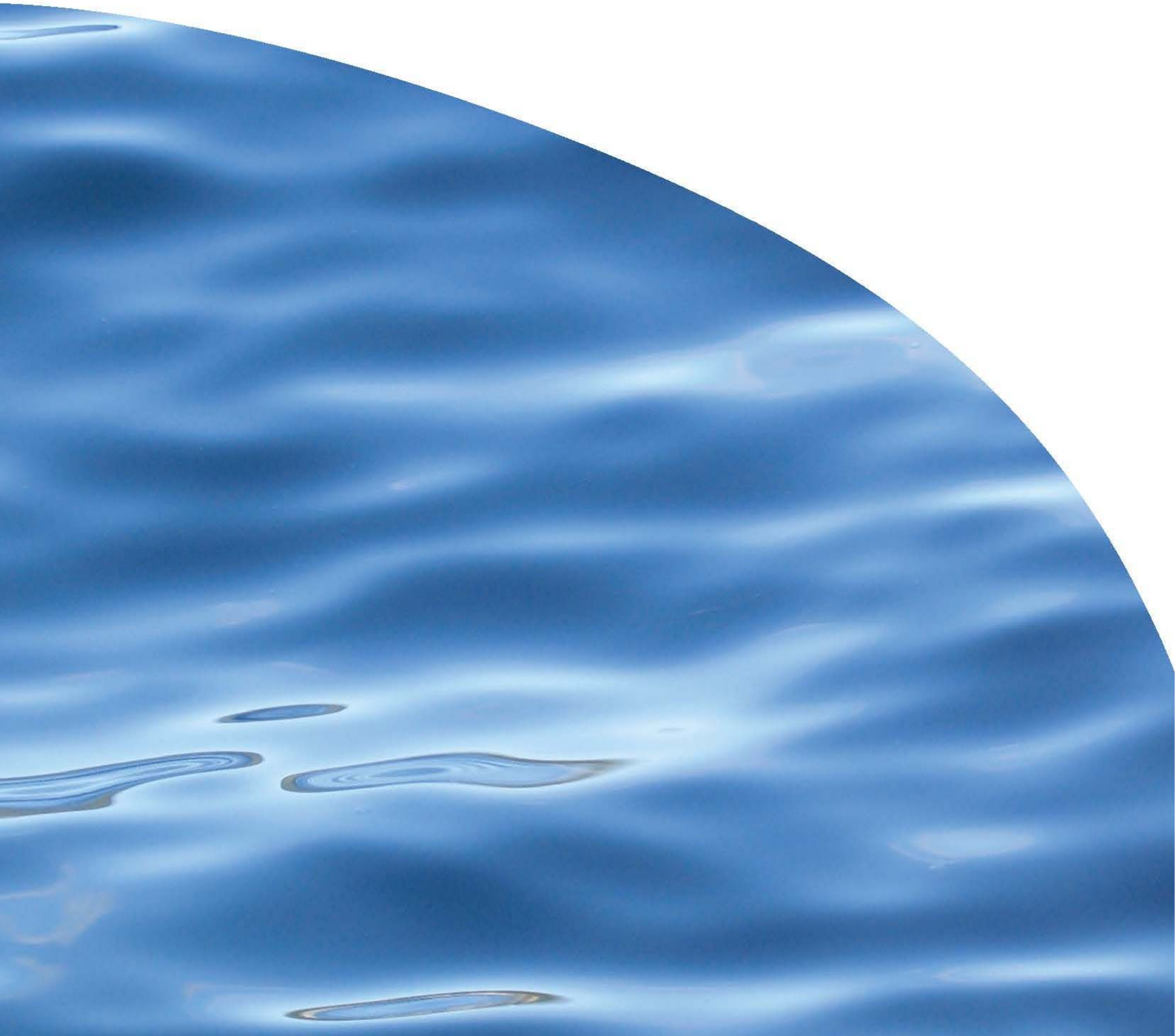
REPORT NO. 2716

ASSESSING THE STATE OF THE MARINE ENVIRONMENT IN TASMAN BAY AND GOLDEN BAY



ASSESSING THE STATE OF THE MARINE ENVIRONMENT IN TASMAN BAY AND GOLDEN BAY

EMMA NEWCOMBE, DANA CLARK, PAUL GILLESPIE,
DON MORRISEY, LINCOLN MACKENZIE

Prepared for Nelson City Council and Tasman 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:
Dave Taylor

APPROVED FOR RELEASE BY:
Chris Cornelisen

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EXECUTIVE SUMMARY

The three top of the South Island councils (Tasman District Council, Nelson City Council and Marlborough District Council) need a summary of available information on the state of the marine environment in both Tasman and Golden Bays. In addition, they seek to identify gaps between what information exists and what is needed to better inform environmental reporting in the bays.

The purpose of this report is to provide a summary of conditions in the bays based on available information that is relevant to a state of the environment assessment. Most of the available information was not collected for the purpose of state of the environment monitoring, so the ability to assess state and trends is limited. Accordingly, we aim to determine the extent to which the state of the environment information can be gleaned from datasets collected for other purposes. The report deals principally with material from the Nelson City Council and Tasman District Council Coastal Marine Areas (CMAs), but this material is also relevant to the Marlborough District Council CMA in Tasman Bay.

As the coastal seas are the receiving environment for activities that occur ‘upstream’, we consider aspects of coastal catchments that impact the marine ecosystem. Changes in land cover, freshwater quality, and the ecosystem health are considered.

Information about the marine environment is drawn from fisheries, from monitoring associated with consented activities such as aquaculture, from marine reserve monitoring, and from research projects. Based on this information, conditions of the water column and the seabed are summarised according to key topics as they relate to the state of the marine environment:

- Primary productivity: Nutrient input to the bays is ocean-dominated, and the larger region seems at limited risk overall to eutrophication. However, nearshore and local-scale effects of nutrient inputs may occur. Phytoplankton removal can occur in association with mussel farming, but no large-scale reduction is apparent.
- Sedimentation: In the last two decades land-based sediment inputs have not been exceptionally high. However, accumulated sediments are disturbed and high levels of suspended sediment have been detected in the water column. Re-suspension is possibly a greater stressor than new sediment input to Tasman Bay and Golden Bay.
- Habitat integrity: Disturbance by fishing has substantially modified soft-sediment habitats, homogenising sediments and reducing biogenic structure within the bays. Many documented communities are characteristic of disturbed environments, but the extent and status of remaining biogenic habitat is not well understood. Less is known about rocky reef habitats, where monitoring focusses on mobile fauna.
- Contamination: Overall, bacterial contamination appears to be low in coastal waters of the bays, but occasional peaks occur following rainfall. Diffuse sources of contamination associated with runoff can be a greater cause of bacterial

contamination than point source discharges. Chemical contamination from consented activity is low-level, and levels high enough to potentially have ecological impacts do not occur on the outer coast.

- Fisheries: Important fish stocks are depleted compared to historical levels within the bays, which suggests that changes to the food-web have occurred. Protected areas show an increase in the numbers of some exploited species. There is some evidence to suggest that fishing is having food-web effects on rocky reefs.
- Invasive species: Biosecurity surveys at ports within the bays have found a number of established invasive species, but substantial negative impacts have not been documented.

This report has also identified knowledge gaps to assist in the development and prioritisation of future research and monitoring for state of the environment purposes. Requirements include higher sampling frequency and better representation of all areas and habitats (spatial variability). Many of the topics outlined above are interrelated, and assessment of the state of the environment requires consideration of interactions between different pressures and components of the ecosystem. State of the environment monitoring will require selecting and validating suitable indicators that can be used to identify and measure changes associated with specific stressors and cumulative effects. Development of frameworks for data sharing and analysis that integrate consent-based and state of the environment monitoring would provide efficiencies in monitoring and maximise the ability to assess long-term environmental change.

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1. INTRODUCTION

The marine environment of Tasman Bay and Golden Bay is a large, relatively sheltered area extending from Farewell Spit in the west to the north-western side of D'Urville Island. The bays are mostly shallow; areas exceeding 50 m in depth within 12 nautical miles of shore occur only on the eastern side of Tasman Bay.

The seabed environment within Tasman Bay and Golden Bay is dominated by soft-sediment habitats that once supported high value scallop, mussel and oyster fisheries, now severely depleted. Finfish harvesting occurs over the majority of the area. Large areas have been designated for marine farming. Three marine protected areas exist: the Separation Point no-trawl zone, and marine reserves at Tonga Island and Hororoirangi. A taiapure is established at Wakapuaka (Figure 1).

Six iwi have rohe in the Tasman Bay, Golden Bay areas. They are Ngāti Koata, Ngāti Rārua, Ngāti Tama, Te Ātiawa, Ngāti Kuia, and Ngāti Toa Rangatira.

The Tasman Bay coastal marine area (CMA) falls under the jurisdiction of Tasman District Council (TDC), Nelson City Council (NCC), and Marlborough District Council (MDC), while Golden Bay is under the jurisdiction of TDC (Figure 1).

Councils are responsible for managing resource consents for activities on land as well as those within the coastal marine area (CMA), defined as the seabed and overlying waters out to 12 nautical miles offshore (Figure 1). Councils are not responsible for managing fishing activity, and under the Resource Management Act 1991 (RMA) they are not able to control fisheries for fisheries management purposes.

Stressors originating from human activity include those that are physical (*e.g.* bottom trawling), chemical (*e.g.* contaminants), and biological (*e.g.* invasive species). Some stressors occur naturally in the marine environment, such as sedimentation associated with flood events, or weather-induced shifts in water temperature or wave climate. Natural stressors can be exacerbated by anthropogenic activities, as in the case of land use changes that increase rates of sedimentation and nutrient delivery to coastal waters. A recent assessment of anthropogenic threats to New Zealand marine habitats concluded that the overall greatest threat to marine habitats was ocean acidification, followed by rising sea level temperatures as a result of global climate change. Next in order of importance were considered to be land-based sedimentation and bottom trawling (based on expert knowledge, MacDiarmid *et al.* 2012). Most of the top-ranked threats to the marine environment result from activities originating wholly or partially from human activities 'upstream' of the marine environment.

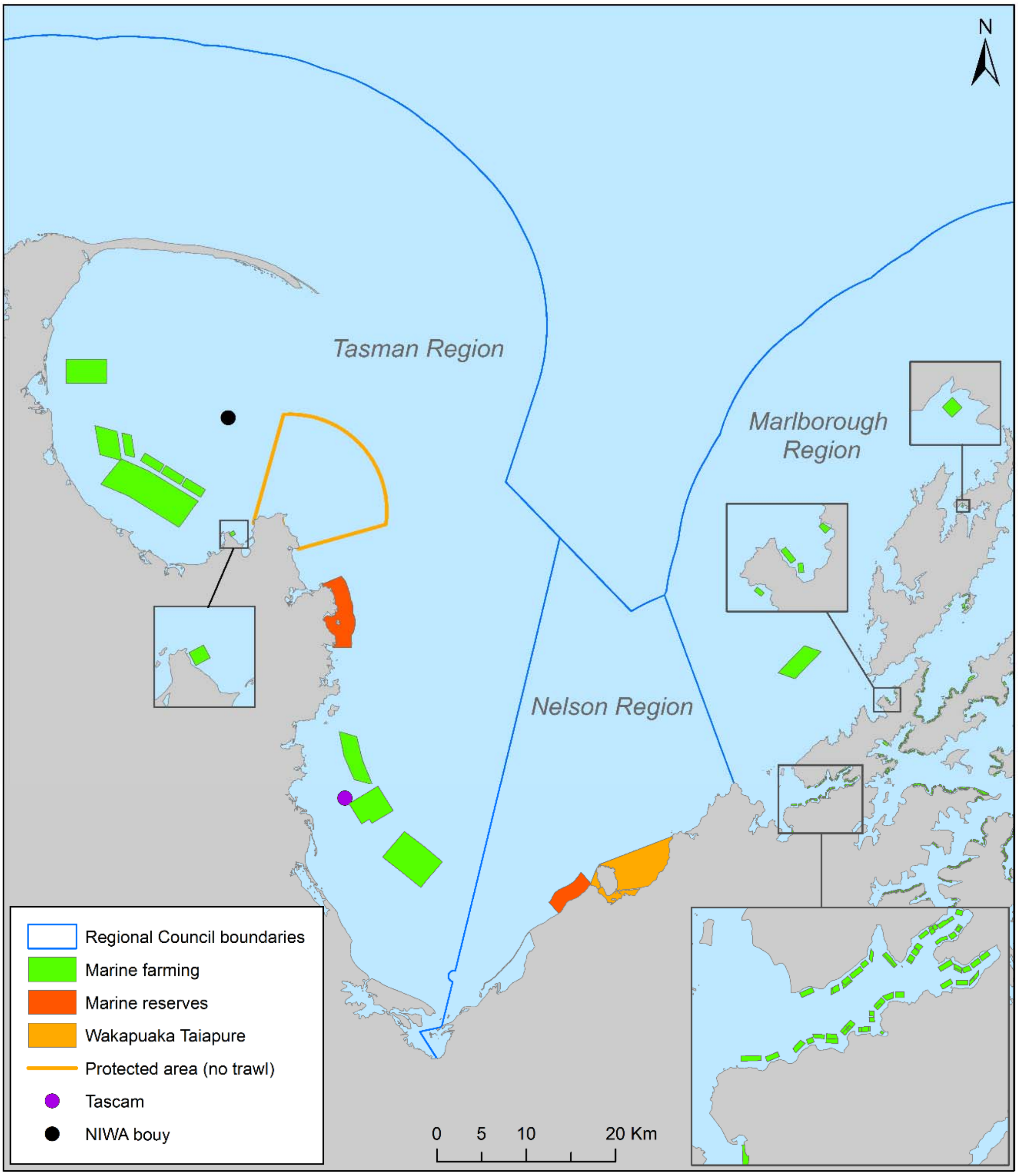

Figure 1. Council boundaries of the coastal marine area (CMA), which extend to 12 nautical miles. Areas consented for aquaculture (not necessarily active) are in green and protected areas (such as marine reserves) are in shades of orange.

Upstream environments—including the land itself and freshwater environments that flow into the sea or through estuaries—are subject to considerable human impacts. The connectivity between 'upstream' environments and the sea is apparent when, for example, beaches are closed and mussels cannot be harvested due to bacterial contamination from land. Human-related impacts that occur immediately in the marine environment include nutrient enrichment (from outfalls), chemical contamination and direct disturbance.

1.1. Report scope and objectives

The three top of the South Island councils (Tasman District Council, Nelson City Council and Marlborough District Council) have identified a need to summarise available information on the state and trend of the environment of Tasman Bay and Golden Bay. An analysis is needed also to identify gaps between what information exists and what is needed to inform coastal ecosystem monitoring priorities as part of the councils' obligations under the NZ Coastal Policy Statement 2010 (NZCPS). Requirements of the NZCPS are outlined in Section 2.

The purpose of this report is to provide a summary of conditions in the bays based on available information that is relevant to state of the environment assessment. Most of the available information was not collected for the purpose of state of the environment monitoring, so the ability to assess the state and trends is limited. Accordingly, we aim to assess the extent to which the state of the environment information can be gleaned from datasets collected for other purposes. The report deals principally with material from the NCC and TDC CMAs, but this material is also relevant to the MDC CMA in Tasman Bay. The MDC publication 'Ecologically Significant Marine Sites in Marlborough'[1] identifies a number of sites within Tasman Bay, although these sites are not representative of the wider Tasman Bay ecosystem.

It is anticipated that this report will constitute the first in an ongoing series. Communications will expand and improve alongside developments in monitoring activity and integration of different information sources. Many approaches to state of the environment monitoring are possible. For example, the Hauraki Gulf Forum's 'State of Our Gulf'[2] publication includes litter and coastal development as environmental indicators, and addresses tāngata whenua relationships. To address all topics relevant to environmental health is beyond the scope of this report.

This report deals primarily with the subtidal area of the bays outside of estuaries, which we term the outer coast. Some port-associated information is included as this is a source of potential contaminants. While estuarine environments and coastal margins are part of the coastal zone, reporting on the state of health in those areas is well-developed in comparison with subtidal areas of the outer coast. However a high-level summary of land-use, freshwater monitoring data, and estuaries is presented (Section 3), as the state of these environments has implications for the marine receiving environment.

Human activities in the marine environment that are relevant to this report include activities requiring resource consent, and fisheries. Some of the information collected in association with these activities is also more broadly informative with respect to the state of the environment. Fisheries are considered because this represents one of the

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[1] www.marlborough.govt.nz/Environment/Coastal/Significant-Marine-Sites.aspx.
[2] www.aucklandcouncil.govt.nz/EN/AboutCouncil/representativesbodies/haurakigulfforum /Documents/hgfstateoftheenvreport2011.pdf.

most important human uses of the marine environment. Biosecurity represents a threat to many values, and is therefore also considered briefly.

This report provides a broad-scale review of existing information on coastal catchments and estuaries and impacts from human activities, and then reviews topics relevant to state of the environment assessment.

The two primary habitats, the water column and the seabed, are considered in terms of the key topics relevant to each habitat:

- primary productivity
- sedimentation
- habitat integrity
- contamination
- fisheries
- biosecurity.

Section 4 outlines coastal activity and associated data collection. Section 5 summarises how the available information provides an indication of environmental conditions. Section 6 considers the extent to which available information fulfils requirements for state of the environment assessments. Knowledge gaps are identified to assist in the development and prioritisation of future research and monitoring.

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 impacts of particular activities. The body of information regarding the state of the environment should reflect the aspects of environmental health most relevant to the the community. These values are a combination of:

- National requirements (*e.g*. requirements of NZCPS ,which are summarised below)
- Locally-relevant issues (location-specific pressures on the environment and community aspirations).

The latter point may require that a process is undertaken to define values that determine management objectives. Many measures of environmental condition are, however, already widely used and broadly informative, and could be adopted with confidence that they would inform a range of management objectives. Accordingly, while consultation and definition of values is desirable, improvement of state of the environment monitoring could begin independently of (ideally in anticipation of) community consultation.

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 activity 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 impacts of human activity precede any formal data collection. In these cases reference sites and informal historical data can 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 primary productivity, but composite measures of multiple aspects of the environment often more effectively reflect environmental status (*e.g*. Keeley *et al.* 2012). Composite indices are increasingly being employed as environmental indicators.

The development of an ideal data-collection and management framework is not possible until the specific purpose of the information-gathering is identified for the region. Consequently, it would be premature to develop a monitoring programme for the region in this report. 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 under development for Waikato Regional Council (WRC) (Forrest & Cornelisen 2015 and related reports) also contain information relevant to the development of SoE monitoring goals. The WRC project is targeted to the place of aquaculture within a SoE framework; nonetheless much information regarding the development of indicators is relevant to coastal management nationally.

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 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[3] 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 stated, as well as restoring water quality 'where practicable'. Stock exclusion is specifically mentioned.

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

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[3] In this report 'the coastal marine environment' refers to the subtidal area on the outer coast, *i.e*., exclusive of estuaries and intertidal areas.

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,[4,5] 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 Treaty of Waitangi and kaitiakitanga[6], in relation to the coastal environment. Local authorities must, as far as is practicable with tikanga Māori[7], incorporate mātauranga Māori[8] in regional policy statements and plans and when considering resource consent applications.

Policy 4 requires coordinated management across local authority boundaries, iwi / hapū[9] boundaries or rohe[10] 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.

2.2.2. Environmental Reporting Bill

In August 2013 the Government introduced an Environmental Reporting Bill[11]. While not yet enacted, the bill includes requirements that the Ministry for the Environment (MoE) and the Government Statistician report every three years on the marine domain[12]. The reports are to describe the state of the domain, including dependent biodiversity and ecosystems, pressures (actual or potential), and impacts on ecological integrity, public health, the economy, te ao Māori, and culture and recreation. A description of changes to the state of the domain over time and how the state of the domain measures against national or international standards will also be

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[4] 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.

[5] 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.

[6] Guardianship, stewardship, trustee.

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

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

[9] Kinship group, clan, tribe, subtribe — section of a large kinship group.

[10] Boundary, district, region, territory, area, border (of land).

[11] http://www.legislation.govt.nz/bill/government/2014/0189/latest/DLM5941105.html. accessed 29-04-15.

[12] Marine is one of five domains. The other domains are air, atmosphere and climate, freshwater, and land.

required. The producers of the report will be required only to report on that information which can be obtained 'using reasonable efforts'. It is not apparent whether further information gathering will be required or supported as a result of this bill.

3. COASTAL CATCHMENTS AND ESTUARIES

The marine environment is not only directly affected by activity undertaken in the sea itself, but can be impacted strongly by activity that takes place 'upstream' in coastal catchments. As the initial receiving environment for freshwater flows, estuaries are important sites for land-sea interactions. Estuarine waters in turn then flow downstream into coastal waters. The connectivity between the land and sea is clearly seen in the sediment plumes that occur after heavy rainfall events (Figure 2).

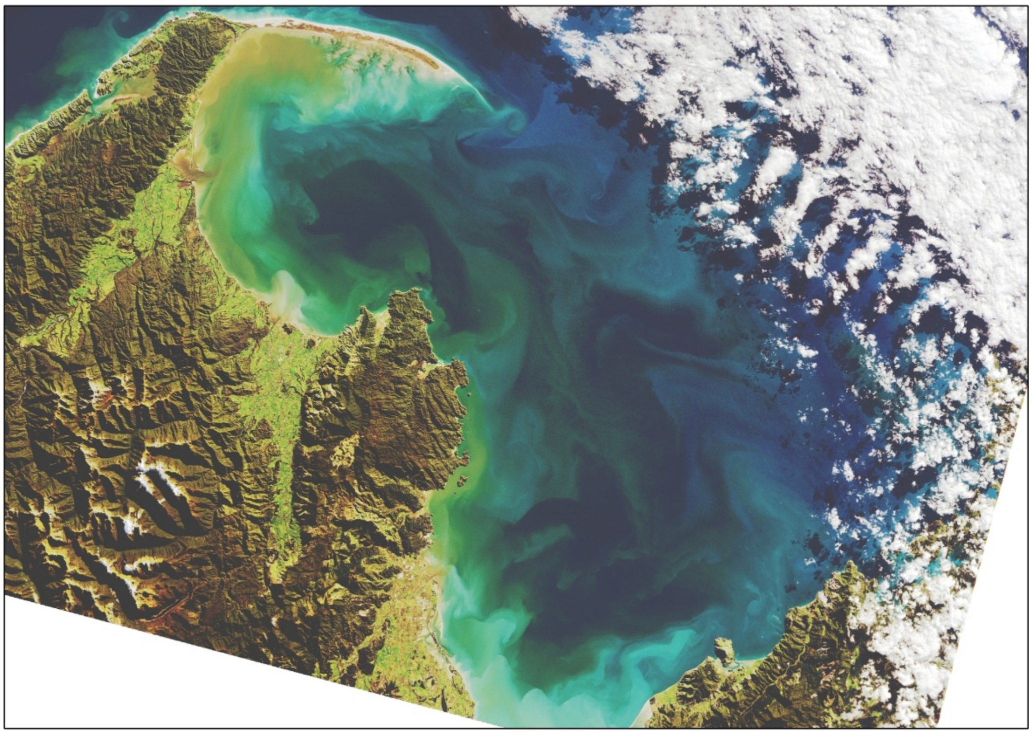

Figure 2. LandSat8 quasi-true colour imagery (Bands 2,3,4) acquired on 6 June 2013, two days after a large rain event in the region. The image shows surface water colour properties in Tasman and Golden Bays. Suspended sediment appears as lighter areas of water. Data credit: NASA / USGS, data processing undertaken by Ben Knight, Cawthron Institute.

As the coastal seas are the receiving environment for these upstream environments, we consider the aspects of these environments that are important in terms of their impact on the marine environment—land cover, freshwater quality, and the key ecosystem health issues and monitoring activity in the region's estuaries.

3.1. Land cover

Natural levels of sedimentation may be high, and are dictated by factors such as vegetation cover, slope, rainfall, and substrate type. Changes in land use, such as conversion of native forest to other purposes, often lead to increases in sediment loading to rivers and the marine receiving environment (Jones 2008).

Material added to land, such as nutrients (*e.g*. fertilisers and effluent discharge), chemicals (*e.g*. pesticides and herbicides), can be introduced to the marine environment via runoff and may negatively affect marine communities (Long *et al*. 1995). Similarly, faecal material from a range of human and animal sources associated with urban or agricultural use may cause bacterial contamination downstream (Cornelisen *et al*. 2011).

Land cover in the catchments of Tasman Bay and Golden Bay is dominated by native vegetation in the upper catchments, with substantial pasture (high and low-producing grassland) near the coast and bordering the rivers in the mid-catchment areas (Figure 3). Exotic forestry is widespread in the catchments of Tasman Bay, but rare in those of Golden Bay. Horticulture is concentrated in the relatively low land of the Waimea Plains and surrounding Motueka.

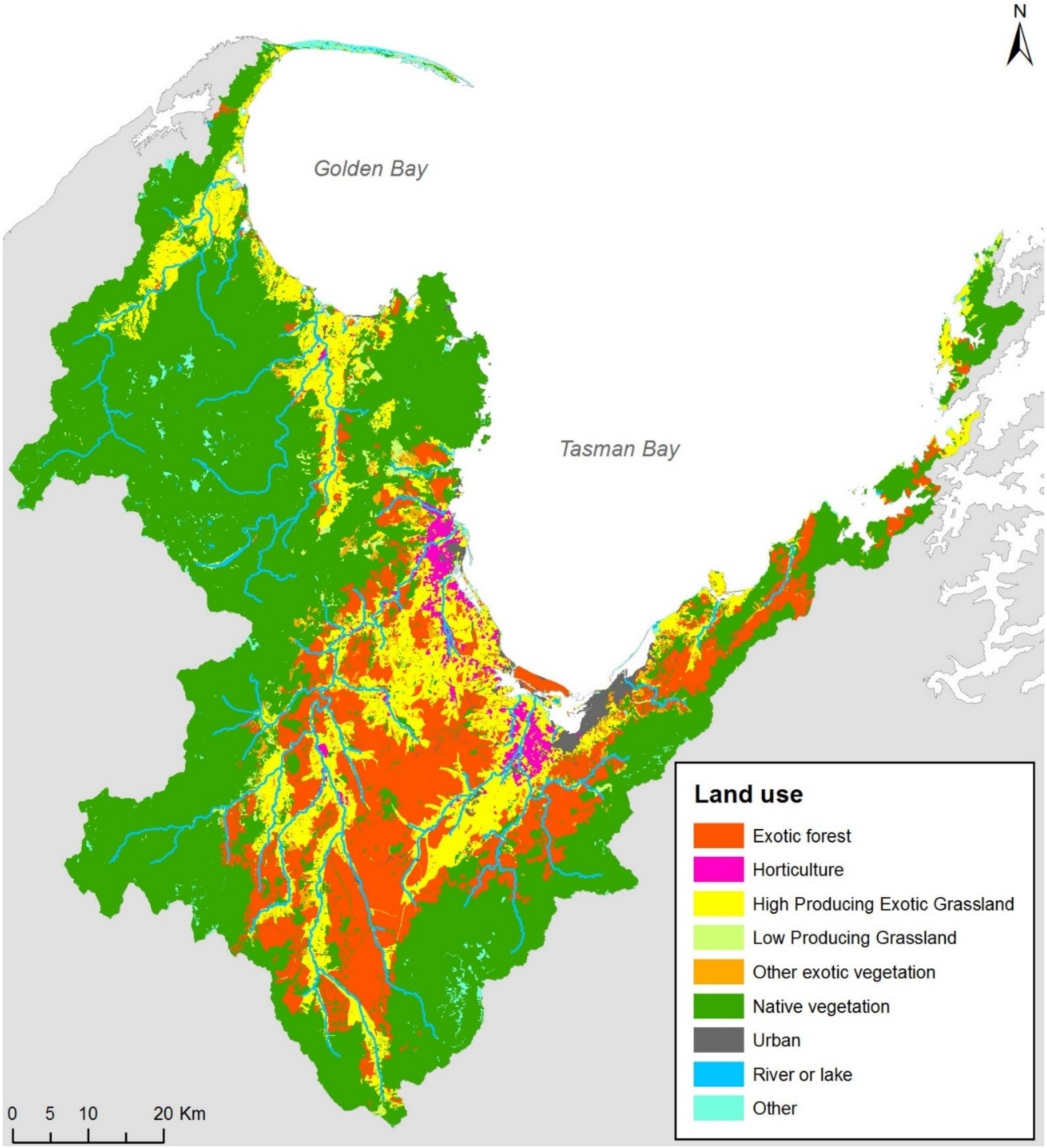

Figure 3. Land cover in catchments of Tasman Bay and Golden Bay. Current land cover was mapped within the study area using the New Zealand Land Cover Database (LCDB) version 4, which provides an estimate of land cover derived from satellite imagery. Map created by Lisa Peacock, Cawthron.

3.2. Freshwater

Aspects of freshwater quality that are important to the marine receiving environment are nitrogen levels and turbidity. Faecal contamination is a principle focus of council monitoring. Faecal contamination in the marine environment is usually from land-based sources, and is delivered to the marine environment via rivers and streams. Measurement of faecal contamination is important for assessment of water quality and shellfish health. While not an indicator of ecological health, it is important for human use of the environment.

As presented on the Land and Water Aotearoa (LAWA) website, streams in the Tasman Bay and Golden Bay catchments display a wide range of water quality values for all of these parameters (Table 1).

Table 1. Data from freshwater monitoring sites in Tasman and Nelson. The site closest to the coast in each catchment was selected from the Land and Water Aotearoa (LAWA) website (www.lawa.org.nz). On LAWA each site is compared to the range of sites across the whole of New Zealand, and placed in one of four "bins" or quartiles. Red = Worst 25%, Orange = worst 50% (but better than the worst 25%), yellow = best 50% (but not in the best 25%) green = best 25%. Each stream was compared with all streams in New Zealand (*i.e.*, rather than within stream type). *E. coli* is the faecal indicator bacteria most commonly reported from freshwater.

Site	Type	*E. coli*	Turbidity	Nitrogen	Ammoniacal N
Golden Bay					
Aorere	rural	best 25	best 25	best 25	-
Onekaka	rural	worst 50	best 25	best 25	-
Takaka at Kotinga	rural	best 25	best 25	best 25	-
Motupipi	rural	best 50	best 25	worst 25	-
Winter Creek	rural	best 50	worst 50	-	-
Tasman Bay					
Riwaka River	rural	best 25	best 25	-	-
Motueka River	rural	best 25	best 25	best 50	best 25
Tasman Valley Stream	rural	worst 25	worst 50	-	worst 25
Seaton Valley	rural	best 50	worst 25	-	worst 25
Waimea	rural	best 25	best 50	best 50	best 25
Reservoir Creek	urban	worst 50	worst 50	-	worst 25
Saxton Creek	rural	worst 25	worst 50	-	worst 25
Orphanage Stream	rural	best 50	best 50	-	best 50
Poorman Stream	urban	best 50	best 50	-	best 25
Jenkins Creek	urban	worst 50	worst 50	-	worst 50
Maitai	urban	best 50[13]	best 25	-	best 25
Todds Valley Stream	rural	worst 50	best 50	-	best 50
Wakapuaka	rural	best 50[14]	best 25	-	best 25
Whangamoa	rural	best 25	best 25	-	best 25

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[13] At the Collingwood St Bridge frequent breaches of recreational bathing limits were recorded

[14] At Paremata Flats frequent breaches of recreational bathing limits were recorded

While the information presented on LAWA is (appropriately) relatively high-level, this indicates the extent of available information for assessing water quality flowing into the marine receiving environment. Though little integrated assessment occurs across ecosystem boundaries, there is nonetheless substantial information available, much of which is held by the relevant local councils.

3.3. Estuaries

Estuaries are often important mediators of terrestrial impacts on the coastal environment, absorbing nutrients and trapping contaminants and sediments. In general estuarine environments are better-studied than those of the outer coast, and substantial council-funded state of the environment monitoring occurs in the region's estuaries.

Estuaries in Tasman Bay and Golden Bay are primarily bar-built[15], fluvial[16] erosion, tidal inlets with varying amounts of freshwater input from rivers or small streams. Apart from one or more outlets to the sea that remain continuously open to tidal flows, they are usually partially enclosed by physical barriers. These barriers may include sand spits, islands and, in one case, a boulder bank (tombolo). One exception is the Motueka River mouth which discharges more directly into Tasman Bay and does not constitute a typically semi-enclosed estuary. The tidal compartment of typical Tasman Bay and Golden Bay estuaries is broad and shallow. The intertidal zone includes extensive sand and mud flats, vegetated wetlands (*e.g*. eelgrass, peripheral salt marsh) and limited coarse-grained (gravel / cobble) habitats. This habitat structure and the associated plant and animal communities make estuaries areas of generally high localised productivity and biodiversity. They have corresponding important linkages to the offshore coastal food-web.

In all cases Tasman Bay and Golden Bay estuaries are rapidly flushed with each tidal exchange, reducing potential impacts from catchment runoff and wastewater discharges. Nonetheless it is important to consider the functional role of the estuaries as a land to sea buffer and how this role has been affected by human activities. Important aspects of estuarine function are the retention and / or processing of sediments, nutrients and contaminants that would otherwise be directly discharged into the bays. These functions have been compromised in many estuaries by the removal of large areas of freshwater and estuarine wetlands through flood control, infilling and various urban, agricultural and industrial developments (Clark & Gillespie 2007; Gillespie *et al*. 2011a). The natural land to sea succession of plant communities, including the terrestrial fringe of scrubland grading into forest cover, has been further interrupted by what is often termed shoreline "hardening". This can be caused by coastal developments that have affected all estuaries in the region to varying extents (*e.g*. harbour infrastructure, roading, and flood control). Such physical

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[15] Formed by sandbars
[16] Of or found in a river

barriers to tidal inundation will reduce the ability of wetland habitats to gradually migrate landward in conjunction with predicted sea level rise.

3.3.1. Issues confronting estuaries in Tasman Bay and Golden Bay

Sediment deposition

The most significant issues for Tasman Bay and Golden Bay estuaries arise through increased erosional input of fine-grained suspended sediments from surrounding catchments. Such changes are, of course, also closely linked with the hydrodynamic regime of the estuary. This can be modified by interventions such as flood control, channel modification, *etc*., or through climate-related causes of sea level rise and / or increased storm activity. Changes in current flows can, for example, have a marked effect on depositional patterns. Ultimately, enhanced sediment deposition within the estuary can drastically alter habitat structure by expanding the area of mud-dominated habitat. Increased sediment deposition may reduce or replace more productive coarser-grained sediment habitats such as those supporting eelgrass communities and / or shellfish (*e.g*. cockle) beds. The expansion of mud flat habitat can therefore reduce estuarine biodiversity with follow-on effects to the coastal food-web. Alternatively (or simultaneously), enhanced sediment export can impact coastal habitats outside the estuary (Gillespie *et al*. 2011, Handley 2006).

Eutrophication

An increased supply of inorganic and/or organic nutrients (particularly the various forms of nitrogen) can result in problems associated with over-enrichment. With respect to general estuary condition, such problems are largely mitigated in most Tasman Bay and Golden Bay estuaries due to the rapid tidal flushing rates. However localised eutrophication effects sometimes occur in close proximity to nutrient enriched freshwater inflows (*e.g*. Robertson & Stevens 2008a). The associated problems generally stem from an overgrowth of macroalgae (*e.g. Ulva* sp.), benthic microalgal or bacterial mat development and / or phytoplankton blooms. In extreme cases of eutrophication, severe oxygen depletion can occur in underlying sediments, thereby drastically changing the community structure of the animals living there. Regions exposed to storm water or wastewater discharges can be particularly vulnerable to enrichment effects.

3.3.2. State of estuarine environmental monitoring

Both the NCC and TDC have implemented a standardised state of environment (SoE) monitoring protocol for estuaries in their adjoining districts. The protocol (Robertson *et al*. 2002) requires a preliminary description of estuary condition, broad-scale mapping of intertidal habitats (vegetation and structural class) and fine-scale benthic surveys that assess of a suite of indicators of ecological health. In each case, point-in-time baseline surveys provide an opportunity for estimating change over time through repetitive (*e.g*. 5-yearly) surveys and also provide context for ongoing consent monitoring. The associated monitoring reports (Table 2) show that Tasman Bay and Golden Bay estuaries have been modified to varying extents by human activities. Results are fed into an inter-estuarine database that can be useful for rating the relative condition of estuaries in the region. Initial ratings to date, however, (*e.g*. Robertson & Stevens 2009) should be interpreted with care until reviewed in conjunction with a more thorough statistical analysis of the available data.

Table 2. State of environment monitoring history for Tasman Bay and Golden Bay estuaries.

	Estuary	Monitoring	Date	Reference
Tasman Bay	Whangamoa	Preliminary survey	2013	Gillespie (2013)
	Nelson Haven	Preliminary survey	2008	Gillespie (2008)
		Habitat map	2009	Gillespie *et al.* (2011a)
		Fine scale survey	2012	Gillespie *et al.* (2012a)
	Delaware	Preliminary survey	2009	Gillespie (2009)
		Habitat map	2009	Gillespie *et al.* (2011b)
		Fine scale survey	2009	Gillespie *et al.* (2009)
	Waimea	Preliminary survey	2002	Robertson *et al.* (2002)
		Habitat map	1999	Robertson *et al.* (2002)
			2006	Clark *et al.* (2008)
			2014	Stevens & Robertson (2014)
		Fine scale survey	2001	Robertson *et al.* (2002)
			2006	Gillespie *et al.* (2006)
			2013/14	Robertson & Robertson (2014)
		Historical map	2003	Tuckey & Robertson (2003)
	Moutere	Habitat map	2004	Clark *et al.* (2006)
		Fine scale survey	2006	Gillespie & Clark (2006)
		Historical map	2007	Clark & Gillespie (2007)
	Motueka Delta	Habitat map	2005	Thompson *et al.* (2005)
		Historical map	2004	Tuckey *et al.* (2004)
Golden Bay	Motupipi	Historical map	2008	Stevens & Robertson (2008)
		Fine scale survey	2008	Robertson & Stevens (2008b)
	Ruataniwha	Preliminary survey	2002	Robertson *et al.* (2002)
		Habitat map	2000	Robertson *et al.* (2002)
		Fine scale survey	2001	Robertson *et al.* (2002)
		Historical map	2003	Tuckey & Robertson (2003)

4. COASTAL ACTIVITIES AND DATA COLLECTION IN TASMAN BAY AND GOLDEN BAY

The primary ongoing activities that occur in the marine environment of Tasman Bay and Golden Bay, and have the potential to impact environmental health, are fishing, port-related activities (including dredge spoil disposal, effluent discharge from outfalls), and aquaculture. Substantial information is collected about these activities. All but fishing are consented activities and potential impacts are addressed in consent-based monitoring requirements.

High frequency water quality data is collected within the footprint of the Motueka river plume at a moored platform (TASCAM) for the purpose of long-term water quality monitoring. Benthic information (biological and physico-chemical data) is also collected at the TASCAM site every 5 years in an effort to measure long-term change.

Other data come from research projects, marine reserves and consented activity. Datasets collected for monitoring purposes (including marine reserves and consented activity) are listed in Appendix 1.

This section outlines each activity and the current information that is collected, while the subsequent section (Section 5) summarises how the available information provides an indication of environmental conditions. Section 6 considers the extent to which available information fulfils requirements for state of the environment assessments.

4.1. Fishing

Marine resources in Tasman Bay and Golden Bay have been exploited by humans for many centuries. Commercial, recreational, and customary fisheries exist. Commercial dredging has occurred in Tasman Bay and Golden Bay since the late 1800s, harvesting oysters and mussels. Commercial dredging for scallops began in Tasman Bay in 1959 and had expanded to Golden Bay by 1967. Commercial trawling for snapper has occurred since at least 1945 (Handley 2006). Commercial catch data from 2007 to 2012 provided by MPI showed that on average the scallop fishery was the largest fishery in terms of landed catch, followed closely by flatfish and red cod. In recent years, however, commercial scallop catch has declined to nil.

Year-round closures to trawling and dredging are in place in the Separation Point area, and fishing is not allowed in the marine reserves of Tonga Island and Hororoirangi (see Figure 1). Additionally, year-round closures are in place in near-shore areas in Golden Bay from Tarakohe to Collingwood, and on the tidal flats of Farewell Spit. In Tasman Bay, closures are in place in Greville Harbour, Okiwi Bay, and from Nelson Haven to the eastern part of Waimea Inlet. Larger near-shore areas covering most of the coast from Pepin Island to Pakawau, are closed from November to April. In Tasman Bay this closure is voluntary (information supplied by MPI).

Bottom trawling was ranked as the third highest overall threat to New Zealand marine habitats, equal with sedimentation (MacDiarmid *et al.* 2012). Bottom-contact fishing gear damages seabed communities by direct disturbance, but also causes changes in sediment grain size (changing from course sand to fine silt), which is an important driver of community structure. Filter feeders and grazers are most affected by fishing disturbance compared with predators and scavengers (including fish), and deposit feeders. The physical effects of dredging and trawling have been shown to reduce the density of common macrofaunal populations (Thrush *et al.* 1995) and to reduce populations of important bioturbators, with implications for the ability of the seafloor to absorb and release nutrients. This can result in the loss of habitat-forming species such as bryozoans and horse mussels (Bradstock & Gordon 1983).

Potential impacts from bottom fishing include:

- Seabed disturbance
- Changes in sediment grain size and habitat
- Sediment resuspension and increased turbidity
- Removal of target and non-target species.

While the environmental damage associated with bottom-trawling and dredging is recognised, it is currently considered that such methods are the only commercially viable way to exploit many of New Zealand's fisheries resources (Ministry for Primary Industries 2013). The extent of trawling throughout the bay is mapped by MPI[17] although no distinction between bottom- and mid-water trawling is made (Figure 4). It is recognised that more spatially-explicit information could be useful.

No commercial landings of scallops were reported from Tasman Bay since a 5 tonne catch in the 2005-2006 season. Landings in Golden Bay have been relatively low (< 128t) and variable since the 2003-2004 season. In 2011-2012 only 1 tonne was landed, and none was taken in 2012-13[18]. The distribution of commercial scallop dredging has reduced over time as the fishery has declined (Figure 5). Dredging for oysters has also continued into recent years, although the fishery yielded less than 1% of the biomass of the scallop fishery (2007–2012).

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[17] www.fish.govt.nz/en-nz/Aquaculture/Maps+of+Commercial+Inshore+Fishing+Activity/default.htm
[18] http://fs.fish.govt.nz/Doc/23459/015_/sca7_November2013.pdf.ashx

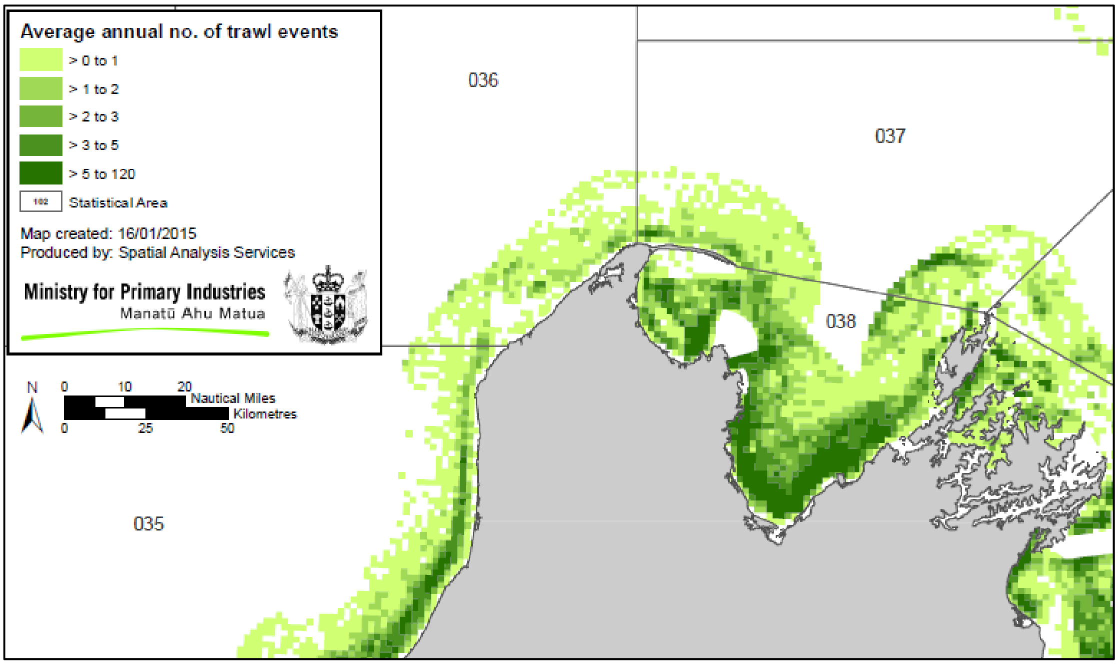

Figure 4. Average annual number of trawl (includes bottom and midwater and single and pair trawling) events from 2007 – 2013. From MPI[19].

MPI holds commercial catch data for all commercially-harvested species. This is available in a range of formats, and not all species are included in a given data set due to different management regimes. Commercial sensitivities often prevent the release of spatially explicit data. Nonetheless summary documents are available online and MPI provide some further data on request.

Recreational harvest estimates have been estimated in a national survey (Wynne-Jones *et al*. 2014). This provided estimates for all of New Zealand's significant marine fisheries, including those taking place in Tasman Bay and Golden Bay. Snapper, kahawai and blue cod were the most popular finfish species, while scallops were by far the most popular invertebrate species. Estimated recreational catches of some species far exceeded that caught commercially, including yellow-eyed mullet, paua and kingfish.

MPI holds data on permits issued for customary fishing take[20], but kaitiaki who issue the permits are not required to send a copy to the ministry so the dataset is incomplete. Moreover, reporting of actual take is voluntary, and does not always occur. Also, units of fish or shellfish reported are not standardised.

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[19] Map disclaimer and data limitations can be viewed at www.fish.govt.nz/en-nz/Aquaculture/Maps+of+Commercial+Inshore+Fishing+Activity/default.htm.

[20] Permits are issued under Regulation 27A of the Fisheries (Amateur Fishing) Regulations 1986

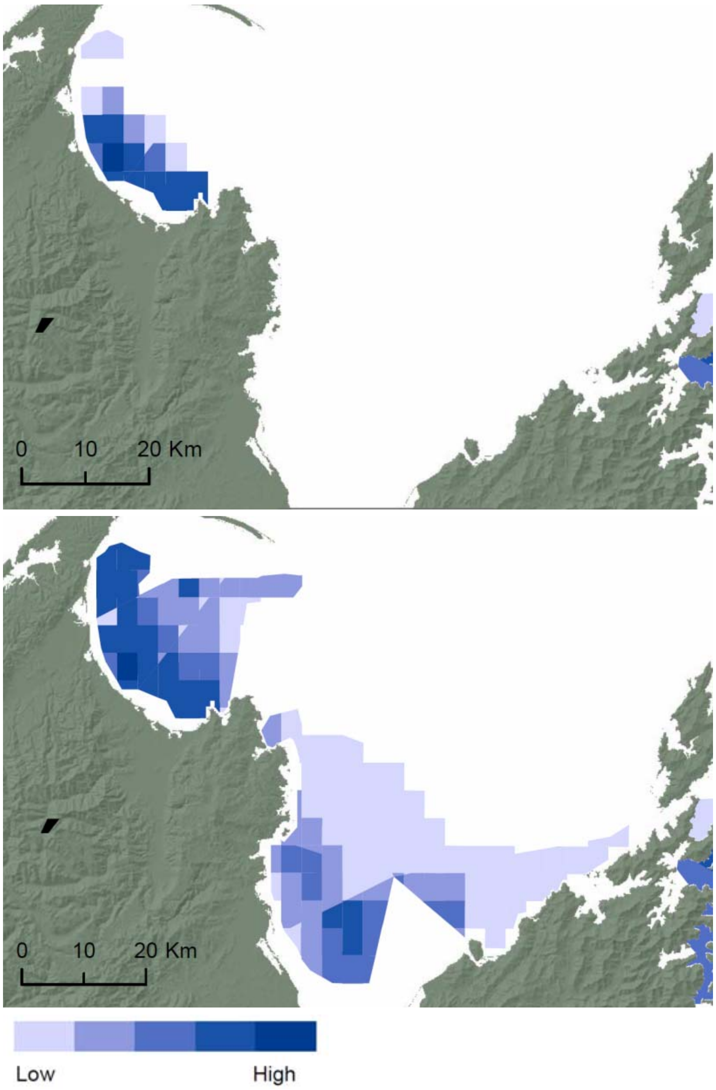

Figure 5. Scallop fishing intensity averaged over 6 years (top) and 16 years (bottom). Data up to 2012. (Osborne *et al*. 2014)

The available information from MPI indicates that scallops are the most commonly harvested customary species in the region, with blue cod, rock lobster, paua and kina also important. Reported permitted and actual take is generally low. Fewer than 100 of any fish species were reported in any given year from 2003 – 2014. Reported permitted take of shellfish was sometimes higher, but apparently well below 1000 individuals, except for scallops, for which reported take was up to ~12,000[21] in some years.

4.2. Port-related activity

Shipping is an important industry for Nelson. As with most ports, contamination exists at Port Nelson. Stressors associated with shipping include introduction of invasive species and the requirement for dredging and spoil disposal. Impacts within the port and marina include maintenance dredging and contamination. Contamination may

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[21] This figure assumes that some reported figures were individuals, even though this was not explicitly stated.

result from historical and current use of metals in antifouling products, or hydrocarbon (diesel and oil) discharges or spills.

A long-term monitoring programme for Port Nelson and Nelson Haven aims to provide Port Nelson Ltd and NCC with a continuing record of environmental quality in benthic areas of the port operational area and the Haven (potentially affected by port activities and other catchment land uses). The long term monitoring plan was first implemented in 2004, but was based on a 1996 baseline survey that focused on chemical contamination in sediments and shellfish. Some changes and gaps have occurred in the programme over the years, but overall the contamination dataset spans 18 years. Benthic community data have been collected since 2010.

The port at Tarakohe in Golden Bay is much smaller than Nelson, but the potential exists for disturbance and contamination as for Port Nelson. A baseline survey of the benthic environment was undertaken at Tarakohe in 2005 (Bennett *et al.* 2006).

Potential impacts from port-related activities include:

- Metal and chemical contamination of seabed and shellfish
- Smothering of benthic habitats (dredge spoil disposal)
- Introduction of invasive species.

4.2.1. Port Nelson channel dredging

Dredging of Port Nelson and disposal of dredge spoils in Tasman Bay has been occurring for over 40 years. Not more than 70,000m^3 of spoils is currently permitted in any year[22]. The spoil disposal area is in southern Tasman Bay has a radius of 600 m and a spreading zone of an additional 800 m from the central point (total area = 616 ha). The environmental effects of spoil disposal are currently monitored every five years, but seven comparable surveys have been undertaken since 1994, most recently in 2012. A baseline survey was undertaken in 1992. To assess long-term effects of spoil-associated contaminants, the survey includes macrofaunal community analysis, contaminant levels in sediments and shellfish tissue, and imposex effects in whelks, which is linked to organotin exposure (Sneddon 2012).

4.2.2. Biosecurity surveys

The Port of Nelson and Nelson Marina are, like other first-entry points for international vessels around New Zealand, relatively high-risk locations for the introduction and spread of non-indigenous species (NIS). In 2000 the Ministry of Fisheries (now MPI) commissioned a series of baseline biological surveys of Nelson and other ports to determine the identity, prevalence and distribution of native, NIS and species of uncertain origin. Nelson was surveyed in January 2002 (Inglis *et al*. 2005) and December 2004 (Inglis *et al*. 2006), and the port and marina at Tarakohe were

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[22] and not more than an average of 50 000m^3 over a three-year period

surveyed in November 2007 (Stuart *et al*. 2009). Samples were taken from wharf piles and other artificial hard structures, and soft sediments.

In 2001 the Ministry of Fisheries also commissioned a programme of six-monthly surveillance for a suite of target species in the port of Nelson and Nelson Marina, including known invasive species not yet present in New Zealand and species known to be present but currently with restricted distributions. This ongoing programme has the secondary objective of opportunistically detecting any non-target NIS. Other surveys in the region have included delimitation studies for the clubbed tunicate (*Styela clava*, 2005–2006) and the Mediterranean fanworm (*Sabella spallanzanii*, 2013–ongoing).

4.3. Outfalls

A number of wastewater treatment plants exist in Tasman Bay and Golden Bay: Nelson North, Bell Island, Motueka, Collingwood, and Takaka. Often monitoring occurs in freshwater or estuarine environments (therefore falling out of the scope of this report), but some information, generally assessment of faecal contamination and nitrogen levels, is collected in association with these plants.

Sealord Group Ltd. discharges fish processing effluent into Tasman Bay via a seabed diffuser approximately 350 m offshore from Nelson’s Boulder Bank. The adjacent seabed area is currently surveyed every five years to monitor potential ecological effects from the discharge. The most recent survey was carried out in 2011. Similar surveys were undertaken in 2006 and 2008 (Sneddon & Clark 2011).

Potential impacts from outfall discharges include:

- Localised seabed enrichment and associated changes in epifaunal communities
- Bacterial contamination
- Enrichment of the water-column.

4.4. Aquaculture

At present, mussels and oysters (bivalve shellfish) are the only species farmed in Tasman Bay and Golden Bay. Shellfish farming is generally considered to present a lower risk of environmental impact, particularly in terms of seabed enrichment, than feed-added finfish farming. No feed-added aquaculture currently occurs in Tasman Bay or Golden Bay. While the Tasman Resource Management Plan now allows for applications to farm new species in existing AMAs, these areas are not currently considered suitable for existing finfish aquaculture species (such as salmon). The Tasman Bay and Golden Bay AMAs were selected for their suitability for farming filter-feeding bivalves, and are likely too shallow and poorly flushed for feed-added farming[23]. Farming of shellfish is overall extractive; *i.e.*, shellfish feed on food occurring naturally in the growing waters, and are then mostly removed through harvest.

Intensive monitoring is required in association with mussel farming activity in the area, through the requirements of their resource consents (*e.g*. Grange 2007, 2010; Clark *et al*. 2012a; Newcombe & Forrest 2013).

Information collected in association with mussel farm monitoring includes:

- Water column characteristics (measurements and modelling, particularly for impacts on phytoplankton)
- Sediment structure and enrichment status
- Epifaunal and infaunal communities
- Shellfish health.

The aquaculture industry also have their own data requirements to assess the state of their products. The Marlborough Shellfish Quality Programme (MSQP) programme makes weekly measurements of phytoplankton composition / biomass and shellfish toxicity, associated with shellfish growing areas in the top of the south. Other ongoing industry-associated data collection also takes place, such as recording of water temperature and shellfish condition. This information is not generally publicly available.

Shellfish farming (mussels and oysters) and spat catching (mussels and scallops) currently occur at a number of sites in Tasman Bay and Golden Bay (Figure 6).

- AMA1 (Collingwood)
- AMA2 (southern Golden Bay)
- Wainui (near-shore, south-east Golden Bay)
- AMA3 (western Tasman Bay)
- Croiselles harbour (near-shore).

Since 2008, the annual tonnage of mussels harvested from the AMAs has ranged from 2,427 to 6,316 tonnes per financial year (data provided by Aquaculture New Zealand, S. Johnson, pers. comm., 8 April 2015). This represents 3-7% of New Zealand's green-lipped mussel production. Additional mussel production occurs around Croisilles Harbour but harvest estimates are unavailable.

Annual tonnage of oysters harvested from the region is estimated to be around 400 tonnes (A. Pannell, Marlborough Oysters Ltd, pers. comm., 26 March 2014).

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[23] http://www.tasman.govt.nz/environment/coastal-marine/coastal-marine-management/aquaculture-and-fisheries-within-nelson-bays/

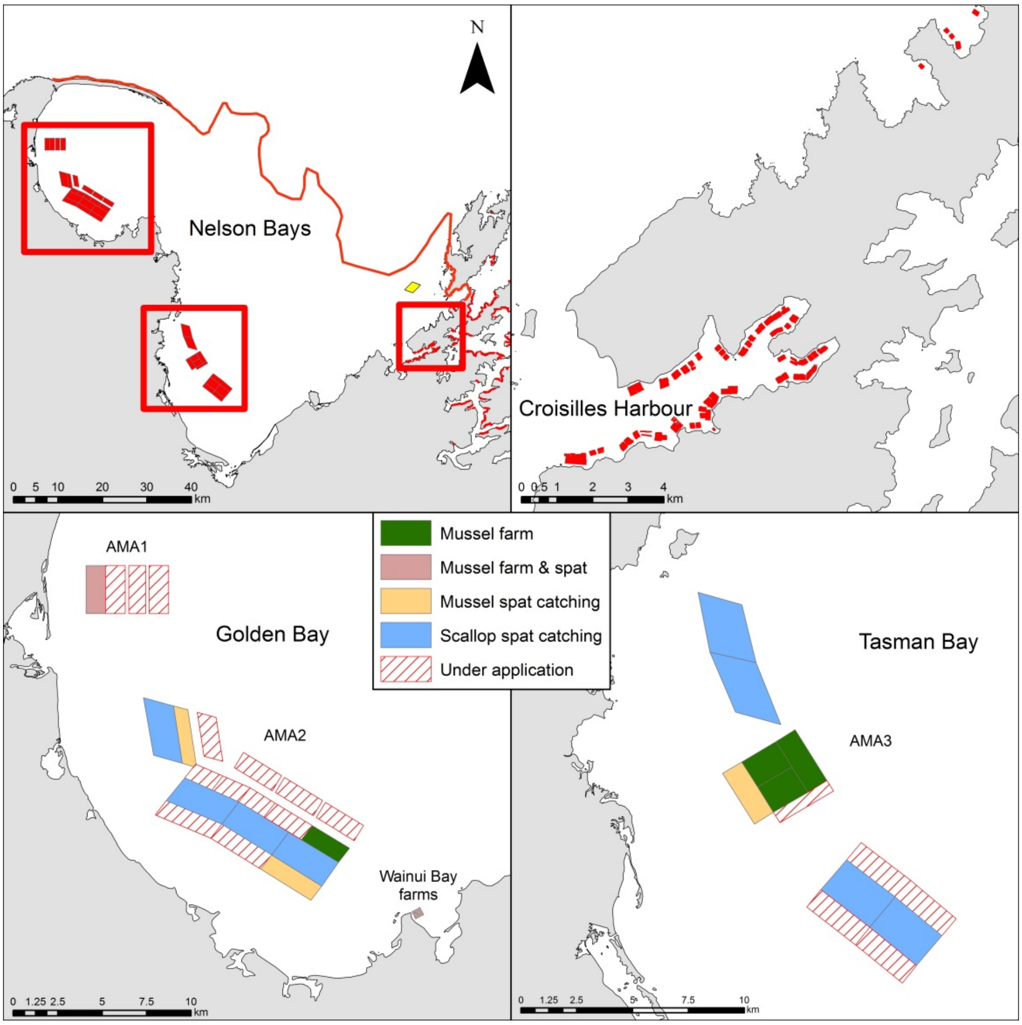

Figure 6. Location of aquaculture activities within Tasman Bay and Golden Bay. Red polygons show areas consented for aquaculture activities. The yellow polygon shown in the overview map (top left) indicates the location of a recently consented mussel farm that is not currently developed. The red line shows the seaward boundary of the case study region in the Marine Ecosystem Services research project, being the 50 m isobath.

Potential impacts of bivalve farming on the environment include[24]:

- Depletion of phytoplankton
- Stimulation of phytoplankton growth through capture and accelerated cycling of nitrogen
- Localised enrichment of seabed from deposition of mussel waste and drop-off
- Addition of bivalves, shell and associated epifauna to the seabed through drop-off.

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[24] A range of other impacts are possible, including hydrodynamic impacts and impacts on fish communities (Keeley *et al.* 2009). Here we limit consideration to issues for which information collection may contribute to state of the environment information.

4.5. Other environmental data

4.5.1. TASCAM

TASCAM is a data collection facility moored in western Tasman Bay, 6 km off the Motueka River mouth (GPS coordinates 2517648E, 6014874N, Figure 1). It collects data on temperature, salinity, turbidity and chlorophyll-*a*. The facility is largely funded by Cawthron, and real-time data is available online[25]. The original purpose of TASCAM was to assess the influence of the river plume on water column characteristics; it also provides a state of the environment (SoE) monitoring site for the assessment of changes in the benthic environment. Surveys are 5-yearly, and were undertaken in 2006 (Gillespie & Keeley 2007) and 2011 (Gillespie & Johnston 2012). The benthic surveys describe the physical, chemical and biological properties of the seabed.

4.5.2. Protected areas

Regular monitoring (commissioned by the Department of Conservation, DOC) occurs at both marine reserves (Horoirangi and Tonga Island). This work focusses on the species for which protection from fishing is expected to produce the largest effects, *i.e*., those commonly over-exploited by humans (Davidson *et al*. 2011a; Davidson & Richards 2013). Soft sediment monitoring has also been initiated at Horoirangi reserve (Keeley *et al*. 2006).

Other research associated with protected areas has also occurred, such as habitat mapping of soft sediment areas of the Tonga Island reserve (Thrush *et al*. 2003), and a study of the bryozoan communities at Separation Point (Grange *et al*. 2003). A recent study addressed the impacts of fishing on soft sediment communities in the Separation Point protected area (Handley *et al*. 2014).

4.5.3. Other research activity

One of the first studies of the benthic environment was a national study that classified benthic communities (McKnight 1969). Handley (2006) reviewed information about historical impacts on the benthic environment. The information pertaining to important fisheries has also been reviewed (Bradford-Grieve *et al*. 1994; Michael *et al*. 2012). The potential for restoration has also been assessed (Brown 2008, Handley & Brown 2012).

The impact of the Motueka river plume has been the focus of a number of studies last decade, many of which occurred as part of the Motueka River Integrated Catchment Management programme (MacKenzie 2004; Forrest *et al*. 2007; Cornelisen *et al.*. 2011; Gillespie *et al*. 2011d; Gillespie *et al*. 2011e):

Nutrient and phytoplankton dynamics have also been addressed in a number of other projects (MacKenzie & Gillespie 1986; MacKenzie & Adamson 2004; Zeldis 2008).

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[25] www.cawthron.org.nz/tascam

A Ministry of Business, Industry and Enterprise (MBIE)-funded project ‘Integrated Valuation of Marine and Coastal Ecosystem Services’ uses Tasman Bay and Golden Bay as a pilot for research to place economic and social-cultural valuations on ecological processes. It aims to develop a more holistic approach toward ecosystem services, values and processes. Existing ecological knowledge of the environment is being brought together and assessed in terms of the ecosystem services provided. The outcomes from this project are expected to be published in the near future. The focus of this work is not to assess the degree or trajectory of change, rather to place a value on the services currently provided.

4.6. Cultural monitoring

In a previous report (Newcombe & Cornelisen 2014) the state of cultural monitoring in the coastal environment was considered. While various cultural monitoring projects have been undertaken in freshwater and estuarine environments (*e.g*. McColgan & Walker 2009; Tiakina Te Taiao 2013), we are not aware of any that have taken place in the marine environment.

Substantial historical and current information will be held by tāngata whenua. Engagement with kaitiaki could provide opportunity to establish cultural indicators for the marine environment. Kaitiaki may also hold valuable information about long term change.

5. REVIEW OF ENVIRONMENTAL CONDITIONS BASED ON EXISTING DATA SETS

A considerable amount of data collection has been undertaken in Tasman Bay particularly, but also in Golden Bay. Much of the research-associated information is valuable in terms of identifying some fundamentals of ecosystem functioning and status. However, there is little information on temporal or spatial trends. The consent-associated information is often collected repeatedly over time, but this is targeted to the effects of individual activities rather than overall state of the environment.

For the purposes of discussion regarding the state of the environment, the sections below are structured by habitat. The water column and the seabed (the benthic environment) are the two primary habitats that can be defined in the marine environment. The seabed can further be considered in terms of physical structure: soft sediments, biogenic habitat (structure created by animals or plants), and rocky reef. Despite these divisions there is substantial connectivity in physical, chemical, and biological aspects between habitats. Many overarching concerns regarding the health status of the marine environment can be considered in both the water column and in the benthic (seabed) environment, although some are more relevant to one environment than the other.

Key topics to consider for gauging marine ecosystem health status in coastal areas include:

1. Primary productivity
   Primary productivity is a term describing the fixing of dissolved carbon (in the form of carbon dioxide (CO_2)) to organic carbon by autotrophic organisms such as microalgae or seaweeds. Organic carbon is the major resource currency in marine ecosystems providing ‘food’ energy on which marine organisms in the bays need to survive and grow. Excessive growth of primary producers can be a symptom of eutrophication, and is typically caused by an increased supply of nutrients (usually nitrogen in coastal environments). Furthermore, some microalgae produce toxins which can be harmful to marine organisms or humans. Similarly, oligotrophication is also possible, whereby primary production is decreased due to the removal or nutrients, reduction of light (*i.e* increased sedimentation), or by a reduction in phytoplankton (*e.g*. due to the intensification of shellfish farming). In the case of Tasman Bay and Golden Bay, both eutrophication and oligotrophication pressures exist. In terms of the NZCPS, primary productivity would have relevance to maintenance of water quality for protection of ecosystems and for aquaculture purposes, as well as management of harmful aquatic organisms.
2. Sedimentation
   Sediments in the water column can reduce water column and seabed light levels, which can reduce primary productivity, and increase survival of bacteria. It can also clog the gills or reduce the feeding efficiency of filter-feeding animals. When deposited on the seafloor, sediments can smother benthic organisms, and

interfere with settlement of juveniles onto underlying substrates. In terms of the NZCPS, sedimentation can be an important indicator of water quality for the protection of ecosystems, and monitoring of sedimentation levels and impacts is a specific requirement.

3. Habitat integrity
   Habitat integrity refers principally to structural aspects of habitat, therefore it is considered here only in terms of the benthic environment. In general, unmodified habitat would have greater structural integrity. Alterations to habitat such as change in sediment grain size or loss of plants and animals that created structure will invariably have implications for biodiversity. Accordingly, habitat integrity is relevant to NZCPS requirements to manage impacts on indigenous species, ecosystems, or habitats.
4. Contamination
   Bacterial and chemical contamination is often a concern associated with human activity, and can have a wide range of effects. Bacterial contamination is generally a human health issue. Chemical contamination can impact both ecological functioning and human health. Contaminants include metals and emerging contaminants such as such as those from pharmaceuticals. Chemical contamination can be high in ports and harbours, and around outfalls. The NZCPS includes requirements directly related to the discharge of contaminants; contamination is also relevant to maintenance of water quality for protection of ecosystems and for aquaculture purposes.
5. Fisheries
   Although not considered in the NZCPS, and substantially outside of the control of councils, fisheries are a particularly valuable aspect of the marine environment in terms of human use. Moreover, changes in abundance of a given species can have important implications for food-web structure. Use of fisheries data as an ecological indicator is nonetheless complicated, and has significant limitations due to the dominance of catch, rather than survey, data[26]. Marine reserve monitoring does, however, give some indication of the effects of fishing in the region.
6. 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 substantial impacts on commercial, recreations, and cultural values. They can have implications for primary productivity, sediment dynamics, habitat integrity, fisheries, and other aspects of biodiversity. In the case of, for example, toxic species, they can cause direct harm to humans. Management of harmful aquatic organisms is a requirement of the NZCPS.

For the topics above, we summarise the state of knowledge and assess the extent to which the available information is useful for assessment of the state of the environment.

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[26] While fishing was presented above as an important impact, it is given lower priority here as an indicator of state of environmental health. Moreover, the Rebuilding Shellfish Fisheries programme and reporting deal directly with data on shellfish fisheries in Tasman Bay and Golden Bay.

5.1. Water column

Tasman Bay and Golden Bay are large systems open to the turbulent waters of Cook Strait and the South Taranaki Bight. The eastward-flowing D'Urville current is enriched by the nutrients from the Kahurangi upwelling plume (Bradford-Grieve *et al.* 1994) and contributes to a nutrient-rich boundary at the entrance to the bays.

The vast majority of work on the water-column in Tasman Bay and Golden Bay has occurred as part of research projects. These studies have provided substantial information regarding the functioning and general status of the water column environment of Tasman Bay in particular. Some water column sampling also takes place as a monitoring requirement associated with consented activity. However, only relatively recently has long-term multi-year monitoring been instituted, in the form of the TASCAM buoy. This is largely a privately funded initiative, with a small contribution made by TDC towards upkeep.

5.1.1. Water column primary productivity

Nutrient input

The supply of essential nutrients to fuel the growth of phytoplankton is critical to the pelagic and benthic ecosystems in marine environments, and originates from the land and from nutrient-rich oceanic waters. The most important limiting nutrient (*i.e.*, the nutrient that restricts plant growth) in Tasman Bay and Golden Bay is nitrogen, in the form of dissolved inorganic nitrogen (DIN). Although inorganic phosphorus, iron, and silica can also be limiting occasionally (MacKenzie 2004), these are not thought to significantly constrain phytoplankton production in the bays.

The relative contributions of oceanic and freshwater nutrient sources were assessed using a theoretical nutrient budget approach in a council-commissioned project (Zeldis 2008). It was calculated that around 90% of the DIN input is from the circulation of offshore waters into the bays. The model also suggests that water in Golden Bay is exchanged more frequently (approximately every 11 days) than Tasman Bay (approximately every 41 days). Quantification of nutrient discharges into Tasman Bay (from extensively modified catchments and point source discharges) (Gillespie *et al*. 2011; Table 3) and investigation of the spatial and temporal distribution of nutrients in the Bay (MacKenzie 2004) indicate the importance of freshwater sources of inorganic nutrients for coastal primary productivity. However, based on these findings and the estimated flushing rate, there seems to be little potential for problems associated with overenrichment (*i.e*. eutrophication) to occur. Although fewer data are available for Golden Bay, a similarly low potential for eutrophication effects would likely hold, particularly considering the more rapid flushing rate.

Table 3. Estimated anthropogenic inputs from land of total nitrogen (TN) to Tasman Bay and nearby waters. Note that oceanic waters (not shown) are estimated to contribute about nine times more nitrogen to the region.

Source	**TN (tonnes / year)**	**% of TN inputs**
Bells Island municipal discharge (Richmond / Nelson)[1]	97	8
Nelson fisheries processing[2]	70	6
Nelson City municipal discharge[2]	102	8
Waimea River[2]	226	19
Small Waimea streams[2]	24	2
Motueka River[3]	613	50
Other tributaries[3]	50	4

[1] Gillespie *et al.* 2001
[2] Forrest *et al.* 2007
[3] Gillespie *et al.* 2011d

Nutrient sinks

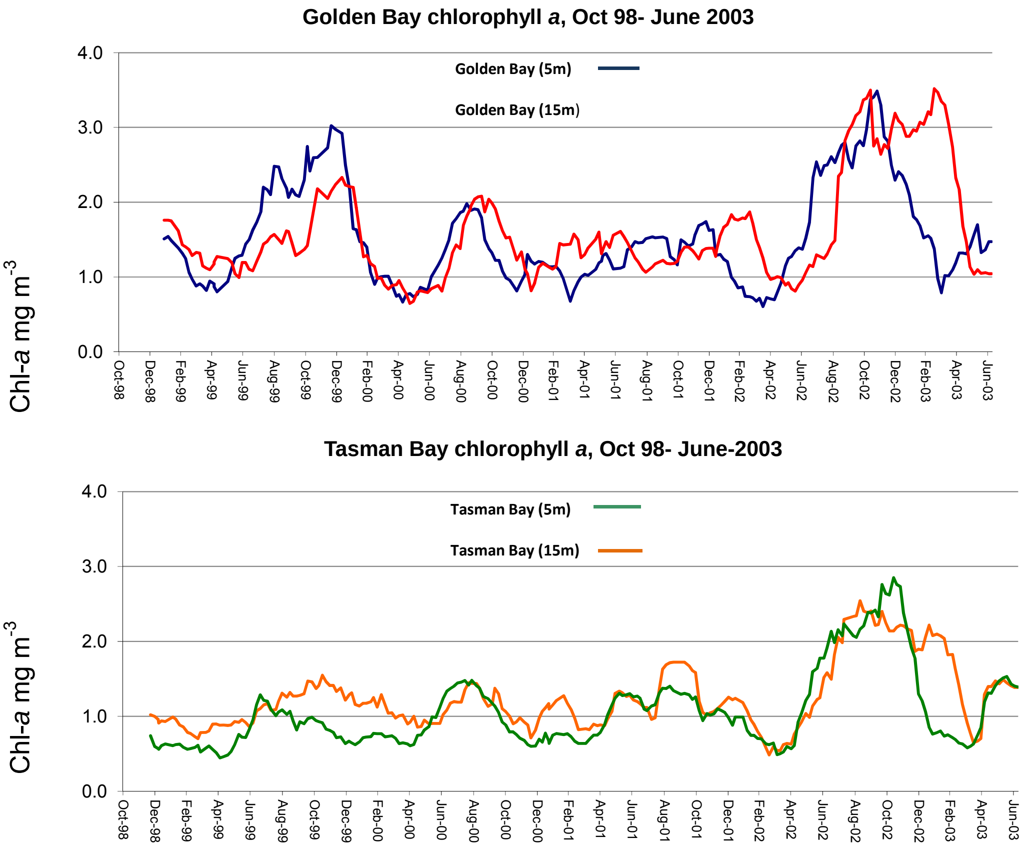
An unknown but possibly significant proportion of inorganic nitrogen is lost from Tasman Bay and Golden Bay via denitrification in the water column (Zeldis 2008; Gillespie *et al*. 2011d). This occurs when nutrient forms of nitrogen (e.g. nitrates (NO_3), ammonium (NH_4)) are converted to nitrogen gas (N_2) via microbe-mediated processes. Although there is a lot of uncertainty about the accuracy of bay-wide extrapolation of these estimates, losses of nitrogen from the ecosystem may at times constrain productivity. Perhaps more importantly, however, these losses may mitigate any adverse enrichment effects from increased anthropogenic nutrient inputs to the marine environment.

Phytoplankton

Phytoplankton are the most important primary producers within the Tasman Bay and Golden Bay ecosystem. Seasonal and inter-annual variations in biomass and specific composition of the phytoplankton affect the productivity of benthic and pelagic food-webs. Phytoplankton can be studied directly, by counting and identifying organisms in water samples. Often, rather than studying individual phytoplankton, a common light-harvesting pigment chlorophyll-*a* is used to estimate the phytoplankton biomass. For example, a florescent sensor is used on the TASCAM buoy located in Tasman Bay to estimate chlorophyll-*a* levels.

Water column chlorophyll-a distribution

Phytoplankton productivity in the near shore (< 30m) regions of the Tasman Bay and Golden Bay is profoundly affected by river inflows that supply essential inorganic nutrients. These inflows also affect estuarine circulation processes, density stratification and light availability, all of which have implications for phytoplankton growth. Freshwater inputs in the bays are generally associated with higher biomass of phytoplankton. For example, Golden Bay generally has higher chlorophyll-*a* concentrations than Tasman Bay, due to the larger quantity of freshwater relative to its volume than Tasman Bay (Figure 7).



Golden Bay chlorophyll *a*, Oct 98- June 2003

Tasman Bay chlorophyll *a*, Oct 98- June-2003

Figure 7. Chlorophyll-*a* (Chl-*a* mg m^{-3}), as a proxy for phytoplankton biomass, in Tasman and Golden Bays October 1998-June 2003

These chlorophyll-*a* concentrations are consistent with the broad classification of productivity of Tasman Bay and Golden Bay as oligotrophic (low) to mesotrophic (moderate)[27].

Primary productivity was estimated across Tasman Bay and Golden Bay (Gillespie *et al*. in press). The increasing depth of water offshore (and therefore greater volume for phytoplankton growth) contributed to a general pattern of greater depth-integrated productivity away from the coast (Figure 8). However, benthic productivity is relatively higher in water column production in shallow waters (e.g. < 20 m). Beyond

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[27] The terms oligotrophic, mesotrophic, and eutrophic correspond to systems receiving low, intermediate, and high inputs of nutrients (Smith *et al.* 1999). These categories are based on international studies (Håkanson 1994), and ranges specific to New Zealand conditions have not been defined.

approximately 40m depth, light and nutrients become progressively more limiting (although this is not discernible in Figure 8).

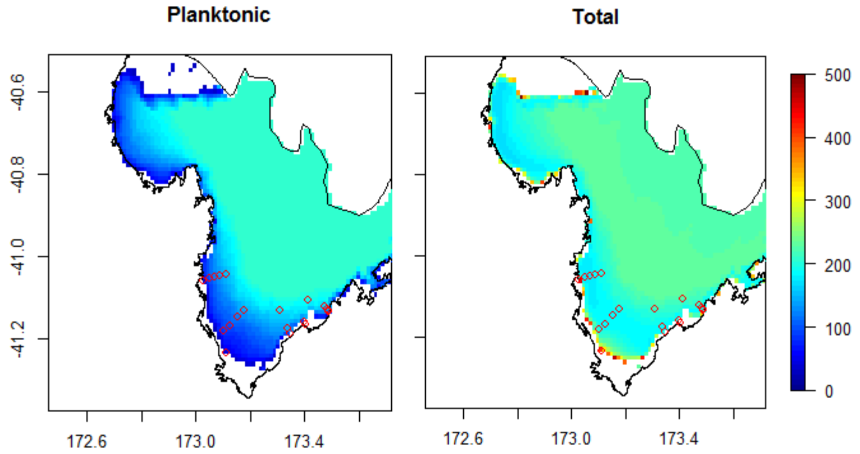

Figure 8. Spatial distribution of estimated planktonic and total primary production in Tasman Bay and Golden Bay (average using light intensities extracted for 2009-2012 from the MODIS dataset). Values of primary production are integrated over the water column and expressed as a rate per planar area. Estuarine areas are not included. (Gillespie *et al*. in press).

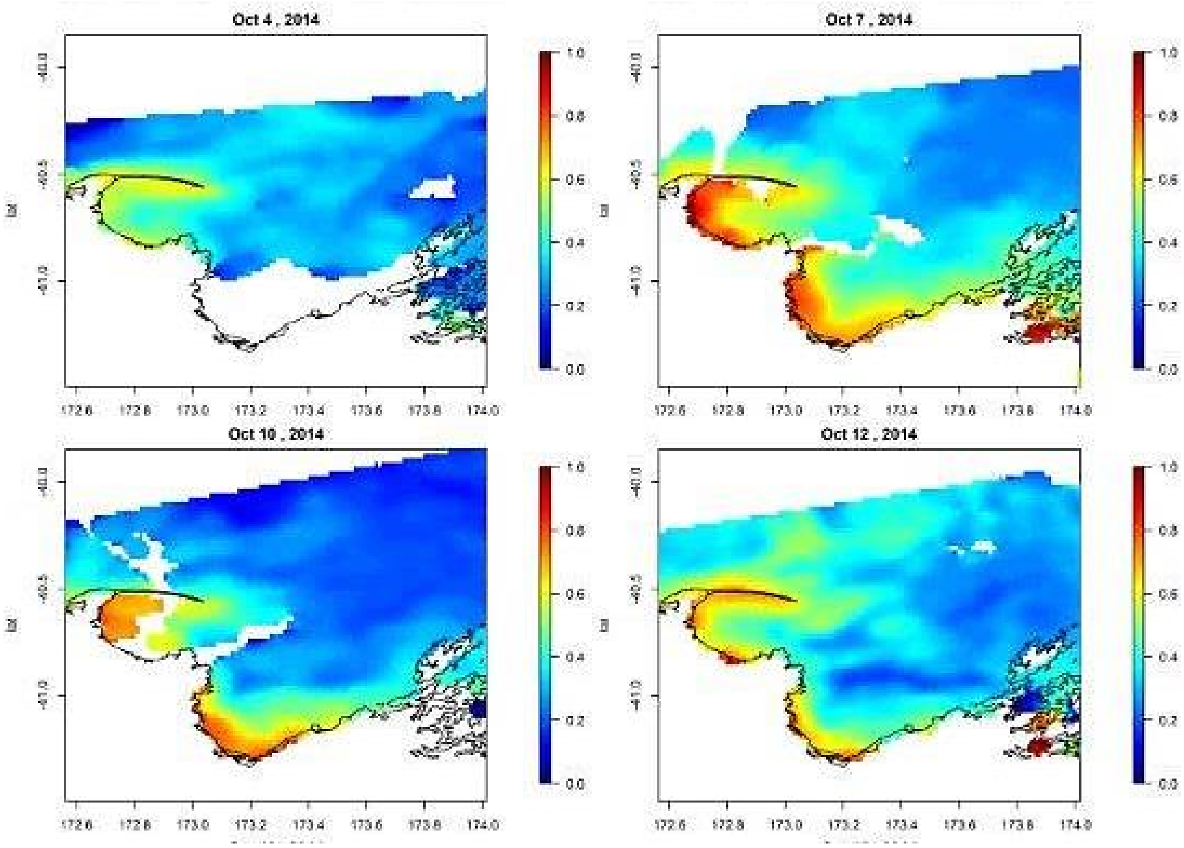

Figure 9. Chlorophyll-*a* concentration in surface waters of Tasman Bay and Golden Bay visualised from freely available ocean colour data (MODIS Aqua level 2), for four days in October 2014. See Jiang *et al.* 2014 for a discussion of the accuracy of the images.

While the modelled average productivity shows a smoothed representation of productivity in the bays, in reality for a given time, depth and location, a large amount of variation in phytoplankton biomass can occur. Preliminary processing of satellite imagery to display surface chlorophyll-*a* showed generally higher levels of chlorophyll-*a* near the coast, but also illustrates high variability (Figure 9). While useful in terms of the data available from existing images, information is only available from surface waters. As seen below, stratification dynamics can have strongly influence the distribution of chlorophyll-*a* throughout the water column. The assessment of chlorophyll-*a* also becomes less reliable in turbid near-shore waters.

The variation observed in satellite images was also present in large multi-month surveys for Tasman Bay undertaken by MacKenzie & Adamson (2004). These surveys show that large gradients in phytoplankton (represented by chlorophyll-*a*) can exist throughout the bay and these can change seasonally (Figure 10).

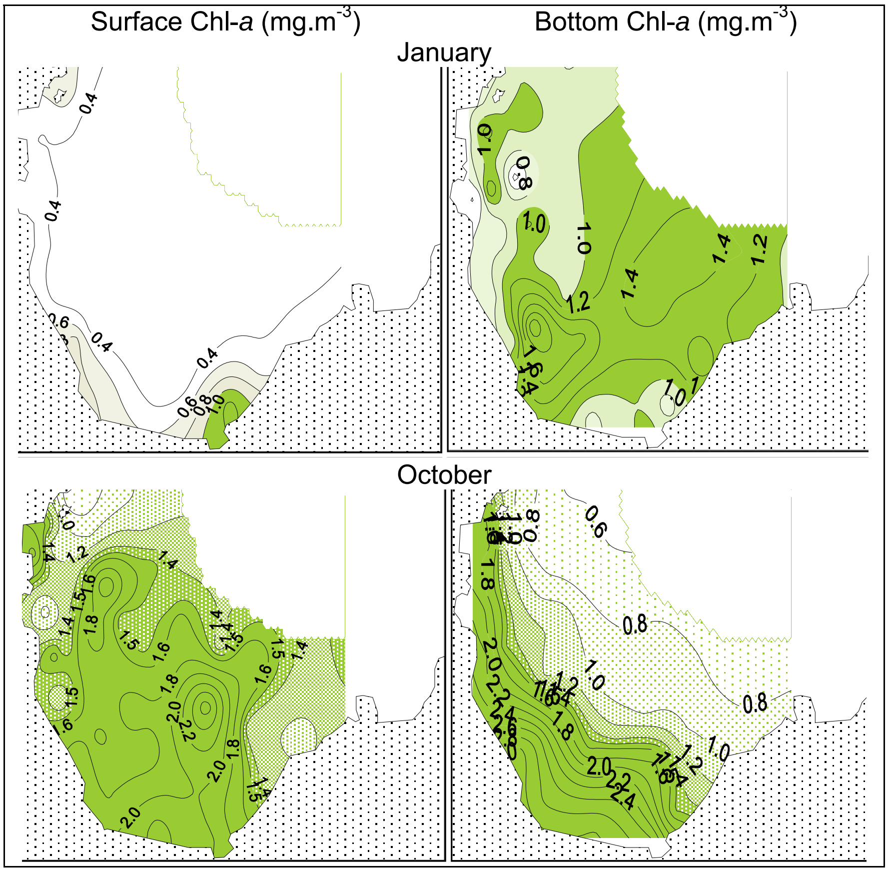

Figure 10. Examples of seasonal changes in phytoplankton biomass (chlorophyll-*a*) concentrations (mg Chl-*a* m^{-3}) in surface and near bottom waters of Tasman Bay within the 30m depth contour. Reproduced from MacKenzie & Adamson (2004).

MacKenzie & Adamson (2004) also observed that temporal changes in the abundance and distribution of phytoplankton biomass in Tasman Bay are associated with changes in water column stratification from river and oceanic entrainment. In winter the water column nitrate / nitrite concentration maximum that develops is due to advection of offshore waters into Tasman Bay, *in situ* re-mineralisation processes and light limitation of phytoplankton productivity at this time. Diatoms respond rapidly to water column mixing and high nitrate concentrations and generally bloom in autumn and spring.

General seasonal patterns were observed with the winter-spring period representing an annual productivity maximum. At these times the conditions for shellfish nutrition are at their best, an important consideration for the aquaculture industry. At most other times flagellate-dominated phytoplankton communities, within concentrated sub-surface layers, are associated with a mid-water column (10-15m), bay-wide, pycnocline[28]. This is a common feature of the structure of the water column of Tasman Bay, coinciding with the depth range within which scallop growth and survival is highest, and mussel nutrition and spat catching is optimal.

Although several snapshots of data over large areas of Tasman Bay are captured in the survey data of MacKenzie & Adamson (2004), it was not until TASCAM was deployed in 2011 that detailed high frequency data could be collected. Chlorophyll-*a* levels measured at TASCAM show high variability over quite short time scales which can obscure seasonal patterns (Figure 11). This is due to the placement of the sensors within the Motueka River plume, where water column properties such as chlorophyll-*a* can be highly variable.

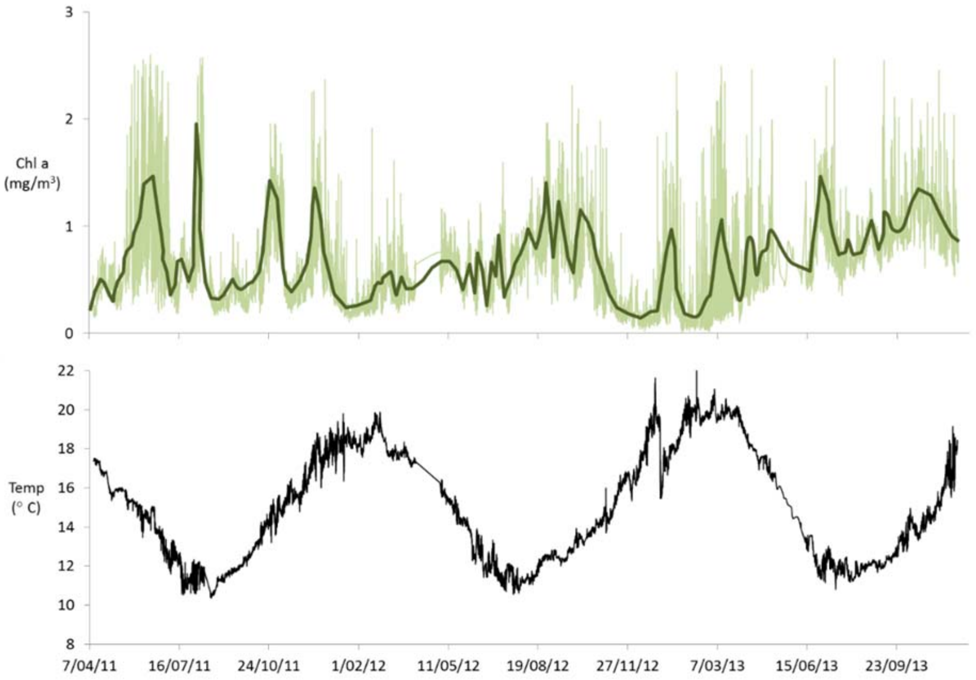

Figure 11. Chlorophyll-*a* (top) and temperature (bottom) recorded at TASCAM over approximately three years (Cawthron data).

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[28] A rapid change in density in a stratified water column

In summary of our knowledge of water column primary productivity has been gathered from a wide number of sources, which include:

- Intensive sampling undertaken for research projects (but this has not been on-going due to, among other issues, funding limitations)
- Resource consent monitoring for marine farms
- TASCAM monitoring buoy, which provides high frequency data collection, but at a single point—the characteristics of which cannot be generalised to the region.

Satellite imagery (once appropriate algorithms are developed in association with ground-truthing) provides the potential for high resolution and relatively high frequency (twice daily) data, over large areas but only for surface waters. Available parameters include temperature, clarity, and chlorophyll-*a*. This technology also provides a means of 'hindcasting' data from the past 12 years.

In combination the existing information suggests that the bays' water column environment has a low to moderate productivity (*i.e*. an oligotrophic to mesotrophic state) although this is variable in space and time. At the scale of the bays, it appears that the productivity per unit area is slightly higher in Golden Bay than Tasman Bay. Due to a lack of consistent long-term data collection, it is not yet possible to determine long-term trends in productivity for the bays, but it may be possible to derive such information from a combination of targeted high frequency data collection (e.g. from buoys) and increased use of historic satellite imagery which has been captured for at least a 12 year period.

Phytoplankton taxonomic composition

The make-up of the phytoplankton community can influence the functioning of the ecosystem. The phytoplankton community structure and phenology in Tasman Bay is typical of a temperate coastal environment, although there are considerable year to year variations in the biomass, taxonomic make-up and the magnitude of photosynthetic productivity (MacKenzie & Adamson 2004). For example, larval stages of species may depend on the availability of particular phytoplankton, or filter-feeding organisms may only be able to gain energy from certain size classes of phytoplankton. Consequently, assessing the state of the water column environment would ideally also consider temporal trends in the taxonomic diversity and succession of phytoplankton.

An example of how different taxa contribute to changes in phytoplankton biomass and productivity in Tasman Bay was provided by Mackenzie & Gillespie (1986) (Figure 12). There were two major biomass and productivity peaks over this period (August 1982– March 1984) during the late winter and early spring. Changes in the relative proportions of phytoplankton size classes were related to species succession.

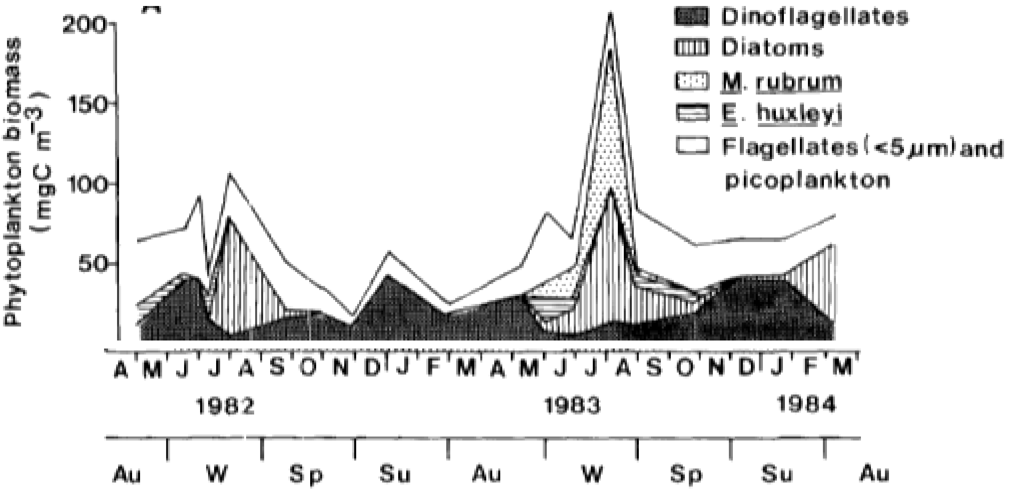

Figure 12. Total phytoplankton biomass (mg C.m^{-3}) and the relative contribution by various taxonomic groups in surface waters of Tasman Bay (reproduced from MacKenzie & Gillespie 1986).

There has never been an attempt to achieve a complete taxonomic characterisation of the phytoplankton flora of Tasman Bay and Golden Bay; to do so would be a major task. A species list was compiled by Mackenzie & Gillespie (1986), although this was in no way comprehensive. New molecular technology such as Next Generation Sequencing (NGS) has recently revealed the presence of numerous species that have not been identified by conventional microscopic examination (Pochon *et al.* 2013). This new tool is likely to be particularly useful in future state of the environment monitoring, because it reveals the existence of cryptic, hard to identify species that could have social, commercial or economic importance to the region (*e.g*. harmful algal species).

Perturbations in the phytoplankton community (for example, increases in primary productivity resulting from increased nutrient inputs) can lead to blooms of nuisance species. Although a number of toxic dinoflagellate species are known to occur in the region, no exceptional blooms of these species have been recorded. To date the incidence of shellfish contamination with algal biotoxins has been low (MacKenzie 2004). The NGS analysis of Tasman Bay sediments (Pochon *et al*. 2013) identified the presence of species with the potential to produce a shellfish toxin known as azaspiracid that has at times caused considerable problems for shellfish aquaculture in Europe (James *et al.* 2000). Only trace levels of azaspiracids have been observed in New Zealand shellfish and the origin of this contamination is unknown so far.

At about 20 year intervals, since at least the 1860s, there have been accounts of the accumulation of very large quantities of mucilage in the Tasman Bay water column[29]. On a few occasions these events have been associated with harmful effects such as

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[29] It was earlier suggested that the colonial form of the haptophyte *Phaeocystis pouchetti* may be responsible for this phenomena (Chang 1983). However, subsequent research has shown that this is unlikely and the cause of these events was definitively identified as a polysaccharide-mucilage producing planktonic dinoflagellate *Gonyaulax hyalina* (MacKenzie *et al*. 2002).

the mass mortalities of marine fauna and the impediment of fishing activities. The last major event that that came to public attention was in 1981, though it is suspected more minor events are not uncommon.

In summary, based on a variety of studies that have investigated the basic phytoplankton community structure of the bays, there is a basic knowledge of the major species and their succession. Based on the collected data it appears there was a 'typical' patterns of winter blooms in diatoms, followed by dinoflagellate dominance in summer.

During the last 30 years a number of anthropogenic changes will have occurred (*e.g*. an increase in aquaculture, harvesting of plantation forests *etc*.) which may have influenced the patterns that were observed previously. Aquaculture-focused MSQP datasets, and those collected for consent-associated monitoring will have a record of changes relating to toxic phytoplankton species. Access to these data would require negotiation with the owners of the data. Additionally, data targeted to toxic species may not necessarily be useful for assessing changes to state of the bays compared to the study of Mackenzie & Gillespie (1986), for which 'full count' data would be required. Nevertheless, unlike phytoplankton biomass data, for which some contemporary data are available for chlorophyll-*a*, it is not possible to assess the present state of phytoplankton community structure in Golden Bay and Tasman Bay.

Effects of mussel farming on the water column

In considering possible state changes to the water column of the bays, it is relevant to consider the potential for the growth of aquaculture, particularly mussel farming, for which considerable expansion has been proposed.

A concern with respect to mussel farming internationally is that intensive farming may deplete phytoplankton communities, to the detriment of other animals that directly consume phytoplankton, or indirectly rely on the flow of organic energy sourced from them. However it is possible that mussel farms can increase phytoplankton productivity through remineralisation during periods of nutrient limitation (Ogilvie *et al*. 2000), *i.e*. making nitrogen that was bound up in organic matter (not necessarily a phytoplankton source) available to phytoplankton.

Theoretical depletion of phytoplankton of up to 40% has been calculated at densely-stocked Golden Bay farms (Gall *et al*. 2002). Subsequent work on less densely-stocked farms has found <12% (Grange 2007) maximum depletion can occur.

A wide range of responses have been observed in the large on-growing areas in AMA 2 and AMA 3 over different monitoring surveys (Clark *et al*. 2012b; Clark *et al*. 2012a). It was no more common to see a reduction than an increase or stable chlorophyll-*a* levels in association with the farm. While farmed areas are large, these mussel lines are widely spaced (33 – 50 m) so it is expected that less-severe reductions would occur than at more densely-farmed areas.

While detectable changes in chlorophyll-*a* beyond the edges of individual farms are generally minor, development over time may require assessment of cumulative effects, for which no framework currently exists. Long-term time series data at TASCAM will also assist in quantifying change and natural variability over time, which in turn is required to provide context for farming effects.

5.1.2. Sediment in the water column

Sedimentation can have important effects on both the water column and the benthic environment. Sediments are transported to and around the marine environment via water movement. Sediments that are suspended in the water column can have a range of effects, for example:

- Reduce water column and seabed light levels, which can reduce primary productivity, and increase survival of bacteria
- Clog the gills or reduce the feeding efficiency of filter-feeders
- Transport of sediments can spread impacts of sediment deposition (such as smothering) across a wide area.

Sediment input

Sediment deposition from land often increases substantially due to human-induced change. Increased sedimentation has been identified as potentially the most important land-based stressor in marine environments (Morrison *et al*. 2009). Sediments are transported into Tasman Bay and Golden Bay in marine currents from the west coast (Michael *et al.* 2012), in the rivers that flow directly into the bays, and directly from coastal erosion.

Mature forest cover is most effective at protecting land from eroding, and erosion is therefore most likely to be accelerated during rainfall onto pastoral land or onto harvested commercial forestland within ~6-8 years of harvest and replanting (Jones 2008). The extent of commercial forestry is greater in Tasman Bay than Golden Bay, but substantial pastoral land borders rivers in the catchments of both bays (Figure 3). LAWA data (Section 3.2) show that large rivers flowing into Tasman Bay and Golden Bay have relatively low turbidity; however, this is not necessarily a good indication of suspended sediment input. Turbidity does not correlate well with suspended sediment loading, and most riverine inputs are flood-associated (Gillespie *et al*. 2011e). Accordingly, total input is unlikely to be well-measured by infrequently-collected periodic monitoring.

Coastal erosion and inundation risks increase during periods of extreme tides, strong onshore winds and storm surge. Although the Tasman Bay / Golden Bay region is a relatively low energy environment, more than 70% of the coastline is subject to some degree of long term, persistent erosion. Significant areas of erosion occur west of Rangihaeata Head in Golden Bay and along the Ruby Bay to Mapua shoreline, exceeding losses of 1 m per year (TDC 2013). Currently, 28% of Tasman Bay (from

Waimea Inlet to Marahau) and 12% of Golden Bay has shoreline armouring (*e.g.* seawalls, causeways, stopbanks and reclamations (Robertson & Stevens 2012)).

While sediment input is apparent, particularly after rainfall events (Figure 13), average annual sediment input into the Tasman Bay / Golden Bay coastal waters is relatively low by national standards (Hicks in Morrison *et al*. 2009). Moreover, sediment input over the last two decades has been relatively low (as calculated with a sediment yield estimator, reported in Michael *et al*. (2012)).

Figure 13. After heavy rainfall, suspended sediment plumes from the Motueka River are clearly visible in Tasman Bay.

Observations, satellite imagery, consent monitoring data, and TASCAM data show highly variable turbidity in Tasman Bay and Golden Bay. Satellite imagery can be used to map surface water plumes, which is valuable in understanding input and immediate transport. This may have restricted value in understanding bay-wide sediment dynamics, however, as the highest suspended sediment levels in the water column within the bays are typically in the near-bottom waters.

Sediment resuspension

While sediment loadings from rivers during storms can be substantial, this is not necessarily the immediate driver of suspended sediment levels observed in coastal waters. Observations of a fluctuating and sometimes persistent near-bottom high turbidity layer in river plume-affected regions of Tasman Bay (Gillespie & Rhodes 2006) suggest that on-going sediment resuspension can affect benthic habitat characteristics for extended periods. Studies of the timing of high winds, rainfall, and turbidity changes have shown that increases in turbidity are associated with wind (*i.e.* wave action), rather than river flow. Peaks in turbidity in marine waters (Figure 14C) occur in closer association with wind speed (Figure 14A), than with river flow (Figure 14B). Where storm events include both high winds and rainfall, it is apparent that the marine turbidity increases before the river discharge increases. It follows that wave action stirring up the seabed, rather than river-input, is the immediate driver of storm-associated turbidity increases. The fine sediments associated with a frequently disturbed seabed are more readily re-suspended, exacerbating the presence and persistence of near-bottom high turbidity (Gillespie & Rhodes 2006).

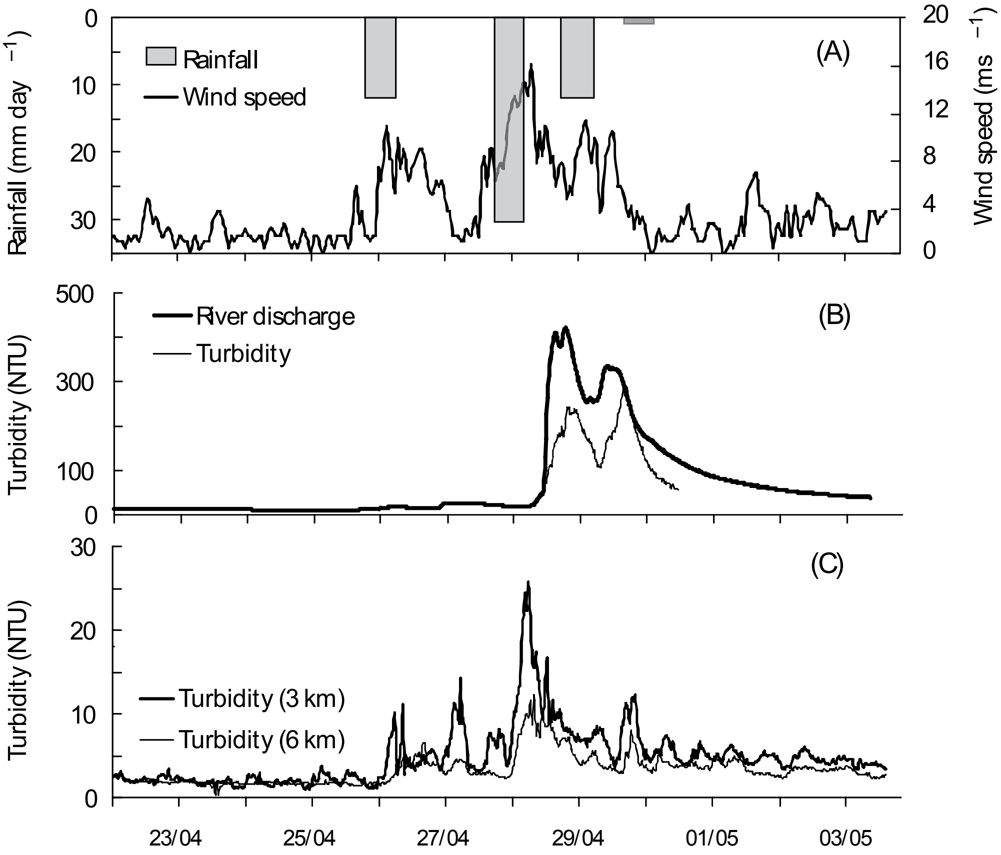

Figure 14. Weather conditions, river flows and water quality conditions in Tasman Bay in April and May 2009. (A) Rainfall measured at Tapawera and wind speed measured at the Nelson Airport. (B) River flow and near bottom turbidity measured at Woodmans Bend. (C) Turbidity (NTU) measured at c. 3m depth at moorings located at 3 and 6 km distance from the river mouth. Modified from Cornelisen *et al.* (2011).

Given that current sediment input to Tasman Bay and Golden Bay is relatively low, sediment resuspension of historically deposited sediment is arguably a more important driver of sediment impacts than the input of new sediments. The effects of this on the benthic environment are discussed in Section 5.2.2.

While dynamics of sediment input and re-suspension are relatively well-understood, the spatial extent and exact nature of environmental impacts are not. Suspended sediment is thought to impact primary productivity, scallop survival, and reestablishment of biogenic habitat (structure created by animals or plants). However, the scale and degree of impact is not easily identifiable with available information, nor is the nature of interactions with other factors (*e.g.*, direct disturbance, nutrient availability).

5.1.3. Watercolumn faecal contamination

Testing of FIBs (faecal indicator bacteria) in the bays occurs for a range of purposes, including council-run recreational water quality surveys and wastewater treatment plants' consenting requirements. Mussel farmers also monitor for food safety assessment, largely through the Marlborough Shellfish Quality Programme. Faecal contamination is a human health, rather than an environmental health issue, and would not be expected to influence ecosystem functioning. However, the cultural perspective on faecal contamination is also an important consideration. Māori are likely to find even very low levels of faecal contamination unacceptable, particularly if the contamination is from human sources. Faecal contamination also affects recreational and customary fisheries, and councils recommend that shellfish are not collected for consumption after large rainfall events or overflows from sewage treatment plants.

There are also financial implications for faecal contamination. The Aquaculture Management Areas (AMAs) selected for marine farming development, lie within the < 30 metre depth contours and are significantly influenced by out-welling river plumes. To avoid the contamination of mussels with faecal material washed off the land, harvesting of shellfish may have to be postponed when river flows are high. In Tasman Bay, harvest closures in the mussel farms occur when flows in the Motueka River exceed 60 m^3/s. Consequently, mussel farms in Tasman Bay are closed to harvesting approximately 30% of the time, which will be equivalent to $4-5 million in lost harvestability once the aquaculture management areas are fully developed (Chris Cornelisen, Cawthron, pers. comm., 28 March 2014).

Overall, faecal contamination is patchy and not strongly associated with consented activity. No outer coast bathing beaches in Tasman Bay and Golden Bay have persistently high levels of faecal indicator bacteria. All beaches monitored by councils usually have less than 140 enterococci (the relevant faecal indicator bacteria) per 100 ml of water; this is the range of the lowest alert level[30]. Levels are frequently very low, nonetheless occasional peaks in bacteria counts occur at beaches in both bays.

The effect of the Bell Island sewage treatment discharge is tested 6-monthly for FIB by placing caged mussels in the two outlets from the Waimea Estuary; the eastern outlet would be expected to be impacted by the Bell Island discharge, while the western (Mapua) outlet would not. A review of the 2008 – 2011 data found that, while data were highly variable, there was no obvious indication of a significant contribution from the outfall discharge and that mussel FIB concentrations were often higher in the vicinity of the Mapua outlet channel than in the vicinity of the Bell Island outlet channel. The bacterial water quality of inner Tasman Bay can apparently be affected to a greater degree by catchment runoff than by FIB contributions from the Bell Island wastewater discharge (Gillespie *et al*. 2011c). Accordingly, non-monitored activity

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[30] http://nelson.govt.nz/environment/water-3/recreational-bathing-water-quality
http://www.tasman.govt.nz/environment/water/swimming-water-quality/about-water-quality-sampling/

may be a greater source of faecal contamination of outer coastal waters than consented and monitored activity.

In other monitoring, for two years after a 2008 upgrade of the Nelson North waste water treatment plant (WWTP) quarterly sampling found that even within the defined mixing zone, FIB concentrations were generally very low (Bailey & Conwell 2010). At the Motueka WWTP coastal (tidal pool) sites showed measurable but generally low levels of FIB, with occasional peaks (MWH NZ Limited 2013). No reference data was presented to indicate whether variability is associated with the WWTP.

A range of data sources exists, which if integrated would provide robust information on levels and patterns of faecal contamination. However, the most important sources of contamination are not captured well by current data collection. Consent monitoring focusses on potential sources of contamination with human faecal material (*i.e.*, WWTPs) but, when molecular methods were used to identify the source of faecal contamination in the Motueka River plume, no genetic markers of human contamination were identified in coastal waters. This technique identified contamination from ruminant animals (*e.g*. sheep and cows) six kilometres from the river mouth (the furthest point tested) after a moderate flood event (Cornelisen *et al*. 2011). Greater use of microbial source tracking would be useful to provide more general information on contaminant sources in Tasman Bay and Golden Bay.

5.2. Seabed

Tasman Bay and Golden Bay are dominated by soft sediment seabed (benthic) habitats. Fringes of rocky reef or boulders are common, but these usually do not extend to deeper regions. Biogenic habitat (structure created by animals or plants) was historically abundant, but much is known to have been destroyed, and the distribution of what remains is not well understood.

Sediment dynamics are an important factor in determining the structure and function of coastal marine systems generally, but are of particular relevance to the extensive mud and sand-dominated regions of Tasman Bay and Golden Bay. While historically a range of methods have been used to characterise the benthic environment, standard methods have been applied to a range of soft sediment data collection and analysis. These generally employ cores of ~13 cm diameter and ~10 cm deep to sample infauna (animals that live in, rather than on the surface of, the sediment). These surveys also often measure sediment grain size, nitrogen, redox potential and organic content (ash-free dry weight). Recently, these data have been combined under an Enrichment Stage (ES) index (Keeley *et al*. 2012) providing a useful measure of overall benthic health status (*e.g*. Forrest 2014). These samples have been widely distributed across the sea floor; however, only some sites are sampled repeatedly. The TASCAM site has been established as a state of the environment benthic monitoring station to be surveyed every five years. Two surveys have so far been undertaken (Gillespie & Keeley 2007; Gillespie & Johnston 2012), and a range of research and monitoring has used comparable methodologies (*e.g*. Keeley *et al*. 2006; Forrest *et al*. 2007; Forrest *et al*. 2012; Gillespie & Johnston 2012; Sneddon 2012). For example, samples are currently being collected approximately every 1–2 years from the same sites in AMA 2 (Golden Bay) and AMA 3 (Tasman Bay). This includes sites under farms and sites in areas impacted by trawling and dredging.

5.2.1. Benthic primary productivity

Primary productivity is more widely used as an indicator of environmental status in the water column than on the seafloor. Nonetheless changes in benthic primary productivity can be associated with important changes in ecosystem functioning. Nutrient supply, light availability and habitat availability all impact benthic primary productivity. Perturbations can result in changes in the degree of productivity, but also in the primary producer community. For example, under fluctuating nutrient levels opportunistic ephemeral algae may replace long-lived species.

Although ‘hot spots’ of benthic plant production occur within the intertidal zone (*e.g*. estuaries) and macroalgal beds within shallow subtidal zones, Tasman Bay and Golden Bay do not support large kelp forests that make substantial contributions to productivity in other coastal regions of New Zealand. Therefore the phytoplankton in the water column and benthic microalgae on the seafloor provide the bulk of the primary productivity within Tasman and Golden Bays.

Microalgal communities on the sediment surface, along with phytoplankton, are major contributors to food-webs of most shallow coastal environments, and are an important food source for scallops (Gillespie 2003). Because Tasman Bay and Golden Bay are relatively shallow (*i.e*. largely < 40 m depth) much of the seabed receives sufficient sunlight to support photosynthetic activity.

Benthic primary productivity was calculated in the same study for which planktonic productivity was displayed in the section ‘Water column chlorophyll-a distribution’ above (Gillespie *et al*. in press; Figure 15). As expected, benthic primary producers becomes an increasingly important contributor to total primary production within the shallower regions (< 20 m) of the bays. Benthic microalgal biomass is dictated primarily by the availability of light at the seabed. Light can also be strongly attenuated by elevated concentrations of suspended fine sediments. The near-bottom turbidity layer, and suspended sediments in general, will therefore impact benthic primary productivity (Gillespie 2003).

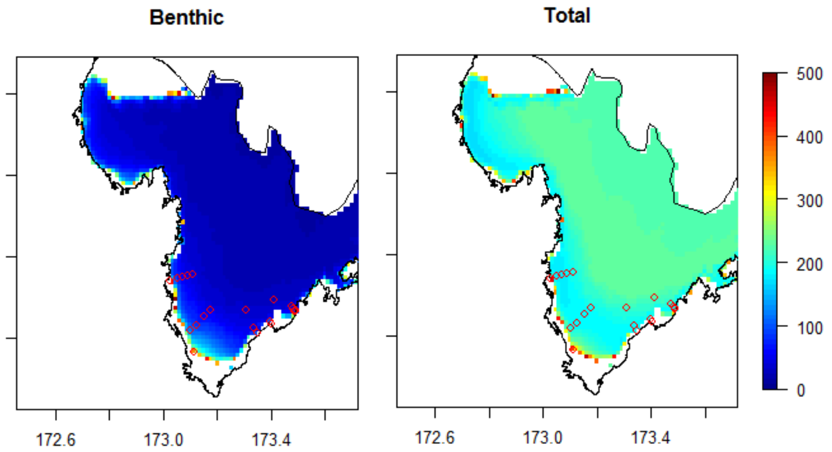

Figure 15. Spatial distribution of estimated benthic and total primary production in Tasman Bay and Golden Bay (averaged using light intensities extracted for 2009-2012 from the MODIS dataset). Values of primary production are integrated over the water column and expressed as a rate per planar area. Intertidal and estuarine areas are not included (Gillespie *et al*. in press).

Many of the benthic surveys discussed above measure levels of nitrogen in sediments. The TASCAM surveys in 2006 and 2011 (Gillespie & Keeley 2007; Gillespie & Johnston 2012) described the seabed as a generally unenriched, fine-textured sediment with moderate productive potential[31]. Sediment nitrogen levels at reference sites for mussel farm monitoring showed quite high variability over time within a similar range. In recent sampling at Golden Bay elevated levels of nitrogen have been measured under mussel farming areas (Forrest 2014), but this is not consistently seen (Forrest *et al*. 2012).

Primary productivity on rocky or biogenic hard substrates is undertaken by seaweeds and coralline algae (including rhodophytes), as well as benthic microalgae. Primary producers are not captured in marine reserve monitoring surveys in Tasman Bay and Golden Bay, and generally little information is available regarding productivity (or standing stock) of primary producers associated with hard substrates. A one-off national study included abundance of seaweeds on number of reefs in two areas of Tasman Bay (Shears & Babcock 2004) (Section 5.2.4 below), although only size and abundance of seaweeds was reported.

In summary, only very general information is available in terms of benthic primary productivity as a state of the environment indicator. Microalgal primary productivity is related to light and habitat disturbance, and direct measurement of these is probably more informative of ecosystem status than benthic primary productivity in itself. Similarly, algal abundance and community structure on rocky reefs, while related to primary productivity, is more informative of multiple indicators of ecological functioning (*e.g*. sedimentation, habitat integrity, and biodiversity – see Section 5.2.4, below).

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[31] Total nitrogen ~1200-1700 mg/kg

5.2.2. Soft sediment habitat and communities

Tasman Bay and Golden Bay are dominated by soft sediment habitat. Sediments and communities have been characterised, but substantial human activity pre-dates this work. Soft sediments are the habitat of the highly valued and seriously depleted scallop and flat oyster populations, and support important food resources for fish and shellfish (Gillespie 2003). Sediment deposition (sedimentation) and disturbance of existing sediment structure (breakdown of habitat integrity) are both important factors in the functioning of soft sediment communities. The result of these two factors is likely to be similar; *i.e*., higher proportion of small particle sizes (fines) in surface sediments. Large-scale studies of sediments and benthic communities have been undertaken in Tasman Bay and Golden Bay (McKnight 1969), and sediments have been mapped (Mitchell 1986). A summary of historical benthic impacts is also available (Handley 2006).

Broad characterisation of soft-bottom faunal communities and sediment characteristics was undertaken as part of a national survey in the 1960s (McKnight 1969). For example, the common *Amphiura rosea*[32] (brittle star) – *Dosinia lambata* (bivalve) community was identified in western Tasman Bay and Golden Bay. This occurred in sandy mud to muddy sediments, from one to 50 m depth. Here bivalves were most abundant, and the community was generally dominated by deposit feeders, although some dominant species were filter feeders. In sandier Golden Bay sediments the turret shell *Maoricolpus* dominated. The communities were defined on a national scale, so substantial variation within community type occurred. The Tasman Bay / Golden Bay region was the southern limit of the *Amphiura rosea* – *Dosinia lambata* community, and assemblages exhibit characteristics of other community types.

Other species lists and material descriptive of community characteristics are available, such as those from trawl-survey bycatch information, and from aquaculture site assessments. Handley (2006) reported a marked change in composition of trawl bycatch between 2000 and 2005, with only 8 of 52 taxa being common between years. This is likely an artifact of sampling as most taxa were found in only one or two trawls, and trawl stations were not the same for the two surveys. Similarly, characterisation of potential marine farming sites included trawl surveys, again, these produced qualitative species lists (Brown & Asher 2000). While suitable for the purposes for which this data was collected, *i.e*., to provide a general community characterisation, the value of this qualitative data for assessing long-term change is limited.

The standard methodology for quantative sampling (introduced in Section 5.2) produces data that are more valuable for reliable assessment of change than qualitative (descriptive) data. Standardisation is particularly important for measures of

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[32] While named according to discriminating species, the discriminating species were not necessarily dominant.

diversity as apparent diversity can be quite different depending on the size of sample taken. The communities quantified in the 2006 and 2011 TASCAM seabed surveys did not show significant changes in benthic community structure (Figure 16). Moreover, they were similar to those in other parts of the bay that were sampled as part of research (*e.g*. Gillespie *et al*. 2011e) and marine reserve monitoring (Keeley *et al*. 2006). Polychaete worms made up nearly half the individuals caught on a 0.5 mm sieve. Crustaceans (including amphipods, which were plotted separately) and bivalves made up the majority of the remaining taxa.

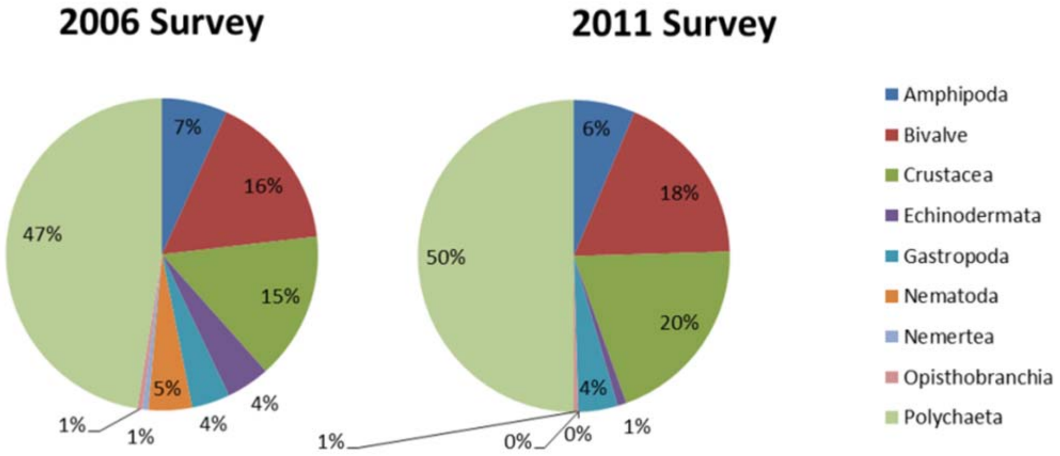

Figure 16. Taxonomic group relative abundance for the 2006 and 2011 benthic surveys at the TASCAM buoy site (Gillespie & Johnston 2012)

The community characteristics were consistent with a generally stressed benthic environment throughout much of Tasman Bay. This is thought to be related to sediment deposition and the fisheries-associated disturbance of the sea floor (Gillespie & Johnston 2012).

Sediments were mapped in 1987 (Mitchell 1987), and a more recent sediment map has been created by NIWA based on this information (Michael *et al*. 2012) (Figure 17). A large area of sand covered much of the northern parts of Golden Bay (near Farewell Spit). Otherwise sediments in the bays were largely fine silts, with some sandy and clay patches. In the east (the area corresponding to the MDC CMA) coarser sediments were mapped.

Figure 17. Sediment map from NIWA (Michael *et al*. 2012)

No integrated assessment of sediment characteristics has been undertaken since 1987, although numerous samples of surface sediments have been collected. These samples could be used to assess current state and possibly even trajectory of change. For example, while SoE monitoring at TASCAM identified no change in sediment characteristics between 2006 and 2011 (silt and clay ≥ 90%), some change over time has been indicated in mussel farm monitoring. Sediments at reference sites for mussel farm monitoring in Golden Bay (surveyed in early 2009) and Tasman Bay (surveyed in late 2008) were very similar. At both sites fine sediments constituted ~98% of total sediments. However, a decline to as low as ~85% fine sediments over five surveys up to 2014 was seen at reference sites in Golden Bay (Forrest 2014). In Tasman Bay, a similar decline over a similar range (~98% down to 80%) has been seen from 2009 to 2014 (Forrest *et al*. 2012). Consent monitoring data may, therefore, be able to detect a change not captured in the less frequent state of the environment monitoring, and could therefore be used to supplement SoE information (Newcombe & Cornelisen 2014; Forrest & Cornelisen 2015 and related reports).

Some differences in sediment structure are also consistently identified during Port Nelson dredge spoil site monitoring. The spoil ground substrate is composed largely of very fine to medium sands, in contrast to the silt-dominated environment typical of wider inshore Tasman Bay. Differences seen across surveys in epifaunal and infaunal communities can be principally attributed to differences in sediment texture between zones and to natural variability between stations (Sneddon 2012).

Another aspect of the seabed environment that is widely measured is sediment ash-free dry weight (AFDW), which is an estimate of the organic content of sediments. Organic content generally constitutes 4 –7.5% of the weight of fine sediments (Grange 2007; Gillespie & Johnston 2012; Forrest 2014), but is lower in areas with coarser sediments (Sneddon & Clark 2011). AFDW is sometimes found to be elevated under mussel farms (*e.g*. Grange 2007; Forrest *et al*. 2012; Gillespie & Johnston 2012). While historically widely measured, it has been shown that AFDW alone is not necessarily a good indicator of change to ecological functioning in soft sediment habitats. Instead, recently developed indices that integrate a range of biological and physico-chemical measures (which are also often collected in monitoring and research projects) appear the best option to effectively identify effects of sedimentation and enrichment (Keeley *et al*. 2012).

Fished vs. unfished soft sediments

Sediments were not mapped before 1987 although the seafloor in Tasman Bay and Golden Bay has a long history of trawling and dredging activities (Handley 2006) which are known to reduce habitat integrity. Organisms which inhabit soft-sediment habitats create much of the habitat diversity (Thrush and Dayton 2002). Too much disturbance leads to a loss of diversity and associated ecosystem functioning. Fishing equipment moved across the seafloor can cause substantial disturbance. An assessment was done to establish a picture of what seafloor habitats were probably like prior to major human-induced change (Handley 2006), and a number of local sites provide information regarding habitat changes in the presence of fishing. In a study using benthic data from a number of research projects in Tasman Bay and Golden Bay, abundance of a number of functional groups[33] decreased with increasing rates of fishing disturbance (Lundquist *et al*. 2013). Tasman Bay and Golden Bay are relatively sheltered from wave disturbance, and the seabed communities are likely to be more sensitive to fishing disturbance than those in more exposed areas (Michael *et al*. 2012).

Reserve areas can provide valuable information about the impacts of fishing in non-protected areas. While reserve areas are generally put in place to protect hard substrate habitats, fortunately the area of fishing restrictions put in place to protect the Separation Point bryozoan beds and the marine reserves included some soft sediment areas. These provide for study of protection from fishing on soft sediment habitats, although only at Separation Point has a robust comparison of fished and protected soft sediment areas occurred (Handley *et al*. 2014). Within the Separation Point no-trawl zone (established in 1980), surface sediments are relatively coarse, while in adjacent fished areas the gravel component of sediments has been buried. Surface sediments at fished sites are dominated by fine mud with little or no shell content. There is reduced biological diversity, and smaller average size of animals, with reductions in biomass and productivity in the presence of fishing activity. Scavengers, predators and deposit feeders were more common in fished areas, while

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[33] Groups of species that fill similar roles in the environment

filter feeders and a grazer characterised the unfished seabed communities (Handley *et al*. 2014).

The soft sediment areas of the Tonga Island marine reserve (gazetted in 1993) were surveyed after approximately 10 years of protection. The importance of shell hash in reserve areas was apparent (Thrush *et al*. 2003), although comparisons within and outside of protected areas was not the focus of the study, and was therefore limited. The Horoiroirangi reserve, which was created in 2006, also includes substantial soft-sediment areas. These areas were surveyed in 2006 (Keeley 2006) and while they have not been re-surveyed since establishment, the baseline survey identified that the sediments are characteristic of the majority of Tasman Bay and much of Golden Bay. These data therefore provide another potential source of information regarding sediment and community structure in the absence of fishing.

Mussel farms also protect the seafloor from trawling although farms create their own impacts. For example, mild enrichment is often found under farmed areas. Sediments are often coarser, resulting at least in part from fallen shell material (Grange 2007; Grange *et al*. 2011; Forrest *et al*. 2012) (Figure 18).

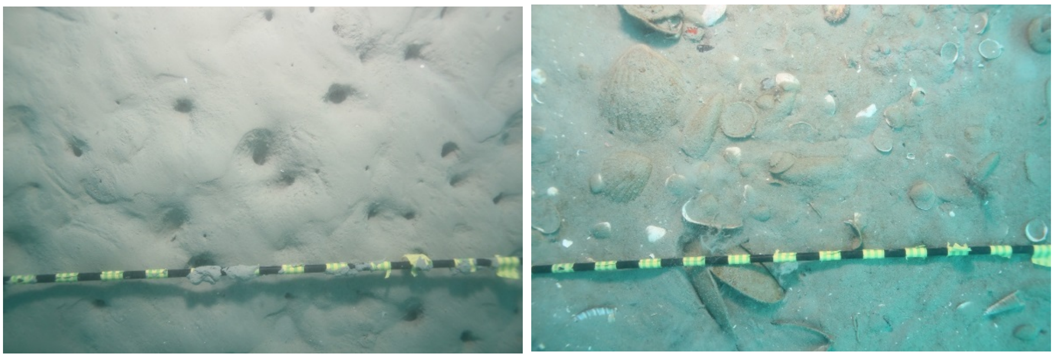

Figure 18. Representative images of the seafloor in unfarmed (left) and farmed (right) areas. In unfarmed areas soft sediments are nearly uniform. Under mussel farms shell hash contributes a gravelly component to the sediments.

Biological communities under mussel farms may have some differences in community structure compared to those in unfarmed, fished sites (*e.g*. Grange 2007; Newcombe & Forrest 2013). Higher diversity may occur in both epifaunal (surface) and infaunal (sub-surface) communities (Table 4). This is likely a combination of the lack of fishing activity, and the fact that a range of animals regularly fall from the farms’ structures on to the seabed below. Fallen mussels also provide a substantial food source for predators such as starfish (Figure 19).

Table 4. Characteristics of seabed and communities under mussel farms in comparison to areas with no mussel farming. This information summarises recent data from mussel farm monitoring in Tasman Bay and Golden Bay. The sites reported on are the Stage 1 development areas; *i.e.*, sites that have been farmed for several years. Note the data are often highly variable, and the differences noted here are not necessarily statistically significant. In general averages of 2-4 sampling stations are averaged to get the data points presented in the source reports (Forrest *et al*. 2012; Forrest 2014).

	Tasman Bay (AMA 3)	Golden Bay (AMA 2)
Sediments	More gravel-sized material	More gravel-sized material
Diversity in sediments (number of taxa)	Similar or higher	Generally higher
Abundance of animals in sediments	Similar or more abundant	Substantially more abundant
Community composition	Slightly more diverse	More diverse
Mussel cover	Present only under farmed areas	Present only under farmed areas
Burrows on the sea floor	Only recorded in reference sites	No pattern – not higher under farms
Animals on the sea floor	Only recorded under farmed areas	Low in 2013 but generally higher in previous years.

Figure 19. Large numbers of mussels can sometimes be found on the sea floor directly below mussel lines. These may fall from lines above, or mussel larvae may settle and grow on fallen shell hash. A range of plants and animal are associated with these benthic mussels, such as the anemone, crabs, and fish in the left image (some of which are likely to have fallen from lines, along with the mussels), and the predatory starfish in the right image.

The material that falls from mussel farms to the sea floor constitutes a notable difference in benthic communities under farms compared to areas not impacted by aquaculture. It may be, however, that this creates an environment similar to the natural biogenic habitat created by shellfish beds and reefs, which were historically far more widespread than they are today.

5.2.3. Biogenic habitat

Biogenic habitats (structure created by animals or plants) can form on relatively undisturbed sediments. Generally, they provide much greater habitat complexity than the surrounding soft sediment environment. The substantial reduction in biogenic habitat that has occurred in Tasman Bay and Golden Bay over the last century or more (Handley 2006) is recognised as a substantial reduction in habitat integrity in the benthic marine environment. However, because fishing and other human activity pre-date any structured assessment of habitat distribution, the nature of change is only broadly documented. Structure-forming species have been predicted to be more sensitive to disturbance than other functional groups. The very low abundances found across the region suggest that even at low-disturbance sites these species are not fully recovered from historical disturbance (Lundquist *et al*. 2013).

Shellfish reefs play an important role in nutrient cycling, water filtration, biodiversity, coastal protection, food-web dynamics and provision of nursery habitat for fish (Grabowski & Peterson 2007). Large beds or reefs of oysters and mussels were historically present in Tasman Bay and Golden Bay, but these were largely destroyed by bottom trawling in the last century. Accordingly, much of the information about the beds is from historic reports (Handley 2006).

- Horse mussel beds are now rare with only a few remaining beds in the region. Separation Point has one of the best representative horse mussel beds in the Nelson / Marlborough region (Davidson 1992). While numbers are observed to fluctuate substantially, horse mussels have been generally more abundant inside the Tonga Island reserve than outside since 2006 (Davidson & Richards 2013).
- Inshore beds of green-lipped mussels were accessible at low tide in the 1800s (Handley 2006). These shallow beds no longer exist and the fishery has moved deeper over time.
- Dredge oysters have been exploited since 1845 and beds were also accessible at low tide, with the exploitation of at least one deepwater bed in Tasman Bay (Drummond 1994). Like green-lipped mussel beds, these shallow water oyster beds no longer exist and the fishery has moved progressively deeper (Handley 2006).

Current knowledge of the distribution of bivalve reefs is limited—trawl surveys show shellfish densities, but not the extent of habitat. It is not possible to establish a trajectory of change. The feasibility of actively restoring Tasman Bay mussel beds has been assessed, and a proposal for experimental testing of the idea has been put forward (Handley & Brown 2012). There is some concern that the very conditions which the restoration of mussel beds would ideally alleviate may prevent successful restoration; the finely-structured settlement surfaces (such as macroalgae and hydroids), which are important for settlement of very small spat, may be unable to establish under current levels of suspended sediment in waters. Farmed mussels and the habitat that forms under mussel farms may act to fill some of the functions of shellfish reefs, but the extent to which this replaces the functions of natural shellfish beds is yet to be determined.

Rhodoliths are unattached growths of coralline algae that create another form of biogenic habitat. Within Tasman Bay and Golden Bay, rhodoliths are found only in a small number of locations. The distribution of these beds is, however, not well-defined. A large (22 ha) bed is found near D'Urville Island (Coppermine and Ponganui Bays) (Davidson *et al*. 2011b).This is the largest known rhodolith bed in the Marlborough Sounds. Two smaller beds are found offshore from Totaranui and Tonga Island and there may be further beds along the Abel Tasman coast that have not yet been mapped (R. Davidson, pers. comm., 29 September 2013). A rhodolith bed is also present is Okiwi Bay, Croisilles Harbour, but has also not yet been mapped (R. Davidson, pers. comm., 29 September 2013). A variety of conspicuous species are associated with these rhodolith beds including sponges, sea stars, gastropods and blue cod (Davidson *et al.* 2010).

Bryozoans are small colonial animals. Habitat-forming bryozoans are particularly abundant and diverse in New Zealand where they provide habitat over hundreds of square kilometres of seafloor (Wood *et al*. 2012). These bryozoan-dominated habitats are ecologically and commercially important because their structures can support a range of species, including juveniles of commercial fish species. The bryozoan beds at Separation Point, between Tasman Bay and Golden Bay, are the only ones in New Zealand that are formally protected from trawling / dredging and are also internationally recognised (invertebrate Red Data Book, I.U.C.N.). While these are protected from fishing disturbance, it appears that they are still stressed by sedimentation, as growth is apparently limited to the tips of the structures where sediment has not settled (Grange *et al*. 2003). Other patches of bryozoans exist, such as those identified by fishers off the north-west of D'Urville Island (Davidson *et al*. 2011b). There are anecdotal reports that others exist, or once existed, but only locals and fishers are aware of these locations.

In summary, while it is known that biogenic habitats have been substantially modified (*i.e*., habitat integrity has been severely reduced), the extent of original habitat, trajectory of change, and ability to restore them remain unknown.

5.2.4. Rocky reefs

Rocky reefs fringe the coast in areas of both Tasman Bay and Golden Bay. The deepest and most extensive rocky reefs in the region occur in north-eastern Tasman Bay in the MDC CMA (Davidson *et al*. 2011b). The two marine reserves, Hororoirangi and Tonga Island, are both centred on rocky reef habitat.

Large brown seaweeds can form extensive, highly productive habitats on rocky reefs. Seaweed forests support distinctive, diverse assemblages of other organisms by providing substrate, shelter, or food. Seaweeds are often less abundant (a reduction in habitat integrity) where fishing pressure is intense, as herbivores such as sea urchins, that would otherwise be consumed by predatory fish, increase in number and graze down seaweeds (Shears & Babcock 2003).

A one-off national study included intensive surveys of a number of reefs in two areas of Tasman Bay (Shears & Babcock 2007) (Figure 20). At each location, sites inside and outside the current marine reserves were surveyed (Hororoirangi and Tonga Island, although only Tonga Island was gazetted at the time of sampling). Summary data were reported, and showed particularly high densities of sea urchins in both areas. Habitat-forming algae were relatively scarce, and only flapjack (*Carpophyllum* spp.) and *Sargassum* were common, the latter only in the Nelson survey. If the source data from this study were available, this would provide the basis for assessment of long-term change on rocky reefs in the region. The citizen science initiative Reef Check[34] may constitute another source of reef habitat information (Appendix 1).

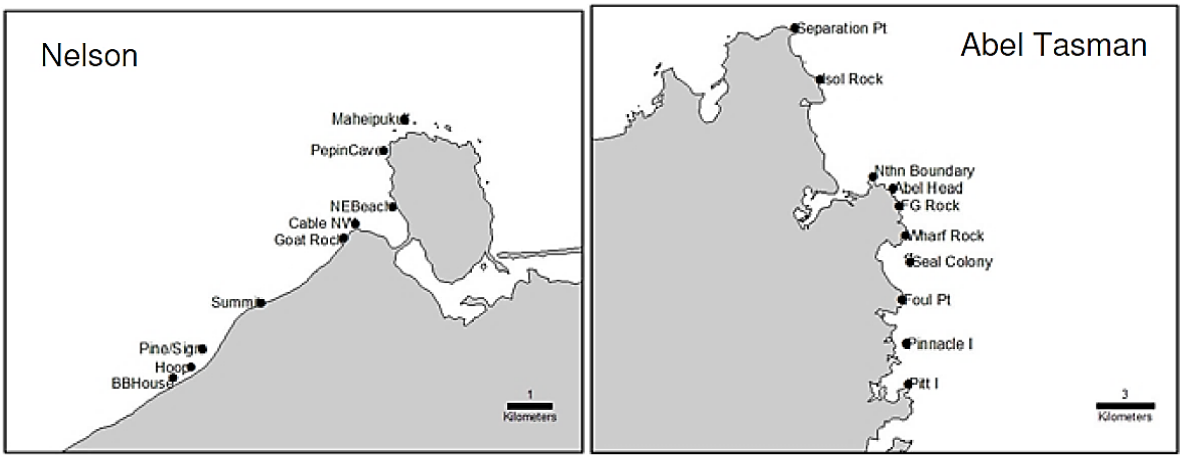

Figure 20. Rocky reef sites surveyed in 1999 (Shears & Babcock 2007). At each location sites inside and outside the current marine reserves (Hororoirangi and Tonga Island respectively) were surveyed. The Nelson sites run west from Pepin Island, and the Abel Tasman sites run south from Separation Point.

5.2.5. Chemical contamination in the seabed

Some inland areas of the Nelson and Tasman regions are known to have high levels of naturally-occurring minerals, and these minerals can be detected in marine sediments derived from these areas. Coastal areas at Waimea and Motueka are known to have elevated levels of nickel and chromium derived from mineral belt areas in their upper catchments. A 50 km^2 footprint associated with the Motueka River plume has been documented by tracking levels of chromium and nickel in the marine sediments (Forrest *et al*. 2007).

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[34] www.reefcheck.org

Chemical contaminants such as heavy metals are generally only measured in association with activity-specific monitoring where contamination is a specific concern. Such contaminants are retained or transported at the highest concentrations in fine sediments, as these have the greatest surface area for chemicals to bind (adsorb) to. While some measures of chemical contamination are made in the outer coastal environment, the limited number of potential contamination sources on open coast, and the potential for dilution are such that this is of less concern than in more enclosed sites, such as estuaries. A historical concern in Tasman Bay has been the Mapua Fruit Growers Chemical Company site, where high levels of contamination occurred at a chemical storage site. Remedial work has been undertaken, and while small areas of contamination are still detectable within the estuary, this is localised and does not extend into the outer coastal environment.

A range of consent-associated monitoring takes place that documents contaminant levels at point sources, and reference sites provide information on sites away from the consented activities. Overall, minor increases in contamination levels can be seen from some consented activity, but no such activity has caused contaminants to reach levels at which environmental effects are considered possible (levels are compared to Australasian guidelines (ANZECC 2000)).

Elevated levels of nickel found in Port Tarakohe were thought to derive from natural sources (Bennett *et al.* 2006), and other contaminants were below the biological effects-based guidelines for sediment quality (ANZECC 2000).

Sediment contaminant levels at the Port Nelson dredge spoil disposal site were well within the specified consent limits (derived from ANZECC 2000). Concentrations of trace metals (copper, lead and zinc) remained lower within the disposal area than for samples from the control and spreading zone sites, consistent with the coarser sediments in this area. Although polycyclic aromatic hydrocarbons (PAH) levels in spoil ground and spreading zone samples were generally slightly higher than those of control samples, concentrations were very low overall. In 2012, there was no evidence of significant contaminant-related ecological impacts from the dredge spoil disposal operation, and no indication of significant change in receiving environment contaminant concentrations. Where detectable, contaminant concentrations measured in tissues of the knobbed whelk *Austrofusus glans* were well within acceptable levels for human consumption of shellfish and did not represent values which have the potential to result in significant adverse ecological effects. Similar tissue levels were found across all stations, including controls. Imposex, a condition linked to tributyltin exposure whereby female gastropods develop male characteristics, has been observed in the spoil ground population of *Cominella adspersa*. In the most recent survey, imposex prevalence was lower than has been observed in all previous spoil ground surveys and well below that which could affect the reproductive capability of the population (Sneddon 2012).

In the long-term monitoring associated with Port Nelson, high variability for some contaminant measurements has hampered the interpretation of trends over shorter time periods. Nonetheless, the 18-year span of the monitoring programme has indicated overall stability in sediment contaminant status for the twelve subtidal monitoring stations (Sneddon 2014a). This applies most strongly to trace metals and organic enrichment for which the highest frequency of sampling and analysis has been maintained. Identification of trends for organic contaminants and organotins has been more problematic. Nonetheless, the overall record for both contaminant groups suggests that sediment concentrations are not increasing. This suggests that ongoing inputs are not causing significant accumulation of contaminants. However, it also points to the retention of historic contamination levels, including those for constituents that are otherwise likely to have decreased in loading (*e.g.* tributyltin). Variability of benthic communities between surveys consistently exceeded spatial variability in each survey. At least partly, this is the nature of dynamic fine sediment environments. Considering all lines of evidence, only the macrofaunal communities at Saltwater Creek and Old Boat Harbour Slipway are believed to reflect significant effects from chemical stressors (Sneddon 2014a).

In surveys near the fisheries outfall off the boulder bank, sediment mercury levels in the vicinity of the outfall were consistently well below the threshold trigger levels listed in current national guidelines for the prediction of potential ecological effects (Sneddon & Clark 2011).

In summary, local point sources of anthropogenic chemical contamination are generally easily identified and subject to resource consent monitoring. This generally also includes the use of reference sites where no contamination is expected. Accordingly, this seems to reasonably capture data collection requirements for this aspect of ecosystem status, and monitoring of the state of the environment for contaminant levels is unlikely to be informative. However, there may be value in incorporating contaminant inputs into a framework for assessment of cumulative effects.

The nature of chemical contamination from more diffuse non-consented human activity is largely unknown. While background levels of target contaminants are assessed at reference sites for consent monitoring, this does not necessarily capture all potential contaminants. 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 internationally[35]. As for other effects of human activity, these are more likely to be detected in more enclosed (*e.g.* estuarine) environments, however the potential exists for expansion of monitoring requirements to incorporate emerging contaminants as knowledge of risk improves.

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[35] www.setac2015.org.nz/programme/workshops/

5.3. Fisheries

Fisheries data are complex in themselves, and problematic as indicators of environmental state. For example, declines in target species may be related not only to extraction, but also to changes in habitat. Below we present summary data on two fisheries which are of particular importance historically, culturally, commercially, and recreationally, and for which biomass estimates are available. Both have declined substantially from historical levels, and these declines imply important changes in food-web structure. These changes are further suggested by results of surveys within local marine reserves.

5.3.1. Shellfish

Historically, large shallow beds of oysters and mussels occurred in the bays, however these have been removed through overexploitation. The status of information and stocks of shellfish are being addressed in the Rebuilding Shellfish Fisheries project (Michael *et al*. 2012), including oyster, scallop, and mussel distribution and density data from population surveys. All species show recent decline.

The longest data series for most fisheries is from catch data. However, this has limited utility for assessing the state of the environment. Catch figures can come from different areas, reflect changes in catch limits, and in fishing behaviour. For example, the zero landings from the early 1980s reflect the closure of the fishery for two years. Scallop enhancement, which occurred in both bays, but was more effective in Golden Bay than Tasman Bay, further complicates the use of scallop catch, or biomass, as in indicator of environmental health status.

Annual scallop surveys have been undertaken since 1994, and stock estimates are made from these data (Figure 21). Estimated scallop biomass has declined to very low levels in both bays, and populations were not surveyed in 2013 because of the expected low abundance of scallops. Decadal cycles have been identified in scallop abundance, with highs occurring throughout the 1970s and 1991-2002, the latter occurring mainly in Golden Bay, during a period of successful enhancement activity.

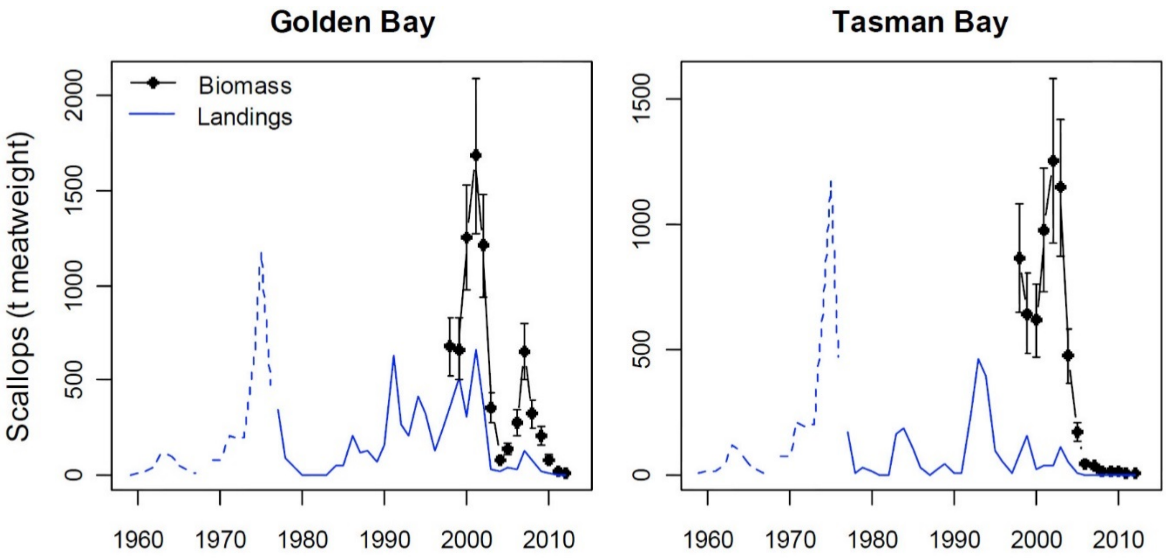

Figure 21. Mean biomass estimates of scallops ≥ 90 mm (black, error bars = CV), and landings in Tasman Bay and Golden Bay (blue). Landings were reported separately for Tasman Bay and Golden Bay only since 1977; earlier landing data is represented with a dotted line. Note the fishery was closed for two seasons from 1981.

5.3.2. Snapper

Snapper landings peaked in the 1960s and have substantially declined since then. Despite controls introduced under the quota management system, snapper populations have remained relatively low. Historical biomass has been estimated based on catch data, and this shows that biomass is less than 10% of that in 1930 (Figure 22). Recent increases in biomass are apparent in this model, although the roles of increased recruitment, fish behaviour (in response to water temperature changes) and fisher behaviour are uncertain (Langley 2013).

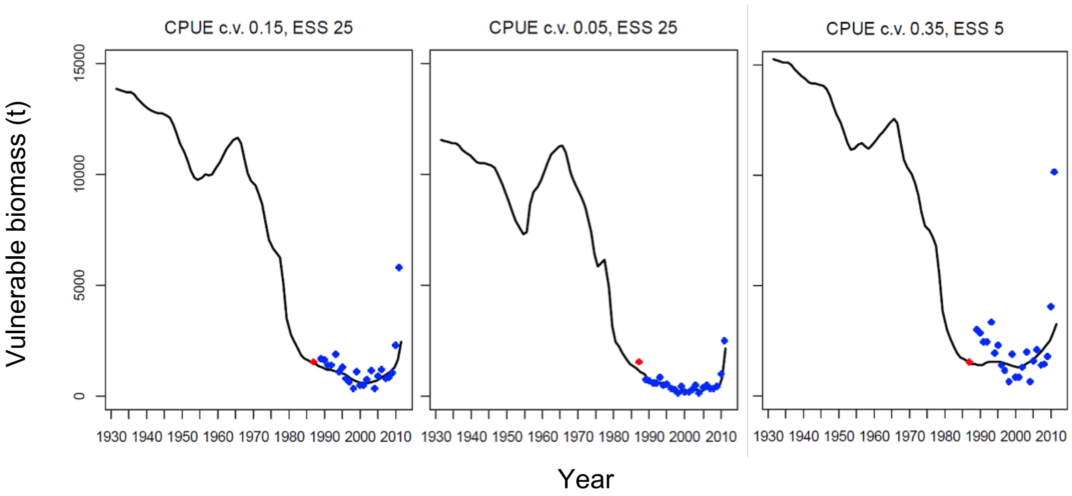

Figure 22. Estimates of snapper biomass in Tasman Bay and Golden Bay since 1930. Biomass trajectories are shown for three alternative model options, with different weighting of the catch per unit effort (CPUE) indices (blue points) and recent size grade data. The red point in 1987 represents the biomass estimate from the SNA 7 tagging programme. From Langley (2013).

Research has also shown that genetic diversity of snapper has changed over time as snapper numbers in Tasman Bay have declined (Smith *et al*. 2003).

5.3.3. Marine reserves

The fish and invertebrate species highly valued by recreational and commercial fishers are the focus of marine reserve monitoring in the Tasman Bay reserves. At the Tonga Island marine reserve (established in 1993), in 13 years of monitoring, an increase in numbers of large blue cod was apparent inside the reserve. Fish were 40 times more abundant in the reserve than in control sites, although no change in sublegal-sized cod was seen. Blue moki showed a moderate increase, while lobsters increased 7 – 8 times (Davidson & Richards 2013). At the Hororoirangi marine reserve (established in 2006) numbers of sublegal-sized blue cod increased in reserve and non-reserve areas, while larger cod increased in the reserve only (Davidson *et al*. 2013). These data provide good evidence that protection from fishing pressure has substantially enhanced these valuable species. Scallop abundance was quite variable within Hororoirangi marine reserve, but relatively stable outside; no clear difference in overall abundance was apparent (Davidson & Richards 2013).

An increase in kina density has been seen outside the Tonga Island reserve while density declined inside the reserve (Davidson & Richards 2013). This indicates that some food-web effects are also occurring; the increase in predatory fish is likely to be reducing herbivore abundance, which in turn may cause habitat-forming seaweeds to increase. As discussed above, the data from Shears and Babcock's survey (2007) could be used to test this hypothesis.

In summary, the substantial changes in biomass estimates from fisheries-related data indicate substantial depletion of fisheries resources. This is likely to have flow-on effects through the marine food-web. Data from marine reserve monitoring similarly indicates that fishing pressure is substantially impacting some species, and some suggestion of food web impacts has also been identified.

5.4. Biosecurity / invasive species

Thirty-five non-indigenous species (NIS) and 72 cryptogenic species were listed in a review of non-native marine species recorded in the top of the South Island region (Morrisey & Miller 2009). This inventory was not complete because it drew largely on data from the ports of Nelson and Picton only. The best-represented groups of animals and plants in the list are those that live attached to the substratum and are therefore likely to be carried as hull fouling (tube-living polychaete worms, bryozoans, hydroids and algae). The inventory included these high-profile pests: cord grass (*Spartina anglica*), the macroalga *Undaria pinnatifida* and the ascidians (sea squirts or tunicates) *Didemnum vexillum* and *Styela clava*. Of these four, three are now established in the region, though limited to the port and marina areas (as far as is known). The exception is cord grass, which has been subject to an apparently successful eradication programme since the 1970s.

More recently-established species include the lightbulb ascidian, *Clavelina lepadiformis* (2008) and the Mediterranean fanworm, *Sabella spallanzanii* (2013), both of which were detected by the surveillance programme. *Clavelina* is now established in Nelson marina. *Sabella* is currently being managed by regular surveys to detect and remove any individuals (in addition to the six-monthly surveillance). The population appears to be small (a maximum of one or two individuals detected per survey) and confined to the marina and slipway basins.

There is continual danger of introductions of new NIS to Tasman and Golden Bays from overseas and from other areas of New Zealand. Vectors include commercial and recreational shipping, and the movement of fishing and aquacultural vessels and equipment. Management of the threats posed by NIS to the economic, cultural and ecological well-being of the region is now coordinated among local councils, MPI and other stakeholders through the Top of the South Marine Biosecurity Partnership[36]. The partnership is a collaborative approach to biosecurity management in the CMAs of TDC, NCC, and MDC. As well as the councils, the partnership includes MPI, DOC, the aquaculture industry, port companies, tangata whenua and other stakeholders. It is funded by the councils and MPI. The partnership has developed a documented monitoring strategy and response protocols.

The main knowledge gaps constraining management are an understanding of non-economic impacts of NIS, and effective strategies for dealing with incursions when they occur.

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[36] See www.biosecurity.govt.nz/pests/surv-mgmt/mgmt-partnerships/top-of-the-south

6. STATE OF THE ENVIRONMENT IN TASMAN AND GOLDEN BAYS

6.1. SoE assessment from available information

Nationally-defined objectives under the NZCPS are generally relatively broad, and do not prescribe state of the environment monitoring requirements. Protection of indigenous biodiversity, maintenance or improvement of water quality for ecosystem functioning or human uses, and monitoring of sedimentation levels and impacts are requirements relevant to the state of the coastal environment. Fishing activity is not considered in the NZCPS, and is substantially outside of the control of councils. Nonetheless, it is an important component of environmental health as the changes caused in soft sediment habitats are substantial, as are effects on targeted species and the wider food web.

No process to define regional values or management aims has occurred for the area of the CMA considered here (*i.e.*, the sub-tidal outer coast). Key aspects of ecosystem health can nonetheless be identified on the basis of local and national knowledge.

Fundamental dynamics of the water column environment have been described in research projects and reports. The seabed environment has been described qualitatively from historical material, research, and monitoring projects. Quantitative sampling of the seabed has occurred for a range of research and monitoring projects, and this could be compiled to map the current community structure across the bay.

Direct effects of those anthropogenic stressors which occur immediately in the marine environment are quite well understood. Fisheries data, consent-associated monitoring, research projects, and marine reserve monitoring all contribute to this knowledge.

In terms of key topics considered for gauging ecosystem health status (discussed in Section 5), we can state the following:

- Primary productivity: nutrient input to the bays is ocean-dominated, and the region seems at limited risk overall of eutrophication. However, nearshore and local-scale effects of nutrient inputs may occur. Phytoplankton removal can occur in association with mussel farming, but no large-scale reduction is apparent.
- Sedimentation: In the last two decades land-based sediment inputs have not been exceptionally high. However, previously deposited sediments are strongly impacted by disturbance (see Habitat integrity below), and high levels of suspended sediment have been detected in the water column. Re-suspension of previously deposited sediment is apparently a greater stressor than new sediment input to Tasman Bay and Golden Bay. Benthic sediment texture may be a more important indicator than sediment deposition, as fine sediments are more easily re-suspended.

- Habitat integrity: Disturbance by fishing has substantially modified soft-sediment habitats, homogenising sediments and reducing biogenic structure within the bays. Many documented communities are characteristic of disturbed environments, but the extent and status of remaining biogenic habitat is not well understood. Less is known about rocky reef habitats, where monitoring focusses on mobile fauna.
- Contamination: Overall, bacterial contamination appears to be low in coastal waters of the bays, but occasional peaks occur, often following periods of rainfall. Non-consented land-based activity can be a greater cause of bacterial contamination than consented activity. Chemical contamination from consented activity is low-level, and levels high enough to potentially have ecological impacts do not occur on the outer coast.
- Fisheries: Important fish stocks are depleted compared to historical levels within the bays, which suggests that substantial changes to the food-web have also occurred. Protected areas show an increase in the numbers of some exploited species. There is some evidence to suggest that fishing is having food-web effects on rocky reefs.
- Invasive species: Biosecurity surveys at ports within the bays have found a number of established invasive species, but substantial negative impacts have not been documented.

6.2. Gaps analysis for assessment of the state of the marine environment

Understanding of environmental processes is important to provide context for observed changes, however many national and international gaps exist. For example, there is generally poor understanding of the impact of land-based stressors in the marine environment (Morrison *et al*. 2009). On a local level, most of the ecological studies that have been carried out on the bays' water column and seabed have been observational and the nature and magnitude of biogeochemical processes have been inferred, obtained from the international literature, or in some cases deduced by numerical modelling. There have been few experimental studies that have attempted to obtain realistic *in situ* rates of nutrient assimilation, remineralisation (*e.g.* ammonification), recycling (*e.g.* nitrification) and loss (*e.g.* de-nitrification), or attempted to identify and quantify the environmental factors that control them.

Relatively limited environmental knowledge is a fundamental challenge of working in the marine environment. Many knowledge gaps are beyond the scope or ability of a council-driven project to solve, but these gaps should be acknowledged and the related uncertainty included in planning decisions. Moreover, contributions to national reporting, and integration of monitoring activity and data sources can contribute to improving the understanding of the marine environment on a regional and national scale.

Most of the information available on the outer coastal environment of Tasman Bay and Golden Bay was not collected for the purpose of measuring the state of the environment. The ability to assess state and trends is therefore limited. Considering the information available at a regional level, the most fundamental issue in determining the state of the environment in Tasman Bay and Golden Bay is the lack of comparable long-term data. Another limitation is lack of spatial replication, particularly in terms of water column monitoring. While TASCAM is a useful resource, it was located to capture impacts from the Motueka River plume. It would be extremely valuable to have other buoys deployed in other parts of the bay to provide comparative data. Collection of data from other areas in the bay would also provide for calibration of algorithms to apply to satellite imagery. This could then provide historical (~12 year) data on surface water parameters throughout the bay.

Many of the topics outlined above (Section 6.1) are interrelated, and assessment of the state of the environment requires consideration of interactions between different components of the ecosystem. For example, suspended sediments can impact seabed and water column primary productivity, prevent recovery of biogenic habitat integrity, and mediate contaminant persistence and dispersal. Sediment resuspension is a prime example of a cumulative effect. The impacts of terrestrial sediment input are exacerbated by disturbance, both from direct fishing disturbance, and because the removal of shellfish has left seafloor sediments more exposed to water movement. Less filtering of particles from the water occurs in the absence of abundant shellfish, which may limit recovery of shellfish populations. Moreover, climate change is expected to exacerbate the situation as increased frequency and severity of storm events will lead to increased wave action and higher sediment input from land.

Many aspects of ecosystem functioning are expected to change with the progress of climate change. For example, changes in temperature will influence the stratification dynamics of the water column, which affects primary productivity. Ocean acidification is also expected to impact the production of calcified structures such as bivalve shells, thereby adding further to the impacts on biogenic habitat formation, as well as other impacts on commercially and ecologically important species. Monitoring is prescribed on a consent-by-consent basis, and no system exists for integrating information across consents. Accordingly, there is no means for identification and assessment of cumulative effects, and insufficient background information exists to provide context for the impacts of climate change.

Requirements beyond current information and data collection are therefore:

- Greater temporal resolution: Plan for more extensive on-going monitoring, where appropriate building on existing data (*e.g.*, marine reserve monitoring, past research projects).
- Better representation of spatial variability: Identify sites which represent a range of degrees of impact (*e.g.*, within / away from river plumes, fishing activity, *etc*) and

habitat types (stations suited to assessment of water column, soft sediment, reef habitat, significant sites)

- Targeting of data to assess the of state of the marine environment
    - identification of relevant indicators and standards to inform ecosystem health status assessments
    - data collection and management designed to identify
        - impacts of land-based stressors
        - impacts of fishing activity
        - assessment of degree and impacts of climate change [37]
        - cumulative impacts[38]
    - stability of data collection over time (less dependence on consenting requirements and research projects for data collection)
    - better data sharing across users (the material in Newcombe & Cornelisen (2014) and Forrest & Cornelisen (2015) and associated reports provide framework approaches for information integration)
- Alignment (or a view to future alignment) with other councils, and national strategies such as MfE reporting requirements.

Ideally a process would be undertaken to define values and management objectives for the marine environment. The Marine Futures process currently underway in Marlborough[39] may provide a useful model for such an approach in Tasman Bay and Golden Bay. Engagement with iwi regarding aspirations for coastal health is also lacking. It would be appropriate to establish relationships and processes that provide for kaitiaki aspirations for the coastal environment and for cultural monitoring activity.

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[37] A recent proposal on ocean acidification was submitted in the 2015 MBIE contestable round; if successful, the project will include expansion of TASCAM to include monitoring of pH and dissolved oxygen.

[38] **Atlantis** (atlantis.cmar.csiro.au) is an ecosystem model that can be used as a predictive management tool that may assist in filling some of these gaps. **Atlantis** was developed by CSIRO in Australia, and is being applied to the Tasman Bay and Golden Bay environment in a NIWA project. In the current version, the bay is divided into 25 areas that are defined by factors such as substrate type, water temperature, and fishing intensity. Small areas, such as patch reef or even the Horoirangi Marine Reserve are too small to be explicitly considered, although future versions may be able to consider more fine-scale habitat definition. The model is still under development, and more data types, such as details of fishing activity and gear, could be added to improve model relevance and predictive ability. In theory the Atlantis model could be used to assess the impacts of management changes such as protection from fishing activity over different areas of the bays, or to predict climate change impacts.

[39] www.marlmarinefutures.co.nz

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8. APPENDIX

Appendix 1. Monitoring activity in Tasman Bay and Golden Bay coastal marine area (CMA). Modified from Newcombe & Cornelisen (2014).

Tasman District Council			
Programme	Data collected	Frequency and duration	Documented in
Bathing water quality monitoring	Enterococci density (approx. 17 beaches in Tasman and Golden Bays, plus approx. seven rivers)	Multiple occasions over summer every second year, subset tested annually	www.tasman.govt.nz/environment/water/swimming-water-quality/
TASCAM[40] benthic	Benthic SoE surveys: • Seabed physical, chemical and biological properties	5-yearly	*e.g.* Gillespie and Johnston (2012)
Collingwood mussel farms (AMA[41] 1)	Benthic surveys • Underwater video • Side scan sonar • Sediment organic content, grain size, infauna	3-yearly	*e.g.* Grange *et al*. (2011)
Golden Bay and Tasman Bay AMA 2 AMA 3 mussel farming	Seabed and water column surveys: • Physical, chemical and biological properties	Approx. every 1–2 years, dependent on stage of farm development	e.g. Clark et al. (2012b; 2012a)
Golden Bay and Tasman Bay AMA: spat catching	Benthic surveys: • Spat / juvenile shellfish on seabed, predator density, shellfish health assessments	After spat-catching season (usually annually)	*e.g.* Forrest (2013a, 2013b)
Tasman Bay wastewater treatment plants	Beach / tidal pools sampled for faecal indicator bacteria and nutrients Intertidal assessed annually for nuisance growths (other data at treatment plants or otherwise inland)	(At least) quarterly Annually	e.g. MWH NZ Limited (2013)
Port Tarakohe benthic baseline	Physical, chemical and biological properties, sediment trace metals	Baseline	Bennett *et al.* (2006)

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[40] TASCAM is a hi-tech coastal monitoring buoy used to remotely collect physical and biological data on the water quality of Tasman Bay, New Zealand.

[41] Aquaculture Management Areas

Nelson City Council			
Programme	Data collected	Frequency and duration	Documented in
Bathing water quality monitoring	Enterococci density (three beaches and seven river sites)	Weekly over summer	nelson.govt.nz/environment/water-3/recreational-bathing-water-quality
Port Nelson / NCC long-term monitoring programme	Benthic surveys: • Sediment physical, chemical and biological properties (grain size distribution, % organic, seven metals plus Hg) • Sediment semi-volatile organic compounds, organotins • Macro-infauna	1-, 2- and 5-yearly (2010-2019) (Baseline in 1996, previous monitoring programme 2004–2007)	*e.g.* Sneddon (2014a)
Effects of Bell Island sewerage discharge[42]	Mussel deployment surveys: • Faecal indicator bacteria (seawater samples and mussel tissue) • Phytoplankton species and abundance • water column profiles of salinity, temperature, light, turbidity, chlorophyll-*a* and dissolved oxygen	6-monthly	*e.g.* Gillespie *et al.* (2011c)
	Benthic surveys: • Sediment physical, chemical and biological properties (organic content, grain size distribution, nutrients metals, epifauna / infauna)	5-yearly	*e.g.* Gillespie *et al.* (2012b)
Outer boulder bank Nelson fisheries outfall seabed effects.	Benthic surveys: • Sediment grain size, organic content, mercury concentration • Epifaunal communities, substrate characterisation	5 yearly (2005–2040)	*e.g.* Sneddon & Clark (2011)
Nelson Harbour and entrance channel (dredge areas)	Sediment surveys: • trace metals (Cu, Pb, Zn) • PAHs • Organotins (Mbt, Dbt, Tbt, Tpht)	Annually (during maintenance dredging)	*e.g.* Sneddon (2014b)

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[42] Effluent quality sampled monthly for *E.coli*, faecal coliforms, total phosphorous, total nitrogen, suspended solids and BOD, programme also includes substantial estuarine component

Nelson City Council, cont.

Programme	Data collected	Frequency and duration	Documented in
Dredge spoil disposal	Water column surveys: • Bathymetry of spoil disposal site	Annually (post spoil disposal)	*e.g.* Sneddon (2012)
	• Turbidity and / or clarity • TSS	Annually (during spoil disposal) for 3–10 years[43]	
	• Sediment (contaminants, grain size, organic content) • Macroinvertebrate quality • *Austrofucus glans*, mercury, PCBs OCPs • Neogastropoda for imposex	5-yearly (beginning 2012)	
Boulder bank fisheries outfall	• Sediment (mercury, grain size, organic content) • Epibenthic communities		Sneddon & Clark (2011)

Department of Conservation: Marine reserve monitoring

Programme	Data collected	Frequency and duration	Documented in
Hororangi Marine Reserve and adjacent areas (reef)	Macrofauna	Annually (fish and lobster), 3- to 4-yearly (other invertebrates). Ongoing from 2006 dependent on funding priorities.	*e.g.* Davidson *et al.* (2013)
Hororangi Marine Reserve and adjacent areas (soft sediment)	Sediment properties (grain size, organic content), infauna, macrobiota	Baseline (2006) May be repeated after 10 years	Keeley *et al.* (2006)
Tonga Island Marine Reserve and adjacent areas (reef)	Macrofauna	Variable, up to annually, 1993–present. Annually (fish and lobster) 3- to 4-yearly (other invertebrates) Ongoing depending on funding.	*e.g.* Davidson & Richards (2013)

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[43] If no effect found in the first three years, again at 11 years. If no effect found in year 11, further monitoring unnecessary.

Department of Conservation: Marine reserve monitoring			
Programme	Data collected	Frequency and duration	Documented in
Tonga Island Marine Reserve and adjacent areas (soft sediment)	Habitat maps, benthic flora / fauna, sediment characteristics (physical and biological)	Baseline data pre-2003	Thrush *et al.* (2003)

Other monitoring efforts and data sources			
Programme	Data collected	Frequency and duration	Documented in
TASCAM buoy[44]	Weather ,water temperature, salinity, turbidity and chlorophyll-*a*, current speed & direction	Continuous (available hourly)	www.cawthron.org.nz/tascam/
NIWA Golden Bay Marine Monitoring Buoy[44]	Maximum wave height, water temperature	Hourly	www.tasman.govt.nz/environment/coastal-marine/metbuoy-2155/
Nelson Port Beacon	Sea level, wave height and frequency	Continuous	www.portnelson.co.nz/shipping-information/harbour-conditions/)
Port Nelson[45] Biosecurity Port Surveys(National Marine High Risk Site Surveillance),	Invasive species detection, species lists	Variable, twice annually since summer 2007 / 08. Future schedule uncertain	*e.g.* Inglis *et al.* (2006).
Survey of scallops and oysters for MPI	Dredge surveys	Usually annually, 1994–2012	*e.g.* Williams and Bian (2012)
Reef check (planned community initiative)	Fish, invertebrate, and substrate surveys along fixed transects in and around marine reserves	Multiple surveys during summer–ongoing	International website: www.reefcheck.org

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[44] Minor financial contribution made by TDC

[45] Also Nelson Haven, Mapua and nearby Waimea estuary, Golden Bay Baseline published in Stuart *et al.* (2009)