The Marlborough Coastal Marine Area: Environmental issues and scientific information needs for environmental management

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Prepared for Marlborough District Council

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Glossary of acronyms

AEE	Assessment of Environmental Effects
AER	Anticipated Environmental Result
CMA	Coastal Marine Area
CSIG	Coastal Special Interest Group
DHB	District Health Board
DOC	Department of Conservation
EBM	Ecosystem based management
EMaR	Environmental Monitoring and Reporting (EMaR) Project
ESMS	Ecologically significant marine sites
FNZ	Fisheries New Zealand
LAWA	Land and Water Aotearoa
LEK	Local ecological knowledge
MDC	Marlborough District Council
MFA	Marine Farming Association
MfE	Ministry for the Environment
MHWS	Mean High Water Springs
MPI	Ministry for Primary Industries
MSQP	Marlborough Shellfish Quality Programme
NPS-FM	National Policy Statement for Freshwater Management
NZCPS	New Zealand Coastal Policy Statement
PMEP	Proposed Marlborough Environment Plan
RMA	Resource Management Act
RPS	Regional Policy Statement
SOE	State of the Environment
SSWG	Southern Scallop Working Group
TOS	Top of the South

Glossary of terms

Term	Description
Eutrophication	Eutrophication results from an increase in the nutrients available in a water body, which can subsequently increase primary productivity and degrade water quality. These processes may result in oxygen reduction, excessive macroalgae, and a reduction in the health or survival or aquatic species.
Marine litter	Marine litter consists of items that have been deliberately discarded, unintentionally lost, or transported by winds and rivers, into the sea and on beaches. Marine litter comprises of items made from various materials and includes plastics.
Tohu	Traditional Māori indicators that relate to the environment and environmental change. Tohu are signs or omens and an important means of interpreting and managing the environment. Tohu are derived from long local observation, they therefore vary from hapū to hapū and place to place.

Acknowledgements

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Executive summary

Marlborough District Council (MDC) is moving toward more integrated management of the coastal marine area (CMA) in collaboration with other agencies, iwi, community and research organisations, including a more strategic approach for the collection of scientific information. This report presents the findings of a review undertaken to support the intended changes.

This report largely takes an MDC-centric perspective; however, it is supported by information of other management agencies (Fisheries New Zealand, FNZ, and the Department of Conservation, DOC), the Kotahitanga mō te Taiao Strategy, accessible iwi management plans and scientific publications.

The Marlborough CMA is exposed to a variety of stressors, both natural and anthropogenic and substantial coastal ecosystem changes have occurred since human settlement in the catchments. Environmental issues of relevance identified for the Marlborough CMA are related to sediment (including sedimentation and suspended sediment), habitat modification and impact on species, water quality and sediment quality degradation (including chemical and bacterial contamination and nutrient/organic enrichment), marine pests, marine litter and climate change. These environmental issues are connected, often compounding and cumulatively can generate complex ecosystem change.

This report describes our current knowledge of the environmental state of the Marlborough CMA in relation to these issues and identifies scientific information needs from regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA and scientific publications.

A large volume of environmental information has been collected in relation to the Marlborough CMA. In addition to environmental monitoring and scientific investigations carried out and commissioned by MDC and consent-related environmental monitoring, the Marlborough CMA attracts extensive research projects that add considerable value to the scientific information base. This information is being actively utilised by MDC and others involved with management of this area.

This report identified challenges and preliminary information gaps for all environmental issues and derived some consistent themes across issues.

Preliminary information gaps identified

1. Preliminary information gaps for environmental issues related to sediment (including sedimentation and suspended sediment):
   - There is a need to better understand sediment loads and the sources of excess sediments in the Marlborough CMA.
   - To inform a more strategic approach to managing sediment-related issues in the Marlborough CMA, there is a need to determine criteria for identifying degraded areas (benthic and water column).
   - There is a need to determine thresholds, limits, standards and the assimilative capacities of different parts of the Marlborough CMA for sediment inputs and suspended sediments.
   - Identification of how continuing land-derived and legacy sediments impact the ability of coastal ecosystems to recover from anthropogenic stressor impacts.
   - Approaches need to be developed for restoring degraded areas in the Marlborough CMA and action plans need to be developed to ensure strategic and integrated actions towards improvement.

- Specific focus needs to be placed on better understanding the importance of legacy sediments and their influence on the ability of coastal ecosystems to be restored.
- While a reasonable knowledge base exists on the sediment impacts on habitats in the Pelorus and QCS, limited information is available on effects in offshore environments and other areas of the Marlborough CMA outside Pelorus and QCS

2. Preliminary information gaps for environmental issues related to habitat modification and impact on species:

   Extensive information on habitats and species in the Marlborough CMA has been gathered and a large number of scientific information needs have been identified in this report. Due to the comprehensive nature and complexity of the information and scientific information needs, it was not possible to create a concise list of specific information gaps. To achieve a more strategic approach for the collection of scientific information on environmental issues related to habitat modification and impacts on species in the Marlborough CMA, it would be helpful to clarify information needs with partners and stakeholders. Importantly, not all information needs identified in this report can be filled due to resourcing limitations. It is therefore critical to prioritise information needs and prepare a strategic plan for collecting information.

3. Preliminary information gaps for environmental issues related to water quality and sediment quality degradation (including chemical and bacterial contamination and nutrient/organic enrichment):
   - To inform a more strategic approach to managing water and sediment quality degradation in the Marlborough CMA, there is a need to determine criteria for identifying degraded areas (sediment and water column).
   - Degraded areas, based on water or sediment quality, in the Marlborough should be identified.
   - While there is a general need to establish baselines of water and sediment quality in the Marlborough CMA, a strategic prioritisation and planning should be carried out prior to commissioning any further work to ensure future work builds on existing work and is fit-for-purpose.
   - There is a need to determine thresholds, limits, standards and the assimilative capacities of water and sediment in different parts of the Marlborough CMA for contaminant input and other environmental change generated by land-based and marine activities and uses.
   - An improved understanding of the bioavailability and fate of contaminants and effects of emerging contaminants is required.
   - Approaches need to be developed for restoring degraded areas in the Marlborough CMA and action plans need to be developed to ensure strategic and integrated actions towards improvement.
   - While a reasonable knowledge base exists on sediment quality in estuaries and water quality in the Marlborough Sounds, limited information is available for offshore environments and nearshore areas of the Marlborough CMA outside the Marlborough Sounds.
   - Identify the impacts of climate change, including increasing heat waves, and ocean acidification on water quality and delineate to what extent regional influences may interact with or further exacerbate these impacts.

4. Preliminary information gaps for environmental issues related to marine pests:
   - There appears to be gaps in the understanding of the impacts of marine pest species on the coastal environment, including native biodiversity, for example, whether U. pinnatifida is out-competing important native species.
   - While comprehensive marine pest surveys are conducted for boats in the Marlborough CMA, there appear to be no systematic surveys of habitat potentially vulnerable to the impacts of marine pests.
   - It is unclear what the ecological risk from potential new introduced marine pest species is and whether (and how) this risk may increase due to climate change.
   - It is unclear to what extent information on the presence of marine pest in the Marlborough CMA is linked to and used for other initiatives, such as marine protection, restoration or consenting.

5. Preliminary information gaps for environmental issues related to marine litter:
   - Determine the fates (including spatial extent) and impacts of microplastics, nanomaterials, and other marine debris

   MDC has already acted to partially address this science need by setting up a research project aimed at ascertaining the source and distribution of microplastic contamination in Queen Charlotte Sound/Tōtaranui.

6. Preliminary information gaps for environmental issues related to climate change:
   - There is a need to establish baselines to confirm impacts of climate change that are presumed to have already occurred (declines in kelp forests and phytoplankton) and gather ongoing information on these impacts.
   - There is a need to determine trends in indicators of climate change, such as temperature change, acidity and sea level rise.
   - Areas vulnerable to climate change need to be identified.
   - The impacts of climate change on ecosystems and marine resources in the Marlborough CMA need to be identified and, if possible, forecast.
   - Improved knowledge is required on what makes estuaries resilient to the effects of climate change and the resilience and capacity for organisms and ecosystems to adapt to climate change.
   - Ways to improve and prioritise coastal restoration efforts to support adaptation to climate change need to be developed.

7. Preliminary information gaps for environmental issues related to cumulative effects:

Information gaps include:

- A need to improve understanding of synergistic and cumulative effects of different/multiple stressors arising from marine and land-based activities and natural events on coastal habitats, species and ecosystems.
- A need to understand how the different factors of global change (temperature increase, ocean acidification, eutrophication, plastic pollution, etc.) act synergistically upon coastal and ocean ecosystem functioning.
- The need to better understand the cumulative effects of marine farming and other fishery practices has been identified. This includes the question of carrying capacity raised in the section on water quality degradation.

- Cumulative effects have been identified as the likely cause of the decline in scallops and degradation of scallop habitat in the Marlborough Sounds. A project has been set up by FNZ to assess the cumulative effect of a range of physical, biological, and ecological stressors (including fishing) on scallops and scallop habitat in the Marlborough Sounds using experimental and modelling techniques.

There are many broad and specific information gaps relating to cumulative effects. Most scientific information needs identified for the Marlborough CMA are, in fact, national scientific information needs. Due to their complexity, these scientific information needs need to be addressed through national partnerships. However, cumulative effects have played an important role in the transformations of ecosystems in the Marlborough since Māori settlement. It will be important to build on this local experience when addressing current and future cumulative effects in the Marlborough CMA.

Consistent themes across environmental issues

Some consistent themes that emerged for most environmental issues examined in this report are:

1. A lot of environmental information exist on the Marlborough CMA and continues to be gathered through SOE monitoring, research, consent-related monitoring and other investigations.
2. A number of information gathering initiatives (monitoring, investigations, and research) aimed at improving environmental management outcomes are not well aligned with policies, plans, strategies or iwi management plans, or earlier initiatives.
3. It is unclear how some scientific information needs identified in policies, plans, strategies or iwi management plans can be translated into actual scientific projects and what measurable environmental outcomes are intended to be achieved.
4. As a consequence of the previous two points, it is difficult to determine to what extent agency scientific information needs are being met through existing information or current projects. Overall, there is a need to work in a more integrated in the Marlborough CMA.
5. It is not clear what processes are being taken to prioritise scientific work being carried out in the Marlborough CMA. While within individual organisations (agency or scientific) there is some alignment of project, there appears to be limited overarching regional alignment, coordination or joint strategising of scientific initiatives. This highlights the importance of developing a joint coastal research strategy for the Marlborough CMA.
6. Environmental information is largely centred on the Marlborough Sounds with only limited information from the CMA outside the Sounds. While this partially reflects the importance of the Marlborough Sounds in terms of use and sensitivity to stressors, it poses a risk of potentially unnoticed environmental degradation in other parts of the Marlborough CMA.
7. There is limited consistent use of indicators of environmental health throughout the Marlborough CMA that would provide for consistent assessments of the state of or changes in the environment. Instead, most science providers or projects use different indicators, standards or even descriptors of environmental state or health. This creates considerable difficulties when attempting to describe the state of the environment on scales beyond individual project. Overall, there is a limited use of standards or thresholds that would provide a more contextualised assessment of the state of the environment or the severity of environmental issues.

8. There is a lack of recognition of te ao Māori in most scientific investigations, monitoring or indicators.
9. There is no systematic approach for assessing cumulative effects in the Marlborough CMA.

Developing solutions through partnerships and integration

Addressing scientific information gaps and developing solutions for the identified environmental issues will require research, investigations and monitoring, and, importantly, integration and partnerships, including recognition of te ao Māori, strategic integration of scientific knowledge and projects, effective implementation of agency environmental management tools, and collaborations among all people and groups with responsibility for management of or interests in the Marlborough CMA.

There currently is no overarching strategic approach for research on the environmental issues in the Marlborough CMA. It is important that common goals will be developed to focus future research. These goals should be aligned to jointly developed strategic management objectives for the Marlborough CMA.

This report is not designed to lead to recommendations for addressing environmental issues on its own. Instead, it is intended to be one of many sources of information that will inform discussion around more integrated management of the Marlborough CMA.

1 Introduction

1.1 Background and objective

Marlborough District Council (MDC) is moving toward more integrated management of the coastal marine area (CMA) in collaboration with other agencies, iwi, community and research organisations. To facilitate this process, it is important for MDC to understand the breadth of research and monitoring that has been undertaken in the Marlborough CMA and whether relevant scientific information needs have been met or are being addressed through current projects. Overall, MDC has identified the need to develop a more strategic approach for the collection of future scientific information on the Marlborough CMA that builds on existing information but provides for improved prioritisation and alignment of projects and gathered information.

This report presents the findings of a review undertaken to support the intended changes by MDC. It describes environmental issues of relevance for the Marlborough CMA, the current knowledge of the environmental state of the Marlborough CMA and scientific information needs described in regulatory and non-regulatory documents of relevance to MDC. This report is supported by a wider literature review of information prepared by and for agencies (specifically the Department of Conservation, DOC, and Fisheries New Zealand, FNZ), iwi and scientific organisations. Of particular importance for this report is the Kotahitanga mō te Taiao Strategy, which describes transformational outcomes sought by Kotahitanga mō te Taiao, an alliance formed by of all Councils and some of the iwi in the top of the South Island, and the Department of Conservation (Kotahitanga mō te Taiao, 2019).

This report largely takes an MDC-centric perspective; however, it is supported by information of other management agencies (FNZ and DOC), the Kotahitanga mō te Taiao Strategy and accessible iwi management plans. Wider perspectives of iwi, communities, industries and other stakeholders are integral to achieving integrated approach to coastal management.

This report provides some preliminary information gaps; however, its primary objective is to provide a systematic collation of information to inform the development of approaches for improved management of the Marlborough CMA. This report is not designed to lead to recommendations for management or other action on its own. Instead, it is intended to be one of many sources of information that will inform discussion around more integrated management of the Marlborough CMA.

1.2 Environmental management of the Marlborough CMA

The marine environment in New Zealand is subject to over 20 statutes and several central and local government organisations overlap in their jurisdiction. An illustration of the key marine legislation is shown in Figure 1. In the Marlborough CMA the key statutory agencies for environmental management, including biodiversity and fisheries, are the MDC, FNZ, the DOC, and, to a lesser extent, the Ministry for the Environment (MFE). Land Information New Zealand and Maritime New Zealand play important roles in maritime safety alongside MDC's harbourmaster. The settling of the Te Tau Ihu iwi treaty claim with statutory acknowledgments for iwi over the Marlborough Sounds, along with the Marine and Coastal Area (Takutai Moana) Act 2011, has facilitated improved tangata whenua involvement in managing Marlborough's CMA.

It has been widely acknowledged that the fragmentation of marine management amongst multiple agencies and different spatial areas creates challenges for integrated management and makes the

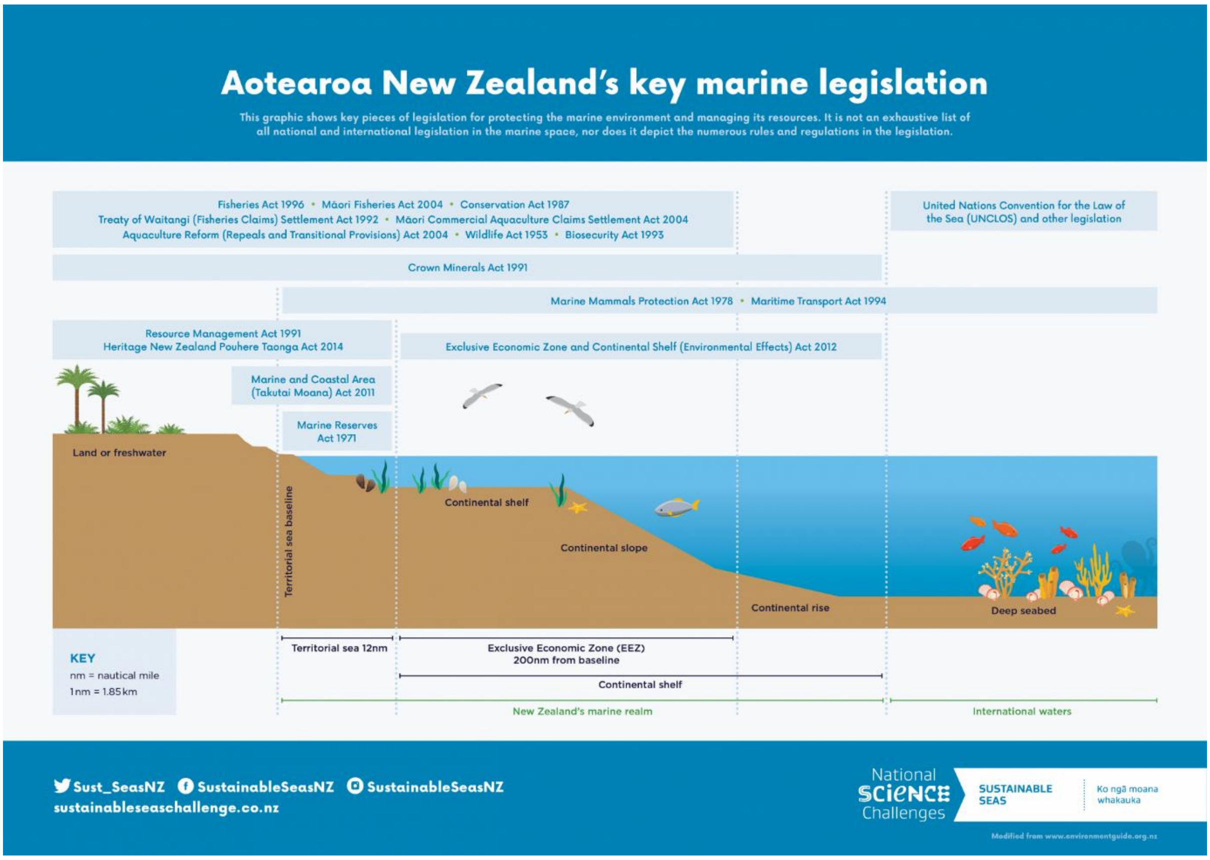

Figure 1. Illustration of key marine legislation in New Zealand. The CMA is the area shown as 'territorial sea 12 nm'. Source: Sustainable Seas National Science Challenge.

CMA vulnerable to environmental degradation, especially from cumulative effects (Kotahitanga mō te Taiao, 2019; Parliamentary Commissioner for the Environment, 2020).

1.3 Information sources

Information in this report was sourced from a range of sources, including:

- Scientific publications describing the state of the environment, stressors, changes over time, and research priorities, including State of the Environment (SOE) monitoring reports, scientific investigation reports, peer-reviewed journal articles.
- Statutory, regulatory and other relevant documents relevant to MDC, DOC and FNZ, including statutes, policies, plans and strategies (listed in Appendix 1).
- The Kotahitanga mō te Taiao Strategy (Kotahitanga mō te Taiao, 2019)**.**
- Accessible iwi management plans:
  - Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan; and
  - Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan.

1.4 The Marlborough Coastal Marine Area (CMA)

The Marlborough CMA covers more than 725,000 ha of water and has 1,814 km of coastline which equates to 10% of New Zealand's coastline (Figure 2). The Marlborough CMA is a diverse marine environment with habitats ranging from the common and typical, through to significant sites that support rare, unique or special species (Davidson et al., 2011). It consists of two quite distinct geographic areas: the Marlborough Sounds (or 'the Sounds') and the south Marlborough coast. Nearly 90% of the coastline is in the Marlborough Sounds, yet the Sounds make up only a small portion of the total area (Figure 2).

The Marlborough Sounds are large drowned river valleys lying between mountain ranges, extending from Cape Soucis in the west to Port Underwood in the east. The main sounds are the Queen Charlotte Sound/Tōtaranui, Pelorus Sound/Te Hoiere and Kenepuru Sound. Tory Channel/Kura Te Au is a major arm of Queen Charlotte Sound/Tōtaranui. They contain sheltered bays and estuaries (particularly in the inner sounds), open bays, channels, multiple islands, tidal passages and highly exposed shores. In contrast, the south Marlborough coast is an open sea coast, extending from Robin Hood Bay (Port Underwood) in the north to Willawa Point in the south. Marlborough's southern coast is markedly different from that of the Sounds, with its largely varied open coast comprising rocky and mudstone reefs, gravel beaches and the shallow Wairau lagoons.

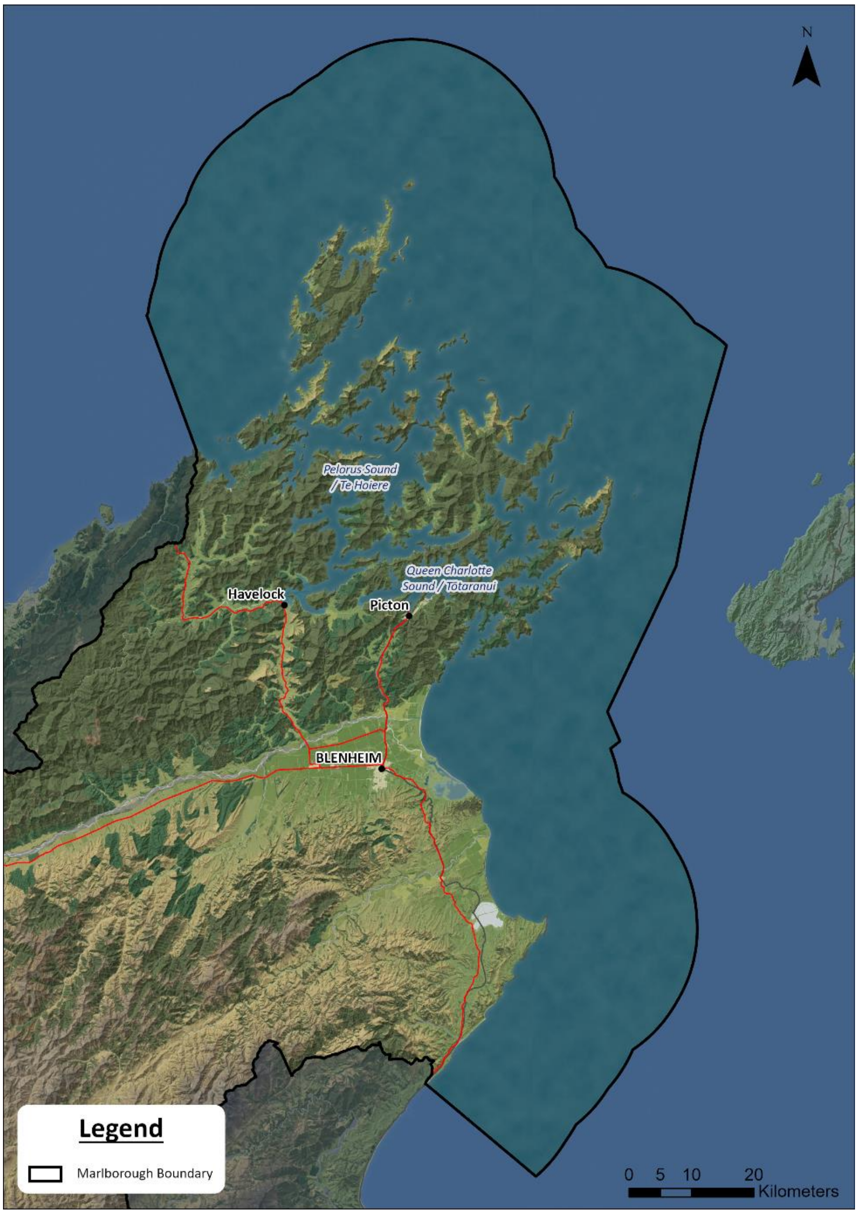

Figure 2. Marlborough Coastal Marine Area (CMA) indicating the locations of Pelorus Sound/Te Hoiere and Queen Charlotte Sound/Tōtaranui. Source: MDC.

2 Overview of environmental issues and considerations for environmental management

2.1 Overview of environmental issues and considerations for environmental management

The Marlborough CMA is exposed to a variety of stressors, both natural and anthropogenic. The combined effects of human activities on land and in the sea (historic and contemporary) introduce new stressors and exacerbate natural processes that can lead to localised or broad-scale environmental change and a variety of environmental issues. Environmental decline of the CMA can also reduce amenity, cultural and social values and economic opportunities, such as fisheries and aquaculture and lead to or exacerbate conflict over the use of space.

Environmental issues occurring in coastal environments are complex and developing solutions is challenging due to a range of factors, including conflicting interests in the use of this public space, inherently complex ecological, physical and hydrodynamic processes, multiple resource management agencies with different priorities and responsibilities, and complex processes for public participation.

As elsewhere in New Zealand, substantial coastal ecosystem changes have occurred since human settlement in the catchments of the Marlborough CMA (Urlich and Handley, 2020). Furthermore, due to the varying geomorphological conditions and natural catchment characteristics, 'natural' ecosystem conditions before human settlement would have differed substantially throughout the area. The combination of these aspects highlights the need for robust information on environmental issues and gives an indication of the challenges inherent in managing the Marlborough CMA, including identifying restoration goals and approaches.

To provide a structure for this report, a conceptual framework has been created that illustrates the associations of individual environmental issues, cumulative effects, and broad considerations within the theme of partnerships and integration (Figure 3). While the report focusses on the inner circles of the framework, it emphasises the importance of partnerships and integration in addressing environmental issues. Critically, the purpose of this report is not to remain an isolated document, but to inform discussions about improving integrated management of the Marlborough CMA.

Specific environmental issues of relevance that were identified for the Marlborough CMA[1] are related to sediment (including sedimentation and suspended sediment), habitat modification and impact on species, water quality and sediment quality degradation (including chemical and bacterial contamination and nutrient/organic enrichment), marine pests, marine litter and climate change. These environmental issues are connected, often compounding and cumulatively can generate complex ecosystem change. The classification of issues used in this report is therefore somewhat arbitrary; however, deemed useful for structuring the information presented. Cumulative effects span across all environmental issues.

Importantly, developing effective and enduring solutions for the identified environmental issues requires partnerships and collaborations among management agencies, tangata whenua/iwi, industries, communities, and scientists as well as integration of different perspectives, methods, and approaches. Figure 3 illustrates the importance of partnerships and integration as the all-encompassing element of the conceptual framework.

[1] These issues or themes emerged during the review of documents. There is overlap among the issues, so this is primarily a grouping to provide structure for this report, rather than a definite classification.

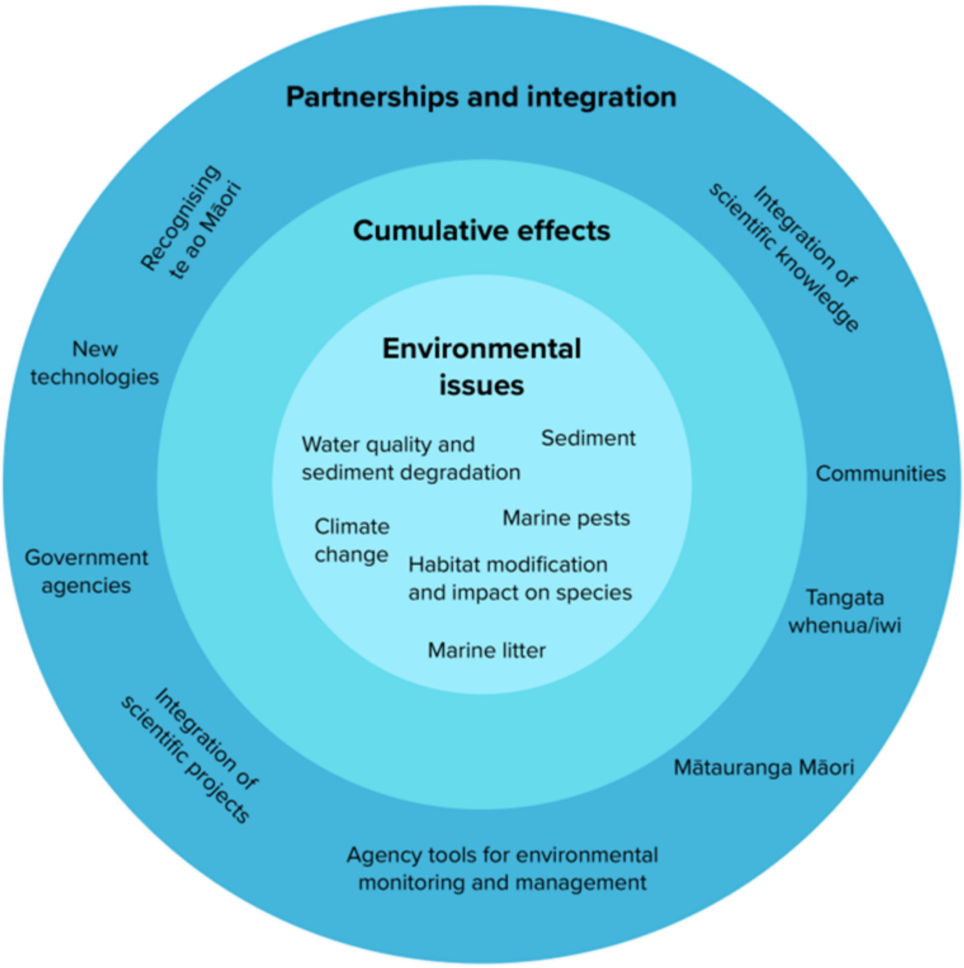

Figure 3. Conceptual framework illustrating the associations of individual environmental issues identified for the Marlborough CMA, cumulative effects, and broad considerations within the theme of partnerships and integration; the critical importance of the latter illustrated as the all-encompassing element of the framework.

2.2 Structure of this report

The structure of this report follows the conceptual framework shown in Figure 3. A robust understanding and consideration of all components of the framework is necessary for developing effective and enduring solutions for the environmental management of the Marlborough CMA. While all components are addressed in this report, it focusses mainly on describing environmental issues and identifying scientific information needs and preliminary information gaps, reflecting the intention of it being used to inform wider discussion around more effective management of the Marlborough CMA.

Section 3 provides information on the individual environmental issues identified for the Marlborough CMA. The report describes what we know about the environmental issues in the Marlborough CMA and scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA. Preliminary information gaps have been identified for each issue. Following a similar structure, section 4 focusses on cumulative effects.

Section 5 provides considerations and information on three themes that are integral aspects for a more strategic approach for addressing environmental issues centred around improved partnerships and integration: recognising te ao Māori, strategic integration of scientific knowledge and projects, and agency tools for environmental monitoring and management. Finally, section 6 summarises the findings of the report, including a description of consistent themes that emerged across environmental issues.

3 Environmental issues

3.1 Overview

In the following sub-sections, each of the six identified environmental issue is described in a New Zealand context, followed by a more extensive presentation of our current knowledge of the issue in the Marlborough CMA and scientific information needs identified in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA. The aim of these sections is not to repeat all available information but to present an overview of what we know, what the scientific information needs are for informing environmental management and to identify some preliminary information gaps. Information sources for this report are briefly described in section 1.3 and references are provided in the respective sections.

3.2 Sediment

3.2.1 The issue

Coastal waters receive sediment from the land, mainly via riverine inflow and landslides caused by intense rainfall events. Soil erosion rates in New Zealand are naturally high because of the steep terrain, weathered and erodible rocks, generally high rainfall and frequency of high-intensity rainstorms (Basher, 2013). Although a natural process, historical catchment deforestation, land conversion to pastoral agriculture, mining and catchment disturbance have increased soil erosion rates and subsequent sediment delivery to nearshore coastal waters, particularly following European settlement in the mid-1800. Throughout New Zealand, the rate at which sedimentation is now occurring is around ten-fold higher than before human activities disturbed the natural land cover (e.g. Hunt, 2019; Thrush et al., 2004).

The increased sediment input has had a widespread impact on new Zealand's marine environment, resulting in more turbid coastal waters, shift from sandy to more muddy environments, accelerated rates of infilling and degradation of ecosystems, including changed composition of the seabed and associated flora and fauna, (Davidson et al., 2011; Thrush et al., 2004).

The guidance note on NZCPS Policy 22 (Sedimentation) provides an overview of adverse effects related to sediment, which is summarised here. Deposited sediments can smother benthic communities and habitats. Suspended and deposited sediments can affect indigenous biodiversity, natural habitats and ecosystems by damaging fish gills and the filter-feeding apparatus of invertebrates. Reduced water clarity can reduce the amount of light penetrating through the water and thus affect light-dependent species. In combination, deposited and suspended sediments can thus reduce estuarine health and productivity, and alter the distribution of plants and animals.

Furthermore, the quality and yield of farmed filter-feeding shellfish can be affected by suspended sediments and sediment can kill spat. Fisheries can be adversely affected directly through increased turbidity and benthic smothering of species such as adult cockles and flatfish, or indirectly by impacting on nursery habitats such as seagrass.

Adverse effects from sediments often occur in parts of the CMA where water quality and ecosystem health are already experiencing multiple stresses from other activities, such as urban and industrial waste and stormwater discharges, and intensive commercial and recreational fishing and shellfish harvesting. These areas are also of particular interest to tangata whenua and water quality is an important issue for places of significance to iwi. For example, both suspended and deposited sediments can alter the distribution and abundance of traditional mahinga kai (customary food gathering) resources.

Suspended sediment can increase turbidity and reduce water clarity and photic zone depth. It can also transport attached pollutants, heavy metals and other urban contaminants into coastal waters, including nutrients. If sediment accumulates in harbours, marinas and ports, navigation problems can arise and dredging may be required to maintain navigation safety.

While some of the sediment entering nearshore coastal waters ultimately gets transported out into offshore environments, in sheltered coastal areas estuarine processes that resuspend and recirculate fine sediment can create natural sediment traps (Swales et al., in preparation). As a result sediments linger and continue to disturb coastal ecosystems long after their initial discharge (Parliamentary Commissioner for the Environment, 2020). Contemporary issues related to sediments, especially in sheltered coastal areas, therefore likely represent a combination of two issues: (1) new catchment-derived sediment loads, and (2) recirculation of legacy sediment.

On a national level, sediment has been ranked the third equal threat to New Zealand's marine habitats with fishing, following the top two threats ocean acidification and increased sea temperatures (MacDiarmid et al., 2012). Sediment is commonly noted as a primary environmental concern because of its direct adverse effects and its contribution to cumulative effects (Ministry for the Environment and Stats NZ, 2019; Parliamentary Commissioner for the Environment, 2020).

3.2.2 What we know about this issue in the Marlborough CMA

Sedimentation from erosion of the land, has been an issue since European occupation of the catchments, driven by deforestation, timber extraction, livestock farming, gold mining and with ongoing effects from land development and forestry (Urlich, 2015; Urlich and Handley, 2020). High rainfall can result in excessive sediment loads due to the underlying lithology and soils, and steep topography, that create sporadic high suspended sediment events (Urlich, 2015). For example, Figure 4 shows high suspended sediments in the Pelorus Sound/Te Hoiere on July 8, 2018 after an estimated 1 in 3.1 year annual return interval rainfall event. The Kotahitanga mō te Taiao strategy identified the challenge that Pelorus Sound/Te Hoiere has some of the muddiest estuarine areas in New Zealand as a result of land-use practices.

Sediment accumulation rates (i.e., the rate of sediment depositing on the seafloor) over the last 150 years have been 5–20 times higher than those before European settlement (i.e., prior to the 1860s) at several sites within the inner Pelorus Sound/Te Hoiere (Handley et al., 2017). The seabed of the Queen Charlotte Sound/Tōtaranui has also been subjected to accelerated sediment discharge relating to land clearance, disturbance from contact fishing gear (finfish trawling, shellfish and kina dredging), and modification on coastal fringes by land development and reclamations (Handley, 2016). A sediment type (classified based on grain size) map has been created by Ribó et al. (2020) for Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au (Figure 5).

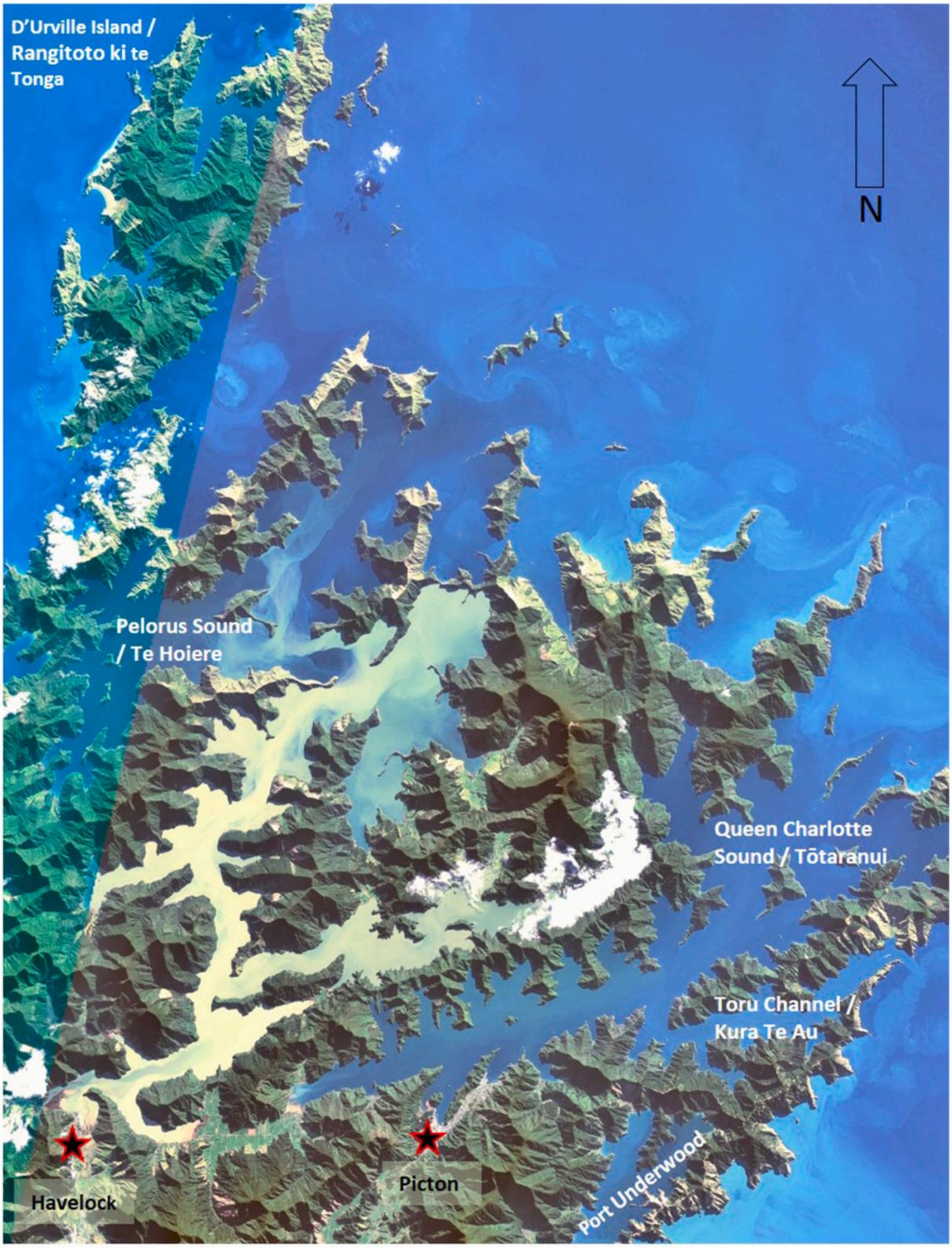

Figure 4. Satellite image of Pelorus Sound/Te Hoiere (discoloured yellow-brown) and Queen Charlotte Sound/Tōtaranui from July 8, 2018 after an estimated 1 in 3.1 year annual return interval rainfall event. Source: Urlich and Handley (2020).

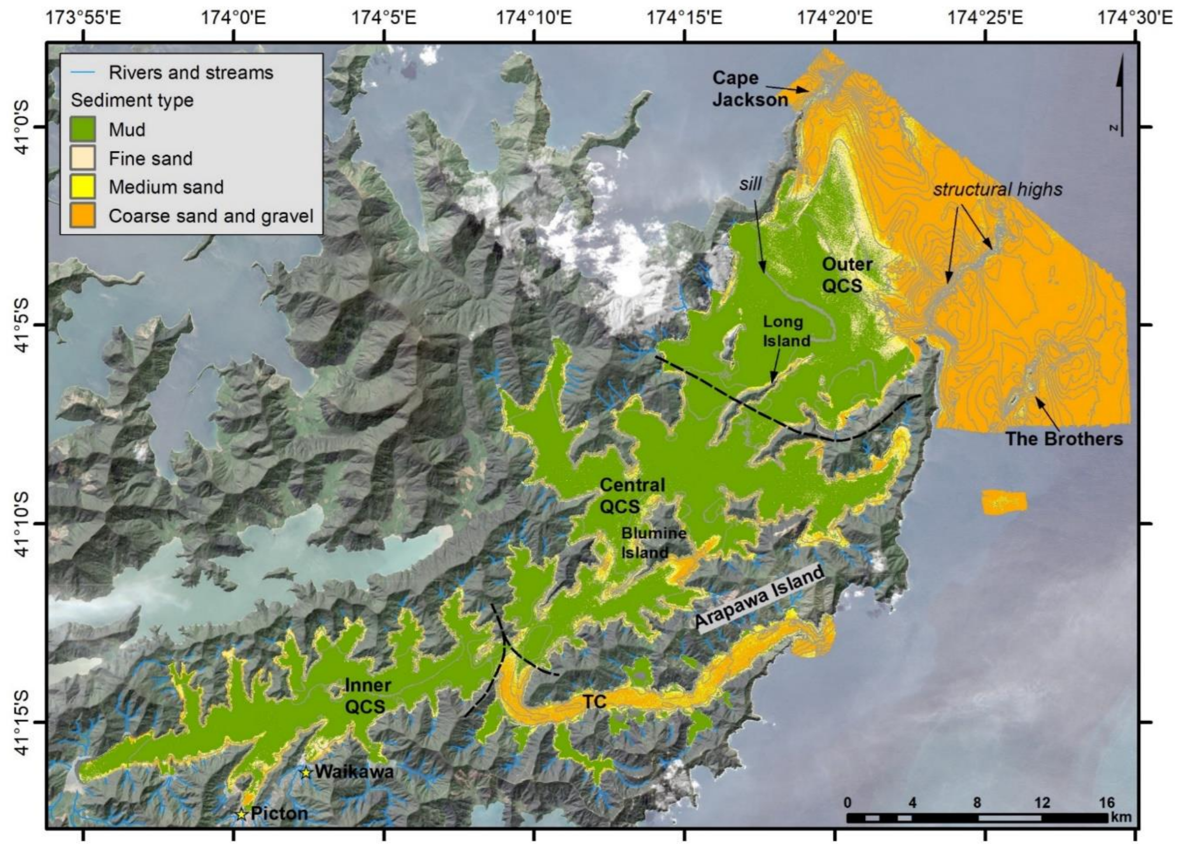

Figure S9. QCS and TC Seafloor Classification (sediment type) map. Contour lines (grey lines) are spaced every 20m.

Figure 5. Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au seafloor classification (sediment type) map. Contour lines (grey lines) are spaced every 20m. Source: Ribó et al. (2020).

Intensive land use in catchments of the inner Pelorus Sound/Te Hoiere ecosystem over the period of European occupation has resulted in complex cumulative effects of sedimentation in this environment (Swales et al., in preparation). Effects of soil erosion and sedimentation have ranged in scale, from localised impacts on cockle beds from early Māori activities in Mahau Sound, to extensive catchment-wide soil erosion and sedimentation since European settlement. Gold mining, native forest clearance, pastoral farming, and more recent widespread harvesting of Pinus radiata plantations (c. 1980–present), have all left their legacy in the coastal waters of the Sound. For example, intertidal species disappeared from the estuary in Hitaua Bay (located within a side bay of Tory Channel/Kura Te Au), following a large sedimentation event, likely caused by a mid-slope failure in 2012 after rainfall of a 1 in 5 year return interval (Urlich, 2015). This sedimentation event reduced the estuaries' ecological value to the extent that it was no longer rated as a significant marine site under the MDC Ecologically Significant Marine Sites (ESMS) programme in 2015 (Davidson et al., 2015; see section 5.4.5 for information on the ESMS programme).

Of high importance for the environmental management of sedimentation is the high proportion of legacy sediments in the inner Pelorus Sound/Te Hoiere. Legacy sediments associated with catchment deforestation, mining, and burning (mid–late-1800s) have accumulated as flood plain deposits and throughout Pelorus Sound/Te Hoiere. Estuarine processes that re-suspend and re-circulate fine sediment create a natural sediment trap within Pelorus Sound/Te Hoiere. Swales et al. (in preparation) consider it likely that legacy sediments will continue to be a major sediment source for decades to come and state that this may diminish the effectiveness of addressing the issue of sedimentation in Pelorus Sound/Te Hoiere through land management in the catchment. In other words, even if new sediment input would be reduced substantially, there will be a potentially long lag time until this intervention shows a positive outcome. Furthermore, the prolonged sediment input may have shifted the ecosystem into a different ecological state, and it may not be possible to return it to its pre-European settlement state. Identifying desirable ecological states and restoring ecosystems to a desired ecological state is further complicated by complex interactions between stressors that are often not well understood. Removing sediment input alone may not necessarily result in positive outcomes to the anticipated extent because of these interactions.

There is some evidence that the concentration of suspended inorganic solids and turbidity have risen since mid-2014 in Pelorus Sound/Te Hoiere (Broekhuizen and Plew, 2018). Water quality monitoring by MDC between 2013 and 2018 shows that near-surface suspended inorganic solid concentrations in the inner Pelorus Sound/Te Hoiere are typically three-fold higher than in the outer Sound (Broekhuizen and Plew, 2018; Swales et al., in preparation). Sediment plumes in the Pelorus Sound/Te Hoiere during river floods have been shown to extend through most of the upper water column in the inner Sound (Broekhuizen and Plew, 2018). Swales et al. (in preparation) concluded that these consistently higher suspended sediment levels in the inner Sound will be less favourable for diatom and seagrass growth due to reduced light availability.

Marine experts providing science advice for the Kotahitanga mō te Taiao Strategy development, concluded that in the Marlborough Sounds and Cook Strait environments:

- Sediment load is more than ten times the background rate without disturbance with far more fine material. Primarily a pressure on estuarine and inner sound environments;
- Numerous small estuaries affected by sediment; and
- Valley wetlands have been converted to farms, so estuaries now disconnected from natural filter, which would reduce sediment loads (Lawless, 2018).

Adverse effects of sediments observed in the Marlborough Sounds include the smothering and modification of seabed habitats by fine sediment; discolouration of the water column, particularly in areas of low current flow; resulting damage to sensitive biogenic (or 'living') habitats and a decline in fish numbers (Urlich, 2015; Urlich and Handley, 2020).

Monitoring conducted in many estuaries of the Marlborough Sounds identified muddy sediment inputs (contemporary and historic) as being the key stressor for Marlborough estuaries (Forrest and Stevens, 2019). For example, five fine-scale monitoring surveys in Havelock Estuary since 2001 have shown that the estuary's main intertidal basin has been considered to be in a moderate-poor state in relation to sedimentation since the beginning of monitoring commenced (Robertson, 2019a). 2020 inaugural monitoring in Ohinetaha Bay and Broughton Bay revealed sediment muddiness issues throughout the intertidal Ohinetaha Bay estuary but only moderate sediment stress in Broughton Bay (Robertson, 2020a). In Elie Bay and Wet Inlet, Pelorus Sound/Te Hoiere, 2020 monitoring showed a lack of excessive muddiness from both estuaries (Robertson, 2020b).

Historical sediment input has also been identified as the most severe impact on marine environmental health in Picton Harbour, Waikawa Bay and Shakespeare Bay, collectively referred to as Picton Bays in a separate ecological health assessment (Newcombe and Johnston, 2016). Deforestation in the area used to be widespread; however, the catchment is now largely vegetated. Hydrodynamic data have shown that sediments deposited into the sheltered Picton Bays are not exported again due to the low water movement experienced in the area (Urlich, 2015) and therefore effects of legacy inputs are expected to persist. It is unlikely that the effects of the very high historical sediment inputs can be reversed in the next decades, and ongoing disturbance of the seabed, notably by ferry wake, maintains fine terrestrial sediments at the surface of the seabed and thereby exacerbates the impacts of sediment input (Newcombe and Johnston, 2016).

Table 1. Scientific information needs related to environmental issue 'sediment' stipulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring. Documents reviewed are shown in Appendix 1.

Document	Scientific information needs/requirement
NZCPS Policy 4 Integration	• Understand effects of land use activities on water quality and marine ecosystems through increasing sedimentation
NZCPS Policy 22 Sedimentation	• Monitor sedimentation levels • Monitor impacts of sedimentation on the coastal environment
MDC PMEP Policy 15.1.32, Implementation method 15.M.3	• As part of undertaking catchment-specific research to establish the capacity of fresh waterbodies to assimilate total contaminant loads from within each catchment, consider the capacity of sensitive receiving environments, such as the enclosed coastal waters of the Marlborough Sounds, to contaminant loads, including sediment loads from rivers. • Identify clarity standards for coastal water (after reasonable mixing)
Kotahitanga mō te Taiao strategy (Top of the South as a whole, TOS 13.0)	• What are ecologically sustainable levels of fine sediment entering the Marlborough Sounds? • Identify degraded estuarine and coastal areas • Understand what is required to restore degraded estuaries
Kotahitanga mō te Taiao strategy (Marlborough Sounds/Cook Strait, MS 7.0, 7.1, 7.2, 7.6)	• What are ecologically sustainable levels of sediment input to the Marlborough Sounds that allow benthic ecosystems to thrive?
Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan	• Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the coastal / marine resources of the rohe
Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan	• This plan lists issues, objectives policies, anticipated environmental results, monitoring requirements for coastal water, relating to taonga species, water quality, kaimoana beds and fish. • Specific science needs should be identified in partnership with Ngati Koata.

3.2.3 Scientific information needs for the Marlborough CMA

3.2.3.1 Scientific information needs identified in scientific surveys and investigations

Forrest and Stevens (2019) recommend that, for improved understanding of monitoring and management priorities for estuaries and intertidal areas, it would be timely to undertake a comprehensive data synthesis and analysis to investigate in detail:

- How is the percentage and area of soft mud changing, if at all?
- Where important spatial or temporal changes exist, can they be related to potential explanatory drivers (e.g., catchment activities and differences in mass loads of sediments, nutrients, etc).

3.2.3.2 Scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA

Specific scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA are listed in Table 1.

3.2.3.3 National scientific information needs of relevance to the Marlborough CMA

Jarvis and Young (2019) identified several national research priorities relating to sediment in their New Zealand Marine Science Horizon Scan carried out as part of a research project. Research questions are found in categories fisheries and aquaculture, coastal and ocean processes, and other anthropogenic factors, illustrating the wide-spread impacts of sediment on coastal ecosystems and are listed in Appendix 2.

Further relevant to the Marlborough CMA are research needs identified by the CSIG, in relation to sediments, particularly those aimed at achieving the stated goal of better understanding the response of coastal ecosystems to stressors in order to effectively manage the CMA (Berkett et al., 2015). Relating to sediments, they include the need to:

- Characterise the existing CMA by collecting appropriate data for establishing baselines
- Identify the effects of stressors within both a spatial and temporal context
- Predict and measure the impact of freshwater flows, loads and limits on the coastal receiving environment
- Develop approaches for the enhancement and restoration of degraded environments in the CMA
- Research environmental thresholds and establish appropriate and relevant limits and standards for stressors impacting on the CMA, including those derived from land-based activities.

3.2.4 Summary and information gaps

What we know[2]

Catchment-derived sediment loads into Pelorus Sound/Te Hoiere and Queen Charlotte Sound/Tōtaranui are high, creating particular pressure on estuarine and inner sound environments. In addition, legacy sediments have accumulated throughout Pelorus Sound/Te Hoiere where their re-suspension and re-circulation is creating a natural sediment trap. Sediment accumulation rates in the Marlborough Sounds have increased greatly over the past 150 years; with contemporary rates in the inner Pelorus Sound/Te Hoiere being 5-20 times higher than those before European settlement.

[2] This is a brief summary of information provided in section 3.2.2.

There are indications that turbidity and suspended solids concentration have increased in Pelorus Sound/Te Hoiere in recent years, and sediment plumes during river floods can extend through most of the upper water column in the inner Sound.

As a consequence of sediment inputs, several estuaries are becoming increasingly muddy and fine sediment inputs (contemporary and historic) has been identified as the key stressor for Marlborough estuaries. Sedimentation has contributed to the modification and degradation of seabed habitats in the Marlborough Sounds (see section 3.3) and turbid waters in the inner Pelorus Sound/Te Hoiere are considered less favourable for diatom and seagrass growth due to reduced light availability.

Legacy sediments will continue to be a major sediment source for decades to come, potentially diminishing the effectiveness of improved land management in the catchment on sediment-related issues in the CMA. Further complexities arise from potential shifts in ecological state of ecosystems and interactions between stressors, many of which are not well understood. Restoration of habitats affected by sediments is therefore challenging. Removing sediment input alone may not necessarily be effective and potentially long lag times need to be anticipated until interventions show positive outcomes.

What scientific information needs have been identified

The scientific information needs identified in section 3.2.3 specifically for the Marlborough CMA and those identified on a national level with relevance for the Marlborough CMA in relation to sediment are:

- Improve understanding of sedimentation levels, loads and spatial extent of elevated sedimentation and habitat muddiness (Berkett et al., 2015; Forrest and Stevens, 2019; NZCPS Policy 22; Jarvis and Young, 2019).
- Identification of explanatory drivers of important spatial or temporal changes in areas of soft mud (Forrest and Stevens, 2019).
- Identify the impact of and responses of ecosystem attributes to sedimentation on coastal ecosystems and species (Berkett et al., 2015; Jarvis and Young, 2019).
- Identification of impacts from current and potential future land uses, terrestrial processes and human activities on land at the coast on the coastal environment (including habitats, primary productivity, carbon pathways, shellfish population and beds, species and ecosystem services) (Jarvis and Young, 2019; NZCPS Policy 4 and 22).
- Identify ecologically sustainable levels of fine sediment entering the Marlborough Sounds (Kotahitanga mō te Taiao Strategy).
- Determination of the assimilative capacity of coastal environments for sediment to inform the identification of assimilative capacities for freshwater bodies (MDC PMEP Policy 15.1.32; Implementation method 15.M.3).
- Research environmental thresholds and establish appropriate and relevant limits and standards for sediments impacting on the CMA, including sediment derived from land-based activities (Berkett et al., 2015).
- Identify the impacts of suspended sediment on primary production and carbon pathways in coastal waters (Jarvis and Young, 2019).
- Development of clarity standards for coastal waters (MDC PMEP Policy 15.1.32; Implementation method 15.M.3).
- Identification of degraded estuaries and coastal areas and development of approaches for restoring these areas (Berkett et al., 2015; Kotahitanga mō te Taiao Strategy).

- Development of approaches for mitigating impacts on coastal environments (Jarvis and Young, 2019).
- Improving methods for monitoring river plumes and impacts on coastal waters (Jarvis and Young, 2019).
- Improve understanding of sedimentation effects in offshore environments (Jarvis and Young, 2019).
- Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the coastal / marine resources of the rohe (Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan)

Preliminary information gaps to inform a more strategic approach for collecting scientific information to address environmental issues related to sediment

Based on the information reviewed and described in this section, the following preliminary information gaps related to sediment have been identified. This is not intended to be a complete list but a starting point for building on existing information and taking a more strategic approach for the collection of further scientific information on environmental issues related to sediment in the Marlborough CMA. Inevitably, there are overlaps with information gaps identified in other sections of this report and future work should ensure alignments among environmental issues are considered.

Information gaps include:

1. There is a need to better understand sediment loads and the sources of excess sediments in the Marlborough CMA.
2. To inform a more strategic approach to managing sediment-related issues in the Marlborough CMA, there is a need to determine criteria for identifying degraded areas (benthic and water column).
3. There is a need to determine thresholds, limits, standards and the assimilative capacities of different parts of the Marlborough CMA for sediment inputs and suspended sediments.
4. Identification of how continuing land-derived and legacy sediments impact the ability of coastal ecosystems to recover from anthropogenic stressor impacts.
5. Approaches need to be developed for restoring degraded areas in the Marlborough CMA and action plans need to be developed to ensure strategic and integrated actions towards improvement.
6. Specific focus needs to be placed on better understanding the importance of legacy sediments and their influence on the ability of coastal ecosystems to be restored.
7. While a reasonable knowledge base exists on the sediment impacts on habitats in the Pelorus and QCS, limited information is available on effects in offshore environments and other areas of the Marlborough CMA outside Pelorus and QCS.

3.3 Habitat modification and impact on species

3.3.1 The issue

New Zealand's marine environment comprises a diverse range of habitats and species. The resulting biological diversity (or biodiversity) provides many ecosystem services and creates ecosystem resilience to stressors. Marine species include shellfish, finfish, marine mammals, birds, invertebrates and algae. Some are kaimoana or taonga species and some have a special conservation status because they have been assessed as threatened or at risk of extinction under the New Zealand Threat Classification System (Townsend et al., 2008). All species play important roles in marine food webs.

Marine habitats can be divided into benthic and pelagic habitats. In this report 'habitat' generally refers to benthic habitats and pelagic habitats are considered under the issue of water quality degradation. Marine habitats can be classified in many ways. For example, MacDiarmid et al. (2012) defined marine habitats by the type of benthic substrate (rock, sand, mud, calcareous rubble, etc.), the dominant biological structural element (saltmarsh, mangrove forest, seagrass, cockle bed, pipi bed, kelp forest, turfing algae, biogenic calcareous reef), or by depth and degree of exposure (harbour, sheltered coast, exposed coast, slope habitats, deep water habitats).

Biogenic habitats are those created by living plants (e.g., kelp forests, seagrass meadows, mangrove forests) or animals (e.g., bryozoan thickets, sponge garden, tubeworm fields) so that their three-dimension structure provides shelter, protection and resources for other marine flora and fauna (Anderson et al., 2019). Biogenic habitats provide a wide range of ecosystem services. They are aesthetically valuable for society for tourism (e.g., swimming, kayaking, diving and boating), commercially and recreationally harvested as food (e.g., scallops, green-lipped mussels, seaweed), and indirectly valuable to the New Zealand economy and culturally through the provision of essential fish habitat for many fishery and taonga species (e.g., snapper, blue cod, tarakihi), especially during crucial life stages (e.g., nursery and spawning grounds) (Anderson et al., 2019). Furthermore, biogenic habitats stabilise coastal sediments, recycle nutrients and mitigate coastal erosion and inundation. Habitat-forming plants, such as kelp forests and seagrass meadows, are some of the most productive habitats on Earth, while habitat-forming invertebrates, such as beds of large bivalves, act as 'marine vacuum cleaners' filtering large volumes of water resulting in cleaner waterways (Anderson et al., 2019). These characteristics provide high ecological value, rendering biogenic habitats a particular focus in environmental management.

Shellfish beds[3] are particularly important biogenic habitats. They are a dominant part of New Zealand's soft-sediment coastal environments and of high importance for environmental management. Large-bodied shellfish in high densities can form stable bed forms that support a diverse range of sessile and motile epibenthic associates (Anderson et al., 2019). Key shellfish species are robust dog cockles (*Tucetona laticostata*), horse mussels (*Atrina zelandica*), New Zealand scallops (*Pecten novaezelandiae*) and green-lipped mussels (*Perna canaliculus*). Edible shellfish species have significant cultural and economic value. For example, green-lipped mussels and scallops are highly prized shellfish species that are harvested both commercially and recreationally, and along with horse mussels are all customary kaimoana and taonga species for local iwi.

Some habitats with high ecological value, such as biogenic habitats, are quite localised and include habitats and species that are very fragile and easily damaged (Anderson et al., 2019; Davidson et al., 2011). For example, in some soft-bottom habitats organisms such as bryozoans and tubeworms can form a biological skin over the seafloor, increasing species diversity as well as providing refuge and food for adult and juvenile fish. These habitats are fragile and vulnerable to physical damage, either directly (e.g., from dredging and bottom trawling) or indirectly (e.g., land clearance increasing sedimentation that can smother marine life).

[3] Defined by Anderson et al. (2019) as the occurrence of large shellfish in densities of ≥ 30% cover over an area of 100 m^2 or more, or where catches contribute 30% or more by weight or volume in a single dredge tow or grab sample.

Bottom-contact fishing activities (e.g., dredging and bottom trawling) can also remove, dislodge or break bivalves, particularly emergent species such as horse mussels (Anderson et al., 2019). Bivalve beds may vary in their exposure and vulnerability to fishing disturbances and damage; for example, species such as the robust dog cockle that lie buried beneath the sediment (with its feeding siphons just coming to the surface) may suffer little impact from gear that does not penetrate the sediment. In contrast, species that emerge above the seabed, such as horse mussels, may be far more vulnerable to being removed, dislodged or broken by dredging and bottom trawling. However, while living infaunal robust dog cockles may be less impacted, the removal of *Tucetona* shell-debris may significantly reduce the biodiversity associated with these relict-shell habitats.

Table 2. Threats to New Zealand marine habitats identified by MacDiarmid et al. (2012).

Threats

Marine Based Threats		
Fishing	**Engineering**	**Invasive species**
Bottom trawling	Sand / gravel abstraction	Space occupiers, competitors
Scallop or oyster dredging	Dredging	Disease
Trapping fish or crayfish	Mining - surface suction	
		Shipping
Paua gathering/ diving	Mining - deep hole extraction	Animal strikes
Seaweed gathering	Mining - other methods	Noise pollution
Spear fishing	Dumping of dredge spoils	Ship grounding, sinking
Set netting	Coastal reclamation	**Ecotourism**
Pelagic low bycatch (e.g. squid jigging)	Causeways	Marine mammal watching
Pelagic high bycatch	Pontoons	Diving
Long-lining	Piled wharfs/sheds	Reef trampling
Shellfish fishing / gathering	Pile moorings/markers	Noise
Recreational line fishing	Seawalls	Feeding wildlife
Displacement of fishing activity		Vehicles
	Pollution (at sea)	
Aquaculture	Oil or oil products	**Other threats**
Benthic accumulation of debris	Plastic	Anchoring
Decreased available I^{o} production	Sewage	Algal blooms - toxic and massive
Increase in habitat complexity	Acoustic discharges / guns	Increased turbidity
	Electromagnetic discharges	

Land based Threats		Global Threats
River inputs	**Pollution (in catchments)**	**Increasing greenhouse gases**
Decreased sediment loading	Oil or oil products	Increase in sea-level
Increased sediment loading	Plastic	Increase in sea temperature
Decreased freshwater discharge	Sewage	Increased intertidal temperatures
Increased freshwater discharge	Heavy metals	Increase in UV radiation
Dampening of flows	Nitrogen and phosphorus	Ocean acidification
	Pesticides including PCBs	Change in currents
	Herbicides	Increased storminess
		Altered rainfall
		Increased stratification

Habitats are at threat from many stressors[4]. MacDiarmid et al. (2012) identified eleven general categories of threats to marine environments deriving from human activities either in the marine environment (e.g., fishing, pollution, coastal engineering), in catchments that discharge into the marine environment (e.g., sedimentation, eutrophication) or indirectly through global threats such as increase in sea temperature, increase in sea level, or acidification, which they subdivided into sixty-five finer categories (Table 2).

Adverse effects on habitats can be assessed in various ways. One concept used in this context is habitat integrity. Habitat integrity can be described as the extent to which the physical structure (either inorganic or biogenic[5]) of the habitat is suitable for its naturally-occurring biological community (Newcombe, 2017). Unmodified habitat has a greater structural integrity, while alterations to habitat, such as changes in sediment grain size or loss of plants and animals that created structure, will invariably have adverse implications for biodiversity (Newcombe, 2017).

While there are commonalities in the nature of stressor impacts on habitats, the sensitivity and vulnerability of different habitats to specific stressors differs and can be site- and species-specific. MacDiarmid et al. (2012) found some common relationships between stressors and habitats. They concluded that the number of threats to New Zealand's marine habitats generally declines with depth, which shallow coastal habitats being impacted by up to fifty-two non-trivial threats derived from human activities, while deep water habitats are threatened by as few as four or five. Likewise, the estimated magnitude or severity of those effects was found to declines steeply with mean depth of the habitat. Reef, sand, and mud habitats in harbours and estuaries and along sheltered and exposed coasts were considered to be the most highly threatened habitats and the least threatened estuarine and harbour habitats were saltmarsh and mangrove forests. Slope and deep water habitats were among the least threatened and lowest ranked. The greatest contribution to the vulnerability of individual habitats was the functional impact of a threat (whether just one or a few species were affected), or the whole ecosystem was impacted. Threat frequency (whether the threat was pulsed and the timing of those pulses), or whether it was persistent, was the second greatest contribution to the vulnerability scores.

3.3.2 What we know about this issue in the Marlborough CMA

3.3.2.1 Impact on species

3.3.2.1.1 General

A list of important species was developed to support the identification of ecologically significant marine sites in the Marlborough CMA by Davidson et al. (2011). Many sites received their significance ranking due to the presence of important species. Some sites provide habitat for important species, while others are feeding and breeding areas or migratory routes. Species were separated into seabirds, marine mammals, fish (including sharks), invertebrates, algae and vascular plants.

Important species in the Marlborough CMA identified by Davidson et al. (2011) are:

- Birds
    - Australasian gannet (*Morus serrator*)
    - Banded rail (*Gallirallus philippensis assimilis*)
    - Fairy prion (*Pachyptila turtur*)
    - Flesh-footed shearwater (*Puffinus carneipes*)

[4] The terms stressors and threats are used interchangeably in this section.

[5] Created by organisms.

    - Fluttering shearwater (*Puffinus gavia*)
    - King Shag (*Leucocarbo carunculatus*)
    - Little penguin (*Eudyptula minor*)
    - Northern diving petrel (*Pelecanoides urinatrix urinatrix*)
    - Red-billed gull (*Larus novaehollandiae scopulinus*)
    - Reef heron (*Egretta sacra sacra*)
    - Sooty Shearwater (*Puffinus griseus*)
    - Spotted shag (*Stictocarbo punctatus punctatus*)
    - White-fronted tern (*Sterna striata*)
- <u>Mammals</u>
    - Bottlenose dolphin (*Tursiops truncatus*)
    - Dusky dolphin (*Lagenorhynchus obscurus*)
    - Hector's dolphin (*Cephalorhynchus hectori hectori*)
    - Humpback whale (*Megaptera novaeangliae*)
    - Killer whale, orca (*Orcinus orca*)
    - Short-beaked common dolphin (*Delphinus delphis*)
    - Southern right whale (*Eubalaena australis*)
    - New Zealand fur seal (*Arctocephalus fosteri*)
- <u>Fish</u>
    - Blue cod (*Parapercis colias*)
    - Elephant fish (*Callorhinchus milii*)
    - Groper, hapuku (*Polyprion oxygeneios*)
    - Lancelet (*Epigonichthys hectori*)
    - Rough skate (*Zearaja natuta*)
    - Snapper (*Pagrus auratus*)
- <u>Invertebrates</u>
    - Black foot paua (*Haliotis iris*)
    - Bryozoan coral (*Galeopsis porcellanicus*)
    - Burrowing anemone (*Cerianthus* sp.)
    - Chiton (*Notoplax latalamina*)
    - Giant lampshell (*Neothyris lenticularis*)
    - Horse mussel (*Atrina zelandica*)
    - Rock lobster (*Jasus edwardsii*)
    - Scallop (*Pecten novaezelandiae*)
    - Separation point coral (*Celleporaria agglutinans*)
    - Tubeworm (*Galeolaria hystrix*)
- <u>Algae</u>
    - Giant kelp (*Macrocystis pyrifera*)
    - Red algae (*Adamsiella chauvinii*)
    - Red algae (*Rhodymenia* spp.)
    - Rhodoliths (*Lithothamnion* sp.)

Urlich and Handley (2020) conclude that ecosystems in the Marlborough Sounds have gone through a series of transformations since Māori settlement and describe that impacts on species include local extinction of marine megafauna (including sea lions, elephant seals, fur seals, Waitaha penguin) and decimation of southern right whale populations. Exacerbated by European settlement, there has also been a decline and/or localised deletion of some fish and shellfish species .

Marine experts providing science advice for the Kotahitanga mō te Taiao Strategy development, drew the following conclusions on species in the Marlborough Sounds and Cook Strait environments (Lawless, 2018):

- Fish and shellfish stocks have declined, and the scallop fishery has collapsed;
- Large predators such as rock lobster and groper are functionally extinct in shallow waters;
- Cod and other species are reduced; and
- Loss of horse mussels, green lipped mussel beds and scallops in some areas, reducing benthic filtration capacity.

The following sections describe information on selected species that have received particular emphasis in research projects and/or other initiatives carried out in the Marlborough CMA.

3.3.2.1.2 King Shag

One species of importance and particular attention in the Marlborough Sounds is the New Zealand King Shag (*Leucocarbo carunculatus*). King Shag are a rare species of marine cormorant found only in the Marlborough Sounds[6]. King Shag at colonies or roost sites are very susceptible to disturbance. The total population comprises around 800 birds who breed at a number of headlands and rock outcrops scattered throughout the Outer Sounds.

The population is thought to have remained relatively stable for the last 50 years; however, little is known about the ecology of King Shag. The Marine Farming Association (MFA) has formed the King Shag Working Group with representatives from the aquaculture industry, the Ministry for Primary Industries, iwi , MDC and the DOC and in 2019, partnered with Seafood Innovations Limited and industry members to fund an extensive research programme on King Shag. The three-year project has already produced information on King Shag foraging behaviour and interactions with marine farms. Project results can be found on the project website[6]. The banding and tracking work under the project is complemented by population census work funded by New Zealand King Salmon; and colony surveys, eDNA analysis and otolith research funded by the Ministry for Primary Industries (MPI) and DOC. King shag breeding and roosting sites are identified in the MDC PMEP (Ecologically Significant Marine Sites 1.6, 2.11, 2.14, 2.21, 3.3 and 3.9).

3.3.2.1.3 Scallop (Pecten novaezelandiae)

Another species of concern is the scallop (*Pecten novaezelandiae*) due to the decline of the commercial catch from the Marlborough Sounds since 2009 (Fisheries New Zealand, 2020a). In 2016, a temporary partial area closure was put in place over the Marlborough Sounds Area, which was extended to the remainder of SCA 7 in 2017. The overall SCA 7 stock has failed to recover to healthy biomass levels, and the fishery is currently closed (Fisheries New Zealand, 2020a).

The Southern Scallop Working Group (SSWG) was set up by the Minister of Fisheries in 2018, and brings together iwi, commercial and recreational sectors of the fishery, scientists and fisheries managers, and community representation. The SSWG has developed the Southern Scallop Strategy – Marlborough Sounds, which has the overarching aim of ensuring the scallop stock rebuilds to a healthy level, and future customary, recreational and commercial fishing activity is sustainable (Fisheries New Zealand, 2020a).

One key reason put forward for the decline in scallops is increasing change in the benthic environment over the last 30 years that is now no longer able to support healthy scallop beds. For example, Figure 6 illustrates the difference between suitable and unsuitable scallop habitat. Fisheries

[6] https://www.marinefarming.co.nz/king-shag-project/

Figure 6. The photo on the left displays healthy, complex habitat which supports scallops. The photo on the right displays habitat that no longer supports healthy scallop populations. Photos taken in SCA 7 in 2018. Source: Fisheries New Zealand (2020a).

New Zealand (2020a) states that there is some evidence that, as for many overseas scallop fisheries, the drivers of this change include a range of human-induced impacts, including fishing and land-based impacts.

3.3.2.1.4 Green-lipped mussels (Perna canaliculus)

Green-lipped mussels were also historically estimated to cover large areas of the seabed in the inner regions of the Marlborough Sounds but many of these mussel beds, for example in Kenepuru Sounds, supported a commercial native harvest, that lead to serious declines (Handley 2015; Anderson et al., 2019). Nowadays beds of native green lipped mussels growing on the seabed are rare, and likely sourced from vagrants from nearby mussel farms (Anderson et al., 2019). A recent NIWA video survey recorded mixed biogenic beds with small isolated clumps of green lipped mussels growing on the seabed on the northern side of Kenepuru Sounds; however, it is unclear whether these reflect motile displacement from nearby farms or represent naturally settled patches (Anderson et al., 2019).

3.3.2.1.5 Effects of sediment on shellfish

A particular stressor repeatedly emphasised in relation to shellfish in the Marlborough CMA, as elsewhere in New Zealand's coastal environment, is excessive deposition of sediments, particularly fine sediment. An experimental study on the infaunal New Zealand cockle, *Austrovenus stutchburyi*, which is widespread and abundant in the Nelson-Marlborough region, showed that it is likely that natural or anthropogenic sediment deposition events (that deposit sediments with similar grain sizes to those already present) would be expected to have only limited direct impacts on local cockle populations (Barrett et al., 2017). In contrast, finer grained sediments (e.g., silts) or those that contain even small compositions of terrestrial clays are likely to have much more significant effects, with potential changes in community structure and loss of critical species likely to occur. Another exacerbating factor impacting cockles is sediment disturbance. The experiment indicated that, if cockles were also physically disturbed (in the experiment this was simulated by burying them upside-down), then some larger cockles would be predicted to die in response to deposition of sediments and mortality would increase with increasing thickness of the sediment deposit.

The current distribution of filter-feeders in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au is highly affected by current dynamics and suspended sediment concentrations in the water column because of sediment load from river and streams and near-bottom sediment resuspension events (Ribó et al., 2020; Figure 7).

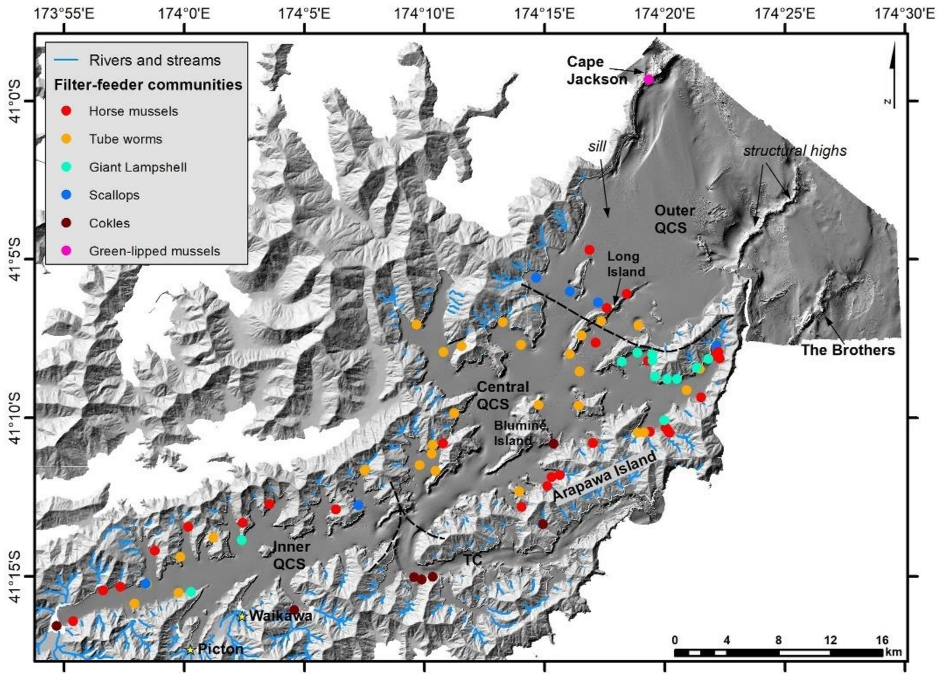

Figure 7. Filter-feeder communities' distribution map within QCS and TC. Dashed lines limit the Inner QCS, Central QCS and Outer QCS areas. Source: Ribó et al. (2020).

3.3.2.1.6 Fish (blue cod and snapper)

Anderson et al. (2020) reported that, although blue cod were commonly recorded throughout Queen Charlotte Sound/Tōtaranui, large legal sized blue cod were rare, as too were other large-sized commercial fish or crayfish. They observed that the few locations where large fish were found were under the path of the ferries or on deep reefs not previously charted, suggesting that these locations provide a natural but very limited refuge from fishing pressure.

In Picton Bays fish species are reported to have been seriously depleted from their historically highly abundant populations, likely as a result of both overfishing and habitat destruction (Newcombe and Johnston, 2016).

Based on interviews with users of Pelorus Sound/Te Hoiere, Urlich and Handley (2020) describe a general trend of decreasing productivity in the Marlborough Sounds since human settlement. The authors describe there are current anecdotal reports from recreational rod and line fishers that snapper are very scarce in the Pelorus and that instead an overabundance of spiny-dog fish (*Squalus acanthias*) are caught. Urlich and Handley (2020) report of fears being raised that the apparent decline in snapper catches over recent years indicates a tipping point has occurred in the health of the Sounds. Anecdotal report of changes to finfish species abundance and composition, with reductions in numbers of large predators including rig, snapper, and crayfish, are also described in Handley (2015).

The 2018 National Blue Cod Strategy[7] developed by FNZ and an expert group comprising members experienced in blue cod fishing from tangata whenua and the recreational and commercial fishing communities, describes that an increasing number of fishers over the past 20 years and improvements in vessel and gear technology have caused a decrease in abundance and the average size of blue cod

[7] https://www.mpi.govt.nz/dmsdocument/32533-National-Blue-Cod-Strategy-2018

in many parts of New Zealand. The strategy aims to improve the way the blue cod fishery is managed, for example, by providing for more national consistency in regulation, changing the rules and limits for blue cod, looking at the broader environmental factors affecting blue cod (such as pollution and warming seas), more encompassing regulatory frameworks (aligned to ecosystem-based fisheries management), and alternative ways of gathering information (such as recreational self-reporting).

Fisheries New Zealand's Fisheries Assessment Plenary provides the best available information on New Zealand fish stock assessments and stock status reports. The Fisheries Assessment Plenary summarises science working group reports for commercial fish species or species groups. It is updated annually and published on the Ministry for Primary Industries website.[8] While anecdotal information is useful, particularly given that fish stocks are manage to a Fisheries Management Area rather than local area scale, it may not necessary reflect the overall health of a stock. The National Panel Survey of Recreational Fishers, which is conducted every 5 to 6 years provides the best snapshot of recreational fishing activity around the country. The most recent survey in 2017-18 shows that fishing effort has decreased across New Zealand since the previous survey. The number of fishing trips in a given year are subject to several variables (e.g., weather, wind, swell, water temperature and fuel prices). Results from a Fisheries New Zealand research project (MAF2014/04)[9] has, however, indicated that recreational fishing effort for snapper in SNA 7 has increased between 2017 and 2019 and the mean weight of individual fish caught increased by 12% between 2015 and 2018.

3.3.2.2 Estuarine intertidal habitats

Many estuaries in the region have significant remaining areas of seagrass and saltmarsh (Forrest and Stevens, 2019). Seagrass and saltmarsh also provide important ecosystem functions by providing protection and nursery habitat and capturing carbon. Their presence indicates ecologically healthy conditions due to their vulnerability to sedimentation and other disturbances. Extensive seagrass beds have been reported in Ngakuta Bay, Shakespeare Bay, Tuna, Harvey and Duncan Bays, Waikawa Bay and Whatamango Bay[10] (Forrest and Stevens, 2019). 2020 inaugural monitoring in Ohinetaha Bay, Broughton Bay, Elie Bay and Wet Inlet revealed that all estuaries supported areas of saltmarsh and seagrass habitat which remain in relatively good condition (Robertson, 2020a, 2020b).

However, seagrass coverage has been found to be low in several estuaries, including Kaiuma Bay, Kenepuru Estuary and Mahakipawa Arm and is likely completely absent in Wairau Estuary and Lagoon (Forrest and Stevens, 2019). In Havelock Estuary, seagrass coverage has decreased by 3 ha, or 10%, between 2014 and 2019 (Robertson, 2019b). Reduced seagrass coverage in large estuaries has been associated with fine sediments. For example, estuary monitoring results indicate such association in Okiwa, Kaimua, Mahakipawa and Havelock estuaries (Figure 9).

Sedimentation, reclamation and construction have contributed to degradation of habitat integrity in Picton Bays (Picton Harbour, Waikawa Bay and Shakespeare Bay) (Newcombe and Johnston, 2016). While the disturbance from ferry wakes occurring late last century has been lessened, the wake from large ferries and other vessels continue to dictate the ecological zonation of shallow environments and the present wake-affected habitat structure has now largely been accepted as the norm (Newcombe and Johnston, 2016). The intertidal estuarine areas at the top of Shakespeare Bay and Waikawa Bay is recognised as important habitat due to the presence of seagrass beds and other biogenic habitat, and for aspects of their biodiversity and functioning (such as sediment trapping).

[8] https://www.mpi.govt.nz/science/fisheries-science-research/about-our-fisheries-research/
[9] Fisheries Research Services for 2019-2020 (https://www.mpi.govt.nz/dmsdocument/34299/direct)
[10] See MDC estuary monitoring programme locations in Figure 8.

Figure 8. Location of broad- and fine-scale survey sites included in and proposed for the MDC estuary monitoring programme. Source: Forrest and Stevens (2019).

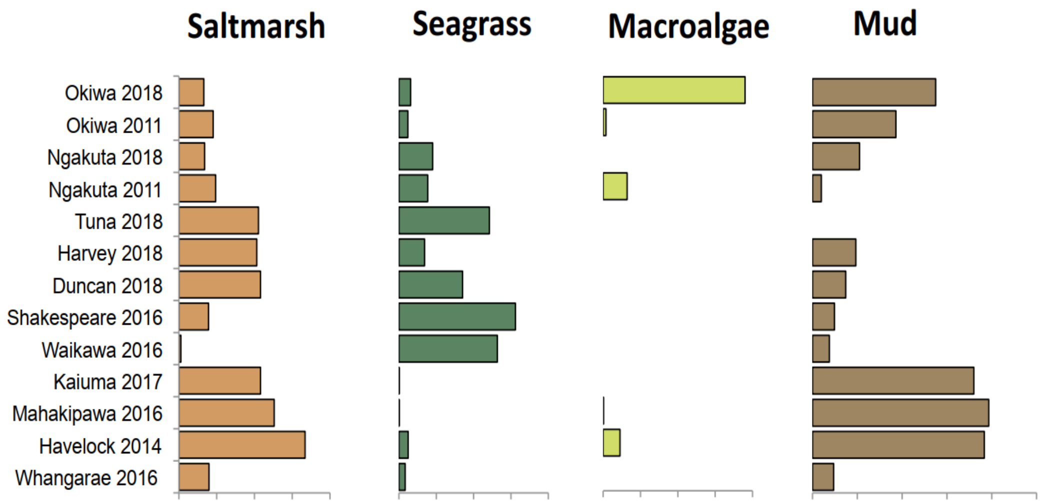

Figure 9. Example of some key features assessed as part of estuarine monitoring. Source: Forrest and Stevens (2019).

3.3.2.3 Subtidal habitats (including biogenic habitats)

Historic loss and degradation of habitats

Since European settlement there has been a significant loss and degradation of biogenic habitat in the Marlborough Sounds, especially shellfish beds, including depletion of dredge oyster beds in Oyster Bay (Tory Channel/Kura Te Au), destruction of subtidal green-lipped mussel beds, overexploitation of scallop beds from dredging caused loss of beds in inner Pelorus (Mahau) and loss of horse mussel beds in outer sounds (Anderson et al., 2019; Urlich and Handley, 2020). Factors causing this change include seabed modified by sedimentation, particularly in the Pelorus Sound/Te Hoiere, direct removal of species and seabed disturbance, mainly from trawling and dredging (Urlich and Handley, 2020). The Kotahitanga mō te Taiao strategy emphasised that benthic habitats in the Marlborough Sounds and Cook Strait have been degraded and destroyed by runoff and direct damage from seabed disturbing activities.

Bryozoan reefs are now mostly limited to the entrance ways into Queen Charlotte Sound/Tōtaranui after historically likely occurring more extensively across the "Duck Pond" (the large sediment bank or sill across the entrance of Queen Charlotte Sound/Tōtaranui; Anderson et al., 2020). The reduction of bryozoan beds has also been identified as concern by marine experts providing science advice for the Kotahitanga mō te Taiao Strategy development (Lawless, 2018). Bryozoan habitats provide important and often critical structural habitat and refuge to a diversity of marine life and are known to act as nursery habitats for many commercial and recreationally important fish species, including blue cod. The consequences of habitat loss may have important consequences, including reduced recruitment of blue cod in this region (Anderson et al., 2020).

Anderson et al. (2020) also reported on wide-spread damage to *Galeolaria* mounds, which are composed of thousands of calcareous tubes formed by the suspension feeding serpulid worm *Galeolaria hystrix* from successive generations settling on top of each other. Damage was recorded at 47 of the 54 sites. *Galeolaria* growing over reefs often had localised damage, with towers toppled or broken into rubble, likely caused by boat anchors. *Galeolaria* mounds across shell-debris slopes, often on exposed lower slopes, often had much more extensive damage, with towers demolished over 10-

100's of metres with just small broken rubble remaining. This damage was indicative of mechanical damage to slope habitats, including areas of biogenic encrusted reefs that appeared to have been sheered clean, along with notable amount of rubble from completely demolished *Galeolaria* mounds at one slope sites, and similar *Galeolaria* rubble found in amongst accumulated shell debris in the main channel. These observations indicate that more substantial *Galeolaria* mounds may previously also have occurred within Tory Channel/Kura Te Au (Anderson et al., 2020).

Hay (1990) reported observations of losses and changes in distribution of *Macrocystis pyrifera* within the Marlborough Sounds between 1942 and 1988 and linked these changes to increases in water temperature.[11] The current geographic distribution of kelp within Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au closely matches that described by Hay in 1990; however, the composition of kelp differed, with the greatest difference being the presence and relative proportions of the exotic kelp *U. pinnatifida* (Wakame), and the absence of *M. pyrifera* at some sites (Anderson et al., 2020). A new dense kelp forest of *E. radiata* was discovered off Waihi Point, near Cape Jackson but while patchy kelp beds were still common along the shallow fringe in Tory Channel/Kura Te Au, with beds comprised of various assortments of giant kelp *Macrocystis pyrifera*, *E. radiata* and *C. flexuosum*, *U. pinnatifida* is now common within the kelp-zone at most sites. Within outer Queen Charlotte Sound/Tōtaranui, rocky reefs and rubble habitats around Motuara Is. and Motungarara Is. that once supported *M. pyrifera*, are now completely replaced by *U. pinnatifida* indicating wide-scale occurrence of *U. pinnatifida* though the Sounds, where it may be out-competing important native species.

Biogenic habitats in the Marlborough Sounds described by Anderson et al. (2019)

In their review of key biogenic habitats in New Zealand, Anderson et al. (2019) described a range of biogenic habitat types occurring in the Marlborough Sounds and wider Marlborough CMA. The following paragraphs summarise information provided in Anderson et al. (2019).[12]

Robust dog-cockle beds have been found in the Rangitoto Channel on the Eastern side of D'Urville Island (Davidson et al., 2017a). Extensive horse mussel beds are known to occur on the eastern side of Chetwode Islands, and in East Bay in Queen Charlotte Sound/Tōtaranui. A horse mussel bed has been characterised and mapped within the Long Island Marine reserve (Haggitt, 2017; in Anderson et al., 2019) covering 0.3 km^2 (representing 0.4% on the MPA) - located between Long Island and the Kokomohua Islands in water depths of 10-20 m. Patchy horse mussel beds also occur across the Banks around the Trios and Chetwode Islands, where significant biogenic material (dominated by sponges and reef-forming bryozoans) has become bound together. Sparse horse mussels also occur throughout the Sounds, but many of these show significant signs of shell damage (e.g., Guards Bank, Waitui Bay and Port Gore - where scallop dredge fishing was historically undertaken), while rare patches of horse mussels are resigned to hollows on the seafloor, that may have provided refuge from past fishing activity. However, while some information exists on the presence and density of horse mussel beds, little is known about the condition or change in extent of these habitats through time.

While scallop populations have declined substantially through the Marlborough Sounds (see description above), large dense scallop beds have been recorded on the western side of Long Island marine reserve, that extends into and is protected by this MPA. This scallop bed has been estimated to cover a 0.17 km^2 area of the seabed (representing 2.6% of the MPA) located in water depths of >30 m along the western boundary of Long Island marine reserve (Haggitt, 2017; in Anderson et al., 2019). Scallops are described as 'common' in the Marlborough Sounds by Anderson et al. (2019).

[11] The work by Hay is described in more detail in section 3.7 (Climate change).
[12] References provided by Anderson et al. (2019) are also shown.

Other subtidal biogenic habitat found in the Marlborough Sounds include Rhodolith beds[13] (French Pass and Admiralty Bay), bryozoan beds (or thickets)[14], calcareous tubeworm mounds[15] and non-calcareous tubeworm fields[16]. Rhodoliths are typically found in clear subtidal water on sediments with coarse sand, gravel or shell debris but little is known about their distribution around New Zealand. The Rodolith beds recorded in Admiralty Bay and French pass in 2017 are described as extensive and dense by Anderson et al. (2019) and are shown in Figure 10. Most habitat-forming bryozoan species are fairly widespread around New Zealand, including the Marlborough Sounds (Anderson et al., 2019).

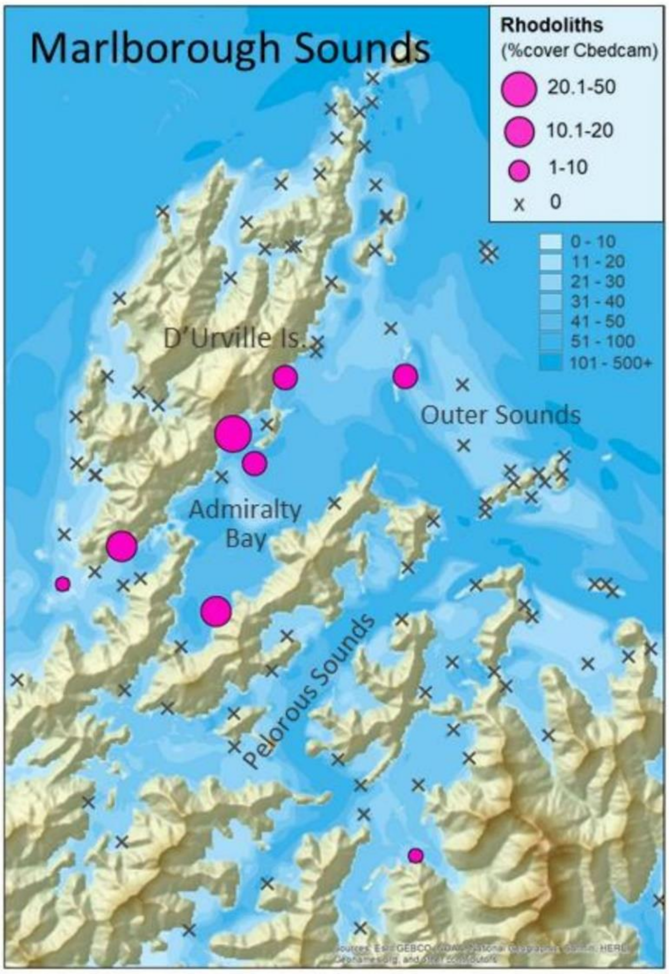

Figure 10. Rhodolith mean percent cover recorded during a NIWA benthic video survey in April-May 2017. Source: Anderson et al. (2019).

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[13] Defined by Anderson et al. (2019) as free-living coralline thalli (individual rhodoliths) that occur on the seabed in greater than ≥10% cover, or a single occurrence of a rhodolith species in a towed or point sample.
[14] Defined by Anderson et al. (2019) as habitats where frame-building bryozoan species dominate (at least) square metres of seafloor. Frame-building bryozoans are defined as heavily-calcified species that regularly attain sizes over 50 mm in three-dimensions.
[15] Defined by Anderson et al. (2019) as raised reef-like structure up to 1.5 m high and 1-100 m in diameter encountered at relatively low densities (e.g., 40 per ha); with a thicket deemed present where one or more mounds are seen, or intertwined tubes contribute ≥10% of the catch in dredges or beam trawls, or where intertwined tubes are collected in a single grab sample.
[16] Defined by Anderson et al. (2019) as areas of contiguous cover or mosaics of higher density tubeworm patches interspersed by bare sediment, where tubeworms (and any attached epifauna) cover >500 m^2 of seafloor, or contribute at least 25% of the weight or volume of the catch from towed sample gear, or occur in two successive samples collected by point sampling gear.

Galeolaria hystrix, the largest and most significant aggregating tubeworm living in calcareous tubes, is generally rare in extent. It occurs throughout sheltered areas of the Marlborough Sounds, though only forms significant mounds in a few locations (Figure 11). The most prominent mounds occur on Perano Shoal in Queen Charlotte Sound/Tōtaranui covering an area of c. 5.5 ha on the upper slope of the shoal; and on two headlands on the eastern side of Port Underwood (the Knobbies) covering 3.4 ha in 3-12 m water depth and Whataroa Bay covering 0.9 ha a in 3-15 m.

The distribution and taxonomy of tubeworm species is very poorly known; however, 2017 surveys across the Marlborough Sounds found tubeworm fields to be an important and abundant biogenic-habitat suggesting that they are likely to be more widespread around New Zealand than reflected in the currently known distribution (Anderson et al., 2019). Tubeworm fields distribution and abundance within 3-30 m deep areas of the Marlborough Sounds mapped during the 2017 surveys are shown in Figure 12.

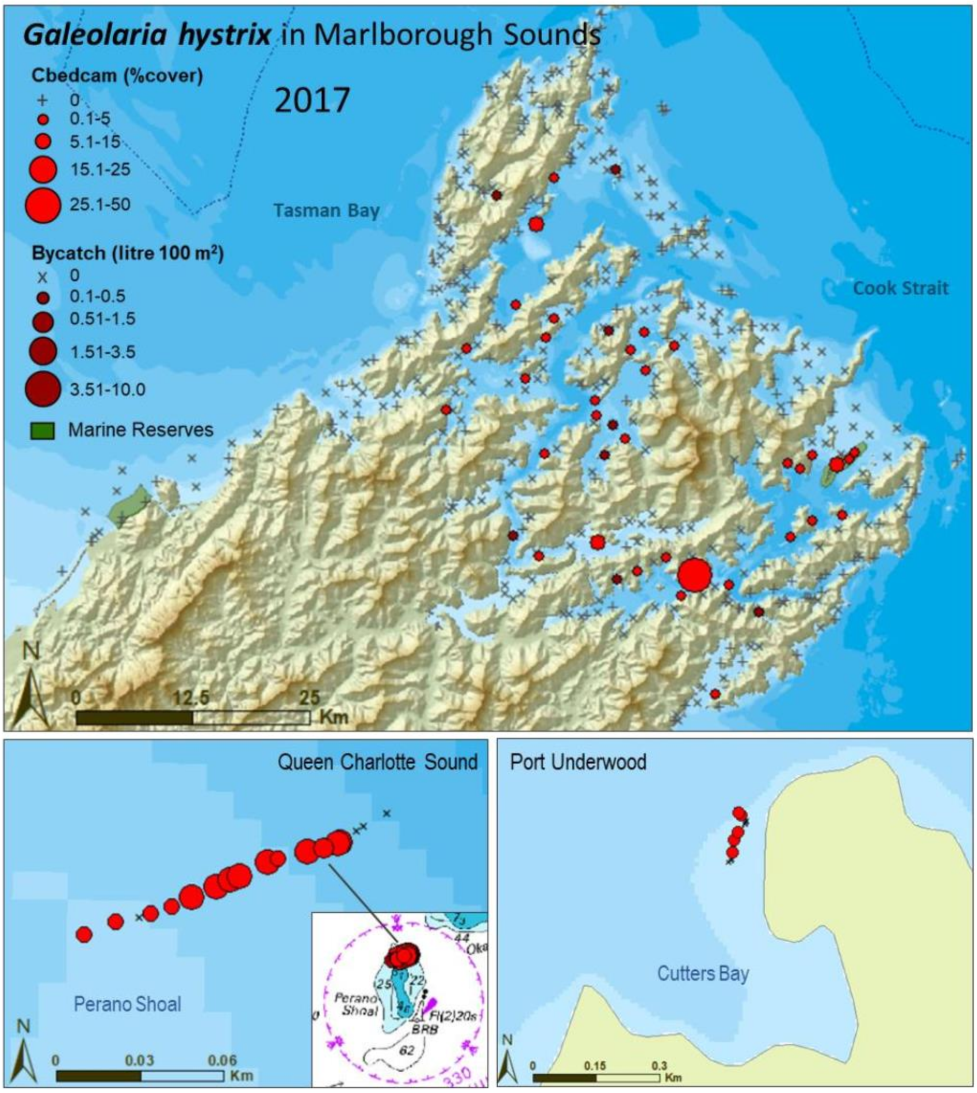

Figure 11. Distribution and abundance of the calcareous mound-building tubeworm, *Galeolaria hystix*, based on surveys conducted in 2017. All samples were collected in 3-30 m water depth. Source: Anderson et al. (2019).

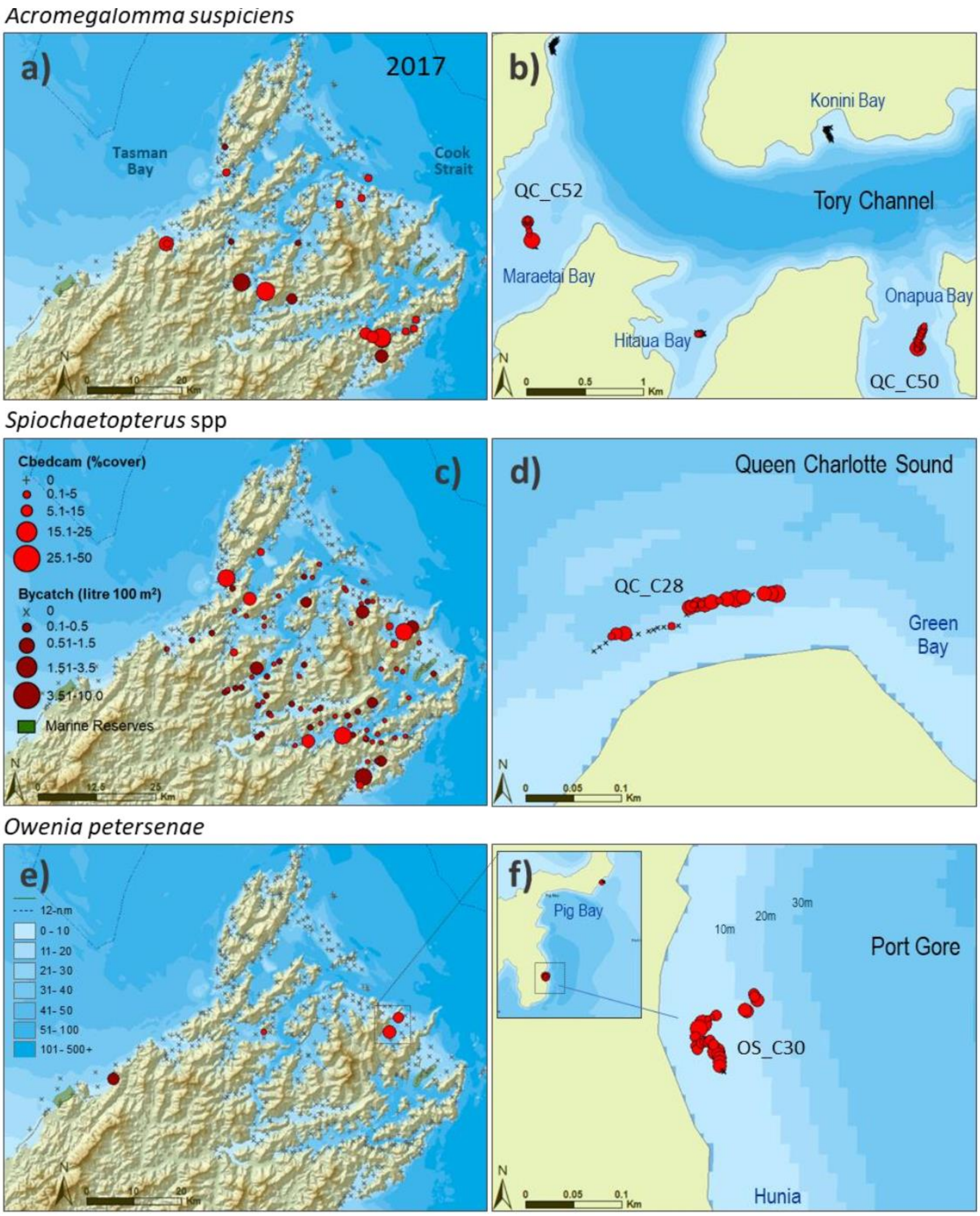

Figure 12. Tubeworm fields distribution and abundance within the Marlborough Sounds derived from surveys conducted in 2017. All samples were collected in 3-30 m water depth. Source: Anderson et al. (2019).

Habitats of Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au and adjacent Cook Strait described by Anderson et al. (2020)

Anderson et al. (2020) undertook a comprehensive survey of habitats and communities across the Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au and Cook Strait regions to build on and ground-truth existing information, including information reported by Anderson et al. (2019) described above. The survey identified many new and notable habitats, communities and species, including new records of species within the Marlborough Sounds, new records of genera/families for New Zealand, and new records of size and colour-morphologies for known species. Overall, the report provides critical knowledge on the nature, state, vulnerability, and relative availability of the diverse habitats and communities that occur within the survey areas and provides new information on the representativeness of habitats, species and communities.

The findings presented by Anderson et al. (2020) are described as one of the most comprehensive stock-takes of marine habitats and associated communities within New Zealand and a full summary of the over 300-page report is out of scope of this report. While declines in biogenic habitats observed by Anderson et al. (2020) are described above, it is important to emphasise that the survey revealed many high value habitats in Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au and Cook Strait, including:

> "highly-diverse and visually-stunning communities on deep reefs in the Cook Strait that had never before been seen, dramatic landscapes of fragile tubeworm towers growing out across the shelldebris slopes across the Sounds, [and] extensive sediment plains that instead of being featureless soft sediment areas as one might expect, were instead inhabited by millions of pink brittlestar arms emerging out through the mud" (Anderson et al., 2020).

Anderson et al. (2020) documented the distribution, abundance and natural character of important biogenic habitats (e.g., bryozoan patch reefs, *Galeolaria* mounds, tubeworm mounds, kelp forests and algal meadows) and the structure and refuge provided by these habitats for a diverse range of sessile invertebrates and fishes, for example the role of bryozoan mounds as important nurseries for blue cod. Other species (e.g., *Tucetona* and horse mussels) were also identified to be important underlying drivers of community structure within Queen Charlotte Sound/Tōtaranui, by providing critical shell substrata for other habitat-forming species to settle and grow on.

Physical variables derived from the multibeam survey by Anderson et al. (2020) along with geographic variables were found to be important predictors of benthic habitats and communities. The authors explain that the next important step will be to formally integrate these data to create habitat suitability maps for key species and broad-scale habitat maps for the entire Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au, and adjacent Cook Strait region.

Physical footprint of anthropogenic activities in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au

Anthropogenic activities can result in temporary or permanent modification of or damage to the seafloor. The physical footprint of anthropogenic activities[17] in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au has recently been mapped by Watson et al. (2020) from high resolution (2 m) multibeam bathymetry.

This study found that the physical anthropogenic footprint in the QCS and TC extends from the shoreline to hundreds of meters water depth is unevenly distributed (Figure 13). The footprint includes marine infrastructure (marine farms, cables/pipelines and wharves; Figure 14 B,D,E) and impacts from maritime activities (mooring blocks, anchor drag marks, and shipwrecks; Figure 14 A,C,F). The greater extent of anthropogenic influence in the inner QCS (c. 6% of the seafloor) is most likely to be related to the high population near the coast in the inner QCS, centered on the township of Picton, and the presence of the Picton and Waikawa ports. Furthermore, the low influence from tidal currents in the

[17] The physical footprint is the area of physical modification or damage of the CMA and does not include the spatial extent of other effects, such as the plume of suspended sediment resulting from the activities.

inner QCS results in minimal scouring, suggesting that human-induced seafloor disturbance may be better preserved in this part of the sounds compared to other higher energy environments (e.g., outer QCS). Watson et al. (2020) expect that the true spatial extent of physical disturbance related to anthropogenic activities is likely to be even more extensive than estimated in this study as the physical anthropogenic footprint measured using the multibeam bathymetric data only captures seabed features observable in the 2 m resolution data (i.e., >2×2 pixels or 4×4 m).

Maritime activities (anchor drag marks, mooring blocks, and shipwrecks; Figure 14 A,C,F) make up c. 72% of the total anthropogenic footprint in QCS and TC, with anchor drag marks making up almost half the entire anthropogenic footprint observed (47.5%; Figure 14). Marine infrastructure represents almost a third of the anthropogenic footprint (28%; Figure 14 G) and includes wharves (3.6%), cables/pipelines (13.8%) and marine farms (11%).

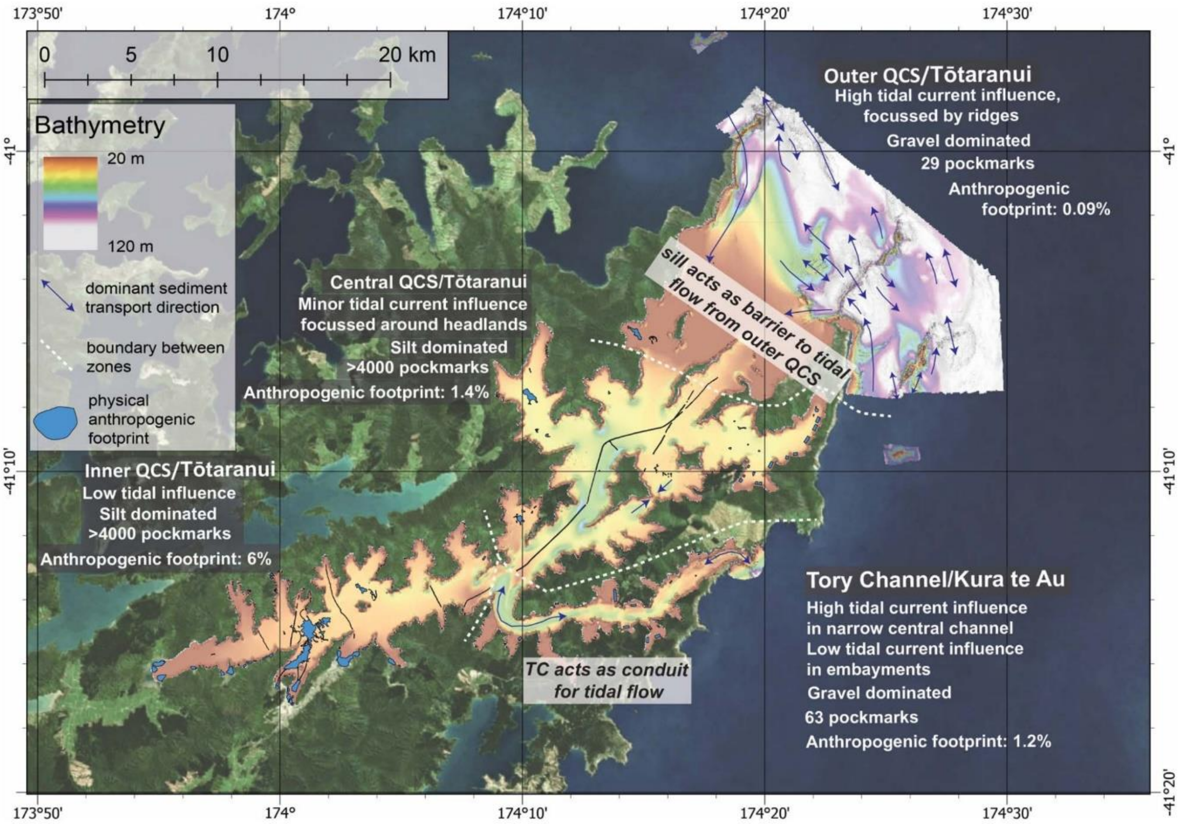

Figure 13. QCS and TC bathymetry (2 m resolution) and physical anthropogenic footprint. The study area is divided into geographic zones (white dashed lines): inner QCS, central QCS, outer QCS and TC. Navy blue arrows show the dominant sediment transport direction as interpreted from seafloor geomorphology. Source: Watson et al. (2020).

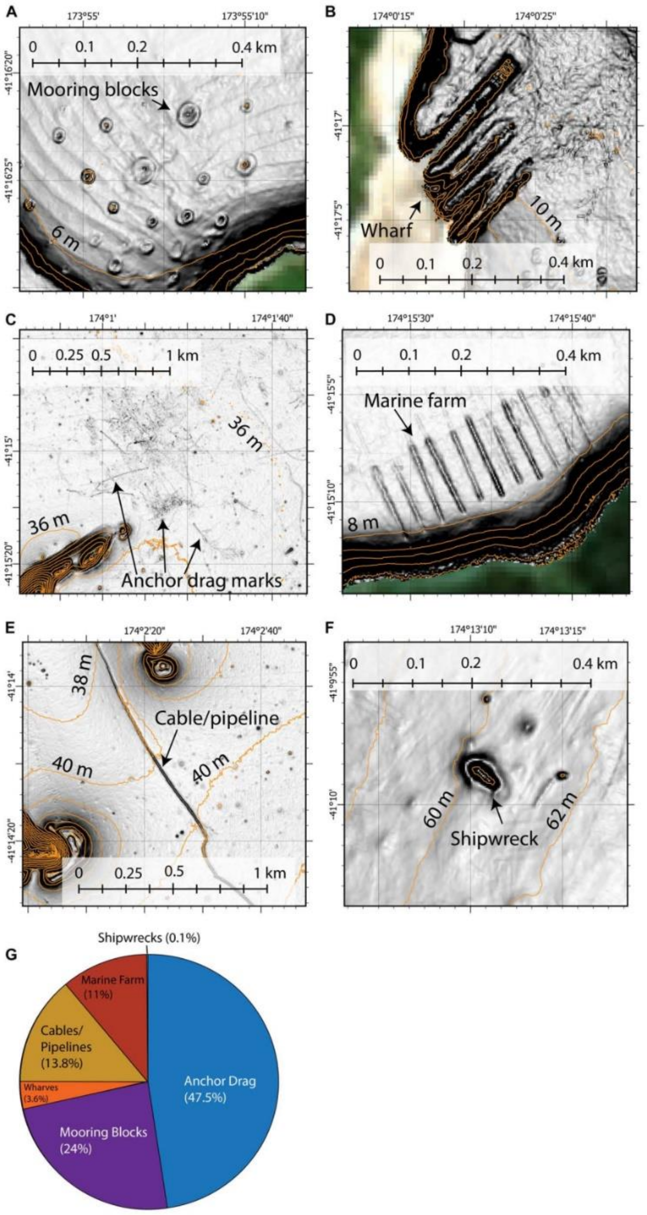

Figure 14. Hill-shaded examples of the anthropogenic footprint observed in the QCS and TC; orange lines are 2 m contours. (A) mooring blocks in the inner QCS, (B) wharves near Picton Port, (C) anchor drag marks at the Picton Anchorage, (D) marine farm in TC, (E) seafloor cable or pipeline in inner QCS, (F) shipwreck in the central QCS, (G) pie chart showing the different types of anthropogenic footprint observed in the QCS and what proportion of area they contribute as a percentage.

Habitats identified through Local Ecological Knowledge (LEK)

Local Ecological Knowledge (LEK) held by people familiar with the environment is a valuable source of information and often complementary to information derived from scientific surveys. Jones et al. (2016) worked with fishers throughout New Zealand to derive LEK of their fishing grounds, recording their knowledge of biogenic habitat, with charts being marked by the fishers themselves before being digitised and collated to provide a national map of fisher-drawn areas of possible biogenic habitat. Many of these sites were noted by fishers for the distinctive habitats/species caught as bycatch.

Forty-five LEK habitat areas were described in the Marlborough Sounds by six fishers (Table 3, Figure 15). The Marlborough Sounds were described as being rich in biogenic habitats. The most commonly mentioned bycatch types were sponge and “coral”. Several areas of both sponges and corals were noted along the coast of D’Urville Island, and areas of sponge were also mentioned along the inner Pelorus and Queen Charlotte Sound/Tōtaranui. Horse mussel beds were also frequently noted. Some areas were mentioned by multiple fishers, such as the east and southern coast of D’Urville Island, but these were recollections from 20–30 years ago, and some comments were made about areas being discovered and “cleaned out”. One fisher thought that sponge habitat in the inner Pelorus Sound/Te Hoiere may have been impacted by mussel farms.

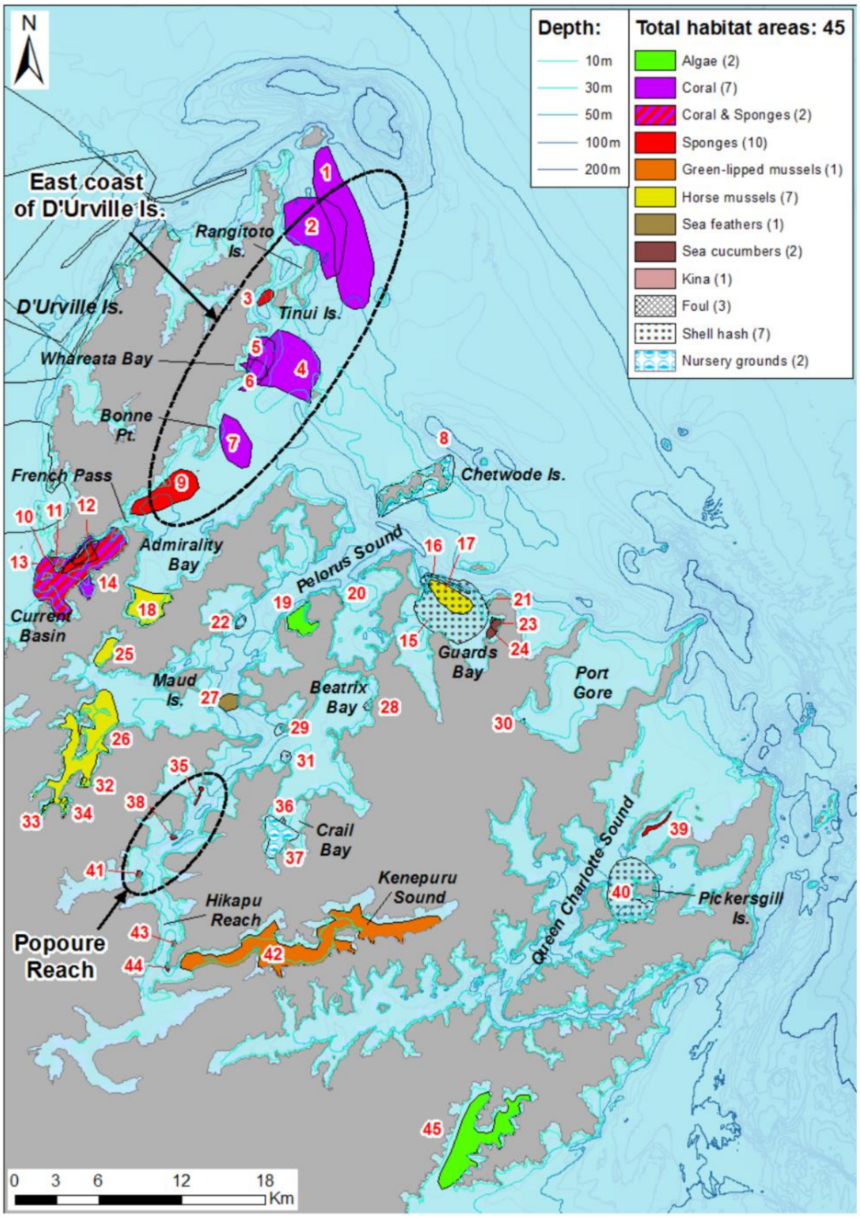

Figure 15. Marlborough Sounds LEK map. Each fisher-drawn area has been assigned a unique number. Information on sites is provided in Table 3. Summary table of sites described based on LEK shown in Figure 15.. Source: Jones et al. (2016).

Table 3. Summary table of sites described based on LEK shown in Figure 15. Source: Jones et al. (2016) Figure 19.

Sites	IDs	Description	Fishing Impacts observed	Freq. of ID
East coast D'Urville Island	1, 2, 3, 4, 5, 6, 7	Multiple fishers marked areas along the eastern coast of D'Urville Island, as "*coral rubble*", one noting its similarity to Separation Point (probably the bryozoan *Celleporaria agglutinans*). These were based on recollections from 20 to more than 30 years ago, with several noting that the areas were hard to fish, due to net damage, and were associated with large catches of juvenile blue cod on occasion.	yes	3
French Pass	9, 10, 11, 12, 13, 14,	The channel south of French Pass was noted as an area of hard ground covered in sponges and '*corals*", with the densest sponge cover in shallow water along the D'Urville Island coast (11), and Waikawa Bay (14) known more for "*corals"*. One fisher noted that this area had been "*cleaned out*" since it was first fished in the 1960s. To the north of French Pass, another fisher marked an area where soft, yellow, dinner plate sized sponges (8–9 inches high) were found, called "*spongey cheeses*".	yes	3
Horse mussel beds; Admiralty Bay and Tennyson Innlet	18, 25, 26, 32, 33, 34	Areas of horse mussels on sand / mud substrate. Beds may not be so extensive now.		2
Inner Pelorus Sound - Popoure Reach	35, 38, 41, 43, 44	Multiple areas within Popure Reach where "*sponge material*" was found. This was an area targeted for scallops.		1
Pelorus Sound, Crail Bay and Beatrix Bay	19, 20, 22, 27, 28, 29, 31 , 36, 37	Small areas of shell hash (22, 29, 31), rock pinnacles / untrawlable areas (28, 36), sea feathers and starfish (*Coscinasterias muricata*) (27) and red algae and scallops (19), with a snapper nursery area also noted in Crail Bay (37)		1
Greenlip mussel beds – Kenepuru Sound	42	Found along the entire coastline of this area. Not known if beds are still this extensive	?	1
Chetwood Island	8	Noted as a blue cod nursery grounds		1
Guards Bay / Alligator Head	15, 16, 17, 21, 23, 24	Large overlapping areas of shell hash and horse mussels (15, 16, 17). Closer to shore, a kina bed (21) and an area nicknamed "*sea cucumber alley*" was described; fish catches were good, but high numbers of sea cucumbers and kelp were also brought up in the nets.		3
Queen Charlotte Sound	39, 40	Small area of sponge and larger area of shell hash associated with large numbers of brittle stars		1

3.3.3 Scientific information needs for the Marlborough CMA

3.3.3.1 Scientific information needs identified in scientific surveys and investigations

Davidson et al. (2011) identified significant sites that require further investigation to determine their ecological value and significance. They emphasised the need for long-term, co-ordinated management of significant marine sites in the Marlborough CMA, including surveying and identifying new sites through a programme that aims to:

- Survey the significant sites identified in this report where the values and boundaries are uncertain.

- Identify and describe new sites through field surveys and interviews with scientists, iwi, fishers, conservationists, and local community groups.
- Identify threats relevant to individual sites (not all sites or values are necessarily threatened).
- Co-ordinate a muliti-agency approach to manage each significant site or group of sites to ensure long-term sustainability and protection.
- Ensure biological information is stored in a database for future use.

As described in section 5.4.5 (MDC ecologically significant marine sites programme), since 2011 several monitoring and investigative surveys have been conducted and reports prepared to improve our knowledge on habitats in the Marlborough CMA and make recommendations for changes to ESMS.

Marine experts providing science advice for the Kotahitanga mō te Taiao Strategy development identified the need to determine the cause of loss of macroalgae, including *Macrocystis*, in the outer Sounds and specifically the contribution of changes in temperature (Lawless, 2018).

Forrest and Stevens (2019) recommended that, for improved understanding of monitoring and management priorities for intertidal estuarine areas, it would be timely to undertake a comprehensive data synthesis and analysis to investigate in detail:

- Where does seagrass occur, how extensive is it, and in what condition? Has any been lost since monitoring began?
- Where important spatial or temporal changes exist, can they be related to potential explanatory drivers (e.g., catchment activities and differences in mass loads of sediments, nutrients, etc).

Anderson et al. (2019) identifies the following information needs:

- Maps of the spatial extent of kelp forests are rare. Recent aerial mapping surveys using small drones has been successfully undertaken to map the spatial extent of nearshore kelp forest (*M. pyrifera*) at several sites on the south coast of Wellington (D'Archino et al. NIWA unpublished data) and Marlborough Sounds (DOC unpublished data). This approach shows great promise for mapping nearshore kelp forest, particularly for *M. pyrifera*, which forms surface canopies. However, this approach is limited to clear shallow water. Mapping deeper kelp forests would require underwater video surveys or remote sensing methods.
- Densities and biomass for non-fished species and areas
- Conditions and processes required to re-establish the once widespread habitats formed by large bivalve species (green-lipped and horse mussel beds),
- A greater understanding of the importance of blue cod in the Marlborough Sounds to accurately determine what may be limiting juvenile recruitment of this commercially important species.
- Small-scale monitoring of some *Galeolaria* mounds has been undertaken (e.g., in relation to marine farm resource consents and activities - Whataroa Bay in Port Underwood, however the area and abundance of other mounds is unknown.
- Little is known about the biology and ecology behind mound formation, specifically what triggers colonial growth and subsequent mound formation relative to isolated clumps or individuals, or what may inhibit mounds.
- Due to large gaps in our knowledge, current estimates of biogenic habitats are likely to greatly underrepresent the real extent and location of biogenic habitats.
  Recommendations for future research:

- Compile existing quantitative data into a national database. Abundance data from sampling surveys and seafloor characterisations from underwater video surveys are currently housed in project-specific databases, that are inaccessible, compiling these would be provide a valuable national-scale data source to address many data gaps.166 Review of New Zealand's Key Biogenic Habitats
- Improved methods and approaches for species not well represented in New Zealand's Collections databases (e.g., tubeworms, rhodoliths and xenophyophores), with collections of these habitats prioritised in future surveys.
- Prioritise mapping and monitoring surveys of key biogenic habitats and areas where threats and stressors are high (e.g., fragile and productive habitats targeted by benthic fishing activities),
- Future surveys to incorporate measures of biogenic habitat extent and condition,
- Existing fine-scale data and maps need to be included in a national data inventory (similar to seagrasses and mangroves within the SeaSketch project) to ensure that disparate datasets are available for national examination.

Bell (2019) and Bell et al. (2020) identified the following information needs that are being addressed as part of the king shag project:

- Confirm if king shag numbers are stable and determine king shag population trends (better account for the effects of interannual variation)
- Provide further information on the spatial at sea distribution and foraging behaviour of King Shags
- Overlay spatial at sea distribution and foraging behaviour of King Shags on maps with marine farm locations to determine any interactions between King Shags and marine farms

The DOC has a range of scientific information needs around the impact of humans on marine mammals (D. Hayes, DOC, pers. comm.). There is a currently a moratorium on the increase of effort on commercial marine mammal interaction in the Sounds because of the need to better identify and understand the impacts before improved management approaches can be developed. Related to this is the need to better understand the effects on marine mammals by recreational boat users. Overall, there is insufficient information on the marine mammal populations in the Marlborough Sounds.

3.3.3.2 Scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA

Specific scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA are listed in Table 4.

Table 4. Scientific information needs related to environmental issue 'habitat modification and impact on species' stipulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring. Documents reviewed are shown in Appendix 1.

Document	Scientific information needs/requirement
NZCPS 11 Indigenous biological diversity (biodiversity)	• Identify: o Areas of predominantly indigenous vegetation o Extent and/or abundance of threatened or at-risk taxa, ecosystems and vegetation types o Extent of indigenous species' habitats (where species are rare or at the limit of natural range) or areas containing nationally significant examples of indigenous community types o Extent of habitats important during vulnerable life stages of indigenous species o Extent of habitats of indigenous species that are important for recreational, commercial, traditional, or cultural purposes o Location and extent of habitats important to migratory species and as ecological corridors • Understand effects of activities on these taxa, ecosystems, vegetation types and habitats
MDC PMEP Policy 8.1.2 and 8.1.3	• Identify remaining areas of indigenous biodiversity • Assess their condition • Understand what action is required to protect, maintain and improve areas of indigenous biodiversity, including their intrinsic values (as defined in Section 2 of the RMA) • Identify sites, areas and habitats with significant indigenous biodiversity value (see below non-significant sites) • Understand the nature and size of buffers required around ecologically significant marine sites to protect them from activities in their vicinity • Gather information on the state of biodiversity in marine environments
MDC PMEP Policy 8.1.9 and 8.1.10	• Identify areas of indigenous biodiversity that have been degraded • Understand how to restore (re-establish and enhance) areas of indigenous biodiversity that have been degraded • Understand how to extend areas of indigenous biodiversity • Improve understanding required to manage marine pests • Monitor the condition of sites with significant indigenous biodiversity value • Understand how to identify loss of or deterioration in the condition of significant sites • Identify ecosystems, habitats and areas of indigenous biodiversity that are not identified as significant but are important for (a) the continued functioning of ecological processes; (b) providing connections within or corridors between habitats of indigenous flora and fauna; (c) cultural purposes (including those associated with taonga species, māhinga kai, underlying cultural values of a place, presence of resources used for rongoā, weaving, food sources, or ceremonial uses); (d) providing buffers or filters

	between land uses and wetlands, lakes or rivers and the coastal marine area; (e) botanical, wildlife, fishery and amenity values; (f) biological and genetic diversity; and (g) water quality, levels and flows.
MDC PMEP Policy 8.3.1 and 8.3.4	• Identify areas, habitats or ecosystems are those set out in Policy 11(a) of the New Zealand Coastal Policy Statement 2010 • Identify areas, habitats or ecosystems are those set out in Policy 11(b) of the New Zealand Coastal Policy Statement 2010 • Understand the nature and size of buffers required around ecologically significant marine sites to protect them from activities in their vicinity • Understand the adverse effects of potential subdivision, use and development on the matters listed under Policy 8.3.4. But note that the explanation to Policy 8.3.4. specifically refers to the need to conduct a case-by-case assessment.
MDC PMEP Implementation method 8.M.4	• Continue to identify ecologically significant marine sites and buffer areas so they can be added to maps in Volume 4 and in Appendix 27 • Continue to identify whale migration routes and dolphin distribution so they can be added to maps in Volume 4
MDC PMEP Implementation method 8.M.5	• Establish baseline monitoring programmes that provide a benchmark for determining the ongoing condition of habitats, ecosystems and areas that have significant indigenous biodiversity values • Carry out and support research and undertake state of the environment monitoring to gain a better understanding of Marlborough's biodiversity (8.M.6 "appropriate investigations to improve our understanding of the nature and state of indigenous biodiversity in Marlborough")
MDC PMEP 8.AER.5 An increase in knowledge of Marlborough's indigenous biodiversity.	• Use of scheduled criteria to identify ecosystems, habitats or areas present with significant indigenous biodiversity value through resource consent applications or where future survey work may be undertaken. • Knowledge and understanding of indigenous biodiversity in Marlborough's coastal marine area is enhanced through maintenance of the marine database of information and from supporting research in areas where little is known about marine biodiversity
MDC PMEP 13.AER.1 The values associated with areas of significance identified on the MEP maps are protected.	• Periodic reassessment of mapped areas of significance for biodiversity and Marlborough's tangata whenua iwi.
Kotahitanga mō te Taiao strategy (Top of the South as a whole, TOS 13.0)	• What are vulnerable biogenic habitats? • Identify degraded estuarine and coastal areas • Understand what is required to restore degraded estuaries
Kotahitanga mō te Taiao strategy (Marlborough Sounds/Cook Strait, MS 7.0, 7.1, 7.2, 7.6)	• Understand how to restore estuarine sites to achieve long term health of our natural spaces and sustainable kaimoana harvests • Understand how to restore the natural functioning of shellfish and biogenic habitats

	• Identify estuarine sites that require restoration. • Understand how to restore and sustain threatened ecosystems and the habitat of threatened species.
Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan	• Monitor ecological health and fish stock (using customary indicators) • Understand how to enhance the indigenous coastal / marine area ecology • Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the coastal / marine resources of the rohe • Understand the ecological health, carrying capacity and cumulative effects of marine farming and other fishery practices within the rohe.
Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan	• This plan lists issues, objectives policies, anticipated environmental results, monitoring requirements for coastal water, relating to taonga species, water quality, kaimoana beds and fish. • Specific science needs should be identified in partnership with Ngati Koata.

3.3.3.3 National scientific information needs of relevance to the Marlborough CMA

Jarvis and Young (2019) identified several national research priorities relating to habitat modification and impact on species in their New Zealand Marine Science Horizon Scan carried out as part of a research project. Research questions are found in all themes identified by Jarvis and Young with direct relevance for the environmental management of the Marlborough CMA (fisheries and aquaculture, biosecurity, climate change, marine reserves and protected areas, ecosystems and biodiversity, coastal and ocean processes, and other anthropogenic factors), illustrating the central role of habitats and species in coastal ecosystems of the Marlborough CMA. Specific research questions are listed in Appendix 2.

Further relevant to the Marlborough CMA are research needs identified by the CSIG, in relation to habitat modification and impacts on species particularly those aimed at achieving the stated goals to 'understand the response of coastal ecosystems to stressors in order to effectively manage the CMA', and to 'understand the regional impacts of climate change and acidification on the CMA to inform decision-making' (Berkett et al., 2015). Relating to habitat modification and impacts on species, they include the need to:

- Characterise the existing CMA by collecting appropriate data for establishing baselines.
- Identify the effects of stressors within both a spatial and temporal context.
- Develop approaches for the enhancement and restoration of degraded environments in the CMA.
- Identify indicators and determining response of ecosystem attributes (e.g., biodiversity, biological and physical processes, water quality) to stressors (individual and cumulative).
- Investigate the feasibility and ecological implications of potential biodiversity offsetting in the CMA.

- Research environmental thresholds and establish appropriate and relevant limits and standards for stressors impacting on the CMA, including those derived from land-based activities.
- Forecast the nature and extent of environmental changes in the CMA in response to global climate change. Identify ecosystems and areas that will be more vulnerable than others.
- Investigate capacity for organisms and ecosystems to adapt to climate change.
- Delineate to what extent regional influences may interact with or further exacerbate effects associated with climate change (e.g., run-off and ocean acidification, coastal hazard risks, biosecurity).

3.3.4 Summary and information gaps

What we know[18]

Many important species and valuable habitats are found in the Marlborough Sounds as reported in a range of extensive scientific reports and journals. A list of regionally important species has been developed to support the identification of ecologically significant marine sites, which are given varying levels of protection from adverse effects of a range of anthropogenic activities in the MDC PMEP[19]. Species of particular attention in the include scallops, green-lipped mussels and blue cod. These species are facing habitat decline Marlborough CMA and degradation, particularly from sedimentation, and adverse effects from overfishing or overharvesting. Research is currently done to better understand the behaviour of and risks from marine farming on king shags, which are of interest because this rare species is only found in the Marlborough Sounds and their colonies and roosting sites are vulnerable to disturbance.

A comprehensive monitoring programme of Marlborough Sounds estuaries and Wairau Lagoon has shown that many estuaries contain significant remaining areas of seagrass and saltmarsh, which provide important ecosystem functions and are indicative of ecologically healthy conditions due to their vulnerability to sedimentation and other disturbances. However, seagrass coverage has been found to be low in several estuaries and in Havelock Estuary seagrass has decreased by 3 ha, or 10%, between 2014 and 2019. Repeat monitoring has not been carried out in many estuaries, precluding an assessment of changes over time for most estuaries.

Comprehensive information has been gathered and reported on subtidal habitats in parts of the Marlborough Sounds (e.g., Anderson et al., 2019; Urlich and Handley, 2020), with a particular focus on Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au (e.g., Anderson et al. 2020, Handley, 2016) and Pelorus Sound/Te Hoiere (e.g., Handley et al., 2017). Key observations include a range of biogenic habitat types in the Marlborough Sounds and the wider Marlborough CMA. Shellfish beds include robust dog-cockle beds and horse mussel beds but little is known about the condition or change in extent of these habitats over time. Scallop populations have declined substantially. Other subtidal biogenic habitat found in the Marlborough Sounds include Rhodolith beds (French Pass and Admiralty Bay), bryozoan beds (or thickets), calcareous tubeworm mounds and non-calcareous tubeworm fields.

Despite the ongoing presence of biogenic habitats, authors consistently describe that since European settlement there has been a significant loss and degradation of biogenic habitat in the Marlborough Sounds, especially shellfish beds, including depletion of dredge oyster beds in Oyster Bay (Tory

[18] This is a brief summary of information provided in section 3.3.2.
[19] More information on the ESMS programme is provided in section 5.4.5.

Channel/Kura Te Au), destruction of subtidal greenlipped mussel beds, overexploitation of scallop beds from dredging in inner Pelorus Sound/Te Hoiere (Mahau) and loss of horse mussel beds in outer sounds. Factors causing this change include seabed modified by sedimentation, particularly in the Pelorus Sound/Te Hoiere, direct removal of species and seabed disturbance, mainly from trawling and dredging. Bryozoan reefs are now mostly limited to the entrance ways into Queen Charlotte Sound/Tōtaranui, which has been identified as concern because bryozoan habitats provide important and often critical structural habitat and refuge to a diversity of marine life and are known to act as nursery habitats for many commercial and recreationally important fish species, including blue cod.

In addition to the broadscale scientific surveys of subtidal habitats, the physical footprint of anthropogenic activities has been mapped in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au, revealing that it extends from the shoreline to hundreds of meters water depth with an uneven distribution including marine infrastructure (marine farms, cables/pipelines and wharves; c. 28% of the total anthropogenic footprint) and impacts from maritime activities (mooring blocks, anchor drag marks, and shipwrecks; c. 72% of the total anthropogenic footprint). The greater extent of anthropogenic influence in the inner QCS (c. 6% of the seafloor) is most likely to be related to the high population near the coast in the inner QCS, centered on the township of Picton, and the presence of the Picton and Waikawa ports.

Information on habitats and changes over time in the Marlborough Sounds has also been gathered by working with fishers to derive local ecological knowledge of their fishing grounds. Consistent to the findings of research surveys, the Marlborough Sounds were described as rich in biogenic habitats but also comprising areas in which habitats have been lost or severely impacted.

What scientific information needs have been identified

The scientific information needs identified in section 3.3.3 specifically for the Marlborough CMA and those identified on a national level with relevance for the Marlborough CMA in relation to sediment are listed below. Due to the large number of scientific information needs, they have been grouped into themes.[20]

- Biogenic habitats
    - Determine the area and abundance of mound-building tubeworms and mounds outside the areas previously monitored for *Galeolaria* mounds, such as those monitored in relation to marine farm resource consents and activities in Whataroa Bay in Port Underwood (Anderson et al., 2019)
    - Improve understanding of the biology and ecology behind mound formation, specifically what triggers colonial growth and subsequent mound formation relative to isolated clumps or individuals, or what may inhibit mounds (Anderson et al., 2019)
    - Improve methods and approaches for species not well represented in New Zealand's Collections databases (e.g., tubeworms, rhodoliths and xenophyophores), with collections of these habitats prioritised in future surveys (Anderson et al., 2019)
    - Prioritise mapping and monitoring surveys of key biogenic habitats and areas where threats and stressors are high (e.g., fragile and productive habitats targeted by benthic fishing activities; Anderson et al., 2019)
    - Incorporate measures of biogenic habitat extent and condition in future surveys (Anderson et al., 2019)

[20] As there inevitably is overlap among themes, they are intended to present only loose groupings for structuring the science needs of this environmental issue.

    - Identify criteria for vulnerable biogenic habitats (Kotahitanga mō te Taiao Strategy)
- Sites of high ecological value (including areas of indigenous biodiversity and ecologically significant marine sites)
    - Identify areas, habitats or ecosystems are those set out in Policy 11(a) and (b) of the New Zealand Coastal Policy Statement 2010 (MDC PMEP Policy 8.3.1 and 8.3.4)
    - Identify remaining areas of indigenous biodiversity and assess their condition (MDC PMEP Policy 8.1.2 and 8.1.3)
    - Identify sites, areas and habitats with significant indigenous biodiversity value (MDC PMEP Policy 8.1.2 and 8.1.3)
    - Use of scheduled criteria to identify ecosystems, habitats or areas present with significant indigenous biodiversity value through resource consent applications or where future survey work may be undertaken (MDC PMEP 8.AER.5)
    - Understand how to identify loss of or deterioration in the condition of significant sites (MDC PMEP Policy 8.1.9 and 8.1.10)
    - Establish baseline monitoring programmes and monitor the condition of sites with significant indigenous biodiversity value (MDC PMEP Policy 8.1.9 and 8.1.10; MDC PMEP Implementation method 8.M.5)
    - Identify areas of indigenous biodiversity that have been degraded (MDC PMEP Policy 8.1.9 and 8.1.10; Jarvis and Young, 2019)
    - Continue to identify ecologically significant marine sites and buffer areas so they can be added to maps in Volume 4 and in Appendix 27 (MDC PMEP Implementation method 8.M.4)
    - Further investigate identified potential significant marine sites to confirm their value and significance (Davidson et al., 2011)
    - Review and, where necessary revise, the ecologically significant marine site programme to ensure long-term and co-ordinated multi-agency management of sites and long-term sustainability and protection (Davidson et al., 2011)
    - Periodically reassess mapped areas of significance for biodiversity (MDC PMEP 13.AER.1)
    - Identify the effects of trawling and dredging on benthic habitats of significance (Jarvis and Young, 2019)
- Biodiversity (general)
    - Gather information (carry out and support research) on the state of biodiversity in marine environments (MDC PMEP Policy 8.1.2 and 8.1.3, Implementation method 8.M.5)
    - Identify ecosystems, habitats and areas of indigenous biodiversity that are not identified as significant but are important for (a) the continued functioning of ecological processes; (b) providing connections within or corridors between habitats of indigenous flora and fauna; (c) cultural purposes (including those associated with taonga species, māhinga kai, underlying cultural values of a place, presence of resources used for rongoā, weaving, food sources, or ceremonial uses); (d) providing buffers or filters between land uses and wetlands, lakes or rivers and the coastal marine area; (e) botanical, wildlife, fishery and amenity values; (f) biological and genetic diversity; and (g) water quality, levels and flows. (MDC PMEP Policy 8.1.9 and 8.1.10)
    - Determine the current baseline of biodiversity and species abundance across different marine habitats (Berkett et al., 2015; Jarvis and Young, 2019).

    - Identify the impact of fishing on coastal marine biodiversity and ecosystems (Jarvis and Young, 2019).
    - Identify the vulnerability, resilience and ability for adaptation of marine species, ecosystems and areas to changes in water temperature and other impacts of climate change (Berkett et al., 2015; Jarvis and Young, 2019).
    - Identify the impact of marine pests and climate change, including marine heat waves, on coastal marine biodiversity and ecological structure (Jarvis and Young, 2019).
    - Determine how biodiversity can be increased to ensure marine communities are resilient to the impacts of pests (Jarvis and Young, 2019)
    - Identify indicators and determine response of ecosystem attributes to stressors (individual and cumulative), including the key indicator species that demonstrate healthy or unbalanced marine ecosystems (Berkett et al., 2015; Jarvis and Young, 2019)
    - Identify tipping points in marine ecosystems (Jarvis and Young, 2019)
    - Identify the relative effects of different land-use types and activities on biodiversity (Jarvis and Young, 2019).
    - Identify and assess the biggest threats to marine habitats to inform their management (Jarvis and Young, 2019)
- Protection and restoration of habitats and species
    - Identify conditions and processes required to re-establish the once widespread habitats formed by large bivalve species (green-lipped and horse mussel beds) (Anderson et al., 2019)
    - Understand what action is required to protect, maintain and improve areas of indigenous biodiversity, including their intrinsic values (as defined in Section 2 of the RMA) (MDC PMEP Policy 8.1.2 and 8.1.3) (Jarvis and Young, 2019)
    - Understand the nature and size of buffers required around ecologically significant marine sites to protect them from activities in their vicinity (MDC PMEP Policy 8.1.2 and 8.1.3; MDC PMEP Policy 8.3.1 and 8.3.4)
    - Understand how to restore (re-establish and enhance) areas of indigenous biodiversity that have been degraded, including factors hindering recovery (MDC PMEP Policy 8.1.9 and 8.1.10; Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan) (Berkett et al., 2015; Jarvis and Young, 2019)
    - Understand how to extend areas of indigenous biodiversity (MDC PMEP Policy 8.1.9 and 8.1.10)
    - Identify degraded estuarine and coastal areas and estuarine sites that require restoration (Kotahitanga mō te Taiao Strategy) (Jarvis and Young, 2019)
    - Identify how restore degraded estuaries and estuarine sites to achieve long term health of our natural spaces and sustainable kaimoana harvests (Kotahitanga mō te Taiao Strategy) (Jarvis and Young, 2019)
    - Identify how to restore the natural functioning of shellfish and biogenic habitat, including the factors preventing recovery to historic levels (Kotahitanga mō te Taiao Strategy; Jarvis and Young, 2019)
    - Identify how to restore and sustain threatened ecosystems and the habitat of threatened species (Kotahitanga mō te Taiao Strategy)
    - Understand the ecological health, carrying capacity and cumulative effects of marine farming and other fishery practices within the rohe (Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan)

    - Identify the effectiveness of current marine protected area (MPA) tools used to protect marine areas (Jarvis and Young, 2019).
    - Identify the most cost-effective techniques for restoration of degraded coastal ecosystems (Jarvis and Young, 2019).
- Marine mammals
    - Continue to identify whale migration routes and dolphin distribution so they can be added to maps in Volume 4 (MDC PMEP Implementation method 8.M.4)
    - Better identify and understand the impacts of commercial activities on marine mammals to inform the development of improved management approaches (D. Hayes, DOC, pers. comm.).
    - Better understand the effects of recreational boat users on marine mammals (D. Hayes, DOC, pers. comm.).
    - General information on marine mammal populations in the Marlborough Sounds (D. Hayes, DOC, pers. comm.).
- Databases
    - Develop a database for biological information on ecologically significant marine sites (Davidson et al., 2011)
    - Compile existing quantitative data on biogenic habitats into a national database (Anderson et al., 2019)
    - Develop and maintain a marine database of information, including supporting research in areas where little is known about marine biodiversity, to enhance knowledge and understanding of indigenous biodiversity in Marlborough's coastal marine area (MDC PMEP 8.AER.5)
    - Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the coastal / marine resources of the rohe (Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan)
- Macroalgae
    - Determine the cause of loss of macroalgae, including *Macrocystis*, in the outer Sounds and specifically the contribution of changes in temperature (Lawless, 2018)
    - Map nearshore kelp forests, particularly *M. pyrifera* (Anderson et al., 2019)
- Intertidal estuarine areas/seagrass
    - Undertake a comprehensive data synthesis and analysis of intertidal estuary data to investigate spatial extent, changes over time and condition of seagrass and, for locations where important spatial or temporal change has taken place, investigate potential explanatory drivers (Forrest and Stevens, 2019).
- Blue cod
    - Improve understanding of the importance of blue cod in the Marlborough Sounds to accurately determine what may be limiting juvenile recruitment of this commercially important species (Anderson et al., 2019)
- King shag
    - Assess whether king shag numbers are stable and determine king shag population trends (better account for the effects of interannual variation) (Bell, 2019; Bell et al., 2020)

  - Improve information on the spatial at sea distribution and foraging behaviour of King Shags (Bell, 2019; Bell et al., 2020)
  - Improve understanding of interactions between King Shags and marine farms (Bell, 2019; Bell et al., 2020)
- Sites of significance to iwi and customary indicators
  - Periodically reassess mapped areas of significance for Marlborough's tangata whenua iwi (MDC PMEP 13.AER.1)
  - Monitor ecological health and fish stock (using customary indicators) (Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan)
  - See item 'Develop a database of mātauranga' under heading 'Databases'
- Other
  - Determine densities and biomass for non-fished species and areas (Anderson et al., 2019)
  - Investigate the feasibility and ecological implications of potential biodiversity offsetting in the CMA (Berkett et al., 2015)

Suggested first step towards informing a more strategic approach for collecting scientific information to address environmental issues related to habitat modification and impacts on species

The information reviewed and described in this section, illustrates that extensive information on habitats and species in the Marlborough CMA has been gathered and that a large number of scientific information needs have been identified. Due to the comprehensive nature and complexity of the information and scientific information needs, it is not possible to identify a concise list of specific information gaps without duplicating much of the previous content of this summary section.

It appears that, to achieve a more strategic approach for the collection of scientific information on environmental issues related to habitat modification and impacts on species in the Marlborough CMA, it would be helpful to clarify and prioritise information needs. There will be a general understanding and awareness that not all information needs identified in this report can be filled due to resourcing limitations. It is therefore critical to prioritise information needs and prepare a strategic plan for collecting information. Considering the extensive existing scientific information, this would benefit from examining the information and how helpful it is to address information needs identified in this report. If existing information is considered of only limited value, it might be beneficial to explore how the work generating the information was motivated and, if it was commissioned by the agencies involved in this report, what process was taken to scope the work and deliverables.

Inevitably, this process will identify overlaps with information gaps identified in other sections of this report and future work should ensure alignments among environmental issues are considered.

3.4 Water quality and sediment quality degradation

3.4.1 The issue

3.4.1.1 Overview

This environmental issue addresses degradation of water quality and sediments resulting from nutrient, chemical and bacterial inputs. Issues related to sediment input (such as sedimentation and turbidity) are primarily addressed under the issue 'sediment'.

3.4.1.2 Water quality degradation

In New Zealand water quality of coastal waters is strongly affected by land-derived contaminants delivered by rivers and, accordingly, correlates broadly with salinity (Dudley et al., 2017). This means that high freshwater influence tends to coincide with high and variable nitrogen concentrations. Deeper, marine-dominated open coast sites have a lower susceptibility to nutrient loads and lowest faecal bacteria concentrations (Dudley et al., 2017).

Nutrient inputs can cause nuisance blooms of macroalgae, for example the green sea lettuce, *Ulva sp*. Opportunistic macroalgae are effective at utilising excess nutrients (primarily nitrogen both from water column and sediment sources) and are therefore commonly used as indicators of estuary eutrophication (Robertson and Savage, 2018). Macroalgae can out-compete other seaweed and macrophyte species and in dense cover adversely impact underlying sediments and fauna, other algae, fish, birds, seagrass, and saltmarsh (e.g., Robertson, 2020a).

Nitrate is one of the main nutrients required by algae for photosynthesis. Therefore, an increase in nitrate concentrations can lead to increased algal growth (typically measured as higher chlorophyll-a concentrations). This can lead to greener or "dirtier" looking water, which can affects the aesthetics and recreational use of water bodies, including the Marlborough Sounds (Marlborough District Council, 2017). Importantly, high algal grown can reduce oxygen concentrations in bottom waters as dead algae sink to the bottom and are broken down through processes that use up the oxygen. Very low dissolved oxygen concentrations can be detrimental to aquatic organisms.

Faecal pathogens (such as viruses and bacteria) are mainly a risk human health. New Zealand's Coastal waters are routinely assessed for their suitability for contact recreation (e.g., swimming)[21] or shellfish gathering[22].

In terms of ecological assessments, chemical contaminants are typically measured in sediments where they accumulate and therefore provide more stable indications of contamination than in the dynamic coastal waters.

3.4.1.3 Sediment quality degradation

Soft-sediments[23] are common intertidal and subtidal habitats that support a diverse range of species, including shellfish and benthic invertebrates. The state of intertidal sediments is often used as an indicator of estuarine health to determine the magnitude and spatial extent of the stressor impacts and to assess the ability of sediment to sustain healthy biological communities.

The ability to sustain healthy biological communities can be compromised if sediment contain chemical or bacterial contaminants or become organically enriched at levels that cause direct harm to benthic organisms or make habitats unsuitable for them. Excessive organic enrichment can result in a reduction or loss of oxygen in sediments and production of hydrogen sulphide and other compounds that can be toxic to organisms.

Chemical contamination can have lethal and sub-lethal effects and often species differ in their sensitivity to particular chemicals (Newcombe, 2017). Sources of chemical contamination can often be identified (such as stormwater, antifouling materials, sewage outfall) and some persistent contamination stems from activities that no longer occur in New Zealand's coastal environments or are now generally better managed (e.g., past discharge of banned chemicals, release of antifouling compounds from vessel cleaning to coastal waters, untreated sewage).

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[21] Through Land Air Water Aotearoa (LAWA), https://www.lawa.org.nz/explore-data/swimming/

[22] Through Ministry of Primary Industries (MPI), https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/where-unsafe-to-collect-shellfish/shellfish-biotoxin-alerts/

[23] The term 'sediment' is used in this report to refer to 'soft-sediment', i.e., muddy and sandy sediments, without (or with little) hard structures

Sediments can be resuspended and redistributed so that organisms in the water column or nearby benthic habitats may be exposed to contaminants. Chemical and bacterial contaminants may accumulate through the food web and eventually pose health risks to humans.

3.4.2 What we know about this issue in the Marlborough CMA

3.4.2.1 Water quality degradation

The Marlborough Sounds has relatively large, scale subtidally-dominated estuaries with long residence times which can be sensitive to nutrient enrichment and water quality fluctuations (Forrest and Stevens, 2019). Water quality in the Sounds can be affected by diffuse land run-off, river input or other point sources of nutrients, sediments, chemical or bacterial contaminants. Water quality monitoring and investigations in the Marlborough CMA have overwhelmingly focussed on the Marlborough Sounds with little information available on other parts of the Marlborough CMA.

Marine experts providing science advice for the Kotahitanga mō te Taiao Strategy development, noted that in the Marlborough Sounds and Cook Strait environments valley wetlands have been converted to farms, which has disconnected estuaries from natural filter which would reduce nutrient loads (Lawless, 2018). The Kotahitanga mō te Taiao strategy identified water quality and sediment degradation as components of the overall degradation of marine ecosystems and calls for restoration of degraded coastal estuaries.

Macroalgae have been used as an indicator of eutrophication in the monitoring of many Marlborough estuaries and eutrophication has generally been assessed as low (Forrest and Stevens, 2019; Robertson, 2020b, 2020a). However, in 2019, Havelock Estuary experienced a moderate degree of eutrophic symptoms, and monitoring since 2001 indicates an increasing risk of eutrophication in the estuary (Robertson, 2019b). Also, extensive macroalgae beds have been found in Okiwa Bay in 2018 and nuisance macroalgae were identified in Wairau Estuary and Lagoon in 2015 (Forrest and Stevens, 2019).

Urlich and Handley (2020) describe historic changes in water column nutrients in the Marlborough Sounds that may have occurred in relation to food web changes associated with ecosystem change following Māori and European settlement, especially the role in nutrient recycling played by northern right whales (*E. glacialis*), pilchards (*S. sagax*) and shellfish beds, including *P. canaliculus*.

Handley et al. (2017) report that terrestrial nutrient availability is in decline. They describe that Pelorus Sound/Te Hoiere has undergone reductions in the supply of terrigenous nutrients since the 1970s following cessation of land clearance (milling, fire), farming (fertiliser subsidies), forestry (urea), and human population decline (sewage discharge). While this is a positive change in terms of eutrophication risk, Handley et al. (2017) note that reduced nutrient availability may be limiting phytoplankton production, which may be a factor contributing to the failed recovery of mussel beds and drop in productivity of the mussel farm industry in Pelorus Sound/Te Hoiere. This unexpected outcome of improved land-based practices has also been described by the Parliamentary Commissioner for the Environment (2020) as an example demonstrating the influence of cumulative pressures on a natural system over time.

A review of monthly water quality monitoring at 11 stations in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au (since July 2011) and 11 stations in Pelorus Sound/Te Hoiere (since July 2012) indicated that these sounds are near the oligotrophic-mesotrophic boundary, in terms of trophic classification (Broekhuizen and Plew, 2018). This means that level of nutrients is low to intermediate. Mesotrophic conditions represent coastal waters that are fairly productive in terms of aquatic animal and plant life and that show emerging signs of water quality problems.

One relatively consistent pattern observed in the Marlborough Sounds was a small increase in nitrate accompanied by a small decrease in ammonia. Broekhuizen and Plew (2018) emphasise that the magnitude of change may not be of any ecological significance. They also do not assign a specific cause to this pattern but point out that while it may be driven by processes or changes within the waters of the sounds, it may also have been driven by changes or processes arising further afield, such as river inflow, freshwater seeps in the seabed of Queen Charlotte Sound/Tōtaranui or ocean-exchange.

Seasonality in nitrate concentrations in the Marlborough Sounds has also been described by MDC in their 2016/17 water quality report card (Marlborough District Council, 2017). MDC further described that chlorophyll a (a proxy for phytoplankton biomass) also shows a seasonal pattern affected by different concentrations of nutrients, mainly nitrate, and seasonal light conditions. MDC explained that nitrate concentrations increase during winter when river flows are higher (Figure 16) transporting nitrate rich water from land. Because no large rivers flow into Queen Charlotte Sound/Tōtaranui, the seasonal nitrate patterns are not as strong there compared to Pelorus Sound/Te Hoiere. MDC also point to nutrient-rich oceanic waters from the Cook Strait as a source of nitrate. In terms of phytoplankton (or algal) biomass, MDC illustrate that despite the higher nitrate concentrations, algal biomass is low in winter due to reduced growth caused by lower water temperatures and shorter days.

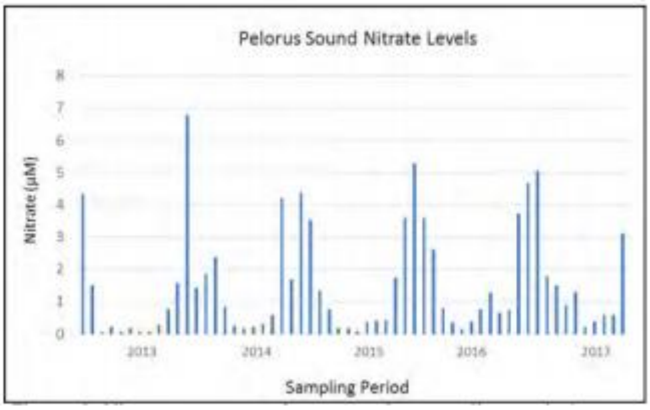

Figure 16. Nitrate concentrations over the sampling period to date in the Te Hoiere/Pelorous Sound. Source: Marlborough District Council (2017).

Water quality measurements in the Marlborough Sounds indicate some minor reduction in chlorophyll over recent decades; however the trend is weak and not apparent at all monitoring locations (Newcombe and Broekhuizen, 2020). Satellite data suggest that near-surface chlorophyll concentrations have fallen around much of the country in this period of time and the reasons for this decline remain unclear. As a potential cause, trends in chlorophyll reduction in the Marlborough Sounds were compared with the expansion of mussel farms but Newcombe and Broekhuizen (2020) found no evidence of a correlation between chlorophyll change and expansion of the marine farming industry. Instead they found evidence that inter-annual fluctuations in river flow are correlated with changes in chlorophyll and stated that it is also possible that rising sea temperatures may play a role. Overall, Newcombe and Broekhuizen (2020) were of the opinion that, at the scale of large bays/reaches, mussel farms are not the dominant influence upon the plankton of the Marlborough Sounds. However, due to limited data, they were not able to determine whether this conclusion also applies to zooplankton.

Dissolved oxygen changes throughout the seasons, largely due to changes in stratification. While the water column tends to be well mixed during the colder months, it becomes stratified (layered) during warmer months (Marlborough District Council, 2017). Near surface dissolved oxygen saturations in the Marlborough Sounds are high (usually, >80%) during the whole year, but near-bed saturations tend to drop during late summer/autumn (Broekhuizen and Plew, 2018).

A specific assessment of Picton Bays has shown that these estuaries receive diffuse input of bacterial contamination, particularly during heavy rainfall, and shellfish are sometimes not suitable for human consumption at some sites (Newcombe and Johnston, 2016). While bacterial contamination in Picton Bays has been greatly reduced since the 1970s, efforts to further reduce faecal contamination are ongoing.

Four regular water quality monitoring programmes are in place for the Marlborough CMA. MDC carries out monthly water quality SOE monitoring in Queen Charlotte Sound/Tōtaranui (since 2011) and in Pelorus/Te Hoiere Sound (since 2012) to collect information on temperature, nutrient levels, phytoplankton and seawater chemistry.[24] MDC also routinely monitors bacterial contamination at ten coastal beaches over the summer months and results are displayed on the Land Air Water Aotearoa (LAWA) website as soon as they become available.[25]

MPI monitors shellfish and seawater for toxic algae weekly at popular shellfish gathering areas around New Zealand.[26] During an algae bloom additional sampling is carried out and if results indicate that shellfish are not safe to eat, public health warnings are issued and signs are erected at affected beaches.

The marine farming industry funds and carries out the Marlborough Shellfish Quality Programme (MSQP), a food safety testing programme in the bivalve shellfish growing areas in the top of the South Island.[27] MSQP covers 22 growing areas active all year round and another 2 that operate seasonally. Water and shellfish flesh samples are tested for harmful algae and algal biotoxins, bacterial contamination of growing areas and heavy metals.

3.4.2.2 Sediment quality degradation

The estuary monitoring programme includes some broad indicators of sediment organic enrichment that generally indicate low enrichment (Forrest and Stevens, 2019; Robertson, 2020a, 2019a).

In Picton Bays past levels of organic enrichment were extreme due to raw sewage and freezing works waste discharge. The responsible freezing works outfall was shut down decades ago and sediments have recovered greatly since the 1970s (Newcombe and Johnston, 2016).

Estuary monitoring in Whangarae Bay and Waikawa Bay has identified relatively high contaminant levels in sediments, which reflected either natural catchment inputs (Whangarae) or historic anthropogenic inputs (Waikawa) (Forrest and Stevens, 2019). In other estuaries included in the fine-scale monitoring programme, sediment-based trace metals were at concentrations that were unlikely to cause toxicity to macroinvertebrates (Forrest and Stevens, 2019; Robertson, 2019a).

In sediments near salmon farms copper and zinc concentrations are occasionally elevated to levels that may indicate localised risk to benthic organisms (Clement et al., 2010). However, different marine

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[24] https://www.marlborough.govt.nz/environment/coastal/coastal-water-quality
[25] https://www.lawa.org.nz/explore-data/swimming/
[26] https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/where-unsafe-to-collect-shellfish/shellfish-biotoxin-alerts/
[27] https://www.marinefarming.co.nz/m-s-q-p/

organisms vary in their relative accumulation and tolerance of metals and information gaps precluded more definite findings. Sediment metal concentrations have been documented to decrease with time, especially zinc, however, as metals do not degrade this indicates that they are either mixed deeper into sediments and/or dispersed from the local environment.

Chemical contamination, such as, zinc, mercury, from stormwater and anti-fouling materials are present in Picton Bays, causing moderate localised impacts and are detectable at low levels over a wider area. Legacy contaminants, for example Tributyltin, are still measurable in Picton Bay but not widely present at harmful concentrations. Contaminant levels are expected to reduce over time (Newcombe and Johnston, 2016).

3.4.3 Scientific information needs for the Marlborough CMA

3.4.3.1 Scientific information needs identified in scientific surveys and investigations

Clement et al. (2010) raised the need to improve information on:

- Bioavailability of metals; and
- Fate of metals once introduced to the marine environment and later during chemical remediation (e.g., during a finfish farm fallowing period).

Newcombe and Johnston (2016) called for an improvement of our understanding of risk from emerging chemical compounds identified as potentially harmful in the marine environment, such as those from pharmaceuticals and personal care products.

Marlborough District Council (2017) identified the need to characterise the seasonal patterns in dissolved oxygen more clearly.

3.4.3.2 Scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA

Specific scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA are listed in Table 5.

Table 5. Scientific information needs related to environmental issue 'water quality sediment quality degradation' stipulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring. Documents reviewed are shown in Appendix 1.

Document	Scientific information needs/requirement
NZCPS Policy 23 Discharge of contaminants	• Identify the sensitivity of the receiving environment to contaminants • Identify the capacity of the receiving environment to assimilate the contaminants
NZCPS Policy 8 Aquaculture	• Understand water quality requirements of aquaculture • Understand effects of coastal development on aspects of water quality relevant to aquaculture
NZCPS Policy 21 Enhancement of water quality	• Identify significant adverse effects on ecosystems, natural habitats, or water based recreational activities • Define the meaning of "deteriorated water quality" • Understand the state of water quality that can support activities and ecosystems and natural habitats • Understand what effects are restricting existing uses, such as aquaculture, shellfish gathering, and cultural activities

NZCPS Policy 23 Discharge of contaminants	• Identify the sensitivity of the receiving environment to contaminants • Identify the nature of discharged contaminants, the particular concentration of contaminants needed to achieve the required water quality in the receiving environment, and the risks if that concentration of contaminants is exceeded • Identify the capacity of the receiving environment to assimilate the contaminants • Requires understanding of contaminant loads into coastal environment • Identify relevant mixing zones
NPS-FM	• Understand connections between freshwater bodies and coastal water in relation to freshwater objectives, quality limits, environmental flows and/or levels • Identify freshwater bodies in the coastal environment
MDC PMEP Objective 15.1a, Policy 15.1.1, 15.1.2, 15.1.14, 15.1.32, Implementation method 15.M.2, 15.M.3, 15.M.4	• Understand whether there are specific scientific requirements informing the mauri of wai • Understand requirements for water quality at beaches to be suitable for contact recreation • Understand requirements for coastal water quality to be suitable for food gathering, cultural, commercial and other purposes • Understand requirements for coastal water quality to support healthy ecosystems • Identified areas where water quality does not meet the requirements of objective 15.1a • Understand what is required to enhance water quality if it does not meet the requirements of objective 15.1a • Establish water quality classifications (and water quality standards) that reflect the values in Policy 15.1.1 and other uses and values, including the values of Marlborough's tangata whenua iwi, supported by the waterbody or coastal waters. • As part of undertaking catchment-specific research to establish the capacity of fresh waterbodies to assimilate total contaminant loads from within each catchment, consider the capacity of sensitive receiving environments, such as the enclosed coastal waters of the Marlborough Sounds, to contaminant loads, including sediment loads from rivers. • Develop a monitoring plan that sets out the methods for monitoring progress toward the achievement of Objectives 15.1a • Understand how to determine the mixing zone for coastal receiving environments based on the criteria in Policy 15.1.14 • Identify clarity standards for coastal water (after reasonable mixing)
Kotahitanga mō te Taiao strategy (Top of the South as a whole, TOS 13.0)	• Identify degraded estuarine and coastal areas • Understand what is required to restore degraded estuaries
Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan	• Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the

	coastal / marine resources of the rohe. • Understand the ecological health, carrying capacity and cumulative effects of marine farming and other fishery practices within the rohe.
Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan	• This plan lists issues, objectives policies, anticipated environmental results, monitoring requirements for coastal water, relating to taonga species, water quality, kaimoana beds and fish. • Identify activities required to progressively improve water quality in the CMA to a level that enables the gathering or cultivation of shellfish for human consumption • Specific science needs should be identified in partnership with Ngati Koata.

3.4.3.3 National scientific information needs of relevance to the Marlborough CMA

Jarvis and Young (2019) identified several national research priorities relating to water and sediment quality degradation in their New Zealand Marine Science Horizon Scan carried out as part of a research project. Research questions are found in categories climate change and other anthropogenic factors and are listed in Appendix 2.

Further relevant to the Marlborough CMA are research needs identified by the CSIG, in relation to water and sediment quality degradation, particularly those aimed at achieving the stated goals to 'understand the response of coastal ecosystems to stressors in order to effectively manage the CMA', and to 'understand the regional impacts of climate change and acidification on the CMA to inform decision-making' (Berkett et al., 2015). Relating to water and sediment quality degradation, they include the need to:

- Characterise the existing CMA by collecting appropriate data for establishing baselines.
- Identify the effects of stressors within both a spatial and temporal context.
- Predict and measure the impact of freshwater flows, loads and limits on the coastal receiving environment.
- Develop approaches for the enhancement and restoration of degraded environments in the CMA.
- Develop better approaches for determining the loading of nutrients into estuaries.
- Identify indicators and determine response of ecosystem attributes (e.g., water quality) to stressors (individual and cumulative).
- Research environmental thresholds and establish appropriate and relevant limits and standards for stressors impacting on the CMA, including those derived from land-based activities.
- Forecast the nature and extent of environmental changes in the CMA in response to global climate change. Identify ecosystems and areas that will be more vulnerable than others.
- Delineate to what extent regional influences may interact with or further exacerbate effects associated with climate change (e.g., run-off and ocean acidification).
- Identify and prioritise adaptation and mitigation opportunities that are feasible in a regional policy context.

3.4.4 Summary and information gaps

What we know[28]

Water quality

The Marlborough Sounds has relatively large estuaries with long residence times, which can be sensitive to nutrient enrichment and water quality fluctuations. Most water quality monitoring and investigations in the Marlborough CMA have focussed on the Marlborough Sounds and consequently little information is available on other parts of the Marlborough CMA.

Eutrophication of Marlborough estuaries has generally been assessed as low; however, an increasing risk of eutrophication in Havelock Estuary has been indicated from monitoring since 2001. Also, extensive macroalgae beds have been found in Okiwa Bay in 2018 and nuisance macroalgae were identified in Wairau Estuary and Lagoon in 2015.

Terrestrial nutrient supply to Pelorus Sound/Te Hoiere has reduced since the 1970s, following cessation of land clearance, farming, forestry and human sewage input, reducing eutrophication risk. The reduced nutrient availability may, however, be limiting phytoplankton production, potentially contributing to the failed recovery of mussel beds and drop in productivity of the mussel farm industry in Pelorus Sound/Te Hoiere.

Monitoring since 2011 indicated that Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au and Pelorus Sound/Te Hoiere are near the oligotrophic-mesotrophic boundary, in terms of trophic classification, meaning that the level of nutrients is low to intermediate.

Dissolved oxygen saturation is generally high in the surface waters of the Marlborough Sounds. Bottom waters are equally high during times of the year when the water column is well mixed but stratification (layering) during warmer months tends to result in reduced near-bed saturations in late summer/autumn.

Chlorophyll in the Marlborough Sounds has reduced slightly over recent decades, consistent with comparable declines throughout New Zealand's coastal environment. The reason for this nation-wide decline is unclear but may be linked to increases in temperature. An investigation of the potential influence of mussel farming on chlorophyll a decline on the scale of the Marlborough Sounds found no evidence of a correlation between chlorophyll change and expansion of the marine farming industry.

Picton Bays are known to receive diffuse input of bacterial contamination, particularly during heavy rainfall, and shellfish are sometimes not suitable for human consumption at some sites. Despite a great reduction in faecal contamination since the 1970s, efforts to further reduce faecal contamination are ongoing.

Sediment quality

Organic enrichment of estuarine sediments is generally low. In most estuaries, trace metals in sediments are at levels below those causing concerns about toxic effects on aquatic organisms; however, in monitoring in Whangarae Bay and Waikawa Bay has identified relatively high contaminant levels, which reflected either natural catchment inputs (Whangarae) or historic anthropogenic inputs (Waikawa). Furthermore, chemical contamination, such as, zinc, mercury, from stormwater and anti-fouling materials are present in Picton Bays, causing moderate localised impacts and are detectable at

[28] This is a brief summary of information provided in section 3.4.2.

low levels over a wider area. Legacy contaminants, for example Tributyltin, are still measurable in Picton Bay but not widely present at harmful concentrations. Contaminant levels are expected to reduce over time.

In sediments near salmon farms copper and zinc concentrations are occasionally elevated to levels that may indicate localised risk to benthic organisms. Sediment metal concentrations tend to decrease with time, indicating that they are either mixed deeper into sediments and/or dispersed from the local environment.

What scientific information needs have been identified

The scientific information needs identified in section 3.2.3 specifically for the Marlborough CMA and those identified on a national level with relevance for the Marlborough CMA in relation to water and sediment quality degradation are:

Water quality

- Better characterise the seasonal patterns in dissolved oxygen (Marlborough District Council, 2017)
- Identify water quality requirements of aquaculture and effects of coastal development on aspects of water quality relevant to aquaculture (NZCPS Policy 8)
- Determine the meaning of "deteriorated water quality" (NZCPS Policy 21)
- Establish water quality classifications (and water quality standards, including clarity standards) that reflect the values in MDC PMEP Policy 15.1.1 and other uses and values, including the values of Marlborough's tangata whenua iwi, supported by the waterbody or coastal waters (within MDC PMEP Objective 15.1a, Policy 15.1.1, 15.1.2, 15.1.14, 15.1.32, Implementation method 15.M.2, 15.M.3, 15.M.4)
- Understand the state of water quality that can support activities and healthy ecosystems and natural habitats, including contact recreation, food gathering, cultural, commercial and other purposes (NZCPS Policy 21, within MDC PMEP Objective 15.1a, Policy 15.1.1, 15.1.2, 15.1.14, 15.1.32, Implementation method 15.M.2, 15.M.3, 15.M.4)
- Understand what effects are restricting existing uses, such as aquaculture, shellfish gathering, cultural activities and water based recreational activities (NZCPS Policy 21; Berkett et al., 2015))
- Identify areas where water quality does not support activities and healthy ecosystems and natural habitats, including the requirements of MDC PMEP Objective 15.1a (within MDC PMEP Objective 15.1a, Policy 15.1.1, 15.1.2, 15.1.14, 15.1.32, Implementation method 15.M.2, 15.M.3, 15.M.4)
- Identify what is required to enhance water quality where it is degraded, including the nature of discharged contaminants, the particular concentration of contaminants needed to achieve the required water quality in the receiving environment, and the risks if that concentration of contaminants is exceeded (NZCPS Policy 23; within MDC PMEP Objective 15.1a, Policy 15.1.1, 15.1.2, 15.1.14, 15.1.32, Implementation method 15.M.2, 15.M.3, 15.M.4; Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan)
- Identify relevant mixing zones (NZCPS Policy 23; within MDC PMEP Objective 15.1a, Policy 15.1.1, 15.1.2, 15.1.14, 15.1.32, Implementation method 15.M.2, 15.M.3, 15.M.4)
- Understand connections between freshwater bodies and coastal water in relation to freshwater objectives, quality limits, environmental flows and/or levels (NPS-FM)
- Identify freshwater bodies in the coastal environment (NPS-FM)

- Understand whether there are specific scientific requirements informing the mauri of wai (MDC PMEP Objective 15.1a, Policy 15.1.1, 15.1.2, 15.1.14, 15.1.32, Implementation method 15.M.2, 15.M.3, 15.M.4)
- Delineate to what extent regional influences may interact with or further exacerbate effects associated with climate change (e.g., run-off and ocean acidification) (Berkett et al., 2015)
- Identify effects of the increasing frequency of marine heatwaves on water quality (Jarvis and Young, 2019)
- Identify the impacts of climate change and ocean acidification on water quality (Jarvis and Young, 2019)

Sediment quality

- Improve information on the bioavailability of metals (Clement et al., 2010)
- Improve information on the fate of metals once introduced to the marine environment and later during chemical remediation (e.g., during a finfish farm fallowing period) (Clement et al., 2010)

Combined

- Identify indicators and determine response of ecosystem attributes to stressors (individual and cumulative) (Berkett et al., 2015)
- Research environmental thresholds and establish appropriate and relevant limits and standards for stressors impacting on the CMA, including those derived from land-based activities (Berkett et al., 2015)
- Establish baselines of the characteristics of the existing CMA (Berkett et al., 2015)
- Identify the sensitivity of the receiving environment to contaminants (NZCPS Policy 23)
- Identify the effects of stressors, including land-use change and future developments, within both a spatial and temporal context (Berkett et al., 2015; Jarvis and Young, 2019)
- Identify degraded estuaries and coastal areas and development of approaches for restoring these areas (Berkett et al., 2015; Kotahitanga mō te Taiao Strategy).
- Identify the capacity of the receiving environment to assimilate contaminants and consider this when undertaking catchment-specific research to establish the capacity of fresh waterbodies to assimilate total contaminant loads from within each catchment, (NZCPS Policy 23; within MDC PMEP Objective 15.1a, Policy 15.1.1, 15.1.2, 15.1.14, 15.1.32, Implementation method 15.M.2, 15.M.3, 15.M.4)
- Determine contaminant loads, including nutrients, into coastal environments (NZCPS Policy 23; Jarvis and Young, 2019)
- Improve understanding of risk from emerging chemical compounds identified as potentially harmful in the marine environment (Newcombe and Johnston, 2016)
- Determine the loading of nutrients into estuaries (Berkett et al., 2015; Jarvis and Young, 2019).
- Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the coastal / marine resources of the rohe (Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan)

Preliminary information gaps to inform a more strategic approach for collecting scientific information to address environmental issues related to water and sediment quality degradation

Based on the information reviewed and described in this section, the following preliminary information gaps related to water and sediment quality have been identified. This is not intended to be a complete list but a starting point for building on existing information and taking a more strategic approach for the collection of further scientific information on environmental issues related to water and sediment quality degradation in the Marlborough CMA. Inevitably, there are overlaps with information gaps identified in other sections of this report and future work should ensure alignments among environmental issues are considered.

Information gaps include:

- To inform a more strategic approach to managing water and sediment quality degradation in the Marlborough CMA, there is a need to determine criteria for identifying degraded areas (sediment and water column).
- Degraded areas, based on water or sediment quality, in the Marlborough should be identified.
- While there is a general need to establish baselines of water and sediment quality in the Marlborough CMA, a strategic prioritisation and planning should be carried out prior to commissioning any further work to ensure future work builds on existing work and is fit-for-purpose.
- There is a need to determine thresholds, limits, standards and the assimilative capacities of water and sediment in different parts of the Marlborough CMA for contaminant input and other environmental change generated by land-based and marine activities and uses.
- An improved understanding of the bioavailability and fate of contaminants and effects of emerging contaminants is required.
- Approaches need to be developed for restoring degraded areas in the Marlborough CMA and action plans need to be developed to ensure strategic and integrated actions towards improvement.
- While a reasonable knowledge base exists on sediment quality in estuaries and water quality in the Marlborough Sounds, limited information is available for offshore environments and nearshore areas of the Marlborough CMA outside the Marlborough Sounds.
- Identify the impacts of climate change, including increasing heat waves, and ocean acidification on water quality and delineate to what extent regional influences may interact with or further exacerbate these impacts.

3.5 Marine pests

3.5.1 The issue

The Marlborough Sounds are at high risk of new introductions of invasive species (Newcombe and Johnston, 2016). Invasive marine pests are a threat to Marlborough's coastal environment because they can compete with, or prey on, other species, change habitats and damage ecosystems. They can affect recreational and customary values, and impact on the economy by competing with economically important native species and reducing overall biodiversity. Invasive species fall into two categories: fouling species (such as the clubbed tunicate *Styela clava* and Mediterranean fanworm) and exotic diseases (such as *Bonamia ostrae*) that can infect fish or shellfish[29].

[29] https://www.marlborough.govt.nz/environment/biosecurity/marine-biosecurity

Marlborough District Council works with a range of partners through the Top of the South Marine Biosecurity Partnership to manage the threat of marine pests and is actively implementing an operational programme of surveillance and response aimed at preventing the establishment of Mediterranean fanworm in particular.

3.5.2 What we know about this issue in the Marlborough CMA

Marine experts providing science advice for the Kotahitanga mō te Taiao Strategy development, concluded that in the Marlborough Sounds and Cook Strait environments:

- Invasive marine species such as Undaria and *Didemnum vexillum* are widespread, *Styela clava* is spreading and *Sabella spallanzi* is established at one location; and
- Further introductions of harmful organisms are inevitable unless pathway controls are strengthened (Lawless, 2018).

A recent survey has shown that the composition of kelp within Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au has changed considerably between the 1990s and today, with the greatest difference being the presence and relative proportions of the exotic kelp *U. pinnatifida* (Wakame), and the absence of *M. pyrifera* at some sites (Anderson et al., 2020). *Undaria pinnatifida* is now common within the kelp-zone at most sites surveyed in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au. Within outer Queen Charlotte Sound/Tōtaranui, rocky reefs and rubble habitats around Motuara Is. and Motungarara Is. that once supported *M. pyrifera*, are now completely replaced by *U. pinnatifida* indicating wide-scale occurrence of *U. pinnatifida* though the Sounds, where it may be out-competing important native species (Anderson et al., 2020).

Since the summer of 2015/16, the Top of The South (TOS) Marine Biosecurity Partnership has conducted regional in-water surveys of recreational boats to check for marine pests and assess levels of boat fouling and checked for pests on adjacent structures like swing moorings. Most of the survey effort has focused on the Marlborough Sounds and Abel Tasman National Park coastline, where active boaters are most prevalent.

The key findings of the surveys (including up to the 2019/20 survey) were[30]:

- No pests that are new to the TOS region have been found over the 5 surveys. With respect to established pests, points of interest are as follows:
    - In 2019/20 the Mediterranean fanworm (*Sabella spallanzanii*, assumed to be juvenile) was recorded in low numbers on 3 vessels (Nelson Harbour, Pelorus Sound/Te Hoiere, Queen Charlotte Sound/Tōtaranui) which were linked to origins outside the TOS. These vessels were cleaned at haul-out facilities. Previously, there had been only one wider regional fanworm find on a vessel, in the 2015/16 survey (although there are separate records from known populations in Picton, Nelson and Tarakohe marinas).
    - Other long-established pests (kelp *Undaria pinnatifida*, sea squirt *Didemnum vexillum*) are widespread regionally on vessels and structures. The more recently-established sea squirt *Styela clava* is becoming increasingly common on structures and/or vessels in a few locations (Tarakohe, Nelson, parts of Pelorus Sound/Te Hoiere). For these established species, the disjointed distribution is consistent with human-mediated spread rather than natural dispersal, highlighting the importance of managing spread by hull fouling.
- The Level of Fouling (LOF) status of boats was largely similar to previous surveys, as follows:

[30] https://marinebiosecurity.gitlab.io/report/key-findings.html

- Around 20-25% of active boats exceeded the 'light fouling' (LOF 2) threshold, with many heavily fouled boats (LOF 4 & 5) active throughout the TOS region.
- Overall, hull fouling tends to be the greatest on vessels originating from Nelson, less on vessels from Marlborough, and least on vessels visiting from outside the region. Fouling is also relatively low on vessels from Tasman, reflecting that many of the boats surveyed are on swing or pile moorings than dry at low tide.
- Data from the 5 surveys shows a clear trend for marine pests to become more prevalent with increasing LOF. However, even LOF 2 vessels (i.e., with light fouling) can have pests present, typically on the bottom of the keel, as this area is difficult to effectively antifoul

Biosecurity New Zealand carries out a marine biosecurity surveillance programme at Picton Harbour (including Shakespeare and Waikawa bays, and Havelock Marina), which is one of the 11 locations surveyed under the programme (Acosta et al., 2020). These locations were selected as they are the ports of first entry for international vessels and are at highest risk of introduction of nonindigenous marine organisms. The surveillance programme aims:

- to detect incursions of new-to-New Zealand nonindigenous organisms listed on the Unwanted Organism Register;
- to detect incursions of new-to-New Zealand nonindigenous organisms or cryptogenic[31] organisms not listed on the Unwanted Organism Register; and
- to detect range extensions of established nonindigenous or cryptogenic organisms that exhibit characteristics of pests and diseases.

Biosecurity New Zealand provides information on marine pest species and access to research findings and distribution records via the Marine Biosecurity Porthole.[32]

3.5.3 Scientific information needs for the Marlborough CMA

3.5.3.1 Scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA

Specific scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA are listed in Table 6.

3.5.3.2 National scientific information needs of relevance to the Marlborough CMA

Jarvis and Young (2019) identified several national research priorities relating to marine pests in their New Zealand Marine Science Horizon Scan carried out as part of a research project. Research questions are found in the category biosecurity and are listed in Appendix 2.

3.5.4 Summary and information gaps

What we know[33]

In the Marlborough Sounds and Cook Strait environments invasive marine species such as *Undaria pinnatifida* and *Didemnum vexillum* are widespread, *Styela clava* is spreading and *Sabella spallanzi* is established at one location.

[31] Species whose origin cannot be clearly classified as either indigenous or non-indigenous
[32] https://www.marinebiosecurity.org.nz/
[33] This is a brief summary of information provided in section 3.5.2.

Table 6. Scientific information needs related to environmental issue 'marine pests' stipulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring. Documents reviewed are shown in Appendix 1.

Document	Scientific information needs/requirement
NZCPS Policy 12: Harmful aquatic organisms	• Identify activities that could have adverse effects on the coastal environment by causing harmful aquatic organisms to be released or otherwise spread
Kotahitanga mō te Taiao strategy (Top of the South as a whole, TOS 13.0)	• Identify degraded estuarine and coastal areas • Understand what is required to restore degraded estuaries
Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan	• Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the coastal / marine resources of the rohe
Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan	• This plan lists issues, objectives policies, anticipated environmental results, monitoring requirements for coastal water, relating to taonga species, water quality, kaimoana beds and fish. • Specific science needs should be identified in partnership with Ngati Koata.

A recent survey has shown that the composition of kelp within Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au has changed considerably between the 1990s and today, with the greatest difference being

The presence and relative proportions of the exotic kelp *U. pinnatifida* (Wakame) in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au has increased considerably since the 1990s, while *M. pyrifera* has become absent at some sites. *Undaria pinnatifida* is now common within the kelp-zone at most sites surveyed in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au and on rocky reefs and rubble habitats around Motuara Is. and Motungarara Is. in outer Queen Charlotte Sound/Tōtaranui that once supported *M. pyrifera*. There are concerns that *U. pinnatifida* may be out-competing important native species.

Since the summer of 2015/16, the TOS Marine Biosecurity Partnership has conducted regional in-water surveys of recreational boats to check for marine pests and assess levels of boat fouling and checked for pests on adjacent structures like swing moorings. Most of the survey effort has focused on the Marlborough Sounds and Abel Tasman National Park coastline, where active boaters are most prevalent.

The key findings of the surveys (including up to the 2019/20 survey) included:

- No pests that are new to the Top of the South region have been found over the 5 surveys.
- The Mediterranean fanworm has occasionally been recorded in low numbers on vessels in Nelson Harbour, Pelorus Sound/Te Hoiere, Queen Charlotte Sound/Tōtaranui, and Picton, Nelson and Tarakohe marinas.

- Other long-established pests (kelp *Undaria pinnatifida*, sea squirt *Didemnum vexillum*) are widespread regionally on vessels and structures.
- The more recently-established sea squirt *Styela clava* is becoming increasingly common on structures and/or vessels in a few locations (Tarakohe, Nelson, parts of Pelorus Sound/Te Hoiere).
- For the established species, the disjointed distribution is consistent with human-mediated spread rather than natural dispersal, highlighting the importance of managing spread by hull fouling.
- The Level of Fouling (LOF) status of boats was largely similar to previous surveys, as follows:
    - Around 20-25% of active boats exceeded the 'light fouling' (LOF 2) threshold, with many heavily fouled boats (LOF 4 & 5) active throughout the TOS region.
    - Overall, hull fouling tends to be the greatest on vessels originating from Nelson, less on vessels from Marlborough and Tasman, and least on vessels visiting from outside the region.
    - There is a clear trend for marine pests to become more prevalent with increasing LOF. However, even LOF 2 vessels (i.e., with light fouling) can have pests present, typically on the bottom of the keel, as this area is difficult to effectively antifoul.

What scientific information needs have been identified

The scientific information needs identified in section 3.5.3 specifically for the Marlborough CMA and those identified on a national level with relevance for the Marlborough CMA in relation to marine pests are:

- Identify activities that could have adverse effects on the coastal environment by causing harmful aquatic organisms to be released or otherwise spread (NZCPS Policy 12)
- Identify estuarine and coastal areas that are degraded as a result of marine pest presence and determine what is required to restore these areas (Kotahitanga mō te Taiao Strategy)
- Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the coastal / marine resources of the rohe (Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan)
- Improve approaches for mitigating the impact of invasive species (Jarvis and Young, 2019)
- Develop approaches for identifying and monitoring the impact of marine pests on native biodiversity (Jarvis and Young, 2019)
- Determine how marine introduced species and climate-change-induced range shift alter ecological structure (Jarvis and Young, 2019)
- Identify the impacts of current and future marine biosecurity risks (Jarvis and Young, 2019)

Preliminary information gaps to inform a more strategic approach for collecting scientific information to address environmental issues related to marine pests

Based on the information reviewed and described in this section, the following preliminary information gaps related to marine pests have been identified. This is not intended to be a complete list but a starting point for building on existing information and taking a more strategic approach for the collection of further scientific information on environmental issues related to marine pests in the Marlborough CMA. Inevitably, there are overlaps with information gaps identified in other sections of this report and future work should ensure alignments among environmental issues are considered.

Information gaps include:

- There appears to be gaps in the understanding of the impacts of marine pest species on the coastal environment, including native biodiversity, for example, whether *U. pinnatifida* is out-competing important native species.
- While comprehensive marine pest surveys are conducted for boats in the Marlborough CMA, there appear to be no systematic surveys of habitat potentially vulnerable to the impacts of marine pests.
- It is unclear what the ecological risk from potential new introduced marine pest species is and whether (and how) this risk may increase due to climate change.
- It is unclear to what extent information on the presence of marine pest in the Marlborough CMA is linked to and used for other initiatives, such as marine protection, restoration or consenting.

3.6 Marine litter

3.6.1 The issue

Marine litter can damage benthic environments, cause a loss of biodiversity and lead to a reduction in overall ecosystem function through various mechanisms (Galgani et al., 2019). Marine organisms can be harmed by ingesting litter or by being exposed to chemical additives associated with litter. Intentionally or accidentally discarded fishing equipment poses particular risks for large, air-breathing marine animals, including endangered species, which may get entangled. Most plastics are non-biodegradable and thus persist in the environment for hundreds of years. Over time they may fragment into small particles that are readily taken up by marine organisms. Microplastics and nanoplastics are of particular concern because they can be ingested by even the smallest zooplankton species, which may transfer them into the trophic webs. Finally, litter may transport marine pest species over long distances, thus facilitating their spread.

Marine litter enters the sea from the land, for example via stormwater drains, road and land runoff, or from beaches or directly from sea-based activities, particularly off recreational or commercial boats. Globally, between 61% and 87% of litter in the marine environment is plastic (Galgani et al., 2019).

Capture fisheries and aquaculture are contributing to the marine plastic stock. Abandoned, lost or otherwise discarded fishing gears are considered the main source of plastic waste coming from the fisheries and aquaculture sectors, but their relative contribution is not well known at regional and global levels (Lusher et al., 2017).

Plastic is widely used in the aquaculture industry; for example, in filament form (in ropes and nets), as floatation for sea-pens, as structural or containment components (in sea-pen collars, buoys, baskets, tanks, pipework, and mooring systems, pond liners, barrier membranes, and packaging; Sustainable Business Network, 2020). Plastics from aquaculture are presumed to have localised impacts and to be relatively low compared to capture fisheries (Sustainable Business Network, 2020). However, due to the likely continued growth of aquaculture, the Sustainable Business Network expects its contribution to increase unless more preventive measures are taken to reduce plastic use, reuse and recycle end of life plastic components and recover lost plastics and other aquaculture-derived debris wherever practical.

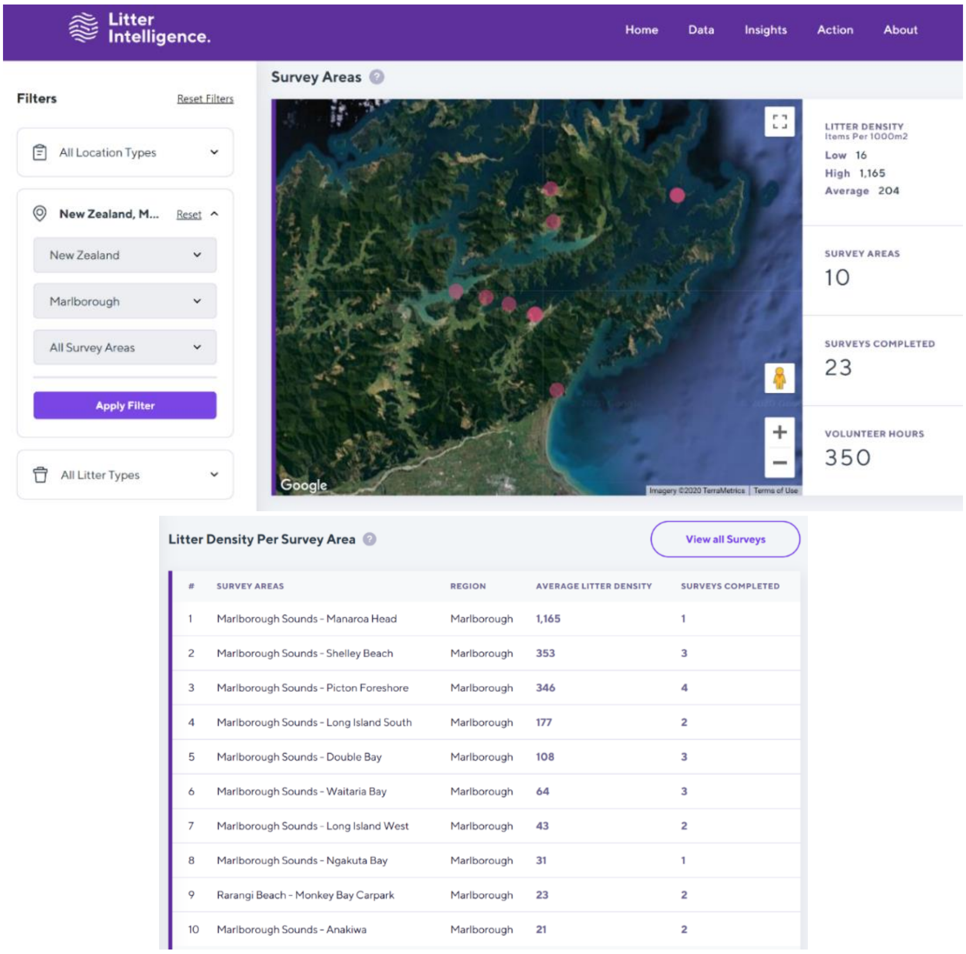
To minimise plastic waste in New Zealand aquaculture, Aquaculture New Zealand and the MPI including Agriculture and Investment Services and Fisheries New Zealand have partnered with the Sustainable Business Network (SBN). The first report released by this partnership presents an overview of the issues, what success would look like and identification of the key opportunities for action (Sustainable Business Network, 2020).

3.6.2 What we know about this issue in the Marlborough CMA

Anderson et al. (2020) recorded marine litter was recorded in over a third of all sites (36%) surveyed in Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au and adjacent Cook Strait, with the highest occurrences in the inner Queen Charlotte Sound/Tōtaranui (65% of sites). The types of litter varied from small items (mostly beer bottles, few soda cans, food-wrappers) and fishing gear (including lines, ropes and burley pots), to large discarded industrial items (e.g., ten gallon drums, pipes, car tyres, and the back end of a tractor), with the latter most common within inner bays, often near homesteads. Macro-plastics however were rare (<6% of all litter).

Litter has been found to be widespread in Picton Bays with site specific clean-up initiatives taking place in the Picton Bays area demonstrate problematic littering areas (Newcombe and Johnston, 2016). There are indications that change in people's behaviour is reducing the amount of material entering and remaining in the sea.

Twenty-three beach litter surveys have been conducted at Marlborough beaches as part of the Litter Intelligence project.[34] An overview of survey locations and average litter density is shown in Figure 17.



#	SURVEY AREAS	REGION	AVERAGE LITTER DENSITY	SURVEYS COMPLETED
1	Marlborough Sounds - Manaroa Head	Marlborough	1,165	1
2	Marlborough Sounds - Shelley Beach	Marlborough	353	3
3	Marlborough Sounds - Picton Foreshore	Marlborough	346	4
4	Marlborough Sounds - Long Island South	Marlborough	177	2
5	Marlborough Sounds - Double Bay	Marlborough	108	3
6	Marlborough Sounds - Waitaria Bay	Marlborough	64	3
7	Marlborough Sounds - Long Island West	Marlborough	43	2
8	Marlborough Sounds - Ngakuta Bay	Marlborough	31	1
9	Rarangi Beach - Monkey Bay Carpark	Marlborough	23	2
10	Marlborough Sounds - Anakiwa	Marlborough	21	2

Figure 17. Summary of Litter Intelligence project surveys conducted on Marlborough beaches. Source: https://litterintelligence.org/.

[34] https://litterintelligence.org/

In 2010, the Marine Farming Association (MFA) has 2010 established an Environmental Certification Programme, which includes objectives to help clean up beaches in the top of the South Island. The programme focuses on areas in which marine farming occurs, including the Marlborough Sounds. In 2019, the MFA collected a total of 2,695 kg of debris, which was considerably less than the 6,319 kg collected in 2018 (Sustainable Business Network, 2020). Of all debris, 38-43% could be attributed to aquaculture activities. The reduced amount of debris collected in 2019 may be a result of considerable staffing shortages throughout 2019 that put pressure on the availability of crews to perform beach clean ups, or it may be a result of the increasing number of organisations and environmental groups also carrying out beach clean ups (Sustainable Business Network, 2020).

3.6.3 Scientific information needs for the Marlborough CMA

The Sustainable Business Network identified opportunities for improving the efficiency of and data collected through the MFA for beach clean ups by automating some of the data analysis and adding more specific fields the form to determine the different types of debris collected (Sustainable Business Network, 2020).

No specific scientific information needs are identified in the regulatory and non-regulatory documents reviewed for this report (listed in Appendix 1). However, MDC has identified that the extent and impact of microplastic pollution in the Marlborough CMA is a knowledge gap for management and has obtained Envirolink funding in October 2020 for a University of Auckland project to ascertain the source and distribution of microplastic contamination in Queen Charlotte Sound/Tōtaranui and to conduct conceptual modelling of plastic particle transport and spatial distribution to identify areas where future plastic deposition is likely to occur (O. Wade, MDC, pers. comm.).

No specific scientific information needs have been identified in the Kotahitanga mō te Taiao strategy or iwi management plans but the holistic nature of these documents clearly demonstrates that issues relating to marine litter are of importance to their objectives.

Jarvis and Young (2019) identified one national research priority relating to marine litter in their New Zealand Marine Science Horizon Scan carried out as part of a research project; namely 'What are the fates and impacts of microplastics, nanomaterials, and other marine debris?'.

3.6.4 Summary and information gaps

What we know[35]

Marine litter is common in Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au and adjacent Cook Strait, with the highest occurrences in the inner Queen Charlotte Sound/Tōtaranui (at 65% of sites). A variety of items have been found, ranging from small items (mostly beer bottles, few soda cans, food-wrappers) and fishing gear (including lines, ropes and burley pots), to large discarded industrial items (e.g., drums, pipes, car tyres, vehicle parts). Macro-plastics were rare (<6% of all litter).

Litter is widespread in Picton Bays but there are indications that change in people's behaviour is reducing the amount of material entering and remaining in the sea.

The Marine Farming Association (MFA) has established an Environmental Certification Programme, under which beaches in areas in which marine farming occurs, are regularly surveyed and cleaned. Of all litter collected in 2018, 38-43% could be attributed to aquaculture activities. Volunteer litter surveys

[35] This is a brief summary of information provided in section 3.6.2.

have been conducted at various Marlborough beaches, continuing to provide information to the open data portal of the Litter Intelligence project.[36]

What scientific information needs have been identified

The scientific information needs identified in section 3.6.3 specifically for the Marlborough CMA and those identified on a national level with relevance for the Marlborough CMA in relation to marine litter are:

- Determine the fates (including spatial extent) and impacts of microplastics, nanomaterials, and other marine debris (Jarvis and Young, 2019), MDC

Preliminary information gaps to inform a more strategic approach for collecting scientific information to address environmental issues related to marine litter

Based on the information reviewed and described in this section, MDC has already acted to partially address the science need identified. A University of Auckland project, for which funding has recently been obtained, aims to ascertain the source and distribution of microplastic contamination in Queen Charlotte Sound/Tōtaranui and conduct conceptual modelling of plastic particle transport and spatial distribution to identify areas where future plastic deposition is likely to occur. Information on other parts of the Marlborough Sounds and nearshore areas outside the sounds (outside the areas of litter surveys conducted by the MFA or volunteers) is limited. It would therefore be helpful to establish whether other parts of the Marlborough CMA would benefit from marine litter surveys to improve the coverage of information on marine litter.

Furthermore, it is not clear whether information exists on marine litter discharge areas, such as population hotspots, river inflows or popular recreational or commercial areas in the Marlborough CMA.

3.7 Climate change

3.7.1 The issue

Climate change, resulting from an increase in global concentrations of atmospheric greenhouse gas due to anthropogenic activities such as burning fossil fuels, transport, and electricity generation, is already causing unprecedented and enduring change in our coastal waters and oceans, including increasing water temperatures and acidity and sea-level rise (Ministry for the Environment and Stats NZ, 2019). As reported by the Ministry for the Environment and Stats New Zealand, New Zealand's ocean temperatures have increased on average 0.2°C per decade since 1981 and marine heatwaves and above-average annual temperatures are becoming more frequent. Ocean acidity[37], a consequence of higher CO_2 levels in the sea, measured off the Otago coast has increased by 7.1 percent in the past 20 years and oceans will continue to become more acidic as more carbon dioxide is absorbed. The rate of sea-level rise in the past 60 years (2.44 millimetres per year) was more than double the rate of the previous 60 years (1.22 millimetres per year) and the rate of sea-level rise is expected to further increase. Extreme wave events may become more frequent and coastal habitats may migrate inland or, if coastal development prevents such shifts, lost due to sea-level rise.

[36] https://litterintelligence.org/

[37] MDC PMEP Chapter 19 states that "Although a serious potential threat to Marlborough's marine ecology, ocean acidification is not an effect of climate change and is therefore not addressed in this chapter".

The consequences of climate change on the marine environment are not fully understood but temperature-related changes in individual species and fish communities have already been observed (Ministry for the Environment and Stats NZ, 2019). These changes have already affected tohu, traditional Māori environmental indicators used, among other purposes, to identify trends in the natural world. Furthermore, ecosystem services delivered by coastal seas and oceans, such as climate regulation and carbon storage, will likely decline. Continuing increases in water temperature and acidity will continue to have impacts on species (including plankton) and food webs as their temperature tolerance levels are exceeded and species vulnerable to increasing acidity, particularly shellfish, experience adverse effects from the environmental change.

Several threats to the marine environment derive from the net accumulation of greenhouse gases in the earth's atmosphere. On a national level, ocean acidification has been ranked by a large margin the highest scoring threat over all marine habitats (MacDiarmid et al., 2012). The second highest overall scoring threat was rising sea temperatures resulting from global climate change. Seven other threats deriving from global climate change (changes in currents, increased storminess, rise in sea-level, increased stratification, increased intertidal temperatures, increase in UV, and altered rainfall) all ranked 19th equal or higher in the assessment of anthropogenic threats to New Zealand marine habitats by MacDiarmid et al. (2012).

3.7.2 What we know about this issue in the Marlborough CMA

Seawater temperatures have been increasing in the Marlborough CMA (Newcombe and Broekhuizen, 2020) but warming has been more rapid on the western and northern side of Cook Strait and may also have been more rapid in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au than in Pelorus Sound/Te Hoiere (Figure 18). Broekhuizen et al. (2021) examined a range of potential causes of warming of near-surface waters within Pelorus Sound/Te Hoiere observed between 2002 and 2020 and conclude that the dominant driver of the decadal-scale warming has been import of oceanic waters that have, themselves, been warming. They observed more rapid warming in Cook Strait than in the Marlborough Sounds and attributed this to catchment and endogenous influences that may have ameliorated the influence of the oceanic warming.

The earliest documented assumed manifestation of climate change effects in the Marlborough CMA is presumed to be the decline in kelp forests in the Marlborough Sounds between 1942 and 1988, reported by Hay (1990). Hay observed that the distribution of the kelp *Macrocystis pyrifera* on the southern side of Cook Strait recorded by Rapson et al. (1942) differed from that of his own observations between 1984 and 1988 and was able to link this shift to localised increases in water temperature. *Macrocystis pyrifera* is confined to open coasts where the highest monthly mean temperature is cooler than 16-17°C and where summer maxima rarely exceed 18-19°C, making *M. pyrifera* a reliable biological indicator of sea surface temperatures in New Zealand coastal waters (Hay, 1990).

Anderson et al. (2019) describe the findings of Hay (1990) and further report that losses of *M. pyrifera* have occurred within Tory Channel/Kura Te Au and other locations in the Marlborough Sounds. In respect to changes on a national level they conclude that currently the decline of *Macrocystis* is largely anecdotal and that there is a lack of baseline data necessary to confirm whether declines in kelp forests have already occurred on a broader scale.

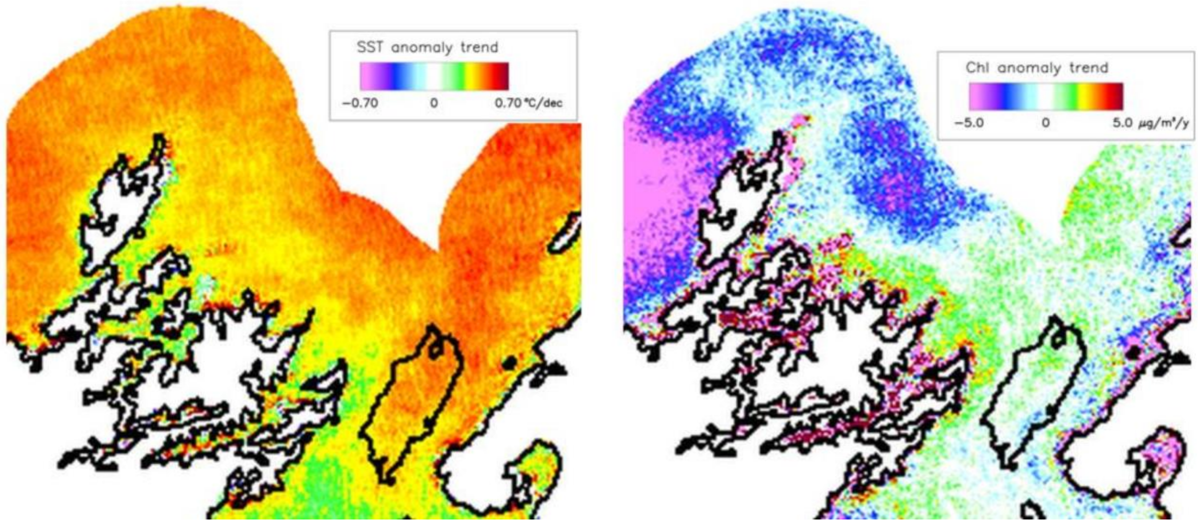


Figure 18. Long-term trends (2002-2018 period) in satellite-sensed near-surface temperature (left) and near-surface chlorophyll a concentration (right). Source: Newcombe and Broekhuizen (2020).

Increased sea temperatures have also been associated with declines in phytoplankton concentration observed at some sites in Pelorus Sound/Te Hoiere since the early 1980s, consistent with observed declines around much of New Zealand's coastline over the past 20–30 years (Newcombe and Broekhuizen, 2020) (Figure 18). Newcombe and Broekhuizen (2020) examined a range of potential causes of the observed decline in Pelorus Sound/Te Hoiere and concluded that rising sea temperatures was the only one that may have played a role.

Warming waters have already impacted the salmon farming industry in the Marlborough Sounds. Salmon have a low tolerance to warm waters and the effects of warming sea temperatures have already impacted the salmon farming industry in the Marlborough CMA with New Zealand King Salmon focussing on new operational strategies to mitigate the effects of rising water temperatures, especially throughout the summer periods.[38]

Broekhuizen et al. (2021) discuss the implications of future warming on aquaculture in the Marlborough Sounds, concluding that additional warming will further reduce the suitability of Pelorus Sound/Te Hoiere waters for salmon farming. A number of potential implications on mussel aquaculture were also discussed by Broekhuizen et al. (2021). Mussels spawning times may change, potentially making it increasingly difficult for the mussel farming industry to secure a year-round wild spat supply. Changes in water temperature and temperature-driven stratification may also alter phytoplankton communities, with unknown (potentially beneficial or detrimental) consequences for mussels. Finally, rising water temperatures may allow infectious agents and competitor/predator-species to establish (better).

Broekhuizen et al. (2021) describe that direct effects on farmed species can potentially be mitigated because salmon and mussels are now bred in culture facilities, which creates opportunities to select for greater tolerance of warmer waters.

[38] https://www.kingsalmon.co.nz/seawater/

3.7.3 Scientific information needs for the Marlborough CMA

3.7.3.1 Scientific information needs identified in scientific surveys and investigations

Anderson et al. (2019) identified that there is a lack of baseline data necessary to confirm whether declines in kelp forests have already occurred.

Forrest et al. (2016) described the following information need:

- Knowledge gaps identified during interviews included long-term datasets for establishing environmental 'baselines', effects of climate change, improved indicators (including cultural indicators) and appropriate spatial and temporal data to facilitate management decisions.

The Aquatic Environment and Biodiversity Annual Review 2019–20 identified as an emerging issue for New Zealand's climate and ocean setting that the causal mechanisms linking the dynamics of the variable marine environment to variations in biological productivity, particularly of fisheries and biodiversity, are not well understood (Fisheries New Zealand, 2020b). It was acknowledged that this issue is the subject of multiple current studies.

Broekhuizen et al. (2021) stated that there are questions related to the susceptibility of mussels to resident or invasive pathogens or competitors. They also identified that work is required to better understand how patterns of nutrient cycling and primary production may change within New Zealand marine farming areas as the marine climate evolves over coming decades.

Table 7. Scientific information needs related to environmental issue 'climate change' stipulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring. Documents reviewed are shown in Appendix 1.

Document	Scientific information needs/requirement
MDC MMEP Implementation method 19.M.4, 19.M.5	• Support research on the implications of climate change on the Marlborough CMA • Share research findings on the implications of climate change on the Marlborough CMA with the community
19.AER.1 The community's understanding of the effects of climate change and sea level rise improves over time.	• The results of research into the local effects of climate change and sea level rise are reported to the Council. • Environmental data, including climate and flooding, is collected and reported to the Council to establish long term trends.
Kotahitanga mō te Taiao strategy (Top of the South as a whole, TOS 13.0)	• Understand what makes estuaries resilient to the effects of climate change
Kotahitanga mō te Taiao strategy (East Coast Marine, ECM 11.2)	• Understand what is required to allow Wairau Lagoons to recover ecologically and to evolve naturally in the future as climate changes.
Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan	• No specific scientific information needs
Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan	• This plan lists issues, objectives policies, anticipated environmental results, monitoring requirements for coastal water, relating to taonga species, water quality, kaimoana beds and fish. • Specific science needs should be identified in partnership with Ngati Koata.

3.7.3.2 Scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA

Specific scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA are listed in Table 7.

3.7.3.3 National scientific information needs of relevance to the Marlborough CMA

Jarvis and Young (2019) identified several national research priorities relating to climate change in their New Zealand Marine Science Horizon Scan carried out as part of a research project. Research questions are found in categories biosecurity, climate change and coastal and ocean processes and are listed in Appendix 2.

Understanding the regional impacts of climate change and acidification on the CMA to inform decision-making has been identified as one of four overarching research goals for councils by the CSIG (Berkett et al., 2015). The associated specific research needs identified on the national level were:

- Forecast the nature and extent of environmental changes in the CMA in response to global climate change. Identify ecosystems and areas that will be more vulnerable than others.
- Investigate capacity for organisms and ecosystems to adapt to climate change.
- Delineate to what extent regional influences may interact with or further exacerbate effects associated with climate change (e.g., run-off and ocean acidification, coastal hazard risks, biosecurity).
- Identify and prioritise adaptation and mitigation opportunities that are feasible in a regional policy context

3.7.4 Summary and information gaps

What we know[39]

Water temperatures have been increasing in the Marlborough CMA but the speed of warming differs throughout the area. Between 1997 and 2018 warming has been more rapid on the western and northern side of Cook Strait compared to the east. In the Marlborough Sounds, the temperature increase has been greatest at locations in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au with considerably lower change in Pelorus Sound/Te Hoiere.

The earliest documented assumed manifestation of climate change effects in the Marlborough CMA is the decline in kelp forests (*Macrocystis pyrifera*) on the southern side of Cook Strait recorded between 1942 and 1988, in response to increases in water temperatures. Further losses of *M. pyrifera* have subsequently been reported in Tory Channel/Kura Te Au and other locations in the Marlborough Sounds but it is unclear whether this constitutes a decline in kelp forests.

Increased sea temperatures have also been associated with declines in phytoplankton concentration observed at some sites in Pelorus Sound/Te Hoiere since the early 1980s, consistent with observed declines around much of New Zealand's coastline over the past 20–30 years.

Warming waters have already impacted the salmon farming industry in the Marlborough Sounds as salmon have a low tolerance for the maximum temperatures that are now more frequently being reached, particularly during marine heat waves.

[39] This is a brief summary of information provided in section 3.7.2.

What scientific information needs have been identified

The scientific information needs identified in section 3.7.3 specifically for the Marlborough CMA and those identified on a national level with relevance for the Marlborough CMA in relation to climate change are:

- Collect baseline data to confirm whether declines in kelp forests have already occurred (Anderson et al., 2019).
- Determine the local effects of climate change and sea level rise (19.AER.1)
- Collect environmental data, including on climate and flooding, to establish long term trends (19.AER.1, Forrest et al., 2016)
- Identify the impacts of climate change on the Marlborough CMA, including ecological structures, ecosystem services, spatial patterns and extent of marine species, food webs, and their interactions within and across ecosystems (MDC MMEP Implementation method 19.M.4, 19.M.5; Jarvis and Young, 2019)
- Identify the impacts of ocean acidification on marine resources (Jarvis and Young, 2019)
- Identify the extent to which regional influences may interact with or further exacerbate effects associated with climate change (Berkett et al., 2015).
- Forecast the nature and extent of environmental changes in the CMA in response to global climate change. Identify ecosystems and areas that will be more vulnerable than others (Berkett et al., 2015)
- Identify how will primary production will respond to future change (Jarvis and Young, 2019)
- Determine how the increasing frequency of marine heatwaves will affect marine ecosystems and the distribution and abundance of marine biodiversity (Jarvis and Young, 2019)
- Determine what makes estuaries resilient to the effects of climate change (Kotahitanga mō te Taiao Strategy)
- Investigate the resilience and capacity for organisms and ecosystems to adapt to climate change (Berkett et al., 2015; Jarvis and Young, 2019).
- Determine what is required to allow Wairau Lagoons to recover ecologically and to evolve naturally in the future as climate changes (Kotahitanga mō te Taiao Strategy).
- Identify ways to improve and prioritise our coastal restoration efforts to ensure we can adapt to climate change (Jarvis and Young, 2019)

Preliminary information gaps to inform a more strategic approach for collecting scientific information to address environmental issues related to climate change

Based on the information reviewed and described in this section, the following preliminary information gaps related to climate change have been identified. This is not intended to be a complete list but a starting point for building on existing information and taking a more strategic approach for the collection of further scientific information on environmental issues related to climat change in the Marlborough CMA. Inevitably, there are overlaps with information gaps identified in other sections of this report and future work should ensure alignments among environmental issues are considered.

Information gaps include:

- There is a need to establish baselines to confirm impacts of climate change that are presumed to have already occurred (declines in kelp forests and phytoplankton) and gather ongoing information on these impacts.
- There is a need to determine trends in indicators of climate change, such as temperature change, acidity and sea level rise.

- Areas vulnerable to climate change need to be identified.
- The impacts of climate change on ecosystems and marine resources in the Marlborough CMA need to be identified and, if possible, forecast.
- Improved knowledge is required on what makes estuaries resilient to the effects of climate change and the resilience and capacity for organisms and ecosystems to adapt to climate change.
- Ways to improve and prioritise coastal restoration efforts to support adaptation to climate change need to be developed.

4 Cumulative effects

4.1 The issue

The effects of human and natural stressors cumulate in the environment. The marine environment is a particularly complex system, and the cumulative effects of multiple stressors within this complexity are not well understood (Ministry for the Environment and Stats NZ, 2019; Parliamentary Commissioner for the Environment, 2020).

Cumulative effects refer to the accumulation of changes in environmental systems over time and across space in an additive or interactive manner (Spaling, 1994). Changes may originate from single or multiple stressors of similar or different type. A unit of environmental change attributable to an individual stressor may be considered insignificant because of limited intensity, confined spatial or temporal scales, but environmental changes originating from repeated, or multiple, stressors can accumulate over time and across space resulting in cumulative effects that are deemed significant (Spaling, 1994).

The interaction of multiple pressures can result in unexpected outcomes (Parliamentary Commissioner for the Environment, 2020). Importantly, the impact of individual stressors can be many times more severe when coupled with other stressors, but combined stressors can also interact in ways that diminish the overall effects. The PCE therefore emphasised that looking at pressures in isolation rather than as a whole might lead to a profound misunderstanding of the processes at play and their likely outcomes, and in turn, misguided management proposals. For example, if two pressures cancel each other out, reducing only one might lead to a worsening of the health of the estuary (Parliamentary Commissioner for the Environment, 2020).

There is growing evidence that interactions between the intrinsic ecological dynamics of marine ecosystems and cumulative stressor effects can lead to the loss of resilience and an increased risk of crossing tipping points, i.e., sudden and dramatic changes (Hewitt and Thrush, 2019).

In the marine environment, cumulative effects are most prevalent in coastal waters, due to their location at the land-sea interface and the high public interest and use (Ministry for the Environment & Stats NZ, 2016). In addition to scientific complexity of these environments, challenges in addressing cumulative effects arise from fragmented science, management and governance, diverse social values, competing interests and capacity limitations (Davies et al., 2018).

4.2 Cumulative effects on the Marlborough CMA

Most environmental issues described in this report are related and caused, at least to some extent, by cumulative effects of natural and anthropogenic stressors originating from the land or the sea. Several descriptions of interacting effects are provided in the proceeding sections. Whether or not those descriptions specifically used the term 'cumulative effects', any accumulation of effects from individual or multiple anthropogenic or natural stressors over time or space contributes to cumulative effects on the Marlborough CMA.

A full review of all cumulative effects in the Marlborough CMA is out of scope of this report. Instead, this section focuses only on a few publications that specifically referred to cumulative effects.

As part of a project focussing on improving water quality monitoring in the Marlborough Sounds, Forrest et al. (2016) presented a snapshot of some of the existing consented activities in Marlborough to highlight this aspect of the considerable pressure on the Marlborough CMA. This snapshot is shown in Figure 19, displaying numerous marine farms and coastal discharges within the CMA and discharges in adjacent contributing catchments that will ultimately affect the CMA. Forrest et al. (2016) used this snapshot to support their suggestion of an integrated regional monitoring programme that, among other benefits, would improve scientific consistency and quality control of monitoring design, methods, data analyses and evaluation; all contributing to a consistent management response and an improved understanding of cumulative effects.

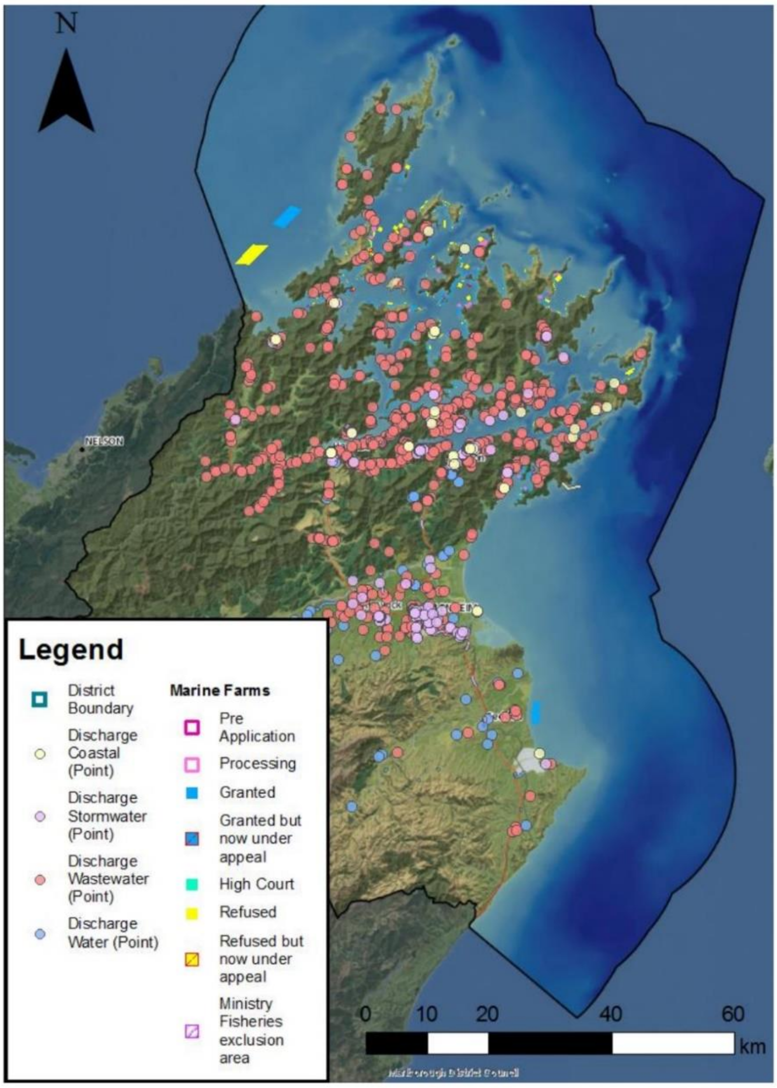


Figure 19. Discharge and marine farm consents in the MDC region obtained from MDC Smart Maps. Source: Forrest et al. (2016).

In addition to consented activities, permitted activities, activities regulated by agencies other than MDC and natural stressors contribute to cumulative effects on the Marlborough CMA. Cumulative effects are further exacerbated by natural dynamics in the coastal environment, such as resuspension of sediments during storm events that temporarily increase turbidity and may redistribute sediments.

Urlich and Handley (2020) described a series of transformations of ecosystems in the Marlborough since Māori settlement. They describe local extinction of marine megafauna, loss of subtidal shellfish beds and biogenic habitats, overharvesting of exploited species, and disruption to ecological functioning through sedimentation and disturbance of marine biogenic communities since European settlement in the 1800s and emphasise the critical role cumulative effects of land-use and sea-based activities have played and continue to play in the observed ecosystem change.

Cumulative effects from a range of human-induced impacts, including fishing and land-based impacts, have been identified as the likely cause of the decline in scallops and degradation of scallop habitat in the Marlborough Sounds (Fisheries New Zealand, 2020a).

4.3 Scientific information needs for the Marlborough CMA

4.3.1 Scientific information needs identified in scientific surveys and investigations

Forrest et al. (2016) described the following information needs:

- Knowledge gaps identified during interviews included long-term datasets for establishing environmental 'baselines', effects of climate change, improved indicators (including cultural indicators) and appropriate spatial and temporal data to facilitate management decisions.
- They specifically identified the need to better understand the cumulative effects of different stressors arising from marine and land-based activities and natural events, particularly the source of stressors (for example, what activities are leading to sedimentation in the Sounds)

A project has been set up by FNZ to address science needs relating to cumulative effects on scallops. The project aims to assess the cumulative effect of a range of physical, biological, and ecological stressors (including fishing) on scallops and scallop habitat in the Marlborough Sounds using experimental and modelling techniques. The project seeks to assess the cumulative effect of key stressors on habitats and ecological processes that support scallops. It is envisaged that the results of this work will provide insight into the recovery potential of scallops in the Marlborough Sounds, guidance as to whether the creation of refuges from bottom-fishing methods may enhance recovery, and an idea of the realistic timeframes required for recovery. In addition, the findings of the project may also help to inform and guide restoration efforts. The project supports the *Southern Scallop Strategy: Marlborough Sounds* which proposes to "get better information" particularly around "what constitutes good scallop conditions".[40]

4.3.2 Scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA

Specific scientific information needs articulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA are listed in Table 8. The Kotahitanga mō te Taiao strategy does not specifically refer to cumulative effects. However, it is apparent from the holistic approach of the strategy that cumulative effects are a cornerstone of the issues described and are expected to be at the centre of developing solutions.

[40] https://www.mpi.govt.nz/dmsdocument/40796/direct (p.211).

Table 8. Scientific information needs related to environmental issue 'cumulative effects' stipulated in regulatory and non-regulatory documents of relevance to environmental research and monitoring. Documents reviewed are shown in Appendix 1.

Document	Scientific information needs/requirement
NZCPS Policy 4 Integration	• Understand cumulative effects of activities on the coastal environment • Define significant adverse cumulative effects and understand how to anticipate them
NZCPS Policy 7 Strategic planning	• Understand threat/risk of coastal processes and resources from adverse cumulative effects • Identify those under threat or at significant risk • Identify thresholds (including zones, standards or targets), or specify acceptable limits to change, to assist in determining when activities causing adverse cumulative effects are to be avoided
Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan	• Understand the ecological health, carrying capacity and cumulative effects of marine farming and other fishery practices within the rohe.
Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan	• This plan lists issues, objectives policies, anticipated environmental results, monitoring requirements for coastal water, relating to taonga species, water quality, kaimoana beds and fish. • Specific science needs should be identified in partnership with Ngati Koata.

4.3.3 National scientific information needs of relevance to the Marlborough CMA

Jarvis and Young (2019) identified several national research priorities relating to climate change in their New Zealand Marine Science Horizon Scan carried out as part of a research project. Research questions are found in categories fisheries and aquaculture, climate change, ecosystems and biodiversity and other anthropogenic factors and are listed in Appendix 2.

Improving the understanding of cumulative effects of multiple stressors is a priority for councils represented on the CSIG (Berkett et al., 2015). The CSIG strategy recognises that activities such as fishing, tourism, shipping, coastal development and land-based activities present multiple stressors that cumulatively interact with each other and with natural processes. It emphasises that the management of the synergistic effects of multiple stressors and cumulative environmental change is a particular challenge, which is further complicated by the fact that many activities (and in their turn effects) operate on different spatial and temporal scales. Under the overall goal of improving the understanding of the response of coastal ecosystems to stressors to effectively manage the CMA, the strategy identifies that the following research needs:

- Identify the effects of stressors within both a spatial and temporal context. Understand the synergistic and cumulative effects of multiple stressors and develop tools to manage these effects.
- Identify indicators and determining response of ecosystem attributes (e.g., biodiversity, biological and physical processes, water quality) to stressors (individual and cumulative).

4.4 Summary of scientific information needs and information gaps

Section 4.2 describes what we know about cumulative effects in the Marlborough CMA as well as linkages between cumulative effects and other environmental issues addressed in this report. In summary, the scientific information needs identified in section 4.3 specifically for the Marlborough CMA and those identified on a national level with relevance for the Marlborough CMA in relation to cumulative effects are:

- Improve understanding of synergistic and cumulative effects of different/multiple stressors arising from marine and land-based activities and natural events on coastal habitats, species and ecosystems (Berkett et al., 2015; Forrest et al., 2016; NZCPS Policy 4; Jarvis and Young, 2019)
- Understand how the different factors of global change (temperature increase, ocean acidification, eutrophication, plastic pollution, etc.) act synergistically upon coastal and ocean ecosystem functioning (Jarvis and Young, 2019)
- Determine the combined effects of very low levels of multiple contaminants with different modes of action on aquatic organisms and ecosystems (Jarvis and Young, 2019)
- Understand the cumulative effects of marine farming and other fishery practices within the rohe (Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan)
- Determine how multiple stressors impact and interact to affect the food security of marine resources in the future (Jarvis and Young, 2019)
- Identify indicators and determining response of ecosystem attributes to cumulative stressors (Berkett et al., 2015).
- Identify thresholds (including zones, standards or targets), or specify acceptable limits to change, to assist in determining when activities causing adverse cumulative effects are to be avoided (NZCPS Policy 7)
- Determine how change and risk to ecosystem function and integrity associated with multiple stressors and cumulative impacts can be quantified (Jarvis and Young, 2019)
- Define significant adverse cumulative effects and understand how to anticipate them (NZCPS Policy 4)
- Improve understanding of the threat/risk of coastal resources from adverse cumulative effects, identify those under threat or at significant risk (NZCPS Policy 7)
- Develop tools to manage cumulative effects (Berkett et al., 2015)

Preliminary information gaps to inform a more strategic approach for collecting scientific information to address environmental issues related to cumulative effects

Based on the information reviewed and described in this section, the following preliminary information gaps related to cumulative effects have been identified. This is not intended to be a complete list but a starting point for building on existing information and taking a more strategic approach for the collection of further scientific information on environmental issues related to climat change in the Marlborough CMA. Inevitably, there are overlaps with information gaps identified in other sections of this report and future work should ensure alignments among environmental issues are considered.

Information gaps include:

- A need to improve understanding of synergistic and cumulative effects of different/multiple stressors arising from marine and land-based activities and natural events on coastal habitats, species and ecosystems.
- A need to understand how the different factors of global change (temperature increase, ocean acidification, eutrophication, plastic pollution, etc.) act synergistically upon coastal and ocean ecosystem functioning.

Specifically for the Marlborough CMA, information gaps include:

- The need to better understand the cumulative effects of marine farming and other fishery practices has been identified. This includes the question of carrying capacity raised in the section on water quality degradation.
- Cumulative effects have been identified as the likely cause of the decline in scallops and degradation of scallop habitat in the Marlborough Sounds. A project has been set up by FNZ to assess the cumulative effect of a range of physical, biological, and ecological stressors (including fishing) on scallops and scallop habitat in the Marlborough Sounds using experimental and modelling techniques.

There are many broad and specific information gaps relating to cumulative effects. Most scientific information needs identified for the Marlborough CMA are, in fact, national scientific information needs. Due to their complexity, these scientific information needs need to be addressed through national partnerships. However, cumulative effects have played an important role in the transformations of ecosystems in the Marlborough since Māori settlement. It will be important to build on this local experience when addressing current and future cumulative effects in the Marlborough CMA.

5 Improving partnerships and integration in addressing environmental issues in the Marlborough CMA

5.1 Introduction

As shown in earlier sections of this report, a lot of environmental information exists on various aspects of the Marlborough CMA, described under the environmental issues categories sediment, habitat modification and impact on species, water quality and sediment quality, marine pests, marine litter, climate change and cumulative effects.

At the same time, a large number of diverse and complex scientific information needs and information gaps have been identified. Examples include the need to better understand basic ecosystem dynamics that are relevant for addressing environmental issues (e.g., the response of ecosystem attributes to sedimentation), determining the assimilative capacity of the environment for contaminants, identifying parts of the Marlborough CMA that are degraded, developing standards and limits, and developing approaches for effectively addressing environmental issues.

There currently is no overarching strategic approach for research on the environmental issues in the Marlborough CMA. It is important that common goals will be developed to focus future research. These goals should be aligned to jointly developed strategic management objectives for the Marlborough CMA that reflect the strategic goals and ambitions of environmental management agencies, iwi, communities, industries and other stakeholders.

For some environmental issues, information is at a level where action can be taken, and specific restoration or protection approaches can be developed. These include actions taken to manage some fisheries or to manage bacterial or chemical contaminant discharges from the land. However, for most environmental issues, a strategic approach of information gathering, prioritisation and solution development is required to ensure actions taken are targeted, effective and aligned.

An important scientific need identified for all environmental issues is the recognition of te ao Māori, which, based on the information reviewed for this report, appears to have been limited thus far.

Addressing scientific information gaps and developing solutions for the identified environmental issues will require research, investigations and monitoring, and, importantly, recognition of te ao Māori and collaborations among all people and groups with responsibility for management of or interests in the Marlborough CMA.

The following sub-sections provide considerations and information on three themes that are integral aspects of environmental management, partnerships and integration: recognising te ao Māori, strategic integration of scientific knowledge and projects, and agency tools for environmental monitoring and management. These three sections are not comprehensive or complete but provide relevant information that should be considered in discussions or initiatives embarked on in response to this report.

5.2 Recognising te ao Māori

5.2.1 The metaphorical framework of Waka-Taurua

There is a need and obvious benefits in better recognising te ao Māori alongside 'western' science. This could be facilitated through the metaphorical framework of Waka-Taurua, recently proposed under the Sustainable Seas Ko ngā moana whakauka National Science Challenge (Maxwell et al., 2020). A Waka-Taurua comprises two separate canoes that are temporarily lashed together to achieve a common purpose. Each canoe represents the worldviews and values of the two groups coming together. Each canoe is a safe and functioning space on its own, recognising that each group is inherently different, and that their knowledge, value and actions are not made to fit into each other.

In the context of knowledge and management of the Marlborough CMA, this framework can be applied to all identified information gaps, including improving our understanding of the environment through research, investigations and monitoring, as well as developing solutions for environmental issues.

5.2.2 Mātauranga Māori

A particularly relevant concept in te ao Māori in the context of this report is mātauranga Māori. Mātauranga Māori is a traditional knowledge system founded on cosmology of the universe and the creation of the world and all living things contained in the world (Kotahitanga mō te Taiao, 2019). Mātauranga Māori has also been described as "a continuum of distinct knowledge with Polynesian origins that grew in Aotearoa New Zealand, including Māori worldview, values, culture and cultural practice, and perspectives that establish Māori identity, responsibilities, and rights to manage and use resources" (Clapcott et al., 2018). For the purpose of this report, mātauranga Māori is discussed as an important source of knowledge and understanding critical for the environmental management of coastal ecosystems.

Better recognising mātauranga Māori would considerably enhance knowledge and understanding of aquatic ecosystems, underpin culturally-appropriate restoration approaches, and provide a more holistic and integrated perspective for resource management and research activities in this realm, including research, monitoring, planning, and policy and resource development (Clapcott et al., 2018).

Mātauranga Māori is only one concept within te ao Māori and needs to be considered within a broad recognition of the role of tangata whenua as kaitiaki of the Marlborough CMA.

5.2.3 The role of mātauranga Māori in the environmental management of the Marlborough CMA as described in the Kotahitanga mō te Taiao Strategy

The role of mātauranga Māori in the environmental management of the Marlborough CMA has recently been brought to the forefront through the Kotahitanga mō te Taiao Strategy, released in June

2019. This strategy has been co-developed by iwi from across the top of the South Island, councils and the Department of Conservation ("the Alliance") as a plan towards achieving significant conservation gains as well as social, cultural and economic benefits to communities that will grow their resilience as a region. The Alliance emphasised that no one entity alone could achieve the transformational outcomes of the strategy.

Core to the Kotahitanga mō te Taiao Strategy is combining 'western' science with mātauranga Māori, Māori knowledge and values, recognising the interconnected relationship between the spiritual world, the natural world and people. The mātauranga Māori information in the strategy reflects a Māori world view for Te Tau Ihu iwi and the strategy notes that other iwi, such Ngāi Tahu Papatipu Runanga, Te Runanga o Ngati Waewae and Ngati Kuri, have their own traditional knowledge that needs to be extended in relation to places, and for the iwi within the Top of the South, that may include differing traditions.

5.2.4 Scientific information needs related to te ao Māori identified in iwi management plans

The Te Ātiawa Iwi Ki Te Tau Ihu Iwi Environmental Management Plan identified the needs to:

- Understand research required to maintain the mauri of the coastal / marine ecosystems; and
- Develop a database of mātauranga – traditional and local ecological knowledge (in tandem with current scientific information), covering the distribution of indigenous species and their habitat needs, seasonal indicators of health and productivity, and other values and information relevant to improving the understanding of cultural values and the natural ecology of the coastal / marine resources of the rohe

The Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan contains the following statements in relation to scientific information needs:

- This plan lists issues, objectives policies, anticipated environmental results, monitoring requirements for coastal water, relating to taonga species, water quality, kaimoana beds and fish.
- Specific scientific information needs should be identified in partnership with Ngati Koata.

Following up on these specific needs identified in iwi management plans could be a valuable step towards better recognition of te ao Māori in knowledge gathering initiatives conducted in the Marlborough CMA.

5.2.5 Scientific information needs related to mātauranga Māori identified on a national level

On a national level, councils have identified research to assist them in better recognising mātauranga Māori and kaitiakitanga in state of the marine environment and marine biodiversity statutory functions as their primary coastal and marine research goal of the CSIG research strategy (Berkett et al., 2015).

Specific research needs identified in the CSIG research strategy are:

- Provide lessons where mātauranga Māori and science have been used collectively to understand environmental issues— particularly with regard to coastal and marine management. This research need will allow for the development (where needed) and strengthening of relationships with mana whenua.
- Investigate processes to co-develop appropriate indicators and supporting monitoring programmes for Māori environmental frameworks.
- Determine the generality and applicability of currently developed indicators (such as, but not limited to, the Cultural Health Index) across the many hapū and iwi of Aotearoa (New Zealand).

5.3 Strategic integration of scientific knowledge and projects

Integration of different approaches to gathering information on the Marlborough CMA and partnership among all groups with a responsibility for or an interest in the Marlborough CMA are critical for improving our knowledge and supporting the development of enduring solutions for environmental issues in the Marlborough CMA. The importance of better recognition of te ao Māori has been discussed in the previous section and will not be repeated here.

Integration and partnerships may be achieved by developing joint research strategies, sharing information, and other joint initiatives that support a strategic and holistic approach to improving our scientific knowledge on the Marlborough CMA.

As demonstrated in this report, a large amount of scientific work has been and continues to be carried out in the Marlborough CMA, particularly the Marlborough Sounds. Most scientific studies are motivated by a desire to improve our understanding of the state of the marine environment, impacts of stressors and historic and contemporary change to inform environmental management, including the management or anthropogenic activities in the CMA and on land and marine restoration.

Scientific information available for the Marlborough CMA has been produced, commissioned and/or funded by many organisations and groups, including:

- Environmental management agencies (e.g., MDC, DOC, FNZ)
- Iwi
- NIWA
- Cawthron
- Universities
- Industry (e.g., MFA, resource consent holders)
- Community groups
- Ministry of Business, Innovation & Employment (through the Envirolink funding programme)

Scientific information has been generated as part of monitoring or research programmes, for regulatory purposes or as part of community or industry initiatives, including:

- SOE monitoring
- Consent-related environmental monitoring
- MDC ESMS surveys
- Sustainable Seas National Science Challenge
- Citizen science initiatives (e.g., Litter Intelligence project)
- Voluntary industry initiatives (e.g., MFA King Shag research project)

In addition to scientific projects conducted in the Marlborough CMA, a range of national project are of relevance to the area. For example, Jarvis and Young (2019) identified a total of 90 priority research questions for New Zealand marine research, classified into nine major themes, most of direct relevance to the Marlborough CMA as shown in Appendix 2.

At the moment there is no strategic oversight across the many scientific activities taking place in the Marlborough CMA. The amount of scientific information being collected in the area appears to be increasing and there is a risk of initiatives, including research projects, being done in isolation of each other. There are opportunities for better and more strategic integration, which would likely improve effectiveness of individual initiatives, overall improved knowledge, and more timely development of better solutions.

5.4 Agency tools for environmental monitoring and management

5.4.1 Introduction

This section describes environment monitoring and management tools available for management agencies (MDC, FNZ, DOC) to describe actions currently being taken by the agencies to gather information and address environmental issues. Environmental monitoring and management tools available to regulatory agencies for identifying, alleviating, and responding to environmental issues include environmental monitoring, mitigation, marine protection and restoration.

5.4.2 Monitoring

5.4.2.1 Current monitoring

MDC conducts SOE monitoring of seabed ecosystems that provide significant habitats for biodiversity (most recently reported by Davidson et al., 2020), the condition of estuaries (overview provided in Forrest and Stevens, 2019), the effects of ship-wakes on coastal ecology (most recently reported by Davidson et al., 2017b), shoreline erosion (most recently reported by Parnell, 2012) and coastal water quality (reviewed by Broekhuizen and Plew, 2018).[41] Monitoring programmes have been underway for varying lengths of time, are periodically reviewed and results are regularly reported by MDC.

In addition to monitoring conducted by MDC, consent holders may be required to conduct environmental monitoring to assess the environmental effects of their activities.

The DOC monitors benthic communities and fish in the Long Island marine reserve. FNZ monitors the impacts of fishing and assesses fish stocks. A full review of monitoring carried out by the DOC and FNZ is outside the scope of this report.

5.4.2.2 Monitoring needs

5.4.2.2.1 Context

Several monitoring needs are identified for the Marlborough CMA, which are presented in the following sub-sections. It is important to note that not all needs and recommendations described in this section relate to agency-directed or funded monitoring. Some recommendations were made based on environmental considerations without determining responsibilities for initiating corresponding programmes. Furthermore, some recommendations were made in isolation, thus not necessarily reflecting priorities in the context of broader ecosystem information needs.

5.4.2.2.2 Recommendations made in scientific publications

Several recommendations for improvements to monitoring have been made in scientific publications. Forrest and Stevens (2019) recommend that, for improved understanding of monitoring and management priorities, it would be timely to undertake a comprehensive data synthesis and analysis of the estuarine monitoring programme to investigate in detail:

- Can sampling design and sampling be optimised? For example, is it necessary to collect ten infaunal cores for each fine-scale survey, given the associated cost?
- Is the current sampling frequency appropriate?

Forrest and Stevens (2019) also recommend establishing a formal process for prioritising estuaries in the region for monitoring, with a clear focus on: (i) the purpose of the monitoring; (ii) delivery of “fit for purpose” outcomes; (iii) integration and refinement of the current disparate approaches used to assess estuary condition; and (iv) consideration of the wider context of other MDC (or broader) monitoring programmes.

[41] https://www.marlborough.govt.nz/environment/coastal

Newcombe (2017) provides specific suggestions for comprehensive monitoring of Picton Bays, including:

- Habitat mapping, including fisheries species/kaimoana
- Monitoring shellfish suitability for consumption
- Addition of a water quality monitoring station (or two) to the wider Marlborough Sounds water quality monitoring programme
- Higher-frequency monitoring of intertidal estuarine habitats, and addition of cockle surveys designed for their assessment as a fisheries species.

She also recommends that historical baselines should be established where possible.

In acknowledgment of the importance to better understand cumulative effects and the challenges arising from disjoint monitoring programmes (e.g., consent-related and SOE monitoring), Forrest et al. (2016) provide suggestions for developing an integrated approach to marine environmental monitoring in the Marlborough Sounds. Most people broadly understand the concept of cumulative effects; however, addressing cumulative effects is inherently complex and is a significant management challenge globally (Forrest et al., 2016). Forrest et al. (2016) suggest that development and eventual implementation of an integrated regional approach to monitoring that aligns consent-related and SOE monitoring is a useful starting point that will better enable cumulative effects to be characterised and addressed in the future. Specific information gaps centred around the need for monitoring data and information identified by interviewees are:

- long-term datasets for establishing environmental 'baselines' and determining environmental carrying capacity
- the cumulative effects of different stressors arising from marine and land-based activities and natural events (note, the source of stressors was of particular interest, for example what activities are leading to sedimentation in the Sounds?)
- the effects of climate change (e.g., on water temperature, acidification) and predictions around future consequences for ecological systems and anthropogenic activities
- appropriate spatial and temporal data to facilitate management decisions (including areas not currently monitored (e.g., Port Underwood)
- sufficient knowledge of the environment to be able to understand how ecosystems could be artificially improved
- algal bloom patterns and spatial and temporal trends for chlorophyll-a (a proxy for phytoplankton biomass)
- water quality information for optimum food production
- spat monitoring counts
- coastal hydrodynamics (e.g., wave action)
- cultural indicators

5.4.2.2.3 Monitoring needs identified in regulatory and non-regulatory documents of relevance to environmental monitoring

Specific monitoring requirements (including anticipated environmental results) articulated in regulatory and non-regulatory documents are listed in Table 9.

In addition, the Kotahitanga mō te Taiao strategy provides specific goals and for each describes what success looks like. Many success descriptors require monitoring to evaluate whether they have been achieved. For example, the success descriptor "estuary condition improves year on year and estuarine areas maintain their ecological structure and function despite the effects of sea level rise" clearly requires long-term monitoring of estuaries. The strategy does not specify specific monitoring needs but requires that provisions are made for cultural monitoring where projects or programmes may affect significant sites, traditional customary areas, mahinga kai, maunga, or wahi tapu.

Table 9. Monitoring requirements stipulated in relevant regulatory and non-regulatory documents.

Document	Requirement
NZCPS Policy 2	• Ensure monitoring programmes reflect cultural understanding • Requires close working relationship with iwi/hapū
NZCPS Policy 22 Sedimentation	• Monitor sedimentation levels • Monitor impacts of sedimentation on the coastal environment
NZCPS Policy 28 Monitoring and reviewing the effectiveness of the NZCPS	• Collect data for and report results of a nationally consistent monitoring and reporting programme • Gather information or monitor and report a national perspective on coastal resource management trends, emerging issues and outcomes
MDC PMEP Policy 8.1.3	• Gather information on the state of biodiversity in marine environments
MDC PMEP Policy 8.2.9	• Monitor the condition of sites with significant indigenous biodiversity value
MDC Implementation method 8.M.5	• Establish baseline monitoring programmes that provide a benchmark for determining the ongoing condition of habitats, ecosystems and areas that have significant indigenous biodiversity values • Carry out and support research and undertake state of the environment monitoring to gain a better understanding of Marlborough's biodiversity (8.M.6 "appropriate investigations to improve our understanding of the nature and state of indigenous biodiversity in Marlborough")
MDC PMEP Policy 13.16.4, Implementation method 13.M.23	• Monitor of the effect of shipping activity (including ship-generated waves) in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au (via use and/or amendment of the monitoring framework and programme established by MDC and DOC) The monitoring framework may include: o near shore benthic and shoreline biological monitoring; o shoreline monitoring of beach profiles • Support the initiatives of Marlborough's tangata whenua iwi to monitor cultural and ecological effects from the wake of ship-generated waves, for example the effects on access to wāaahi tapu and other sites of significance, the passing of tikanga Māori to future generations and the effects on the gathering of kaimoana
MDC PMEP Policy 13.19.11	• Implement a Coastal Monitoring Strategy
MDC PMEP Implementation method 15.M.4	• Develop a monitoring plan that sets out the methods for monitoring progress toward the achievement of Objectives 15.1a
MDC PMEP 8.AER.2	• Baseline monitoring programmes established for a representative sample of intertidal areas show no loss of indigenous biodiversity

Maintenance and enhancement of the condition of ecosystems, habitats and areas with indigenous biodiversity value.	values over the life of the MEP. • Measured against baseline monitoring programmes established for ecologically significant marine sites in 2015/2016, there is no loss of indigenous biodiversity values over the life of the MEP. • There is no increase in the extent or distribution of known aquatic pest species identified as declared pests in the Regional Pest Management Plan for Marlborough.
MDC PMEP 13.AER.9 Waves generated from ships do not create adverse effects on the environment.	• A five yearly assessment is carried out to determine the need to undertake monitoring specified in Policy 13.16.4 and the monitoring method (13.M.23) set out for water transportation. • Monitor erosion of coastal areas caused by ships. • No adverse change to the shoreline or benthic communities as a result of waves from the shipping activity
MDC PMEP 15.AER.2 Water quality in Marlborough's coastal waters is suitable to support and sustain swimming, food gathering and marine ecosystems.	• All coastal water bathing sites are graded either good or very good, in accordance with the Ministry for the Environment's Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas.
Te Ātiawa Iwi Ki Te Tau Ihu – Iwi Environmental Management Plan	• Understand how to monitor the integrity of coastal ecology • Monitor ecological health and fish stock (using customary indicators) • Monitor cumulative effects from activities being undertaken or proposed in Te Tau Ihu coastal and marine areas (using customary indicators) • Research, identify, develop and apply the use of cultural indicators for state of the environment monitoring and reporting in relation to the coastal / marine resources of the rohe
Ngati Koata No Rangitoto Ki Te Tonga Trust Iwi Management Plan	• This plan lists issues, objectives policies, anticipated environmental results, monitoring requirements for coastal water, relating to taonga species, water quality, kaimoana beds and fish. • Specific monitoring needs should be identified in partnership with Ngati Koata.

5.4.3 Marine protection and restrictions of use

5.4.3.1 Marine protection and restrictions of use of the Marlborough CMA

Parts of the Marlborough CMA are protected through a marine mammal sanctuary and a marine reserve. The Clifford and Cloudy Bay Marine Mammal Sanctuary provides restrictions on seismic surveying and seabed mining (Figure 20).

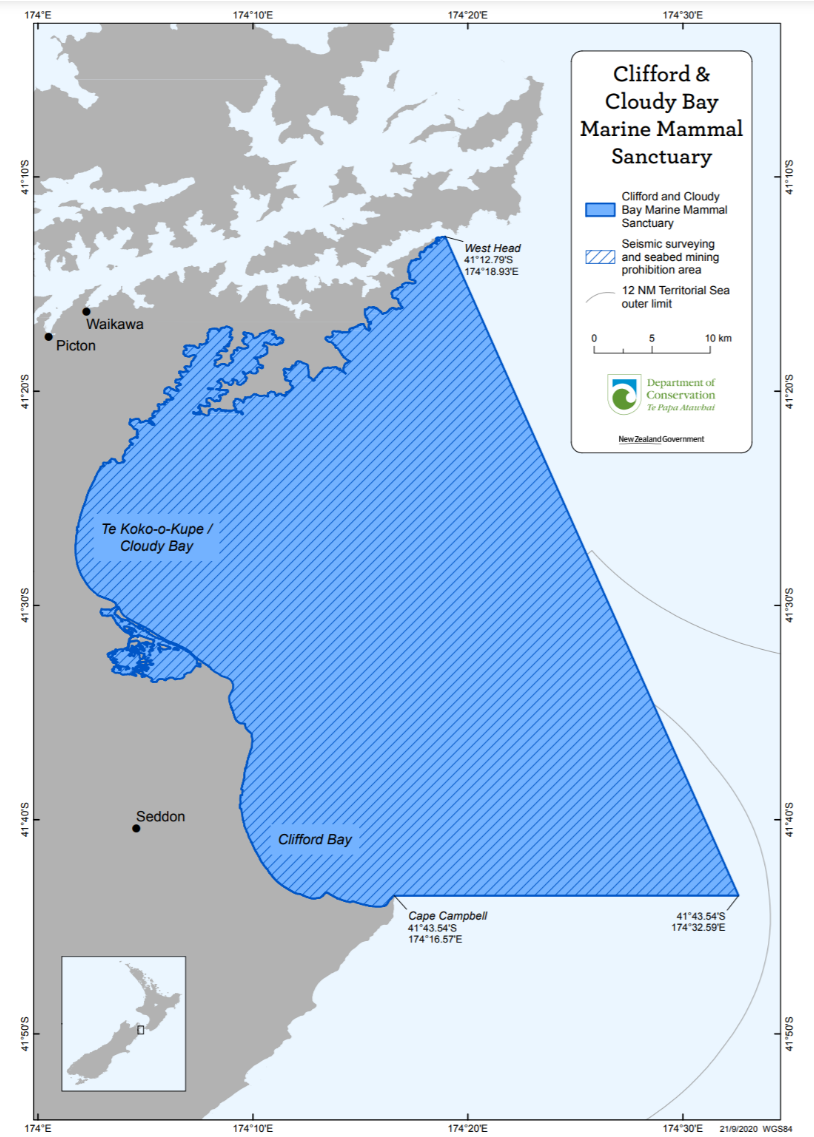


Figure 20. Map of the Clifford and Cloudy Bay Marine Mammal Sanctuary. Source: DOC.

The Long Island-Kokomohua Marine Reserve is a fully protected reserve located in the entrance to Queen Charlotte Sound/Tōtaranui (Figure 21). The reserve is approximately 6.5 km in long with an area of 619 ha and extends a quarter nautical mile (463 metres) offshore around Long and Kokomohua Islands and an unnamed charted rock, north-east of Kokomohua Island (Davidson et al., 2014). The marine reserve was formally established on 30 April 1993 and for the four years prior to the formation of the marine reserve, local dive clubs had established a self-imposed voluntary ban on the taking of marine life from the area and had encouraged others to do the same (Davidson et al., 2014). Davidson et al. (2014) present data collected from Long Island-Kokomohua Marine Reserve and adjacent control sites over a period of 22 years (1992 to 2014). Their key findings were:

- In 2014, legal sized blue cod were 3 times more abundant in the reserve than at control sites. Unexpectedly, the mean size of blue cod within the reserve had decreased since the previous survey. The reason was primarily due to an increase in the number of small blue cod in the catch. At control sites, the mean size of blue cod changed over the duration of the study and was often linked to changes in fisheries legislation. The drop in the bag limit for cod appears to have had a positive impact on the mean size of blue cod at control sites.

- For other edible reef fish species, an increase in the size of blue moki was the only documented change attributable to reservation.
- The density of lobsters inside the reserve increased dramatically from 1.39 individuals per 100 m^2 in 1992 to 13.5 individuals per 100 m^2 in 2014. In 2014, lobsters were 11.5 times more abundant in the reserve than at control sites. Large reproductive males and females dominated the reserve lobster population. This suggests that relative to a similar area of unprotected coastline, where large males and females were relatively uncommon, egg production within the reserve will be significantly greater.
- Black foot paua were larger and more abundant in the reserve compared to control sites. Paua mean size did however, decline over the study. This combined with observations of paua scars on rocks suggests that some poaching occurs.
- The abundance of small kina <45 mm diameter has decreased within the reserve since 1992. This may be related to predation by large blue cod or snapper. This may represent the first indirect change related to reservation recorded for this marine reserve.

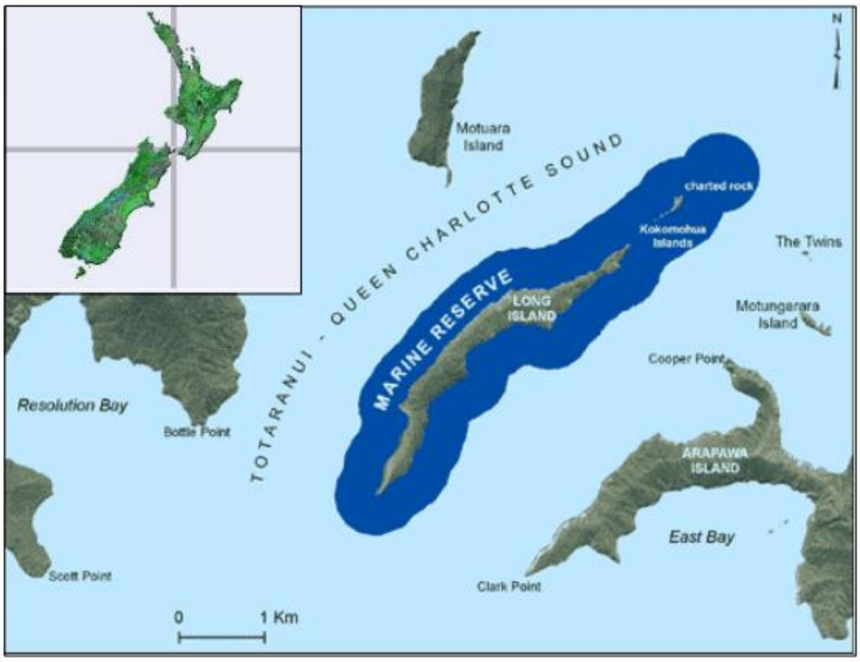


Figure 1. Location of Long Island-Kokomohua Marine Reserve in outer Queen Charlotte Sound.

Figure 21. Location of Long Island-Kokomohua Marine Reserve in the Outer Queen Charlotte Sound/Tōtaranui. Source: Davidson et al. (2014).

5.4.3.2 *Recreational fishing restrictions*

The MPI sets recreational fishing rules to manage fish stocks.[42] Rules include daily bag limits (how many fish can be kept), legal size limits, species restrictions, and closed and restricted areas. Restricted areas are areas where the use of particular fishing methods (e.g., set nets) is restricted or where catch limits may be different.

The Marlborough CMA is part of the Challenger East Area, but some specific rules apply to the Marlborough Sounds. Blue cod restricted areas, set net and set line restricted areas and closure areas in the Marlborough CMA are shown in Appendix 3. MPI advise to source information on local restrictions and recent closures by contacting the local MPI Fisheries Compliance Office.

5.4.3.3 *Recommendations and scientific information needs for marine protection and restrictions of use of the Marlborough CMA*

Marine experts providing science advice for the Kotahitanga mō te Taiao Strategy development, concluded that in the Marlborough Sounds and Cook Strait environments:

- There are few marine protected areas with one marine reserve at Long Island; and
- The MDC is, however, very active in assembling information on vulnerable areas in the sea and trying to protect them (through their significant marine sites programme[43]).

Anderson et al. (2019) describe that biogenic habitats over soft-sediments, especially extensive tubeworm field, are poorly represented in marine reserves. Despite some tubeworm fields having been identified by fishers as important habitat for fishery species, little is known about their resilience or recovery following benthic fishing impacts.

The MDC PMEP aims to facilitate an increase in the number and extent of ecosystems, habitats and areas with indigenous biodiversity value that are formally protected or covenanted (where practicable), specified in Anticipated Environmental Result 8.AER.1.

5.4.4 Restoration

Restoration is conducted by many groups and individuals in the Marlborough CMA, often in collaborative initiatives. Collating information on restoration activities is best done in collaboration with these groups and individuals, which was out of scope of this report. Instead, this section presents information and recommendations related to restoration provided in the publications reviewed for this report.

Potential suitable habitat areas for filter-feeders such as horse mussel (*Atrina zelandica*) or green-lipped mussels (*Perna canaliculus*) in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au have been identified by Ribó et al. (2020) to inform focus areas for shellfish restoration management in this part of the Marlborough Sounds. Overall, the most suitable habitats predicted for filter-feeders in Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au are inner bays or embayments on the inner Queen Charlotte Sound/Tōtaranui and Tory Channel/Kura Te Au, and near the shoreline along the central and outer Queen Charlotte Sound/Tōtaranui. Ribó et al. (2020) emphasises that understanding the physical oceanography and sedimentary processes is crucial to accurately predict suitable areas of benthic communities to ensure effective restoration and broader spatial habitat management.

[42] https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/fishing-rules/challenger-region-fishery-management-area/
[43] See section 5.4.5

A PhD project by Trevyn Toone, University of Auckland, is currently being carried out on the decline and recovery potential of mussels in the Kenepuru Sound[44].

Handley (2017) recommends:

- Trialling restoration of green-lipped mussels in the Pelorus Sound/Te Hoiere.
- Predicting where green-lipped mussel bed restoration might be best trialled in the Pelorus Sound/Te Hoiere, by coupling the hydrodynamic model of Broekhuizen et al. (2015) with assessment of resuspension of fine sediments (e.g., Hadfield 2015).
- Using a combined approach of restoration trials at several sites along a gradient of sheltered to exposed sites in the inner and mid Pelorus Sound/Te Hoiere, with in-situ hydrodynamic measurements to validate model outputs is recommended.

Urlich and Handley (2020) suggest that ecosystem-based management (EBM) is needed to conserve and restore Marlborough Sounds ecosystems. They identify the following approaches to achieve transformative change:

- Manage seabed disturbance to protect remaining biogenic habitat and encourage habitat regeneration and restoration and enhance connectivity between existing habitats.
- Undertake a participatory process to co-develop and institute a network of different types of protected marine areas, including notake to provide biodiversity sanctuaries.
- Rebuild populations of pilchards (*S. sagax*).
- Manage exploitation of fisheries within the Sounds such that top predators are more numerous and widespread to control populations of the urchin (*E. chloroticus*).
- Reduce sedimentation by stabilising land to reduce frequent and extensive disturbance through retirement of steep erosion-prone faces and gullies from plantation forestry.
- Co-create and implement just-transition schemes to buy out forestry cutting rights and transition commercial fishers to less environmentally damaging fishing methods.
- Co-develop a research strategy to inform management and meet community aspirations.
- Include a Māori approach to ecosystem-based management through recognition of traditional knowledge (mātauranga Māori) and indigenous stewardship (kaitiakitanga).

Marine experts providing science advice for the Kotahitanga mō te Taiao Strategy development, suggest that the following actions are need to make the Marlborough Sounds and Cook Strait environments flourish (Lawless, 2018):

1. Stop direct seabed disturbance.
2. Reduce fine sediment and nutrient input substantially (delivery mechanism is different, but effects of sediment are similar).
3. Restore shellfish beds to restore filtration to enable benthic systems to recover, including getting sunlight to the seabed.
4. Restore fish stocks and habitat.
5. Manage fish complexes at local scales.
6. Protection for remnant areas, e.g., rhodolith beds.
7. Protect whale migration route via Cook Strait

Ribó et al. (2020) recommend further investigations on resilience of filter-feeders to disturbance and disturbance-recovery dynamics together with added mātauranga Māori and historical knowledge to improve chances of successful restoration initiatives.

[44] https://unidirectory.auckland.ac.nz/profile/ttoo112

5.4.5 MDC Ecologically Significant Marine Sites programme

MDC has a comprehensive programme aimed at improving information on rare or special features, habitats and marine life to support decision-making on the management of the Marlborough CMA. Seventy-two areas or habitats assessed as having significant ecological values within the Marlborough CMA are specifically identified in the Marlborough PMEP and are referred to as 'ecologically significant marine sites' (ESMS). Sites are classified in MDC PMEP Appendix 27 as Category A and B sites and given varying levels of protection from adverse effects of a range of anthropogenic activities, including dredging, bottom trawling, anchoring, deposition and reclamation, through several MDC PMEP rules. At present only one significant site in the Marlborough Sounds is protected as a marine reserve.

The ESMS were based on surveys that identified a total of 129 sites of ecological significance in the Marlborough CMA, stretching from Cape Soucis (Croisilles Harbour), through the Marlborough Sounds and down the east coast of Marlborough to Willawa Point (Davidson et al., 2011).

The type and size of identified significant marine sites varies greatly, ranging from large marine areas with highly mobile marine mammals, such as the Hector's dolphin in Cloudy and Clifford Bays, through to small sites occupied by non-mobile species such as the 1.9 ha rhodolith bed in Picnic Bay, Tawhitinui Reach. Some significant sites support threatened species, such as the sea sedge, and others are significant for their broader biodiversity or ecological values. Some sites, such as biogenic reefs, are significant because environmental conditions have enabled a species or number of species to become so abundant that they form three dimensional structures on the sea floor. These biogenic reefs provide habitat for many other species including commercially important ones. Many of the identified significant sites are fragile and therefore vulnerable to human disturbance and damage from a variety of sources.

The ESMS currently identified in the MDC PMEP only represent a proportion of ecologically significant sites because large areas of Marlborough's CMA have never or only recently been surveyed and knowledge of these ecosystem is limited. In addition, more sites could be considered significant in the future if they were managed and allowed to recover to the state they would have been before human activities degraded them (Davidson et al., 2011).

Monitoring and targeted investigations continue to be commissioned by MDC to improve knowledge on existing and inform potential new ESMS. Annual monitoring of ESMS since 2015 has provided new information on habitats in the Marlborough CMA, resulting in recommendations of new ESMS and calling for more formal protection of ESMS to address the observed significant deterioration of some ESMS (e.g., Davidson et al., 2020). Monitoring has also demonstrated that Marlborough's significant marine sites are the remnants of much larger areas and that these sites continue to be degraded or lost.

For example, Davidson and Richards (2015) suggested that, in Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au and Port Gore, of nine ESMS monitored, two had disappeared altogether while seven had diminished in size and that, overall, there had been a decline of 71.6% in the size of the sites over a four year period of monitoring. Monitoring continues to refine our knowledge of these sites. Davidson et al. (2020) monitored sites in Queen Charlotte Sound/Tōtaranui, Tory Channel/Kura Te Au and Port Underwood and, based on the greater level of resolution and precision in data, suggested that one site should be rejected, three new sites established, and the remaining 14 sites (and sub-sites) should be either increased or decreased in size relative to previous surveys.

In addition to monitoring surveys, science investigations have been commissioned by MDC to improve knowledge of habitats on larger scales and from areas not accessible through routine monitoring methods (Anderson et al., 2020; Neil et al., 2015). For example, the multibeam echo-sounder survey by Neil et al. was carried out to map the seabed of Significant Marine Site 2.3 and the adjacent area through Stephens Passage and revealed a range of seafloor features, including sediment-wave fields, seafloor depressions, strike ridges, flat-lying seafloor and nearshore rocky reefs. The survey by Anderson et al. (2020; described in section 3.3.2.3) provides, among other, new information on the representativeness of habitats, species and communities to inform MDC's ESMS planning.

MDC's protocols for monitoring and surveying of significant sites and for assessing significance at new and existing sites as well as all ESMS monitoring and review reports, and scientific reports, are provided on the MDC website.[45]

5.4.6 Management of environmental effects of specific industries or activities

The effects of activities that may generate adverse environmental effects are managed under legislation and regulations. It is out of scope to describe all approaches taken to manage effects of activities in the Marlborough CMA. Instead, example publications are described that illustrate the need for good scientific information in managing the effects of activities. In addition, scientific information needs identified in government or agency strategies are listed in Table 10.

Two best management practice guidelines for salmon farming in the Marlborough Sounds have been developed by a working group comprising members from MDC, FNZ, New Zealand King Salmon, the Sounds Advisory Group, NIWA and Cawthron to provide consistent and clear requirements for the monitoring and management of benthic and water column effects of salmon farming (Elvines et al., 2019; Keeley et al., 2019). The guidelines provide environmental quality standards and details of how and when to conduct monitoring surveys and how to respond to potential non-compliances. The guidelines are regularly reviewed.

An example of a comprehensive assessment of impacts on habitats in the Marlborough Sounds through a specific activity was that by Morrisey et al. (2018) who investigated effects of swing moorings for boats, of which there are over 3,000 in the Marlborough Sounds. This review identified the following habitats and species of particular ecological, cultural or conservation significance that are particularly sensitive to the effects of block-and-chain moorings:

- rocky reefs and cobble fields (moorings are not likely to be located on these substrata but may be close enough that the reef is within the area swept by the chain)
- macroalgal beds (where these are growing on reef, moorings are not likely to be located within them but may be close enough that the bed is within the area swept by the chain)
- beds of rhodoliths, hydroids, bryozoans, shellfish, brachiopods, burrowing anemones or sea grass (eelgrass)
- sponge and bryozoan gardens
- tubeworm mounds, reefs and beds
- areas of shell hash (shell hash can provide important habitat diversity in soft sediments and chain sweep will enhance rates of breakdown of the hash)
- fish spawning and nursery areas not included in above (through direct destruction and through loss of structures to which eggs are attached and in which juveniles may shelter).

The assessment by Morrisey et al. (2018) has led to suggestions for guidelines for assessing consents for moorings and environmentally friendly moorings.

[45] https://www.marlborough.govt.nz/environment/coastal/ecologically-significant-marine-habitats

Table 10. Scientific information needs and requirements related to management of activities in the CMA stipulated in government strategies. Documents reviewed are listed in Appendix 1.

Strategy document	Scientific information needs/requirement
Fit for a better world – Accelerating our economic potential (2020 roadmap, NZ Government)	• Develop systems, data and decision support tools to help farmers and fishers make better choices • Identify and fill potential knowledge gaps related to 'unlocking' open ocean aquaculture • Identify research and science needs contained in primary sector's strategic direction and align research and science • Identify and fill potential knowledge gaps related to transitioning to new fishing methods that enhance environmental performance and reduce unwanted catch
The New Zealand Government Aquaculture Strategy	• Test ecosystem-based management and monitoring of aquaculture • Develop best practice standards and new technologies to mitigate environmental effects of aquaculture • Build on the beneficial ecosystem services of aquaculture by restoring shellfish reefs, and supporting biodiversity and wild populations • Develop and implement indicators of overall aquatic health relating to aquaculture • Develop tools to improve coastal and catchment management in collaboration with the Sustainable Seas National Science Challenge • Assess the ability of seaweeds and shellfish to sequester carbon and buffer ocean acidification • Forecast the effects of climate change on the aquatic environment. Plan and support actions for resilience and adaptation for aquaculture
National Blue Cod Strategy (FNZ)	• Increase knowledge of recreational fishing harvest • Support blue cod customary research • Examine the level of environmental impacts on blue cod fisheries and the level of habitat loss • Review current default target levels and limits for blue cod • Improve understanding and protect blue cod habitat
Southern Scallop Strategy: Marlborough Sounds (FNZ, July 2020)	• Identify appropriate scallop biomass threshold for reopening • Identify sustainable catch targets • Understand what actions could be taken to improve scallop habitat quality and quantity in the Marlborough Sounds. • Obtain better scallop catch information • Improve understanding of the wider scallop fishery, including habitat • Understand the causes of the observed reduced scallop distribution and decline in scallop abundance. • Understand what constitutes good scallop conditions, and what and where interventions (such as habitat restoration) are most likely to be successful. • Conduct ongoing research to determine whether changes in fishing gear are required, and what role disease and other factors may be having in suppressing the productivity of the scallop beds.

6 Conclusions

This report has been prepared to support the goal to move toward a more integrated management of the Marlborough CMA through collaboration between agencies, iwi, community and research organisations.

It describes environmental issues of relevance for the Marlborough CMA, the current knowledge of the environmental state of the Marlborough CMA and scientific information needs of agencies with responsibility for managing the area (MDC, DOC and FNZ) identified in scientific publications as well as statutory, regulatory and other relevant documents, including agency policies and plans, the Kotahitanga Strategy and iwi management plans. The report also presents the scientific information needs specified in documents of relevance to the participating agencies (MDC, FNZ and DOC) and identifies preliminary information gaps.

The environmental issues of relevance identified for the Marlborough CMA are sediment (including sedimentation and suspended sediment), habitat modification and impact on species, water quality and sediment quality degradation (including chemical and bacterial contamination and nutrient/organic enrichment), marine pests, marine litter, climate change and cumulative effects. While there are clearly overlaps among these issues, they provided a helpful structure for this report.

A large volume of environmental information has been collected in relation to the Marlborough CMA. In addition to environmental monitoring and scientific investigations carried out and commissioned by MDC and consent-related environmental monitoring, the Marlborough CMA attracts extensive research projects that add considerable value to the scientific information base. This information is being actively utilised by MDC and others involved with management of this area.

Also, a large number of diverse and complex scientific information needs and information gaps have been identified. While for some environmental issues information is at a level where environmental management actions can be taken, for most issues a strategic approach of information gathering, prioritisation and solution development is required to ensure actions taken are targeted, effective and aligned.

An important need identified for all environmental issues is the recognition of te ao Māori, which, based on the information reviewed for this report, has been limited thus far.

Addressing scientific information gaps and developing solutions for the identified environmental issues will require research, investigations and monitoring, and, importantly, integration and partnerships, including recognition of te ao Māori, strategic integration of scientific knowledge and projects, effective implementation of agency environmental management tools, and collaborations among all people and groups with responsibility for management of or interests in the Marlborough CMA.

Some consistent themes that emerged for most environmental issues examined in this report are:

1. A lot of environmental information exist on the Marlborough CMA and continues to be gathered through SOE monitoring, research, consent-related monitoring and other investigations.
2. A number of information gathering initiatives (monitoring, investigations, and research) aimed at improving environmental management outcomes are not well aligned with policies, plans, strategies or iwi management plans, or earlier initiatives.

3. It is unclear how some scientific information needs identified in policies, plans, strategies or iwi management plans can be translated into actual scientific projects and what measurable environmental outcomes are intended to be achieved.
4. As a consequence of the previous two points, it is difficult to determine to what extent agency scientific information needs are being met through existing information or current projects. Overall, there is a need to work in a more integrated in the Marlborough CMA.
5. It is not clear what processes are being taken to prioritise scientific work being carried out in the Marlborough CMA. While within individual organisations (agency or scientific) there is some alignment of project, there appears to be limited overarching regional alignment, coordination or joint strategising of scientific initiatives. This highlights the importance of developing a joint coastal research strategy for the Marlborough CMA.
6. Environmental information is largely centred on the Marlborough Sounds with only limited information from the CMA outside the Sounds. While this partially reflects the importance of the Marlborough Sounds in terms of use and sensitivity to stressors, it poses a risk of potentially unnoticed environmental degradation in other parts of the Marlborough CMA.
7. There is limited consistent use of indicators of environmental health throughout the Marlborough CMA that would provide for consistent assessments of the state of or changes in the environment. Instead, most science providers or projects use different indicators, standards or even descriptors of environmental state or health. This creates considerable difficulties when attempting to describe the state of the environment on scales beyond individual project. Overall, there is a limited use of standards or thresholds that would provide a more contextualised assessment of the state of the environment or the severity of environmental issues.
8. There is a lack of recognition of te ao Māori in most scientific investigations, monitoring or indicators.
9. There is no systematic approach for assessing cumulative effects in the Marlborough CMA.

Overall, MDC has identified the need to develop a more strategic approach for the collection of future scientific information on the Marlborough CMA that builds on existing information but provides for improved prioritisation and alignment of projects and gathered information. This report provides a starting point for discussions and initiatives aimed at addressing this need.

References

Acosta, H., Earl, L., Growcott, A., MacLellan, R., Marquetoux, N., Peacock, L., Phiri, B., Stanislawek, W., Stevens, P., Tana, T., van Andel, M., Watts, J., Gould, B., 2020. Atlas of Biosecurity Surveillance. Ministry for Primary Industries.

Anderson, T., Morrison, M., MacDiarmid, A., Clark, M., D'Archino, R., Nelson, W., Tracey, D., Gordon, D.P., Read, G., Kettles, H., Morrisey, D., Wood, A., Anderson, O., Smith, A.M., Page, M., Paul-Burke, K., Schnabel, K., Wadhwa, S., 2019. Review of New Zealand's Key Biogenic Habitats. NIWA Client Report No: 2018139WN. Prepared for the Ministry for the Environment.

Anderson, T., Stewart, R., D'Archino, R., Stead, J., Eton, N., 2020. Life on the seafloor in Queen Charlotte Sound, Tory Channel and adjacent Cook Strait. NIWA Client Report No: 2019081WN. Prepared for Marlborough District Council.

Barrett, H., Anderson, T., Morrisey, D., 2017. Effects of sediment deposition on the New Zealand cockle, Austrovenus stutchburyi. NIWA Client report no. 2017214NE. Prepared for Marlborough District Council.

Basher, L., 2013. Erosion processes and their control in New Zealand, in: Dymond, J. (Ed.), Ecosystem Services in New Zealand – Conditions and Trends. Manaaki Whenua Press, Lincoln, New Zealand.

Bell, M., 2019. King Shag research project: Year One update report (Unpublished Technical Report). Prepared by Wildlife Management International for the Marine Farming Association and Seafood Innovations Limited.

Bell, M., Frost, P., Melville, D., 2020. Population assessment during the non-breeding season of King Shag in the Marlborough Sounds, February 2020. Unpublished Technical Report. Prepared for New Zealand King Salmon.

Berkett, N., Wade, O., Cornelisen, C., Newton, M., Bell, K., 2015. Guiding coastal and marine resource management: The Coastal Special Interest Group Research Strategy. Prepared for the Coastal Special Interest Group.

Broekhuizen, N., Plew, D., 2018. Marlborough Sounds Water Quality Monitoring review of Marlborough District Council monitoring data 2011-2018. NIWA Client report no. 2018248HN. Prepared for Marlborough District Council.

Broekhuizen, N., Plew, D.R., Pinkerton, M.H., Gall, M.G., 2021. Sea temperature rise over the period 2002–2020 in Pelorus Sound, New Zealand – with possible implications for the aquaculture industry. New Zealand Journal of Marine and Freshwater Research 55, 46–64. https://doi.org/10.1080/00288330.2020.1868539

Clapcott, J., Ataria, J., Hepburn, C., Hikuroa, D., Jackson, A.-M., Kirikiri, R., Williams, E., 2018. Mātauranga Māori: shaping marine and freshwater futures. New Zealand Journal of Marine and Freshwater Research 52, 457–466. https://doi.org/10.1080/00288330.2018.1539404

Clement, D., Keeley, N., Sneddon, R., 2010. Ecological Relevance of Copper (Cu) and Zinc (Zn) in Sediments Beneath Fish Farms in New Zealand. Cawthron Report No. 1805. Prepared for Marlborough District Council.

Davidson, R., Duffy, C., Gaze, P., Baxter, A., DuFresne, S., Courtney, S., Hamill, P., 2011. Ecologically significant marine sites in Marlborough, New Zealand. Co-ordinated by Davidson Environmental Limited for Marlborough District Council and Department of Conservation.

Davidson, R., Richards, L., Abel, W., Aviss, M., 2014. Long Island-Kokomohua Marine Reserve, Queen Charlotte Sound: update of biological monitoring, 1992 – 2014. Survey and Monitoring Report No. 796. Prepared by Davidson Environmental Limited for Department of Conservation.

Davidson, R., Richards, L., Rayes, C., 2017a. Significant marine site survey and monitoring programme (survey 3): Summary report 2016-2017. Survey and monitoring report number 859. Prepared by Davidson Environmental Limited for Marlborough District Council.

Davidson, R., Richards, L., Rayes, C., Abel, W., 2017b. Biological monitoring of the ferry route in Tory Channel and Queen Charlotte Sound: 1995-2017. Survey and monitoring report number 854. Prepared by Davidson Environmental Limited for Marlborough District Council.

Davidson, R., Richards, L., Rayes, C., Scott-Simmonds, T., 2020. Significant marine site survey and monitoring programme (survey 6): Summary report 2019-2020. Survey and monitoring report number 1023. Prepared by Davidson Environmental Limited for Marlborough District Council.

Davies, K., Fisher, K., Foley, M., Greenaway, A., Hewitt, J., Le Heron, R., Mikaere, H., Ratana, K., Spiers, R., Lundquist, C., 2018. Navigating collaborative networks and cumulative effects for Sustainable Seas. Environmental Science & Policy 83, 22–32. https://doi.org/10.1016/j.envsci.2018.01.013

Dudley, B., Zeldis, J., Burge, O., 2017. New Zealand Coastal Water Quality Assessment (Prepared for Ministry for the Environment. NIWA Client Report No: 2016093CH. Ministry for the Environment.

Elvines, D., Preece, M., Baxter, A., Broekhuizen, N., Ford, R., Knight, B., Schuckard, R., Urlich, S., 2019. Best management practice guidelines for salmon farms in the Marlborough sounds Part 2: Water quality standards and monitoring protocol (Version 1.0). New Zealand Aquatic Environment and Biodiversity Report No. 230. Ministry for Primary Industries.

Fisheries New Zealand, 2020a. Southern Scallop Strategy Marlborough Sounds.

Fisheries New Zealand, 2020b. Aquatic Environment and Biodiversity Annual Review 2019–20. Compiled by the Aquatic Environment Team, Fisheries Science and Information, Fisheries New Zealand, Wellington.

Forrest, B., Knight, B., Barter, P., Berkett, N., Newton, M., 2016. Opportunities for an integrated approach to marine environmental monitoring in the Marlborough Sounds. Cawthron Report No. 2924. Prepared for Marlborough District Council.

Forrest, B.M., Stevens, L.M., 2019. Synoptic overview of the Marlborough District Council estuarine State of the Environment monitoring programme. Salt Ecology Report 010. Prepared for Marlborough District Council.

Galgani, L., Beiras, R., Galgani, F., Panti, C., Borja, A., 2019. Editorial: Impacts of Marine Litter. Front. Mar. Sci. 6. https://doi.org/10.3389/fmars.2019.00208

Handley, S., 2017. Advice for mussel restoration trials in Pelorus Sound/Te Hoiere, Marlborough (No. NIWA Client Report No. 2017215NE). Prepared for Marlborough District Council.

Handley, S., 2016. History of benthic change in Queen Charlotte Sound/Totaranui, Marlborough. Prepared for Marlborough District Council.

Handley, S., 2015. The history of benthic change in Pelorus Sound (Te Hoiere), Marlborough (No. NIWA Client Report No. NEL2015-001). Prepared for Marlborough District Council.

Handley, S., Gibbs, M., Swales, A., Olsen, G., Ovenden, R., Bradley, A., 2017. A 1,000 Year History of Seabed Change in Pelorus Sound/Te Hoiere, Marlborough. Nelson. NIWA Client Report No.

2016119NE. Prepared for Prepared forMarlborough District Council, Ministry of Primary Marlborough District Council, Ministry of Primary Industries and the Marine Farming Association.

Hay, C.H., 1990. The distribution of Macrocystis (Phaeophyta: Laminariales) as a biological indicator of cool sea surface temperature, with special reference to New Zealand waters. Journal of the Royal Society of New Zealand 20, 313–336. https://doi.org/10.1080/03036758.1990.10426716

Hewitt, J.E., Thrush, S.F., 2019. Monitoring for tipping points in the marine environment. J. Environ. Manage. 234, 131–137. https://doi.org/10.1016/j.jenvman.2018.12.092

Hunt, S., 2019. Summary of historic estuarine sedimentation measurements in the Waikato region and formulation of a historic baseline sedimentation rate. Waikato Regional Council Technical Report No. 2019/08. Waikato Regional Council, Hamilton.

Jarvis, R.M., Young, T., 2019. Key research priorities for the future of marine science in New Zealand. Marine Policy 106, 1–7. https://doi.org/10.1016/j.marpol.2019.103539

Jones, E.G., Morrison, M., Davey, N., Hartill, B., Sutton, C., 2016. Biogenic habitats on New Zealand's continental shelf. Part I: Local Ecological Knowledge. New Zealand Aquatic Environment and Biodiversity Report No. 174. Ministry for Primary Industries.

Keeley, N., Gillard, M., Broekhuizen, N., Ford, R., Schuckard, R., Urlich, S., 2019. Best Management Practice guidelines for salmon farms in the Marlborough Sounds: Part 1: Benthic environmental quality standards and monitoring protocol (Version 1.1 January 2018). New Zealand Aquatic Environment and Biodiversity Report No 219. Prepared for Fisheries New Zealand.

Kotahitanga mō te Taiao, 2019. Kotahitanga mō te Taiao Strategy.

Lawless, P., 2018. Kotahitanga Strategy Report on Science Workshop. Prepared for the Nelson City Council as part of the Kotahitanga mō te Taiao Alliance.

Lusher, A., Hollmann, P., Mendoza-Hill, J., 2017. Microplastics in fisheries and aquaculture: status of knowledge on their occurrence and implications for aquatic organisms and food safety. FAO Fisheries and Aquaculture Technical Paper. No. 615. Rome, Italy.

MacDiarmid, A., McKenzie, A., Sturman, J., Beaumont, J., Mikaloff-Fletcher, S., Dunne, J., 2012. Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report No. 93.

Marlborough District Council, 2017. Coastal Water Quality - Monitoring 2016/2017 - Report Card.

Maxwell, K.H., Ratana, K., Davies, K.K., Taiapa, C., Awatere, S., 2020. Navigating towards marine co-management with Indigenous communities on-board the Waka-Taurua. Marine Policy 111, 103722. https://doi.org/10.1016/j.marpol.2019.103722

Ministry for the Environment & Stats NZ, 2016. New Zealand's Environmental Reporting Series: Our marine environment 2016. Available from www.mfe.govt.nz and www.stats.govt.nz.

Ministry for the Environment, Stats NZ, 2019. New Zealand's Environmental Reporting Series: Our marine environment 2019 (ME 1468). Available from www.mfe.govt.nz and www.stats.govt.nz.

Morrisey, D., Cameron, M., Newcombe, E., 2018. Effects of moorings on different types of marine habitat. Cawthron Report No. 3098. Prepared for Marlborough District Council.

Neil, H., Pallentin, A., Mitchell, J., Kane, T., 2015. Multibeam echo-sounder mapping to identify seafloor habitats northwest of D'Urville Island. NIWA Client Report No. WLG2015-38. Prepared for Marlborough District Council.

Newcombe, E., 2017. Environmental monitoring opportunities in Picton Bays. Cawthron Report No. 2998. Prepared for Marlborough District Council.

Newcombe, E., Broekhuizen, N., 2020. Measuring mussel farming effects on plankton in the Marlborough Sounds. Cawthron Report No. 3550. Prepared for Marlborough District Council.

Newcombe, E., Johnston, O., 2016. Picton Bays environmental information and health assessment. Cawthron Report No. 2805. Prepared for Marlborough District Council.

Parliamentary Commissioner for the Environment, 2020. Managing our estuaries.

Parnell, K., 2012. Shoreline Monitoring in Tory Channel and Queen Charlotte Sound November 2009 – April (May) 2012. Prepared for Marlborough District Council.

Rapson, A., Moore, L., Elliott, I., 1942. Seaweed as a source of potash in New Zealand. NZ Journal of Science and Technology 23, 150B-170B.

Ribó, M., Macdonald, H., Watson, S.J., Hillman, J.R., Strachan, L.J., Thrush, S.F., Mountjoy, J.J., Hadfield, M., Lamarche, G., 2020. Predicting habitat suitability of filter-feeder communities in a shallow marine environment, New Zealand. Marine Environmental Research 105218. https://doi.org/10.1016/j.marenvres.2020.105218

Robertson, B., 2020a. Broughton and Ohinetaha Bays - Broad Scale Habitat Mapping and Ecological Assessment. Prepared for Marlborough District Council.

Robertson, B., 2020b. Elie Bay and Wet Inlet, Pelorus Sound - Broad Scale Habitat Mapping and Ecological Assessment. Prepared for Marlborough District Council.

Robertson, B., 2019a. Havelock Estuary, Marlborough - Fine Scale Habitat Mapping and Ecological Assessment. Prepared for Marlborough District Council.

Robertson, B., 2019b. Havelock Estuary, Marlborough - Broad Scale Habitat Mapping and Ecological Assessment. Prepared for Marlborough District Council.

Robertson, B.P., Savage, C., 2018. Mud-entrained macroalgae utilise porewater and overlying water column nutrients to grow in a eutrophic intertidal estuary. Biogeochemistry. https://doi.org/10.1007/s10533-018-0454-x

Spaling, H., 1994. Cumulative effects assessments: Concepts and principles. Impact Assessment 12, 231–251. https://doi.org/10.1080/07349165.1994.9725865

Sustainable Business Network, 2020. Tackling plastic waste in New Zealand aquaculture.

Swales, A., Gibbs, M., Handley, S., Olsen, G., Ovenden, R., Wadhwa, S., Brown, J., in preparation. Sources of fine sediment and contribution to sedimentation in the inner Pelorus Sound/Te Hoiere. NIWA Client Report No. 2020247HN. Prepared for Marlborough District Council.

Thrush, S.F., Hewitt, J.E., Cummings, V.J., Ellis, J.I., Hatton, C., Lohrer, A., Norkko, A., 2004. Muddy Waters: Elevating Sediment Input to Coastal and Estuarine Habitats. Frontiers in Ecology and the Environment 2, 299–306. https://doi.org/10.2307/3868405

Townsend, M., de Lange, P., Duffy, C.A.J., Miskelly, C., Molloy, J., Norton, D., 2008. New Zealand Threat Classification System manual. Department of Conservation, Wellington.

Urlich, S., 2015. Mitigating Fine Sediment from Forestry in Coastal Waters of the Marlborough Sounds. MDC Technical Report No: 15-009. Marlborough District Council.

Urlich, S.C., Handley, S.J., 2020. From 'clean and green' to 'brown and down': A synthesis of historical changes to biodiversity and marine ecosystems in the Marlborough Sounds, New Zealand. Ocean & Coastal Management 198, 105349. https://doi.org/10.1016/j.ocecoaman.2020.105349

Watson, S.J., Neil, H., Ribó, M., Lamarche, G., Strachan, L.J., MacKay, K., Wilcox, S., Kane, T., Orpin, A., Nodder, S., Pallentin, A., Steinmetz, T., 2020. What We Do in the Shallows: Natural and Anthropogenic Seafloor Geomorphologies in a Drowned River Valley, New Zealand. Front. Mar. Sci. 7. https://doi.org/10.3389/fmars.2020.579626

Appendix 1: Regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA reviewed

Regulatory and non-regulatory documents of relevance to environmental research and monitoring of the Marlborough CMA reviewed and used in this report to identify scientific information needs for the Marlborough CMA include:

- RMA
- NZCPS
- NPS-FM
- PMEP
- Kotahitanga mō te Taiao Strategy
- Te Mana o Te Taiao - Aotearoa New Zealand Biodiversity Strategy 2020 (DOC)
- New Zealand Biodiversity Action Plan 2016 – 2020 (DOC)
- Conservation and Environment Science Roadmap 2017 (MFE)
- Nelson/Marlborough Conservation Management Strategy (CMS) 1996-2006 (DOC)
- Regional Council Research, Science and Technology Strategy 2016
- Coastal Special Interest Group Strategy 2015
- Fit for a Better World (roadmap for primary sector economy) (MPI)
- Aquaculture Strategy (New Zealand Government)
- National Blue Cod Strategy (FNZ)
- Fisheries New Zealand focus areas and work programme (FNZ)
- Southern Scallop Strategy: Marlborough Sounds (FNZ)
- MDC 2018-28 Long term plan
- Te Atiawa Iwi Environmental Management Plan
- Ngati Koata Iwi Management Plan

Appendix 2: Research priorities for the future of marine science in the Marlborough CMA

Table A2-1. Key research priorities identified by Jarvis and Young (2019) that were found to be of direct relevance for the environmental management of the Marlborough CMA. Research question numbering refers to numbering in the publication. Each priority research question was assessed for relevance to the environmental management of the Marlborough CMA and assigned to one or several environmental issues or environmental management tools described in this report. Environmental issues: (1) Sediment, (2) Habitat modification and impact on species, (3) sediment and water quality degradation, (4) marine pests, (5) marine litter, (6) climate change, (7) cumulative effects, (8) decline in ecosystem functions and services; environmental management tools: (9) monitoring, (10) marine protection, (11) restoration, (12) mitigation, (13) management of activities in the CMA.

Themes and research questions	1	2	3	4	5	6	7	8	9	10	11	12	13
Fisheries and aquaculture													
2. How can fisheries management be improved to reduce impacts on marine environments and species?													✓
3. How can we design an integrated management system that includes networks of marine protected areas (MPAs) to enable commercial, customary, and recreational fisheries to be sustainable?										✓			✓
4. What is the impact of fishing on coastal marine biodiversity and ecosystems?		✓											✓
6. How does trawling and dredging affect productivity on continental shelves, and benthic habitats of significance?		✓											✓
7. What are the factors preventing wild shellfish stocks from recovering to historic levels?		✓											
9. How do terrestrial coastal processes, and human activities on land and the coast, impact shellfish populations and shellfish bed recovery?	✓	✓											
10. How will multiple stressors impact and interact to affect the food security of marine resources in the future?		✓					✓						
Biosecurity													
1. How can we better mitigate the impact of invasive species?				✓					✓				
2. What new molecular techniques can be developed to improve the early detection of invasive species?				✓									

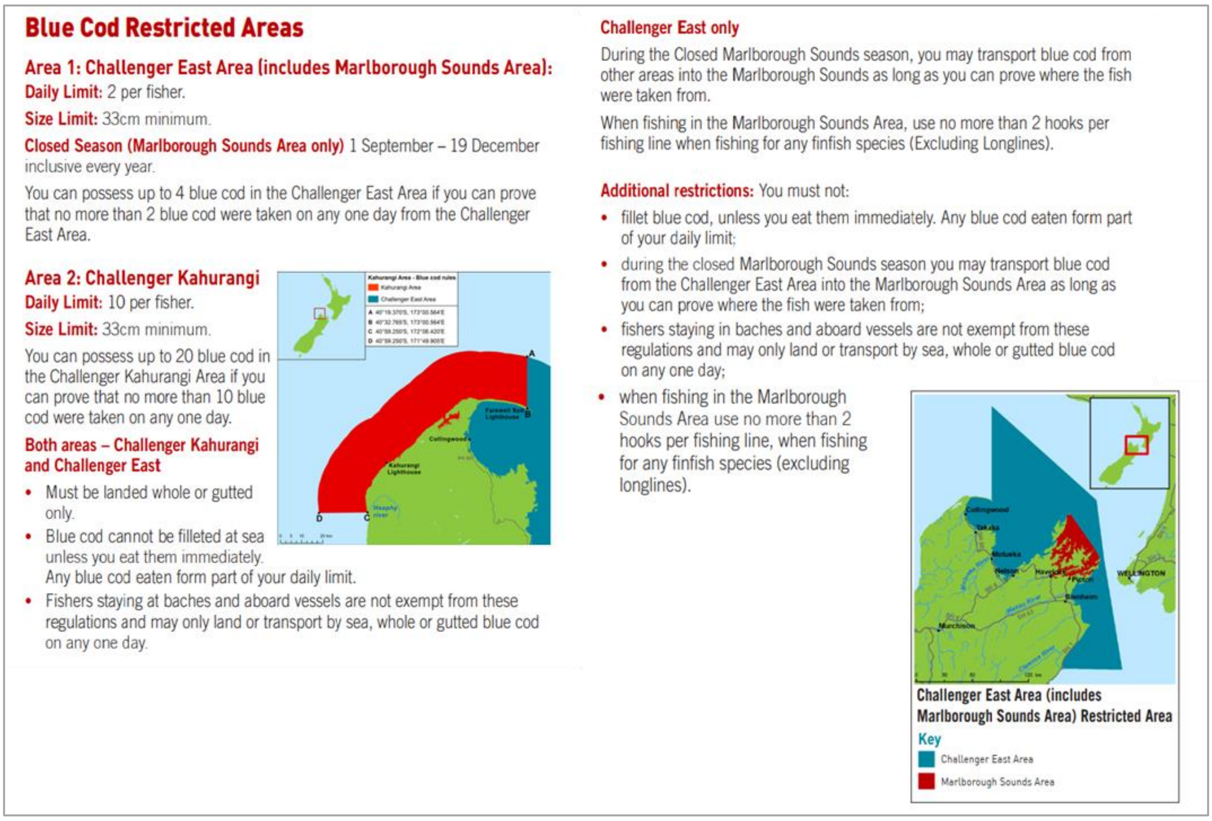
3. How can we identify and monitor the impact of marine pests on native biodiversity?		✓		✓									
4. How do marine introduced species and climate-change-induced range shift alter ecological structure?		✓		✓		✓							
5. How can biodiversity be increased to ensure marine communities are resilient to the impacts of pests?		✓		✓									
6. What are the impacts of current and future marine biosecurity risks?				✓									
7. How can we use genomic-scale DNA taxonomy to identify where alien species came from and when they arrived in NZ?				✓									
8. Which newly invasive toxin-producing microalgae might establish in NZ waters due to future expansion of the subtropical latitudes?		✓		✓									
9. What is the reproductive potential of biofouling species on commercial and recreational ships arriving into the NZ Exclusive Economic Zone (EEZ)?				✓									✓
10. How do invasive marine invertebrates get distributed over long distances?		✓		✓									
Climate change													
1. How will primary production that supports coastal and ocean food webs respond to future change?		✓				✓							
2. How will the increasing frequency of marine heatwaves affect marine ecosystems and the distribution and abundance of marine biodiversity?		✓	✓			✓							
3. What impacts will climate change and ocean acidification have on marine resources and how can this best be managed to ensure sustainability?		✓	✓			✓							
4. How resilient are marine species to changes in water temperature, and what impact will this have on local biodiversity?		✓				✓							
5. How can we improve and prioritise our coastal restoration efforts to ensure we can adapt to climate change?						✓					✓		
6. How will climate change affect the spatial patterns and extent of marine species, food webs, and their interactions within and across ecosystems?		✓				✓							
7. How does the changing climate, and its impacts on our waters and the Southern Ocean, affect the oceanography around NZ?						✓							

8. How will the different factors of global change (temperature increase, ocean acidification, eutrophication, plastic pollution, etc.) act synergistically upon coastal and ocean ecosystem functioning?						✓	✓	✓					
9. How will ocean ecosystem services be affected by, and respond to, climate change?						✓		✓					
10. How will global change affect biophysical interactions and ocean processes?		✓	✓			✓							
Marine reserves and protected areas													
1. What are the spatial requirements for an effective, national marine reserve network?										✓			
2. Where and how should we implement more marine protected areas (MPAs)?										✓			
3. What additional areas could be designated as marine protected areas (MPAs) or reserves in order to protect ecosystems that are not currently represented?		✓								✓			
4. How effective are mixed-model marine protected areas (MPAs) (e.g., taiāpure, mātaitai, some rāhui) at protecting and restoring marine system function?		✓						✓		✓			
5. What are the environmental, social, cultural, and economic values of marine reserves?								✓		✓			
6. What is the protection value of different marine protected area (MPA) tools (e.g., no-take, partially protected, etc) for different species and habitats?		✓								✓			
8. Should an expanding marine reserve network focus on many small or few large reserves to deliver the most benefits while ensuring representation, adequacy, and effectiveness?										✓			
9. What are the benefits and impacts of marine reserves and marine protected areas (MPAs) that are currently designated?										✓			
10. Can a traditional 'no take' rāhui that is well-enforced locally provide benefits that are equivalent to a nationally designated marine reserve?										✓			✓
Ecosystems and biodiversity													
1. How can degraded benthic habitats be restored to resume critical ecosystem functions?		✓						✓			✓		

2. What is NZ's current baseline of biodiversity and species abundance across its different marine habitats?		✓											
3. What are the most cost-effective techniques for restoration of degraded coastal ecosystems?		✓									✓		
4. What are the factors hindering the recovery of depleted marine species, and what are the factors required to counteract depletion?		✓											
5. How can we identify and assess the biggest threats to marine habitats to inform their management?		✓											
6. How will multi-stressor impacts affect coastal species?		✓					✓						
7. How can we quantify change and risk to ecosystem function and integrity associated with multiple stressors and cumulative impacts?		✓					✓						
8. How can we best predict tipping points in marine ecosystems?		✓											
9. How do coastal, benthic, and pelagic ecosystems respond to natural and human-induced perturbations?		✓											
10. What are the key indicator species that demonstrate healthy or unbalanced marine ecosystems?		✓	✓					✓	✓				
Coastal and ocean processes													
1. How do long-term changes in ocean water masses around NZ impact the marine ecosystem?		✓				✓							
2. What are the impacts of suspended sediment on primary production and carbon pathways in coastal waters?	✓	✓											
3. What is the impact of sedimentation on nearshore ecosystems and species?	✓	✓											
5. How do current impacts of terrigenous fine sediment on key coastal processes and ecosystem services vary nationally, and how are these likely to change in the future?	✓							✓					
7. How is the increase of sedimentation affecting the behaviour and survival of benthic and non-benthic organisms in offshore sites?	✓	✓											
10. What approaches can be used to better determine the loading of nutrients and sediments into estuaries?	✓		✓										
Other anthropogenic factors													
1. How can we better mitigate the impacts of land-use on the coastal	✓		✓									✓	

ocean?													
2. What are the impacts of runoff from terrestrial farms on marine environments?	✓	✓	✓										
3. What are the combined effects of very low levels of multiple contaminants (e.g., pesticides, natural resource extraction contaminants, salinity, pharmaceuticals and personal care products, endocrine disrupting chemicals) with different modes of action on aquatic organisms and ecosystems?		✓	✓				✓						
4. What are the impacts of land-use change and future development on coastal ecosystems and the marine environment?	✓	✓	✓										
5. What are the relative effects of different land-use types and activities on coastal water quality and biodiversity?	✓	✓	✓										
6. How can we best monitor river plumes and their pollution burden on coastal waters?	✓		✓										
8. How do we develop appropriate regulatory guidelines and standards specifically for contaminants of emerging concern that account for multiple modes of toxicity and multi-generational sublethal effects?		✓	✓										
9. How do the interrelated and interacting effects of human activity on land and resource use in the sea affect marine ecosystems?		✓					✓						
10. What are the fates and impacts of microplastics, nanomaterials, and other marine debris?					✓								

Appendix 3: Recreational fishing restrictions in the Marlborough CMA



Blue Cod Restricted Areas

Area 1: Challenger East Area (includes Marlborough Sounds Area):
Daily Limit: 2 per fisher.
Size Limit: 33cm minimum.
Closed Season (Marlborough Sounds Area only) 1 September – 19 December inclusive every year.

You can possess up to 4 blue cod in the Challenger East Area if you can prove that no more than 2 blue cod were taken on any one day from the Challenger East Area.

Area 2: Challenger Kahurangi
Daily Limit: 10 per fisher.
Size Limit: 33cm minimum.

You can possess up to 20 blue cod in the Challenger Kahurangi Area if you can prove that no more than 10 blue cod were taken on any one day.

Both areas – Challenger Kahurangi and Challenger East

- Must be landed whole or gutted only.
- Blue cod cannot be filleted at sea unless you eat them immediately. Any blue cod eaten form part of your daily limit.
- Fishers staying at baches and aboard vessels are not exempt from these regulations and may only land or transport by sea, whole or gutted blue cod on any one day.

Challenger East only

During the Closed Marlborough Sounds season, you may transport blue cod from other areas into the Marlborough Sounds as long as you can prove where the fish were taken from.

When fishing in the Marlborough Sounds Area, use no more than 2 hooks per fishing line when fishing for any finfish species (Excluding Longlines).

Additional restrictions: You must not:

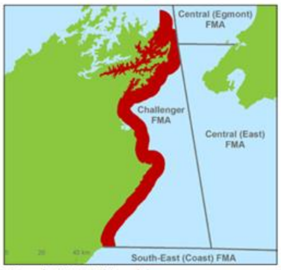
- fillet blue cod, unless you eat them immediately. Any blue cod eaten form part of your daily limit;
- during the closed Marlborough Sounds season you may transport blue cod from the Challenger East Area into the Marlborough Sounds Area as long as you can prove where the fish were taken from;
- fishers staying in baches and aboard vessels are not exempt from these regulations and may only land or transport by sea, whole or gutted blue cod on any one day;
- when fishing in the Marlborough Sounds Area use no more than 2 hooks per fishing line, when fishing for any finfish species (excluding longlines).

Figure A3-1. Blue cod restricted areas in the Challenger East Area. Source: MPI (https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/fishing-rules/challenger-region-fishery-management-area/)

Set net restrictions

Map 1: Set netting is totally prohibited from Cape Jackson to the Clarence River (extends out to 4 nautical miles and includes the entire Queen Charlotte Sound, Tory Channel, Port Underwood, Cloudy Bay, Clifford Bay, and Cape Campbell areas).

Map 2: Set netting is totally prohibited on the West Coast from Farewell Spit to Awarua Point (extends out to 2 nautical miles). Check the regulations for co-ordinates.



Map 1: Set Net Closed Area

Map 2: Set Net Closed Area

- **Exemption:** Queen Charlotte Sound inside a line from West Head Point (Ruakaka Bay) to Deiffenbach Point – refer to the red area on **Map 3**. Applies between 1 April and 30 September for Flatfish set nets only (a net that is 9 meshes deep or less, is anchored at each end, does not exceed a total length of 60 metres, has a mesh size greater or equal to 100mm and a monofilament diameter less than 0.35mm).
- **Exemption:** East Coast.
- Fishers must stay with their nets at all times and set no more than 200m from shore, between Cape Jackson and Rarangi Port Underwood and then Cape Campbell to Needles Point between 1 January – 30 April inclusive. (See purple line on **Map 3**).

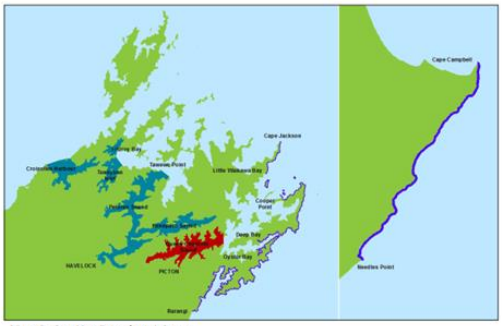
Map 3: Set netting may only be undertaken using set nets with a net mesh size greater than or equal to 100mm which do not exceed 9 meshes in height and must be set in direct contact with the seabed. These restrictions apply to the following (all blue areas on **Map 3**):

Pelorus Sound: inside a line from Tawero Point to Opani-Aputa Point.

Tennyson Inlet and Hallam Cove: inside a line from Sheep Point to Camel Point to Cregoe Point.

Croisilles Harbour: inside a line from Cape Soucis, outside the Islands to Kakaho Point.

Within Kenepuru Sound: set netting is totally prohibited from 1 October to 31 March inclusive.



Map 3: Set Net Restricted Areas

Set line restricted areas

Map 4: Possession and use of set lines is prohibited in Pelorus Sound inside a line from Tawero Point to Opani-Aputa Point and in Kenepuru Sound.

Map 4: Set Line Restricted Areas

Figure A3-2. Set net restrictions and set line restricted areas in the Challenger East Area. Source: MPI (https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/fishing-rules/challenger-region-fishery-management-area/)

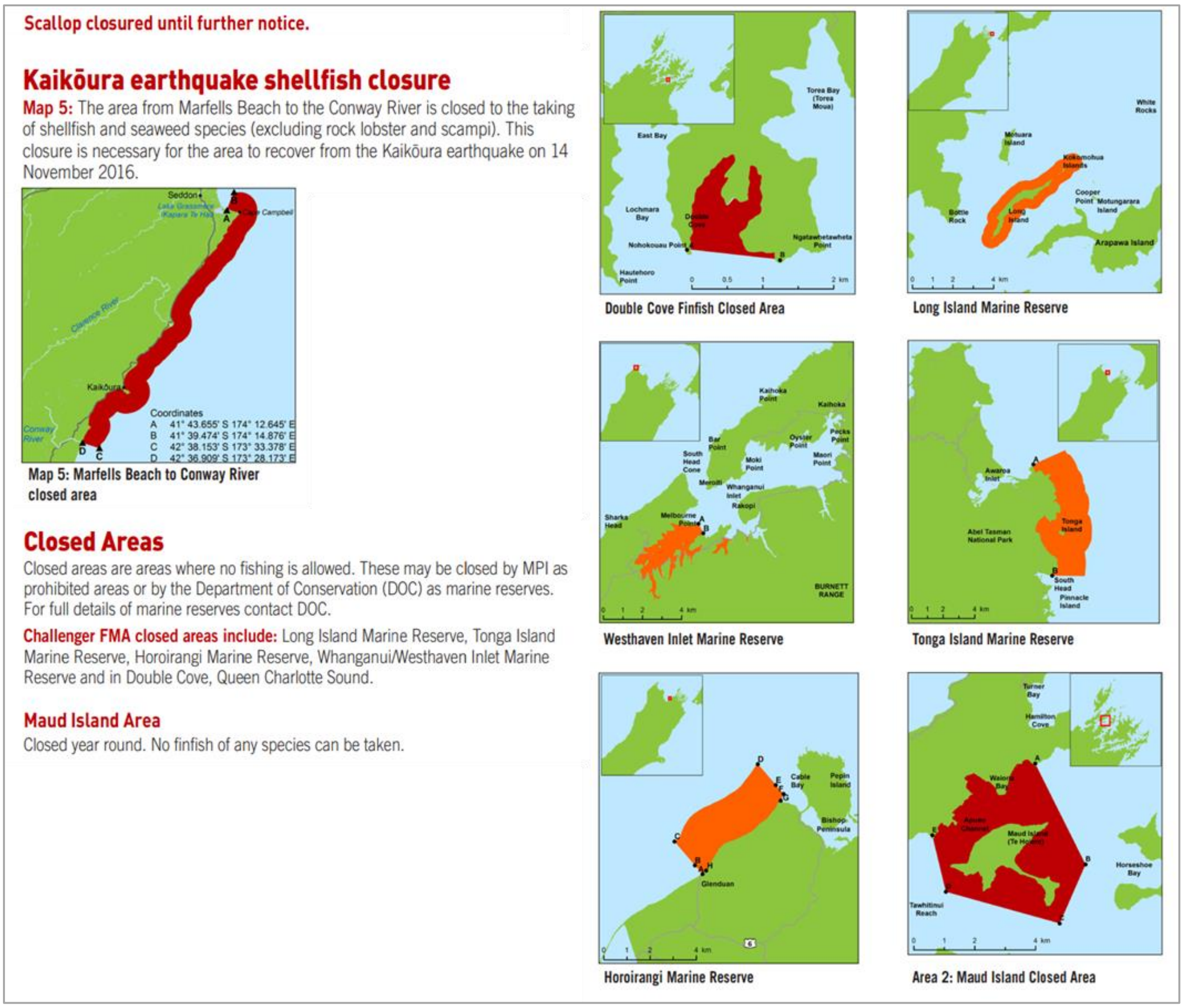


Figure A3-3. Closure areas in the Challenger East Area. Source: MPI (https://www.mpi.govt.nz/fishing-aquaculture/recreational-fishing/fishing-rules/challenger-region-fishery-management-area/)