbidity can be caused by heavy rainfall, disturbance of the river bed or bank by heavy machinery, or direct discharges. Turbidity is usually measured in nephelometric turbidity units (NTUs), which measure light scatter. **Suspended sediments** Living (e.g. plankton) and non-living (e.g. sand, silt, clay) organic material within the water column. This could be measured as the suspended sediment concentration (SSC) or total suspended solids (TSS) – SSC is preferable as it accounts for larger grain sizes such as sand, which is useful if monitoring near river mouths or at depth. **Absorbance** The light absorbed by a water sample is proportional to the amount of organic carbon, nitrates and other matter in the sample. Measurement of the amount of ultraviolet and visible light absorbed with a spectrophotometer can provide information about the presence of contaminants, carbon, nitrates and other elements. **Nitrogen and phosphorus** Includes nitrate nitrogen, nitrite nitrogen, nitrate-nitrite nitrogen, ammoniacal nitrogen, total nitrogen, particulate/dissolved organic nitrogen, total phosphorus and dissolved reactive phosphorus. Nutrient supply is a controlling factor in the proliferation of aquatic macrophytes and algae in association with eutrophication. Nitrogen is generally considered the primary limiting nutrient for phytoplankton biomass accumulation in estuarine to coastal environments, and there are positive relationships among nitrogen and phosphorus flux, phytoplankton primary production, and fisheries yield.

Continued on next page

Table 8.2 continued

Data elements	**Carbon** Includes dissolved organic carbon, particulate carbon and total organic carbon. Carbon levels give an indication of the amount of carbon consumed in photosynthesis and released from remineralisation. DOC is an important component of water quality, as it regulates water acidity and biological activity and is the main source of carbon for aquatic plant assimilation.
Links to other measures	3.2.1: Ocean regime and temperature (Theme 3 – Climate change) 4.2.1: Marine biological function (Theme 4 – Key species) 6.2.1: Ecosystem primary productivity (Theme 6 – Water quality) 6.3.1: Sedimentation and sediment quality (Theme 6 – Water quality)
Indicator 6.2: Ecosystem function	
Measure 6.2.1: Ecosystem primary productivity	
Description	Ecosystem primary productivity is a fundamental data layer for a range of applications. Net primary production (NPP) in the ocean is the rate of photosynthesis, not including phytoplankton respiration (Halsey et al. 2010) – i.e. it is essentially the amount of carbon available for the food chain (Pinkerton 2016). However, it is not possible to measure phytoplankton physiology remotely. Chlorophyll *a* concentration is a good estimator of primary productivity because it accounts for 70% of the NPP and can be measured remotely (Huot et al. 2007; Pinkerton 2016).
Data elements	**Chlorophyll *a*** Chlorophyll *a* is used as an estimation of biomass. Site-specific measures and ecosystem descriptions need to be associated with this measure to identify sensitivities and unusual levels.
Links to other measures	4.2.1: Marine biological function (Theme 4 – Key species)

Future updates will expand this to include measures relating to sedimentation and sediment quality (Table 8.3).

Table 8.3. Indicators, measures and data elements that are to be implemented in future iterations of the Marine Monitoring and Reporting Framework.

Indicator 6.3: Substrate quality	
Measure 6.3.1: Sedimentation and sediment quality	
Description	Sedimentation threatens marine and freshwater environments through both anthropogenic and natural mechanisms, and the rate and cumulative effects of sedimentation are important. Benthic marine species are particularly vulnerable to sedimentation on the seabed through smothering of their photosynthetic structures, clogging of their respiratory structures, or interference with their ability to settle, forage, defend themselves from predators or interact with conspecifics. In Aotearoa New Zealand, sediment has been identified as one of the top three types of pollutants of concern in freshwater environments and is arguably the most important land-based stressor in the country's marine environment (Schallenberg et al. 2011; Parliamentary Commissioner for the Environment 2013). Furthermore, sedimentation associated with upstream land use is the highest ranked threat for several coastal habitats in Aotearoa New Zealand, including kelp forest and subtidal mud flats (Thrush et al. 2011), and the threat of increased sediment loading is ranked third equal with bottom trawling across all of the country's coastal and marine habitats, with only ocean acidification and increased sea temperature associated with climate change ranking higher.
Data elements	**Specific conductivity** The ability of water to pass an electrical current; measured in Siemens/cm. **Visual clarity** The clarity of the water column; measured using a Secchi disc. **Turbidity** The 'murkiness' caused by suspended sediments scattering light; measured in nephelometric turbidity units (NTUs). **Suspended sediments** The total quantity of solid material in a given volume of water. **Absorbance** The amount of ultraviolet and/or visible light absorbed by a given sample.
Links to other measures	4.2.1: Marine biological function (Theme 4 – Key species) 9.1.2: Riverine and coastal alteration (Theme 9 – Extreme events) 9.1.3: Anthropogenic landform and substrate disturbance (Theme 9 – Extreme events) 10.1.2: Non-nutrient contaminants (Theme 10 – Pollution)

8.3.2 Selecting monitoring programmes

Water quality monitoring programmes in Aotearoa New Zealand are led by regional councils in collaboration with MfE, the Ministry of Health and other government bodies, depending on the purpose of the monitoring. To achieve the objectives of this theme, DOC will work with regional councils to extend their water quality sampling locations to marine reserves and to expand their sampling regimes to include additional physicochemical and nutrient measures (Table 8.4).

Regional councils follow Part 4 of the NEMS guidance for water quality sampling (Milne 2020). This guidance provides details on how to manage over 30 water quality variables related to nutrient, physicochemical and bacterial properties. Additional guidance can be obtained from the Australia New Zealand Guidelines (ANZG), which explain how to measure and analyse variables and describe how to develop guidance values to enable the assessment of significant changes in these variables.

8.3.3 Developing a sampling design

The selection of data elements for this theme is driven by the contribution they make to determining ecological integrity, water quality guidance recommendations and pre-existing data or sampling sites. Consistency in the sampling location and programme continuity are key elements to succeed in this monitoring programme. Additional data elements that can be measured for this theme can be found in Appendix 3.

How are the characteristics to be selected?

PHYSICOCHEMICAL AND OPTICAL

Unusual physicochemical or optical values (i.e. too high or too low) can indicate an imbalance in the equilibrium of the ecosystem (Milne 2020). Unfortunately, guidance values have only been developed for a few of these parameters in marine ecosystems (i.e. pH and salinity), but changes in trends may indicate a risk for the ecosystem, and will require further research and investigation.

NUTRIENTS

Primary production in the marine environment depends on the presence of nutrients among other parameters, but nitrogen and phosphorus can be limited in temperate waters during spring and summer (Hanisak 1993). These elements can appear in different forms, and measures of water quality will include different variables, such as nitrate and nitrite nitrogen, ammoniacal nitrogen, and dissolved reactive phosphorus. The chlorophyll *a* level is related to the level of photosynthesis and a key element for measuring primary productivity.

Table 8.4. Water quality measurements made by regional councils around Aotearoa New Zealand.

Variable/ product	Nomenclature	Unit	Sensor accuracy	Resolution / detection limit	Test method(s)	Previously monitored (regional councils)	References	Stressor/ rationale
Physicochemical and optical properties								
Temperature	Temp	°C	± 0.3°C	0.1°C		AC, BOPRC, CRC, ICC, WRC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Dudley et al. 2017*	Climate change / ecological integrity (global change)
pH	pH (field)	pH units at 25°C	± 0.2 pH units	0.01	APHA 4500-H+ B	AC, BOPRC, CRC, ICC, WRC, GDC, HBRC, HRC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Ecological integrity (local and global change)
Salinity	Sal (field)	ppt		0.2	APHA 2520 B	AC, BOPRC, CRC, ICC, WRC, GDC, GWRC, MDC, NRC	• NEMS • Toolbox	Freshwater inputs; stratification
Dissolved oxygen	DO % SAT (field)	%	± 3% between 0 and 200%	0.10%		AC, BOPRC, CRC, WRC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Pollution / ecological integrity
	DO (concent)	mg/L	± 0.3 mg/L between 0 and 20 mg/L	0.01–0.1 mg/L		AC, BOPRC, CRC, ICC, WRC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	
Specific conductivity	SpC (field)	mS/m at 25°C		5	APHA 2510 B	AC, BOPRC, ICC, WRC, GDC, GWRC, HBRC, HRC, MDC	• NEMS	
Visual clarity	VC – SD (Secchi disc)	m		1%		AC, BOPRC, WRC, HBRC, HRC, MDC, NRC	• NEMS • Dudley et al. 2017*	Sedimentation / ecological integrity; recreation
	VC – BD (horizontal black disc)	m		1%			• NEMS • Dudley et al. 2017*	
Turbidity	Turb (field)	FNU	± 0.3 from 0 to 999 FNU and 5% for 1000 to 4000 FNU	0.1	ISO 7027 – near infrared light at 90°	AC, BOPRC, CRC, WRC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Sedimentation / ecological integrity; recreation
Total suspended solids	TSS	mg/L		1	APHA 2540 D	AC, BOPRC, CRC, WRC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Sedimentation / ecological integrity; recreation
Absorbance (at 340, 440 and 780 nm)	Absorb	m^{-1}		0.002	APHA 5910 B		• NEMS • Toolbox	Organic material; sedimentation
Nutrients								

Continued on next page

Table 8.4 continued

Variable/ product	Nomenclature	Unit	Sensor accuracy	Resolution / detection limit	Test method(s)	Previously monitored (regional councils)	References	Stressor/ rationale
Chlorophyll *a*	CHLA (lab) CHLA (field)	mg/L RFU	± 0.1 from 0 to 100 RFU	0.0001	APHA 10200 H	AC, BOPRC, CRC, ICC, WRC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Photosynthetic biomass; primary productivity
Nitrate nitrogen	NO_3-N	mg/L		0.002	APHA 4500-NO3 I	AC, CRC, ICC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Common contaminant in waterways in rural and urban areas
Nitrite nitrogen	NO_2-N	mg/L		0.002	APHA 4500-NO3 I	AC, GDC, GWRC, HBRC, HRC, NRC	• NEMS • Dudley et al. 2017*	
Nitrite-nitrate nitrogen	NNN (calculation)	mg/L		0.002	APHA 4500-NO3 I	AC, BOPRC, CRC, WRC, GDC, GWRC, HBRC, NRC	• NEMS	
Ammoniacal nitrogen	NH_4-N	mg/L		0.005	APHA 4500-NH3 H	AC, BOPRC, CRC, ICC, WRC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Toxic to aquatic life at high concentrations
Total nitrogen	TN-A	g/m^3 (= mg/L)		0.01	APHA 4500-N C persulphate digestion, then analysis by APHA 4500-NO3 I	AC, BOPRC, CRC, WRC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Eutrophication
Particulate nitrogen / dissolved organic nitrogen	PN DON	g/m^3 (= mg/L)				MDC	• Toolbox	Algal growth / eutrophication
Dissolved reactive phosphorus	DRP	mg/L		0.001	APHA 4500-P G	AC, BOPRC, CRC, ICC, WRC, GDC, GWRC, HBRC, HRC, MDC, NRC	• NEMS • Toolbox • Dudley et al. 2017*	Algal blooms
Total phosphorus	TP	mg/L		0.002	APHA 4500-P B 5 or J persulphate digestion, then analysis by APHA 4500-P E or H	AC, BOPRC, CRC, WRC, GDC, GWRC, HBRC, HRC, NRC	• NEMS • Dudley et al. 2017*	
Dissolved organic carbon / particulate carbon	DOC PC	mg/L		0.2	APHA 5310-C B	CRC, MDC	• NEMS • Toolbox	

Regional council abbreviations: AC, Auckland Council; BOPRC, Bay of Plenty Regional Council; CRC, Canterbury Regional Council; GDC, Gisborne District Council; GWRC, Greater Wellington Regional Council; HBRC, Hawke's Bay Regional Council; HRC, Horizons Regional Council; ICC, Invercargill City Council; MDC, Marlborough District Council; NRC, Northland Regional Council; WRC, Waikato Regional Council.

Other abbreviations: FNU, formazin nephelometric units; NEMS, National Environmental Monitoring Standards; RFU, relative fluorescent units.

* See supporting recommendations table 6-3 in Dudley et al. (2017).

How are sites to be selected?

Both the sampling design and site selection will aim to maximise synergies with existing monitoring programmes, and the creation of a network of water quality sample points in the marine reserves around Aotearoa New Zealand will follow the principles of representativeness and consistency (see below). Current water quality monitoring by regional councils is summarised in Appendix 3, so this can be used to identify gaps in the network.

REPRESENTATIVENESS

Aotearoa New Zealand lacks a national coastal/marine water quality monitoring strategy, and data collected by regional councils are not representative at a national scale (Dudley et al. 2017). State of the Environment reports and the Land Air Water Aotearoa (LAWA) website[51] provide coastal water quality information but are not sufficient to describe marine reserve ecological integrity. Acknowledging the initial inability to monitor all parameters in all marine reserves, this theme aims to fulfil representativeness by bioregion, with as many data elements as possible being represented in each bioregion.

The sampling design process should assess needs, objectives and management activities within each marine reserve and wider area, giving special attention to potential water quality pressures (pollution, sedimentation, etc.). Adding data elements to the monitoring should be considered on a case-by-case basis. The number and location of sampling sites in each marine reserve will be decided in the individual marine reserve monitoring plans, in consultation with regional councils and tangata whenua. Existing datasets can help to estimate the minimum numbers of sites required (Larned & Unwin 2012).

CONSISTENCY

Regional council water quality sampling sites are generally outside marine reserve boundaries. However, some of these measurements can be assumed to be representative of marine reserve data where they are a distance of 2 km in a straight line from the marine reserve boundary. NEMS procedures (and DOC toolboxes where relevant) should be followed to ensure consistency.

How often should measurements be taken at these sites or a subset of these sites?

The recommended frequency for discrete water sample collection is determined by the defined monitoring objective (Milne 2020). Larned et al. (2015) stated that trend analysis is only meaningful for a specified time period over which the dataset being analysed has few missing values. Larned et al. (2015) and Dudley et al. (2017) undertook trend analyses using regional council datasets with variable sampling frequencies (monthly or quarterly) and variable numbers of missing values. Based on these studies and knowledge of monitoring capabilities, the recommended frequency of sampling is **monthly**, but **quarterly** measurements are acceptable where the cost/benefit balance supports this.

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51 www.lawa.org.nz/

8.4 Monitoring protocols

The guidance for monitoring protocols given in this section is intended to provide an overview only. Preparation for monitoring must include the development of a robust survey design, including prior consultation with water quality experts and statisticians, to ensure the design is suitable for meeting the monitoring objectives. This will be undertaken in collaboration with regional councils.

This theme follows the discrete water quality recommendations of Milne (2020). Both NEMS (Milne 2020) and the DOC toolbox (Laferriere 2016) describe coastal water quality sampling procedures and standards to ensure that maximum quality standards are achieved. Table 8.5, in combination with Table 8.4, aims to provide guidance on these sampling processes in the MMRF context. These best practices cover bottle and filling requirements in the field and laboratory test method details for coastal water quality variables.

Continuous monitoring instruments are increasingly being used by regional councils to characterise the temporal variability of water quality. Such instruments are usually suspended beneath a moored surface buoy and can be telemetered to provide near real-time information. Discrete water quality sampling is typically required to calibrate the instruments or to convert the instrument trace into a meaningful measure of some water quality parameter, such as converting turbidity into suspended sediment concentration.

Table 8.5. Field equipment deployment (National Environmental Monitoring Standards (NEMS)).

Meter sensors	The meter sensors shall be deployed in open water at a depth of at least 0.3 m and time will be allowed for stabilisation in accordance with the manufacturer's specifications.
Secchi disc **Black disc**	The viewer and disc shall be deployed so that the path of sight is uniformly lit and bed disturbance is absent prior to measurement. A viewer shall be used to obtain measurements.
Dissolved oxygen	If electrochemical sensors are used, a mechanical stirrer or flow cell shall also be used to ensure that the velocity of water past the sensor exceeds 0.3 m/s.
Profile measurements	The depth below the water's surface (± 0.02 m) shall be recorded with all profile measurements.
Bottle type and filling requirements	The correct laboratory sample bottles shall be used for the variable(s) being measured, with filling requirements met as follows (and as outlined in table 5, section 5.4.3 of NEMS (Milne 2020)): **Specific conductivity, pH, turbidity, absorbance, nutrients and dissolved metals**: Unpreserved bottle completely filled with no air gap. **Total suspended solids:** Unpreserved bottle filled to the top. **Dissolved organic carbon:** Unpreserved and furnaced brown glass bottle completely filled with no air gap. **Total metals:** Nitric or hydrochloric acid-preserved bottle, filled to the shoulder and sample inverted to mix.
Sample collection	**Surface samples** shall be collected from approximately 0.3 m below the water's surface. **Fixed-depth samples** shall be collected using a Van Dorn or Nisken type water sampling device. **Depth-integrated samples** shall be collected using a weighted sample tube or a throttled weighted bottle. The depth below the water's surface (± 0.02 m) shall be recorded for any profile samples.
Sample handling	Samples shall be promptly removed from the light and transferred to chilled storage bins to rapidly reduce the sample temperature to below 10°C. Microbial samples shall not be subject to freezing at any time, even in part.
Sample filtration	Samples collected for chlorophyll *a*, absorbance, or dissolved organic carbon, nutrient or metal measurements shall be dispatched to the laboratory for filtering.
Sample traceability and integrity	Samples shall be unequivocally identifiable and accompanied by a completed Chain of Custody form that provides sample traceability from the field to the laboratory.

8.5 Data management

DOC does not currently have the infrastructure to collate and store water quality data, so all data collected will be stored with regional councils using their data management procedures (Table 8.6). The NEMS protocol makes specific recommendations for managing laboratory analysis data and for storing field data (see section 2.5.5), and these recommendations are generally followed by regional councils. In particular, it is recommended that site metadata (information about the sampling site), visit metadata (observations about each sampling visit) and water quality data should all be stored in a database, as should raw data from field forms or electronic records. It is also recommended that samples are quality coded to allow comparisons to be made between data series. These quality codes can be found in Fig. 8.2.

Errors in field measurements, sample collection, pre-treatment, transport or storage can affect water quality data. Therefore, it is important that the specific quality assurance (QA) and quality control (QC) recommendations outlined in sections 1.3 and 6 of NEMS (Milne 2020) are followed.

Table 8.6. Data management for laboratory measurements.

Certification	The laboratory shall hold current International Accreditation New Zealand (IANZ) accreditation for the test method being used to measure each water quality variable.
Sample arrival at the laboratory	
Documentation	Laboratory staff shall record confirmation of the date and time of receipt of samples on the accompanying Chain of Custody form, together with: • The sample temperature on arrival (°C). • Any anomalies in sample condition that could affect the laboratory measurement (e.g. a damaged or incorrectly filled sample bottle).
Temperature	Unpreserved and microbial samples shall be less than 10°C (or at a temperature less than the sample collection temperature where samples are delivered within 2 h of collection), unfrozen and free of ice crystals.
Processing and testing timeframes	All microbial, pH and turbidity testing shall commence within 36 h of sample collection.
	Laboratory filtration for unpreserved samples for chlorophyll *a*, phaeophytin, absorbance, dissolved organic carbon or dissolved nutrient testing shall be completed within 36 h of sample collection.
Measurement resolution	All laboratory measurements shall be reported to one, two or three significant figures, as dictated by the uncertainty of measurement for the test method.
Data records	The laboratory measurements shall be provided in a report that specifies the: • Date and time of sample collection and receipt at the laboratory. • Type of measurement made (e.g. dissolved vs. total). • Measurement value and units. • Uncertainty of the measurement (95% confidence level). • Measurement method and standard method detection limit, including details of any modifications made to these (e.g. from diluting samples). • Any anomalies with the condition of the sample upon receipt (e.g. temperature on arrival, bottle type and/or filling) or the subsequent measurement value, including unexpected differences between dissolved and total nutrient concentrations.
Quality coding	All data shall be quality coded as per the quality control code flowchart (Fig. 8.2).
Data storage	The following information shall be filed, archived indefinitely and backed up regularly in a time-series database: • Site and field visit metadata. • Field meter validation results and calibration details. • Field measurements together with the meter/sensor make and model. • Censored and uncensored laboratory values and the associated uncertainty of measurement values. • The date, time and condition of samples received at the laboratory. • Any sample or measurement anomalies, including quality checks performed on these.

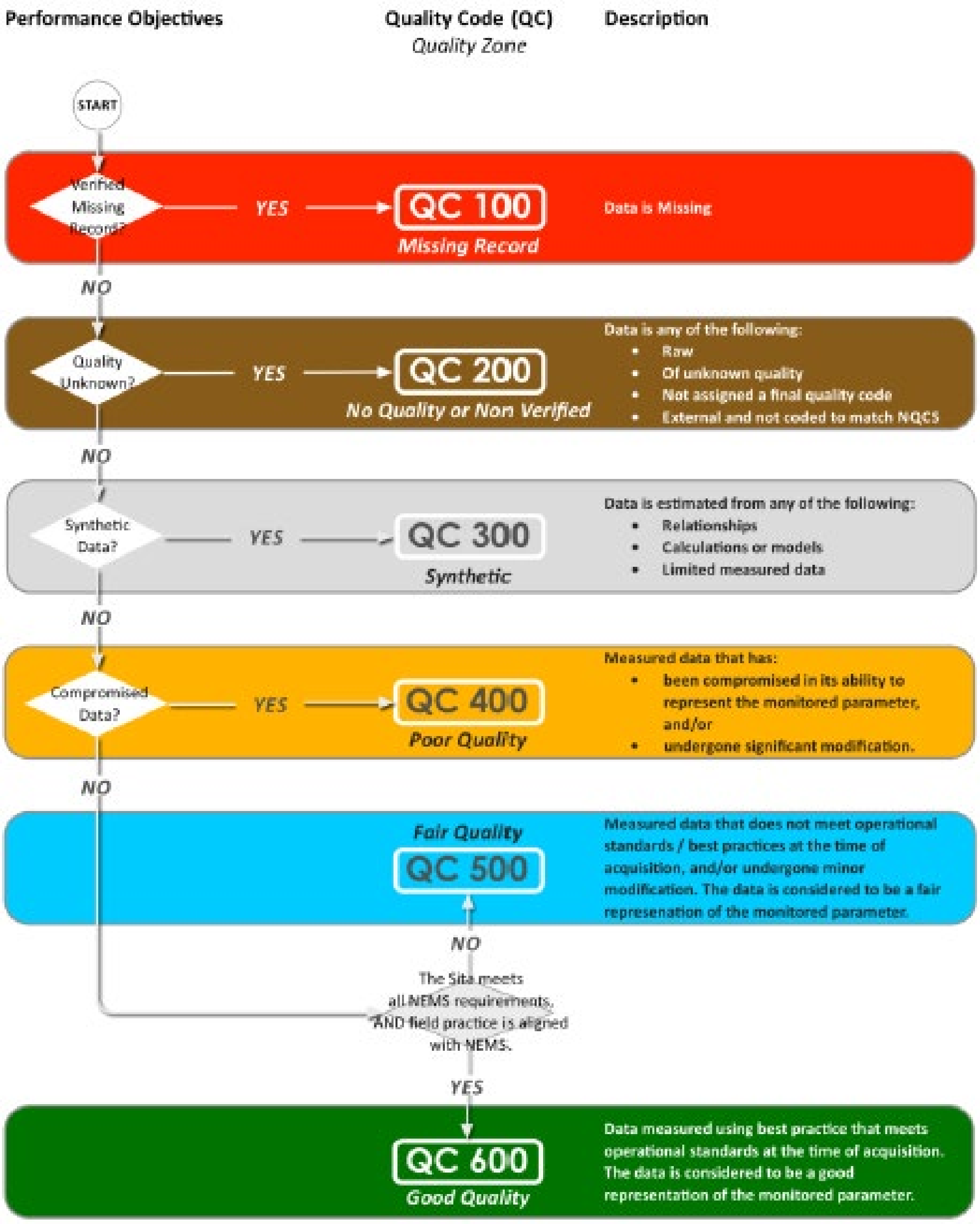

Figure 8.2. Quality control code flow chart. Source: National Environmental Monitoring Standards (NEMS) National Quality Control Schema (www.nems.org.nz/documents/quality-code-schema/). Reproduced under a Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by/4.0/).

8.6 Data analysis

Tables 8.7 to 8.11 provide a general overview of how water quality data may be analysed and must be read alongside Tables 8.2 and 8.4. The approach for analysing specific variables will be decided in the marine reserve monitoring plans, with the guidance of a statistician.

Table 8.7. Summary of analytical approaches for data relating to the physicochemical data elements dissolved oxygen, dissolved reactive phosphorus and particulate carbon.

<table>
<tr><th colspan="6">Data elements: Dissolved oxygen (DO), dissolved reactive phosphorus (DRP), particulate carbon (PC)</th></tr>
<tr><th>Methods</th><th>Required data</th><th>Data preparation</th><th>Analysis</th><th>Visualisation</th><th></th></tr>
<tr>
<td rowspan="2">• Buoy
• Satellite
• Sensors (discrete)
• Secchi disc
• Bottle sampling</td>
<td rowspan="2">• Oxygen concentration (mg/L)
• Dissolved oxygen saturation (%)
• Dissolved reactive phosphorus (µmol/L; g/m^3 = mg/L; or parts per billion (ppb), where 1 ppb = 0.001 g/m^3)
• Particulate carbon</td>
<td rowspan="2">If data are collected from buoys or a satellite they may need to be adjusted based on additional environmental parameters, such as temperature, barometric pressure and salinity. The following edits may also be needed:
• Changes in the baseline due to sensor drift and/or ramping (where the baseline drifts steadily up or down).
• Smoothing of noisy data.
If data are collected from a bottle sample, the results should be expressed as percentage saturation using the following equation:
DO (% sat)
$= \frac{DO_m}{DO_{100\%}} \times 100$
where sat = saturation, DO_m is the measured DO (mg/L) and $DO_{100\%}$ is DO at 100% saturation (mg/L). Other corrections that may be required can be found in table 7 of the NEMS (2000) protocol.</td>
<td>Compare with historical data for that site, other sites within the study, samples at increasing distances from a point source pollution site (e.g. sewage outfall), Australian and New Zealand Environment and Conservation Council (ANZECC) thresholds, chemical property specific thresholds and/or risk indicators.</td>
<td>Use box plots to compare DO values across sites (e.g. see Fig. 8.3). DO can be presented over depth gradients or as distance from a point source that might influence its values.</td>
<td>Objective 6.1 – Spatial</td>
</tr>
<tr>
<td>As above but with a time variable added (year, month, season).
It is important that seasonality is accounted for in any time series analysis.</td>
<td>Use line/dot charts to compare DO (%sat) over time and look for any changes in concentration (e.g. see Fig. 8.4). It is important that the seasonality is also plotted.</td>
<td>Objective 6.2 –Temporal</td>
</tr>
</table>

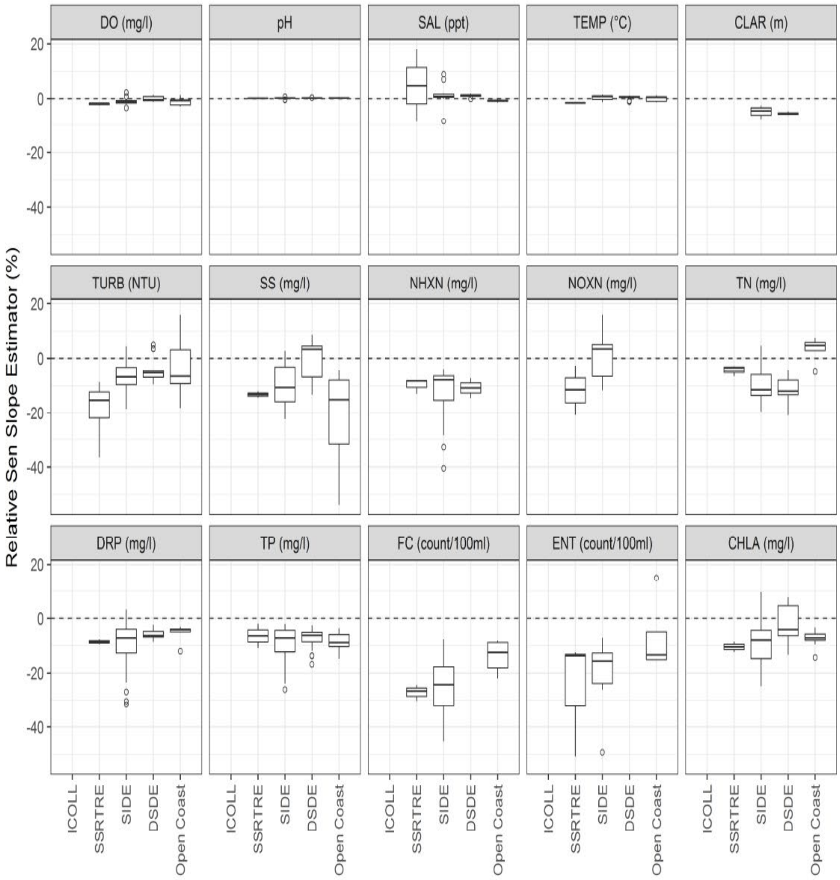

Figure 8.3. Box-and-whisker plots showing the distributions of 8-year site trends within Estuary Trophic Index classes. The line within each box indicates the median of the site trends, the box indicates the interquartile range and the whiskers extend from the box to the largest value within 1.5 x the interquartile range. Outliers (any data beyond the whiskers) are indicated by open circles. Source: Dudley et al. 2017. Abbreviations: CHLA, chlorophyll *a*; CLAR, clarity; DO, dissolved oxygen; DRP, dissolved reactive phosphorus; ENT, enterococci; FC, faecal coliform bacteria; NHXN, ammonia/ammonium; NOXN, nitrate-nitrite nitrogen; SAL, salinity; SS, suspended solids; TEMP, temperature; TN, total nitrogen; TP, total phosphorus; TURB, turbidity.

Table 8.8. Summary of analytical approaches for data relating to the physicochemical data element salinity.

Data element: Salinity					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Buoy • Satellite • Sensors (discrete) • Secchi disc • Bottle sampling	• Practical salinity unit (PSU). This unit is based on the properties of seawater conductivity and is equivalent to per thousand or g/kg of water.	Estimates of salinity require in-depth preparation (see Zweng et al. (2013) for guidance).	The analysis of salinity data is beyond the scope of this report. See Zweng et al. (2013) for guidance on the analysis of continuous data.	Use box plots to compare values from different sites (e.g. see Fig. 8.3). Values can also be displayed as a heat map (e.g. see Fig. 8.5).	Objective 6.1 – Spatial
				Use line/dot charts to compare values across time (e.g. see Fig. 8.4).	Objective 6.2 – Temporal

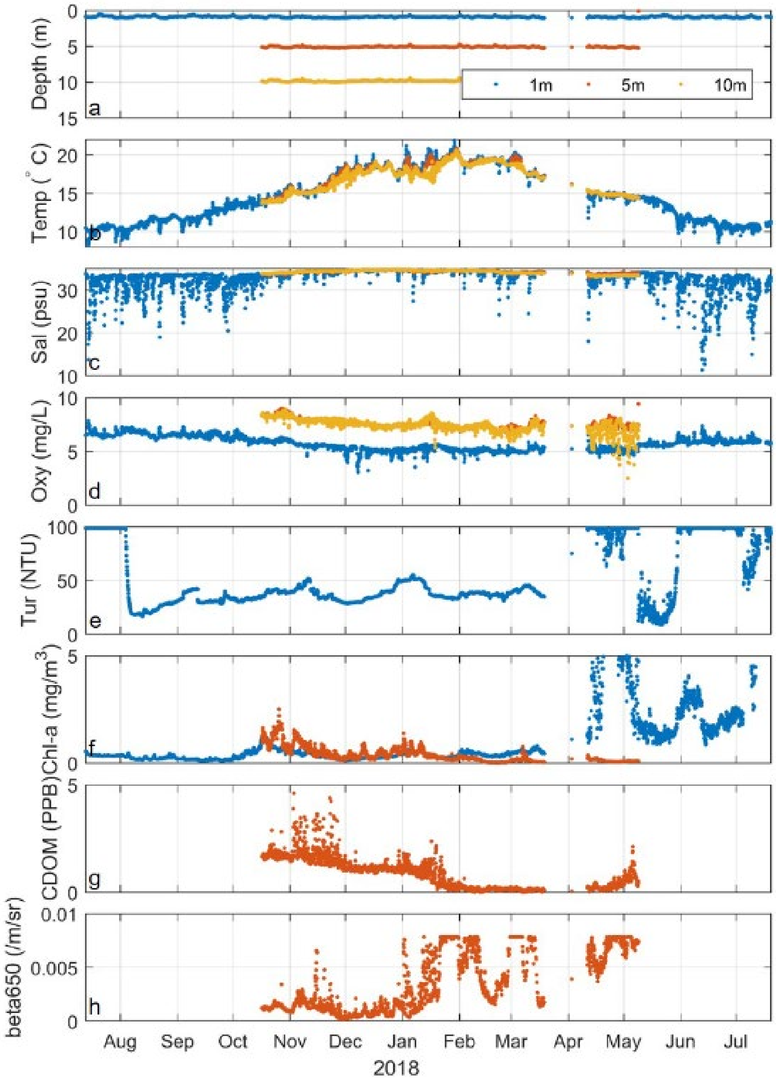

Figure 8.4. Time series of various parameters obtained from instruments on Wellington Region Integrated Buoy Observations (WRIBO): (a) instrument depth, (b) temperature, (c) salinity, (d) dissolved oxygen concentration, (e) turbidity, (f) chlorophyll *a*, (g) chromophoric dissolved organic matter (CDOM) and (h) backscatter. Source: O'Callaghan et al. 2019. Kindly reproduced with permission of the authors.

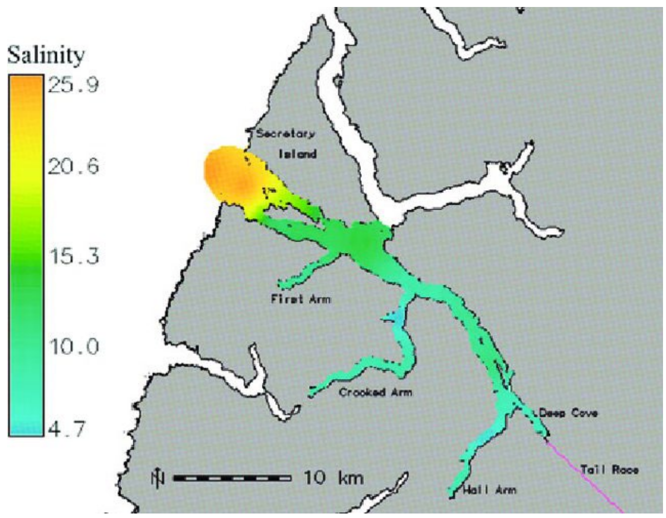

Figure 8.5. Interpolated surface salinity in Doubtful Sound, Aotearoa New Zealand, in May 2005.
Source: Gonsior et al. (2008).

Table 8.9. Summary of analytical approaches for data relating to the optical data elements turbidity, suspended sediments, visual clarity and absorbance.

Data elements: Turbidity, suspended sediments, visual clarity, absorbance					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Buoy • Satellite • Sensors (discrete) • Secchi disc • Bottle sampling	• NTUs – a measurement of light scatter • Concentration of particles in the water column measured in ppm, mg/L, g/L or % • Dry weight of particles trapped by a filter	This will be specific to each method. Water turbidity varies in natural marine ecosystems, so guidelines and recommendations are extremely difficult to provide.	Identify anomalies between sites. The standard level for optical data elements should be site specific.	Use box plots to compare values from different sites (e.g. see Fig. 8.6).	Objective 6.1 – Spatial
			Identify anomalies from historic data.	Use line charts, with points and their associated error bars representing the different optical data elements.	Objective 6.2 – Temporal

Abbreviations: NTU, nephelometric turbidity unit.

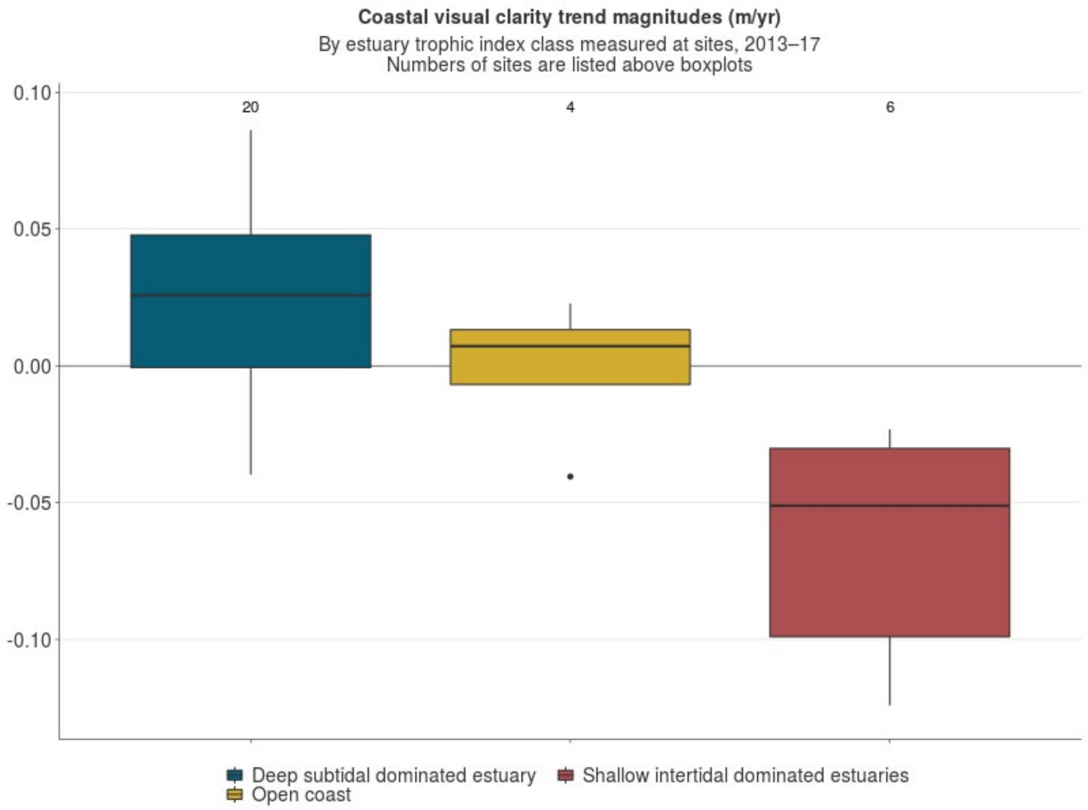

Figure 8.6. Trend magnitude for visual clarity by Estuary Trophic Index class.

Table 8.10. Summary of analytical approaches for data relating to the nutrient data element nitrate nitrogen.

Data element: nitrate nitrogen (NNN, NO_2-N, NO_3-N)					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Sensors (discrete) • Buoy	• Oxidised nitrogen (NOXN) – NO_2-N and NO_3-N. Nitrite is an intermediate product of organic nitrogen oxidation; NH_4-N is toxic in high concentrations in water; measurements of total nitrogen and dissolved organic nitrogen in the water show the use of nitrogen in photosynthesis.	Calculate the mean concentration and corresponding statistical variance. Concentrations from each replicate sample for a site are summed and an average is calculated for that site.	Compare with historical data for that site, other sites within the study, samples at increasing distances from a point source pollution site (e.g. sewage outfall), ANZECC thresholds, chemical property specific thresholds and/or risk indicators.	Use box plots to compare values from different sites (e.g. see Fig. 8.7).	Objective 6.1 – Spatial
			As above, with an emphasis on changes over time.	Use line charts, with points and their associated error bars representing the different nutrient data elements.	Objective 6.2 – Temporal

Abbreviations: ANZECC, Australian and New Zealand Environment and Conservation Council; NH_4-N, ammoniacal nitrogen; NNN, nitrite-nitrate nitrogen; NO_2-N, nitrite nitrogen; NO_3-N, nitrate nitrogen.

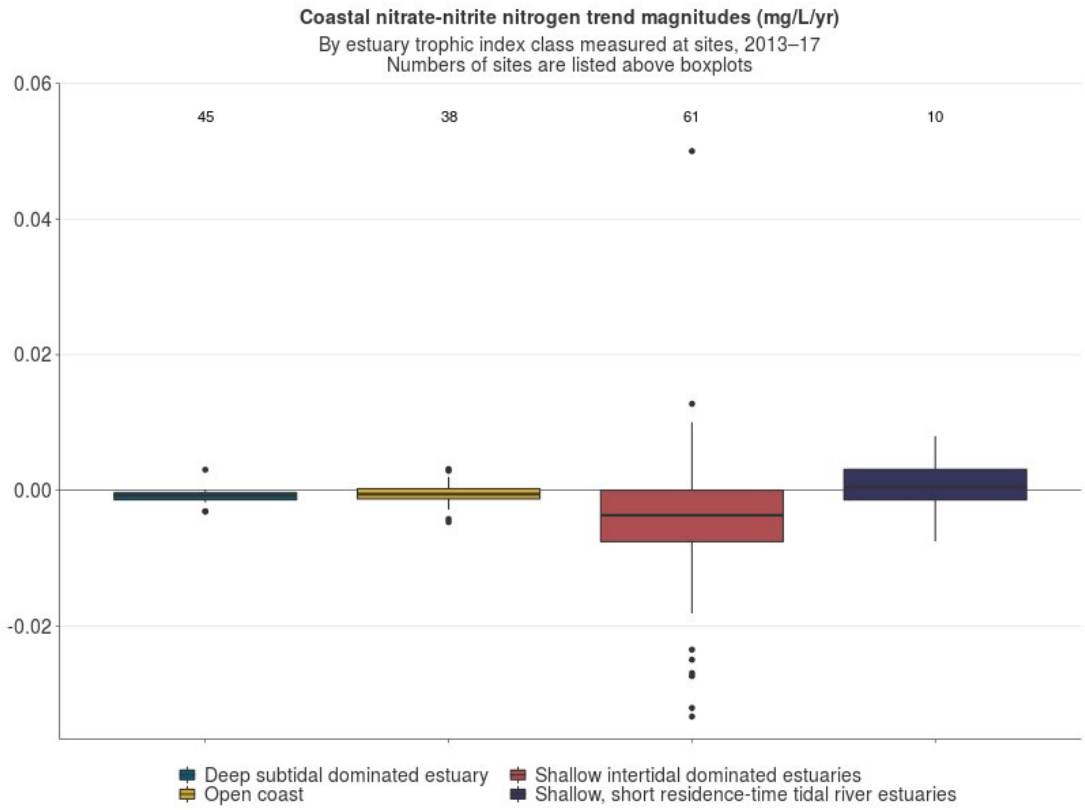

Figure 8.7. Trend magnitude for nitrate-nitrite nitrogen by Estuary Trophic Index class.

Table 8.11. Summary of analytical approaches for data relating to the microbiological data element chlorophyll *a*.

Data element: Chlorophyll *a*					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Satellite • Sensors (discrete) • Buoy	• Chlorophyll *a* concentration (mg chlorophyll *a*/m^3) often by depth over time	Calculate the mean concentration and corresponding statistical variance. Concentrations from each replicate sample for a site are summed and an average is calculated for that site.	Analyse how the concentration of chlorophyll *a* varies with depth gradients and between different sites.	Use side-by-side box plots to compare different locations (e.g. see Fig. 8.8).	**Objective 6.1 – Spatial**
			As above, with an emphasis on changes over time.	Use line charts, with points and their associated error bars representing the different microbiological data elements.	**Objective 6.2 – Temporal**

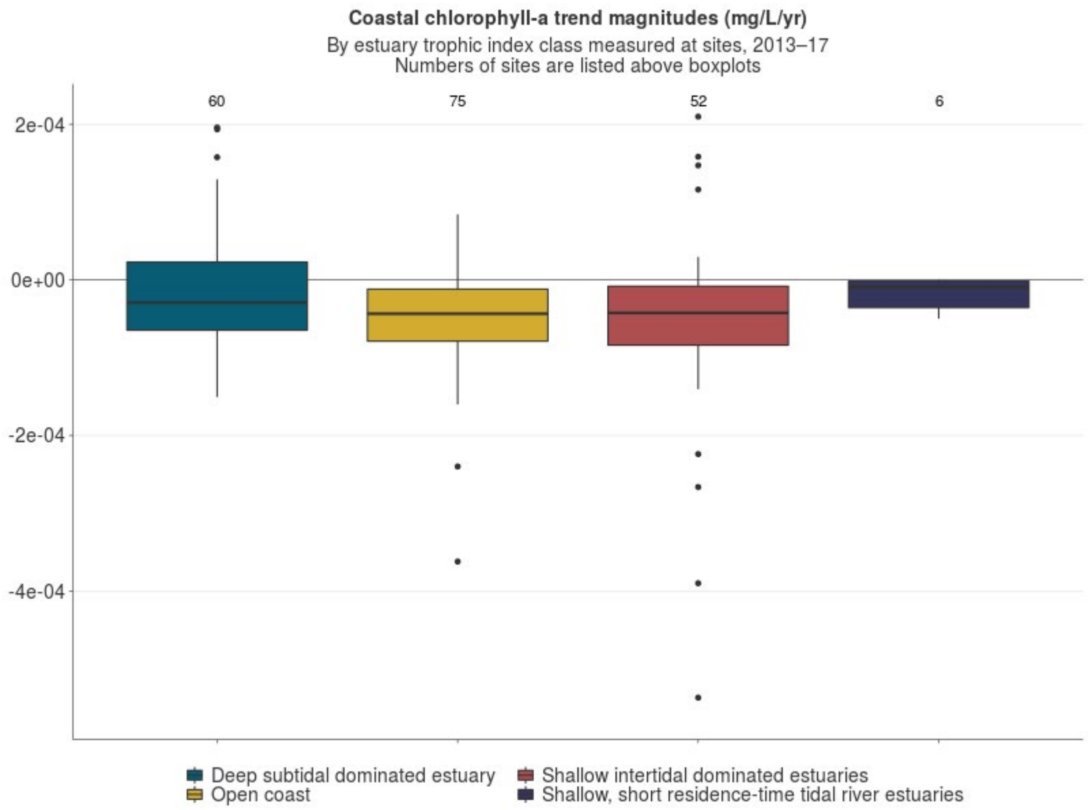

Figure 8.8. Trend magnitude for chlorophyll *a* by Estuary Trophic Index class.

8.7 Reporting and communicating

Some of the water quality measurement data can be included in the marine reserve report cards (Table 8.12). Dissolved oxygen measures reflect the oxygen absorbed by a water body as a result of the interaction with the atmosphere and primary production/photosynthesis. A variation of this measure is the biological/biochemical oxygen demand, which is sometimes used as a measure of the amount of pollution in the water (NEMS). An excess of dissolved reactive phosphorus is responsible for algal blooms, as soluble phosphorus compounds in water are readily available for use by plants and algae. The dissolved organic carbon / particulate carbon level reflects carbon consumption through photosynthesis and the release of carbon through remineralisation. Salinity, or the amount of salts dissolved in the water, is directly related to water conductivity and is a factor that limits the distribution of aquatic species. Thus, it is usually derived from conductivity measures in the field and helps to define the water environment. Suspended solids (suspended sediment concentration (SSC) and total suspended solids (TSS)) include phytoplankton, zooplankton and bacterial blooms, suspended organic and humic acids, and suspended silt and clay particles, all of which contribute to the level of turbidity in aquatic environments. Water turbidity varies in natural marine ecosystems, and some species, such as mussels, are more resilient to cloudy waters than others. Therefore, guidelines and recommendations are extremely difficult to provide, so the standard level for suspended solids should be site specific. The collection of these data, in collaboration with regional councils in most cases, will contribute to an improved understanding of the status of marine reserves when considered alongside other parameters in the MMRF.

Table 8.12. Information relating to Theme 6 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective	Maintaining ecosystem processes
Indicator	**Water quality and quantity**
Data element	Physicochemical and optical
Reporting	• Differences between sites and changes over time in physicochemical and optical data elements
Data element	Nutrients
Reporting	• Differences between sites and changes over time in nutrient data elements
Data element	Microbiological
Reporting	• Differences between sites and changes over time in microbiological data elements

8.7.1 Marine reserve reports and report cards

The greatest value for the water quality reporting will come from the status and trend analysis. Some water quality parameters can vary greatly, so longer-term trends can provide a better understanding of the situation in marine reserves and inform the development of management actions. The NEMS protocol provides directions and recommendations for reporting purposes, and some regional councils have existing reporting channels. Therefore, these cases will be considered and adapted to the reporting cards. The definitions for reporting on the status of the measures monitored under this theme are described in Table 8.13 (see Table 2.5 for definitions of trend).

Table 8.13. Definitions for reporting on the status of the measures for Theme 6 – Evaluate environmental water quality indicators.

Status	Definition
Excellent	The water quality data elements measured do not present any anomalies, or all parameters measured are within normal ranges or guidance values where these exist.
Good	More than 75% of the data elements measured are within normal ranges or guidance values where these exist.
Fair	More than 50% of the data elements measured are within normal ranges or guidance values where these exist.
Poor	Less than 50% of the data elements measured are within normal ranges or guidance values where these exist. Some of the key elements are not stable (i.e. temperature, pH, dissolved oxygen, salinity, clarity and nutrients.)
Undetermined	The status of this measure cannot be determined.

Guidance values for water quality

Guidance values define a measurable level of change from a natural reference condition that, although the ecological consequences are unknown, is considered unlikely to result in adverse effects.[52] Thus, there is a risk of an impact occurring if a guidance value is exceeded (modified from the 'trigger value' definition in NEMS; Milne 2020). Guidance values help with understanding the effect of water quality changes in the marine environment. The MMRF will contribute to building a long-term record of water quality values to provide references and targets against which performance can be measured, the definitions of which will be supported by guidance values. These targets can be described as numerical concentrations or narrative statements based on local knowledge or mātauranga Māori (i.e. visual clarity, turbidity, TSS). The preferred approach to derive guidance values for toxicants / physical and chemical stressors is to use local field- and/or laboratory-effects data. However, this is expensive, so reference-site data are generally used instead, especially if the reference site has distinct physicochemical characteristics (Milne 2020).

Site-specific guidance values

Site-specific guidance values are the ideal option for establishing specific water quality targets for a marine reserve because they are relevant to the local condition or situation. However, developing these guidance values requires a robust monitoring programme and long-term data record. ANZECC Water Quality Guidelines provide guidance on methods for deriving these values, which focus on the use of biological field-effects data, laboratory-effects data, reference-site data and the use of multiple lines of evidence (Huynh & Hobbs 2019). In the absence of site-specific guidance values, ANZECC provides default guidance values (DGVs) as a starting point for assessing water quality (Fig. 8.9; Milne 2020).

52 www.waterquality.gov.au/anz-guidelines/guideline-values/derive

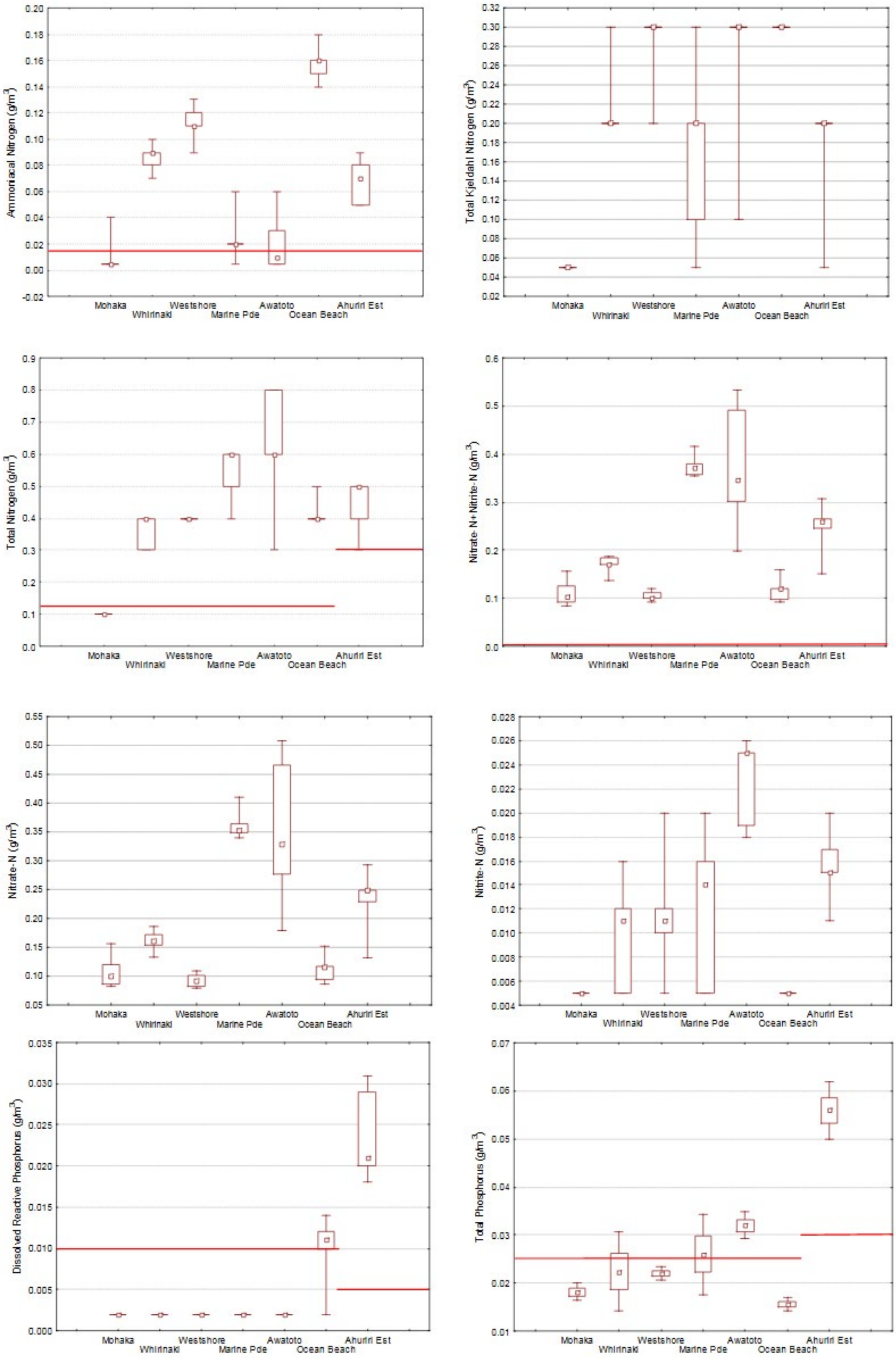

Figure 8.9. Nutrient concentrations of coastal waters at seven sites in the Hawke's Bay. Red line indicates Australian and New Zealand Environment and Conservation Council (ANZECC) 2000 default trigger (guidance) values for slightly disturbed ecosystems (guidelines not yet available for Aotearoa New Zealand waters, so values listed for southeastern Australian waters are currently used, as recommended by ANZECC). Guidance values may differ between marine and estuarine systems. Source: www.hbrc.govt.nz/assets/Document-Library/Projects/TANK/TANK-Key-Reports/Nearshore-Coastal-Water-Quality-in-Hawkes-Bay-2006.pdf.

8.7.2 Other reporting opportunities

The data collected will be publicly available and regional councils may be involved in the data collection and the sampling of sites. The water quality measurements could contribute to regional and national environmental reporting.

Environmental reporting – State of the Environment

Under the Environmental Reporting Act 2015, the Secretary for the Environment and the Government Statistician must produce regular State of the Environment reports. This requires that a report on the marine domain is produced every 6 months and a whole-of-environment (or synthesis) report is produced every 3 years.[53]

Regional councils – environmental management

Some regional councils develop their own state of the environment reports in their regions. Councils such as Greater Wellington, Auckland and Waikato have a series of environmental reports, including marine and coastal water quality reports. This theme will likely contribute to these reports.

MfE, Cawthron Institute and regional councils created the LAWA platform. Environmental data and information are presented in this platform for public access, but the marine-related information is currently limited to the presence of enterococci in areas selected by each regional council.[54]

53 https://environment.govt.nz/publications/our-marine-environment-2019/

54 www.lawa.org.nz/about

9 Theme 7 – Understand human uses of and relationships with marine reserves

What	Visitor numbers and demographics, types and levels of use, attitudes and motivations, experience and satisfaction, impacts and benefits
Who	DOC, whānau, hapū, iwi, universities, regional councils, tourism operators
When	Year round, with a focus on the season of peak use (summer)
Where	All marine reserves (where possible) and comparative non-reserve sites
How	Observation and surveillance, in situ and other surveys, commercial activity data
Why	To understand how people view and engage with marine reserves and what influences this

9.1 Background and objectives

There are opportunities for people to use, engage with and appreciate marine reserves through recreation (e.g. sailing, kayaking, snorkelling and diving), allowing them to see and experience marine creatures and their environments. Where the foreshore is a part of a marine reserve, there are also opportunities for beach activities, such as relaxation, sightseeing, swimming, walking, dog walking, horse riding, and beach and water sports.

Understanding where and how people use marine reserves and public opinion about marine reserves in general, as well as specific reserves, is crucial to the effective management of these places. Monitoring the awareness, attitudes, values and benefits of users and non-users can enable reporting between and across marine reserves at a regional or national level. A monitoring programme that covers existing marine reserves and comparative non-reserve sites can build understanding, including how human uses and relationships vary between reserves and change over time.

The purpose of this theme is to understand human uses of and relationships with marine reserves. It covers why this information is needed, what type of information is needed and how a programme can be developed to collect it.

Understanding human uses of and relationships with marine reserves can:

- Show where and how people are using marine reserves, including visitor activity levels.
- Inform active management of use and impacts.
- Enable and encourage appropriate use and behaviours to realise benefits.
- Encourage understanding of and support for marine protection.
- Facilitate MPA processes and build support for marine reserves.
- Build an understanding of why people use marine reserves and how more people can be encouraged to be engaged.
- Show the benefits of marine reserves to society (social, cultural and economic) as well as their intrinsic benefits.
- Show the value of marine reserves to science.

Information on human uses of and relationships with marine reserves should include demographics (who are the users and what are they doing?), psychographics (why do people use or not use these places?) and sociographics (what influences people and their activities?) (see Box 9.1). This can answer questions such as:

- Who are the users (and non-users)?
- What are users' activities, motivations and experiences?
- What are user and non-user attitudes towards marine reserves?
- Are users and non-users aware of marine reserves and their different rules (covered in this section) and do they follow the rules (see section 7, Theme 5 – Compliance)?
- What are the impacts of use (see also section 12, Theme 10 – Pollution)?
- What are the values and benefits of marine reserves (e.g. intrinsic, individual, societal, cultural, economic)?

This theme focuses on understanding visitor activity, demographics, psychographics and sociographics. It also covers user and non-user awareness of marine reserves and the different rules at a local scale. Other sections also include some indicators of visitor impacts – for example, Theme 10 'Pollution' covers litter and Theme 4 'Key species' covers the abundance of key species in marine reserves.

Values and benefits could be included in monitoring in the future, but there are currently no standard approaches or methods for measuring these aspects of use. DOC research projects are underway (as part of the MPA research programme) that are looking at awareness of, and attitudes towards, marine protection and the values and benefits of MPAs, including at a national scale. These may result in baseline data and a methodology for use in future monitoring programmes.

9.1.1 Objectives

Monitoring objective 7.1 (spatial): To understand human uses of and relationships with marine reserves and how these vary between different marine reserves.

Research question: How do people use marine reserves, what do they think about them, and what impacts result from and benefits are gained from this use?

Box 9.1: Demographics, psychographics and sociographics

Demographics are the characteristics of people that help describe who they are. Demographic information is used to describe populations and focuses on external or physical factors, such as age, ethnicity, gender and location.

Psychographics help to describe what people think and why they behave in certain ways. Psychographic information is used to describe people and populations based on psychological factors, such as motivations, beliefs, attitudes or priorities.

Sociographics help to understand the factors that affect how people receive and perceive information. Sociographic information is used to describe how people find and use information and how it influences their behaviour and choices. It includes personal needs and passions, technology and information consumption, and social networks.

Monitoring objective 7.2 (temporal): To understand how human uses of and relationships with marine reserves change over time.

Research question: How and why do the uses of and attitudes towards marine reserves change and what does this mean for the impacts and benefits of use?

9.2 Existing monitoring programmes

Monitoring programmes undertaken by DOC and others, such as universities, vary and are inconsistent on a national scale. Table 9.1 summarises known current monitoring programmes.

Numerous social research studies and publications exist, many of which were carried out in the 1990s and 2000s following the establishment of 14 new marine reserves between 1990 and 2000 and an additional 17 between 2000 and 2010 (e.g. Wolfenden et al. 1994; Cocklin et al. 1998; Taylor & Buckenham 2003; Arnold 2004; Warren & Procter 2005; Rojas Nazar 2013; DOC 2020b). Many of these studies have been undertaken in long-established and well-visited marine reserves (see Table 9.1 for some known examples of visitor surveys) and most have used a variety of case studies and/or qualitative approaches to explore perceptions, values, attitudes and support. However, some have also used quantitative approaches with multiple choice or rating scale questions.

Individual marine reserve monitoring plans should include a literature review of research and DOC studies of relevance to the specific reserve to identify and summarise whether useful historic data exist and to inform future monitoring programmes (see Appendix 4 for examples).

Table 9.1. Summary of past and present monitoring programmes for Theme 7 undertaken by the Department of Conservation Te Papa Atawhai (DOC) and other stakeholders, by bioregion.

Bioregion	DOC monitoring programmes	Other monitoring programmes
All marine reserves	• Commercial use data (where available) • DOC activity counters on adjacent land (where relevant) • DOC marine ranger data (where undertaken in/near marine reserves)	• Past visitor research and studies may provide baseline data (see Table 9.2) • Adjacent land activity counters managed by others (where relevant)
North Eastern	• Cape Rodney-Okakari Point Marine Reserve – visitor survey (2017–2019) • Long Bay-Okura Marine Reserve – visitor use and awareness (2018–2020) • Whanganui A Hei (Cathedral Cove) Marine Reserve – surveillance cameras (2019–present)	• Auckland Regional Council monitoring programmes for Long Bay Regional Park (adjoins Long Bay-Okura Marine Reserve)
East Coast South Island	• Marine reserve recreational compliance app • Recreational boat survey • Tourism vessel tracking • Tourism activity app • Marine mammal encounter app	

9.3 Sampling design

9.3.1 Selecting indicators

This theme provides guidance on how to measure data elements that will contribute to Objective 7 'All New Zealanders have the skills, knowledge and capability to be effective' and Objective 8 'Resourcing and support are enabling connected, active guardians of nature' from the ANZBS (DOC 2020c; Table 9.2).

Table 9.2. Indicators, measures and data elements relating to Theme 7 – Understand human uses of and relationships with marine reserves. Adapted from McGlone et al. (2020).

Indicator 7.1: Current demand for recreation in marine reserves	
Measure 7.1.1: Outdoor recreation demand being met by DOC in marine reserves: number of participants by activity, location, destination category, experience, etc.	
Description	This measures the state and trends of levels of visitation to marine reserves based on various sources, including national surveys or datasets for broad participation trends, activity counters or other visitor monitoring tools, and on-site or other observations or intention records.
Data elements	**Numbers of visitors** Numbers of visitors at specific sites and times. **Visit characteristics** Details about the visit, including duration, weather, access (boat, foot), etc.
Links to other measures	5.1.1: Illegal hunting and harvesting of indigenous species from marine reserves (Theme 5 – Compliance) 7.2.1: Attitudes towards interaction with natural ecosystems (Theme 7 – Human use) 7.2.2: Demographic/psychographic profiles of users and non-users of marine reserves (Theme 7 – Human use)

Abbreviations: DOC, Department of Conservation Te Papa Atawhai.

Future updates will expand this to include measures relating to demographic/psychographic profiles of recreationists and non-recreationists on public conservation lands and waters, as well as attitudes towards interaction with natural ecosystems, which contributes to Outcome Objective 1.8 'Human use and interaction with natural heritage' (Table 9.3).

Table 9.3. Indicators, measures and data elements that are to be implemented in future iterations of the Marine Monitoring and Reporting Framework. Additional relevant measures are listed in Appendix 4.

Indicator 7.2: Human health and wellbeing and natural ecosystems	
Measure 7.2.1: Attitudes towards interaction with natural ecosystems	
Description	This measures what people think and value about marine reserves and how this contributes to health and wellbeing on an individual and community scale. It deals with the engagement and emotional benefits of recreation, whereas Indicator 3.4.2 'Contribution of recreation in marine reserves to individual and societal wellbeing' deals with the physical aspects.
Data elements	Surveys of users and non-users to measure attitudes and values.
Links to other measures	5.1.1: Illegal hunting and harvesting of indigenous species from marine reserves (Theme 5 – Compliance) 7.1.1: Outdoor recreation demand being met by DOC in marine reserves: number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use) 7.2.2: Demographic/psychographic profiles of users and non-users of marine reserves (Theme 7 – Human use)
Measure 7.2.2: Demographic/psychographic profiles of users and non-users of marine reserves	
Description	This measure moves beyond numbers to use surveys and in-depth research to understand use/non-use and demand for marine reserves.
Data elements	Activities, interests and opinions, attitudes, values, behaviours (including motivations, preferences, choices, etc.), influences, lifestyle, barriers, and constraints.
Links to other measures	5.1.1: Illegal hunting and harvesting of indigenous species from marine reserves (Theme 5 – Compliance) 7.1.1: Outdoor recreation demand being met by DOC in marine reserves: number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use) 7.2.1: Attitudes towards interaction with natural ecosystems (Theme 7 – Human use)

Abbreviations: DOC, Department of Conservation Te Papa Atawhai.

9.3.2 Selecting monitoring programmes

Existing monitoring programmes already or could collect data to inform indicators and measures for this theme. These include:

- DOC's national network of visitor activity counters.
- Marine reserve operational patrol data, including from the marine ranger compliance app.
- National visitor surveys, such as the international visitor survey or survey of New Zealanders.
- Observations from the MPA visitor monitoring programme, including from marine ranger patrols or surveillance cameras.
- Commercial use, including from Permissions data or returns, tourism vessel tracking tools, and the tourism activity app.
- Records of other use by specific groups (e.g. recreation or stakeholder groups/clubs, school/educational groups).
- On-site visitor surveys undertaken as part of the MPA or other visitor monitoring programmes, including the recreational boat survey.
- Availability and use of information and education resources.

Different reserves have different characteristics that influence visitor opportunities and use – for example, different locations, sizes and connections to the land. Therefore, monitoring human use needs to be reserve specific and consider how the type and extent of visitor use varies between and within reserves. In some cases, use measures should include visitors to the reserve and/or visitors in the vicinity of the reserves. This will be particularly relevant where adjacent recreation opportunities enable an experience of the reserve without necessarily entering the reserve itself.

Coverage of marine reserves in the wider social monitoring programme is currently ad hoc or limited to individual sites for specific reasons. Therefore, a coordinated approach is needed to develop a more focussed and expansive programme. Advice should be sought from the relevant technical and local operations staff within DOC to set up new monitoring programmes for marine reserves. Systems, roles and processes for DOC social monitoring and evaluation should be followed (Baxendale 2019).

9.3.3 Developing a sampling design

The population or sample frame for marine reserves includes all 44 marine reserves, as well as, where appropriate, comparative or adjacent non-reserve sites – for example, data from adjacent non-reserve sites could inform visitor measures where adjacent recreation opportunities enable an experience of the reserve without entering the reserve; and data from comparable non-reserve sites can help build an understanding of why people use the reserve instead of other similar areas, or whether marine protection causes a concentration of recreational use around reserve edges.

For monitoring human use, a practical sample frame can be defined as the subset of marine reserves (and comparative non-reserve sites) in which social monitoring can be undertaken at place – for example, all marine reserves with an adjacent land boundary and/or with established visitor use patterns. It is unlikely to include marine reserves with very low levels of human visitation, such as the subantarctic or Kermadec islands, although data from other sources (e.g. permission activity returns) may inform visitor activity or other measures.

Existing visitor monitoring is mostly associated with operational work or monitoring programmes and DOC patrols, and this approach will likely be continued initially. Expansion of a monitoring programme within a marine reserve and to include other sites should be coordinated and activated over time as resources allow. Advice on the overall sampling design should be sought from a statistician for new or expanded programmes.

How are sites to be selected?

Sampling sites will be selected from across the population of marine reserves and comparative non-reserve sites and within each marine area or reserve. Each marine area will have different visitor use patterns depending on the opportunities available, accessibility, and proximity to land and population bases. They may also have different levels of operational patrol activity with which monitoring can be aligned.

Sampling sites for each marine reserve will depend on the nature of the reserve and visitor use patterns – for example, whether adjacent non-reserve land provides visitor use opportunities and/or access or gathering points, such as boat ramps or beaches, and what opportunities exist to intercept and interact with water-based and other users within and adjacent to the reserve. Comparable non-marine reserve sites should be included to provide direct data if they offer opportunities to experience the reserve without entering it or to provide human use or relationship information for comparable non-marine reserve areas.

How often should measurements be taken at these sites or a subset of these sites?

The timing of programmes needs to be coordinated to ensure the regular or targeted collection of data and consistent reporting within and between marine reserves. Monitoring should occur year round but with a focus on the season of peak use (i.e. summer). Anecdotal or other information can identify high-pressure sites (e.g. those that are known to have high levels of use, are close to urban areas or are well-known tourism sites). Such sites should be monitored annually, while other sites could be monitored on a 3-year rotation.

The timing will depend on the data being collected and the method used. For example, camera installations will capture data on an on-going year-round basis, whereas *in situ* surveys will need to be undertaken when visitors are present and should use appropriate randomisation and replication to enable statements to be made about the visitor population.

Timing around the collection of marine app data will depend on work programming. A record of the timing and intensity of effort is needed to allow findings to be reported in a consistent and comparable way across marine reserves.

9.4 Monitoring protocols

No formal DOC protocols or toolbox methods currently exist for monitoring human uses of and relationships with marine reserves. However, DOC does have identified systems, roles and processes in place for social monitoring and evaluation (Baxendale 2019), and advice can be obtained from technical advisors in DOC's Design and Evaluation team. Established approaches and methods are used to measure demographic, psychographic and sociographic characteristics and should be followed where relevant for marine monitoring (Table 9.4). The following tools are currently in use or under development:

- Visitor activity measures and methods (e.g. from track or road counter triggers).
- Established and/or standardised visitor surveys or survey questions, including the format and wording (e.g. recreational boat user survey, previous studies or research).
- App-based platforms that run on a tablet or smartphone to record data (including spatial data) in a standard format for various aspects of ranger patrols, tourism operations and marine mammal encounters.

Table 9.4. Methods for monitoring human use in marine reserves (Theme 7).

	Visitor activity	Commercial use data	CCTV	DOC-led patrols	On-site visitor surveys	National surveys	Impacts and benefits studies
Description	Levels of visitor asset utilisation	Numbers of permissions, approved and actual use levels	Photographic or video recordings	Ranger patrols in marine reserves	Intercept surveys, GNSS tracking	Questions to track awareness and attitudes to marine protection	Studies to determine the statuses and trends in impacts and benefits
Tools/ equipment	• Track or road activity counters	• Permissions databases • Return forms	• On-site cameras	• Ranger app • Other hardcopy forms or surveys	• Standard questions • Surveyor • Hardcopy/ electronic survey forms	• Integrate into existing survey instruments OR develop a standalone tool	To be developed
Site selection	Existing	Existing	Specific for selected reserves	Aligned with operations	Reserve specific; depends on visitor use and access	Population-scale survey	Reserve specific; depends on visitor use and access
Timing selection	Ongoing	Ongoing	Ongoing	Ongoing	Annual for high-use sites, 3-yearly for other sites	Annual, biannual or triennial for high-level questions	To be decided
Sampling effort	All visitors to a site; a counter calibration programme is needed	All commercial users who hold a permission from DOC	All visitors to a site within coverage of the camera(s)	All visitors present on patrol days; depends on effort/timing	Visitors present on survey days	Entire population of Aotearoa New Zealand; tie in with existing national surveys; likely to use internet panels	Reserve specific; consider users and non-users, as well as local residents, businesses and other stakeholders
Effort	Assess existing counter locations and consider future needs	Assess existing permissions information	In response to needs and available funding	Aligned with operations	Aim for a sample size of approximately 400 individuals per site/season	Aim for a sample size of 1000+ individuals nationally; weight the results to reflect the population	To be decided
Responsibility	• D&E • Ops	• Ops	• Ops • D&E • Others (e.g. councils)	• Ops • D&E	• D&E • Ops	• D&E • MET	• MET
Data elements	• Activity	• Number of permissions • Activity types and levels	• Photographic, video and observation data generated	• Activity • Demographics • Psychographics (awareness, attitudes)	• Demographics • Psychographics • Sociographics	• Demographics • Psychographics • Sociographics	• Psychographics • Economics data
Data storage	• AMIS	• Permissions database	• Local Ops teams • docCM	• Local Ops teams • docCM	• Survey Monkey • docCM • NDS	• Survey Monkey • docCM • NDS	• Survey Monkey • docCM • NDS • Other
Toolbox link	None, but a website reporting tool is available (www.doc.govt.nz/our-work/monitoring-reporting/visitor-asset-utilisation-reports/)	None	None	None, app available	None, but some established DOC approaches	None; TA currently to look at societal awareness	None; TA currently to develop methodology for benefits

Abbreviations: AMIS, Asset Management Information System; CCTV, closed-circuit television; D&E, DOC's Design and Evaluation team; DOC, Department of Conservation Te Papa Atawhai; docCM, DOC's document management system; GNSS, Global Navigation Satellite System; MET, DOC's Marine Ecosystems Team; NDS, Nelson Data Systems Ltd; Ops, DOC's Operations team. TA, Task Assignment.

9.5 Data management

Social monitoring data are managed and stored in accordance with DOC's existing systems, roles and processes for social monitoring and evaluation (Baxendale 2019). Some data types have specific processes or repositories in place, such as the Asset Management Information System (AMIS) and the Permissions database (see Table 9.5). In addition, all visitor survey data are currently collected or entered into a Survey Monkey enterprise licence account administered by DOC's Design and Evaluation team, and all survey data are backed up daily by Nelson Data Systems Ltd (NDS). There is a need to consolidate data held by local operations teams or in docCM to enable better reporting of data in the future at a national scale.

Table 9.5. Summary of analytical approaches for data relating to the numbers of visitors.

Data element: Numbers of visitors at specific sites and times					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Visitor activity • Commercial use data • CCTV • DOC-led patrols • On-site visitor surveys	• Numbers of visitors to each marine reserve over time • Visitor use patterns within and adjacent to each marine reserve	Data to be compiled by month or by year on an annual or seasonal basis	Absolute and/or percentage change in visitor numbers at specific sites and times	Data should be presented as bar or line graphs for each reserve or across different reserves	Objective 1 – Presence/absence
			Absolute and/or percentage change in visitor numbers at specific sites and times	Data may be presented as bar or line graphs	Objective 2 – Temporal

Abbreviations: CCTV, closed-circuit television; DOC, Department of Conservation Te Papa Atawhai.

Table 9.6. Summary of analytical approaches for data relating to visit characteristics.

Data element: Visit characteristics					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Visitor activity • Commercial use data • CCTV • DOC-led patrols • On-site visitor surveys	• Activity types and levels • Visitor demographics • Visitor psychographics • Visitor sociographics	• Compile data by month or by year on an annual or seasonal basis. • Compile on-site visitor survey responses into individual site or study reports.	Determine the absolute and/or percentage change in visit characteristics. Use on-site survey reports to present top-line results by question.	Use bar or line charts to present the data for each reserve or across different reserves and for each data or question type.	Objective 7.1 – Spatial
			Determine the absolute and percentage change in visitor characteristics. Compile multi-year visitor survey reports to compare absolute or percentage changes in visit characteristics over time once data are available.	Use bar or line charts to show changes in visitor characteristics over time.	Objective 7.2 – Temporal

Abbreviations: CCTV, closed-circuit television; DOC, Department of Conservation Te Papa Atawhai.

9.6 Data analysis

Some standard approaches and best practice exist for analysing and reporting on top-level results for visitor data, but these have not yet been formalised. Reporting on marine data should be aligned with wider social monitoring reporting practices as these are developed.

DOC's Design and Evaluation team can provide advice and will coordinate data collection, analysis and reporting in accordance with DOC's existing systems, roles and processes for social monitoring and evaluation (Baxendale 2019), as well as any further developments aimed at consolidating or automating these systems and processes. The analytical approaches that can be used for each of the data elements shown in Table 9.3 are summarised in Tables 9.6 and 9.7.

9.7 Reporting and communicating

As for data analysis, some standard approaches and best practice exist but have not yet been formalised. DOC's Design and Evaluation team can provide advice and will coordinate data reporting in accordance with DOC's current systems and processes.

Regular reporting should occur to ensure that data are accessible as visitor statistics become available across reserves and over time – for example, annual visitor or commercial use estimates, activity types and awareness levels (Table 9.7).

Possible responses or interventions for addressing critical issues arising from this theme include:

- Community-based monitoring
- Public awareness campaigns
- Socio-economic research
- Monitoring local business and community infrastructure
- Monitoring human use

Table 9.7. Information relating to Theme 7 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective	Demand for recreation experiences using marine reserves is understood
Indicator	**Current demand for recreation on PCL&W**
Data element	Numbers of visitors at specific sites and times Visit characteristics
Reporting	• Numbers of participants (by activity and location) and visit and visitor experience characteristics obtained from various sources, including national surveys or datasets for broad participation trends, activity counters or other visitor monitoring tools, and on-site or other observations or intention records

Abbreviations: PCL&W, public conservation lands and waters.

9.7.1 Marine reserve reports and report cards

Once monitoring programmes have been established, seasonal or annual survey reports for specific reserves and/or studies can be produced regularly, or on an ad hoc basis, as information becomes available. These could capture or summarise key findings from monitoring programmes, such as ranger patrols, *in situ* visitor surveys or CCTV data.

Simple and standardised social statistics, such as activity counts or marine app observation data, could be added to marine reserve report cards regularly to show the status and trends for each reserve (see Table 9.8 for definitions of status and Table 2.5 for definitions of trend). Relevant social monitoring information should be added as it becomes available, with an initial focus on:

- Measures of use and use characteristics for each reserve (e.g. annual visitor or commercial use estimates and activity types).
- Awareness of the existence of marine reserves and the marine mammal protection regulations rules.
- Summary results from local or national visitor surveys, including the status and trends if available.

Table 9.8. Definitions for reporting on the status of the measures for Theme 7 – Understand human uses of and relationships with marine reserves.

Status	Definition
Excellent	Current demand for recreation in the marine reserve is well understood. Information on visitors and their experience is regularly collected, reported on and used to inform management. The marine reserve is actively managed to ensure a high-quality visitor experience and sustainable visitor use in the context of any visitor pressures or impacts, allowing visitors to connect, protect and thrive in the marine environment.
Good	Some information is available on current demand for recreation in the marine reserve. Information on visitors and their experience is being collected and used to build an understanding of visitor use and demand and to inform management.
Fair	A small amount of information is available on some aspects of visitor demand for and use of the marine reserve. Existing information may or may not be useful or used to inform management. No regular or targeted programmes exist to improve information collection or to help build an understanding of visitor use and demand.
Poor	Very little or no information is available about visitor demand for or use of the marine reserve. The visitor experience sought or achieved is not well understood and there is little or no active management of visitors.
Undetermined	The status of this measure cannot be determined.

9.7.2 Other reporting opportunities

Primarily, results should be produced for monitoring programmes or site-specific visitor surveys. Further analysis may enable the results to be published in scientific journals.

10 Theme 8 – Detect non-indigenous species

What	Occurrence of non-indigenous species in marine reserves
Who	DOC, MPI, regional councils, people engaged in citizen science
When	Year round
Where	All marine reserves where possible
How	Produce a marine reserve species inventory and keep it up to date with information from biosecurity and marine life surveys and citizen science observations
Why	To prevent the establishment and spread of non-indigenous species inside or near marine reserves through early detection and planned management intervention

10.1 Background and objectives

More than 350 non-indigenous marine species have been recorded from Aotearoa New Zealand's waters, almost 200 of which are considered to have established self-sustaining populations.[55] Most of these species have arrived in Aotearoa New Zealand via international shipping, either as fouling organisms on vessel hulls, as inhabitants of niche spaces (e.g. sea chests, water intakes, box coolers) or in ballast water (Cranfield et al. 1998), with some introductions dating back to the sealing and whaling fleets of the 1700s and 1800s. In addition, a small number of species have probably rafted here, and some pathogens and parasites may have been introduced via imported bait or aquaculture feed (Hine 1996; Jones et al. 1997; Cranfield et al. 1998). A recent example of benthic invertebrates rafting to Aotearoa New Zealand are the pectinids *Mimachlamys asperrima* and *Scaeochlamys livida*, which were attached to the hull of a runabout that capsized off Sydney in September 2017 and washed ashore at Ōtaipango/Henderson Bay in Northland on 4 March 2019. The doppelganger cunjevoi (*Pyura doppelgangera*) may also have reached Northland from Tasmania by rafting (Hayward & Morley 2009; Rius & Teske 2011). Some species have also been deliberately introduced and subsequently established self-sustaining wild populations, such as Chinook salmon (*Oncorhynchus tshawytscha*) and three species of cord grass (*Sporobolus* spp.).

Non-indigenous marine species are taxonomically diverse and include protozoans, algae, sponges, cnidarians, polychaete worms, bivalve and gastropod molluscs, a wide range of crustaceans, bryozoans, ascidians, and several fishes (Cranfield et al. 1998; Willis et al. 1999; Francis et al. 2003). Deliberate introductions of fishes have involved several attempts to establish wild fisheries and at least two releases of live bait fishes from foreign fishing vessels (Cranfield et al. 1998), while accidental introductions of marine fishes are generally thought to have occurred via introductions of larvae in ballast water (Francis et al. 2003), although 22 individuals of 10 species of tropical reef fishes were found alive in the sea chest of a cruise ship that arrived in Waitemata Harbour from French Polynesia in 2017. Aside from Chinook salmon and sea-run brown trout (*Salmo trutta*), which were deliberately introduced, the only non-indigenous marine fishes that are considered to have become established in Aotearoa New Zealand's waters are an

55 www.stats.govt.nz/indicators/marine-non-indigenous-species#:~:text=In%202009%2C%20when%20the%20baseline,established%20populations%20in%20our%20waters

intertidal species of blenny (*Omobranchus anolius*) and two gobies (*Arenigobius bifrenatus* and *Acentrogobius pflaumii*). In 2013, an adult barred knifejaw (*Oplegnathus fasciatus*) was speared near Cape Rodney in the Hauraki Gulf,[56] but as yet there is no evidence that this species has become established.

Non-indigenous marine species have the potential to become ecological and economic pests. Internationally, it has been shown that non-indigenous species can cause fundamental alterations to population, community and ecosystems processes (Thomsen et al. 2014a). Estuaries appear to be particularly vulnerable, although this may reflect the fact that more research has been conducted on non-indigenous species in estuaries and harbours (Thomsen et al. 2014b). While the ecological impacts of most non-indigenous species occurring in Aotearoa New Zealand are unknown, introduced marine species have been found to have negative effects on biodiversity within a trophic level or functional group, possibly due to competition for food and space, and positive effects on the biodiversity of higher trophic levels and different functional groups due to the provision of habitat for mobile species or food for predators (Lohrer et al. 2008; Thomsen et al. 2014a). Non-indigenous predators such as the northern Pacific seastar (*Asterias amurensis*) and Asian paddle crab (*Charybdis japonica*) may have serious adverse effects on populations of indigenous prey species and competitors and represent a major threat to native assemblages, bivalve fisheries and aquaculture (Ross et al. 2003). Potential and observed negative effects of non-indigenous marine species on cultural and amenity values in Aotearoa New Zealand include the smothering or displacement of shellfish beds used as customary sources of kaimoana by the Asian date mussel (*Arcuatula senhousia*) and doppelganger cunjevoi and the fouling of beaches, rocky shores and boat ramps by Pacific oysters (*Crassostrea gigas*) (Dromgoole & Fostert 1983; Cranfield et al. 1998; Lohrer et al. 2008; Miossec et al. 2009; Aguirre et al. 2016).

Aotearoa New Zealand's biosecurity system is led by Biosecurity New Zealand (a business unit within MPI) under the Biosecurity Act 1993 and involves the management of biosecurity risks at pre-border (international), border, national, regional and local scales (Smith et al. 2016). Responsibilities include recording and coordinating reports of suspected new organisms and managing appropriate responses to them. The system aims to manage most biosecurity risks offshore through the specification of requirements for people, vessels and goods coming into the country. This includes an Import Health Standard for ballast water (MPI 2016) and a Craft Risk Management Standard for biofouling (MPI 2018), with the latter taking effect in November 2018. Border controls include requirements for all vessels arriving in Aotearoa New Zealand to travel directly to an approved port of entry or notified port or destination for inspections of imported goods and equipment and levels of biofouling on hulls. Post-border controls include general and targeted programmes to detect harmful pests and diseases and to eradicate or control new organisms where appropriate. Long-term post-border management at a national scale is led by MPI, while regional management is primarily led by regional councils through regional pest management and pathway plans. The abundance of non-indigenous species may also be managed at a local scale to protect specific values at place (MPI 2018).

Not all non-indigenous species are classified as unwanted organisms. Under the Biosecurity Act 1993, an unwanted organism is any organism that a chief technical officer (MPI) believes is capable or potentially capable of causing unwanted harm to any natural or physical resource or human health. Non-indigenous marine species that have been formally identified as unwanted organisms by MPI are:

- Asian paddle crab
- Chinese mitten crab (*Eriocheir sinensis*)
- European shore crab (*Carcinus maenus*)
- Mediterranean fanworm (*Sabella spallazanii*)
- Northern Pacific seastar

56 www.inaturalist.org/observations/1005414

- Australian droplet tunicate (*Eudistoma elongatum*)
- Clubbed tunicate (*Styela clava*)
- Doppelganger cunjevoi
- Mediterranean clone of caulerpa (*Caulerpa taxifolia*)
- Wakame (*Undaria pinnatifida*)
- Asian clam (*Potamocorbula amurensis*)

All vessels visiting the Kermadec and subantarctic islands must comply with the 'Regional Coastal Plan: Kermadec and Subantarctic Islands' (DOC 2017b). This plan includes controls on how close visiting vessels may approach the shore without a resource consent, acceptable levels of hull biofouling, and methods of reporting vessel anti-fouling systems, anti-fouling maintenance, and hull and niche area inspections.

10.1.1 MPAs and non-indigenous species

The ability of non-indigenous species to establish self-sustaining populations in a new environment (post-introduction success) is likely to depend on multiple factors, including the health and diversity of the recipient ecological system (Duncan et al. 2013). Ecological theory suggests that ecosystems containing healthy, diverse native assemblages may be more resilient to invasion due to the presence of predators, competitors or other key species that are able to disrupt or exclude non-indigenous colonisers (Stachowicz et al. 2002; Lohrer et al. 2008). Consequently, MPAs may be more resilient to invasion by non-indigenous species than nearby areas with less natural assemblages. However, the composition and health of native communities are not static. Natural or anthropogenic disturbances may create opportunities for invasion (e.g. through the creation of bare space), and the establishment of a dominant species may facilitate the establishment of more invasive species (Lohrer et al. 2008). MPAs that are located close to major commercial ports or popular anchorages are also likely to be subject to higher propagule pressure, making the establishment of non-indigenous species more likely.

Since the ecological impacts of most non-indigenous species occurring in Aotearoa New Zealand are unknown, their effects on indigenous biodiversity within individual MPAs and the wider network are also unknown, making them difficult to predict. However, effective management of MPAs will increasingly require an understanding of these effects. Any decision to eradicate or control non-indigenous species in marine reserves will need to consider the likelihood of the species establishing a self-sustaining population if nothing is done, the location of the source population and probable vector, the likelihood of success of the operation and of further incursions, and the potential impacts on the marine reserve and the purpose for which it was established. Unnecessary control operations are likely to be costly and, if poorly managed, could do more ecological harm than the target species, whereas not responding in a timely manner to the introduction of a competitively dominant species is likely to considerably increase the cost of eradication or control or even make it impossible, which could lead to permanent changes in biological assemblages and the loss of site-specific biodiversity values.

Detecting and understanding or predicting the effects of non-indigenous species on marine reserves requires comprehensive knowledge of the species assemblages and ecological processes within them. Detailed habitat maps and comprehensive species lists are available for very few marine reserves, and most existing species lists are not actively curated and updated. Without this information, it is not possible to assess exotic species occurrence or dominance, and the lack of knowledge of what exotic species are already present in an area can complicate the recognition of new incursions.

While some unwanted organisms are easy to detect and monitor because they are large and easily recognisable, others can be easily confused with native species belonging to the same family or genus. Furthermore, most non-indigenous marine species that are not listed as unwanted organisms require taxonomic expertise for correct identification. Establishing comprehensive baseline information on the species occurring within MPAs is a necessary first step towards an effective monitoring programme. However, there is currently no large-scale targeted monitoring of non-indigenous species in marine reserves by DOC.

10.1.2 Objectives

Monitoring objective 8.1 (spatial): To establish baseline presence–absence and relative abundance estimates for all non-indigenous species present in marine reserves.

Research question: Which non-indigenous species are present in marine reserves and how common are they?

Monitoring objective 8.2 (temporal): To monitor trends in abundance and biomass of non-indigenous species within marine reserves.

Research question: How are the abundances of non-indigenous species, particularly unwanted organisms, in marine reserves changing over time?

10.2 Existing monitoring programmes

MPI's marine biosecurity operations include vessel inspections, the Marine High Risk Site Surveillance and Port Biological Baseline Surveys (PBBS) programmes, and passive surveillance through public reporting of suspected new organisms. These operations are supported by the Marine Invasives Taxonomic Service (MITS), which is funded by MPI and provided by NIWA. MITS is responsible for identifying and managing collections of all marine samples collected under MPI's marine biosecurity operations, including samples collected by the public and other agencies and reported via MPI's Exotic Pest and Disease Hotline, and has a dedicated biosecurity database and museum collection. Data and information on the occurrence and abundance of non-indigenous species recorded during MPI's marine biosecurity operations are published in Marine High Risk Site Surveillance and PBBS reports and can be accessed via the Marine Biosecurity Porthole.[57] Some passive monitoring is achieved through research, monitoring and compliance activities in marine reserves, public reporting, and monitoring citizen science observations posted on platforms such as iNaturalist.[58]

Existing biosecurity monitoring programmes are briefly summarised in Table 10.1. At present, the Fiordland (Te Moana o Atawhenua) Marine Area and associated marine reserves are the only MPAs actively monitored by DOC for invasive marine species (i.e. the seaweed *Undaria pinnatifida*).

57 www.marinebiosecurity.org.nz/
58 www.inaturalist.org/

Table 10.1. Existing marine biosecurity monitoring programmes being conducted by the Department of Conservation Te Papa Atawhai (DOC) and other stakeholders, by bioregion.

Bioregion	DOC monitoring programmes	Other monitoring programmes
Subantarctic Islands	• Vessel hull and niche area inspections (Regional Coastal Plan Compliance Database)	• MPI (see Marine Biosecurity Porthole)*
Southern		• MPI –PBBS†
Fiordland	• Invasive species surveillance at various structures and anchorages throughout Fiordland • *Undaria* monitoring‡	• MPI – PBBS† • Southland Regional Council§
West Coast South Island		• MPI
East Coast South Island		• MPI – PBBS†
South Cook Strait		• MPI – PBBS† • Top of the South Marine Biosecurity Partnership
North Cook Strait	• iNaturalist projects for Taputeranga Marine Reserve and wider Kapiti environment	• MPI – PBBS†
Western North Island		• MPI – PBBS¶
Eastern North Island		• MPI – PBBS†
North Eastern	• iNaturalist projects for Poor Knights Islands, Cape Rodney-Okakari Point, Tarwharanui, Long Bay-Okura, Motu Manawa-Pollen Island, Te Matuku and Whanganui A Hei (Cathedral Cove) marine reserves and Hauraki Gulf Marine Park	• MPI – PBBS† • Northland Regional Council hull surveys (October–May)
Kermadec Islands	• Vessel hull and niche area inspections • iNaturalist marine reserve project • Kermadec Islands Checklist	• MPI
Chatham Islands		• MPI

Abbreviations: MPI, Ministry for Primary Industries; PBBS, Port Biological Baseline Surveys.
* www.marinebiosecurity.org.nz/
† https://marinebiosecurity.org.nz/baselinesurveys/
‡ www.doc.govt.nz/nature/pests-and-threats/weeds/common-weeds/asian-seaweed/
§ www.es.govt.nz/environment/biosecurity-and-biodiversity/marine-biosecurity
¶ https://web.archive.org/web/20100602071523/http://www.biosecurity.govt.nz/files/pests/salt-freshwater/2008-port-of-taranaki.pdf

10.3 Sampling design

10.3.1 Selecting indicators

This theme provides guidance on how to measure data elements that will contribute to Objective 11 'Biological threats and pressures are reduced through management' from the ANZBS (DOC 2020c; Table 10.2).

Future updates will expand this to include measures relating to the abundance and distribution of invasive pests and weeds (Table 10.3).

10.3.2 Selecting monitoring programmes

The purpose of the sampling design for this indicator is detection, not enumeration. Therefore, the goal is to develop and regularly update a checklist or inventory of species for each MPA. Keeping this up to date will require inputs from national and regional biosecurity programmes and DOC's key species monitoring (Theme 4), as well as reporting by members of the public involved in citizen science through platforms such as iNaturalist, the marine biosecurity hub and regional councils.

Table 10.2. Indicators, measures, and data elements relating to Theme 8 – Detect non-indigenous species. Adapted from McGlone et al. (2020).

Indicator 8.1: Non-indigenous species occurrence and dominance	
Measure 8.1.1: Occurrence of self-maintaining populations of non-indigenous species	
Description	Approximately 200 non-indigenous species are considered to have established self-sustaining populations in Aotearoa New Zealand's waters. Although the ecological effects of most of these establishments are unknown, they have the potential to adversely affect native species and alter community and ecosystem processes. Little is currently known about the occurrence of non-indigenous species in MPAs, and the detection of non-indigenous species is often complicated by the difficulty of observing and adequately sampling marine habitats, an incomplete knowledge of the native marine biota, and the level of taxonomic skill required to correctly distinguish closely related indigenous and non-indigenous species from each other. Therefore, baseline information on the occurrence of indigenous and non-indigenous species needs to be compiled for all marine reserves. This should be undertaken using a combination of existing information, rapid surveys and passive surveillance. For many species, correct identification will not be possible in the field, so photographs and voucher specimens will need to be collected for later identification by taxonomic experts in MITS, museums and universities.
Data elements	**Species** Accepted species names and any synonyms. **Biosecurity status** Current status of the organism, which allows it to be classified in the system (non-indigenous, unwanted organism, cryptogenic, native). **Relative abundance** Abundance of the organism (categorised as rare, common, abundant or unknown).
Links to other measures	3.2.4: Range shifts (Theme 3 – Climate change) 4.1.5: Changes in species diversity (Theme 4 – Key species) 4.2.1: Marine biological function (Theme 4 – Key species) 6.2.1: Ecosystem primary productivity (Theme 6 – Water quality) 9.1.5: Toxic blooms (Theme 9 – Extreme events) 9.1.6: Disease and invertebrate pest outbreaks (Theme 9 - Extreme events)

Abbreviations: MITS, Marine Invasives Taxonomic Service; MPA, marine protected area.

Table 10.3. Indicators, measures and data elements that are to be implemented in future iterations of the Marine Monitoring and Reporting Framework but are not directly measured.

Indicator 8.1: Non-indigenous species occurrence and dominance	
Measure 8.1.2: Abundance and distribution of non-indigenous species	
Description	Non-indigenous species have the potential to adversely affect populations of native species and alter community and ecosystem processes. To understand the significance of their effects on indigenous biodiversity, particularly that within MPAs, there is a need to collect quantitative information on their abundances, life histories and population dynamics. It will be possible to obtain some of this information through targeted research, but monitoring will be required to understand colonisation processes and their long-term effects on the indigenous biodiversity of different habitats and ecosystems. The methods used to monitor populations and the spread of non-indigenous species within an MPA are the same as those required to monitor habitat extent and composition (Theme 2) and key species (Theme 4).
Data elements	**Abundance, density, size, maturity** **Percentage cover** **Biomass** **Area of occupation** **Area free of non-indigenous species** **Area free of unwanted organisms**
Links to other measures	2.1.1: Habitat fragmentation (Theme 2 – Habitat changes) 2.1.2: Habitat availability (Theme 2 – Habitat changes) 3.2.2: Biological responses to extreme climate events (Theme 3 – Climate change) 3.2.3: Phenological response to climatic regime change (Theme 3 – Climate change) 3.2.4: Range shifts (Theme 3 – Climate change) 4.1.2: Abundance and demography of common and widespread taxa (Theme 4 – Key species) 4.1.5: Changes in species diversity (Theme 4 – Key species) 4.2.1: Marine biological function (Theme 4 – Key species) 6.2.1: Ecosystem primary productivity (Theme 6 – Water quality) 8.1.1: Occurrence of self-maintaining populations of non-indigenous species (Theme 8 – Detect non-indigenous species) 9.1.6: Disease and invertebrate pest outbreaks (Theme 9 – Extreme events)

10.3.3 Developing a sampling design

How are sites to be selected?

Sampling sites include all marine reserves and thought should also be given to working with MPI and regional councils to inspect high-risk sites adjacent to marine reserves. Regular monitoring that employs methods such as searches and sampling gears (active surveillance) will be prioritised for readily accessible sites that are most at risk from incursions.

How often should measurements be taken at these sites or a subset of these sites?

Database searches, including of the Marine Biosecurity Porthole, regional councils and iNaturalist, should occur at least every 3–4 months. Species lists from DOC key species surveys should also be reviewed after each survey. Observations from the public should be confirmed by MPI or regional councils and recorded in the inventory for the marine reserve immediately.

10.4 Monitoring protocols

The first stage of monitoring for non-indigenous species is to compile a checklist of all species reported from the marine reserve and to identify the different habitat types present within the marine reserve. The taxonomic status of species recorded from the marine reserve will need to be checked to ensure that currently recognised names are used and to avoid the duplication of species occurrences due to misidentification or changed taxonomy. The biosecurity status of all species that are known to occur in the reserve should be determined and any records requiring confirmation should be flagged.

Existing marine reserve species lists will be updated and new lists will be generated for those without one. These will be updated as new information for each marine reserve becomes available. The following data must be recorded for each species:

- Accepted name (Latin binomial) and authority
- Common name
- Higher taxonomic level classification (i.e. kingdom, phylum, class, order, family)
- Synonyms
- Source

If available, the following data should also be captured:

- Latitude and longitude (WGS1984)
- Collection date
- Collection depth (m)
- Habitat
- Digital photographs (or the file name and location)
- Collector
- Identifier
- MITS investigation number, number and locality code
- Collection names and internationally recognised institutional abbreviations
- Registration numbers of voucher specimens and/or genetic samples
- Comments

Note: date and location (latitude, longitude) data can be captured automatically from digital photograph metadata.

The data used to compile these lists will come from a range of sources that will need to be checked regularly for new observations. These include the scientific literature (ecological and taxonomic), marine reserve applications, contract reports, natural history collections, the Marine Biosecurity Porthole, regional councils, DOC's key species monitoring, hull and niche area inspections, and iNaturalist. Hull and niche area inspections for vessels intending to visit the Kermadec and subantarctic islands must follow the protocol described in the 'Regional Coastal Plan: Kermadec and Subantarctic Islands' (DOC 2017b).

These sources may also be complemented by active monitoring inside the marine reserve. The survey technique should allow the presence or absence of non-indigenous species to be determined rapidly over a relatively large area. Brief summaries of the available methods are given below, and Inglis et al. (2006) also provide useful descriptions of the different sampling gears, methods and strategies for each survey type.

10.4.1 Observation

Any suspected non-indigenous species or unwanted organism that is found in a marine reserve should be immediately reported to MPI's Exotic Pest and Disease Hotline (0800 80 99 66), and local body biosecurity staff should also be notified of the find. Photographs and specimens should be retained for submission to MITS after the sighting has been reported to the hotline (photographs may also be uploaded to iNaturalist). If it is a new organism or a new distribution record for an unwanted organism, MPI will determine if further action (e.g. delimitation survey, eradication) is required. MPI is responsible for the eradication or control of new incursions and national-scale post-border responses, whereas regional councils are responsible for regional-scale post-border management through regional pest management and pathway plans.

Local offices should liaise with local regional council and MPI biosecurity staff to stay informed of any new observations that are found in or near the marine reserve. Any new records should be added to the marine reserve inventory.

10.4.2 iNaturalist

All marine reserves will have an iNaturalist page to which species sightings can be uploaded by staff and the public. This page must be checked regularly for observations of unwanted organisms. Should new observations arise, then the protocol for observations should be followed to ensure the data are captured by MPI.

10.4.3 Key species surveys

Intertidal species shoreline searches

Shoreline searches for intertidal species should be timed to follow the tide as it falls. A digital camera with built-in GPS should be used to document major habitats and species assemblages that are present at the site, as well as the identity, location and microhabitats of all species encountered. Rocks should be turned over to search for mobile and encrusting species. Fishes and some invertebrates may need to be photographed submerged in sea water to enable identification from photographs. A macro lens may be required to adequately document small mobile and encrusting species, and samples / voucher specimens may need to be collected to verify identifications.

Subtidal surveys

A combination of diver searches and the deployment of a variety of active and passive gears will be required for subtidal surveys, as described by Inglis et al. (2006). Voucher specimens should be collected for any species that cannot be readily identified in the field or from photographs. The creation of biosystematic catalogues for marine reserves will also aid in the identification of new invasive species.

Settlement arrays

The use of settlement arrays for the surveillance of non-indigenous biofouling species may be appropriate in some instances, but this method is very labour intensive and requires specialist taxonomic expertise to identify the organisms in the assemblages that develop on them (Tait & Inglis 2016). They are most likely to be deployed in marine reserves by other agencies as part of a regional- or national-scale surveillance programme.

Environmental DNA (eDNA)

Although still a relatively new technology, eDNA can be used to survey large areas of marine reserves for the presence of invasive species simply by collecting water samples and analysing their contents. Once a biological signature has been developed for the species in question, it can be easily and quickly identified in samples. There are some drawbacks, such as not being able to pinpoint the exact location of the incursion, but eDNA can be a useful tool.

10.5 Data management

The compilation and maintenance of marine reserve species lists will be undertaken collaboratively between DOC's Biodiversity Group and District Office biodiversity staff. Lists for each marine reserve will initially be compiled by Aquatic Unit staff using available information. They will be responsible for curation of the lists, including the correct identification and taxonomic classification of species, and liaison with subject experts and local biodiversity staff to ensure that all important contributions to the knowledge of the area have been captured. Local biodiversity staff will be responsible for documenting species occurrences within MPAs and ensuring that these are brought to the attention of the curator of the species list and captured appropriately. In the case of the discovery of an unwanted organism or a suspected new incursion to an offshore island, the responsibility for making a report to the Exotic Pest and Disease Hotline (MPI) and any subsequent follow-up actions will rest with the person who first receives the report.

10.6 Data analysis

The non-native species indicator has one data element – biosecurity status – for which data can be collected from iNaturalist, observations or key species surveys (Table 10.4). No complex analysis is required for this theme, with the reporting instead focusing on any new intrusions. This information will simply be presented as a cumulative graph of new non-native species.

Table 10.4. Summary of the analytical approaches for data relating to biosecurity status.

Data element: Biosecurity status					
Methodologies	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• iNaturalist • Observation • Key species surveys	• Status (non-indigenous, unwanted organism, cryptogenic, native) • Date • Location name • Site (latitude, longitude – WGS1984) • Sample unit (type and size) • Sample number/ identifier	All taxonomic identifications must be confirmed.	No analysis is needed for these data, but the number and name of non-native species must be reported.	Data should be presented in a table, or the names of the unwanted organisms should be published in the marine reserve report or report card.	Objective 8.1 – Spatial
			Over time, the number of new non-native organisms that occur in marine reserves can be reported.	Data may be presented as a bar or line chart.	Objective 8.2 – Temporal

10.7 Reporting and communicating

Reporting on the spread of non-native species through marine reserves will be an important contribution to understanding their overall integrity. Non-native species can pose significant threats, so their early detection and reporting will be essential for making relevant management decisions. An important output of the MMRF will be regular reporting on the numbers and types of non-native species that are occurring in marine reserves (Table 10.5).

10.7.1 Marine reserve reports and report cards

The data element monitored by Theme 8 can be included in marine reserve reports and report cards using the analytical products. This theme currently focuses on the presence or absence of a non-indigenous species rather than the establishment or some other such metric. Therefore, the status definitions of non-native species in marine reserves shown in Table 10.6 reflect this current focus of the MMRF (see Table 2.5 for definitions of trend). Future iterations will move beyond presence/absence reporting.

10.7.2 Other reporting opportunities

Ensuring that Biosecurity New Zealand[59] is immediately made aware of any new pests found in marine reserves will be key to making timely management decisions. Reports of exotic pests or diseases can be made over the phone (0800 80 99 66), and DOC marine reserve rangers will be trained to recognise, collect and report non-native species to Biosecurity New Zealand. The data will be uploaded to the Marine Biosecurity Porthole[60] and used to make strategic decisions about marine biosecurity in Aotearoa New Zealand.

59 www.mpi.govt.nz/biosecurity/marine-pest-disease-management/marine-pest-management-system/
60 www.marinebiosecurity.org.nz/

Table 10.5. Information relating to Theme 8 that can be included in reporting using products derived from analyses of the data element that will be monitored.

Outcome Objective	Reducing spread and dominance of exotic species
Indicator	**Exotic species occurrence**
Data element	Biosecurity status
Reporting	• Number and names of non-native species discovered inside marine reserves • Number of marine reserves with new observations of non-native species

Table 10.6. Definitions for reporting on the status of the measures for Theme 8 – Detect non-indigenous species.

Status	Definition
Excellent	No invasive species are present within the marine reserve (or near its boundaries) and a well-established surveillance network is in place to detect any potential incursions.
Good	No invasive species are present within the marine reserve but no surveillance network is established to detect any future incursions.
Fair	One known invasive species is present within the marine reserve and its distribution and effects are being monitored.
Poor	More than one known invasive species is present within the marine reserve and they are well established and having detrimental effects on the native assemblages.
Undetermined	The status of this measure cannot be determined.

11 Theme 9 – Determine the effects of extreme events

What	Record and monitor the impacts of extreme events on marine reserves
Who	DOC, whānau, hapū, iwi, MPI, regional councils
When	The frequency of monitoring will be determined by the type and impacts of the extreme event
Where	Marine reserves and their surroundings impacted by extreme events
How	Post-event monitoring will be dictated by pre-event monitoring data, the type of extreme event and the extent of the impact
Why	To determine how extreme events contribute to the substantial changes of marine habitats and biodiversity

11.1 Background and objectives

Extreme events are an integral part of the cycles and trends of natural processes that shape ecosystems and communities over long (sometimes geological) time scales (see Box 11.1).[61] As an island nation, Aotearoa New Zealand is subjected to a wide range of known extreme events in the coastal marine space. The natural forces that create the country's rugged and diverse landscapes, including earthquakes, tsunamis, volcanic eruptions, weather events, floods, sea storms and landslides, present many hazards that affect marine ecosystems.

Monitoring extreme events will allow Aotearoa New Zealand to meet its national and international obligations and the country's protected areas to be more effectively managed. Aotearoa New Zealand has committed under the CBD to protect a representative range of its marine habitats (Aichi Target 11),[62] to ensure that the rate of habitat loss and degradation is significantly reduced (Aichi Target 5),[63] to enhance ecosystem resilience through conservation and restoration (Target 15),[64] and to widely share and transfer the knowledge relating to biodiversity (Target 19).[65] The Aichi Targets suggest several measures that can be used to determine if habitats are changing through time, including identifying trends in habitat extent, fragmentation and condition. Monitoring and reporting on the impacts of extreme events on marine habitats and biodiversity would fulfil all four of the Aichi Targets mentioned above.

61 https://niwa.co.nz/natural-hazards/hazards/coastal-hazards
62 www.cbd.int/aichi-targets/target/11
63 www.cbd.int/aichi-targets/target/5
64 www.cbd.int/aichi-targets/target/15
65 www.cbd.int/aichi-targets/target/19

Box 11.1: What is an extreme event?

An extreme event can be described as a disturbance to the environment, where a disturbance is defined as any physical or biotic event that has the potential to have long-lasting ecosystem effects, for the most part extending over decades. A marine disturbance can affect the entire seabed of an MPA or adjacent coastal substrates.

Extreme events are classified as abiotic or biotic, depending on their origins:

- **Abiotic extreme events** are accidental events that are related to human activities (e.g. chemical spills), geology, weather or the climate.
- **Biotic extreme events** are sudden or unexpected significant changes in a population.

In general, biotic extreme events are linked to abiotic extreme events either directly (e.g. heat waves, floods) or indirectly (the destruction of healthy ecosystems by extreme events can lead to population booms in opportunistic organisms).

In October 2011, the cargo ship *Rena* ran aground on Astrolabe Reef in the Bay of Plenty, which was a catastrophic event for the surrounding ecosystem. A review of the response to this event concluded that 'Despite the Department of Conservation's regional presence, infrastructure, and the responsibilities shared for environmental protection, there was no response-specific policy-level agreement about cooperation between MNZ [Maritime New Zealand] and the department, and no response-specific protocols on interoperability issues in the national contingency plan' (Murdoch 2013). While the MMRF does not specifically address this gap, it will go some way towards ensuring that DOC will have a monitoring response for future extreme events.

In the absence of extreme events, ecosystems and species populations tend to maintain a state of stable equilibrium or exhibit a gradual trend of change. Extreme events can disrupt this stability and speed up the overall trend or move it in a different direction, which can drive the evolution of ecosystems. Extreme events can expend very high levels of energy and impart these to the environment, exceeding the thresholds or tipping points that determine ecosystem responses (Hawkins et al. 2009). Extreme events can also sometimes dominate the longer, but more gradual, impacts of 'normal' conditions by causing changes that the system is less able to withstand or recover from (Jentsch et al. 2007). For instance, a severe sea storm can create waves that move very large quantities of sediment or detach biota from their substrate; a large river flood can bring down large amounts of sediment that fill estuaries or smother seabed life; a tectonic event can strand shore life 'high and dry' or cause the mass failure of submarine canyon slopes; and a shipping disaster can smother beaches with toxic oil and debris.

The distinction between a 'normal' event and an 'extreme' event cannot readily be defined, but the intent is for this section to focus on the latter. Marine monitoring needs to allow the detection and measurement of both gradual changes over time and substantial changes brought about by sudden extreme events.

11.1.1 Why is post-event monitoring important?

Many weather and climate extremes are a result of climate variability, and natural decadal and multidecadal variations in the climate provide information that informs anthropogenic variability. Climate change has disrupted the natural cycles of weather-related extreme events, and it is anticipated that the number and intensity of these events will increase in the future, which may lead to an increase in the frequency of extreme biotic events, such as algal blooms or population crashes, which, in turn, can lead to a reduction of resilience in some habitats. Other extreme events, such as earthquakes, landslides and volcanic eruptions, occur less frequently but have the potential to significantly disrupt ecosystems.

Monitoring how ecosystems respond to extreme events of different types and intensities is crucial to gaining an increased understanding of the resilience of ecosystems and changes over longer timeframes, as well as the conservation management required to sustain these ecosystems after the event. The use of monitoring programmes can clarify the short- and long-term impacts of different types of events, their intensity, and their cumulative effects on the environment. The most efficient monitoring of extreme events will be supported through robust monitoring of the area prior to the event, such as is outlined for other themes in the MMRF.

Monitoring and analysing environmental responses to various types of extreme events also helps in finding the optimum level of protection required for lesser impacts to ensure ecological resilience. Most past decisions in MPA planning have assumed a relatively stable environment and have not taken into consideration the cumulative effects of extreme events.

Being prepared to respond to the devastating impacts of these events on the marine environment, especially in marine reserves, will lead to a wealth of information that will help to:

- Improve monitoring techniques.
- Understand the differences, if any, in ecosystem and habitat responses to disturbances within and outside marine reserve boundaries.
- Improve understanding of the cumulative effects of these events (including recurrent climate events) on marine reserves.
- Gain insight into how extreme events shape marine ecosystems (through both sudden and accumulated changes).
- Provide opportunities to study how marine ecosystems react, recover and adapt to such events.

11.1.2 Objectives

This theme focuses on listing extreme events that have and could occur in Aotearoa New Zealand's waters and describing how to choose appropriate monitoring tools to gain insights from these extreme events and support decision making to efficiently restore damaged ecosystems and habitats.

Monitoring objective 9.1 (spatial): To monitor and compare the changes in habitats and biodiversity in protected and unprotected marine areas after an extreme event.

Research question: Do marine reserves provide more ecosystem resilience?

Monitoring objective 9.2 (temporal): To monitor and report on the impacts and temporal changes to habitats and associated biodiversity within marine reserves after an extreme event.

Research question: Are there detectable changes in marine reserves after extreme events?

11.2 Existing monitoring programmes

Monitoring programmes for extreme events need to be divided into pre- and post-event monitoring. Most pre-event monitoring programmes (baseline monitoring) are detailed in other sections of this report, including habitat mapping (Theme 2), water quality (Theme 6) and climate-related monitoring (Theme 3).

Long-term datasets that track change in the marine environment are essential for an ecosystem-based approach to marine protection and resource management. Where relevant historical monitoring information exists, Theme 9 can build on these historical data as a pre-event baseline (temporal dataset) in a marine reserve and the surrounding environment.

Post-event monitoring uses a wide range of monitoring toolboxes[66] to document short- and long-term changes in the marine environment. Over the years, Aotearoa New Zealand has been subjected to a wide range of extreme events, some of which have directly impacted MPAs and have led to substantial post-event monitoring programmes (Table 11.1).

11.3 Sampling design

11.3.1 Selecting indicators

This theme provides guidance on how to measure data elements that will contribute to Objective 13 'Biodiversity provides nature-based solutions to climate change and is resilient to its effects' from the ANZBS (DOC 2020c; Table 11.2). As extreme events often occur over defined areas, their measurement needs to identify the areal extent, magnitude and duration of the event.

Future updates will expand this to include measures relating to the extent and impact of fire, toxic algal blooms, and disease and invertebrate pest outbreaks (Table 11.3).

11.3.2 Selecting monitoring programmes

This theme does not draw on any single monitoring programme but instead the entire MMRF, requiring monitoring to be established in marine reserves such that post-event monitoring can build on a baseline.

Pre-event monitoring

Monitoring is important for the efficient management of all marine reserves. It is important that marine reserves are monitored both before and after an extreme event, so that the pre-monitoring data can be used to inform the post-event management response. The pre-event information that will be most useful for monitoring the impacts of extreme events are:

- **Habitat mapping** – this is the most important information for detecting post-event changes (see section 4, Theme 2 – Habitat changes).
- **Species inventories** – for example, using eDNA or drawing on information from key species surveys (see section 6, Theme 4 – Key species).
- **Visual records** – aerial surveys, drones, land-based photopoints, fixed cameras, drop cameras, underwater filming and photography.

These data should be collected as a priority for all marine reserves, subject to feasibility.

66 www.doc.govt.nz/our-work/biodiversity-inventory-and-monitoring/marine/

Table 11.1. Extreme events that can occur in Aotearoa New Zealand, listed roughly in order from small- to large-scale events. Note: An extreme event can also be a combination of several of these events (e.g. volcanic eruption and tsunami, floods and landslides).

Event category	Type of event	Impacts on ecosystems	Example and biogeographic region	Reference/link
	Localised events (ca. 1–50 km)			
Geological	Coastal landslide	Smothering/collapse	Te Angiangi landslide (Eastern North Island)	Macpherson 2013
Geological	Volcanic eruption	Water quality, substrate smothering, wildlife impacts, species stress, community changes		
Geological	Submarine landslide	Canyon collapse / sedimentation	Kaikōura earthquake (East Coast South Island)	New Zealand Coastal Society 2018
Biogenic	Organism die-off due to disease (e.g. seaweed)	Habitat change		
Geological	Seismic (uplift, downlift)	Intertidal/subtidal shifts in habitat range	Kaikōura earthquake (East Coast South Island)	New Zealand Coastal Society 2018
Biogenic	Pest incursion	Community change	*Undaria pinnatifida* (Fiordland)	www.doc.govt.nz/nature/pests-and-threats/weeds/common-weeds/asian-seaweed/
Anthropogenic	Oil spill or other discharge (e.g. plastic pollution, other pollutants)	Water quality, substrate smothering, wildlife impacts, species stress, community changes	Fox Glacier/Te Moeka o Tuawe clean-up (West Coast South Island); *Rena* oil spill (North Eastern)	New Zealand Coastal Society 2014
	Widespread events (ca. 50–1000 km)			
Biogenic	Algal bloom	Trophic effects, toxicity	Algal bloom monitoring (North Eastern)	Roth 2014
Climate	Flood/sedimentation/ freshwater event	Siltation, water quality, altered seabed		
Geological	Tsunami	Wave damage, inundation, sedimentation		
Climate	Major meteorological storm (cyclone, storm surge)	Habitat and community change, extreme water levels		
Climate	Warming or cooling event (sea/air)	Species stress	Shellfish die-off in Long Bay-Okura Marine Reserve (North Eastern)	C. Duffy, DOC (pers. comm.)

Abbreviations: DOC, Department of Conservation Te Papa Atawhai.

Table 11.2. Indicators, measures and data elements relating to Theme 9 – Determine the effects of extreme events. Adapted from McGlone et al. (2020).

Indicator 9.1: Disturbance	
Measure 9.1.1: Mass movement	
Description	Disturbance of the marine landscape may produce a catastrophic local loss of ecological integrity or may simply be part of natural landscape regeneration. Massive tsunamis and landslides (submarine and subaerial) have been a recurrent feature of the coast and shelf of Aotearoa New Zealand.
Data elements	**Habitat changes** Extent and types of habitats impacted/lost or created by the erosion, flux and deposition of mass movement materials. **Water quality** Quality of the water after an extreme event, as described by the data elements in Theme 6. **Key species** Abundance, distribution and diversity of selected key species.
Links to other measures	6.2.1: Ecosystem primary productivity (Theme 6 – Water quality) 6.3.1: Sedimentation and sediment quality (Theme 6 – Water quality)
Measure 9.1.2: Riverine and coastal alteration	
Description	Rivers, coastlines and seabeds are constantly changing as a result of natural events (storms, earthquakes, tsunamis, floods and mudslides). The coast will be impacted by climate change, and coasts and rivers will be impacted by anthropogenic modification of water flow. It is important to keep track of these changes to better understand their effects on the indigenous ecosystems they support. This measure differs from Measure 1.1.5.3 'Anthropogenic landform and substrate disturbance' in that it encompasses only natural changes or indirect anthropogenic alteration (e.g. erosion, rising sea levels), whereas Measure 1.1.5.3 relates to direct, human-caused disturbances. This distinction is maintained because changes resulting from direct human activity have a simple (although politically fraught) remedy of halting the activity, whereas natural drivers of erosion do not. Natural erosion is the movement of natural material, usually through the forces of water and wind.
Data elements	As for mass movement (see above).
Links to other measures	6.2.1: Ecosystem primary productivity (Theme 6 – Water quality) 6.3.1: Sedimentation and sediment quality (Theme 6 – Water quality)
Measure 9.1.3: Anthropogenic landform and substrate disturbance	
Description	Mining, dredging, trawling, marine and freshwater installations, roading, infrastructure, off-road vehicle recreation, and other human activities disturb indigenous ecosystems. Where these pose a serious threat to ecological integrity, they should be documented and monitored. The direct removal of natural soils and ecosystems is a major consequence of these activities, as is increased sedimentation, which is of particular concern in freshwater and marine situations and is addressed by this measure.
Data elements	As for mass movement (see above).
Links to other measures	6.2.1: Ecosystem primary productivity (Theme 6 – Water quality) 6.3.1: Sedimentation and sediment quality (Theme 6 – Water quality)

Table 11.3. Indicators, measures and data elements that are to be implemented in future iterations of the Marine Monitoring and Reporting Framework.

Indicator 9.1: Disturbance	
Measure 9.1.4: Extent and impact of fire	
Description	Floods can carry debris and diverse pollutants after extreme fires.
Data elements	**Pollutants** Substances that pollute the water. **Sedimentation** The settling or deposition of material on the ocean floor.
Links to other measures	6.2.1: Ecosystem primary productivity (Theme 6 – Water quality)
Measure 9.1.5: Toxic algal blooms	
Description	Toxic algal blooms are largely a human health issue, but effective monitoring has meant that no human poisonings have been reported in recent years (Rhodes et al. 2013). Mats or blooms of cyanobacteria, dinoflagellates and diatoms occur under conditions that are characterised by warm temperatures, sunlight, low or stable river flows, and nutrients. Under some circumstances, they may be an indicator of adverse human impacts, but there appears to be no obvious anthropogenic trigger to these blooms.
Data elements	**Bloom species** Types and concentrations (in water and tissues) of bloom species. **Bloom characteristics** Toxicology and chemistry of the bloom. **Species survival** Survival parameters (mortality and health) of the likely affected species.
Links to other measures	6.2.1: Ecosystem primary productivity (Theme 6 – Water quality)
Measure 9.1.6: Disease and invertebrate pest outbreaks	
Description	Outbreaks of diseases and algal and invertebrate pests have had a substantial effect on Aotearoa New Zealand's ecosystems in the past – for instance, mass seal deaths in the subantarctic islands, an increasing trade intensity (with numerous potential sources of disease and associated vectors), climate change and the human disruption of ecosystems will undoubtedly result in increased episodic outbreaks of diseases that are important to the biota. Therefore, unusual outbreak events should be recorded where possible, even when they appear to be of no immediate concern. It will be important to have baseline data so that it can be determined whether the observed phenomena are genuinely unusual or of concern or are merely cyclic ecosystem fluctuations. The majority of these events will not be uncovered by surveillance monitoring but rather by happenstance. It is important that they are documented adequately once discovered, with determination of the biodiversity element impacted; causal event, disease or pest involved; area affected with some indication of intensity; and duration.
Data elements	**Infection rate** The rate at which indigenous species become infected with disease. **Mortality** A measure of the number of indigenous species deaths due to disease.
Links to other measures	8.1.1: Occurrence of self-maintaining populations of exotic species (Theme 8 – Non-indigenous species)

11.3.3 Developing a sampling design

The sampling design will depend on the type of event that occurred, its impact and its locality (i.e. the accessibility of the marine reserve). The frequency of monitoring and the types of toolboxes that have previously been used in post-event monitoring are detailed in the guidance table in Appendix 5.

How are sites to be selected?

Extreme events mostly occur over large areas and their impacts need to be recorded and monitored both inside and outside marine reserves to understand their real impacts and capture differences in change. The detailed monitoring protocols to choose sampling sites for each of the toolboxes are available within the toolbox manuals, so this section focuses on providing guidance on how to choose the appropriate toolbox(es).

How often should measurements be taken at these sites or a subset of these sites?

Guidance on the frequency of measurement at sampling sites for each type of monitoring tool is provided in Appendix 5. Further details and complementary information can be found in the individual toolbox manuals and in other sections of this report.

11.4 Monitoring protocols

Every extreme event, and the impact it has on a marine reserve, will be different. Therefore, it is important for a monitoring programme to be designed to meet the specific needs of tangata whenua, the community, marine reserve managers and other agencies at the time of the event and in the subsequent days and weeks. This section is designed to provide managers of marine reserves with options and considerations to help design a monitoring plan in response to an extreme event, but the information does not need to be considered prescriptive. The type, locality and magnitude of the event (or cumulative events) will be determining factors to decide on the choice of toolbox(es) and the sampling frequency of the monitoring programme. Other considerations that are not specifically mentioned in this section, such as community interest, may also influence the type and duration of monitoring.

The design of a plan for post-event monitoring will depend on multiple factors and should follow the process outlined in steps 1–3 below (see Figs 11.1–11.3).

Step 1: What is the preliminary assessment of the impact on the marine reserve after the extreme event?

First, consider the type, location, and severity of the extreme event:

- Identify and confirm that the event of interest is classified as an extreme event.
- Consider the locality of the marine reserve and surroundings that are affected by the extreme event, as this is one of the key considerations for prioritising monitoring toolboxes. The locality and types of impacts (e.g. seabed lift, landslide) will determine the accessibility of the sites for post-event monitoring.
- Consider whether the event was localised or widespread – for example, a temperature spike will affect a specific number of species or vulnerable habitats, whereas an earthquake will have an ecosystem-wide impact. For localised impacts, monitoring might be spatially restricted, whereas wide-scale impacts will require long-term monitoring to fully capture changes in communities and habitats within and outside an MPA. The severity of an extreme event integrates its magnitude and its persistence.

Then, undertake a brief assessment of the apparent impact of the event on habitats and species:

- From a safe standpoint or by aerial means, assess if the site can be accessed safely. If visible, assess the extent of the impacted area (e.g. mudslide, coverage of oil leak, area of lifted seabed by an earthquake).
- Obtain advice from one or more experts on whether the extent of the impact requires the implementation of a post-event monitoring plan.

Also consider the health and safety risks for undertaking monitoring in the area:

- Discuss the health and safety risks and issues with undertaking monitoring within and around the boundary of the marine reserve. Any discussions and subsequent recommendations should be in collaboration with other agencies involved in any emergency response.

Step 2: Does the post-event response and design of a monitoring programme need to be coordinated with a wider task force?

Consider whether the selected post-event monitoring programme needs to tie in with a national response:

- If so, then DOC must coordinate with that task force. This is usually through a Coordinated Incident Management System structure.

Step 3: What needs to be considered to design a post-event monitoring programme?

Before starting the design:

- Ensure that whānau, hapū and iwi are informed and involved.
- Consider whether the initial monitoring programme (which will be based on ecological considerations) needs to be adapted to include social and cultural concerns and priorities.
- Consider the cost of the designed monitoring programme (e.g. the cost of the selected toolboxes, number of sites and duration of the programme). Some toolboxes or the sampling frequency may need to be adjusted based on the available budget.
- Consider interest from other organisations, agencies or the community to understand the impact of the event on marine reserve ecology.

In developing the design, also consider:

- The accessibility of the marine reserve and potential sites.
- The pre-event baseline information that is available.
- The sampling designs detailed in other themes and toolboxes.
- The opportunity presented to influence post-event management and knowledge.
- Whānau, hapū and iwi objectives for the marine reserve.
- The frequency of sampling – seasonal variation must be taken into consideration. If the post-event monitoring extends beyond 1 year, then recurring yearly sampling must be done in the same month as at the start of the monitoring.
- The duration of monitoring – the long-term monitoring should cease when the environment has reached a set of pre-determined end-point criteria (e.g. population stabilisation, recovery, removal of oil residues from the environment). This will need to be assessed yearly based on an analysis of the data.

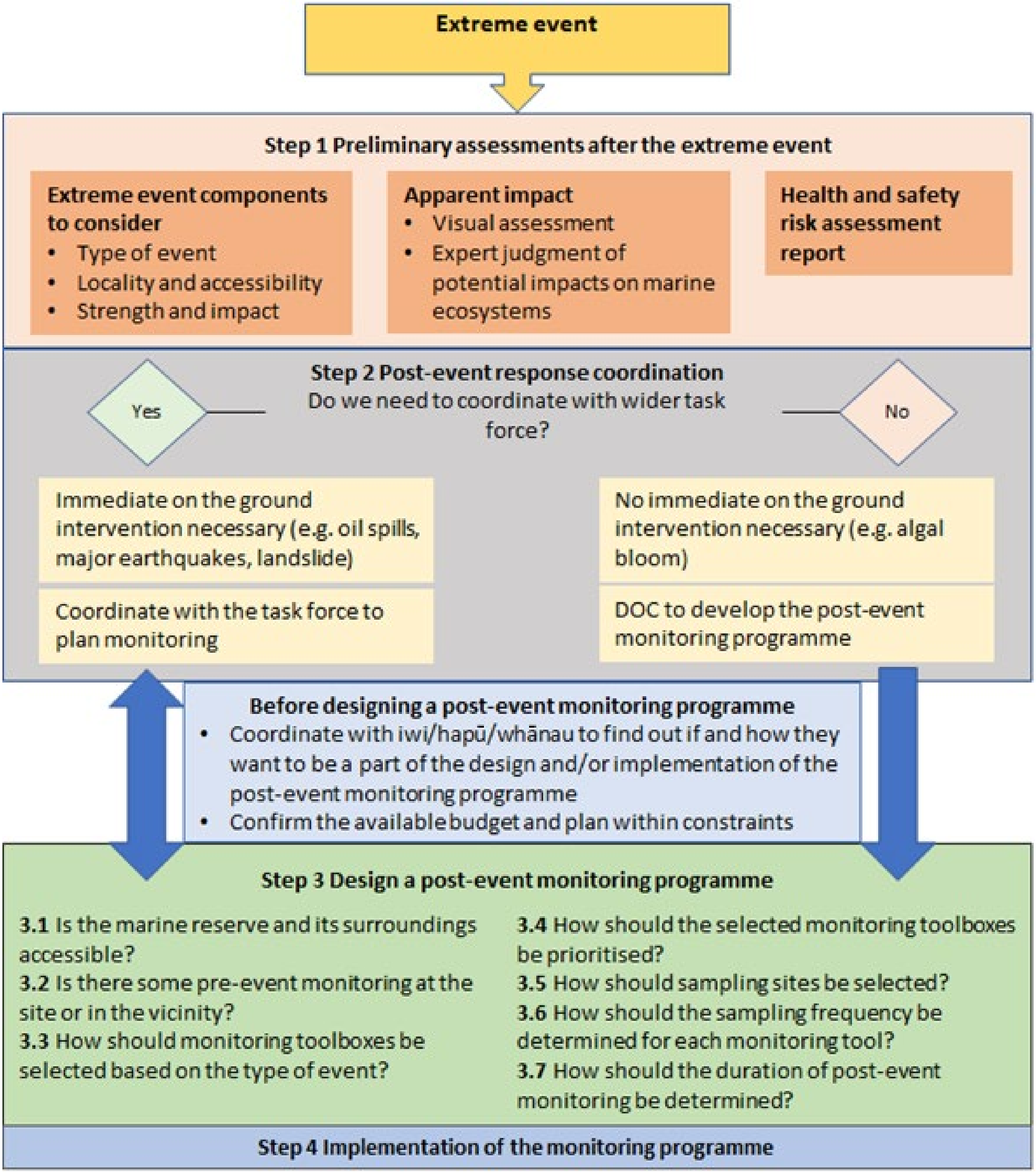

Figure 11.1. Overall guidance for designing a plan for monitoring the impacts of an extreme event in a marine reserve. Abbreviations: DOC, Department of Conservation Te Papa Atawhai.

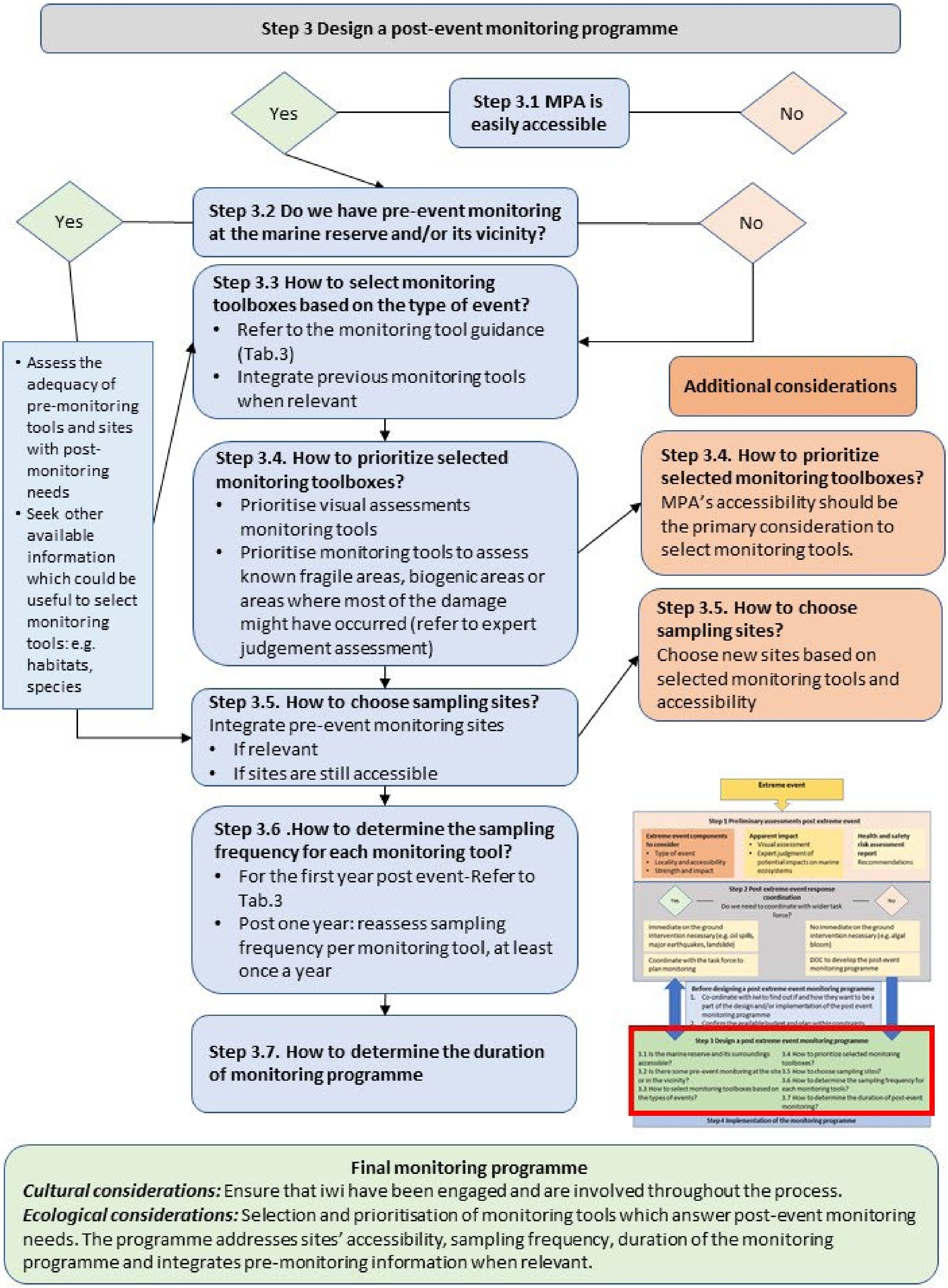

Figure 11.2. Detailed guidance on the steps required for Step 3 – Design a post-event monitoring programme.

Step 3.7 How should the duration of post-event monitoring be determined?

- Experts will determine a set of end-point criteria based on type of extreme event, its impact, the results of the preliminary assessment and other available data
- Experts will estimate the duration of the post-event monitoring based on the set of end-point criteria
- A yearly review of the data during monitoring will determine when the end-point criteria have been reached

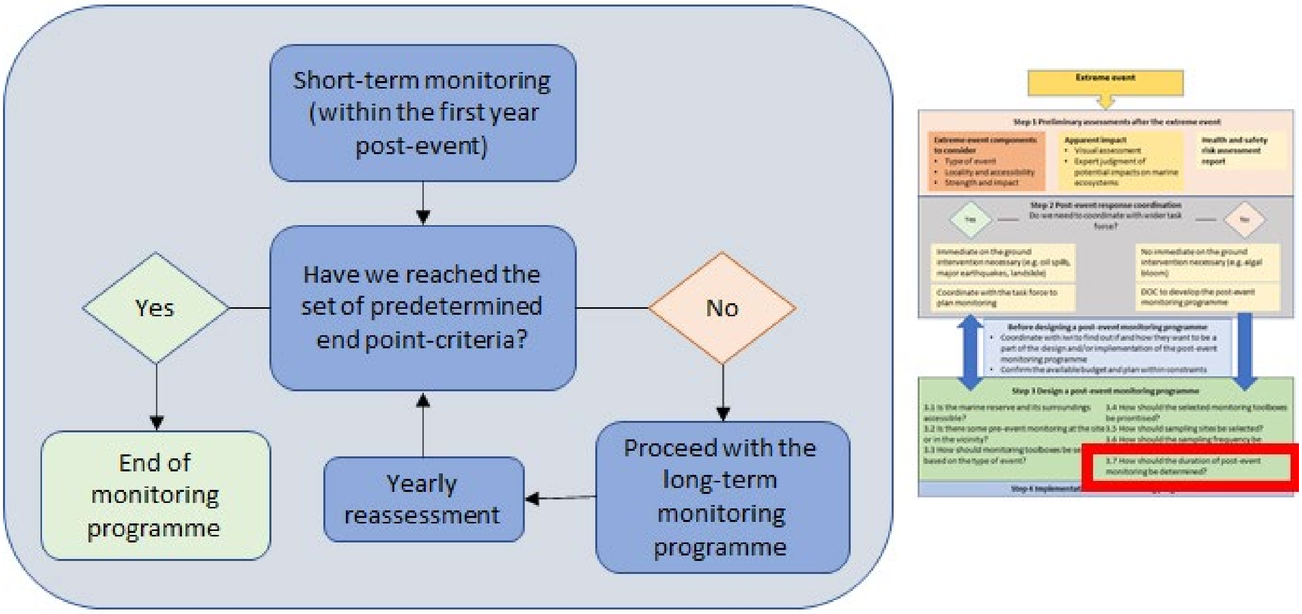

Figure 11.3. Detailed guidance on the steps required to determine the length of post-event monitoring (Step 3.7).

11.5 Data management

Details of how data management is currently approached by DOC are provided in section 2.5.5.

11.6 Data analysis

This section provides guidance on the selection of toolboxes for monitoring after an extreme event. Detailed protocols on monitoring and reporting for each type of monitoring toolbox have been developed under other themes in the MMRF and within toolboxes.

Data preparation/pre-processing, hypothesis testing and data visualisation should be followed as described for the themes and toolboxes. A statistician should be consulted for any analysis of data collected for this theme.

11.7 Reporting and communicating

Reporting on extreme events can shed light on the effects of large-scale environmental changes (Table 11.4). These reports will be used as general guidance to improve scientific knowledge on the responses of marine ecosystems to different impacts.

Reporting on the impacts of extreme events will provide information on the long-term effects of various disturbances, as well as their cumulative effects.

Reporting on long-term monitoring of different categories of extreme events will enhance our ability to determine their projected impacts on the natural environment and hence improve decision making in protecting marine areas and designing a more resilient MPA network. The gathered knowledge can also feed into adaptative conservation planning decision making.

Together, this information will not only improve understanding of natural processes (fragility, adaptation, resilience and recovery of species, habitats and ecosystems) but will also offer an opportunity for understanding the broader socio-economic impacts of such events. Community interests in understanding the impacts of extreme events on their environment should also be reflected in the report.

Table 11.4. Information relating to Theme 9 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective	**The diversity of our natural heritage is maintained and restored**
Indicator	**Disturbance**
Data elements	Habitat changes Water quality Key species
Reporting	• Extent and types of habitats impacted (Theme 2 – Habitat changes) • Abundance, distribution and diversity of selected key species (Theme 4 – Key species) • Water quality – Suspended sediment load / turbidity (Theme 6 – Water quality) • Water quality – pollutants (Theme 6 – Water quality)

11.7.1 Marine reserve reports and report cards

Extreme events can be reported on through the report card format. It is likely that this would be ad hoc across the marine reserve network, as this theme may not be relevant to report on if no events have occurred within the reserve vicinity.

The definitions for reporting on the status of the measures monitored under this theme are described in Table 11.5 (see Table 2.5 for definitions of trend).

Table 11.5. Definitions for reporting on the status of the measures for Theme 9 – Determine the effects of extreme events.

Status	Definition
Excellent	The habitats and species in the marine reserve appear to be unaffected by the event or have returned to their pre-event state. There are no detectable negative impacts from the event on the ecological integrity of the habitats and species within the marine reserve.
Good	Changes to the composition and ecological function of biodiversity within the marine reserve have occurred because of an extreme event, but the ecological integrity of the biodiversity is comparable to that at other unaffected sites. Local populations appear to be performing their functional role in the environment and there have been minimal negative impacts on biodiversity within the reserve.
Fair	Changes to the composition and ecological function of biodiversity within the marine reserve have occurred because of an extreme event and the ecological integrity of habitats and species has been somewhat degraded. As a result of the event, local populations of species that were previously found within the marine reserve have been displaced, harmed or killed but are showing signs of recovery.

Continued on next page

Table 11.5 continued

Poor	Changes to the composition and ecological function of biodiversity within the marine reserve have occurred because of an extreme event and the ecological integrity of habitats and species has been severely degraded. As a result of the event, local populations of species that were previously found within the marine reserve are functionally extinct.
Undetermined	The status of this measure cannot be determined.
Not applicable	No extreme event has occurred in this marine reserve.

11.7.2 Other reporting opportunities

When an extreme event does occur, it can garner very high, sometimes immediate, community and media interest. Reporting on the event's impact on the marine ecosystem can take time, so it is important to consider the information needs of the community and tailor the reporting outputs accordingly – and any particular needs of whānau/hapū/iwi/Māori to be kept informed of monitoring responses and findings need to be prioritised. The format of these communications will need to be flexible and could take the form of short email updates through to more comprehensive long-term reports with summarised, easy-to-read factsheets.

12 Theme 10 – Understand the impact of pollution

What	Beach-cast marine litter
Who	DOC, Sustainable Coastlines, whānau, hapū and iwi, communities
When	Every 3 months
Where	All marine reserves where possible
How	Litter Intelligence monitoring protocol
Why	To understand where litter needs to be removed from marine reserves

12.1 Background and objectives

Marine pollution is a significant issue that is affecting species and ecosystems globally. Marine pollutants include agricultural run-off, discharges of nutrients and pesticides, untreated sewage, oil spills, noise, light, and litter (see Box 12.1). In particular, marine litter on the coastline is one of the most obvious signs of marine pollution and can have either land- or sea-based origins. Land-based sources of marine litter include inputs from rivers, sewage and storm water outflows, tourism and recreation, illegal dumping, and waste disposal sites, while sea-based sources include commercial shipping, fisheries and aquaculture activities, pleasure crafts, and offshore installations. The slow rate at which most marine litter degrades, combined with its continuous accumulation, is leading to a wide spectrum of environmental, economic, safety, health and cultural impacts (Ryan & Moloney 1993; Otley & Ingham 2003; UNEP 2005; Cheshire et al. 2009) including entanglements and ghost fishing, ingestion (leading to intestinal blockage, malnutrition and poisoning), blockage of organisms' filter-feeding apparatus, physical damage to fragile habitats, vectors for marine pests, a loss of aesthetics and indigenous values, costs to tourism, the leaching of poisons, and hazards to recreational users (Laist 1987; Barnes 2002; Derraik 2002; Cheshire et al. 2009).

Box 12.1: Definitions of pollution and litter in the marine context

Marine pollution refers to the:

> *... direct or indirect introduction by humans of substances or energy into the marine environment (including estuaries), resulting in harm to living resources, hazards to human health, hindrances to marine activities including fishing, impairment of the quality of sea water and reduction of amenities.* (UNEP 1997)

Marine litter or marine debris is defined by the United Nations Environment Programme (UNEP) as any persistent, manufactured or processed solid material that has been discarded, disposed of, abandoned or lost in the marine and coastal environment (UNEP 2005).

DOC has international and national obligations towards limiting the impacts of pollution on species and ecosystems. Internationally, Aotearoa New Zealand has committed under the CBD to ensure sustainable management of living resources, with Aichi Target 8[67] requiring that 'by 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity'. The Aichi Targets suggest several indicators that can be used to determine the impact of pollution on biodiversity. The indicator of most relevance to this goal is 'Trends in pollution deposition rate'.

The specific Outcome Objective under the OMF relating to pollution is 1.2 – Limiting environmental contaminants. While there are several environmental contaminants that can be monitored, this section initially focuses on Measure 1.2.1.4 'Marine litter'. Marine litter is just one of many different types of marine pollution and is not necessarily an indicator for other types of pollution (e.g. nutrients), but has been chosen as an initial focus because it has known impacts on marine wildlife and natural character; it has a high level of public interest and involvement in Aotearoa New Zealand; robust monitoring protocols have been established for beach-cast litter; and there is good potential for monitoring to inform and contribute to clear management actions.

12.1.1 Pollution and marine reserves

Marine reserves are often intended to represent the natural conditions of particular marine areas in terms of the ecology, landscape quality and natural character. Beach litter and other pollution tend to degrade these qualities and can affect the structure and functioning of communities within marine reserves. Although there is no difference in the regulation of marine litter inside and outside a marine reserve (i.e. littering is illegal in both areas), the presence of a marine reserve can encourage actions that either reduce or increase the amount of litter within its boundaries and its nearby environment. For example, people might be more careful about disposing of their waste, less likely to drop rubbish and more inclined to pick up beach litter if they know they are in or near a marine reserve. Alternatively, a marine reserve could attract a greater number of people than other locations, which might result in increased amounts of litter within the area. Even without increased visitation, marine reserve boundaries are no barrier to the dispersal of marine litter, so marine reserves are not immune to the general incursion and effects of marine debris.

12.1.2 Objectives

Monitoring objective 10.1 (spatial): To evaluate changes in the quantity and type of marine litter across and between marine reserves and non-reserve sites.

Research question: What is the amount and type of marine litter at a given site and does this vary between marine reserves and non-reserve sites?

Monitoring objective 10.2 (temporal): To assess the magnitude and trend of the quantity and type of marine litter in marine reserves over time.

Research question: Are the magnitudes and trends of marine litter in marine reserves changing?

67 www.cbd.int/aichi-targets/target/8

12.2 Existing monitoring programmes

The most comprehensive marine litter monitoring programme in Aotearoa New Zealand is Litter Intelligence,[68] which is run by the charitable organisation Sustainable Coastlines.[69] Litter Intelligence is a long-term beach-cast litter monitoring programme that aims to provide full monitoring coverage of all of Aotearoa New Zealand's mainland bioregions. Its medium-term aim is to establish a network of sites over a full range of bioregions, beach types and urban–rural locations, and in February 2020, these efforts extended over 122 sites, albeit with some gaps in the network. Figure 12.1 shows where the current sampling sites are in relation to marine reserves and their 1-km and 5-km buffer zones. The methods used by the Litter Intelligence programme to monitor beach-cast litter were co-developed with DOC, based on the 'UNEP/IOC [United National Environmental Programme / Intergovernmental Oceanographic Commission] guidelines on survey and monitoring of marine litter' (Cheshire et al. 2009), and were approved by MfE and Stats NZ for use in Aotearoa New Zealand's environmental domain reporting following a review of methodological rigour.

Surveys and monitoring programmes for benthic and floating litter are undertaken around the world (Ryan et al. 2009), although only a few such surveys have been conducted in Aotearoa New Zealand (Backhurst & Cole 2000) and there are no established monitoring programmes here. The 'UNEP/IOC guidelines on survey and monitoring of marine litter' provide international guidelines for benthic litter assessments (using benthic trawl, towed net and visual survey methods) and guidelines for floating litter assessments (using trawl and visual survey methods).

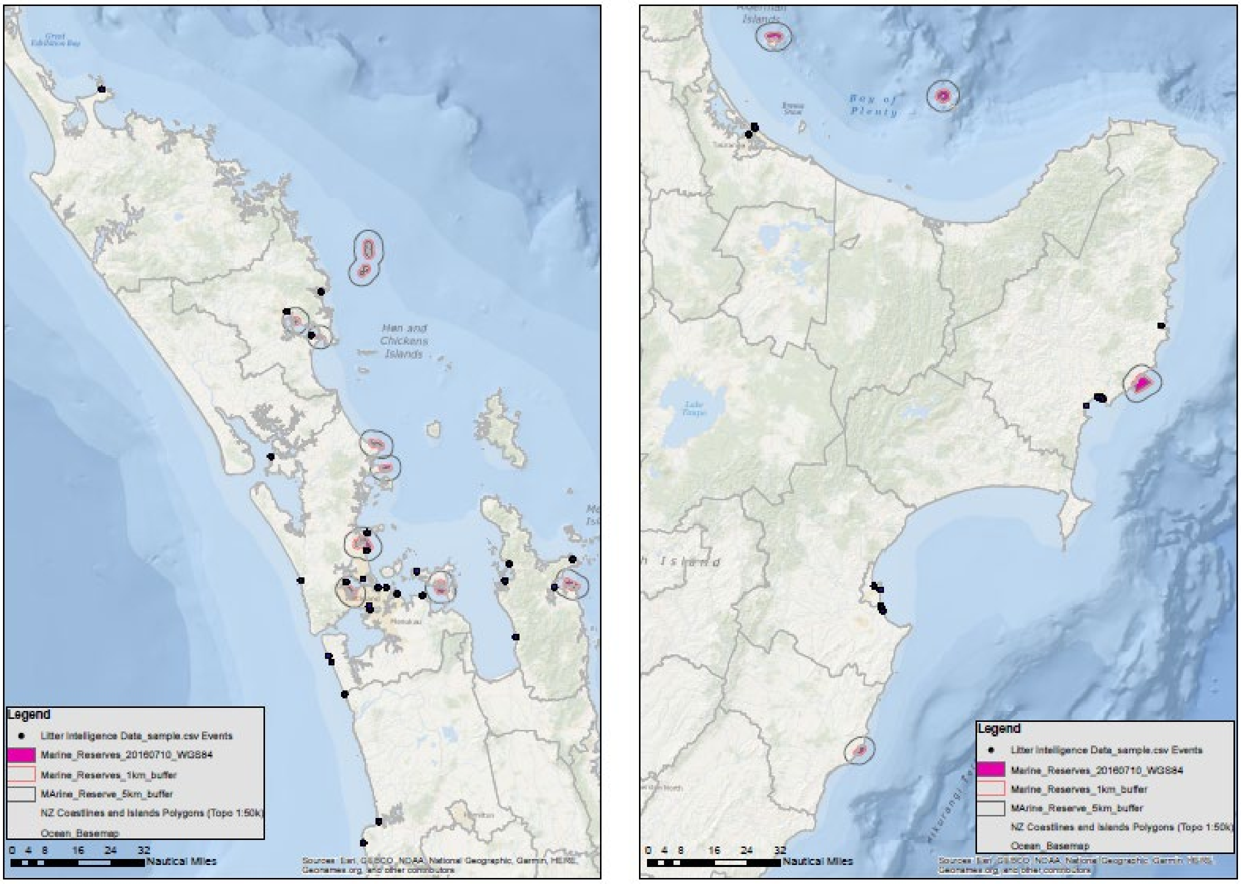

Figure 12.1. Maps of current Sustainable Coastlines sampling locations and marine reserves with 5-km boundaries.

68 https://litterintelligence.org/
69 https://sustainablecoastlines.org/

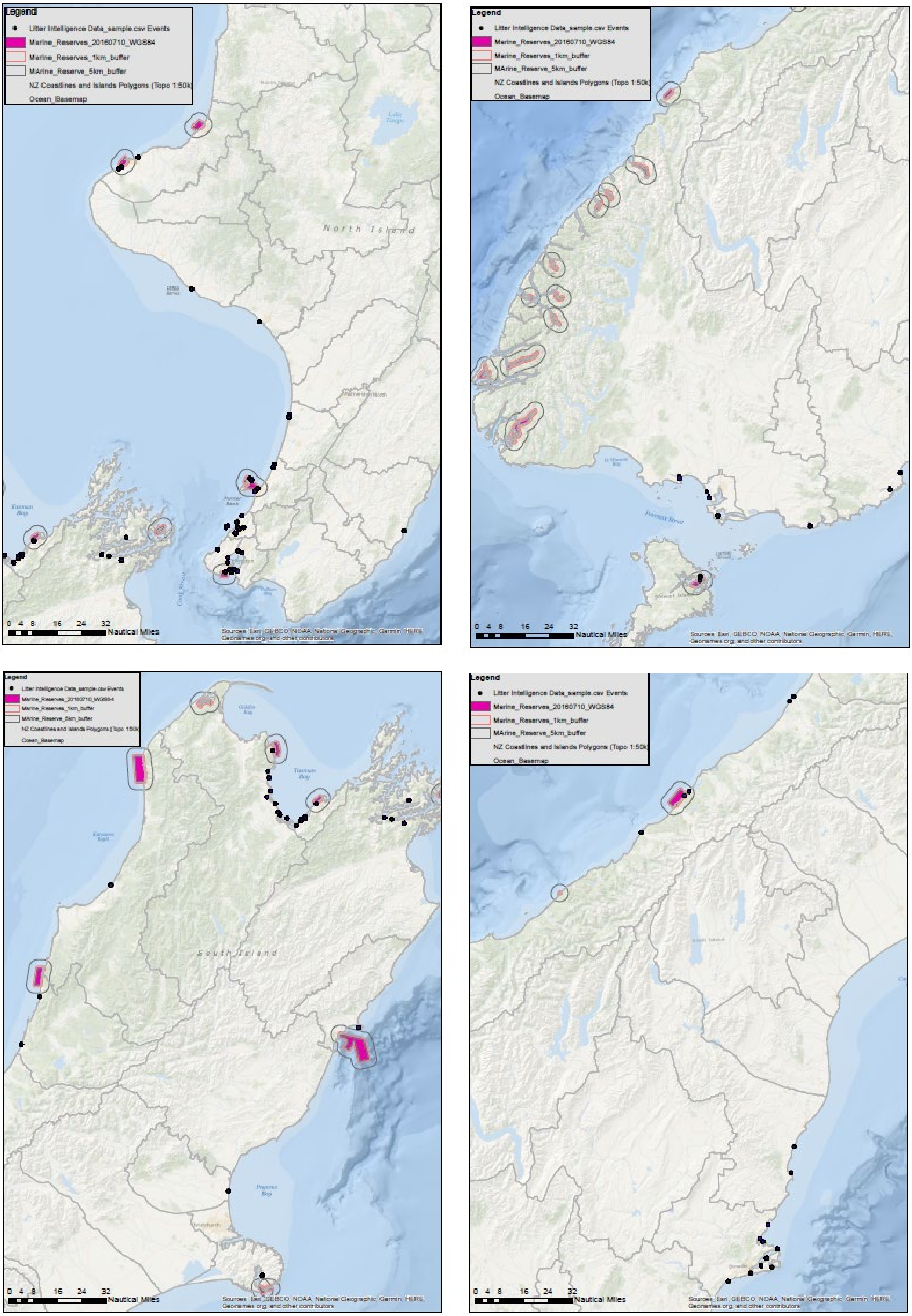

Figure 12.1. Maps of current Sustainable Coastlines sampling locations and marine reserves with 5-km boundaries.

12.3 Sampling design

12.3.1 Selecting indicators

This theme provides guidance on how to measure data elements that will contribute to Objective 12 'Natural resources are managed sustainably' from the ANZBS (DOC 2020c; Table 12.1) and, more specifically, Objective 12.7.1 'The most ecologically damaging pollutants (e.g. excess nutrients, sediment, biocides, plastics, light and sound) and pollutant sources have been identified, and an integrated plan for their management is in place'.

Table 12.1. Indicators, measures and data elements relating to Theme 10 – Understand the impact of pollution. Adapted from McGlone et al. (2020).

Indicator 10.1: Non-nutrient contaminants	
Measure 10.1.1: Marine litter	
Description	Litter presents risks to the fauna in aquatic environments, including through entanglement, smothering and ingestion. The effects of litter on marine mammals and water birds through ingestion is a primary concern, while the release of plasticisers that act as hormonal mimics is a secondary concern. This measure is ranked as being of high importance in Thrush et al. (2011). In addition to its effects on ecological integrity, beach litter can affect natural character and landscape values.
Data elements	**Density** The amount of litter found in a given space, usually presented as the number of items per square metre. **Flux** The change in litter density over time. **Type** The type of litter collected (e.g. plastics, organic, harmful items). **Source** Where the litter is expected to have come from.
Links to other measures	Not closely connected to any other measures

Future updates will expand this to include measures relating to non-nutrient contaminants, toxins in the tissues of biota and noise pollution (Table 12.2).

Table 12.2. Indicators, measures and data elements that are to be implemented in future iterations of the Marine Monitoring and Reporting Framework.

Indicator 10.1: Non-nutrient contaminants	
Measure 10.1.2: Non-nutrient contaminants	
Description	Non-nutrient contaminants, including faecal bacteria, persistent vertebrate toxins, invertebrate pesticides, herbicides, petroleum hydrocarbons and artificial hormones or hormone mimics, may severely disrupt species and communities. Many have long-term impacts and may remain in the environment for several decades or longer.
Data elements	Extent, distribution and bioaccumulation of heavy metals, organochlorines, pesticide residues and faecal bacteria.
Links to other measures	4.2.1: Marine biological function (Theme 4 – Key species) 6.1.1: Water physicochemical factors (Theme 6 – Water quality) 6.2.1: Ecosystem primary productivity (Theme 6 – Water quality) 6.3.1: Sedimentation and sediment quality (Theme 6 – Water quality)

Continued on next page

Table 12.2 continued

Measure 10.1.3: Toxins in biotic tissues	
Description	This measure addresses the presence and persistence of heavy metals and pesticide and herbicide compounds in biotic tissues. The potential influence of environmental chemicals, especially those that are used as toxins for animal and plant control, on the whole ecosystem is essential information that is of great interest to the general public. Heavy metals are much more of a concern in estuarine settings.
Data elements	Regular but not necessarily frequent national surveys of heavy metals in tissues would be desirable for establishing background levels.
Links to other measures	4.2.1: Marine biological function (Theme 4 – Key species) 6.1.1: Water physicochemical factors (Theme 6 – Water quality) 6.2.1: Ecosystem primary productivity (Theme 6 – Water quality) 6.3.1: Sedimentation and sediment quality (Theme 6 – Water quality) 10.1.2: Non-nutrient contaminants (Theme 10 – Pollution)
Measure 10.1.4: Noise	
Description	Because sound carries well in water and the underwater marine soundscape is of vital importance to many species, including cetaceans, many fishes and reef crustaceans, monitoring of the marine soundscape in marine reserves should be considered.
Data elements	Hydrophone measures of marine noise volumes, frequencies and intensities in marine reserves.
Links to other measures	Not closely connected to any other measures

12.3.2 Selecting monitoring programmes

To achieve the objectives of this theme, there will initially be a focus on implementing surveys for beach litter at a selection of priority marine reserves, with a view to expanding monitoring in the future to incorporate survey methods for other litter forms (e.g. benthic or floating litter; Appendix 6) and pollutants (e.g. eutrophication, noise, sewerage pollution).

For beach-cast litter, this theme employs the Litter Intelligence methodology to ensure methodological consistency with existing monitoring programmes and the integration of DOC data into a broader national dataset for beach-cast marine litter. The intention is for all monitoring that is undertaken using this method to be incorporated into the publicly accessible database managed by Litter Intelligence. This will involve implementing the Litter Intelligence beach litter monitoring protocol at a selection of marine reserves, which requires agreement between Sustainable Coastlines and DOC to determine the share of effort across both organisations – for example, DOC may be better placed to monitor some of the offshore islands and less accessible Fiordland reserve sites. The intention is to run the beach litter monitoring as a citizen science project to as great an extent as possible, so that local communities are engaged with their local marine reserves and evaluate the effects of marine litter in their own neighbourhoods. DOC's role will be to encourage, recruit, coordinate and sometimes carry out the monitoring of beach litter in and around marine reserves as part of the wider Litter Intelligence monitoring programme.

Benthic and floating litter surveys are not routinely conducted in Aotearoa New Zealand at present. However, the UNEP/ICO guidelines for benthic and floating marine litter surveys are international best practice and could be easily adopted within an Aotearoa New Zealand context. Selection of the appropriate marine litter monitoring method from these guidelines should therefore concurrently consider if and how the monitoring will contribute towards larger, national-scale monitoring programmes, the environment that litter is most prevalent in (e.g. the beach versus benthic and water column environments) and the impact that litter is having on local biota. Information relating to these types of surveys can be found in Appendix 6).

12.3.3 Developing a sampling design

How many sites (marine reserves) are needed for monitoring beach litter?

Recommended options for a network of beach litter monitoring sites are given in Appendix 6. All of Aotearoa New Zealand's marine reserves are listed here, and monitoring is suggested at nearly all of them. If it is not feasible to undertake monitoring at all the sites listed, it is recommended that the nationwide network includes **at least** (Cheshire et al. 2009):

- One representative marine reserve site from each bioregion (each site is to have one reserve and one non-reserve transect).
- One bioregion with a more intensive network of locations that cover all threat types (urban, rural, industrial), so that this variable can be analysed more readily.
- Six sites that are monitored quarterly, with no more than two sites being monitored less frequent than annually.

Additional sites could then be added to:

- Increase the variety of beach types and threat types within bioregions.
- Provide for a greater number of willing citizen scientists and DOC staff.
- Assist Sustainable Coastlines' goals of nationwide coverage (e.g. remote bioregions such as Fiordland or Subantarctic Islands).

The methodological robustness of the Sustainable Coastlines protocol has been demonstrated by the adoption of current data at high levels, such as in IUCN reporting and 'Our marine environment 2019' (MfE & Stats NZ 2019).

How are sites to be selected?

- Sites will be selected based on a set of criteria, including (in approximate order of priority):
- The ability to achieve the objectives
- The presence of sediment (sand or gravel) beaches[70]
- Practicality, including accessibility and safety
- Tangata whenua aspirations and priorities
- The availability of involvement by citizen scientists or other personnel
- The general willingness and ability of DOC Operations to encourage, assist or undertake the work where citizen scientists cannot
- The feasibility of regular (e.g. 3-monthly) long-term monitoring
- The contribution to the objectives of the entire Litter Intelligence beach litter monitoring network (beyond marine reserves), including:
    - Representation and replication of bioregions
    - Threat levels (e.g. urban/rural, natural/developed, marine industries/fisheries, remote)
    - Beach types (e.g. boulder shore, gravel beach, sand beach, estuarine flat/beach)
- Cost (time and $)

The proposed network of marine litter monitoring locations can be found in Appendix 6.

70 Beach type is a low-priority variable for the monitoring, with sediment beaches expected to give the best results.

How often should measurements be taken at these sites or a subset of these sites?

To achieve the temporal aspects of these objectives, the project aims to create long and continuous time series (minimum of 20 years, ideally > 25 years) of marine litter data by re-measuring each beach litter site every 3 months and continuing this for an indefinite period (Sustainable Coastlines 2020). Including a seasonal component (e.g. 3-monthly repeat surveys) will help to distinguish temporal variability and flux from interannual trends. However, this will not be possible at all sites and some remote reserve sites may only be re-measured every few years.

12.4 Monitoring protocols

A toolbox is available that contains the detail needed to implement beach litter surveys. In brief, the approach involves establishing a minimum of two 100 × 20 m GPS-marked transects ('survey areas') centred along the high-tide line, one of which is within the reserve and one of which is in a comparable area outside the reserve (control) (although three transects inside and three transects outside the reserve is preferable). For each transect, all items of beach litter > 5 mm diameter are collected and classified into the nine marine litter categories used by the Litter Intelligence programme. The items within each category should then either be counted or their combined weight should be recorded (to the nearest g) and a photograph of the items in each category taken. Each transect is surveyed by a trained team of between 1 and 10 people. Litter flux determines the rate and amount of litter arriving on a beach over a fixed period and can be calculated from these surveys. By making an initial clearance, the litter load is set to zero, so future surveys can be used to determine the rate at which litter accumulates between surveys. With this approach, standing stock can be calculated from the initial removal of litter from the beach and litter flux can be determined from future surveys, with each survey involving the removal of all litter from the beach.

Other monitoring toolboxes could be developed in the future for wildlife–pollution interactions, sewerage, eutrophication, marine noise and light pollution.

12.5 Data management

It is essential that all raw data and associated metadata are completed, digitised, backed up and uploaded into a single database to facilitate ease of access and to build a better understanding of the litter problem. Data will be uploaded to, stored and managed in the Litter Intelligence database,[71] where they are expected to remain publicly available indefinitely for analysis and use.[72] The data are stored in an SQL database in Azure, and the summary of data is contained in a Data dictionary. The database may be downloaded into a single spreadsheet for analysis, using the 'Download Source Data' link on the Insights page.[73] The data may also be linked to a GIS platform to assist with spatial analysis (e.g. using a marine reserve / protection status overlay). The Litter Intelligence system is live and fully operational, but aspects of both the user interface and the backend data management continue to be improved.

71 www.LitterIntelligence.org

72 A new method for submitting collected data via a phone app is currently in development. As soon as this is available, the methodology on how to lodge data in this way will be provided.

73 www.litterintelligence.org/insights/

12.6 Data analysis

The marine litter indicator incorporates three separate data elements relating to litter density, litter flux and litter types. Outputs of these data elements can be interpreted in different ways to address each of the objectives included in Theme 10. For example, type of litter can be examined to determine which items are characteristic of certain types of users of the marine environment (source characterisations of litter types are available from the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR)[74] and Sustainable Coastlines) and which items present specific risks to wildlife present at the survey site. The analytical approaches that can be used for each of these data elements are summarised in Tables 12.3–12.5.

Table 12.3. Summary of analytical approaches for data relating to litter density.

Data element: Litter density					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Beach litter • Benthic litter survey • Floating litter survey	• Area of transect sampled • Survey area surface type • Survey and audit hours • Count and weight of litter items per standardised litter category per transect • Number of sites and transects	Calculate the litter density (number of items per unit area surveyed).	Sites inside marine reserves will be compared with control sites outside and, in the case of beach litter, with other relevant sites from the monitoring network. Data may also be analysed for differences between seasons.	Use pie charts or bar charts to present the densities of different litter types in different sampling locations. Data may also be presented as the density of litter types inside and outside marine reserves.	Objective 10.1 – Spatial
			Trends in litter density may be analysed after at least 5 years of data have been collected.	Use line charts to show annual and seasonal trends in litter density over time.	Objective 10.2 – Temporal

Table 12.4. Summary of analytical approaches for data relating to litter flux.

Data element: Litter flux					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Beach litter survey • Benthic litter survey	Flux rates can only be determined by measuring the amount of litter that arrives at a site over a fixed period of time. By making an initial clearance, the litter load is set to zero. A future survey can then estimate the litter load (e.g. g m^{-2}), which can be transformed to a flux rate (e.g. g m^{-2} d^{-1}) based on the time interval since the site was cleared.	Litter flux is calculated as the rate at which litter accumulates (i.e. the amount of litter arriving at a site over a given period, expressed as unit quantity of litter per unit area per unit time). This is equivalent to net litter flux, which accounts for debris deposition and removal from a site. Net litter flux can be calculated for each type of litter or as an overall value across all litter types.	Sites inside marine reserves will be compared with control sites outside and, in the case of beach litter, with other relevant sites from the monitoring network. Data may also be analysed for differences between seasons.	Plot the average flux rates with error bars for sites inside and outside marine reserves.	Objective 10.1 – Spatial
			If surveys are being conducted regularly, then the change in flux at a particular site may be analysed. Surveys must have occurred within at least 90 days for trends to be analysed.	Plot the average flux with 95% confidence intervals over time.	Objective 10.2 – Temporal

74 https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/marine-litter/beach-litter/

Table 12.5. Summary of analytical approaches for data relating to litter type.

Data element: Litter type					
Methods	**Required data**	**Data preparation**	**Analysis**	**Visualisation**	
• Beach litter survey • Benthic litter survey • Floating litter survey	• Presence/ absence of items within each standardised litter category • Counts of items within each standardised litter category • Weights of items within each standardised litter category	Calculate the number of items for each litter category, standardised by survey area (items per unit area). Calculate weights for each litter category, standardised by survey area (weight per unit area).	Sites inside marine reserves will be compared with control sites outside and, in the case of beach litter, with other relevant sites from the monitoring network. Data may also be analysed for differences between seasons.	Use a pie chart or bar chart to show the proportional or absolute abundance (represented as weight or count data) of each category at each sampling site (e.g. see Fig. 12.2). Data may also be presented as the proportional or absolute abundance of litter categories inside and outside marine reserves.	**Objective 10.1 – Spatial**
			Trends in litter density may be analysed after at least 5 years of data have been collected.	Use a line chart to show changes in the proportional or absolute abundance of litter categories over time.	**Objective 10.2 – Temporal**

Figure 12.2. A selection of beach-cast litter survey locations in the North Island and the proportions of different litter types found at those locations.

12.7 Reporting and communicating

The results of this monitoring will continue to be reported at local, regional, national and international levels (Table 12.6), and Sustainable Coastlines, NIWA and other local networks (along with DOC) will be encouraged to use the data generated to learn more about marine reserves and to advocate for marine conservation. The endorsement of Stats NZ for the beach litter methodology and the adoption of the 'UNEP/IOC guidelines on survey and monitoring of marine litter' (Cheshire et al. 2009) lend strength to the quality of the monitoring methodologies and resulting data.

Reporting could include:

- IUCN themes and CBD targets
- State of the Environment reports (regional and national)
- Annual reports
- Feedback to local communities and citizen scientists

Reporting could be carried out by a variety of people and organisations, including Sustainable Coastlines, DOC, tangata whenua, the community and advocacy groups. DOC's main aim would be to produce reports in relation to the monitoring objectives and research questions stated earlier.

Table 12.6. Information relating to Theme 10 that can be included in reporting using products derived from analyses of the data elements that will be monitored.

Outcome Objective	Maintaining ecosystem processes
Indicator	**Ecosystem function**
Data element	Litter density
Reporting	Difference in litter density between marine reserves and non-reserve sites. Relationships between litter density and other parameters (e.g. site usage) measured in the same locations.
Data element	Litter flux
Reporting	Change in letter density over time within a survey area. Magnitudes and trends in beach litter occurrence and flux in marine reserves. Comparison of changes over time between survey sites and areas.
Data element	Litter type
Reporting	• Comparison of types of litter between sites and areas. • Changes in types and densities of litter over time.

12.7.1 Marine reserve reports and report cards

The data elements monitored by Theme 10 can be included in marine reserve reports and report cards using the analytical products. This theme currently focuses on monitoring litter in marine reserve and will report on litter density, flux and type. The ideal status for marine litter is that all marine reserves are free of all rubbish (i.e. in a pristine state). The definitions for reporting on the status of the measures monitored under this theme are described in Table 12.7 (see Table 2.5 for definitions of trend). Future iterations of the MMRF will include other types of pollution monitoring.

Table 12.7. Status definitions for the measures for reporting on Theme 10 – Understand the impact of pollution.

Status	Definition
Excellent	The total density (by weight) of litter in the marine reserve and of all or nearly all (>95%) of the litter types is less than 1 g.
Good	The total density (by weight) of litter in the marine reserve and of all or nearly all (>95%) of the litter types is between 1 g and 50 g.
Fair	The total density (by weight) of litter in the marine reserve and of all or nearly all (>95%) of the litter types is between 50 g and 100 g.
Poor	The total density (by weight) of litter in the marine reserve and of all or nearly all (>95%) of the litter types is more than 100 g.
Undetermined	The status of this measure cannot be determined.

12.7.2 Other reporting opportunities

Citizen scientists and others will be encouraged to explore and analyse the beach litter data for a wide range of purposes. Because the beach litter data are publicly available for exploration and download, there are unlimited opportunities for others to use them. Individual beach litter survey datasets can be explored, viewed and downloaded through the Litter Intelligence data page,[75] while the Insights page[76] provides more powerful aggregation, filtering and visualisation tools.

Litter Intelligence has already informed national-level monitoring efforts towards the United Nations Sustainable Development Goals (SDGs),[77] and the programme was included in Aotearoa New Zealand's first Voluntary National Review of the SDGs, which was presented at the High-Level Political Forum on Sustainable Development on 17 July 2019 (for SDG indicator 14.1.1 on marine plastics). Consequently, these data are expected to have a global impact on policy (MFAT 2019).

In October 2019, Litter Intelligence citizen science data on beach litter were also included in 'Our Marine Environment' – an official New Zealand Government environmental report that was co-produced by Stats NZ and MfE. This was the first time that marine litter data had been included in official government reporting, as well as the first time that citizen science data had been accepted at this highest national reporting level (MFAT 2019: 29–31).

75 www.litterintelligence.org/data/
76 www.litterintelligence.org/insights/
77 https://sdgs.un.org/goals

13 Reviewing and auditing

As a ‘living document’, the MMRF is expected to be reviewed and improved in the future (Fig. 13.1 & Table 13.1). Review is critical to identify gaps in system standards, field collection protocols and resourcing. It makes the framework and its implementation resilient to new events and changes to organisations that invariably occur over time. The frequency and intensity of review will be based on the needs of different aspects of a programme. The analysis of datasets to inform measures and indicators may be appropriate as a single national rotation of measurements (e.g. every 5 years), whereas the review of field method standards is more sensibly undertaken as research findings become available.

The findings of previous internal and external reviews of DOC’s monitoring work have highlighted the strengths and weaknesses of DOC’s ad hoc and fragmented approach to the design and implementation of monitoring programmes and subsequent uptake and promulgation of monitoring results (Lee et al. 2005; Office of the Auditor-General New Zealand 2012; State Services Commission et al. 2014). Underlying many of these findings is the need to maintain the necessary staff and funding resources to retain the integrity of monitoring programmes so that they meet their stated objectives and fully realise DOC’s investment in this fundamental component of conservation management. Costs are associated with developing, improving and maintaining supporting systems and processes.

The MMRF review will require a cross-agency reporting process and both internal and external reviews of each subsequent update. There will be the need for a continual review of the methods as new technologies are developed and as monitoring datasets become available. Method-specific quality assurance and quality control measures will be included within each of the monitoring toolboxes (separate from the MMRF). Reviews could consider the adequacy of coverage and monitoring frequency and the expansion of monitoring to include other measures under each theme.

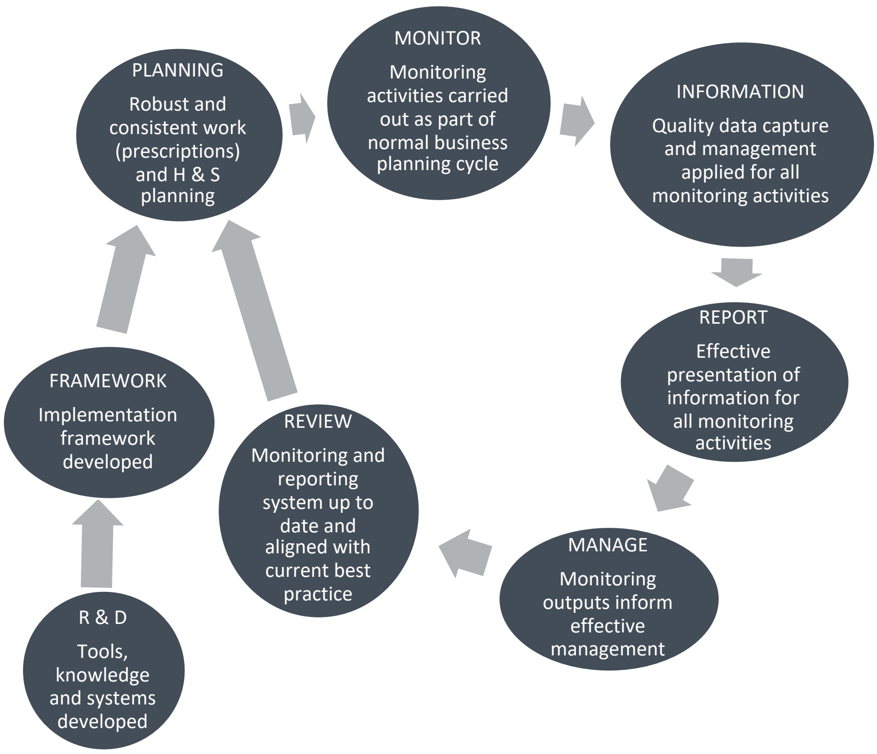

Figure 13.1. Flow diagram showing the process of developing, implementing and reviewing the Marine Monitoring and Reporting Framework.

Table 13.1. Aspects of the Marine Monitoring and Reporting Framework (MMRF) that will need to be reviewed.

Category	Aspect to be reviewed	Detail to be reviewed	Review frequency
Research and development	• Toolboxes	• Advances in technology • Efficiencies in data collection	Every 3–5 years
Framework	• Framework: • Purpose • Objectives • Measures	• Purpose of the MMRF and priorities • Progress towards objectives for each theme • Using the right measures to achieve DOC's objectives • Governance structure	Every 5 years
Planning	• Marine reserve monitoring plan • Prescriptions	• Accountability • Sampling design • Capacity changes for tangata whenua or DOC	Every 5 years Every 5–10 years
Information	• Data quality and assurance	• Appropriate data analyses • Scientific rigour of data collection • Cost–benefit analyses of monitoring	Every year?
Reporting	• Marine reserve reports • Marine reserve report cards		Every 3–5 years Every 5 years
Management interventions	• Impact of any management decisions		Every year
Governance			

Abbreviations: DOC, Department of Conservation Te Papa Atawhai.

If field and/or laboratory data collection methodologies change in the future, the NEMS protocol suggests that duplicate measurements should be taken using both the old and new methods. Ideally, this should be done for a 12-month period (where sampling occurs monthly) to provide sufficient data to enable a conversion factor to be derived to 'align' the old and the new data.

After data collection is complete, the data should be checked for quality assurance before being added to any databases. In particular, as stated in the NEMS protocol:

- The historical site measurement range and relationships with other variables should be used as a guide to check the 'validity' of measurements. This should be done immediately following each round of sampling to ensure sensors are collecting correct data and the sampling protocol was followed correctly.
- Measurements reported by the laboratory should be checked by the collection agency within 2 weeks of receipt to enable sample re-testing if necessary.
- A 12-monthly interagency audit should be carried out to verify measurement practices. This should include:
  - Field meter calibration, deployment and measurement.
  - All other field measurements and observations.
  - Water sample collection, pre-treatment and handling, with the dispatch of blind duplicate water samples for laboratory analysis.

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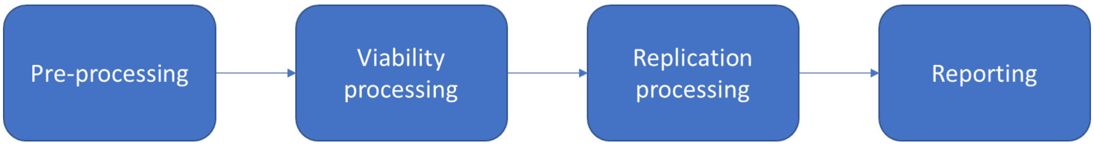
Appendix 1

Network guidance process for Theme 1 – Identify the proportion of ecosystems protected

Using the existing marine protected area (MPA) habitat classification out to the Territorial Sea as an initial example, the steps for the analysis are shown below.



Pre-processing

Geoprocessing inputs (see Fig. A1.1) will require two feature classes:

- National habitat classification (located in Natis 2).
- An area-based protection layer with individual fields for the level of protection offered (e.g. [MarineReserve], [Dredge], [BottomTrawl]). This will include a classification for the type of protection afforded – i.e. Type 1, Type 2a or Type 2ab, where Type2a refers to where only part (a) of the protection standard is theoretically being met (the requirement to prohibit mobile bottom fishing methods); and Type 2ab refers to where additional restrictions are in place (MPAs assessed in the 2011 gaps analysis are included in this class).

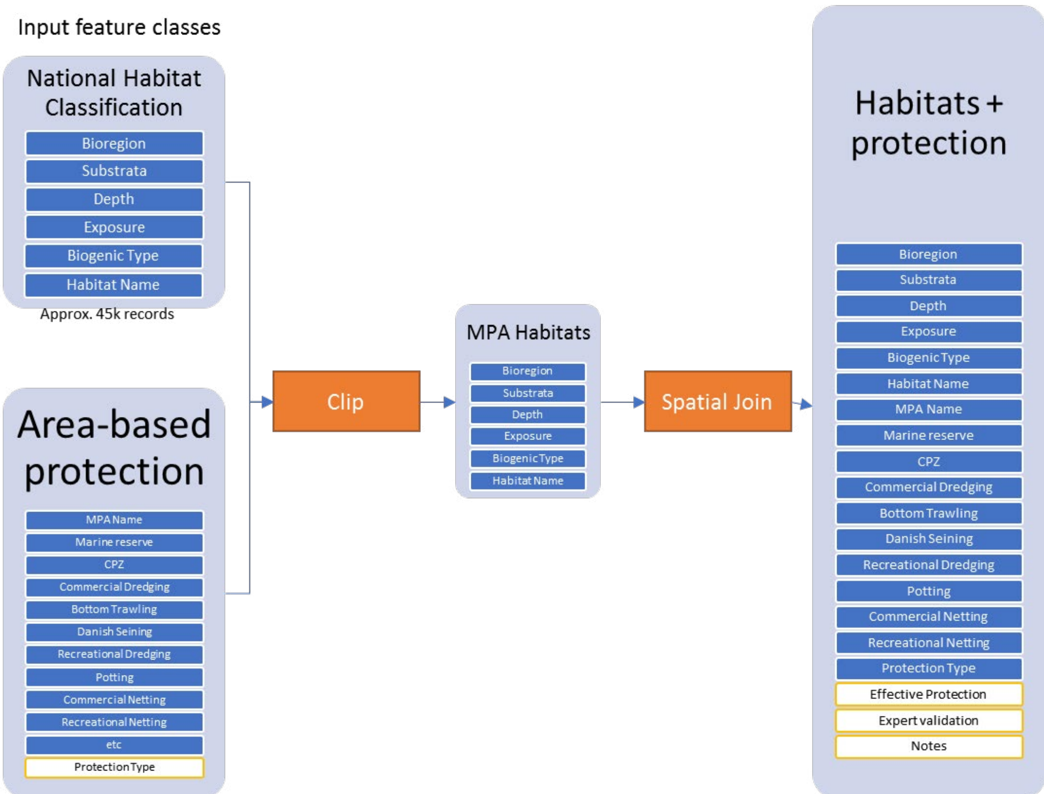


Figure A1.1. Pre-processing steps.

A clip and spatial join of these two input feature classes will result in a feature class that identifies each habitat patch and the level of protection that overlays it, including the area of each habitat patch (in km^2). The feature class will include the fields from both the habitat and protection feature class. At this point, an additional two fields should be created to assess whether the protection type is adequate for each habitat type:

The first field will be [Effective Protection], which will classify each habitat patch according to whether it is effectively protected or not. Initially the rules will be:

- If [Protection Type] = Type1, all habitats are 'Y'.
- If [Protection Type] = Type2ab, all habitats are 'Y'.
- If [Protection type] = Type2a, all reef is 'N'.

The second field will be [Expert Validation]. This is required because general rules on whether a habitat is afforded adequate protection or not will not be accurate in all cases. For example, sensitive habitats may require all benthic fishing methods to be restricted (rather than just mobile bottom fishing methods); or certain areas of habitat may not contribute to representation of that habitat in general, as is the case for the intertidal habitats of Taipari Roa (Elizabeth Island) Marine Reserve due to them being highly modified by the hydropower tailrace.

It is envisioned that when new effective area-based protection is included in the list, there will be an assessment by a panel of experts.

Viability processing

The lookup table will hold the minimum habitat patch sizes required to be viable and the distances of separation between individual patches of habitat required to be considered replicates. Initially, these values can be set to zero if needed, so that all habitats are included as represented and all patches that are not directly connected are counted as replicates. Following scientific agreement on what is 'viable', the figures in the lookup table can be edited and the analysis re-run (i.e. there is no need to alter the geoprocessing script).

The level of protection is classified based on specific management tools, so it does not matter if it is a type 2 MPA or benthic protection area. The process will make an assessment based on the restrictions that are necessary to meet the protection standard, and either exclude or include the habitat.

Representation processing

The representation analysis (see Fig. A1.2) will be automated by taking the pre-processing output feature class, assessing individual habitat patches against the lookup table and outputting each viable habitat patch into a new feature class. This feature class will hold each viable habitat patch, including whether it is adequately protected, and the area of each patch (this will be in excess of 45 000 records using the current habitat classification).

A further step will combine (dissolve) like-habitat patches into a feature class that will allow the percentage representation to be calculated. This dissolved feature class will contain less than 1000 records, one for each full habitat type (bioregion*habitat type).

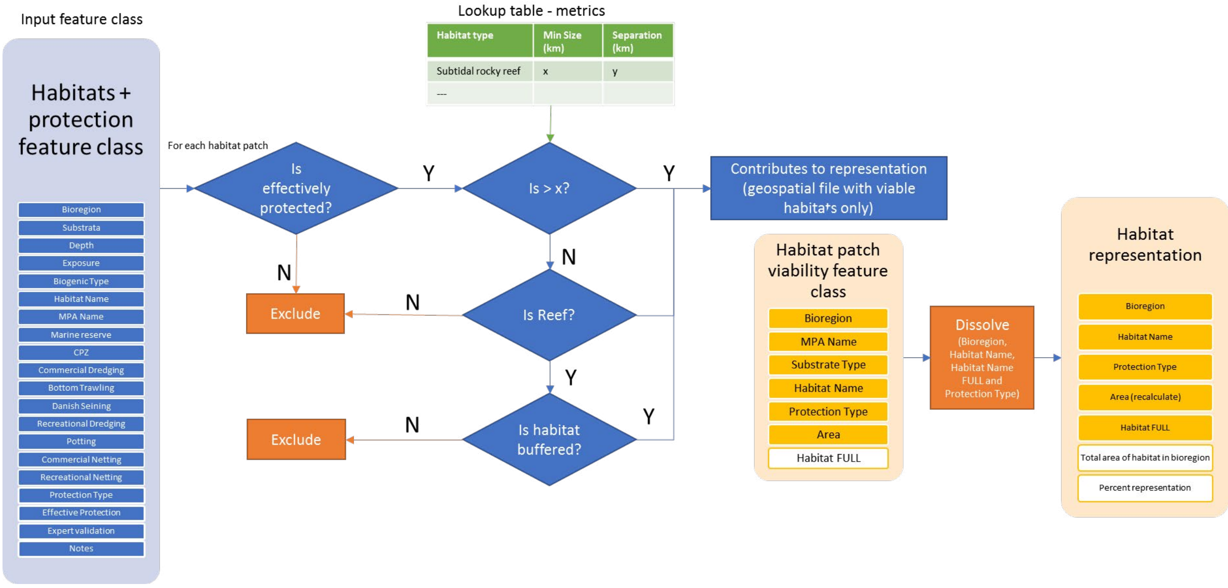


Figure A1.2. Decision-tree for including habitat types in the estimation of representation.

Geoprocessing for replication

To obtain replication information, the habitat patch viability feature class will be run through a 'Proximity Tool' to identify patches that are separated by the value in the lookup table. From this, a list of replicates will be identified and incorporated into the reporting for the network.

The main elements that need to be captured by this measure are:

- The proportion of each marine habitat and key ecological area (KEA) represented within marine reserves (including the spatial distribution – maps).
- The proportion of each marine habitat and KEA represented within other effective area-based protection (including any other protection level that meets the minimum requirements for representing that habitat type).
- The amount of habitat replication within a network (the distance between habitat patches will be used to assess replication).
- Progress in establishing ecological representation, including gaps analysis.

Appendix 2

Additional data sources for Theme 3 – Define and track climate change indicators

Data from remote satellites / conductivity-temperature-depth (CTD) sensors / buoys

In remote locations where frequent sampling is impractical, data gaps for various climate change indicators can be filled with data from NIWA's database of remote satellite data or with data from regional council or research CTD sensors or buoys. To do this, the Department of Conservation Te Papa Atawhai (DOC) will request temperature data from the relevant data owner outlining the required timeframes, frequencies and regions. For further detail, see Theme 6 – Evaluate environmental water quality indicators.

Collating data

Data from all relevant sources should be collated into one Excel spreadsheet. These data include:

- Site
- Date and time of collection
- Field conditions
- Sampling notes
- Source (satellite, lab, etc.)
- Sample ID (if from water collection)
- Raw temperature from the New Zealand Ocean Acidification Observing Network (NZOA-ON) (°C)
- Raw temperature from NIWA satellite, buoy or CTD sensor (°C)
- Raw pH from NZOA-ON
- Corrected satellite sea surface temperature (SST) (if necessary)
- Final temperature (with no gaps)
- Final pH

After the data have been collected, and before they are added to any databases, they should be checked for quality assurance. NZOA-ON regularly maintains and calibrates its sensors, takes duplicate samples, and uses Certified Reference Materials for the laboratory analyses to ensure data quality. NIWA's satellite temperature data have been validated with an *in situ* buoy and have been shown to record the same variability as *in situ* recorded temperatures (Shears & Bowen 2017; Chiswell & Grant 2018). The quality assurance procedures for buoys and CTD sensors must be checked with the relevant authority.

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Shears, N.T.; Bowen, M.M. 2017: Half a century of coastal temperature records reveal complex warming trends in western boundary currents. *Scientific Reports 7(1)*: 1–9.

Appendix 3

Selection of water quality variables for Theme 6 – Evaluate environmental water quality indicators

This appendix gives national context and then suggests a method for choosing which environmental water quality variables to measure in marine reserves based on the objectives and purpose of Theme 6. Synergies with other ongoing initiatives, contributions to other goals of the Marine Monitoring and Reporting Framework (MMRF), cost and logistic capacity have been considered.

The analysis below includes the observations collected between 2013 and 2017 on the following parameters: temperature (T), salinity (Sal), pH, ammoniacal nitrogen (NHXN), chlorophyll *a* (Chl*a*), dissolved oxygen (DO), dissolved reactive phosphorus (DRP), enterococci (ENT), faecal coliforms (FC), nitrate-nitrite nitrogen (NOx), suspended solids (SS), total nitrogen (TN), total phosphorus (TP), turbidity (TURB) and visual clarity (CLA).

Stats NZ classifies 'Coastal and estuarine water quality' data as deep subtidal-dominated estuaries (DSDEs), shallow intertidal-dominated estuaries (SIDEs), and intermittently closing and opening lagoons (ICOLLs). ICOLL sites now all fall under the 'shallow, short residence-time tidal river estuaries (SSRTREs)' type (Dudley et al. 2017), the measures for which are potentially less relevant for marine reserves. Therefore, these measures, all of which are concentrated in the North Island (including the central section, the west coast up to Taranaki, Hawke's Bay and Bay of Plenty), are summarised in Table A3.1 but are not considered further in this appendix.

Measurements made at DSDEs and SIDEs between 2013 and 2017 in all regions are summarised in Table A3.2. Temperature was most commonly measured ($n = 188$), but all measures except CLA totalled between 94 and 188 observations over the 5-year period, with measurements of DRP, NOX and Sal being made on more than 150 occasions each. The distribution of these observations highlight gaps on the West Coast and in the southeast of the South Island, and in the Northland and Taranaki regions.

While Tables A3.1 and A3.2 only show the total numbers of observations in this 5-year period, they give an indication of the sampling capacity for these variables in the regions and current gaps in the data, which can be used to inform the decisions to measure different parameters in the MMRF.

Table A3.1. Summary of the number of observations made in shallow, short residence-time tidal river estuaries by parameter between 2013 and 2017. See the text for explanations of the variable abbreviations. Source: Stats NZ dataset.

Variable	No. observations	Variable	No. observations
Chl*a*	9	ENT	12
CLA	3	FC	12
DO	17	NHXN	11
DRP	12	NOX	13
pH	17	Sal	5
SS	10	T	19
TN	11	TP	13
TURB	18		

Table A3.2. Summary of the number of observations made in deep subtidal-dominated estuaries and shallow intertidal-dominated estuaries by parameter between 2013 and 2017. See the text for explanations of the variable abbreviations. Source: Stats NZ dataset.

Variable	No. observations	Variable	No. observations
Chl*a*	123	ENT	118
CLA	33	FC	95
DO	130	NHXN	126
DRP	156	NOX	153
pH	108	Sal	153
SS	124	T	188
TN	94	TP	132
TURB	143		

Analysis levels and criteria

Three analysis levels are proposed for monitoring water quality in a marine protected area (MPA), the criteria for which are outlined below. Level 1 is considered the basic requirement for measuring water quality, while level 3 integrates fewer common variables. These levels and criteria should be used as a guide of what to measure at each site, noting that different objectives and capacity will determine whether different parameters are measured.

Level 1 analysis

Water parameters that meet at least one of the following criteria will be included in the analysis:

- **Core criteria:** The parameter is already being measured near the sampling site by another organisation.
- **Overlap:** The parameter contributes to another monitoring goal or programme (e.g. pH contributes to understanding climatic change, regional council measures).
- **Significance:** The parameter has a significant influence on ecosystem health.

Level 2 analysis

In addition to the level 1 parameters, those parameters that meet at least one of the following criteria should be considered in the analysis:

- **Core criteria:** Aotearoa New Zealand trigger/recommended values have been described for the parameter.[78]
- **Significance:** The parameter contributes to understanding of ecological integrity or water quality for human health or mahinga kai (food-gathering places).
- **Presence:** A toxin or pollutant has previously been detected in the area.

The presence of unusual levels of metal elements in water quality samples generally indicates pollution. Estuaries and coastal areas closer to industrial areas are more likely to be affected by unusual levels of heavy metals, while marine reserves are likely to have negligible levels of these elements. However, it may be worth considering checking for them in some cases (e.g. downstream of catchments where industrial, urban or agricultural activities occur).

Some of the metals and metalloids that can be measured as part of a level 2 analysis are listed in Table A3.3. They include arsenic, cadmium, copper, chromium, lead, zinc and aluminium. Note that the presence of heavy metals will be better represented by analysing sediment samples.

78 www.waterquality.gov.au/anz-guidelines/guideline-values/default

Table A3.3. Level 2 water/sediment quality measurements.

Variable/ product	Nomen-clature	Units	Resolution / detection limit	Test method(s)	Previously monitored (regional councils)	Guidelines
Sediment grain size distribution						Toolbox
Arsenic (diss)	As	mg/L	0.001	APHA 3125 B		NEMS
Cadmium (diss)	Cd	mg/L	0.0005			NEMS
Copper (diss)	Cu	mg/L	0.0005		NRC	NEMS
Chromium (diss)	Cr	mg/L	0.0005			NEMS
Lead (diss)	Pb	mg/L	0.0001		NRC	NEMS
Zinc (diss)	Zn	mg/L	0.001		NRC	NEMS
Total aluminium	Al total	mg/L	0.005	PHA3030 E or F nitric and/or hydrochloric acid digestion, then analysis by APHA 3125 B		NEMS
Total arsenic	As total	mg/L	0.001			NEMS
Total cadmium	Cd total	mg/L	0.0001			NEMS
Total copper	Cu total	mg/L	0.0005			NEMS
Total chromium	Cr total	mg/L	0.0005			NEMS
Total lead	Pb total	mg/L	0.0005			NEMS
Total zinc	Zn total	mg/L	0.001			NEMS

Abbreviations: diss, dissolved; NEMS, National Environmental Monitoring Standards; NRC, Northland Regional Council.

Level 3 analysis

In addition to the level 1 and 2 parameters, any parameter that meets at least one of the following criteria is suitable for consideration in the analysis:

- **Core criteria:** There is a risk of an unusual presence in the area (e.g. as a result of an accident).
- **Significance:** The parameter is considered an emerging contaminant[79] (Stewart et al. 2016).
- **Presence:** The presence and monitoring of the parameter are suitable for developing site-specific guidance values.[80]

The measurements proposed at this level are listed in Table A3.4 which includes core contaminants taken from 'An update on emerging organic contaminants of concern for New Zealand with guidance on monitoring approaches for councils' (Stewart et al. 2016).

79 www.cawthron.org.nz/research/emerging-organic-contaminants/
80 www.waterquality.gov.au/anz-guidelines/guideline-values/derive

While the presence of some of these components will be more relevant in fresh water, they can still be significant in some marine protected areas.

EMERGING ORGANIC CONTAMINANTS (EOCS)

Emerging organic contaminants (EOCs):

> *… are natural or manufactured chemicals in household and personal care products, pharmaceuticals, and agrichemicals* [81]

EOCs can include chemicals ranging from medications through to cleaning products, and can be carcinogenic or hormone/endocrine disruptors. They are likely to be present in areas close to urban areas and human activities.

EOCs are proposed as suitable variables for measurement at Level 3 following some regional council interest and initiatives. However, while the various monitoring programmes that are led by regional councils currently include legacy persistent organic pollutants (POPs), they do not include EOCs, despite evidence suggesting that some EOCs may cause deleterious environmental effects. Regional councils develop the measures they consider necessary to meet their obligations for environmental protection, but the need for measuring EOCs is unclear. To address this, Aotearoa New Zealand's three largest regional councils, Auckland Council, Environment Canterbury Regional Council and Greater Wellington Regional Council, initiated a review on the status of EOCs in the country (Stewart et al. 2016), which had two main goals:

- To undertake a literature review summarising recent national strategies to identify EOC research priorities, along with national and international legislation, guidelines and research on EOCs.
- To provide recommendations for future monitoring of EOCs in the urban environment, primarily (but not restricted to) sediments.

The MMRF can potentially measure some EOCs in marine reserves around the country to mitigate the lack of understanding of these contaminants, with a focus on those MPAs that are likely to receive large volumes of wastewater discharge.

81 www.esr.cri.nz/our-research/our-science-in-action/managing-the-risk-of-emerging-organic-contaminants/

Table A3.4. Analysis of measurements undertaken by regional councils between 2008 and 2017 and proposals to measure in marine reserves. See the text for explanations of the measurement and bacteria abbreviations.

	Regional council	Measurements	Marine reserve	Within 2 km of a marine reserve (* = 10 km)	Proposals to measure	Bacteria	Buoys
North Island	Northland Regional Council	DO, Chla, T, NOXN, NHXN, DRP, TP, TN, Sal, TURB, SS, CLAR				ENT, FC	
			Poor Knights Islands				
	Auckland Council					ENT	
			Whangarei Harbour	SS, TURB, Sal, TP, DRP, NHXN, NOXN, pH, T, Chla, DO	Measurements well represented.		
		Chla, T, pH, NOXN, NHXN, DRP, TP, TN, Sal, TURB, SS, DO	Cape Rodney-Okakari Point		Measurements well represented.		
			Tāwharanui	Chla*, T*, pH*, NOXN*, NHXN*, DRP*, TP*, TN*, Sal*, TURB*, SS*, DO*	Not enough measures, but Cape Rodney-Okakari Point close by.		
			Long Bay-Okura	DO, Chla, T, pH, NOXN, NHXN, DRP, TP, TN*, Sal, TURB, SS	Measurements well represented.		
			Motu Manawa-Pollen Island	DO, Chla, T, pH, NOXN, NHXN, DRP, TP, TN*, Sal, TURB, SS*	measurements well represented.		
			Te Matuku	Chla*, T*, NOXN*, DRP*, TP*, TN*, TURB*, SS*	No measures nearby. Regional council measures in other areas.		
	Waikato Regional Council	NOXN, DRP, TP, TN, TURB, SS				ENT, FC	
			Whanganui A Hei (Cathedral Cove)	T, Sal	No measures nearby. Regional council does not measure all parameters.		
	Bay of Plenty Regional Council	DO, Chla, T, pH, NOXN, NHXN, DRP, TP, TN, Sal, TURB, SS, CLAR				ENT, FC	www.boprc.govt.nz/environment/fresh-water/monitoring-science-and-research
			Tuhua (Mayor Island)		No measures nearby. Regional council measures in other areas. At least Te Paepae o Aotea (Volkner Rocks) or Tuhua (Mayor Island) should be measured.		
			Te Paepae a Aotea (Volkner Rocks)		No measures nearby. Regional council measures in other areas. At least Te Paepae o Aotea (Volkner Rocks) or Tuhua (Mayor Island) should be measured.		

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Table A3.4. continued

	Regional council	Measurements	Marine reserve	Within 2 km of a marine reserve (* = 10 km)	Proposals to measure	Bacteria	Buoys
North Island	Gisborne Regional Council	DO, SS, TURB, Sal, TN, TP, DRP, NOXN, pH, T, Chla				ENT, FC	
			Te Tapuwae o Rongokako		No measures nearby. Regional council measures parameters in other areas.		
	Taranaki Regional Council						
			Parininihi		No measures nearby. Regional council does not measure water quality. At least Parininihi or Tapuae should be added.		
			Tapuae		No measures nearby. Regional council does not measure water quality. At least Parininihi or Tapuae should be added.		
	Manawatu Regional Council						
	Hawkes's Bay Regional Council	SS, TURB, TN, TP, DRP, NOXN, pH, T, Chla, DO				ENT, FC	Since 2012 https://data.hbrc.govt.nz/hydrotel/cgi-bin/hydwebserver.cgi/sites/details?site=2782&treecatchment=1844
			Te Angiangi		No measures nearby. Regional council measures parameters in other areas.		
	Wellington Regional Council	T, Sal, (Porirua: SS, TURB, TN, TP, DRP, NHXN, NOXN, DO)					Since 2018 http://graphs.gw.govt.nz/?siteName=Wellington%20Harbour%20at%20WRIBO%20(2km%20SE%20of%20Somes%20Is)&dataSource=Zero%20Crossing%20Wave%20Period%20(Tz)
			Kapiti		No measures nearby. Regional council measures parameters in other areas.		Since 2021
			Taputeranga		No measures nearby. Regional council measures parameters in other areas. High-density population.		

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Table A3.4. continued

	Regional council	Measurements	Marine reserve	Within 2 km of a marine reserve (* = 10 km)	Proposals to measure	Bacteria	Buoys
South Island	Tasman District Council						Since 2017 https://cawthron.org.nz/tascam/
			Tonga Island		No measures. At least Tonga Island or Horoirangi should be added.		
			Westhaven (Te Tai Tapu)		No measures, but low-density population in the area. Potential interest as pristine area.		
	Nelson City Council						
			Horoirangi		No measures. At least Tonga Island or Horoirangi should be added.		
	Marlborough District Council						
			Long Island - Kokomohua	CLAR, SS, TURB, Sal, TN, DRP, NHXN, NOXN, pH, T, Chl*a*	Parameters well represented. Missed DO.		
	West Coast District Council						
			Punakaiki		No measures. At least one marine reserve on the West Coast should be added.		
			Kahurangi		No measures. At least one marine reserve on the West Coast should be added.		
			Hautai		No measures. At least one marine reserve on the West Coast should be added.		
			Waiau Glacier Coast		No measures. At least one marine reserve on the West Coast should be added.		
			Tauparikaka		No measures. At least one marine reserve on the West Coast should be added.		
	Environment Canterbury Regional Council	TP, DRP, DO, CLAR				ENT, FC	
			Hikurangi				
			Pohatu	SS*, TURB*, Sal*, TN*, NHXN*, NOXN*, pH*, T*, Chl*a**	Not well represented. Close to Akaroa.		
			Akaroa	SS*, TURB*, Sal*, TN, NHXN, NOXN, pH, T, Chl*a**	Well represented and a sample site nearby. Recommended to add more parameters to this site.		

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Table A3.4. continued

	Regional council	Measurements	Marine reserve	Within 2 km of a marine reserve (* = 10 km)	Proposals to measure	Bacteria	Buoys
South Island	Otago Regional Council						
South Island	Environment Southland Regional Council	(Invercargill: DO, Chla, T, pH, NOXN, NHXN, DRP)				ENT, FC	In Fiordland
			Piopiotahi (Milford Sound)		No measures. At least some Fiordland marine reserves should be added.		
			Te Hapua (Sutherland Sound)		No measures. At least some Fiordland marine reserves should be added.		
			Hawea (Clio Rocks)		No measures. At least some Fiordland marine reserves should be added.		
			Kahukura (Gold Arm)		No measures. At least some Fiordland marine reserves should be added.		
			Te Awaatu Channel (The Gut)		No measures. At least some Fiordland marine reserves should be added.		
			Kutu Parera (Gaer Arm)		No measures. At least some Fiordland marine reserves should be added.		
			Taipari Roa (Elizabeth Island)		No measures. At least some Fiordland marine reserves should be added.		
			Moana Uta (West Jacket Arm)		No measures. At least some Fiordland marine reserves should be added.		
			Taumoana (Five Finger Peninsula)		No measures. At least some Fiordland marine reserves should be added.		
			Te Tapuwae o Rongokako		No measures. At least some Fiordland marine reserves should be added.		
	(Rakiura)		Ulva Island - Te Wharawhara		Not measured.		
Offshore Islands (out of scope)	Subantarctic Islands						
			Moutere Ihupuku / Campbell Island				
			Auckland Islands - Motu Maha				
			Moutere Hauriri / Bounty Islands				
			Moutere Mahue / Antipodes Island				
	Kermadec Islands		Kermadec Islands				

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Appendix 4

Additional measures for Theme 7 – Understand human uses of and relationships with marine reserves

Table A4.1 below lists additional measures for Theme 7 for implementation in future iterations of the Marine Monitoring and Reporting Framework (MMRF). It includes further measures from intermediate outcome (IO) 1 'The diversity of our natural heritage is maintained and restored' and IO3 'New Zealanders and our visitors are enriched by outdoor experiences'. There may also be indicators and measures from IO4 'New Zealanders connect and contribute to conservation', but these are currently still in draft form. Table A4.2 then lists the known socio-economic studies to date that have focused on marine reserves.

Table A4.1. Additional measures and data elements relating to Theme 7 – Understand human uses of and relationships with marine reserves. Adapted from McGlone et al. (2020).

Indicator 7.2: Human health and wellbeing and natural ecosystems	
Measure 7.2.3: Current use of PCL&W natural ecosystems for human health and wellbeing	
Description	This measures which activities people seek to enhance their health and wellbeing and how often they do or would like to do these activities through surveys of users at place or at a national scale.
Data elements	People's engagement with marine reserves and/or preferences for engagement, including volunteering activity
Links to other measures	7.1.1: Outdoor recreation demand being met by DOC on PCL&W: number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use)
Indicator 7.3: Exploration, appreciation and investigation of natural ecosystems	
Measure 7.3.1: Nature appreciation	
Description	This measures how people engage with nature appreciation – who, what, why and how often – through survey of users at place or at a national scale, or analysis of use of citizen science sites such as iNaturalist.
Data elements	Levels of engagement, preferences, experiences, benefits Types and levels of use of iNaturalist and similar citizen science sites
Links to other measures	7.2.3: Current use of PCL&W natural ecosystems for human health and wellbeing (Theme 7 – Human use)
Indicator 7.4: Contribution of recreation on PCL&W to local, regional and national economic prosperity	
Measure 7.4.1: Total economic benefits to communities (region, district, township) from leisure/recreational activity on PCL&W	
Description	This measures the contribution of marine reserves to attracting visitors to the region and how this generates economic activity, investment or employment opportunities.
Data elements	High-level estimates or regional surveys of the economic value arising from the existence and use of marine reserves in a region – for example, costs of homes in proximity to marine reserves, business activity measures, visitation/visitor spend.
Links to other measures	7.1.1: Outdoor recreation demand being met by DOC on PCL&W: number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use)
Measure 7.4.2: Total economic benefits to the nation from leisure/recreational activity on PCL&W	

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Table A4.1 continued

Description	This measures the contribution of marine reserves to attracting visitors to the country and how this generates economic activity, investment or employment opportunities.
Data elements	High-level estimates or regional surveys of the economic value arising from the existence and use of marine reserves nationally.
Links to other measures	7.1.1: Outdoor recreation demand being met by DOC on PCL&W: number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use) 7.4.1: Total economic benefits to communities (region, district, township) from leisure/recreational activity on PCL&W
Indicator 7.5: Contribution of recreation in marine reserves to individual and societal wellbeing	
Measure 7.5.1: Contribution to improved public health from people recreating in marine reserves	
Description	This measures what people think of and value about marine reserves, and how this contributes to health and wellbeing on an individual and community scale. This measure deals with the physical benefits of recreation, while the engagement and emotional aspects are dealt with under Indicator 7.2 'Human health and wellbeing and natural ecosystems'.
Data elements	It is unclear how this measure will be implemented but data are likely to come from DOC in conjunction with other agencies such as the Ministry of Health.
Links to other measures	7.2.1: Attitudes towards interactions with natural ecosystems
Measure 7.5.2: Contribution to national, group and cultural identity and social cohesion from people recreating in marine reserves	
Description	This measures how the existence and use of marine reserves contributes to the creation of a distinct national identity and the flow-on effects of that to social cohesion, willingness to support conservation and Aotearoa New Zealand's image.
Data elements	National-scale survey or in-depth research – for example, marine stakeholder perspectives, scientist perceptions of marine reserves. Can draw on the Treasury Living Standards Framework.*
Links to other measures	7.1.1: Outdoor recreation demand being met by DOC in marine reserves: number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use) 7.2.2: Demographic/psychographic profiles of users and non-users of marine reserves
Measure 7.5.3: Contribution to environmental awareness and understanding from people recreating in marine reserves	
Description	This measures to what degree recreational activities in marine reserves contribute to an increase in environmental awareness and understanding.
Data elements	Awareness measures through a national survey; analysis of specific information, facilities or services provided to measure the difference made.
Links to other measures	7.1.1 Outdoor recreation demand being met by DOC in marine reserves: number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use) 3.1.1.2 Demographic/psychographic profiles of recreationists using marine reserves 3.1.2.2 Demographic/psychographic profiles of non-recreationists to marine reserves 3.5.1.1: Effects of recreation on natural heritage values; water quality; ecosystems; species; landscapes; etc. 4.1.1.1: Public awareness and understanding of conservation
Indicator 7.6: Significant conservation values are protected from harm resulting from recreation	
Measure 7.6.1: Effects of recreation on natural heritage values; water quality; ecosystems; species; etc.	
Description	This measures the impacts of visitor use, with a focus on well-used locations that are at risk of adverse effects of human use. In the marine context, this could include iconic places or areas frequently used for wildlife viewing. It is important that DOC identifies places with significant or increasing impacts and intervenes accordingly.
Data elements	Investigation to select and document at-risk sites, and regular monitoring if needed of the impacts on wildlife and the environment as measured by biological indicators (see Theme 10 – Understand the impact of pollution and Theme 4 – Describe the abundance and demography of key species). Data elements might include wildlife disturbance, human waste and litter, and landscape and soundscape degradation.
Links to other measures	Informs relevant intermediate outcome 1 indicators 7.1.1: Outdoor recreation demand being met by DOC in marine reserves: number of participants by activity, location, destination category, experience, etc. (Theme 7 – Human use) 7.2.2: Demographic/psychographic profiles of users and non-users of marine reserves

Abbreviations: DOC, Department of Conservation Te Papa Atawhai.

* www.treasury.govt.nz/information-and-services/nz-economy/higher-living-standards/our-living-standards-framework

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Table A4.2. Known socio-economic studies on marine reserves.

Bioregion	Marine reserve and study	Reference
North Eastern	Poor Knights Islands Marine Reserve, socio-economic impacts report, 1999	Teague 1999
North Eastern	Poor Knights Islands Marine Reserve, visitor number report, 2003/2004	Edney 2004
North Eastern	Cape Rodney-Okakari Point Marine Reserve, visitor survey, 1983–1984	Department of Lands and Survey 1984
North Eastern	Cape Rodney-Okakari Point Marine Reserve, visitor impacts assessment report, 1993	Jeffs 1993
North Eastern	Cape Rodney-Okakari Point Marine Reserve, visitor use and survey data, 2000–2001	DOC 2001
North Eastern	Cape Rodney-Okakari Point Marine Reserve, visitor survey, 2002–2003	Duncan 2003
North Eastern	Cape Rodney-Okakari Point Marine Reserve, economic impact analysis, 2008	Hunt 2008
North Eastern, South Cook Strait, East Coast South Island	Cape Rodney-Okakari Point, Tonga Island and Pohatu marine reserves, social impacts study, 2003	Taylor & Buckenham 2003
Western North Island	Parininihi Marine Reserve, attitudes and outcomes report, 2003	Steward 2003
North Eastern	Te Whanganui A Hei (Cathedral Cove) Marine Reserve, community survey, 1994	Wolfenden et al. 1994
North Eastern	Te Whanganui A Hei (Cathedral Cove) Marine Reserve, community survey post-marine reserve establishment, 1994	McAuley & Cocklin 1994
North Eastern	Whanganui A Hei (Cathedral Cove) Marine Reserve, socio-economic effects report, 1994/1995	Craw & Cocklin 1995
North Eastern	Te Whanganui A Hei (Cathedral Cove) Marine Reserve, 10-year impact and use assessment, 2002	Risely 2002
North Eastern	Te Whanganui A Hei (Cathedral Cove) Marine Reserve, human impact study, 2005/2006	Robertson 2006
North Cook Strait	Kapiti Marine Reserve, recreational user survey, 1986/1987	Baxter 1987
North Cook Strait	Kapiti Marine Reserve and Taputeranga Marine Reserve, economic social and biological attributes study, 2013	Rojas Nazar 2013
North Cook Strait	Taputeranga Marine Reserve, recreational fishing survey pre-marine reserve establishment, 1998	Bell 1998

Appendix 5

Toolbox selection for Theme 9 – Determine the effects of extreme events

After an extreme event it is essential that the impacted area is monitored. The type of event and the monitoring method used (as outlined in a toolbox) will affect the frequency at which the impacts should be monitored. Tables A5.1 and A5.2 below provide guidance on the toolboxes that should be used for different types of extreme events.

Table A5.1. Guidance on toolboxes to use for monitoring the effects of extreme fires, extreme floods, coastal storms and tsunami, earthquakes, and volcanic eruptions. The guidance highlights the frequency of monitoring required within a year. For long-term monitoring (1 year +), the frequency of monitoring must be evaluated based on the environmental changes observed. Habitat mapping includes drop camera, video sled and map construction; aerial includes drone and fixed-wing surveys; and quadrats are for invertebrate and macroalgal communities. Fires refer to those that occur on land and wash off into the marine environment; volcanos should be evaluated on a case-by-case basis alongside a risk assessment.

	Extreme fires					Extreme floods					Coastal storms and tsunami					Earthquakes					Volcanic eruptions				
MONITORING TOOLBOXES	Hrs	Wk	1 Mth	6 Mth	1 Yr+	Hrs	Wk	1 Mth	6 Mth	1 Yr+	Hrs	Wk	1 Mth	6 Mth	1 Yr+	Hrs	Wk	1 Mth	6 Mth	1 Yr+	Hrs	Wk	1 Mth	6 Mth	1 Yr+
Baited underwater video surveys for fish (BUV)			✓		✓			✓		✓			✓		✓			✓		✓			✓		✓
Underwater transects for sampling reef fish (UVC)			✓		✓			✓		✓			✓		✓			✓		✓					✓
Transects for mobile invertebrates (UVC)			✓		✓			✓		✓			✓		✓			✓		✓					✓
Lobster potting			✓		✓			✓		✓			✓		✓			✓		✓					✓
Quadrats			✓		✓			✓		✓			✓		✓			✓		✓					✓
Soft sediment sampling for infaunal communities			✓		✓			✓		✓			✓		✓			✓		✓					
Functional trait surveys for benthic organisms																									
Secchi disc monitoring of water clarity		✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓			✓	✓	✓
Sampling of water and sediment chemistry		✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓			✓		✓			✓	✓	✓
Sampling environmental contaminants		✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓								✓	✓	✓
Habitat mapping			✓	✓	✓			✓	✓	✓			✓	✓	✓			✓	✓	✓			✓	✓	✓
Beach litter surveys		✓	✓		✓		✓	✓		✓		✓	✓		✓										
Shoreline surveys for seal colonies			✓		✓			✓		✓			✓		✓										
Shoreline surveys for seabirds			✓		✓			✓		✓			✓		✓										
Rocky intertidal monitoring			✓	✓	✓			✓	✓	✓			✓	✓	✓			✓	✓	✓				✓	✓
Remote operated vehicles													✓		✓		✓						✓	✓	✓
Environmental DNA (eDNA)			✓	✓	✓			✓	✓	✓			✓	✓	✓		✓	✓	✓	✓				✓	✓
Aerial surveys	✓				✓	✓				✓	✓				✓	✓				✓	✓				✓

Table A5.2. Guidance on toolboxes to use for monitoring the effects of landslides, oil spills, plastic pollution, marine heatwaves, and toxic blooms and mass mortality events. The guidance highlights the frequency of monitoring required within a year. For long-term monitoring (1 year +), the frequency of monitoring must be evaluated based on the environmental changes observed. Habitat mapping includes drop camera, video sled and map construction; aerial includes drone and fixed-wing surveys; and quadrats are for invertebrate and macroalgal communities. Heatwaves are a result of temperature spikes that cause mass mortality event of sensitive species.

	Landslides					Oil spills					Plastic pollution					Marine heatwaves					Toxic blooms and mass mortality events				
MONITORING TOOLBOXES	Hrs	Wk	1 Mth	6 Mth	1 Yr+	Hrs	Wk	1 Mth	6 Mth	1 Yr+	Hrs	Wk	1 Mth	6 Mth	1 Yr+	Hrs	Wk	1 Mth	6 Mth	1 Yr+	Hrs	Wk	1 Mth	6 Mth	1 Yr+
Baited underwater video surveys for fish (BUV)			✓		✓	✓		✓	✓	✓															
Underwater transects for sampling reef fish (UVC)			✓		✓	✓		✓	✓	✓							✓	✓	✓	✓		✓	✓	✓	✓
Transects for mobile invertebrates (UVC)		✓	✓		✓	✓		✓	✓	✓							✓	✓	✓	✓		✓	✓	✓	✓
Lobster potting			✓		✓	✓	✓	✓	✓	✓															
Quadrats		✓	✓	✓	✓	✓		✓	✓	✓							✓	✓	✓	✓		✓	✓	✓	✓
Soft sediment sampling for infaunal communities		✓	✓	✓	✓	✓	✓	✓	✓	✓															
Functional trait surveys for benthic organisms																									
Secchi disc monitoring of water clarity		✓	✓	✓	✓																✓	✓	✓		
Sampling of water and sediment chemistry		✓	✓	✓		✓	✓	✓	✓	✓						✓	✓	✓			✓	✓	✓	✓	
Sampling environmental contaminants		✓	✓	✓		✓	✓	✓	✓	✓						✓	✓	✓			✓	✓	✓	✓	
Habitat mapping		✓	✓	✓	✓	✓		✓	✓	✓		✓			✓		✓	✓	✓	✓		✓	✓	✓	✓
Beach litter surveys											✓	✓	✓	✓	✓										
Shoreline surveys for seal colonies		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓										
Shoreline surveys for seabirds		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓						✓	✓	✓		✓
Rocky intertidal monitoring		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓							✓	✓		✓
Remote operated vehicles		✓	✓	✓	✓	✓	✓			✓		✓			✓		✓			✓					
Environmental DNA (eDNA)			✓		✓	✓	✓	✓	✓	✓						✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Aerial surveys	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓				✓	✓	✓			✓

Appendix 6

Litter monitoring programmes for Theme 10 – Understand the impact of pollution

Beach litter monitoring network

Table A6.1 lists all of Aotearoa New Zealand's marine reserves, most of which would be suitable for beach litter monitoring. Based on the site selection criteria, it is recommended that the nationwide beach litter monitoring network includes **at least** the sites shaded in column 1, with one reserve site and one non-reserve site ('control') for each.

Table A6.1. Recommended marine reserve litter sampling sites.

Marine reserve	Litter monitoring led by	Continue or new?	Minimum frequency (quarterly preferred)	Bioregion	Control site available?	Intensive network in one bioregion	Suggested surveyors	Suggested location(s)
Kermadec Islands	DOC	New	1 year	Kermadecs	N	N	DOC rangers	TBD
Poor Knights Islands	nf	–	–	NENI	–	N	–	–
Whangarei Harbour	SC	New	< 1 year	NENI	Y	Y	EMR	TBD
Cape Rodney-Okakari Point	SC	New	< 1 year	NENI	Y	Y	DOC rangers	Goat Island Beach
Long Bay-Okura	SC	Continue	Quarterly	NENI	Y	Y	–	–
Te Matuku	SC	New	< 1 year	NENI	Y	Y	EMR	TBD
Tāwharanui	SC	New	< 1 year	NENI	Y	Y	EMR	Anchor Bay
Motu Manawa-Pollen Island	DOC	New	< 1 year	NENI	Y	Y	DOC	TBD
Whanganui o Hei (Cathedral Cove)	DOC	New	< 1 year	NENI	Y	Y	DOC	TBD
Te Paepae o Aotea (Volkner Rocks)	nf	–	–	NENI	–	N	–	–
Tuhua (Mayor Island)	nf	–	–	NENI	–	N	–	–
Te Tapuwae o Rongokako	SC	New	Quarterly	ECNI	Y	N		Multiple existing sites
Te Angiangi	SC	New	1 year	ECNI	Y	N		Blackhead Beach
Parininihi	DOC	New	1 year	WCNI	Y	N	DOC	TBD
Tapuae	SC	Continue	Quarterly	WCNI	Y	N		Multiple sites
Kapiti	SC	Continue	< 1 year	NCS	Y	N		Tokahaki Point
Taputeranga	SC	Continue	Quarterly	NCS	Y	N		TBD

Continued on next page

Table A6.1 continued

Marine reserve	Litter monitoring led by	Continue or new?	Minimum frequency (quarterly preferred)	Bioregion	Control site available?	Intensive network in one bioregion	Suggested surveyors	Suggested location(s)
Long Island - Kokomohua	DOC	New	< 1 year	SCS	Y	N	DOC	Multiple existing sites
Tonga Island	SC	Continue	1 year	SCS	Y	N		Onetahuti Bay
Horoirangi	SC	Continue	Quarterly	SCS	Y	N		Glenduan
Westhaven (Te Tai Tapu)	DOC	New	1 year	SCS	N	N	DOC	TBD
Hikurangi	DOC	New	< 1 year	ECSI	Y	N	DOC	TBD
Pohatu	DOC	New	Quarterly	ECSI	Y	N	DOC	TBD
Akaroa	nf	–	–	ECSI	–	N		
Kahurangi	DOC	New	1–2 years	WCSI	Y	N	Seal taggers, hut warden	TBD
Punakaiki	SC	New	< 1 year	WCSI	Y	N	WCPT, School	TBD
Waiau Glacier Coast	SC	Continue	Quarterly	WCSI	Y	N	OCA, DOC	Ōkārito
Tauparikākā	DOC	New	1 year	WCSI	Y	N	DOC	TBD
Hautai	DOC	New	5 years	WCSI	Y	N	DOC	TBD
Piopiotahi (Milford Sound)	SC	New	Quarterly	Fiordland	N	N		Wharf area
Te Awaatu Channel (The Gut)	nf	–	–	Fiordland	–	N		
Hawea (Clio Rocks)	nf	–	–	Fiordland	–	N		
Kutu Parera (Gaer Arm)	nf	–	–	Fiordland	–	N		
Te Hapua (Sutherland Sound)	nf	–	–	Fiordland	–	N		
Kahukura (Gold Arm)	nf	–	–	Fiordland	–	N		
Taipari Roa (Elizabeth Island)	nf	–	–	Fiordland	–	N		
Taumoana (Five Finger Peninsula)	nf	–	–	Fiordland	–	N		
Moana Uta (Wet Jacket Arm)	DOC	New	–	Fiordland	–	N	DOC (or Fiordland supplier)	TBD
Te Tapuwae o Hua (Long Sound)	nf	–	–	Fiordland	–	N		

Table A6.1 continued

Marine reserve	Litter monitoring led by	Continue or new?	Minimum frequency (quarterly preferred)	Bioregion	Control site available?	Intensive network in one bioregion	Suggested surveyors	Suggested location(s)
Ulva Island - Te Wharawhara	SC	Continue	Quarterly	SSI	Y	N	Local group	Ulva Island
Moutere Hauriri / Bounty Islands	nf	–	–	Subantarctics	–	N		
Moutere Mahue / Antipodes Island	nf	–	–	Subantarctics	–	N		
Auckland Islands - Motu Maha	DOC	New	1 year	Subantarctics	N	N	Sea lion workers, Sandy Bay	Enderby Island
Moutere Ihupuku / Campbell Island	nf	–	–	Subantarctics	–	N		TBD

Bioregion abbreviations: ECNI, East Coast North Island; ECSI, East Coast South Island; NCS, North Cook Strait; NENI, North East North Island; SCS, South Cook Strait; SSI, Southern South Island; WCNI, West Coast North Island; WCSI, West Coast South Island.

Other abbreviations: DOC, Department of Conservation Te Papa Atawhai; EMR, Experiencing Marine Reserves group; nf, not feasible (e.g. due to poor access or lack of beach); OCA, Ōkārito Community Association; SC, Sustainable Coastlines community / citizen scientists; TBD, to be determined; WCPT, West Coast Penguin Trust.

Benthic and floating litter

Section 12, Theme 10 only addresses the monitoring of beach-cast litter. In the future, the monitoring programme could be expanded to include other types of pollution, including benthic and floating litter. Therefore, these types of litter are discussed in this appendix.

Globally, surveys and monitoring programmes are undertaken for benthic and floating litter (Ryan et al. 2009), although only a few such surveys have been conducted in Aotearoa New Zealand (Backhurst & Cole 2000) and there are no established monitoring programmes here. The 'UNEP/IOC [United Nations Environment Programme / Intergovernmental Oceanographic Commission] guidelines on survey and monitoring of marine litter' (Cheshire et al. 2009) provide international guidelines for both benthic litter assessments (using benthic trawls, towed net and visual survey methods) and floating litter assessments (using trawl and visual survey methods).

Presently, benthic and floating litter surveys are not routinely conducted in Aotearoa New Zealand. However, the UNEP/ICO guidelines for benthic and floating marine litter surveys are international best practice and could be easily adopted within an Aotearoa New Zealand context. Selection of the appropriate marine litter monitoring method from these guidelines should therefore concurrently consider if and how the monitoring will contribute to larger, national-scale monitoring programmes, the environment that litter is most prevalent in (e.g. the beach versus benthic and water column environments) and the impact that litter is having on local biota.

Developing a sampling design

HOW ARE SITES SELECTED FOR MONITORING BENTHIC AND FLOATING LITTER?

At marine reserve sites where litter is particularly prevalent in the benthic environment or water column or has known adverse impacts on benthic environments or species that forage within the water column (such as marine mammals and seabirds), surveys of benthic and/or floating litter may be undertaken using the UNEP/ICO guidelines in addition to, or instead of, beach litter surveys.

HOW OFTEN SHOULD MEASUREMENTS BE TAKEN AT THESE SITES OR A SUBSET OF THESE SITES?

Because there is no existing national-scale monitoring programme for either benthic or floating marine litter, monitoring will initially be conducted on a site-by-site basis. Sites for benthic litter surveys should be selected to ensure they are areas with uniform substrate and uniform depth that are known to generate/accumulate marine litter and where the survey method would not affect sensitive and/or pristine habitats or endangered or protected species. Sites for floating marine litter should be selected with a focus on areas that are known to generate or accumulate marine litter and where there is low likelihood of accidental catch of endangered or protected species. Both benthic and floating litter surveys should be conducted annually or, in the case of benthic surveys, conducted in proximity (e.g. offshore) to beach litter surveys sites at the same time as one of the beach litter surveys. This will provide an opportunity to evaluate the relationship between benthic litter loads and the flux onto beaches.

Monitoring protocols

BENTHIC LITTER SURVEYS

The UNEP/ICO guidelines include two different monitoring protocols for benthic marine litter: (i) towed benthic trawls or camera equipment; and (ii) diver visual assessment surveys in shallow-water, near-shore environments. Details on each of these methods are provided in Cheshire et al. (2009) but summarised briefly below.

Trawl surveys are usually conducted at three sites within a survey location. At each site, five 800-m parallel trawls are conducted with the vessel moving in a straight line against the current at a speed of 3–4 knots, with each shot separated by a minimum of 200 m. Data on all litter collected should be reported as kg/km.

Visual litter surveys are modelled on standardised fish underwater visual census (UVC) surveys using a 100-m (or longer) belt transect that is run at a fixed depth parallel to shore. Pairs of divers swim in parallel along either side of the transect recording litter items found within 2 m either side of the transect line. Small litter items should be collected and anything that cannot to collected should be marked for removal later. Transects should be separated by a minimum of 50 m, and at least three sites should be sampled within a survey location, with five transects per site.

Benthic litter collected by either method should be categorised using the standardised litter classification system used by Litter Intelligence, and items within each category should then be counted, their combined weight recorded (to the nearest g) and a photograph of all items within each category taken. A monitoring toolbox for benthic marine litter will be created if this survey method is incorporated within marine reserve monitoring plans.

FLOATING LITTER SURVEYS

The UNEP/ICO guidelines include trawl surveys for floating marine litter. Details for trawl surveys for floating litter are provided in Cheshire et al. (2009) but summarised briefly below.

Trawl surveys are usually conducted at three sites within a survey location. At each site, five 800-m parallel trawls are conducted with the vessel moving in a straight line against the current at a speed of 3–4 knots, with each shot separated by a minimum of 200 m. Floating litter should be categorised using the standardised litter classification system used by Litter Intelligence, and items within each category should then be counted, their combined weight recorded (to the nearest g) and a photograph of all items within each category taken. The width of the trawl net (when set) needs to be incorporated to provide a measurement of the area of sea surface trawled (distance in metres multiplied by width of the trawl net) and the data will then be reported as kg of litter per square metre of sea surface. A monitoring toolbox for floating marine litter will be created if this survey method is incorporated within marine reserve monitoring plans.

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