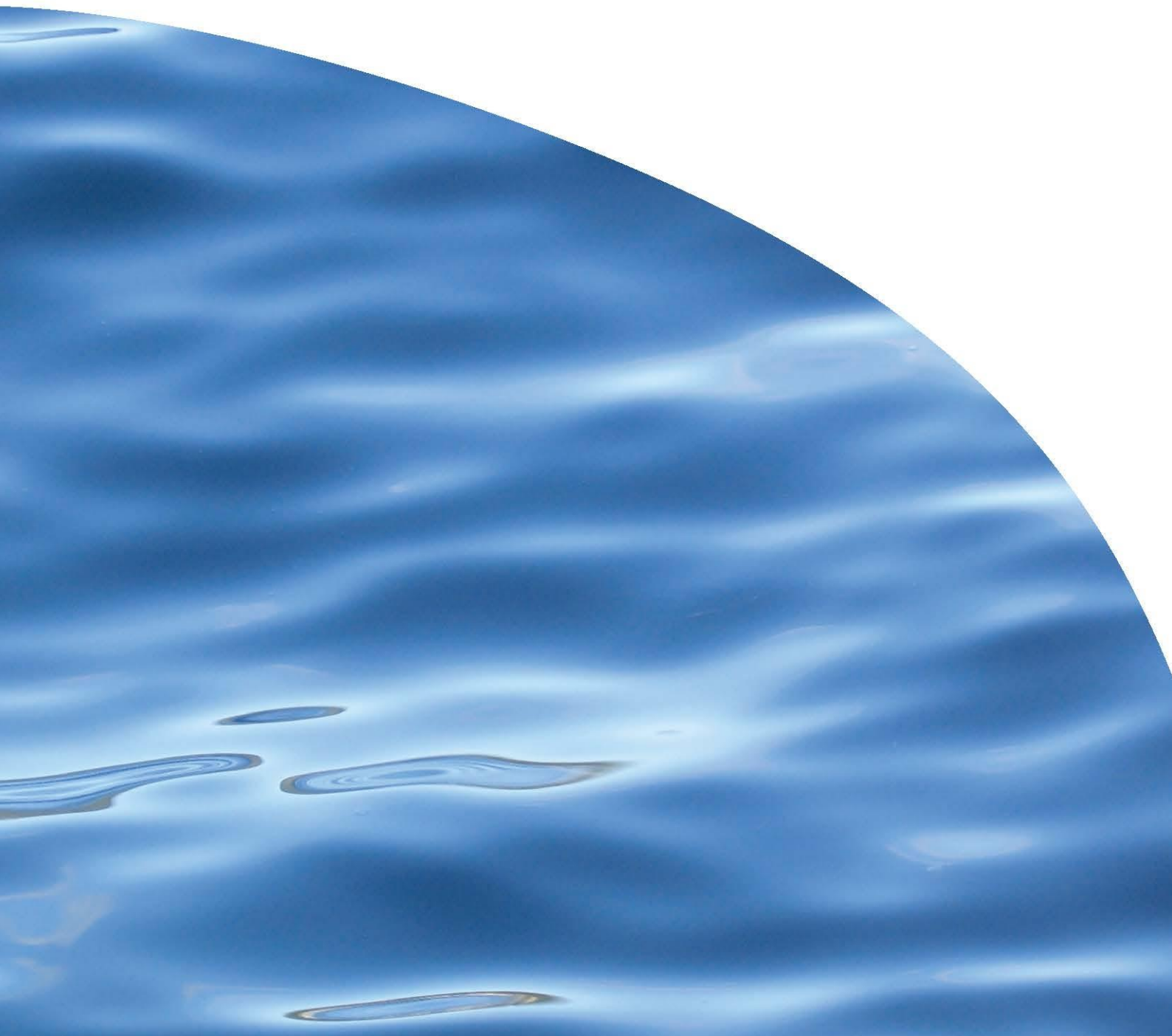




REPORT NO. 2805

PICTON BAYS ENVIRONMENTAL INFORMATION AND HEALTH ASSESSMENT



PICTON BAYS ENVIRONMENTAL INFORMATION AND HEALTH ASSESSMENT

EMMA NEWCOMBE, OLIVIA JOHNSTON

Prepared for Marlborough District Council

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Paul Gillespie



APPROVED FOR RELEASE BY:
Roger Young



ISSUE DATE: 9 March 2016

RECOMMENDED CITATION: Newcombe E, Johnston O 2016. Picton Bays environmental information and health assessment. Prepared for Marlborough District Council. Cawthron Report No. 2805. 52 p.

© COPYRIGHT: Cawthron Institute. This publication may be reproduced in whole or in part without further permission of the Cawthron Institute, provided that the author and Cawthron Institute are properly acknowledged.



Picton and harbour circa 1920s. Smith, Sydney Charles, 1888-1972: Photographs of New Zealand. Ref: 1/2-049257-G. Alexander Turnbull Library, Wellington, New Zealand)



Modern day (2015) Picton Harbour. Photo: Peter Hamill, MDC

Frontispiece: Picton Harbour, 1920s and now.

EXECUTIVE SUMMARY

Picton Harbour, Waikawa Bay and Shakespeare Bay, known collectively as Picton Bays, are the gateway to the Marlborough Sounds and are used recreationally and commercially by thousands of people. The Picton Bays are important at a local, regional, and national level for cultural, social, recreational, and commercial reasons. Marlborough District Council wishes to assess the state and trend of the environmental integrity of Picton Bays. This process will also identify knowledge gaps to assist in the identification and prioritisation of future research and monitoring, and acknowledge tangata whenua aspirations to be involved in that process. This report summarises the extent to which pressures, state, and trends of environmental health are known in Picton Bays.

Natural marine communities in Picton Bays are similar to those in much of Queen Charlotte Sound / Tōtaranui, with only the estuarine areas, and possibly the tubeworm beds at Bob's Bay being of special interest. The marine environment in Picton Bays has suffered substantial negative human impacts over the last century or more, but many pressures have been reduced since the 1970s.

The most severe damage to marine environmental health in Picton Bays may have been historical input of sediment, which has presumably reduced seabed habitat integrity. Deforestation in the area was widespread; however, the area is now largely vegetated. Degradation of habitat integrity due to reclamation and construction has also been substantial. The very high disturbance from ferry wakes that was occurring late last century has been lessened, although large ferries continue to dictate the habitat zonation of nearshore environments. A range of types of contamination are present, although the worst sources of biological and chemical contamination have been eliminated. Chemical contamination from anti-fouling materials is likely to be reducing over time, but differences in sampling methodology and lack of recent available data make it difficult to identify clear patterns. Past contamination by organic matter was extreme, with raw sewage and freezing works waste causing high levels of enrichment and faecal contamination. These sources of pollution have been largely eliminated. Fisheries are much depleted from their historic highly abundant state. Picton Bays, and the Marlborough Sounds generally, are at high risk of new introductions of invasive species.

There are gaps in our understanding of the pressures or stressors, state, and trends of marine environmental health in the Picton Bays area. Information gathering tends to be targeted to monitoring of a particular activity, rather than designed to support a general assessment of environmental health relevant to values in the area. Design of state of the environment monitoring specific to the Picton Bays should occur in response to an assessment or summary of values. Te Ātiawa have mana whenua in Picton Bays, and Waikawa is of particular importance to them. The Te Ātiawa Iwi Environmental Management Plan provides a comprehensive statement of the values, aspirations, and plans that Te Ātiawa hold for the region. State of the environment monitoring should ideally be coordinated with scheduling of consent, community, and iwi monitoring initiatives.

TABLE OF CONTENTS

1. INTRODUCTION	1
1.1. Information availability	2
1.2. Report scope	3
2. MEASURING THE STATE OF THE MARINE ENVIRONMENT	4
2.1. Information needs	4
2.2. Council obligations	4
2.2.1. <i>New Zealand Coastal Policy Statement</i>	4
2.3. Topics	6
3. LAND AND FORESHORE USE IN PICTON BAYS	7
3.1.1. <i>Key inputs from land</i>	12
4. ENVIRONMENTAL INFORMATION AND STATUS	14
4.1. Baseline information	14
4.2. Contamination	17
4.2.1. <i>Key types and sources of contamination</i>	17
4.2.2. <i>Monitoring for contamination in Picton Bays</i>	17
4.2.3. <i>Overview: contamination</i>	28
4.3. Habitat integrity / structural change	30
4.3.1. <i>Reclamation and construction</i>	30
4.3.2. <i>Ferry wake disturbance</i>	31
4.3.3. <i>Sea level rise</i>	33
4.3.4. <i>Seabed integrity and sediments</i>	34
4.4. Biosecurity / invasive species	35
4.5. Fisheries decline	36
5. VALUES AND ASPIRATIONS	38
5.1. Marlborough Marine Futures	38
5.2. Te Ātiawa Iwi Environmental Management Plan	38
5.2.1. <i>KAITIAKITANGA (Section 2.1, IEMP)</i>	39
5.2.2. <i>Te Ātiawa IEMP: Sustainable management of MOANA - (sea –coastal / marine area)</i>	39
6. CONCLUSIONS	42
7. ACKNOWLEDGEMENTS	46
8. REFERENCES	47

LIST OF FIGURES

Figure 1. Picton Bays consists of three bays in Tootaranui/Queen Charlotte Sound: Shakespeare Bay, Picton Harbour, and Waikawa Bay	1
Figure 2. Picton Harbour, date unknown	8
Figure 3. Picton Harbour circa 1920s	8
Figure 4. Land cover near Picton Bays (2012).	9
Figure 5. Waikawa Bay.	10
Figure 6. Picton Harbour waterfront, looking south.	11

Figure 7.	Proposed development (left, Knox & Bolton 1977) would have overtaken much of the head of Shakespeare Bay, however a smaller area was developed, and sand/mudflats remain at the head of the bay (right).....	12
Figure 8:	Picton Bays benthic and water quality monitoring locations, from 1977 to 2015.	16
Figure 9.	Enterococci levels at Picton foreshore and Waikawa Bay.....	27
Figure 10.	A Google Earth image taken in 2013 shows the extent of modified coast in Picton Bays..	31
Figure 11.	Intertidal mid-tide cobble shore, Picton Point, January 2010.	33

LIST OF TABLES

Table 1.	Key types, sources, and possible effects of contaminants in Picton Bays.	18
Table 2.	Water quality data from Land Air Water Aotearoa for two streams which feed into the study area.	26
Table 3.	Range of predicted sea level rise (SLR) scenarios added onto the current MHWS.....	33
Table 4.	State, trends, and data quality of a range of stressors that are likely to be affecting the marine environment in Picton Bays	43

1. INTRODUCTION

'Picton Bays' is used to describe the area of Picton Harbour, Waikawa Bay and Shakespeare Bay. This area is an iconic part of Marlborough. It is the gateway to the Marlborough Sounds and is used recreationally and commercially by thousands of people. The ecological health of the Picton Bays is important for the wider community; however, Marlborough District Council (MDC) does not currently possess an overall integrated understanding of the state of this environment. To effectively respond to environmental management issues, councils and communities require robust information regarding the state of the environment and pressures on it. MDC has identified a need to undertake a stocktake of existing monitoring information on the state and trend of the environment of Picton Harbour. This process will also identify knowledge gaps to assist in the identification and prioritisation of future research and monitoring and acknowledge tangata whenua aspirations to be involved in that process.



Figure 1. Picton Bays consists of three bays in Queen Charlotte Sound / Tōtaranui: Shakespeare Bay, Picton Harbour, and Waikawa Bay (image edited from Google Earth)

The Picton Bays lie on the southern side of inner Queen Charlotte Sound / Totaranui. Waikawa Bay is the eastern-most of the three. It lies between Karaka Point in the east, and The Snout to the west. To the west of The Snout lie Picton Harbour and Shakespeare Bay, which are separated by Kaipupu Point (Figure 1).

The Picton Bays are important on a local and national scale in extremely diverse ways. Te Ātiawa have mana whenua over the area, and seven other iwi are tāngata whenua. They are Rangitane, Ngati Kuia, Ngati Apa, Ngati Toa, Ngati Koata, Ngati Rarua, and Ngati Tama. Picton Harbour and Shakespeare Bay have wharves that are used for commercial vessels including passenger ferries, cruise liners, and log ships. Both Picton Harbour and Waikawa have marinas for private and commercial vessels. Shipyards and numerous other commercial operations occur in the area, and stormwater and treated sewage are discharged into the harbour. The area is important recreationally. It is used by small and large recreational vessels including power boats and waka ama. Swimming, scuba diving, and fishing for finfish and shellfish are common.

1.1. Information availability

Limited state of the environment monitoring has taken place in the marine environment in New Zealand (e.g. Forrest & Cornelisen 2015; Newcombe *et al.* 2015). However, in recent years relatively large amounts of information in the coastal marine environment have been collected as part of consent-associated monitoring. Available information about the marine environment in Picton Bays includes benthic (seabed) and water quality testing associated with outfalls and stormwater, surveys of antifouling compounds, recreational bathing surveys, significant marine site monitoring (at Bob's Bay only), ferry-wake monitoring, and biosecurity surveys. Most of this information is targeted to potential impacts of a specific activity rather than for the assessment of the state of the environment. Nonetheless, this information has some potential to inform wider environmental health.

Not all activity that can affect the health of the marine environment is consented or closely documented. Land-based activity such as urbanisation, farming, and forestry can all have effects on the health of the marine environment, but information on effects is usually scarce. Some of these effects may be captured in council-run freshwater monitoring, which is generally more rigorous than monitoring in the marine environment. Fisheries activity information is not generally available for small areas such as Picton Bays. Larger scale impacts, such as the effects of climate change, are often estimated for large areas, but little monitoring of local effects is undertaken.

1.2. Report scope

This report aims to summarise the extent to which pressures (or stressors), state, and trends of environmental health are known in Picton Bays. Source information is taken largely from published environmental data such as monitoring reports, but some information from the news media and from informal interviews was also used, particularly with respect to fishing. It is beyond the scope of the report to undertake an intensive review of historical land use and reclamation activity.

The report addresses broad-scale land use and land-based activity that is likely to affect the health of the marine environment. Selected summaries from key information sources are presented, and informal data sources are exploited where data is scarce. General conclusions about the state of marine environmental health in Picton Bays were drawn on the basis of the best available information.

The state and trends of a range of stressors is determined to the extent possible from available information. Some likely high-impact stressors are not well documented locally, and it was necessary to acknowledge the limitations of available information. Accordingly, categorisation of data availability (from non-existent to high data availability) for each stressor was undertaken. This summary information will assist council and the community to recognise areas of uncertainty, and to identify priorities for management and state of the environment monitoring in Picton Bays.

Management and monitoring priorities should be informed by local values. An assessment of these values is beyond the scope of this report. Nonetheless we include reference to the Marlborough Marine Futures process, which is one relevant initiative currently underway. Also, to acknowledge the role as kaitiaki of Te Ātiawa, and to recognise the extensive work undertaken to document their aspirations and plans for the marine environment, we reproduce some of the most relevant material from Te Ātiawa's Iwi Environmental Management Plan.

It is anticipated that this work will provide a basis for discussion and facilitate information sharing between iwi, stakeholders and Council, to better inform decision-making into the future.

2. MEASURING THE STATE OF THE MARINE ENVIRONMENT

2.1. Information needs

State of the environment information should provide a broad picture of environmental condition, and provide a context for assessing effects of particular activities. The body of information regarding the state of the environment should reflect the aspects of environmental health most relevant to the community. These values are a combination of:

- National requirements (e.g. requirements of the New Zealand Coastal Policy Statement 2010 (NZCPS), which are summarised below)
- Locally-relevant issues (location-specific pressures on the environment and community aspirations).

To make a robust assessment of the state of the environment, information is required that identifies the state and trend of human impacts and wider environmental change. This requires identification of activities and stressors on a local and regional scale (consented and non-consented) and on a larger scale. Information requirements are:

- Data from impacted and non-impacted sites. Ideally, baseline data are collected, but in many cases, effects of human activity precede any formal data collection. In these cases reference sites and informal historical data can sometimes be used to reconstruct presumed baseline conditions.
- Replication over time and space to separate signal from noise, and to capture a variety of sites (considering representativeness, sensitivity, etc.). Integration with national reference data can assist in assessing change on a scale larger than the target region.
- Relevant ways of measuring and assessing the environment (indicators) that inform the values of interest and allow for assessment of cumulative effects. Indicators can be a single measure, such as a number describing primary productivity, but composite indices of multiple environmental measurements often more effectively reflect environmental status (e.g. Keeley *et al.* 2012 for use in aquaculture effects). Composite indices are increasingly being employed as environmental indicators.

2.2. Council obligations

2.2.1. New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement 2010 (NZCPS) sets out the Government's objectives and policies in order to achieve the purpose of the Resource Management Act 1991 (the RMA) in relation to the coastal environment of New Zealand. Many issues addressed in the NZCPS are unrelated, or only indirectly related, to ecological

issues, e.g. amenity values, historic heritage, and public access concerns. Other components are directly concerned with terrestrial coastal margins, which, depending on the issue, may also be indirectly related to the health of marine waters, or may be unrelated.

Key ecological concerns of the coastal marine environment are captured in policies 11, 21 and 22. Indigenous biological diversity (biodiversity) is addressed in Policy 11. Broadly speaking, Policy 11 includes requirements that activities do not cause adverse effects on species or ecosystems that are rare, threatened, or protected by legislation. For other indigenous species, ecosystems, or habitats, *significant adverse effects* are to be avoided, and *adverse effects* are to be avoided, remedied, or mitigated.

Enhancement of water quality is primarily addressed in Policy 21. This requires that where coastal water quality 'has deteriorated so that it is having a significant adverse effect on ecosystems, natural habitats...or is restricting existing uses, such as aquaculture, shellfish gathering, and cultural activities' priority should be given to improving that water quality. Policy approaches are highlighted, and restoration of water quality is to be given priority 'where practicable'.

Sedimentation is specifically addressed in Policy 22, which requires assessment and monitoring of sedimentation levels and impacts. It also requires controls on effects of land-based activity (subdivision and development, forestry, and others) that can increase the discharge of fine sediments and sediment deposition in coastal habitats.

Specific reference to aquaculture requirements and the need for high water quality is made in Policy 8, so that 'development in the coastal environment does not make water quality unfit for aquaculture activities in areas approved for that purpose'.

There are also ecological implications related to the management of harmful aquatic organisms (Policy 12) and discharge of contaminants (Policy 23).

Many activities considered generally beyond council control, most notably fishing,^{1,2} are not considered in the NZCPS. Climate change is, however, referred to in several policies, requiring that councils adopt a precautionary approach to use of coastal resources potentially vulnerable to climate change.

Engagement with tāngata whenua is required by many policies, but specifically in Policy 2, which prescribes how local authorities take into account the principles of the

¹ Under the Fisheries Act, 1996, MPI is required to take into account impacts of fishing activity, such as adverse effects of fishing on the aquatic environment, and maintenance of biodiversity.

² A legal opinion sought by MDC found that while councils may not, under the RMA, control fishing activity for fisheries management purposes, the RMA does not limit control of fishing activity for other purposes, such as protection of biodiversity.

Treaty of Waitangi and kaitiakitanga³, in relation to the coastal environment. Local authorities must, as far as is practicable with tikanga Māori⁴, incorporate mātauranga Māori⁵ in regional policy statements and plans and when considering resource consent applications.

Policy 4 requires coordinated management across local authority boundaries, iwi / hapū⁶ boundaries or rohe⁷ and ‘the local authority boundary between the coastal marine area and land’, therefore recognising that land management should include consideration of the marine environment. This policy also recognises that particular consideration of cumulative effects may be required to provide for integrated management.

2.3. Topics

Aspects of environmental health can be categorised in many different ways. Invariably, aspects of environmental status and health are interrelated. For example, ‘biosecurity’ is a subset of ‘biodiversity’. ‘Habitat integrity’ relates to many other topics, including ‘primary productivity’, ‘fisheries’, and ‘biodiversity’. Primary productivity is closely related to nutrient input, which may be considered contamination when excessive. Topics⁸ may be addressed at different levels of detail; the term ‘contamination’ may incorporate sediment input, but this could realistically be addressed as a separate topic. Similarly, litter may or may not be considered contamination.

Ultimately, the selection of topics is guided by the most important issues in a given region, the information available, the purpose of reporting and the level of analysis as dictated by project size.

For the purposes of this report, environmental stressors or pressures are considered under four topics or themes:

1) Contamination

- Bacterial contamination is often a concern associated with human activity, and is generally a human health issue. Bacterial contamination can indicate a range of pathogens, including viruses.

³ Guardianship, stewardship, trustee.

⁴ Correct procedure, custom, habit, lore, method, manner, rule, way, code, meaning, plan, practice, convention.

⁵ Māori knowledge — the body of knowledge originating from Māori ancestors, including the Māori world-view and perspectives, Māori creativity and cultural practices.

⁶ Kinship group, clan, tribe, subtribe — section of a large kinship group.

⁷ Boundary, district, region, territory, area, border (of land).

⁸ Some analyses broadly define many aspects of environmental health as ‘indicators’, for example, fisheries, sediment, sediment contamination, and nutrients. For our purposes, we reserve the term ‘indicators’ for metrics which can be used to quantify a specific aspect of environmental health, e.g., an index of enrichment, or a specific measure of biodiversity.

- An increased supply of nutrients (usually nitrogen in coastal environments) can increase growth of primary producers. This can impact both human uses, and ecosystem functioning.
 - Chemical contamination can impact both ecological functioning and human health. Contaminants include metals, semi-volatile organic compounds, and emerging contaminants such as those from pharmaceuticals.
 - Sediments in the water column can block light and physically damage some organisms. When deposited on the seafloor, sediments can smother benthic organisms, and interfere with settlement of juveniles onto underlying substrates.
 - Litter can reduce aesthetic values, and affect ecosystem functioning.
- 2) Habitat integrity / structural change
Habitat integrity refers here particularly to structural aspects of habitat. In general, unmodified habitat would have greater structural integrity. Alterations to habitat such as introduction of artificial structures, disturbance, changes in sediment characteristics, or loss of plants and animals that create structure will invariably have implications for biodiversity.
- 3) Biosecurity / invasive species
Presence of invasive species is not necessarily an indicator of important environmental change, but pest species (which are often introduced) can have important impacts on commercial, recreational, and cultural values. For example, invasive species can have implications for primary productivity, sediment dynamics, habitat integrity, fisheries, and other aspects of biodiversity. In the case of toxic species, they can also cause direct harm to humans.
- 4) Fisheries decline
Fisheries are a particularly valuable aspect of the marine environment in terms of human use. Fisheries can decline due to overexploitation, loss of habitat or contaminant issues.

Sediment and/or sedimentation is often considered as a separate topic, but here we incorporate sediment input under contamination, and sediment structure under habitat integrity. Primary productivity could also be considered as a separate topic, but due to the small size of our focal area it is more realistic to consider nutrient input (which can lead to an increase in primary productivity) in the contaminants section.

3. LAND AND FORESHORE USE IN PICTON BAYS

Most human impacts on the marine environment stem from land-based activity. Accordingly, before addressing the marine environment directly (Section 4), we outline key land-based activity in Picton Bays. Natural land cover (primarily forest) has been removed in much of New Zealand since the beginning of human occupation, and particularly since European colonisation. Marlborough is no exception. Much of the

land around the Picton Bays has been modified, and widespread removal of native bush is apparent in early photographs (Figure 2, Figure 3). Substantial urban development and foreshore modification date back over a century (Figure 3).



Figure 2. Picton Harbour, date unknown. Photograph supplied by MDC.



Figure 3. Picton Harbour circa 1920s. (Smith, Sydney Charles, 1888-1972: Photographs of New Zealand. Ref: 1/2-049257-G. Alexander Turnbull Library, Wellington, New Zealand)

Currently, the land surrounding the Picton Bays has large areas of 'broadleaf indigenous hardwoods' (New Zealand Land Cover Database classification, pale yellow in Figure 4) and 'indigenous forest' (purple, Figure 4). Small stands of exotic forest (green, Figure 4) are present, including one at the head of Shakespeare Bay. Limited farmed areas ('high producing exotic grassland') occur in the area; one of these is at the head of Shakespeare Bay. Built-up areas dominate the heads of both Picton and Waikawa Bay, and those areas are connected by a corridor of urban development. Less of the land-area of Shakespeare Bay is built up, the key development there is the log-storage area adjacent to Waimahara Wharf.

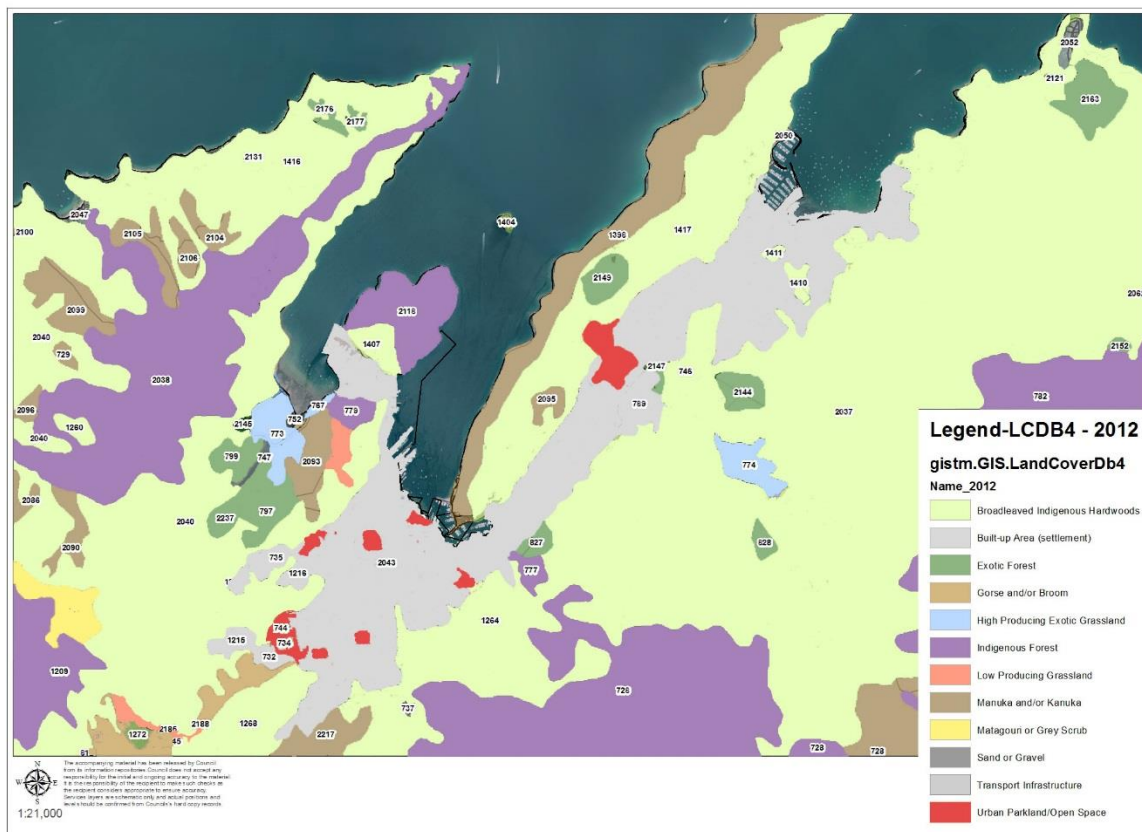


Figure 4. Land cover near Picton Bays (2012). Modified from material supplied by MDC, created from the New Zealand Land Cover Database (LCDB) DB4.

In Waikawa Bay, the western side of the bay is taken up by a marina, while a small area of intertidal sand or mud flats remains on the eastern side (Figure 5). In August 2015 a change to the Marlborough Sounds Resource Management Plan became operative, allowing extension of the Waikawa Marina to the north⁹.



Figure 5. Waikawa Bay. The marina occupies much of the western side of the head of the bay, while small remnant wetlands are apparent on the south-east of the marina. Urban development fringes much of the remainder of the bay. <http://maps.marlborough.govt.nz>

⁹ <http://www.marlborough.govt.nz/Your-Council/RMA/Marlborough-Sounds-Resource-Management-Plan/Plan-Changes/PC21-Waikawa-Bay-Mooring-Management-Areas-and-Marina-Zone-Extension.aspx>

The south-eastern head of Picton Harbour was originally the Kaiaua Lagoon (visible at the right of the image in Figure 2). The lagoon was partially filled in to create Memorial Park, roadways and parking, and the remainder was converted to the Picton Marina. At the centre of the head of the bay lies a popular waterfront area and beach. Wharves have existed for over 100 years on the western side of Picton Harbour. This is now the berthing point for ferries to the North Island. Ferries have increased in size over the years, and from 1994 to 2000 fast ferries operated. These were controversial, and were ultimately restricted, because high-energy wakes eroded the shoreline and disturbed communities.



Figure 6. Picton Harbour waterfront, looking south. The Picton marina was built over the Kaiaua Lagoon. Urban development, including wharves, dominates the head of the harbour. Photo: Peter Hamill, MDC, 2002

Shakespeare Bay is the site of Waimahara Wharf, which is used primarily for storage and transport of logs from local forestry operations. Waimahara Wharf was constructed in the 1990s. The initial proposal was to reclaim land around three sides of the bay (Figure 7, left), however this plan was modified and only the eastern side of the proposed development was implemented. As a result, intertidal mud / sandflats still remain at the head of the bay (Figure 7, right).

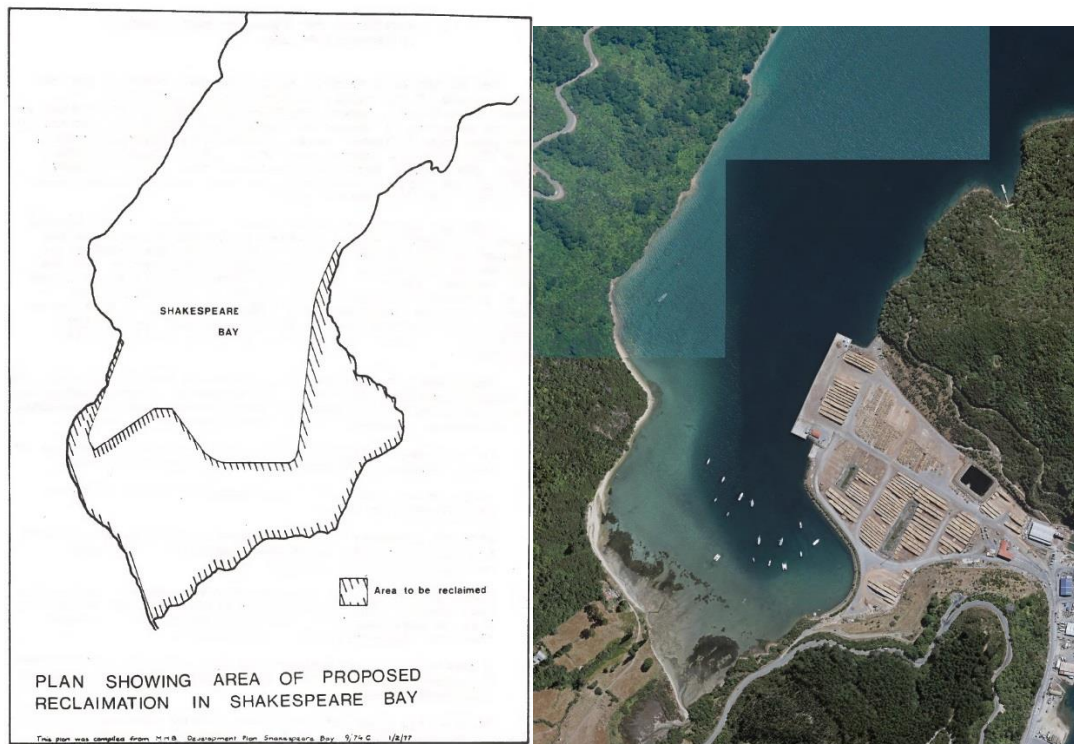


Figure 7. Proposed development (left, Knox & Bolton 1977) would have overtaken much of the head of Shakespeare Bay however a smaller area was developed, and sand/mudflats remain at the head of the bay (right). Image on right from maps.marlborough.govt.nz.

3.1.1. Key inputs from land

Land inputs may arise naturally, or as intended or unintended consequences of human activity. Land cover has important effects on the amount and types of contaminants (chemicals, sediments, etc.) likely to be discharged into the sea. While some sediment input is natural, any activity that disturbs the land is likely to increase sediment loadings in waters flowing into the sea. The historical deforestation and development of land for other purposes will have increased sediment inputs into the Bays.

Raw sewage was discharged at Kaipupu Point up until December 1999 after which MDC commissioned a new, upgraded, wastewater treatment facility. Treated sewage (activated sludge subjected to UV disinfection) continued to be discharged until the

end of 2012, via a shoreline pipeline to a submarine outfall at Kaipupu Point. In 2012, a new outfall was built to relocate the discharge further to the south in Picton Harbour.

For most of the last century, a freezing works existed in Shakespeare Bay. The works discharged wastewater and by-products into the bay from 1900 until the 1970s. To reduce impacts of the outfall, it was moved approximately 600 m in 1972 to a site with more efficient flushing (Knox & Bolton 1977). The works closed in the early 1980s.

Stormwater is discharged into the marine environment at Waikawa, Picton, and Shakespeare Bay. Council has been working on improving infrastructure to limit water quality problems at the Picton foreshore (Henkel 2015). Other current discharges include input from damaged or otherwise compromised septic tank systems, discharge from vessels, and the Wharetukura outfall in Waikawa Bay. Other minor discharges are not listed here.

4. ENVIRONMENTAL INFORMATION AND STATUS

4.1. Baseline information

There is limited information available to describe general historical characteristics of marine ecosystems in Picton Bays. A current project to assess benthic change on the basis of existing literature will be informative of broad change in Queen Charlotte Sound / Totaranui (Handley, in prep), and findings from that work will apply to historical change in Picton Bays. The lack of information preceding the impacts of human activity is recognised in Marlborough (Davidson *et al.* 2011; Handley 2015), as it is in much of the world.

In general, marine habitat in Queen Charlotte Sound / Totaranui consists of a narrow band of rubble or cobble that forms a nearshore reef. Beyond reef areas, soft sediments dominate, and generally become finer with depth. Few estuarine wetlands are found in the Sound, and those that exist are small. Unlike Pelorus Sound, no large rivers discharge into Queen Charlotte Sound, and the water there is generally clearer than in Pelorus Sound (Lucas Associates 1997). A project to identify ecologically significant marine sites in Marlborough (Davidson *et al.* 2011) identified Bob's Bay as a potentially important habitat, but no other areas within Picton Bays have been identified as ecologically significant. Marine reserves provide an indication of how the environment may change in the absence of fishing pressure, but no marine reserves exist in Picton Bays, or in areas comparable to the Picton Bays.

State of the environment surveys are planned for estuarine areas in Picton Bays. Surveys are to be conducted in Waikawa and Shakespeare Bay in late summer 2016, and will assess physical and biological characteristics of the estuaries. These surveys are designed to be repeated over time, which allows for an assessment of trends in estuarine health. Estuaries are important ecologically as they mediate land-sea interactions, and provide a range of important habitat types. For example, both of the bays are known to support seagrass beds. Seagrass plays a particularly valuable role in marine ecosystems as a benthic primary producer, and provider of high biodiversity and nursery habitat.

A number of projects have undertaken local habitat characterisations and biodiversity measurements, although these are targeted to particular purposes, such as environmental assessments prior to construction projects (Bolton 1991, Roberts 1993; Davidson 1996; Conwell & Sneddon 2009a; Sneddon 2010b), and biosecurity surveys (Inglis *et al.* 2006). In general, these environmental assessments have been undertaken near areas of the sea bed that are already highly disturbed by existing activity (*e.g.*, ferry berthing near Picton wharf, Davidson 1996) or in areas representative of the communities of the wider Queen Charlotte Sound / Totaranui. Unique communities have not been identified in the course of these assessments. Many recorded species have been associated with artificial structures rather than

natural substrates, but potentially habitat-forming species such as horse mussels have also been recorded (Davidson 1996). Davidson identified large amounts of scallop shell material near the Picton wharf in 1996, which implied both a live population of scallops, and areas of more structure than the soft mud seabed that dominated. It was noted, however, that coarser seabed materials may have been scoured out by water movement resulting from ferry activity. Red algae beds on soft sea bed were also observed near Picton wharves.

Prior to the construction of the wharf at Shakespeare Bay an ecological survey was undertaken (Bolton 1991) to facilitate assessment of the impacts of construction in the bay. This area was still recovering from the effects of contamination from freezing works waste, and the survey was targeted at the effects of wharf construction, rather than establishing a broad-scale baseline. The report recognised the ecological importance of the estuarine area at the head of the bay. Biological communities in the bay were diverse and patchy, and the author noted that extensive study would be required to fully characterise some communities.

Intensive surveying was undertaken in Waikawa in consideration of an extension to the Waikawa marina (Sneddon 2010b). The communities present were typical of those found in the wider area of the Marlborough Sounds, dominated by sessile invertebrates in the intertidal zone, and macroalgae in the immediate subtidal. Much of the area (as surveyed by sidescan sonar) consisted of uniform soft sediments, although the sloping areas of seabed were made of coarser material (cobble, shell, pebble and coarse sand and gravel). The soft sediment areas had fewer organisms on the surface (epifauna) than reef and cobbled areas. The communities within sediments (infauna) were also made up of common invertebrates, largely crustaceans, polychaete worms, and bivalves. No biogenic reef structures were identified in the area surveyed.

Anecdotal information gives some indication of environmental change. For example, a local who regularly swam in the bays decades ago reported a decline in seaweed along the rocky reefs (reported to Ian Shapcott, Te Ātiawa o te Waka a Māui). It is likely that formal collection of such observations could yield further observations of habitat change.

Despite limited historical and baseline information, knowledge of coastal environments generally, and of historical and current activities in the area (see Section 2.3), enables identification of key topics regarding environmental stressors / pressures. For the purposes of this report, key topics are:

- contamination
- habitat integrity / structural change
- biosecurity / invasive species
- fisheries decline.

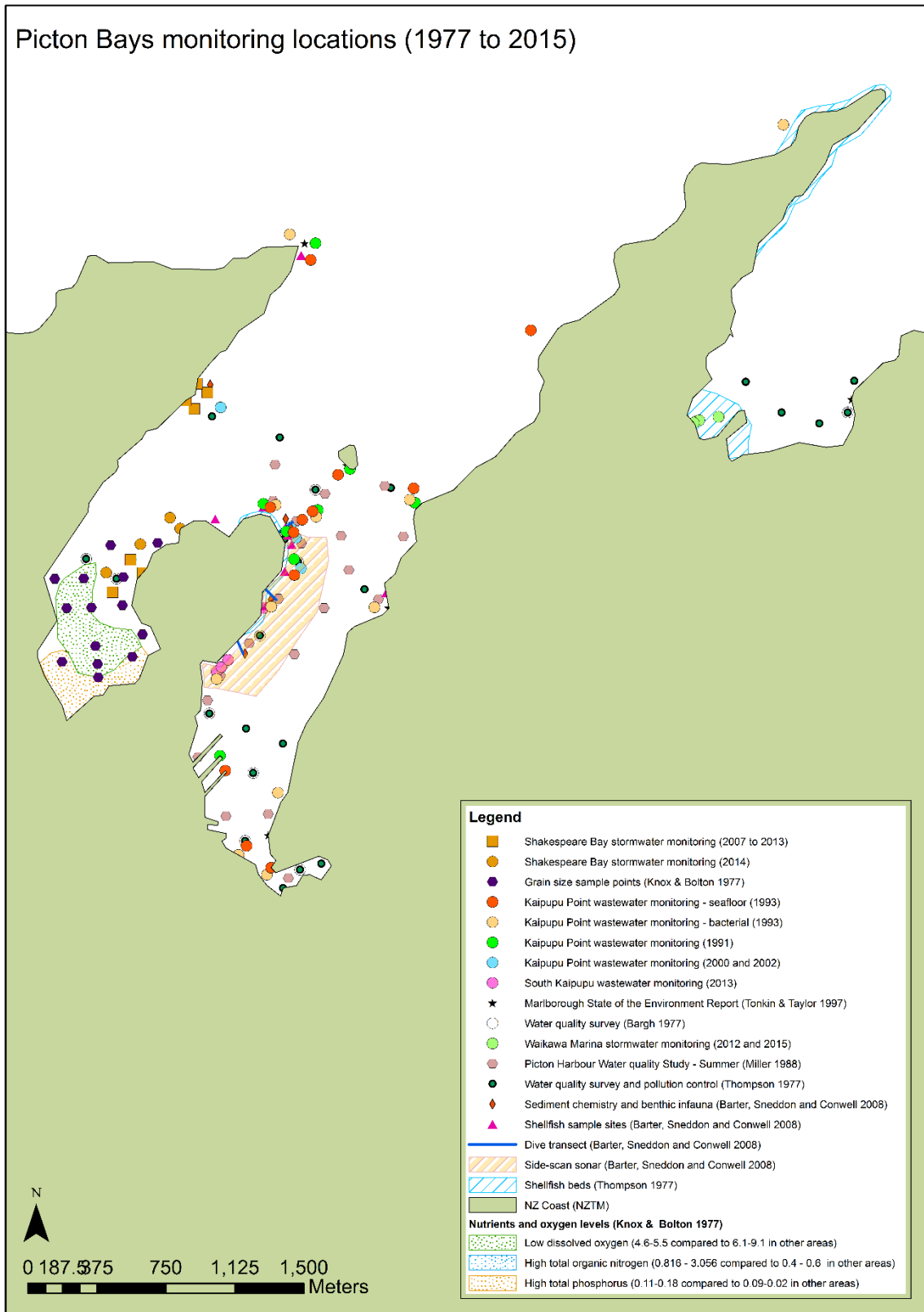


Figure 8. Picton Bays benthic and water quality monitoring locations, from 1977 to 2015.

4.2. Contamination

Contamination is a broad term for inputs of a number of substances that can have detrimental effects. It can have negative impacts in the water column (e.g. excess nutrients can cause algal blooms) and on the seabed (e.g., toxins can build up and damage natural communities). The following sections will describe the key contamination types and sources in the Picton Bays marine area. Sample distribution is mapped in Figure 8.

4.2.1. Key types and sources of contamination

The coastal environment in Picton Bays is likely to be affected by contamination from adjacent coastal areas, direct runoff from land, and riverine inputs. Local dispersal patterns¹⁰ will also spread contaminants far beyond the region of the original discharge. In the near-shore marine environment key types of contamination that can potentially result in adverse effects are: bacterial/viral, organic matter, nutrients, chemicals (hydrocarbons, pesticides, metals, *etc.*), inorganic sediment and litter. These are described in Table 1.

4.2.2. Monitoring for contamination in Picton Bays

Information about contamination in Picton Bays is available in numerous reports (summary supplied to council). Selected summaries from each body of information are presented below and a map of all available sampling locations is provided in Figure 8. To provide an overall picture of the status of different kinds of contamination in Picton Bays, we provide an overview by contaminant type in Section 4.2.3.

Early surveys

A series of surveys were undertaken in the 1970s in response to environmental concerns about discharges, principally the sewage discharges at Waikawa and Kaipupu Point, and freezing works waste discharges into Shakespeare Bay. These constitute the first formal environmental measurements that we are aware of. The general finding of the studies and some related observations are outlined below.

¹⁰ Hydrodynamic models have been developed for the Marlborough Sounds: Knight & Beamsley (2012) and Hadfield *et al.* (2014).

Table 1. Key types, sources, and possible effects of contaminants in Picton Bays.

Contamination type and sources	Potential effects	Monitoring method
Organic material and nutrients (incl. animal wastes, sewage, fertilisers)	<p>Eutrophication/enrichment from the oversupply of nutrients (e.g. nitrogen and phosphorus) causing:</p> <ul style="list-style-type: none"> Decreases in water transparency (increased turbidity), and perceived aesthetic value of the water body. Colour and smell Dissolved oxygen depletion Overproduction of phytoplankton, and/or benthic / epiphytic algae. Changes in phytoplankton species composition (e.g. increases in numbers of potentially toxigenic or noxious species). Loss of desirable fish species (fish kills), reductions in harvestable fish and shellfish Reduction of aesthetic and recreational values (e.g. tourism, swimming, fishing) Changes in community structure (e.g. increased dominance of opportunistic species), and reductions in taxonomic diversity <p>Pathogens (bacteria and viruses) associated with faecal material can cause:</p> <ul style="list-style-type: none"> Infections and illness either from contact with the water (usually accidental ingestion), or from consuming contaminated shellfish. Pollution of swimming beaches, risk to human health. Reductions in harvestable fish and shellfish (bioaccumulation). 	<p>Concentration of nitrogen, the amount of organic material in sediments, and the structure of the biological community.</p>
	<p>The indicators of faecal contamination usually used are certain types of bacteria (which may not in themselves be pathogenic).</p>	
Diverse chemical inputs: caused by e.g., fuels and oils associated with transport and power generation, other chemicals used in industrial processes, antifouling paints, emerging contaminants from human activity	<p>The oversupply of heavy metal/metalloids (e.g. arsenic, lead and copper) and trace organic compounds; including semi-volatile organic compounds (SVOCs) such as tributyltin (Tbt), a range of pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), pentachlorophenol (PCP), dioxins. Examples of related impacts include:</p> <ul style="list-style-type: none"> Stress or mortality of organisms; e.g. due to cellular damage, endocrine disruption, reproductive failure, imposex. Pollution of swimming beaches, risk to human health. Reductions in harvestable fish and shellfish (bioaccumulation and bio-magnification for some compounds). Changes in community structure (e.g. increased dominance of opportunistic species) and reduction in taxonomic diversity. 	<p>Laboratory analysis to detect compounds of interest (relating to activities in area). Sediments usually analysed, but can also be tested in water.</p>
Sediment (caused by e.g. agriculture, forestry, roading and other construction, shoreline erosion)	<p>Increased suspended sediment loads and sediment deposition causing:</p> <ul style="list-style-type: none"> Reduced light available for plant production. Smothering of benthic animals and plants. Clogging of gills and feeding structures of benthic and pelagic animals Avoidance of area by mobile taxa Changes in community structure (e.g. increased dominance of opportunistic species) and reductions in taxonomic diversity 	<p>Suspended sediment issues can be monitored through analysis of water samples or <i>in situ</i> water column measures of light transparency (e.g. turbidity, % transmission).</p> <p>Depositional effects can be monitored through analysis of changes in particle size distribution of underlying sediments.</p>
Litter	<p>Waste products that have been disposed of improperly. These include, plastic, glass, metal. Problems associated with litter include:</p> <ul style="list-style-type: none"> Plastics are eaten by many organisms and can cause mechanical injury, strangulation, or starvation. Smothering of seabed communities. Toxicity as some items break-down. 	<p>Visual assessment of the seabed and foreshore is normally adequate. If a finer scale assessment is required, incidental observations of anthropogenic debris in sediment samples can also be performed.</p>

Water quality surveys, 1977 Waikawa, Picton Harbour, Shakespeare Bay

A report on water quality from 1977 (Thompson *et al.* 1977) discusses improvements made by council over the preceding 10 years. Water quality in the Picton Bays was generally considered good, except near the sewer outfalls in Picton and Waikawa, and at inner Shakespeare Bay.

Freezing works waste discharges into Shakespeare Bay were seen to be enriching the receiving environment to the point that sulphide gasses were released from sediments and bubbled up to the surface. The area affected was large, with an approximate radius of 300 m. The pollution was localised but severe: 'the waters in areas of the inner bay are polluted by meat works effluent and have a pungent odour, are highly turbid in parts, contain particles of organic material, and at times, are red with blood around the discharge pipe.' (Page 20, Thompson *et al.* 1977). Heavy bacterial pollution was recorded, with faecal coliform concentrations 200 m from the outfall of up to 32,000¹¹ per 100 mL, and samples in the area frequently measuring greater than 1000 per 100mL. Other activity that could have damaged natural communities was also observed; 'hot water was seen being discharged into the southern end of the bay, but the effects of this were not investigated'. In response to a complaint in 1979 that Shakespeare Bay was badly polluted by fats, an investigation found that '[i]nner Shakespeare Bay was completely discoloured a deep red-brown...The foreshore of the inner bay for an extent of about 700 meters was covered from the high tide mark to the water with a greasy white foam which extended on the water surface a further three to four metres out....The discolouration was due mainly to blood and particles of fat, meat and animal faeces. The discoloured water was overlain by a thick transparent layer of fat'¹².

In a corresponding winter survey, light faecal coliform pollution detected in inner Shakespeare Bay was considered likely to be residual from previous summer discharges (Bargh 1977). Inner Picton Harbour had considerably lower faecal coliform pollution at some sites, compared to the summer survey (Thompson *et al.* 1977), however contamination at the marina was much the same as summer levels. This contamination was attributed to the stormwater drain in the marina. In Waikawa Bay, faecal indicator bacteria were similar to the summer survey levels.

Shakespeare Bay benthic survey, 1977

This survey included reference to a study of Shakespeare Bay by Knox in 1972, for which details were not available during the writing of the present report. In 1972, the seabed contained zones of severe pollution, to the point that no animals survived on beaches adjacent to the outfall from the freezing works. The 1977 benthic survey

¹¹ By way of comparison, standards for shellfish gathering (refer MfE 2003) require that not more than 10% of samples over a season exceed 43 faecal coliforms per 100mL.

¹² A letter from the Chief Engineer to the Chairman of the Marlborough Catchment and Regional Water Board. Downloaded 06-11-15 <http://www.marlborough.govt.nz/> Marlborough District Council Property Files, Resource consent application to discharge polluted water containing meat and by-products wastes for a period of five years from date of issue into Shakespeare Bay from a factory on property Pt Secs 1, 2, 3 and 4 Dist of Shakespeare Bay Blk XII Linkwater SD Marlborough LD. Ref MLB750101, 'Application and Decision'.

found some improvement due to the outfall pipe having been moved into a deeper area with higher water movement. Nonetheless, impacts of freezing works discharges were apparent, including heavy bacterial contamination.

Waikawa Bay stormwater

Treated stormwater is discharged into Waikawa Bay. There are six reports concerning the effects of Waikawa Bay stormwater on water quality (ranging from 1977 to 2014) (Bargh 1977; Thompson *et al.* 1977; Tonkin & Taylor 1997; Barter 2012; Barter & Elvines 2012; Elvines & Allen 2015).

- **Metal concentrations in water:** Assessment of the metals (copper, zinc and lead; as part of consent monitoring), found levels of copper that exceeded the ANZECC (2000) trigger values identified for protection of 80% of species. Copper levels decreased with increasing distance from the outfall, however levels at the most distant site ('control') were also still often over the guideline levels (Elvines & Allen 2015). Zinc (another key ingredient in anti-fouling products) also generally exceeded guideline levels near the outfall, and had been recorded at guideline levels¹³ at the farthest site in recent monitoring (December 2015).

Visual effects: Clarity (via visual estimate¹⁴) was generally high (~4 m) within 10-20 m of the discharge point. An exception occurred in 2014, when turbidity was 2–3 times higher than the control values (0.5–3.1 NTU) and total suspended solids (TSS) were up to 5 times the control site values (1–9 g/m³; Elvines & Allen 2015).

Port Shakespeare industrial stormwater

Stormwater is discharged into Port Shakespeare from the port facilities. Monitoring specific to this activity is relevant to contamination by sediments and chemicals, and addresses both water column and sediment characteristics. Selected findings are summarised below.

Sediment quality monitoring

The following parameters were measured at Port Shakespeare over a baseline survey (KMA 1995)¹⁵ and five monitoring events (Barter & Thompson 2003; Hopkins & Barter 2005; Sneddon *et al.* 2007; Conwell & Sneddon 2009b, 2009c; Sneddon 2014a), to determine benthic quality relating to stormwater discharges into Shakespeare Bay.

- **Sediment observations:** Sediments in the study area were soft and grey-brown in appearance with an underlying shell / gravel mix noted (in 2014) closer to the discharge point. No sediment anoxia¹⁶ was noted, however slightly darker sediments were noted near the outfall in 2014.

¹³ The acceptability of lead levels (and to a lesser extent, copper and zinc) was reported to be difficult to assess against guideline levels as the test used was not sufficiently sensitive.

¹⁴ Unclear whether this was estimated was made via eye, or if a black/secchi disk was used.

¹⁵ KMA 1995. Port Shakespeare baseline environmental monitoring programme. Results referenced in subsequent Cawthron monitoring reports.

¹⁶ Such as black colouration or a 'rotten egg' smell (due to iron or magnesium sulphide and hydrogen sulphide) which are qualitative indicators of enriched conditions.

- **Sediment grain size:** Silt and clay content at the monitored mixing zone and controls sites ranged from 27–56% and 30–52% silt and clay respectively. The 2009 report mentioned that the higher percentage fines detected throughout all sites, was ‘likely due to regional changes in sediment properties or to small-scale benthic variability, rather than to a stormwater-related effect’ (Conwell & Sneddon 2009b).
- **Sediment organic and nutrient content:** An increasing trend of organic enrichment with increasing distance from the discharge source suggested the outfall was not an important enrichment source.
- **Sediment metal concentrations:** In general, concentrations of copper, lead and zinc were below the best available guidelines indicating possible ecological effects (ANZECC 2000), and also increased with increasing distance from the discharge point. The 2014 report suggests this trend might relate to a historic influence from the former Kaipupu Point wastewater discharge location.
- **Petroleum hydrocarbons and organotin compounds:** These compounds were below detection limits in sediments from all four stations, consistent over all monitoring surveys (where tested).
- **Biological community characteristics:** The baseline study (KMA 1995) found that sediments closer to the outfall supported a more diverse infaunal community than the control sites (200 m sites). In most survey years (1995, 2003, 2007¹⁷, 2009, 2014) there were no clear distinction between the communities near the outfall (mixing zone) and the 200 m zone. The 2005 results were the exception to this, but variability was considered to have arisen mostly from factors unrelated to the outfall. Overall, the community assemblage featured common benthic macroinvertebrates such as crustaceans, a variety of polychaetes, and small bivalves; all characteristic of a surface detritus/mud/sand habitat. Opportunistic taxa *Theora lubrica*¹⁸ and *Prionospio* sp.¹⁹, were particularly abundant in the mixing zone in 2007, but dropped in abundance in 2009 and 2014.
- **Shellfish bioaccumulation:** Blue mussel (*Mytilus edulis galloprovincialis*) tissue concentrations of three metals (Hg, Cu, Pb and Zn) and a suite of polycyclic aromatic hydrocarbons (PAHs) were tested. All trace metals were consistently below relevant national and international guidelines for food consumption at the time. No patterns of metal or PAH/SVOC accumulation in blue mussels were reported in relation to distance from the stormwater outfall, and differences between surveys were considered to be within natural metal concentration ranges. However, PAHs results were difficult to compare between surveys, as there was variability in the organic compound analyses.

¹⁷ In 2007 more sampling sites were introduced in an effort to more effectively detect discharge related impacts along a likely dispersion gradient. Results showed an increase of abundance at the mixing zone edge however, similar to previous years interpretation, the high abundances were not supported by patterns in sediment nutrient and organics content, and were thought to be related to the finer substrate at these sites.

¹⁸ *Theora lubrica* is a short-lived introduced Japanese bivalve species that can rapidly colonise disturbed and muddy habitats. It is thought to be tolerant of pollution, low oxygen levels and disturbance.

¹⁹ *Prionospio* sp. or close relatives are thought to be indicator species for organic enrichment.

Water quality monitoring

The water quality results from Port Shakespeare monitoring relate mostly to samples taken from the logging yard settlement pond outlet rather than environmental samples. Results have been summarised from the 1995 baseline report (KMA 1995) and annual monitoring results²⁰ (Sneddon 2006; Forrest & Sneddon 2007; Sneddon 2008; Sneddon 2009, 2010a, 2011b, 2012, 2013, 2014b). These have been supplied to council in an electronic appendix, but because they were not monitored in the natural environment, are not included here. In summary, effluent concentrations of metals were much lower than consent condition requirements. Nutrients were generally low, although dissolved reactive phosphorous sometimes exceeded consent conditions. Biochemical oxygen demand also occasionally exceeded consent conditions, but fell within the range of natural variability. Suspended solids were generally below consent limits, and effluent measurement and field measurements of clarity did not indicate problematic impacts.

Kaipupu Point and Picton Harbour sewage outfalls

Reports relating to the untreated and treated sewage ranging from 1977 (broad scale reports; Bargh 1977; Thompson *et al.* 1977; Miller 1988; Tonkin & Taylor 1997), through to 2014 (activity-driven monitoring; Mackenzie 1991; Roan 1993; Barter 2000; 2002; Barter *et al.* 2008; Sneddon & Barter 2013; BECA 2014), have been reviewed. Wedge Point was often used as a control site in these studies (Figure 8). Selected findings are summarised below.

- **Sediment grainsize:** Silt and clay fractions (fine sediments) ranged from 30–65% and 13–77%, at the control stations and stations close to the outfall (close-proximity stations), respectively.
- **Sediment odour:** Characteristic hydrogen sulphide odour indicative of reduced sediment oxygen concentrations was noted frequently at the close-proximity stations up until 2008, after which no odour was noted.
- **Sediment organic and nutrient content:** Organic enrichment at the close-proximity stations was apparent in the 1990s. An overall improvement has been seen since the plant was upgraded.
- **Metal concentrations in sediments:** Concentrations of mercury in close proximity to the Kaipupu Point outfall were often at a level that might possibly have biological effect, according to recognised standards. However, low levels of contamination were a pre-existing condition at the new discharge site (Sneddon & Barter 2013), and mercury was often elevated at the control site as well, suggesting an anthropogenic source other than the outfall.
- **Metal concentrations in shellfish:** A 2014 report found copper and mercury at concentrations < 5% of median international standards (MIS) for trace elements in shellfish at 5 sites in or near Picton Bays, including Kaipupu Point and Picton

²⁰ Sneddon (2006) reports on 2004-2005 results.

- Wharf. Zinc was between approximately half and three-quarters of the MIS (BECA 2014). Zinc has exceeded the MIS in the past, but this was attributed to storm water runoff rather than from the wastewater treatment plant.
- **Faecal coliform concentration in shellfish:** In early monitoring, shellfish at both the control sites and the outfall sites were deemed unsuitable for human consumption, or at best marginally acceptable for consumption (based on MfE/MoH 2003). By 2008, faecal coliform content in shellfish flesh had been deemed acceptable for consumption for the first time since monitoring began. At five sites in or near Picton Bays, including Kaipupu Point and Picton Wharf, in 2014 faecal indicator bacteria were measured at or below approximately 1% of Ministry of Health guideline levels that indicate marginal suitability for human consumption (BECA 2014).
 - **Enterococci concentration in seawater:** Limited results from 1988, 1993 and 1997 suggest that prior to treatment upgrades beginning in 1999, enterococci levels around the outfall were variable and often in exceedance of guideline levels for contract recreation. For example, concentrations ranging from <5 to 10,000²¹ enterococci/100 mL were reported at Kaipupu Point in 1997 (Tonkin & Taylor 1997). Moderately high measurements of faecal coliforms away from the outfall post-upgrade suggested that other sources were contributing to faecal contamination.
 - **Benthic biological community characteristics:** Seabed infaunal community structure near the outfall was historically affected by effluent discharge, but this was also seen to recover after the treatment upgrade.

Boat yard and anti-fouling contaminants

Compounds including, zinc, copper, and tributyltin (Tbt) can be applied to surfaces such as boat hulls to prevent the build up of problematic biological communities. These compounds work by poisoning the organisms that would otherwise foul surfaces. Accordingly, when the compounds are released into the environment they can continue having toxic effects. Anti-fouling compounds can enter the environment either by leaching into the water column, or by particles such as paint flakes being deposited on the seafloor. Hotspots of contamination often occur near boat-washing facilities, where high volumes of paint particles are deposited as boats are cleaned.

Carey's Boatyard was situated on the southern side of inner Picton Harbour, between the footbridge, which was previously the marina entrance, and the Picton town wharves. It is understood that this boatyard had been in operation for around a century, however the Picton Harbour premises was closed down on 19 August 2005.

A national survey in 2002 (Stewart 2003) found that sediment concentrations of the anti-fouling compound diuron at the Picton Boatyard site were higher than at all of the

²¹ Concentrations over 140 enterococci/100 mL trigger "alert mode" surveillance for recreation contact: MfE/MoH 2003

other 11 tested sites. Water column levels were higher than most of the other 11 tested sites, exceptions being the Nelson marina and Waikawa slipway. In the Picton Marina, however, diuron was not detectable in sediments, although it was detected in water samples. This is consistent with the author's statement that hull washing facilities were not necessarily the source of all contamination at sites nationally, and that leaching of contaminants from boat hulls was also contributing. Hull-washing can cause variable and high levels of contamination in sediments due to paint flakes being washed into sediments, while leaching may impact just water column concentrations of contaminants.

In 2004 and 2005 benthic infauna analyses and bioaccumulation studies in wild and transplanted mussel populations were undertaken as part of monitoring of antifouling compounds (Stewart 2004; Stewart & Bennett 2006). Between sampling events in June 2004 and December 2005, the overall health of benthic communities in Picton Harbour was reported to increase, with statistically significant increases in benthic community abundance, richness and diversity increasing over this period. Explanations for this change were speculative, but it is relevant that since Carey's Boatyard closed down their Picton Harbour premises on 19 August 2005, inputs of hull-washing wastewaters would also have ceased around that time.

Results from a 2009 study addressing dredge disposal risks from contaminants in the area of Picton Harbour boatyard (Conwell & Sneddon 2009a) concluded that:

- **Sediment grainsize:** Sediments were generally dominated by silt/clay (~20-30%) and fine sand fractions, with a significant component also of very coarse sand and gravel.
- **Sediment odour:** Sediments closest to the boatyard had a characteristic hydrogen sulphide odour and were black in appearance, indicating a state of anoxia close to the surface. This was not noted at stations further away from the boatyard.
- **Metal and organotin concentrations in sediments:** Sediment metal concentrations at all boatyard stations exceeded best-available guidelines for probable ecological effects (ISQG-High; ANZECC 2000). However, concentrations decreased markedly within a short distance (e.g. 10 m) from the boatyard. While some further afield stations exceeded indicating possible ecological effects for mercury, copper and lead, the concentrations were significantly lower than those recorded closer to the boatyard. No guideline concentrations existed for the organotin compounds: dibutyltin, monobutyltin or triphenyltin. However, detectable levels were found at many of the close-proximity boatyard stations.
- **Semi-volatile organic compounds (SVOC):** Sediment concentrations of low molecular weight PAHs (polycyclic aromatic hydrocarbons) exceeded guidelines indicating possible ecological effects (ISQG-Low, ANZECC 2000) at all stations. The further afield stations exceeded the ISQG-Low criteria for high molecular

weight PAHs while the boat yard stations exceeded the ISQG-High criteria for this component.

- **Biological community characteristics:** The boatyard stations recorded the highest numbers of sediment infauna individuals, but these were largely dominated by opportunistic polychaetes (*Prionospio* sp. and *Capitella capitata*), nematodes and amphipods. Stations further afield supported generally higher species richness, but it was noted that there were no species of special ecological or scientific importance identified.

In Waikawa Bay, a survey of organotins undertaken in 2001 indicated historical²² contamination by the antifouling compound tributyltin (Tbt) (Stewart 2002). Levels were above guidelines for possible ecological effects (ANZECC 2000), indicating that sensitive species may have been affected. This survey concluded that the Waikawa boatyard was not a clear point source of the contamination, as Tbt was detectable at Double Cove as well. The 2002 national survey (Stewart 2003) found that sediment levels of the contaminant diuron were elevated at the Waikawa marina and slipway. Water column concentrations at the slipway were at the highest concentrations detected at the 12 sites tested with one sampling exceeding New Zealand Environmental Exposure limits. In 2009, sediments in Waikawa marina were elevated compared to those outside the breakwater, but only copper exceeded the guidelines for possible ecological effects (Sneddon 2010). In nearby areas outside the breakwaters, the concentrations of trace metals (chromium, copper, nickel, lead and zinc) were all below the corresponding ANZECC (2000) ISQG-Low guideline levels and semi-volatile organic compounds (SVOCs) were universally below trace-level detection limits (Sneddon 2010).

Diffuse runoff

Diffuse runoff often enters the nearshore coastal environment via rivers and streams. The Land Air Water Aotearoa (LAWA²³) website presents council data on a range of freshwater parameters for catchments across the country. Data are available for two catchments that discharge into or near the Picton Bays area; Waitohi River, and Graham River. These data are relevant to bacterial contamination and nutrient input. Both sites are classified as lowland forest sites, and are compared to all similar sites nationwide. Trends are also reported on LAWA, however the only trend detected in this data was an increase in turbidity over 5 years at the Graeme River site.

²² The age of the contamination is indicated by the ratio of different forms of organotin in the sediments, which change as Tbt degrades

²³ www.lawa.org.nz

Table 2. Water quality data from Land Air Water Aotearoa for two streams that feed into the study area.

Water quality parameter	Waitohi River at State Highway One	Graeme River at road bridge
Bacteria	Best 50%	Best 50%
Turbidity	Best 50%	Best 25%
Total oxidised nitrogen	Best 25%	Best 25%
Ammoniacal nitrogen	Best 25%	Best 25%
Dissolved reactive phosphorous	Worst 50%	Worst 50%
pH	Best 25%	Best 25%

Picton Bays area - litter

Litter may be considered diffuse contamination as it can be blown into the sea, or washed in from the shore (or directly deposited by people). There is little monitoring-related literature available on the amounts of litter or anthropogenic debris in the Picton Bays area. However, while the pressures on the environment increase with increasing population, the number of clean-up initiatives also appears to have increased. Site specific clean-up initiatives taking place in the Picton Bays area demonstrate problematic littering areas. Occasionally the events report on the amount of litter being collected. Some community clean-ups are undertaken on land, including in Victoria Domain (where household rubbish is regularly dumped over the edges of the road), and on beaches.

Community groups also undertake clean-ups in the sea. For example, a series of dives to collect rubbish from the marine environment have been coordinated by local divers. The results from these events have been posted online²⁴ as part of the Project Aware Dive Against Debris initiative. In summary, dives at Waikawa Bay and Double Cove (opposite side of the Queen Charlotte Sound to Picton Bays) in 2013 and 2015 have yielded over 1500 items, dominated by glass, plastic, and metal. On occasion the rubbish has exceeded the ability of volunteers to transport it away²⁵. While rubbish is still an issue, one participant stated the belief that people's behaviour is slowly improving²⁶. Accordingly, while contamination of the marine environment with rubbish still occurs, it is probable that far less material is both entering and remaining in the sea than in past years.

Picton Foreshore and Waikawa Bay - swimming site monitoring

While consent-associated monitoring is focussed on the potential for a particular environmental effect, swimming site monitoring is focussed on use—*i.e.*, bacterial contamination and risk associated with recreational contact with water. A number of

²⁴ <http://www.waikawadivecentre.co.nz/page23/page27/DiveAgainstDebrisMap.html>

²⁵ <http://www.stuff.co.nz/marlborough-express/news/66918415/Boatloads-of-trash-retrieved-from-cove>

²⁶ <http://www.stuff.co.nz/marlborough-express/67976926/dive-clean-up-reveals-boaties-dirty-habits>

freshwater and marine sites are sampled by council throughout the summer, two of which, the Picton foreshore and Waikawa Bay, are within Picton Bays.

Seawater enterococci²⁷ concentrations over successive 5-year periods show that concentrations at Waikawa have been very steady, and lower than at Picton (Henkel 2015). The concentration at Picton has, nonetheless, been declining steadily, and while in 2012 the 5-year 95th percentile was in the 'unsafe' zone, in the past three sampling periods contamination over the preceding 5-year period has placed it in the 'increased risk' zone (Henkel 2015). Most samples are of course much lower than the 95th percentile, and those peaks in concentration that do occur (in Picton more so than at Waikawa), are considered to be associated with rainfall.

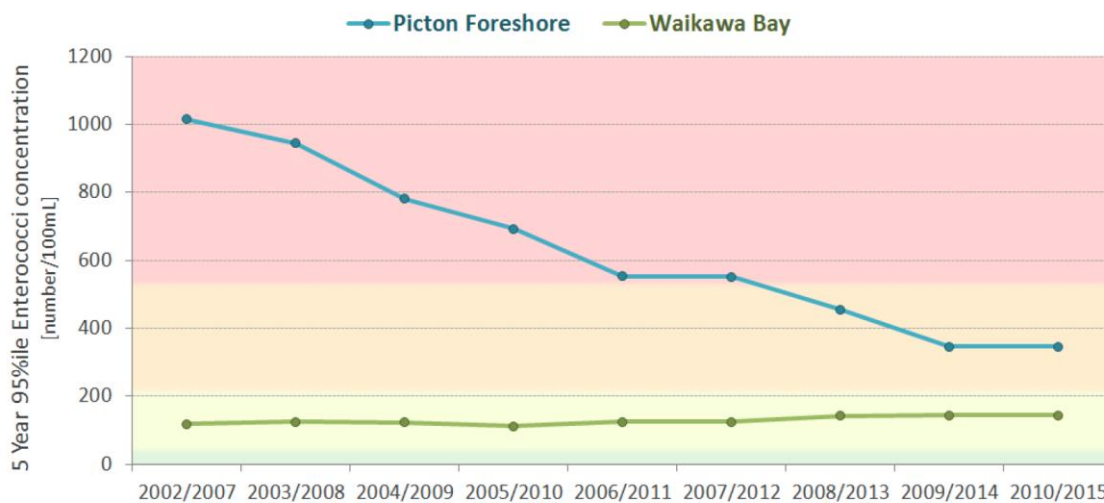


Figure 9. Enterococci levels at Picton foreshore and Waikawa Bay. 95th percentile results integrated over progressive 5-year periods. Shading indicates Unsafe (pink) Increased Risk (yellow) and Safe (green) ranges (Henkel 2015). (Ref Henkel)

While swimming site monitoring data were not collected for the purpose of assessing suitability of waters for shellfish gathering, it is possible to make an estimate. At both Waikawa and Picton the 5-year 95th percentile is over 100 enterococci per 100 mL. One hundred enterococci equates to approximately 170 faecal coliforms²⁸ (MfE/MoH 2003). The Ministry for the Environment guidance (MfE/MoH 2003) states that for shellfish gathering waters, not more than 10% of samples over a season should exceed 43 faecal coliforms per 100mL of water. This is approximately the same as saying that the 90th percentile should not exceed 43 faecal coliforms per 100 mL. It therefore appears that the water at both Waikawa and Picton waterfronts is overall unsuitable for shellfish gathering.

²⁷ Enterococci are a kind of bacteria used to indicate faecal contamination. Guidelines use three ranges, termed 'modes' to categorise risk to health on each sampling occasion (MfE 2003).

²⁸ Faecal coliforms are another kind of bacteria that indicates faecal contamination.

It is important to note, however, that water column measurements are not a good indicator of bacterial loading in shellfish, and direct measurement of shellfish flesh is recommended for this assessment.

4.2.3. Overview: contamination

While the above summarises contamination information by source, below we consider the state of knowledge about each type of contamination. This includes summary of the information above, but also consideration of other less-targeted information sources that may be relevant.

Bacterial

The largest causes of bacterial contamination have historically been the discharge of raw sewage at Waikawa and Kaipupu Point, and the extreme contamination caused by freezing work effluent in Shakespeare Bay. These sources have been eliminated, and extreme levels of contamination recorded in the past would not be expected now. Information on current levels of faecal contamination is provided by council monitoring of bathing water, and freshwater monitoring information (both data sets are publically available on LAWA). Some background level of faecal contamination is expected due to the presence of birds and other animals. Human activities such as untreated sewage discharges are often responsible for peaks in indicators of faecal contamination. Improvements in the treatment of municipal sewage have occurred, and stormwater systems are being upgraded to retain material during high rainfall events. A clear improvement has been documented at the Picton foreshore over the last decade. Diffuse sources of faecal contamination do persist, however. Ongoing improvement of diffuse sources of contamination (septic tanks, discharge from vessels, faecal contamination of streams and land-runoff) will continue the trend of improving water quality. The sources of diffuse faecal contamination can be identified with microbial source tracking (MST). This uses genetic techniques to identify the source of the bacteria (e.g. human, ruminant, avian) (Cornelisen *et al.* 2011).

Organic matter and nutrients

As for bacterial contamination, the largest causes of organic enrichment have historically been the discharge of raw sewage at Waikawa and Kaipupu Point, and the freezing work effluent in Shakespeare Bay. These were visible on the sea surface and caused odour problems, as well as having substantial impacts on the water quality and seabed communities. The elimination of these sources of enrichment has seen the environment recover, and seabed enrichment is presently not generally related to these inputs.

LAWA data shows that relatively high levels of phosphorous enter the Picton Bays via streams, but nitrogen inputs are relatively low (*i.e.* the streams fall within the best [lowest inputs] quartile of comparable New Zealand streams). In general, marine environments are nitrogen-limited, therefore nitrogen inputs are more likely to cause

enrichment than phosphorous. LAWA data did not identify a trend over the timeframe of available data.

Chemical contaminants: e.g. metals, antifouling compounds, emerging contaminants.

Only relatively recent data on these contaminants is available, and no consistent trends have been identified. Nonetheless, restrictions on particularly environmentally damaging substances such as Tbt have been introduced nationally, which has reduced or eliminated new inputs of these toxins. Some evidence that contamination levels are diminishing is available.

Some chemical contamination, such as zinc, mercury, and Tbt, is measurable in Picton Bays, but available information indicates that this is not widely present at harmful concentrations. Moderate or high contaminant levels that have been found at the boat yard sites, or in marinas, are localised and decrease markedly over short distances. Several monitoring studies refer to residual impacts of chemical inputs, or more diffuse inputs, which are measurable in the monitoring studies, but are not related to the activity being monitored.

Numerous other compounds are, however, being identified as potentially harmful in the marine environment. Initiatives addressing potential risks of a broader range of contaminants (such as those from pharmaceuticals and personal care products) are underway locally (Stewart *et al.* 2015) and internationally²⁹. The potential exists for expansion of monitoring requirements to incorporate emerging contaminants as knowledge of risk improves.

Sediment

Little information on small-scale sediment inputs is available³⁰, although substantial historical deforestation will have caused high sediment inputs to the marine environment. While the limitation of large-scale deforestation in the immediate area limits new inputs, other sources persist. For example, iwi have expressed concern at sediment input into Waikawa Bay associated with earthworks activity, and reports of numerous slips resulting from roading activity include 400 m³ of material entering Shakespeare Bay in 1990³¹.

Because local soils are very fine-grained, the Marlborough Sounds are particularly susceptible to coastal contamination by terrestrial sediment. Moreover, sediment contamination in areas such as Picton Bays would be expected to have particularly enduring effects, as the bays are very sheltered, with limited tidal exchange of water and associated currents (Urlich 2015).

²⁹ www.setac2015.org.nz/programme/workshops/

³⁰ Inputs into different coastal areas of New Zealand have been modelled and estimated by NIWA (Hicks in Morrison *et al.* 2009), <https://www.niwa.co.nz/freshwater/management-tools/sediment-tools/suspended-sediment-yield-estimator>

³¹ Anonymous report supplied to MDC by retired Marlborough Roads engineer.

Coastal erosion has been identified at a number of sites, and may be exacerbated by ferry wakes and foreshore modification. Bob's Bay and Shelley Beach have been closely studied. While the focus of this work is not the marine environment, it nonetheless identifies additional sources of sediment contamination (Ward & Edwards 2015a, 2015b). Beach replenishment with harbour dredge and river materials has also been reported at Shelley Beach (Ward & Edwards 2015b), and it is recognised that this could cause smothering of benthic organisms.

Insufficient information exists to identify trends in sediment input into Picton Bays. Sediment coring in combination with a variety of dating methodologies is a useful approach to understanding historical sediment input. The Pelorus Sound seabed sediment coring project is currently underway in partnership with the Ministry for Primary Industries (MPI) and the Marine Farming Association (MFA). Results are to become available in 2016, and are expected to provide information on seabed characteristics before human settlement.

Litter

Information on littering is largely informal and anecdotal. Pre-human background levels of litter would obviously have been zero. While littering is generally considered less socially acceptable than in the past, litter is still discarded in such a way that it can end up in the sea. No quantification of the amount of litter in the sea is available, and the impact on the immediate environment of Picton Bays is uncertain. This is, however, an issue of importance to the community, as evidenced by the voluntary effort assigned to clean-up initiatives.

4.3. Habitat integrity / structural change

Habitat integrity, as used in the present report, refers to the extent to which the physical structure of the habitat is suitable for the naturally-occurring biological community. This can refer to either inorganic or biogenic (created by organisms) structure. In general, unmodified habitat would have greater structural integrity. Alterations to habitat such as changes in sediment grain size or loss of plants and animals that created structure will invariably have implications for biodiversity. Human impacts on the hydrodynamic environment can also be considered an aspect of habitat integrity, as water movement can cause physical disturbance or zonation.

4.3.1. Reclamation and construction

Substantial changes in the nearshore seabed and coast have taken place in all three bays, although it should be recognised that in Waikawa and Shakespeare bays larger developments were proposed. Limitation of these developments has seen the retention of intertidal sand/mud flats at the head of Shakespeare Bay, and a small area in Waikawa Bay.

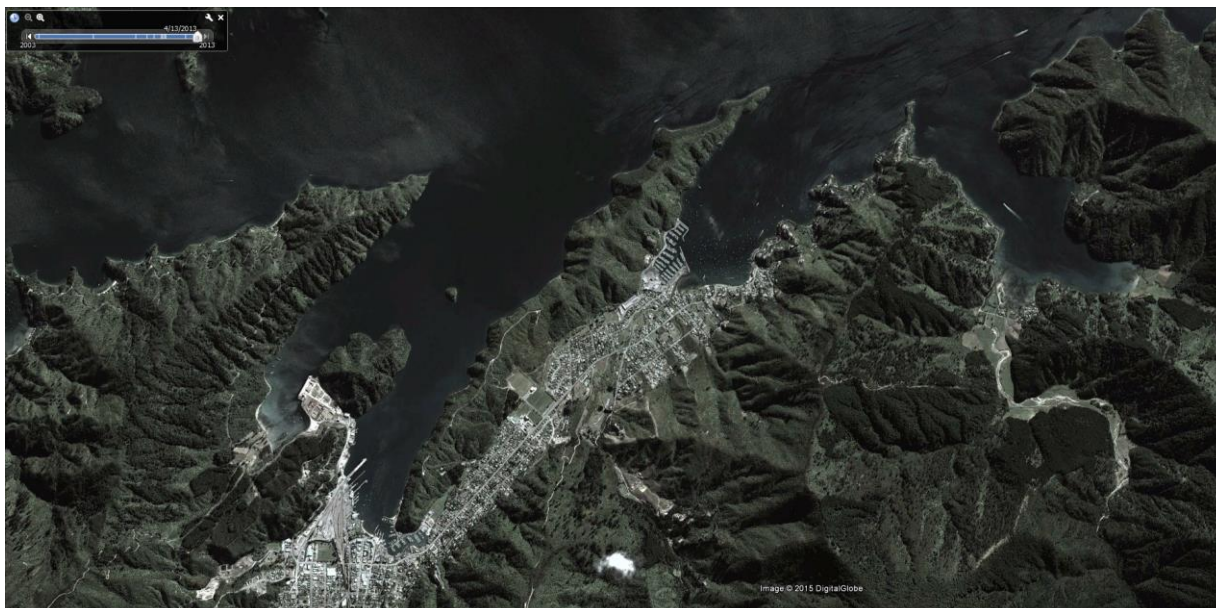


Figure 10. A Google Earth image taken in 2013 shows the extent of modified coast in Picton Bays. No natural coastal habitat remains at the head of Picton Harbour, while substantial modification has occurred in Waikawa and Shakespeare Bays. Small remnant sandflats are apparent on the eastern side of the Waikawa Stream.

In Picton Harbour, all the areas of natural intertidal sand/mud flats have been converted to reclaimed land, port, or marina. The Waitohi lagoon once held significant saltmarsh wetland habitat. This area is now the site of the large wharves and ferry terminal on the west of Picton Harbour. The loss of this habitat is considered by iwi to have been very detrimental to the health of the Picton Harbour (Ian Shapcott, Te Ātiawa o te Waka a Māui. pers. comm.).

Wharfs, jetties, and mooring blocks have also been created over top of natural habitats. In some cases, artificial structures can support communities that are similar to natural communities, such as in parts of the marina breakwaters in Waikawa (Sneddon 2010). In some areas, the effects of the artificial structure and other associated impacts (such as toxicity from anti-fouling compounds) are difficult to separate (Sneddon 2010). It is therefore unclear the extent to which reclamation itself has adversely affected community structure in a functional sense.

4.3.2. Ferry wake disturbance

Physical alterations of habitat structure would have begun in conjunction with wake disturbances from early shipping traffic and the initial implementation of the Cook Strait ferry between Picton and Wellington. Notable changes in structure of shoreline communities (shallower than 1 m deep) occurred with the advent of higher speed ferries in the 1990s (see Gillespie 1996). Cobble/boulder shore communities were the most impacted by wave effects, however the extent to which communities were already changed due to existing wake effects was unknown (Gillespie 1996).

A comprehensive dataset from rocky intertidal and subtidal coastal areas in the region was collected and analysed to assess the effects of fast ferry wakes (Davidson *et al.* 2010). This study was undertaken at the request of MDC and the Department of Conservation (DOC) in response to the introduction of an 18-knot speed limit for ferries in the Marlborough Sounds. Some historical data was presented (from 1995 onwards), while surveys of some sites began just prior to the speed restriction coming into force in late 2000. Study sites were mostly outside the immediate area that this report is concerned with; however, the impacts of ferries would be expected to be observable across the ferry route extending into the Picton Bays. Some of the data was collected at Picton Point (The Snout), and the sites at Allports Island, Golden Point, and Monkey Bay are all close to the focal area of this report.

Disturbance of cobbled shores was apparent (Davidson *et al.* 2010), and was attributed to ship wake effects. After the speed restriction on fast ferries was implemented, recovery of biological communities on both cobbled and bedrock shores was documented (Davidson *et al.* 2010), indicating that the disturbance caused by the fast ferry wakes had consequences beyond that caused by other vessel traffic. There was also evidence to suggest that very large conventional ferries have also significantly impacted shoreline habitats (Davidson *et al.* 2010). The same view was expressed by an interviewee for this report (Tom Norton, Te Atiawa and long-time resident of the Marlborough Sounds), who stated that he has observed effects of the powerful wakes generated by the 'Kaitiaki', which began operation in 2005.

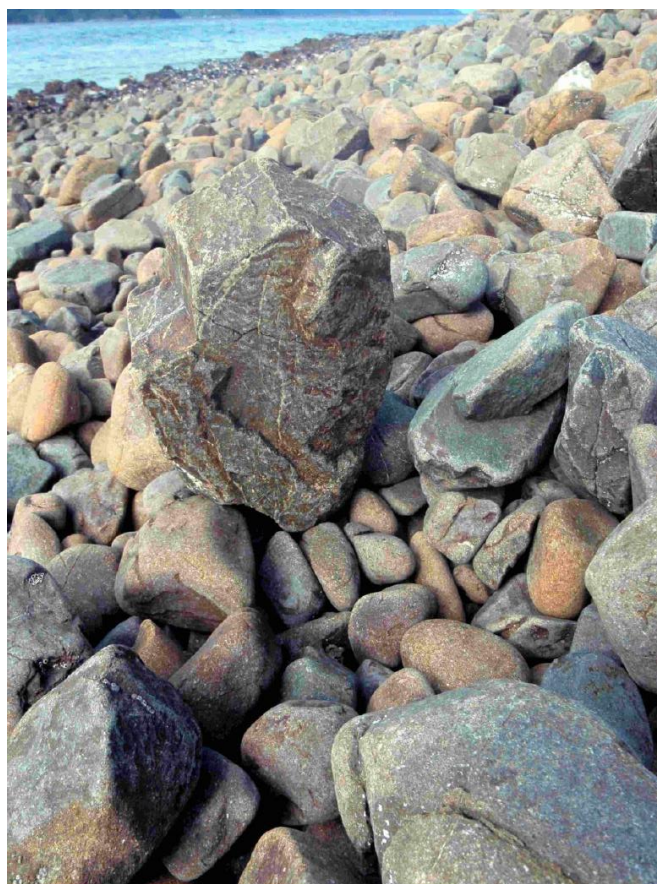


Figure 11. Intertidal mid-tide cobble shore, Picton Point, January 2010. Note: jumbled clean appearance of cobbles and a lack of fine substrata such as sand, broken shell and pebbles. (Davidson *et al.* 2010)

4.3.3. Sea level rise

In terms of the effects on near-shore communities, sea-level rise can be considered a reduction in habitat integrity. Hardened shoreline in the form of roads, rock walls/jetties, wharfs, *etc.* prevents tidal intrusion and natural habitat development. If shallow-water and intertidal biological communities cannot migrate up-shore (for example, if the foreshore has been modified), then changing water depths and wave exposures will have implications for those communities. Predicted sea level rise of up to nearly a metre by the year 2115 (Table 3) will change near-shore habitats, and likely increase coastal erosion in Picton Bays and in the marine environment generally.

Table 3. Range of predicted sea level rise (SLR) scenarios added onto the current mean high water spring tide level (MHWS). Results are assumed to be $\pm 0.25\text{m}$ to account for potential effects of ENSO and IPO. (Ward & Edwards 2015b)

	Current (m)	SLR 2030 0.15 – 0.20 m	SLR 2060 0.31 – 0.45 m	SLR 2115 0.65 – 0.95 m
MHWS	1.49	1.64 – 1.69	1.80 – 1.94	2.14 – 2.44

4.3.4. Seabed integrity and sediments

The structural integrity of the seabed can be reduced by input of fine sediments, but also by disturbance, removal or death of organisms that create structure, e.g., animals that create burrows.

As discussed in the contamination section above, substantial sediment input has occurred in Picton Bays, but no measurements of historical or current inputs are available. From monitoring data in all three bays, it is apparent that fine sediments are a large component of soft sediment areas of the seabed. Particle size composition of sediments ranges from approximately an eighth to three-quarters of the total.

Activity such as trawling or dredging (Handley 2006; Handley *et al.* 2014), anchoring or mooring (Sneddon 2010), and large vessel manoeuvrings (Davidson 1996) can disturb soft-sediment communities. Some disturbance exacerbates the effects of sediment input by re-suspending and mobilising fine sediment, and preventing burial under larger particles. Disturbance also prevents establishment of mature communities that stabilise the sediment surface and create heterogeneity. Destructive fishing practices are a concern in many areas of New Zealand, and Marlborough Sounds in particular³². The degree of contact fishing that takes place in the immediate area of Picton Bays is not known, however lower levels of fishing activity are likely to be the result of depleted stocks. Fishing activity would be expected to increase should stocks recover. Current fishing regulations permit trawling in Picton Bays for part of the year, subject to conditions. A commercial scalloping prohibition exists just west of the focal area (Ministry for Primary Industries 2015).

Dredging of marina and harbour areas has also taken place over the years and maintenance dredging is ongoing. This represents further degradation of seafloor habitat integrity. It was not possible to detail dredging history within the scope of this report.

It is likely that sediment input and disturbance has degraded seabed habitats, but no data were collected on seabed characteristics prior to deforestation and associated high sediment input. It is therefore not currently possible to describe or substantiate the change. Once again, coring surveys such as the Pelorus Sound seabed sediment coring project described above (with respect to sediment input) can provide historical information on seabed characteristics.

Significant site: Bob's Bay

One of the areas deemed an ecologically significant site in the Marlborough Sounds, Bob's Bay, falls within the Picton Bays (Davidson *et al.* 2011). In Bob's Bay, the

³² <http://www.stuff.co.nz/business/farming/aquaculture/71011779/biologist-calls-for-dredging-ban-in-the-marlborough-sounds>

polychaete *Bispira bispira* A. forms a bed of tubes that covers the sediments at water depths between 3 and 6 m. Tubeworm beds can be an important biogenic habitat, stabilising sediments and providing niches for other organisms. In the case of *Bispira bispira* A., however, it is not clear whether or not the species is native. Cawthron scientists plan to use genetic techniques to determine the origin of the species. Clearly the value of the tubeworm bed may be viewed differently if they are found to be a non-native species. Notably, small areas of tubeworm bed were identified in a survey at Waikawa Bay (Sneddon 2010), although it is not known if this is the same species.

4.4. Biosecurity / invasive species

Invasive species are undesirable for environmental, cultural, social, and commercial reasons. Part of the concern with invasive species in ports and marinas is that these locations are hubs where new vessels can be infested and the pest transported to and from other locations. Fouling species (those that grow on hard structures) can disrupt natural communities, and can cause a range of problems in aquaculture operations. At a meeting of Marine Biosecurity Management³³ in 2015, attendees agreed that social and cultural costs of invasive species incursions need to be considered as well as the economic costs. Ian Shapcott (Te Ātiawa o Te Waka a Māui) confirmed that from an iwi perspective, any incursion is unacceptable (meeting minutes, supplied by MDC).

The 2001 Port of Picton baseline survey for non-indigenous marine species (Inglis *et al.* 2006) identified nine non-indigenous species which included bryozoans, seaweeds, an annelid worm, a sponge and a sea squirt. Only one of these, the kelp *Undaria pinnatifida*, was on the register of unwanted marine species. Since that survey, two further incursions of unwanted species have occurred: the stalked sea squirt, *Styela clava*, and the Mediterranean fanworm, *Sabella spallanzanii*. Both, like *Undaria*, are considered by Biosecurity NZ as 'established' in New Zealand, but they are not distributed as widely throughout the country as *Undaria*³⁴.

Styela and *Sabella* may impact the local community by outcompeting native species for space and food, and changing the structure of the community. For both species, containment was attempted. In June 2013 during MPI's routine marine harvest site surveillance, four *Styela* were found in Picton's inner marina basin. A joint agency response was initiated with MDC, MPI, Marine Farming Association (MFA), Port Marlborough, and DOC. In mid-2014, *Styela* populations were found in Picton Marina and Waikawa Bay. The discovery in Waikawa meant that the plan to control *Styela*

³³ A meeting with representatives from MDC, Marine Farming Association, Port Marlborough, Te Ātiawa o Te Waka a Maui, Department of Conservation, and Ministry for Primary Industries

³⁴ Information on other pest species can be found at <http://www.biosecurity.govt.nz/files/pests/salt-freshwater/2012-New-Zealands-Marine-Pest-Identification-Guide.pdf>

was no longer formally operative, as it was proof that containment to the original Picton marina population had not occurred. At least one instance of a heavily infested vessel has also occurred (indicating new introductions). Eradication of *Styela* is currently considered unfeasible.

Multiple introductions of *Sabella* were also detected. In January 2014, *Sabella* was found on the hull of one vessel, but surveys indicated that no populations established from this introduction. However, since then further introductions have been identified, and *Sabella* has been found growing in Picton Marina.

Picton remains at high risk of future invasions. Wider surveillance was undertaken in 2015 around the Picton commercial area and Shakespeare Bay. The trial gave confidence that the area was relatively clean with no *Styela*, *Sabella* or other marine pests. Formal surveys of other areas in the Marlborough Sounds have not been undertaken. Discussions between Council and MPI to decide on future activity are underway.

4.5. Fisheries decline

Fisheries are an important component of biodiversity for recreational, commercial, and food-provisioning reasons. All commonly-exploited species are mobile (either as adults or larvae) and populations are connected on a much larger scale than that of Picton Bays. Management of fisheries is the responsibility of the Ministry for Primary Industries, and management units employed for stock assessment are also much larger than the area considered in this report. Nonetheless, informal reports indicate that fisheries in and around Picton Bays have declined over time. Here we report only briefly on fisheries information, some of which is from further afield than the Picton Bays themselves.

It is clear that abundant inshore fish stocks were present in Picton Bays and surrounds in the mid to late 19th century. A herring referred to as the Picton bloater was abundant at this time, and large hauls (up to four tons) were taken from Picton Wharf. Kahawai and flounder were also abundant. 'Miraculous' catches of up to 10 tons of kahawai and flounder in a day were reported³⁵. Processing (canning and smoking) operations were also established in the area in the late 19th century, and operations on a smaller scale occurred in the early- to mid-20th century (Tom Norton, pers. comm; Friends of the Marlborough District Library³⁶). The Kaiaua lagoon was named due to the large numbers of herrings and pilchards found there (Ian Shapcott, Te Ātiawa o te Waka a Māui. pers. comm.), suggesting that fisheries in the immediate

³⁵ As *High as the Hills*, by Henry Kelly, reported by Friends of Marlborough District Libraries:

<http://www.stuff.co.nz/marlborough-express/your-marlborough/73906759/sound-research-reveals-fishing-history>

³⁶ <http://www.stuff.co.nz/marlborough-express/your-marlborough/73906759/sound-research-reveals-fishing-history>

area of Picton Harbour were productive, and that the removal of this habitat has impacted fisheries.

Notable decline of fish stocks in more recent years is also reported, such as the reduction in cod over a 70 and 30-year time scale (Tom Norton, Ian Shapcott, pers. comms). Groper were caught regularly near Dieffenbach Point (to the east of the Picton Bays) approximately 70 years ago (Tom Norton, pers. comm.). Just over the past decade, a decline in flounder numbers has been observed³⁷.

Iwi and other community members also report that shellfish were much more plentiful in the past. Decline is due in part to loss of intertidal habitat (e.g. reclamation of intertidal sand or mudflats where cockle beds existed), but severe depletion of subtidal scallop beds is also widely recognised. Cockle beds in Waikawa now consist of only very small areas where shellfish are sufficiently large and numerous to collect for food. Scallops have been observed there, but numbers tend to be sparse (Sneddon 2010). Some shellfish beds were mapped in the 1970s (Thompson *et al.* 1977, Figure 8), but no current map was available to compare current distributions.

Shellfish populations in particular can be reconstructed from benthic coring, as shells can be buried over time by ongoing sediment deposition after shellfish die. Preliminary findings from the Pelorus Sound seabed sediment coring project include evidence of abundant shellfish beds (S. Ulrich, pers. comm.). Coring studies and other research may compliment cultural and other community knowledge in terms of quantifying and delineating historical shellfish beds.

³⁷ oral history reported by Marilyn Cowe, Friends of Marlborough District Libraries.
<http://www.stuff.co.nz/marlborough-express/your-marlborough/73906759/sound-research-reveals-fishing-history>

5. VALUES AND ASPIRATIONS

Numerous initiatives have been undertaken or are underway that capture values and aspirations of the tāngata whenua and residents of Picton Bays. It is beyond the scope of this report to attempt to capture all views, however two key elements in the development or articulation of values are:

- the Marlborough Marine Futures initiative, which is a developing multi-stakeholder process that aims to '[enable] citizen leadership in caring for our marine environment'³⁸
- Te Ātiawa Iwi Environmental Management Plan, which captures iwi aspirations and plans for environmental management

5.1. Marlborough Marine Futures

Marlborough Marine Futures is a process run by the Marlborough Sounds Integrated Management Trust, which is funded by MDC and the Canterbury Community Trust. The Marine Futures process was formally begun in 2015 in response to the need for an integrated multi-stakeholder approach to marine management. Concerns identified as motivations for the process include pressures on recreational and commercial fisheries, the substantial marine farming in the area and litigation surrounding this activity, the existence of only a single marine reserve, and absence of Māori management areas. The trust aims to increase citizen leadership and create a more collaborative and integrated marine management environment. Marlborough Marine Futures draws on models of marine management developed in the Fiordland Marine Guardians³⁹ and the Te Korowai o Te Tai o Marokura Kaikoura Coastal Guardians⁴⁰ processes.

5.2. Te Ātiawa Iwi Environmental Management Plan

The Te Ātiawa Iwi Environmental Management Plan⁴¹ (IEMP) expresses iwi concern about the state of the environment, and outlines wide-ranging resource management strategies and implementation frameworks. A key aspect of the relationship of iwi to the natural environment is the concept of kaitiakitanga, the text regarding this is therefore reproduced below⁴². Following that, some of the key information regarding the sustainable management of the moana is also reproduced. Reference to the full document is recommended for important context and complete information on the sea and other environments.

³⁸ www.marlmarinefutures.co.nz

³⁹ www.fmg.org.nz

⁴⁰ www.teamkorowai.org.nz

⁴¹ Available at www.teatiawatrust.co.nz

⁴² Text taken directly from the IEMP is italicised

5.2.1. KAITIAKITANGA (Section 2.1, IEMP)

Te Ātiawa ki Te Tau Ihu is kaitiaki in its Te Tau Ihu rohe. Te Tau Ihu is their unique place and it is the essence of identity and as kaitiaki Te Ātiawa is obligated to ensure that the environment is sustainably used and managed. This concept is kaitiakitanga.

For Te Ātiawa, kaitiakitanga means more than just mere guardianship and/or stewardship. It is an inherited and intergenerational responsibility to care for the environment for future generations. The purpose of kaitiakitanga is not only about protecting the life supporting capacity of resources, but of fulfilling spiritual and inherited responsibilities to the environment, of maintaining mana over those resources, and of ensuring the welfare of the people those resources support. Kaitiakitanga is the key cultural means by which sustainability is achieved.

In order for Te Ātiawa to meet their kaitiaki obligations, the IEMP has been developed as a tool for progressive implementation along with regular monitoring of the 'state of the rohe' and of principal taonga. To ensure the IEMP remains relevant, an Implementation Programme and a Monitoring Programme have been established; further differentiated through the use of key 'indicators', both scientific and cultural.

Kaitiakitanga in the rohe of Te Ātiawa ki te Tau Ihu will be about active commitment to sustainable management. It will involve day-to-day participation in resource and conservation management processes. The IEMP will inform all participants involved in the management of the rohe of the specific position and aspirations of the iwi.

It is important to note the natural world knows no boundaries on its ecosystems such as an IEMP. In Māori terms this is often referred to in the whakataukī – ki uta ki tai – literally a metaphor for the movement of water across the landscape from the mountains to the sea, and a reference to the relationship of the land, the interior of the country, to the coast. It is expected therefore that activities outside the rohe of Te Ātiawa will impinge on activities within the rohe. Partly this can be mitigated through valuable relationships with relevant parties so that co-management is possible or at least allowing each other to understand their respective actions.

5.2.2. Te Ātiawa IEMP: Sustainable management of MOANA - (sea –coastal / marine area)

Focus of kaupapa:

- Coastal / marine water quality
- Habitat integrity
- Provision for customary practices, including access

Kaupapa and context, (Section 6.7, IEMP)

Context:

The coast is the meeting place of Papatūānuku and Tangaroa. Traditionally, Te Ātiawa fished in lagoons, estuaries, river mouths and at sea. Fishing and the taking of shellfish, beached whales and marine flora all played an important role in Te Ātiawa economy and in social and spiritual life. The relationship of Te Ātiawa with the coastal and marine environments is of the utmost importance, both in terms of maintaining relevant customs and traditions associated with the sea, and as kaitiaki.

Historically, Te Ātiawa have lived by, travelled on, been sustained by, and made their living from the sea. The sea has an enduring spiritual importance. In many ways, this is still the case today. What has changed, however, is the pressure put on the sea and its natural resources by the behaviour of contemporary society; what's out of sight is out of mind and so the precious moana has often been used as a dumping ground for waste – solid and liquid – and the ecosystem has further suffered damage (e.g. removal of salt-marsh wetlands) and it has been heavily over-fished.

Indicative ... management concerns

The management of the rohe coastal and marine resources currently lies with the Ministry for Primary Industries, the Department of Conservation and the Marlborough District Council. Until recently, there has been a lack of recognition of the customary and spiritual relationship between Te Ātiawa and the coastal and marine resources in current legislation, policies and planning documents.

Also until relatively recently, there has been no integrated management framework for the lands, resources and coastal waters of the rohe, and there has been little recognition of the fact that there are clear associations (physical and spiritual) between land and water ecosystems. For example, tuna/eels move from one ecosystem to another.

There is also a lack of information available regarding the cumulative effects of a range of activities undertaken in the coastal waters of the rohe. Past and continuing degradation of the marine environment, deterioration of ecological health, the decrease in the abundance of key fish species and changes in water quality all indicate that current management of the rohe coastal resources is far from sustainable. As a result, the mauri, or life supporting capacity of the coastal and marine environments is being compromised.

There remains a loss of access to, and protection and enhancement of, Te Ātiawa customs, associated with mahinga mataitai, waahi tapu and waahi taonga, and a lack of involvement by Te Ātiawa in the management of islands and marine reserves. Marine reserves have also been established prior to the provision of customary fisheries, such as taiapure and mahinga mataitai.

Implementation framework, (Section 7.8, IEMP)

HEADLINE OBJECTIVE

The mauri of the coastal / marine resources will be sustained in perpetuity, and traditional Te Ātiawa practices and iwi aspirations will be realised

Objective 1: The quality of coastal / marine water throughout the rohe will be a priority outcome for all managers.

Objective 2: The integrity of the coastal / marine habitat, inclusive of saltwater wetlands and the coastal riparian habitat, which forms the coastal / marine ecosystem throughout the rohe, will be a priority outcome for the community and all the managers of the rohe.

Objective 3: Te Ātiawa Iwi will be able to freely participate in both traditional and contemporary cultural practices, in engaging the coastal marine resources of the rohe.

Management methods are also identified in Te Ātiawa's plan, and include activity in the areas of:

- Leadership
- Relationships
- Participation
- Capacity-building
- Advocacy
- Monitoring

The last management method, monitoring, is particularly relevant to the scope of this report. Monitoring needs are in response to 'the lack of data on ecological health and fish stocks [which] underscores the importance of monitoring, including monitoring of cumulative effects and use of customary indicators to ensure no further degradation results from activities being undertaken or proposed in Te Tau Ihu coastal and marine areas.' Development of pilot cultural indicators is planned locally. This initiative is also relevant to a number of other national projects that consider the development and use of cultural indicators in the marine environment. For example, there is a Department of Conservation project to work initially with Ngāti Toa to develop marine cultural indicators, and the project 'A Framework for the Development of a Coastal Cultural Health Index (CCHI) for Te Awanui' undertaken as part of the Maanaki taha Moana project in Tauranga Moana⁴³. Such projects are increasingly building positive relationships between traditional knowledge and western science kaupapa.

⁴³ www.mtm.ac.nz

6. CONCLUSIONS

The Picton Bays are an important and relatively high-use area of the Marlborough Sounds. They have particular importance to iwi, residents, visitors, and commercial operators. Human impacts on the marine environment are to some extent unavoidable, and in many cases are considered to be an acceptable trade-off for benefits received. In many (but not all) respects it may not be possible to recover any reasonable resemblance to the pre-existing 'natural' ecological state of the Picton Bays. Nonetheless it will be important to recognise and maintain or enhance the existing ecological state and attached values. Increasingly, both legislative requirements and public expectations require mitigation, if not elimination, of negative impacts of human activity on the marine environment.

Natural marine communities in Picton Bays are apparently similar to those in much of Queen Charlotte Sound / Totaranui, with only the estuarine areas, and possibly the tubeworm beds at Bob's Bay being of 'special' interest as defined by MDC and DOC. The marine environment in Picton Bays has suffered substantial negative human impacts over the last century or more, but many pressures have been reduced since the 1970s. The state of environmental health and impacts of human activity on the marine environment of Picton Bays are not well documented. Information collected about consented activity occurring in the marine environment can be quite robust, but information addressing larger scale, historical, and land-based stressors is limited.

The most severe impact on marine environmental health in Picton Bays may have been historical sediment input, which has presumably reduced seabed habitat integrity. Deforestation in the area was widespread, however the area is now largely vegetated. While the effects of very high historical sediment inputs are unlikely to be reversible in the next decades, measurement and reduction of further inputs could be addressed. Disturbance of the seabed maintains fine terrestrial sediments at the surface of the seabed, and accordingly exacerbates the impacts of sediment input.

Degradation of habitat integrity due to reclamation and construction has also been substantial. The very high disturbance from ferry wakes that was occurring late last century has been lessened, although large ferries and other vessels continue to dictate the ecological zonation of shallow environments. The present wake-affected habitat structure has now largely been accepted as the norm. It is noteworthy that at least some wetlands remain in the area despite plans having been put forward for reclamation.

A range of types of contamination are present, although the worst sources of contamination have been eliminated. Chemical contamination from anti-fouling materials is likely to be reducing over time, but differences in sampling methodology and lack of recent available data make it difficult to identify clear patterns. Contamination by organic matter, including faecal material, has been greatly reduced

since the 1970s, and council efforts to further reduce faecal contamination are on-going. In many cases consent-associated monitoring has identified background levels of contamination, *i.e.* those not associated with the activity being monitored.

Fish species have been seriously depleted from their historically highly abundant populations. This is likely the result of both overfishing and habitat destruction. Picton Bays, and the Marlborough Sounds generally, is at high risk of new introductions of invasive species.

A summary of stressors (or pressures) and the state and trends of environmental health in Picton Bays are presented in Table 4. A qualitative assessment of data quality* has also been made.

Table 4. State, trends, and data quality* of a range of stressors that are likely to be affecting the marine environment in Picton Bays

<p>Stressor: Sediment input State: Unknown Trend: Historically high, ongoing probably at a lower level Data quality: Non-existent⁴⁴</p>
<p>Stressor: Toxic chemical contamination State: Moderate localised impacts, minor wider detectability Trend: Unknown Data quality: Point-source focussed, Moderate (anti-fouling) High (stormwater) Note: emerging contaminants are not well-understood globally.</p>
<p>Stressor: Organic matter contamination State: Historically high Trend: Greatly improved Data quality: Medium</p>
<p>Stressor: Bacterial contamination (relevant to human health, rather than ecosystem functioning) State: Present, particularly from diffuse sources that enter the marine environment during heavy rainfall. Shellfish not fit for human consumption in some sites. Trend: Much less contamination than in 1970s, and on-going gradual improvement Data quality: Medium to high</p>
<p>Stressor: Litter State: Widespread impact, environmental impact unknown Trend: Ongoing but possibly decreasing Data quality: Low</p>

⁴⁴ Current sediment yield can be calculated with the tool at www.niwa.co.nz/freshwater/management-tools/sediment-tools/suspended-sediment-yield-estimator

Table 4., continued

Stressor: Construction degrading habitat integrity
State: Substantial degradation has occurred
Trend: Ongoing but possibly decreasing. The recent extension to Waikawa Marina is an example of current activity.
Data quality: Variable: Little data on communities impacted by historical change. Current changes thoroughly documented through RMA processes.

Stressor: Disturbance degrading habitat integrity – ferry wake
State: Moderate
Trend: Reduced from high in 1990s, currently stable. Could increase with larger vessels in future.
Data quality: High

Stressor: Disturbance degrading habitat integrity – seabed disturbance such as destructive fishing practices, harbour maintenance dredging (not ferry wakes or construction)
State: Probably at least moderate ongoing disturbance
Trend: Unknown
Data quality: Low

Stressor: Invasive species
State: Non-native species repeatedly being transported to the region
Trend: Pressure increasing
Data quality: Moderate

Stressor: Overfishing
State: Fisheries depleted, likely due to both overfishing and habitat removal
Trend: Absolute fishing pressure may be lower than in the past, but this is due to reduced fish stocks, relative pressure likely higher.
Data quality: Low (locally)

***Data quality classifications:**
 Non-existent = indirect information sources (e.g. anecdotal, estimated) only
 Low = some direct measurement, not ongoing
 Medium = measured on more than one occasion but inconsistent methods
 High = repeated consistent measurements available

There are gaps in our understanding of the pressures or stressors, state, and trends of marine environmental health in the Picton Bays. This is the case in much of New Zealand, and most of the world's marine environments. While a lot of information is available about some aspects of environmental status, this is generally targeted to a particular activity, rather than to making a general assessment of environmental health relevant to values in the area. Accordingly, there is a lack of repeated measurements with consistent sites and methodologies over time. Assessment of the state of the environment, as outlined in Section 2.1, requires:

- data from a range of representative areas (impacted and non-impacted)
- replication over space and time

- indicators that are relevant to the values that have provided the impetus for monitoring

Regional councils and unitary authorities in New Zealand are increasingly focussing attention on monitoring their Coastal Marine Areas. MDC has recently instituted a marine water quality monitoring programme⁴⁵. This will provide an ongoing data set from the Marlborough Sounds, and will provide context for some environmental information in the Picton Bays. Waikawa and Shakespeare Bay estuarine areas are to be surveyed for state of the environment monitoring in early 2016. These studies will also be of value in understanding pressures on Picton Bays, particularly as these surveys are designed to be repeated over time.

Design of further state of the environment monitoring specific to the Picton Bays may be appropriate, but would most likely occur in response to an assessment or summary of values in the area, which would allow for prioritisation of information. A range of aspects of environmental health could be measured, for example,

- species abundances for general biodiversity assessments or specific to fisheries resources⁴⁶
- a bays-wide assessment of contaminant levels
- changes in biogenic habitat (e.g. shellfish beds)
- sediment inputs and impacts on estuaries, the subtidal seabed, water clarity, or other factors
- local effects of sea level rise.

Integration of monitoring is also an important consideration. Some general considerations of how monitoring might be integrated between consent and state of the environment (SoE) are considered in Newcombe & Cornelisen (2014). The reports produced for Waikato Regional Council (WRC) (Forrest & Cornelisen 2015 and related reports) also contain information relevant to the development of SoE monitoring goals. Monitoring may occur for a range of reasons, and be undertaken by different sectors of society (e.g., iwi, community groups, schools, council, commercial operators or scientific institutions). Alignment of different types of monitoring can be beneficial to all stakeholders as it can provide efficiencies and synergies which add value to each individual aspect of monitoring. Suitable metrics or indicators could be developed dependent on the focus and purpose of monitoring, with regard to information collected in other monitoring work. This would allow for more effective comparison of data between monitoring programmes. Alignment can also occur in the identification of reference sites, timing of surveys, use of consistent data formats, and integration of communication initiatives.

⁴⁵ www.marlborough.govt.nz/Environment/Coastal/Coastal-Ecosystems/Sounds-Water-Quality.aspx

⁴⁶ MPI commission NIWA to undertake surveys of recreational fishing catch at boat ramps including several around Picton. This may represent a data source of interest to a local monitoring programme.

As signalled by Te Ātiawa, development of cultural indicators is anticipated, and alignment of Māori monitoring programmes and western science approaches may be considered desirable. Te Ātiawa have mana whenua in Picton Bays, and Waikawa is of particular importance to them. The Te Ātiawa Iwi Environmental Management Plan provides a comprehensive statement of the values, aspirations, and plans that Te Ātiawa hold for the region. Increasing engagement of Te Ātiawa and other iwi in environmental management is anticipated by iwi, and by council and other stakeholders (e.g., through the Marlborough Marine Futures process).

7. ACKNOWLEDGEMENTS

Many thanks to Ian Shapcott and Tom Norton for taking the time to share their knowledge of the Picton Bays

This report was funded by Envirolink Advice Grant 1606-MLDC106.

8. REFERENCES

- ANZECC 2000. National water quality management strategy paper Number 4: Australian and New Zealand guidelines for fresh and marine water quality, Volume 1, The Guidelines.
- Bargh BJ 1977. Water quality survey of Picton Harbour, Waikawa and Shakespeare Bays during August - September 1977. 10 p.
- Barter P 2000. Benthic ecological monitoring of the Picton sewage outfall. Prepared for Marlborough District Council. Cawthron Report No. 558. 16p plus appendices.
- Barter P 2002. Benthic ecological monitoring of the Picton sewage outfall: 2002. Prepared for Marlborough District Council. Cawthron Report No. 732. 15 p. plus appendices.
- Barter P 2012. Waikawa Marina stormwater monitoring - Feb 2012. Prepared for Port Marlborough NZ Ltd. Cawthron Report No. 2113. 7 p. plus appendices.
- Barter P, Elvines D 2012. Waikawa Marina stormwater monitoring - June 2012. Prepared for Port Marlborough NZ Limited. Cawthron Report No. 2212. 10 p. plus appendices.
- Barter P, Sneddon R, Conwell C 2008. Ecological investigations into discharge options for the MDC sewage treatment plant, Picton. Prepared for Marlborough District Council. Cawthron Report No. 1471. 70 p plus appendices.
- Barter P, Thompson S 2003. Shakespeare Bay stormwater consent monitoring. Prepared for Port Marlborough New Zealand Ltd. Cawthron Report No. 830. 15 p. plus appendices.
- BECA 2014. Picton Sewage Treatment Plant consent compliance report - July 2013 to June 2014. Prepared for Marlborough District Council. 15 p. plus appendices.
- Bolton LA 1991 Shakespeare Bay development marine ecology survey. 47 p. plus appendices.
- Conwell C, Sneddon R 2009a. Assessment of marine environmental effects for the London Quay Foreshore Revitalisation Project, Picton. Marlborough District Council, Nelson. Cawthron Report No. 1590. 24 p. plus appendices.
- Conwell C, Sneddon R 2009b. Assessment for disposal of dredge material from Stage 1 Picton Marina Development. Port Marlborough New Zealand Ltd, Nelson. Cawthron Report No. 1603. 13 p. plus appendices.
- Conwell C, Sneddon R 2009c. Shakespeare Bay stormwater consent benthic monitoring: 2009. Prepared for Port Marlborough New Zealand Ltd. Cawthron Report No. 1612. 29 p.

- Cornelisen C, Gillespie P, Kirs M, Young R, Forrest R, Barter P, Knight B, Harwood V 2011. Motueka River plume facilitates transport of ruminant faecal contaminants into shellfish growing waters, Tasman Bay, New Zealand. *New Zealand Journal of Marine and Freshwater Research* 45: 477-495.
- 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. 172 p.
- Davidson R, Richards L, Abel W 2010. Biological monitoring of the ferry route in Tory Channel and Queen Charlotte Sound: 1995-2010. Davidson Environmental research, survey and monitoring report number 643. Prepared for Marlborough District Council and Department of Conservation. 77 p. plus appendices.
- Davidson RJ 1996. Ecological report related to proposed port modifications, Picton Harbour, Queen Charlotte Sound. Davidson Environmental survey and monitoring report 142. Prepared for Marlborough District Council. 12 p.
- Elvines D, Allen C 2015. Waikawa Marina stormwater monitoring: April, June and December 2014. Report prepared for Port Marlborough NZ Limited. Cawthron Report No. 2554. 14 p. plus appendices.
- Forrest B, Cornelisen C 2015. Monitoring framework for the Waikato Coastal Marine Area: Report 1–Rationale and key elements. Waikato Regional Council Technical Report 15/38. Cawthron Report No. 2415. 36 p. plus appendices.
- Forrest R, Sneddon R 2007. Annual review of resource consent monitoring for Shakespeare Bay, Port Marlborough 2006-2007. Prepared for Port Marlborough New Zealand Ltd. Cawthron Report No. 1362. 16 p.
- Gillespie P 1996. Monitoring of the ecological effects of fast ferry wash in Tory Channel and Queen Charlotte Sound, November 1995-January 1996. Report prepared for Tranz Rail Limited, Nelson. Cawthron Report No. 334. 47 p.
- Hadfield M, Broekhuizen N, Plew D 2014. A biophysical model for the Marlborough Sounds, Part 1: Queen Charlotte Sound and Tory Channel, NIWA Client Report number CHC2014-116, prepared for Marlborough District Council. 183 p.
- Handley S 2006. An analysis of historical impacts and composition of the benthic environment of Tasman and Golden Bays. NIWA report NEL2006-002. 28 p.
- Handley S 2015. The history of benthic change in Pelorus Sound (Te Hoiere), Marlborough. NIWA report NEL2015-001. Prepared for Marlborough District Council. 47 p.
- Handley SJ, Willis TJ, Cole RG, Bradley A, Cairney DJ, Brown SN, Carter ME 2014. The importance of benchmarking habitat structure and composition for understanding the extent of fishing impacts in soft sediment ecosystems. *Journal of Sea Research* 86: 58-68.

- Handley, S. 2016. Historic benthic change, Queen Charlotte Sound, Marlborough. NIWA client report prepared for Marlborough District Council, NEL2015-018, Project ELF16205. In prep.
- Henkel S 2015. Recreational water quality report 2014-2015. MDC Technical Report No: 15-006. 35 p plus appendices.
- Hopkins S, Barter P 2005. Shakespeare Bay stormwater consent monitoring: 2005. Cawthron Report No. 1056. Prepared for Port Marlborough New Zealand Ltd. 18 p. plus appendices.
- Inglis G, Gust N, Fitridge I, Floerl O, Woods C, Hayden B, Fenwick G. 2006. Port of Picton baseline survey for non-indigenous marine species (Research Project ZBS2000/04) Biosecurity New Zealand Technical Paper No: 2005/03. Prepared for BNZ Post-clearance Directorate. 49 p. plus appendices.
- Keeley NB, Forrest BM, Crawford C, Macleod CK 2012. Exploiting salmon farm benthic enrichment gradients to evaluate the regional performance of biotic indices and environmental indicators. *Ecological Indicators* 23: 453–466.
- KMA 1995. Report on the Port Shakespeare baseline environmental monitoring programme. Prepared for Port Marlborough New Zealand Ltd. Kingett Mitchell & Associates Ltd. 51 p. plus appendices.
- Knight B, Beamsley B 2012. Calibration and methodology report for hydrodynamic models of the Marlborough Sounds. Prepared for New Zealand King Salmon Company Limited. 42 p.
- Knox G, Bolton L 1977. An ecological survey of Shakespeare Bay, Queen Charlotte Sound. *Estuarine Research Unit Report No. 18*. 130 p. plus appendices.
- Lucas Associates 1997. Marlborough Sounds land & marine ecosystems, Report prepared with and for the Department of Conservation and Marlborough District Council. 47 p.
- Mackenzie L 1991. Picton Sewer Outfall. An examination of effluent composition and the environmental effects of the discharge. Prepared for Marlborough District Council. Cawthron Report No. 183. 29 p.
- MfE/MoH 2003. Ministry for the Environment, Ministry of Health. Microbiological water quality guidelines for marine and freshwater recreational areas. Ministry for the Environment, Wellington. 90 p. plus appendices.
- Miller E 1988. Picton Harbour water quality study. Catchment and Regional Waterboard Marlborough. 28 pp plus appendices.
- Ministry for Primary Industries 2015. Marlborough Sounds blue cod regulatory review, Appendix 1: Blue cod fishery characterisation. 62 p.

- Morrison MA, Lowe ML, Parson DM, Usmar NR, McLeod IM 2009. A review of land-based effects on coastal fisheries and supporting biodiversity in New Zealand. Wellington, Prepared by NIWA for the Ministry of Fisheries. New Zealand Aquatic Environment and Biodiversity Report No. 37. 100 p.
- Newcombe E, Cornelisen C 2014. Towards an integrated monitoring programme for Nelson Bays coastal marine area. Prepared for Tasman District Council and Nelson City Council. Cawthron Report No. 2544. 44 p. plus appendices.
- Newcombe E, Clark D, Gillespie P, Morrisey D, MacKenzie L 2015. Assessing the state of the marine environment in Tasman Bay and Golden Bay. Prepared for Nelson City Council and Tasman District Council. Cawthron Report No. 2716. 70 p. plus appendix.
- Roan P 1993. Impacts of the Kaipupu Point sewage discharge on Picton Harbour. Prepared for Marlborough District Council. Cawthron Report No. 213. 46 p.
- Roberts R 1993. Evidence on ecological and water quality issues relating to a port development in Shakespeare Bay, Picton. Marlborough District Council, Nelson. 205. 20 p.
- Sneddon R 2006. Annual report and review of resource consent monitoring for Shakespeare Bay, Port Marlborough. Cawthron Report No. 1088. 34 p. plus appendices.
- Sneddon R 2008. Annual review of resource consent monitoring for Shakespeare Bay, Port Marlborough 2007-2008. Prepared for Port Marlborough New Zealand Limited. Cawthron Report No. 1515. 17 p.
- Sneddon R 2009. Annual review of resource consent monitoring for Shakespeare Bay, Port Marlborough 2008-2009. Prepared for Port Marlborough New Zealand Ltd. Cawthron Report No. 1671. 17 p.
- Sneddon R 2010a. Annual review of resource consent monitoring for Shakespeare Bay, Port Marlborough 2009-2010. Prepared for Port Marlborough New Zealand Ltd. Cawthron Report No. 1813. 18 p. plus appendices.
- Sneddon R 2010b. Assessment of potential effects on benthic ecology from proposed rezoning of areas in Waikawa Bay. Prepared for Port Marlborough New Zealand Limited. Cawthron Report No. 1615. 25 p.
- Sneddon R 2011a. Derivation of a TSS-based effluent limit to allow effective consent monitoring of the potential for stormwater discharge to affect receiving water clarity in Shakespeare Bay. Letter Report to Johnathan Duffy, Port Marlborough NZ Ltd. Dated 26 Jan 2011.
- Sneddon R 2011b. Annual review of resource consent monitoring for Shakespeare Bay, Port Marlborough 2010- 2011. Prepared for Port Marlborough New Zealand Ltd. 16 p. plus appendices.

- Sneddon R 2012. Annual review of resource consent monitoring for Shakespeare Bay, Port Marlborough: 2011-2012. Prepared for Port of Marlborough NZ Ltd. 18 p. plus appendices.
- Sneddon R 2013. Annual review of resource consent monitoring for Shakespeare Bay, Port Marlborough: 2012-2013. Prepared for Port Marlborough NZ Ltd. 17 p. plus appendices.
- Sneddon R 2014a. Port Shakespeare stormwater consent benthic monitoring: 2014. Prepared for Port Marlborough New Zealand Ltd. Cawthron Report No. 2521. 27 p. plus appendices.
- Sneddon R 2014b. Annual review of resource consent monitoring for Shakespeare Bay, Port Marlborough: 2013-2014. Cawthron Report 2578. Prepared for Port of Marlborough NZ Ltd. 19 p. plus appendices.
- Sneddon R, Barter P 2013. Baseline benthic and dispersion surveys for the relocated Picton Wastewater Treatment Plant outfall. Prepared for Marlborough District Council. 26 p. plus appendices.
- Sneddon R, Barter P, Clark K, Dunmore R 2007. Shakespeare Bay stormwater consent benthic monitoring: 2007. Prepared for Port Marlborough New Zealand Ltd. Cawthron Report No. 1327. 27 p.
- Stewart C 2002. Interpretation of organotin data for sediments and shellfish, Waikawa Bay, Picton. Report prepared for Marlborough District Council. 12 p.
- Stewart C 2003. Antifouling co-biocides in New Zealand waters. Report prepared for the Ministry for the Environment. 27 p. plus appendices.
- Stewart C 2004. Sediment quality assessment, Careys Boatyard, Picton Harbour. Marlborough District Council Client Report. 42 p. plus appendices.
- Stewart C, Bennett C 2006. Picton Harbour sediment quality assessment, December 2005. Marlborough District Council Client Report. 26 p. plus appendices.
- Stewart M, Northcott G, Gaw S, Tremblay L 2015. An update on emerging organic contaminants of relevance for Regional Council marine sediment contaminant monitoring. A report prepared for Auckland Council, Environment Canterbury Regional Council and Greater Wellington Regional Council. In press.
- Thompson P, Carr R, Bargh B 1977. Picton Harbour, Waikawa and Shakespeare Bays water quality survey January 1977. Marlborough Catchment and Regional Water Board. 29 p. plus appendices.
- Tonkin, Taylor 1997. Marlborough state of the environment report. Published by Marlborough District Council, PO Box 443, Blenheim, New Zealand, May 1998. ISBN 0-9583733-0-2.
- Ulrich SC 2015. Mitigating fine sediment from forestry in coastal waters of the Marlborough Sounds. MDC Technical Report No: 15-009. 30 p. plus appendices.

Ward H, Edwards S 2015a. Bob's Bay erosion options assessment. Opus International Consultants Ltd. Prepared for Marlborough District Council. 27 p.

Ward H, Edwards S 2015b. Shelly Beach erosion assessment and options analysis. Opus International Consultants Ltd. Prepared for Marlborough District Council. 31 p. plus appendices.