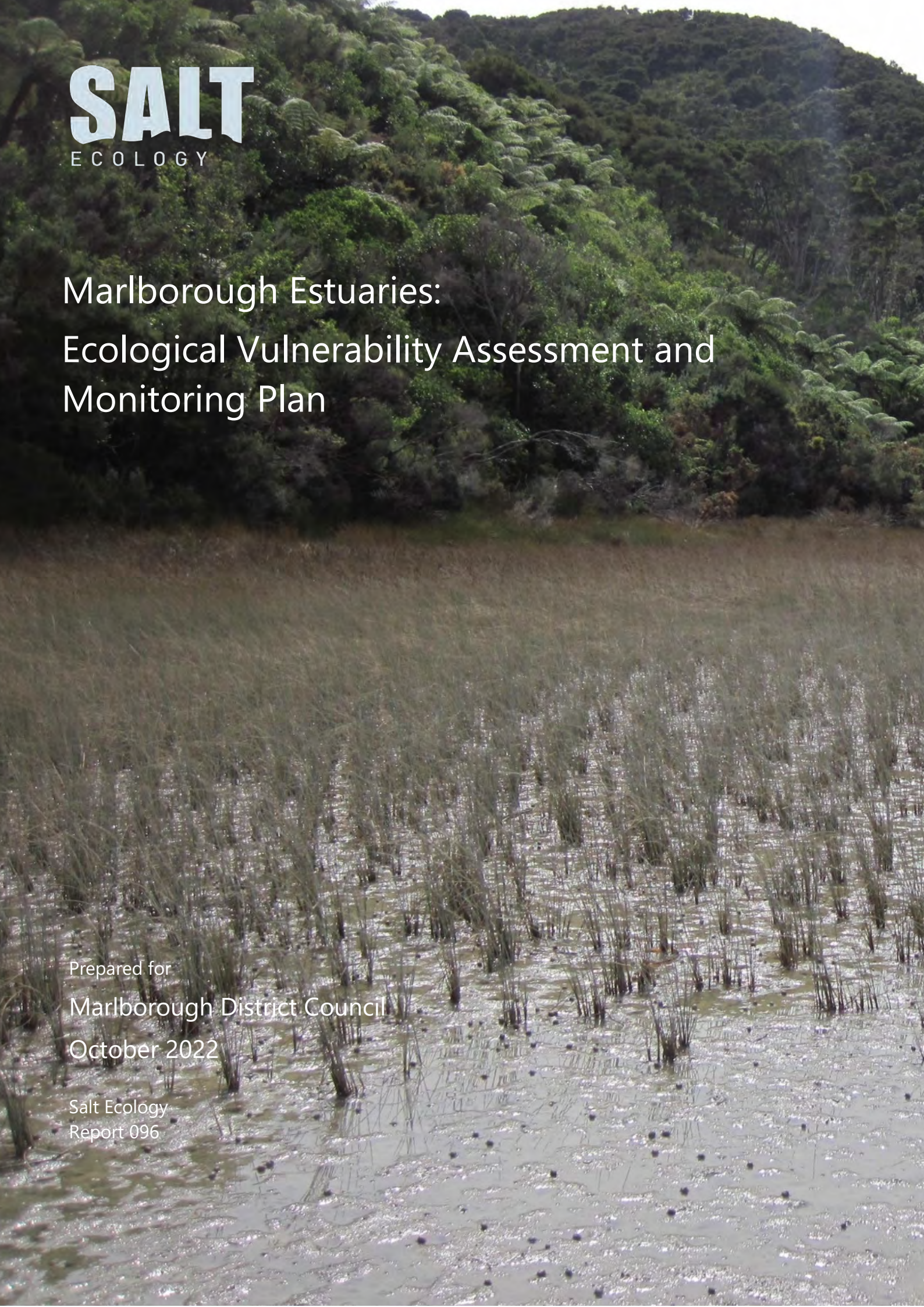
Environment Committee Meeting

20 April 2023

This Report relates to Item **5** in the Agenda

“Marlborough Estuaries: Ecological Vulnerability Assessment and Monitoring Plan”



SALT
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Marlborough Estuaries: Ecological Vulnerability Assessment and Monitoring Plan

Prepared for

Marlborough District Council

October 2022

Salt Ecology
Report 096

Cover photo: Whangarae Estuary (2016), rushland and steep native bush catchment

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Marlborough Estuaries: Ecological Vulnerability Assessment and Monitoring Plan

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GLOSSARY

CMA	Coastal Marine Area
ESMS	Ecologically Significant Marine Site
ETI	Estuary Trophic Index
EVA	Ecological Vulnerability Assessment
HEC	High Enrichment Conditions
MDC	Marlborough District Council
MHWS	Mean High Water Spring
NEMP	National Estuary Monitoring Protocol
NPSFM	National Policy Statement for Freshwater Management 2020
NZCPS	New Zealand Coastal Policy Statement
PMEP	Proposed Marlborough Environment Plan
REA	Rapid Estuary Assessment
QCS	Queen Charlotte Sound
RMA	Resource Management Act 1991
SoE	State of Environment (monitoring)

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SUMMARY

Marlborough District Council (MDC) has monitored estuaries across the region since 2001 as part of its State of the Environment (SoE) programme using methodologies described in New Zealand's National Estuary Monitoring Protocol (NEMP) or extensions of that approach. While baseline information has been collected in several estuaries, information gaps remain including the extent of intertidal seagrass and salt marsh habitats across the Marlborough Sounds and the impacts of sediment, the key stressor, on estuary health. Consequently, MDC engaged Salt Ecology to develop a long-term SoE estuary monitoring programme with the primary aim to monitor key intertidal habitats (e.g. seagrass, salt marsh) and identify the contribution of stressors (e.g. sediment) affecting ecological health (Urlich 2018), with the purpose to support informed decision making and maintain and/or improve estuary health. Building on this aim, MDC requested a tiered monitoring approach that would include the following:

(1) Frequent (~5-yearly) quantitative long term SoE type monitoring (i.e. fine scale, broad scale, sedimentation), at a subset of representative sites (Tier 1), that would meet the councils statutory requirements and track broad changes in estuary condition over time.

(2) Less frequent (~10-yearly) quantitative habitat and substrate mapping in a broader range of estuaries (Tier 2) to track changes in estuary condition over time.

(3) Where appropriate, use new approaches to fill knowledge gaps and support the council in understanding estuary health more broadly across the region.

With baseline information gathered for most estuaries within the region, there is an underlying assumption that where estuaries may be impacted by an activity (e.g. marina development, exotic forest harvest, reclamation), monitoring of the environment will be included in the assessment of environmental effects and the subsequent consent conditions. As such, the monitoring plan presented in the report does not focus on a specific activity but rather key stressors on the environment.

The main body of the report describes the approach used to develop a long-term monitoring plan following the steps in the table below. Because monitoring has only occurred in a small subset of estuaries to date, a stocktake of intertidal estuaries was undertaken prior to the prioritisation of sites for monitoring. Short summaries for 60 estuaries are presented in Appendix 1.

1. Set objective
To '*...monitor intertidal habitats and identify the contribution of key stressors affecting ecological health*' (Urlich, 2018) to support informed decision making and maintain and/or improve estuary health.
2. Prioritise sites for monitoring
A stocktake of intertidal areas in Marlborough was undertaken and an Ecological Vulnerability Assessment (EVA) was applied to 60* key sites identified, as a basis for prioritising them for monitoring. A range of EVA frameworks have been used previously in New Zealand to prioritise estuaries for monitoring and management. In this report existing EVA methods were reviewed and optimised. Sites were selected based on the values, condition, pressures and susceptibility.
3. Select indicators
Indicators were selected based on previous New Zealand and international studies. Indicators were chosen that measure a response to key stressors and detect change within a reasonable timeframe to allow for a management intervention.
4. Establish thresholds
Thresholds of concern are useful to trigger a management response. Established and developing thresholds exist for several New Zealand estuary indicators (e.g. Robertson et al. 2002a-c; Robertson et al. 2016).
5. Select monitoring methods
Existing SoE methods are based on the NEMP or extensions of that approach. Additional method considerations are detailed in the current report to improve data reliability, and achieve consistency over time and between different practitioners. Methods for new approaches (e.g. site-specific seagrass monitoring and water quality monitoring, i.e. Wairau Lagoon) are also outlined.
6. Develop monitoring plan
A monitoring programme is proposed that aligns with MDC's objective, is 'fit for purpose' and within the resources available.

We recommend a tiered approach to monitoring as follows, with specific sites outlined in the table below:

- Tier 1 & Tier 2: Focus on quantitative SoE type monitoring following NEMP methods (Robertson et al. 2002a-c) or extensions of that approach (Robertson et al. 2016) described in this report.
- Tier 3: The council undertake synoptic monitoring in smaller estuaries to maintain a broad overview of estuary health across the region.
- Targeted sediment monitoring: Sediment is a significant issue in the Te Hoiere/Pelorus Sound with sedimentation rates in the inner sound ~10 times higher than natural conditions. Sediment has been identified a key stressor in five estuaries (Mutweka/ Havelock, Kaiuma, Kenepuru, Mahakipawa and Ohinetaha) at the head of Te Hoiere/Pelorus Sound. At these sites we recommend tracking sedimentation and sediment grain size annually and following events, where applicable, to improve MDC's understanding of fine sediment deposition.
- Targeted seagrass monitoring: The extent of intertidal seagrass across Marlborough estuaries is not well understood and there is a lack of information on the condition of seagrass beds and how they respond to different pressures. Over the next 5-years we recommend monitoring seagrass extent across several estuaries and seagrass condition in a subset of eight estuaries using site-specific monitoring techniques.

The monitoring schedule for Tier 1 and targeted monitoring is outlined on the next page, the schedule is based on MDC's current coastal budget and in-house resourcing, these factors may vary over time. If schedule changes are required due to a shift in council resourcing Tier 1 sites should be prioritised to maintain a long-term monitoring dataset.

Monitoring	Sub-region	Estuary	Broad scale	Fine scale	Sedimentation
Tier 1	Pelorus	Motuweka (Havelock)	✓(5y)	✓(5y)	✓(1y)
	QCS	Ōkiwa Bay	✓(5y)	✓(5y)	✓(1y)
	Outer Sounds	Anakoha Bay	✓(5y)		
	Outer Sounds	Whangarae Estuary (reference estuary)	✓(10y)	✓(5y)	✓(*)
	East Coast	Wairau Lagoon	✓(5y)#		
Tier 2	Pelorus	Broughton Bay	✓(~10y)		
	Pelorus	Ohinetaha Bay	✓(~10y)		
	Pelorus	Crail Bay (Elie Bay & Wet Inlet)	✓(~10y)		
	Pelorus	Kaiuma Bay	✓(~10y)		
	Pelorus	Kenepuru Estuary	✓(~10y)		
	Pelorus	Mahakipawa Arm	✓(~10y)		
	Pelorus	Tennyson Inlet (Tuna, Harvey & Duncan Bays)	✓(~10y)		
	Pelorus	Nydia Bay North/ South	✓(~10y)		
	Pelorus	Clova Bay	✓(~10y)		
	QCS	Ahuriri Bay	✓(~10y)		
	QCS	Shakespeare Bay	✓(~10y)		
	QCS	Waikawa Bay	✓(~10y)		
	QCS	Whatamango Bay	✓(~10y)		
	QCS	Ngakuta Bay	✓(~10y)		
	D'Urville Island	Greville Harbour (Mill Arm, Smylies, Punt)	✓(~10y)		
Tier 3	Marlborough	Remaining small estuaries	Council field visits		
Targeted sediment monitoring	Pelorus	Motuweka (Havelock)			✓(1y)
	Pelorus	Kaiuma Bay			✓(1y)
	Pelorus	Kenepuru Estuary			✓(1y)
	Pelorus	Mahakipawa Arm			✓(1y)
	Pelorus	Ohinetaha			✓(1y)
Targeted seagrass monitoring	Pelorus	Motuweka (Havelock)	Intensive sampling over the next 5-years to characterise seagrass condition and map extent across the region. Replication to be reviewed in 10-year programme review.		
	Pelorus	Crail Bay (Elie Bay)			
	QCS	Okiwa Bay			
	QCS	Big Bay			
	QCS	Shakespeare Bay			
	QCS	Waikawa Estuary			
	Outer Sounds	Anakoha Bay			
	Outer Sounds	Whangarae Estuary			

*Due to the remote location of Whangarae Estuary monitoring frequency depends on the capacity of the council.
#Wairau lagoon is a unique estuary in the Marlborough region and monitoring includes both intertidal and subtidal monitoring.

Monitoring schedule for Tier 1 and targeted seagrass and sediment monitoring

TIER 1	Estuary	Interval	2000/01		2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	10-yr programme review	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2040/41	2041/42	2042/43
			Year																																	
Broad scale mapping	Motuweka (Havelock)	5-yr	✓				✓					✓					✓					✓					✓					✓			
	Ōkiwa Bay	5-yr			✓						✓							✓					✓						✓				✓		
	Anakoha Bay	5-yr																✓					✓						✓				✓		
	Whangarae Estuary	10-yr							✓							✓										✓										
	Wairau Lagoon	5-yr						✓(Int)						✓(Sub)						✓	✓								✓					✓		
Fine scale monitoring	Motuweka (Havelock)	5-yr	✓				✓	✓		✓		✓					✓					✓						✓				✓			
	Ōkiwa Bay	5-yr																✓	✓	✓^					✓					✓					✓
	Whangarae Estuary	5-yr							✓							✓					✓						✓				✓				
Sediment plates	Motuweka (Havelock)	1-yr					✓(A,B)	✓(C,D)			✓(E,F)	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Okiwa Bay	1-yr																(A,B)	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Kaiuma Bay	1-yr								✓(A,B)				T		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Kenepuru Estuary	1-yr												T		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Mahakipawa Arm	1-yr												T		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ohinetaha	1-yr												T		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Whangarae Estuary	*							✓(A,B)							✓(FS)				✓(FS)							✓(FS)				✓(FS)				
Targeted seagrass monitoring	Motuweka (Havelock)	#															✓		Analyse and report on regional seagrass extent and condition																	
	Okiwa Bay	#																✓																	
	Anakoha Bay	#																✓																	
	Whangarae Estuary	#														✓																			
	Big Bay	#														✓																			
	Crail Bay - Elie Bay	#																	✓																
	Shakespeare Bay	#																	✓																
	Waikawa Estuary	#																	✓																

^Review data from year 1 and 2 to determine whether a third fine scale baseline year is required.
*Due to the remote location of Whangarae Estuary monitoring frequency depends on the capacity of the council.
#10-year programme review to determine whether seagrass monitoring should be repeated.

1. INTRODUCTION

1.1 BACKGROUND

Estuaries provide many ecotones between freshwater and saltwater and are a valuable habitat for a broad range of vegetation, birds, fish, shellfish and other invertebrates. Because estuaries are transitional zones between the terrestrial, riverine and marine environment they are particularly vulnerable to anthropogenic pressures, including but not limited to, increased nutrient and sediment loads from the catchment, reclamation and shoreline hardening, invasive species, and impacts from recreational and commercial use.

Estuary monitoring is undertaken by most councils in New Zealand as part of their State of the Environment (SoE) programmes. Marlborough District Council (MDC) has undertaken monitoring of selected estuaries in the region since 2001 (Table 1) based on the methods outlined in New Zealand's National Estuary Monitoring Protocol (NEMP; Robertson et al. 2002a-c), or extensions of that approach (e.g. Estuary Trophic Index, ETI, and others; see Forrest & Stevens 2019).

In Marlborough, previous monitoring has focused on capturing baseline information across a subset of sites, using NEMP broad scale mapping and fine scale monitoring techniques, with repeat monitoring only occurring in a few estuaries (Table 1). While 24 estuaries have now been monitored to different extents, information gaps remain including the extent of intertidal seagrass and salt marsh habitats across the Marlborough Sounds, and the impacts of sediment, a key stressor, on estuary health. Furthermore, there remain many estuaries where no previous monitoring or assessment has been undertaken. Consequently, MDC

Table 1. Broad- and fine scale surveys undertaken to date in 24 Marlborough estuaries.

Estuary	Broad scale	Fine scale	Science Provider	Reference
Ahuriri Bay	2020		Robertson Environmental	Robertson (2020a)
Broughton Bay	2020		Robertson Environmental	Robertson (2020b)
Elie Bay	2020		Robertson Environmental	Robertson (2020c)
Havelock	2001	2001	Cawthron	Robertson et al. (2002a-c)
	2014		Wriggle	Stevens & Robertson (2014)
		2014	Wriggle	Robertson & Robertson (2014)
		2015	Wriggle	Stevens & Robertson (2015)
		2017	Wriggle	Stevens (2017)
	2019	2019	Robertson Environmental	Robertson (2019a-b)
Greville Harbour (5 estuaries)	2018		Salt Ecology	Stevens (2018b)
Kaiuma Bay	2017		Wriggle	Stevens & Robertson (2017a)
Kenepuru Estuary	2018		SLR	SLR (2018)
Mahakipawa Arm	2017	2017	SLR	Skilton & Thompson (2017)
Ngakuta Bay	2011		Cawthron	Gillespie et al. (2012)
	2018		Wriggle	Stevens (2018a)
Ohinetaha Bay	2020		Robertson Environmental	Robertson (2020b)
Ōkiwa Bay	2011		Cawthron	Gillespie et al. (2012)
	2018		Wriggle	Stevens (2018a)
Shakespeare Bay	2016	2016	Cawthron	Berthelsen et al. (2016)
Tuna, Harvey & Duncan Bays	2018		Wriggle	Stevens (2018c)
Waikawa Bay	2016		Wriggle	Stevens & Robertson (2016a)
		2016	Wriggle	Robertson & Stevens (2016a)
Wairau Lagoon (intertidal)	2015	2015	Cawthron	Berthelsen et al. (2015)
Wairau Lagoon (subtidal)	2021		Salt Ecology	Roberts et al. (2021)
Wet Inlet	2020		Robertson Environmental	Robertson (2020c)
Whangarae Bay	2016		Wriggle	Stevens & Robertson (2016b)
		2016	Wriggle	Robertson & Stevens (2016b)
Whatamango Bay	2018		Cawthron	Berthelsen et al. (2018)

engaged Salt Ecology to develop a long-term SoE estuary monitoring programme to address these information gaps and provide a more targeted approach to monitoring.

1.2 PROJECT AIM AND SCOPE

The primary aim of the MDC programme is to monitor key intertidal habitats (e.g. seagrass, salt marsh) and identify the contribution of key stressors (e.g. sediment) affecting ecological health (Urlich, 2018), with the purpose to support informed decision-making and maintain and/or improve estuary health. Building on this aim, MDC requested a tiered monitoring approach that would include the following:

(1) Tier 1: Frequent (~5-yearly) quantitative long term SoE type monitoring (i.e. fine scale, broad scale, sedimentation), at a subset of representative sites, that would meet the councils statutory requirements (see Section 1.2) and track changes in estuary condition over time.

(2) Tier 2: Less frequent (~10-yearly) quantitative habitat and substrate mapping in a wider range of estuaries to track broad changes in estuary habitat condition over time.

(3) Tier 3: Where appropriate, use new approaches (e.g. rapid assessment methods) to fill knowledge gaps and support the council in understanding estuary health more broadly across the region.

There is an underlying assumption that where estuaries may be impacted by an activity (e.g. marina development, exotic forest harvest, reclamation), monitoring of the environment will be included in the assessment of environmental effects and the subsequent consent conditions. As such, the monitoring plan does not focus on any specific activity but rather on key stressors on the environment.

Queen Charlotte Sound looking toward Cook Strait (Image ref: MDC 'Copy QCS', Courtesy of Marlborough District Council)

The general approach to developing a long-term monitoring plan follows the steps outlined in Table 2. Briefly, the report summarises the main intertidal areas within the region (Appendix 1), applies a framework to prioritise sites, and then details a monitoring plan for the selected sites. The report details proposed indicators, thresholds and methods for monitoring in addition to a long-term schedule that covers a 20-year time period.

1.3 STATUTORY CONTEXT

There are a number of national and regional statutes that require MDC to understand the extent and condition of the estuarine areas within its region. These are outlined below.

The Resource Management Act

The Resource Management Act 1991 (RMA) requires local authorities to monitor the state of the whole or any part of the environment (s35(2)(a)). MDC has specific management responsibilities over regional coastal waters and habitats which lie within New Zealand's territorial seas between the mean high water spring tide mark (MHWS) out to 12 nautical miles offshore – the Coastal Marine Area (CMA). Regional councils must recognise and provide for the matters of national importance listed in Section 6 of the RMA. Particularly, the preservation of natural character (Section 6(a)) and the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna (Section 6(c)). There also exist a variety of other obligations such as managing indigenous biodiversity (s30(1)(g)(a)).

The New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement 2010 (NZCPS) contains several policies and objectives relating to estuary monitoring, of which the most relevant to Marlborough are:

- Objective 1 seeks to safeguard the integrity, form, functioning, and resilience of the coastal environment and sustain its ecosystems.
- Objective 6 seeks to enable people and communities to provide for their social, economic, cultural wellbeing and their health and safety.
- Objective 7 requires that the management of the coastal environment (including the CMA) recognises and provides for New Zealand's international obligations for biodiversity.

Table 2. Approach to develop the monitoring plan adopted in this report.

1. Set objective
To *'...monitor intertidal habitats and identify the contribution of key stressors affecting ecological health'* (Urlich, 2018) to support informed decision making and maintain and/or improve estuary health.
2. Prioritise sites for monitoring
A stocktake of intertidal areas in Marlborough was undertaken and an Ecological Vulnerability Assessment (EVA) was applied to 60* key sites identified, as a basis for prioritising them for monitoring. A range of EVA frameworks have been used previously in New Zealand to prioritise estuaries for monitoring and management. In this report existing EVA methods were reviewed and optimised. Sites were selected based on the values, condition, pressures and susceptibility.
3. Select indicators
Indicators were selected based on previous New Zealand and international studies. Indicators were chosen that measure a response to key stressors and detect change within a reasonable timeframe to allow for a management intervention.
4. Establish thresholds
Thresholds of concern are useful to trigger a management response. Established and developing thresholds exist for several New Zealand estuary indicators (e.g. Robertson et al. 2002a-c; Robertson et al. 2016).
5. Select monitoring methods
Existing SoE methods are based on the NEMP or extensions of that approach. Additional method considerations are detailed in the current report, to improve data reliability, and achieve consistency over time and between different practitioners. Methods for new approaches (e.g. site-specific seagrass monitoring and water quality monitoring, i.e. Wairau Lagoon) are also outlined.
6. Develop monitoring plan
A monitoring programme is proposed that aligns with MDC's objective, is 'fit for purpose' and within the resources available.

*While most intertidal areas were captured in the assessment, those not part of the initial assessment can be included at a later date.

Big Bay, Endeavour Inlet, Queen Charlotte Sound

- Policy 11 seeks to protect indigenous biological diversity in the coastal environment.
- Policy 12 requires controls on activities in or near the CMA that will promote harmful aquatic organisms to be released or otherwise spread.
- Policy 22 requires that the impacts of sedimentation on the coastal environment are assessed and monitored.
- Policy 23 requires discharges to the coastal environment to be managed to avoid adverse effects on ecosystems and habitats.
- Several policies cover human use in the coastal environment including access (Policies 18-20) and development within the CMA (e.g. Policy 25).

Exotic forestry above Yncyca Bay, Pelorus Sound

Ferry terminal in Picton

The National Policy Statement for Freshwater Management

The National Policy Statement for Freshwater Management (NPSFM) applies to "all freshwater (including groundwater) and, to the extent they are affected by freshwater, to receiving environments (which may include estuaries and the wider coastal marine area)" (NPSFM 2020). Specifically, Policy 3 requires freshwater to be "managed in an integrated way that considers the effects of the use and development of land on a whole-of-catchment basis, including the effects on receiving environments", which includes estuaries.

The NPSFM requires councils to set limits to resource use that will meet target freshwater objectives. Generally freshwater objectives will prevent further degradation, start making improvements and reverse past damage. To maintain or improve freshwater health it also requires an understanding of the downstream receiving environment (e.g. an estuary). Where the receiving environment is the most sensitive, nutrients, river levels and flows need to meet the environmental outcomes of the downstream receiving environment (Rules 3.13, 3.16). Fish passage also needs to be considered under Rule 3.26.

The Proposed Marlborough Environment Plan

MDC has reviewed the Marlborough Regional Policy Statement, the Marlborough Sounds Resource Management Plan and the Wairau/Awatere Resource Management Plan to create a single resource management document for the district. The Proposed Marlborough Environment Plan (PMEP) guides individuals, businesses and the wider community on the use of public resources such as fresh water and the coastal space, in addition to what people can do on their land (MDC 2022).

Chapter 8 of the PMEP - Indigenous Biodiversity - sets out the objectives, policies and methods to be used, and the anticipated environmental results in recognising and providing for the protection of areas of significant indigenous vegetation and significant habitats of indigenous fauna. Issue 8A of the PMEP identifies that there has been a reduction in the extent and condition of indigenous biodiversity in Marlborough over time. It recognises that "Tidal wetlands, although mostly small and widely spread throughout Marlborough, form an important network for mobile species of wetland bird. Larger estuaries do exist, including those at Whangarae (Croisilles Harbour), Havelock, Kaiuma and Wairau Lagoons. These larger estuaries provide habitat and feeding areas for a wide variety of fish, invertebrates and birds."

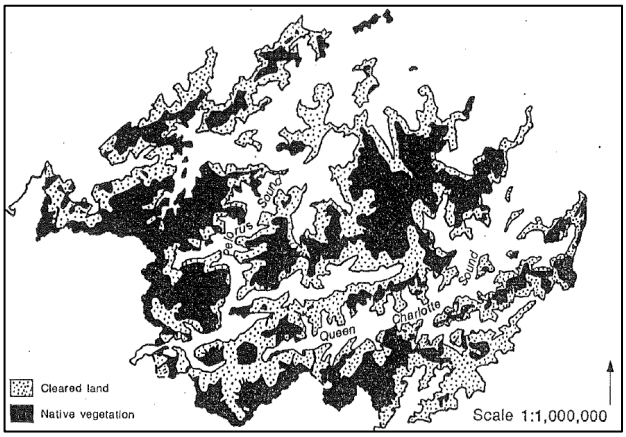
Specifically, Policy 8.1.3 in the PMEP describes the need for ongoing information gathering on the state of marine environments to enable decision makers to assess the impacts on biodiversity of various activities. This policy also acknowledges that there are significant gaps in our knowledge, and that Council will undertake surveys to improve awareness of biodiversity patterns and condition in the CMA.

2. SYNOPSIS OF ESTUARIES IN MARLBOROUGH

Approximately 90% of the Marlborough coastline is within the Marlborough Sounds, which itself represents about 10% of the New Zealand coastline. The Marlborough Sounds comprise large, deep subtidally dominated estuaries (i.e. Tōtaranui/Queen Charlotte, Te Hoiere/Pelorus, Kenepuru Sound, Rangitoto ki te Tonga/D'Urville Island, Croisilles Harbour) that have many small intertidal areas at the heads of bays and inlets. These small areas generally have a steep intertidal profile and a short, steep, and often bush clad catchment. The intertidal areas within the Sounds contain a range of high value habitats including salt marsh, seagrass and shellfish beds. Larger intertidal areas are typically found at the heads of the main Sounds (e.g. Motuweka/Havelock Estuary; Ōkiwa Bay). These areas are to varying degrees impacted by fine sediment and nutrient inputs from larger, relatively modified catchments. Outside of the Sounds estuarine areas are uncommon in Marlborough, except for two large lagoon systems on the east coast (Wairau Lagoon and Lake Grassmere).

Wairau Lagoon

Urlich and Handley (2020) assessed historic changes in biodiversity and marine ecosystems across the Marlborough Sounds, highlighting a significant decline in marine life since Māori settlement (~700 years ago), with a rapid acceleration in the decline following European settlement in the 1800's. European settlement led to extensive burning and land clearance, with over 50% of native bush cleared by 1910 (Lauder 1987; see map). Present day, land use in the Sounds is a mix of indigenous forest remnants, regenerating indigenous shrublands and forests, farmland, and exotic forestry. The steep topography of the Sounds and soft geology make the land highly erodible. The catchment characteristics and high annual rainfall combined with land-based activities such as farming, forestry and roading, mean that sediment is one of the most significant stressors on the coastal environment. This is especially the case in Pelorus Sound, where a recent study demonstrated that sedimentation rates in estuaries within the inner Sound are currently 10 times higher than under historic natural conditions (Swales et al. 2021).



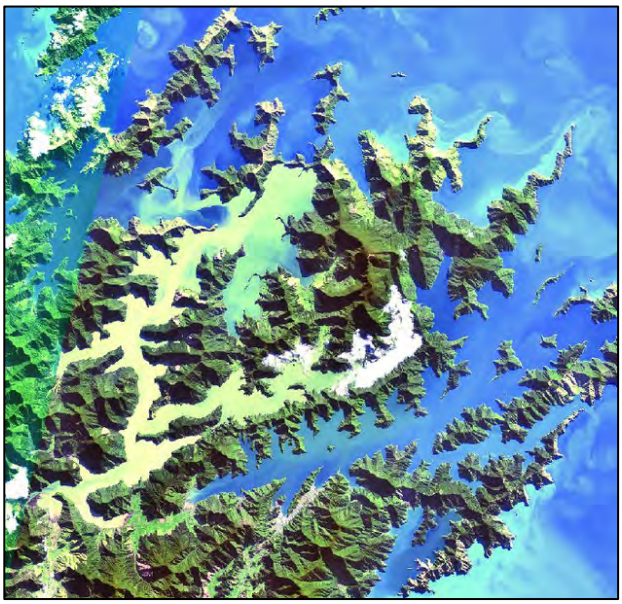
Estimated area of land clearing up to 1910 from Lauder (1987)

Steep bush clad catchment on D'Urville Island

While sediment is likely the most significant stressor arising from land development and population growth in the region, increased nutrient loads and direct discharges of contaminants to the coastal environment are also common. Nutrients, in particular nitrogen, can lead to excess algal growth, either intertidal macroalgae or subtidal phytoplankton, which can have negative impacts on the surrounding environment (e.g. oxygen depletion, light limitation, displacement of fauna). The effects of other contaminants are more varied and generally have the greatest impact near ports and developed coastal areas where discharges occur (Davidson et al. 2011).

Intertidal estuaries across the region have also been subjected to reclamation and drainage, which can cause the permanent loss of estuarine habitat (Davidson et al. 2011). While reclaimed areas are typically relatively small, the cumulative effect is significant because intertidal estuarine areas are uncommon in Marlborough. Examples from Marlborough include large reclamations in Waikawa Estuary (see photos) and Shakespeare Bay for the marina and port respectively, through to small areas of reclamation along estuary margins for farming and urban development (e.g. Waterfall Bay and Ōkiwa

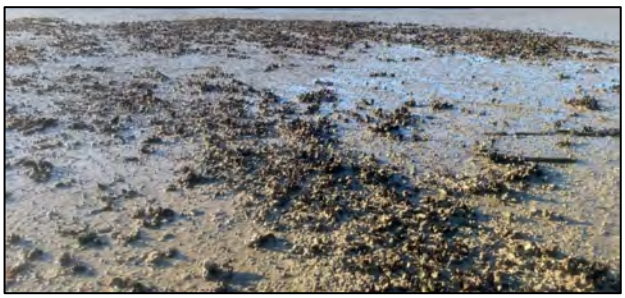
Bay). Further, drainage and reclamation of adjacent freshwater wetlands is common, with significant areas historically lost. These lost wetland areas would have provided habitat for numerous birds and fish, helped slow water flow during flood events, in addition to acting as a natural filter of sediment and contaminants.



European Space Agency Satellite Sentinel-2 image of Pelorus Sound/Te Hoiere (discoloured yellow/ brown) and Queen Charlotte Sound/Tōtaranui (blue) after an annual rainfall event, July 2018 (source: Ulrich et al. 2019).

Waikawa Estuary in 1957 (top) and 2021 (bottom) after the marina development, with >70% reduction in the intertidal area

Introduced exotic species are often present in estuaries and can displace native species and alter natural estuarine dynamics. For example, the exotic cord grass *Spartina anglica* has been present in Motuweka (Havelock) Estuary for over 70 years (Davidson & Brown 2000) and is the focus of an ongoing eradication programme by the Department of Conservation. *Spartina* traps sediment and can rapidly expand in extent, reclaiming large areas of the intertidal zone and displacing natural salt marsh habitat. The Pacific oyster (*Crassostrea gigas)*, which was discovered in New Zealand in the 1970s, is another common introduced species in Marlborough. It is now well-established across several intertidal areas (e.g. Havelock Estuary) where its formation of high-density oyster reefs fundamentally alters estuary habitats. Significant vessel numbers, ports, marinas and other areas of coastal development increase the likelihood of new species incursions, which once established are difficult to contain and eradicate (Davidson et al. 2011; Forrest & Hopkins 2013).



Pacific oysters in Mahakipawa Arm, Pelorus Sound

Other anthropogenic pressures in Marlborough include dredging and bottom trawling in subtidal areas, overfishing, shipping, boating and other recreational and commercial activities (Davidson & Brown 2000; Handley 2015; Handley 2016; PMEP Appeal Version 2022; Urlich & Handley 2020). Furthermore, future climate change pressures will likely include ocean acidification, warming sea surface temperatures, sea level rise, and an increased frequency and intensity of storm events.

Because intertidally-dominated estuaries are uncommon in Marlborough, ~30 sites are classified as ESMS's because they retain high ecological values that are rare in the region (e.g. salt marsh, seagrass, important habitats for wildlife; Davison et al. 2011). While not all estuaries are in the ESMS programme, many of those not included still retain high ecological, cultural and social values, and should be managed to increase their ecological health, improve resilience and minimise the impact of anthropogenic stressors (Urlich & Hendley 2020).

3. SELECTING ESTUARIES FOR MONITORING

A formal process for ranking estuaries across Marlborough is required to set priorities for long term monitoring (Forrest & Stevens 2019). A precursor to this step is a stocktake of intertidal estuaries across the Marlborough region, which is outlined in the next section. We then describe and apply a site prioritisation framework to select sites for long term monitoring (Table 2; Step 2).

3.1 STOCKTAKE OF INTERTIDAL ESTUARIES

Several studies refer to the rarity of intertidal estuarine areas within the Marlborough Sounds (e.g. Davidson et al. 2011). However, a preliminary stocktake undertaken by MDC for the purposes of this report identified 60 intertidal estuaries within the Marlborough region. These 60 estuaries are listed in Table 3 and Fig. 1, and were used in the prioritisation process. A three-page summary of each estuary is presented in Appendix 1.

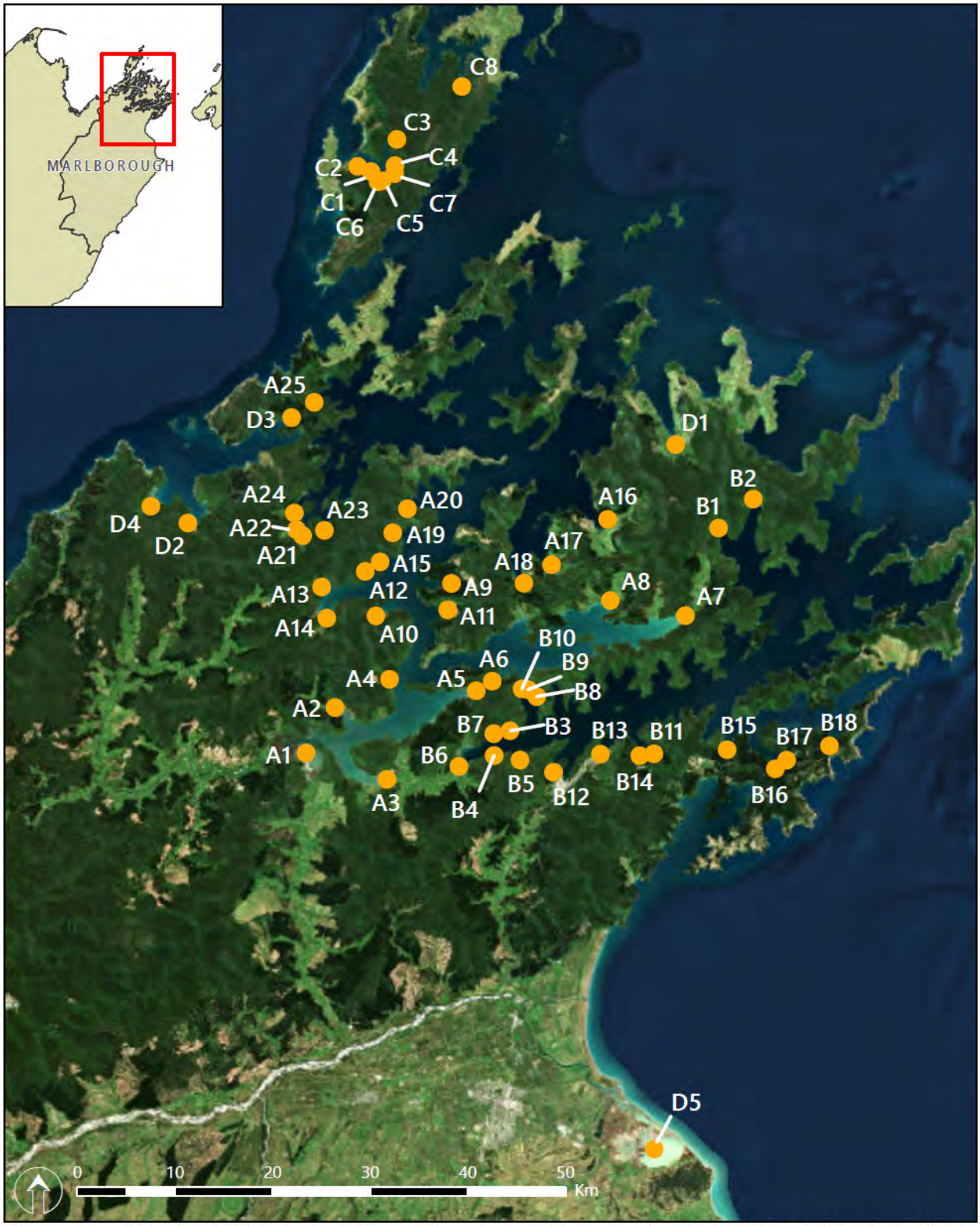
MDC recognise that their preliminary assessment did not capture all intertidal estuaries in the region (it is estimated that ~90% are represented). Examples of estuaries not included are the heads of Deep Bay, Paradise Bay, Yncyca Bay, and other small intertidal areas in Wells Arm of D'Urville Island. As such, it is proposed that the Table 3 estuary list and the prioritisation framework described in this report be treated as a living document and be updated over time (e.g. at the time of a recommended 10-year monitoring programme review).

Te Hoiere/Pelorus Sound, looking down on Yncyca Bay

Table 3. List of 60 estuaries included in the report.

ID	Estuary name	Region	Sub-region	Area (ha)	ESMS
A1	Havelock Estuary	PS	Inner Pelorus	565.0	✓ (3.20)
A2	Kaiuma Bay	PS	Inner Pelorus	52.8	✓ (3.19)
A3	Mahakipawa Arm	PS	Inner Pelorus	137.5	✓ (3.20)
A4	Mud Bay	PS	Inner Pelorus	7.1	-
A5	Ohinetaha Bay	PS	Inner Pelorus	48.4	-
A6	Broughton Bay	PS	Keneperu Sound	10.5	-
A7	Kenepuru Head	PS	Keneperu Sound	43.2	✓ (3.21)
A8	Waitaria Bay	PS	Keneperu Sound	37.5	-
A9	Four Fathom Bay	PS	Hikapu Reach	1.8	-
A10	Maori Bay	PS	Hikapu Reach	5.2	-
A11	Nikau Bay	PS	Hikapu Reach	2.4	-
A12	Chance Bay	PS	Nydia Bay	5.2	✓ (3.17)
A13	Nydia Bay North	PS	Nydia Bay	11.0	-
A14	Nydia Bay South	PS	Nydia Bay	29.1	-
A15	Penguin Bay	PS	Nydia Bay	3.6	-
A16	Clova Bay	PS	Mid Pelorus	19.1	✓ (3.14)
A17	Crail Bay / Elie Bay	PS	Mid Pelorus	14.6	-
A18	Crail Bay / Wet Inlet	PS	Mid Pelorus	16.8	-
A19	Fairy Bay	PS	Mid Pelorus	3.2	-
A20	North West Bay	PS	Mid Pelorus	3.1	-
A21	Duncan Bay	PS	Tennyson Inlet	8.8	✓ (3.10)
A22	Harvey Bay	PS	Tennyson Inlet	13.1	✓ (3.10)
A23	Ngawhakawhiti Bay	PS	Tennyson Inlet	7.5	✓ (3.9)
A24	Tuna Bay	PS	Tennyson Inlet	19.0	✓ (3.10)
A25	Savill Bay	PS	Fitzroy Bay	3.8	-
B1	Big Bay	QCS	Endeavour Inlet	2.9	✓ (4.27)
B2	Endeavour Inlet	QCS	Endeavour Inlet	8.1	✓ (4.27)
B3	Bottle Bay	QCS	Grove Arm	1.2	✓ (4.3)
B4	Momorangi bay	QCS	Grove Arm	1.0	-
B5	Ngakuta Bay	QCS	Grove Arm	11.8	✓ (4.5)
B6	Okiwa Bay	QCS	Grove Arm	80.4	✓ (4.1)
B7	Umungata Bay	QCS	Grove Arm	3.0	✓ (4.3)
B8	Fence Bay	QCS	Onahau Bay	0.5	-
B9	Mistletoe Bay	QCS	Onahau Bay	0.9	-
B10	Waterfall Bay	QCS	Onahau Bay	1.4	-
B11	Ahuriri Bay	QCS	Southern shore	6.6	-
B12	Shakespeare Bay	QCS	Southern shore	5.4	✓ (4.10)
B13	Waikawa Bay	QCS	Southern shore	2.8	-
B14	Whatamango Bay	QCS	Southern shore	9.1	✓ (4.12)
B15	Hitaua Bay	QCS	Tory Channel	0.8	✓ (5.5)
B16	Onapua Bay	QCS	Tory Channel	1.5	-
B17	Opua Bay	QCS	Tory Channel	0.9	-
B18	Oyster Bay	QCS	Tory Channel	0.9	-
C1	Bullock Bay	DI	Greville Harbour	1.2	✓ (1.7)
C2	Camping Bay	DI	Greville Harbour	0.4	✓ (1.7)
C3	Mill Arm	DI	Greville Harbour	9.0	✓ (1.7)
C4	Mokau Bay	DI	Greville Harbour	1.0	✓ (1.7)
C5	Punt Arm	DI	Greville Harbour	2.6	✓ (1.7)
C6	Smylies Arm	DI	Greville Harbour	3.2	✓ (1.7)
C7	Wharairiki	DI	Greville Harbour	3.8	✓ (1.7)
C8	Wells Arm 1	DI	Port Hardy	1.8	-
C8	Wells Arm 2	DI	Port Hardy	1.5	-
C8	Wells Arm 3	DI	Port Hardy	1.1	✓ (2.2)
D1	Anakoha Bay	O	Outer Sounds	8.5	✓ (2.25)
D2	Okiwi Bay North East	O	Croisilles Harbour	11.0	-
D2	Okiwi Bay South West	O	Croisilles Harbour	18.2	-
D3	Squally Cove North	O	Croisilles Harbour	2.7	-
D3	Squally Cove South	O	Croisilles Harbour	6.6	-
D4	Whangarae	O	Croisilles Harbour	116.2	✓ (1.1)
D5	Wairau Lagoon	O	East Coast	~1700	✓ (8.2)

PS = Pelorus Sound, QCS = Queen Charlotte Sound, DI = D'Urville Island, O = other



Imagery sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand license.

Fig. 1. Map of estuaries included in the current report, labels cross-reference to estuary names in Table 3.

3.2 SITE PRIORITISATION METHOD

3.2.1 Overview

The primary aim of the selection process was to prioritise estuaries for Tier 1 and Tier 2 monitoring as described in Section 1.1. A secondary aim of the prioritisation process was to identify estuaries that are not currently classified as ESMS's, but would be eligible for consideration based on the criteria outlined in Davidson et al. (2013).

An Ecological Vulnerability Assessment (EVA) was used to prioritise estuaries for monitoring. A range of EVA frameworks have been used previously for this purpose in New Zealand (e.g. Robertson et al. 2002a; Robertson & Stevens 2007a-b, Stevens 2018d, Stevens & Robertson 2017b). Based on the recommendations in Forrest & Stevens (2019), existing EVA methods were reviewed and optimised to provide a unified and logical framework for assessing priorities, based on a transparent and integrated scoring system. The current report presents the first iteration of the revised EVA approach, with improvements through its application expected to be incorporated over time. As well as incorporating learnings from previous applications in New Zealand, this revised approach also draws on more recent international studies (e.g. GBRMP Authority 2017; UNESCO/IOC 2020).

The EVA approach is based on key characteristics (and their interactions) that affect the priority of an estuary for monitoring, which can be partitioned into four categories as follows:

- Ecological Values: Habitat types, species of conservation significance and habitat intactness.
- Pressures: Natural and anthropogenic pressures on the ecological values.
- Susceptibility: Vulnerability to future changes in state.
- Condition: Current estuary condition with respect to qualitative or quantitative indicators of health.

Forrest & Stevens (2019) recommended "management" be considered as a standalone category to determine whether there is potential to avoid emerging or impending problems, remediate degraded conditions, or restore an estuary to a more natural state. However, in reviewing the assessment criteria it was identified that management was already captured within the other categories including 'pressures', 'susceptibility' and 'condition'.

The EVA is intended to enable different estuaries to be compared in a consistent manner, and to identify ecological values and the main pressures impacting the habitat features present. While there are still some limitations to the approach (e.g. data availability, data quality, thresholds under development) the EVA provides a coarse screening tool to highlight susceptibility and key pressures, and to set priorities for future monitoring and management.

3.2.2 Data sources

MDC hold a breadth of information on pressures affecting the CMA (e.g. land use, discharges, coastal structures). However, there are limited data available on the ecological values and the current condition of many of the region's estuaries. As such, information on these categories was derived in three ways:

(1) For the 24 estuaries monitored to date (Table 1), existing monitoring data and reports were used, recognising that data quality is variable across these locations; 24 estuaries have been assessed using broad scale mapping (see Section 6.1) methods and of these, six have been monitored using fine scale (see Section 6.2) monitoring methods.

(2) Using expert knowledge and aerial photographs, an additional 36 estuaries were identified that have not been previously assessed. For these we developed a field-based Rapid Estuary Assessment (REA) tool to facilitate systematic collection of the minimum information needed to provide a broad overview of values, condition and current pressures. MDC staff carried out REA's in 14 of the 24 estuaries already monitored and 29 of the un-monitored estuaries.

(3) Desktop information was obtained for the remaining 7 estuaries for which field-based data could not be collected in the project timeframe.

Data on pressures and susceptibility were captured from the field surveys, a desktop assessment of literature, and/or MDC information. Specific data sources are listed in Appendix 2. The raw data used in the assessment are partly provided in Appendix 1, with a more detailed electronic output delivered to MDC.

Smylies Arm, Greville Harbour

3.2.3 Rapid Estuary Assessment (REA)

The Rapid Estuary Assessment (REA) approach was developed as a high-level screening tool to identify key habitats and pressures, and support council decision making (e.g. site prioritisation). The REA was developed using the broad scale mapping principles in the NEMP (Robertson et al. 2002a-c) and ETI (Robertson at al. 2016a-b), in addition to the field-based experience of the authors. The REA is intended to take <1hr of field time for intertidal estuaries <20ha, with a greater effort likely required for larger systems. The REA focuses on ecological values (i.e. estuary habitats and habitat intactness; Table 4) and current condition. It combines aerial photography and high-level ground-truthing, with NEMP methods (Appendix 3) used to map and categorise intertidal estuary substrate and vegetation. A brief description of the sampling methods for each main estuary feature and associated attributes is provided on the REA field sheet in Fig. 2. Where possible, the assessments should be carried out during September to May when most estuary plants (e.g. nuisance macroalgae) are still visible and seasonal vegetation has not died back.

Applying the REA in the field requires drawing dominant habitat features and their estimated extent onto laminated aerial photographs at a scale less than 1:5000. Data are also recorded onto the REA field sheet (Fig. 2). For data collected in the current report, MDC used a Survey123 custom-built electronic template for data recording. Pre-specified constraints on data entry (e.g. with respect to data type, minimum or maximum values) ensured that the risk of erroneous data recording was minimised. The information collected in the REA was then used in the EVA to prioritise sites for monitoring.

Gravel and cobble substrate in Duncan Bay, Pelorus Sound

Seagrass habitat in Ngākuta Bay, Grove Arm of Queen Charlotte Sound

Table 4. Overview of the ecological significance of key estuary habitats.

Habitat	Description
Substrate	Substrate provides habitat for both fauna and plants (e.g. rock field provides a hard substrate for mussel attachment and firm muddy sands provide good substrate for seagrass). More diverse substrate types within an estuary generally support a more diverse biological community.
Salt marsh	Salt marsh (vegetation able to tolerate saline conditions where terrestrial plants are unable to survive) is important in estuaries as it is highly productive, naturally filters and assimilates sediment and nutrients, acts as a buffer that protects against introduced grasses and weeds and provides an important habitat for a variety of species including fish and birds.
Seagrass	Seagrass (*Zostera muelleri*) beds are important ecologically because they enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for a range of invertebrates and fish. Although tolerant of a wide range of conditions, seagrass is vulnerable to fine sediments in the water column (reducing light), sediment smothering (burial), excessive nutrients (primarily secondary impacts from macroalgal smothering), and sediment quality (e.g., low oxygen).
Opportunistic macroalgae	Opportunistic macroalgae are a primary symptom of estuary eutrophication (nutrient enrichment). They are highly effective at utilising excess nitrogen, enabling them to out-compete other seaweed species and, at nuisance levels, can form mats on the estuary surface that adversely impact underlying sediments and fauna, other algae, fish, birds, seagrass, and salt marsh.

Rapid Estuary Assessment

Field based assessment of ecological values and condition

SALT ECOLOGY

Site:

Date/Time:

Tide Time:

Field Observer/s

Weather prior to sampling (i.e. dry, rainfall etc)

Photos of key habitats Y/N

Photos of key pressures Y/N

VALUE - Habitat Intactness							
Method	A subjective appraisal of the overall intactness and health of the site relative to estimated natural state.						
% of the site is considered healthy and intact compared to natural state	>80 to 100% ☐	>60 to ≤80% ☐	>40 to ≤60% ☐	>20 to ≤40% ☐	0 to ≤20% ☐	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

VALUE - Substrate Habitat Diversity							
Method	The number of different substrate types. Including mud, shell/sand, gravel/cobble recorded if >5% intertidal area and boulder/bedrock, zootic recorded if >1% intertidal area (outside of saltmarsh areas).						
Common substrates present (tick)	Mud-dominated (>5% intertidal area) ☐	Sand/Shell-dominated (>5% intertidal area) ☐	Gravel/cobble (>5% intertidal area) ☐	Boulder/Bedrock (>1% intertidal area) ☐	Zootic (mussel etc) (>1% intertidal area) ☐	Notes:	
Approximate % of total substrate (estimate)	_____%	_____%	_____%	_____%	_____%		
Number of substrate types (circle)	≥5	4	3	2	1	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

CONDITION - Mud Extent							
Method	Estimate or measure extent of intertidal mud-dominated sediments e.g. >50% mud content.						
% Intertidal Area	<1% ☐	1-5% ☐	>5-15% ☐	>15-50% ☐	>50% ☐	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

VALUE - Salt marsh							
Method	Estimate or measure the area of intertidal salt marsh extent.						
Intertidal salt marsh extent (%) (tick and estimate extent)	>20% ☐ ___%	>10-20% ☐ ___%	>5-10% ☐ ___%	>0-5% ☐ ___%	0% ☐	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

CONDITION - Salt marsh							
Method	Five common pressures are listed. Two metrics are used. 1) to identify whether salt marsh is under single or multiple pressures; and 2) the percentage of the salt marsh impacted by the pressures present. The attribute with the lowest score determines the final score.						
Common pressures present (tick)	Grazing or Vehicle damage ☐	Reclamation ☐	Drainage ☐	Erosion ☐	Weeds ☐	Notes:	
% of salt marsh affected (estimate)	_____%	_____%	_____%	_____%	_____%		
List any additional pressures:							
Total count of pressures (circle)	1	2	3	4	≥5		
Total salt marsh area affected (circle)	0%	>0 to 5%	>5 to 10%	>10 to 20%	>20%	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

VALUE - Seagrass							
Method	Estimate or measure extent of intertidal seagrass.						
Intertidal seagrass extent (%) (tick and estimate extent)	>20% ☐ ___%	>10-20% ☐ ___%	>5-10% ☐ ___%	>0-5% ☐ ___%	0% ☐	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

Fig. 2. Field sheet for Rapid Estuary Assessment.

CONDITION - Seagrass							
Method	Five common pressures are listed. Two metrics are used. 1) to identify whether seagrass is under single or multiple pressures; and 2) the percentage of the seagrass impacted by the pressures present. The attribute with the lowest score determines the final score. NA, where no seagrass is present.						
Common pressures present (tick)	Macroalgae smothering ☐	Epiphytic growth ☐	Sediment smothering ☐	Leaf die-off/discolouration ☐	Physical erosion or grazing (e.g. swans) ☐	Notes:	
% of seagrass affected (estimate)	_____%	_____%	_____%	_____%	_____%		
Total count of pressures (circle)	1	2	3	4	≥5		
Total seagrass area affected (circle)	0	>0-5%	>5-10%	>10-20%	>20%	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

CONDITION - Macroalgae (growths of opportunistic macroalgae)							
Method	% cover of the intertidal area with >5% opportunistic nuisance macroalgae cover (e.g. *Ulva* spp., *Agarophyton* spp. or other known bloom forming species in the region).						
% of intertidal area with >5% macroalgae cover	0 to ≤5 ☐	>5 to ≤15 ☐	>15 to ≤25 ☐	>25 to ≤75 ☐	>75 to 100% ☐	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

CONDITION - High Enrichment Conditions (HECs)							
Method	Estimate the intertidal area expressing High Enrichment Conditions (>50% macroalgae, low sediment oxygen {i.e. shallow aRPD}, mud>25% or anoxic muds devoid of life). These areas are usually relatively small and located in deposition areas where fine muds accumulate.						
% of intertidal area with HECs	0ha or 0% ☐	>0-0.5ha or >0-1% ☐	0.5-5ha or 1-5% ☐	>5-20ha or >5-10% ☐	>20ha or >10% ☐	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

CONDITION - Estuary margin hardening (e.g. reclamation or artificial rock wall)							
Method	Percent of the estuary margin (high tide line) that has been reclaimed or hardened, compromising the natural connectivity of the estuary to the surrounding terrestrial areas. e.g. seawalls, reclamation, roading						
% of high tide line modified	0 to ≤20% ☐	>20 to ≤40% ☐	>40 to ≤60% ☐	>60 to ≤80% ☐	>80 to 100% ☐	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

CONDITION - Invasive species							
Method	Record the presence of invasive species and their level of establishment. e.g. Pacific oyster, *Undaria* sp. and *Spartina* sp.						
Existing presence of invasive species (individual per area or % across estuary)	Absent No visible individuals ☐	Rare <1 indiv./ 10m^2 or <1% across estuary ☐	Occasional 1 to <10 indiv./ 10m^2 or ≥1 to <5% across estuary ☐	Frequent ≥10 to <100 indiv./10m^2 or ≥5 to <10% across estuary ☐	Common ≥10% across estuary including high density areas ≥10 indiv./1m^2 ☐		
List any invasive species seen or recorded from the site:						VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

CONDITION - Toxicants							
Method	Five common sources are listed to indicate whether inputs are likely from single or multiple pressures. List any other potential toxicant sources.						
Common pressures present (tick)	Urban stormwater ☐	Industrial discharges ☐	Sewage discharges (e.g. outfalls, septic tanks) ☐	Landfills ☐	Catchment viticulture, horticulture, cropping ☐	*List other pressures:*	
Total count of pressures (circle)	1	2	3	4	≥5	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

CONDITION - Pathogens							
Method	Five common sources are listed to indicate whether inputs are likely from single or multiple pressures. List any other potential pathogen sources						
Common pressures present (tick)	Urban stormwater ☐	Dairy shed or other industrial discharges ☐	Sewage discharges (e.g. outfalls, septic tanks) ☐	Large waterfowl populations ☐	Catchment intensive agriculture (e.g. sheep, dairy, cattle, deer) ☐	*List other pressures:*	
Total count of pressures (circle)	1	2	3	4	≥5	VALUE SCORE	CONDITION SCORE
SCORE	**5**	**4**	**3**	**2**	**1**		

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VALUE SCORE	0	/20
CONDITION SCORE	0	/45

Fig. 2. continued. Field sheet (page 2) for Rapid Estuary Assessment.

3.2.4 Ecological Vulnerability Assessment

Each of the four main categories of the EVA framework described in Section 3.2.1 were partitioned into the detailed attributes shown in Table 5, with a five-point rating scale for each attribute based on qualitative, semi-quantitative or fully quantitative descriptors that we developed as part of the project. Using this approach, each attribute was scored out of five, with five being the highest possible score.

Where data were unavailable (e.g. sedimentation rate, shellfish, biogenic reef, phytoplankton, and site-level climate change attributes), the attribute was excluded for all estuaries, and has been highlighted to MDC as a knowledge gap and, where appropriate (e.g. sedimentation rate measurement), has been included in the monitoring plan.

To emphasise attributes deemed by the authors to have a greater relative importance, a five-point weighting (in even increments from 0.2 to 1.0) was applied, with 1.0 being the highest weight. For example, often marine contaminants represent a localised issue (weighting 0.2) while catchment land uses such as exotic forestry and intense agriculture can cause widespread problems (weighting 1.0).

While weightings can be assigned with a site-specific or a regional focus, in the current study each attribute was weighted independently by four of the report authors (KR, LS BF, OW) in the broader context of New Zealand estuaries (Appendix 4). Where there were discrepancies between weighted attributes, these were worked through until consensus was reached, or the weightings were averaged across the four authors to produce a final weighting. While the weightings for each attribute varied, the same weighting for a given attribute was applied consistently across each of the 60 Marlborough estuaries to allow their direct comparison. Weightings were applied following Equation 1.

$$\text{Final attribute score} = \text{raw score} \times \text{weighting} \qquad \text{Eq. 1}$$

Pasture on coastal margin, Elie Bay, Pelorus Sound

To calculate a score for each of the four main categories of estuary characteristics (i.e. ecological values, pressures, condition and susceptibility) the final attribute scores were averaged and standardised to 1.0 using the maximum possible score (i.e. average of final attribute scores, assuming all raw scores were 5) for each category (Equation 2).

$$\text{Final category score} = \frac{\text{Average(final attribute scores for category)}}{\text{Average (maximum possible attribute scores for category)}} \qquad \text{Eq. 2}$$

To calculate an overall EVA score, the four final category scores were averaged to give a final score out 1. However, while an overall EVA score is useful, the final scores for each of the four main categories are also important, as they enable closer interrogation of the EVA data to support site prioritisation. For example, the category scores can distinguish estuaries that have high ecological values and are at high-risk of future degradation (e.g. significant pressures and high susceptibility). Conversely, the category scores can also be used to identify estuaries with high ecological values in good condition with minimal pressures.

To aid visual interpretation of summary scores for each category within each estuary, the following rating colour scheme was used:

Category	Rating & Score				
	5	4	3	2	1
Values	VG	G	F	P	VP
Pressures	VL	L	M	H	VH
Susceptibility	VL	L	M	H	VH
Condition	VG	G	F	P	VP

VG = very good; G = good; F = fair; P = poor; VP = very poor

VH = very high; H = high, M = moderate; L = low; VL = very low

A high rating score represents an estuary with high values, in good condition combined with low pressures and susceptibility. A low rating score represents low values, poor condition and high pressures and susceptibility.

Table 5. Ecological vulnerability assessment – Ecological Values.

	Very Good (5)	Good (4)	Fair (3)	Poor (2)	Very Poor (1)
Ecological Values					
Area of estuary (ha) Value of the estuary increases with the area of the resource	>50ha	>20-50ha	>5-20	0.5-5ha	<0.5ha
Habitat Intactness (%) A subjective appraisal of the overall intactness and health of the site relative to estimated natural state.	>80 to 100% of the site is considered healthy and intact	>60 to 80% of the site is considered healthy and intact	>40 to 60% of the site is considered healthy and intact	>20 to 40% of the site is considered healthy and intact	>0 to 20% of the site is considered healthy and intact
Seagrass (extent; % of intertidal area) Provides erosion control, nutrient uptake, sediment deposition and wave dissipation, shelter and nursery for fish and other biota and carbon sequestration.	>20%	>10 to 20%	>5 to 10%	>0 to 5%	0
Salt marsh (extent; % of intertidal area) Provides erosion control, nutrient uptake, sediment deposition and wave dissipation, habitat, shelter and nursery for fish, roosting area for birds, and carbon sequestration.	>20%	>10-20%	>5-10%	>0-5%	0
Mangroves (extent; % of intertidal area) Provides erosion control, nutrient uptake, sediment deposition, wave dissipation, shelter and habitat and nursery for fish and other biota and carbon sequestration.	>20%	>10-20%	>5-10%	>0-5%	0
Intertidal shellfish beds (indigenous) Filter feeders improve water clarity, filter sediment and microphytobenthos	Common ≥10% across estuary including high density areas ≥10 individuals per 1m^2	Frequent ≥5 to <10% across estuary or ≥10 - <100 individuals per 10m^2	Occasional ≥1 to <5% across estuary or 1 - <10 individuals per 10m^2	Rare <1% across estuary or <1 individual per 10m^2	Absent No visible individuals
Biogenic reef (% across estuary) Increases habitat complexity, nursery for juvenile fish. e.g. tube worms, bryozoans, mussel beds, oyster reefs, sponges	Common ≥10%	Frequent ≥5 to <10%	Occasional ≥1 to <5%	Rare <1%	Absent 0%
Species of conservation significance Threatened or at-risk species e.g. birds: Caspian tern, banded rail e.g. diadromous fish: giant kokopu, lamprey, koaro, longfin eel	Supports nationally endangered or vulnerable species which are not commonly found in other countries.	Supports nationally endangered or vulnerable species or part of known range for nationally critical species.	Supports species in serious or gradual decline or known habitats for endangered or vulnerable species.	Supports endemic and non-threatened species or known habitats for at risk or endemic species.	Supports only non-threatened or migrant species
Protected status (within or adjacent to estuary i.e. terrestrial or marine) e.g. significant marine area, regionally significant wetland (inc. salt marsh), conservation areas, parks or reserves.	Designated Significant Marine Sites or regionally significant wetland within the estuary margin.		Designated Protected Area adjacent to the estuary margin.		None

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Table 5. continued. Ecological vulnerability assessment – Pressures.

	Very low (5)	Low (4)	Moderate (3)	High (2)	Very High (1)
Pressures					
Catchment					
Indigenous Vegetation Cover (% catchment) Indigenous vegetation types generally release less sediment and nutrients and provide connective habitat for indigenous species.	≥ 80 to 100	≥ 50 to 80	≥ 25 to 50	≥ 10 to 25	< 10
Exotic Forest (% catchment) During establishment and harvest this land use can lead to excess sediment run-off compared to natural land cover.	< 10	≥ 10 to 25	≥ 25 to 50	≥ 50 to 80	≥ 80 to 100
High producing grassland (% catchment) Land use results in higher levels of sediment and nutrient run-off compared to natural land cover.	< 10	≥ 10 to 25	≥ 25 to 50	≥ 50 to 80	≥ 80 to 100
Urban & industrial development (% catchment) Results in more impervious surfaces that promote run-off of stormwater. Increased probability of wastewater and industrial discharges (i.e. increased nutrients, heavy metals, bacteria, viruses).	0 No industrial or urban development.	>0 to 5 Low urban or industrial development	5 to 10 Moderate urban or industrial development.	10 to 15 High urban or industrial development.	>15 Extensive urban or industrial development.
Horticulture (% catchment) Land use generally leads to higher use of pesticides and trace elements to promote crop growth.	0 No horticulture present.	>0 to 5 Low horticultural development.	5 to 10 Moderate horticultural development.	10 to 15 High horticultural development.	>15 Extensive horticultural development.
Nutrient Load Thresholds for symptoms of eutrophication (e.g. macroalgae growth)	Very low (<5 mg/m^2/d)	Low (>5 to ≤10 mg/m^2/d)	Moderate (>10 to ≤50 mg/m^2/d)	High (>50 to ≤250 mg/m^2/d)	Very High (>250mg/m^2/d)
Sedimentation rate (CSR:NSR ratio*) *CSR = Current sedimentation rate, NSR = natural sedimentation rate	CSR 1 to 1.1 x NSR	CSR 1.1 to 2 x NSR	CSR >2 to 5 x NSR	CSR >5 to 10 x NSR	CSR >10 x NSR
Grazing animals in estuary and on margin Grazing animals can lead to direct destruction of high value habitat and increase bank erosion.	Very Low No access to estuary by farmed animals. No known signs of wild animal activity.	Low No access to estuary by farmed animals. Signs (e.g. browsing, pugging, rooting) of wild animal activity (e.g. deer, pigs)	Moderate Potential access for farmed animals i.e. farming on margin and possibility animals could break through fence on occasion.	High Unrestricted access for farmed animals i.e. no fencing and open access to the estuary.	Very High Unrestricted access for farmed animals (i.e. no fencing and open access to the estuary) and evidence of damage to the margin.
Altered Hydrology Modification of freshwater input or tidal flow (e.g. flap gates, culvert, channelised watercourse, high water abstraction etc).	Very low No modification, natural hydrology.		Moderate Localised modification of hydrology.		Very high Extensively modified hydrology

Table 5. continued. Ecological vulnerability assessment – Pressures continued.

	Very low	Low	Moderate	High	Very High
Pressures					
Contaminants (chemical & biological)					
Chemical contaminants - marine e.g. Trace metals, SVOCs, emerging contaminants	Little or no connectivity Remote location with little or no vessel activity. No marine structures or known anchorages within 500m.	Low connectivity Anchorage or 1 to 5 private berths/ moorings but no other marine structures within 500m.	Moderate connectivity Moderate density (>5-20) private berths/ moorings or other marine structures within 500m.	High connectivity High density (>20-50) private berths/ moorings or other marine structures within 500m, or commercial vessel route within 500m.	Very high connectivity Very high density (>50) private berths/ moorings or other marine structures within 500m, or commercial vessel route or port/ marina within 500m.
Chemical contaminants - terrestrial e.g. Trace metals, SVOCs, emerging contaminants	Very Low Unmodified catchment. No contaminant inputs.	Low	Moderate Moderate contaminant inputs (e.g. moderate urban, industrial or horticultural development in catchment)	High	Very High Likely significant contaminant inputs (e.g. stormwater, wastewater, horticulture etc)
Marine oil spill risk Proximity of shipping/vessel activity or port to intertidal estuary	Little or no connectivity Remote location with little or no vessel activity. No marine structures or known anchorages within 5km.	Low connectivity Anchorage or 1 to 5 private berths/moorings but no other marine structures within 5km.	Moderate connectivity Moderate density (>5-20) private berths/moorings or other marine structures within 5km.	High connectivity High density (>20-50) private berths/ moorings or other marine structures within 5km, or commercial vessel route within 5km.	Very high connectivity Very high density (>50) private berths/ moorings or other marine structures within 5km, or commercial vessel route or port/ marina within 5km.
Introduced marine species Connectedness to main source populations of estuarine non-indigenous species. Pathways include vessels, structures or proximity to known populations.	Little or no connectivity Remote location with little or no vessel activity. No marine structures or known anchorages within 5km.	Low connectivity Anchorage or 1 to 5 private berths/moorings but no other marine structures within 5km.	Moderate connectivity Moderate density (>5-20) private berths/moorings or other marine structures within 5km.	High connectivity High density (>20-50) private berths/ moorings or other marine structures within 5km, or commercial vessel route within 5km.	Very high connectivity Very high density (>50) private berths/ moorings or other marine structures within 5km, or commercial shipping route or port/ marina within 5km.

Table 5. continued. Ecological vulnerability assessment – Pressures continued.

	Very low (5)	Low (4)	Moderate (3)	High (2)	Very High (1)
Pressures					
Contaminants (chemical & biological)					
Phytoplankton algal blooms Phytoplankton blooms reduce water clarity, can lead to low oxygen conditions upon breakdown and can be harmful to shellfish/ fish.	No previous blooms		Occasional blooms		Re-occurring blooms (e.g. annual)
Pathogens Risk to ecology if exotic or indigenous pathogens are introduced (e.g. shellfish/fish) or emerge due to environmental pressures.	Very low pressures or little or no connectivity to likely terrestrial or marine (see biosecurity) sources.	Low pressures or low connectivity to likely terrestrial or marine (see biosecurity) sources.	Moderate pressures or moderate connectivity to likely terrestrial or marine (see biosecurity) sources.	High pressures or high connectivity to likely terrestrial or marine (see biosecurity) sources.	Very high pressures or very high connectivity to likely terrestrial or marine (see biosecurity) sources.
Human use					
Direct Human use Non-commercial use (e.g. recreation)	Very low Little or no use	Low Occasional use	Moderate Seasonal use	High High year-round use	Very High Very High year-round use
Direct Human use Commercial marine species harvest or aquaculture within estuary (e.g. shellfish harvest or marine farms)	Very low None	Low Occasional harvest, no permanent aquaculture structures	Moderate Seasonal harvest, no permanent aquaculture structures	High Year-round harvest, no permanent aquaculture structures	Very High Year-round harvest and/or permanent aquaculture structures
Disturbance of wildlife Direct human access - level of protection.	Restricted e.g. fence around important habitat or breeding area.		Limited e.g. signage to prevent dog access		Unrestricted
Habitats					
Salt Marsh pressures (number of recorded pressures) Pressures include grazing/ vehicle damage, reclamation, drainage, erosion, weeds and other	≤1	2	3	4	≥5
Seagrass pressures (number of recorded pressures) Pressures include macroalgal smothering, epiphytic growth on leaves, sediment smothering, leaf die-off, physical erosion and grazing or other	≤1	2	3	4	≥5
Fish passage Many of New Zealand's fish species migrate between freshwater and marine environments as part of their lifecycles. Infrastructure can inhibit the natural connectivity reducing the abundance of these species.	Very Low No barriers to fish passage		Moderate Partial barrier to fish passage (i.e. not all access is restricted)		Very High Complete barrier to fish passage (i.e. all access is restricted)

Table 5. continued. Ecological vulnerability assessment – Susceptibility.

	Very low (5)	Low (4)	Moderate (3)	High (2)	Very High (1)
Susceptibility					
Current physical susceptibility to eutrophication					
Estimated Physical Susceptibility Overall susceptibility of an estuary is, in part, dependent on dilution and flushing (see Robertson et al. 2016a)	High export Low susceptibility		Moderate export Moderate susceptibility		Low export High Susceptibility
Mixing status (i.e. well mixed, partially mixed, stratified) i.e. Stratification can influence dissolved oxygen concentration and phytoplankton growth.	Unlikely to stratify or experience mouth constriction.		Potential to stratify for short periods (<1 week)		Likely to stratify (>1week)
Extent of increase in pressures in <10 years					
Catchment pressures (e.g. forestry harvest, farming intensification, land disturbance)	Low		Moderate		High
Contaminants (chemical & biological) (e.g. increase in vessel numbers, marine structures, development)	Low		Moderate		High
Human Use (e.g. aquaculture expansion or intensification, population increase, increased accessibility to estuary)	Low		Moderate		High
Extent of increase in pressures in >10 y					
Catchment pressures (e.g. forestry harvest, farming intensification, land disturbance)	Low		Moderate		High
Contaminants (chemical & biological) (e.g. increase in vessel numbers, marine structures, development)	Low		Moderate		High
Human Use (e.g. aquaculture expansion or intensification, population increase, increased accessibility to estuary)	Low		Moderate		High
Adaptive capacity of estuary to sea level rise Ability of estuary to migrate landward with sea level rise (e.g. physical barriers to migration artificial or natural)	Very high No barriers to landward migration.	High Intensive land use on estuary margin and high gradient coastal plain (slow inundation).	Moderate Intensive land use on estuary margin and low gradient coastal plain (rapid inundation).	Low Artificial barrier to landward migration (e.g. artificial rock wall).	Very low Natural barrier to landward migration (e.g. steep margin, rock cliff)
Coastal vulnerability Index Coastal erosion and sea level rise (see Stevens & Robertson 2017)	CVI <13.7	CVI 13.7 to 15	CVI >15 to 17	CVI >17	
Climate change adaptation and resilience (e.g. to rising sea temperatures, marine heat waves, ocean acidification, increased storm frequency etc)	Needs further development The criteria should consider exposure, sensitivity, and adaptive capacity. However, high resolution data at a regional scale is required to make a meaningful assessment.				

Table 5. continued. Ecological vulnerability assessment – Condition.

	Very Good (5)	Good (4)	Moderate (3)	Poor (2)	Very Poor (1)
Condition					
Habitat					
Estimated historical salt marsh extent (% of historic salt marsh remaining) **estimated from known data sources or historic imagery*	≥ 80 to 100	≥ 60 to <80	≥ 40 to <60	≥20 to <40	< 20
Proportion (%) of current salt marsh degraded *Pressures include grazing/ vehicle damage, reclamation, drainage, erosion, weeds and other	< 20	≥20 to 40	≥ 40 to 60	≥ 60 to 80	≥ 80 to 100
% Seagrass decline from estimated baseline **estimated from known data sources or historic imagery*	<5	≥ 5 to 10	≥ 10 to 15	≥ 15 to 20	≥ 20
Proportion (%) of current seagrass degraded *Pressures include macroalgal smothering, epiphytic growth on leaves, sediment smothering, leaf die-off, physical erosion, grazing etc.	< 20	≥20 to 40	≥ 40 to 60	≥ 60 to 80	≥ 80 to 100
Substrate					
Diversity of substrate types * Based on REA criteria.	≥5	4	3	2	1
Predicted sedimentation rate (mm/y)	0	>0 to <0.5	≥0.5 to <1	≥1 to <2	≥2
Mud extent (% intertidal)	<1%	1 to 5%	>5 to 15%	>15 to 50%	>50%
Eutrophication					
Opportunistic macroalgae extent (% intertidal)	0 to 5%	>5 to 15%	>15 to 25%	>25 to 75%	>75 to 100%
Phytoplankton (µg/L) **Categories dependent on salinity (ppt)**	<3µg/L (>30ppt) <5µg/L (≤30ppt)	>3 to 8µg/L (>30ppt) <5 to 10µg/L (≤30ppt)	>8 to 12µg/L (>30ppt) >10 to 16µg/L (≤30ppt)	>12 to 16µg/L (>30ppt) >16 to 32 µg/L (≤30ppt)	>16µg/L (>30ppt) >32µg/L (≤30ppt)
High Enrichment Conditions (Ha or % intertidal area)	0ha OR 0%	>0-0.5ha OR >0-1%	0.5-5ha OR 1-5%	>5-20ha or >5-10%	>20ha or >10%
Invasive Species					
Existing presence of invasive species in the estuary (e.g. *Spartina* sp., pacific oysters, *Undaria* sp.)	Absent No visible individuals	Rare <1 individual per 10m^2 or <1% across estuary	Occasional 1 - <10 indiv. per 10m^2 or ≥1 to <5% across estuary	Frequent ≥10 - <100 indiv. per 10m^2 or ≥5 to <10% across estuary	Common ≥10% across estuary with high density areas ≥10 individuals per 1m^2

Table 5. continued. Ecological vulnerability assessment – Current State.

	Very Good (5)	Good (4)	Moderate (3)	Poor (2)	Very Poor (1)
Current State					
Modification					
Reclamation and/or drainage of habitat (% area affected)	<1%	1-5%	5-10%	>10 to 25%	>25%
Shoreline length modified/ disturbed (% shoreline modified) (e.g. grassland, infrastructure, exotic bush etc)	< 20	≥ 40 to 20	≥ 40 to 60	≥ 60 to 80	≥ 80 to 100
Hardening of estuary margin (% hardened) (e.g. artificial rock wall, earth bund, reinforcement armouring)	< 20	≥ 40 to 20	≥ 40 to 60	≥ 60 to 80	≥ 80 to 100
200m terrestrial margin (% densely vegetated) (LCDB classes 45-71)	≥ 80 to 100	≥ 50 to <80	≥ 25 to <50	≥10 to >25	<10

Kenepuru Sound, Pelorus Sound

Multivariate analysis procedures in the software Primer v7.0.13 (Clarke et al. 2014) were used to assess similarities and differences among estuaries in terms of the four main categories of estuary characteristics that were evaluated (values, pressures, susceptibility, condition). For pairwise comparisons of all estuaries, a resemblance matrix was constructed from similarity scores calculated using the Euclidean distance measure. Based on the matrix, the grouping of estuaries according to similarities in values, pressures, susceptibility, and condition was assessed using a non-metric multidimensional scaling (nMDS) ordination. Overlay vectors and bubble plots of scores for each category, as well as estuary size, were used to visualise the features that characterised each estuary or groups of estuaries. Wairau Lagoon was excluded from the multivariate analysis because it represents a largely subtidal estuary and is characteristically different from the other shallow intertidally-dominated estuaries in the site list (Table 3).

In addition to the multi-variate approach, the site selection process was supported by the information gathered in the summaries (Appendix 1), and considered the geographic location of each estuary. For example, to ensure the programme provided a good representation of the Marlborough region, sites were selected from the Pelorus, Queen Charlotte and outer Sounds.

3.3 PRIORITISING SITES FOR MONITORING

3.3.1 Tier 1 monitoring sites

Tier 1 monitoring consists of regular (~5-yearly), quantitative, long-term SoE type monitoring (i.e. fine scale or broad scale NEMP monitoring), which is intended to be undertaken at a subset of representative sites to meet the councils statutory requirements and track changes in estuary condition over time. Five sites are proposed for Tier 1 monitoring as shown in Table 6. These estuaries were selected using the output of the EVA (Table A1 in Appendix 1) and the multivariate analysis. The nMDS ordination produced by the analysis is shown in Fig. 3. The 2-dimensional plot shows sites with similar EVA scores close to each other, while less similar sites are further apart. The vector overlays in Fig. 3 show that the values category most strongly separated the estuaries on the vertical axis, with condition, pressures and susceptibility explaining the separation on the horizontal axis. Bubble plot overlays visually represent the influence of each category, with the bubble size scaled to intertidal area (Fig. 3) or the category scores (Figs. 4 & 5).

Fig. 3 reveals four estuaries with high values and poorer condition that are also under pressure and susceptible to change: Motuweka (Havelock), Kaiuma and Waitaria Estuaries in Pelorus Sound, and Ōkiwa Bay in Queen Charlotte Sound. Of these, two estuaries were selected for Tier 1 monitoring, Motuweka (Havelock) Estuary and Ōkiwa Bay (Table 6). Motuweka (Havelock) Estuary was selected over Kaiuma and Waitaria estuaries because it has the largest area of high value habitats, a good historic monitoring record, and is directly affected by the Pelorus and Kaituna Rivers, whereas the other two sites are only indirectly affected. The Motuweka (Havelock) Estuary also provides a good representative site for the other mud-dominated estuaries at the head of Pelorus Sound (i.e. Kaiuma, Mahakipawa, Kenepuru, Ohinetaha). While not included in the Tier 1 monitoring, targeted sediment monitoring should also be considered at these sites (see Section 3.3.4).

Ōkiwa Bay, Queen Charlotte Sound

Table 6. Tier 1 sites selected for SoE monitoring.

Estuary Name	Reason
Motuweka (Havelock) Estuary	Representative site in Pelorus Sound (selected based on all EVA categories)
Ōkiwa Bay	Representative site in Queen Charlotte Sound (selected based on all EVA categories)
Whangarae Estuary	Reference estuary of comparable size to Motuweka (Havelock) Estuary and Ōkiwa Bay
Anakoha Estuary	Representative site in Outer Sounds (selected based on EVA categories values & pressure)
Wairau Lagoon	Unique estuary type and receiving environment for Marlborough's most populated and developed catchment.

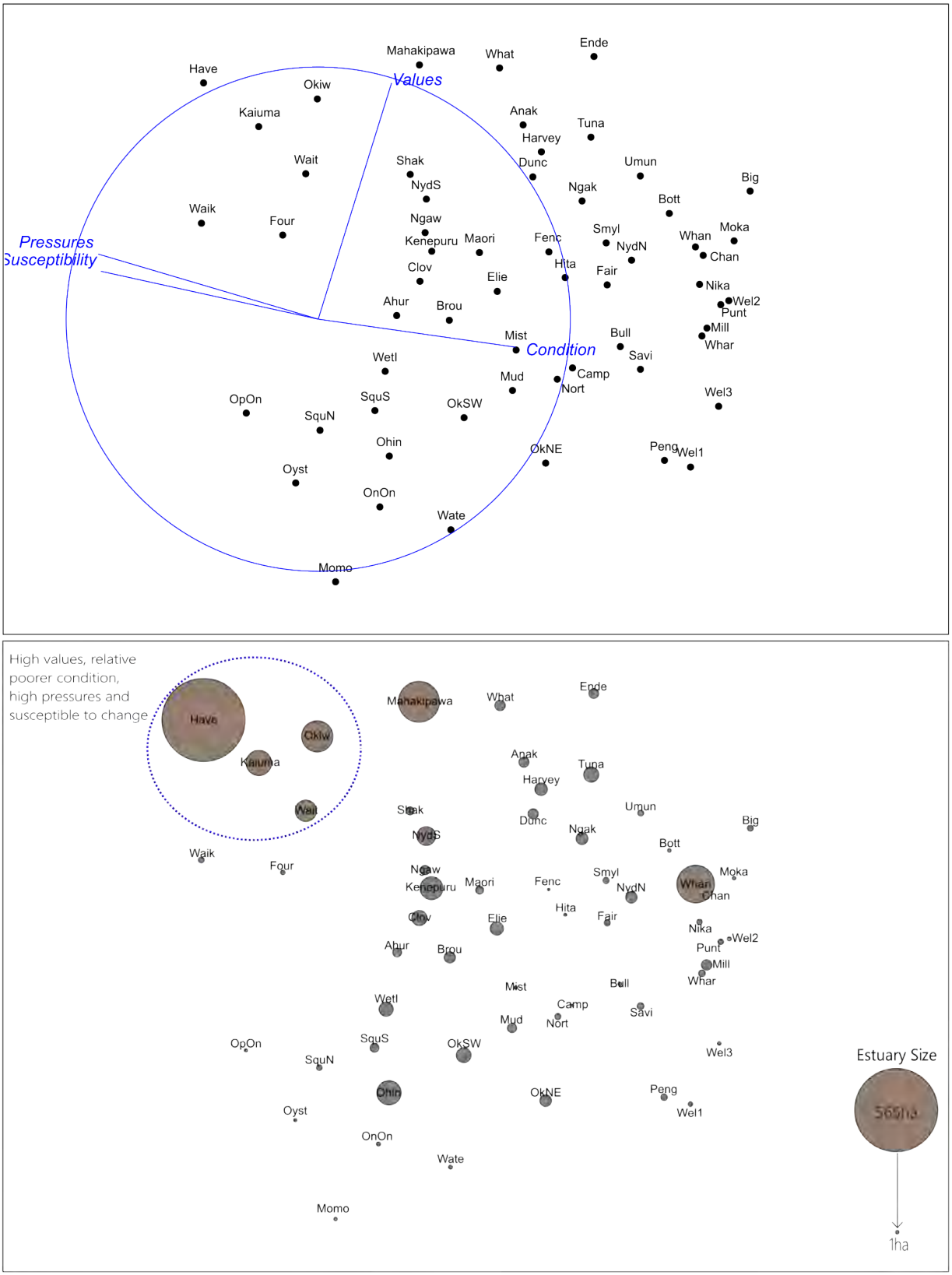


Fig. 3. Non-metric MDS ordination of Marlborough estuaries (excluding Wairau Lagoon) according to scores for the four categories of estuary characteristics. Bubble sizes in the bottom panel are scaled to estuary size.

Estuaries are positioned on the plot such that those most similar in terms of the four category scores are closest to each other. Conversely, those furthest apart are the least similar. A 'stress' value of 0.12 for the nMDS indicates that a 2-dimensional plot provides a reasonable representation of similarities and differences. Vector overlays indicate the direction and strength of association (length of line relative to circle) of grouping patterns in terms of the four categories, with the similar trajectory of pressures and susceptibility indicating that these attributes are significantly correlated (Pearson r=0.72, p<0.001).

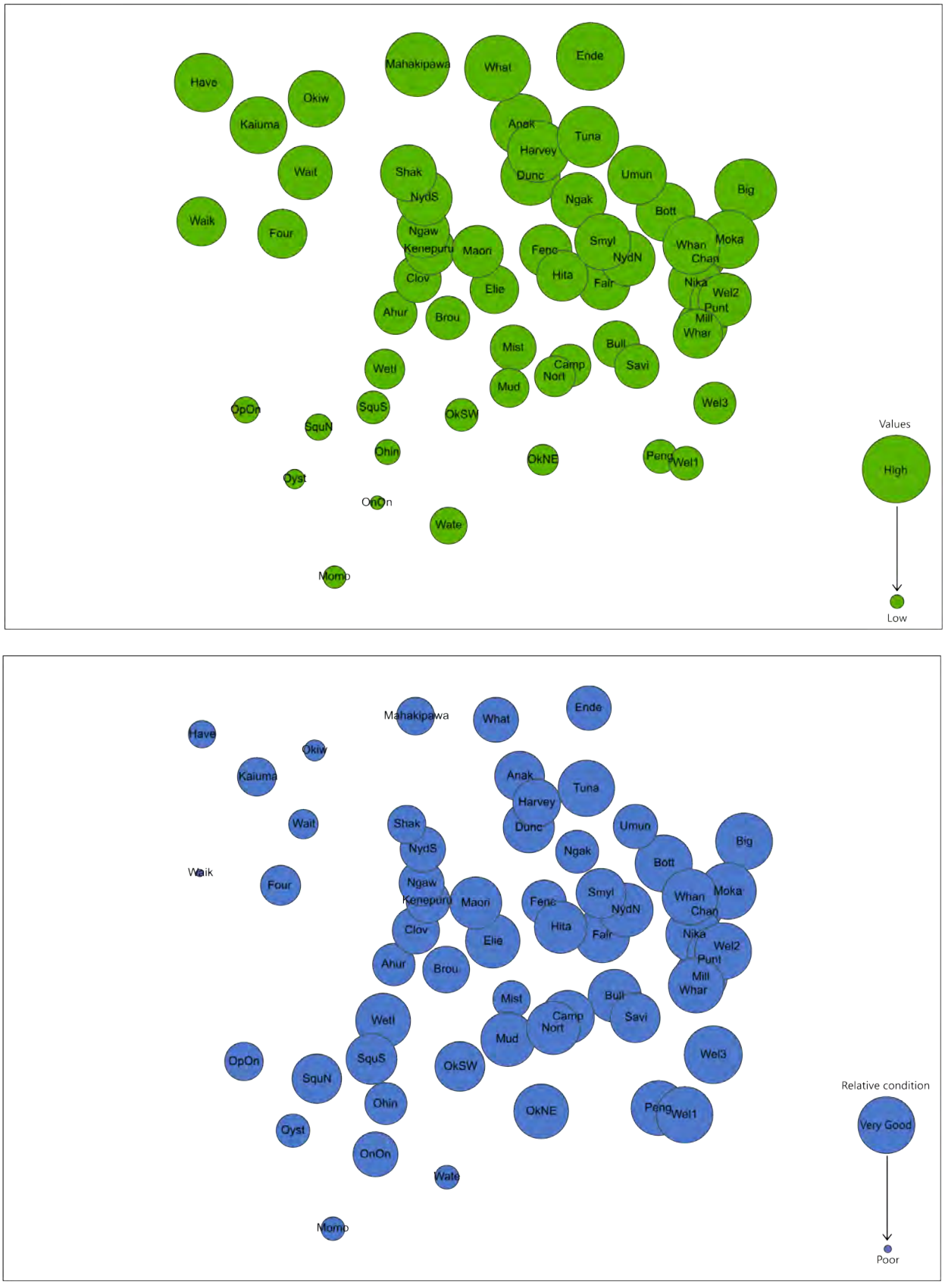


Fig. 4. Non-metric MDS ordination of Marlborough estuaries (excluding Wairau Lagoon) according to scores for the four categories of estuary characteristics. Bubble sizes are scaled to category scores for values (top) and condition (bottom).

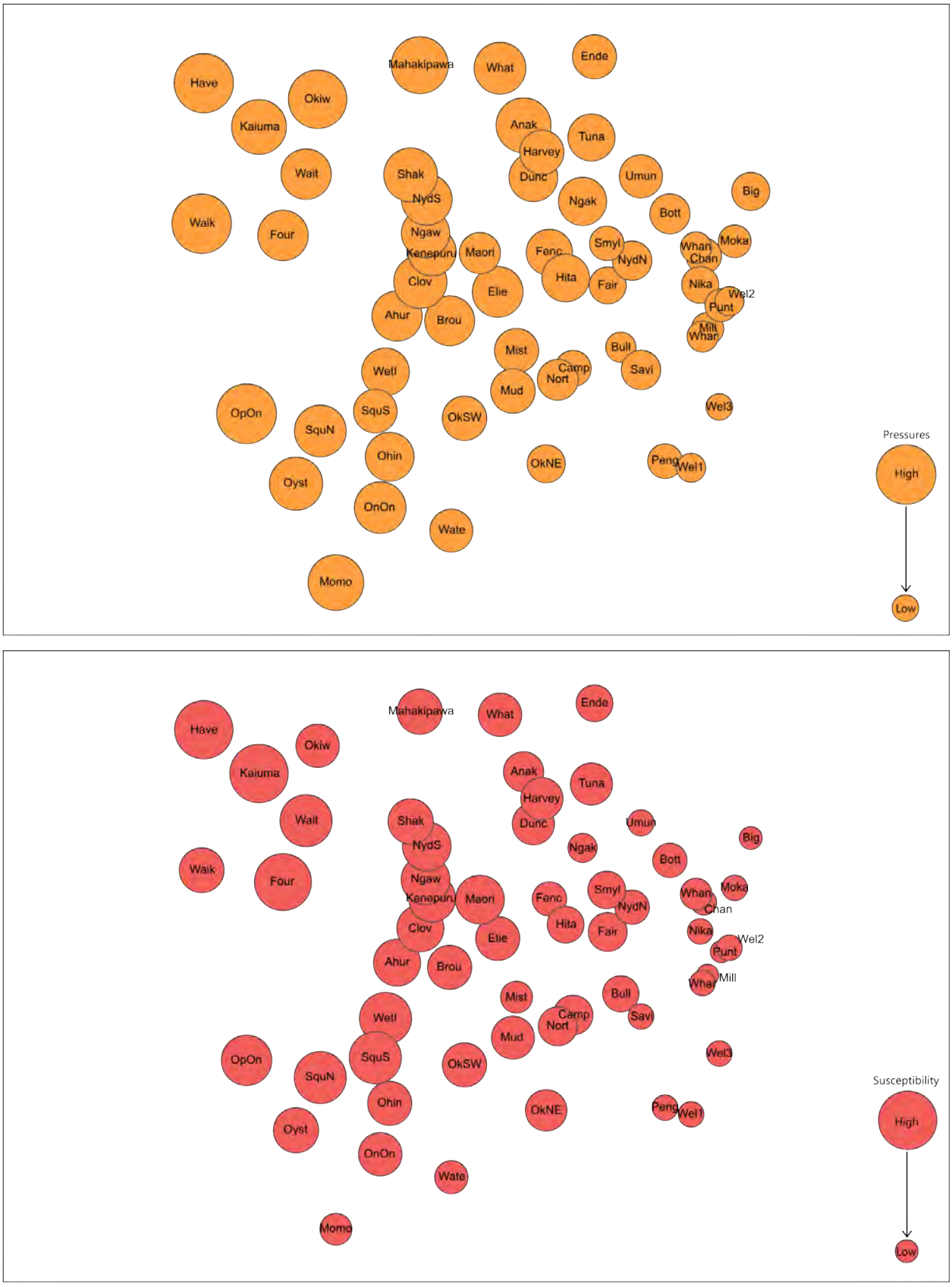


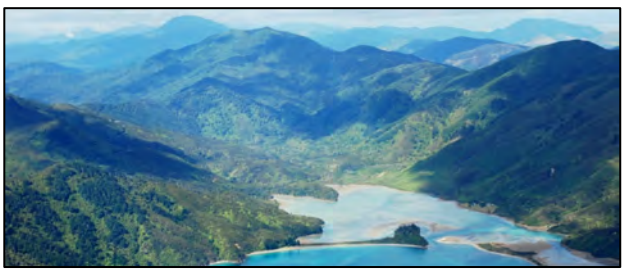
Fig. 5. Non-metric MDS ordination of Marlborough estuaries (excluding Wairau Lagoon) according to scores for the four categories of estuary characteristics. Bubble sizes are scaled to the category scores for pressures (top) and susceptibility (bottom).

Motuweka (Havelock) Estuary looking downstream of Kaituna River (source: stuff.co.nz)

To distinguish changes owing to natural variability from human-induced stressors it is important to include reference estuaries in the monitoring programme. A reference estuary represents an estuary in pristine or near-pristine condition, that can be used as a point of comparison for other estuaries. For Tier 1 monitoring purposes the only suitable candidate of similar size to Motuweka (Havelock) Estuary and Ōkiwa Bay is Whangarae Estuary (Fig. 3; Table 6).

The EVA rated condition 'very good' and pressures and susceptibility 'very low' for Whangarae Estuary, but the method did not score the values category as highly as expected (see Figs. 3 & 4). The estuary has seagrass and salt marsh habitats; however, proportionately these areas are small relative to the estuary size and therefore were ranked lower. However, the present-day catchment is 99.8% native vegetation despite historic land clearance, with a small area of duneland at the estuary entrance. Overall, the presence of vegetated habitats and the diversity of substrate types in Whangarae Estuary make it comparable to Motuweka (Havelock) Estuary and Ōkiwa Bay, and therefore a suitable reference system.

Although having only a single Tier 1 reference estuary is not ideal, there are other smaller estuaries in near pristine condition (e.g. Big Bay, Mill Arm, Punt Arm, Bottle Bay, Chance Bay) that are proposed to be included in Tier 2 and Tier 3 monitoring, thereby providing supporting information (although less quantitative) on long-term changes.



Whangarae Estuary (Image courtesy of MDC)

To provide a Tier 1 estuary representative of the outer Sounds, Anakoha Bay has been proposed. The estuary at the head of Anakoha Bay scored highest with respect to values, and was under moderate pressure, compared to other outer Sounds estuaries (Fig. 4; Appendix 1).

Anakoha Bay (outer Sounds), at high tide (source: cruiseguide.co.nz)

Furthermore, modelled freshwater flows and nutrient loads for Anakoha Bay are similar to Ōkiwa Bay and Whangarae Estuary; however, because the estuary is connected directly to Cook Strait, its circulation is driven by ocean currents meaning it is better flushed than the other systems.

Wairau Lagoon east of Blenheim was selected as the final Tier 1 monitoring site (Table 6). The EVA results highlight that Wairau Lagoon has high values, is under pressure and is susceptible to change (Appendix 1). It was selected as a Tier 1 site because it represents a unique estuary type in the region. It is comprised of three shallow connected lagoons, and has high value salt marsh habitat and large areas of the macrophyte *Ruppia* spp., which is rare in both a regional and national context. The estuary is also the main receiving environment for Marlborough's most populated and modified catchment.

Except for Anakoha Bay, NEMP broad scale and/or fine scale monitoring has previously been carried out at all Tier 1 sites (see Table 1).

Ruppia spp. with filamentous algae in Wairau Lagoon

Salt marsh herbfield (top) and intertidal area (bottom) in Wairau Lagoon

3.3.2 Tier 2 monitoring sites

Table 7 presents 22 proposed Tier 2 monitoring sites. The site list mainly represents estuaries of moderate size (>10ha) that have been previously monitored. The exceptions are as follows:

- Some of the previously monitored estuaries are <10ha, but given the significant investment MDC have put into establishing quantitative baselines, we recommend continued broad scale monitoring at these sites (e.g. Waikawa Bay, Shakespeare Bay).
- There are two additional sites (>10ha) where no monitoring has been undertaken:
    - Nydia Bay (Pelorus Sound): has several moderate-sized intertidal areas with large areas of salt marsh habitat, particularly herbfield on the southern flats, with the northern flats draining a native bush catchment.
    - Clova Bay (Pelorus Sound): has two moderate-sized intertidal areas. Both the catchment and estuary are modified; however, the estuary retains a large area of high value salt marsh and seagrass beds.
- Big Bay (Endeavour Inlet): does not meet the moderate size criteria; however, it is recommended for inclusion because it has a native bush catchment and extensive seagrass beds. Big Bay represents a good reference estuary for seagrass.

Nydia Bay north (top), Clova Bay (middle) and Big Bay (bottom; images courtesy of Marlborough District Council)

Table 7. Tier 2 sites selected for SoE monitoring.

Estuary Name
Pelorus
Pelorus - Broughton Bay
Pelorus - Ohinetaha Bay
Pelorus - Crail Bay x 2 (Elie Bay & Wet Inlet)
Pelorus - Kaiuma Bay
Pelorus - Kenepuru Estuary
Pelorus - Mahakipawa Arm
Pelorus - Tennyson Inlet x 3 (Tuna, Harvey & Duncan)
Pelorus - Nydia Bay x 2 (North/ South)
Pelorus – Clova Bay
Queen Charlotte Sound
QCS - Ahuriri Bay
QCS - Shakespeare Bay
QCS - Waikawa Bay
QCS - Whatamango Bay
QCS - Ngākuta Bay
QCS - Big Bay/ Endeavour Inlet
D'Urville Island
Greville Harbour - Mill Arm
Greville Harbour - Punt Arm
Greville Harbour - Smylies Arm

Two estuaries >10ha are not recommended for Tier 2 monitoring, as follows:

- Waitaria Bay: is one of many intertidal areas in Kenepuru Sound, and these estuaries are adequately represented by monitoring in Kenepuru Head Estuary and Broughton Bay.
- Okiwi Bay: this estuary in the outer Sounds has not had a field visit and therefore the EVA was based on desktop information only. Due to uncertainty regarding the accuracy of the estuary information provided for Okiwi Bay in Appendix 1, it is recommended this site be prioritised in Tier 3 monitoring and its inclusion re-assessed as part of a 10-year programme review.

Of the selected Tier 2 monitoring sites, Big Bay, Wells Arm, Punt Arm and Mill Arm represent good reference estuaries for the following reasons:

- Big Bay (Endeavour Inlet): as discussed, Big Bay has a native bush catchment (>99%) and extensive seagrass beds.
- Punt Arm (D'Urville Island): has a native bush catchment (>99%) and the intertidal flats comprise both salt marsh and seagrass habitats.
- Mill Arm (D'Urville Island): has a native bush catchment (>99%), the intertidal flats comprise mud-dominated sediments representing ~46% of the intertidal area making it a good reference site for other muddy estuaries.

3.3.3 Tier 3 monitoring sites

Tier 3 monitoring sites represent all of the remaining estuaries not included in Tier 1 or 2 monitoring, which were listed above in Table 3. Any additional minor intertidal estuary areas that are identified during future MDC surveys, and which warrant some form of monitoring should be added to this list. Of the Tier 3 monitoring sites Bottle Bay and Chance Bay represent good reference estuaries for the following reasons:

- Bottle Bay (Queen Charlotte Sound): has a native bush catchment (>99%), seagrass and salt marsh habitats.
- Chance Bay (Pelorus Sound): has a native bush catchment (>99%) and high value salt marsh habitat.

In general, the proposed Tier 3 estuaries are small (<10ha), and their health can be quickly assessed by trained council staff using the REA tool and/or broad scale mapping techniques.

3.3.4 Targeted sediment monitoring sites

Catchment-derived sediment input is a significant issue in Pelorus Sound, with sedimentation rates in the inner Sound ~10 times higher than natural conditions. Sediment has already been identified as a key stressor in five inner Pelorus estuaries: Motuweka (Havelock), Kaiuma, Kenepuru, Mahakipawa and Ohinetaha. In these locations the aerial extent of mud-dominated (>50% mud) sediments exceeds 70% of the intertidal area. As such, at these locations we recommend targeted sediment monitoring as described in Section 6.3.

Muddy sediments in Kaiuma Estuary, inner Pelorus Sound

3.3.5 Targeted seagrass assessment sites

The extent of intertidal seagrass across Marlborough estuaries is not well understood, and there is a lack of information on the condition of seagrass beds and how they respond to different pressures. In addition to mapping seagrass extent using broad scale methods in Tier 1-3 estuaries, we recommend seagrass condition be assessed in a subset of eight estuaries using methods described in Section 6.5. This subset was selected to cover the broad range of pressures on seagrass habitats within the Sounds, as follows:

- Whangarae Estuary: large reference estuary, moderate freshwater input and native bush catchment.
- Big Bay: small reference estuary, small freshwater input and intact catchment.
- Motuweka (Havelock): large estuary with a large, modified catchment, sedimentation issues and high freshwater flows.
- Ōkiwa Bay: moderate sized estuary with macroalgal problems and a large, modified catchment.
- Anakoha Bay: well-flushed estuary in the outer Sounds, modified but stable catchment.

- Elie Bay: moderate-sized estuary with modified catchment; however, expressing no significant signs of sediment or eutrophication problems.
- Shakespeare Bay: industrial port in close proximity, modified margin and catchment, and high recreational use.
- Waikawa Bay: urbanisation in the catchment and development within the estuary for the marina. Significantly modified margin. High recreational use.

Seagrass in Waikawa Bay, Queen Charlotte Sound

3.3.6 Sites for consideration in the Ecologically Significant Marine Sites programme

A secondary aim of the estuary inventory and site selection process was to highlight estuaries that may be suitable for inclusion in the ESMS programme. While an assessment against ESMS criteria is out of scope, it is recommended the following estuaries be considered:

- Wells Arm (D'Urville Island) intertidal areas. One small area within Wells Arm (Wells Arm 3; see Appendix 1: C8) is already classified as an ESMS because of the nationally declining *Carex litorosa*. However, other intertidal areas within Wells Arm are in very good condition and have high value salt marsh habitat, of which one area (Wells Arm 2) is classified as a regionally significant wetland. The catchment comprises native bush and there are few other pressures. Other estuaries within the ESMS programme have been included based on the criteria outlined above.

Intertidal areas in Wells Arm, Porty Hardy

- Crail Bay (Elie Bay and Wet Inlet) intertidal areas have high value seagrass and salt marsh habitats. The subtidal area within Crail Bay is classified as an ESMS based on the presence of horse mussel beds. These estuaries are in close proximity and comparable to Clova Bay intertidal areas which are already classified as an ESMS.

Crail Bay, Wet Inlet (Image courtesy of Marlborough District Council)

Crail Bay, Elie Bay (Image courtesy of Marlborough District Council)

4. INDICATORS

Estuaries have been monitored in Marlborough and across New Zealand using a range of health indicators (Cornelisen et al. 2017; Robertson et al. 2002a-c; Robertson et al. 2016). The indicators recommended here focus on ecosystem health, with human health for recreation and cultural indicators considered outside of scope. Ecosystem health indicators that have a clear relationship between pressure (e.g. nutrient) and response (e.g. macroalgae) are recommended at two scales; estuary-wide (i.e. broad scale) and site specific (i.e. fine scale). Pressures include direct catchment inputs and estuary modification. A list of recommended indicators and a rationale for their use are outlined in Tables 8 to 10.

Table 8. Summary of estuary-wide indicators and rationale for their use.

Habitat	General rationale	Supporting reference
Estuary Trophic Index (ETI Score)	The Estuary Trophic Index (ETI) is a multi-metric index developed in New Zealand to assess the condition of an estuary with respect to eutrophication. It uses a suite of primary (i.e. macroalgae or phytoplankton) and secondary indicators (e.g. macrofauna, sediment chemistry) to derive a score between 1 (poor) and 0 (very good).	Robertson et al. (2016b)
Mud-dominated sediments (Extent)	Fine sediments (i.e. mud <63µm) carry contaminants, including nutrients, organic matter, metals and other emerging contaminants. Enriched muddy sediments can fuel algal growth and deplete sediment oxygen, degrading the benthic community. In addition to grain size and sediment deposition (see Table 10), the spatial extent of mud across an estuary can increase its susceptibility to algal growth and oxygen depletion, and lead to loss of habitats such as seagrass and cockle beds.	Robertson et al. (2016b)
Opportunistic macroalgae (OMBT-EQR)	Opportunistic macroalgae are a primary symptom of estuary eutrophication (nutrient enrichment). They are highly effective at utilising excess nitrogen, enabling them to out-compete other seaweed species and, at nuisance levels, can form mats on the estuary surface that adversely impact underlying sediments and fauna, other algae, fish, birds, seagrass, and salt marsh. The Opportunistic Macroalgal Blooming Tool (OMBT) is a multi-metric index that combines % cover, biomass and level of entrainment (i.e. growth into the sediment) to calculate an Ecological Quality Rating (EQR) between 1 (very good) and 0 (very poor). The OMBT-EQR has been directly linked to nitrogen loads in New Zealand estuaries (Robertson et al. 2016; Stevens et al. 2022).	Robertson et al. (2016b); Stevens et al. (2022); Cornelisen et al. (2017)
High Enrichment Conditions (Extent)	High enrichment conditions (HEC) represent severe signs of eutrophication where there are the combined effects of mud-dominated sediments with >50% macroalgal cover entrained in stable beds, and low sediment oxygen. On occasion, mud-dominated sediments with no macroalgal cover are classified as HECs because they are devoid of oxygen and sulfur oxidizing bacteria are present on the sediment surface; but this only occurs when sediments are severely enriched. HECs capture the extreme end of eutrophication that may not be evident in other indicators (e.g. macroalgae).	Robertson et al. (2016b); Stevens & Forrest (2020)
Seagrass (Extent, % loss)	Seagrass (*Zostera muelleri*) beds are important ecologically because they enhance primary production and nutrient cycling, stabilise sediments, elevate biodiversity, and provide nursery and feeding grounds for a range of invertebrates and fish. Although tolerant of a wide range of conditions, seagrass is vulnerable to fine sediments in the water column (reducing light), sediment smothering (burial), excessive nutrients (primarily secondary impacts from macroalgal smothering), and sediment quality (e.g., low oxygen). Seagrass extent (spatial extent and % cover) and loss from an established baseline provide good measures of estuary condition.	Robertson et al. (2002a); Robertson et al. (2016b)
Salt marsh (Extent, historic loss)	Salt marsh (vegetation able to tolerate saline conditions where terrestrial plants are unable to survive) is important in estuaries as it is highly productive, naturally filters and assimilates sediment and nutrients, acts as a buffer that protects against introduced grasses and weeds and provides an important habitat for a variety of species including fish and birds. As for seagrass, salt marsh extent and loss provide good measures of estuary condition.	Robertson et al. (2002a)
Terrestrial margin vegetation (% densely vegetated)	A densely vegetated terrestrial margin filters and assimilates sediment and nutrients, acts as an important buffer that protects against introduced grasses and weeds, is an important food source and habitat for a variety of species and, in waterway riparian zones, provides shade to help moderate stream temperature fluctuations, and improves estuary biodiversity.	Stevens (2018d)

Table 9. Summary of fine scale site-based indicators and rationale for their use.

Indicator	General rationale	Supporting reference
Physical and chemical		
Sediment grain size	Indicates the relative proportion of fine-grained sediments that have accumulated. Mud (<63µm particle size) is often associated with elevated nutrient concentrations. Excess mud can smother important habitats such as shellfish and seagrass beds and lead to loss of sensitive species benthic infauna (e.g. pipi).	Robertson et al. (2002a); Robertson et al. (2016b); Cornelisen et al. (2017)
Sedimentation rate	Sedimentation in estuaries is a natural process; however, catchment development and altered hydrology has accelerated sedimentation in most estuaries. Sedimentation rate measures the level of accrual and erosion at a site, and coupled with sediment grain size can provide detail on fine sediment deposition.	Townsend and Lohrer (2015); Hunt (2019); Cornelisen et al. (2017)
Nutrients (nitrogen and phosphorus) and organic matter	Nutrients such as nitrogen and phosphorus can influence primary production (e.g. algae and plant growth). Increases in the availability of nutrients can cause negative effects such as algal blooms, sediment oxygen depletion and other symptoms of enrichment.	Robertson et al. (2002a); Robertson et al. (2016b); Cornelisen et al. (2017)
Trace metals (copper, chromium, cadmium, lead, nickel, zinc)	Common toxic contaminants generally associated with human activities. High levels of trace metals can affect the abundance and distribution of infauna. The impact of toxicants is based on the risk of toxicity-related adverse effects.	Robertson et al. (2002a); ANZG (2018); Cornelisen et al. (2017)
Depth of apparent redox potential discontinuity layer (aRPD)	The aRPD is a subjective time-integrated measure of the enrichment state of sediments according to the visual transition between oxygenated surface sediments and deeper deoxygenated black sediments. Higher levels of organic matter and nutrients, lead to increased rates of microbial decomposition resulting in depletion of oxygen in the sediment which can have negative impacts on sediment infauna. The aRPD can occur closer to the sediment surface as organic matter loading increases.	Robertson et al. (2002a); Robertson et al. (2016b)
Biological		
Macrofauna	The abundance, composition and diversity of macrofauna, especially the infauna living with the sediment, are commonly-used indicators of estuarine health. The abundance and ecological sensitivity of macrofauna differ depending on the condition of the sediment (e.g. mud, metals, oxygen condition).	Robertson et al. (2002a); Robertson et al. (2016b); Cornelisen et al. (2017)
Epibiota (epifauna)	Abundance, composition and diversity of epifauna are commonly-used indicators of estuarine health.	Robertson et al. (2002a)
Epibiota (macroalgae)	The composition and prevalence of macroalgae are indicators of nutrient enrichment. Macroalgal blooms can smother important habitats (e.g. seagrass) and are often a consequence of high nutrient loads. Macroalgal growths can also have secondary impacts such as sediment oxygen depletion during decomposition and they also promote the trapping of fine sediments.	Robertson et al. (2002a); Robertson et al. (2016b)
Epibiota (microalgae)	The composition and prevalence of microalgae are indicators of nutrient enrichment. Increased microalgae growth indicates higher nitrogen loads.	Robertson et al. (2002a)

Table 10. Summary of water quality and site-specific seagrass condition indicators, and rationale for their use. Note water quality indicators are only needed for Wairau Lagoon.

Indicator	General rationale	Supporting reference
Water quality		
Secchi depth visibility (m)	Field indicator of water clarity and potential for light penetration into the water column for plant growth. Water quality can be limited by catchment sediment inputs, resuspension of sediment, water colour or phytoplankton growth.	Cornelisen et al. (2017); Dudley & Milne (2019); Robertson et al. (2016b)
Chlorophyll-*a* (µg/L)	Field measure that provides a proxy indicator for phytoplankton biomass. Phytoplankton biomass generally increases with nutrient loading from upstream sources and is a primary symptom of eutrophication.	Cornelisen et al. (2017); Dudley & Milne (2019); Robertson et al. (2016b)
Water column nutrients (mg/L)	Total nitrogen (TN) and total phosphorus (TP) concentrations help to characterise the trophic status of shallow lakes and lagoons. Nutrients generally increase with nutrient loading from upstream sources, but can also be influenced by the oxidative state of the sediments.	Cornelisen et al. (2017); Dudley & Milne (2019); Robertson et al. (2016b)
Dissolved oxygen (mg/L or % saturation)	Field indicator of oxygen saturation (algal productivity) or depletion (organic decay). Dissolved oxygen levels can often have a diel and seasonal cycle. During daylight hours oxygen concentrations will be higher due to photosynthetic oxygen production by primary producers (plants).	Dudley & Milne (2019); Robertson et al. (2016b)
Salinity (ppt)	Field indicator of the extent of seawater influence. Can change significantly on a tidal cycle or near freshwater inputs.	Dudley & Milne (2019); Roberts et al. (2021)
Seagrass condition		
% Cover	Seagrass cover will decrease in response to anthropogenic stressors (e.g. light limitation through poor water clarity, epiphytic growth, sediment smothering)	Crawshaw (2020); CSIG seagrass monitoring guidance (in draft)
Leaf length and width (mm)	Seagrass leaf length generally decreases in response to stressors. In the New Zealand species of seagrass (*Zostera muelleri*) previous work has shown that under light limitation the width of the leaf increases to boost photosynthetic activity (Crawshaw 2020 and references therein).	Crawshaw (2020); CSIG seagrass monitoring guidance (in draft)
Above ground biomass (optional) (g dw/m^2)	Above ground biomass (i.e. leaves) is a good measure of seagrass health, with high biomass indicating high cover and seagrass leaves for photosynthesis. Above ground biomass also responds quickly to perturbation (Crawshaw 2020 and references therein).	Crawshaw (2020); CSIG seagrass monitoring guidance (in draft)
% Smothering by sediment, macroalgae, epiphyte	Light limitation caused by smothering (e.g. sediment, epiphytic growth, macroalgae) can lead to a decrease in seagrass cover and overall health. While there may be an initial increase in seagrass growth in response to increased nutrients, eventually macroalgae and epiphytic growth will outcompete it (Matheson et al. 2009).	Matheson et al. (2009); CSIG seagrass monitoring guidance (in draft)
% Fungal wasting disease	Seagrass fungal wasting disease caused by the marine slime mould, *Labyrinthula zosterae*, has been recorded in New Zealand, but does not appear to be causing widespread declines or losses of seagrass. If present leaves characteristically have brown/black lesions on them.	Matheson et al. (2009); Crawshaw (2020)
% Physical damage (e.g. grazing, vehicle tracks)	Physical damage to seagrass leads to direct losses (e.g. swan grazing on above ground biomass, or vehicle tracks).	Crawshaw (2020)

5. THRESHOLDS

5.1 OVERVIEW

To supplement expert analyses and interpretation of monitoring data, results can be assessed within the context of various estuarine health metrics ('condition ratings'), drawing on approaches from New Zealand and overseas. These metrics assign different indicators to one of four colour-coded 'health status' bands, as shown in Tables 11 and 12. Most of the condition ratings in these tables were derived from a New Zealand Estuary Trophic Index (Robertson et al. 2016a, b), which includes purpose-developed criteria for eutrophication, and also draws on wider national and international environmental quality guidelines. As many of the scoring categories in Tables 11 and 12 are still provisional, they should be regarded only as a general guide to assist with interpretation of estuary health status. Accordingly, it is major spatio-temporal changes in the rating categories that are of most interest, rather than their subjective condition descriptors (e.g. 'poor' health status should be regarded more as a relative rather than absolute rating).

5.2 BROAD SCALE THRESHOLDS

Broad scale monitoring thresholds are outlined in Table 12. The key elements are as follows:

- *New Zealand Estuary Trophic Index (ETI):* The ETI provides screening guidance for assessing where an estuary is positioned on a eutrophication gradient. We recommend the use of ETI eutrophication metrics and thresholds which are intended to be applied to the estuary as a whole. We recommend those thresholds, except: (i) for the "% estuary area with soft mud (>25% mud content)" metric, we propose this be refined to "% intertidal with >50% mud extent (i.e. mud-dominated substrate)" to reflect improvements made to the NEMP substrate classification method (see Stevens & Forrest 2020), and exclude difficult to assess sub-tidal substrate; and (ii) for areas included as 'gross nuisance areas' (GNA) in the online version of ETI Tool 2 (Zeldis et al. 2017), we present a simplified representation of GNA characteristics termed 'high enrichment conditions' (HEC) that can be assessed in situ, i.e. mud-dominated soft-sediments with >50% macroalgal cover, with macroalgae predominantly present as stable beds 'rooted' (entrained) within the sediment. Note, sediments typically also have elevated organic content and a sediment aRPD depth shallower than 10mm due to sediment anoxia.
- *Opportunistic macroalgae:* The condition rating descriptors used in the four-point rating scale in the ETI (i.e. between 'very good' and 'poor') differ from the five-point scale in the macroalgal OMBT-EQR tool. Further, the thresholds used to place biomass into OMBT bands have also been recently revised for use in New Zealand (see Plew et al. 2020 and Stevens et al. 2022).
- *Sedimentation:* For analysis of broad scale data, sedimentation has two metrics: (i) the CSR:NSR ratio as described in Robertson et al. (2016b), and (ii) the ANZECC sedimentation guideline of 2mm of sediment accumulation per year above natural deposition rates proposed by Townsend and Lohrer (2015).
- Thresholds for seagrass, salt marsh and densely vegetated terrestrial margin were derived from previous broad scale mapping experience and have been applied to other estuaries across New Zealand (e.g. Skilton & Thompson 2017; Stevens & Robertson 2014, 2017; Robertson 2020a).

5.3 FINE SCALE THRESHOLDS

Fine scale monitoring thresholds are outlined in Table 13. The key elements are as follows:

- *New Zealand Estuary Trophic Index (ETI):* The ETI provides screening guidance for assessing where an estuary is positioned on a eutrophication gradient. While many of the constituent metrics are intended to be applied to the estuary as a whole (i.e. in a broad scale context), site-specific thresholds for %mud, TOC, TN, aRPD and macrofauna AMBI (a macrofauna index) are described by Robertson et al. (2016b). We recommend those thresholds, except: (i) for %mud we propose a refinement to the ETI thresholds described by Robertson et al. (2016c); and (ii) for aRPD we modified the ETI ratings based on FGDC (2012).
- *ANZG (2018) sediment quality guidelines*: The condition rating categories for trace contaminants were benchmarked to ANZG (2018) sediment quality guidelines as described in the footnote to Table 12. The Default Guideline Value (DGV) and Guideline Value-High (GV-high) specified in ANZG are thresholds that can be interpreted as reflecting the potential for 'possible' or 'probable' ecological effects, respectively. Until recently, these thresholds were referred to as ANZECC (2000) Interim Sediment Quality Guideline low and Interim Sediment Quality Guideline high values, respectively.

Table 11. Preliminary thresholds for broad scale Indicators. See footnotes and main text for explanation of the origin or derivation of the different metrics.

Indicator	Unit	Very good	Good	Fair	Poor
Broad scale Indicators					
ETI score[1]	No unit	≤ 0.25	>0.25 to 0.5	>0.5 to 0.75	>0.75 to 1.0
Mud-dominated substrate[2]	% of intertidal area >50% mud	< 1	1 to 5	> 5 to 15	> 15
Macroalgae (OMBT)[1]	Ecological Quality Rating (EQR)	≥0.8 to 1.0	≥0.6 to <0.8	≥0.4 to <0.6	0.0 to <0.4
Seagrass[2]	% decrease from baseline	< 5	≥ 5 to 10	≥ 10 to 20	≥ 20
Salt marsh extent (current)[2]	% of intertidal area	> 20	> 10 to 20	> 5 to 10	0 to 5
Historical salt marsh extent[2]	% of historical remaining	≥ 80 to 100	≥ 60 to 80	≥ 40 to 60	< 40
200m terrestrial margin[2]	% densely vegetated	≥ 80 to 100	≥ 50 to 80	≥ 25 to 50	< 25
High Enrichment Conditions[1]	ha	< 0.5	≥ 0.5 to 5	≥ 5 to 20	≥ 20
High Enrichment Conditions[1]	% of estuary	< 1	≥ 1 to 5	≥ 5 to 10	≥ 10
Sedimentation rate[1]	CSR:NSR ratio*	1 to 1.1 xNSR	1.1 to 2	2 to 5	> 5
Sedimentation rate[3]	mm/yr	< 0.5	≥0.5 to < 1	≥1 to < 2	≥ 2
Sediment quality					
aRPD depth[1]	mm	≥ 50	20 to < 50	10 to ≤ 20	≤ 10

[1] General indicator thresholds derived from a New Zealand Estuary Tropic Index (Robertson et al. 2016b), with adjustments for aRPD (FGDC 2012).

[2] Subjective indicator thresholds derived from previous broad scale mapping assessments.

[3] Ratings derived or modified from Townsend and Lohrer (2015).

*CSR=Current Sedimentation Rate, NSR=Natural Sedimentation Rate (predicted from catchment modelling)

Table 12. Preliminary thresholds for fine scale indicators. See footnotes and main text for explanation of the origin or derivation of the different metrics.

Indicator	Unit	Very good	Good	Fair	Poor
General indicators [1]					
Sedimentation rate[a]	mm/yr	< 0.5	≥0.5 to < 1	≥1 to < 2	≥ 2
Mud content[b]	%	< 5	5 to < 10	10 to < 25	≥ 25
aRPD depth[c]	mm	≥ 50	20 to < 50	10 to < 20	< 10
TN[b]	mg/kg	< 250	250 to < 1000	1000 to < 2000	≥ 2000
TOC[b]	%	< 0.5	0.5 to < 1	1 to < 2	≥ 2
AMBI[b]	na	0 to 1.2	> 1.2 to 3.3	> 3.3 to 4.3	≥ 4.3
Trace elements [2]					
As	mg/kg	< 10	10 to < 20	20 to < 70	≥ 70
Cd	mg/kg	< 0.75	0.75 to <1.5	1.5 to < 10	≥ 10
Cr	mg/kg	< 40	40 to <80	80 to < 370	≥ 370
Cu	mg/kg	< 32.5	32.5 to <65	65 to < 270	≥ 270
Hg	mg/kg	< 0.075	0.075 to <0.15	0.15 to < 1	≥ 1
Ni	mg/kg	< 10.5	10.5 to <21	21 to < 52	≥ 52
Pb	mg/kg	< 25	25 to <50	50 to < 220	≥ 220
Zn	mg/kg	< 100	100 to <200	200 to < 410	≥ 410

1. Ratings derived or modified from: [a]Townsend and Lohrer (2015), [b]Robertson et al. (2016) with modification for mud content described in text, [c]FGDC (2012).

2. Trace element thresholds scaled in relation to ANZG (2018) as follows: Very good = < 0.5 x DGV; Good = 0.5 x DGV to < DGV; Fair = DGV to < GV-high; Poor = > GV-high. DGV = Default Guideline Value, GV-high = Guideline Value-high. These were formerly the ANZECC (2000) sediment quality guidelines whose exceedance roughly equates to the occurrence of 'possible' and 'probable' ecological effects, respectively.

- The ANZECC sedimentation guideline of 2mm of sediment accumulation per year above natural deposition rates was proposed by Townsend and Lohrer (2015). Where the natural deposition rate is not known, conservatively it is assumed to be 0mm/yr. The sedimentation guideline has been broken down into four categories, to signal any early changes in sediment accrual (see Table 12).

5.4 SITE-SPECIFIC SEAGRASS THRESHOLDS

There are currently no thresholds for site-specific seagrass condition indicators; however, these metrics are intended to be compared within and across sites and against other fine scale indicators (e.g. grain size, metals, nutrients, organic matter). Reference estuaries such as Big Bay and Whangarae Estuary provide a good point of comparison for more heavily impacted estuaries. If site-specific seagrass metrics are measured over time, trends can be used to assess change.

5.5 WATER QUALITY THRESHOLDS

Water quality monitoring thresholds are outlined in Table 13, the key elements are as follows:

- *New Zealand Estuary Trophic Index (ETI):* Dissolved oxygen and phytoplankton criteria were derived from the ETI for intermittently closed/open lakes and lagoon estuaries.
- *National Policy Statement for Freshwater Management (2020):* The attributes for lakes were used to derive the thresholds for Total Nitrogen and Total Phosphorus, acknowledging that the results from a one-off survey do not meet the statistical requirements of the attribute.

6. MONITORING METHODS

6.1 OVERVIEW

Table 14 summarises the type of monitoring proposed for each of the 60 Marlborough estuaries assessed in this report. Indicators and thresholds to be used in monitoring are outlined in Sections 4 and 5 and this section describes methods for broad scale, fine scale, sedimentation, and targeted seagrass assessment.

6.2 BROAD SCALE METHODS

Broad scale surveys involve describing and mapping estuaries according to dominant surface habitat features (substrate and vegetation). The type, presence and extent of substrate, salt marsh, macroalgae or seagrass reflects multiple factors; for example the combined influence of sediment deposition, nutrient availability, salinity, water quality, clarity and hydrology. As such, broad scale mapping provides time-integrated measures of prevailing environmental conditions that are generally less prone to small scale temporal variation associated with instantaneous water quality measures.

Broad scale monitoring is based on NEMP methods (Appendix 3), with improvements described in the following sections. The mapping procedure combines up-to-date aerial or satellite imagery (resolution ≤0.3m/pixel), detailed ground-truthing, and digital mapping using Geographic Information System (GIS) technology. Once a baseline map has been constructed, changes in the position and/or size or type of dominant habitats can be monitored by repeating the mapping exercise. Broad scale mapping is typically carried out during September to May when most plants are still visible and seasonal vegetation has not died back. Aerial photographs are ideally assessed at a scale of less than 1:5000, as at a broader scale it becomes difficult to accurately determine changes over time.

Table 13. Preliminary thresholds for water quality indicators. See footnotes and main text for explanation of the origin or derivation of the different metrics.

Indicator	Unit	Very good	Good	Fair	Poor
Water quality indicators[1]					
Dissolved oxygen[a]	mg/L	≥5.5	≥5.0 to <5.5	≥4.0 to <5.0	<4.0
Phytoplankton (chl-*a*)[a]	mg/m^3	<5	≥5 to <10	≥10 to <16	≥16
Total Nitrogen[b]	mg/m^3	≤160	>160 to ≤350	>350 to ≤750	>750
Total Phosphorus[b]	mg/m^3	≤10	>10 to ≤20	>20 to ≤50	>50

1. Ratings derived or modified from: [a]Robertson et al. (2016) with modification for mud content described in Appendix 2, [b]NPSFM (2020)

Broad scale mapping should be undertaken by experienced practitioners, who assess the estuary on foot to map the spatial extent of dominant vegetation and substrate. In the field, the key features are drawn directly onto laminated aerial photographs. Broad scale features are subsequently digitised into GIS shapefiles using a drawing tablet and combined with field notes and georeferenced photographs. In most instances features with readily defined edges can be mapped at a scale of ~1:2000 to within 1-2m of their boundaries.

Forrest & Stevens (2019) highlighted mapping extent varied significantly across providers. For future MDC mapping purposes, it is recommended that the estuary entrance (i.e seaward boundary) be defined as a straight line between the seaward-most points of land that enclose the estuary, with the upper estuary boundary (i.e. riverine boundary) based on the estimated upper extent of saline intrusion (i.e. where ocean derived salts during average annual low flow are <0.5ppt). For further detail see FGDC (2012).

Table 14. Estuaries selected for different monitoring types. For Tier 3 estuaries see Table 3.

Monitoring	Sub-region	Estuary	Broad scale	Fine scale	Sedimentation
Tier 1	Pelorus	Motuweka (Havelock)	✓(5y)	✓(5y)	✓(1y)
	QCS	Ōkiwa Bay	✓(5y)	✓(5y)	✓(1y)
	Outer Sounds	Anakoha Bay	✓(5y)		
	Outer Sounds	Whangarae Estuary (reference estuary)	✓(10y)	✓(5y)	✓(*)
	East Coast	Wairau Lagoon	✓(5y)#		
Tier 2	Pelorus	Broughton Bay	✓(~10y)		
	Pelorus	Ohinetaha Bay	✓(~10y)		
	Pelorus	Crail Bay (Elie Bay & Wet Inlet)	✓(~10y)		
	Pelorus	Kaiuma Bay	✓(~10y)		
	Pelorus	Kenepuru Estuary	✓(~10y)		
	Pelorus	Mahakipawa Arm	✓(~10y)		
	Pelorus	Tennyson Inlet (Tuna, Harvey & Duncan Bays)	✓(~10y)		
	Pelorus	Nydia Bay North/ South	✓(~10y)		
	Pelorus	Clova Bay	✓(~10y)		
	QCS	Ahuriri Bay	✓(~10y)		
	QCS	Shakespeare Bay	✓(~10y)		
	QCS	Waikawa Bay	✓(~10y)		
	QCS	Whatamango Bay	✓(~10y)		
	QCS	Ngakuta Bay	✓(~10y)		
	D'Urville Island	Greville Harbour (Mill Arm, Smylies, Punt)	✓(~10y)		
Tier 3	Marlborough	Remaining small estuaries	Council field visits		
Targeted sediment monitoring	Pelorus	Motuweka (Havelock)			✓(1y)
	Pelorus	Kaiuma Bay			✓(1y)
	Pelorus	Kenepuru Estuary			✓(1y)
	Pelorus	Mahakipawa Arm			✓(1y)
	Pelorus	Ohinetaha			✓(1y)
Targeted seagrass monitoring	Pelorus	Motuweka (Havelock)	Intensive sampling over the next 5-years to characterise seagrass condition and map extent across the region. Replication to be reviewed in 10-year programme review.		
	Pelorus	Crail Bay (Elie Bay)			
	QCS	Okiwa Bay			
	QCS	Big Bay			
	QCS	Shakespeare Bay			
	QCS	Waikawa Estuary			
	Outer Sounds	Anakoha Bay			
	Outer Sounds	Whangarae Estuary			

*Due to the remote location of Whangarae Estuary monitoring frequency depends on the capacity of the council.

#Wairau lagoon is a unique estuary in the Marlborough region and monitoring includes both intertidal and subtidal surveys.

6.2.1 Substrate classification and mapping

Substrate classification in the NEMP is based on the dominant surface features present, e.g. rock, boulder, cobble, gravel, sand, mud. Salt Ecology has revised the NEMP substrate classifications for sand and mud (summarised in Appendix 3) by dividing previously merged categories of 'firmness' and 'muddiness' into independent categories. Four 'muddiness' categories are defined relative to sediment mud content, which can be subjectively assessed in the field and validated using laboratory analyses. Validation of subjective substrate classifications is particularly important for substrates with >10% mud. The number of validation samples collected depends on the estuary size and substrate diversity. In general, <10 samples are adequate.

Based on the above approach, the area (horizontal extent) of mud-dominated sediment can be derived as a primary indicator of sediment mud impacts, and used to assess susceptibility to nutrient enrichment impacts (trophic state). Salt Ecology has also extended the NEMP methodology to record the substrate present beneath vegetation and we recommend this be applied to future monitoring in Marlborough. This extension enables a continuous substrate layer for the estuary to be produced.

6.2.2 Sediment oxygenation

The apparent Redox Potential Discontinuity (aRPD) depth is used to assess the trophic status (i.e. extent of excessive organic or nutrient enrichment) of soft sediment. The aRPD depth is the visible transition between oxygenated surface sediments (typically brown in colour) and deeper less oxygenated sediments (typically dark grey or black in colour). The aRPD depth provides an easily measured, time-integrated, and relatively stable indicator of sediment enrichment and oxygenation conditions. Sediments are considered to have poor oxygenation if the aRPD is consistently <10mm deep and shows clear signs of organic enrichment indicated by a distinct colour change to grey or black in the sediments. As significant sampling effort is required to map sub-surface conditions accurately, the approach is intended as a preliminary screening tool to determine the need for additional sampling effort. The aRPD depth should be recorded at all grain size validation sites and macroalgal biomass stations (see 6.1.3).

Example of colour change see in the sediment when measuring aRPD

6.2.3 Macroalgae assessment

The NEMP provides no guidance on the assessment of macroalgae beyond recording its presence when it is a dominant surface feature. To address this issue, the ETI (Robertson et al. 2016b) adopted the United Kingdom Water Framework Directive (WFD-UKTAG 2014) Opportunistic Macroalgal Blooming Tool (OMBT) approach. The OMBT, described in detail in Appendix 5, is a five-part multi-metric index that provides a comprehensive measure of the combined influence of macroalgal growth and distribution in an estuary. It produces an overall Ecological Quality Rating (EQR) ranging from 0 (major disturbance) to 1 (minimally disturbed) and rates estuarine condition in relation to macroalgal status within five overall quality status threshold bands (bad, poor, good, moderate, high). The individual metrics that are used to calculate the EQR include:

- *Percentage cover of opportunistic macroalgae:* The spatial extent and surface cover of opportunistic algae (usually species of *Agarophyton* or *Ulva*) present in intertidal soft sediment habitat in an estuary provides an early warning of potential eutrophication issues.
- *Macroalgal biomass:* Biomass provides a direct measure of opportunistic macroalgal growth (wet weight biomass). Measurements and estimates of mean biomass are made within areas affected by macroalgal growth, as well as across the total estuary intertidal area.
- *Extent of algal entrainment into the sediment matrix:* Opportunistic macroalgae is defined as entrained when growing in stable beds or with thalli (i.e. 'roots') deep (e.g. >30mm) within the sediments, which indicates that persistent macroalgal beds have established.

If an estuary supports <5% opportunistic macroalgal cover in total within the Available Intertidal Habitat (AIH), then the overall quality status using the OMBT method is reported as 'high' (EQR score ≥ 0.8 to 1.0) with no further sampling required. A numeric EQR score can be calculated for the 'high' band using the approach described in and Equation 3 (see Roberts et al. 2022; Stevens et al. 2022).

Eq. 3

$$\text{EQR } (\leq 5\% \text{ cover AIH}) = 1 - \left(0.2 \times \left[\frac{\text{Measured \% cover AIH}}{5}\right]\right)$$

Using the OMBT approach, opportunistic macroalgae patches are mapped during field ground-truthing using a 6-category rating scale (modified from FGDC 2012) as a guide to describe percentage cover (Fig. 6). Within these percent cover categories, representative patches of comparable macroalgal growth are identified and the biomass and the extent of macroalgal entrainment measured. Substrate type should be recorded beneath macroalgae.

Biomass can be measured by collecting algae growing within a defined area (e.g. 25x25cm quadrat) and placing it in a sieve bag. The algal material should be rinsed to remove sediment. Any non-algal material including stones, shells and large invertebrate fauna (e.g. crabs, shellfish) should also be removed. Remaining algae can then be hand squeezed until water stops running, and wet weight recorded to the nearest 10g (a 1kg Pesola light-line spring scale is ideal for this purpose). When sufficient representative patches have been measured to enable biomass to be reliably estimated, additional biomass estimates can be made following the OMBT method. Using the macroalgal cover and biomass data, macroalgal OMBT scores can be calculated using the WFD-UKTAG Excel template. The scores can then be categorised on the five-point scale adopted by the method as noted above.

Sampling macroalgal biomass

6.2.4 Seagrass assessment

As for macroalgae, the percent cover of seagrass patches should be visually estimated through ground-truthing, based on the 6-category percent cover scale in Fig. 6. Substrate should be recorded beneath seagrass habitat.

6.2.5 Salt marsh

NEMP methods should be used to map and categorise salt marsh, with dominant estuarine plant species used to define broad structural classes (e.g. rush, sedge, herb, grass, reed, tussock; Robertson et al. 2002c; Appendix 3). Substrate should be recorded beneath salt marsh habitat. Two measures are used to assess salt marsh condition: i) intertidal extent (percent cover) and ii) current extent compared to estimated historical extent.

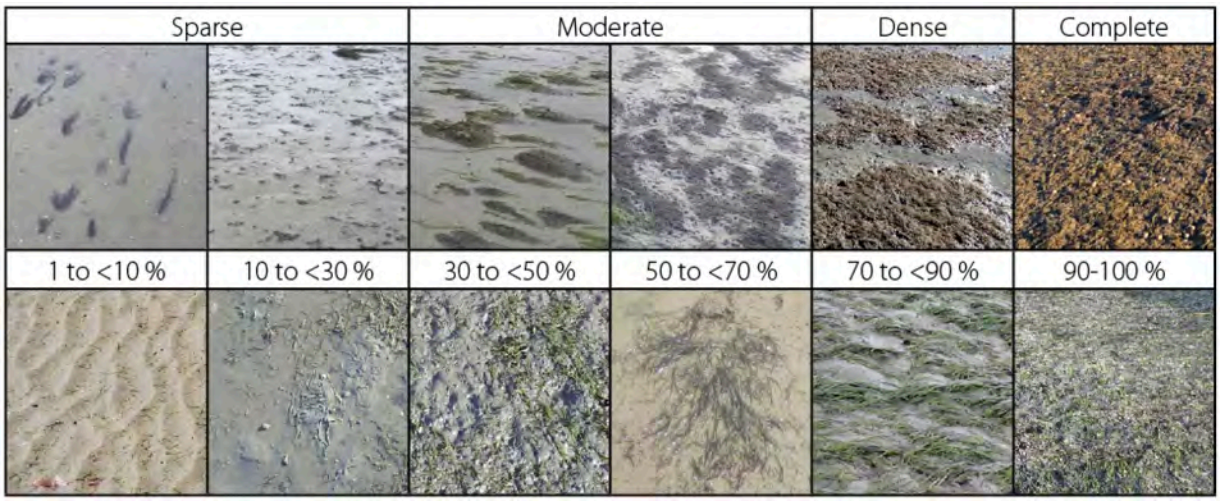


Fig. 6. Visual rating scale for percentage cover estimates. Macroalgae (top), seagrass (bottom). Modified from FGDC (2012).

Historic extent can be estimated from historic aerial imagery and LiDAR data, where available.

6.2.6 Terrestrial margin

Broad scale NEMP methods should be used to map and categorise the 200m terrestrial margin using the dominant land cover classification codes described in the Landcare Research Land Cover Data Base (LCDB) detailed in Appendix 3.

6.2.7 Sediment quality and macrofauna (optional)

Sediment quality and macrofauna are supporting indicators used to calculate an ETI score for the estuary (Robertson et al. 2016b). If budget allows, sediment quality and macrofauna samples should be collected from areas representative of the 10% of the estuary most susceptible to eutrophication (Zeldis et al. 2017). At the chosen site(s), a surface (~20mm) sediment sample should be collected, stored on ice, and sent to an analytical laboratory for analysis of the following: particle grain size in three categories (%mud <63µm, sand <2mm to ≥63µm, gravel ≥2mm); organic matter (total organic carbon, TOC); nutrients (total nitrogen, TN; total phosphorus, TP) and total sulfur (TS). These represent supporting indicators for the ETI.

Depending on budget, between 1 to 3 samples for macrofauna should be collected using a large sediment core (130mm diameter, 150mm deep). The core should be extruded into a 0.5mm mesh sieve bag, which should be gently washed in seawater to remove fine sediment. The retained animals can be preserved in a mixture of 70% isopropyl alcohol and 30% seawater for later sorting and taxonomic identification by the preferred taxonomic provider. The macrofauna data can be used to calculate an AMBI score (see Section 6.2), which is a supporting indicator for the ETI.

6.2.8 Data recording and QA/QC

General data recorded guidance is presented in section 6.8. Following digitising of habitat features in GIS the following systematic quality assurance steps should be carried out:

- Check for duplicated or overlapping GIS polygons.
- Check all vegetation patches have been assigned a substrate classification.
- Check all seagrass patches have been assigned a percent cover and substrate classification.
- Check all macroalgae patches have been assigned a percent cover, biomass and entrainment value.
- Validate typology (i.e. check field codes are correct).
- Standardise estuary coverage with previous surveys.

These are critical steps that, if not undertaken, can lead to poor quality GIS data, as has been identified for many of the historic broad scale surveys that have been carried out. After this quality assurance process, summary tables of areas and percentages for the broad scale features can be produced.

6.2.9 Data presentation and reporting

The level of reporting required should be determined by the needs of the council at the time of the survey. However, because the presentation of data varies between providers, we recommend the following as a minimum output:

- Map representation of substrate, macroalgae (percent cover and biomass), seagrass, salt marsh, terrestrial margin and, where applicable, high enrichment conditions.
- Summary tables for substrate, macroalgae (percent cover and biomass), seagrass, salt marsh, terrestrial margin and, where applicable, high enrichment conditions.
- Calculation of the OMBT-EQR for macroalgae.
- Calculation of the ETI, where applicable.
- Assessment of the broad scale data against the condition rating criteria in Table 11.
- A written summary of the broad scale survey results, to provide an interpretation of any temporal changes. The raw data alone may not provide this level of understanding, for example, as shifts in macroalgae and seagrass in particular can vary spatially (e.g. there may have been a 1ha loss in seagrass in one area and 1ha expansion in another, yet the overall raw data outputs will not reflect a change).

At a minimum, GIS outputs should include the following:

- Shapefiles, or similar, of intertidal area, subtidal area and estuary outline.
- Shapefiles, or similar, of substrate, seagrass, salt marsh, macroalgae, high enrichment conditions and terrestrial margin.
- The GIS outputs should also include meta data (e.g. survey time, provider, GPS tracks of groundtruthing, sampling locations, photos and imagery to which the layers were digitised, estimated spatial accuracy of mapping, reference to associated reports) and evidence of the quality assurance steps having been undertaken.

6.3 FINE SCALE MONITORING

Fine scale monitoring has been undertaken at several estuaries across the Marlborough region (see Table 1), but has been sporadic and, to date, there has only been repeat monitoring in Motuweka (Havelock) Estuary. The Tier 1 estuaries described in Table 6 are intended for regular, quantitative monitoring. However, we do not recommend fine scale NEMP monitoring at all Tier 1 locations for two reasons: (i) it is not appropriate for Wairau Lagoon, as it is a subtidal dominated system, and (ii) budget constraints, reflecting the relatively high costs of the macrofauna component of NEMP fine scale surveys. By selecting a smaller subset of estuaries, a long-term record can be established to better assess changes over time. Hence, for MDC purposes, three estuaries are proposed for regular fine scale monitoring, as per Table 15.

6.3.1 Site selection within each estuary

Mapping the main habitats in an estuary using the NEMP broad scale approach provides a good basis for identifying representative areas to establish fine scale sampling and sedimentation sites. The NEMP advocates that fine scale monitoring is undertaken in soft sediment (sand/mud) habitat in the mid to low tidal range of priority estuaries. The actual tidal elevation is often determined by the location of suitable, stable soft-sediment habitat.

For cost reasons we recommend monitoring two sites per estuary. Sites have already been established in Motuweka (Havelock) Estuary and Whangarae Estuary (Table 1). For budget reasons we recommend reducing the number of sites in Motuweka (Havelock) down from four sites to two that are considered most representative. For Ōkiwa Bay, Stevens (2018) recommended one site be located in the dominant firm sandy mud habitat in the mid estuary, and the other site in a soft mud deposition zone that was identified during broad scale mapping.

6.3.2 Site installation

A schematic of the recommended fine scale sampling approach is provided Fig. 7, with sampling details described in Tables 16 and 17. As fine scale sites are already established in Motuweka (Havelock) and Whangarae Estuary, it is only the two new sites Ōkiwa Bay that will need to be established. These should be set up as 30 x 60m rectangular sampling plots as per NEMP recommendations.

For these two new sites, sediment plates should also be installed along the upstream 30m margin of each site as described in Section 6.4. To assist relocation, fine scale site corners, and the locations of sediment plates, should be marked with wooden pegs (~100mm above the sediment surface). Coordinates for each of these features should be recorded.

6.3.3 Sediment sampling & analysis

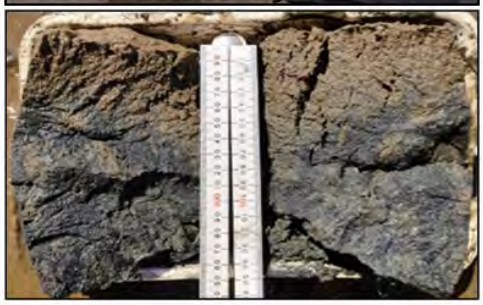
Each fine scale site should be divided into a 3 x 3 grid of nine plots (Fig. 7). Fine scale sampling for sediment indicators should be conducted in each plot, with Fig. 7 showing a standard numbering sequence that can be used for replicates 1-9, and the designation of zones X, Y and Z (i.e. columns in the grid within which sediment subsamples can be composited). A summary of the sediment indicators and biological indicators, including laboratory methods, data analysis, and QA/QC methods are described in Table 16 and 17. Note, for Havelock, 10-12 samples were collected previously (for historic reasons), and sampling sufficiency should be assessed before reducing sampling effort to 9 cores.

Table 15. Recommended list of estuaries for ongoing fine scale monitoring. It is recommended that the four sites sampled in Motuweka (Havelock) Estuary are reduced to two, however sediment monitoring should continue at all sites (see Section 6.4).

Estuary name	Site name	Easting	Northing	% Mud	TN (mg/kg)	TOC (%)	Sedimentation
Motuweka (Havelock) Estuary[1]	Site A	1664422	5430910	28.7	633	0.6	✓
	Site B	1664816	5430902	18.5	<500	0.2	✓
	Site C	1664292	5430909	60.6	1067	1.2	✓
	Site D	1664946	5430919	49.3	667	0.8	✓
Ōkiwa Bay	2 x fine scale sites to be established.						
Whangarae Estuary[2]	Site A	1651846	5450140	13.6	<500	0.2	✓
	Site B	1652162	5449779	72.0	633	0.6	✓

[1]Robertson (2019b); [2]Robertson & Stevens (2016)

Macrofauna



Sediment plate monitoring

Macrofauna:

- New sites: 9 x cores macrofauna & aRPD
- Havelock: 10 x cores (as above) pending review of sampling sufficiency

Sediment quality:

- 3 x sediment quality samples composited across X1-3, Y4-6 & Z7-9

Epibiota & macroalgae:

- Site-wide SACFOR assessment

Sediment plate:

- Measure sediment depth at 4 sediment plates
- Measure peg height using the straight edge as a cross-check

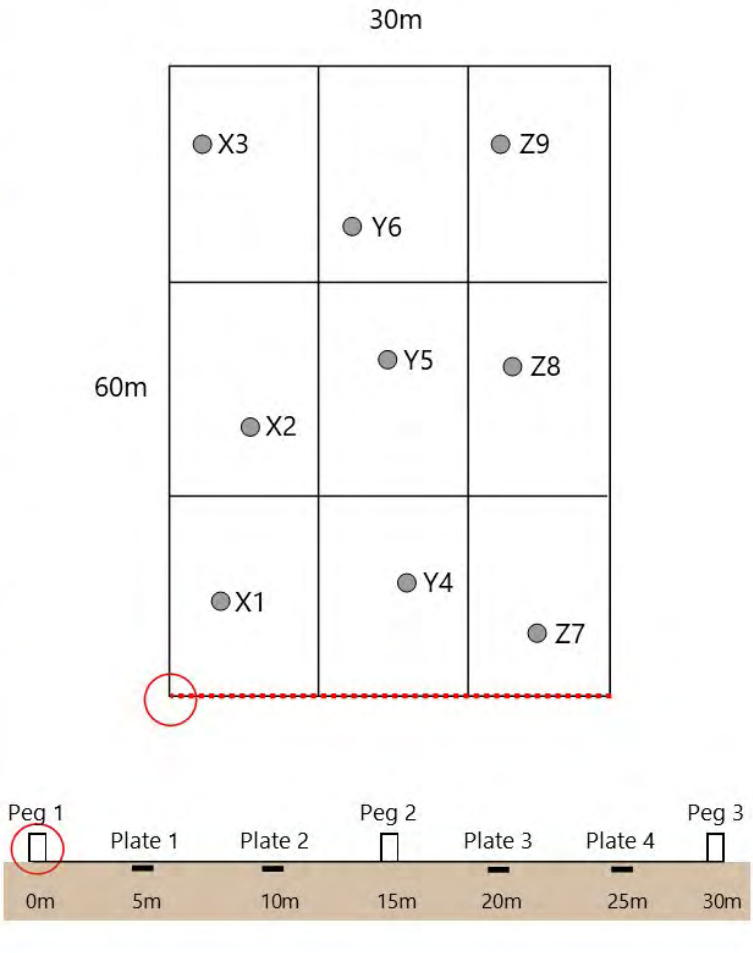


Fig. 7. Schematic illustrating fine scale and sediment plate methods.

Table 16. Summary of fine scale sediment indicators, sampling method, laboratory method and data analysis/ presentation. Any meaningful departures from NEMP are described in footnotes.

Sampling method	Lab Method	Data analysis/ presentation
Sediment grain size		
1 x surface scrape to 20mm sediment depth, with 3 composited samples taken across 9 or 10 plots (see note 1). Recommend: photo record of at least 3 representative cores and narrative description of grainsize and core composition.	Samples wet sieved, as received, with dispersant through sieves to get the size classes >2.00mm, 2.00 to 0.63µm and <0.63µm. Calculation by mass difference after drying for 16 hours at 103°C.	Graphical presentation of mean ± standard error over time. Graphical presentation can include condition bands for % mud. Variables in multivariate analysis.
Nutrients (nitrogen and phosphorus) and organic matter		
1 x surface scrape to 20mm sediment depth, with 3 composited samples taken across 9 plots (see notes 1, 2).	TOC - Acid pre-treatment to remove carbonates present followed by Catalytic Combustion (900°C, O_2), separation and analysed on an Elemental Analyser. TN – Catalytic Combustion (900°C, O_2), separation and analysed on an Elemental Analyser. TP - Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	Graphical presentation of mean ± standard error over time. Graphical presentation can include condition bands for TN and TOC. Variables in multivariate analysis.
Trace metals (copper, chromium, cadmium, lead, nickel, zinc)		
1 x surface scrape to 20mm sediment depth, with 3 composited samples taken across 10 plots (see notes 1, 2, 3).	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	Graphical presentation of mean ± standard error for each metal over time. Graphical presentation can include condition bands for metals and comparison to ANZG (2018) guidelines. Variables in multivariate analysis.
Depth of apparent redox potential discontinuity layer (aRPD)		
1 x 130mm diameter sediment core to 150mm deep for each of 10 plots, split vertically, with aRPD recorded as the depth from sediment surface to transition between oxygenated surface (brown/grey) sediments and deeper deoxygenated black sediments, where visible.	Recorded *in situ*.	Graphical presentation of mean (± standard error) over time. Graphical presentation can include condition bands for aRPD. Variable in multivariate analysis.
Sedimentation rate		
4 x sediment plates. Plates are positioned at 5, 10, 20 and 25m along the boundary of the fine scale site and are relocated by wooden pegs (see Fig. 6). Plates are measured using a 2m straight edge to average out any small-scale irregularities in surface topography. The depth (in mm) to each plate is measured in triplicate (as a minimum) by vertically inserting a probe into the sediment until the plate is located. A composite grain size sample is collected as above, adjacent to each plate.	Sediment depth recorded *in situ*. Grain size measured as above.	Sedimentation rate (±standard error) versus year or cumulative change from baseline depth (±standard error) versus date. Annual mean sedimentation rate tabulated (5-year data set ideal). *The number of days between measurements varies and sediment data should be normalised to a year (i.e. 365 days between measurements).

[1] Sediment quality is assessed in 3 composite samples, rather than 10 discrete samples as specified in the NEMP.

[2] Where results are below analytical detection limits, averaging (if undertaken) uses half of the detection limit value, according to convention.

[3] Arsenic and mercury are not required by NEMP but are usually included in the trace element suite.

Sediment quality assessment

At each fine scale site, three composite sediment samples (each ~250g) should be pooled from sub-samples collected to 20mm depth across each of zones X, Y and Z (replicates 1-3, 4-6 and 7-9, respectively; see Fig. 7). Samples should be stored on ice and sent to a laboratory for analysis of the following constituents: particle grain size in three categories (%mud <63µm, sand <2mm to ≥63µm, gravel ≥2mm); organic matter (total organic carbon, TOC); nutrients (total nitrogen, TN; total phosphorus, TP); and trace contaminants (arsenic, As; cadmium, Cd; chromium, Cr; copper, Cu; mercury, Hg; lead, Pb; nickel, Ni; zinc, Zn). Where results for sediment quality parameters are below analytical detection limits, averaging (if undertaken) should use half of the detection limit value, according to convention. Details of laboratory methods and data analysis are described in Table 16.

Because the sediment sampling is only taken from the surface 20mm and macrofauna cores are collected down to 150mm, we recommend taking a photo record of at least three representative cores and making a narrative description of grain size and core composition to support the macrofauna data.

Field sediment oxygenation assessment

To assess sediment oxygenation, the apparent redox potential discontinuity (aRPD) depth is measured. The aRPD is the visible transition between oxygenated surface sediments (typically brown in colour) and deeper less oxygenated sediments (typically dark grey or black in colour; see Fig. 7; Table 16). The aRPD depth is measured (to the nearest mm) after extracting a large sediment core (130mm diameter, 150mm deep) from each of the nine plots, placing it on a tray, and splitting it vertically. Details of data analysis are described in Table 16.

6.3.4 Biological sampling & analysis

Sediment-dwelling macrofauna

To sample sediment-dwelling macrofauna, each of the large sediment cores used for assessment of aRPD should be placed in separate 0.5mm sieve bags and gently washed in seawater to remove fine sediment. The retained animals can be preserved in a mixture of 70% isopropyl alcohol and 30% seawater for later sorting and taxonomic identification by the preferred taxonomic provider. The types of animals present in each sample, as well as the range of different species (i.e. richness) and their abundance, are well-established indicators of ecological health in estuarine and marine soft sediments. Laboratory methods and data analysis are described in Table 17.

Before macrofaunal analyses, the data should be screened to remove species that are not regarded as a true part of the macrofaunal assemblage; i.e. planktonic life-stages and non-marine organisms (e.g. terrestrial beetles). To facilitate comparisons with future surveys, and other Marlborough estuaries, the data should be cross-checked with the regional species list (recommended) to ensure consistent naming of species and higher taxa (Table 17). This process could be facilitated by having archived voucher specimens of regional species. Checks should also be made to ensure that any macrofauna differences among surveys are not due to name changes. For this purpose, names accepted by the World Register of Marine Species (WoRMS) website can be used. Data analysis is described in Table 17.

Surface-dwelling epibiota

In addition to macrofaunal core sampling, epibiota (macroalgae, microalgae, seagrass and conspicuous surface-dwelling animals nominally >5mm body size) visible on the sediment surface at each site should be semi-quantitatively categorised using 'SACFOR' abundance (animals) or percentage cover (macroalgae, microalgae, seagrass) ratings, as follows:

SACFOR category	Code	Density per m^2	% cover
Super abundant	S	> 1000	> 50
Abundant	A	100 - 999	20 - 50
Common	C	10 - 99	10 - 19
Frequent	F	2 - 9	5 - 9
Occasional	O	0.1 - 1	1 - 4
Rare	R	< 0.1	< 1

These ratings represent a scoring scheme simplified from established monitoring methods (MNCR 1990; Blyth-Skyrme et al. 2008). The SACFOR method is ideally suited to characterise intertidal epibiota with patchy or clumped distributions. It is recommended as an alternative to the quantitative quadrat sampling specified in the NEMP, which is known to poorly characterise scarce or clumped species. Note the epibiota assessment does not include infaunal species that may be visible on the sediment surface, but whose abundance cannot be reliably determined from surface observation (e.g. cockles).

Epibiota, such as mud snails, live on the sediment surface

6.3.5 Data recording and QA/QC

Data recording as per section 6.8. Quality assurance methods are described in Table 16 and 17.

Table 17. Summary of fine scale biological indicators, sampling method, laboratory method and data analysis/ presentation. Any meaningful departures from NEMP are described in footnotes.

Sampling method	Lab Method	Data analysis/ presentation
Macrofauna		
1 x 130mm diameter sediment core to 150mm deep (0.013m^2 sample area, 2L core volume) for each plot (see Fig. 7), sieved to 0.5mm to retain macrofauna (see note 1). Preserved with 70% isopropyl alcohol. Recommend: For cost reasons and to provide a more balanced sampling grid, at new sites macrofauna should be assessed in 9 discrete samples, rather than 10. At historic sites (i.e. Havelock) an analysis of sampling sufficiency should be carried out to determine the optimum number of cores to be sampled.	Samples sent to taxonomic provider for sorting and ID. Generally, samples are stained with Rose Bengal prior to sorting, which is then done systematically by eye, and specimens are preserved for ID in 50% isopropyl alcohol solution. Macrofauna counted and identified to lowest practicable level, which at a minimum should be consistent with previous surveys. Recommend: Prepare a regional species list and maintain a regional voucher collection of reference species to improve consistency over time (or among providers). Specify the level of taxonomic resolution in contract agreement with the taxonomic provider.	Data preparation: Screen data to remove species that are not regarded as a true part of the macrofaunal assemblage i.e. planktonic life-stages and non-marine organisms (e.g. terrestrial beetles). Ensure consistent naming of species and higher taxa. For this purpose, naming convention accepted by the World Register of Marine Species (WoRMS, www.marinespecies.org/). Data analysis (example): - Mean richness (± standard error) - Mean abundance (± standard error) - AMBI (mean ± standard error, main eco-groups at each site; Borja et al. 2000). - National Benthic Health Model – Mud and metals (Clark et al. 2020) - Other multi-variate analysis (e.g. Clarke et al. 2014)
Epibiota (epifauna)		
Abundance score based on ordinal SACFOR scale (see note 2).	Recorded *in situ*.	SACFOR score and rating tabulated.
Epibiota (macroalgae and seagrass)		
Percent cover score based on ordinal SACFOR scale (see note 2).	Recorded *in situ*.	SACFOR score and rating tabulated.
Epibiota (microalgae)		
Visual assessment of conspicuous growths based on ordinal SACFOR scale (see notes 2, 3).	Recorded *in situ*.	SACFOR score and rating tabulated.

[1] For cost reasons, and to provide a balanced sampling grid, macrofauna can be assessed in 9 discrete samples (one per plot) rather than 10 discrete samples as specified in the NEMP (latter will be continued at Havelock Estuary, unless the recommended analysis of sampling sufficiency suggests <10 samples can be collected).

[2] Assessment of epifauna, macroalgae and microalgae use SACFOR in favour of quadrat sampling outlined in NEMP. Quadrat sampling is subject to considerable within-site variation for epibiota that have clumped or patchy distributions.

[3] NEMP recommends taxonomic composition assessment for microalgae but this is not typically undertaken due to unavailability of expertise nationally, and lack of demonstrated utility of microalgae as a routine indicator.

6.3.6 Data presentation and reporting

The level of reporting required should be determined by the needs of the council at the time of the survey. However, because the data analyses vary between providers, we recommend the following as a minimum for a data only output:

- Raw macrofauna and sediment chemistry data that has been QA checked (e.g. do the sediment chemistry results make sense? Does the macrofauna taxonomic resolution and naming match previous monitoring?).
- Comparison of results against condition ratings in Table 12.
- Graphical displays of nutrients, organic matter, metals, aRPD, sedimentation rate and AMBI comparing the current survey with previous years, where applicable.
- A brief summary of site characteristics and main points of the results.

The above will allow the council scientist to detect any significant changes between monitoring dates and will allow for any errors to be rectified at the time of the survey. Multivariate analysis should be considered when undertaking full reporting.

Fine scale monitoring, measuring aRPD

6.4 TARGETED SEDIMENT MONITORING

Sediment plate monitoring has been undertaken at several sites across the region, however, monitoring at times has been sporadic. The monitoring plan aims to focus the sediment plate monitoring to estuaries with fine scale sites or where sedimentation has been identified as a significant issue (Table 18). Sediment plate configuration follows the general principles outlined in Hunt (2019).

6.4.1 Site selection within an estuary

As discussed in Section 6.3.2 sediment plates are typically installed on the 30m edge of the fine scale sites. In addition to the Tier 1 fine scale monitoring sites in Table 18, four additional estuaries are identified for sediment plate monitoring. These are estuaries where fine scale monitoring is not proposed, but where broad scale mapping has revealed fine sediment deposition as a significant current issue (i.e. Mahikipawa, Kaiuma, Ohinetaha) or a potential issue in future (i.e. Smylies Arm). Transect sediment plate monitoring has already been established in these estuaries to assess sedimentation across a broader spatial scale than the fine scale sites (Table 18).

6.4.2 Site installation

Sedimentation monitoring at fine scale sites

Four concrete 'plates' (i.e. pavers, 19cm x 23cm) for sediment plate monitoring should be installed at each fine scale site, positioned at 5, 10, 20 and 25m along the upstream/landward site boundary (Fig. 7). Note this configuration differs to plates installed for MDC prior to 2018 (Robertson & Stevens 2016, Stevens 2017; Stevens & Robertson 2017). Below the plates a 40mm waratah is hammered into the substrate for two reasons: (i) to stabilise the plate, and (ii) the plate can be relocated with a metal detector if the pegs are lost. Plates should be buried between 50-100mm depth in the sediment. After leveling, baseline depths (from the sediment surface to each buried plate) can be measured as per Section 6.4.3.

Installation of sediment plates at a fine scale site as per the configuration in Fig. 7.

Sedimentation monitoring in other locations

For sediment plate monitoring outside of fine scale sites, sediment plates are configured in two ways; (i) as per the fine scale method (e.g. Havelock sediment plate sites described in Stevens 2017) or (ii) installed along a transect line to assess sedimentation across a larger spatial scale. For transect monitoring, plates are installed as described above, however sediment plates are installed on a transect line (e.g. 100-200m length), with a single plate installed at a known distance along the transect. A single peg should be used to mark the location of each plate (i.e. with the peg 5m from the plate as per the fine scale method).

6.4.3 Measuring sediment plate depth

A 2m straight edge should be placed over each plate position to average out irregularities in surface topography. The depth to each plate should be measured in triplicate (as a minimum) by vertically inserting a probe into the sediment until the plate is located. Depth is measured to the nearest millimeter (Table 16).

It is good practice to cross-check the sediment plate depth relative to the marker peg height. While there will be some scouring around the pegs, the 2m straight edge will average out surface irregularities and scouring. Peg height is recorded (in mm) as the distance from the top of the peg down to the straight edge.

Table 18. List of estuaries for ongoing sediment plate monitoring. Coordinates for all installed sediment plates are listed in Appendix 6.

Estuary name	Site name	Easting	Northing	% Mud	% Sand	% Gravel	Date est.	Monitoring frequency
Havelock Estuary (FS)	Site A	1664422	5430910	28.7	68.9	2.4	2014	Annual
	Site B	1664816	5430902	18.5	81.2	0.2	2014	
	Site C	1664292	5430909	60.6	39.5	<0.1	2015	
	Site D	1664946	5430919	49.3	49.7	1.0	2015	
	Site E	1663894	5430726	78.1	21.9	<0.1	2017	
	Site F	1664016	5430692	73.2	26.8	0.1	2017	
Mahikipawa Estuary	Transect	Transect layout see coordinates in Appendix 6.					2020	Annual
Kaiuma Estuary	Transect A	Transect layout see coordinates in Appendix 6.					2017	Annual
	Site B	1667013	5434079	94.8	5.1	<0.1	2017	
	Transect C	Transect layout see coordinates in Appendix 6.					2020	
Ohinetaha Estuary	Transect	Transect layout see coordinates in Appendix 6.					2020	Annual
Kenepuru Head	Transect	Transect layout see coordinates in Appendix 6.					2020 2020 2020	Annual
Ōkiwa Bay (FS)	Sediment plates to be installed at fine scale sites.							Annual
Whangarae Estuary (FS)	Site A	1651846	5450140	13.6	85.0	1.4	2016	*
	Site B	1652162	5449779	72.0	27.5	0.5	2016	
Smylies Arm	Transect P1	1669837	5475398	63.3	23.7	13.0	2018	*
	Transect P2	1669818	5475407	40.7	33.8	25.4	2018	
	Transect P3	1669799	5475413	19.3	22.3	58.3	2018	
	Transect P4	1669779	5475422	21.3	35.7	43.1	2018	

*Due to the remote location of Whangarae Estuary and Smylies Arm monitoring frequency depends on the capacity of the council.

Measuring sediment plate depth (top) and peg height (bottom)

6.4.4 Sediment sampling at sediment plate sites

At fine scale sites a single sediment sample should be composited from sub-samples 20mm deep taken next to each plate. For transect monitoring a grain size sample should be collected adjacent to each plate down to 20mm depth. The samples should be sent for laboratory analysis of grain size, using the methods described for fine scale monitoring (see Table 16). At the time of sediment collection, the aRPD and subjective substrate type is recorded as described in Section 6.1.1. As the sediment plate measurements are expected to be undertaken annually, the grain size data can be used to assess any changes in sediment muddiness.

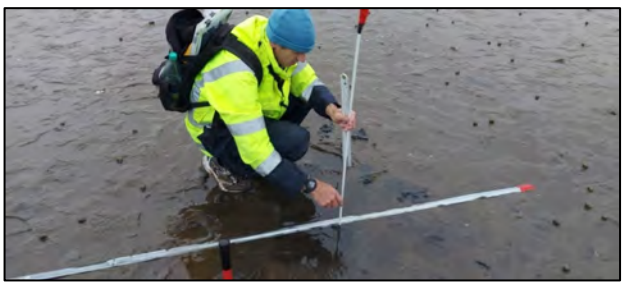
6.4.5 Event-based sedimentation sampling

While annual monitoring of sedimentation gives a broad overview of changes in sediment deposition it does not necessarily capture the impacts of large deposition events (i.e. floods). As such we recommended that sediment plates be monitored after a significant flood event. To support the sediment plate monitoring and better characterise changes owing to flood events, substrate type (i.e. subjective substrate classification see Section 6.2.1) can be recorded every 50-100m between the shore and the sediment plate site. Substrate type, aRPD, a photo and notes can be recorded in an electronic template (e.g. Survey123). Recording a narrative of substrate change during events can support the understanding of any large changes in substrate extent captured in routine broad scale mapping.

6.4.6 Data presentation and reporting

The level of reporting required should be determined by the needs of the council at the time of the survey. We recommend reporting sediment plate data in either a short report format or with fine scale monitoring data (as relevant). At a minimum we recommend the following data-only outputs be created annually:

- Raw sediment plate and grain size data (QA checked).
- Graphical or table presentation of annual sedimentation rate, grain size and aRPD data comparing the current survey with previous years, where applicable, with assessment against condition ratings in Table 12.



Example of measuring sediment depth to plate

6.5 SUBTIDAL & WATER QUALITY MONITORING (WAIRAU LAGOON)

Unlike other estuaries in Marlborough, Wairau Lagoon is largely subtidal and therefore requires different techniques to assess estuary health. Monitoring methods combine intertidal broad scale monitoring (see Section 6.2) and subtidal monitoring which includes mapping substrate type and vegetation, as well as measuring common water quality and sediment indicators. Subtidal monitoring for Wairau Lagoon is described in detail Roberts et al. (2021) and summarised below.

6.5.1 Subtidal survey

Water and sediment quality should be recorded at a number of subtidal sites (58 sites in 2021). For logistical and safety reasons, sampling of the upper lagoons

should primarily be conducted on the incoming tide due to the shallow nature of those lagoons. The tidal range at the Wairau Bar (estuary entrance) varies significantly between neap tides (approx. 0.3-1.4m) and spring tides (approx. 0.05-1.7m; NIWA Tide Forecaster) which in turn influences water depth and boat access within the lagoon.

At all sites, the subtidal habitat should be assessed by either wading or by sampling from a boat, to measure the following variables:

- Water depth
- Secchi disk clarity
- Surface (~20cm below surface) and (at sites >0.5m), bottom (~20cm above bottom) water quality variables: temperature, salinity, pH, dissolved oxygen, chlorophyll-*a* (proxy for phytoplankton)
- Thermocline depth (if present)
- Halocline depth (if present)
- Substrate type (as per Section 6.1.1)
- Sediment oxygenation (as per Section 6.1.2)
- At a subset of sites, collect samples for water quality (nutrient concentrations) and sediment quality (i.e. trace metals, nutrients, organic content) analysis. See indicators listed in Table 9 and 10.

6.5.2 Data presentation and reporting

The level of reporting required should be determined by the needs of the council at the time of the survey. However, because the lagoon was under significant stress in 2021 and large areas of salt marsh had not been mapped during previous surveys, we recommend reporting at the next monitoring interval. Minimum data outputs should be in line with the broad scale monitoring (Section 6.2.9) and fine scale monitoring (6.3.6).

Subtidal sediment sampling in Wairau Lagoon using a specialised sampling hoe

6.6 TARGETED SEAGRASS ASSESSMENT

To improve MDC's understanding of intertidal seagrass habitat extent and condition, and to better understand the health of seagrass beds in response to pressures within the Sounds, we recommend the following:

- Select a subset of estuaries along a pressure gradient from unimpacted through to impacted e.g. under pressure from sedimentation, macroalgae, development. Eight proposed sites are listed in Section 3.3.5.
- Map seagrass extent and undertake a one-off assessment of seagrass condition (see details below; Table 10).
- Compile seagrass extent from individually monitored estuaries (see Table 1) into a single seagrass dataset (e.g. shapefile) for the region. This dataset should include meta data (e.g. percent cover, substrate type, provider, monitored year).
- Where seagrass was highlighted as a prominent feature in the EVA and is not included in the Tier 1 and Tier 2 estuary monitoring (i.e. Tier 3), MDC staff should map seagrass extent in those smaller estuaries. These data should be included in the seagrass extent dataset described above.

The need to repeat the one-off targeted seagrass assessment should be reviewed following the completion of the work.

6.6.1 Seagrass extent

Seagrass extent and percent cover should be measured using broad scale mapping techniques as described in Section 6.2, specifically 6.2.4. Physical damage, such as grazing or vehicle tracks, or the prevalence of smothering by fine sediment, macroalgae, epiphytic growth, or fungal wasting disease, should also be recorded as a percentage of the seagrass bed (see following section for further detail).

6.6.2 Site selection for condition assessment within seagrass beds

At the eight proposed sites listed in Section 3.3.5, use broad scale mapping results to guide the selection of more detailed seagrass condition assessment sites. Sites should avoid obvious areas of physical disturbance, e.g. stream scouring or erosion, should be representative of seagrass beds within the wider estuary, and ideally be roughly standardised between estuary sites. For example, wherever possible sites should have similar seagrass cover (i.e. >80%), be located at a comparable tidal elevation (i.e. have a similar period of intertidal exposure) and have a similar substrate type. This is to

facilitate regional estuary comparisons in seagrass condition along a pressure gradient from unimpacted through to impacted e.g. under pressure from sedimentation, macroalgae, development.

6.6.3 Measuring site-specific seagrass indicators

When an appropriate seagrass bed has been selected (the site boundary can be marked with pegs if future reassessment is considered likely), any physical damage to seagrass such as grazing or vehicle tracks should be recorded as a percentage of the seagrass impacted.

Seagrass percentage cover should then be measured within a defined area, e.g. 10m x 25m grid comprising ten 5m x 5m cells, by the random placement of a single quadrat (50cm x 50cm) within each of the cells. GPS coordinates should be recorded, and a photo taken of each quadrat. Percent cover (based on the surface area covered by seagrass at low tide) should be assessed using the percent cover scale in Fig. 6, or via quantitative methods as desired (e.g. gridded quadrat, image analysis of photographs). Where seagrass is patchy a subdivided quadrat helps with percent cover estimates (Duarte & Kirkman, 2001).

Within each quadrat, the occurrence of smothering covers of fine sediment, macroalgae, epiphytic growths, or fungal wasting disease, should be recorded as a percentage of the seagrass impacted.

Consistent with the principles described in Crawshaw (2020), within a smaller subsection of each of the 10 quadrats, e.g. 10cm x 10cm, the average length and width of 5 representative mature leaves should be recorded using digital callipers (a total of 50 measurements/site), and seagrass shoot density/m^2 recorded.

An optional indicator is to also measure above ground biomass following the method presented in Duarte & Kirkman (2001). Briefly, the above ground biomass from a defined area is cut from the sediment surface, epiphytes (if present) are scraped off the leaves, and the biomass samples are subsequently oven-dried at 60°C until there is no weight change (i.e. all water has been lost). Dry biomass is then measured (Crawshaw 2020). Below ground biomass measurements are not recommended for the proposed condition assessment.

As detailed in Section 6.3.3, supporting information on sediment characteristics related to seagrass condition should also be obtained through the collection of three composite sediment samples from adjacent to the seagrass quadrats for the analysis of grain size, nutrients, organic content and metals. In situ measurements should be made of the aRPD depth (to assess sediment oxygenation) with representative cores photographed, and surface dwelling epifauna should be semi-quantitatively categorised using 'SACFOR' abundance method (as described in Section 6.3.4.).

If desired, the macrofauna community could also be assessed (see Section 6.3.4).

Example sediment core in seagrass bed

6.6.4 Data recording and QA/QC

To minimise errors in the collection of field data we recommend using an electronic template (e.g. Survey123) for data collection. This allows for pre-specified constraints on data entry (e.g. with respect to data type, minimum or maximum values) to reduce the risk of erroneous data recording.

6.6.5 Data presentation and reporting

The level of reporting required should be determined by the needs of the council at the time of the survey. At a minimum we recommend the reporting output include:

- Raw site-specific seagrass data, sediment chemistry, epifauna and macrofauna (QA checked).
- Graphical or table presentation site-specific seagrass indicators and comparison across sites/times.
- Statistical analyses to identify differences between estuaries and potential drivers.
- A shapefile, or similar, including all mapped areas of seagrass within the Sounds and a summary of the total extent of seagrass in the Sounds.
- A written summary of the results including the importance of seagrass in the region and possible drivers of change.

Seagrass in Crail Bay – Elie Bay

Seagrass beds in Waikawa Bay, Queen Charlotte Sound

Seagrass beds in Ōkiwa Bay

6.7 TIER 3 MONITORING

We recommend Tier 3 monitoring be undertaken by council staff using two approaches, as follows:

- New sites: carry out a rapid estuary assessment as per Section 3.2.3.
- Previously visited sites: broad scale map main habitat and substrate features as per Section 6.2 until all intertidal estuaries have a quantitative baseline map.
- When all estuaries have a baseline map, broad changes in estuary condition can be assessed with the REA method. We recommend 5-yearly intervals for monitoring unless there has been a known change in the estuary or catchment.

6.8 GENERAL DATA RECORDING

To minimise errors in the collection of field data, we recommend using an electronic template (e.g. Survey123, Fulcrum app) for data recording. This allows for pre-specified constraints on data entry (e.g. with respect to data type, minimum or maximum values) to reduce the risk of erroneous data recording.

7. MONITORING SCHEDULE

The monitoring schedule prepared in the following tables is based on the recommended monitoring methods for each estuary outlined in Table 14. The schedule is based on MDC's current coastal budget and in-house resourcing, factors which may vary over time. If schedule changes are required due to a shift in council resourcing, Tier 1 sites should be prioritised to maintain a long-term monitoring dataset. We recommend an interim review of the program after 5-years and a full review of the program after 10-years to assess whether the program remains 'fit for purpose' and is filling the council's information needs. An interim review at 5-years allows for schedule revisions if there are any changes to resourcing or council priorities.

Table 19 outlines the Tier 1 monitoring schedule for broad scale and fine scale monitoring and targeted sediment and seagrass monitoring. Table 20 outlines the Tier 2 monitoring schedule. Table 21 presents an example of a Tier 3 monitoring schedule. Because Tier 3 monitoring is heavily dependent on council staff resourcing, the schedule can be updated accordingly.

Table 19. Monitoring schedule for Tier 1 and targeted seagrass and sediment monitoring.

TIER 1	Estuary	Interval	2000/01		2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	10-yr programme review	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2040/41	2041/42	2042/43
Broad scale mapping	Motuweka (Havelock)	5-yr	✓				✓					✓					✓					✓						✓					✓			
	Ōkiwa Bay	5-yr			✓						✓							✓					✓						✓					✓		
	Anakoha Bay	5-yr																✓					✓						✓					✓		
	Whangarae Estuary	10-yr							✓							✓											✓									
	Wairau Lagoon	5-yr						✓(Int)						✓(Sub)						✓	✓									✓					✓	
Fine scale monitoring	Motuweka (Havelock)	5-yr	✓				✓	✓		✓		✓					✓					✓						✓					✓			
	Ōkiwa Bay	5-yr																✓	✓	✓^					✓						✓					✓
	Whangarae Estuary	5-yr							✓							✓					✓						✓					✓				
Sediment plates	Motuweka (Havelock)	1-yr					✓(A,B)	✓(C,D)			✓(E,F)	✓				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Okiwa Bay	1-yr																(A,B)	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Kaiuma Bay	1-yr								✓(A,B)				T		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Kenepuru Estuary	1-yr												T		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Mahakipawa Arm	1-yr												T		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Ohinetaha	1-yr												T		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Whangarae Estuary	*							✓(A,B)							✓(FS)					✓(FS)						✓(FS)					✓(FS)				
Targeted seagrass monitoring	Motuweka (Havelock)	#															✓		Analyse and report on regional seagrass extent and condition																	
	Okiwa Bay	#																✓																		
	Anakoha Bay	#																✓																		
	Whangarae Estuary	#														✓																				
	Big Bay	#														✓																				
	Crail Bay - Elie Bay	#																	✓																	
	Shakespeare Bay	#																	✓																	
	Waikawa Estuary	#																	✓																	

^Review data from year 1 and 2 to determine whether a third fine scale baseline year is required.
*Due to the remote location of Whangarae Estuary monitoring frequency depends on the capacity of the council.
#10-year programme review to determine whether seagrass monitoring should be repeated.
For 2026/27 to 2028/29 for budget reasons it is recommended Wairau Lagoon be split across 2 years with sample collection in year 1 and reporting in the following financial year, if fine scale monitoring is not required in Ōkiwa Bay this can be completed within one year.

Table 20. Tier 2 monitoring schedule.

TIER 2	Estuary	Interval	2000/01		2011/12	2012/13	2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	10-yr programme review	2032/33	2033/34	2034/35	2035/36	2036/37	2037/38	2038/39	2040/41	2041/42	2042/43
Broad scale mapping	QCS - Ahuriri Bay	~10-yr											✓											✓											✓	
	QCS - Shakespeare Bay	~10-yr							✓										✓											✓						
	QCS - Waikawa Bay	~10-yr							✓										✓											✓						
	QCS - Whatamango Bay	~10-yr									✓													✓											✓	
	QCS - Ngakuta Bay	~10-yr			✓						✓									✓											✓					
	Pelorus - Broughton Bay	~10-yr											✓											✓											✓	
	Pelorus - Ohinetaha Bay	~10-yr											✓											✓											✓	
	Pelorus - Crail Bay (Elie Bay & Wet Inlet)	~10-yr											✓												✓											✓
	Pelorus - Kaiuma Bay	~10-yr								✓												✓											✓			
	Pelorus - Kenepuru Estuary	~10-yr									✓														✓											✓
	Pelorus - Mahakipawa Arm	~10-yr								✓													✓											✓		
	Pelorus - Tennyson Inlet (Tuna, Harvey & Duncan Bays)	~10-yr									✓													✓											✓	
	Pelorus - Nydia Bay	~10-yr															✓												✓							
	Pelorus - Clova Bay	~10-yr																		✓											✓					
	D'Urville - Mill, Smylies, Punt Arms	~10-yr									✓														✓											✓

Ngakuta, Queen Charlotte Sound

Table 21. Example of Tier 3 monitoring schedule.

TIER 3	2020/21	2021/22	2022/23	2023/24	2024/25	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32
Pelorus Sound												
Savill Bay (Fitzroy)	✓					BS				✓		
Ngawhakawhiti Bay		✓			BS(s)					✓		
Northwest Bay			✓REA			BS				✓		
Yncyca Bay			✓REA			BS				✓		
Fairy Bay	✓	✓			BS(s)					✓		
Chance Bay	✓	✓			BS(s)					✓		
Penguin Bay		✓			BS					✓		
Godsiff (Maitai Bay)			✓REA			BS				✓		
Tawa Bay			✓REA			BS				✓		
Maori Bay	✓				BS(s)					✓		
Mud Bay			✓REA			BS				✓		
Paradise Bay			✓REA			BS				✓		
Waitaria Bay	✓					BS				✓		
Four Fathom Bay	✓				BS(s)					✓		
Nikau Bay			✓REA		BS(s)					✓		
Queen Charlotte Sound												
Endeavour Inlet		✓		BS					✓			
Mistletoe Bay		✓		BS(s)					✓			
Waterfall Bay		✓		BS(s)					✓			
Fence Bay		✓		BS(s)					✓			
Umungata Bay		✓		BS(s)					✓			
Bottle Bay		✓		BS(s)					✓			
Momorangi Bay		✓		BS					✓			
Tory Channel												
Hitaua Bay		✓	BS					✓				
Opua Bay		✓	BS(s)					✓				
Onapua Bay		✓	BS(s)					✓				
Oyster Bay		✓	BS					✓				
Outer Sounds												
Okiwi Bay North-east			✓REA				BS					✓
Okiwi Bay South-west			✓REA(s)				BS					✓
Squally Cove South			✓REA(s)				BS					✓
Squally Cove North			✓REA				BS					✓
D'Urville Island												
Greville Harbour												
Mokau Bay		✓				BS					✓	
Waharairiki Bay						BS					✓	
Camping Bay											✓	
Bullock Bay											✓	
Port hardy (East arm)												
Wells Arm 1		✓				BS					✓	
Wells Arm 2		✓				BS					✓	
Wells Arm 3		✓				BS					✓	

Ticks represent a rapid estuary assessment (REA), BS = broad scale mapping, (s) = requires mapped extent for targeted seagrass mapping project

8. CONCLUSION

MDC has monitored estuaries across the Marlborough region since 2001 as part of its State of the Environment (SoE) programme, using methodologies described in New Zealand's National Estuary Monitoring Protocol (NEMP) or extensions of that approach. While baseline information has been collected in several estuaries, monitoring has often been sporadic, and information gaps remain including the extent of intertidal seagrass and salt marsh habitats across the Marlborough Sounds, and the impacts of sediment, the key stressor, on estuary health. Furthermore, there remain many estuaries where no previous monitoring or assessment has been undertaken.

The current report outlines a long-term SoE estuary monitoring programme with the primary aim to monitor key intertidal habitats (e.g. seagrass, salt marsh) and identify the contribution of key stressors (e.g. sediment) affecting ecological health, with the purpose being to support informed decision-making and maintain and/or improve estuary health. A tiered monitoring approach is proposed that includes the following:

(1) Frequent (~5-yearly) quantitative long term SoE type monitoring (i.e. fine scale, broad scale, sedimentation), at a subset of representative sites (Tier 1), that would meet the councils statutory requirements and track broad changes in estuary condition over time.

(2) Less frequent (~10-yearly) quantitative habitat and substrate mapping in a broader range of estuaries (Tier 2) to track changes in estuary condition over time.

(3) Broad overview monitoring that can be carried out by council staff (Tier 3).

(4) Targeted sediment monitoring at a subset of estuaries expressing excessive muddiness and ongoing fine sediment deposition.

(5) Targeted assessment of seagrass extent and condition in estuaries across a stressor gradient (i.e. unimpacted through to heavily impacted).

Based on the recommendations in Stevens & Forrest (2019), the report also outlines indicators and monitoring methods which aim to improve consistency and quality in data collection and reporting across different providers.

Further to the monitoring plan outlined here, we recommend MDC consider the following:

- Identify whether monitoring efficiencies or complementarities can be gained through parallel programmes such as the Ecologically Significant Marine Sites programme, freshwater monitoring, recreational bathing and regionally significant wetland habitat monitoring.
- Improve estimates for nutrient and sediment loads - a knowledge gap highlighted in the EVA.
- The utility of using other indicators (e.g. human health and cultural indicators) that were outside the scope of the current report, but which may be appropriate for monitoring.

Mixed exotic forest and high producing grassland catchment. Intertidal flats with seagrass and *Ulva* spp. growing on gravel/cobble (image source: Bayleys, Marlborough)

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APPENDIX 1: ESTUARY SUMMARIES

The following appendix presents a summary for each individual estuary. For clarity, each estuary is labelled with a unique identifier (see Estuary Inventory Index in Table A1), with a letter denoting the sub-region and a number denoting the individual estuary. The estuary summaries distil the information captured in the EVA into a more user-friendly format. Each estuary summary is presented over three pages as follows:

Page 1: provides a written summary and two summary tables that include general information on the estuary and catchment and the results of the EVA.

EVA results are colour-coded as a general guide to assist with interpretation of estuary health status. The bandings have been derived from the EVA results for estuaries presented in this report and represent a relative comparison across the Marlborough region. Bandings for each colour were derived from the minimum and maximum scores in each category and the range split into 5 even bands. The EVA is colour coded as follows:

Category	Rating & Score				
	Very Poor	Poor	Fair	Good	Very Good
Values	0.33 to <0.44	0.44 to <0.56	0.56 to <0.67	0.67 to <0.79	≥0.79
Condition	0.59 to <0.66	0.66 to <0.72	0.72 to <0.79	0.79 to <0.86	≥0.86
	Very High	High	Moderate	Low	Very Low
Pressures	0.33 to <0.45	0.45 to <0.56	0.56 to <0.68	0.68 to <0.80	≥0.80
Susceptibility	0.51 to <0.60	0.60 to <0.70	0.70 to <0.79	0.79 to <0.88	≥0.88

The highest overall score (i.e. when averaged across categories) for an estuary reflects 'very good' values and condition combined with 'very low' pressures and susceptibility.

Page 2: presents two figures, the first a land use catchment map (catchment boundaries provided by MDC unless stated) and the second an aerial photo of the estuary with key habitat features (e.g. salt marsh, seagrass, macroalgae and substrate) highlighted.

Page 3: presents a series of photos of the estuary's main habitat types and key pressures.

Table A1. Inventory of intertidal estuaries in Marlborough, including unique ID and summary of EVA results for each estuary. Estuaries designated by MDC as Ecologically Significant Marine Sites (ESMS) are shown.

ID	Estuary name	Region	Sub-region	Area (ha)	ESMS	Values	Pressures	Susceptibility	Condition	Avg. Score
A1	Havelock Estuary	PS	Inner Pelorus	565.0	✓ (3.20)	0.75	0.61	0.43	0.61	0.60
A2	Kaiuma Bay	PS	Inner Pelorus	52.8	✓ (3.19)	0.73	0.66	0.43	0.71	0.63
A3	Mahakipawa Arm	PS	Inner Pelorus	137.5	✓ (3.20)	0.83	0.64	0.66	0.70	0.71
A4	Mud Bay	PS	Inner Pelorus	7.1	-	0.50	0.78	0.69	0.92	0.72
A5	Ohinetaha Bay	PS	Inner Pelorus	48.4	-	0.38	0.73	0.67	0.75	0.64
A6	Broughton Bay	PS	Keneperu Sound	10.5	-	0.55	0.72	0.67	0.81	0.69
A7	Kenepuru Head	PS	Keneperu Sound	43.2	✓ (3.21)	0.63	0.74	0.63	0.77	0.69
A8	Waitaria Bay	PS	Keneperu Sound	37.5	-	0.68	0.72	0.54	0.62	0.64
A9	Four Fathom Bay	PS	Hikapu Reach	1.8	-	0.62	0.72	0.46	0.73	0.63
A10	Maori Bay	PS	Hikapu Reach	5.2	-	0.65	0.81	0.60	0.88	0.74
A11	Nikau Bay	PS	Hikapu Reach	2.4	-	0.68	0.85	0.89	0.94	0.84
A12	Chance Bay	PS	Nydia Bay	5.2	✓ (3.17)	0.72	0.86	0.89	0.91	0.84
A13	Nydia Bay North	PS	Nydia Bay	11.0	-	0.69	0.83	0.80	0.91	0.81
A14	Nydia Bay South	PS	Nydia Bay	29.1	-	0.70	0.71	0.60	0.79	0.70
A15	Penguin Bay	PS	Nydia Bay	3.6	-	0.45	0.86	0.89	0.93	0.78
A16	Clova Bay	PS	Mid Pelorus	19.1	✓ (3.14)	0.59	0.68	0.63	0.82	0.68
A17	Crail Bay / Elie Bay	PS	Mid Pelorus	14.6	-	0.61	0.71	0.67	0.92	0.73
A18	Crail Bay / Wet Inlet	PS	Mid Pelorus	16.8	-	0.51	0.75	0.54	0.93	0.68
A19	Fairy Bay	PS	Mid Pelorus	3.2	-	0.66	0.85	0.74	0.93	0.79
A20	North West Bay	PS	Mid Pelorus	3.1	-	0.52	0.81	0.74	0.90	0.74
A21	Duncan Bay	PS	Tennyson Inlet	8.8	✓ (3.10)	0.76	0.73	0.70	0.87	0.77
A22	Harvey Bay	PS	Tennyson Inlet	13.1	✓ (3.10)	0.79	0.78	0.70	0.82	0.77
A23	Ngawhakawhiti Bay	PS	Tennyson Inlet	7.5	✓ (3.9)	0.66	0.74	0.60	0.79	0.70
A24	Tuna Bay	PS	Tennyson Inlet	19.0	✓ (3.10)	0.79	0.75	0.70	0.95	0.80
A25	Savill Bay	PS	Fitzroy Bay	3.8	-	0.56	0.83	0.89	0.85	0.78
B1	Big Bay	QCS	Endeavour Inlet	2.9	✓ (4.27)	0.80	0.84	0.91	0.96	0.88
B2	Endeavour Inlet	QCS	Endeavour Inlet	8.1	✓ (4.27)	0.90	0.78	0.77	0.78	0.81
B3	Bottle Bay	QCS	Grove Arm	1.2	✓ (4.3)	0.75	0.82	0.80	0.96	0.83
B4	Momorangi bay	QCS	Grove Arm	1.0	-	0.37	0.65	0.83	0.58	0.61
B5	Ngakuta Bay	QCS	Grove Arm	11.8	✓ (4.5)	0.70	0.74	0.86	0.76	0.76
B6	Okiwa Bay	QCS	Grove Arm	80.4	✓ (4.1)	0.72	0.62	0.68	0.56	0.65
B7	Umungata Bay	QCS	Grove Arm	3.0	✓ (4.3)	0.75	0.79	0.88	0.78	0.80
B8	Fence Bay	QCS	Onahau Bay	0.5	-	0.66	0.76	0.80	0.78	0.75
B9	Mistletoe Bay	QCS	Onahau Bay	0.9	-	0.58	0.78	0.83	0.70	0.72
B10	Waterfall Bay	QCS	Onahau Bay	1.4	-	0.48	0.79	0.81	0.58	0.67
B11	Ahuriri Bay	QCS	Southern shore	6.6	-	0.54	0.72	0.63	0.76	0.66
B12	Shakespeare Bay	QCS	Southern shore	5.4	✓ (4.10)	0.71	0.68	0.66	0.71	0.69
B13	Waikawa Bay	QCS	Southern shore	2.8	-	0.62	0.60	0.66	0.51	0.60
B14	Whatamango Bay	QCS	Southern shore	9.1	✓ (4.12)	0.87	0.70	0.68	0.79	0.76
B15	Hitaua Bay	QCS	Tory Channel	0.8	✓ (5.5)	0.64	0.75	0.77	0.89	0.76
B16	Onapua Bay	QCS	Tory Channel	1.5	-	0.33	0.70	0.68	0.79	0.62
B17	Opua Bay	QCS	Tory Channel	0.9	-	0.39	0.60	0.57	0.71	0.57
B18	Oyster Bay	QCS	Tory Channel	0.9	-	0.35	0.68	0.66	0.66	0.59

PS = Pelorus Sound, QCS = Queen Charlotte Sound

Table A1. continued. Inventory of intertidal estuaries in Marlborough, including unique ID and summary of EVA results for each estuary.

ID	Estuary name	Region	Sub-region	Area (ha)	ESMS	Values	Pressures	Susceptibility	Condition	Avg. Score
C1	Bullock Bay	DI	Greville Harbour	1.2	✓ (1.7)	0.58	0.90	0.78	0.90	0.79
C2	Camping Bay	DI	Greville Harbour	0.4	✓ (1.7)	0.54	0.85	0.73	0.90	0.76
C3	Mill Arm	DI	Greville Harbour	9.0	✓ (1.7)	0.63	0.88	0.92	0.90	0.83
C4	Mokau Bay	DI	Greville Harbour	1.0	✓ (1.7)	0.74	0.88	0.89	0.96	0.87
C5	Punt Arm	DI	Greville Harbour	2.6	✓ (1.7)	0.66	0.88	0.92	0.93	0.85
C6	Smylies Arm	DI	Greville Harbour	3.2	✓ (1.7)	0.71	0.87	0.76	0.85	0.80
C7	Wharairiki	DI	Greville Harbour	3.8	✓ (1.7)	0.62	0.89	0.89	0.94	0.83
C8	Wells Arm 1	DI	Port Hardy	1.8	-	0.45	0.91	0.89	0.95	0.80
C8	Wells Arm 2	DI	Port Hardy	1.5	-	0.67	0.91	0.89	0.96	0.85
C8	Wells Arm 3	DI	Port Hardy	1.1	-	0.67	0.92	0.89	0.98	0.86
D1	Anakoha Bay	O	Outer Sounds	8.5	✓ (2.25)	0.79	0.66	0.73	0.85	0.76
D2	Okiwi Bay North East	O	Croisilles Harbour	11.0	-	0.43	0.84	0.71	0.92	0.72
D2	Okiwi Bay South West	O	Croisilles Harbour	18.2	-	0.44	0.78	0.67	0.85	0.69
D3	Squally Cove North	O	Croisilles Harbour	2.7	-	0.39	0.70	0.54	0.85	0.62
D3	Squally Cove South	O	Croisilles Harbour	6.6	-	0.44	0.79	0.54	0.87	0.66
D4	Whangarae	O	Croisilles Harbour	116.2	✓ (1.1)	0.73	0.89	0.83	0.94	0.85
D5	Wairau Lagoon	O	East Coast	~1700	✓ (8.2)	0.83	0.59	0.33	0.63	0.60

DI = D'Urville Island, O = other (e.g. outer Sounds, east coast and Croisilles Harbour)

A. PELORUS SOUND

Pelorus Sound (Te Hoiere) is classified as a drowned river valley estuary (Hume et al. 2016), with smaller estuarine intertidal areas being a subset of the wider composite system. Circulation in Pelorus Sound is primarily driven by the two dominant freshwater inputs; the Pelorus River (annual mean flow 43 m^3/s) and the Kaituna River (annual mean flow $5m^3/s$; Broekhuizen et al, 2015). While surface salinities increase moving toward the outer Sound, large river flow events can cause surface freshening throughout the system (Broekhuizen et al, 2015).

Soils of Pelorus Sound are rich in clay and are prone to slips, sheet, and rill erosion once the vegetation cover is removed (Handley et al. 2017). Development of the catchment, combined with its erosion prone soils, leads to high sediment loads, particularly from the two largest freshwater inputs. Because the Pelorus River and Kaituna River drive estuarine circulation in Pelorus Sound, sediments are transported throughout the Sound and to the Cook Strait (see photo pg. 3). The large freshwater inputs at the head of the Sound, coupled with land disturbance in the immediate catchments of individual bays, means sedimentation is a significant environmental issue in Pelorus Sound.

Sedimentation in Pelorus Sound increased up to 10 times post-European settlement, when compared to natural sediment rates (Handley et al. 2017; Swales et al. 2021). Increased rates of sedimentation are attributed to extensive forest clearance in the late 1800's to early 1900's, followed by sheep farming, regular burning of scrub and application of superphosphate through the mid-1900's (Handley et al. 2017). Many areas of pasture were abandoned ~40 years ago and there has been widespread regeneration of native scrub since then. More recently there has been an increase in plantings of exotic pine forestry across the region (Handley et al. 2017). Ongoing sediment sources include pasture, slips (particularly those associated with farming and roading) and, more recently, pine forest-derived sediment (Handley et al. 2017). Fig. A1 illustrates sediment transport patterns in Pelorus Sound.

While sediment inputs from periodic storms and episodic disturbances have likely always occurred in the Pelorus Sound, the amount of sediment transported into the Sound has increased. As a result, estuaries located at the head of Pelorus Sound are generally muddy. For example, the Havelock Estuary (Robertson 2019a; 2019b), Kaiuma Bay (Stevens & Robertson 2017), Mahakipawa Arm (Skilton & Thompson 2017), Ohinetaha Bay (Robertson 2020) and Keneperu Head (SLR 2018) are characterised by large muddy intertidal flats.

Further out in Pelorus Sound the intertidal areas are generally in good condition. They are characterised by predominantly gravel substrate and some have large areas of seagrass. Catchments are generally in full or partial native vegetation cover; however, some have large areas of pine forestry that are a known source of sediments during harvest and the post-harvest period

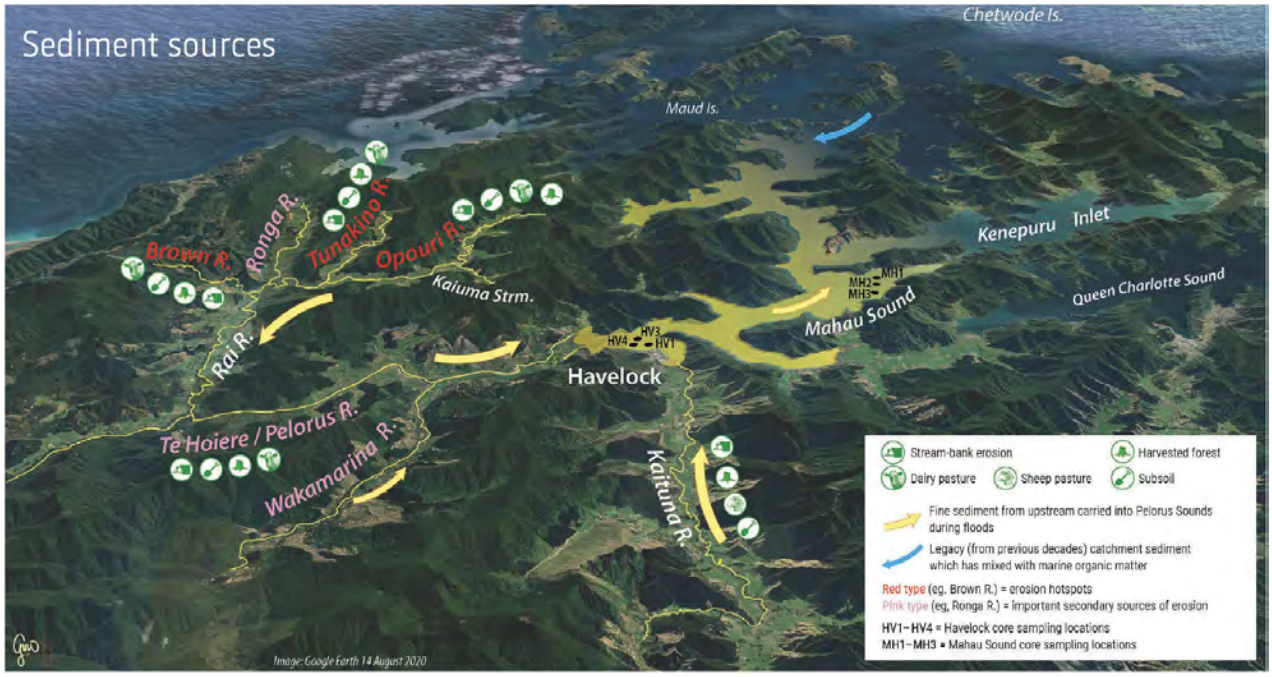

Fig. A1. Graphical abstract from Swales et al. (2021) showing sediment transport through Pelorus Sound.

before replanted forest reaches a closed canopy state (Swales et al. 2021).

The sheltered bays of Pelorus Sounds make it a favoured environment for marine farming, with mussels farmed since the 1960's and salmon since the 1980's (MDC 2022). Farmed species include green-lipped mussels, salmon, oysters, paua and seaweed. While the clean waters of the Sounds in general are ideal for marine farming, aquaculture operations increase vessel activity and there is an increased risk of oil spills, invasive species incursions, contaminants and pathogens. Most marine farming occurs in the mid to outer Sounds, and Kenepuru Sound, which is less influenced by Pelorus and Kaituna Rivers than inner Sound areas.

The small town of Havelock is the gateway to Pelorus Sound, with other smaller settlements including Tennyson Inlet, Kenepuru Head and Mahau Sound. While the area is not as populous as other parts of the Marlborough Sounds it remains popular with seasonal holiday makers, with most bays containing holiday homes, accommodation and/or camp sites. Higher human use can increase the likelihood of invasive species incursions, discharge of contaminants, vehicle damage, habitat loss, disturbance of wetland birds, and over-harvesting of shellfish and fish. Other indirect impacts include high vessel use and infrastructure for both commercial and recreational vessels, including a wharfs, jetties and marinas.

While Pelorus Sound retains high social, cultural and ecological values there are a number of pressures, as discussed, which compromise the ecological integrity of the estuaries, bays and subtidal areas. In this section, intertidal estuarine areas are summarised for Pelorus Sound (see Fig. A2, Table A1), including key habitats, catchment characteristics and the output of the EVA for each estuary. These estuaries range in size from 1.8ha to 565ha, with the larger estuaries toward the head of Pelorus Sound and smaller intertidal areas north of Kenepuru Sound (Table A1; Fig. A1).

Table A1. List of intertidal estuaries summarised in Pelorus Sound

ID	Estuary Name	Sub-region	Intertidal area (ha)	ESMS	Baseline monitoring
A1	Havelock Estuary	Inner Pelorus	565.0	✓ (3.20)	2001-2020 (FS, BS)
A2	Kaiuma Estuary	Inner Pelorus	52.8	✓ (3.19)	2016 (BS)
A3	Mahakipawa Arm	Inner Pelorus	137.5	✓ (3.20)	2016 (BS)
A4	Mud Bay	Inner Pelorus	7.1	-	-
A5	Ohinetaha Bay	Inner Pelorus	48.4	-	2020 (BS)
A6	Broughton Bay	Keneperu Sound	10.5	-	2020 (BS)
A7	Keneperu Head	Keneperu Sound	43.2	✓ (3.21)	2018 (BS)
A8	Waitaria Bay	Keneperu Sound	37.5	-	-
A9	Four Fathom Bay	Hikapu Reach	1.8	-	-
A10	Maori Bay	Hikapu Reach	5.2	-	-
A11	Nikau Bay	Hikapu Reach	2.4	-	-
A12	Chance Bay	Nydia Bay	5.2	✓ (3.17)	-
A13	Nydia bay-North	Nydia Bay	11.0	-	-
A14	Nydia bay-South	Nydia Bay	29.1	-	-
A15	Penguin Bay	Nydia Bay	3.6	-	-
A16	Clova Bay	Mid Pelorus	19.1	✓ (3.14)	-
A17	Crail Bay - Elie Bay	Mid Pelorus	14.6	-	2020 (BS)
A18	Crail Bay - Wet Inlet	Mid Pelorus	16.8	-	2020 (BS)
A19	Fairy Bay	Mid Pelorus	3.2	-	-
A20	Northwest Bay	Mid Pelorus	3.1	-	-
A21	Duncan Bay	Tennyson Inlet	8.8	✓ (3.10)	2018 (BS)
A22	Harvey Bay	Tennyson Inlet	13.1	✓ (3.10)	2018 (BS)
A23	Ngawhakawhiti Bay	Tennyson Inlet	7.5	✓ (3.9)	-
A24	Tuna Bay	Tennyson Inlet	19.0	✓ (3.10)	2018 (BS)
A25	Savill Bay	Fitzroy Bay	3.8	✓ (3.8)	-

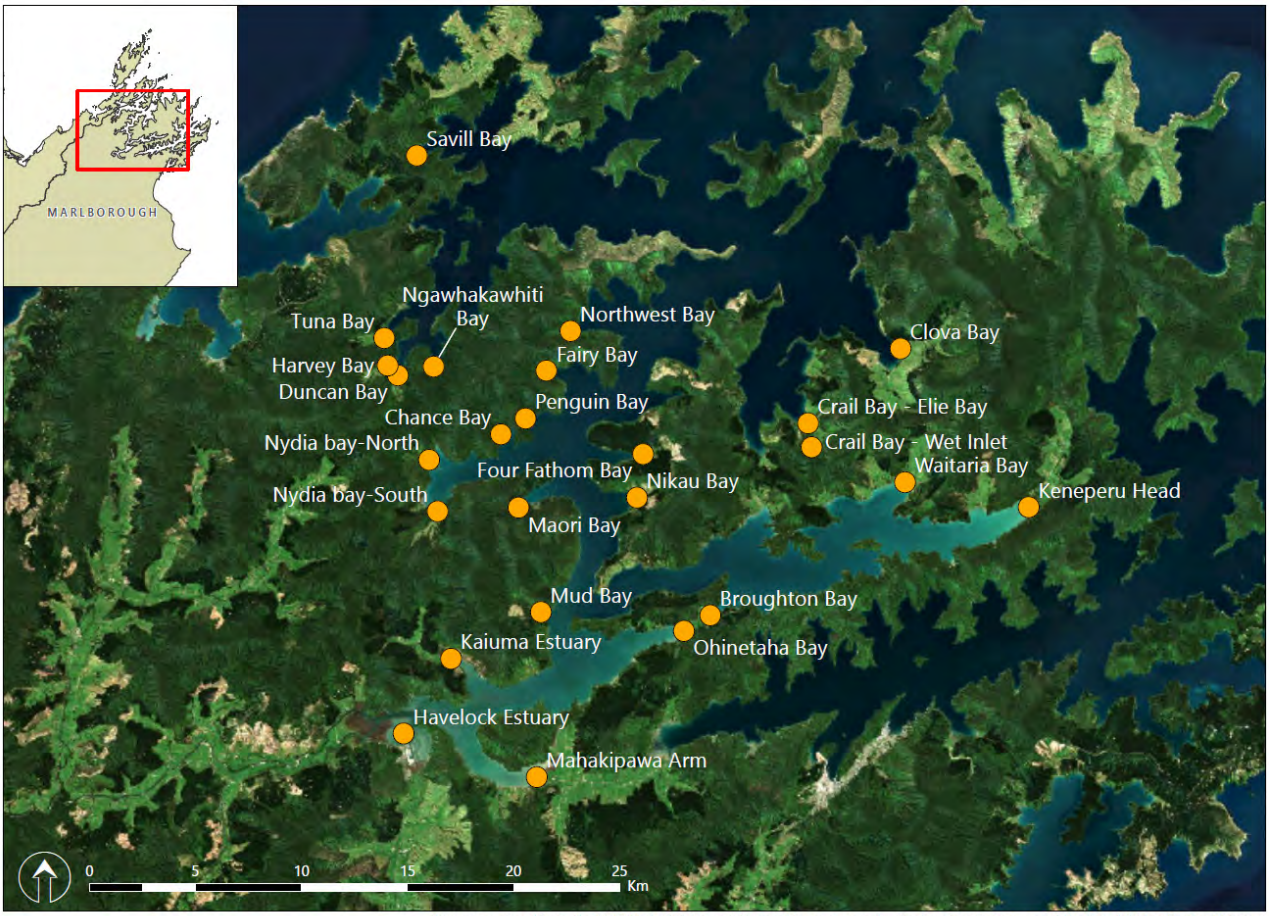

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Fig. A1. Intertidal areas within Pelorus Sound included in the current report.

Looking down on Yncyca Bay, Pelorus Sound

A1. Motuweka (Havelock) Estuary (Inner Pelorus)

Motuweka (Havelock) Estuary is a large (801ha) intertidally dominated estuary at the head of Pelorus Sound near the Havelock township. The estuary comprises two parts, Kaituna Estuary and Pelorus Estuary that together make up the wider Motuweka (Havelock) Estuary (Davidson & Brown 2000). The estuary drains a very large catchment (Table A1.1). The upper catchment is dominated by indigenous forest and protected within the Mount Richmond Forest Park. In the mid to lower catchment land has been cleared and the main land uses are exotic forest on the hill slopes and producing grassland on the lowland areas.

Soils are rich in clay and are prone to slips, and sheet and rill erosion once the vegetation cover is removed (Handley et al. 2017). Development of the catchment and erosion prone soils have led to high sediment loads, in both the Pelorus and Kaituna Rivers, the main freshwater inputs to Motuweka (Havelock) Estuary. Sedimentation is an issue in the estuary with sediment deposition rates significantly higher when compared to natural land cover (Handley et al. 2017). This is reflected in the estuary where the dominant substrate type is very soft mud on the main tidal flats, with gravels localised to the channel margins (Fig. A1.2; Robertson 2019). On the lower tidal flats there is a large area (25ha) of the introduced Pacific oyster (Robertson 2019).

Robertson (2019) recorded an increase in nuisance macroalgal growths in the estuary. In that survey nuisance growths were recorded in the upper Kaituna Arm and along the banks of the Pelorus River. High Enrichment Conditions also comprised 3% of the intertidal area. Motuweka (Havelock) Estuary is an ESMS because of the extensive areas of salt marsh habitat that support an array of birdlife (Table A1.1) and invertebrates. The salt marsh area (197ha) is the largest in the Marlborough Sounds and is dominated by rushland (*Juncus kraussii* and *Apodasmia similis*) and a small area of the nationally declining *Carex litorosa* (Robertson 2019). Seagrass is not a dominant feature in the estuary and is located only on the lower tidal flats (Fig. A1.2).

The main pressures in the Motuweka (Havelock) Estuary include high nutrient and sediment loads from the developed catchment, reclamation and shoreline hardening for the marina, and stormwater and wastewater discharges. The marina and high number of boats increase the likelihood of marine contaminants, pests, and pathogens being introduced to the area.

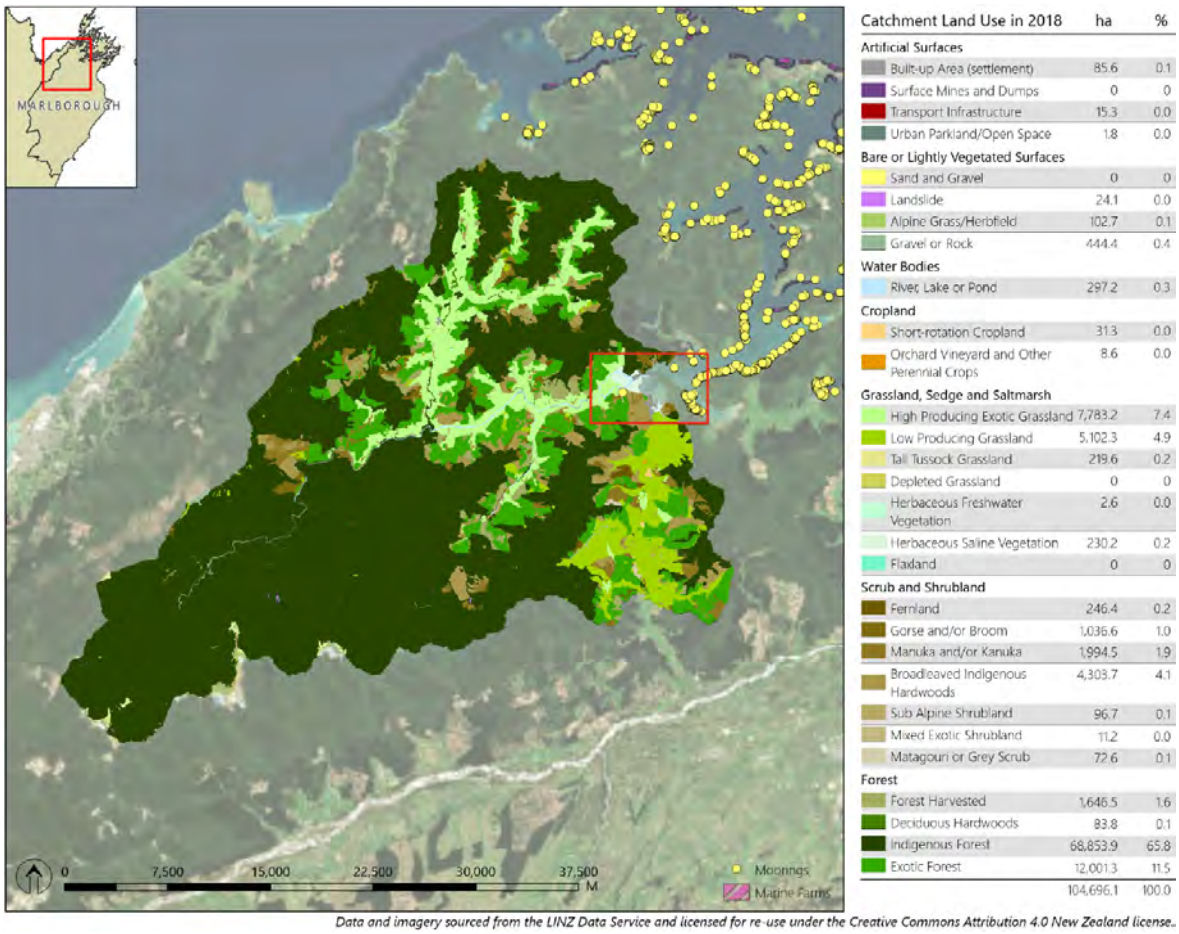
Table A1.1 Summary information for Motuweka (Havelock) Estuary.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	801.0	-
Intertidal Area (Ha; % Estuary)[1]	565.0	70.5
Dominant Estuary Substrate[1]	Very soft mud	
Mud extent (>50% mud content)	259.9	70.6
Macroalgae (Ha; cover >50%)[1]	21.0	3.7
Seagrass (Ha; cover >50%)[1]	19.5	3.5
Salt Marsh (Ha; % intertidal)[1]	197.0	34.9
High Enrichment Conditions (HEC)[1]	16.0	2.8
Catchment		
Catchment Area (Ha)[2]	104,696	
Dominant Catchment Land Cover[2]	Indigenous forest	
% Catchment indigenous vegetation[2]	72.4	
% Catchment exotic forest[2]	11.5	
% Producing grassland[2]	12.3	
Mean Freshwater Flow (m^3/s)[3]	44.0	
Catchment Nitrogen Load (T/y)[3]	434.6	
Catchment Phosphorus Load (T/y)[3]	126.7	
Catchment Sediment Load (KT/y)[3]	341.6	
Catchment Geology[4]	Mixed	
Biodiversity		
ESMS	Y – 3.20	
Significant Wetland[5]	Y – salt marsh	
Birds[6]	Banded rail, black-fronted tern, white-fronted tern, Caspian tern	
Fish[6]	Banded kokopu, short-jaw kokopu, koaro, lamprey, bullies	
Shellfish[6]	Cockles, pipi, wedge shell	
Pressures		
Sedimentation – catchment development		
Shoreline hardening & reclamation for the marina		
Stormwater and wastewater discharges		
Urban development for the township of Havelock		
Marina and high number of moorings		
Public access to the estuary		
Pacific oyster		

[1]Robertson (2019); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps; [6]Davidson et al. (2000)

Table A1.2. Ecological Vulnerability Assessment, Motuweka (Havelock) Estuary

Category	Score
Values	0.75
Pressures	0.61
Susceptibility	0.43
Condition	0.61
Average Score	**0.60**



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	85.6	0.1
Surface Mines and Dumps	0	0
Transport Infrastructure	15.3	0.0
Urban Parkland/Open Space	1.8	0.0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	24.1	0.0
Alpine Grass/Herbfield	102.7	0.1
Gravel or Rock	444.4	0.4
Water Bodies		
River, Lake or Pond	297.2	0.3
Cropland		
Short-rotation Cropland	31.3	0.0
Orchard Vineyard and Other Perennial Crops	8.6	0.0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	7,783.2	7.4
Low Producing Grassland	5,102.3	4.9
Tall Tussock Grassland	219.6	0.2
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	2.6	0.0
Herbaceous Saline Vegetation	230.2	0.2
Flaxland	0	0
Scrub and Shrubland		
Fernland	246.4	0.2
Gorse and/or Broom	1,036.6	1.0
Manuka and/or Kanuka	1,994.5	1.9
Broadleaved Indigenous Hardwoods	4,303.7	4.1
Sub Alpine Shrubland	96.7	0.1
Mixed Exotic Shrubland	11.2	0.0
Matagouri or Grey Scrub	72.6	0.1
Forest		
Forest Harvested	1,646.5	1.6
Deciduous Hardwoods	83.8	0.1
Indigenous Forest	68,853.9	65.8
Exotic Forest	12,001.3	11.5
	104,696.1	100.0

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Fig. A1.1. Havelock Estuary catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

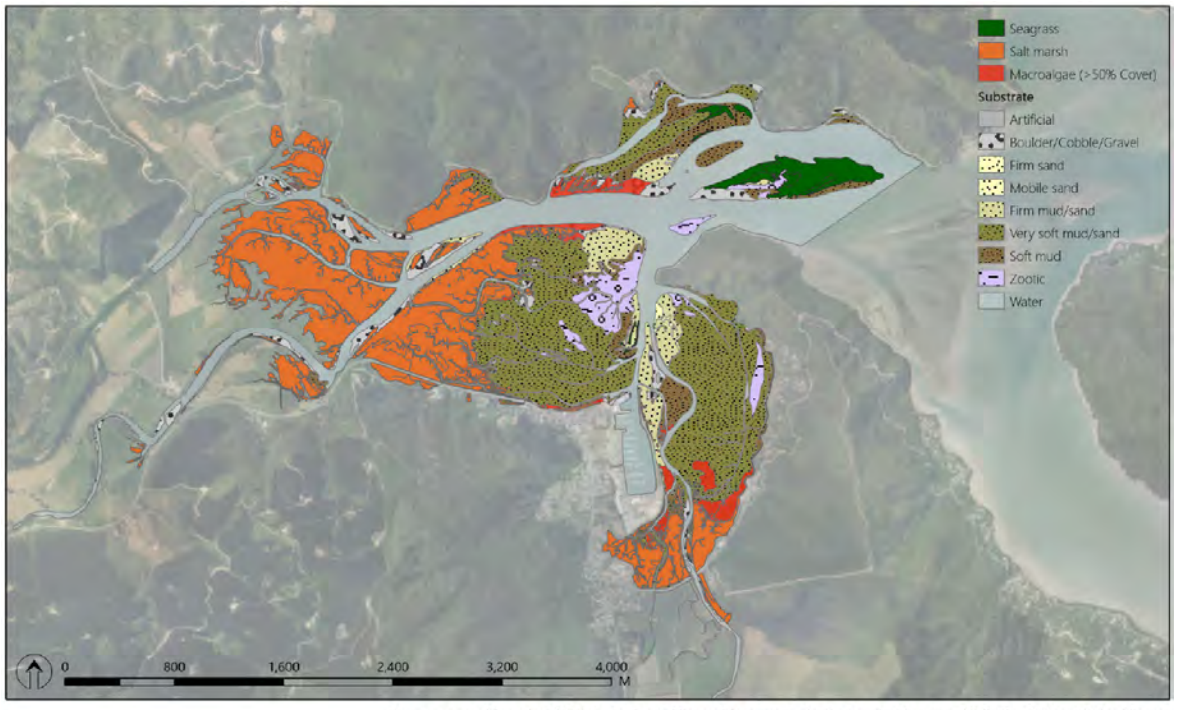

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Fig. A1.2. Havelock Estuary dominant vegetation and substrate features (data source: Robertson 2019).

Very soft muds

Marina and lower mudflats with *Ulva* spp.

Rushland in the upper estuary

Pacific oysters growing on the mud flats

Kaituna River input and salt marsh on the upper flats

Pelorus River input and extensive rushland on the upper flats

A2. Kaiuma Bay (Inner Pelorus)

Kaiuma Estuary is a medium-sized (89.5ha) shallow intertidally dominated estuary in inner Pelorus Sound (Table A2.1). The upper catchment is dominated by indigenous forest however the mid-catchment comprises exotic forest on the hill slopes and the lower catchment is dominated by high producing grassland and a settlement (Fig. A2.1). Relative to the freshwater flow the estuary receives moderate nutrient and sediment loads.

The dominant substrate type is very soft mud on the central tidal flats with cobble on the seaward edge of the salt marsh (Fig. A2.2). Mud-dominated sediments comprise 72% of the intertidal area, similar to other estuaries at the head of Pelorus Sound. Sediment deposition in the estuary is likely a combination of catchment inputs and sediment loads from the Pelorus and Kaituna Rivers at the head of the sound (Stevens & Robertson 2017).

Seagrass is a minor feature in the estuary, with sparse beds smothered in sediment (Stevens & Robertson 2017). No nuisance macroalgae was recorded in the estuary in 2017 (Stevens & Robertson 2017). While areas of High Enrichment Conditions were not present at the time of the survey, very soft muds were exhibiting symptoms of low sediment oxygen (Stevens & Robertson 2017).

Kaiuma Estuary is classified as an ESMS because of the intact vegetation transition from estuarine habitat through to coastal forest. The salt marsh is also classified as a regionally significant wetland. Salt marsh (21.6% of intertidal area) was mainly rushland (*Juncus kraussii*) with herbfield on the seaward edge (Stevens & Robertson 2017).

The most significant pressure in Kaiuma Estuary is sedimentation, with a significant increase in sedimentation observed in recent decades (Stevens & Robertson 2017). Other pressures include development on the estuary margin with road access to the estuary, and a residential development on the northwest margin. These developments will likely limit landward migration of the estuary with sea level rise. The area is also popular for recreational users, with the Nydia Bay track start/end at the head of Kaiuma Bay and boat access via a marina and moorings in the lower subtidal zone. On the lower intertidal flats there is a 10ha marine farm that comprises fixed racks for Pacific oyster spat collection. All of these factors increase the likelihood of marine contaminants, pests, and pathogens being introduced to the area.

Table A2.1. Summary information for Kaiuma Bay

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	89.5	-
Intertidal Area (Ha; % Estuary)[1]	52.8	59.0
Dominant Estuary Substrate[1]	Very soft mud	
Mud extent (>50% mud content)	29.9	72.1
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.02	0.04
Salt Marsh (Ha; % intertidal)[1]	11.4	21.6
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	3127.2	
Dominant Catchment Land Cover[2]	Indigenous forest	
% Catchment indigenous vegetation[2]	64.4	
% Catchment exotic forest[2]	27.1	
% Producing grassland[2]	5.3	
Mean Freshwater Flow (m^3/s)[3]	1.0	
Catchment Nitrogen Load (T/y)[3]	8.8	
Catchment Phosphorus Load (T/y)[3]	2.1	
Catchment Sediment Load (KT/y)[3]	10.9	
Catchment Geology[4]	Sandstone (gravels)	
Biodiversity		
ESMS[5]	Y – 3.19	
Significant Wetland[6]	Y – salt marsh	
Birds[5]	Banded rail	
Fish[6]	Redfin bully	
Shellfish	nd	
Pressures		
Catchment development		
Sedimentation		
Marine farming on the intertidal flat		
Pacific oyster		
Residential development – stormwater and wastewater discharges		
Marina & moorings		

[1]Stevens & Robertson (2017); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A2.2. Ecological Vulnerability Assessment, Kaiuma Bay

Category	Score
Values	0.73
Pressures	0.66
Susceptibility	0.43
Condition	0.71
Average Score	0.63

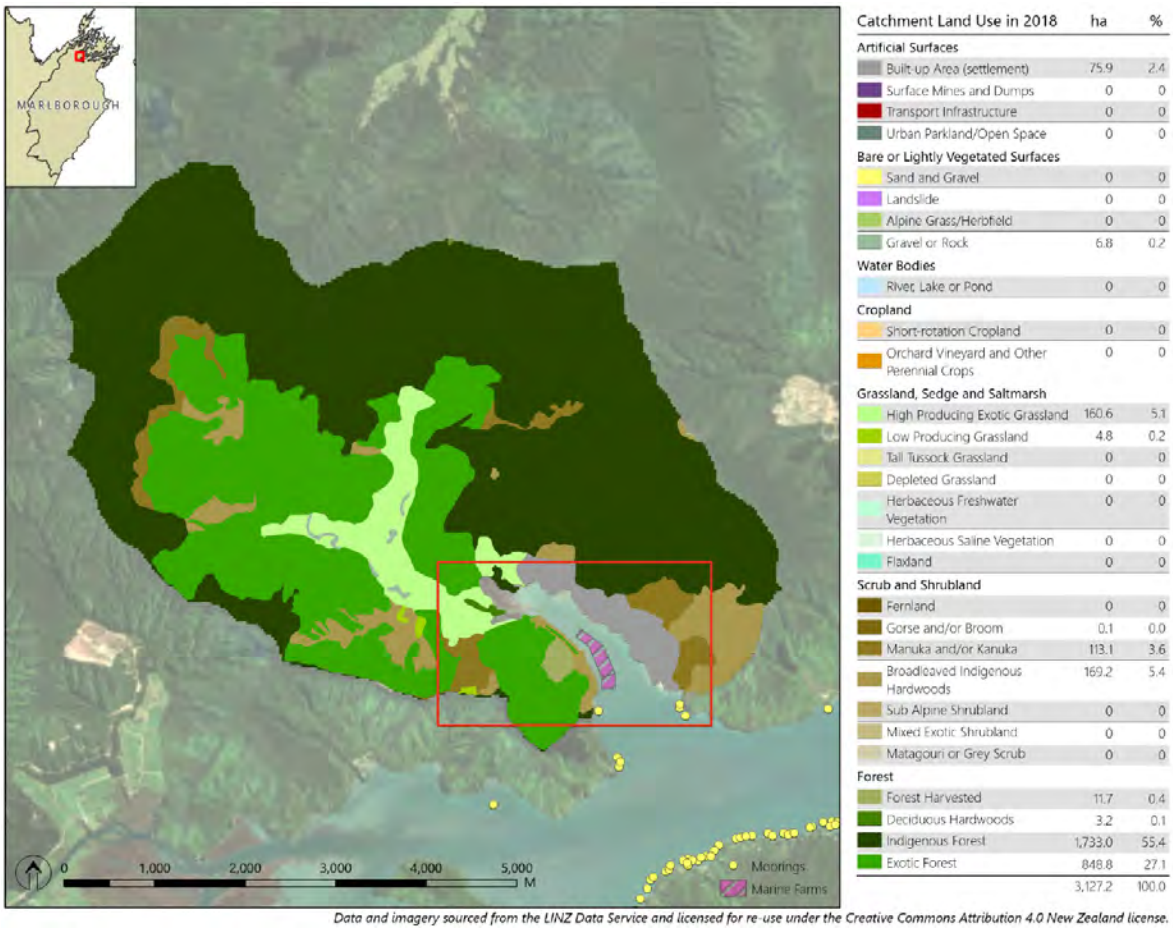

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Fig. A2.1. Kaiuma Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

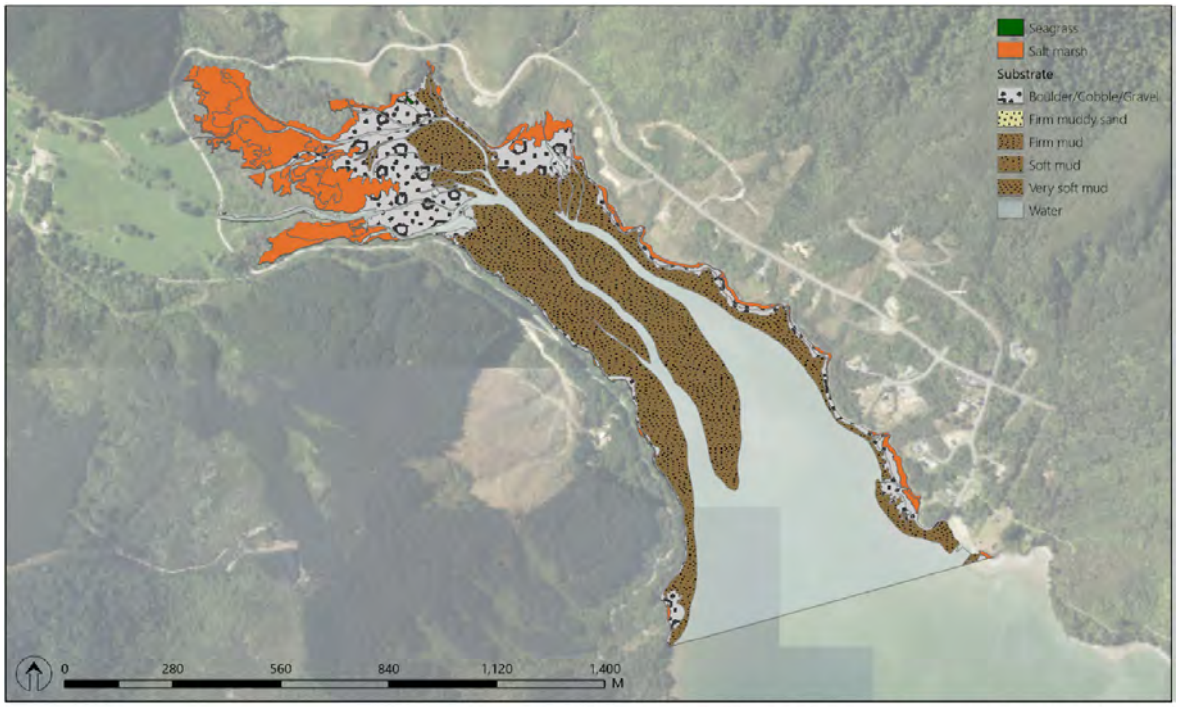

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Fig. A2.2. Kaiuma Bay dominant vegetation and substrate features (data source: Stevens & Robertson 2017).

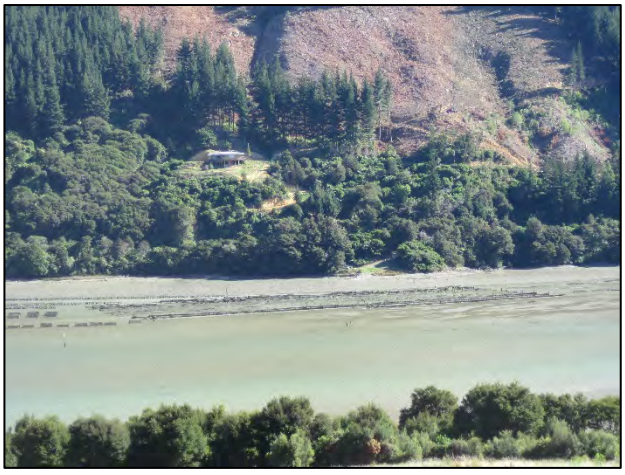
Looking upstream, salt marsh and exotic forest in background

Transition from cobble to very soft muds

Very soft muds in the mid and lower estuary

Salt marsh habitat in upper estuary

Pacific oysters in Kaiuma Estuary



Oyster racks in Kaiuma Estuary

A3. Mahakipawa Arm (Inner Pelorus)

Mahakipawa Arm is a large (137.5ha) shallow intertidally dominated estuary in inner Pelorus Sound (Table A3.1). The upper catchment is dominated by indigenous forest however the mid-catchment comprises exotic forest on the hill slopes and the lower catchment high producing grassland and a settlement (Fig. A2.1). Relative to the freshwater input the estuary receives moderate to high nutrient and sediment loads, likely attributed to the land uses in the catchment.

Mud-dominated sediments comprise 85.5% of the intertidal area (Skilton & Thompson 2017; Table A3.1). Fine sediment deposition is likely a combination of catchment inputs and sediment loads from the Pelorus and Kaituna Rivers at the head of the sound. Further, reduced tidal flows into the estuary limit flushing and promote fine sediment deposition. Skilton & Thompson (2017) postulated that the near absence of seagrass and low diversity of epifauna in the estuary was attributed to the large area of very soft muds. The absence of nuisance macroalgae and High Enrichment Conditions indicate current nutrient loads are below thresholds of concern (Skilton & Thompson 2017).

Mahakipawa Arm is an ESMS because of the extensive areas of salt marsh habitat that support an array of birdlife (Table A1.1) and invertebrates. Salt marsh comprises 25.2% of the intertidal area and is mainly rushland (*Juncus kraussii*), with only a small area of herbfield recorded near the main freshwater input and on the southern margin (Skilton & Thompson 2017). Some historic reclamation of salt marsh habitat and freshwater wetland have occurred on the estuary margin to accommodate farming. Vehicle use through rushland is also visible on aerial imagery.

The main pressure in Mahakipawa Arm is fine sediment deposition, as discussed. Residential development within the estuary margin means both storm water and domestic wastewater discharges are also occurring. Other pressures include farming up to the estuary margin, which increases the likelihood of animals breaking through fences and grazing on salt marsh, and moorings in the subtidal zone that increase the likelihood of marine contaminants, pests, and pathogens being introduced to the area.

Table A3.1. Summary information for Mahakipawa Arm.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	137.5	-
Dominant Estuary Substrate[1]	Soft/very soft mud	
Mud extent (>50% mud content)	117.6	85.5
Macroalgae (Ha; cover >50%)[1]	0.09	0.07
Seagrass (Ha; cover >50%)[1]	0.02	0.01
Salt Marsh (Ha; % intertidal)[1]	34.7	25.2
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	5007.4	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	62.2	
% Catchment exotic forest[2]	16.9	
% Producing grassland[2]	16.5	
Mean Freshwater Flow (m^3/s)[3]	1.3	
Catchment Nitrogen Load (T/y)[3]	17.5	
Catchment Phosphorus Load (T/y)[3]	4.4	
Catchment Sediment Load (KT/y)[3]	11.4	
Catchment Geology[4]	Sandstone & gravels	
Biodiversity		
ESMS[5]	Y – 3.20	
Significant Wetland[6]	Y – salt marsh	
Birds[5]	Banded rail, marsh crake, black-fronted tern, white-fronted tern, banded dotterel, Caspian tern	
Fish[5]	Short-jaw kokopu, redfin bully	
Shellfish[1]	Cockles and pipi	
Pressures		
Fine sediment deposition (i.e. very soft muds)		
Developed catchment – exotic forestry and grassland		
Sediment loads from Pelorus and Kaituna Rivers		
Reclamation and farming on estuary margin (fenced)		
High number of moorings within 5km		
Pacific Oysters		

[1]Skilton & Thompson (2017); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; Davison et al. (2011); [6]MDC Smart Maps

Table A3.2. Ecological Vulnerability Assessment, Mahakipawa Arm.

Category	Score
Values	0.83
Pressures	0.64
Susceptibility	0.66
Condition	0.70
Average Score	0.71

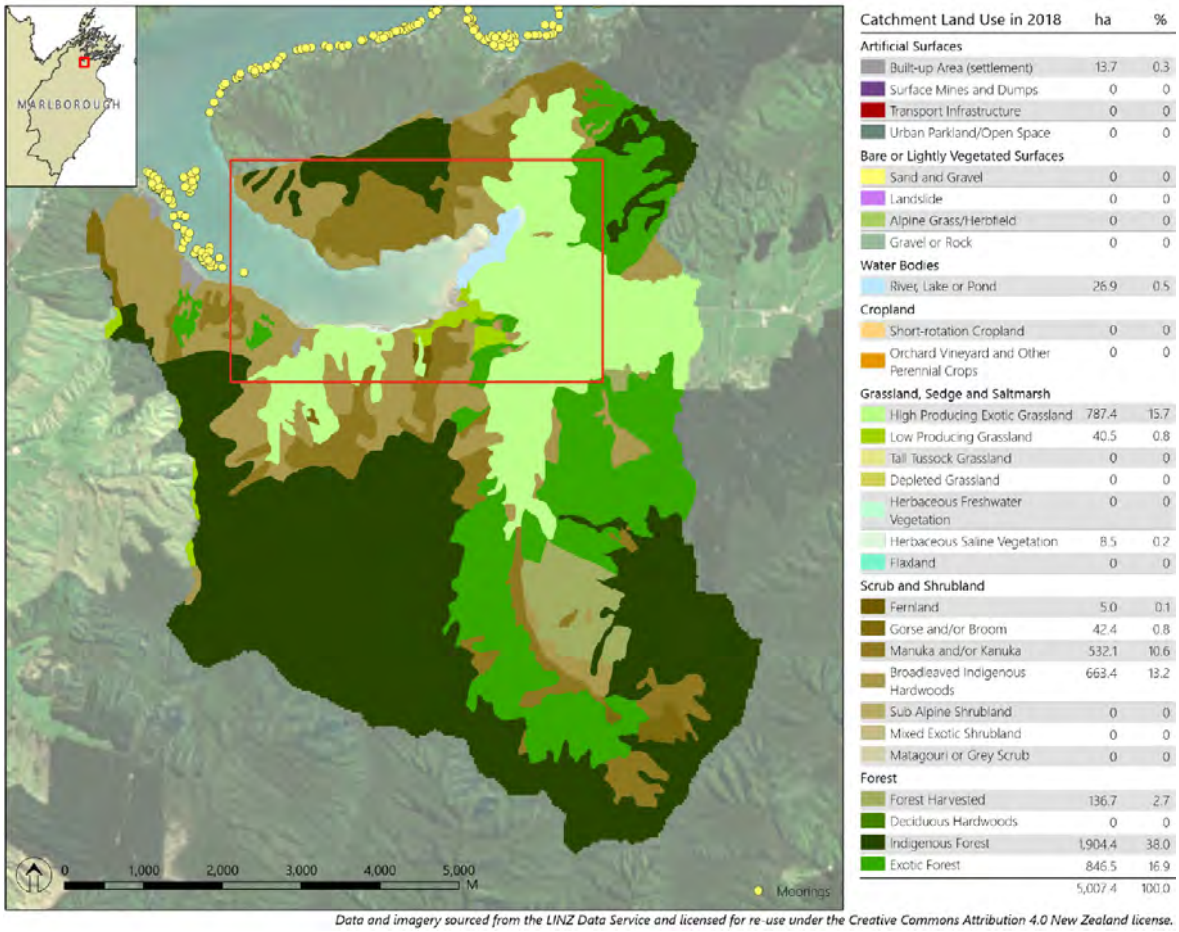


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Fig. A3.1. Mahakipawa Arm catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

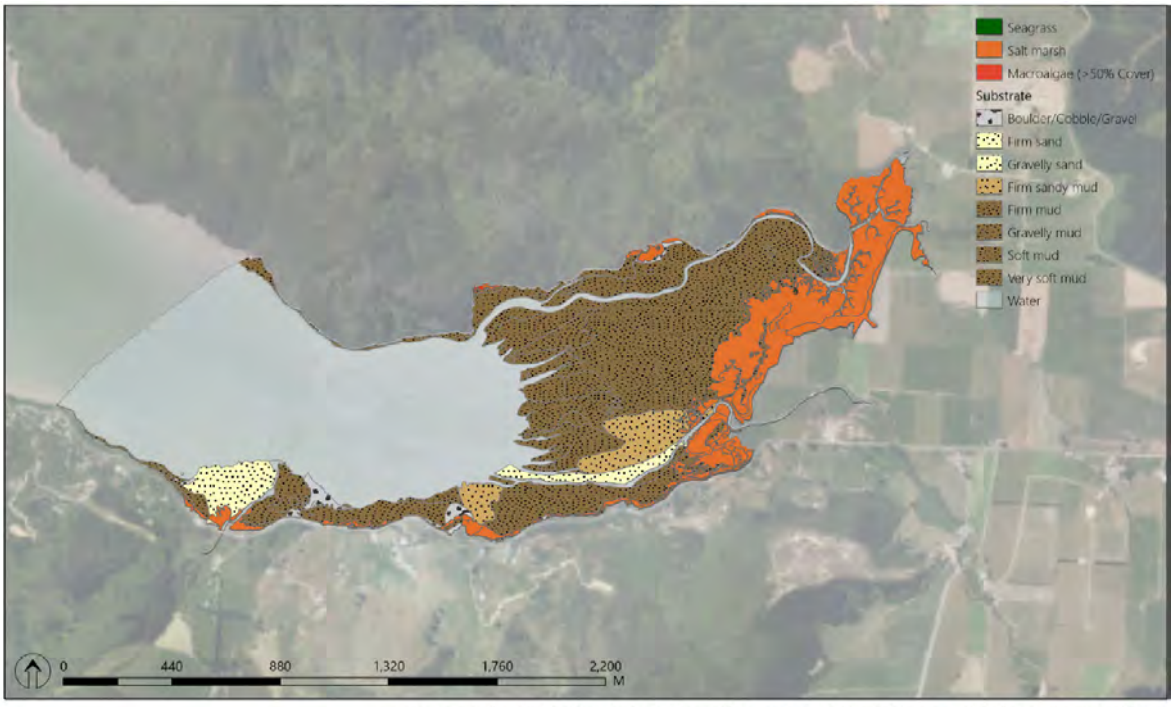

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Fig. A3.2. Mahakipawa Arm dominant vegetation and substrate features (data source: Skilton & Thompson 2017).

Saltmarsh in the upper estuary

Rushland and herbfield in the upper estuary

Soft muds and mud snails on the surface

Soft muds mixed with gravel

Pacific oysters growing in soft muds

Pacific oyster beds

A4. Mud Bay (Inner Pelorus)

Mud Bay is a small (7.1ha) shallow intertidally dominated estuary in inner Pelorus Sound. The catchment is mainly regenerating native bush with the dominant vegetation type being indigenous forest (68.9%). The headwaters in the upper catchment are protected within the Paradise Bay Scenic Reserve. Between 2010-2020 a small steep area of exotic forest was harvested in the lower catchment. Roads were excavated to transport logs from an existing barge loading area on the lower intertidal flats (see photos).

A recent field assessment has not been undertaken at Mud Bay; hence the following information is based on a desktop assessment and should be treated with caution. As the name alludes to, Mud Bay, is a tidal estuary with a large mud flat area (Consent: U130121). Sedimentation in the estuary likely reflects historic land clearing, however contemporary sources also remain in the catchment. Based on aerial imagery and photos the upper margins are gravel/cobble dominated.

Salt marsh comprises ~15% of the intertidal area and is dominated by rushland, with some herbfield on the seaward edge. From the aerial imagery it appears that salt marsh transitions into freshwater wetland vegetation. No significant growths of nuisance macroalgae can be seen on the imagery, however some *Ulva* spp. appears to be growing in low tide channels. Low nutrient loads and the native forest catchment mean it is unlikely that macroalgae will reach nuisance levels. It is uncertain whether seagrass is present in the estuary from the information available.

Pressures in Mud Bay include the small areas of exotic forestry on steep hillslopes that may be a potential future source of sediment during and post-harvest. The main access to the bay is via boat and there are a few residential properties within the margin that have permanent jetties. Further, there are some moorings within the Bay but a very high number in the main Pelorus channel, increasing the likelihood of marine contaminants, pests ,and pathogens being introduced to the area.

While the estuary is subject to some localised pressures, overall the estuary appears to have high ecological values with a large area of salt marsh vegetation that transitions to freshwater wetland vegetation. However, a field visit would be required to confirm these findings.

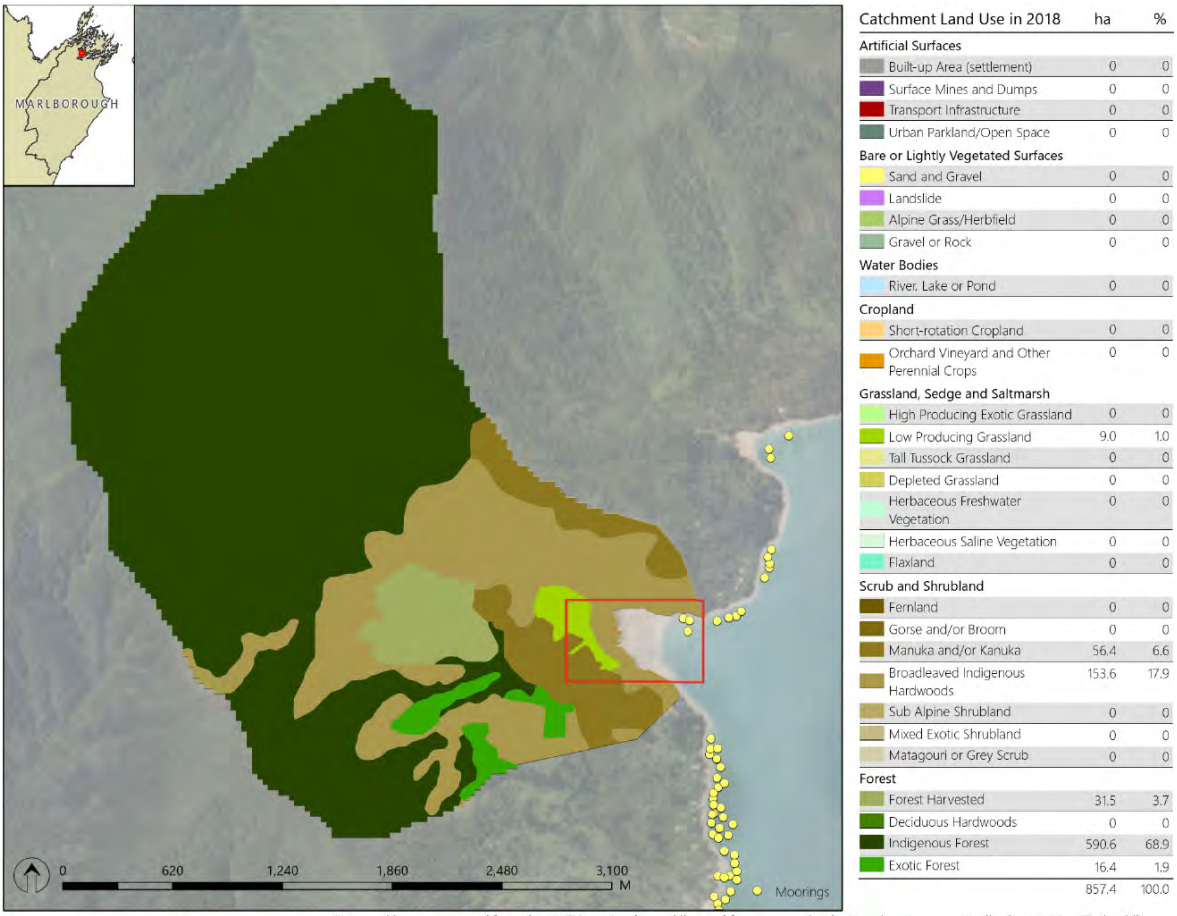
Table A4.1. Summary information for Mud Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	
Intertidal Area (Ha; % Estuary)[1]	7.1	-
Dominant Estuary Substrate[1]	mud	
Mud extent (>50% mud content)	-	>15-50
Macroalgae (Ha; cover >50%)[1]	-	<5
Seagrass (Ha; cover >50%)[1]	-	nd
Salt Marsh (Ha; % intertidal)[1]	-	15
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	857.4	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	93.4	
% Catchment exotic forest[2]	5.6	
% Producing grassland[2]	1.0	
Mean Freshwater Flow (m^3/s)[3]	0.3	
Catchment Nitrogen Load (T/y)[3]	2.2	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	2.6	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS	N	
Significant Wetland[5]	N	
Birds	nd	
Fish[5]	Redfin Bully	
Shellfish[1]	nd	
Pressures		
Exotic forest in the lower catchment Sedimentation Boat access High number of moorings within 5km		

[1]Assessment based on aerial imagery only, treat with caution;; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A4.2. Ecological Vulnerability Assessment, Mud Bay.

Category	Score
Values	0.50
Pressures	0.78
Susceptibility	0.69
Condition	0.92
Average Score	0.72



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	0	0
Low Producing Grassland	9.0	1.0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	0	0
Manuka and/or Kanuka	56.4	6.6
Broadleaved Indigenous Hardwoods	153.6	17.9
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	31.5	3.7
Deciduous Hardwoods	0	0
Indigenous Forest	590.6	68.9
Exotic Forest	16.4	1.9
	857.4	100.0

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Fig. A4.1. Mud Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings. Catchment boundary derived from CLUES 10.3.

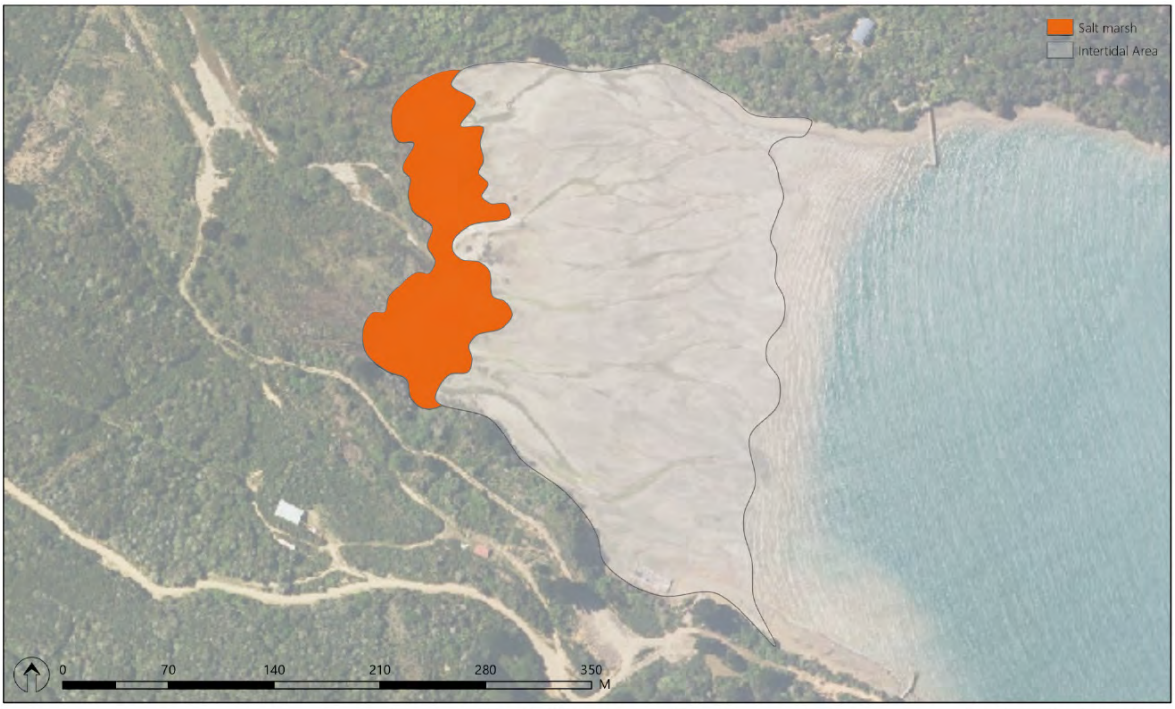

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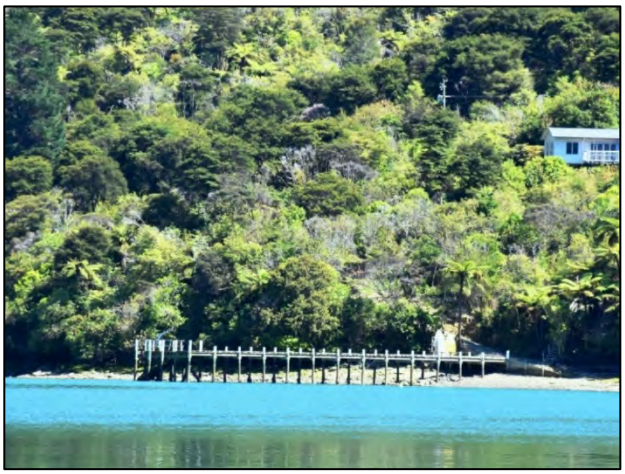
Fig. A4.2. Mud Bay intertidal area. Boundaries are based on aerial imagery and require ground-truthing.

Mud Bay mainly native bush catchment and a small area of recent exotic forest harvest on the hillslope (Image ref: MDC 'OS AdmiraltyBay PukateaMudBay 12 Bright', Courtesy of Marlborough District Council)

Mud Bay with a jetty and barge on the margin and rushland to the right of the image (Image ref: MDC 'Pelorus MudBay Panorama 04', Courtesy of Marlborough District Council)



Jetty in the subtidal zone (Image ref: MDC 'Pelorus MudBay 35 Bright', Courtesy of Marlborough District Council)

Barge loading area in the lower estuary (source: Consent U110567 taken 2014)

A5. Ohinetaha Bay - Mahau Sound (Inner Pelorus)

Ohinetaha Bay is a medium-sized (53.4ha) intertidal estuary at the head of Mahau Sound in inner Pelorus Sound. The catchment is dominated by manuka and/or kanuka, with an overall 73.1% indigenous vegetation cover. High producing grassland (11.9%) is at the head of the estuary and exotic forestry comprises 15.0% of the catchment (Fig. A5.1).

The dominant substrate type in the estuary is very soft mud on the central tidal flats, with boulder/cobble on the margins and in the lower estuary (Fig. A5.2). Mud-dominated sediments comprise 80% of the intertidal area, similar to other estuaries at the head of Pelorus Sound. While sediments from the Ohinetaha catchment have likely contributed to deposition over time, sediment sources to Mahau Sound include legacy catchment sediments that have been re-worked and deposited in the estuary and contemporary sources including subsoil (i.e. soils from bare land, slips, erosion etc) and bank erosion. In addition to small freshwater inputs, the Pelorus and Kaituna Rivers are also a source of fine sediment to the head of Mahau Sound.

Salt marsh comprises a small area (2.6% of the intertidal area) at the head of the estuary and on the fringing margin. Salt marsh comprises rushland (*Juncus kraussii)*, sedgeland *(Schoenoplectus pungens)* and herbfield *(Samolus repens*; Robertson 2020). Seagrass is patchy and only a minor feature in the estuary (Fig. A5.2). No areas of nuisance macroalgal growth (>50% cover) have been recorded in the estuary and there is no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen). However, very soft muds on the central tidal flats have symptoms of low sediment oxygen (Robertson 2020). Cockle beds have been observed in the mid-estuary.

Catchment pressures include high producing grassland at the head of the estuary and exotic forestry blocks on the southern margin that are due for harvest within the next decade. Robertson (2020b) postulated high sediment loads from the Pelorus and Kaituna Rivers are contributing to sedimentation in Ohinetaha Bay.

Other pressures include a small incursion of Pacific oysters, and moorings within 5km that could increase the risk of oil spills, pathogens, and marine pest incursions. There is also road access to the estuary foreshore and several houses surrounding the estuary with minor domestic wastewater discharges.

Table A5.1. Summary information for Ohinetaha Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	53.4	
Intertidal Area (Ha; % Estuary)[1]	48.4	90.6
Dominant Estuary Substrate[1]	Very soft mud	
Mud extent (>50% mud content)	38.7	80.0
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.2	0.4
Salt Marsh (Ha; % intertidal)[1]	1.4	2.6
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	581.9	
Dominant Catchment Land Cover[2]	Mānuka and/or kānuka	
% Catchment indigenous vegetation[2]	73.1	
% Catchment exotic forest[2]	15.0	
% Producing grassland[2]	11.9	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	1.5	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	2.3	
Catchment Geology[4]	Sandstone (breccia & gravels)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	N	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish[1]	Cockle beds present	
Pressures		
Fine sediment deposition (i.e. very soft muds)		
Catchment derived sediments		
Sediments from Pelorus and Kaituna Rivers		
Margin modification		
Domestic wastewater		
Road access to the estuary edge		
Recreational use: boat use in the subtidal areas		

[1]Robertson (2020b); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A5.2. Ecological Vulnerability Assessment, Ohinetaha Bay.

Category	Score
Values	0.38
Pressures	0.73
Susceptibility	0.67
Condition	0.75
Average Score	0.64

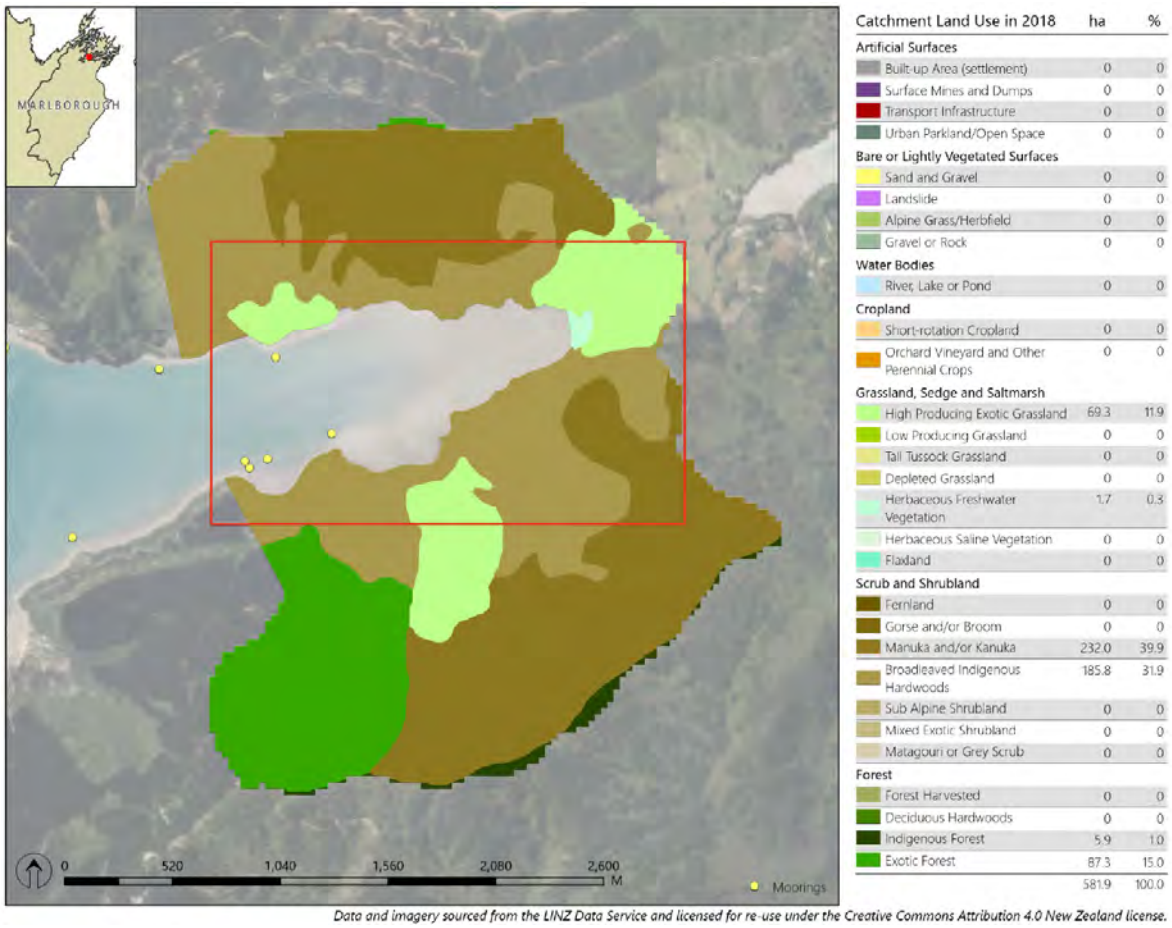


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Fig. A5.1. Ohinetaha Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

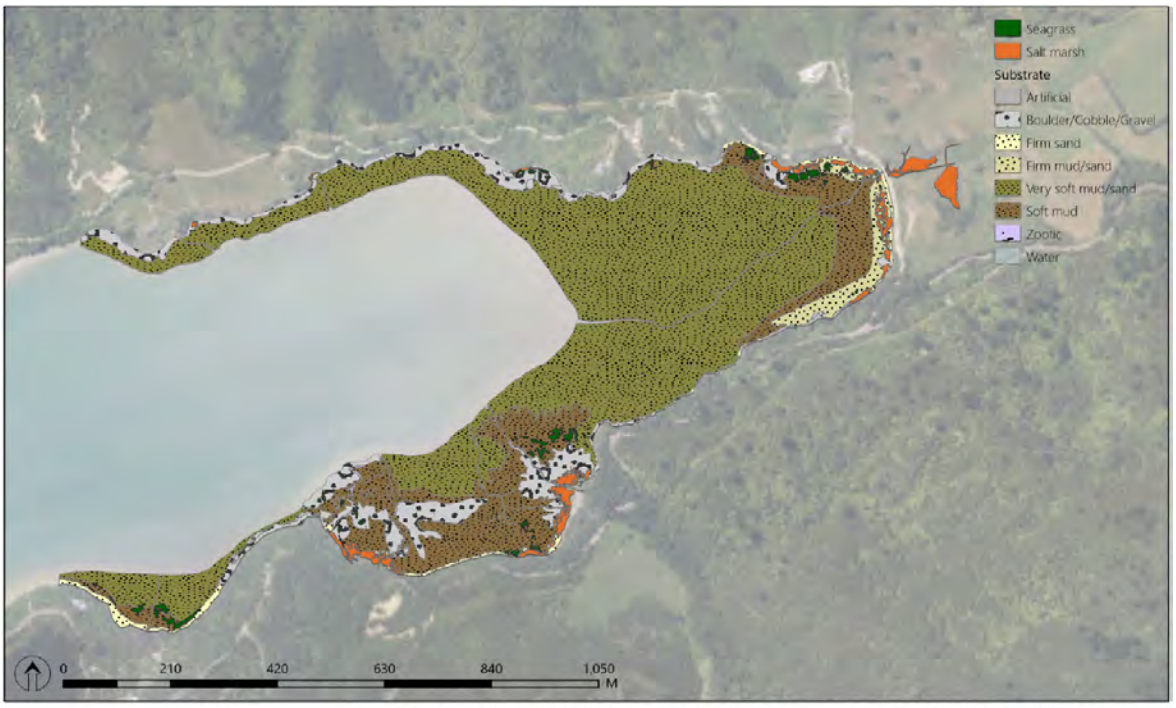

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Fig. A5.2. Ohinetaha Bay dominant vegetation and substrate features (data source: Robertson 2020b).

Rushland in the upper estuary (source: Robertson 2020b)

Seagrass beds growing in soft muds

Ohinetaha, mud flats (source: Robertson 2020b)

Steep terrestial margin (source: Robertson 2020b)

Shellbanks (source: Robertson 2020b)

Pacific Oysters growing on hard substrates (source: Robertson 2020b)

A6. Broughton Bay (Kenepuru Sound)

Broughton Bay is a small (12.9ha) intertidal estuary in Kenepuru Sound in the greater Pelorus Sound. The catchment is dominated by broadleaved indigenous hardwoods, with the overall catchment having 67.6% indigenous vegetation cover. High producing grassland (12.9%) is at the head of the estuary and exotic forestry comprises 18.1% of the southern catchment (Fig. A6.1).

The dominant substrate type in the estuary is firm muddy sand on the central tidal flats with gravels localised to the margins and around the main freshwater input (Fig. A6.2). Salt marsh comprises a small area (4.4% of the intertidal area) at the head of the estuary and on the fringing margin (Table A6.1). Salt marsh comprises rushland (*Juncus kraussii)*, estuarine shrub *(Plagianthus divaricatus)* and herbfield *(Samolus repens*; Robertson 2020). Seagrass is patchy and only a minor feature in the estuary (Fig. A6.2). No areas of nuisance macroalgal growth (>50% cover) have been recorded in the estuary and is was no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen). However, soft sediments have been observed accumulating on the northern margin of the lower tidal flats, and symptoms of low sediment oxygen have been recorded in that area (Robertson 2020). Cockle beds occur in the lower tidal range.

The main pressures in Broughton Bay include development in the catchment (e.g. forestry, pasture, housing) and close proximity to marine structures (e.g. moorings, jetties and marine farms) that increase the risk of oil spills, pathogens, and marine pest incursions. Broughton Bay also has many dwellings compared to other estuaries in the region and recreational activity in the subtidal zone is common.

Exotic forestry blocks on the southern margin are due for harvest within the next decade. It is well known that exotic forestry is a source of sediments to estuaries particularly during harvest and post-harvest. Given that the estuary remains in good condition, with only a small area of mud-dominated sediments, it will be important to manage potential sediment sources in the catchment.

Table A6.1. Summary information for Broughton Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	12.9	-
Intertidal Area (Ha; % Estuary)[1]	10.5	81.4
Dominant Estuary Substrate[1]	Firm muddy sand	
Mud extent (>50% mud content)	0.4	4.0
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.08	0.8
Salt Marsh (Ha; % intertidal)[1]	0.5	4.4
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	348.9	
Dominant Catchment Land Cover[2]	Broadleaved Indigenous Hardwoods	
% Catchment indigenous vegetation[2]	67.6	
% Catchment exotic forest[2]	18.1	
% Producing grassland[2]	13.3	
Mean Freshwater Flow (m^3/s)[3]	0.10	
Catchment Nitrogen Load (T/y)[3]	0.67	
Catchment Phosphorus Load (T/y)[3]	0.21	
Catchment Sediment Load (KT/y)[3]	0.77	
Catchment Geology[4]	Sandstone (breccia & gravels)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish[1]	Cockle beds present, tube worm also present	
Pressures		
Catchment development: pasture and exotic forestry		
Moorings and marine farms within 5km		
Domestic wastewater		
Road access to the estuary edge		
Recreational use: boat use in the subtidal areas		

[1]Robertson (2020b); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap
[5]MDC Smart Maps;

Table A6.2. Ecological Vulnerability Assessment, Broughton Bay.

Category	Score
Values	0.55
Pressures	0.72
Susceptibility	0.67
Condition	0.81
Average Score	0.69

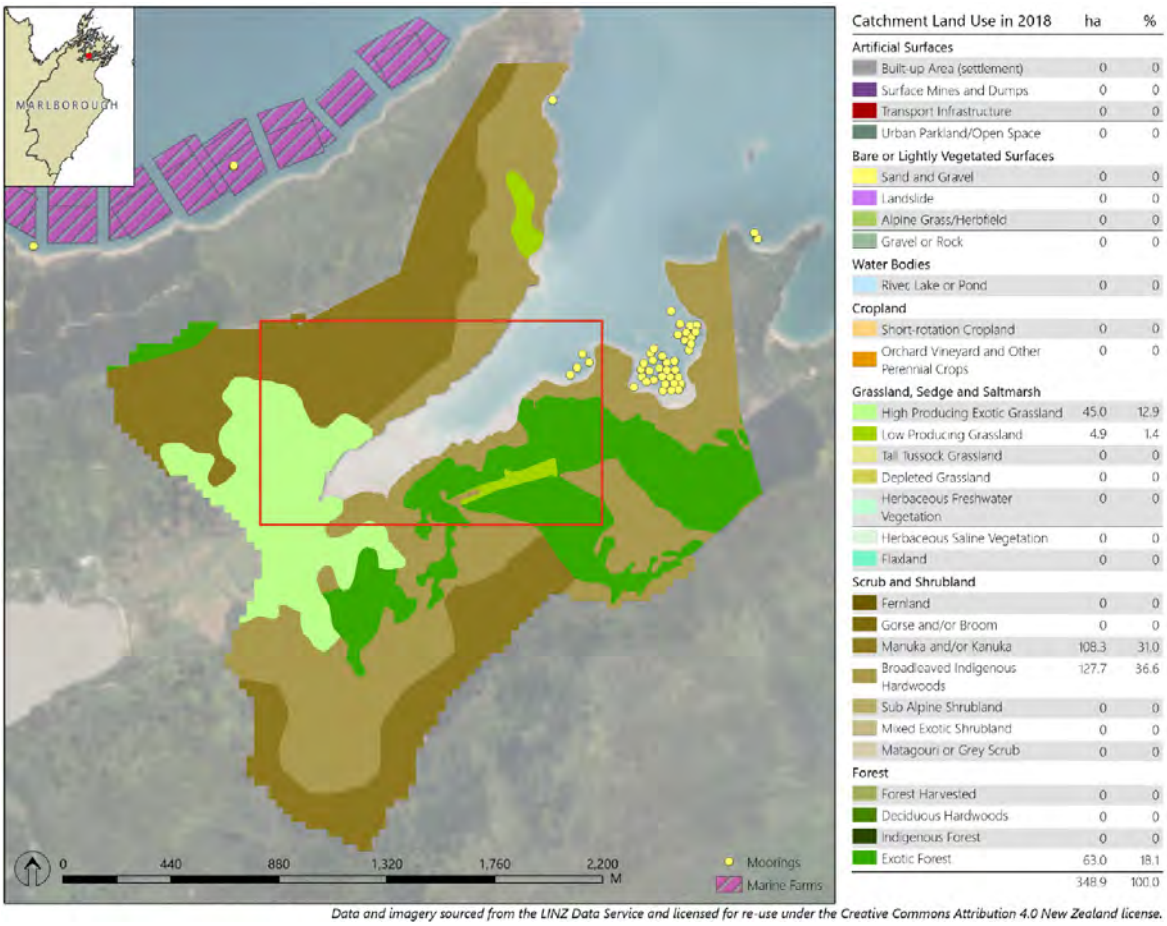

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Fig. A6.1. Broughton Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

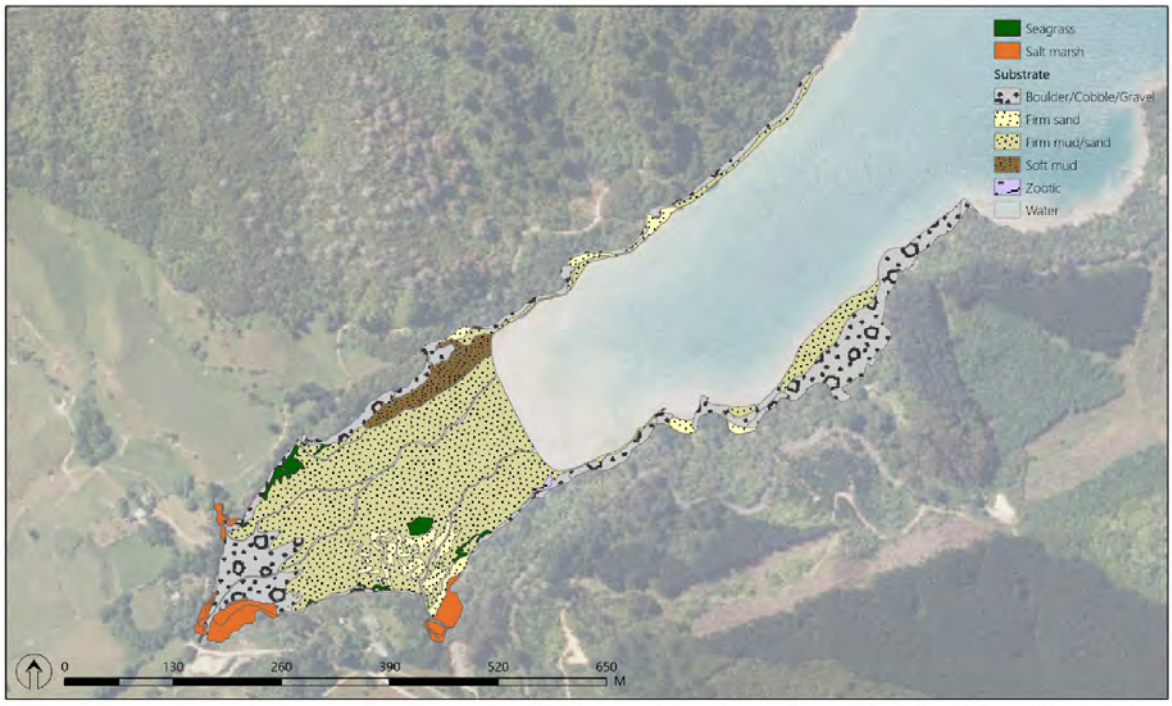

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Fig. A6.2. Broughton Bay dominant vegetation and substrate features (data source: Robertson 2020b).

Rushland in the upper estuary, with erosion on the margin (source: Robertson 2020b)

Broughton Bay seagrass (source: Robertson 2020b)

Broughton Bay mud flats (source: Robertson 2020b)

Steep terrestrial margin (source: Robertson 2020b)

Shellfish beds (source: Robertson 2020b)

Tube worm habitat growing on rock substrate (source: Robertson 2020b)

A7. Kenepuru Head Estuary (Kenepuru Sound)

Kenepuru Head Estuary is a medium-sized (43.2ha) intertidally dominated estuary at the head of Kenepuru Sound in the greater Pelorus Sound. The catchment is dominated by indigenous forest, with the catchment overall having 70% indigenous vegetation cover. The lower catchment comprises high producing grassland (14.5%) at the head of the estuary and exotic forestry (9.8%) on the hill slopes (Fig. A7.1).

The dominant substrate types are soft and very soft muds with a narrow strip of cobble on the estuary margins and near the main freshwater inputs (Fig. A7.2; SLR 2018). Salt marsh comprises a small area (4.4% of the intertidal area) at the head of the estuary and is mainly rushland (*Juncus kraussii)*, estuarine shrub *(Plagianthus divaricatus)* and herbfield *(Samolus repens*; SLR 2018). SLR (2018) recorded only a few small patches of seagrass on the southern margin (Fig. A7.2), attributing the lack of seagrass to the soft mud substrate and fine sediment deposition in the estuary. Nuisance macroalgae is a minor feature and associated with a small stream input on the south-east corner (SLR 2018). There are no areas of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen; Table A7.1). However, sediments near stream inputs exhibit signs of enrichment and low sediment oxygenation (SLR 2018).

Fine sediment deposition is the most significant pressure in Kenepuru Head Estuary. Sediment cores collected in Kenepuru Sound suggest sedimentation rates are 10-fold higher when compared to natural sedimentation rates (Handley et al. 2017). In addition to development in the catchment (e.g. exotic forestry and pasture), under storm conditions the Pelorus River contributes a significant amount of terrigenous sediment that is deposited in the smaller embayment's within Pelorus Sound, including Kenepuru Head (Swales et al. 2021).

Other pressures include an incursion of Pacific oyster, and a high number of moorings and marine farms within 5km, which could increase the risk of oil spills, pathogens, and marine pest incursions. Farming also occurs close to the estuary margin and the natural hydrology has been altered in parts. Human use of the estuary is also high with a DOC campsite on the estuary margin and road access to the estuary.

Table A7.1. Summary information for Kenepuru Head.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	43.2	-
Dominant Estuary Substrate[1]	Soft/ very soft mud	
Mud extent (>50% mud content)	40.7	94.2
Macroalgae (Ha; cover >50%)[1]	0.7	1.7
Seagrass (Ha; cover >50%)[1]	0.02	0.04
Salt Marsh (Ha; % intertidal)[1]	1.9	4.4
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	4964.2	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	70.0	
% Catchment exotic forest[2]	9.8	
% Producing grassland[2]	14.5	
Mean Freshwater Flow (m^3/s)[3]	1.4	
Catchment Nitrogen Load (T/y)[3]	15.0	
Catchment Phosphorus Load (T/y)[3]	3.5	
Catchment Sediment Load (KT/y)[3]	14.3	
Catchment Geology[4]	Sandstone (breccia & gravel)	
Biodiversity		
ESMS	Y – 3.21	
Significant Wetland[5]	Y – salt marsh	
Birds	Banded rail, spoonbills, waterfowl, variable oystercatcher	
Fish[5]	Redfin bully	
Shellfish[1]	Cockle beds	
Pressures		
Fine sediment deposition (i.e. very soft muds)		
Catchment derived sediments		
Sediments from Pelorus and Kaituna Rivers		
Pacific oysters		
Farming close to estuary margin and altered hydrology		
Road access to estuary		
Kenepuru Head campsite on southern margin		

[1]SLR (2018); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A7.2. Ecological Vulnerability Assessment, Kenepuru Head.

Category	Score
Values	0.63
Pressures	0.74
Susceptibility	0.63
Condition	0.77
Average Score	0.69

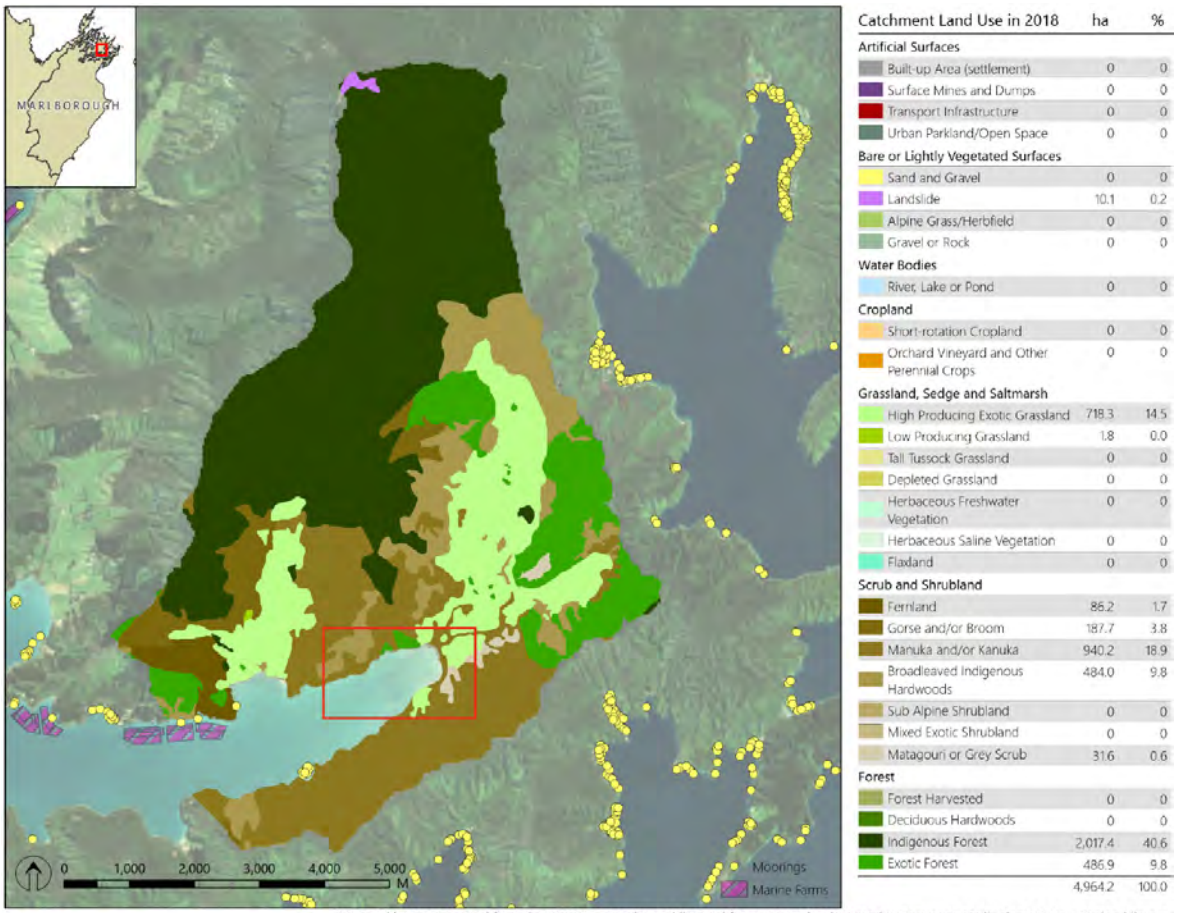

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Fig. A7.1. Kenepuru Head catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

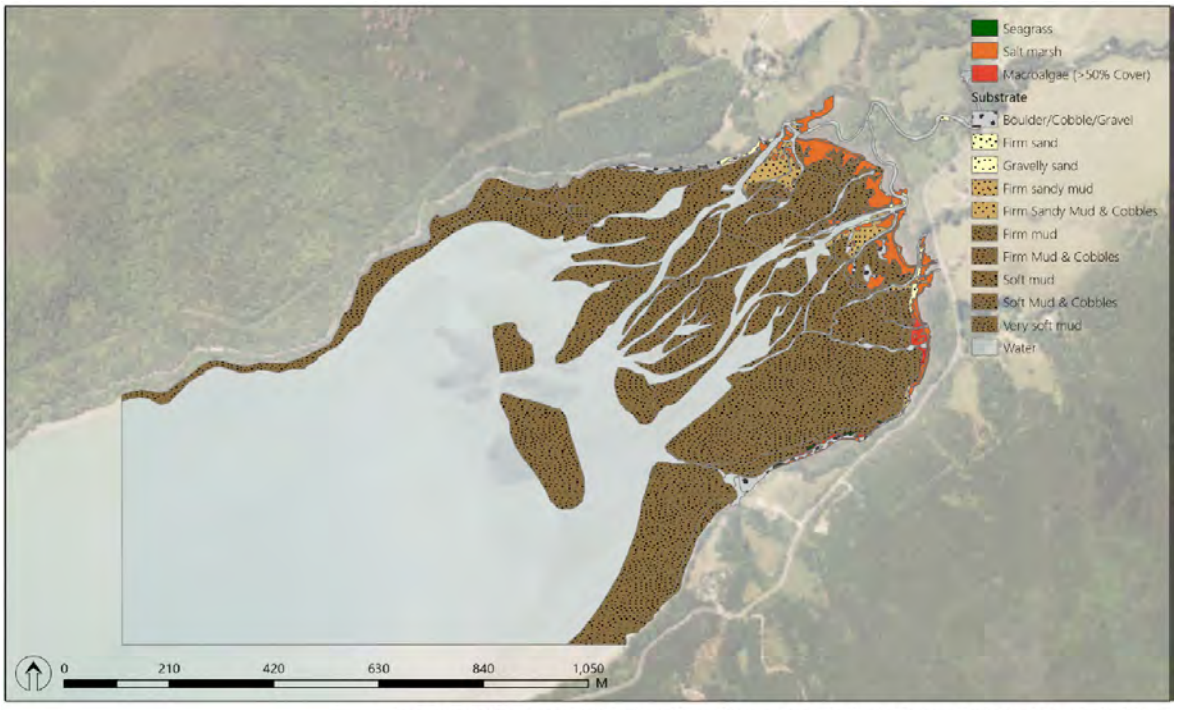

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Fig. A7.2. Kenepuru Head dominant vegetation and substrate features (data source: SLR 2018).

Looking upstream, salt marsh and exotic forest in background

Grazing within the estuary margin

Gravel/cobble field on the estuary margin and soft muds on the tidal flats

Soft muds on the tidal flats

Kenepuru Sound

A8. Waitaria Bay (Kenepuru Sound)

Waitaria Bay is a medium-size (37.5ha) intertidally dominated estuary in the Kenepuru Sound which is connect to the greater Pelorus Sound. The catchment is dominated by high producing grassland in the lower catchment with small areas of exotic forestry on the hill slopes. Indigenous vegetation types, mainly in the upper catchment, make up 56.1% of the catchment area (Fig. A8.1).

The dominant substrate type is gravel/cobble in the upper estuary and along the estuary margin. Mud-dominated sediments are on the estuary tidal flats. A small area of salt marsh (~20%) is at the head of the estuary near the main freshwater input. A small area of seagrass has been recorded in the estuary. Nuisance macroalgae, particularly *Ulva* spp. have been recorded growing in subtidal channels and in patches on the lower intertidal flats. Drift *Ulva* spp. has been recorded accumulating on the estuary margin smothering herbfield. While nuisance macroalgal growths are not associated with poor sediment conditions, the localised growths particularly around freshwater inputs suggest nutrient inputs may be elevated. In the most recent survey (January 2021) no High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen) were recorded.

Catchment development (e.g. forestry, pasture) is a pressure in Waitaria Bay. Sheep farming is common in the lower catchment and farmed paddocks are only separated from the estuary by a road. Some exotic forest blocks on the hill slopes are due for harvest within the next decade and a small vineyard is located northwest of the main intertidal flats. Nutrients and sediments to Waitaria Bay should both be managed given early signs of nuisance macroalgal growth and the spatial extent of mud-dominated sediments across the intertidal area (Table A8.1).

Other pressures include the estuary's close proximity to marine structures (e.g. moorings, jetties and marine farms), which increases the risk of oil spills, pathogens, and marine pest incursions. Pacific oysters have been recorded in the estuary. Fish passage is limited in parts where streams have been piped underneath the road and raised pipes discharge from a hardened margin. There is also road access to the estuary foreshore and several houses surrounding the estuary, with minor domestic wastewater discharges.

Table A8.1. Summary information for Waitaria Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	
Intertidal Area (Ha; % Estuary)[1]	37.5	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	20
Macroalgae (Ha; cover >50%)	-	15-25
Seagrass (Ha; cover >50%)	-	7
Salt Marsh (Ha; % intertidal)	-	~20
High Enrichment Conditions (HEC)	-	0.0
Catchment		
Catchment Area (Ha)[2]	1398.7	
Dominant Catchment Land Cover[2]	High Producing Grassland	
% Catchment indigenous vegetation[2]	56.1	
% Catchment exotic forest[2]	12.4	
% Producing grassland[2]	31.1	
Mean Freshwater Flow (m^3/s)[3]	1.0	
Catchment Nitrogen Load (T/y)[3]	5.49	
Catchment Phosphorus Load (T/y)[3]	1.63	
Catchment Sediment Load (KT/y)[3]	5.71	
Catchment Geology[4]	Sandstone (breccia & gravels)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish[1]		
Pressures		
Nutrient inputs from the catchment		
Fine sediment deposition		
Pacific oysters		
Farming close to estuary margin and altered hydrology		
Road access to estuary		
Marine farms, jetty, moorings		
Restricted fish passage in parts		
Domestic discharges		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A8.2. Ecological Vulnerability Assessment, Waitaria Bay.

Category	Score
Values	0.68
Pressures	0.72
Susceptibility	0.54
Condition	0.62
Average Score	0.64

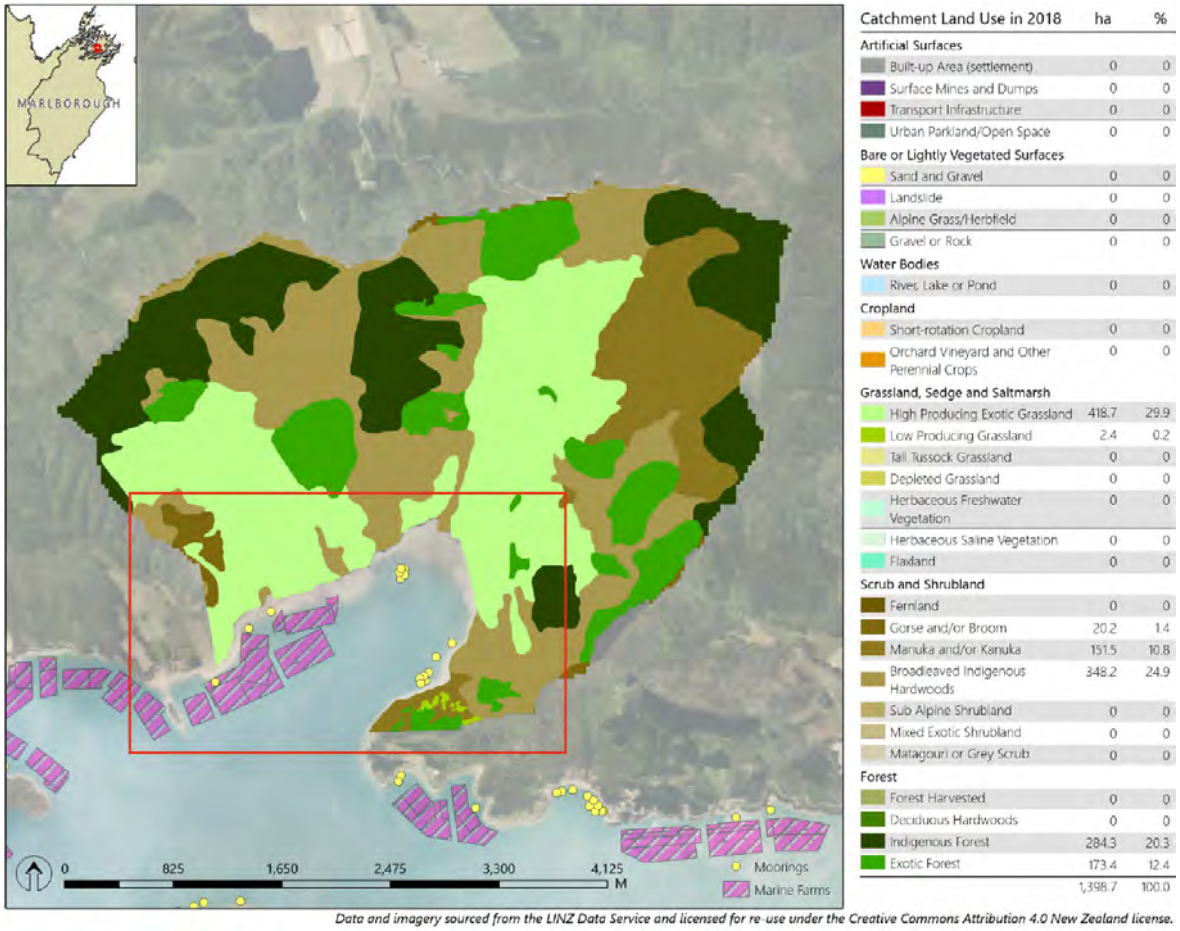

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Fig. A8.1. Waitaria Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

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Fig. A8.2. Waitaria Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Drigft macroalgae on salt marsh herbfield and eroding grass margin in the background

The dominant substrate gravel/cobble

Patches of *Ulva* spp. growing on gravel/cobble substrate

Mixed catchment, high producing grassland, exotic forestry and regenerating native bush

A9. Four Fathom Bay (Hikapu Reach)

Four Fathom Bay is a small (1.8ha) intertidally dominated estuary in the Hikapu Reach of Pelorus Sound. The catchment is dominated by exotic forest (56.5%), with only 35.6% of the catchment remaining in indigenous vegetation cover that is localised to the upper catchment. A mix of high producing grassland and exotic forest is on the immediate estuary margin (Fig. A9.1).

The dominant substrate type is gravel/cobble, with mud-dominated sediments comprising only 10% of the intertidal area. Salt marsh at the head of the estuary mainly comprises rushland, with some herbfield on the seaward edge. A thin strip of rushland is also present on the edges of the estuary. Seagrass is a common feature on the intertidal flats, with nuisance macroalgae, particularly *Ulva* spp., growing on seagrass beds in parts. *Ulva* spp. has also been recorded from channel margins and within subtidal channels. Nuisance macroalgae growths are associated with gravel/ cobble. In the most recent survey (December 2020) no High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen) were recorded.

The main pressures to Four Fathom Bay are nutrients and fine sediment inputs from the catchment, which includes large areas of exotic forestry and to a lesser extent high producing grassland. Plantation forestry is a known source of sediment during and post-harvest (Swales et al. 2021). Harvesting of exotic forest has already occurred in the catchment with further harvest planned within the next 10 years.

Other pressures include marine farming within the subtidal zone and a high number of moorings, which increase the likelihood of marine pest incursions, pathogens, and marine contaminants. It is unknown whether Pacific oysters have established on the intertidal flats, however, this is common in other intertidal areas within Pelorus Sound. Four Fathom Bay is only accessed by boat and has a number of dwellings on the margin, with minor domestic wastewater discharges.

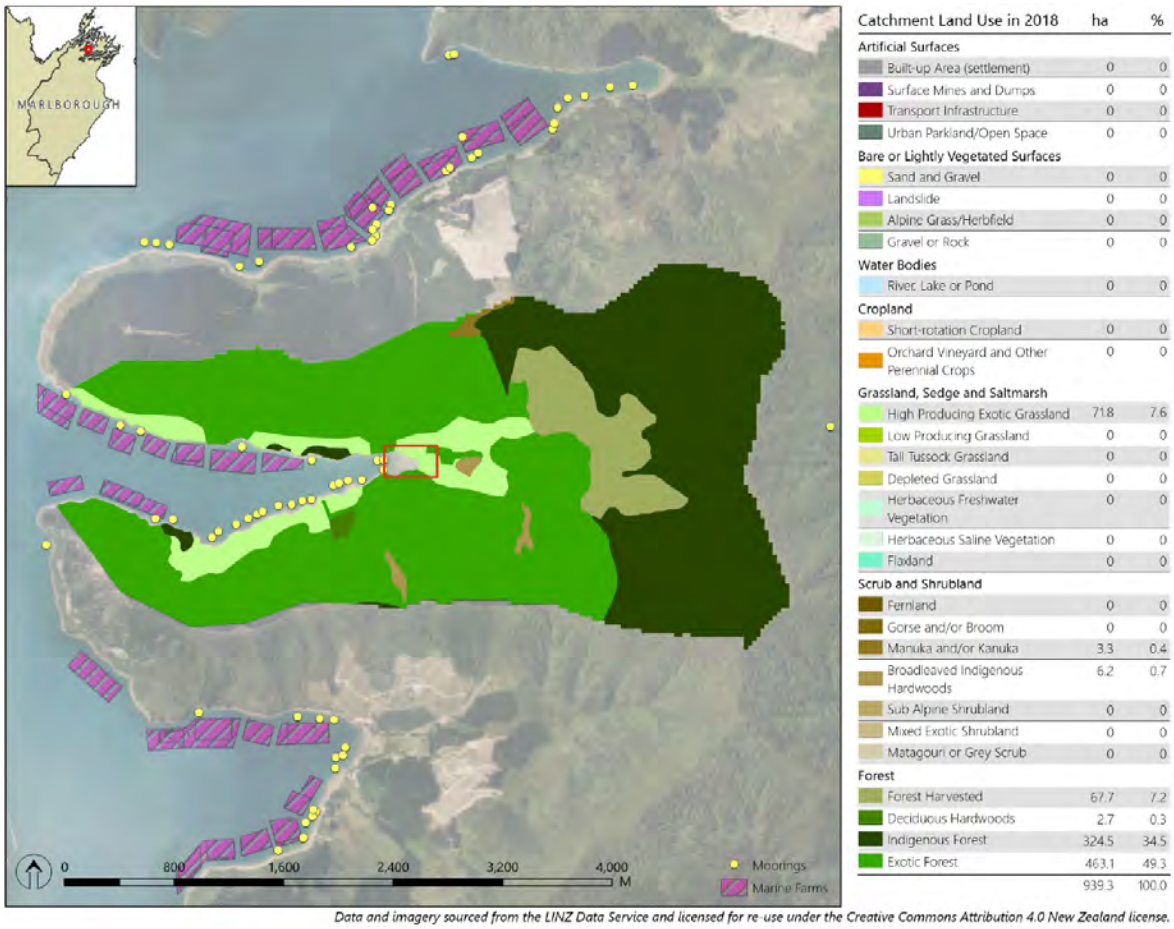
Table A9.1. Summary information for Four Fathom Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	1.8	-
Dominant Estuary Substrate[1]	Gravel/cobble	
Mud extent (>50% mud content)	-	10
Macroalgae (Ha; cover >50%)[1]	-	15-25
Seagrass (Ha; cover >50%)[1]	-	40
Salt Marsh (Ha; % intertidal)[1]	-	30
High Enrichment Conditions (HEC)[1]	-	0.0
Catchment		
Catchment Area (Ha)[2]	939.3	
Dominant Catchment Land Cover[2]	Exotic Forest	
% Catchment indigenous vegetation[2]	35.6	
% Catchment exotic forest[2]	56.5	
% Producing grassland[2]	7.6	
Mean Freshwater Flow (m^3/s)[3]	0.3	
Catchment Nitrogen Load (T/y)[3]	2.1	
Catchment Phosphorus Load (T/y)[3]	0.5	
Catchment Sediment Load (KT/y)[3]	4.3	
Catchment Geology[4]	Sandstone (breccia & gravel)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	N	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish	nd	
Pressures		
Developed catchment (exotic forest and producing grassland) Nutrient and sediment inputs from the catchment Marine farms, jetty, moorings Domestic discharges		

[1]Aerial imagery. [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps

Table A9.2. Ecological Vulnerability Assessment, Four Fathom Bay.

Category	Score
Values	0.62
Pressures	0.72
Susceptibility	0.46
Condition	0.73
Average Score	0.63



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	71.8	7.6
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	0	0
Manuka and/or Kanuka	3.3	0.4
Broadleaved Indigenous Hardwoods	6.2	0.7
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	67.7	7.2
Deciduous Hardwoods	2.7	0.3
Indigenous Forest	324.5	34.5
Exotic Forest	463.1	49.3
	939.3	100.0

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Fig. A9.1. Four Fathom Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

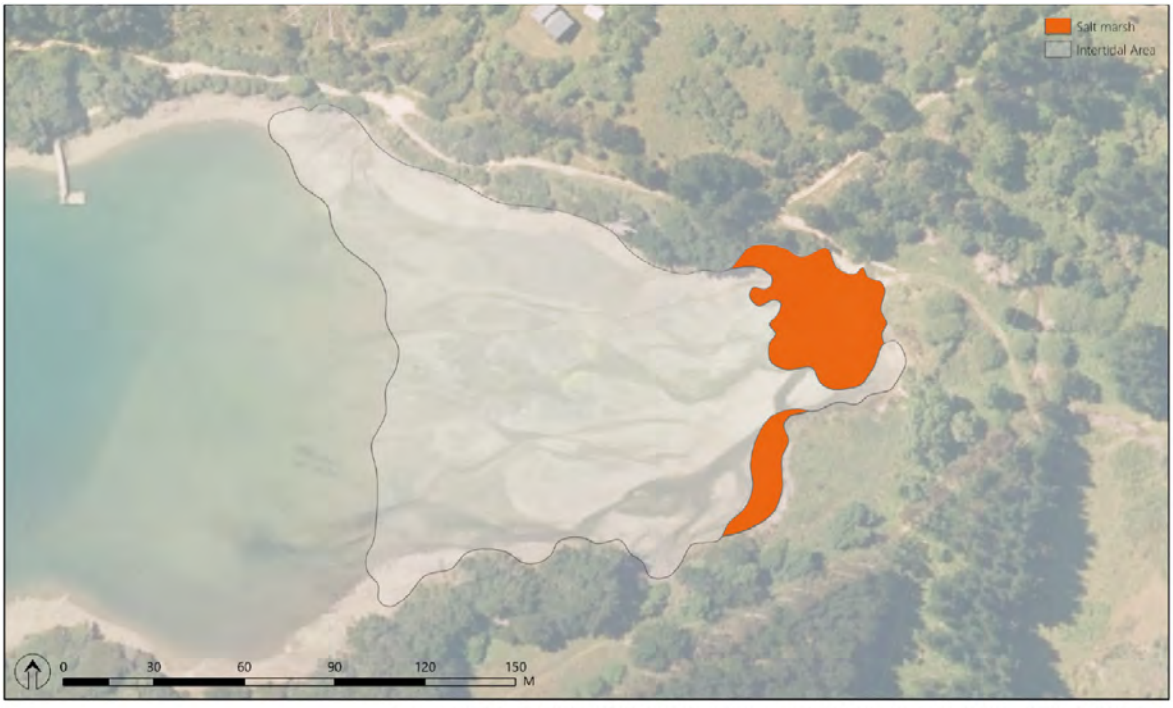

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Fig. A9.2. Four Fathom Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Harvested forest on the margin of Four Fathom Bay

Exotic forest on the margin and marine farm in the foreground

Patches of *Ulva* spp. and seagrass growing on gravel/cobble intertidal flats. Jetty near the intertidal area, harvested exotic forest in the background and mature exotic forest in the foreground (source: Bayleys, Marlborough)

Mixed exotic forest and high producing grassland catchment. Intertidal flats with seagrass and *Ulva* spp. growing on gravel/cobble (source: Bayleys, Marlborough)

A10. Māori Bay (Hikapu Reach)

Māori Bay is a small (5.2ha) intertidally dominated estuary in the Hikapu Reach of Pelorus Sound. The catchment is dominated by indigenous vegetation cover (89.9%) that is a mix of indigenous forest and mānuka and/or kānuka (Fig. A10.1). Exotic forestry is on the northwest side of the estuary and on the margin of the wide bay (Fig. A10.1).

The dominant substrate type in the estuary is gravel/cobble with no mud-dominated sediments recorded (Table A10.1). Salt marsh is at the head of both intertidal flats and mainly comprises rushland with some herbfield on the seaward edge. The salt marsh is classified as a regionally significant wetland. Vehicle tracks traverse across the tidal flats (see photo) and use appears frequent with no rushland remaining in that area. Seagrass has been recorded on the western flats and is localised to the low tide boundary on the southern margin. Nuisance macroalgae, mainly *Ulva* spp., has been recorded across 5-15% of the intertidal area, however growths are associated with gravel/ cobble. In the most recent survey (December 2020) no High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen) were recorded.

While exotic forestry in Māori Bay is only a minor feature in the catchment, it has the potential to have a high relative impact because it is on the estuary margin, adjacent to the intertidal area. Plantation forestry is a known source of sediment during and post-harvest (Swales et al. 2021). Harvesting of exotic forest has already occurred on the southern margin with further harvest planned within the next 10 years.

Other pressures include marine farming within the subtidal zone and a small number of moorings, which increase the likelihood of marine pest incursions, pathogens, and marine contaminants. A localised area of Pacific oysters was recorded in December 2020. While Maori Bay is only accessed by boat, there is vehicle use on the estuary margin and within the estuary, as discussed.

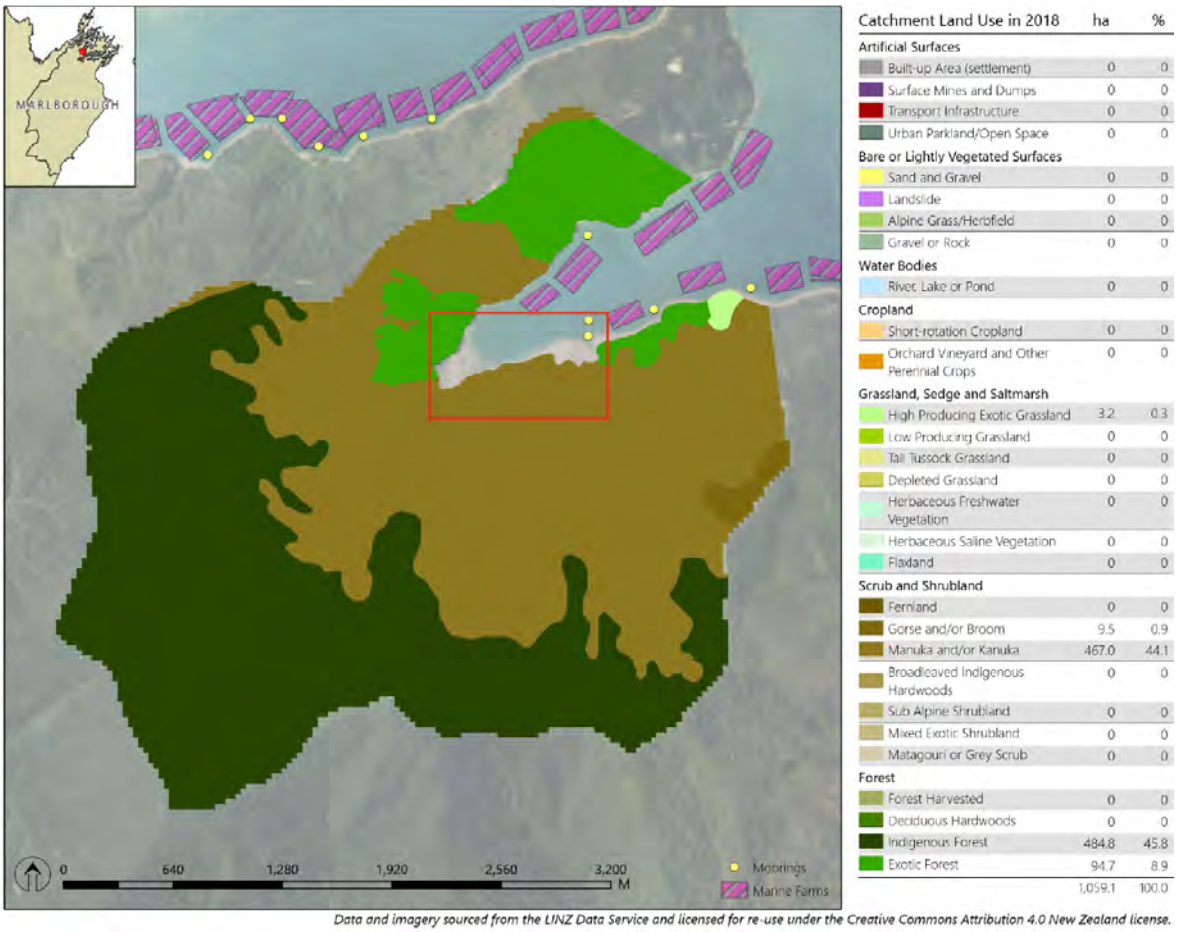
Table A10.1. Summary information for Māori Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	5.2	-
Dominant Estuary Substrate[1]	Gravel/cobble	
Mud extent (>50% mud content)	-	0.0
Macroalgae (Ha; cover >50%)[1]	-	5-15
Seagrass (Ha; cover >50%)[1]	-	3
Salt Marsh (Ha; % intertidal)[1]	-	25
High Enrichment Conditions (HEC)[1]	-	0.0
Catchment		
Catchment Area (Ha)[2]	1059.1	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	89.9	
% Catchment exotic forest[2]	8.9	
% Producing grassland[2]	0.3	
Mean Freshwater Flow (m^3/s)[3]	0.3	
Catchment Nitrogen Load (T/y)[3]	2.7	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	3.3	
Catchment Geology[4]	Sandstone (breccia & gravel)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish[1]	nd	
Pressures		
Vehicle tracks through the salt marsh		
Exotic forest on estuary margin		
Marine farming and moorings		
Recreational boat use		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A10.2. Ecological Vulnerability Assessment, Māori Bay

Category	Score
Values	0.65
Pressures	0.81
Susceptibility	0.60
Condition	0.88
Total	0.74



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	3.2	0.3
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	9.5	0.9
Manuka and/or Kanuka	467.0	44.1
Broadleaved Indigenous Hardwoods	0	0
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	0	0
Deciduous Hardwoods	0	0
Indigenous Forest	484.8	45.8
Exotic Forest	94.7	8.9
	1,059.1	100.0

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Fig. A10.1. Maori Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

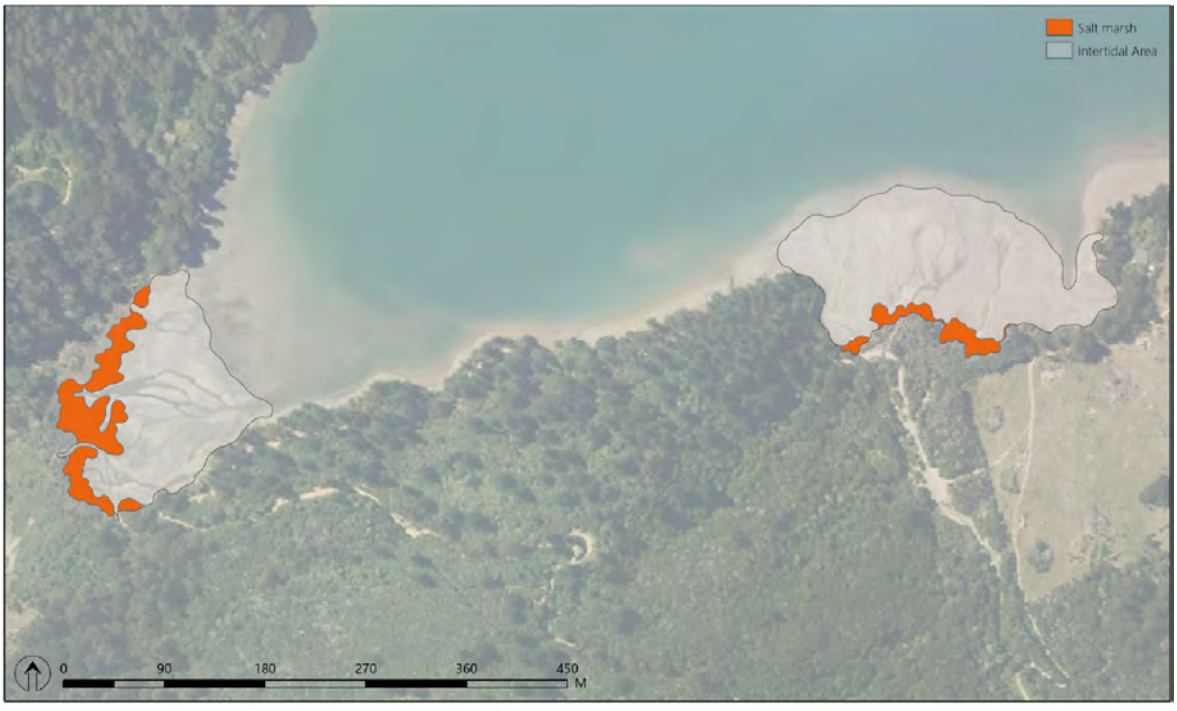

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Fig. A10.2. Maori Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Western intertidal area of Maori Bay

Eastern intertidal area of Maori Bay

Gravel/cobble and salt marsh habitat

Western flats, vehicle tracks through rushland and seagrass on left

Gravel/cobble field

Wildling pines on the steep margin

A11. Nikau Bay (Hikapu Reach)

Nikau Bay is a small (2.4ha) intertidally dominated estuary in the Hikapu Reach of Pelorus Sound. The catchment is mainly indigenous vegetation cover (69.6%), dominated by indigenous forest with small areas of mānuka and/or kānuka (Fig. A11.1). Exotic forest is on the hill slopes in the lower catchment and high producing grassland on the lowland areas (Fig. A11.1).

A recent field assessment has not been undertaken at Nikau Bay; hence the following information is based on a desktop assessment and should be treated with caution. Based on aerial imagery and photos the estuary is dominated by gravel/cobble. It is uncertain whether mud-dominated sediments are present in the estuary. However, sediment inputs from catchment activities such as forestry could lead to sedimentation in the estuary, and has been recorded on a small scale in previous consent monitoring (Consent: U130695).

Salt marsh comprises ~10% of the intertidal area and is dominated by rushland. From the aerial imagery and photos there is also a large freshwater wetland on the estuary margin. The darker green areas on the aerial imagery (see photo) indicate seagrass is present on the lower estuary margin. Nuisance macroalgae, likely *Ulva* spp., can be seen observed on the imagery as bright green patches in the subtidal channels and on the intertidal flats, and comprises ~15-25% of the intertidal area (see photo). Current nutrient and sediment loads are below thresholds of concern and therefore High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen) are unlikely to be present in the estuary. However, a field visit would be required to confirm these findings.

The main pressures to Nikau Bay are nutrients and fine sediment inputs from the catchment, which includes areas of exotic forestry and to a lesser extent high producing grassland. Plantation forestry is a known source of sediment during and post-harvest (Swales et al. 2021). Harvesting of exotic forest has already occurred in the catchment with further harvest likely within the next 10 years.

Other pressures include marine farming within the subtidal zone and a small number of moorings, which increase the likelihood of marine pest incursions, pathogens, and marine contaminants. It is unknown whether Pacific oysters have established on the intertidal flats, however, this is common in other intertidal areas within Pelorus Sound. Nikau Bay is only accessed by boat, however forestry roads exist around the margin, and there are a number of dwellings on the margin with minor domestic wastewater discharges.

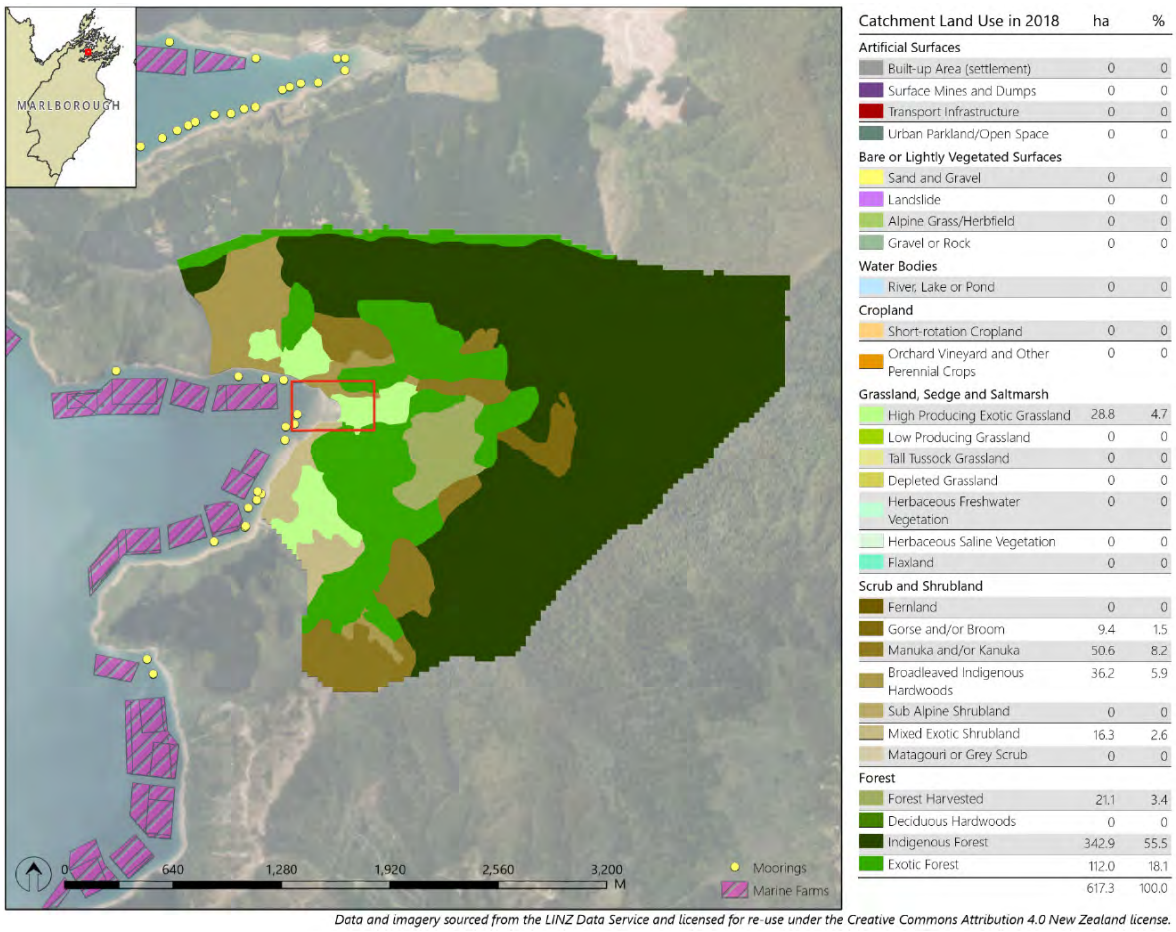
Table A11.1. Summary information for Nikau Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	2.4	-
Dominant Estuary Substrate[1]	Gravel/cobble	
Mud extent (>50% mud content)	-	nd
Macroalgae (Ha; cover >50%)[1]	-	~15-25
Seagrass (Ha; cover >50%)[1]	-	~10
Salt Marsh (Ha; % intertidal)[1]	-	~10
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	617.3	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	69.6	
% Catchment exotic forest[2]	21.5	
% Producing grassland[2]	4.7	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	1.7	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	3.6	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS	N	
Significant Wetland[5]	N	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish	nd	
Pressures		
Developed catchment (exotic forest and producing grassland)		
Nutrient and sediment inputs from the catchment		
Marine farms, jetty, moorings		
Domestic discharges		

[1]Assessment based on aerial imagery only, treat with caution; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A11.2. Ecological Vulnerability Assessment, Nikau Bay

Category	Score
Values	0.68
Pressures	0.85
Susceptibility	0.89
Condition	0.94
Average Score	0.84



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	28.8	4.7
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	9.4	1.5
Manuka and/or Kanuka	50.6	8.2
Broadleaved Indigenous Hardwoods	36.2	5.9
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	16.3	2.6
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	21.1	3.4
Deciduous Hardwoods	0	0
Indigenous Forest	342.9	55.5
Exotic Forest	112.0	18.1
	617.3	100.0

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Fig. A11.1. Nikau Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms. Catchment boundary derived from CLUES 10.3.

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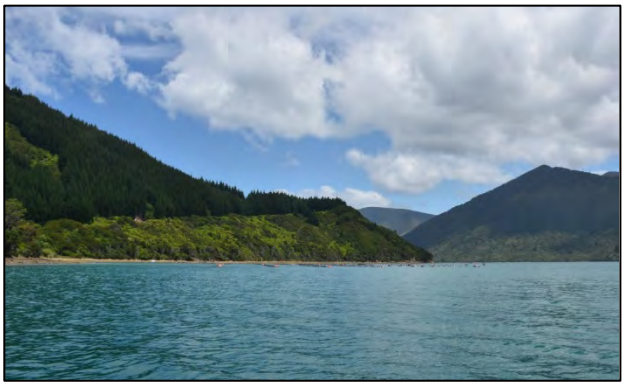
Fig. A11.2. Nikau Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Gravel/cobble and rushland at the head of the estuary, freshwater wetland on the margin



Marine farms in the subtidal zone (Image ref: MDC 'Pelorus NikauBay 32 Bright', Courtesy of Marlborough District Council)

Dark green areas are likely seagrass and the bright green is likely *Ulva* spp. growing on the intertidal flats. There is a freshwater wetland at the head of the estuary and jetties in the subtidal zone.

Nikau Bay intertidal area and catchment (Image ref: MDC 'Pelorus NikauBay 20 Bright', Courtesy of Marlborough District Council)

A12. Chance Bay (Nydia Bay)

Chance Bay is a small (5.2ha) intertidal estuary in Nydia Bay within the greater Pelorus Sound. The steep native bush catchment is 100% indigenous vegetation and is protected within the Chance, Penguin and Fairy Bays Scenic Reserve. Chance Bay is classified as an ESMS because protected native forest catchments adjacent to the sea are uncommon in the region (Davidson et al. 2011).

The dominant substrate type in the estuary is gravel/cobble with no mud-dominated sediments recorded (Table A12.1). Salt marsh comprises ~15% of the intertidal area and is mainly rushland (*Juncus kraussii*) that transitions into indigenous forest. The salt marsh is classified as a regionally significant wetland. Seagrass is sparse and only recorded across 5% of the intertidal area.

In the recent rapid estuary assessment macroalgae was recorded across <5% of the intertidal area. *Ulva* spp. was observed growing in shallow subtidal channels on gravel/cobble substrate (see photo). The localised areas of macroalgae growth were not associated with any poor sediment condition, and no High Enrichment Conditions were recorded in the estuary. Pacific oysters growing on gravel/ cobble are common across the intertidal flats (see photos).

Catchment pressures in Chance Bay are low due to the protected catchment. Human use is the most significant pressure. While there are no permanent moorings, Chance Bay is popular for anchorage because the steep terrain provides good shelter from winds. Camping on the foreshore is also common. The number of boat users increases the risk of introduced marine pests, pathogens, and other marine contaminants. Aside from the incursion of the Pacific oyster the estuary is in very good condition with high value salt marsh and a protected catchment.

Steep indigenous forest catchment and salt marsh in the upper estuary

Table A12.1. Summary information for Chance Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	5.2	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	0.0
Macroalgae (Ha; cover >50%)	-	<5
Seagrass (Ha; cover >50%)	-	5.0
Salt Marsh (Ha; % intertidal)	-	15.0
High Enrichment Conditions (HEC)	-	0.0
Catchment		
Catchment Area (Ha)[2]	537.3	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.1	
Catchment Nitrogen Load (T/y)[3]	1.3	
Catchment Phosphorus Load (T/y)[3]	0.2	
Catchment Sediment Load (KT/y)[3]	2.0	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS[5]	Y – 3.17	
Significant Wetland[6]	Y – salt marsh	
Birds	nd	
Fish[6]	Redfin bully, koaro	
Shellfish	nd	
Pressures		
Pacific oysters		
Human use – boat users/ camping		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al. (2011); [5]MDC Smart Maps;

Table A12.2. Ecological Vulnerability Assessment, Chance Bay

Category	Score
Values	0.72
Pressures	0.86
Susceptibility	0.89
Condition	0.91
Average Score	0.84

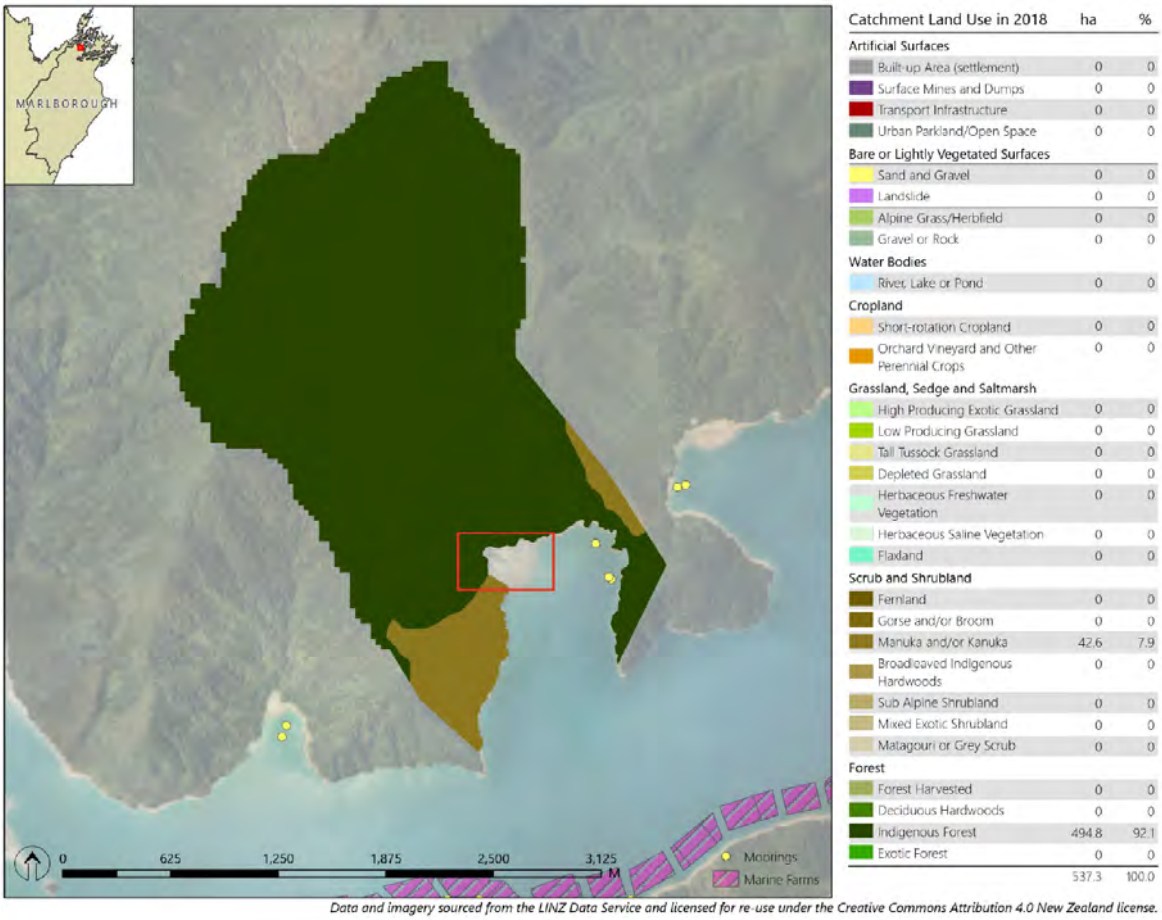


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Fig. A12.1. Chance Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

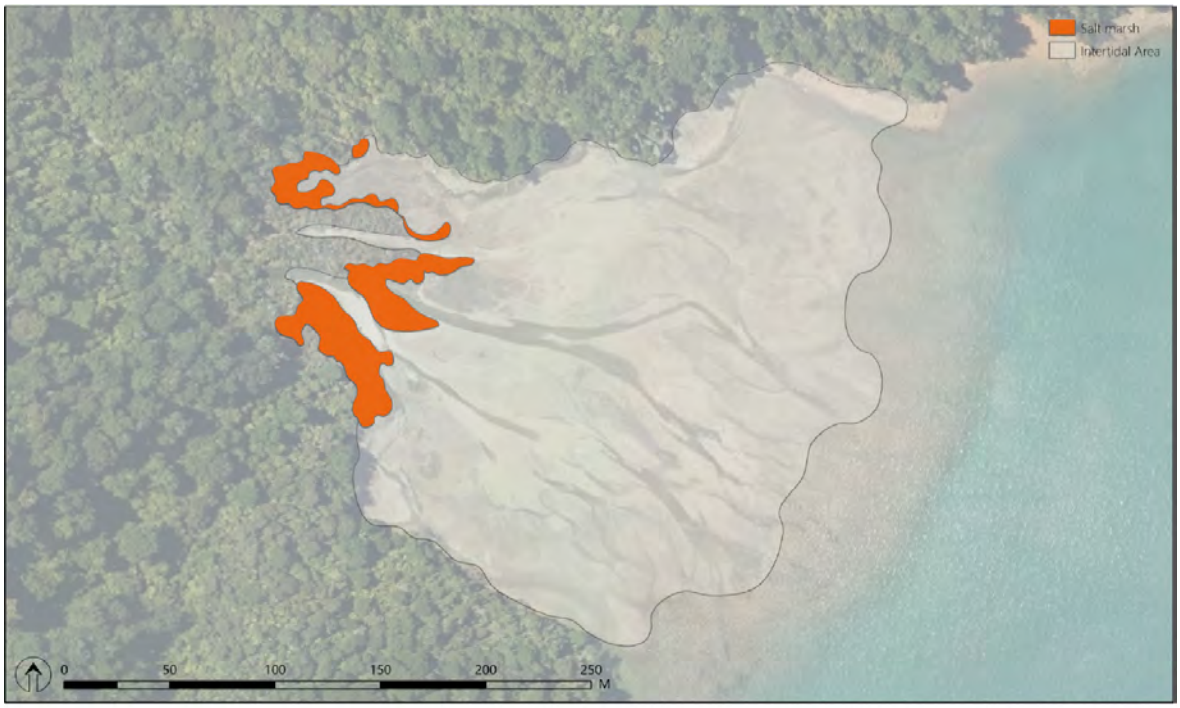

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Fig. A12.2. Chance Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Aerial view of estuary and the steep native bush catchment

Rushland and gravel/cobble substrate

Pacific oysters growing on gravel/cobble

Aerial view of the salt marsh habitat at the head of the estuary and green *Ulva* spp. in the gravel/cobble channels

The dominant substrate type gravel/cobble and steep native bush catchment

A13. Nydia Bay North (Nydia Bay)

Nydia Bay North comprises two small intertidal estuaries in inner Nydia Bay within the greater Pelorus Sound (Fig. A13.2). The steep native bush catchment is dominated by indigenous forest (98.6% indigenous vegetation cover; Fig. A13.1) and is mostly protected within the Nydia Bay Scenic Reserve. A small area of exotic forest is in the southern catchment outside the scenic reserve.

The dominant substrate type in the estuary is gravel/cobble with mud-dominated sediments recorded on the lower tidal flats (Table A13.1). Salt marsh is at the head of both intertidal flats and mainly comprises rushland, with herbfield on the seaward edge. The salt marsh is classified as a regionally significant wetland and transitions into mānuka and/or kanuka forest. In the recent (June 2022) rapid estuary assessment seagrass was only recorded across 7% of the intertidal area and in parts it was being smothered by macroalgae (see photo). Overall, nuisance macroalgae was recorded across <5% of the intertidal area and *Ulva* spp. was observed growing in small patches on gravel/cobble substrate. The localised areas of macroalgae growth were not associated with any poor sediment condition, and no High Enrichment Conditions were recorded in the estuary. Pacific oysters growing on gravel/cobble are frequent across the intertidal flats.

Catchments pressures in Nydia Bay North are low due to the mostly protected catchment. In the southern catchment there is a small area of exotic forest (1.4%) and a few dwellings with a jetty in the most southern embayment. Human use is the most significant pressure. There are a small number of moorings within the bay and a DOC campsite on the shoreline to support recreational use. The number of boat users increases the risk of introduced marine pests, pathogens, and other marine contaminants. Aside from the incursion of the Pacific oyster, the estuary is in very good condition with a relatively large area of high value salt marsh and a protected catchment.

Macroalgae growing on seagrass

Table A13.1. Summary information for Nydia Bay North.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	11.0	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	10
Macroalgae (Ha; cover >50%)	-	<5
Seagrass (Ha; cover >50%)	-	7
Salt Marsh (Ha; % intertidal)	-	20
High Enrichment Conditions (HEC)	-	0.0
Catchment		
Catchment Area (Ha)[2]	1084	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	98.6	
% Catchment exotic forest[2]	1.4	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.3	
Catchment Nitrogen Load (T/y)[3]	2.6	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	3.4	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS	N	
Significant Wetland	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish	nd	
Pressures		
Pacific oysters		
Human use – boat users/ camping		
Small area of exotic forest in catchment		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Maps;

Table A13.2. Ecological Vulnerability Assessment, Nydia Bay North.

Category	Score
Values	0.69
Pressures	0.83
Susceptibility	0.80
Condition	0.91
Average Score	0.81

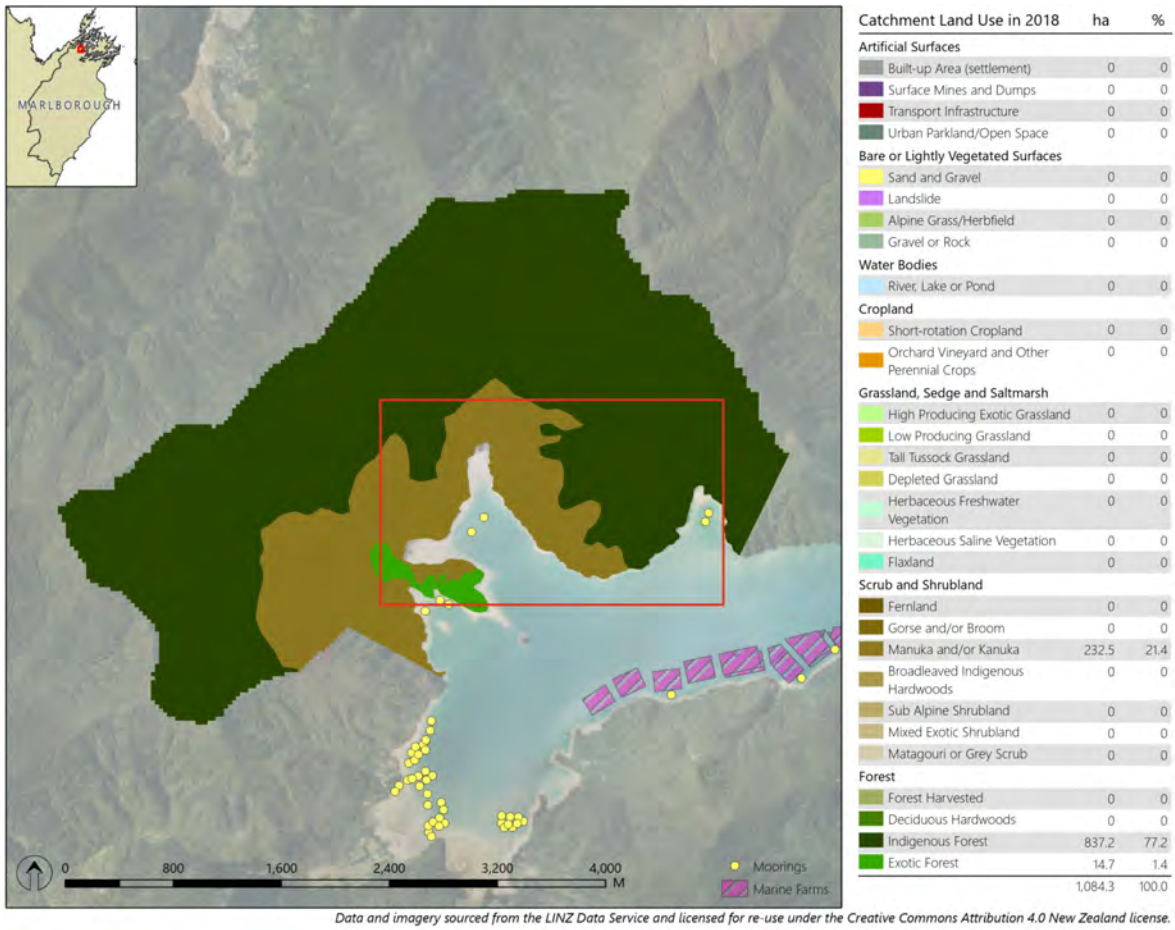

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Fig. A13.1. Nydia Bay North catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

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Fig. A13.2. Nydia Bay North intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Aerial view of estuary and the steep native bush catchment

Rushland and gravel/cobble substrate

Pacific oysters growing on gravel/cobble

Seagrass growing on firm muddy sands

The dominant substrate type gravel/cobble, rushland and steep native bush catchment

A14. Nydia Bay South (Nydia Bay)

Nydia Bay South comprises two medium-sized (29ha) intertidal estuaries in inner Nydia Bay within the greater Pelorus Sound (Fig. A14.2). The catchment is dominated by indigenous forest (93.7% indigenous vegetation cover; Fig. A14.1), with the upper catchment protected within the Nydia Bay Scenic Reserve and Paradise Bay Scenic Reserve. In the lower catchment there is a mix of indigenous vegetation, exotic forest and high producing grassland (Fig. A14.1).

The dominant substrate type in the estuary is gravel/cobble with mud-dominated sediments recorded across 15% of the intertidal area (Table A14.1). Salt marsh occurs at the head of both intertidal flats and mainly comprises rushland in the upper estuary and extensive areas of herbfield, particularly on the eastern intertidal flats. Salt marsh on the western flats is classified as a regionally significant wetland. There has been some historic drainage and reclamation of salt marsh on both flats.

In the recent (June 2022) rapid estuary assessment seagrass was recorded across 15% of the intertidal area with some signs of sediment smothering. Nuisance macroalgae was recorded across 5-15% of the intertidal area with patches localised to subtidal channels and the lower tidal range, growing on gravel/cobble substrate. The localised areas of macroalgae growth were not associated with any poor sediment condition, and no High Enrichment Conditions were recorded in the estuary. Pacific oysters growing on gravel/cobble are frequent across the intertidal flats.

Catchments pressures in Nydia Bay South include the high producing grassland at the head of the estuary and some small areas of exotic forest in the lower catchment. The estuary margin has also been modified, with historic drainage and reclamation of salt marsh evident on both tidal flats. The western flats also have two channels dredged through the intertidal flats for boat access. Human use is high with accommodation within the margin and the Nydia Track following the estuary edge. There are also a high number of moorings in Nydia Bay South and marine farms within the wider Nydia Bay that increase the risk of introduced marine pests, pathogens, and other marine contaminants. Overall, the estuary remains in good condition.

Table A14.1. Summary information for Nydia Bay South.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	29.1	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	15
Macroalgae (Ha; cover >50%)	-	5-15
Seagrass (Ha; cover >50%)	-	15
Salt Marsh (Ha; % intertidal)	-	20
High Enrichment Conditions (HEC)	-	0.0
Catchment		
Catchment Area (Ha)[2]	2203	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	93.7	
% Catchment exotic forest[2]	2.8	
% Producing grassland[2]	3.5	
Mean Freshwater Flow (m^3/s)[3]	0.7	
Catchment Nitrogen Load (T/y)[3]	6.0	
Catchment Phosphorus Load (T/y)[3]	1.2	
Catchment Sediment Load (KT/y)[3]	2.3	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish	nd	
Pressures		
Small area of catchment modification – grassland and exotic forest Pacific oysters Human use – boat users/ accommodation/ walking track High number of moorings and marine farms within 5km		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Maps;

Table A14.2. Ecological Vulnerability Assessment, Nydia Bay South.

Category	Score
Values	0.70
Pressures	0.71
Susceptibility	0.60
Condition	0.79
Average Score	0.70

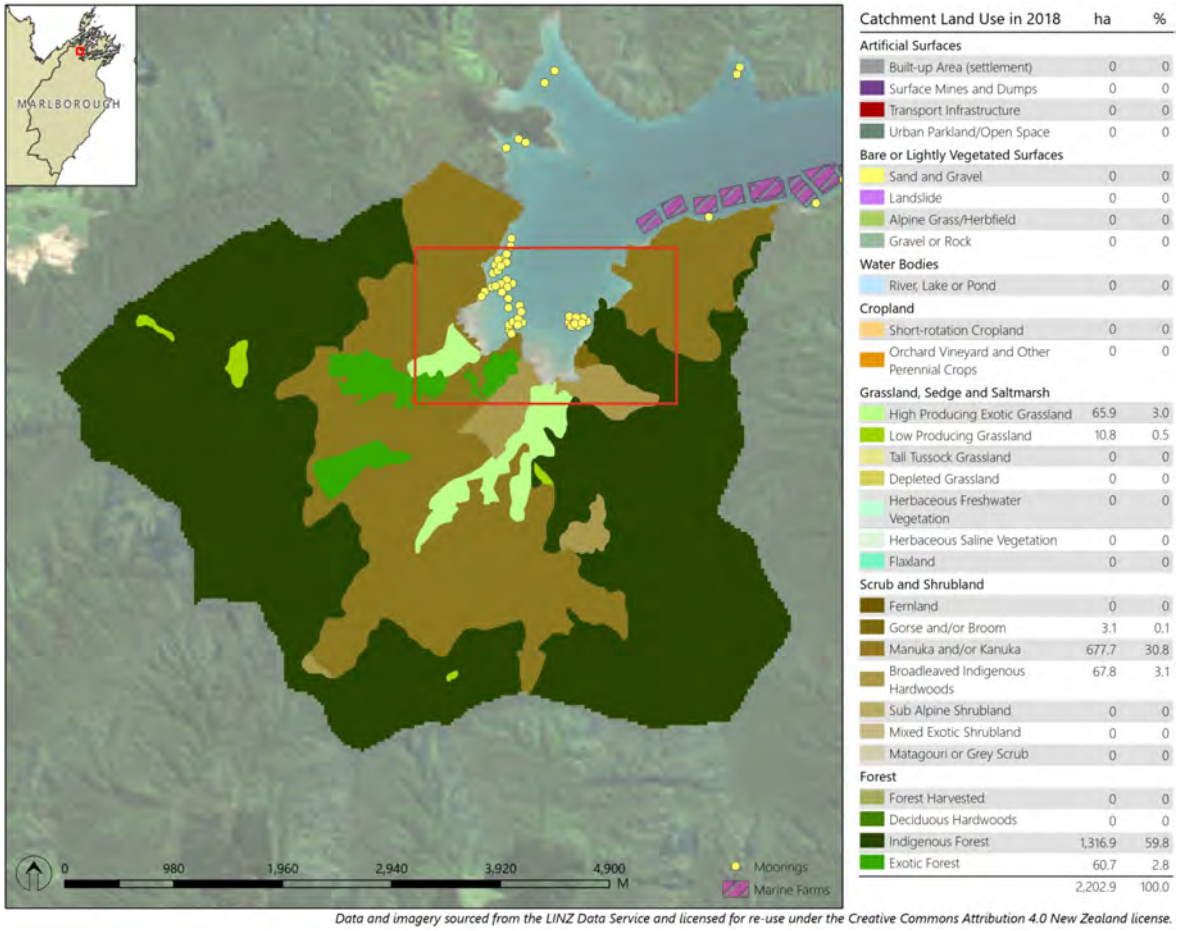

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Fig. A14.1. Nydia Bay South catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

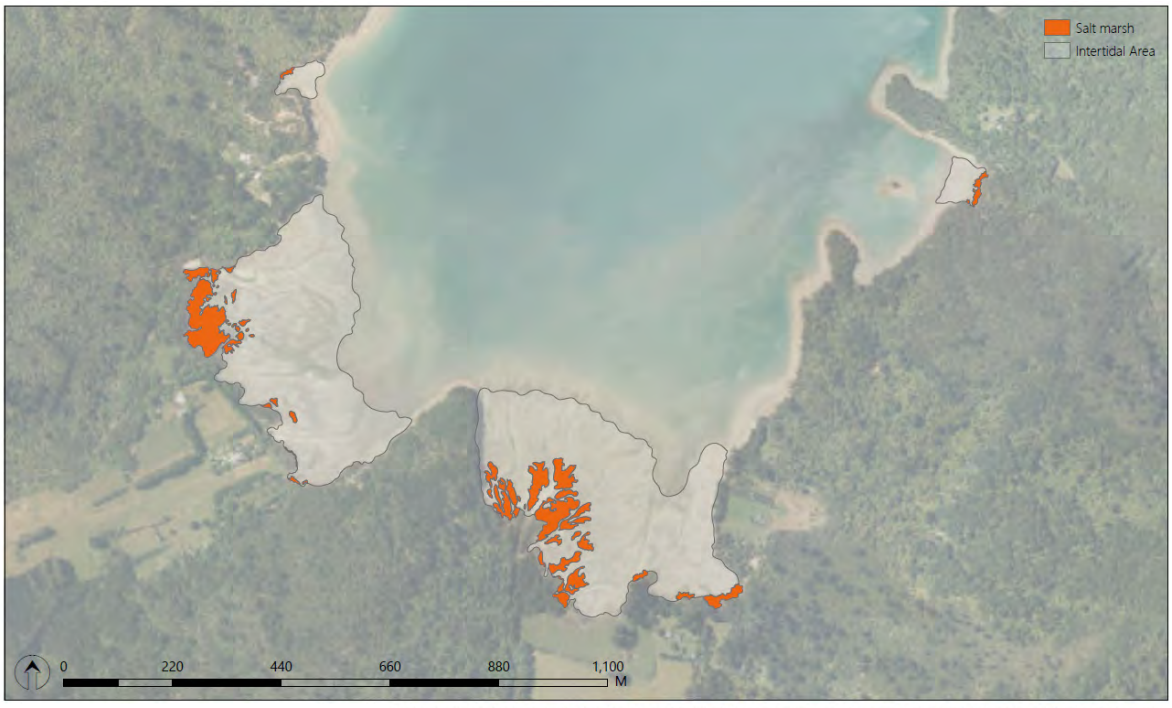

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Fig. A14.2. Nydia Bay South intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Western intertidal flats, with artificial channel in middle of estuary

Eastern intertidal flats, dominated by salt marsh herbfield

Channel in the middle of the western flats with Pacific oysters growing on gravel/cobble

Seagrass growing on firm muddy sands in between gravel and cockle shells

Nydia Bay South catchment with grassland up to the estuary margin and mixed native and exotic forest

A15. Penguin Bay (Nydia Bay)

Penguin Bay is a small (3.6ha) intertidal estuary in outer Nydia Bay within the greater Pelorus Sound. The steep catchment is 100% indigenous vegetation cove, and is protected within the Chance, Penguin and Fairy Bays Scenic Reserve.

The dominant substrate type in the estuary is gravel/cobble with no mud-dominated sediments recorded (Table A15.1). Salt marsh is localised to a small area near the main freshwater input, which transitions into indigenous forest. In the recent (June 2022) rapid estuary assessment, seagrass was not recorded, macroalgae was recorded across <5% of the intertidal area, and no High Enrichment Conditions were evident. Small mussels were observed growing in between gravel/cobble (see photo).

Catchments pressures in Penguin Bay are low due to the protected catchment. Human use is the most significant pressure. There are two jetties and two permanent moorings within Penguin Bay to support recreational use and service two properties on the margin. The number of boat users increases the risk of introduced marine pests, pathogens, and other marine contaminants. Aside from the incursion of the Pacific oyster the estuary is in very good condition, with a small area of high value salt marsh, mussels on the intertidal flats and a protected catchment.

Intertidal flats of Penguin Bay, jetty in background and native bush catchment

Table A15.1. Summary information for Penguin Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	3.6	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	0
Macroalgae (Ha; cover >50%)	-	<5
Seagrass (Ha; cover >50%)	-	0
Salt Marsh (Ha; % intertidal)	-	8
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	231.1	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.05	
Catchment Nitrogen Load (T/y)[3]	0.6	
Catchment Phosphorus Load (T/y)[3]	0.1	
Catchment Sediment Load (KT/y)[3]	0.5	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish	mussels	
Pressures		
Pacific oysters		
Human use – boat users/ baches		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Maps;

Table A15.2. Ecological Vulnerability Assessment, Penguin Bay.

Category	Score
Values	0.45
Pressures	0.86
Susceptibility	0.89
Condition	0.93
Average Score	0.78

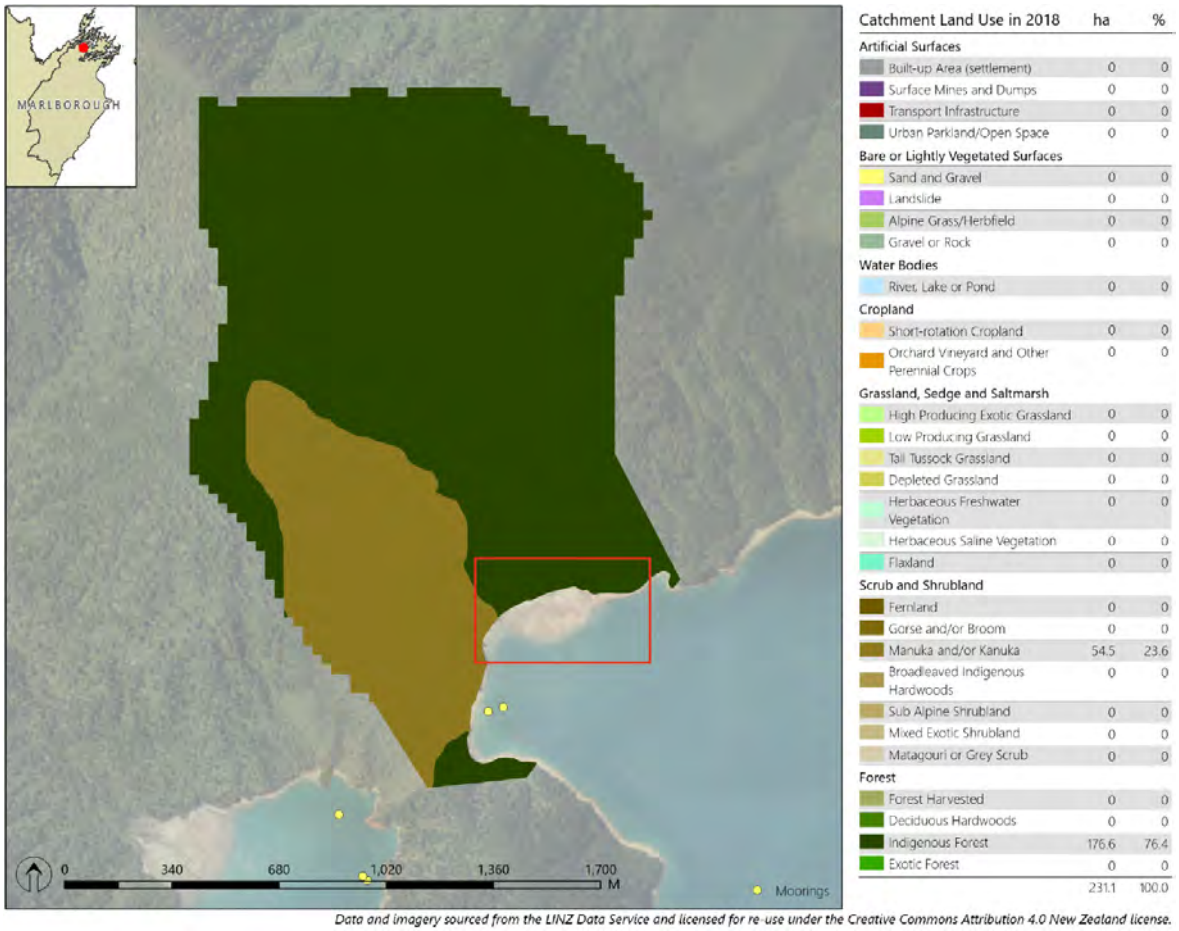

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Fig. A15.1. Penguin Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

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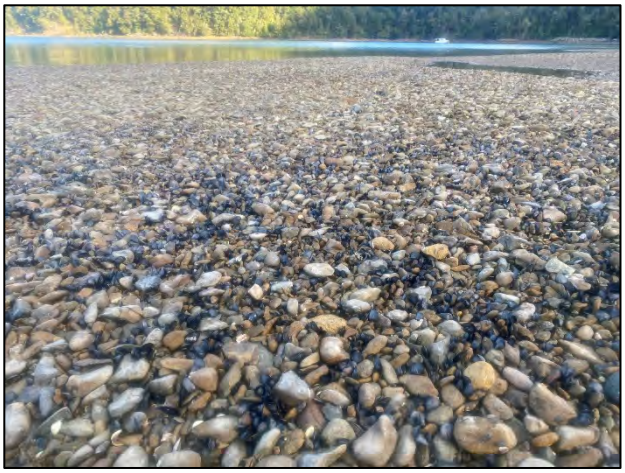
Fig. A15.2. Penguin Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Gravel/cobble at the main freshwater input

Steep native bush catchment



Mussels within gravel/cobble

Large boulders in front of an eroding estuary margin

Rushland and steep native bush catchment

A16. Clova Bay (Mid Pelorus)

Clova Bay is a medium-sized (19.1ha) intertidal estuary in between Beatrix and Crail Bays, in mid Pelorus Sound. The catchment is dominated by indigenous forest (69.1% indigenous vegetation cover; Fig. A16.1). However, the lower catchment is extensively developed for high producing grassland (15.4%) and exotic forestry (9.3%) on the steep hill slopes. Two small settlements are at the head of the Bay, Manaroa and Totaranui.

The estuary has been historically modified with the adjacent land cleared for farming and forestry. A sawmill used to exist on the estuary edge near Totaranui. The area has now been developed into a marina and barge loading site (i.e. for log loading). A channel to the marina is dredged to maintain access and the marina supports both the marine farming and forestry industry.

The dominant substrate type in the estuary is gravel/cobble with <5% mud-dominated sediments recorded across the intertidal flats (Table A16.1). Salt marsh comprises ~45% of the intertidal area and is mainly rushland with some herbfield vegetation on the seaward edge of the rushes. Salt marsh pressures include reclamation, drainage and weeds. Clova Bay is classified as an ESMS due to the relatively intact salt marsh and important adjacent shallow subtidal habitats (i.e. horse mussels and scallops). The salt marsh near Totaranui is classified as a regionally significant wetland. Seagrass is a minor feature in the estuary representing ~2% of the intertidal area. Macroalgae cover has been recorded as 5-15% of the intertidal area, however it is not associated with poor sediment conditions.

Compared to other small estuaries in the Marlborough region, nutrient and sediment loads to the estuary are relatively high likely owing to the developed catchment. Other pressures include marine farming within the subtidal zone of Clova Bay that could lead to an increase in marine pests, contaminants and pathogens. In a recent survey Pacific oysters were recorded as present on the intertidal flats. Further, several applications have been made to establish marine farms within the intertidal zone but to date have not been granted. In addition to commercial use (i.e. marina/barge transport), recreational use of Clova Bay is also relatively high with both boat access and road access to the estuary margin and vehicle access onto the intertidal flats. While the estuary is currently in good condition and retains high value salt marsh, the estuary is under stress from multiple pressures.

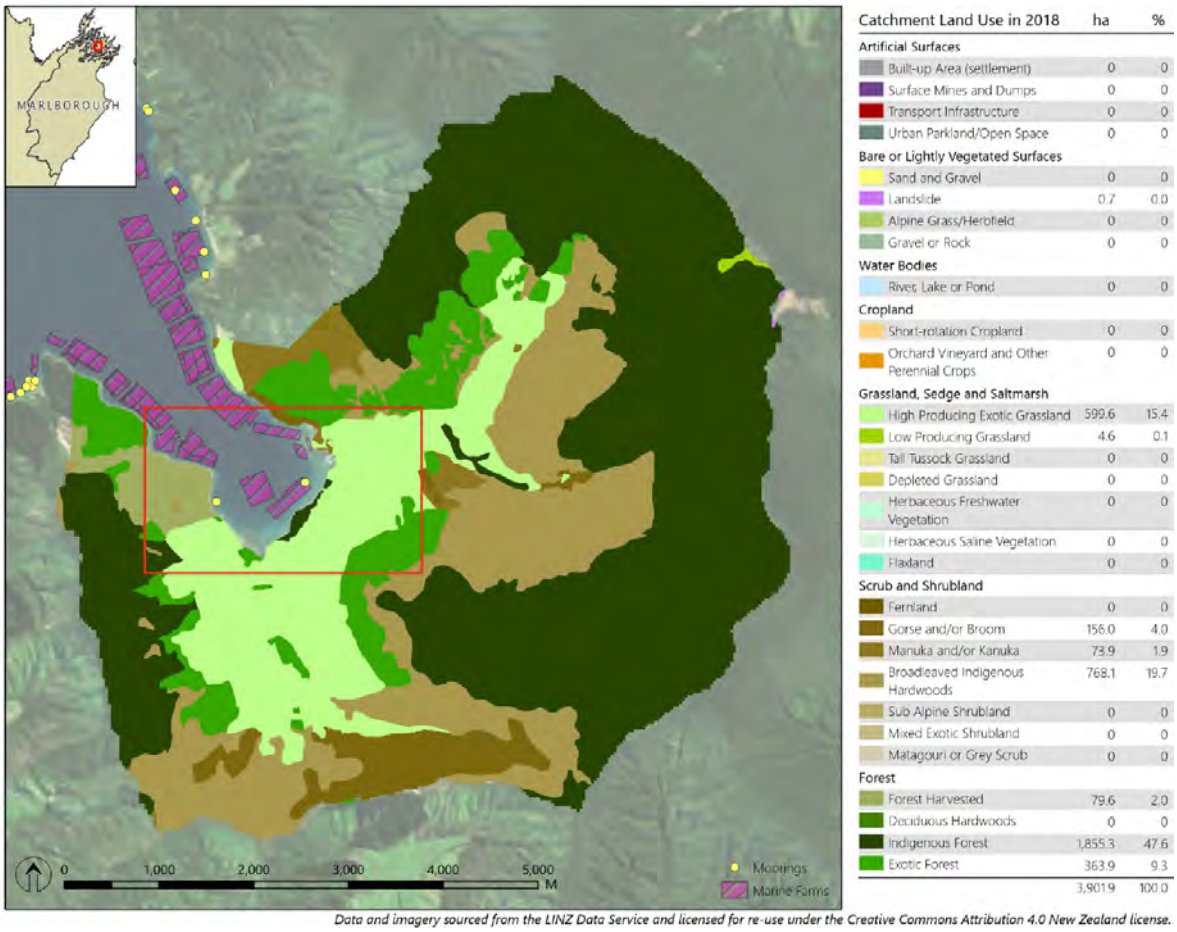
Table A16.1. Summary information for Clova Bay

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	19.1	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	5
Macroalgae (cover >50%)	-	5-15
Seagrass (cover >50%)	-	2
Salt Marsh (% intertidal)	-	45
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	3902	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	69.1	
% Catchment exotic forest[2]	9.3	
% Producing grassland[2]	15.5	
Mean Freshwater Flow (m^3/s)[3]	1.7	
Catchment Nitrogen Load (T/y)[3]	11.8	
Catchment Phosphorus Load (T/y)[3]	3.3	
Catchment Sediment Load (KT/y)[3]	12.0	
Catchment Geology[4]	Sandstone (breccia & gravels)	
Biodiversity		
ESMS	Y – 3.14	
Significant Wetland	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin Bully	
Shellfish	nd	
Pressures		
Catchment development – high producing grassland and exotic forestry Marina/ barge loading site Modification to the estuary margin (i.e. reclamation) Incursion pacific oysters Marine farms Vehicle access to the intertidal flats.		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Map; nd = no data

Table A16.2. Ecological Vulnerability Assessment, Clova Bay

Category	Score
Values	0.59
Pressures	0.68
Susceptibility	0.63
Condition	0.82
Average Score	0.68



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0.7	0.0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	599.6	15.4
Low Producing Grassland	4.6	0.1
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	156.0	4.0
Manuka and/or Kanuka	73.9	1.9
Broadleaved Indigenous Hardwoods	768.1	19.7
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	79.6	2.0
Deciduous Hardwoods	0	0
Indigenous Forest	1,855.3	47.6
Exotic Forest	363.9	9.3
	3,901.9	100.0

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Fig. A16.1. Clova Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

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Fig. A16.2. Intertidal areas within Clova Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Drone image of Clova Bay intertidal area (Image ref: MDC 'Pelorus ClovaBay 04 Bright, Courtesy of Marlborough District Council)

Drone image of Clova Bay intertidal area (Image ref: MDC 'Pelorus ClovaBay 06 Bright, Courtesy of Marlborough District Council)

A17. Crail Bay – Elie Bay (Mid Pelorus)

Elie Bay is a medium-sized (16.8ha) shallow intertidally dominated estuary in Crail Bay in mid Pelorus Sound. The catchment is dominated by broadleaved indigenous hardwoods (75.7% indigenous vegetation cover; Table A17.1). High producing grassland is at the head of the estuary and exotic forestry comprises 12.3% of the northeast and southwest catchment.

Robertson (2020c) recorded cobble as the dominant substrate type, with firm muddy sand on the mid to lower intertidal flats and around the main freshwater input (Fig. A17.2). The sediments were described as well oxygenated with low levels of enrichment in the most recent survey (Robertson 2020c).

Salt marsh comprises a small area (5.5% of the intertidal area) at the head of the estuary and a narrow strip on the northeast margin (Robertson 2020c). Salt marsh is mainly rushland (*Juncus kraussii)* with herbfield *(Samolus repens*) on the seaward edge of the rushland (Robertson 2020c). Seagrass was present across the intertidal flats growing on firm muddy sands and in depressions within the cobble beds (Fig. A17.2; Robertson 2020c). No areas of nuisance macroalgal growth (>50% cover) were recorded in the estuary and there was no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen; Robertson 2020c). Mud-dominated sediments were not a common feature in the estuary (Robertson 2020c). Cockle beds were observed in the mid to lower tidal range.

The main pressures in Elie Bay are development in the lower catchment including high producing grassland on the estuary margin and exotic forestry due for harvest within the next 10 to 15 years. Other pressures include marine farming within the subtidal zone of Elie Bay that could lead to increased marine pests, pathogens and contaminants. A localised area of Pacific oysters was recorded on the intertidal flats in the most recent survey (Robertson 2020c). Shoreline hardening to support roading infrastructure is along common on the northern margin.

While the estuary is currently in good condition activities that increase sediment and nutrient loads to the estuary could threaten existing habitats including seagrass and cockle beds.

Table A17.1. Summary information for Crail Bay – Elie Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	16.8	-
Intertidal Area (Ha; % Estuary)[1]	14.6	86.9
Dominant Estuary Substrate[1]	Cobble	
Mud extent (>50% mud content)	0.0	0.0
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	1.9	12.9
Salt Marsh (Ha; % intertidal)[1]	0.8	5.5
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	984.9	
Dominant Catchment Land Cover[2]	Broadleaved indigenous hardwoods	
% Catchment indigenous vegetation[2]	75.7	
% Catchment exotic forest[2]	12.3	
% Producing grassland[2]	12.0	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	2.9	
Catchment Phosphorus Load (T/y)[3]	0.7	
Catchment Sediment Load (KT/y)[3]	2.2	
Catchment Geology[4]	Gravel (breccia & sandstone)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	N	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish[1]	Cockles	
Pressures		
Development in the catchment – exotic forestry and high producing grassland		
Marine farms in the wider bay		
Pacific Oyster		
Modified margin including shoreline hardening		
Moorings within 5km		

[1]Robertson (2020c); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap
[5]MDC Smart Maps

Table A17.2. Ecological Vulnerability Assessment, Crail Bay – Elie Bay.

Category	Score
Values	0.61
Pressures	0.71
Susceptibility	0.67
Condition	0.92
Average Score	0.73

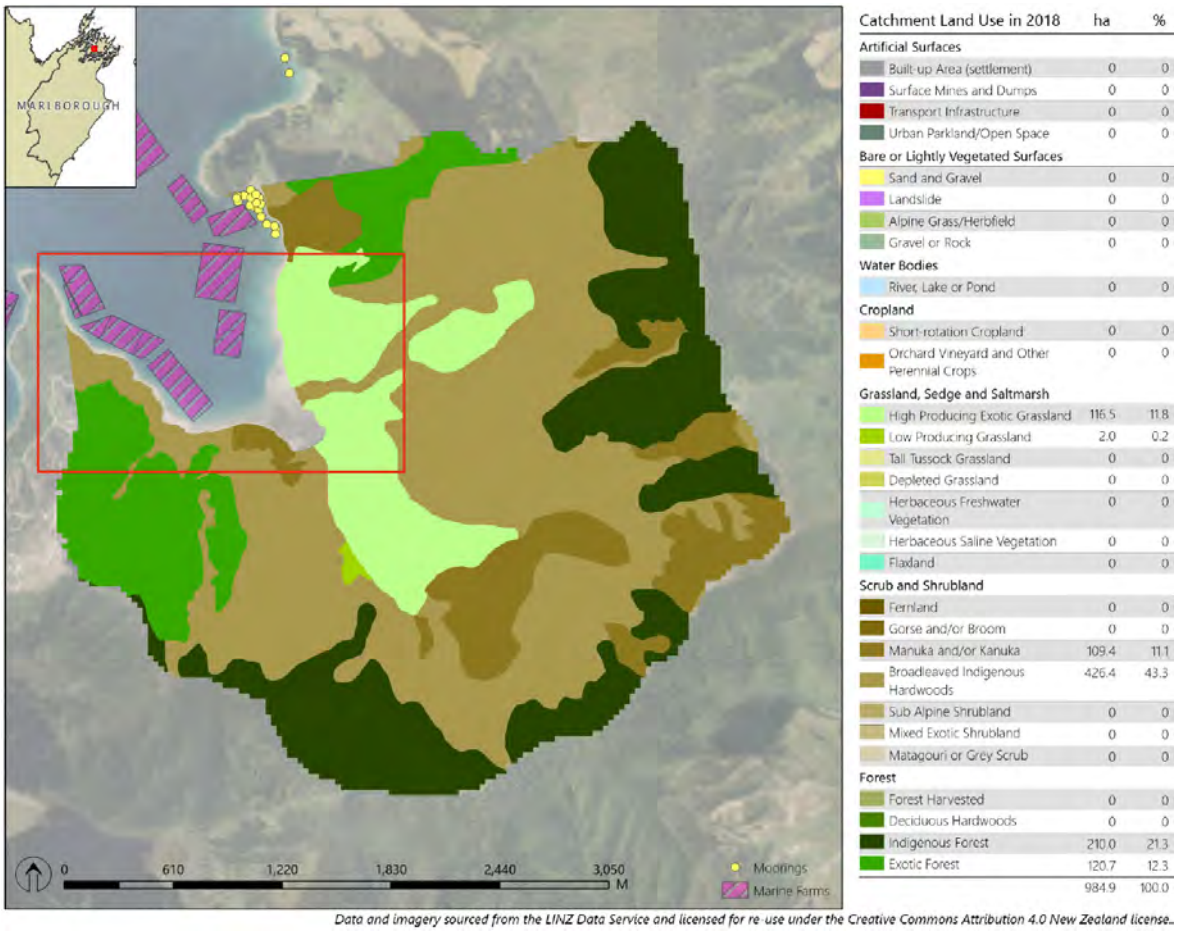

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Fig. A17.1. Crail Bay – Elie Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

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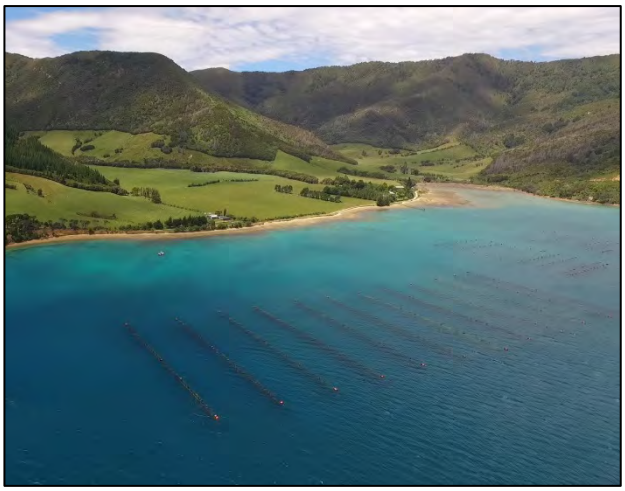
Fig. A17.2. Crail Bay – Elie Bay dominant vegetation and substrate features (data source: Robertson 2020c).

Rushland on the upper estuary margin and bushy backdrop (source: Robertson 2020)

Salt marsh (rushland and herbfield) and seagrass beds (source: Robertson 2020)

Shoreline hardening in Crail Bay – Elie Bay (source: Robertson 2020)



Marine farms in Elie Bay, intertidal area in background (Image ref: MDC 'Pelorus ElieBay 05 Bright', Courtesy of Marlborough District Council)

Seagrass and epibiota (source: Robertson 2020)

Seagrass beds on firm muddy sand (source: Robertson 2020)

A18. Crail Bay – Wet Inlet (Mid Pelorus)

Wet Inlet is a medium-sized (18.9ha) shallow intertidally dominated estuary in Crail Bay in mid Pelorus Sound. The catchment is dominated by indigenous forest (68.5% indigenous vegetation cover; Table A18.1). High producing grassland (3.7%) is at the head of the estuary and exotic forestry comprises 23.2% of the catchment. Native bush remains in the upper catchment (Fig. A18.1).

The dominant substrate type in the estuary is firm muddy sand with gravel/cobble on the mid estuary flats and along the margin (Robertson 2020c). In a broad scale survey mud-dominated (>50% mud) sediments were not recorded.

Salt marsh comprises a small area (4% of the intertidal area) at the head of the estuary and a narrow strip on the southwest margin. Salt marsh comprises estuarine shrub (*Plagianthus divaricatus*) and rushland (*Juncus kraussii)* in the upper estuary and herbfield *(Samolus repens*) on the seaward tidal flats (Robertson 2020c). Seagrass was present across the intertidal flats growing on firm muddy sands and in depressions within the cobble beds (Fig. A18.2; Robertson 2020c). No areas of nuisance macroalgal growth (>50% cover) were recorded in the estuary and there was no evidence of high enrichment conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

The main pressures in Wet Inlet are development in the lower catchment including exotic forestry due for harvest in the next 10 to 15 years, and to a lesser extent high producing grassland at the head of the estuary. There is the potential for sediment inputs to increase following future forest harvesting (Robertson 2020c). While human use is not as high in the mid to outer Sounds there is road access to the estuary margin, with some historic reclamation also in that area. Other pressures include marine farming within the subtidal zone of Wet Inlet that could lead to an increase in marine pests, contaminants and pathogens. A localised area of Pacific oysters was recorded in the broad scale survey (Robertson 2020c).

While the estuary is currently in good condition, activities that increase sediment and nutrient loads to the estuary could threaten existing habitats including seagrass and salt marsh.

Table A18.1. Summary information for Crail Bay – Wet Inlet.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	18.9	
Intertidal Area (Ha; % Estuary)[1]	16.8	88.9
Dominant Estuary Substrate[1]	Firm muddy sand	
Mud extent (>50% mud content)	0.0	0.0
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	1.3	7.4
Salt Marsh (Ha; % intertidal)[1]	0.7	4.0
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	1072.8	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	68.5	
% Catchment exotic forest[2]	23.2	
% Producing grassland[2]	3.7	
Mean Freshwater Flow (m^3/s)[3]	0.4	
Catchment Nitrogen Load (T/y)[3]	3.7	
Catchment Phosphorus Load (T/y)[3]	0.6	
Catchment Sediment Load (KT/y)[3]	3.4	
Catchment Geology[4]	Sandstone (breccia & gravel)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish	nd	
Pressures		
Development in the catchment – exotic forestry and high producing grassland		
Marine farms in the wider bay		
Pacific Oyster		
Modified margin		
Moorings within 5km		

[1]Robertson (2020c); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A18.2. Ecological Vulnerability Assessment, Crail Bay – Wet Inlet.

Category	Score
Values	0.51
Pressures	0.75
Susceptibility	0.54
Condition	0.93
Average Score	0.68

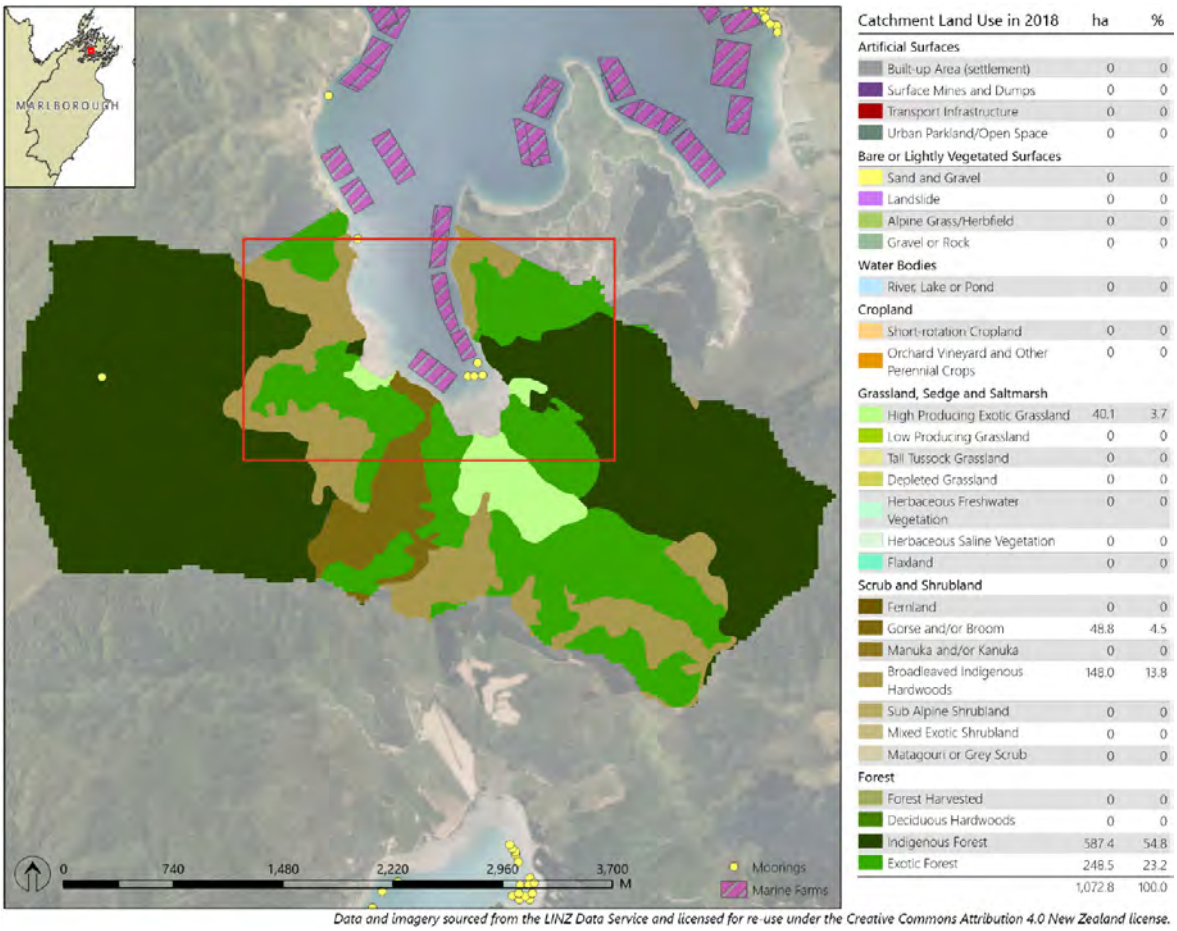


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Fig. A18.1. Crail Bay – Wet Inlet catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

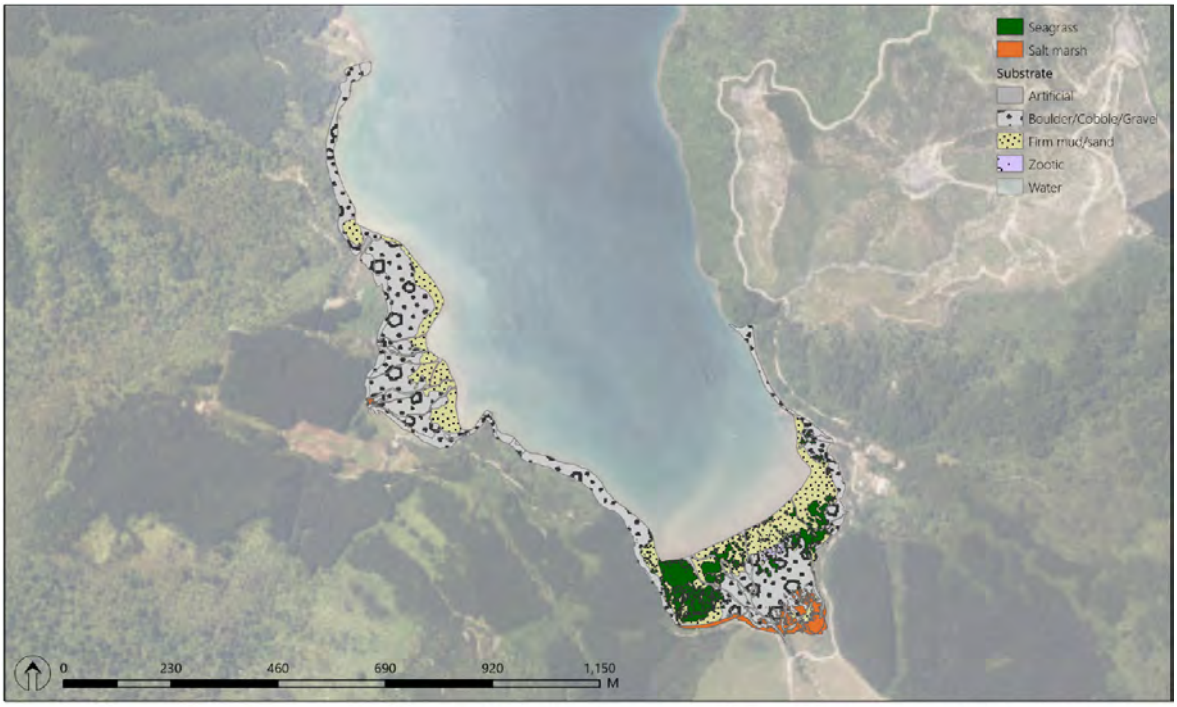

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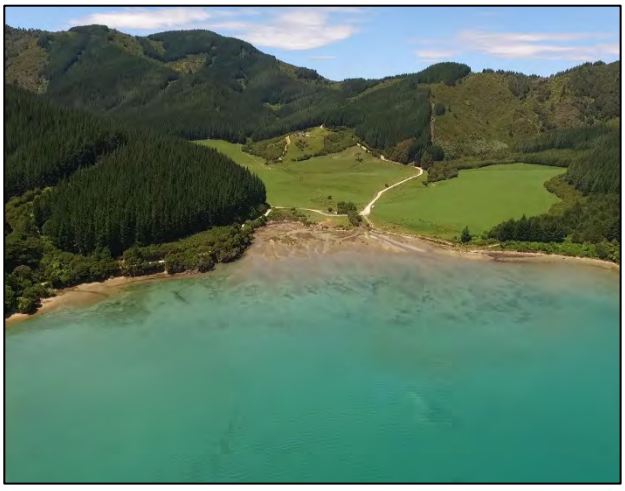
Fig. A18.2. Crail Bay – Wet Inlet dominant vegetation and substrate features (data source: Robertson 2020c).

Rushland in the upper estuary

Salt marsh (rushland and herbfield)



Aerial view of Wet Inlet and lower catchment (Image ref: MDC 'Pelorus WetInlet 03', Courtesy of Marlborough District Council)

Aerial view of the tidal flats and marine farming in the background (Image ref: MDC 'Pelorus WetInlet 06', Courtesy of Marlborough District Council)

Cobbles and seagrass beds

Seagrass beds in the lower estuary and a jetty

A19. Fairy Bay (Mid Pelorus)

Fairy Bay is a small (3.2ha) intertidally dominated estuary in mid Pelorus Sound. The steep catchment is dominated by indigenous forest (99.5% indigenous vegetation cover; Table A19.1), and almost completely protected within the Chance, Penguin and Fairy Bays Scenic Reserve.

The dominant substrate type in the estuary is gravel/cobble with no mud-dominated sediments recorded (Table A19.1). Salt marsh comprises ~15% of the intertidal area and is mainly rushland with some estuarine shrubs on the upper margin. Salt marsh transitions into indigenous vegetation cover, however there are some mixed exotics at the head of the estuary. The salt marsh is classified as a regionally significant wetland. Seagrass is sparse and has been recorded across only 5% of the intertidal area.

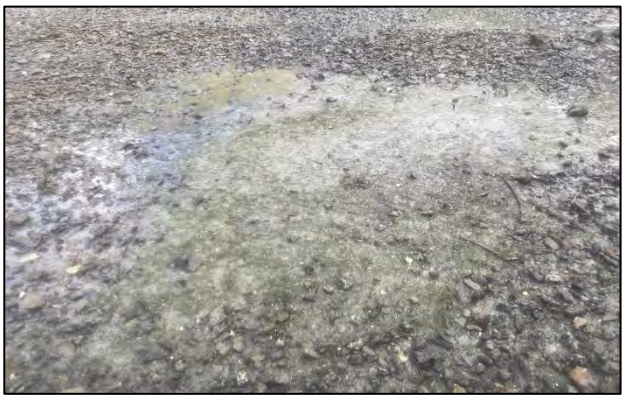
In the recent rapid estuary assessment macroalgae was recorded across <5% of the intertidal area. *Ulva* spp. was observed growing in shallow subtidal channels on gravel/cobble substrate (see photo). The localised areas of macroalgae growth were not associated with any poor sediment condition, and no High Enrichment Conditions were recorded. Pacific oysters growing on gravel/cobble are common across the intertidal flats (see photos).

Catchment pressures in Fairy Bay are low due to the protected catchment. Human use is the most significant pressure. Fairy Bay is popular with boat users and recreation is supported by both permanent moorings and safe anchorage within the bay. There are several private baches within the estuary margin and a jetty on the lower tidal flats and others further out in the Bay. These factors increase the likelihood of marine contaminants, pests and pathogens being introduced to the area. Overall, the estuary has high value salt marsh and is in good condition.

Table A19.1. Summary information for Fairy Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	
Intertidal Area (Ha; % Estuary)[1]	3.2	-
Dominant Estuary Substrate	gravel/cobble	
Mud extent (>50% mud content)	-	0
Macroalgae (Ha; cover >50%)	-	<5
Seagrass (Ha; cover >50%)	-	1
Salt Marsh (Ha; % intertidal)	-	15
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	730.6	
Dominant Catchment Land Cover[2]	Indigenous forest	
% Catchment indigenous vegetation[2]	99.5	
% Catchment exotic forest[2]	0.5	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	1.6	
Catchment Phosphorus Load (T/y)[3]	0.3	
Catchment Sediment Load (KT/y)[3]	2.8	
Catchment Geology[4]	Sandstone (breccia & gravel)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin bully, koaro	
Shellfish	nd	
Pressures		
Remote boat access		
High number of moorings		
Local baches with jetties		
Species incursion – Pacific oysters		

[1]Aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;



Seagrass growing in Fairy Bay

Table A19.2. Ecological Vulnerability Assessment, Fairy Bay.

Category	Score
Values	0.66
Pressures	0.85
Susceptibility	0.74
Condition	0.93
Average Score	0.79

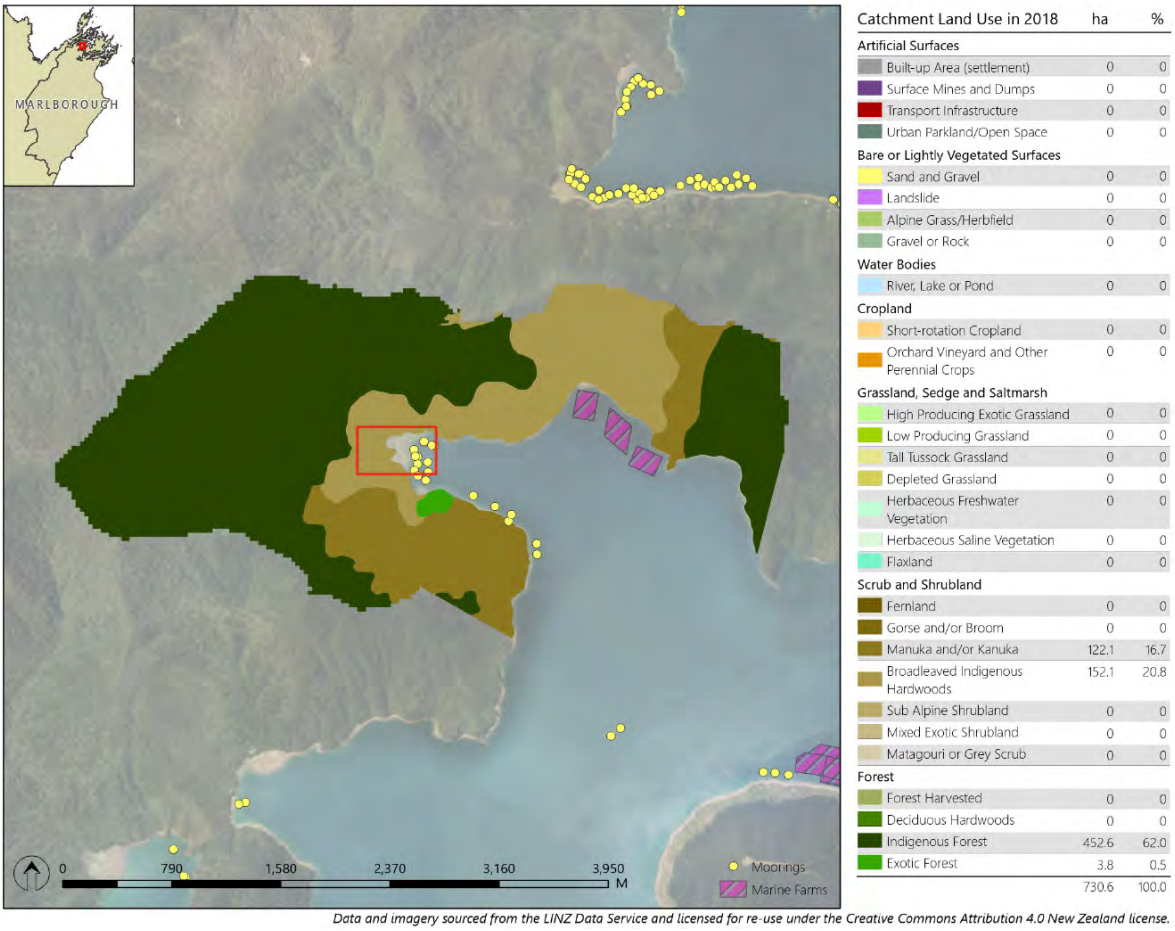


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Fig. A19.1. Fairy Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

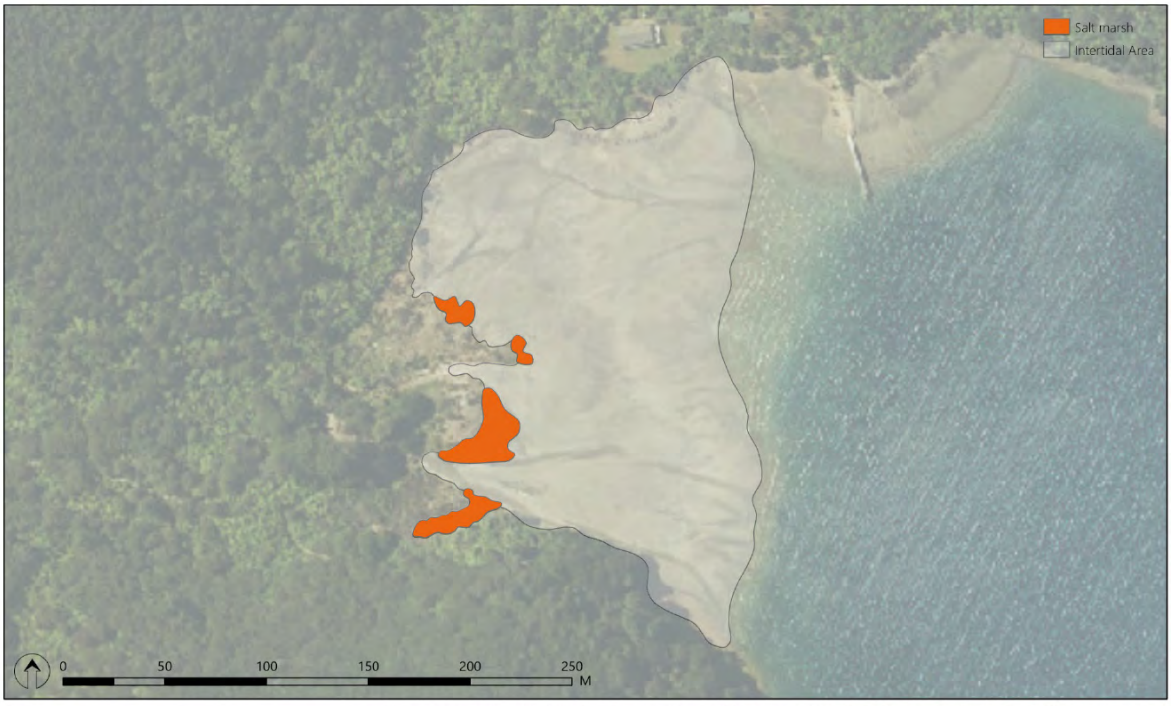

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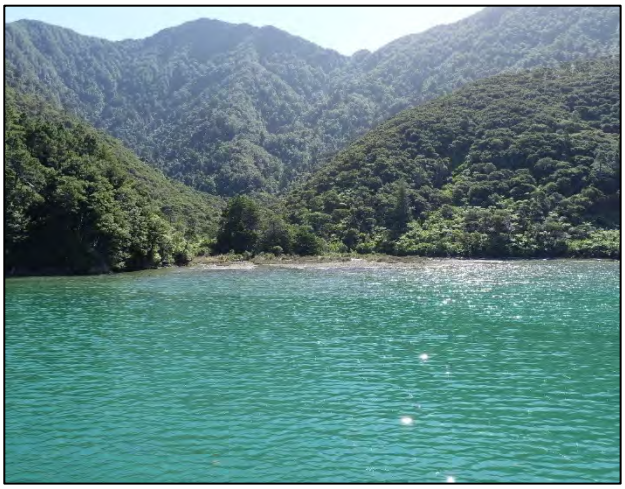
Fig. A19.2. Fairy Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Rushland growing in gravel/cobble in the upper estuary

Rushland and native bush catchment in the background



Steep native bush catchment

Drone image of intertidal flats showing salt marsh in the upper estuary

Pacific oyster beds in the lower estuary

Ulva spp. growing on gravel/cobble channel margin

A20. North West Bay (Mid Pelorus)

North West Bay is in mid Pelorus Sound and has a number of small intertidal areas, with two considered to be small (3.1ha) shallow intertidally dominated estuaries. The catchment is mainly broadleaved indigenous hardwoods with indigenous forest in the upper catchment. In total the catchment comprises 96.6% indigenous vegetation cover. In the wider bay there is a small area of high producing grassland and exotic forest to the north, however these catchment land uses are unlikely to directly affect the small intertidal estuaries to the south (Fig. A20.1).

A recent field assessment has not been undertaken at North West Bay; hence the following information is based on a desktop assessment and should be treated with caution. Based on aerial imagery and photos the estuary is dominated by gravel/ cobble. It is uncertain whether mud-dominated sediments are present, and fine sediment deposition is unlikely to be an issue if the catchment remains in indigenous vegetation cover.

Salt marsh comprises ~5% of the intertidal area and is dominant around the main freshwater inputs. The main salt marsh type is rushland, with some herbfield on the seaward edge (see photos). Salt marsh on the southwest intertidal flats is classified as a regionally significant wetland, and from the aerial imagery it appears that salt marsh transitions into freshwater wetland vegetation. No significant growths of nuisance macroalgae can be seen on the imagery. Low nutrient loads and the native forest catchment mean it is unlikely that macroalgae will reach nuisance levels. It is uncertain from the information available whether seagrass is present in the estuary.

The main pressures to the intertidal areas in North West Bay are human use. The main access to North West Bay is via boat and there are a number of residential properties within the margin that have permanent jetties, with minor domestic wastewater discharges. There are also a high number of moorings within the bay increasing the likelihood of marine contaminants, pests and pathogens being introduced to the area.

While the estuary is subject to some localised pressures, overall it appears to be in good condition with a small area of salt marsh habitat that transitions to freshwater wetland vegetation. However, a field visit would be required to confirm these findings.

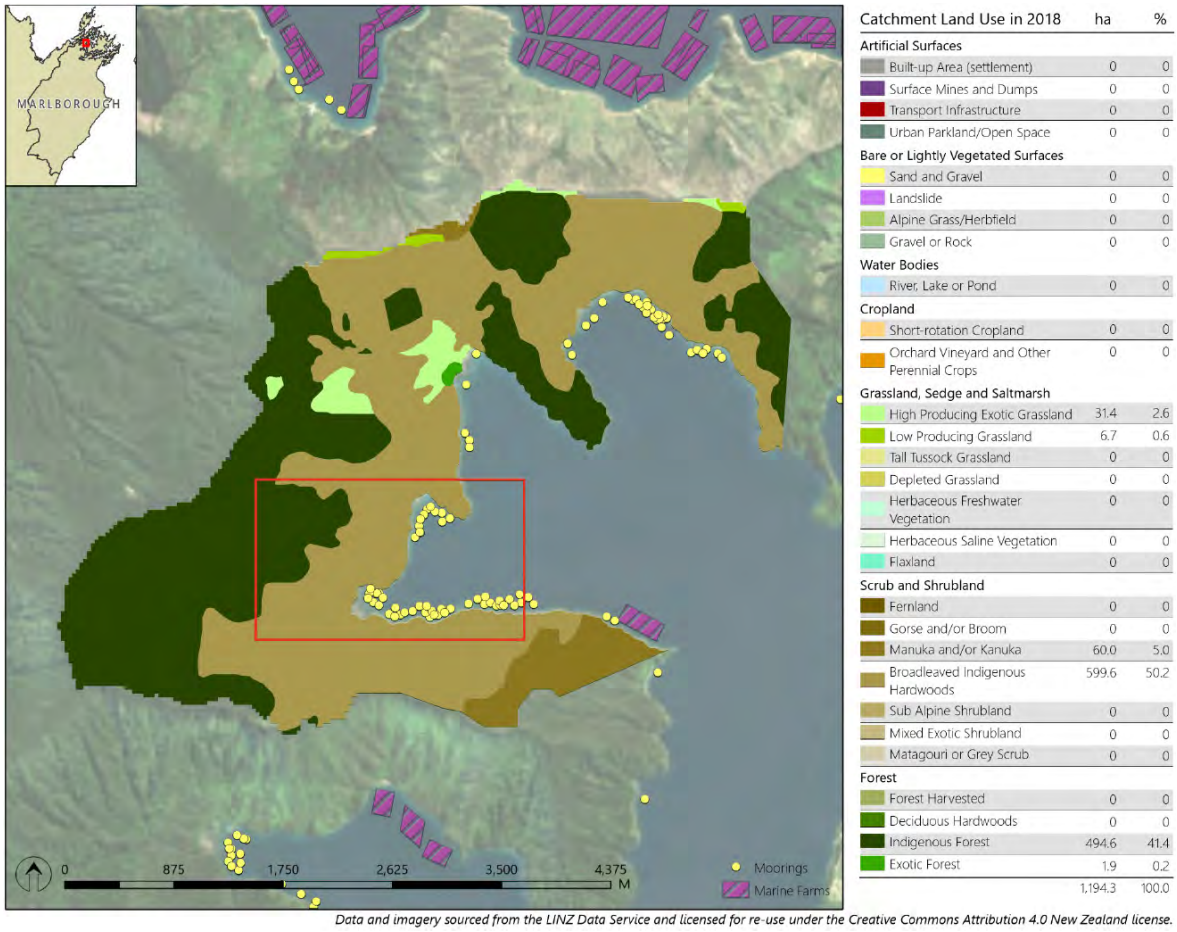
Table A19.1. Summary information for North West Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	3.1	-
Dominant Estuary Substrate	gravel/cobble	
Mud extent (>50% mud content)	-	nd
Macroalgae (Ha; cover >50%)	-	<5
Seagrass (Ha; cover >50%)	-	nd
Salt Marsh (Ha; % intertidal)	-	~5
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	1194	
Dominant Catchment Land Cover[2]	Broadleaved indigenous hardwoods	
% Catchment indigenous vegetation[2]	96.6	
% Catchment exotic forest[2]	0.2	
% Producing grassland[2]	3.2	
Mean Freshwater Flow (m^3/s)[3]	0.3	
Catchment Nitrogen Load (T/y)[3]	2.5	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	2.8	
Catchment Geology[4]	Sandstone (breccia & gravel)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	Y – salt marsh	
Birds	nd	
Fish[5]	Redfin bully, koaro	
Shellfish	nd	
Pressures		
Remote boat access		
High number of moorings		
Local baches with jetties		
Pacific oyster - unknown		

[1]Aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap [5]MDC Smart Maps;

Table A19.2. Ecological Vulnerability Assessment, North West Bay.

Category	Score
Values	0.52
Pressures	0.81
Susceptibility	0.74
Condition	0.90
Average Score	0.74



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	31.4	2.6
Low Producing Grassland	6.7	0.6
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	0	0
Manuka and/or Kanuka	60.0	5.0
Broadleaved Indigenous Hardwoods	599.6	50.2
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	0	0
Deciduous Hardwoods	0	0
Indigenous Forest	494.6	41.4
Exotic Forest	1.9	0.2
	1,194.3	100.0

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Fig. A20.1. North West Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

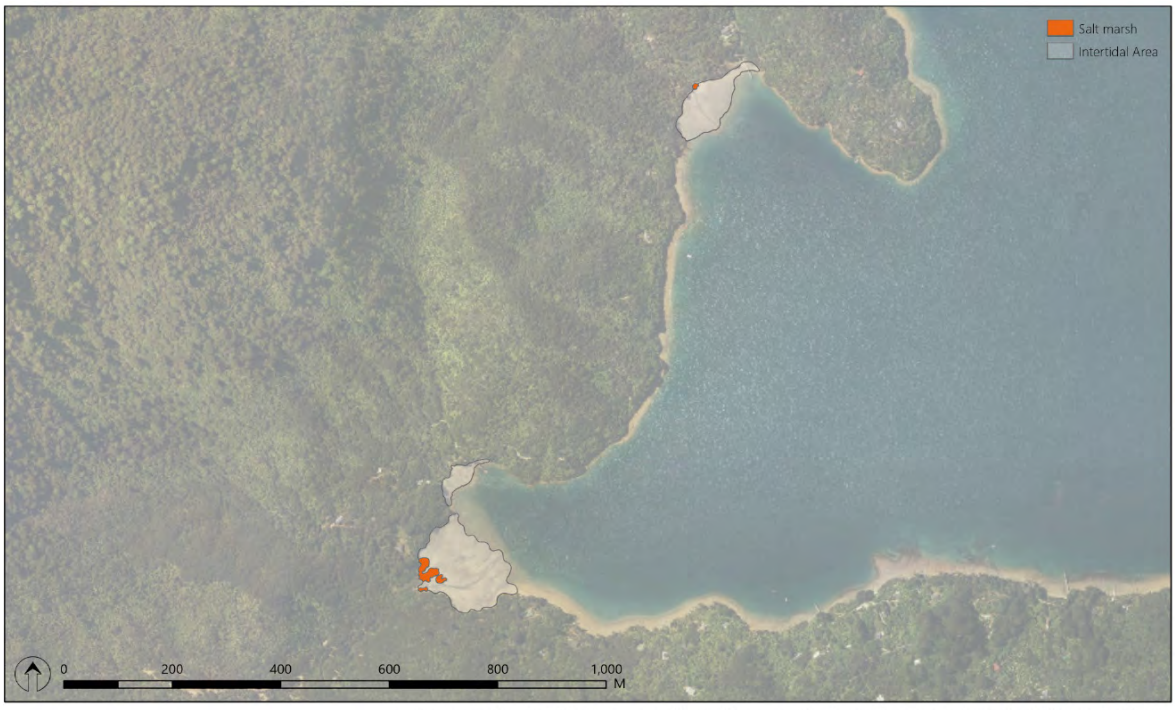

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Fig. A20.2. North West Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Aerial view of North West Bay - the intertidal areas are within the background embayments (source: Matthew Croad)

Intertidal area in North West Bay (source: Matthew Croad)

A21. Duncan Bay (Tennyson Inlet)

Duncan Bay is a moderate- sized (14.2ha) intertidally dominated estuary in Tennyson Inlet in the greater Pelorus Sound. The catchment is dominated by indigenous vegetation cover (95.3%) and is mainly protected within the Tennyson Inlet Scenic Reserve. The lower catchment is more developed with high producing grassland (3.2%) and a settlement (1.2%) at the head of the estuary.

The dominant substrate type in the estuary is cobble (Fig. A21.2). Mud-dominated sediments overlay buried cobble on the lower shoreline, and accumulate within Pacific oyster beds (Stevens 2018c). Salt marsh comprises 21.6% of the intertidal area at the head of the estuary. Salt marsh consists of rushland (*Juncus kraussii* and *Apodasmia similis*), estuarine shrub (*Plagianthus divaricatus*) and herbfield (*Samolus repens*; Stevens 2018). While the salt marsh is classified as a regionally significant wetland, aerial imagery shows there is vehicle access to the estuary flats through the salt marsh habitat.

Seagrass is relatively widespread across the intertidal flats (Fig. A21.2) with high cover in subtidal channels and patchy cover growing within depressions in cobble and in sand or muddy sand (Stevens 2018c). In the 2018 broad scale survey, seagrass beds in the low tide zone were covered in a fine layer of mud (Stevens 2018c). No areas of nuisance macroalgal growth (>50% cover) were recorded and there was no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

While mud-dominated sediments were recorded in the estuary, these areas are unlikely to deteriorate if the native forest cover in the catchment remains stable (Stevens 2018c). However, the valley at the head of the estuary has been historically cleared and converted to pasture and could be a minor source of nutrients and sediment. There is also a small residential settlement at the head of the estuary with minor domestic wastewater discharges. Human use of the estuary is high, with Duncan Bay being the end point of the Nydia track, and there is both boat and road access. A boat ramp, jetty and high number of permanent moorings within the bay increase the likelihood of marine pests, contaminants and pathogens being introduced to the area. Pacific oysters have already been recorded in the estuary.

Overall, Duncan Bay is in good condition and is not expressing signs of eutrophication. It has both high value seagrass beds and salt marsh habitat, and is classified as an ESMS (Table A21.1).

Table A21.1. Summary information for Duncan Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	14.2	
Intertidal Area (Ha; % Estuary)[1]	8.8	62.0
Dominant Estuary Substrate[1]	Cobble	
Mud extent (>50% mud content)	0.8	9.1
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.4	4.5
Salt Marsh (Ha; % intertidal)[1]	1.9	21.6
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	801.0	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	95.3	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	3.2	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	2.1	
Catchment Phosphorus Load (T/y)[3]	0.5	
Catchment Sediment Load (KT/y)[3]	3.5	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS[5]	Y – 3.10	
Significant Wetland[6]	Y – salt marsh	
Birds[5]	Banded rail	
Fish[6]	Redfin bully	
Shellfish		
Pressures		
Development in the catchment – pasture		
Some areas of soft mud habitat		
Pacific Oyster		
High human use: boat use/ road access/ Nydia Track		
High number of moorings		
Residential area – domestic wastewater		
Vehicle access to the estuary through salt marsh		

[1]Stevens (2018c); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al. (2011); [6]MDC Smart Maps

Table A21.2 Ecological Vulnerability Assessment, Duncan Bay.

Category	Score
Values	0.76
Pressures	0.73
Susceptibility	0.70
Condition	0.87
Average Score	0.77

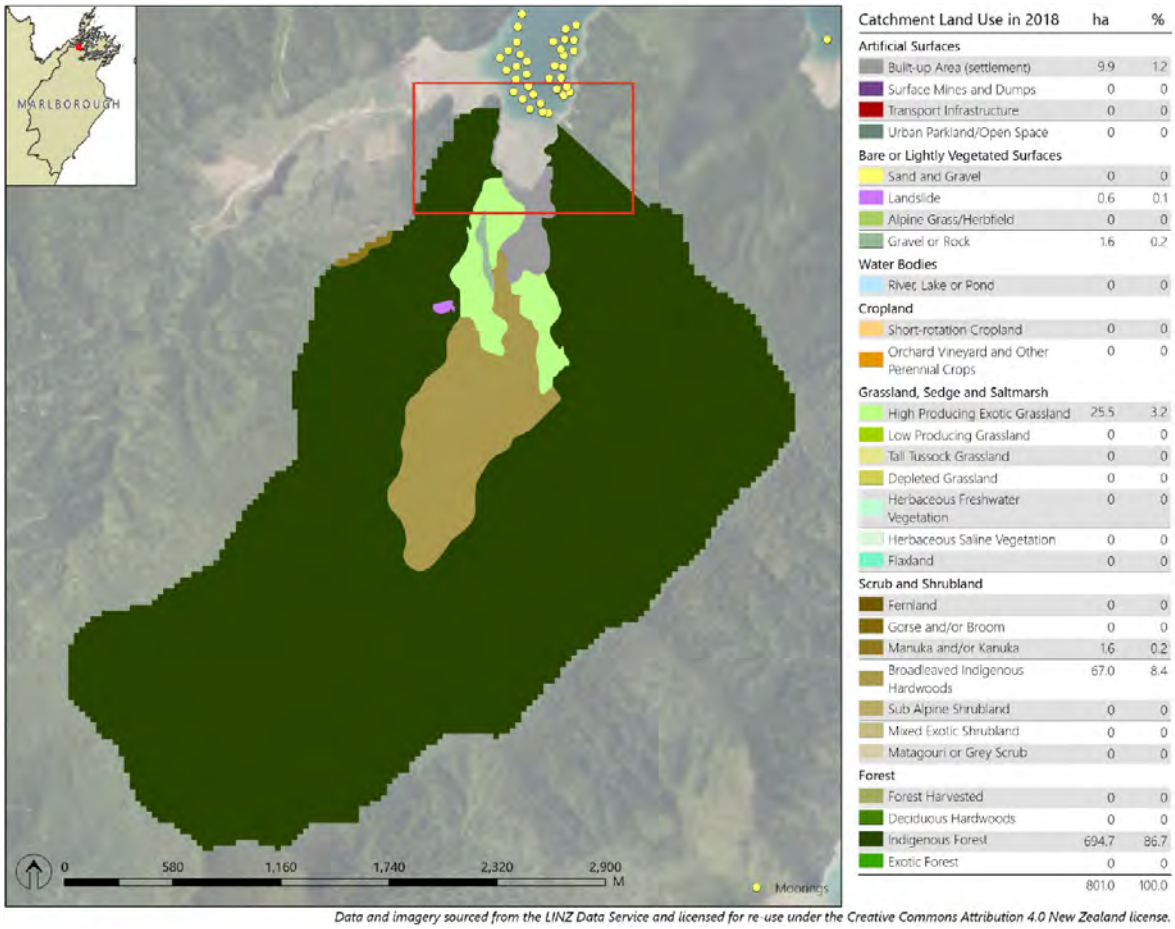

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Fig. A21.1. Duncan Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

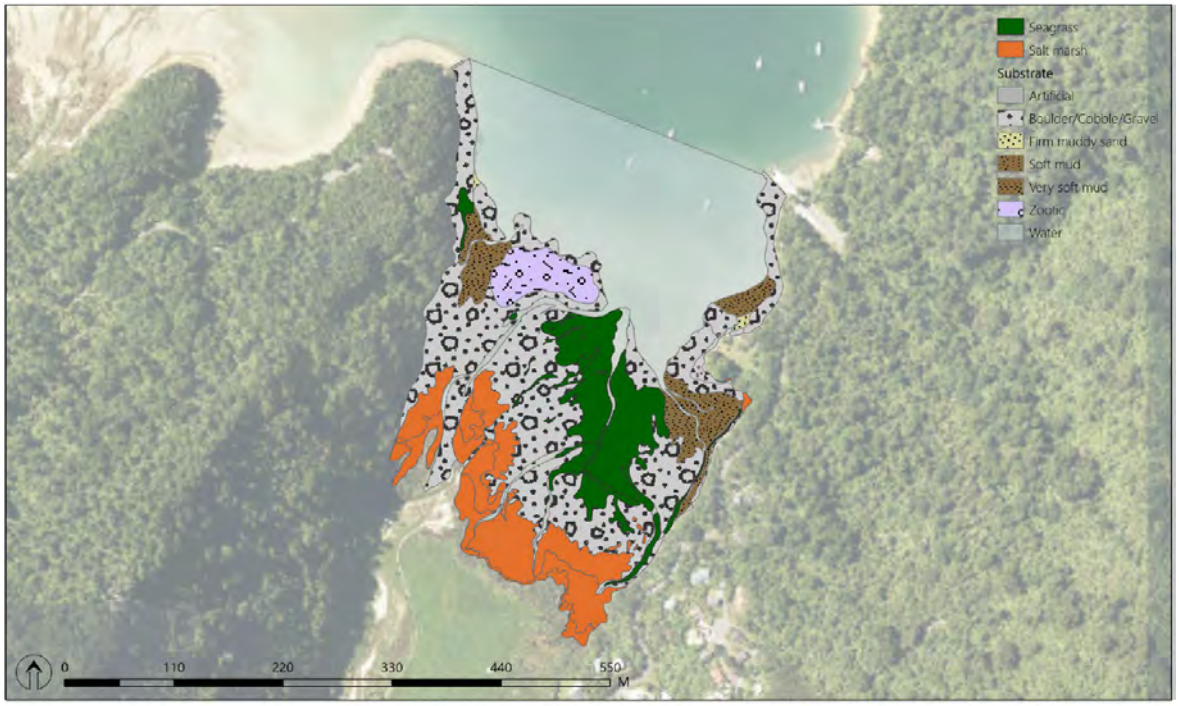

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Fig. A21.2. Duncan Bay dominant vegetation and substrate features (data source: Stevens 2018c).

Duncan Bay catchment and intertidal flats at high tide (Image ref: MDC 'Pelorus DuncanBay 03 Bright', Courtesy of Marlborough District Council)

Thin strip of salt marsh and native vegetation cover on the estuary margin

Pacific oysters

Macroalgae growing in shallow channels

Soft muds and gravel/cobble on the margin

Sparse seagrass cover on firm muddy sands

A22. Harvey Bay (Tennyson Inlet)

Harvey Bay is a moderate-sized (16.0ha) intertidally dominated estuary in Tennyson Inlet in the greater Pelorus Sound. The catchment is dominated by indigenous vegetation cover (91.8%) and is mainly protected within the Tennyson Inlet Scenic Reserve. The lower catchment is more developed with high producing grassland (7.3%) and a very small area of exotic forest (0.3%) adjacent to the main freshwater input.

The dominant substrate type in the estuary is cobble (Fig. A22.2). Mud-dominated sediments are present on the lower shoreline and accumulate within Pacific oyster beds (Stevens 2018c). These areas of fine sediment deposition likely reflect reduced current flows and sheltered deposition zones (Stevens 2018c). Salt marsh comprises 20.6% of the intertidal area at the head of the estuary, and consists of rushland (*Juncus kraussii*), estuarine shrub (*Plagianthus divaricatus*) and herbfield (*Selliera radicans*; Stevens 2018). The salt marsh is classified as a regionally significant wetland.

Seagrass is located on the mid estuary tidal flats and on the southern margin (Fig. A22.2). In the 2018 broad scale survey, high cover seagrass beds were recorded in subtidal channels, with patchy cover growing within depressions in cobble and in sand or muddy sand (Stevens 2018c). Seagrass beds in the low tide zone were covered in a fine layer of mud. No areas of nuisance macroalgal growth (>50% cover) were recorded and there was no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

While mud-dominated sediments were recorded in the estuary these areas are unlikely to deteriorate if the native forest cover in the catchment remains stable (Stevens 2018). However, the head of the estuary has been cleared and converted to pasture and a very small area of exotic forest (2.3ha), which could be minor sources of nutrients and sediment. Direct access to the estuary is across private land, however there are a high number of permanent moorings within the bay that could increase the likelihood of marine pests, contaminants and pathogens being introduced. Pacific oysters have already been recorded in the estuary. The estuary is also used recreationally for fishing and swimming (cruiseguide.co.nz).

Overall, Harvey Bay is in good condition and is not expressing signs of eutrophication. It has both high value seagrass beds and salt marsh habitat, and is classified as an ESMS (Table A22.1).

Table A22.1. Summary information for Harvey Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	16.0	-
Intertidal Area (Ha; % Estuary)[1]	13.1	81.9
Dominant Estuary Substrate[1]	Cobble	
Mud extent (>50% mud content)	2.0	15.3
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.6	4.6
Salt Marsh (Ha; % intertidal)[1]	2.7	20.6
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	775.6	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	91.8	
% Catchment exotic forest[2]	0.3	
% Producing grassland[2]	7.7	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	2.3	
Catchment Phosphorus Load (T/y)[3]	0.5	
Catchment Sediment Load (KT/y)[3]	5.4	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS[5]	Y – 3.10	
Significant Wetland[6]	Y – salt marsh	
Birds[5]	nd	
Fish[6]	Redfin bully	
Shellfish	nd	
Pressures		
Development in the catchment – pasture and exotic forest		
Some areas of soft mud habitat		
Pacific Oyster		
Moderate human use: boat use/ road access		
High number of moorings		

[1]Stevens (2018c); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al. (2011); [6]MDC Smart Maps

Table A22.2. Ecological Vulnerability Assessment, Harvey Bay.

Category	Score
Values	0.79
Pressures	0.78
Susceptibility	0.70
Condition	0.82
Average Score	0.77

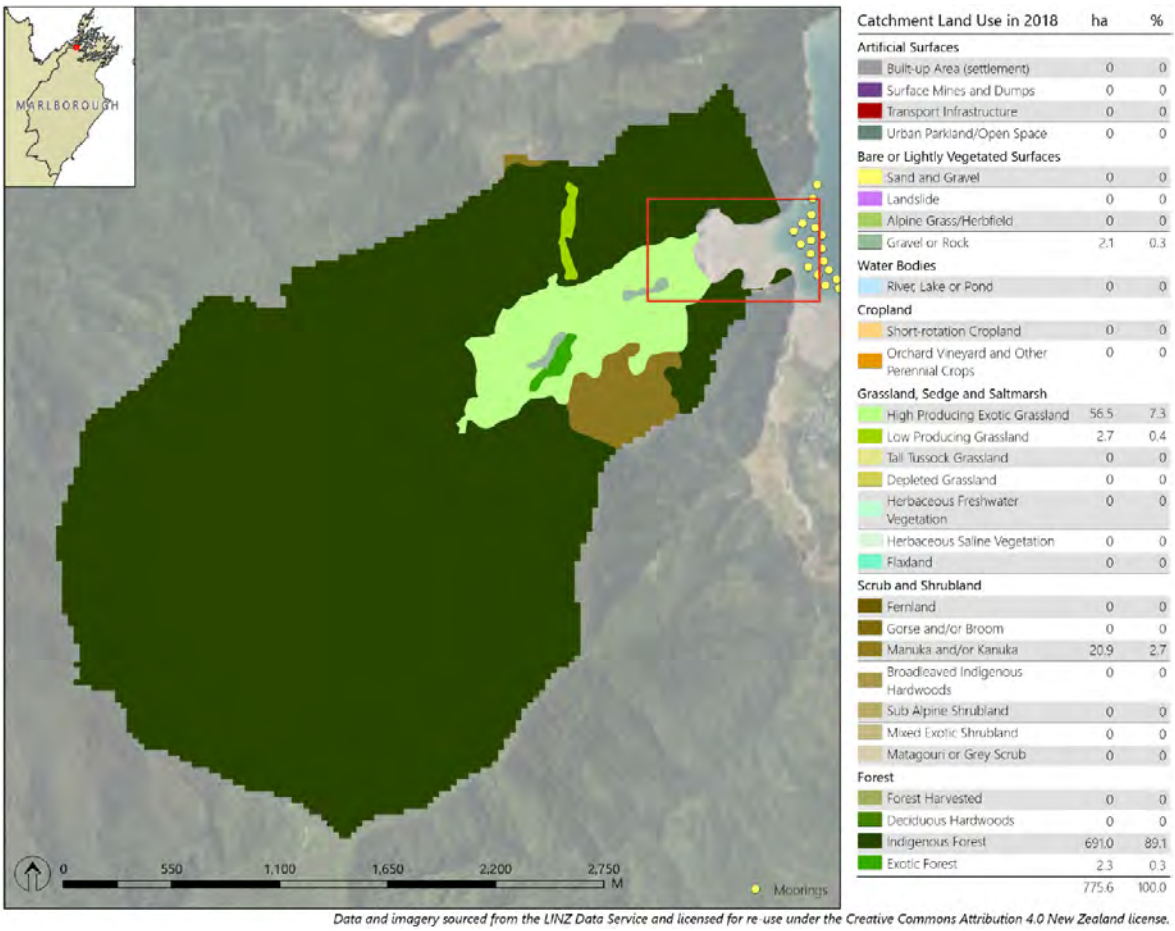

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Fig. A22.1. Harvey Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings. Catchment boundary provided by MDC.

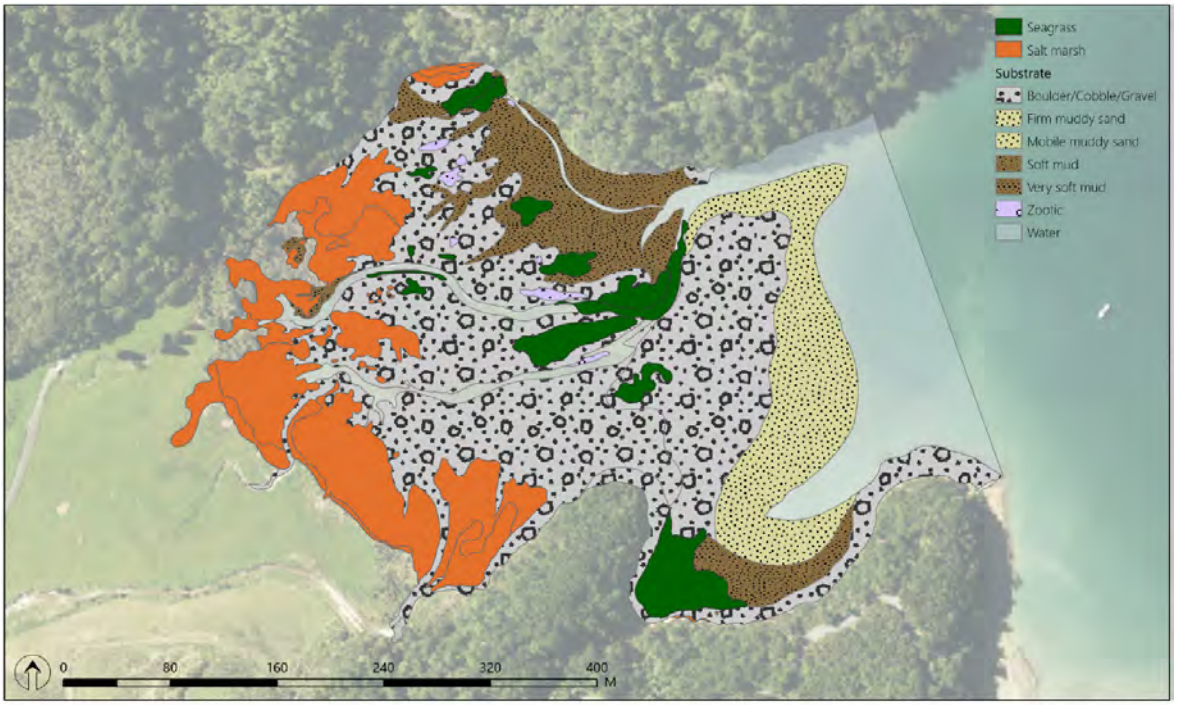

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Fig. A22.2. Harvey Bay dominant vegetation and substrate features (data source: Stevens 2018c).

Pacific oysters growing on the channel margins in mixed gravel/ cobble with fine sediment deposition on surface

Harvey Bay catchment and intertidal flats at high tide (Image ref: MDC 'Pelorus HarveyBay 03 Bright', Courtesy of Marlborough District Council)

Herbfield adjacent to gravel/cobble substrate

Rushland growing in gravel/cobble

Soft muds in Harvey Bay

Seagrass in the mid to lower estuary

A23. Ngāwhakawhiti Bay (Tennyson Inlet)

Ngāwhakawhiti Bay has a number of small (7.5ha) intertidally dominated estuaries and is in Tennyson Inlet in the greater Pelorus Sound. The catchment is dominated by indigenous forest (99.8%) and is completely protected within the Tennyson Inlet Scenic Reserve. Tennyson Inlet, including Ngāwhakawhiti Bay, is classified as an ESMS because it represents the largest marine area in Marlborough that is almost completely surrounded by a catchment of protected native forest (Davidson et al. 2011).

The dominant substrate type in the estuary is gravel/cobble, with no mud-dominated sediments recorded (Table A25.1). Salt marsh is localised to the freshwater inputs and is mainly rushland, with some herbfield on the seaward edge of the rushland. Salt marsh extent, and potential migration with sea level rise, is limited by the steep margin (see photos).

Seagrass has been recorded across 10% of the intertidal area. Nuisance macroalgae have been recorded across <5% of the intertidal area, with no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

Catchment pressures in Ngāwhakawhiti Bay are low due to the protected catchment. Human use is the most significant pressure. There are two permanent moorings in Ngāwhakawhiti Bay and anchorage is common under the right conditions. The bay is popular for diving, swimming and fishing, and there is also access to the Nydia Bay walking track from the southern tidal flats. The number of boat users increases the risk of introduced marine pests, pathogens and other marine contaminants. Aside from the incursion of Pacific oysters, the estuary is in very good condition with high value salt marsh and a protected catchment.

Table A23.1. Summary information for Ngāwhakawhiti Bay.

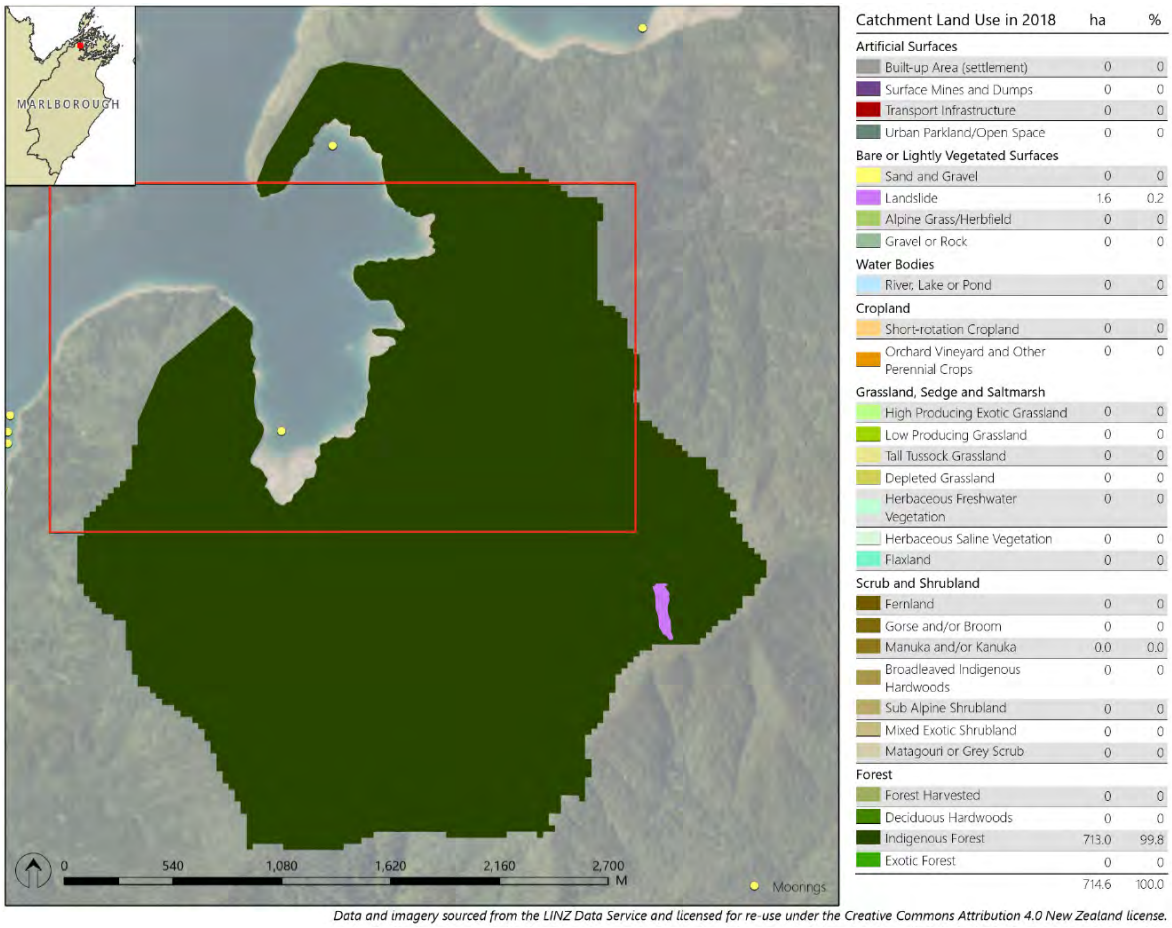
Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	
Intertidal Area (Ha; % Estuary)[1]	7.5	-
Dominant Estuary Substrate[1]	Gravel/cobble	
Mud extent (>50% mud content)	-	0
Macroalgae (Ha; cover >50%)[1]	-	<5
Seagrass (Ha; cover >50%)[1]	-	10
Salt Marsh (Ha; % intertidal)[1]	-	15
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	714.6	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	99.8	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	2.2	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	2.6	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS[5]	Y – 3.9	
Significant Wetland[6]	N	
Birds[5]	nd	
Fish[6]	Redfin bully, koaro	
Shellfish	nd	
Pressures		
Pacific oysters		
Human use – boat users/ camping		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al. (2011); [6]MDC Smart Maps

Narrow strip of salt marsh and steep native bush catchment

Table A23.2. Ecological Vulnerability Assessment, Ngāwhakawhiti Bay.

Category	Score
Values	0.66
Pressures	0.74
Susceptibility	0.60
Condition	0.79
Average Score	0.70



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	1.6	0.2
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	0	0
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	0	0
Manuka and/or Kanuka	0.0	0.0
Broadleaved Indigenous Hardwoods	0	0
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	0	0
Deciduous Hardwoods	0	0
Indigenous Forest	713.0	99.8
Exotic Forest	0	0
	714.6	100.0

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Fig. A23.1. Ngāwhakawhiti Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings. Catchment boundary provided by MDC.

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Fig. A23.2. Ngāwhakawhiti Bay intertidal areas. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground-truthing.

Salt marsh, rushland, growing around the main freshwater input, Pacific oysters growing in the channel

Steep indigenous forest catchment and the Ngāwhakawhiti intertidal flats

Gravel/cobble dominant substrate on the intertidal flats and salt marsh on the upper tidal flats

Pacific oysters growing on gravel/ boulders and steep native bush catchment in the background

A24. Tuna Bay (Tennyson Inlet)

Tuna Bay is a moderate-sized (25.0ha) intertidally dominated estuary in Tennyson Inlet in the greater Pelorus Sound. The catchment is dominated by indigenous vegetation cover (94.6%) and is mainly protected within the Tennyson Inlet Scenic Reserve. The lower catchment is more developed with high producing grassland (3.0%), exotic forest (1.5%) and a settlement (0.9%) to the northeast of the intertidal flats.

The upper estuary comprises cobble and the mid to lower estuary is dominated by gravel (Fig. A24.2). Mud-dominated were not recorded in the estuary in a 2018 survey (Stevens 2018c). Salt marsh comprises 20.6% of the intertidal area at the head of the estuary, consisting of rushland (*Juncus kraussii*), estuarine shrub (*Plagianthus divaricatus*) and herbfield (*Selliera radicans*; Stevens 2018). A small area of the nationally declining sea sedge *Carex litorosa* was recorded growing in cobble in the northwest of the estuary. While the salt marsh is classified as a regionally significant wetland, aerial imagery shows there is vehicle access to the estuary flats through the salt marsh habitat.

Seagrass is located on the mid to lower estuary tidal flats with only a small area of dense cover on the northwest tidal flats (Table A24.1). A moderate seagrass cover (20-50%) occurs on the main gravel flats (Fig. A24.2). No areas of nuisance macroalgal growth (>50% cover) have been recorded in the estuary and there is no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

The head of the estuary has been cleared and converted to pasture and exotic forest, which could be minor sources of nutrients and sediment in future (i.e. the exotic forest block on the estuary margin is due for harvest within the next 10 years). However, the majority of the catchment remains in native vegetation cover. Other pressures include road access to the estuary margin, the wharf, and a high number of permanent moorings near the settlement, which that could increase the likelihood of marine pests, contaminants and pathogens being introduced. While present in nearby estuaries, Pacific oysters have not yet been recorded in Tuna Bay. The estuary is also used recreationally for fishing and swimming (cruiseguide.co.nz).

Overall, Tuna Bay is in good condition and is not expressing signs of eutrophication. It has both high value seagrass beds and salt marsh habitat, and is classified as an ESMS (Table A24.1).

Table A24.1. Summary information for Tuna Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	25.0	
Intertidal Area (Ha; % Estuary)[1]	6.0	75.9
Dominant Estuary Substrate[1]	Gravel	
Mud extent (>50% mud content)	0.0	0.0
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.3	1.6
Salt Marsh (Ha; % intertidal)[1]	4.0	21.1
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	2174.4	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	94.6	
% Catchment exotic forest[2]	1.5	
% Producing grassland[2]	3.0	
Mean Freshwater Flow (m^3/s)[3]	0.5	
Catchment Nitrogen Load (T/y)[3]	5.64	
Catchment Phosphorus Load (T/y)[3]	1.09	
Catchment Sediment Load (KT/y)[3]	8.60	
Catchment Geology[4]	Gravel (Sandstone)	
Biodiversity		
ESMS[5]	Y – 3.10	
Significant Wetland[6]	Y – salt marsh	
Birds[5]	Banded rail	
Fish[6]	Redfin bully	
Shellfish[1]	cockles	
Pressures		
Development in the catchment – pasture and exotic forest		
Moderate human use: boat use/ road access/ Nydia Track		
High number of moorings		
Residential area – domestic wastewater		
Vehicle access to the estuary through salt marsh		

[1]Stevens (2018c); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap
[5]Davidson et al. (2011); [6]MDC Smart Maps

Table A24.2. Ecological Vulnerability Assessment, Tuna Bay.

Category	Score
Values	0.79
Pressures	0.75
Susceptibility	0.70
Condition	0.95
Average Score	0.80

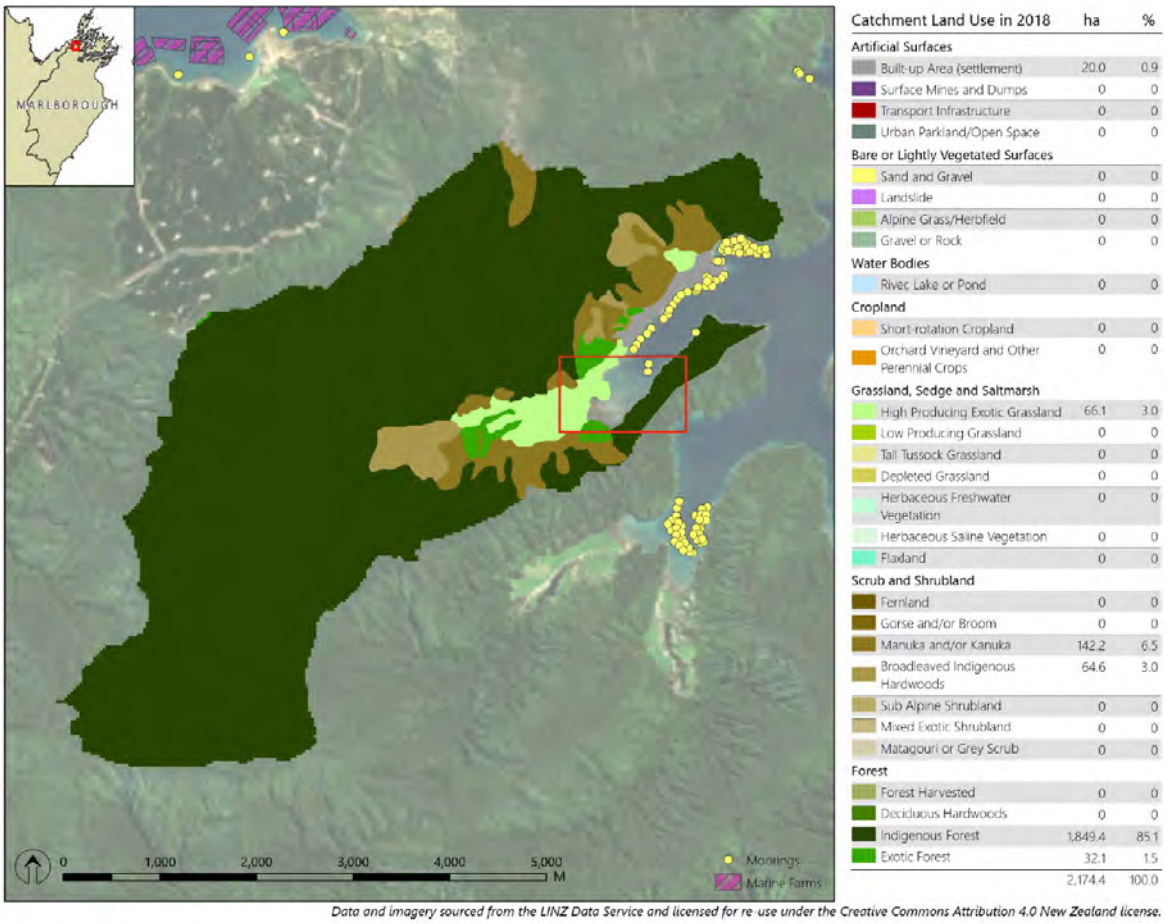

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Fig. A24.1. Tuna Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

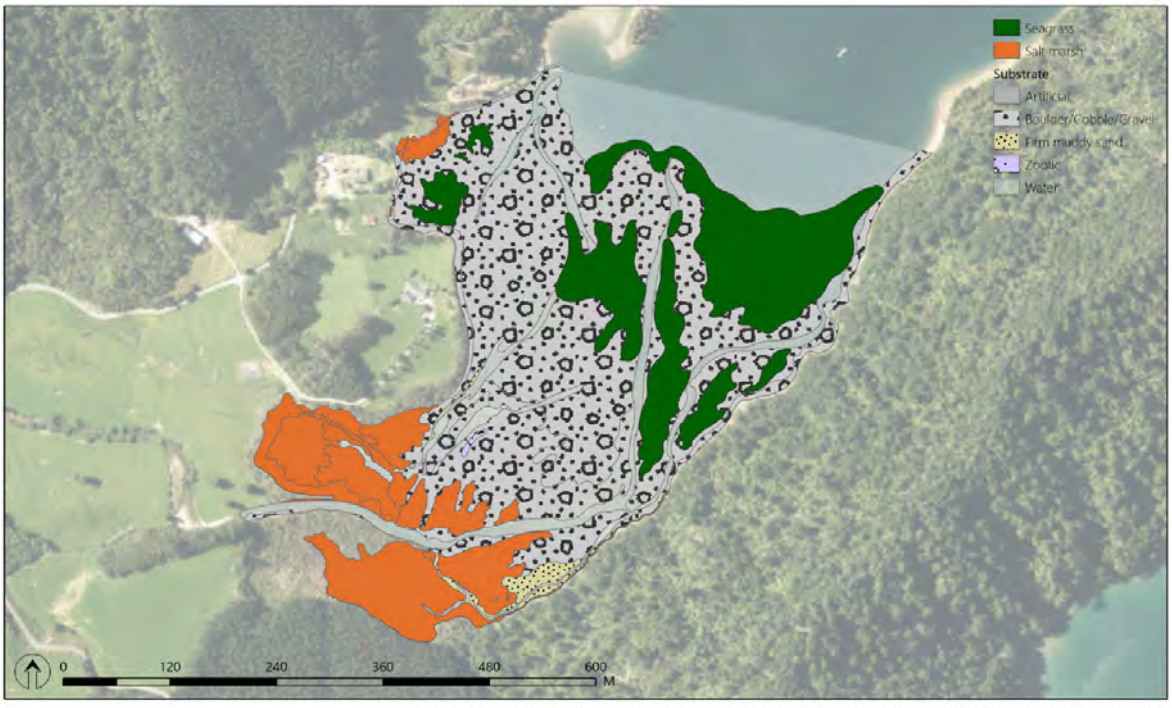

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Fig. A24.2. Tuna Bay dominant vegetation and substrate features (data source: Stevens 2018c).

Rushland and forestry on the estuary margin

Herbfield on seaward edge of rushland in the upper estuary

Nationally declining *Carex litorosa* growing in cobble habitat, northwest intertidal flats

Aerial view of catchment and estuary at high tide (Image ref: MDC 'Pelorus TunaBay 08 Bright', Courtesy of Marlborough District Council)

Cockle beds in the lower estuary

Seagrass beds growing on gravel

A25. Savill Bay (Fitzroy Bay)

Savill Bay is a small (3.8ha) intertidally dominated estuary in Fitzroy Bay in the greater Pelorus Sound. The steep catchment is dominated by broadleaved indigenous hardwoods (96.1% indigenous vegetation cover; Table A25.1), and is mostly protected within the Garne and Savill Bays Scenic Reserve. High producing grassland (2.4%) is within the 200m terrestrial margin, with most native vegetation having been cleared from the immediate estuary margin.

The dominant substrate type in the estuary is gravel/cobble with only 5% mud-dominated sediments recorded (Table A25.1). Salt marsh is localised to the southwest intertidal flats and covers ~15% of the intertidal area. Salt marsh is mainly rushland with some herbfield on the seaward edge of the rushland, and transitions into indigenous vegetation cover. The upper margin of the remaining salt marsh habitat is characteristic of a steep beach, with very little salt marsh vegetation (see photo).

During a site visit (November 2020) quad bike tracks were observed within salt marsh habitat. Seagrass was recorded across 5% of the intertidal area and was localised to the southwest intertidal flats (see photo). Nuisance macroalgae was recorded across <5% of the intertidal area and there was no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

Catchments pressures in Savill Bay are minimal, with only one small area of high producing grassland on the margin and the rest of the catchment protected within a scenic reserve. There is limited road access to the estuary and an airstrip within the margin. There are also a small number of dwellings close to the margin with minor domestic wastewater discharges. There are two permanent moorings with the bay and marine farms within 5km, increasing the risk of marine pests, contaminants and pathogens being introduced.

Overall, Savill Bay is in good condition and is not expressing signs of eutrophication. It has small areas of high value seagrass beds and salt marsh habitat. The subtidal areas of Fitzroy Bay, including Savill Bay, are classified as an ESMS because it represents one of two areas in the Marlborough Sounds where elephant fish spawn in the shallows (Table A25.1).

Table A25.1. Summary information for Savill Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	
Intertidal Area (Ha; % Estuary)[1]	3.8	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	5
Macroalgae (Ha; cover >50%)	-	<5
Seagrass (Ha; cover >50%)	-	5
Salt Marsh (Ha; % intertidal)	-	15
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	352.7	
Dominant Catchment Land Cover[2]	Broadleaved Indigenous Hardwoods	
% Catchment indigenous vegetation[2]	96.1	
% Catchment exotic forest[2]	1.5	
% Producing grassland[2]	2.4	
Mean Freshwater Flow (m^3/s)[3]	0.07	
Catchment Nitrogen Load (T/y)[3]	0.74	
Catchment Phosphorus Load (T/y)[3]	0.10	
Catchment Sediment Load (KT/y)[3]	0.64	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS	N	
Significant Wetland[5]	N	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish	nd	
Pressures		
Development in the catchment – pasture		
Human use: boat use/ limited road access/ airstrip		
Moorings and marine farms within 5km		
Residential – domestic wastewater		
Vehicle damage to salt marsh		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Maps

Table A25.2. Ecological Vulnerability Assessment, Savill Bay.

Category	Score
Values	0.49
Pressures	0.83
Susceptibility	0.89
Condition	0.85
Average Score	0.78

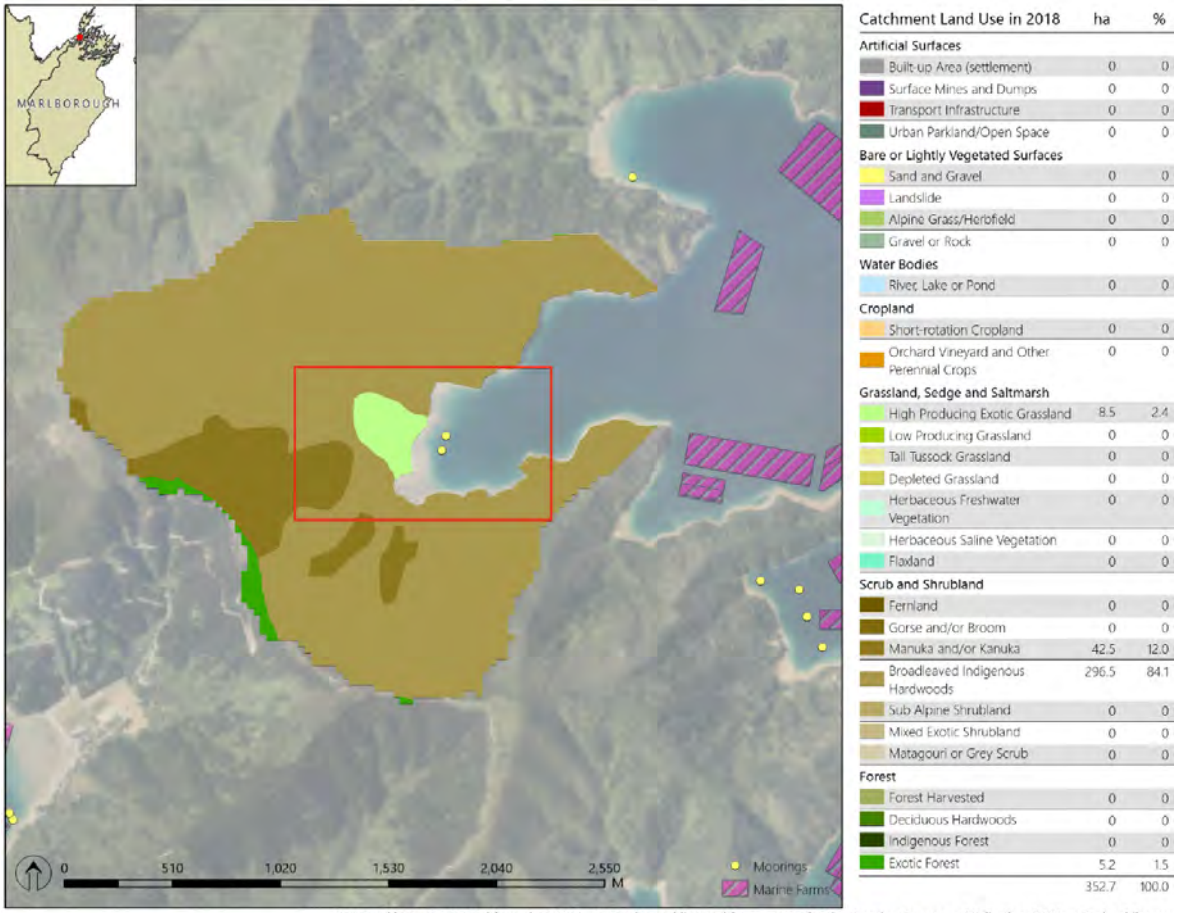

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Fig. A25.1 Savill Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

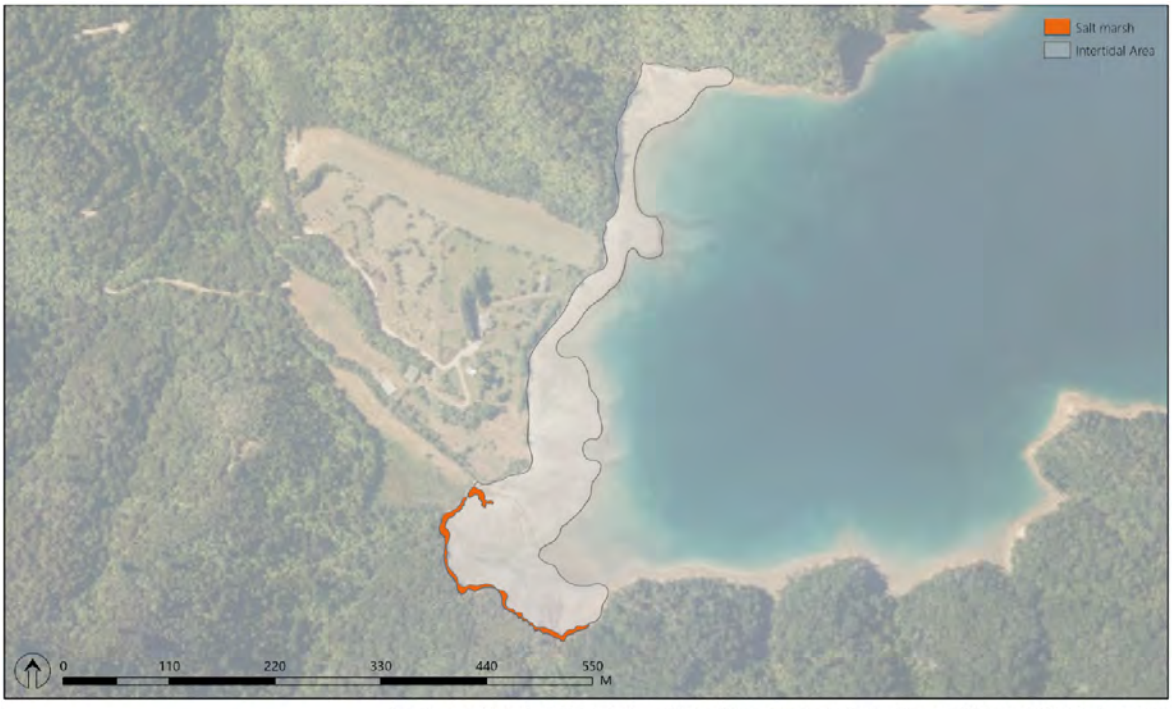

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Fig. A25.2. Savill Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground truthing.

Salt marsh habitat and mostly native bush catchment, with some exotic vegetation near margin

Aerial view of Savill Bay intertidal area, dark green represents seagrass

Gravel/cobble and fringing salt marsh

Steep catchment and clearing on estuary margin (Image ref: MDC 'Pelorus Savill Bay 28 Cropped', Courtesy of Marlborough District Council)

B. QUEEN CHARLOTTE SOUND & TORY CHANNEL

Queen Charlotte Sound (Totāranui) and Tory Channel (Kura Te Au) are large, drowned river valley estuaries (Hume et al. 2016). The estuary systems comprise bays, inlets and smaller intertidal areas that would be classified as shallow intertidally dominated estuaries (Robertson et al., 2016). There are no large river systems influencing Queen Charlotte Sound; instead the main driver of water circulation is the tidal flows through Tory Channel delivering large volumes of oceanic water (Hadfield et al. 2014). Oceanic water generally carries far smaller sediment loads than riverine inputs, therefore sedimentation impacts are localised and restricted to sedimentation events resulting from activities in the catchment.

Neil et al. (2018) highlighted that coastal soils between the shoreline of Queen Charlotte Sound and 200m elevation are generally clay-rich, highly weathered and prone to erosion. Land clearance within the highly erodible landscape has led to hillslope instability and frequent surficial slips during intense rain events (Lauder 1987). While some previously cleared areas are now regenerating native forest, erosion events within the catchment remain common in developed areas (i.e. pasture and forestry). For example, in 2015 the deposition of fine sediment was recorded smothering intertidal habitats in Hitaua Estuary following forestry harvesting in the catchment (Davidson & Richards 2015; see photos).

Stream at head of Hitaua Bay 2003 (left) and 2015 (right) from Davidson & Richards (2015)

Subtidal sediments in Queen Charlotte Sound comprise fine muds and are likely a mix of catchment derived sediments and marine sediments (Lauder 1987; Neil et al. 2018). Strong currents through the Tory Channel prevent fine sediment deposition and benthic sediments are coarse sand and gravels, with settling of fine sediments localised to shallow bay areas (Neil et al. 2018).

Queen Charlotte Sound is the most populous part of the Marlborough Sounds with large towns at Waikawa and Picton and smaller settlements at Anakiwa and Ngākuta Bay. The area is also popular with seasonal holiday makers, with most bays containing holiday homes, accommodation and/or camp sites. Higher human use can increase the likelihood of invasive species incursions, discharge of contaminants, vehicle damage, shoreline hardening, habitat loss, disturbance of wetland birds, and over-harvesting of shellfish and fish. Other indirect impacts include high vessel use and infrastructure for both commercial and recreational vessels, including a large port at Shakespeare Bay, the Interislander ferry terminal in Picton and a marina in Waikawa Bay.

While Queen Charlotte Sound retains high social, cultural and ecological values there are a number of pressures, as discussed, that compromise the ecological integrity of the estuaries, bays and subtidal areas. In this section, intertidal estuarine areas are summarised for Queen Charlotte Sound and Tory Channel (see Fig. B1), including key habitats, catchment characteristics and the output of the EVA for each estuary. These estuaries range in size from 0.5ha to 80ha, and are confined to Grove Arm, the south side of Queen Charlotte Sound between Picton and Tory Channel, and Endeavour Inlet (Table B1).

Picton Harbour, Queen Charlotte Sound

Ōkiwa Bay, Queen Charlotte Sound

Table B1. List of intertidal estuaries summarised in Queen Charlotte Sound & Tory Channel.

ID	Estuary Name	Sub-region	Intertidal area (ha)	ESMS	Baseline monitoring
B1	Big Bay	Endeavour Inlet	2.94	✓ (4.27)	-
B2	Endeavour Inlet	Endeavour Inlet	8.06	✓ (4.27)	-
B3	Bottle Bay	Grove Arm	1.18	✓ (4.3)	-
B4	Momorangi Bay	Grove Arm	1.03	-	-
B5	Ngakuta Bay	Grove Arm	11.80	✓ (4.5)	2011, 2018 (BS)
B6	Okiwa Bay	Grove Arm	80.40	✓ (4.1)	2011, 2018 (BS)
B7	Umungata Bay	Grove Arm	2.97	✓ (4.3)	-
B8	Fence Bay	Onahau Bay	0.53	-	-
B9	Mistletoe Bay	Onahau Bay	0.93	-	-
B10	Waterfall Bay	Onahau Bay	1.40	-	-
B11	Ahuriri Estuary	Southern shore of QCS	6.60	-	2020 (BS)
B12	Shakespeare Bay	Southern shore of QCS	5.37	✓ (4.10)	2016 (FS, BS)
B13	Waikawa Bay	Southern shore of QCS	2.82	-	2016 (FS, BS)
B14	Whatamango Bay	Southern shore of QCS	9.13	✓ (4.12)	2018 (BS)
B15	Hitaua Bay	Tory Channel	0.82	✓ (5.5)	-
B16	Onapua Bay	Tory Channel	1.47	-	-
B17	Opua Bay	Tory Channel	0.91	-	-
B18	Oyster Bay	Tory Channel	0.91	-	-

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Fig. B1. Intertidal estuaries within Queen Charlotte Sound included in the current report.

B1. Big Bay (Endeavour Inlet)

Big Bay is a small (2.9ha) shallow intertidally dominated estuary that connects to the larger subtidal Endeavour Inlet in Queen Charlotte Sound. The catchment is near pristine and dominated by indigenous forest (Table B1.1; Fig. B1.1). The estuary comprises fringing salt marsh, seagrass and substrates of sand and cobble (Fig. B1.2). The recent (10 February 2022) REA recorded no visible signs of eutrophication (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

Big Bay is classified as an ESMS under the umbrella of intertidal areas within Endeavour Inlet. The intertidal flats provide habitat for birds and the shortjaw kokopu, a nationally vulnerable diadromous fish species, that has been recorded in adjacent streams. The area is particularly important because the estuarine salt marsh merges into lowland forest and then montane beech dominated forest, sub-alpine scrub and true alpine herbfield (Davidson et al 1990). It represents the only intact coast to alpine vegetation sequence in Marlborough (Davidson et al 1990).

Big Bay is a near pristine catchment and estuary, pressures include limited walking and boat access and a minor incursion of the non-indigenous Pacific oyster. Habitat damage attributed to feral animals has been previously recorded in the area (Davidson et al. 1990). Relative to other estuaries in Queen Charlotte Sound, Big Bay has minimal pressures and low overall susceptibility to change owing to the protected catchment (i.e. Big Bay Scenic Reserve, adjacent regionally significant wetland) and the physical characteristics of the estuary itself (i.e. almost completely drains on low tide). The EVA results show Big Bay is in 'very good' condition and retains high ecological values in both the estuary and the catchment (Table 15).

Big Bay (Image ref: MDC 'Big Bay Endeavour Inlet', Courtesy of Marlborough District Council)

Table B1.1. Summary information for Big Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	2.9	-
Dominant Estuary Substrate[1]	Sand & cobble	
Mud extent (>50% mud content)	-	<1
Macroalgae (cover >50%)[1]	-	0-5
Seagrass (cover >50%)[1]	-	25
Salt Marsh (% intertidal)[1]	-	15
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	730.5	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	99.8	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.2	
Mean Freshwater Flow (m^3/s)[3]	0.3	
Catchment Nitrogen Load (T/y)[3]	1.92	
Catchment Phosphorus Load (T/y)[3]	0.30	
Catchment Sediment Load (KT/y)[3]	1.25	
Catchment Geology[4]	Sandstone (Breccia & Gravel)	
Biodiversity		
ESMS[6]	Y – 4.27	
Significant Wetland	Adjacent freshwater wetland	
Birds[5]	Caspian tern, white-faced heron, New Zealand falcon	
Fish[6,7]	Redfin Bully, Short-jawed kokopu	
Shellfish	nd	
Pressures		
Remote boat access		
Remote walking access		
Species incursion – pacific oysters (rare)		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Crowe (2018); [6]Davidson et al (2011); [7]MDC Smart Maps

Table B1.2. Ecological Vulnerability Assessment, Big Bay.

Category	Score
Values	0.80
Pressures	0.84
Susceptibility	0.91
Condition	0.96
Average Score	**0.88**

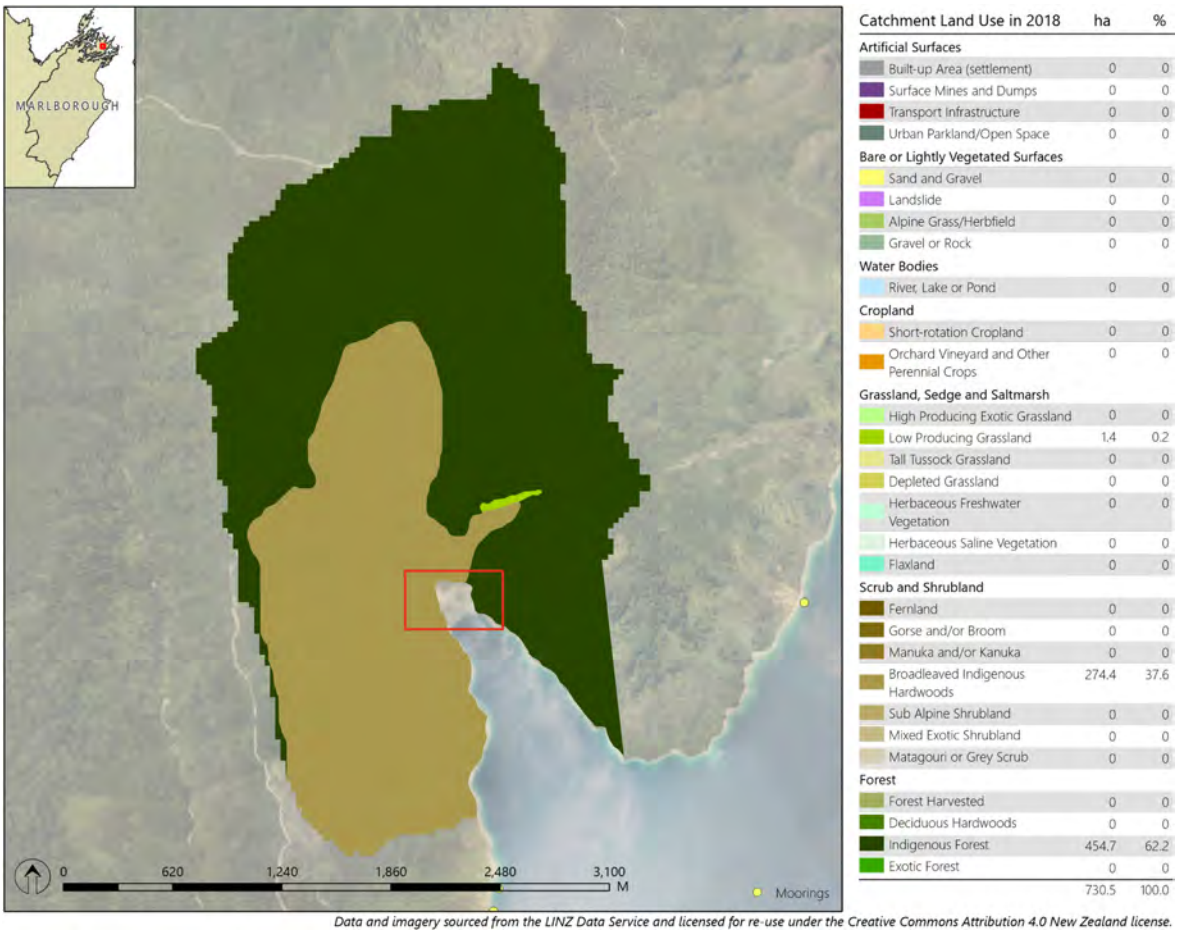

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Fig. B1.1. Big Bay catchment land use classifications from LCDB5 (2017/2018) database.

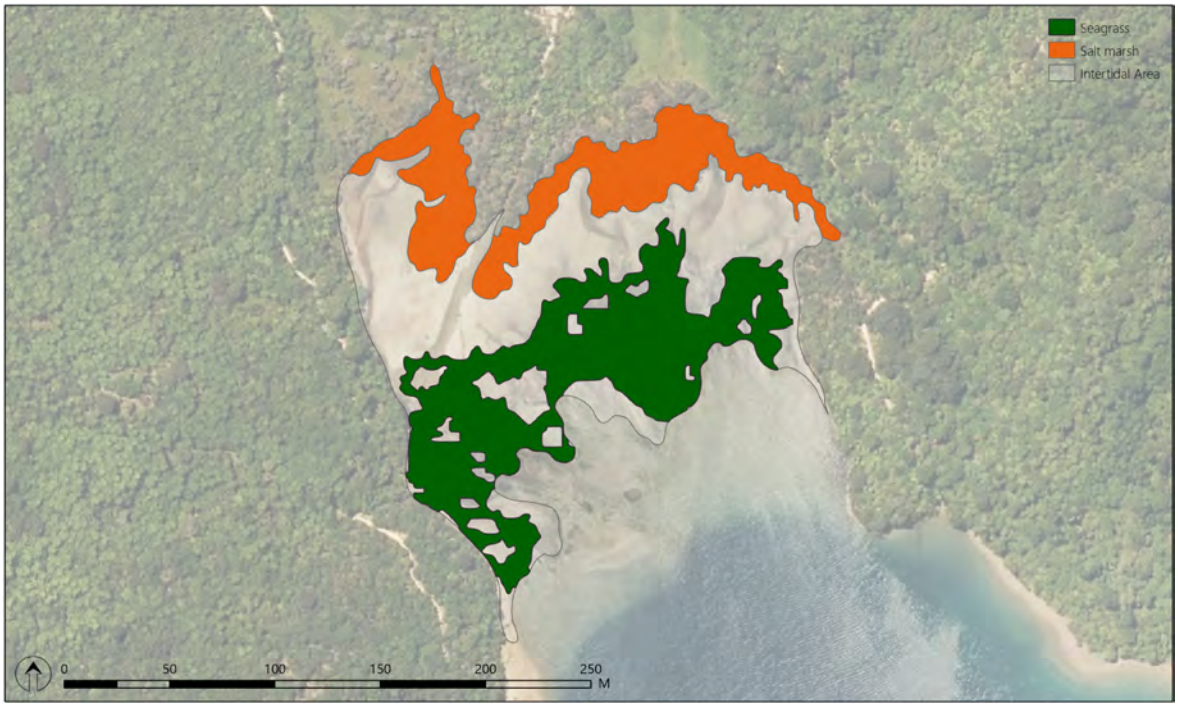

Fig. B1.2. Intertidal areas within Big Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC). Boundaries require ground truthing and should be treated as best estimates only.

Looking upstream, salt marsh and native forest in background

Firm muddy sand and cobble on estuary edge, Big Bay

Herbfield and rushland, Big Bay

Transition from salt marsh through to indigenous vegetation

Cobble, firm muddy sand and salt marsh looking down stream, Big Bay

B2. Endeavour Inlet (Endeavour Inlet)

Endeavour Inlet has two small intertidal areas comprising ~8ha in total that connect to the larger subtidal area of Endeavour Inlet in Queen Charlotte Sound. The catchment is dominated by indigenous forest (99.2%) and there is a small area of residential development at the head of both intertidal areas (Table B2.1; Fig. B2.1). The estuary comprises fringing salt marsh on the northern flats and seagrass across both intertidal flats (Neil et al. 2018; MDC Multibeam Seagrass). Substrate comprises both sand and cobble (Fig. B2.2). In a recent (10 February 2022) REA there were no visible signs of eutrophication.

The intertidal areas in Endeavour Inlet are classified as an ESMS because they are uncommon in the Marlborough region. These areas provide habitat for a range of wildlife including both vulnerable and threatened species of birds and fish (Table B2.1). During the rapid estuary assessment both cockles and pipi were recorded as present. The northern salt marsh and adjacent wetland habitat are also acknowledged as a regionally significant wetland.

An antimony mine and smelter operated ~2km inland from the Endeavour Inlet coast and was active in the late 1800's leading to the development of a small port and housing (theprow.org.nz). Present day, only a small number of dwellings, remain near the coast with minor domestic wastewater discharges and other areas previously developed are now regenerating forest. The inlet is a popular summer recreational area with only walking/biking or boat access. The high number of moorings within the inlet (Fig. B2.2) increases the likelihood of marine contaminants, pests and pathogens being introduced to the area. Overall, the estuary is in 'very good' condition and retains high ecological values.

Endeavour Inlet, Queen Charlotte Sound

Table B2.1. Summary information for Endeavour Inlet.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	8.1	-
Dominant Estuary Substrate[1]	Sand & gf/cf	
Mud extent (>50% mud content)	-	<1
Macroalgae (Ha; cover >50%)[1]	-	0-5
Seagrass (Ha; cover >50%)[1]	-	15
Salt Marsh (Ha; % intertidal)[1]	-	15
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	1751.1	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	99.2	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.8	
Mean Freshwater Flow (m^3/s)[3]	0.5	
Catchment Nitrogen Load (T/y)[3]	4.30	
Catchment Phosphorus Load (T/y)[3]	0.63	
Catchment Sediment Load (KT/y)[3]	3.84	
Catchment Geology[4]	Sandstone (Breccia & Gravel)	
Biodiversity		
ESMS[5]	Y – 4.27 (intertidal)	
Significant Wetland	Y – salt marsh	
Birds[5]	Caspian tern, white-faced heron, New Zealand falcon	
Fish[6,7]	Redfin Bully, Short-jawed kokopu	
Shellfish	Pipi and cockles	
Pressures		
Remote boat access		
Remote walking/ biking access		
Permanent moorings		
Domestic wastewater discharges		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Crowe (2018); [6]Davidson et al (2011); [7]MDC Smart Maps

Table B2.2. Ecological Vulnerability Assessment, Endeavour Inlet.

Category	Score
Values	0.90
Pressures	0.78
Susceptibility	0.88
Condition	0.78
Average Score	**0.84**

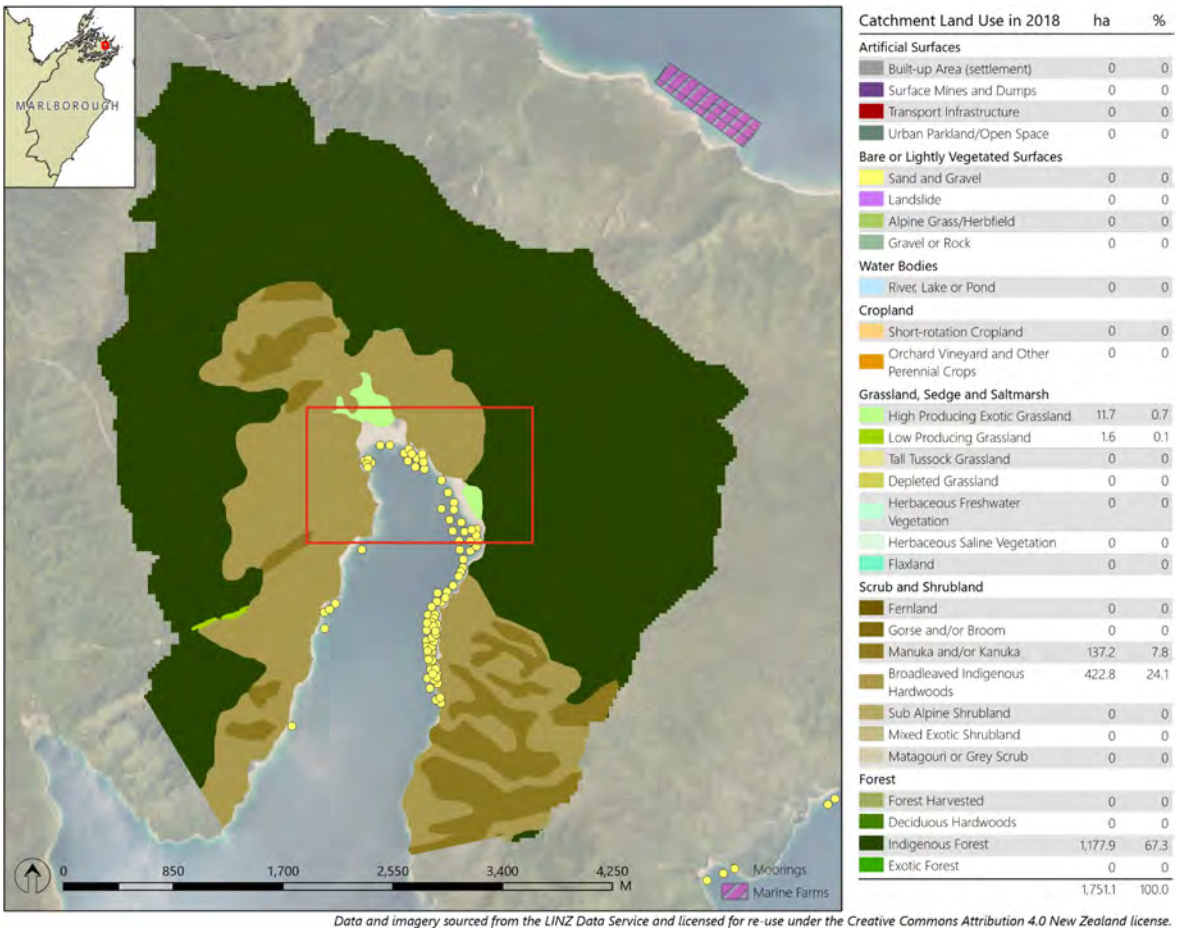

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Fig. B2.1. Endeavour Inlet catchment land use classifications from LCDB5 (2017/2018) database.

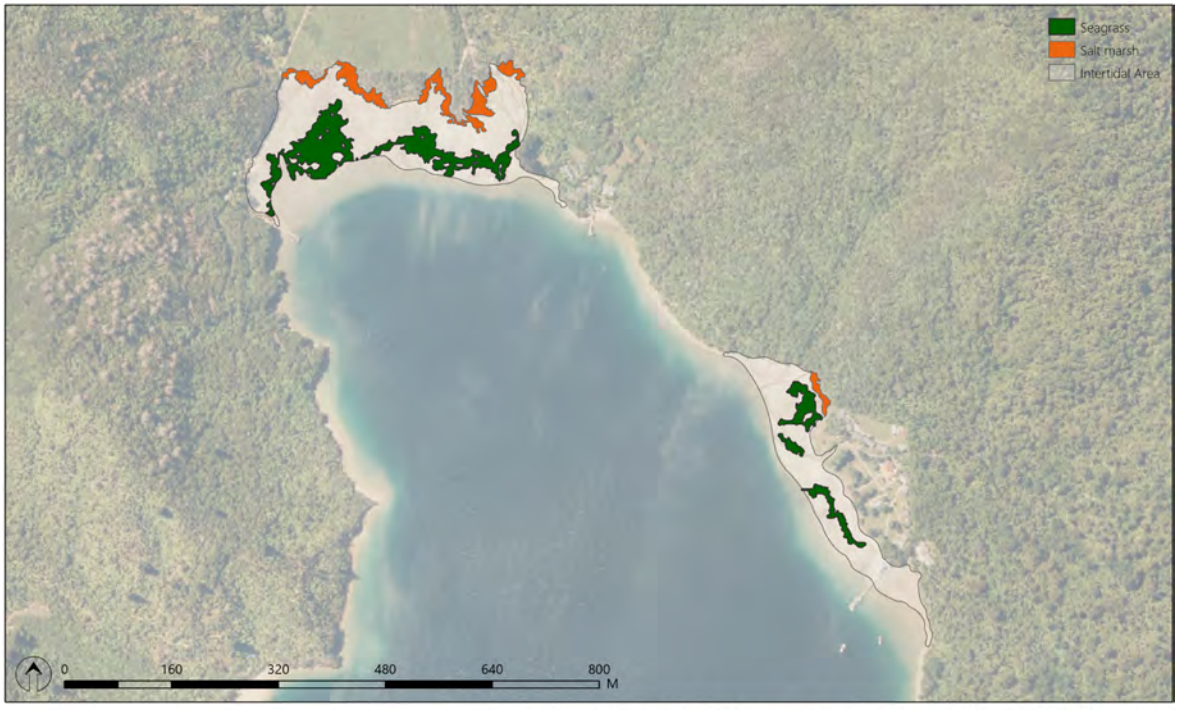

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Fig. B2.2. Intertidal areas within Endeavour Inlet. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC). Boundaries require ground truthing and should be treated as best estimates only.

Mobile sands and seagrass in Endeavour Inlet

Seagrass and salt marsh, Endeavour Inlet

Gravel and shell in the lower estuary

Discolouration of seagrass leaves, Endeavour Inlet

Gravel and cobble in the upper estuary and salt marsh, Endeavour Inlet

B3. Bottle Bay (Grove Arm)

Bottle Bay is a small (~1.2ha) shallow intertidally dominated estuary that connects to a large subtidal area of Grove Arm in Queen Charlotte Sound. The catchment is dominated by mature coastal beech forest protected within the Iwituaroa Scenic Reserve (Table B3.1; Fig. B3.1). Seagrass is the dominant vegetation type on sandy intertidal flats and salt marsh is restricted to the stream entrance (Fig. B3.2). In a recent (16 February 2022) site visit no signs of eutrophication were observed. This reflects low catchment nutrient and sediment loads and the well-drained intertidal flats that connect to the deeper bay.

Bottle Bay is classified as an ESMS because the catchment is protected mature native forest and the tidal flats feature a variety of habitats, including salt marsh and seagrass which support wildlife. Relative to other estuaries in Queen Charlotte Sound, Bottle Bay has minimal pressures and low overall susceptibility to change owing to the protected catchment (i.e. Iwituaroa Scenic Reserve) and the physical characteristics of the estuary itself (i.e. almost completely drains on low tide). Minor pressures include remote boat access, particularly for recreational use such as kayaking and water skiing, with a designated water-skiing lane on the eastern shore. However, there are no permanent moorings because strong winds funnel down the valley making it unsuitable for anchorage (cruiseguide.co.nz).

The EVA results show Bottle Bay is in 'very good' condition and retains high ecological values in both the estuary and the catchment (Table B3.2).

Bottle Bay, Queen Charlotte Sound

Table B3.1. Summary information for Bottle Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	~1.2	-
Dominant Estuary Substrate[1]	Sand	
Mud extent (>50% mud content)	-	<1
Macroalgae (cover >50%)[1]	-	0-5
Seagrass (cover >50%)[1]	-	25
Salt Marsh (% intertidal)[1]	-	5
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	118.5	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.6	
Catchment Nitrogen Load (T/y)[3]	0.28	
Catchment Phosphorus Load (T/y)[3]	0.04	
Catchment Sediment Load (KT/y)[3]	0.18	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS[5]	Y – 4.3	
Significant Wetland	N	
Birds	nd	
Fish[6]	Redfin Bully	
Shellfish	nd	
Pressures		
Remote boat access		
Kayaking and waterskiing common		
Low adaptive capacity to sea level rise (i.e. natural barrier)		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al. (2011); [6]MDC Smart Maps nd = no data

Table B3.2. Ecological Vulnerability Assessment, Bottle Bay.

Category	Score
Values	0.75
Pressures	0.82
Susceptibility	0.80
Condition	0.96
Average Score	**0.83**

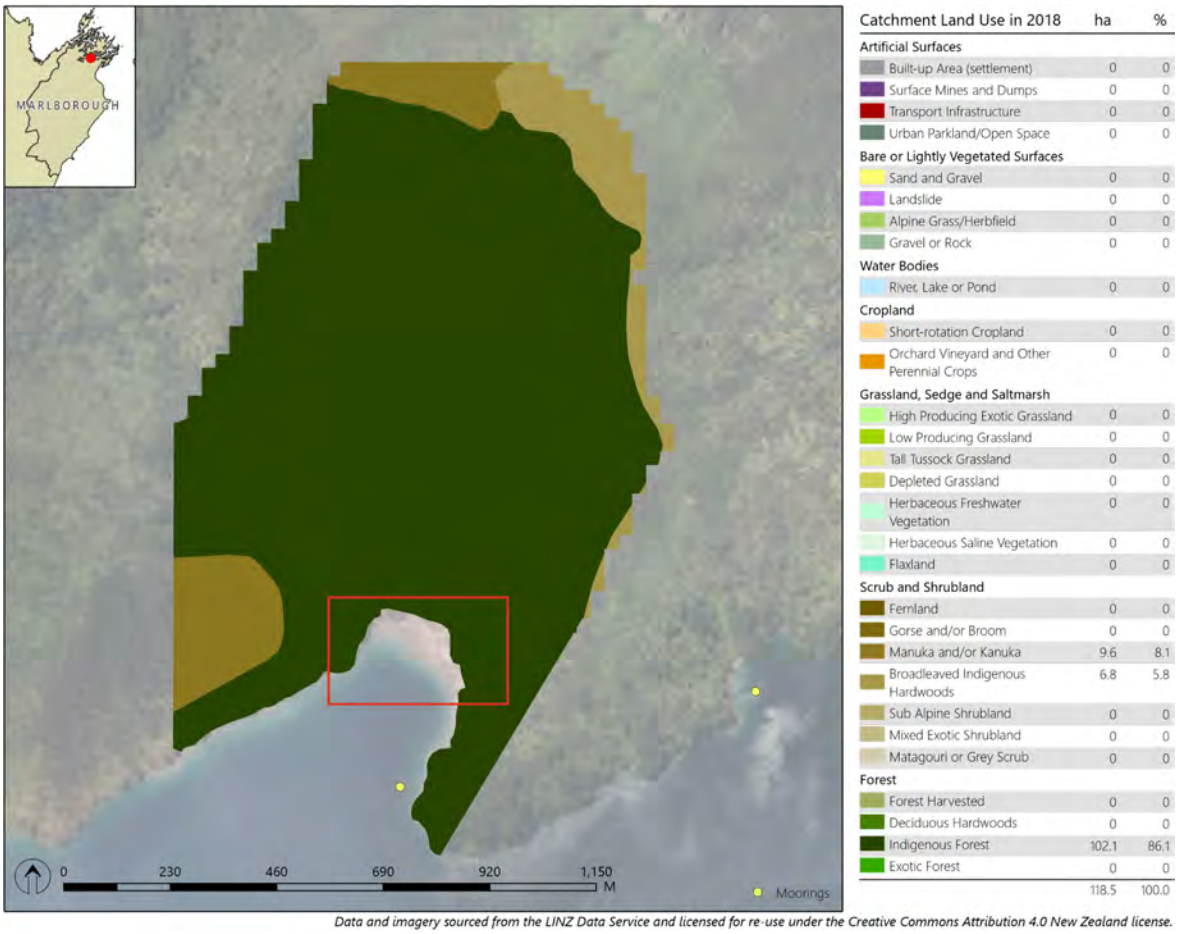

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Fig. B3.1. Bottle Bay catchment land use classifications from LCDB5 (2017/2018) database.

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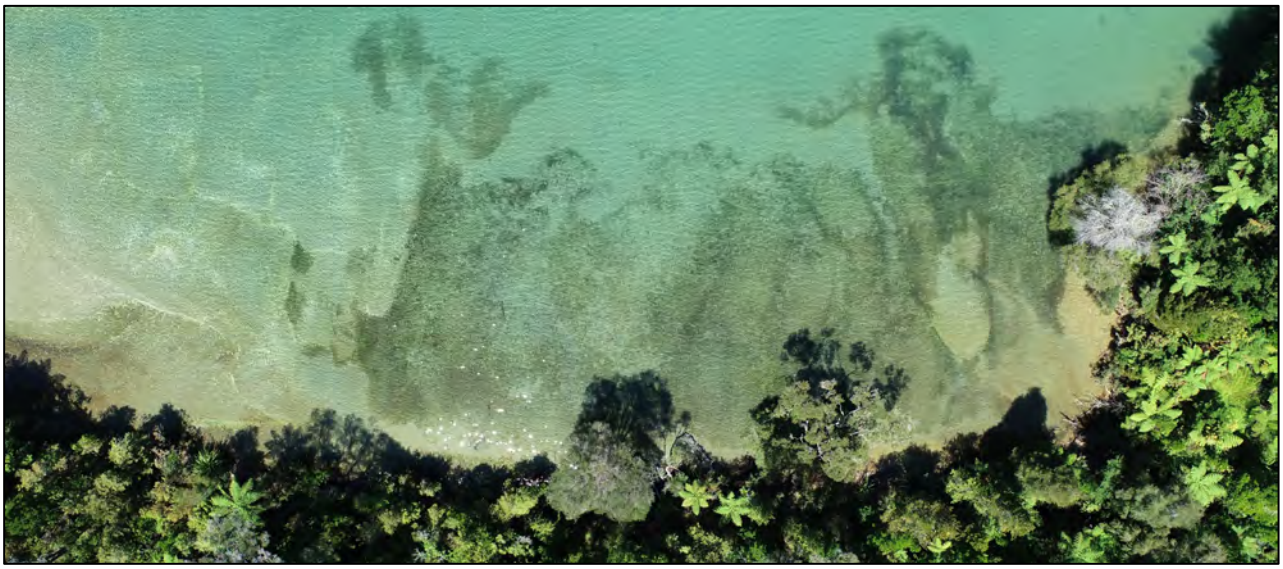
Fig. B3.2. Intertidal area in Bottle Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC). Boundaries require ground truthing and should be treated as best estimates only.

Steep native bush catchment, salt marsh and gravel

Eastern intertidal flats, gravel and seagrass on seaward edge

Western intertidal flats with seagrass (dark areas) and native bush catchment



Drone image of Bottle Bay, dark areas represent seagrass and orange shades gravel

B4. Momorangi Bay (Grove Arm)

Momorangi Bay is a small (1.0ha) shallow intertidally dominated estuary in Grove Arm of Queen Charlotte Sound. The catchment is dominated by mānuka and/or kānuka (88.3%) and there is a small area of residential development on the estuary margin (Table B4.1; Fig. B4.1). The estuary has been heavily modified with <1% of the intertidal area comprising salt marsh, reflecting historic reclamation, and hardening of the margin. The estuary substrate comprises mostly sand and shell with gravel near the main freshwater inputs. During a site visit seagrass was observed growing on the eastern margin and toward the seaward edge (Fig. B4.2). Macroalgae while present was not recorded at nuisance levels and no areas of High Enrichment Conditions were recorded.

From the 1860's the hill slopes in the Momorangi catchment were cleared and burned to keep mānuka and kānuka under control and then farmed until the Momorangi Bay hill slopes were gazetted as a scenic reserve in 1954 (cruiseguide.co.nz). Present day the catchment is mostly regenerating mānuka and/or kānuka forest. The lowland areas of the catchment are designated as a recreation reserve, and a DOC campsite is located on the estuary foreshore. The estuary has a high number of recreational users (e.g. boating, kayaking, swimming) because there is easy road access, a wharf and a boat ramp. Vehicle use on the estuary is also common with vehicle tracks observed during the previous site visits (see photos). Further, a high number of moorings are present throughout the bay increasing the likelihood of marine contaminants, pests and pathogens being introduced to the area.

Ecological values in Momorangi Bay have been compromised by the combination of high recreational use and the heavily modified terrestrial margin with shoreline hardening common for infrastructure and erosion control. This modification has likely led to loss of historic salt marsh habitat and significantly reduced the estuaries adaptive capacity to sea level rise. Despite the high degree of modification, the estuary retains a small area of seagrass and pipis are abundant. However, high recreational use, particularly vehicles, continues to put pressure on these habitats.

Table B4.1. Summary information for Momorangi Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	1.0	-
Dominant Estuary Substrate	Sand	
Mud extent (>50% mud content)	-	1-5
Macroalgae (Ha; cover >50%)	-	>0-5
Seagrass (Ha; cover >50%)	-	7
Salt Marsh (Ha; % intertidal)	-	1
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	155.5	
Dominant Catchment Land Cover[2]	mānuka and/or kānuka	
% Catchment indigenous vegetation[2]	97.4	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.1	
Catchment Nitrogen Load (T/y)[3]	0.42	
Catchment Phosphorus Load (T/y)[3]	0.06	
Catchment Sediment Load (KT/y)[3]	0.25	
Catchment Geology[4]	Schist	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish[5]	Redfin Bully	
Shellfish	Pipis	
Pressures		
Modified margin habitat		
Recreational use: campground, wharf, boat ramp		
Shoreline hardening		
Domestic wastewater		
Road and boat access – vehicle use on estuary		
High number of moorings		
Low adaptive capacity to sea level rise		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Map; nd = no data

Table B4.2. Ecological Vulnerability Assessment, Momorangi Bay.

Category	Score
Values	0.37
Pressures	0.65
Susceptibility	0.83
Condition	0.58
Average Score	**0.61**

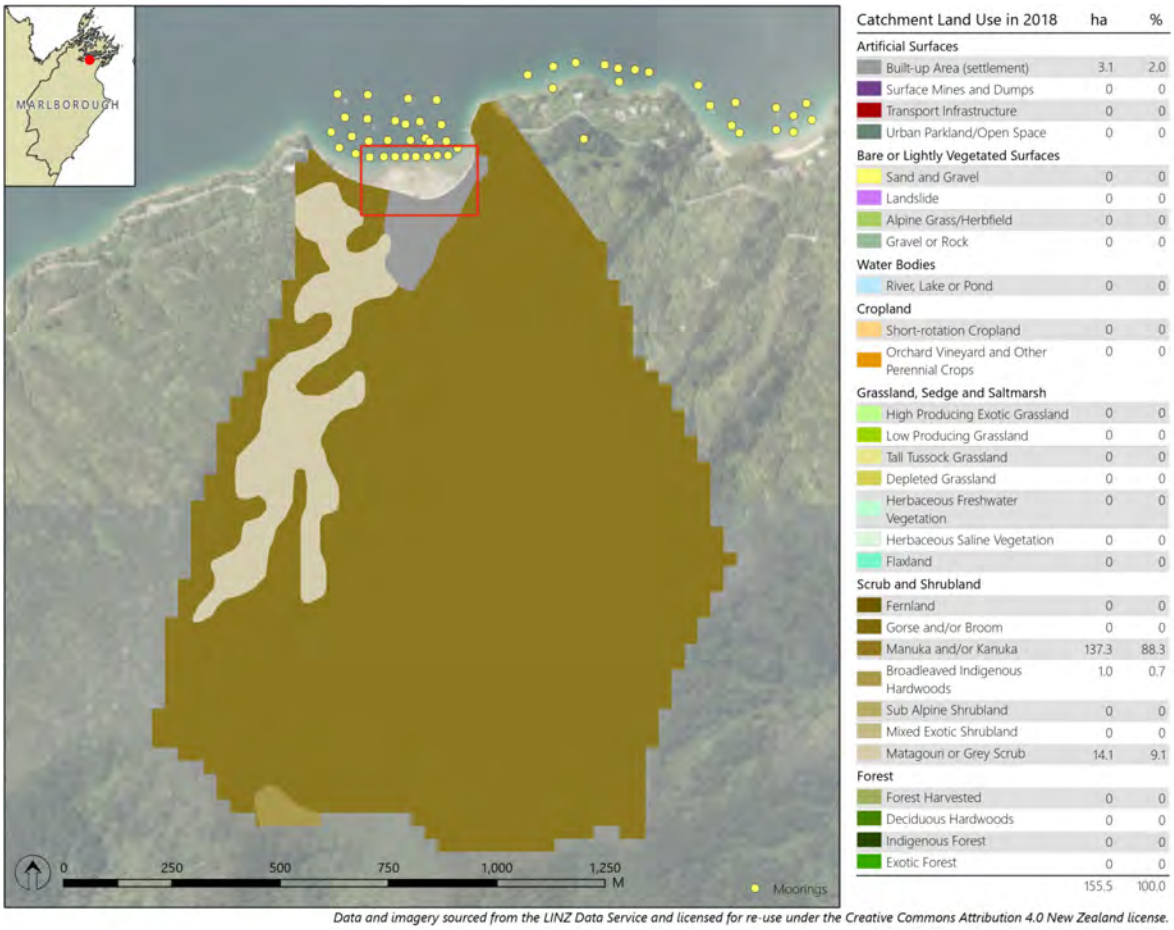


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Fig. B4.1. Momorangi Bay catchment land use classifications from LCDB5 (2017/2018) database.

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Fig. B4.2. Intertidal areas within Momorangi Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC). Boundaries require ground truthing and should be treated as best estimates only.

Birds feeding in Momorangi Bay

Vehicle tracks on estuary

Stormwater discharge, shoreline hardening and seagrass beds

Pipi present in gravels

Signage at the boat ramp, Momorangi Bay

Seagrass growing on sands and in gravel, Momorangi Bay

Gravel substrate, boat ramp and grass up to the estuary margin and shoreline hardening

B5. Ngākuta Bay (Grove Arm)

Ngākuta Bay is a medium (~12ha) shallow intertidally dominated estuary that connects to a large subtidal area of Grove Arm in Queen Charlotte Sound. Land cover in the steep, erodible catchment is dominated by broadleaved indigenous hardwoods (58.2%), indigenous forest (22.8%) and mānuka and/or kānuka (10.3%; Fig. B5.1). Exotic forestry comprises only 0.7% of the catchment area (Fig. B5.1). Near the estuary the land has been developed for a settlement and farming. The estuary itself has been extensively modified with shoreline hardening and a jetty (Davidson et al. 1990). The substrate is dominated by firm muddy sands and gravel with only a small area of soft mud localised around freshwater inputs (Stevens 2018a). In 2018, salt marsh and seagrass were both present and in good health (Fig. B5.2), which was confirmed during the recent (11 April 2022) rapid estuary assessment. There were no signs of eutrophication (i.e. macroalgal blooms, enriched sediments) indicating current sediment and nutrient loads are below thresholds of concern.

Ngākuta Bay is classified as a significant marine site; despite its small intertidal area it is an important roosting area for Caspian tern and reef heron, and a feeding area for wide range of other birds (Davidson et al. 1990; Davidson et al. 2011). The estuary supports a small area of salt marsh that is classified as a regionally significant wetland.

The foreshore is designated a recreation reserve and has a high number of users because there is easy road access, a jetty and a boat ramp. Kayaking, swimming, fishing, and water skiing are common. Vehicle use on the estuary is common, with vehicle tracks observed during the previous site visits (see photos). Further, a high number of moorings are present throughout the bay increasing the likelihood of marine contaminants, pests and pathogens being introduced to the area.

Aside from recreational users the largest pressure on Ngākuta Bay is the modified terrestrial margin, with shoreline hardening common for infrastructure protection and erosion control. This modification has led to loss of salt marsh habitat and significantly reduced the estuaries natural adaptive capacity to sea level rise. Overall, the estuary is in 'good' condition with cockle beds, a small area of salt marsh and high value seagrass beds still present.

Table B5.1. Summary information for Ngākuta Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	12	-
Intertidal Area (Ha; % Estuary)[1]	11.8	98.3
Dominant Estuary Substrate[1]	Firm sand	
Mud extent (>50% mud content)	2.6	22.0
Macroalgae (cover >50%)[1]	0.0	0.0
Seagrass (cover >50%)[1]	1.0	9.6
Salt Marsh (% intertidal)[1]	0.9	7.5
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	606.9	
Dominant Catchment Land Cover[2]	Broadleaved indigenous hardwoods	
% Catchment indigenous vegetation[2]	96.5	
% Catchment exotic forest[2]	0.7	
% Producing grassland[2]	1.1	
Mean Freshwater Flow (m^3/s)[3]	0.24	
Catchment Nitrogen Load (T/y)[3]	1.58	
Catchment Phosphorus Load (T/y)[3]	0.22	
Catchment Sediment Load (KT/y)[3]	1.55	
Catchment Geology[4]	Schist & gravels	
Biodiversity		
ESMS	Y – 4.5	
Significant Wetland[5]	Y – salt marsh	
Birds[6]	Caspian tern, reef heron, variable oyster catcher	
Fish[5]	Redfin Bully	
Shellfish	Extensive cockle beds	
Pressures		
Modified margin habitat		
Recreational use: jetty, boat use, kayak, accommodation		
Shoreline hardening		
Domestic wastewater		
Road and boat access – vehicle use on estuary		
High number of moorings		
Limited scope for landward migration with sea level rise		

[1]Stevens (2018a); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Map; [6]Davidson et al (2011); nd = no data

Table B5.2. Ecological Vulnerability Assessment, Ngākuta Bay.

Category	Score
Values	0.70
Pressures	0.74
Susceptibility	0.86
Condition	0.76
Average Score	**0.76**

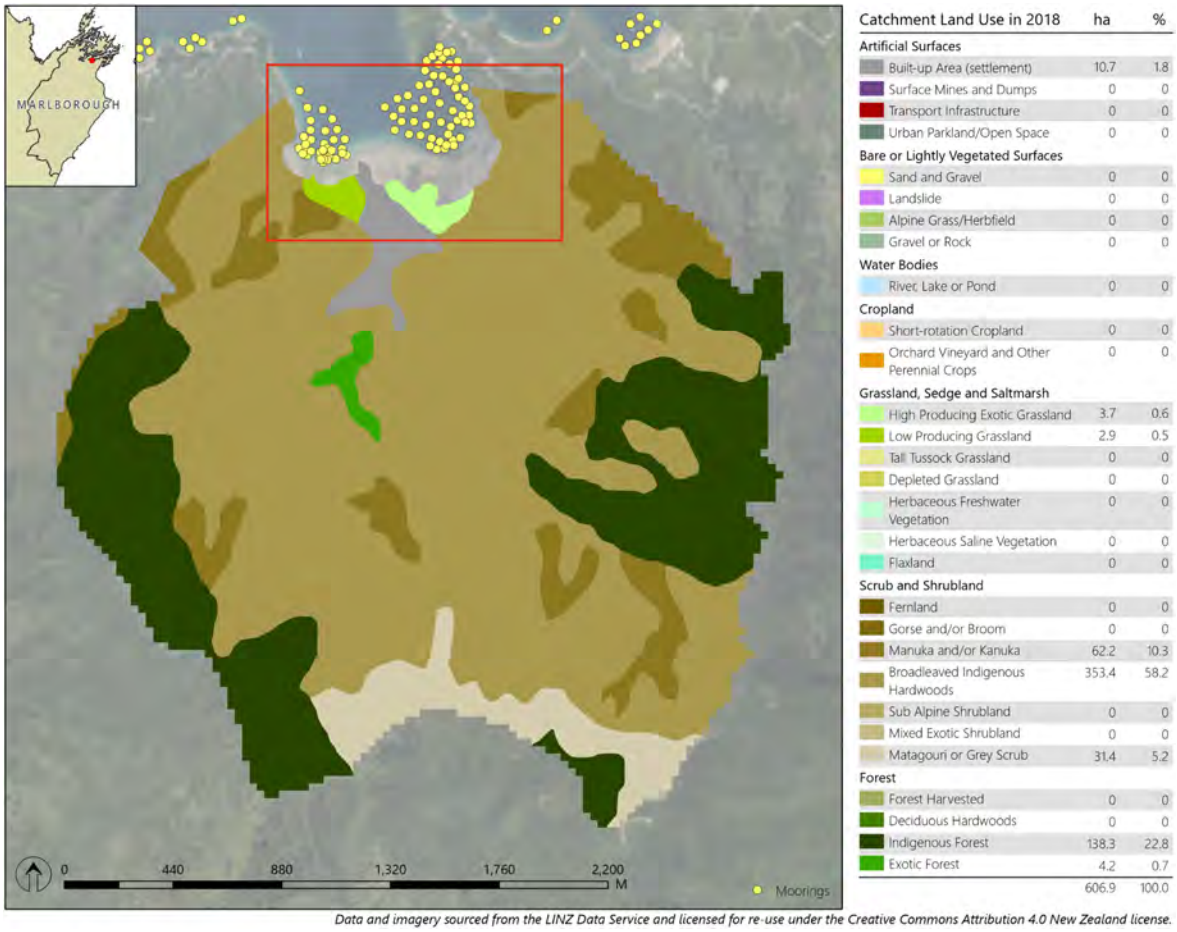

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Fig. B5.1. Ngākuta Bay catchment land use classifications from LCDB5 (2017/2018) database.

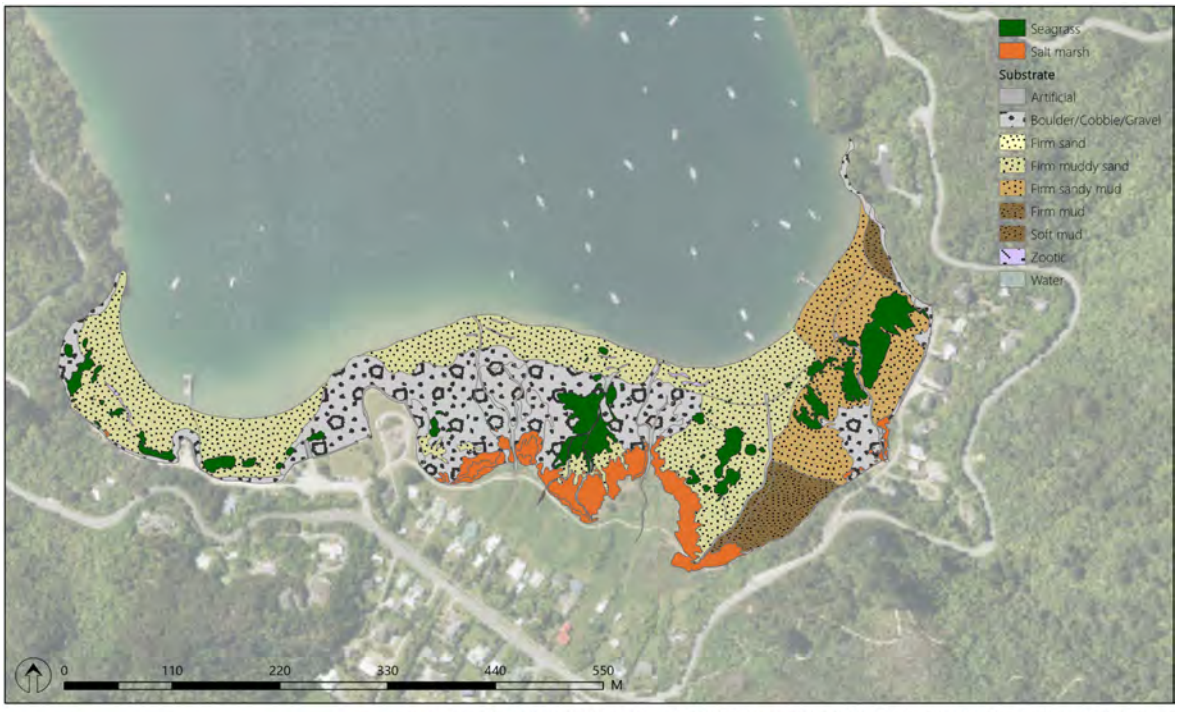

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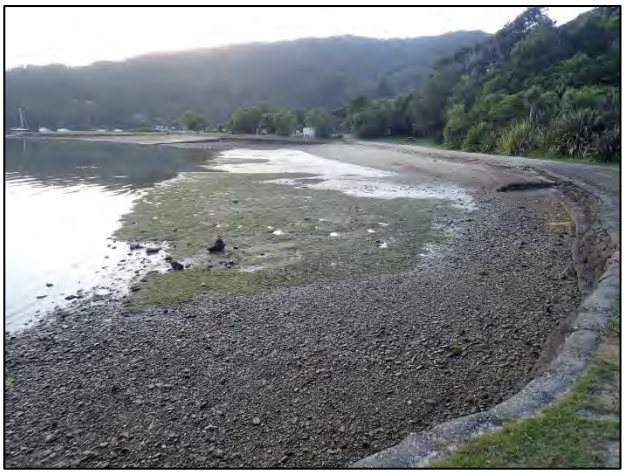
Fig. B5.2. Intertidal area in Ngākuta Bay. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens 2018a).

Rushland, Ngākuta Bay

Vehicle tracks through seagrass beds, Ngākuta Bay

Seagrass in the lower estuary, Ngākuta Bay

Cockle beds, Ngākuta Bay



Estuary margin hardening and boat ramp, Ngākuta Bay

Grassland and shoreline hardening on margin, Ngākuta Bay

B6. Ōkiwa Bay (Grove Arm)

Ōkiwa Bay is a medium (~85ha) shallow intertidally dominated estuary that connects to a large subtidal area of Grove Arm in Queen Charlotte Sound. The upper catchment is dominated by indigenous forest and broadleaved indigenous hardwoods (Table B6.1; Fig. B6.1). However, the mid and lower catchment comprise exotic forest (25.7%) and high producing grassland (15.2%). A small settlement is also present on the estuary margin.

The intertidal substrate is dominated by firm sands and firm muddy sands that support extensive cockle beds. Seagrass is restricted to the lower estuary margin (Fig. B6.2). Salt marsh has significantly reduced in extent when compared to historical coverage, however remaining salt marsh is dominated by rushland and herbfield

Both mud-dominated sediments and macroalgae expression have increased over time with macroalgae covering most of the lower tidal flats (Stevens 2018a). Some signs of eutrophication were evident during the recent (18 May 2022) site visit with localised areas of poorly oxygenated muddy sediments, particularly on the estuary margin and dense beds of macroalgae (i.e. *Agarophyton* spp.) growing in soft muds in the centre of the estuary.

Ōkiwa Bay is classified as a significant marine site because it represents the largest tidal wetland in Queen Charlotte Sound. It is an important habitat for wildlife, particularly birds including the Caspian tern, white heron, and the banded rail. The salt marsh is also recognised as a regionally significant wetland. The subtidal area adjacent to the intertidal flats is classified as a significant marine site due to a large population of the solitary ascidian (sea squirt).

The main pressures to Ōkiwa Bay are nutrients and fine sediment inputs from the catchment which includes large areas of forestry and high producing grassland. In the next 10 years, plantation forestry will be a potential source of sediment during and post-harvest with large areas due to reach maturity. Other pressures include historic drainage and reclamation of salt marsh habitat limiting landward migration with sea level rise. The subtidal bay is also a popular area for boats with over 50 moorings (Fig. B6.1) increasing the risk of marine contaminants and introduced marine species.

Overall, the estuary is in 'moderate' condition with some signs of excessive muddiness and nuisance macroalgal growth. However, the estuary retains high ecological values with seagrass, salt marsh and cockle beds present.

Table B6.1. Summary information for Ōkiwa Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	85	-
Intertidal Area (Ha; % Estuary)[1]	80.4	94.6
Dominant Estuary Substrate[1]	Sand/ Firm muddy sand	
Mud extent (>50% mud content)	41.4	51.5
Macroalgae (cover >50%)[1]	32.7	38.4
Seagrass (cover >50%)[1]	2.5	3.3
Salt Marsh (% intertidal)[1]	5.3	6.6
High Enrichment Conditions (HEC)	-	1-5%
Catchment		
Catchment Area (Ha)[2]	3536.3	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	56.8	
% Catchment exotic forest[2]	25.7	
% Producing grassland[2]	15.7	
Mean Freshwater Flow (m^3/s)[4]	2.2	
Catchment Nitrogen Load (T/y)[4]	12.45	
Catchment Phosphorus Load (T/y)[4]	2.93	
Catchment Sediment Load (KT/y)[4]	7.39	
Catchment Geology[4]	Sandstone & gravels	
Biodiversity		
ESMS[5]	Y – 4.1	
Significant Wetland[6]	Y – salt marsh	
Birds[5]	Caspian tern, white heron, reef heron, banded rail	
Fish[6]	Redfin Bully	
Shellfish[1]	Extensive cockle beds	
Pressures		
Sedimentation		
Elevated nutrient inputs		
Developed catchment – forestry and pasture		
Stormwater and wastewater discharges		
Drainage and reclamation of salt marsh		
Marine contaminants/ introduced species		
Recreational use: bach owners and kayakers		

[1]Stevens (2018a); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al (2011); [6]MDC Smart Map; nd = no data

Table B6.2. Ecological Vulnerability Assessment, Ōkiwa Bay.

Category	Score
Values	0.72
Pressures	0.62
Susceptibility	0.68
Condition	0.56
Average Score	0.65

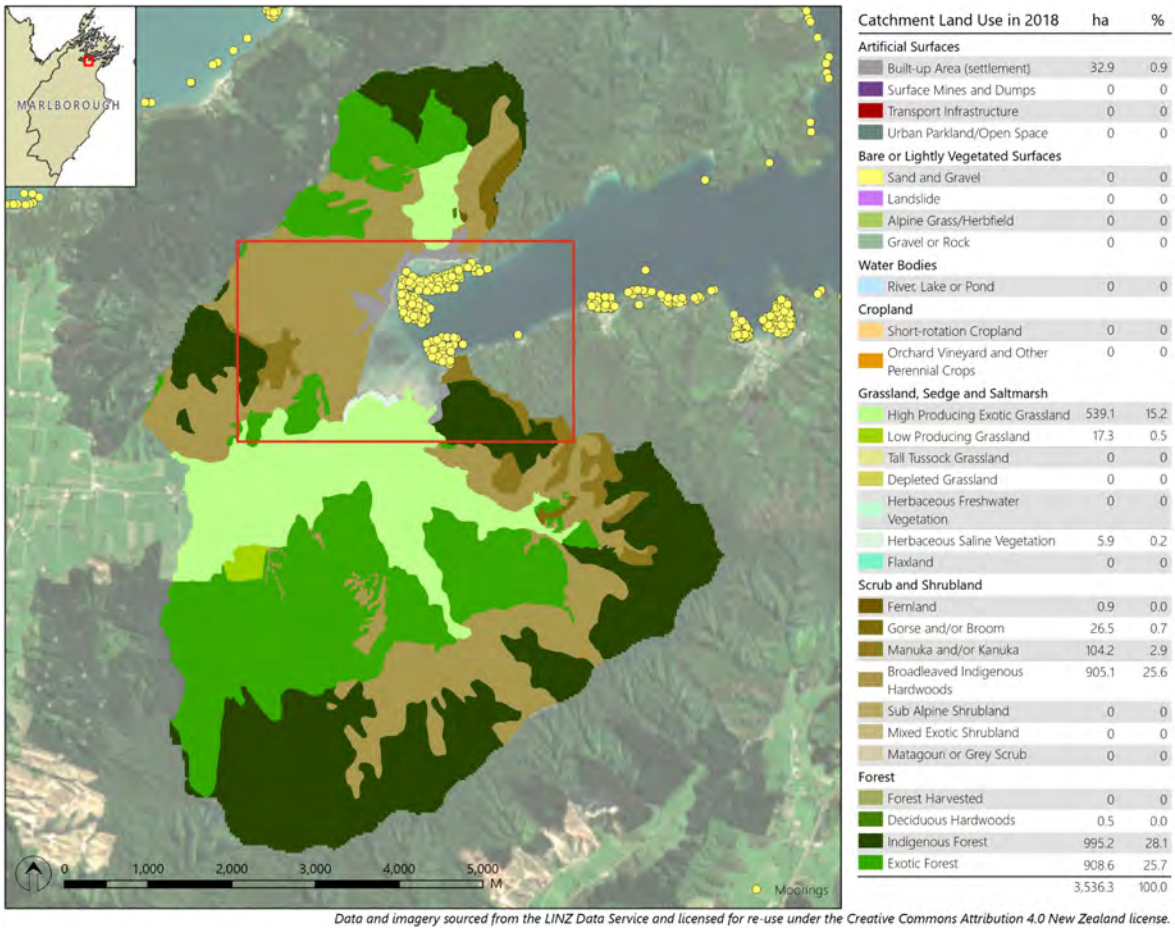


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Fig. B6.1. Ōkiwa Bay catchment land use classifications from LCDB5 (2017/2018) database.

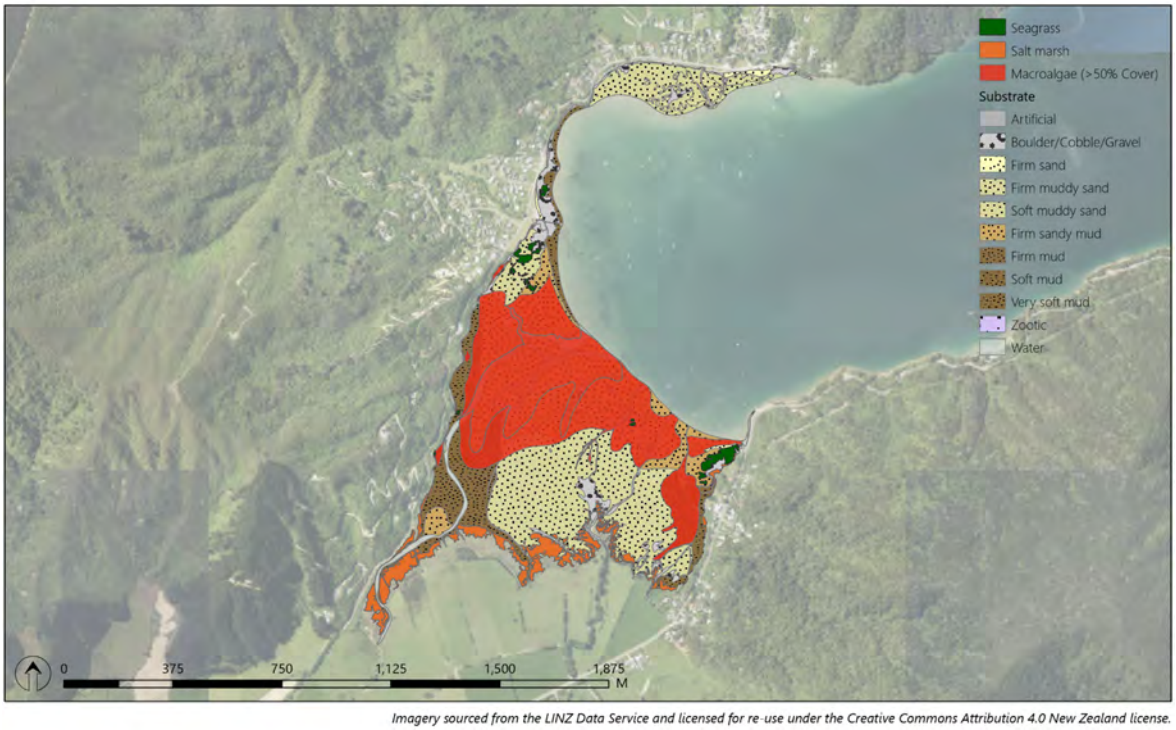

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Fig. B6.2. Intertidal area in Ōkiwa Bay. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens 2018a).

Rushland and firm mud substrate, Ōkiwa Bay

Soft muds near salt marsh habitat, Ōkiwa Bay

Seagrass in the lower estuary, Ōkiwa Bay

Intertidal flats, Ōkiwa Bay

Dense cover of macroalgae in the lower estuary, Ōkiwa Bay

Gravel, Ōkiwa Bay

B7. Umungata (Davies) Bay

Umungata (Davies) Bay is a small sized (~3.0ha) shallow intertidally dominated estuary that connects to a large subtidal area of Grove Arm in Queen Charlotte Sound. The catchment is dominated by mature coastal beech forest protected within the Iwituaroa Scenic Reserve (Table B7.1; Fig. 7.1). Healthy seagrass beds (>50% intertidal area) dominate the gravel intertidal flats. In a recent (16 February 2022) REA there were no visible signs of eutrophication.

Salt marsh is scarce and restricted to the entrance of the freshwater stream input (Fig. B7.2). Vegetation clearing on the estuary margin has likely led to loss of salt marsh habitat (~40-60%) when compared to historic extent. Erosion of salt marsh habitat was also observed in the most recent site visit (February 2022). The immediate estuary margin comprises a mix of regenerating native bush and grass on the waterfront.

Umungata (Davies) Bay is classified as a significant marine site because the estuary catchment is protected mature native forest and the tidal flats feature a variety of habitats including salt marsh and seagrass which support an array of wildlife (Davidson et al. 2011).

There are limited pressures from the catchment due to its native forest cover. However, other pressures include remote boat access, particularly for recreational use such as kayaking and water skiing, with a designated water-skiing lane on the western shore. The immediate estuary margin is clear of vegetation for a DOC campsite. Access to the campsite is via boat, walking or biking and has high seasonal use. There are no permanent moorings, but anchorage is possible on the north side of the bay. Even though the margin is modified (i.e. grassland) there is scope for some managed retreated with sea level rise given the coastal gradient.

Despite some margin modification, the catchment is protected within scenic reserve and the intertidal flats support high values seagrass beds. The EVA results show that overall, pressures are low, and the estuary is not highly susceptible to future change.

Table B7.1. Summary information for Umungata Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	3.0	-
Dominant Estuary Substrate	Gravel	
Mud extent (>50% mud content)	-	<1
Macroalgae (cover >50%)	-	0-5
Seagrass (cover >50%)	-	50
Salt Marsh (% intertidal)	-	2
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	371.7	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.04	
Catchment Nitrogen Load (T/y)[3]	0.97	
Catchment Phosphorus Load (T/y)[3]	0.16	
Catchment Sediment Load (KT/y)[3]	1.48	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS[5]	Y – 4.3	
Significant Wetland	N	
Birds	nd	
Fish[6]	Redfin Bully	
Shellfish		
Pressures		
Remote boat access		
Kayaking and waterskiing common		
Campsite on the estuary margin		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al. (2011); [6]MDC Smart Maps nd = no data

Table B7.2. Ecological Vulnerability Assessment, Umungata (Davies) Bay.

Category	Score
Values	0.75
Pressures	0.79
Susceptibility	0.88
Condition	0.78
Average Score	**0.80**

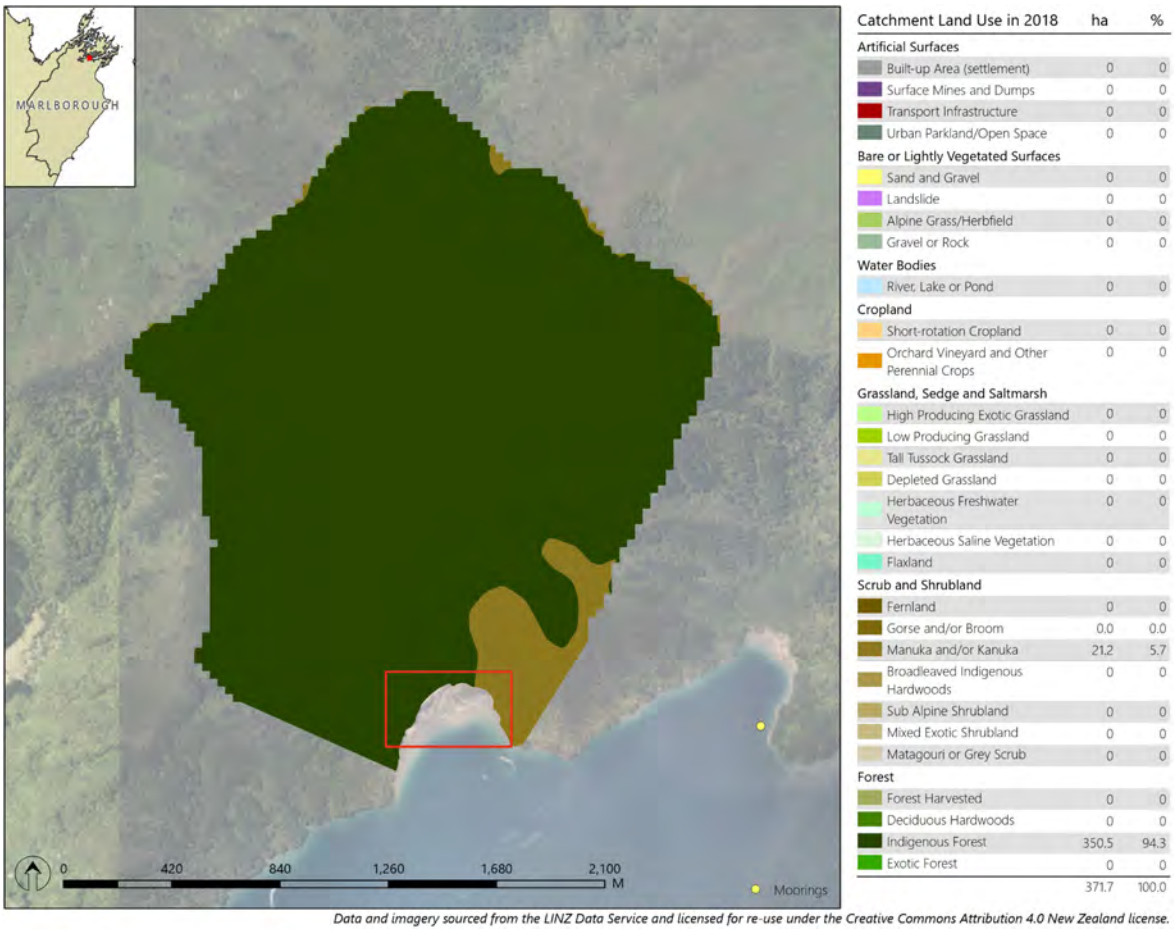

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Fig. B7.1. Umungata (Davies) Bay catchment land use classifications from LCDB5 (2017/2018) database.

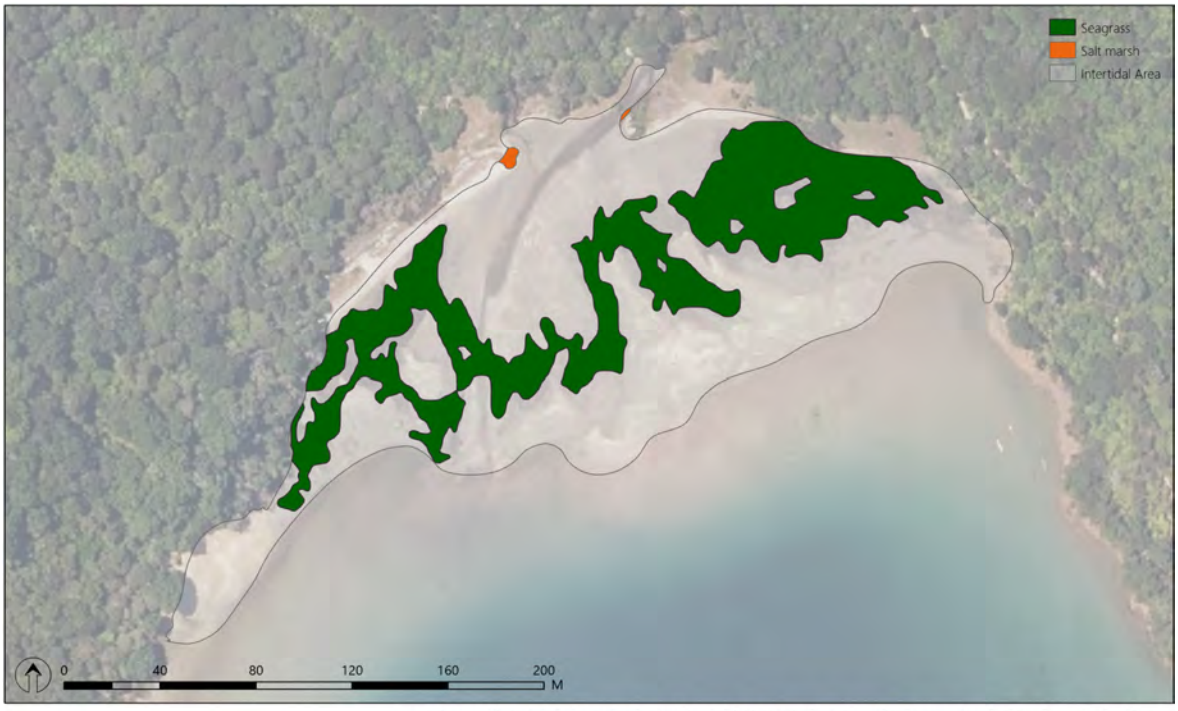

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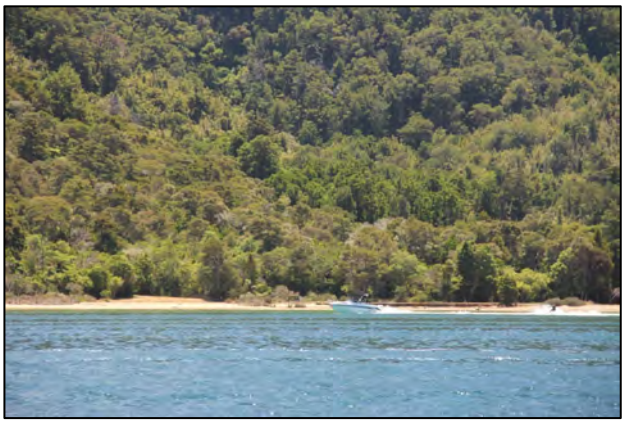
Fig. B7.2. Intertidal area in Umungata (Davies) Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC). Boundaries require ground truthing and should be treated as best estimates only.

Grass up to the estuary edge to accommodate DOC campsite (image source: Department of Conservation)



Waterskiing in Umungata (Davies) Bay (Image ref: MDC 'Anakiwa 1', Courtesy of Marlborough District Council)

Umungata (Davies) Bay with native bush catchment (Image ref: MDC 'QCS DaviesBay 01', Courtesy of Marlborough District Council)

B8. Fence Bay (Onahau Bay)

Fence Bay is a very small (~0.5ha) shallow intertidally dominated estuary that connects to the larger subtidal Onahau Bay in Queen Charlotte Sound. The catchment is dominated by broadleaved indigenous hardwoods with only a small area of exotic forest (Table B8.1; Fig. B8.1). The estuary comprises a small area of fringing salt marsh (rushland; see photo). Seagrass is the dominant vegetation type expanding across most of the intertidal area (Fig. B8.2; see photo) and growing in substrates of sand and firm muddy sand (Table B8.1). The intertidal flats support high abundances of pipi and cockles.

While there is limited development in the catchment, a small area (<1%; Table B8.1) of very soft mud and low oxygen sediment was recorded in a recent (16 February 2022) REA. Despite the absence of high macroalgal cover these areas were recorded as exhibiting 'High Enrichment Conditions', due to poor condition of the sediments. Localised enrichment of sediments is consistent with other estuaries in the Onahau Bay (e.g. Waterfall Bay). However, the lack of widespread macroalgal growth in the estuary suggests that current nutrient and sediment loads are below thresholds of concern.

The main pressures in Fence Bay include the high number of private baches, jetties and moorings. While recreational use is mostly limited to the local bach owners the number of structures and boat users increases the likelihood of marine contaminants, pests and pathogens being introduced to the area. A minor incursion of the non-indigenous Pacific oyster was recorded in the estuary on a recent site visit. There is some modification to the upper estuary margin and due to the steep topography of the margin there is limited adaptive capacity (i.e. landward migration) to sea level rise. Overall, the estuary is in 'good' condition. Catchment pressures are currently low, however the bay and estuary are subject to high recreational use.

Table B8.1. Summary information for Fence Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	0.5	-
Dominant Estuary Substrate[1]	Sand	
Mud extent (>50% mud content)	-	1-5
Macroalgae (cover >50%)[1]	-	<5
Seagrass (cover >50%)[1]	-	90
Salt Marsh (% intertidal)[1]	-	15
High Enrichment Conditions (HEC)[1]	-	<1
Catchment		
Catchment Area (Ha)[2]	77.7	
Dominant Catchment Land Cover[2]	broadleaved indigenous hardwoods	
% Catchment indigenous vegetation[2]	93.6	
% Catchment exotic forest[2]	6.4	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.5	
Catchment Nitrogen Load (T/y)[3]	0.16	
Catchment Phosphorus Load (T/y)[3]	0.03	
Catchment Sediment Load (KT/y)[3]	0.07	
Catchment Geology[4]	Sandstone & Breccia	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish[7,8]	Redfin bully	
Shellfish	Pipi and cockles	
Pressures		
Remote boat access		
High number of moorings		
Local baches with jetties		
Species incursion – Pacific oysters (rare)		
Low adaptive capacity to sea level rise (i.e. natural barrier)		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [4]CLUES; [4]QMap; [5]MDC Smart Maps nd = no data

Steep estuary margin and native bush catchment

Table B8.2. Ecological Vulnerability Assessment, Fence Bay.

Category	Score
Values	0.66
Pressures	0.76
Susceptibility	0.80
Condition	0.78
Average Score	**0.75**

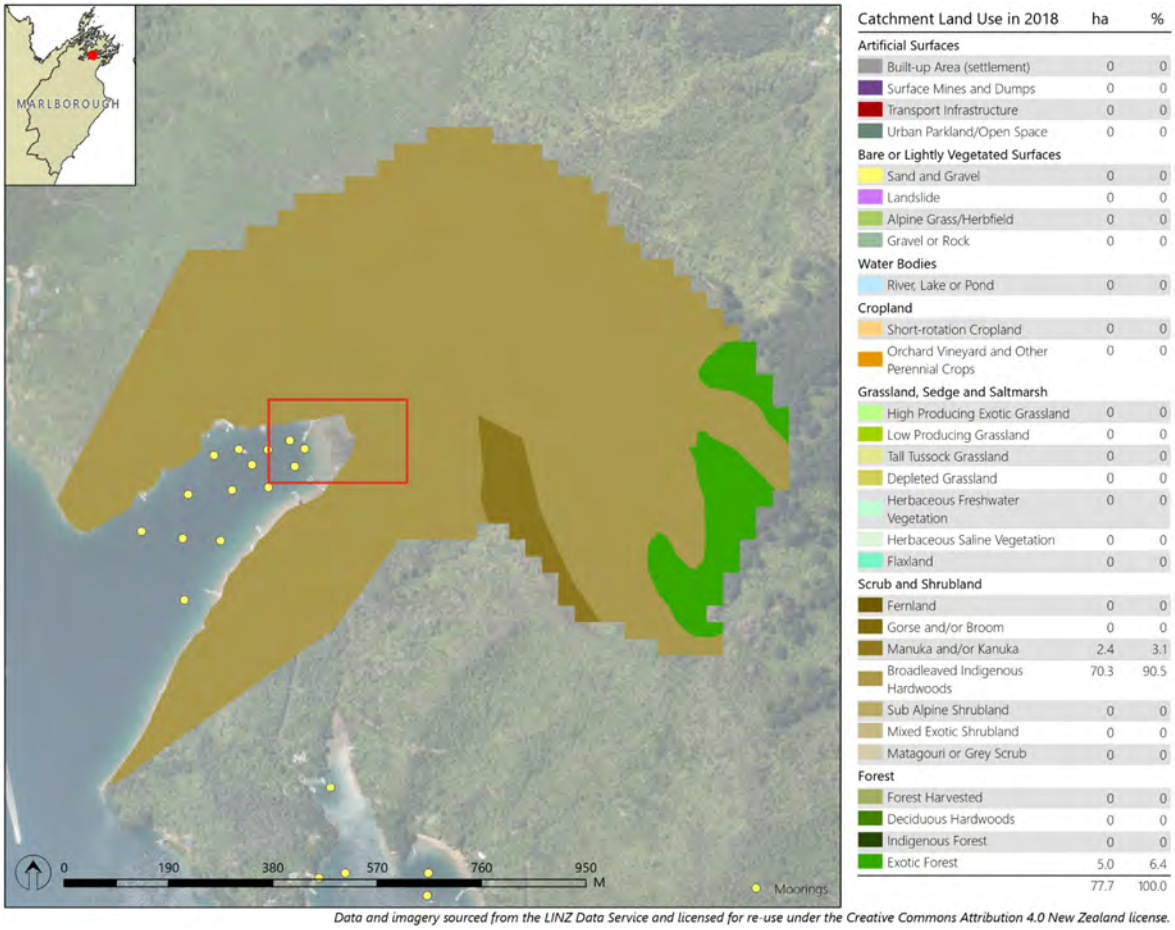


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Fig. B8.1. Fence Bay catchment land use classifications from LCDB5 (2017/2018) database.

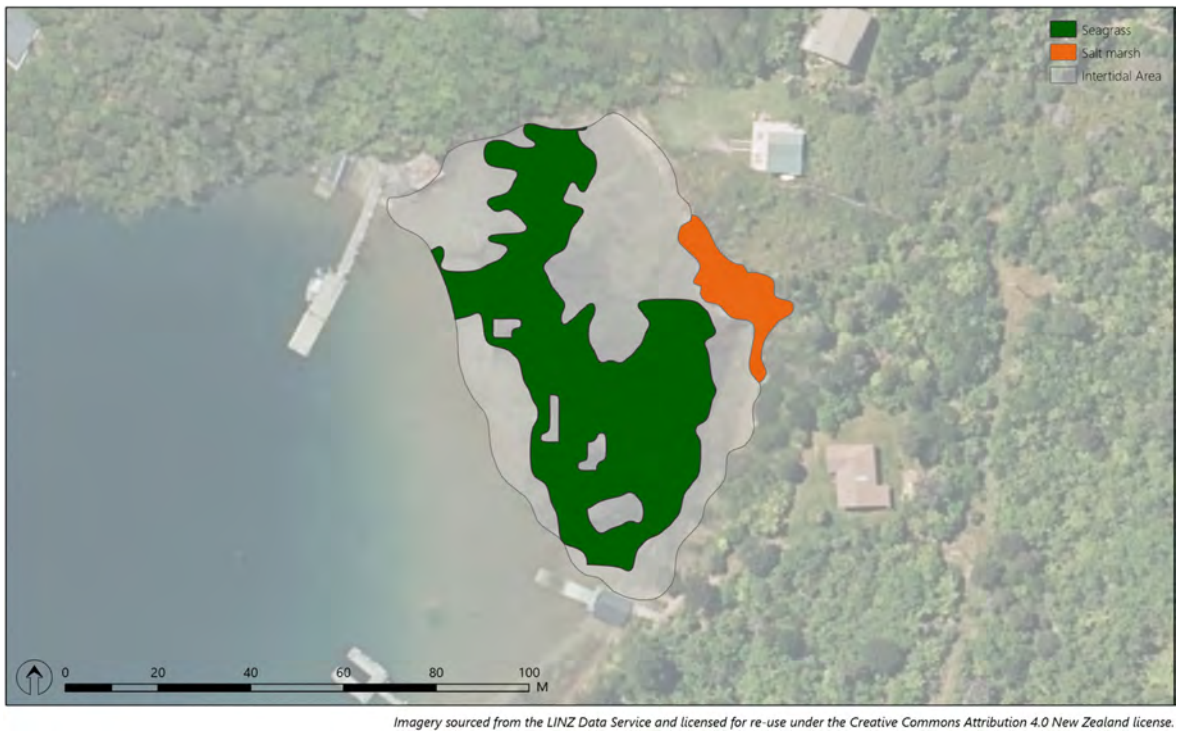

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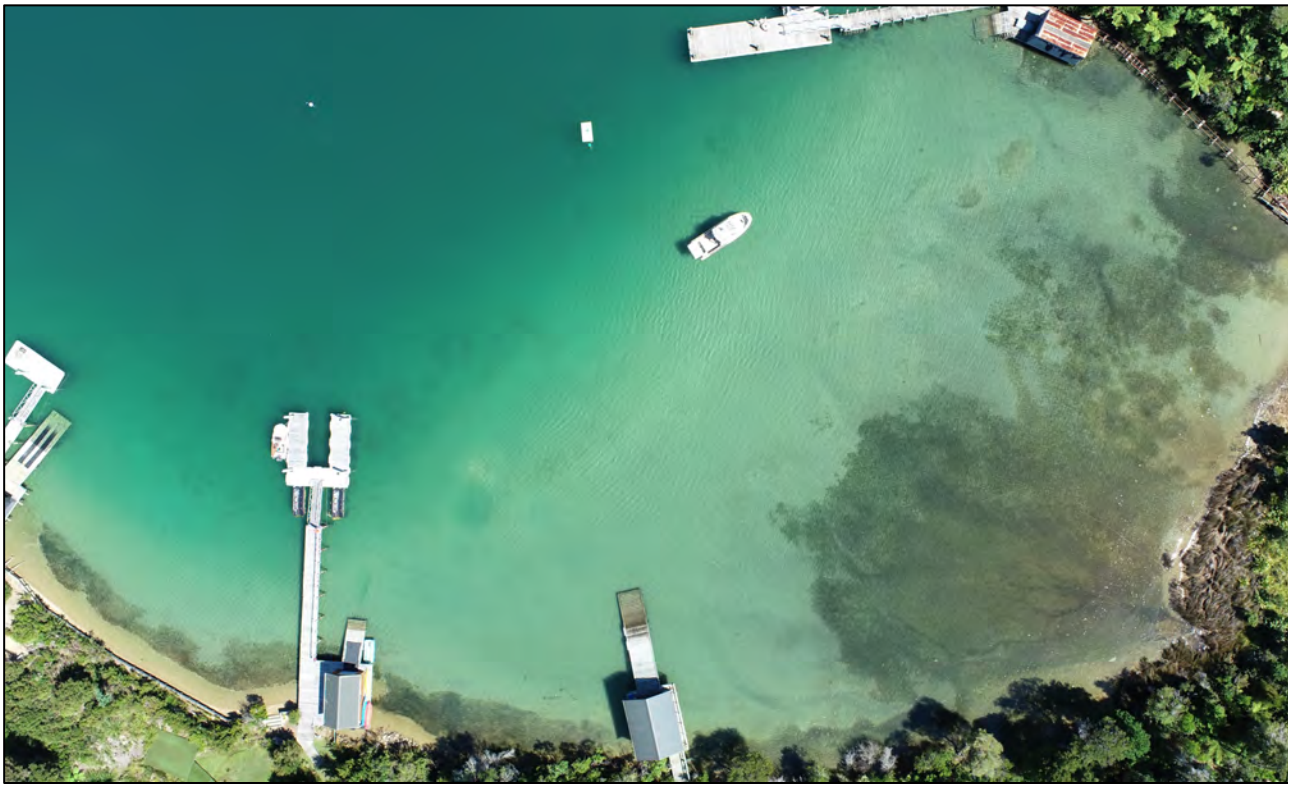
Fig. B8.2. Intertidal areas within Fence Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC). Boundaries require ground truthing and should be treated as best estimates only.

Drone image of Fence Bay, dark areas represent seagrass and a small area of rushland on the shoreline



Drone image of Fence Bay, large number of jetties and structures in close proximity to the estuary

B9. Mistletoe Bay (Onahau Bay)

Mistletoe Bay is a small (0.9ha) shallow intertidally dominated estuary at the head of Onahau Bay in Queen Charlotte Sound. The catchment is dominated by broadleaved indigenous hardwoods (Table B9.1; Fig. B9.1). The intertidal flats are dominated by clean sands with seagrass cover across ~80% of the area (Fig. 9.2). Salt marsh is scarce (~3% intertidal area) owing to the heavily modified margin (i.e. reclamation for grassland and shoreline hardening). At the time of a recent site visit macroalgae was sparse (<5%) and not considered a problem in the estuary. No areas of High Enrichment Conditions were recorded.

The margin of Mistletoe Bay has been heavily modified with a grass camp site and shoreline hardening present on the eastern margin for the jetty (see photo). Mistletoe Bay is popular with boat users with both permanent moorings and anchorage increasing the likelihood of marine contaminants, pests and pathogens being introduced to the area. Recreational uses, such as camping, kayaking and swimming are high and supported by an eco-village on the estuary margin with road access up to the estuary edge. Minor domestic wastewater discharges occur within the estuary margin. There is limited scope for managed retreat with sea level rise due to the modified nature of the margin and artificial rock wall.

While seagrass is expansive, the limited salt marsh habitat and impact of margin modification and high human use have compromised the ecological values of the estuary. The overall 'good' condition of the estuary is largely attributed to low sediment and nutrient loads from the mostly native bush catchment and the well-drained intertidal flats.

Mistletoe Bay intertidal area and shoreline hardening for jetty (Image ref: MDC 'QCS Mistletoe Bay 0140', Courtesy of Marlborough District Council)

Table B9.1. Summary information for Mistletoe Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	0.9	-
Dominant Estuary Substrate	Sand	
Mud extent (>50% mud content)	-	<1
Macroalgae (cover >50%)	-	>0-5
Seagrass (cover >50%)	-	80
Salt Marsh (% intertidal)	-	3
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	99.9	
Dominant Catchment Land Cover[2]	Broadleaved Indigenous Hardwoods	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.03	
Catchment Nitrogen Load (T/y)[3]	0.24	
Catchment Phosphorus Load (T/y)[3]	0.04	
Catchment Sediment Load (KT/y)[3]	0.11	
Catchment Geology[4]	Sandstone & Breccia	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish[5]	Redfin Bully	
Shellfish	nd	
Pressures		
Modified margin habitat		
Recreational use: camping & eco-village		
Shoreline hardening on eastern margin (i.e. jetty)		
Domestic wastewater		
Road and boat access		
Low adaptive capacity to sea level rise		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Map; nd = no data

Table B9.2. Ecological Vulnerability Assessment, Mistletoe Bay.

Category	Score
Values	0.58
Pressures	0.78
Susceptibility	0.83
Condition	0.70
Average Score	**0.72**

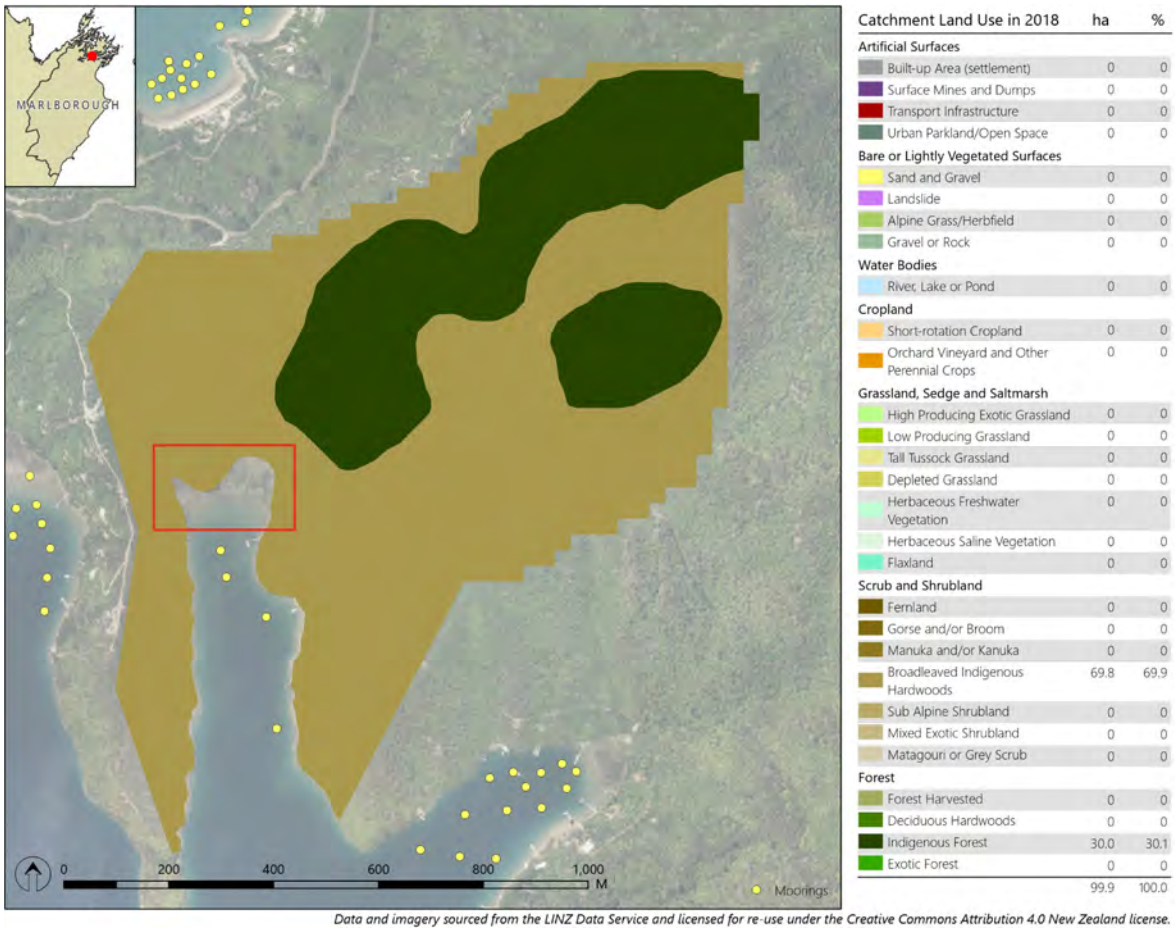


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Fig. B9.1. Mistletoe Bay catchment land use classifications from LCDB5 (2017/2018) database.

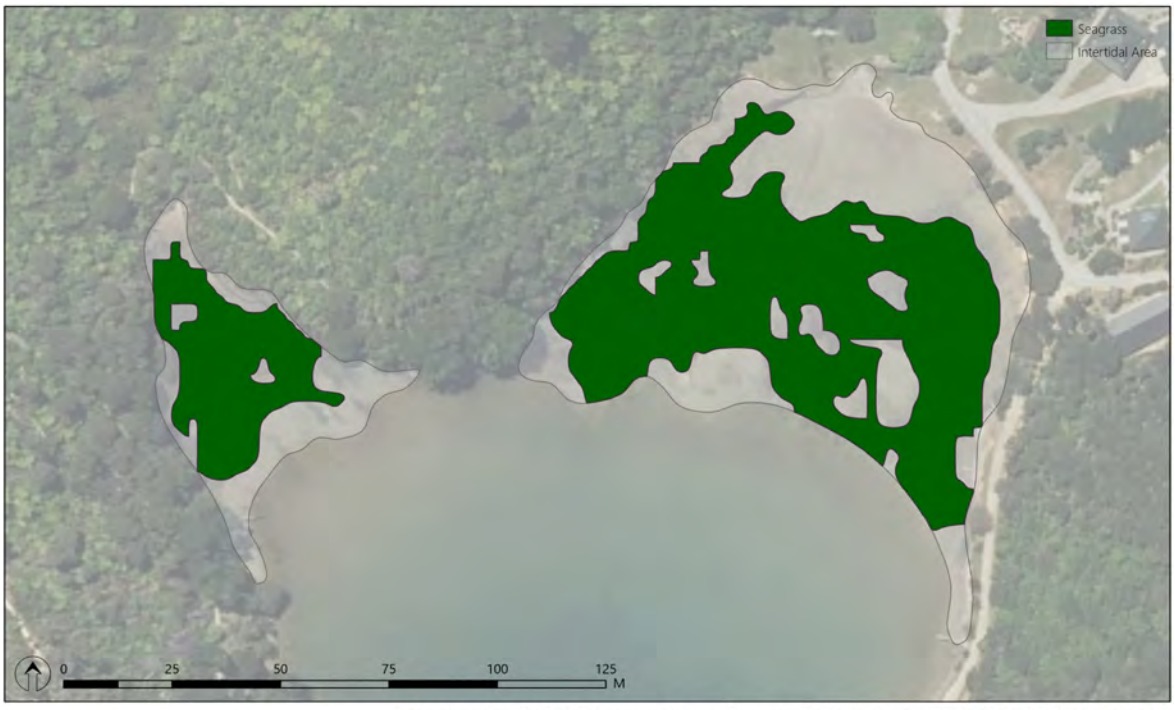

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Fig. B9.2. Intertidal areas within Mistletoe Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC). Boundaries require ground truthing and should be treated as best estimates only.

Drone image of western intertidal area of Mistletoe Bay, dark areas represent seagrass

Drone image of eastern intertidal area of Mistletoe Bay, dark areas represent seagrass

B10. Waterfall Bay (Onahau Bay)

Waterfall Bay has two small (~0.7ha each) shallow intertidally dominated estuaries that connect to a large subtidal area at the head of Onahau Bay in Queen Charlotte Sound. The catchment was cleared in the early 1900's and is now dominated by regenerating broadleaved indigenous hardwoods (Table B10.1; Fig. B10.1).

In the late 1970's to early 80's a large area of the northern intertidal flats was reclaimed. Present day, seawalls comprise a large part of the estuary margin of both tidal flats, to support a road and minor residential development. The upper margin of the northern flats is the most heavily modified, with reclamation, shoreline hardening and historic vegetation clearing evident. Extensive shoreline hardening across both tidal flats will limit landward migration with sea level rise

Seagrass dominates the intertidal area (Table B10.1) growing on sand substrate. Restricted by steep banks and margin modification, only a small patch of salt marsh is present on the western intertidal flats. Mud deposition (10-20% extent) on both the northern and western intertidal flats was evident during a recent REA survey (16 February 2022), likely owing to poorer flushing in that area and historic development within the terrestrial margin. Some signs of eutrophication were evident during the REA comprising very soft mud with low oxygen content. Despite the absence of high macroalgal cover these areas were recorded as exhibiting 'High Enrichment Conditions', due to poor condition of the sediments. Localised enrichment of sediments was consistent with other estuaries in the Onahau Bay (e.g. Fence Bay). However, the lack of widespread macroalgal growth in the estuary suggests that current nutrient and sediment loads are below thresholds of concern.

While the catchment remains largely intact, past development on the margin has a high relative impact on the estuary. Recreational use of the estuary is also high with boat and road access to the estuary margin. Waterfall Bay is popular with boat users and recreation is supported by both permanent moorings and safe anchorage within the bay. These factors increase the likelihood of marine contaminants, pests and pathogens being introduced to the area.

While seagrass is expansive, the limited salt marsh habitat, the impact of margin modification, and high human use have compromised the ecological values and condition of the estuary.

Table B10.1. Summary information for Waterfall Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	1.4	-
Dominant Estuary Substrate	Sand & gf/cf	
Mud extent (>50% mud content)	-	10-20
Macroalgae (cover >50%)	-	0-5
Seagrass (cover >50%)	-	60-70
Salt Marsh (% intertidal)	-	<3
High Enrichment Conditions (HEC)	-	>10%
Catchment		
Catchment Area (Ha)[2]	321.7	
Dominant Catchment Land Cover[2]	Broadleaved Indigenous Hardwoods	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	0.86	
Catchment Phosphorus Load (T/y)[3]	0.14	
Catchment Sediment Load (KT/y)[3]	1.03	
Catchment Geology[4]	Sandstone & Breccia	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish[5]	Redfin Bully	
Shellfish	nd	
Pressures		
Fine sediment deposition with poor sediment oxygen		
Residential and tourism		
Domestic wastewater		
Modified margin habitat		
Shoreline hardening		
Boat and road access		
High number of moorings within 5km		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Maps nd = no data

Table B10.2. Ecological Vulnerability Assessment, Waterfall Bay.

Category	Score
Values	0.48
Pressures	0.79
Susceptibility	0.81
Condition	0.58
Average Score	**0.67**

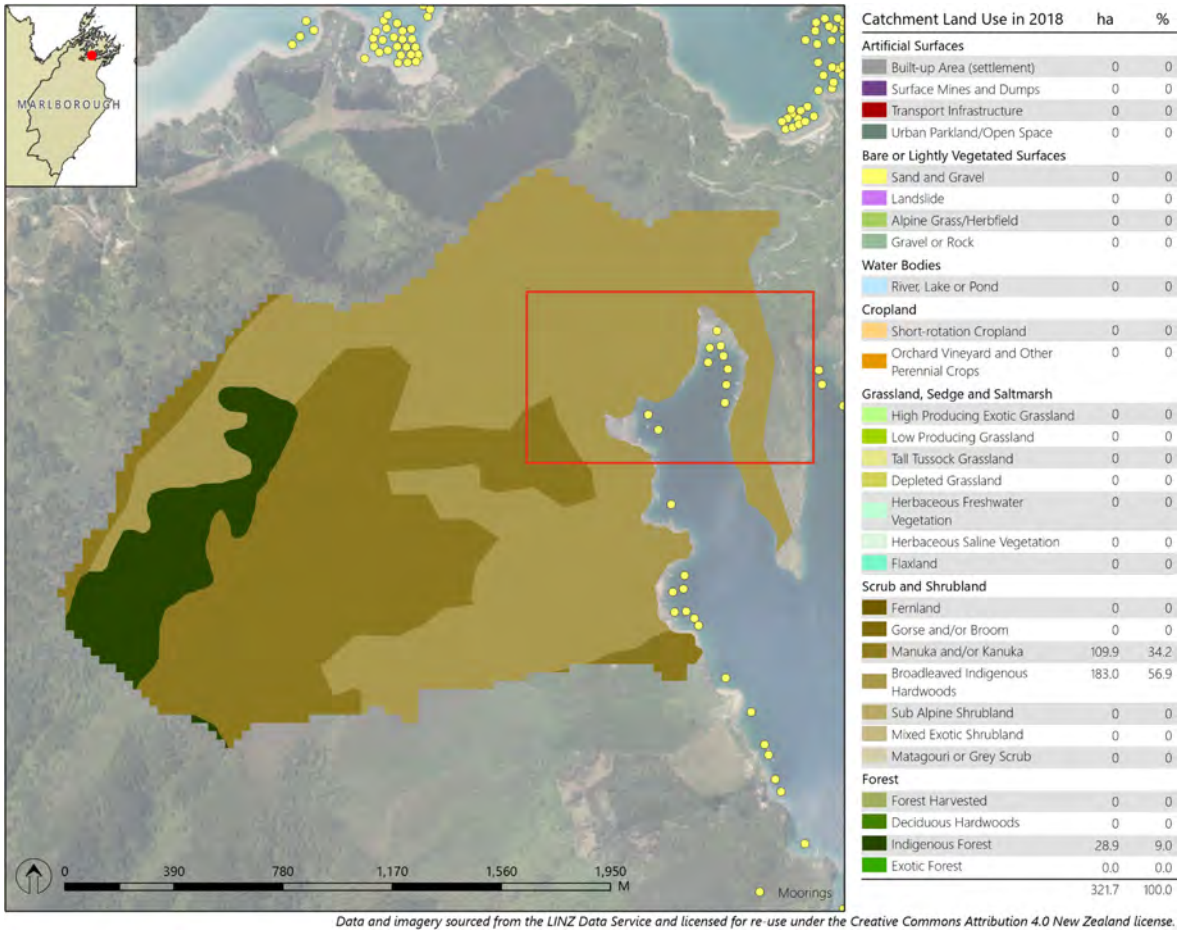

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Fig. B10.1. Waterfall Bay catchment land use classifications from LCDB5 (2017/2018) database.

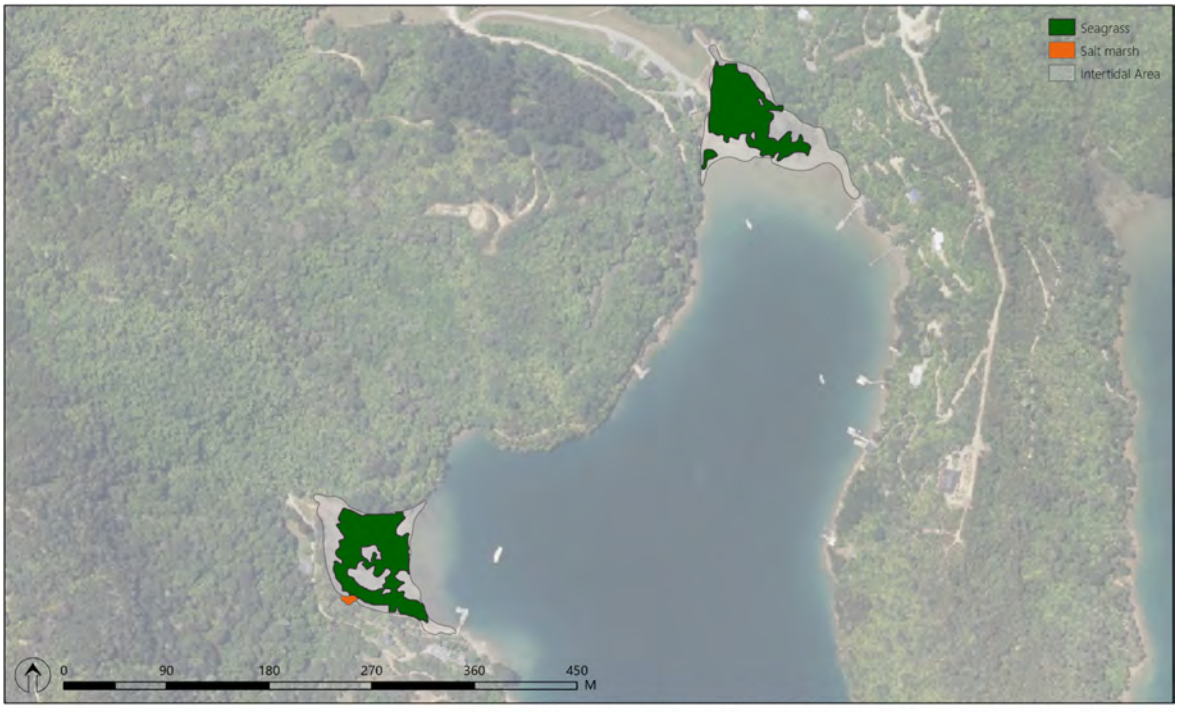

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Fig. B10.2. Intertidal areas within Waterfall Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC). Boundaries require ground truthing and should be treated as best estimates only.

Intertidal flats, Waterfall Bay (west)

Drone image of Waterfall Bay (west)

Artificial boudler, gravel and seagrass, Waterfall Bay (east)

Seagrass on sandy muds and gravel, Waterfall Bay (east)

Shoreline hardening on water front, Waterfall Bay (east; image ref: MDC 'AQCS Waterfall Bay 0083', Courtesy of Marlborough District Council)

Drone image of Waterfall Bay (east)

B11. Ahuriri Bay (Southern shore of QCS)

Ahuriri Bay is a small (8.4ha) intertidal estuary that connects to Whatamango Bay in Queen Charlotte Sound. The catchment is dominated by indigenous forest (82.7%) with high producing grassland and exotic forestry in the lower catchment (Fig. B11.1). Salt marsh comprises a small area (<1% of the intertidal area) on the fringing margin and is mainly rushland (*Juncus kraussii*; Robertson 2020). The dominant vegetation type, seagrass, comprised ~17% of the intertidal area and was found growing in cobble, gravel, sand and muddy sand substrate (Robertson 2020a; Fig. B11.2). In both the broadscale survey and the more recent (6 January 2022) rapid estuary assessment there was no evidence of eutrophic conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen). However, soft sediments were observed accumulating near freshwater inputs, with potential sources including bank erosion and catchment land use activities (e.g. pasture and forestry).

The salt marsh and fringing vegetation are an important habitat for roosting birds including the Caspian tern, reef heron and other estuarine birds (Table B11.1). Davidson et al (1990) reported that the intertidal flats support extensive shellfish beds.

While the estuary is modified (i.e. loss of salt marsh and clearing on the terrestrial margin) it retains high ecological values (i.e. seagrass). Currently the most significant pressure on the estuary is fine sediment deposition (Robertson 2020a). While the catchment is currently stable, large areas of plantation forestry, which will reach harvest size in the next 10 years, are a potential future source of sediment during and post-harvest. Other pressures include pasture on the estuary margin and the high number of moorings (and associated vessels) within 5km, which increases the likelihood that potentially harmful organisms (e.g. marine pests) will be introduced.

The EVA results show Ahuriri Bay is in 'good' condition with high value seagrass beds, salt marsh and diverse substrates (Table 19.2). The absence of eutrophic symptoms indicate that current nutrient and sediment loads are below thresholds of concern. However, the catchment is modified, and the estuary is potentially exposed to marine pests and pathogens given its proximity to a high number of moorings. The estuary is also susceptible to future changes in catchment land use (i.e. forest harvest) that could lead to a shift in estuary condition if not managed.

Table B11.1. Summary information for Ahuriri Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	8.4	-
Intertidal Area (Ha; % Estuary)[1]	6.6	78.6
Dominant Estuary Substrate[1]	Firm mud/sand	
Mud extent (>50% mud content)	0.7	10.6
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.9	13.9
Salt Marsh (Ha; % intertidal)[1]	0.05	0.8
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	607.5	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	82.7	
% Catchment exotic forest[2]	15.3	
% Producing grassland[2]	1.8	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	0.8	
Catchment Phosphorus Load (T/y)[3]	0.1	
Catchment Sediment Load (KT/y)[3]	0.4	
Catchment Geology[4]	Sandstone & Gravel	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds[5]	Caspian tern, reef heron, gulls, shags and waterfowl	
Fish[6]	Redfin Bully	
Shellfish[7]	Present (species not specified)	
Pressures		
Sedimentation		
Forestry in the lower catchment		
Pasture on estuary margin		
Margin modification		
High number of moorings within 5km		

[1]Robertson (2020a); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap
[5]Davidson et al (2011); [6]MDC Smart Maps; [7]Davidson et al. 1990

Table B11.2. Ecological Vulnerability Assessment, Ahuriri Bay.

Category	Score
Values	0.54
Pressures	0.72
Susceptibility	0.63
Condition	0.76
Average Score	**0.66**

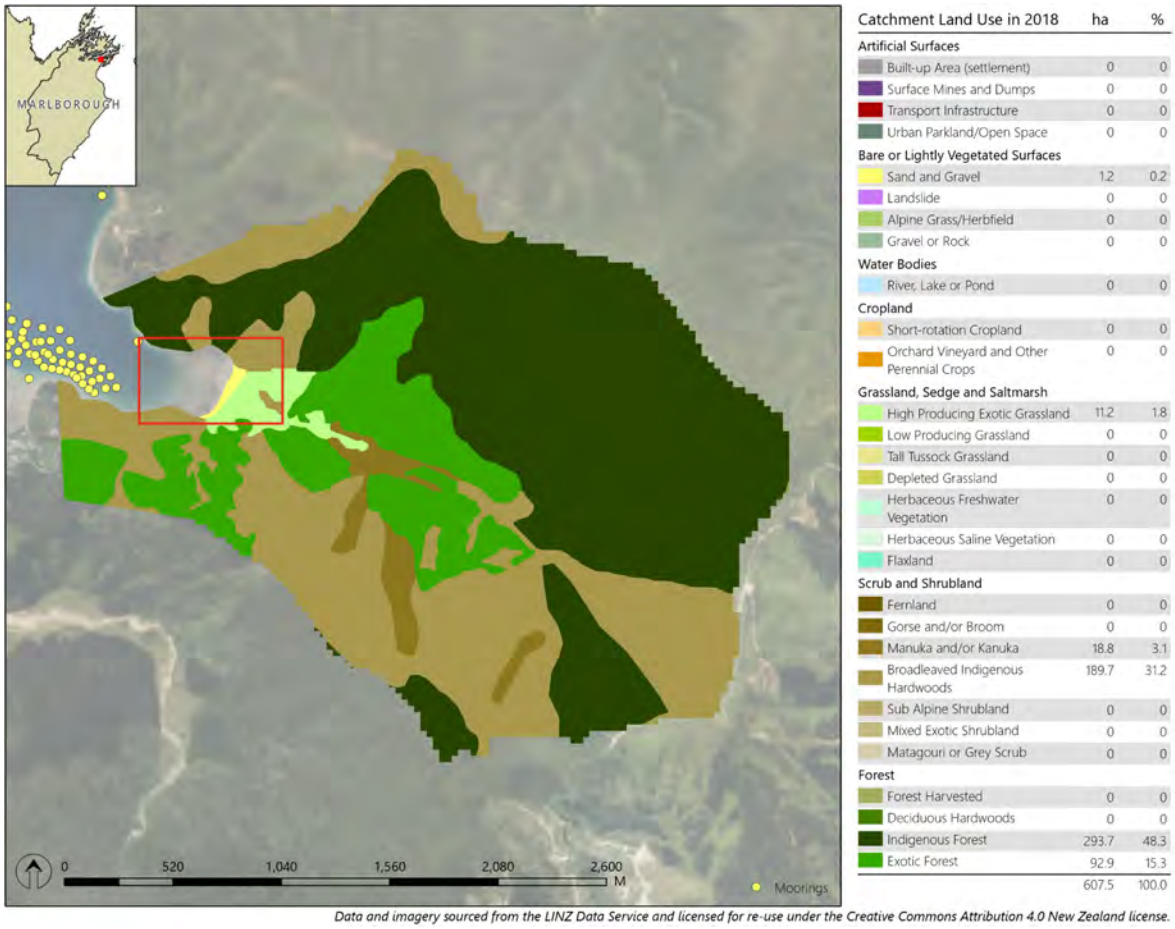

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Fig. B11.1. Ahuriri Bay catchment land use classifications from LCDB5 (2017/2018) database, and other pressures including moorings.

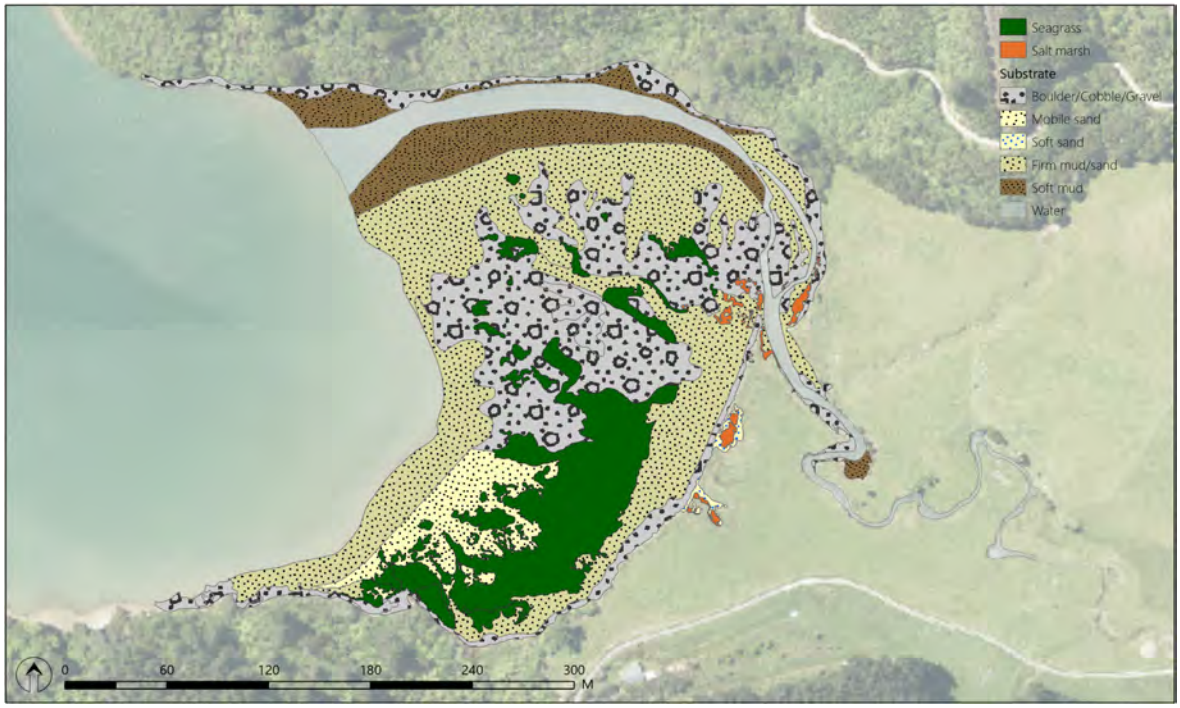

Fig. B11.2. Ahuriri Bay dominant vegetation and substrate features (data source: Robertson 2020a).

Patches of rushland growing in gravels

Mixed gravel and cobble substrate

Seagrass growing in firm mud/sand

Seagrass in foreground and exotic forestry in background

Grass margin and riverine debris

Eroding estuary margin and cobble

B12. Shakespeare Bay (Southern shore of QCS)

Shakespeare Bay is a small (~5.4ha) shallow intertidally dominated estuary that connects to a large subtidal area of Picton Harbour in Queen Charlotte Sound. The northwest catchment is dominated by indigenous forest and broadleaved indigenous hardwoods (Fig. B12.1). The lower and southeastern catchment are developed for high producing grassland (4.7%), exotic forestry (16.9%) and port infrastructure (3.7%). While the land use contribution of the port is low the relative impact on the estuary is high with land reclamation and shoreline hardening along the eastern boundary.

The estuary comprised firm mud/sand and gravel/cobble (Berthelsen et al. 2016). The most abundant vegetation type was seagrass growing on firm mud/sand across 30.8% of the intertidal area (Fig. B12.2). Salt marsh mostly rushland comprised of searush (*Juncus kraussii*) and jointed wirerush (*Apodasmia similis*; Fig. B12.2). The estuary also supports high value cockles and mussels. Observations from the most recent (11 April 2022) site visit highlighted nuisance macroalgae had increased since 2016. With nuisance macroalgae and softs mud associated with low tide channels. While these conditions do not appear to be widespread, they represent an early warning sign that nutrients may be in excess.

Shakespeare Bay is classified as an ESMS due to high value seagrass beds and because intertidal areas are considered uncommon in the Marlborough sounds. The salt marsh is also classified as a regionally significant wetland.

Historically, the Bay has been subject to a number of human impacts including commercial discharges from freezing works (1900-1980), wharf development (1900), deforestation and plantation forestry. Current pressures include forestry in the catchment, with large areas reaching maturity within the next 10 years and pasture on the estuary margin. The port and to a lesser extent moorings significantly increase the likelihood of marine contaminants, pests and pathogens being introduced to the area.

Table B12.1. Summary information for Shakespeare Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	5.41	-
Intertidal Area (Ha; % Estuary)[1]	5.37	99.3
Dominant Estuary Substrate[1]	Firm mud/sand	
Mud extent (>50% mud content)	1.9	35.1
Macroalgae (cover >50%)[1]	0	0
Seagrass (cover >50%)[1]	1.7	30.8
Salt Marsh (% intertidal)[1]	0.4	7.8
High Enrichment Conditions (HEC)[1]	0	0
Catchment		
Catchment Area (Ha)[2]	256.6	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	74.3	
% Catchment exotic forest[2]	16.9	
% Producing grassland[2]	4.7	
Mean Freshwater Flow (m^3/s)[3]	0.24	
Catchment Nitrogen Load (T/y)[3]	1.58	
Catchment Phosphorus Load (T/y)[3]	0.22	
Catchment Sediment Load (KT/y)[3]	1.55	
Catchment Geology[4]	Schist & gravels	
Biodiversity		
ESMS[5]	Y – 4.10	
Significant Wetland[6]	Y – salt marsh	
Birds[7]	Banded rail, Caspian tern, white-faced heron, variable oyster catcher	
Fish[6]	Redfin Bully	
Shellfish	Cockles, mussels	
Pressures		
Developed catchment – pasture and forestry Shoreline hardening Port and moorings Commercial discharges Margin modification Recreational use: watercraft, restricted public access by land		

[1]Berthelsen et al. (2016); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al (2011); [6]MDC Smart Map; [7]ebird

Table B12.2. Ecological Vulnerability Assessment, Shakespeare Bay.

Category	Score
Values	0.71
Pressures	0.68
Susceptibility	0.66
Condition	0.71
Average Score	0.69

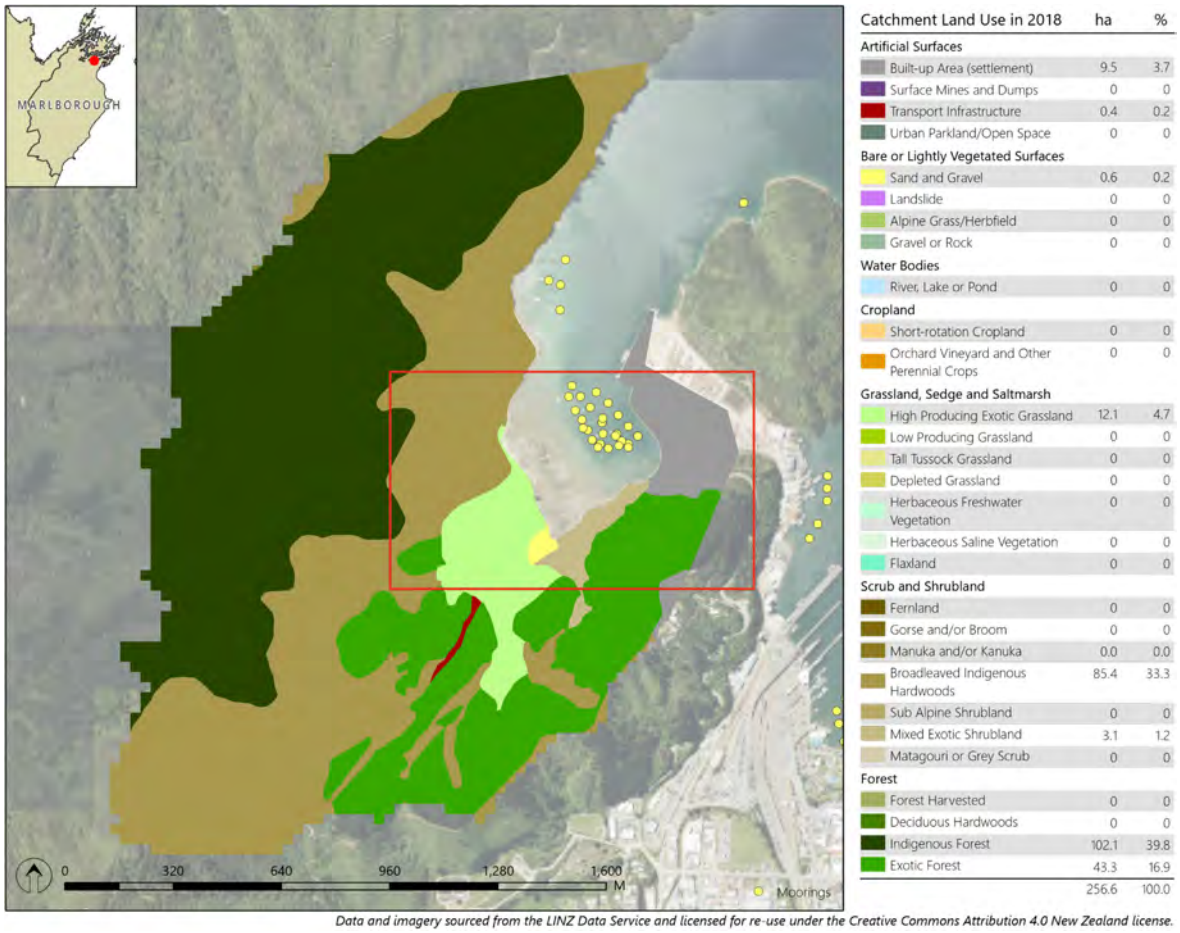

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Fig. B12.1. Shakespeare Bay catchment land use classifications from LCDB5 (2017/2018) database.

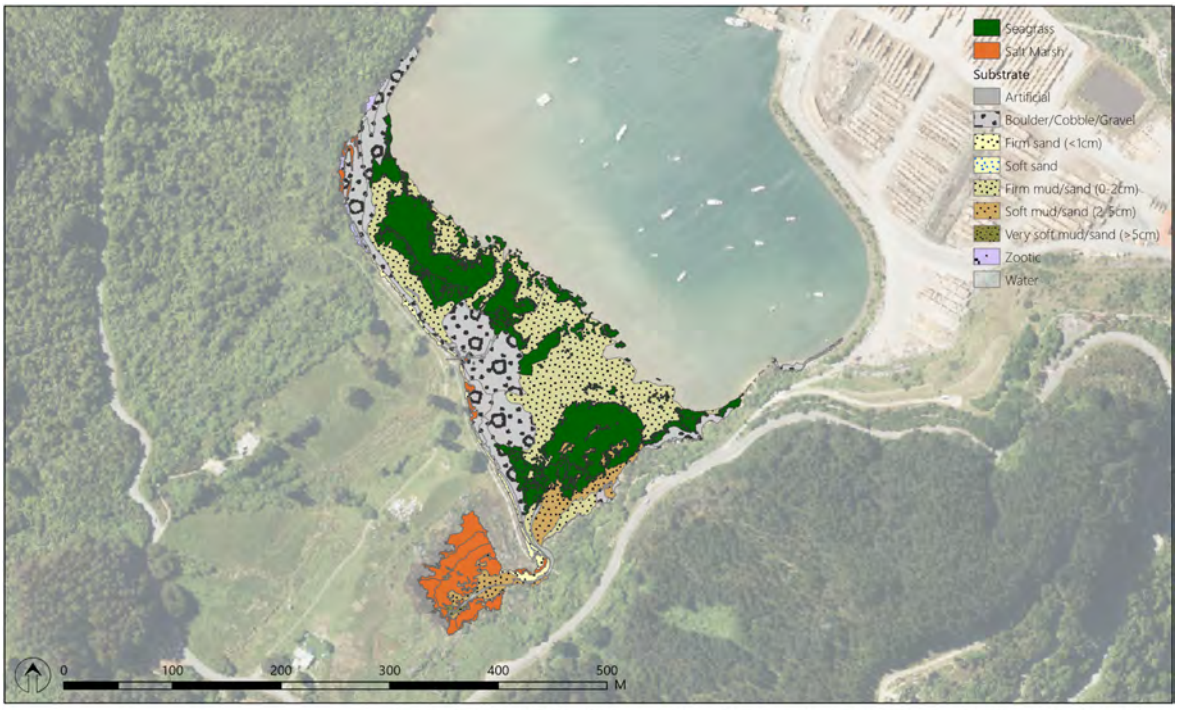

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Fig. B12.2. Intertidal area in Shakespeare Bay. Data for the estuary habitat map and substrate sourced from ground truthed broad scale mapping survey (Berthelsen et al. 2016).

Timber port on the margin of Shakespeare Bay

Shakespeare Bay tidal flats, port in the background

Seagrass beds in the estuary and forestry in the background

Rushland and pasture in the background

Mussels growing on hard substrate and seagrass

Cockles, Shakespeare Bay

B13. Waikawa Estuary (Southern shore of QCS)

Waikawa Estuary is a small (~3.4ha) shallow intertidally dominated estuary that connects to a large subtidal area of Waikawa Bay in Queen Charlotte Sound. The upper catchment is dominated by broadleaved indigenous hardwoods and indigenous forest, while the lower catchment is developed for the settlement of Waikawa (Table B13.1; Fig. B13.1). Approximately 60-70% of the estuary has been reclaimed for the Waikawa Marina with most of the shoreline hardened to protect infrastructure. Gravels are also dredged from Waikawa Stream to manage flooding.

The dominant estuary substrate is gravel/ cobble with fine sediments deposited on the upper intertidal flats and close to channel margins and firm muddy sands on the lower tidal flats. Due to the significant modification of the estuary margin natural areas of salt marsh have been lost. To enhance the estuary, salt marsh restoration has been undertaken on the upper shoreline. The shoreline was re-shaped, and cobble deposited on the site before rushes and estuarine shrubs were planted (see photo). The rushes are now established, and infill plantings have been carried out.

Seagrass is a common feature in the estuary, however in a recent site visit (2022) some sediment and macroalgal smothering were recorded. Localised patches of dense macroalgae were recorded near the high tide mark and along the river channel. Drift macroalgae and seagrass leaves were also observed accumulating on the high tide mark.

Historically, the estuary has been subject to a number of human impacts including reclamation and urban development. Further development is planned with the expansion of the marina. Discharges to the coast (e.g. stormwater) are common in the developed area and the marina and the high number of permanent moorings within the bay increase the likelihood of marine contaminants, pests and pathogens being introduced to the area. Human use and access to the estuary is also high.

Ongoing pressures in Waikawa Estuary will continue to degrade the remaining ecological values. The current estuary condition is 'moderate' resulting from the significant modification to the estuary margin, loss of high value habitats such as salt marsh and pressures on remaining habitats (e.g. seagrass).

Table B13.1. Summary information for Waikawa Estuary.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	3.4	-
Intertidal Area (Ha; % Estuary)[1]	2.8	82.9
Dominant Estuary Substrate[1]	cobble	
Mud extent (>50% mud content)		40
Macroalgae (cover >50%)		0-5
Seagrass (cover >50%)		60
Salt Marsh (% intertidal)		1
High Enrichment Conditions (HEC)		0-1
Catchment		
Catchment Area (Ha)[2]	1434.1	
Dominant Catchment Land Cover[2]	Broadleaved indigenous hardwoods	
% Catchment indigenous vegetation[2]	84.5	
% Catchment exotic forest[2]	2.1	
% Producing grassland[2]	1.0	
Mean Freshwater Flow (m^3/s)[3]	0.45	
Catchment Nitrogen Load (T/y)[3]	4.06	
Catchment Phosphorus Load (T/y)[3]	0.60	
Catchment Sediment Load (KT/y)[3]	2.74	
Catchment Geology[4]	Gravel	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds[5]	Caspian tern, white-faced heron, gulls, shags and waterfowl	
Fish[6]	Redfin Bully	
Shellfish	nd	
Pressures		
Shoreline hardening		
Significant reclamation for marina		
Stormwater and wastewater discharge		
Urban and industrial development in the catchment		
Marina and high number of moorings		
Public access		

[1]Stevens & Robertson (2016); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]ebird; [6]MDC Smart Map; nd = no data

Table B13.2. Ecological Vulnerability Assessment, Waikawa Bay.

Category	Score
Values	0.62
Pressures	0.60
Susceptibility	0.66
Condition	0.51
Average Score	**0.60**

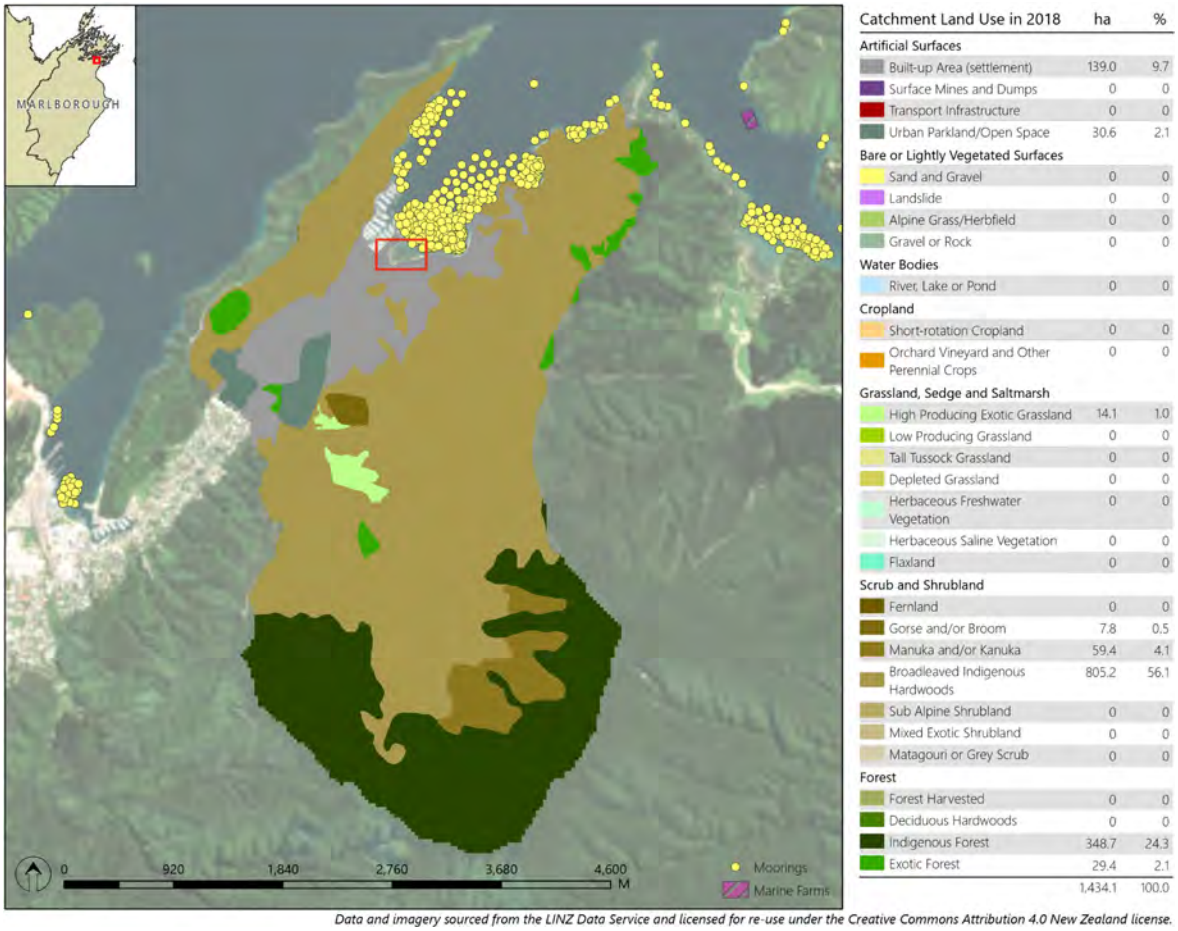

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Fig. B13.1. Waikawa Bay catchment land use classifications from LCDB5 (2017/2018) database.

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Fig. B13.2. Intertidal area in Waikawa Bay. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens & Robertson 2016). Substrate and vegetation may have changed since mapping due to dredging and reshaping of the river channel.

Seagrass in Waikawa Estuary

Shoreline hardening and boats moored in subtidal area, Waikawa

Dense seagrass beds, Waikawa Estuary

Salt marsh restoration in Waikawa Estuary, planting rushes

Erosion along estuary margin, Waikawa Estuary

Highly modified inflow to the estuary, with margin hardening

B14. Whatamango Bay (Southern shore of QCS)

Whatamango Bay is a medium (~11.9ha) shallow intertidally dominated estuary that connects to the larger subtidal Whatamango Bay in Queen Charlotte Sound. The upper catchment is dominated by indigenous forest and the mid and lower catchment is a mix of broadleaved indigenous hardwoods and manuka and/or kanuka (Table B14.1; Fig. B14.1). Exotic forest is present in the mid to lower catchment and evidence of pine debris has been observed in the estuary (see photo).

In a 2018 broad scale survey, the estuary was in generally good health with a range of important ecological habitats noted (i.e. salt marsh, seagrass and unvegetated firm mud/sand, cobble and gravel; Berthelsen et al. 2018). No signs of excess macroalgal cover, poor sediment conditions or other symptoms of eutrophication were recorded at the time of the survey. Some small areas of low oxygenated sediments were recorded on the high tide line in the most recent site visit by MDC (2022), however these were localised and not classified as High Enrichment Conditions.

Whatamango Bay's intertidal area is classified as an ESMS (Davidson et al. 2011). The area has fringing native scrub and supports a combination of sand and mudflats, seagrass, salt marsh and shellfish beds. Reef heron are common, and it is an important roosting area for Caspian tern, gulls, shags and waterfowl (Davidson et al. 2011).

The foreshore is designated a recreation reserve and has a high number of users because there is easy road access, a camp site and a boat ramp. Further, a high number of moorings are present throughout the bay increasing the likelihood of marine contaminants, pests and pathogens being introduced to the area. Other pressures include high producing pasture and forestry in the catchment. In the next 10 years, plantation forestry will be a potential source of sediment during and post-harvest with large areas due to reach maturity. Overall, Whatamango Bay is in good condition with both high value seagrass beds and salt marsh habitat.

Table B14.1. Summary information for Whatamango Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	11.9	-
Intertidal Area (Ha; % Estuary)[1]	9.1	76.7
Dominant Estuary Substrate[1]	Firm mud/sand	
Mud extent (>50% mud content)	0.6	7.0
Macroalgae (cover >50%)[1]	0.0	0.0
Seagrass (cover >50%)[1]	2.9	33.7
Salt Marsh (% intertidal)[1]	0.6	6.5
High Enrichment Conditions (HEC)	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	2654.5	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.72	
Catchment Nitrogen Load (T/y)[3]	5.11	
Catchment Phosphorus Load (T/y)[3]	0.96	
Catchment Sediment Load (KT/y)[3]	4.34	
Catchment Geology[4]	Sandstone & gravels	
Biodiversity		
ESMS[5]	Y – 4.12	
Significant Wetland	Y – salt marsh	
Birds[5]	Caspian tern, reef heron	
Fish[6]	Redfin Bully	
Shellfish	Cockle beds present, not dominant	
Pressures		
Boat ramp access to estuary		
High producing pasture in lower catchment		
Forestry in the catchment		
Domestic wastewater discharges		
Recreational camping on the estuary margin		

[1]Berthelsen et al. (2016); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]Davidson et al (2011); [6]MDC Smart Map; nd = no data

Table B14.2. Ecological Vulnerability Assessment, Whatamango Bay.

Category	Score
Values	0.87
Pressures	0.70
Susceptibility	0.68
Condition	0.79
Average Score	**0.76**

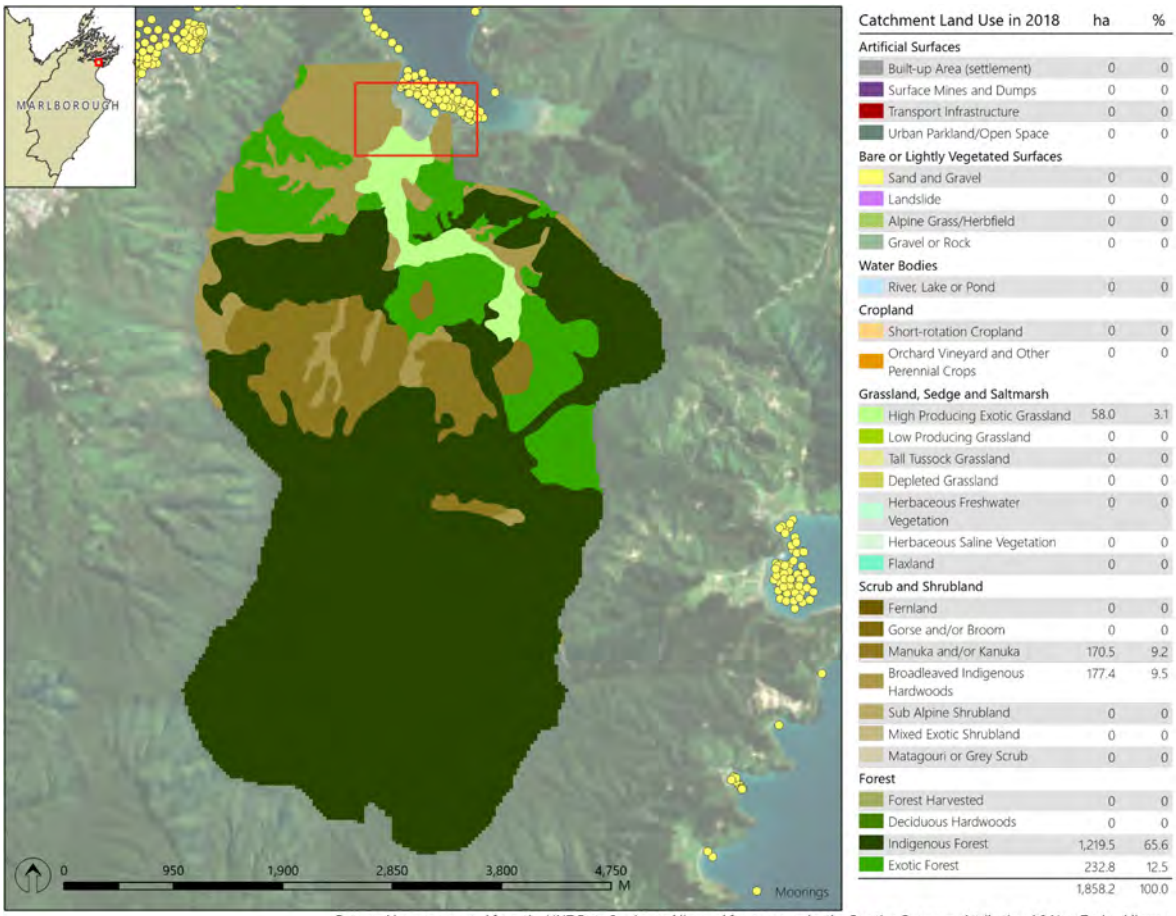

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Fig. B14.1. Whatamango Bay catchment land use classifications from LCDB5 (2017/2018) database.

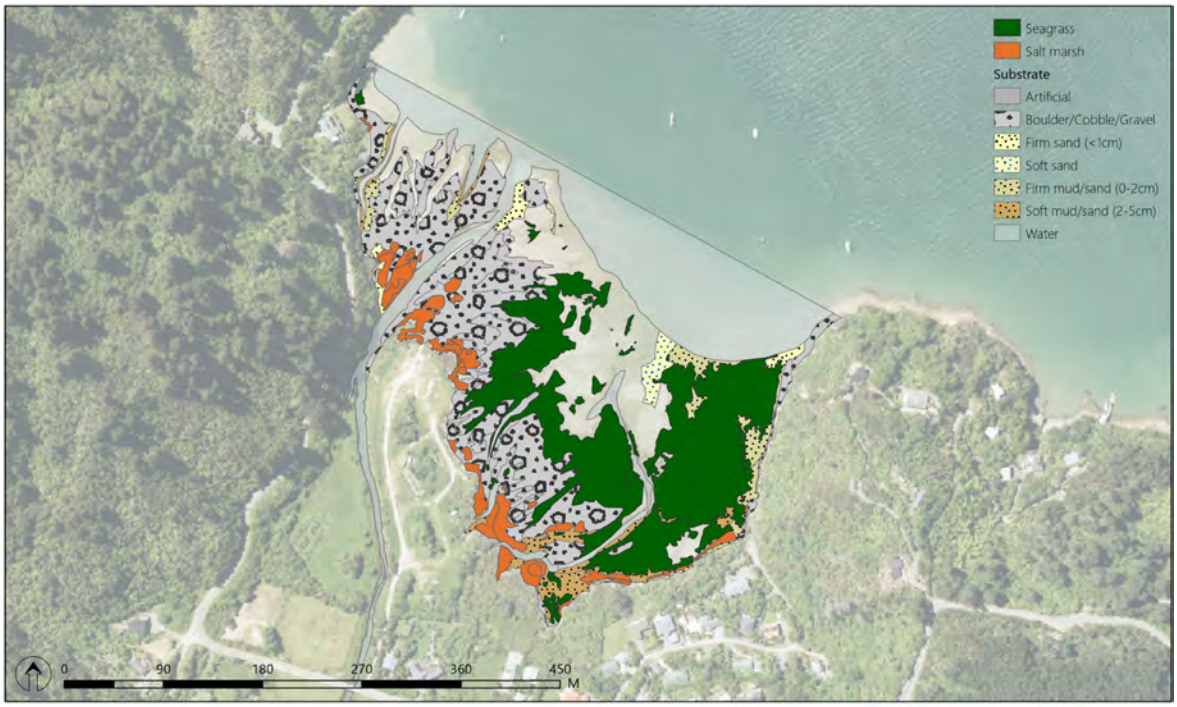

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Fig. B14.2. Intertidal area in Whatamango Bay. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Berthelsen et al. 2018).

Pine debris within seagrass beds, Whatamango Bay

Extensive seagrass cover across intertidal flats

Gravel and seagrass, Whatamango Bay

Freshwater inflow and salt marsh in upper estuary

Grassed camping area on estuary margin

Erosion of margin near grassed areas, Whatamango Bay

B15. Hitaua Bay (Tory Channel)

Hitaua Bay is a small sized (0.8ha) shallow intertidally dominated estuary on the southern shoreline of the Tory Channel near the entrance to Queen Charlotte Sound. The whole catchment is privately owned and dominated by exotic forest that has undergone various stages of harvest and replanting since 2000 (Table B15.1; Fig. B15.1; Davidson & Richards 2003). The intertidal flats are gravel/ cobble dominated with fine sediments localised near the two main freshwater inputs (see photos). In 2003, monitoring post forestry harvest identified minor impacts of fine sediment deposition in the estuary. However, by 2015, Davidson & Richards (2015) noted that sedimentation had worsened with significant deposition of fine sediments recorded smothering cobble habitat post-harvest.

Although detected in the multibeam survey (Neil et al. 2018; Fig. B15.2), ground truthing revealed seagrass is a minor feature (<5%) in the estuary and is localised to the eastern margin (Table 22; Davidson et al. 2011). The head of Hitaua Bay supports a regionally significant freshwater wetland that grades into salt marsh habitat (Davidson & Richards 2003). Salt marsh comprised rushland and was a narrow strip near the high-water mark (Table 22). Macroalgae was sparse (<5%) and not considered a problem in the estuary. The rapid estuary assessment recorded no high enrichment conditions in the estuary, however fine sediment deposition was a cause for concern.

In addition to the heavily modified catchment, the wider Hitaua Bay is used recreationally by boat users and there are two small batches near the head of the Bay. The Wellington-Picton ferry route is within 5km and bays in the area are subject to regular ferry wash, although the head of the bay is partly protected. The risk of marine pests and oil spills are higher in this area due to the shipping channel.

While the estuary retains high ecological values with a freshwater wetland transitioning to salt marsh and subtidal cockle beds (Davidson et al. 2011). While overall, pressure and susceptibility are classified as 'low', the key stressor driving down the scores is the modified catchment (i.e. exotic forestry) and proximity of the estuary to the shipping channel (Table 23). Evidence of fine sediment deposition following exotic forestry harvest and increases in mud extent, particularly around stream inputs, over the last 20 years indicate fine sediments are a cause for concern.

Table B15.1. Summary information for Hitaua Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	0.8	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	10%
Macroalgae (cover >50%)	-	0-5%
Seagrass (cover >50%)	-	1%
Salt Marsh (% intertidal)	-	~20%
High Enrichment Conditions (HEC)	-	0%
Catchment		
Catchment Area (Ha)[2]	376.6	
Dominant Catchment Land Cover[2]	Exotic forest	
% Catchment indigenous vegetation[2]	9.6	
% Catchment exotic forest[2]	74.2	
% Producing grassland[2]	1.3	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	0.6	
Catchment Phosphorus Load (T/y)[3]	0.09	
Catchment Sediment Load (KT/y)[3]	0.35	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS	Y (5.5 intertidal)	
Significant Wetland	N	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish[8]	Cockles in shallow subtidal zone	
Pressures		
Fine sediment deposition		
Modified catchment – exotic forest		
Recreational use: boating		
Minor domestic wastewater discharges		
Close to commercial vessel route (Ferry)		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Maps [8]Davidson et al (2011), nd = no data

Table B15.1. Ecological Vulnerability Assessment, Hitaua Bay.

Category	Score
Values	0.64
Pressures	0.75
Susceptibility	0.77
Condition	0.89
Average Score	0.76

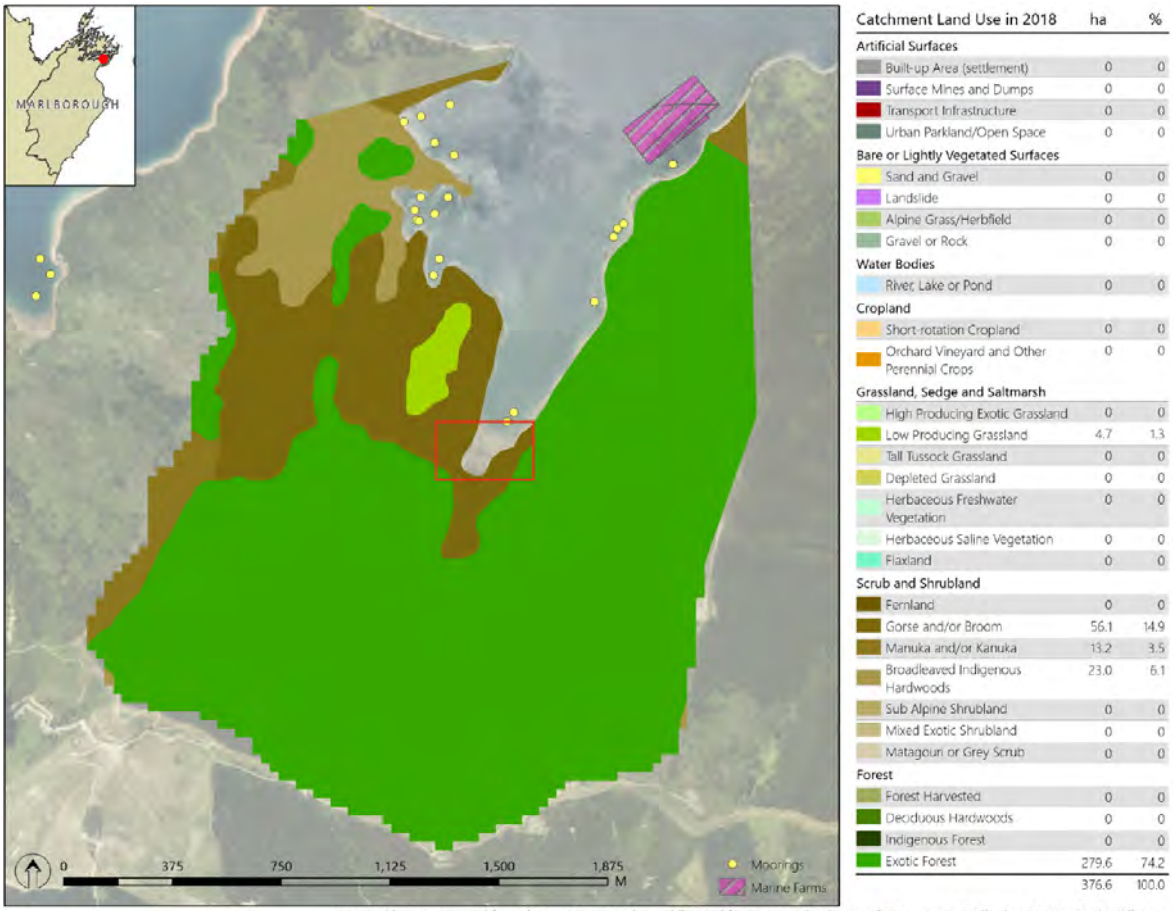

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Fig. B15.1. Hitaua Bay catchment land use classifications from LCDB5 (2017/2018) database.

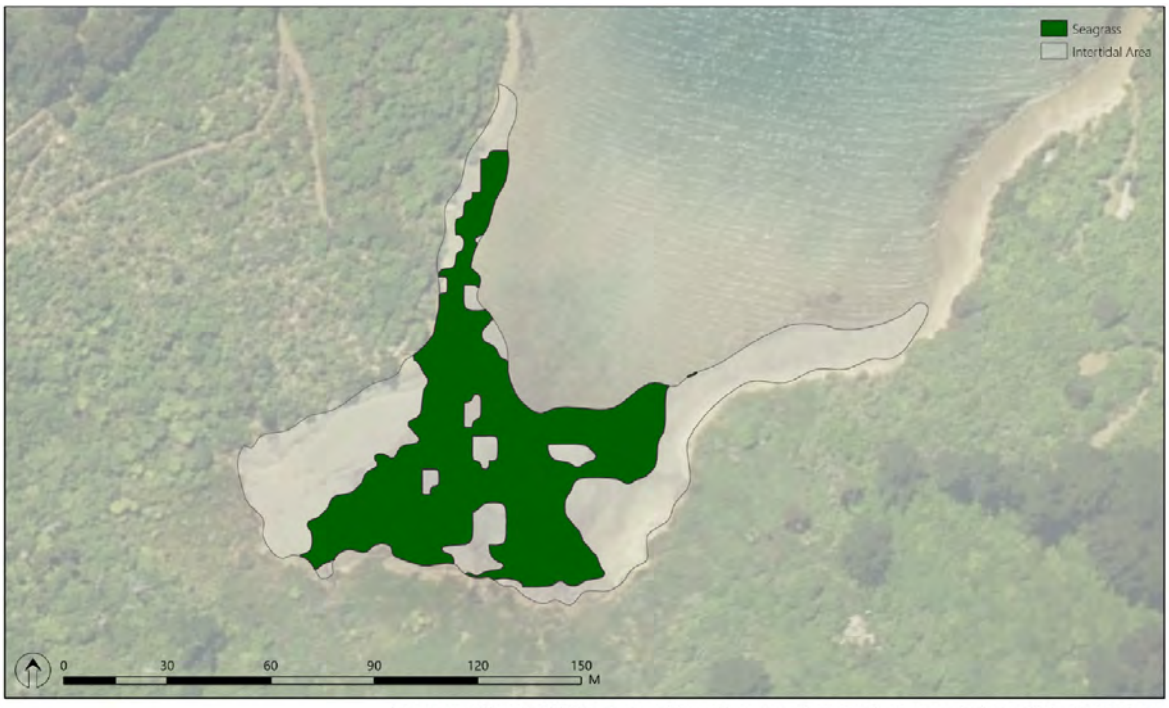

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Fig. B15.2. Intertidal areas within Hitaua Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC), boundaries require ground truthing and should be treated as best estimates only.

Gravel/ cobble intertidal flats on the eastern margin, Hitaua Bay

Thin strip of salt marsh, mainly rushland, on the estuary margin

Fine sediments deposited over gravel/ cobble in Hitaua Bay

Mud dominated near the freshwater stream input and exotic forest catchment in the background, Hitaua Bay

B16-B17. Onapua Bay & Opua Bay (Tory Channel)

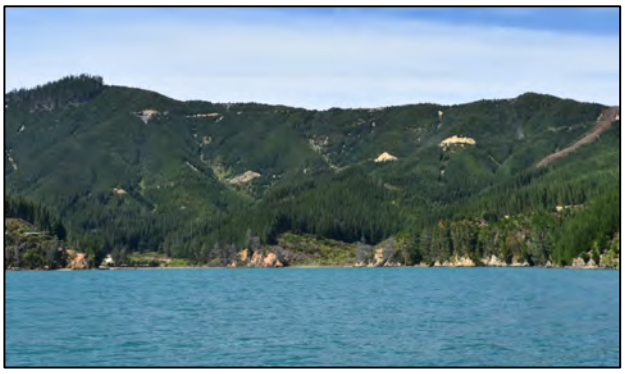
Onapua Bay is connected to the Tory Channel and has a number of intertidal areas including Opua Bay and the head of Onapua Bay (Fig. B16.1). The estuaries are small shallow intertidally dominated estuaries, that are connected to the deep subtidal zone of Onapua Bay.

Historically the catchments were cleared and used for sheep farming. Present day, the catchments are dominated by exotic forestry and have undergone various stages of harvest then replanting since the 1990's (Consent U040323). It can be expected that the cycle of harvest and replanting will continue.

Both estuaries were gravel/ cobble dominated with some fine sediment deposition around stream inputs. It is well known that exotic forestry can cause high sediment inputs, particularly during harvest and in the post-harvest period before replanted forest reaches a closed canopy state (Swales et al. 2021). Significant fine sediment deposition was not recorded in either estuary and is likely due to the flushing effect of wave and tidal action that prevents accumulation of fine sediments (Fransen et al. 1998). Short-term monitoring during and post-forest harvest in Onapua Bay, highlighted the complexities of assessing the impacts of forestry on near-shore environments (Fransen et al. 1998; Gillespie & Asher 1995). In that study, no significant forestry impacts were observed, however, it was acknowledged that the accumulation of fine sediment within the central Bay may occur over the longer term as more of the catchment is logged.

The intertidal areas at the head of Onapua Bay comprise only a small area of salt marsh and seagrass (B16.1). There has been some reclamation of the estuary margin for a jetty, that is protected by rock battering. Clearing of vegetation on the southern margin has led to historic losses of salt marsh habitat and remaining salt marsh is under stress from weeds and erosion. Macroalgae was sparse (<5%) and the rapid estuary assessment recorded no high enrichment conditions in the estuary.

Gravel/ cobble dominated estuary with exotic forest catchment (photo source: Consent U040323, taken 2010)



Opua Bay, steep catchment dominated by exotic forestry (Image ref: MDC 'TC OpuaBay Panorama 01', Courtesy of Marlborough District Council)

Opua Bay is highly modified, with a large area of the estuary reclaimed in the 1950's for farming. This area is now reinforced with rock battering and has been used for log storage prior to its transport to Picton via barge. Prior to the construction a pre-consent site visit recorded historic shellfish beds, however no live shellfish were present. No shellfish were recorded in a recent site visit.

Opua Bay is highly modified and as a result seagrass (<1%) and salt marsh (<5%) are only a minor feature in the estuary (Table B17.1). Remaining salt marsh habitat is under stress with weeds, erosion and direct damage observed. Macroalgae was sparse (<5%) and the rapid estuary assessment recorded no high enrichment conditions in the estuary. The margin of the estuary comprises weeds, gorse and exotic forest and most of the eastern shoreline is harden with rock battering protecting the reclaimed area.

The main pressures in both the head of Onapua Bay and Opua Bay are the heavily modified catchments (i.e. exotic forestry) and estuary reclamation. Further, moorings and jetties within the bays support recreational boat use and access to private baches. The risk of marine pests and oil spills are higher in the bay due to its close proximity to the shipping channel, marine farms and the barge transport from Opua Bay. The Wellington-Picton ferry route is within 5km and bays in the area are subject to regular ferry wash, although the head of bays are partially protected.

In both bays significant modification in the estuary and catchment have diminished the estuaries' ecological values, with losses of salt marsh, seagrass and shellfish habitat recorded (Table 33; Table 35). The low diversity of habitats (e.g. gravel/ cobble) that remain are in reasonably good condition. However, the output of the EVA highlights that pressures on both estuaries remain with both marine and catchment (i.e. exotic forest harvest) pressures contributing to the overall score.

Head of Onapua Bay, Tory Channel

Opua Bay, gravel/ cobble substrate and reclaimed area for log storage and barge transport (photo source: Consent U040323, taken 2010)

Head of Onapua Bay, extensive areas of salt marsh and freshwater wetland in 1958 (top) and present day wetland cleared and exotic forestry dominates the hillslopes

Opua Bay, reclamation in the 1950's and cleared land for sheep farming (Top; source: retrolens.co.nz) and present day (bottom) reclamation of the estuary for log storage and exotic forestry

Table B16.1. Summary information for Onapua Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	2.2	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	5
Macroalgae (cover >50%)	-	0-5
Seagrass (cover >50%)	-	5
Salt Marsh (% intertidal)	-	5
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	388.9	
Dominant Catchment Land Cover[2]	Exotic Forest	
% Catchment indigenous vegetation[2]	1.8	
% Catchment exotic forest[2]	97.1	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	0.92	
Catchment Phosphorus Load (T/y)[3]	0.12	
Catchment Sediment Load (KT/y)[3]	0.53	
Catchment Geology[4]	Sandstone	
Biodiversity		
Significant Marine Site	N	
Significant Wetland	N	
Birds	nd	
Fish	nd	
Shellfish	Cockles present	
Pressures		
Modified catchment – exotic forest		
Mature exotic forest on estuary margin due for harvest		
Recreational use: boating, jetty		
Minor domestic wastewater discharges		
Minor domestic wastewater discharges		
Close to commercial vessel route (Ferry)		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; nd = no data

Table B17.1. Summary information for Opua Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	1.1	-
Dominant Estuary Substrate[1]	Gravel/cobble	
Mud extent (>50% mud content)	-	5
Macroalgae (cover >50%)[1]	-	0-5
Seagrass (cover >50%)[1]	-	1
Salt Marsh (% intertidal)[1]	-	5
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	278.6	
Dominant Catchment Land Cover[2]	Exotic Forest	
% Catchment indigenous vegetation[2]	0.0	
% Catchment exotic forest[2]	94.7	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[4]	0.2	
Catchment Nitrogen Load (T/y)[4]	0.61	
Catchment Phosphorus Load (T/y)[4]	0.08	
Catchment Sediment Load (KT/y)[4]	0.52	
Catchment Geology	Sandstone	
Biodiversity		
ESMS	N	
Significant Wetland	Adjacent freshwater wetland	
Birds[6]	nd	
Fish[7]	nd	
Shellfish[1]	Historic shellfish beds	
Pressures		
Modified catchment – exotic forest		
Mature exotic forest on estuary margin due for harvest		
Significant reclamation of the intertidal area		
Margin habitat comprises weeds, gorse and exotics		
Recreational use: boating, jetty		
Commercial use: barge transport of logs to Picton		
Minor domestic wastewater discharges		
Close to commercial vessel route (Ferry)		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; nd = no data

Table B16.2. Ecological Vulnerability Assessment, Onapua Bay.

Category	Score
Values	0.33
Pressures	0.70
Susceptibility	0.68
Condition	0.79
Average Score	**0.62**

Table B17.2. Ecological Vulnerability Assessment, Opua Bay.

Category	Score
Values	0.39
Pressures	0.60
Susceptibility	0.57
Condition	0.71
Average Score	**0.57**

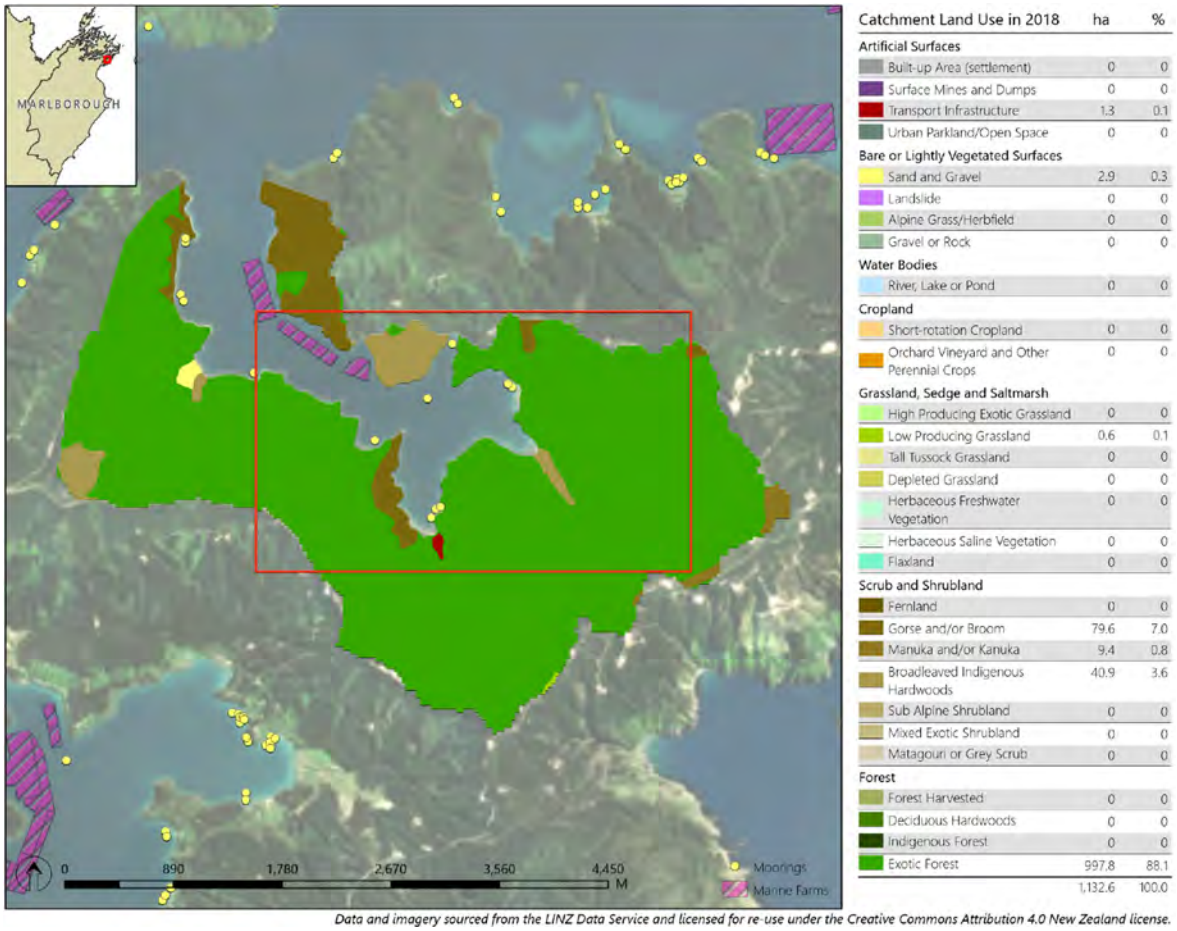


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Fig. B16.1. Onapua Bay (sub-areas Opua Bay and Onapua Bay) catchment land use classifications from LCDB5 (2017/2018) database.

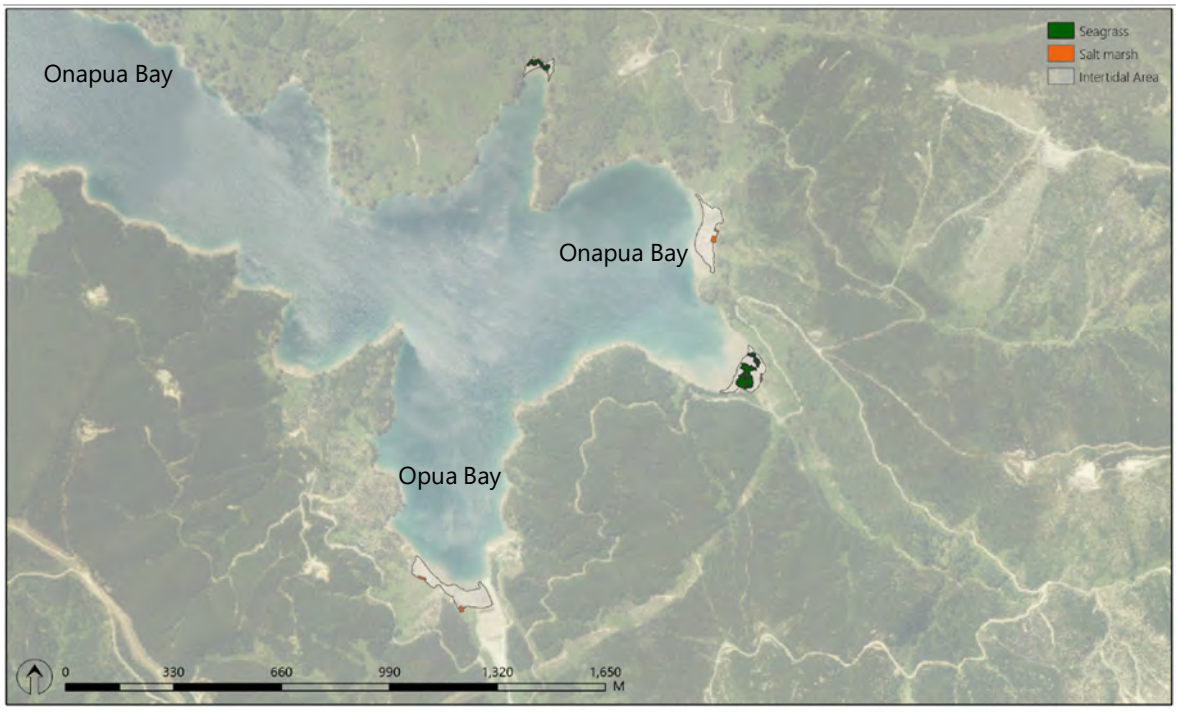

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Fig. B16.1. Intertidal areas in Onapua Bay (sub-areas Opua Bay and Onapua Bay). Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass via multibeam (Neil et al. 2018; MDC), boundaries require ground truthing and should be treated as best estimates only.

B18. Oyster Bay (Tory Channel)

Oyster Bay is connected to the Tory Channel and has a small shallow intertidally dominated estuary at the head of the bay. The catchment was historically cleared and used for farming until it was converted to exotic forestry in the 1970's (Consent U220226). Exotic forestry is now the dominant land use type comprising 77% of the catchment area. Since the 1970's exotic forest has been harvested and replanted in the catchment, with ongoing harvesting occurring.

The intertidal flats were gravel/ cobble dominated. Mud-dominated sediments were recorded on the eastern margin and near freshwater inputs, the area represented ~10% of the estuary. Salt marsh habitat comprises rushland and herbfield and is localised to the main freshwater input with smaller fragments scattered on the upper intertidal flats. Erosion of salt marsh was common, and weeds and grasses were also present. While seagrass was recorded in the multibeam survey it was not observed in the rapid estuary assessment, highlighting the importance of ground truthing. In the most recent site visit a small area of pipi was recorded.

The western margin of the estuary has been hardened with rock battering protecting a road and jetty. Further, vegetation has been cleared from part of the margin and a man-made lake is adjacent to the estuary shoreline. A small regionally significant wetland is situated upstream of the estuaries' main freshwater input (see photos). While there is access (i.e. moorings and a jetty) to Oyster Bay for recreational boat users there are also several marine farms within the bay. Coupled with its close proximity to the shipping channel there is a higher risk of marine contaminants, pests and oil spills.

Ecological values in Oyster Bay were rated low, owing to the lack of seagrass, minimal salt marsh habitat and significant modification. Further, fine sediment deposition has been recorded in the estuary (~10% extent) and the high proportion of exotic forestry in the catchment means the estuary is prone to high sediment inputs, particularly during harvest and in the post-harvest period before replanted forest reaches a closed canopy state (Swales et al. 2021).

Table B18.1. Summary information for Oyster Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	1.5	-
Dominant Estuary Substrate[1]	Gravel/cobble	
Mud extent (>50% mud content)	-	10
Macroalgae (cover >50%)[1]	-	0-5
Seagrass (cover >50%)[1]	-	0
Salt Marsh (% intertidal)[1]	-	5
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	478.2	
Dominant Catchment Land Cover[2]	Exotic Forest	
% Catchment indigenous vegetation[2]	19.9	
% Catchment exotic forest[2]	76.9	
% Producing grassland[2]	1.8	
Mean Freshwater Flow (m^3/s)[4]	0.1	
Catchment Nitrogen Load (T/y)[4]	0.89	
Catchment Phosphorus Load (T/y)[4]	0.13	
Catchment Sediment Load (KT/y)[4]	0.28	
Catchment Geology	Sandstone	
Biodiversity		
ESMS[5]	N	
Significant Wetland[5]	Adjacent freshwater wetland	
Birds	nd	
Fish[5]	Redfin bully	
Shellfish	Small area of pipi	
Pressures		
Modified catchment – exotic forest		
Sedimentation		
Reclamation of the intertidal area		
Shoreline hardening on western margin for road/ jetty		
Recreational use: boating		
Marine farms in the wider bay		
Minor domestic wastewater discharges		
Close to commercial vessel route (Ferry)		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Map; nd = no data

Table B18.1. Ecological Vulnerability Assessment, Oyster Bay.

Category	Score
Values	0.35
Pressures	0.68
Susceptibility	0.66
Condition	0.66
Average Score	0.59

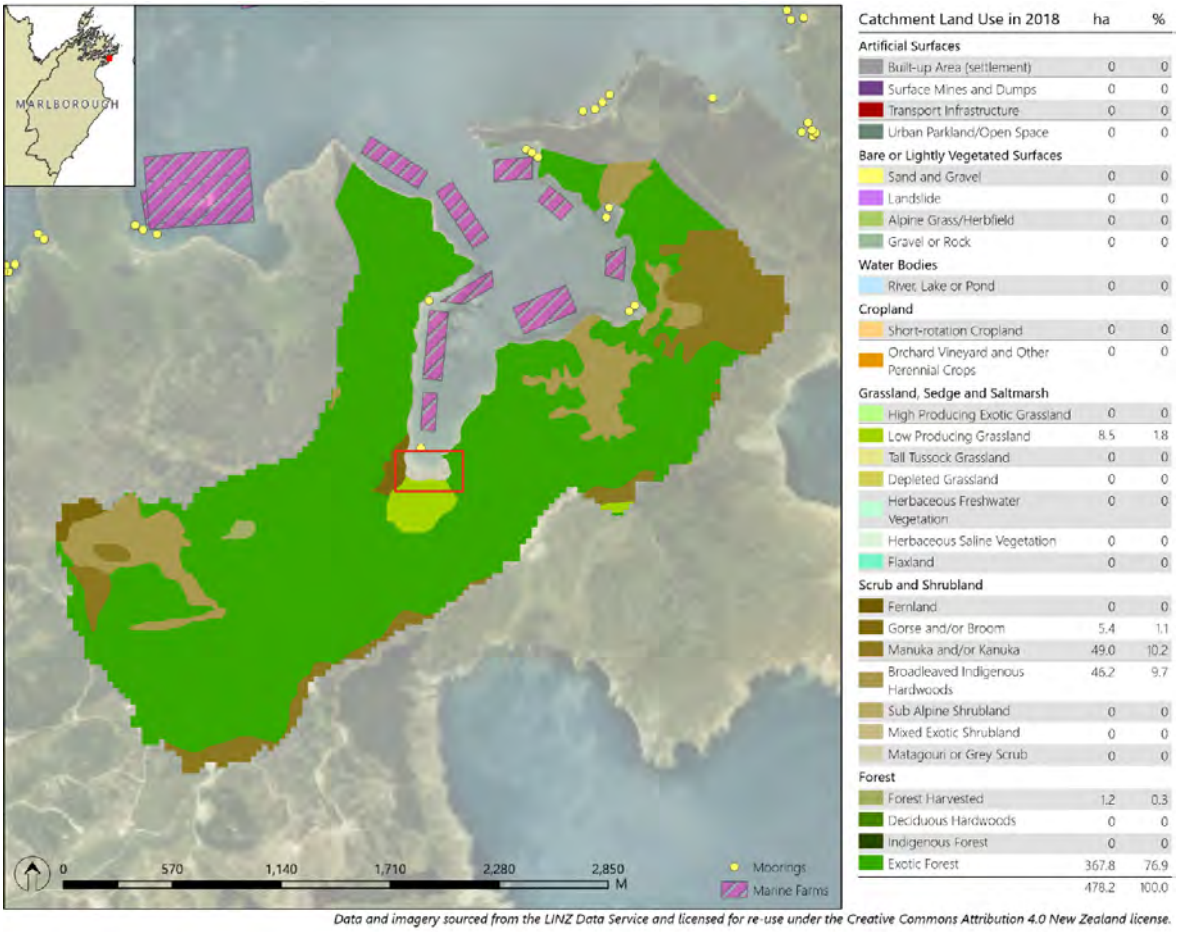

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Fig. B18.1. Oyster Bay catchment land use classifications from LCDB5 (2017/2018) database.

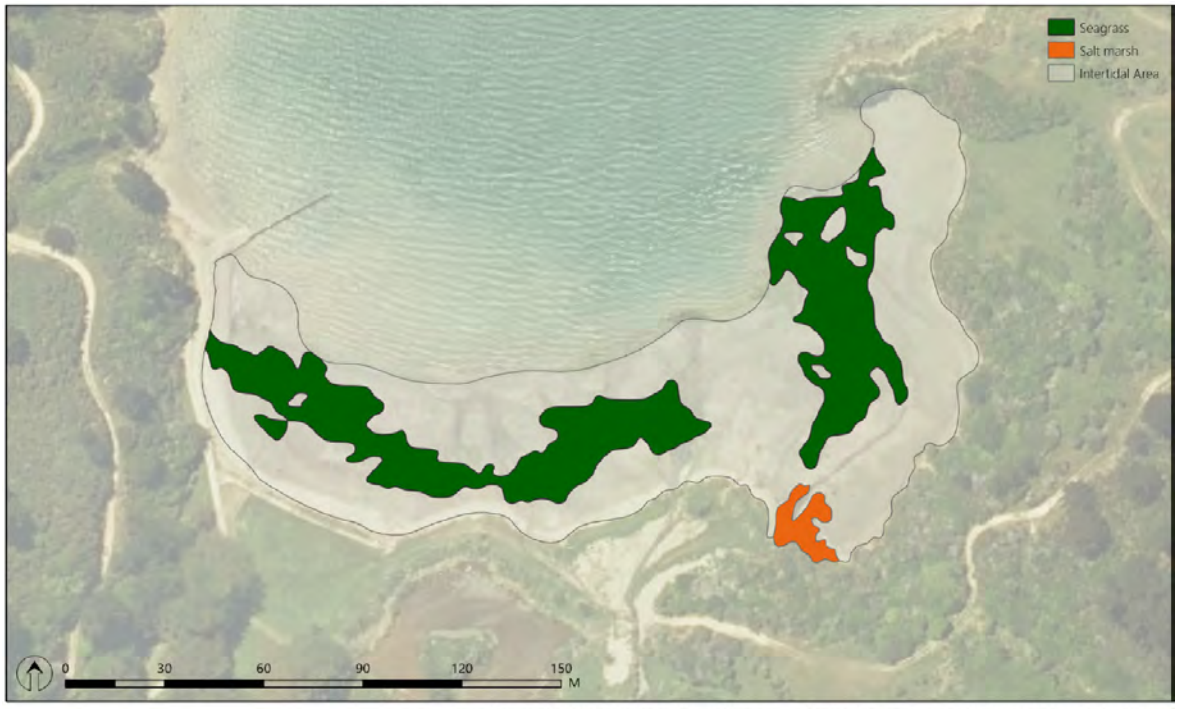

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Fig. B18.2. Intertidal areas within Oyster Bay. Intertidal and salt marsh boundaries were estimated from aerial imagery and seagrass was measured during the multibeam survey (Neil et al. 2018; MDC) however no seagrass was recorded in the REA.

Gravel/ cobble beach with exotic forest catchment

Rushland and herbfield on estuary margin, Oyster Bay

Aerial photo in 1958 (top) and present day (bottom) showing reclamation, jetty and man-made lake

Fine sediment deposition over gravel/ cobble substrate and salt marsh in the background

Jetty and shoreline hardening on the western shore and gravel/cobble intertidal flats

C. D'URVILLE ISLAND

D'Urville Island (Rangitoto ki te Tonga) is an island in the northern Marlborough Sounds. The Island is separated from the mainland by the narrow French Pass (Te Aumiti). The eastern shoreline of D'Urville Island is characterised by steep hillsides that slope directly down to the sea, and there are few intertidal areas. The western shore has three large, drowned valley systems, Greville Harbour, Port Hardy and Manuhakapakapa Bay. Intertidal estuarine flats are largely confined to the upper tidal reaches of the narrow arms of Greville Harbour and Port Hardy. While there are many intertidal areas on the western margin of D'Urville Island for the purposes of this report only the largest areas were monitored and summarised. This does not preclude other intertidal estuarine areas on from having ecologically important habitats.

There are no large river systems influencing D'Urville Island; instead, the main driver of water circulation is the D'Urville current that flows from Tasman into Cook Strait. Tidal circulation is partly restricted in inner Greville Harbour due to a boulder bank, likely increasing the residence time of water within the harbour. Oceanic water generally carries far smaller sediment loads than riverine inputs, therefore sedimentation impacts are localised and restricted to sedimentation events resulting from activities in the catchment.

Large areas of D'Urville island were cleared in the mid-1800 's for farming, present day land use on the island comprises farmland, regenerating native bush and a few small areas of plantation forestry. While there are large areas of regenerating forest, about two thirds of the island is privately owned with only part protected within the D'Urville Island Scenic Reserve. If catchment land use remains stable it can be expected the nutrient and sediment loads from the catchment remain low.

Residents on the island mainly live on the east coast with some houses scattered in other parts. While there are roads on the island many of the intertidal estuarine areas can only be accessed remotely by boat. There are also some marine farms scattered around the island. Boat use and aquaculture increase the likelihood of invasive species incursions, contaminants and pathogens. Pacific oysters have been recorded in Greville Harbour intertidal areas. Other pressures include wild animal (e.g. pigs and deer) browsing/damage in salt marsh habitat and recreational use.

Intertidal estuarine areas within D'Urville Island retain high social, cultural and ecological values. Compared to other parts of the Marlborough Sounds pressures are limited. In this section, intertidal estuarine areas are summarised for D'Urville Island (see Fig. C1), including key habitats, catchment characteristics and the output of the EVA for each estuary. These estuaries range in size from 0.4ha to 8ha and are confined to Greville Harbour and Port Hardy (Table C1).

Boulder bank at the entrance of Greville Harbour

Table C1. List of intertidal estuaries summarised in D'Urville Island.

ID	Estuary Name	Sub-region	Intertidal area (ha)	ESMS	Baseline monitoring
C1	Bullock Bay	Greville Harbour	1.2	✓ (1.7)	2018 (BS)
C2	Camping Bay	Greville Harbour	0.4	✓ (1.7)	2018 (BS)
C3	Mill Arm	Greville Harbour	9.0	✓ (1.7)	2018 (BS)
C4	Mokau Bay	Greville Harbour	1.0	✓ (1.7)	-
C5	Punt Arm	Greville Harbour	2.6	✓ (1.7)	2018 (BS)
C6	Smylies Arm	Greville Harbour	3.2	✓ (1.7)	2018 (BS)
C7	Wharairiki Bay	Greville Harbour	3.8	✓ (1.7)	-
C8	Wells Arm	Port Hardy	1.1 to 1.8	-	-

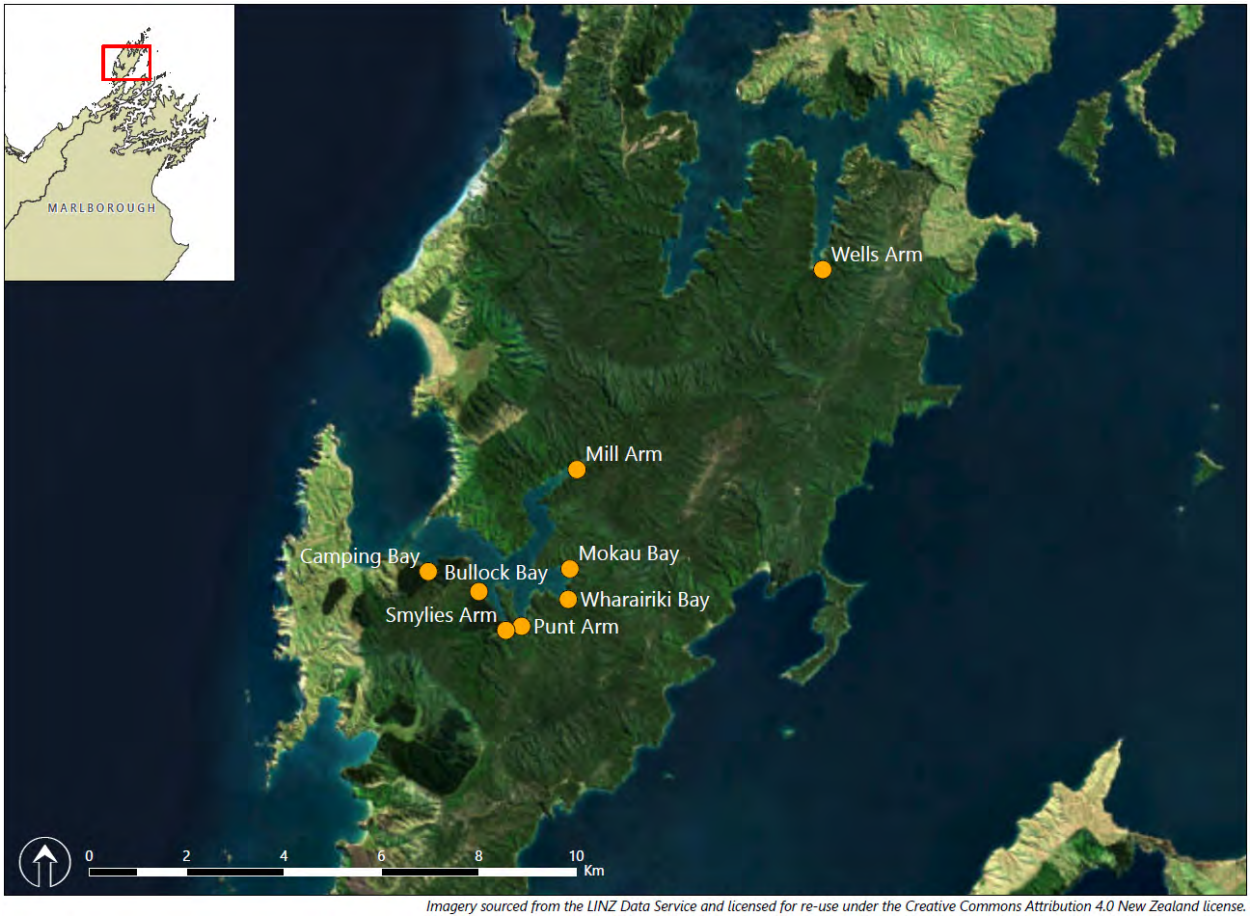

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Fig. C1. Intertidal estuaries within D'Urville Island included in the current report.

Punt Arm in Greville Harbour

C1. Bullock Bay (Greville Harbour)

Bullock Bay is a small (1.2ha) shallow, intertidally dominated estuary that connects to Greville Harbour on D'Urville Island in the outer sounds. The catchment was historically cleared and is now mainly regenerating native bush (92.3%; Table C1.1), with a small area on the south-west margin that remains planted in mature pine forest (Fig. C1.1). The 200m terrestrial margin is densely vegetated, comprising a mix of native and exotic vegetation. Gorse and weeds are also present on the estuary margin.

Greville Harbour is classified as an ESMS (Table C1.1). Bedrock underlies the dominant cobble substrate on the intertidal flats (Stevens 2018b). A small area of boulder is located in the northern estuary and there is a rocky outcrop toward the southern intertidal flats. Freshwater inputs are small and as such no nuisance macroalgae or fine sediment deposition was observed in the estuary by Stevens (2018b). During the broad scale survey water clarity was excellent and there was also no evidence of mud accumulating in the shallow subtidal zone. A small area of intertidal salt marsh (0.02Ha) comprising sea rush and herbfield was located on the central part of the upper shoreline (Stevens 2018b). No seagrass was recorded in the estuary.

While there is dirt road access to Bullock Bay, human use is considered low because D'Urville Island is not connected to the mainland and the catchment sits within private property. Remote boat access is also possible, with anchorage common in other, more protected parts, of Greville Harbour. While most of the catchment remains in native forest, the catchment is privately owned and there is a small dwelling on the estuary margin. The main pressure to the estuary is the potential harvest of mature exotic forestry on the margin. Even with sediment controls it is likely some sediments will be transported to the estuary and coastal area.

The modified margin and the low diversity of habitat types in the estuary mean overall ecological values are low. Despite this, the habitats that are present are in good condition.

Table C1.1. Summary information for Bullock Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	1.2	-
Intertidal Area (Ha; % Estuary)[1]	1.2	100
Dominant Estuary Substrate[1]	cobble	
Mud extent (>50% mud content)	0	0
Macroalgae (Ha; cover >50%)[1]	0	0
Seagrass (Ha; cover >50%)[1]	0	0
Salt Marsh (Ha; % intertidal)[1]	0.02	4.9
High Enrichment Conditions (HEC)[1]	0	0
Catchment		
Catchment Area (Ha)[2]	78.5	
Dominant Catchment Land Cover[2]	Manuka and/or Kanuka	
% Catchment indigenous vegetation[2]	92.3	
% Catchment exotic forest[2]	7.8	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.02	
Catchment Nitrogen Load (T/y)[3]	0.19	
Catchment Phosphorus Load (T/y)[3]	0.02	
Catchment Sediment Load (KT/y)[3]	0.07	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS[5]	Y – 1.7	
Significant Wetland	N	
Birds	nd	
Fish[6]	Redfin bully	
Shellfish	nd	
Pressures		
Exotic forestry on catchment margin		
Limited migration possible with sea level rise		
Weeds and gorse on estuary margin		

[1]Stevens (2018b); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table C1.2. Ecological Vulnerability Assessment, Bullock Bay.

Category	Score
Values	0.58
Pressures	0.91
Susceptibility	0.78
Condition	0.90
Average Score	**0.79**

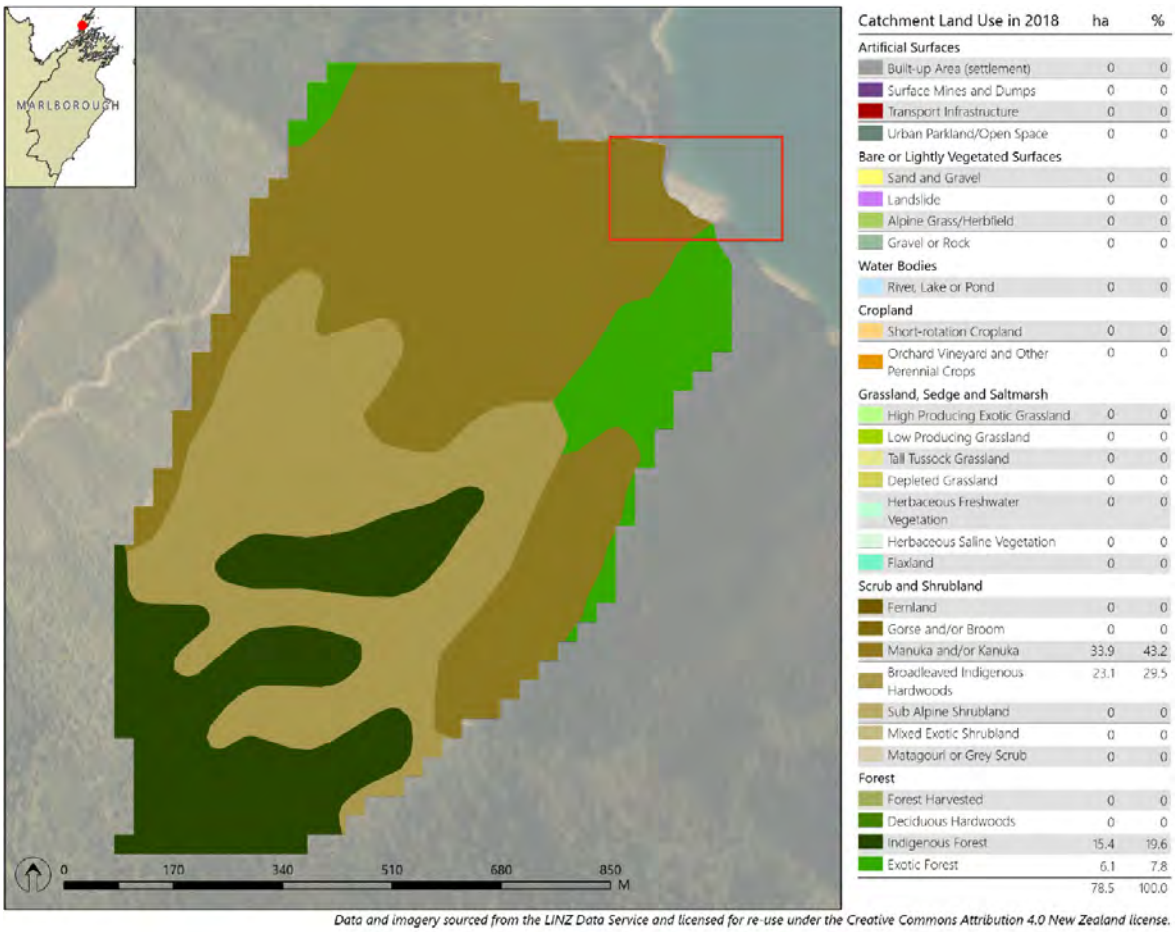

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Fig. C1.1. Bullock Bay catchment land use classifications from LCDB5 (2017/2018) database.

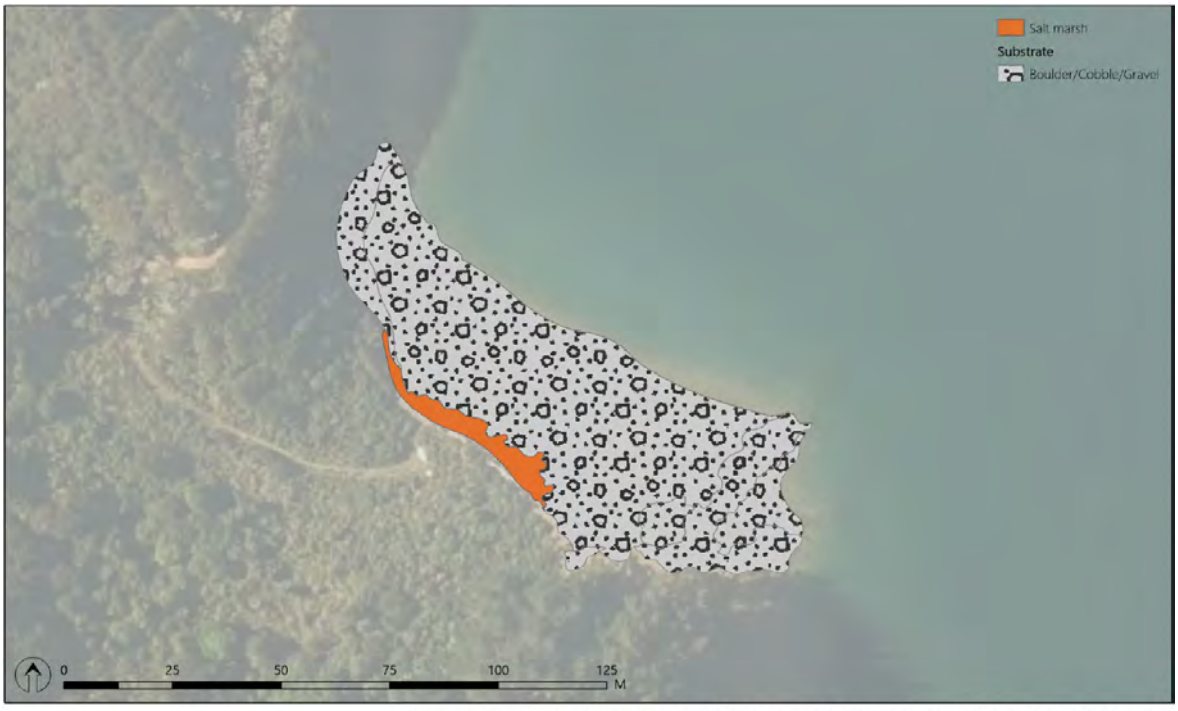

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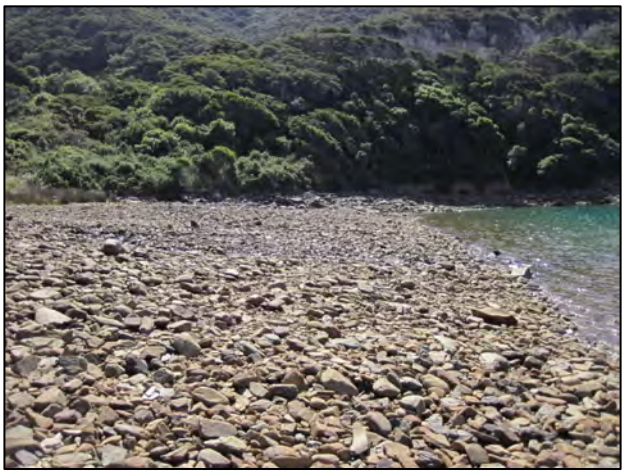
Fig. C1.2. Intertidal area in Bullock Bay. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens 2018b).

Salt marsh on the upper shoreline and native bush catchment



Cobble beach and native bush in the background

Small freshwater input to Bullock Bay

Exotic forest on the south-east margin

Boulder on northern intertidal flats

Salt marsh (rushland) growing in cobble substrate

C2. Camping Bay (Greville Harbour)

Camping Bay is a small (0.5ha) shallow intertidally dominated estuary that connects to Greville Harbour on D'Urville Island in the outer sounds. The catchment was historically cleared and is now mainly regenerating native bush (73.9%), however, there is a large area of exotic forestry on the south-east estuary margin and in the lower catchment. Some gorse and weeds are present in the estuary margin.

Greville Harbour is classified as an ESMS (Table C2.1). Bedrock underlies the dominant cobble substrate on the intertidal flats (Stevens 2018b). On the lower shore, two areas of firm muddy sand are present (Stevens 2018b). Stevens (2018b) recorded a large bed of dense and healthy seagrass at the eastern end of the beach (Fig. C2.2). There is no salt marsh in Camping Bay, likely because the Bay is relatively more exposed near the harbour entrance (Stevens 2018b). Although still within the protection of the mid-harbour boulder bank, it was noted during the Stevens (2018b) survey that significant wave energy reaches the upper shoreline and likely precludes the establishment of salt marsh.

Freshwater inputs are small and as such no nuisance macroalgae or very fine sediment deposition was observed in the estuary (Stevens 2018b). During the broad scale survey water clarity was excellent and there was also no evidence of mud accumulating in the shallow subtidal zone.

While there is dirt road access to Camping Bay, human use is considered low because D'Urville Island is not connected to the mainland and the catchment sits within private property. Remote boat access is also possible, with anchorage common in other, more protected, parts of Greville Harbour. While most of the catchment remains in native forest, the catchment is privately owned and there is a small dwelling on the estuary margin. The main pressure to the estuary is the potential harvest of mature exotic forestry on the margin and in the lower catchment, despite sediment controls it is likely some sediments will be transported to the estuary and coastal area.

The modified margin and the low diversity of habitat types in the estuary mean overall ecological values are low. Despite this, the habitats that are present are in good condition.

Table C2.1. Summary information for Camping Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	0.5	-
Intertidal Area (Ha; % Estuary)[1]	0.4	95.1
Dominant Estuary Substrate[1]	cobble	
Mud extent (>50% mud content)	0	0
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.05	12.5
Salt Marsh (Ha; % intertidal)[1]	0	0
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	143.5	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	73.9	
% Catchment exotic forest[2]	24.6	
% Producing grassland[2]	1.6	
Mean Freshwater Flow (m^3/s)[3]	0.02	
Catchment Nitrogen Load (T/y)[3]	0.19	
Catchment Phosphorus Load (T/y)[3]	0.02	
Catchment Sediment Load (KT/y)[3]	0.07	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS[5]	Y – 1.7	
Significant Wetland	N	
Birds	nd	
Fish[6]	Redfin bully	
Shellfish	nd	
Pressures		
Exotic forestry on catchment margin		
Limited migration possible with sea level rise		
Weeds and gorse on estuary margin		

[1]Stevens (2018b); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table C2.2. Ecological Vulnerability Assessment, Camping Bay.

Category	Score
Values	0.54
Pressures	0.86
Susceptibility	0.73
Condition	0.90
Average Score	**0.76**

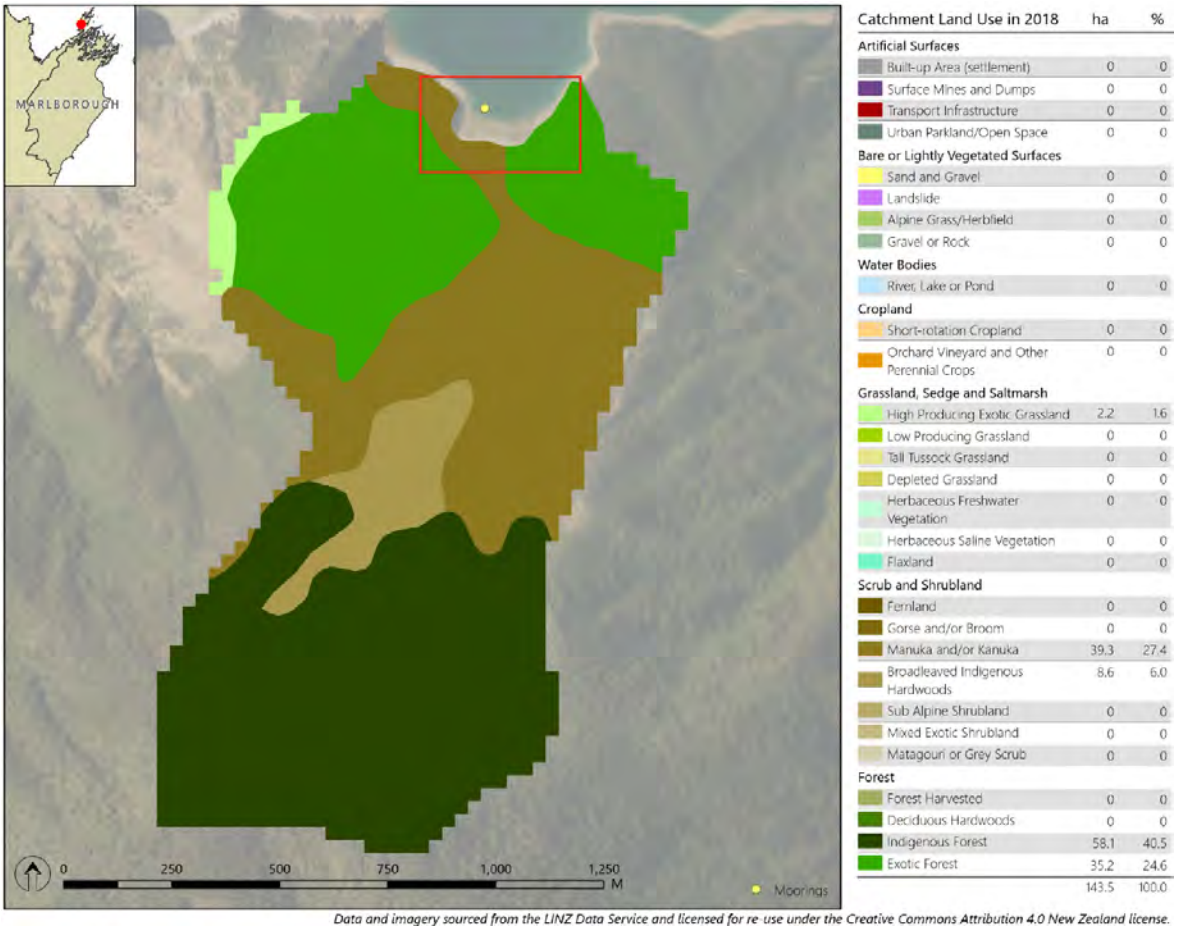


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Fig. C2.1. Camp Bay catchment land use classifications from LCDB5 (2017/2018) database.

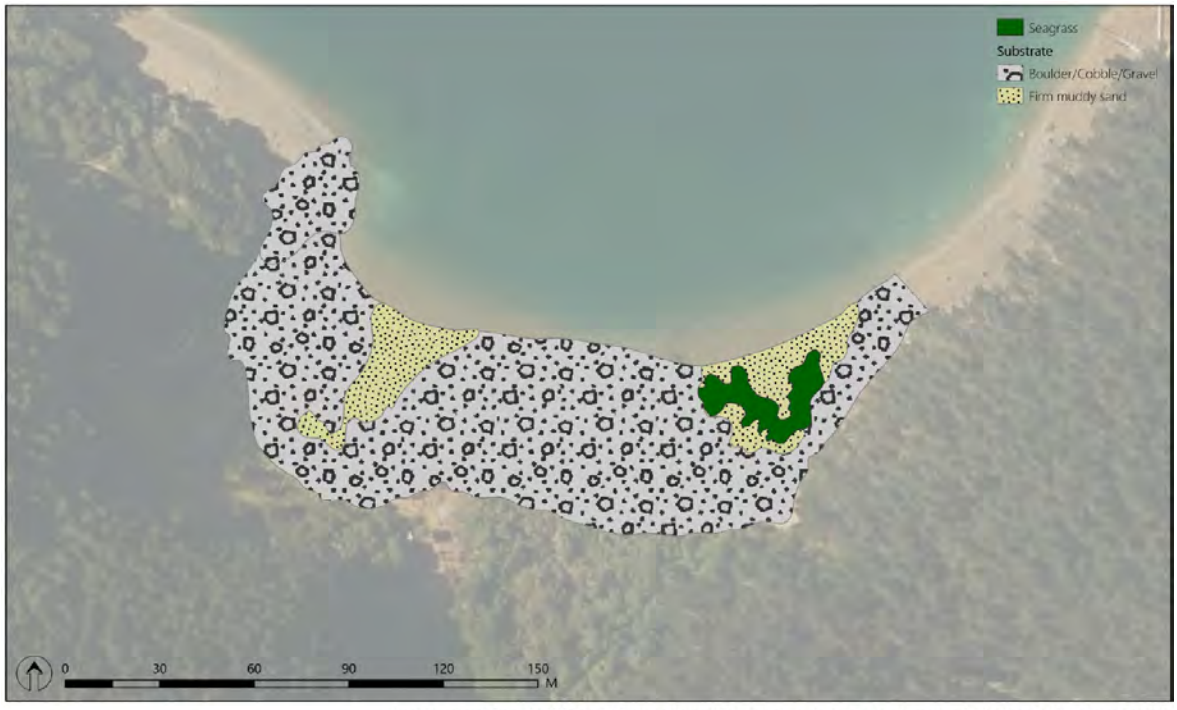

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Fig. C2.2. Intertidal area in Camp Bay. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens 2018b).

Seagrass growing in firm muddy sand on the southern intertidal flats

Cobble and firm muddy sand

Cobble, Camp Bay

Woody debris accumulating on the margin

Cobble and boulder, exotic forest on margin and native bush in background

Woody debris and exotic forestry in background, Camp Bay

C3. Mill Arm (Greville Harbour)

Mill Arm, located on the north-east side of Greville Mill Arm, located on the north-east side of Greville Harbour, is a long, narrow arm with a south-west facing aspect. The catchment is 97.3% indigenous vegetation cover, and the terrestrial margin comprises native forest with freshwater wetland plants common near the stream delta at the head of the estuary.

A mix of cobble and gravel substrates is present in a narrow strip along the shoreline and across the upper tidal flats of the estuary stream delta. The lower estuary comprises extensive soft muds, which is the dominant substrate type in the estuary (Fig. C2.2).

The head of the estuary supports small areas of salt marsh herbfield (remu remu and sea primrose) with occasional glasswort growing on the gravel and sand flats in the upper tidal reaches. Jointed wire rush and sea rush are present in small patches among herbfields, with the nationally declining sea sedge *Carex litorosa* present as a subdominant cover throughout the areas where salt marsh grows (see photo; Stevens 2018b). No seagrass was observed in Mill Arm (Stevens 2018b).

Nuisance macroalgae (*Agarophyton* spp.) was recorded growing on the lower estuary soft muds (see photo). However, both percent cover (<5%), and biomass (<250g/m^2 wet weight) were low, indicating the growth is not currently an issue in the estuary. While the patches were growing entrained in the sediment (i.e. 'roots' down to ~3cm) low nutrient loads and the native forested catchment mean it is unlikely that *Agarophyton* spp. will reach problematic levels.

Greville Harbour, including intertidal areas, is classified as an ESMS (Table C3.1) and the salt marsh is classified as a regionally significant wetland. While most of the Mill Arm catchment is in native forest it is only partly protected within the D'Urville Island Scenic reserve, with the rest of the catchment privately owned.

Pressures are limited in Mill Arm, with human use restricted to remote boat access. There is a small incursion of the introduced Pacific oyster. In other bays within Greville Harbour wild animal browsing by deer and feral pigs has been observed, and is a potential threat to the nationally declining *Carex litorosa*. The low-lying wetland at the head of the estuary will allow for some migration of salt marsh with sea level rise, however this area represents only a narrow band for landward migration. Ecological values were scored relatively low in the EVA because the estuary has no seagrass and only a small area of salt marsh. Despite this situation, the habitats present are in very good condition and the estuary has minimal pressures.

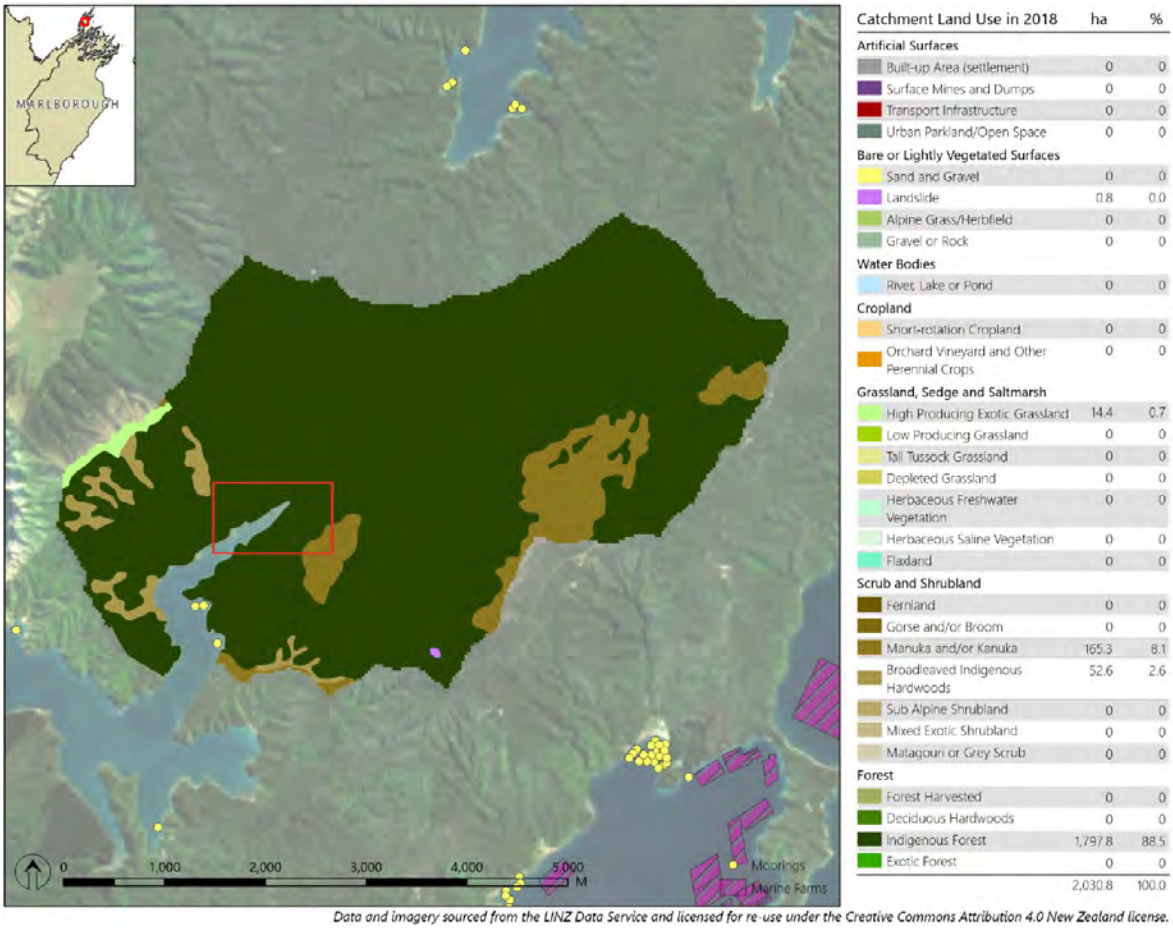
Table C3.1. Summary information for Mill Arm.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	10.9	-
Intertidal Area (Ha; % Estuary)[1]	10.6	97.2
Dominant Estuary Substrate[1]	Very soft mud	
Mud extent (>50% mud content)	5.0	46.0
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.0	0.0
Salt Marsh (Ha; % intertidal)[1]	0.3	2.8
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	2031	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	97.3	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.7	
Mean Freshwater Flow (m^3/s)[3]	0.4	
Catchment Nitrogen Load (T/y)[3]	3.68	
Catchment Phosphorus Load (T/y)[3]	0.42	
Catchment Sediment Load (KT/y)[3]	1.26	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS[5]	Y - 1.7	
Significant Wetland	Y - salt marsh	
Birds	nd	
Fish[6]	Redfin bully	
Shellfish	nd	
Pressures		
Remote boat access		
Pacific oyster incursion		
Potential for wild animal browsing and physical damage		

[1]Stevens (2018b); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table C3.2. Ecological Vulnerability Assessment, Mill Arm.

Category	Score
Values	0.63
Pressures	0.89
Susceptibility	0.92
Condition	0.90
Average Score	**0.83**



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0.8	0.0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	14.4	0.7
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	0	0
Manuka and/or Kanuka	165.3	8.1
Broadleaved Indigenous Hardwoods	52.6	2.6
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	0	0
Deciduous Hardwoods	0	0
Indigenous Forest	1,797.8	88.5
Exotic Forest	0	0
	2,030.8	100.0

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Fig. C3.1. Mill Arm catchment land use classifications from LCDB5 (2017/2018) database.

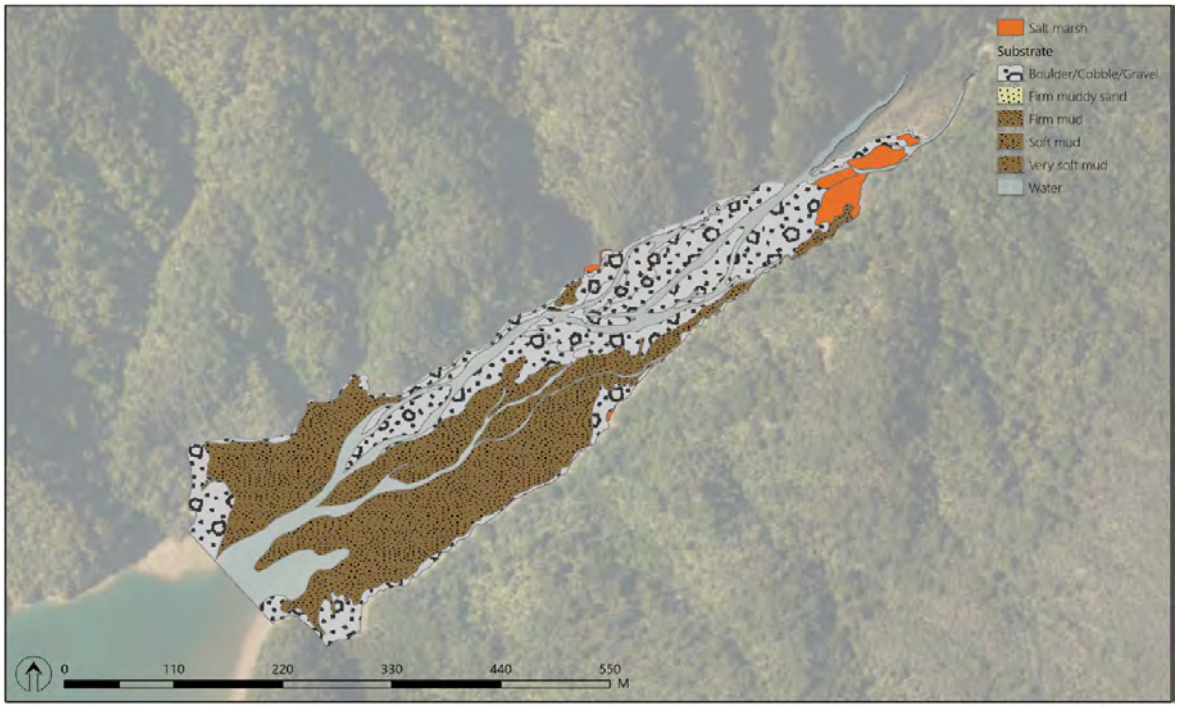

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Fig. C3.2. Intertidal area in Mill Arm. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens 2018b).

Cobbles at the estuary edge and soft muds on the lower intertidal flats

Sparse growth of *Agarophyton* spp. in the lower estuary growing in soft muds

Nationally declining *Carex litorosa* growing among herbfield

Gravel/cobble dominated mid-estuary

Mill Arm, native bush catchment

Upper estuary, looking downstream

C4. Mokau Bay (Greville Harbour)

Mokau Bay is located on the east side of Greville Harbour, and has a small (1.0ha) intertidal area with a south-west facing aspect at the head of the bay. The catchment is 100% indigenous vegetation cover that is dominated by manuka and/or kanuka. The margin is densely vegetated with a small clearing for a dwelling close to the estuary margin. The estuary has one small freshwater input that has very low nutrient and sediment loads (Table 54).

A REA in Mokau Bay was carried out on 28 February 2022. The dominant substrate type was gravel/cobble and there was <10% mud-dominated sediments across the intertidal flats.

Greville Harbour, including intertidal areas, is classified as an ESMS (Table C4.1). Salt marsh comprised ~15% of the intertidal area and was mainly rushland. Davidson et al. (2011) noted that good populations of the nationally declining sea sedge *Carex litorosa* were present within intertidal areas of Greville Harbour. The presence of *Carex litorosa* was confirmed in the most recent MDC site visit. However, browsing and physical damage from wild pigs was evident within the salt marsh habitat, and is a potential threat to this nationally declining species.

Seagrass was recorded across <5% of the intertidal area. Nuisance macroalgae was not recorded above 5% cover. Low nutrient loads and the native forest catchment mean it is unlikely macroalgae will grow to nuisance levels in the estuary.

Pressures are limited in Mokau Bay with human use restricted to remote boat access. While most of the catchment remains in native forest, the catchment is privately owned and there is a small dwelling on the estuary margin. Wild animal browsing has been observed by deer and feral pigs and is a threat to salt marsh habitat. The steep catchment will limit landward migration of salt marsh habitat with sea level rise. Overall, the estuary has both high ecological values, is in very good condition and is subject to minimal pressures.

The loss of *Carex litorosa* in other estuaries in Greville Harbour, and the damage to the salt marsh habitat in Mokau Bay, suggest that the management of deer and feral pig populations may be needed to sustain the small remaining areas of *Carex litorosa*.

Table C4.1. Summary information for Mokau Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	1.0	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	10
Macroalgae (Ha; cover >50%)	-	1-5
Seagrass (Ha; cover >50%)	-	5
Salt Marsh (Ha; % intertidal)	-	15
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	62.1	
Dominant Catchment Land Cover[2]	Manuka and/or Kanuka	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.01	
Catchment Nitrogen Load (T/y)[3]	0.12	
Catchment Phosphorus Load (T/y)[3]	0.01	
Catchment Sediment Load (KT/y)[3]	0.03	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS[5]	Y – 1.7	
Significant Wetland	N	
Birds	nd	
Fish[6]	Redfin bully	
Shellfish	nd	
Pressures		
Remote boat access		
Bach		
Wild animal browsing and physical damage		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table C4.2. Ecological Vulnerability Assessment, Mokau Bay.

Category	Score
Values	0.74
Pressures	0.89
Susceptibility	0.89
Condition	0.96
Average Score	0.87

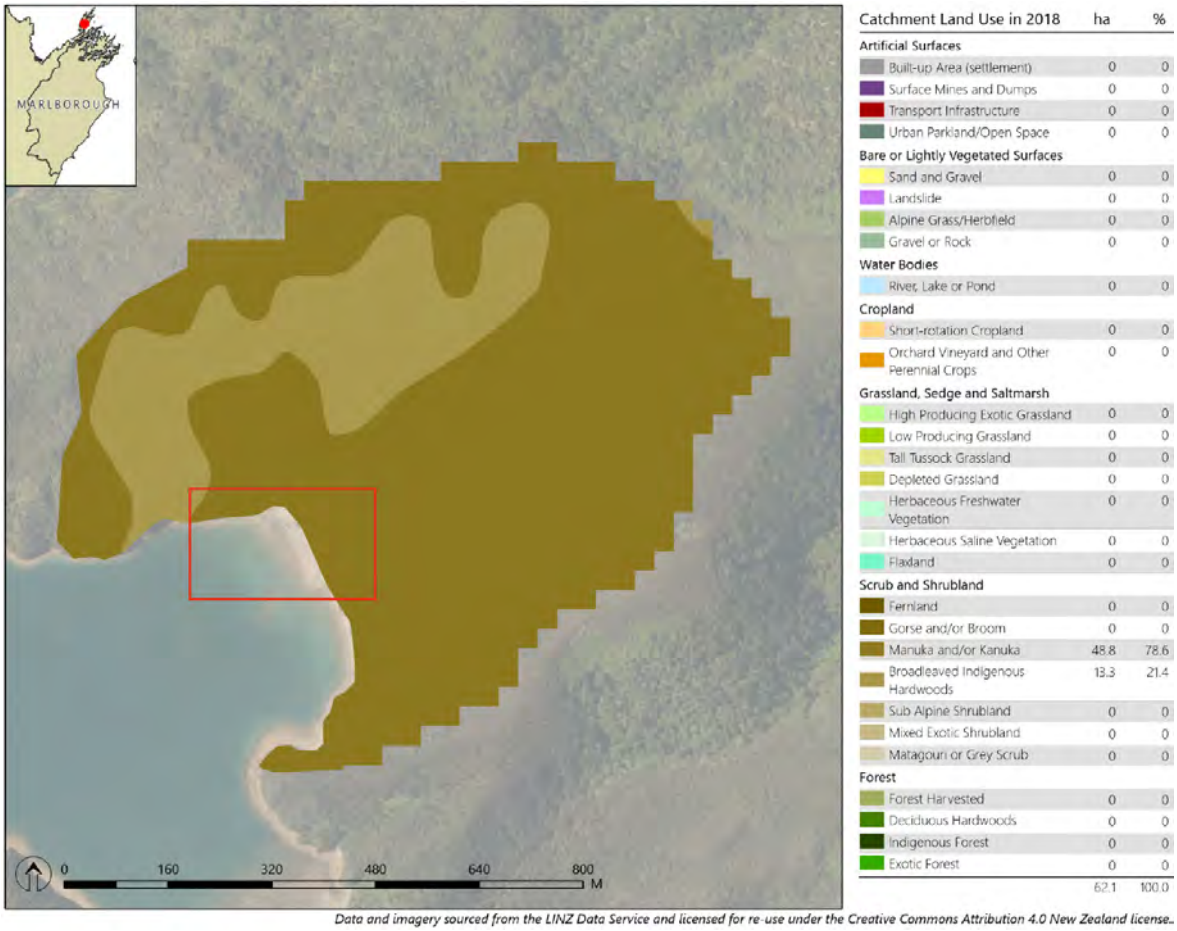

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Fig. C4.1. Mokau Bay catchment land use classifications from LCDB5 (2017/2018) database.

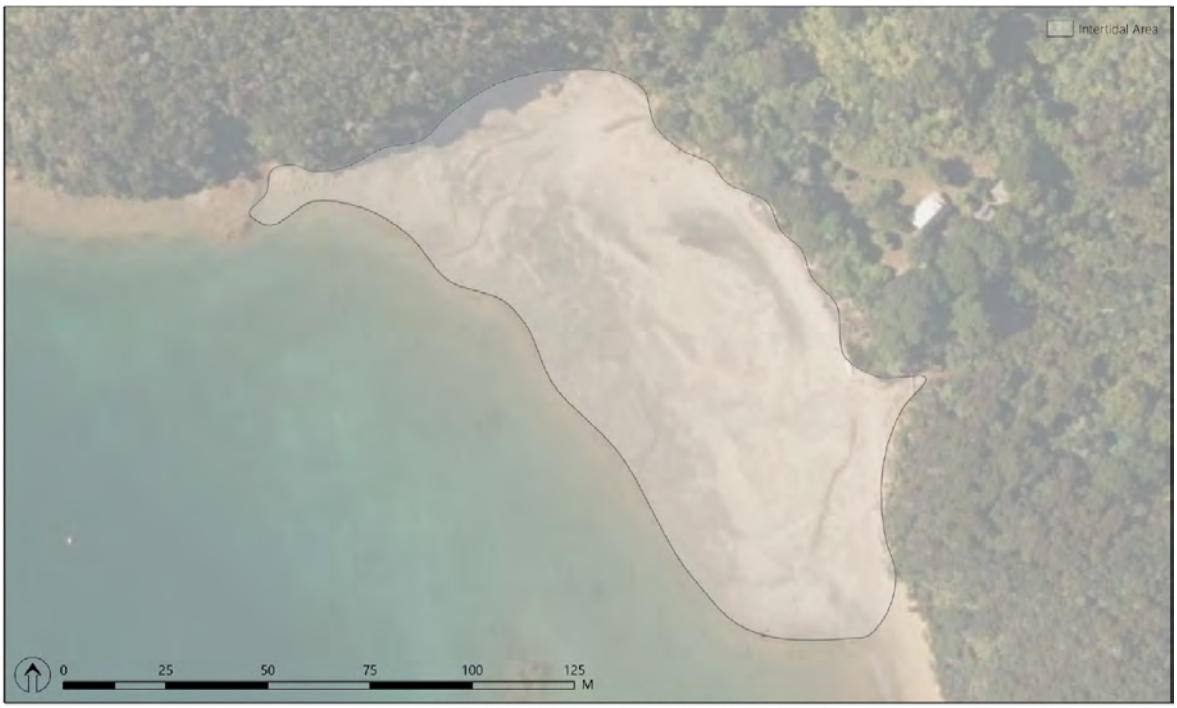

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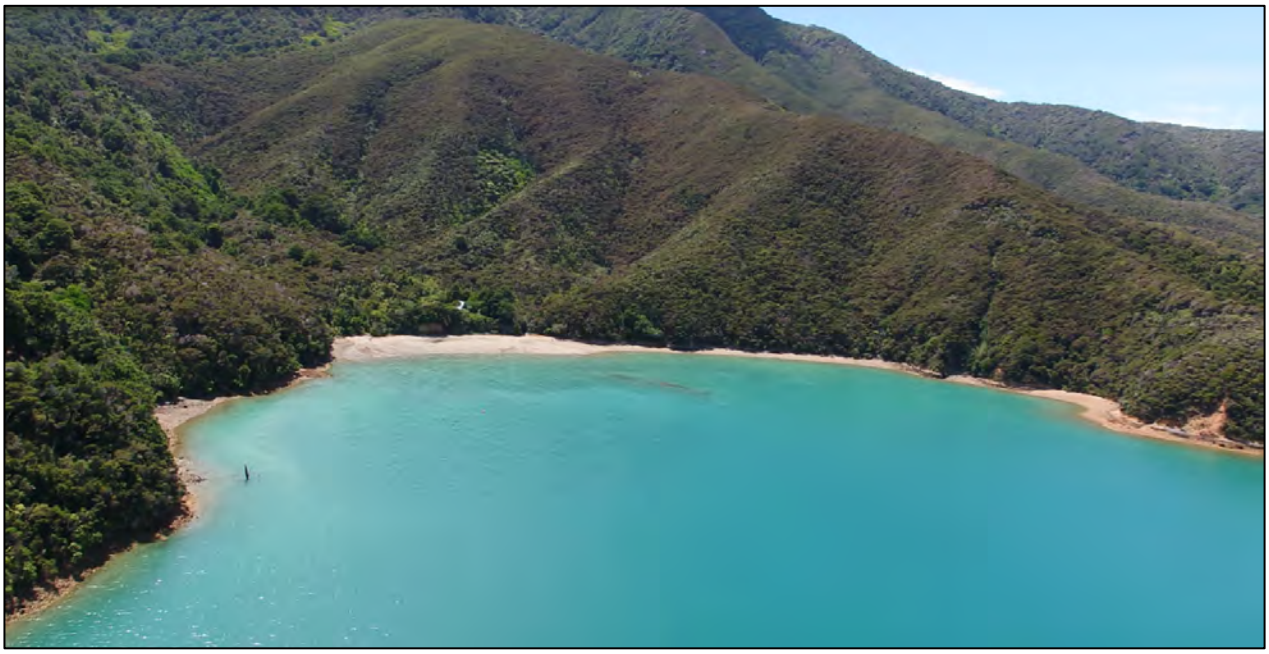
Fig. C4.2. Intertidal area in Mokau Bay.



Intertidal area in Mokau Bay (**Image ref: 'DUrville GrevilleHarbour-MokauBay-01', Courtesy of Marlborough District Council**)

Mokau Bay to the left and Wharairiki Bay intertidal area to the right (**Image ref: 'DUrville GrevilleHarbour-MokauBay-02', Courtesy of Marlborough District Council**)

C5. Punt Arm (Greville Harbour)

Punt Arm, located on the south side of Greville Harbour, is a long, narrow arm with a north facing aspect. The catchment is 100% indigenous vegetation cover that is dominated by manuka and/or kanuka. The terrestrial margin comprises native forest with freshwater wetland plants at the head of the estuary

The substrate is a mix of cobble and gravel with only a small area (2.5%) of soft muds on the lower tidal flats adjacent to the stream channel. Salt marsh in the upper estuary comprises salt marsh ribbon wood, jointed wire rush and sea rush. Herbfield (remu remu and sea primrose) was also present with occasional patches of glasswort growing on the gravel and sand flats. Davidson et al. (2011) noted that good populations of the nationally declining sea sedge *Carex litorosa* were present in Punt Arm. However, in 2018 only a single plant of *Carex litorosa* was recorded and in a site visit in February 2022 no plants were recorded (Stevens 2018; REA site visit). Indicating there has been a significant decline in this species in recent years. In the most recent MDC site visit (2022) browsing and physical damage from wild pigs was recorded and could be a plausible explanation for the decline.

Stevens (2018) recorded seagrass growing in high density patches in the lower tidal range, and it was also evident on the shallow subtidal delta at the seaward edge of the estuary. Nuisance macroalgae (*Agarophyton* spp.) was not recorded above 5% cover. Low nutrient loads and the native forest catchment mean it is unlikely that macroalgae will reach nuisance levels.

Greville Harbour, including intertidal areas, is classified as an ESMS (Table C5.1). While most of the catchment remains in native forest, it is privately owned. A jetty and mooring in the subtidal zone provide boat access to a small dirt road and a dwelling on the north-east margin. Pressures are limited in Punt Arm with human use restricted to remote boat access. Due to the steep nature of the catchment, there is limited scope for landward migration with sea-level rise. Only a small area of low-lying wetland at the head of the estuary allows for some migration of salt marsh. Overall, the estuary has both high ecological values, is in good condition and is subject to minimal pressures.

Table C5.1. Summary information for Punt Arm.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	3.5	-
Intertidal Area (Ha; % Estuary)[1]	2.5	70.4
Dominant Estuary Substrate[1]	Gravel	
Mud extent (>50% mud content)	0.09	2.5
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.08	2.3
Salt Marsh (Ha; % intertidal)[1]	0.1	3.3
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	252.9	
Dominant Catchment Land Cover[2]	Manuka and/or Kanuka	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.1	
Catchment Nitrogen Load (T/y)[3]	0.53	
Catchment Phosphorus Load (T/y)[3]	0.06	
Catchment Sediment Load (KT/y)[3]	0.21	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS[5]	Y – 1.7	
Significant Wetland	N	
Birds	nd	
Fish[6]	Redfin bully	
Shellfish	nd	
Pressures		
Remote boat access		
Jetty and bach		
Wild animal browsing and physical damage		

[1]Stevens (2018b); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table C5.2 Ecological Vulnerability Assessment, Punt Arm.

Category	Score
Values	0.66
Pressures	0.89
Susceptibility	0.92
Condition	0.93
Average Score	**0.85**

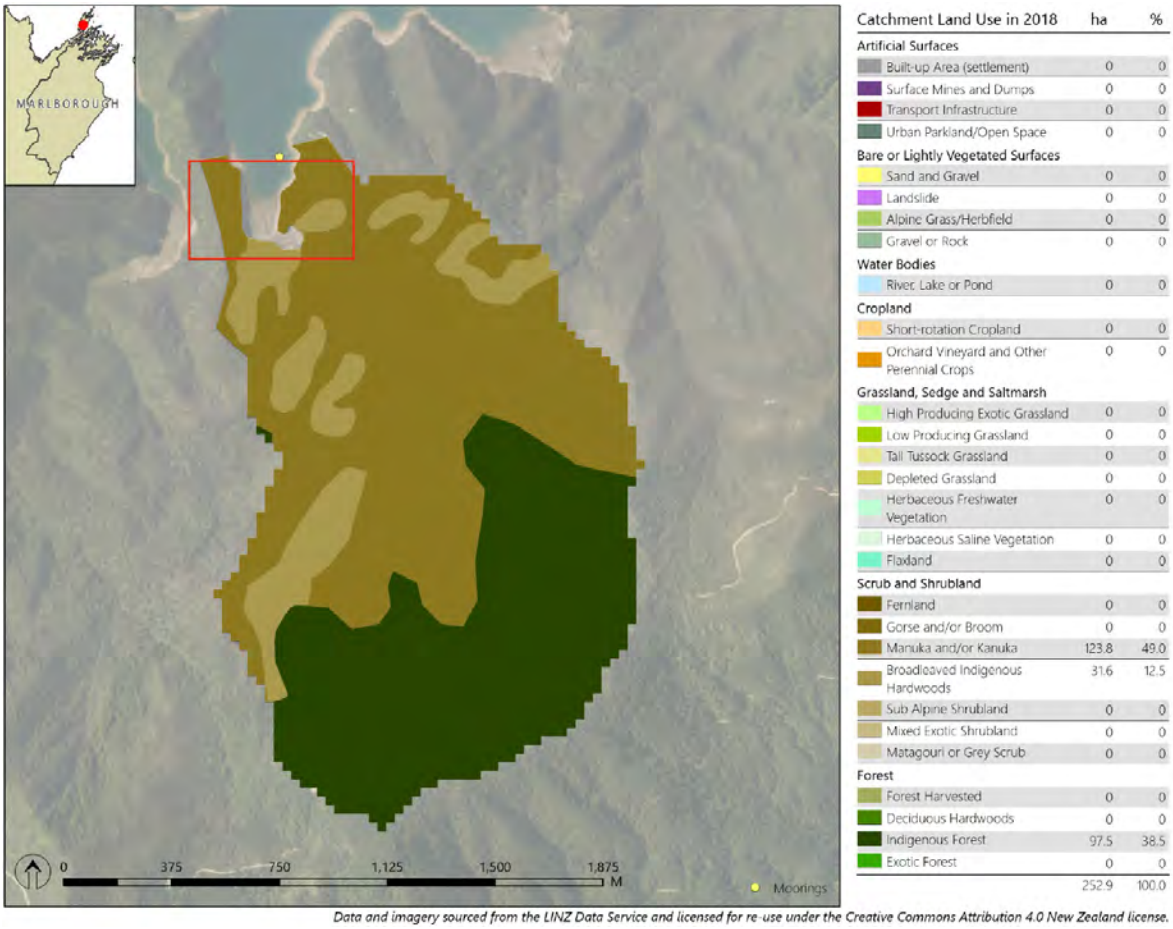


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Fig. C5.1. Punt Arm catchment land use classifications from LCDB5 (2017/2018) database.

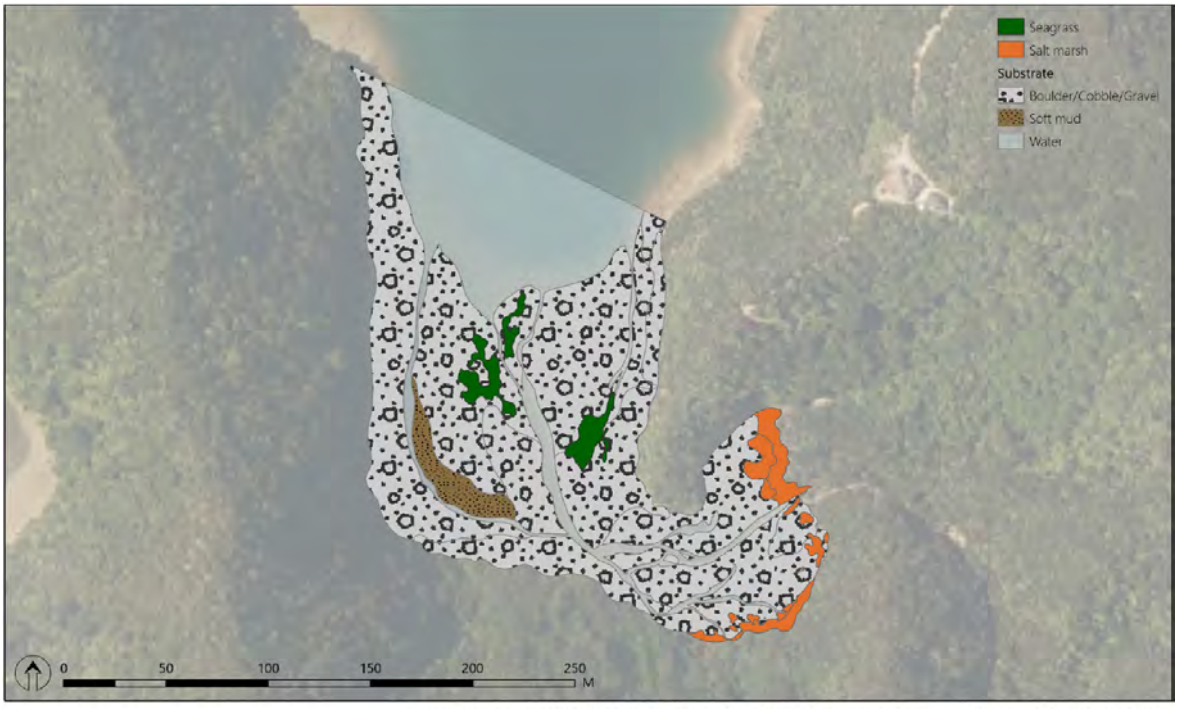

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Fig. C5.2. Intertidal area in Punt Arm. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens 2018b).

Steep native bush catchment, gravel/cobble

Small area of soft sediments on the channel margin

Seagrass growing in gravel

Steep native bush catchment of Punt Arm (left)

Gravel/ cobble in the lower estuary and pontoon jetty in the background

Rushland in the upper estuary

C6. Smylies Arm (Greville Harbour)

Smylies Arm, located on the south side of Greville Harbour, is a long, narrow arm with a north facing aspect. The catchment is 96% indigenous vegetation cover, comprising mainly indigenous forest. The terrestrial margin comprises manuka and/or kanuka and exotic forest on the western margin. Freshwater wetland plants are present at the head of the estuary.

The substrate is a mix of cobble and gravel in the upper estuary, while the lower estuary comprises soft mud, which is the dominant substrate type (Stevens 2018). Fine sediment deposition in the estuary likely occurred during the historic clearing of land on the north-west margin. In the cleared area pines were planted in the 1970's and are now well-established. To date the pine forest has not been harvested, however, a consent to harvest is currently active.

Salt marsh in the upper estuary comprises salt marsh ribbon wood, jointed wire rush and sea rush. Herbfield (remu remu and sea primrose) was also present with occasional patches of glasswort growing on the gravel and sand flats. Davidson et al. (2011) noted that good populations of the nationally declining sea sedge *Carex litorosa* were present in Smylies Arm. However, in 2018 no *Carex litorosa* was observed (Stevens 2018). Indicating there has been a significant decline in this species in recent years. The cause of the decline is uncertain, however, browsing and physical damage from wild pigs was recorded in a nearby estuary (Punt Arm), although it has not observed in Smylies Arm.

Stevens (2018) recorded seagrass growing in low density (<25% cover) patches in the lower tidal range where soft muds are present. Seagrass was also evident on the shallow subtidal delta at the seaward edge of the estuary. Nuisance macroalgae (*Agarophyton* spp.) was not recorded above 5% cover. Low nutrient loads and the native forest catchment mean it is unlikely macroalgae will reach nuisance levels.

Greville Harbour, including intertidal areas, is classified as an ESMS (Table C6.1). While most of the catchment remains in native forest, it is privately owned. The main pressure to the estuary is the potential harvest of mature exotic forestry on the north-west margin. Even with sediment controls it is likely some sediments will be transported to the estuary and coastal area. Other pressures include remote boat access and animal browsing. Overall, the estuary is presently in very good condition.

Table C6.1. Summary information for Smylies Arm.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	3.7	-
Intertidal Area (Ha; % Estuary)[1]	3.5	92.5
Dominant Estuary Substrate[1]	Soft mud	
Mud extent (>50% mud content)	1.34	35.8
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.9	23.0
Salt Marsh (Ha; % intertidal)[1]	0.3	7.5
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	320.9	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	96.0	
% Catchment exotic forest[2]	4.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.08	
Catchment Nitrogen Load (T/y)[3]	0.68	
Catchment Phosphorus Load (T/y)[3]	0.08	
Catchment Sediment Load (KT/y)[3]	0.58	
Catchment Geology[4]	Sandstone	
Biodiversity		
ESMS[5]	Y – 1.7	
Significant Wetland	Y – salt marsh	
Birds		
Fish[6]	Redfin bully	
Shellfish		
Pressures		
Remote boat access		
Exotic forestry on margin		
Sedimentation		
Wild animal browsing and physical damage		

[1]Stevens (2018b); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table C6.2. Ecological Vulnerability Assessment, Smylies Arm.

Category	Score
Values	0.71
Pressures	0.88
Susceptibility	0.76
Condition	0.85
Average Score	**0.80**

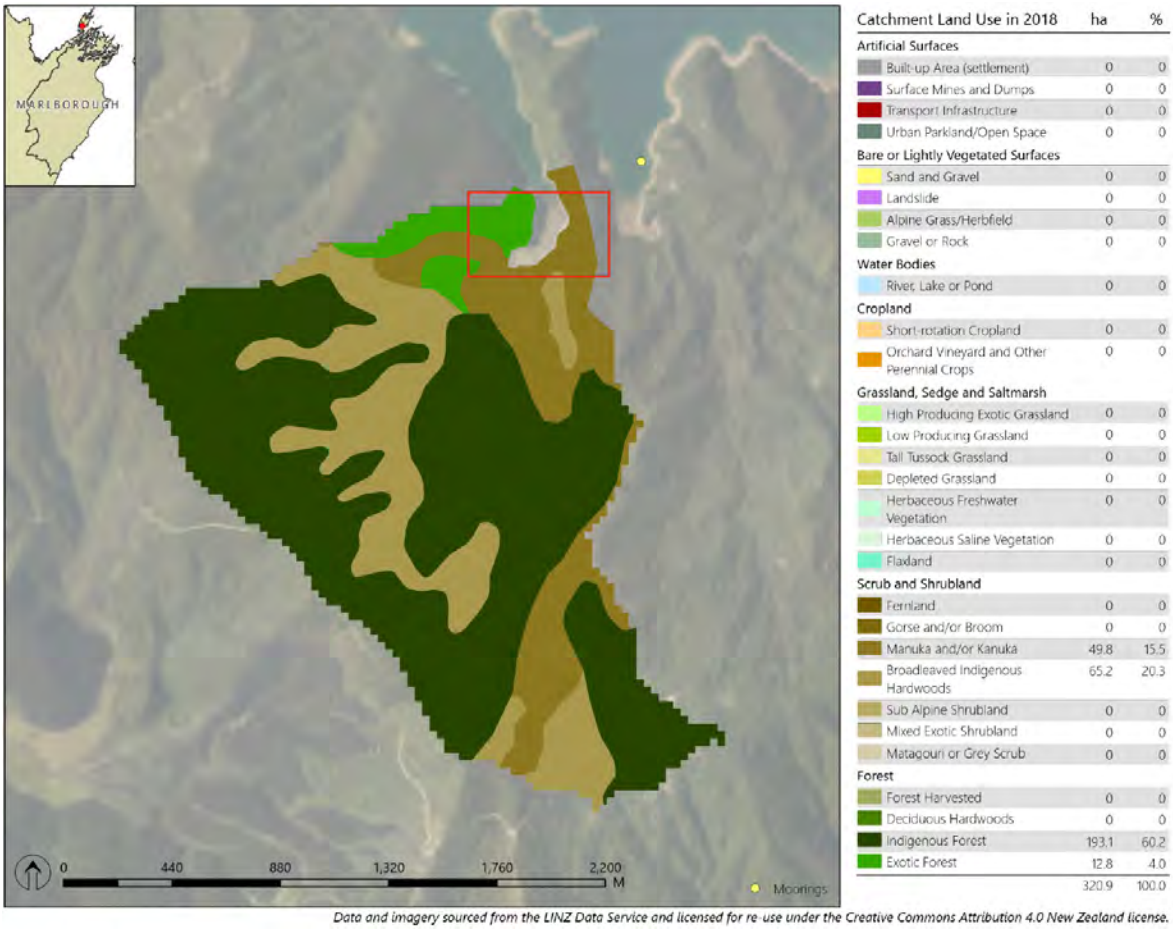

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Fig. C6.1 Smylies Arm catchment land use classifications from LCDB5 (2017/2018) database.

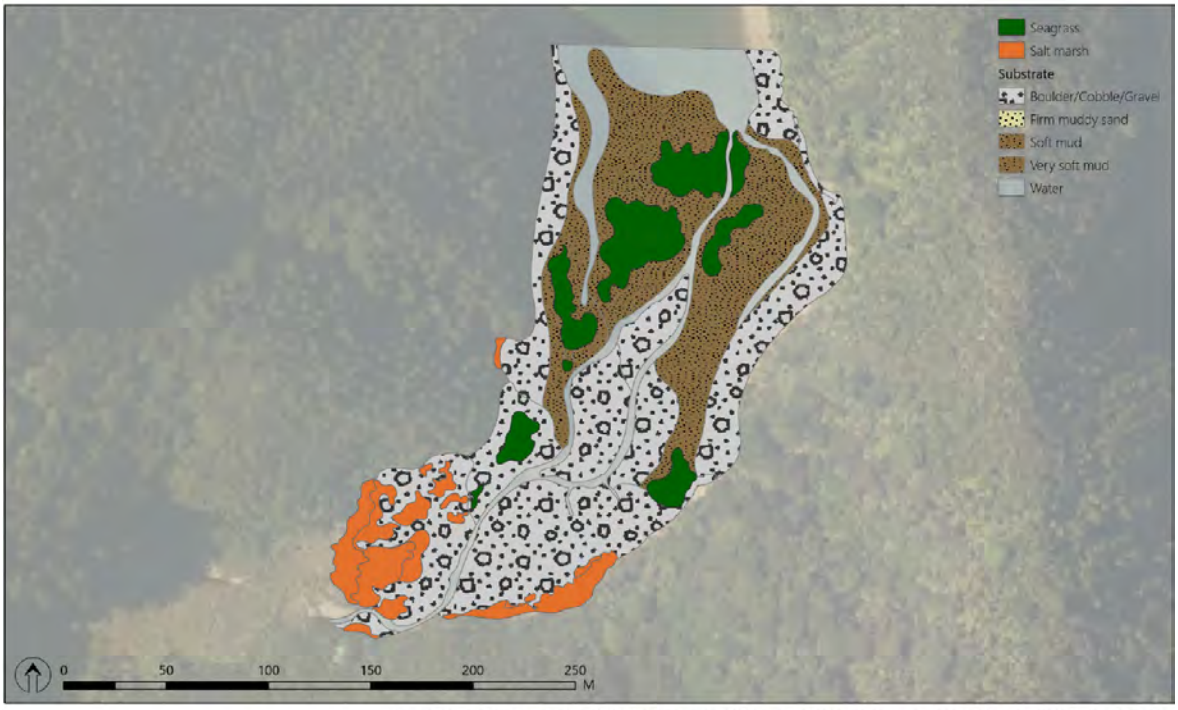

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Fig. C6.2. Intertidal area in Smylies Arm. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens 2018b).

Salt marsh transitioning into freshwater wetland and a mix of native bush and exotic forestry in the background

Steep catchment of Smylies Arm (right) with a mix of native bush and exotic forestry

Seagrass growing in soft muds

Mid-estuary gravel/cobble

Pine forest on the estuary margin

Soft muds in the lower estuary

C7. Wharairiki Bay (Greville Harbour)

Wharairiki Bay is located on the east side of Greville Harbour, and has an intertidal delta at the head of the bay with a north-west facing aspect. The catchment is 100% indigenous vegetation cover that is dominated by manuka and/or kanuka. The terrestrial margin also comprises manuka and/or kanuka, with freshwater wetland plants present at the head of the estuary. The estuary has two small freshwater inputs that are relatively low in nutrients and sediments (Table 60).

A recent field assessment has not been undertaken at Wharairiki Bay, hence the following information is based on a desktop assessment and should be treated with caution. The dominant substrate type is gravel/cobble and from the imagery available the estuary appears to have <10% mud-dominated sediments across the intertidal flats.

Salt marsh comprises 3.4% of the intertidal area and is a mix of rushland and herbfield. Davidson et al. (2011) noted that good populations of the nationally declining sea sedge *Carex litorosa* were present in Wharairiki Bay. Since that study, *Carex litorosa* has not been recorded in nearby estuaries and therefore it is uncertain whether this species remains in Wharairiki Bay.

Nuisance macroalgae does not appear to be an issue in the estuary, with no visible areas of growth on the aerial imagery available. Low nutrient loads and the native forest catchment make it is unlikely that macroalgae will reach nuisance levels. It is uncertain whether seagrass is present in the estuary from the information available. Greville Harbour, including intertidal areas, is classified as an ESMS (Table C6.1).

Pressures are limited in Wharairiki Bay, with human use restricted to remote boat access. While most of the catchment remains in native forest, it is privately owned. In other bays within Greville Harbour wild animal browsing has been observed by deer and feral pigs and is a potential threat to the nationally declining *Carex litorosa*. Significant volumes of woody debris can be seen on the drone images accumulating in the upper tidal zone with the potential to damage underlying salt marsh habitat (see photo). The steep catchment will limit landward migration of salt marsh habitat with sea level rise. Overall, the estuary appears to have high ecological values and be in good condition, and is subject to minimal pressures. However, a field visit would be required to confirm these findings.

Table C7.1. Summary information for Wharairiki Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	3.9	-
Dominant Estuary Substrate	Gravel/cobble	
Mud extent (>50% mud content)	-	<10
Macroalgae (Ha; cover >50%)	-	<5
Seagrass (Ha; cover >50%)	nd	nd
Salt Marsh (Ha; % intertidal)	-	3
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	369.1	
Dominant Catchment Land Cover[2]	Manuka and/or Kanuka	
% Catchment indigenous vegetation[2]	100.0	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	0.09	
Catchment Nitrogen Load (T/y)[3]	0.79	
Catchment Phosphorus Load (T/y)[3]	0.09	
Catchment Sediment Load (KT/y)[3]	0.24	
Catchment Geology[4]	Sandstone & gravel	
Biodiversity		
ESMS[5]	Y – 1.7	
Significant Wetland	N	
Birds	nd	
Fish[6]	Redfin bully, Koaro	
Shellfish	nd	
Pressures		
Remote boat access		
Accumulation of woody debris		
Wild animal browsing and physical damage		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table C7.2. Ecological Vulnerability Assessment, Wharairiki Bay.

Category	Score
Values	0.62
Pressures	0.90
Susceptibility	0.89
Condition	0.94
Average Score	**0.84**

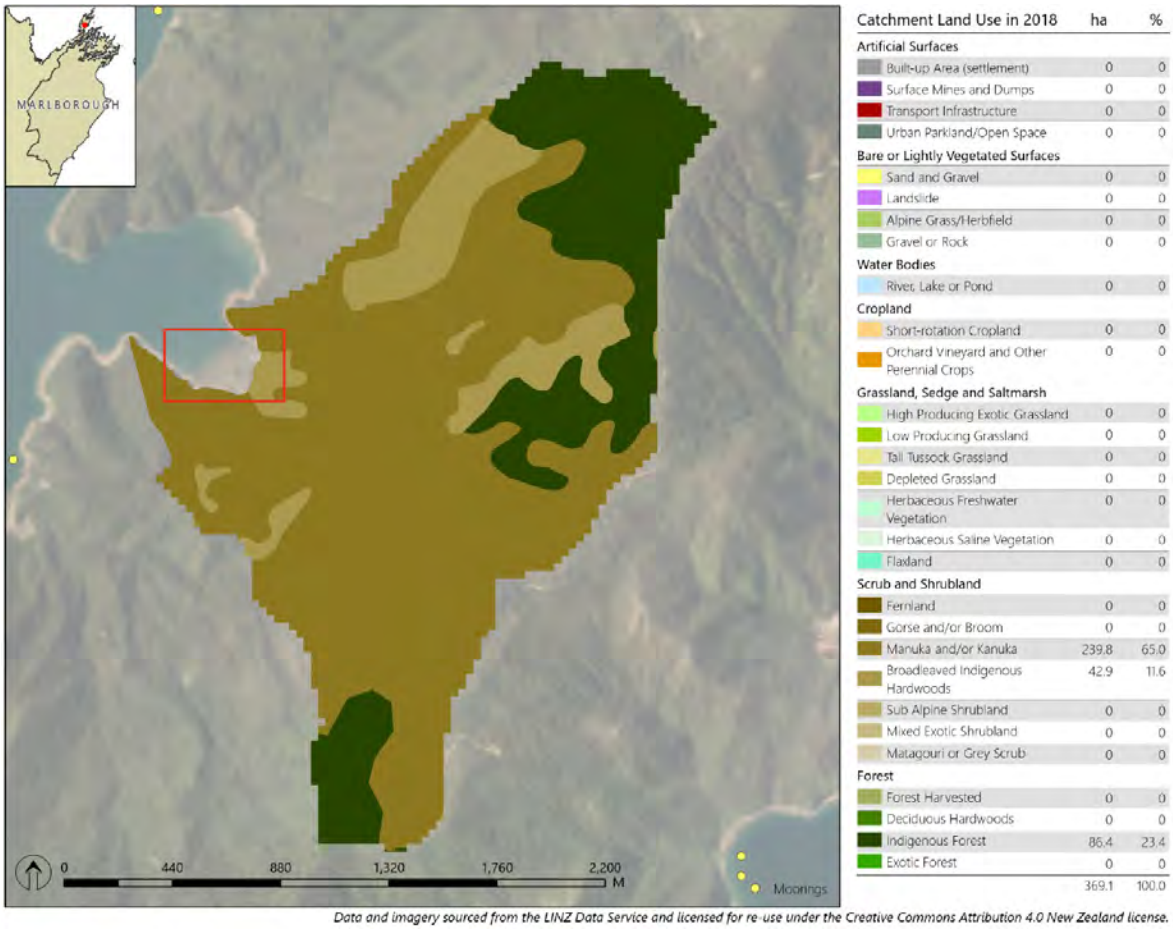

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Fig. C7.1. Wharairiki Bay catchment land use classifications from LCDB5 (2017/2018) database.

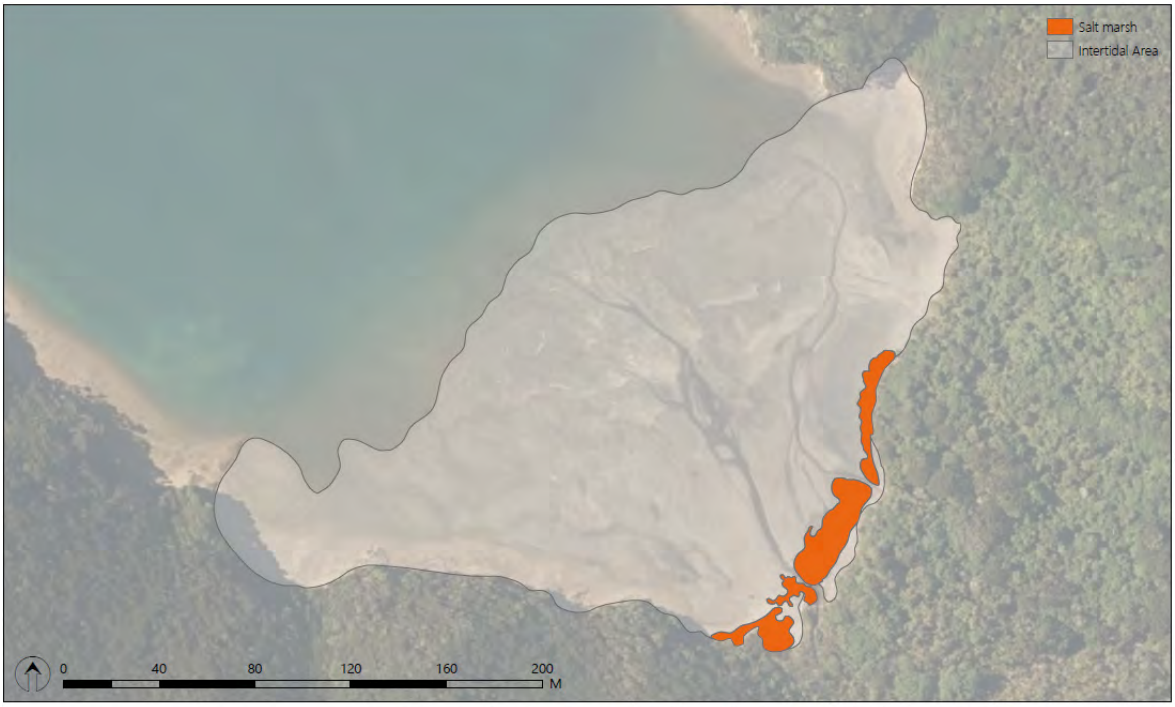

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Fig. C7.2. Intertidal area in Wharairiki Bay.

Intertidal area in **Wharairiki** Bay and steep native bush catchment (photo credit: Paul Fisher)

Drone image of **Wharairiki intertidal area (Image ref: 'DUrville GrevilleHarbour BoulderSpitPoint 02', Courtesy of Marlborough District Council)**

C8. Wells Arm (Port Hardy – East Arm)

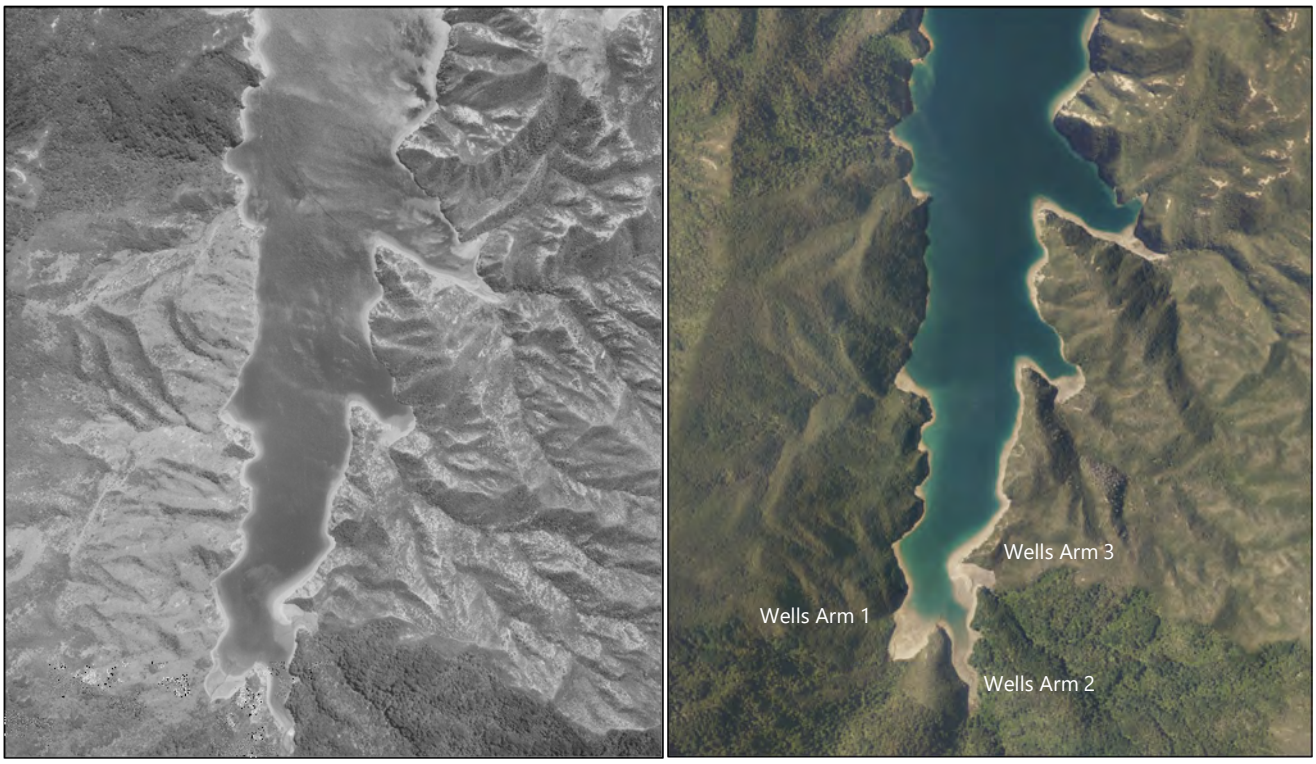
Wells Arm is a deep subtidal estuary within Port Hardy on D'Urville Island. Within the arm there are six small intertidal areas. For the purpose of this report the three largest intertidal areas at the head of the arm were visited in 2022 and a REA carried out. The intertidal areas are referred to as Wells Arm 1, 2 and 3 (see photo below). They are all small shallow intertidally dominated estuaries, that are connected to the deep subtidal zone.

Historically the western margin of Wells Arm appears to have been cleared and is now mainly regenerating manuka and/or kanuka. Moreover, historically the margin of Wells Arm 1 was partially cleared for a dwelling, however, present day the margin comprises regenerating native bush. Other areas to the south have remnant patches of indigenous forest. Today, all three catchments are dominated by indigenous vegetation cover comprising a mix of indigenous forest and manuka and/ or kanuka (Table C8.1, Figs. C8.1, C8.3, C8.5). The heads of Wells Arm 1 and 2 catchments are within the D'Urville Island Scenic Reserve while the remaining area is privately owned. The native bush catchments are reflected in the low nutrient and sediment loads to the estuary (Table C8.1).

The intertidal areas in Wells Arm are gravel/cobble dominated. No seagrass was recorded across all three intertidal areas. Salt marsh, particularly rushland was recorded in all three estuaries. The most extensive area of salt marsh was in Wells Arm 2 and is also classified as a regionally significant wetland (see photos). In Wells Arm 2 both rushland and herbfield were recorded growing in gravels. Where salt marsh was growing on the channel margins some erosion was observed however, no other significant pressures on salt marsh were recorded. Wells Arm 3 is classified as an ESMS, because it has a small area of the nationally declining sea sedge (*Carex littorosa*). The steep margins of Wells Arm will naturally limit landward migration of salt marsh with sea level rise.

The native bush catchments combined with limited human use (i.e. restricted to remote boat access) reduce the number of pressures on the estuaries within Wells Arm. Pressures in the outer bays of Port Hardy (within 5km of Wells Arm) include one marine farm, a few moorings, anchorage, and farming on the northern margin. Further, on other parts of D'Urville Island wild animal browsing and physical damage to salt marsh has been observed, however this was not observed during the recent site visit.

For Wells Arm 1, ecological values were scored lower in the EVA because the estuary has no seagrass, a small area of salt marsh, and no protection within the catchment or estuary. In all the estuaries pressures and susceptibility to change were rated low and despite the low diversity of habitats present all the estuaries were in very good condition.



Aerial image from 1958 (left; image source: retrolens.co.nz) and present day (right) showing historic land use in the catchment

Table C8.1. Summary information for Wells Arm intertidal areas.

Summary Information	Wells Arm 1		Wells Arm 2		Wells Arm 3	
Estuary	Ha	%				
Estuary Area[1]	-	-	-	-	-	-
Intertidal Area (Ha; % Estuary)[1]	1.8	-	1.5	-	1.1	-
Dominant Estuary Substrate[1]	Gravel/cobble		Gravel/cobble		Gravel/cobble	
Mud extent (>50% mud content)	-	0.0	-	5.0	-	0.0
Macroalgae (Ha; cover >50%)[1]	-	<5	-	<5		<5
Seagrass (Ha; cover >50%)[1]	-	0.0	-	0.0	-	0.0
Salt Marsh (Ha; % intertidal)[1]	-	5	-	20	-	15
High Enrichment Conditions (HEC)[1]	-	0.0	-	0.0	-	0.0
Catchment						
Catchment Area (Ha)[2]	215.1		157.5		64.7	
Dominant Catchment Land Cover[2]	Indigenous Forest		Indigenous Forest		Indigenous Forest	
% Catchment indigenous vegetation[2]	100.0		100.0		100.0	
% Catchment exotic forest[2]	0.0		0.0		0.0	
% Producing grassland[2]	0.0		0.0		0.0	
Mean Freshwater Flow (m^3/s)[3]	0.05		0.04		0.02	
Catchment Nitrogen Load (T/y)[3]	0.45		0.37		0.15	
Catchment Phosphorus Load (T/y)[3]	0.05		0.04		0.02	
Catchment Sediment Load (KT/y)[3]	0.15		0.11		0.04	
Catchment Geology[4]	Sandstone		Sandstone		Sandstone	
Biodiversity						
Significant Marine Site	N		N		Y – 2.2	
Significant Wetland[5]	N		Y – salt marsh		N	
Birds	nd		nd		nd	
Fish[5]	Redfin bully, Koaro		Redfin bully		Redfin bully	
Shellfish	nd		nd		nd	
Pressures						
Remote boat access Privately owned land Wells Arm 2 – some fine sediment deposition around freshwater inputs. Unknown source. Potential for wild animal browsing/ physical damage based on observations in other estuaries on D'Urville Island						

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [5]MDC Smart Maps nd = no data

Table C8.2. Ecological Vulnerability Assessment, Wells Arm intertidal areas.

Category	Wells Arm 1	Wells Arm 2	Wells Arm 3
Values	0.45	0.67	0.67
Pressures	0.91	0.91	0.92
Susceptibility	0.89	0.89	0.89
Condition	0.95	0.96	0.98
Average Score	**0.80**	**0.85**	**0.86**

Wells Arm 1, rushland and native bush catchment

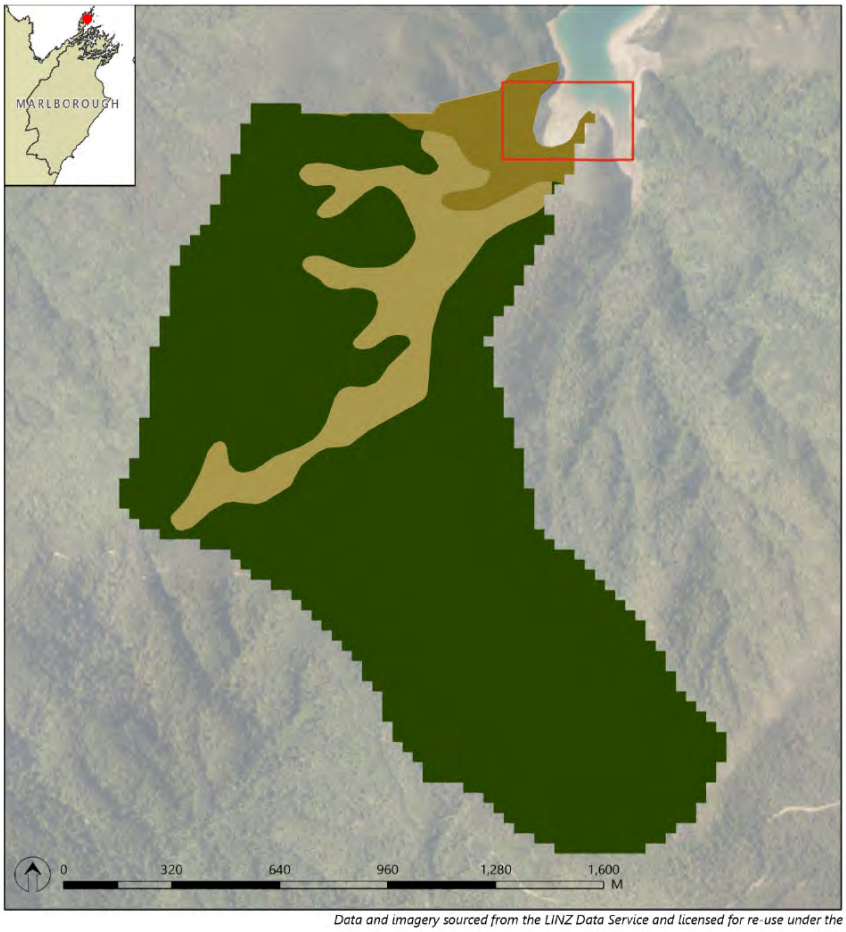
Wells Arm 1, mixed gravel and cobble substrate

Wells Arm 2, native bush catchment and cobble/gravel substrate

Wells Arm 2, rushland at the head of the estuary and steep margin

Wells Arm 3, gravel/cobble and steep native bush catchment

Wells Arm 3, rushland in the upper estuary



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	0	0
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	0	0
Manuka and/or Kanuka	10.9	5.0
Broadleaved Indigenous Hardwoods	26.8	12.5
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	0	0
Deciduous Hardwoods	0	0
Indigenous Forest	177.4	82.5
Exotic Forest	0	0
	215.1	100.0

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Fig. C8.1. Wells Arm 1 catchment land use classifications from LCDB5 (2017/2018) database.

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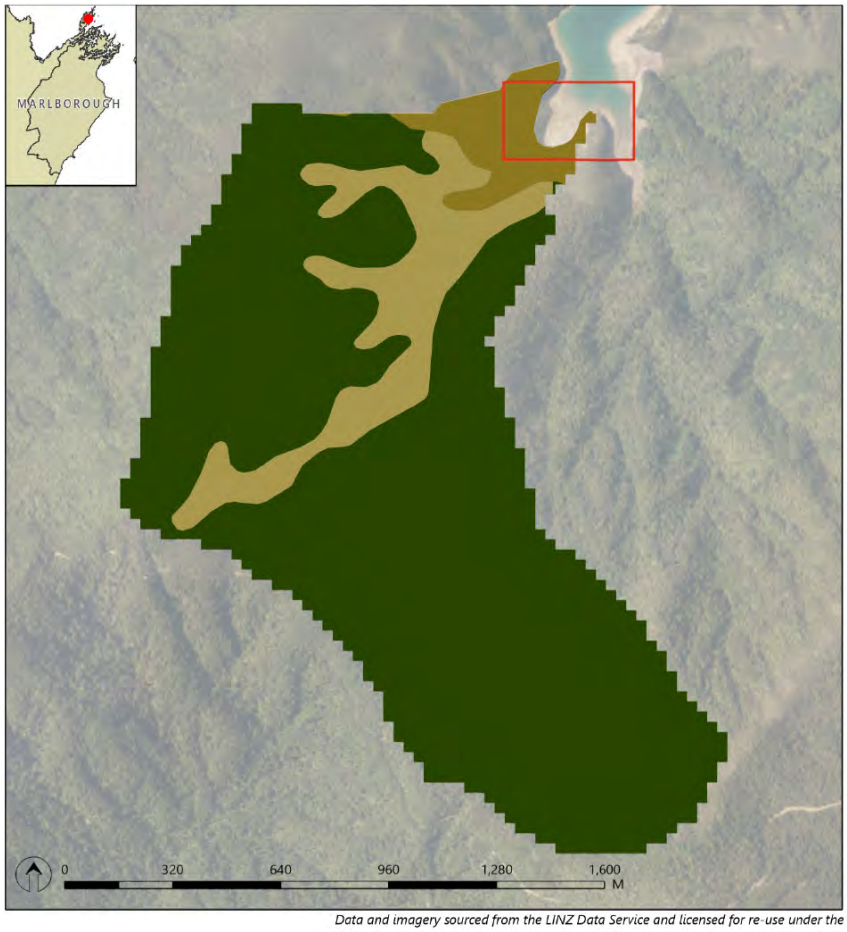
Fig. C8.2. Intertidal area in Wells Arm 1. Boundaries are based on aerial imagery and require ground-truthing.



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	0	0
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	0	0
Manuka and/or Kanuka	10.9	5.0
Broadleaved Indigenous Hardwoods	26.8	12.5
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	0	0
Deciduous Hardwoods	0	0
Indigenous Forest	177.4	82.5
Exotic Forest	0	0
	215.1	100.0

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Fig. C8.3. Wells Arm 1 catchment land use classifications from LCDB5 (2017/2018) database.

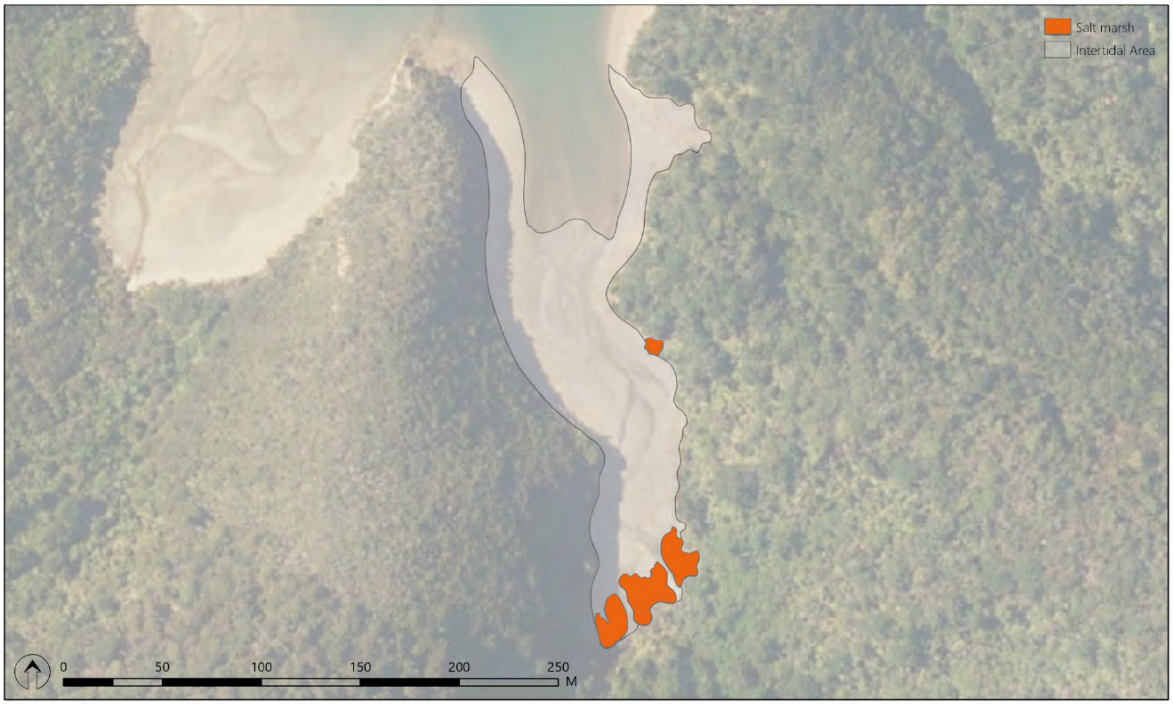

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Fig. C8.4. Intertidal area in Wells Arm 2. Boundaries are based on aerial imagery and require ground-truthing.

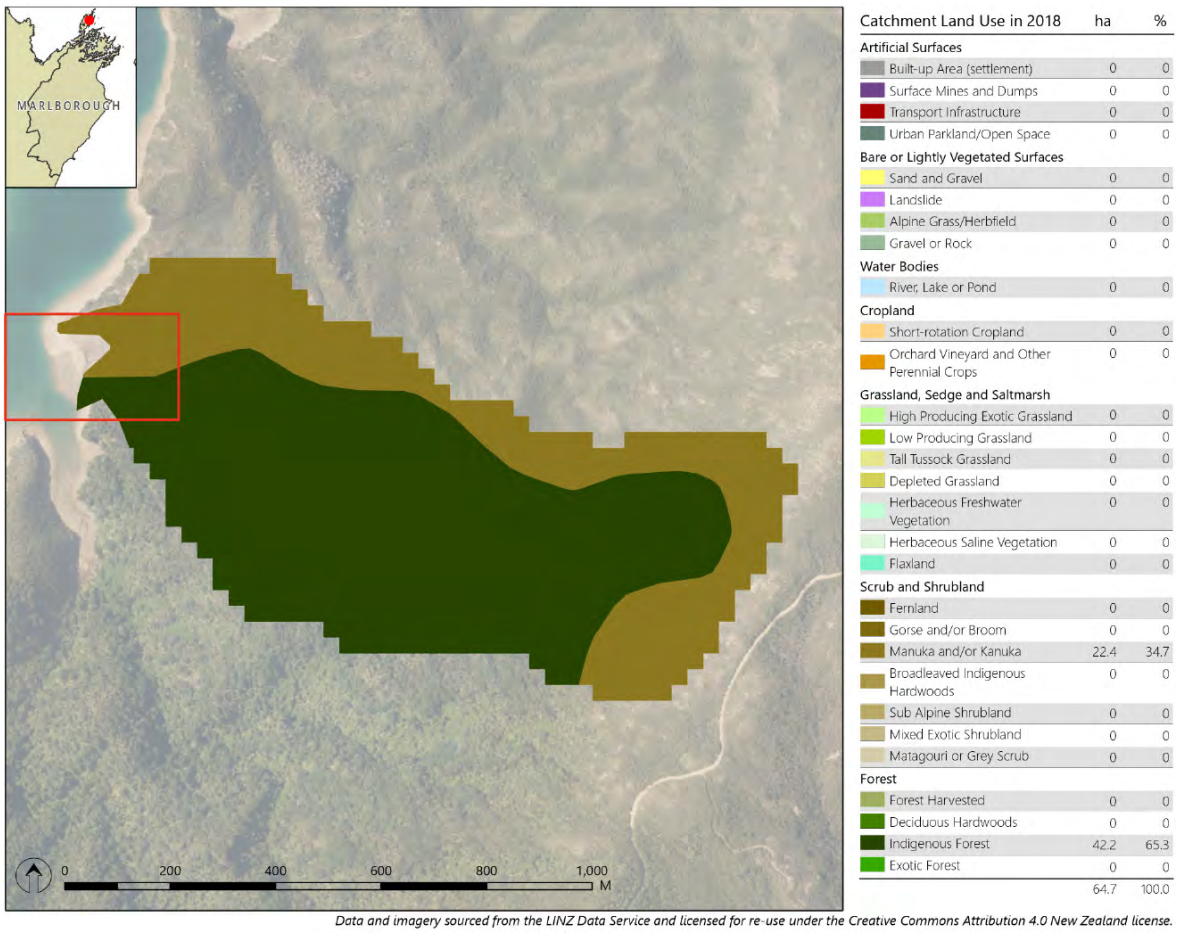

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Fig. C8.5. Wells Arm 1 catchment land use classifications from LCDB5 (2017/2018) database.

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Fig. C8.6. Intertidal area in Wells Arm 3. Boundaries are based on aerial imagery and require ground-truthing.

D. OTHER

Section D represents estuaries not covered in the sub-regions of Pelorus Sound, Queen Charlotte Sound and DÚrville Island. Estauries in this section represent estuaries in the outer Sounds and the east coast. Fig. D1 and Table D1 list the estuaries summarised in this section.

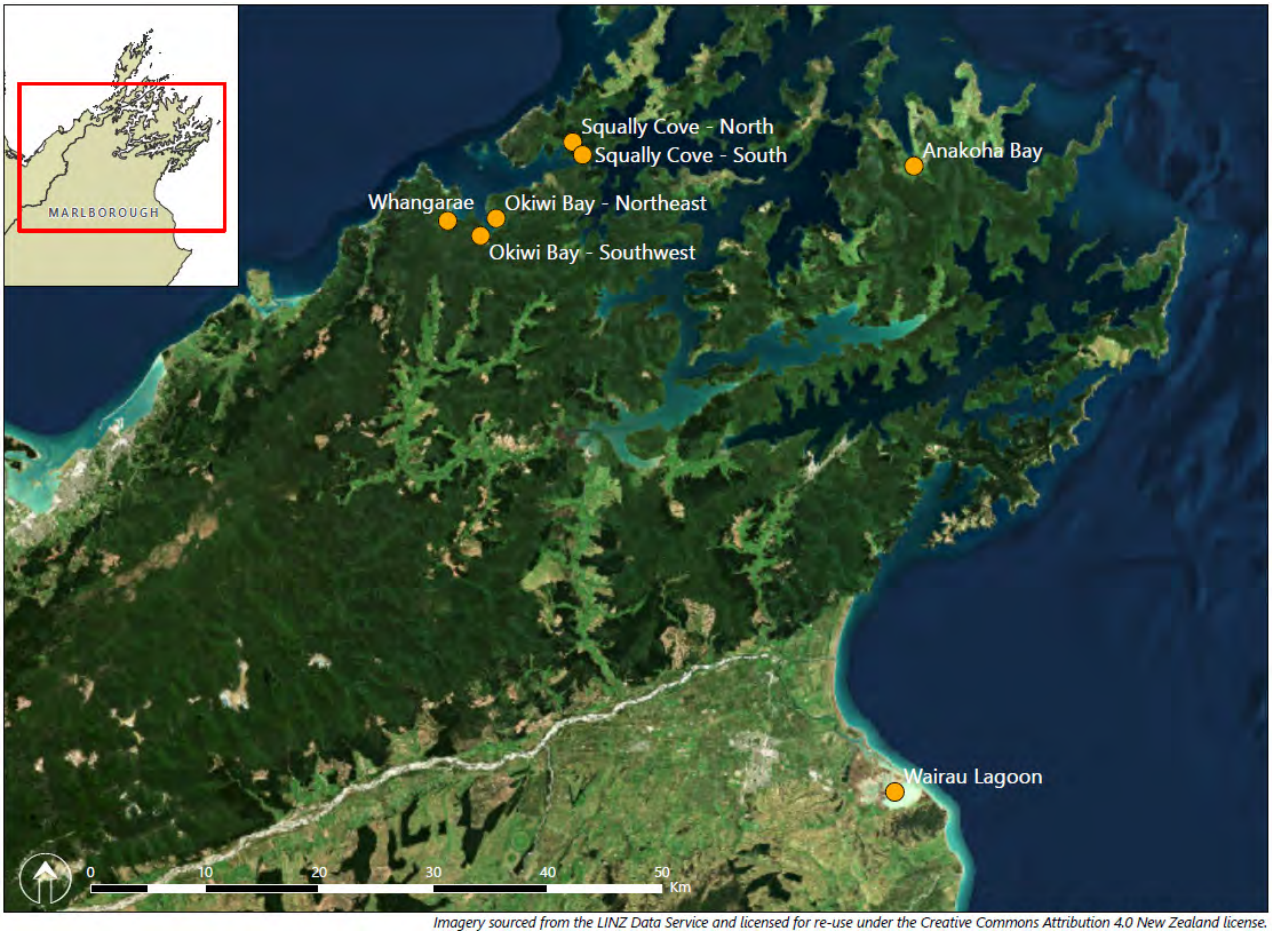

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Fig. D1. Remaining intertidal areas in Marlborough.

Table D1. List of intertidal estuaries summarised in Section D, representing the remaining estuaries in the Marlborough region summarised in the current report.

ID	Estuary Name	Sub-region	Intertidal area (ha)	ESMS	Baseline monitoring
D1	Anakoha Bay	Outer Sounds	8.5	✓ (2.25)	-
D2	Okiwi Bay North East	Croisilles Harbour	11.0	-	-
D2	Okiwi Bay South West	Croisilles Harbour	18.2	-	-
D3	Squally Cove North	Croisilles Harbour	2.7	-	-
D3	Squally Cove South	Croisilles Harbour	6.6	-	-
D4	Whangarae	Croisilles Harbour	116.2	✓ (1.1)	2016 (BS)
D5	Wairau Lagoon	East Coast	~1700*	✓ (8.2)	2015/2021 (BS)

*Total area of the lagoon (intertidal and subtidal area)

D1. Anakoha Bay (Outer Sounds)

Anakoha Bay, is located east of Forsyth (Te Paruparu) Island. At the head of Anakoha Bay is a small (8.5ha) intertidally dominated estuary. Unlike other intertidal estuary areas within the Sounds the bay is directly connected to Cook Strait. The area is classified as an ESMS because the head of the bay has ~20ha of coastal forest and it represents one of the best examples of salt marsh vegetation leading into mature coastal forest in Marlborough (Davidson et al. 2011).

The catchment is 73.3% indigenous vegetation cover, comprising mainly indigenous forest. However, the lower catchment hill sides and valley at the head of the estuary have been cleared for pasture (23.9%) and a small area of exotic forest (2.7%; Fig. D1.1.).

Sand is the dominant substrate type on the intertidal flats, with gravel on the upper estuary margin and ~10% of the flats comprising mud-dominated sediments (Table D.1). Salt marsh comprises ~8% of the intertidal area and is mainly herbfield with a sub-dominant cover of rushland. Rushland as the dominant cover has been recorded in a narrow strip on the upper estuary margin.

Seagrass has been recorded across 25% of the intertidal area on the mid-lower estuary flats, transitioning into large dense beds within the subtidal zone (see photos) Historic imagery shows the seagrass beds have been reasonably stable over time. Nuisance macroalgae has been recorded across <5% of the intertidal area and there is no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

The main pressure to Anakoha Bay is development (i.e. high producing grassland and to a lesser extent exotic forestry) of the steep hill slopes that are prone to erosion and run off. Other pressures include marine farming, a small number of moorings, a wharf and ship anchorage within the subtidal zone, all of which increase the likelihood of marine pests, pathogens and contaminants being introduced. The main access to Anakoha is via boat, with road access limited (i.e. closure due to slips), although vehicles can access the estuary margin.

Overall, the estuary is in good condition with high values seagrass beds, salt marsh and coastal beach forest on the margin. Anakoha Bay likely represents the largest area of seagrass (*Zostera muelleri*) within the Marlborough Sounds.

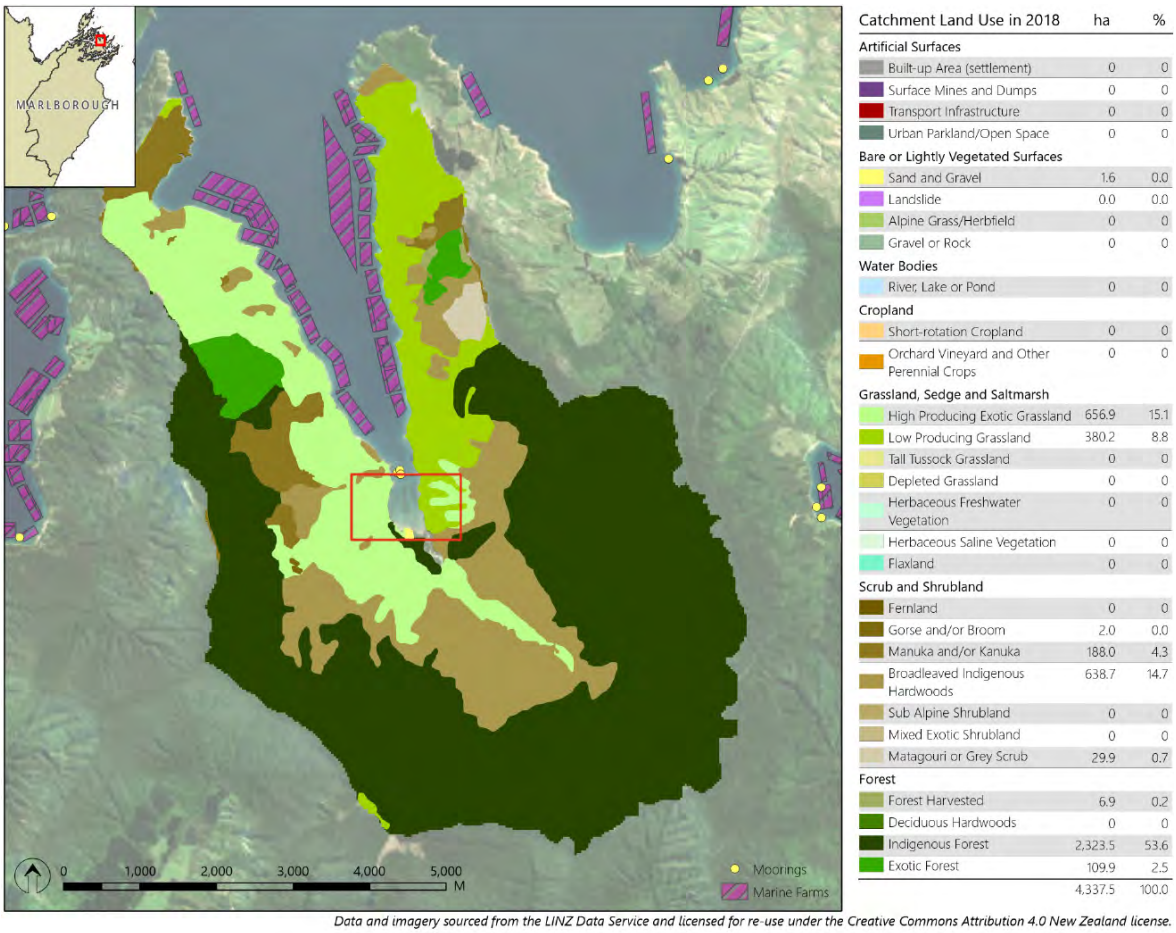
Table D1.1. Summary information for Anakoha Bay.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	
Intertidal Area (Ha; % Estuary)[1]	8.5	-
Dominant Estuary Substrate[1]	Sand	
Mud extent (>50% mud content)	-	10
Macroalgae (Ha; cover >50%)[1]	-	<5
Seagrass (Ha; cover >50%)[1]	-	25
Salt Marsh (Ha; % intertidal)[1]	-	8
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	4337.5	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	73.3	
% Catchment exotic forest[2]	2.7	
% Producing grassland[2]	23.9	
Mean Freshwater Flow (m^3/s)[3]	1.5	
Catchment Nitrogen Load (T/y)[3]	10.8	
Catchment Phosphorus Load (T/y)[3]	3.4	
Catchment Sediment Load (KT/y)[3]	12.0	
Catchment Geology[4]	Sandstone (Breccia & gravel)	
Biodiversity		
ESMS[5]	Y – 2.25	
Significant Wetland	Y – salt marsh	
Birds	nd	
Fish[6]	Redfin bully, koaro	
Shellfish	nd	
Pressures		
Developed lower catchment (pasture and exotic forest)		
Marine farms, moorings, wharf and big ship anchorage		
Human use: boat and road access		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table D1.2. Ecological Vulnerability Assessment, Anakoha Bay.

Category	Score
Values	0.79
Pressures	0.66
Susceptibility	0.73
Condition	0.85
Average Score	0.76



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	1.6	0.0
Landslide	0.0	0.0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	656.9	15.1
Low Producing Grassland	380.2	8.8
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	2.0	0.0
Manuka and/or Kanuka	188.0	4.3
Broadleaved Indigenous Hardwoods	638.7	14.7
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	29.9	0.7
Forest		
Forest Harvested	6.9	0.2
Deciduous Hardwoods	0	0
Indigenous Forest	2,323.5	53.6
Exotic Forest	109.9	2.5
	4,337.5	100.0

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Fig. D1.1. Anakoha Bay catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

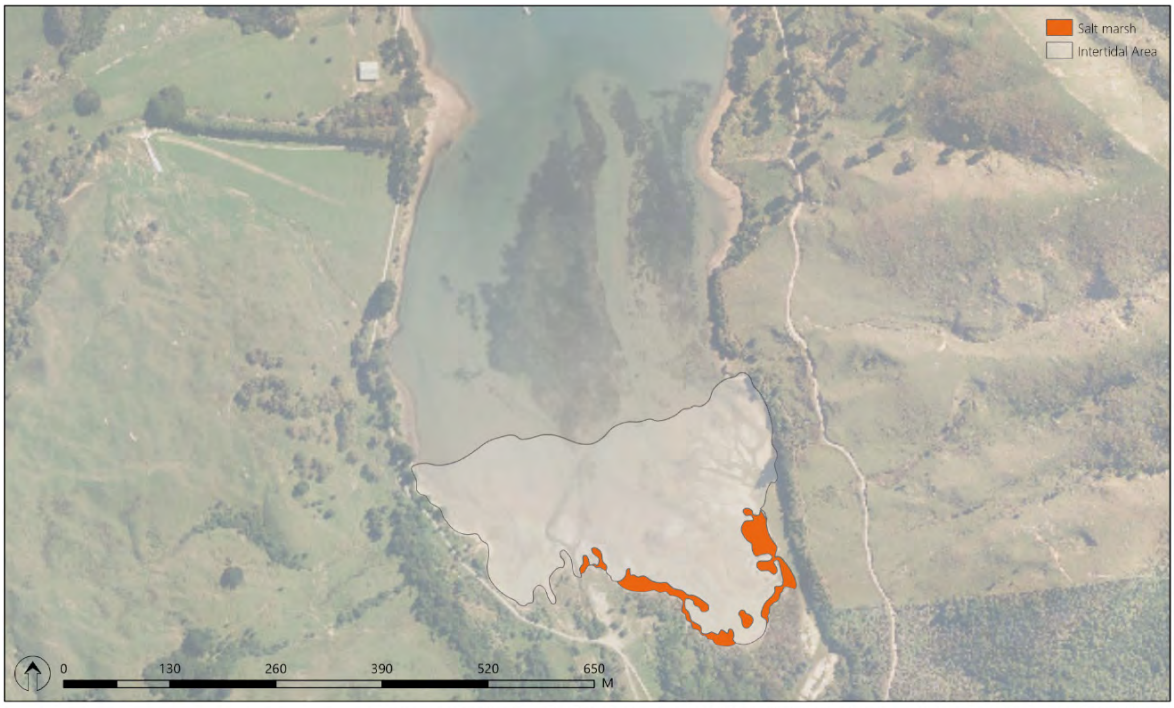

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Fig. D1.2. Anakoha Bay intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground truthing.

High producing grassland on the estuary margin, photo looking down on the intertidal flats

Herbfield in the upper estuary and seagrass on the intertidal flats growing in muddy sand

Seagrass growing in muddy sand, drift *Ulva* spp. on seagrass beds

Raised input pipe, hinders fish passage

Aerial view of Anakoha Bay, dark areas represent seagrass beds (Image ref: MDC 'Anakoha Bay 1', Courtesy of Marlborough District Council)

D2. Ōkiwi Bay (Croisilles Harbour)

Ōkiwi Bay is located 8km south-east of Cape Soucis and forms the south-eastern arm of Croisilles Harbour. For the purpose of the summaries presented in Table D2.1-2.4 the Bay is split into two parts (northeast and southwest) to account for the different land uses within the catchments. Both catchments are dominated by indigenous vegetation cover, however, the southwest intertidal areas border a small town (Fig. D2.3) and exotic forestry occurs within the catchment of the northeast intertidal areas (Fig. D2.1).

A recent field assessment has not been undertaken at Ōkiwi Bay; hence the following information is based on a desktop assessment and should be treated with caution. Based on aerial imagery and photos, the southwest intertidal flats are dominated by gravel/ cobble. It is uncertain whether mud-dominated sediments are present in the estuary, however, sediment inputs from catchment activities such as development in the margin could be potential sources. The tidal flats in the northeast are sheltered within a small embayment, and aerial imagery shows gravel/cobble is present toward the entrance with the remaining area likely comprised of muddy sands. However, a field visit would be required to confirm these findings

No significant growths of nuisance macroalgae can be seen in the imagery (Fig. D2.2 and D2.4). Low nutrient loads, and the mainly native forest catchments, mean it is unlikely that macroalgae will reach nuisance levels. It is uncertain whether seagrass is present on the northeast intertidal flats. However, seagrass is visible on the aerial imagery in the lower tidal range of the southwest flats.

Salt marsh is limited in Ōkiwi Bay for two reasons: (i) the steep margins limit the available habitat for salt marsh, particularly on the northeast flats and the southern end of the southwest flats, and (ii) the margin on the southwest flats is modified. Of the small area of salt marsh present, rushland is the dominant type.

The town of Ōkiwi Bay is on the foreshore of the southwest flats and provides easy road access and a boat ramp. Kayaking, swimming, fishing, and water skiing are common. Further, a high number of moorings are present throughout the bay, increasing the likelihood of marine contaminants, pests and pathogens being introduced to the area. Aside from recreational users the largest pressure on the southwest flats of Ōkiwi Bay is the modified terrestrial margin, with shoreline hardening along the esplanade, and vegetation clearing for property development.

Shoreline hardening along the esplanade of the southwest intertidal flats (Image ref: MDC 'OS CroisillesHarbour OkiwiBay 10', Courtesy of Marlborough District Council)

Within the catchment of the northwest flats there is a small area of exotic forest that will be due for harvest in the next 20 years, and presents a potential future sediment source. There are also two small marine farms (oysters) near the entrance of Hobbs Bay and within Matapihi Bay in Ōkiwi Bay (northeast) increasing the likelihood of marine contaminants, pests and pathogens being introduced to the area. Given the presence of oyster racks within the Bay it is likely that Pacific oysters are present on the intertidal flats.

While there are some pressures, mainly related to human use, the catchments are largely in indigenous vegetation cover and from the limited information available the intertidal areas appear to be in good condition, except for the likely presence of Pacific oysters.

Ōkiwi Bay looking over the southeast intertidal flats (Photo credit: Whistling Frog Media)

Table D2.1. Summary information for Ōkiwi Bay Northeast.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	11.0	-
Dominant Estuary Substrate	Gravel & muddy sand	
Mud extent (>50% mud content)	-	nd
Macroalgae (cover >50%)	-	0
Seagrass (cover >50%)	-	nd
Salt Marsh (% intertidal)	-	<5
High Enrichment Conditions (HEC)	-	0
Catchment		
Catchment Area (Ha)[2]	879	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	89.4	
% Catchment exotic forest[2]	8.7	
% Producing grassland[2]	0.8	
Mean Freshwater Flow (m^3/s)[3]	0.2	
Catchment Nitrogen Load (T/y)[3]	2.3	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	2.3	
Catchment Geology[4]	Mixed	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish	nd	
Shellfish	nd	
Pressures		
Recreation – boat use, diving, water skiing		
Moorings, small marine farm		
Developed catchment – exotic forest		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; nd = no data

Table D2.2. Ecological Vulnerability Assessment, Ōkiwi Bay Northeast.

Category	Score
Values	0.43
Pressures	0.84
Susceptibility	0.71
Condition	0.92
Average Score	0.72

Table D2.3. Summary information for Ōkiwi Bay Southwest.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	18.2	-
Dominant Estuary Substrate[1]	Gravel/cobble	
Mud extent (>50% mud content)	-	<5
Macroalgae (cover >50%)[1]	-	<5
Seagrass (cover >50%)[1]	-	5
Salt Marsh (% intertidal)[1]	-	<5
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	1085	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	81.2	
% Catchment exotic forest[2]	0.9	
% Producing grassland[2]	0.6	
Mean Freshwater Flow (m^3/s)[4]	0.3	
Catchment Nitrogen Load (T/y)[4]	2.9	
Catchment Phosphorus Load (T/y)[4]	0.5	
Catchment Sediment Load (KT/y)[4]	6.2	
Catchment Geology	Mixed	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish	nd	
Shellfish	nd	
Pressures		
Recreation – boat use, diving, water skiing, boat ramp		
Moorings, small marine farm		
Developed catchment - Ōkiwi Bay township		
Direct stormwater discharges		
Hardened margin		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; nd = no data

Table D2.4. Ecological Vulnerability Assessment, Ōkiwi Bay Southwest.

Category	Score
Values	0.44
Pressures	0.78
Susceptibility	0.67
Condition	0.85
Average Score	0.69

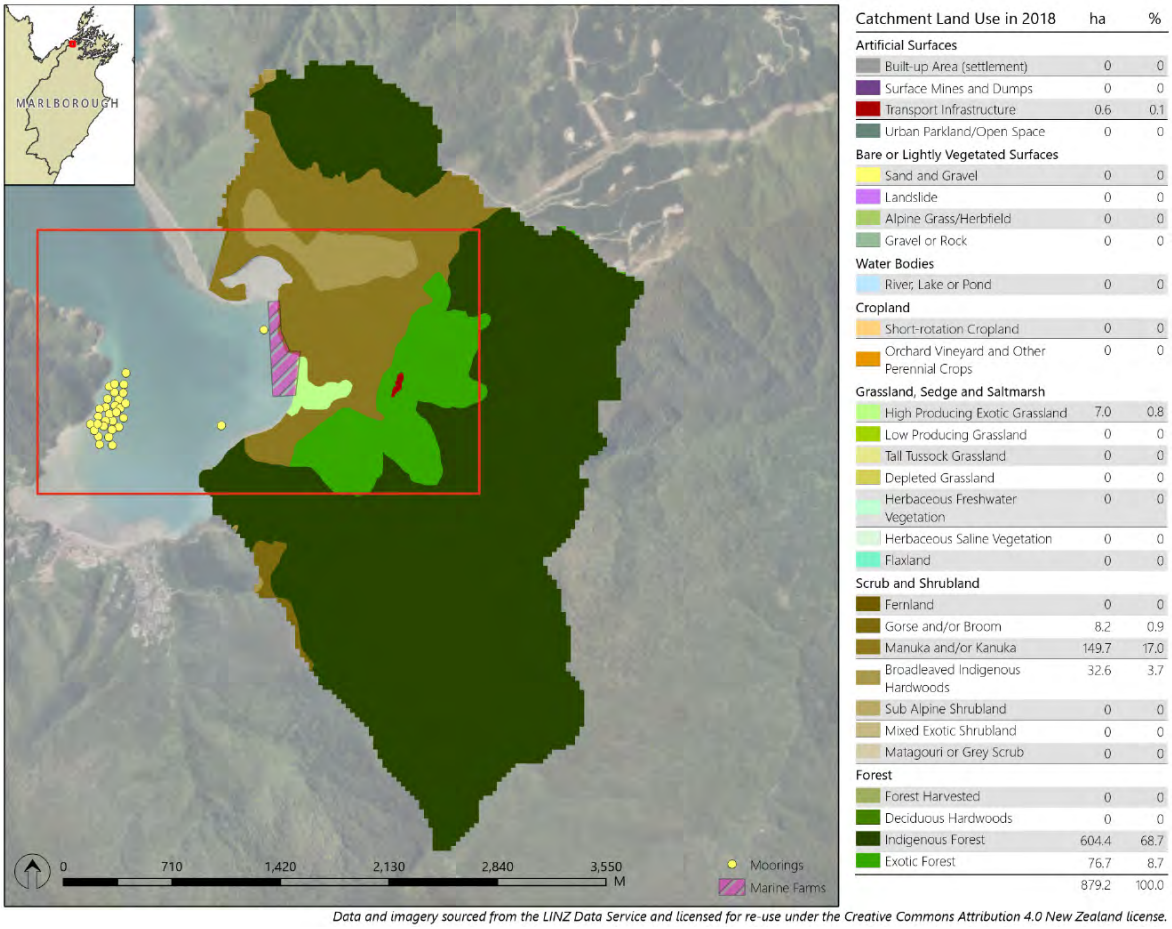

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Fig. D2.1. Ōkiwi Bay Northeast catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

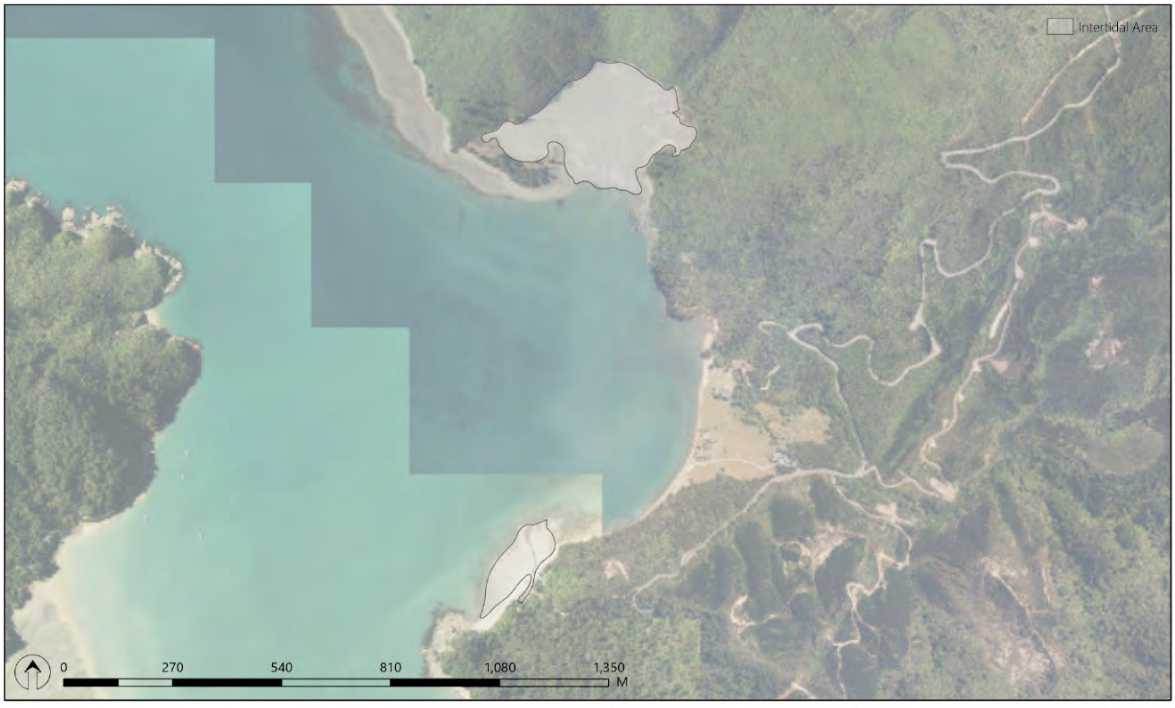

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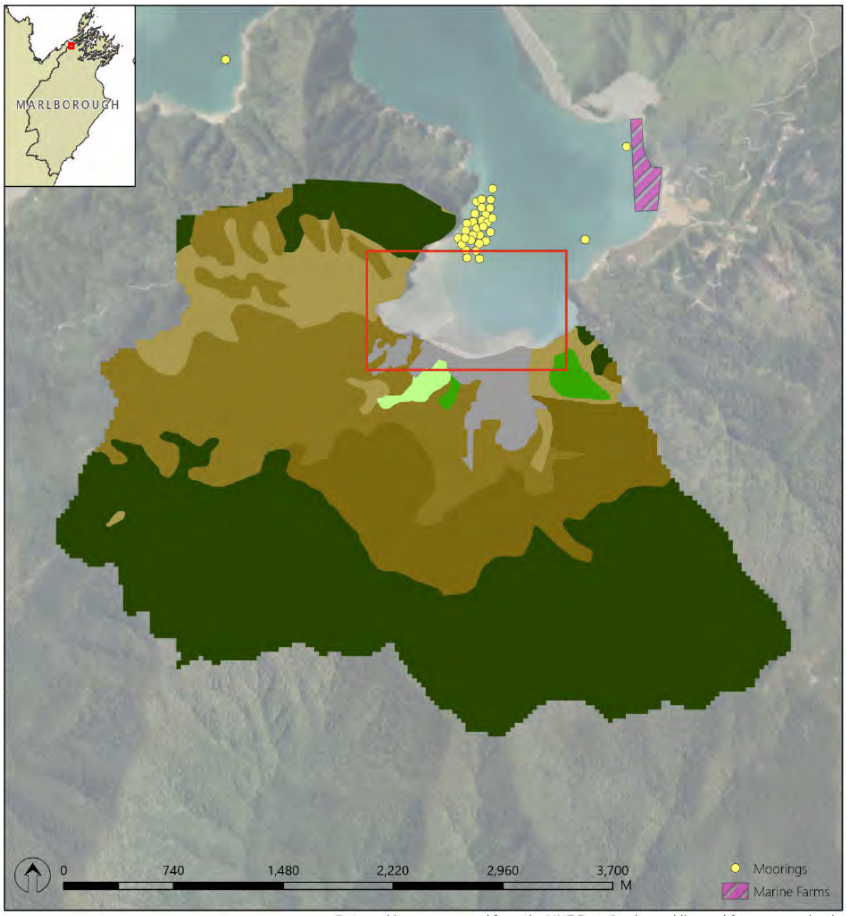
Fig. D2.2. Ōkiwi Bay Northeast intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground truthing.



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	34.7	3.2
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	6.1	0.6
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	153.7	14.2
Manuka and/or Kanuka	232.3	21.4
Broadleaved Indigenous Hardwoods	91.0	8.4
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	0	0
Deciduous Hardwoods	0	0
Indigenous Forest	557.9	51.4
Exotic Forest	9.5	0.9
	1,085.2	100.0

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Fig. D2.3 Ōkiwi Bay Southwest catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

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Fig. D2.4. Ōkiwi Bay Southwest intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground truthing.

Ōkiwi Bay Southeast intertidal flats (source: Whistling Frog Media)

Aerial view of Ōkiwi Bay southeat to the top of the image and northwest on the bottom of the image (Image ref: MDC 'OS CroisillesHarbour OkiwiBay HobbsBay AirplaneImage01 Bright', Courtesy of Marlborough District Council)

D3. Squally Cove (Croisilles Harbour)

Squally Cove is located 10km north-east of Cape Soucis and forms the northeast arm of Croisilles Harbour. For the purpose of the summaries presented in Table D3.1-3.4 the Bay is split into north and south. There are a number of small intertidal areas within Squally Cove, however the summary focuses on the larger areas at the head of Wairangi Bay (Squally Cove North) and Whakakitenga Bay (Squally Cove South). Both catchments have a large portion of indigenous vegetation cover (Table D3.1 & D3.3), however the dominant single land use type is exotic forest.

A recent field assessment has not been undertaken at Squally Cove; hence the following information is based on a desktop assessment and should be treated with caution. Based on aerial imagery and literature the intertidal flats are dominated by gravel/cobble (Davidson & Davidson 1994). It is uncertain whether mud-dominated sediments are present in the estuary, however, sediment inputs from catchment activities such as exotic forestry could be potential sources. No significant growths of nuisance macroalgae can be seen on the imagery (Fig. D3.2 and D3.4). However, a field visit would be required to confirm these findings.

It is uncertain from the information available whether seagrass is present on the intertidal flats of Wairangi Bay. However, based on aerial imagery alone there appears to be some seagrass on the eastern shore of Whakakitenga Bay. The margins of the Squally Cove intertidal areas are raised (~0.5-1m) and prone to erosion, therefore salt marsh is limited to only a few small patches. The elevated margins also limit landward migration with sea level rise.

At the head of each estuary a small area of land has been cleared for pasture and on the hill slopes there are large areas of exotic forest. Plantation forestry is a known source of sediment during and post-harvest (Swales et al. 2021). Harvesting of exotic forest has already occurred at the southern end of Squally Cove and further harvest is likely within the next 10 years. From the information available it does not appear that fine sediment deposition is currently an issue in the intertidal areas. However, a field visit would be required to confirm these findings.

Other pressures include recreational use, with both road and boat access to the area. Kayaking, swimming, fishing, and water skiing also occur within Squally Cove. There are a high number of marine farms within Squally Cove increasing the likelihood of marine contaminants, pests and pathogens being introduced to the area. Pacific oysters are likely to be present on the intertidal flats, as some of the marine farms are used for subtidal floating line culture of this species.

There is limited information available on the condition of the intertidal areas within Squally Cove, as such these areas should be prioritised for a field visit to confirm the desktop findings.

Squally Cove, Wairangi Bay to the left at the head of cove and Whakakitenga Bay to the right (Image ref: MDC 'OS CroisillesHarbour SquallyCove AirplaneImage 02', Courtesy of Marlborough District Council)

Table D2.1. Summary information for Squally Cove North.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area	-	-
Intertidal Area (Ha; % Estuary)[1]	2.7	-
Dominant Estuary Substrate[2]	Gravel/cobble	
Mud extent (>50% mud content)	-	nd
Macroalgae (cover >50%)[1]	-	<5
Seagrass (cover >50%)	-	nd
Salt Marsh (% intertidal)[1]	-	<5
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	1081	
Dominant Catchment Land Cover[2]	Exotic Forest	
% Catchment indigenous vegetation[2]	63.7	
% Catchment exotic forest[2]	32.8	
% Producing grassland[2]	2.1	
Mean Freshwater Flow (m^3/s)[3]	-	
Catchment Nitrogen Load (T/y)[3]	2.2	
Catchment Phosphorus Load (T/y)[3]	0.4	
Catchment Sediment Load (KT/y)[3]	2.7	
Catchment Geology[4]	Sandstone & gravel	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish	nd	
Shellfish	nd	
Pressures		
Recreation – boat use, diving, water skiing, kayaking, jetty		
Moorings, marine farms		
Developed catchment – exotic forest		
Small areas of grassland at the head of the estuary		
Eroding margin		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; nd = no data

Table D2.2. Ecological Vulnerability Assessment, Squally Cove North.

Category	Score
Values	0.39
Pressures	0.70
Susceptibility	0.54
Condition	0.85
Average Score	0.62

Table D2.3. Summary information for Squally Cove South.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	-	-
Intertidal Area (Ha; % Estuary)[1]	6.6	-
Dominant Estuary Substrate[2]	Gravel/cobble	
Mud extent (>50% mud content)	-	nd
Macroalgae (cover >50%)[1]	-	<5
Seagrass (cover >50%)	-	5
Salt Marsh (% intertidal)[1]	-	<5
High Enrichment Conditions (HEC)[1]	-	0
Catchment		
Catchment Area (Ha)[2]	1609	
Dominant Catchment Land Cover[2]	Exotic Forest	
% Catchment indigenous vegetation[2]	59.4	
% Catchment exotic forest[2]	40.3	
% Producing grassland[2]	0.3	
Mean Freshwater Flow (m^3/s)[4]	-	
Catchment Nitrogen Load (T/y)[4]	3.7	
Catchment Phosphorus Load (T/y)[4]	0.6	
Catchment Sediment Load (KT/y)[4]	4.2	
Catchment Geology	Melange & Sandstone	
Biodiversity		
ESMS	N	
Significant Wetland	N	
Birds	nd	
Fish	nd	
Shellfish	nd	
Pressures		
Recreation – boat use, diving, water skiing, kayaking		
Moorings, marine farms		
Developed catchment – exotic forest		
Small areas of grassland at the head of the estuary		
Eroding margin		

[1]Estimated from aerial imagery; [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; nd = no data

Table D2.4. Ecological Vulnerability Assessment, Squally Cove South.

Category	Score
Values	0.44
Pressures	0.79
Susceptibility	0.54
Condition	0.87
Average Score	0.66

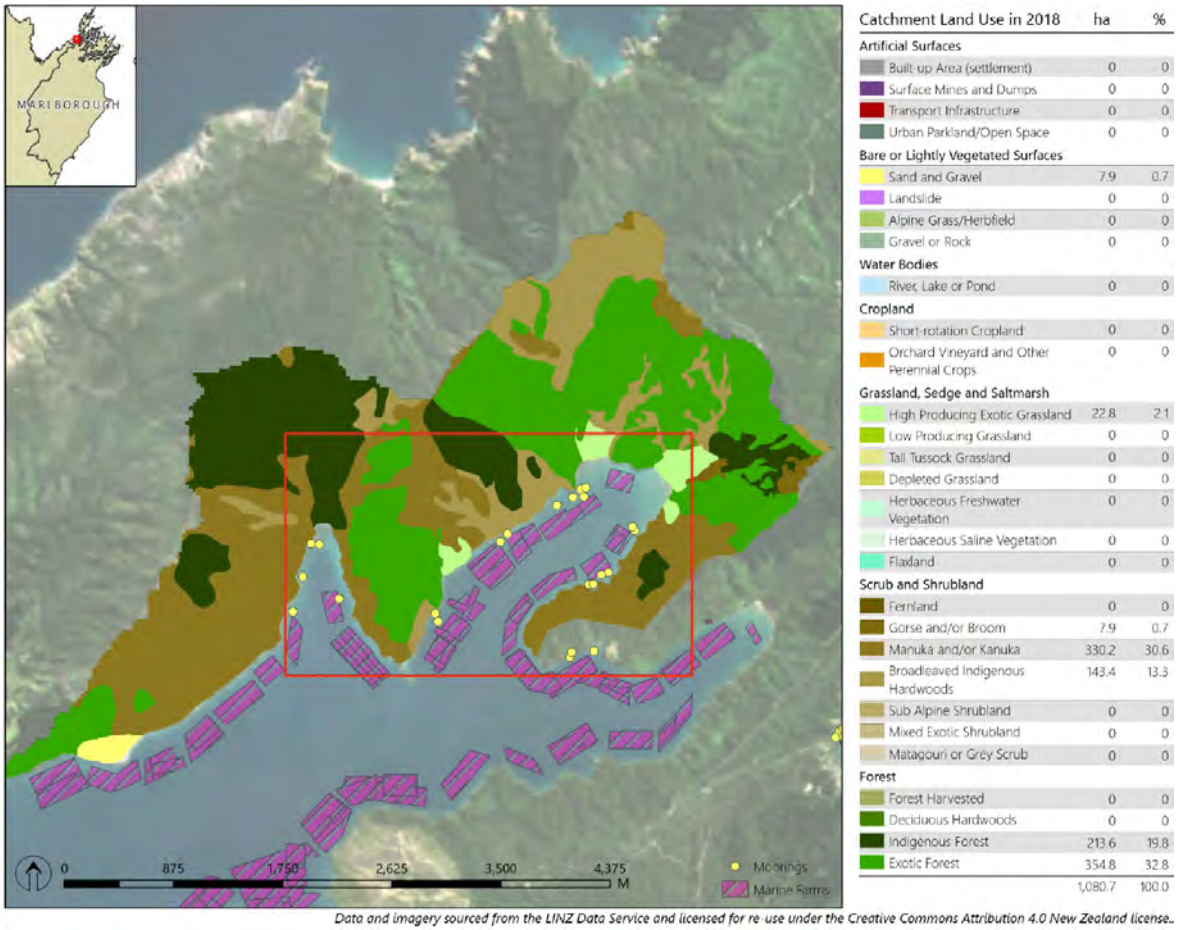

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Fig. D3.1 Squally Cove North catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

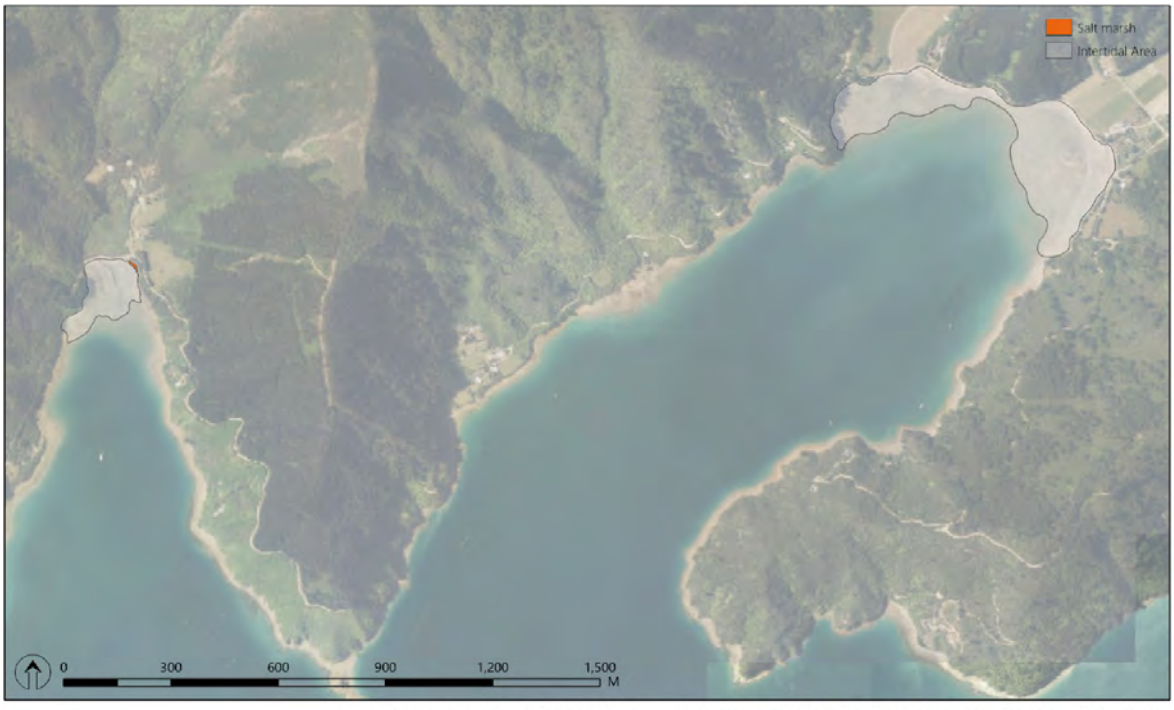

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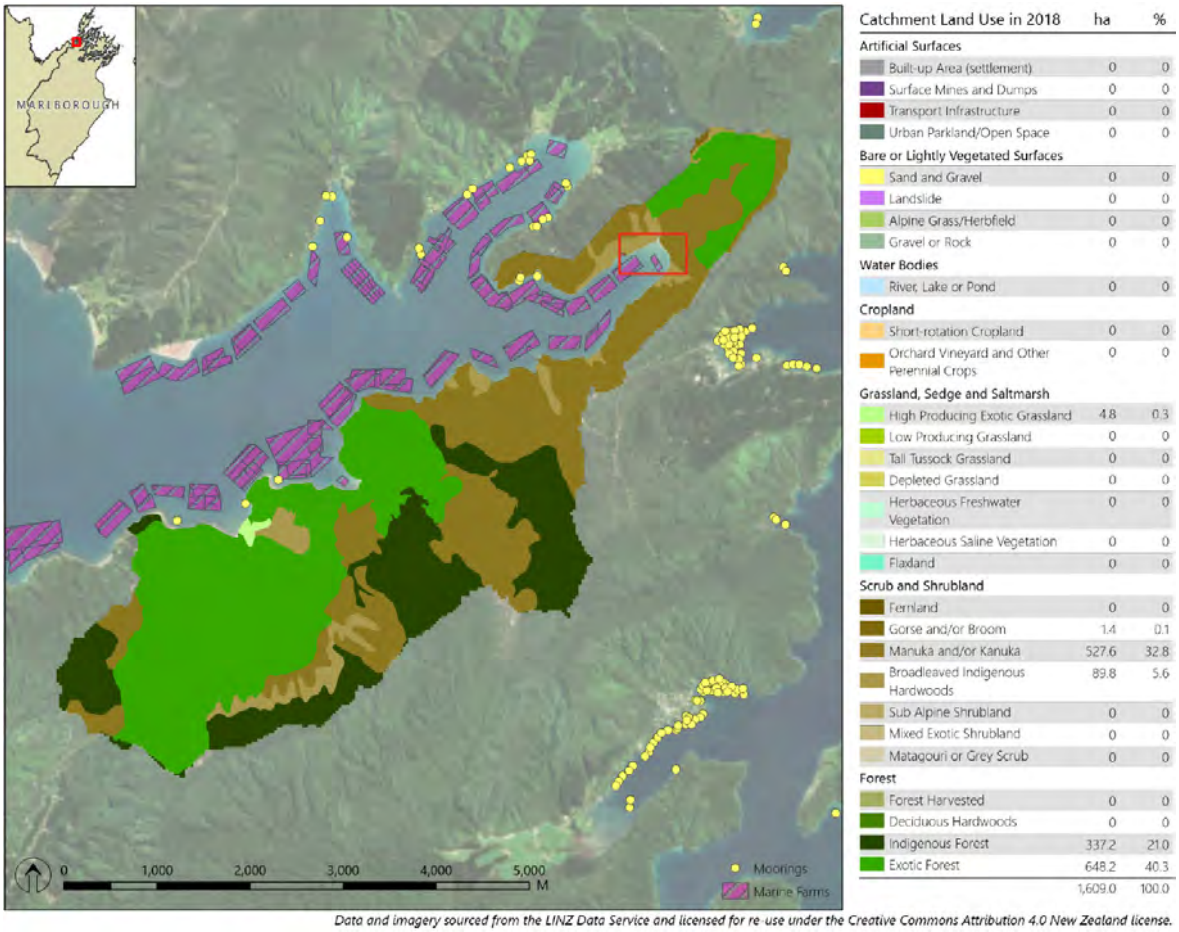
Fig. D3.2. Squally Cove North intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and ground truthing.



Catchment Land Use in 2018	ha	%
Artificial Surfaces		
Built-up Area (settlement)	0	0
Surface Mines and Dumps	0	0
Transport Infrastructure	0	0
Urban Parkland/Open Space	0	0
Bare or Lightly Vegetated Surfaces		
Sand and Gravel	0	0
Landslide	0	0
Alpine Grass/Herbfield	0	0
Gravel or Rock	0	0
Water Bodies		
River, Lake or Pond	0	0
Cropland		
Short-rotation Cropland	0	0
Orchard Vineyard and Other Perennial Crops	0	0
Grassland, Sedge and Saltmarsh		
High Producing Exotic Grassland	4.8	0.3
Low Producing Grassland	0	0
Tall Tussock Grassland	0	0
Depleted Grassland	0	0
Herbaceous Freshwater Vegetation	0	0
Herbaceous Saline Vegetation	0	0
Flaxland	0	0
Scrub and Shrubland		
Fernland	0	0
Gorse and/or Broom	1.4	0.1
Manuka and/or Kanuka	527.6	32.8
Broadleaved Indigenous Hardwoods	89.8	5.6
Sub Alpine Shrubland	0	0
Mixed Exotic Shrubland	0	0
Matagouri or Grey Scrub	0	0
Forest		
Forest Harvested	0	0
Deciduous Hardwoods	0	0
Indigenous Forest	337.2	21.0
Exotic Forest	648.2	40.3
	1,609.0	100.0

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Fig. D3.3 Squally Cove North Southwest catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings and marine farms.

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Fig. D3.4. Squally Cove North intertidal zone. Intertidal and salt marsh boundaries were estimated from aerial imagery and require ground truthing.

Oyster Bay (left) and Wairangi Bay (right), marine farms in the wider bay areas (Image ref: MDC 'OS SquallyCove WairangiBay AirplaneImage 01 Bright', Courtesy of Marlborough District Council)

Wairangi Bay at high tide, exotic forest on hill slopes and marine farms in the wider bay (source: Bayleys, Marlborough)

D4. Whangarae Estuary (Croisilles Harbour)

Whangarae Estuary is located 5km southeast of Cape Soucis and forms the south-western arm of Croisilles Harbour (Davidson et al. 2011). The estuary is a medium-sized (124ha) intertidally dominated estuary that drains to the sea through a small permanent opening (Stevens & Robertson 2016). The catchment has been logged historically and is now predominantly regenerating coastal forest (Table D4.1). Except for a small area on the eastern hill slopes the catchment is privately owned.

The main intertidal flats are dominated by firm muddy sand with occasional shell banks and small patches of gravel/cobble (Stevens & Robertson 2016). Gravel/ cobble dominate the estuary entrance where tidal flushing is high (Stevens & Robertson 2016). There is a small deposition zone in the upper estuary, toward the southeast, where mud-dominated sediments accumulate, representing 11.8% of the intertidal area (Fig. D4.2). Fine sediment deposition is likely associated with historic land clearance in the catchment.

Seagrass comprises only a small area of the estuary and is confined to areas near the main entrance where there is strong tidal flushing (Fig. D4.2). Stevens & Robertson (2016) postulated the absence of seagrass across the wider flats was driven by high tidal elevations and long air exposure periods that make it unsuitable for seagrass growth. Only a sparse cover of nuisance macroalgae has been recorded in a few localised areas, particularly around low tide channels on the main intertidal flats. However, there is no evidence of High Enrichment Conditions (i.e. excess macroalgae and mud-dominated sediments with low oxygen).

Salt marsh comprises 8.1% of the intertidal area, with the largest areas in the northern and southern embayments and only a narrow fringe around the remaining margin (Fig. D4.2). Salt marsh comprises rushland (*Juncus kraussii* and *Apodasmia similis*) and herbfield (*Sarcocornia quinqueflora and Suaeda novae-zelandiae*; Stevens & Robertson 2016). The estuary is classified as an ESMS because it has an uninterrupted vegetation sequence from salt marsh through to coastal forest (Davidson et al. 2011).

Without significant changes to the catchment, it is unlikely that the 'very good' condition of the estuary will deteriorate. Access to the estuary is remote and predominantly limited to locals. Some localised vehicle damage was recorded on the western margin where dwellings are accessed, by vehicle, directly from the estuary. Whangarae Estuary represents a good reference estuary.

Table D4.1. Summary information for Whangarae Estuary.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1]	124	-
Intertidal Area (Ha; % Estuary)[1]	115.9	93.5
Dominant Estuary Substrate[1]	Firm muddy sand	
Mud extent (>50% mud content)	12.6	11.8
Macroalgae (Ha; cover >50%)[1]	0.0	0.0
Seagrass (Ha; cover >50%)[1]	0.9	0.8
Salt Marsh (Ha; % intertidal)[1]	9.4	8.1
High Enrichment Conditions (HEC)[1]	0.0	0.0
Catchment		
Catchment Area (Ha)[2]	1696.2	
Dominant Catchment Land Cover[2]	Indigenous Forest	
% Catchment indigenous vegetation[2]	99.8	
% Catchment exotic forest[2]	0.0	
% Producing grassland[2]	0.0	
Mean Freshwater Flow (m^3/s)[3]	1.5	
Catchment Nitrogen Load (T/y)[3]	10.8	
Catchment Phosphorus Load (T/y)[3]	3.4	
Catchment Sediment Load (KT/y)[3]	12.0	
Catchment Geology[4]	Sandstone (gravel)	
Biodiversity		
ESMS[5]	Y – 1.1	
Significant Wetland	Y – salt marsh	
Birds[5]	Banded rail, fern bird	
Fish[6]	Redfin bully, koaro	
Shellfish[1]	present	
Pressures		
Limited human use Vehicle damage on the western margin		

[1]Stevens & Robertson (2016); [2]MDC catchment clip of LCDB5; [3]CLUES; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data

Table D4.2. Ecological Vulnerability Assessment, Whangarae Estuary

Category	Score
Values	0.73
Pressures	0.89
Susceptibility	0.83
Condition	0.94
Average Score	0.85

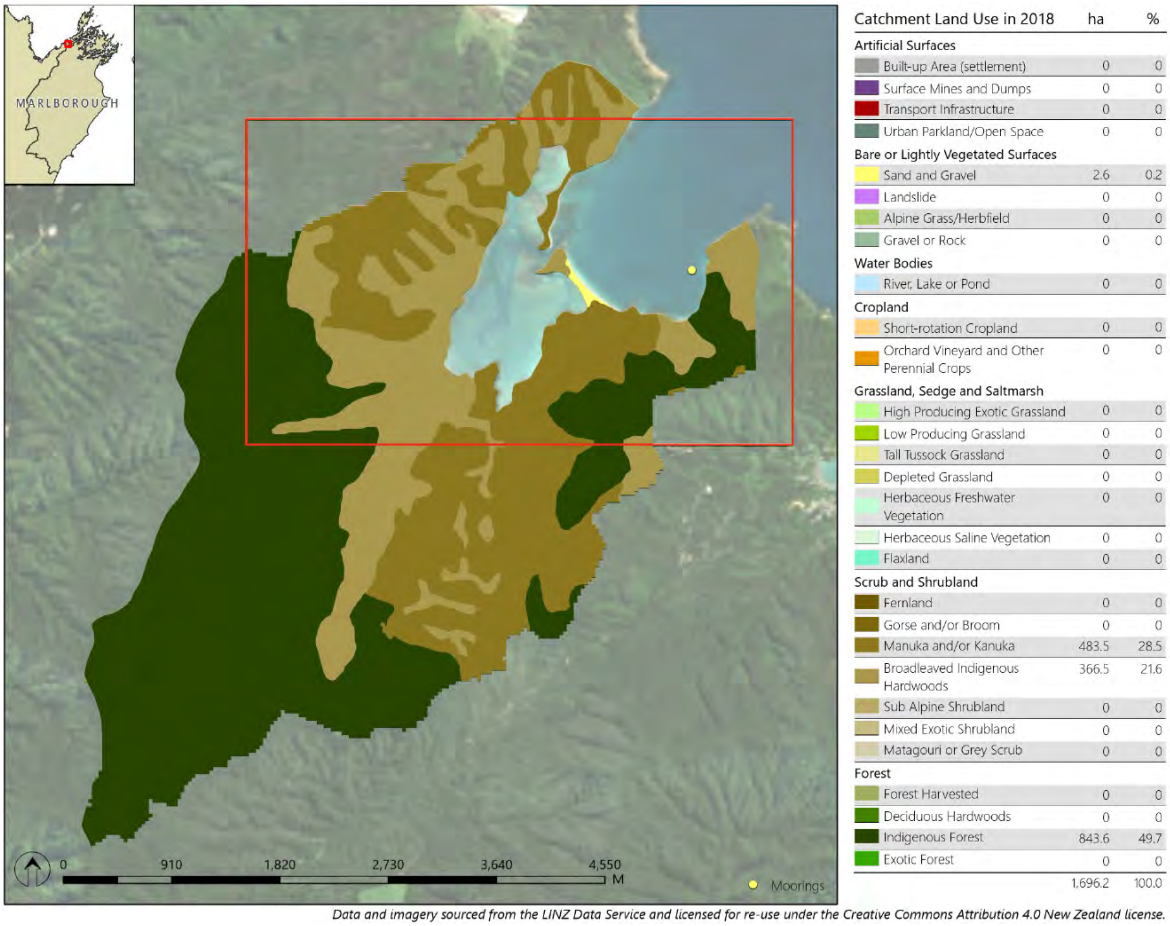

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Fig. D4.1 Whangarae Estuary catchment land use classifications from LCDB5 (2017/2018) database and other pressures including moorings.

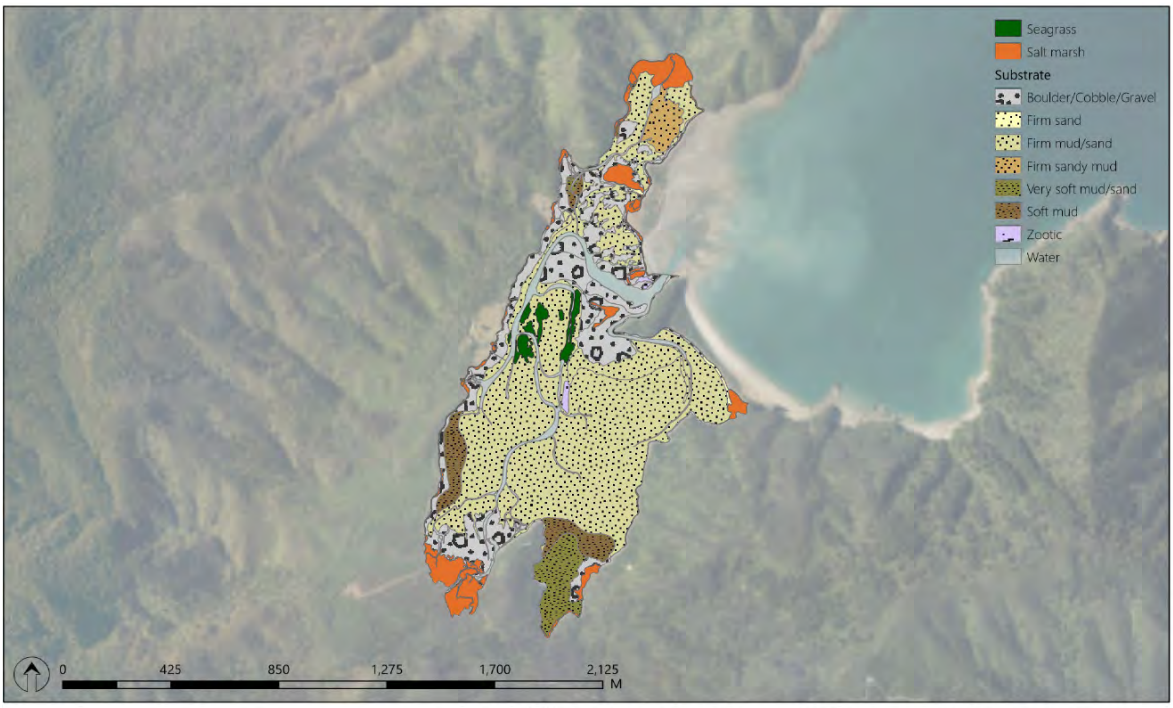

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Fig. D4.2. Whangarae Estuary intertidal area. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Stevens & Robertson 2016).

Rushland and steep native bush catchment in Whangarae Estuary

Localised impacts from vehicle access on the western margin

Seagrass growing in muddy sand

Shellfish beds in the lower estuary

Aerial view of Whangarae Estuary and native vegetation catchment (Image ref: MDC 'OS CroisillesHarbour WhangaraeBay AirplaneImage 02 Bright', Courtesy of Marlborough District Council)

D5. Wairau Lagoon (East Coast)

Wairau Lagoon (a.k.a. Waikārapi or Vernon Lagoons), east of Blenheim, is comprised of three shallow (<0.5m) connected lagoons; Big Lagoon (~800ha), Upper Lagoon (~250ha) and Chandlers Lagoon (~100ha; Hayward et al. 2010). The total area of ~1,677ha is ~25% intertidal. A boulder bank separates the lagoon from the sea (Cloudy Bay), and a narrow channel (Te Aropipi Channel) links the lagoon to Wairau River. The estuary mouth (Wairau Bar) has been artificially stabilised to create a permanent opening.

The 58,555ha surrounding catchment is dominated by high producing pasture to the south (41%) and orchard/vineyard or other perennial crops (24%) to the north. The steeper upper catchment is dominated by manuka and/or kanuka (10%), fragments of indigenous forest (3%) and low producing grassland in the foothills (4%; Fig. D5.1).

Subtidal substrate is dominated by soft/very soft muds while the intertidal areas are primarily firm muddy sands (Fig. D5.1; Berthelsen et al 2015; Roberts et al. 2021). Big Lagoon has extensive beds (16.2%) of the native macrophyte *Ruppia* spp., which is rare in a regional and national context (Table D5.1; Roberts et al. 2021). However, in 2021 the macrophyte beds were under considerable stress due to extensive blooms of filamentous algae (Roberts et al. 2021). Nuisance blooms of macroalgae were also recorded in Te Aropipi Channel and Upper Lagoon. The lagoon overall is under significant stress with >30% experiencing High Enrichment Conditions (Roberts et al. 2021).

Salt marsh bordering Wairau Lagoon is extensive and dominated by the herbfield species glasswort (*Sarcocornia quinqueflora*), and to a lesser extent rushland (Roberts et al. 2021). Historically, large tracts of salt marsh have been cleared or drained for pasture or localised infrastructure development (e.g. the Blenheim Wastewater Treatment Plant). Remaining salt marsh, while extensive, is compromised in many areas by reduced connectivity with the main estuary due to the presence of flood banks, and flapgates on drains that prevent seawater inflow (Roberts et al. 2021). Wairau Lagoon is classified as an ESMS and the salt marsh is a regionally significant wetland.

While nutrient and sediment loads are not defined, monitoring data emphasise that inputs from the heavily modified catchment are currently exceeding the lagoons assimilative capacity. Important habitats (e.g. *Ruppia* spp.) are showing symptoms of severe eutrophication (i.e. excess filamentous algae and nuisance macroalgae).

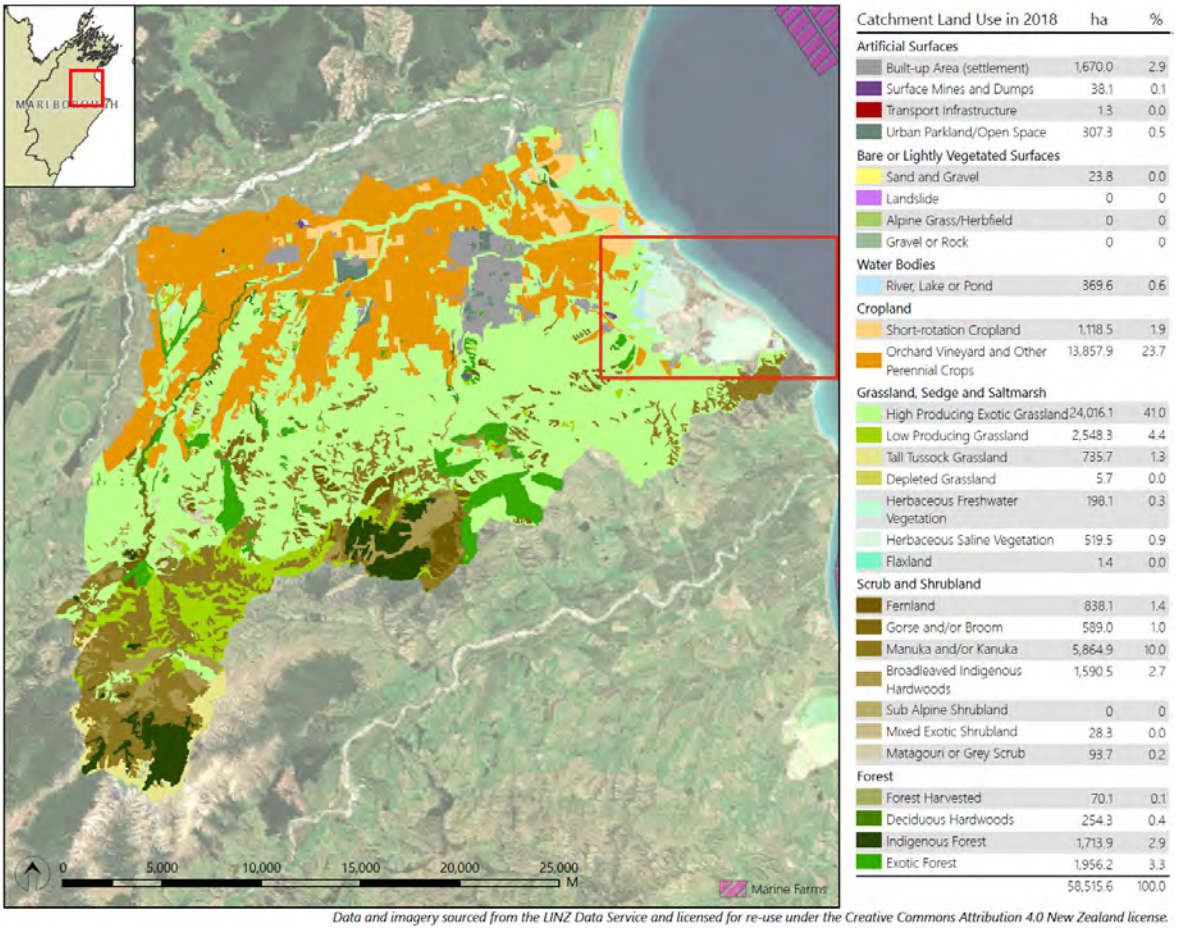
Table D5.1. Summary information for Wairau Lagoon. *Note mud extent, macroalgae and seagrass (i.e. macrophyte) represent subtidal metrics.

Summary Information		
Estuary	**Ha**	**%**
Estuary Area[1,2]	~1677	75.1
Intertidal Area (Ha; % Estuary)[2]	~418	24.9
Dominant Estuary Substrate[1]	Soft/very soft mud	
Mud extent (>50% mud content)*	1206.4	98.5
Macroalgae (Ha; cover >50%)[1]	80	6.5
Seagrass – *Ruppia* spp. (Ha; cover >50%)[1]	199	16.2
Salt Marsh (Ha; % intertidal)[2]	59	-
High Enrichment Conditions (HEC)[1]	480	30
Catchment		
Catchment Area (Ha)[3]	58,555	
Dominant Catchment Land Cover[3]	High producing grassland	
% Catchment indigenous vegetation[3]	20.1	
% Catchment exotic forest[3]	3.4	
% Producing grassland[3]	45.4	
Mean Freshwater Flow (m^3/s)[4]	nd	
Catchment Nitrogen Load (T/y)[4]	nd	
Catchment Phosphorus Load (T/y)[4]	nd	
Catchment Sediment Load (KT/y)[4]	nd	
Catchment Geology[5]	Mixed	
Biodiversity		
ESMS[6]	Y – 8.2	
Significant Wetland[7]	Y – salt marsh	
Birds[1]	>90 bird species	
Fish[1]	Flounder, eels	
Shellfish	Cockles, pipi	
Pressures		
Heavily modified catchment		
Excess sediments and nutrients		
Reclamation and drainage of salt marsh		
Direct discharge from the wastewater treatment plant		
Public access to the estuary – boat use		
Limited flushing in the Upper Lagoon		

[1]Roberts et al. (2021); Berthlesen et al. (2015); [2]MDC catchment clip of LCDB5; [3]No data, unknown contribution from the Wairau River and Operoa Rivers; [4]QMap; [6]Davidson et al (2011); [5]MDC Smart Map; nd = no data; *subtidal

Table D5.2. Ecological Vulnerability Assessment, Wairau Lagoon.

Category	Score
Values	0.83
Pressures	0.59
Susceptibility	0.33
Condition	0.63
Average Score	0.60



Data and imagery sourced from the LINZ Data Service and licensed for re-use under the Creative Commons Attribution 4.0 New Zealand license.

Fig. D5.1 Wairau Lagoon catchment land use classifications from LCDB5 (2017/2018) database.

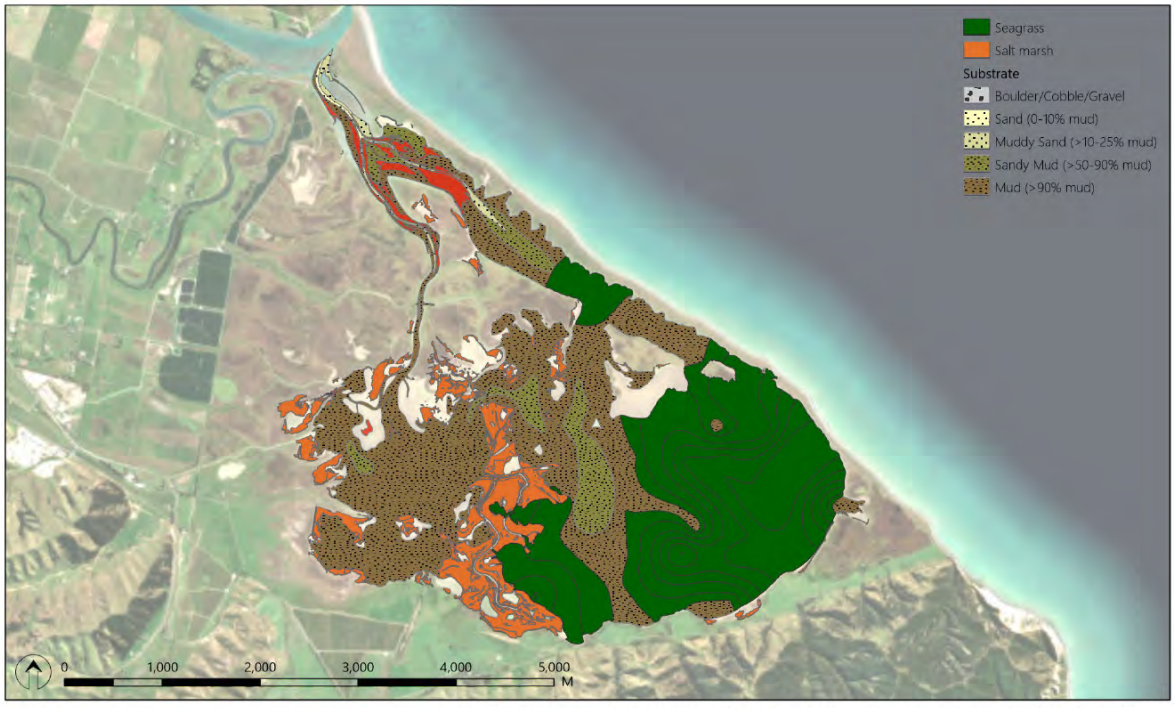


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Fig. D5.2. Wairau Lagoon subtidal area. Data for the estuary habitat map and substrate sourced from ground-truthed broad scale mapping survey (Roberts et al. 2021).

Ruppia spp. with filamentous algae growing on the surface

Resuspension of fine sediments in unvegetated areas

Salt marsh in Wairau Lagoon consisting of rushland and herbfield (*Sarcocornia quinqueflora*; glasswort)

Big Lagoon (top) and firm muddy sands on intertidal flats (bottom)

APPENDIX 2. EVA DATA SOURCES

Category	Data Sources
Ecological Values	
Area of estuary (ha) ** Area of intertidal	Monitored estuaries - Broadscale mapping report Unmonitored estuaries - intertidal area digitised in ArcMap 10.8
Habitat Intactness	Monitored estuaries - Monitoring reports, photos, aerial imagery Unmonitored estuaries - rapid estuary assessment
Seagrass (extent; % of intertidal area)	Broadscale mapping report, where available, or rapid estuary assessments
Salt marsh (extent; % of intertidal area)	Broadscale mapping report, where available, or rapid estuary assessments
Mangroves (extent; % of intertidal area)	Not applicable
Intertidal shellfish beds (indigenous)	No data
Biogenic reef	No data
Species of conservation significance	Davidson et al. (2011), eBird, supporting habitats - see salt marsh, MDC GIS layers: National Environmental Standards for Plantation Forestry Fish Spawning Indicator, New Zealand Freshwater Fish Database
Protected status (within or adjacent to estuary i.e. terrestrial or marine)	Department of Conservation Maps (https://www.doc.govt.nz/map/index.html) MDC GIS layers: significant marine sites, regionally significant wetlands
Pressures	
Catchment Land Use – % Indigenous Vegetation Cover	LCDB5 (Catchment Clip supplied by MDC)
Catchment Land Use – % Exotic Forest	LCDB5 (Catchment Clip supplied by MDC)
Catchment Land Use – % High producing grassland	LCDB5 (Catchment Clip supplied by MDC)
Catchment Land Use – % Urban & industrial development	LCDB5 (Catchment Clip supplied by MDC)
Catchment Land Use – % Horticulture	LCDB5 (Catchment Clip supplied by MDC)
Nutrient Load Thresholds (macroalgae)	CLUES Estuaries (Clues_TasREc2_10.3 software version CLUES 10.8) Run date 04/05/2022
Sedimentation rate (CSR:NSR ratio*)	No data
Grazing animals in estuary and margin	Aerial imagery and site visits
Altered Hydrology	Aerial imagery and site visits
Fish passage	Aerial imagery and site visits
Chemical contaminants - marine	Cruiseguide.co.nz for anchorage information MDC GIS layers: marine Farms, moorings, aerial imagery
Chemical contaminants - terrestrial	Monitoring reports and/or rapid estuary assessments MDC GIS layers: Resource consents, aerial imagery
Marine oil spill risk	Cruiseguide.co.nz for anchorage information. MDC GIS layers: marine farms, moorings, aerial imagery (e.g. jetties, ports, marina)
Introduced marine species	Cruiseguide.co.nz for anchorage information. MDC GIS layers: marine farms, moorings, aerial imagery (e.g. jetties, ports, marina)
Phytoplankton blooms	Media releases & news reports of previous blooms in the region
Pathogens	Monitoring reports and/or rapid estuary assessments, MDC GIS layers: resource consents, marine farms, moorings, aerial imagery (e.g. jetties, ports, marina)
Direct Human use - Non-commercial use	Cruiseguide.co.nz for recreational use, aerial imagery to review accessibility - e.g. ease of vehicle and boat access, MDC Coastal Scientists local knowledge
Direct Human use - Commercial use	MDC GIS layers: resource consents, marine Farms
Direct human access - Level of protection to prevent disturbance of wildlife.	Local knowledge
Salt Marsh pressures (#recorded pressures)	Broadscale mapping report, where available, or rapid estuary assessments
Seagrass pressures (#recorded pressures)	Broadscale mapping report, where available, or rapid estuary assessments

Susceptibility	
Estimated Physical Susceptibility	Based on principles in ETI Tool 1, expert assessment
Mixing status	Based on principles in ETI Tool 1, expert assessment
Likelihood catchment pressures within <10 years	MDC GIS layers: resource consents, forestry blocks, LCDB5
Likelihood contaminants (chemical & biological) within < 10 years	MDC Coastal Scientist local knowledge MDC GIS layers: resource consents
Likelihood human use pressures increase within < 10 years	MDC Coastal Scientist local knowledge MDC GIS layers: resource consents
Likelihood catchment pressures within >10 years	MDC GIS layers: resource consents, forestry blocks, LCDB5
Likelihood contaminants (chemical & biological) within >10 years	MDC Coastal Scientist local knowledge MDC GIS layers: resource consents
Likelihood human use pressures increase within >10 years	MDC Coastal Scientist local knowledge MDC GIS layers: resource consents
Adaptive capacity of estuary to sea level rise	Site visits and photos MDC GIS layers: aerial imagery, contours
Coastal vulnerability Index	No data
Climate adaptation and resilience	Under development
Condition	
Estimated historical salt marsh extent (% of historical remaining)	Broadscale mapping report, where available, or rapid estuary assessments Retrolens.co.nz to assess historic imagery
Proportion (%) of current salt marsh degraded	Broadscale mapping report, where available, or rapid estuary assessments
% Seagrass decline from estimated baseline	No data
Proportion (%) of current seagrass degraded	Broadscale mapping report, where available, or rapid estuary assessments
Diversity of substrate types	Broadscale mapping report, where available, or rapid estuary assessments
Predicted sedimentation rate (mm/y)	No data
Mud extent (% intertidal)	Broadscale mapping report, where available, or rapid estuary assessments
Opportunistic macroalgae extent (% intertidal)	Broadscale mapping report, where available, or rapid estuary assessments
Phytoplankton (µg/L)	No data
High Enrichment Conditions (Ha or % intertidal area)	Broadscale mapping report, where available, or rapid estuary assessments
Existing presence of invasive species in the estuary	Broadscale mapping report, where available, or rapid estuary assessments
Reclamation and/or drainage (Percentage of area affected)	Broadscale mapping report, where available, or rapid estuary assessments Retrolens.co.nz to assess historic imagery
Shoreline length modified/ disturbed	Estimated from aerial imagery and site photos
Hardening of estuary margin (e.g. artificial rock wall, earth bund)	Broadscale mapping report, where available, or rapid estuary assessments MDC GIS layer - aerial imagery
200m terrestrial margin (Densely vegetated)	Broadscale mapping report, where available, or rapid estuary assessments

APPENDIX 3. BROAD SCALE HABITAT CLASSIFICATION DEFINITIONS

Estuary vegetation was classified using an interpretation of the Atkinson (1985) system described in the NEMP (Robertson et al. 2002) with minor modifications as listed. Revised substrate classes were developed by Salt Ecology to more accurately classify fine unconsolidated substrate. Terrestrial margin vegetation was classified using the field codes included in the Landcare Research Land Cover Database (LCDB5) - see following page.

VEGETATION (mapped separately to the substrates they overlie and ordered where commonly found from the upper to lower tidal range).

Estuarine shrubland: Cover of estuarine shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh (density at breast height).

Tussockland: Tussock cover is 20-100% and exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples occur in all species of *Cortaderia, Gahnia*, and *Phormium*, and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla*, and *Celmisia*.

Sedgeland: Sedge cover (excluding tussock-sedges and reed-forming sedges) is 20-100% and exceeds that of any other growth form or bare ground. "Sedges have edges". If the stem is clearly triangular, it's a sedge. If the stem is flat or rounded, it's probably a grass or a reed. Sedges include many species of *Carex, Uncinia*, and *Scirpus*.

Grassland[1]: Grass cover (excluding tussock-grasses) is 20-100% and exceeds that of any other growth form or bare ground.

Introduced weeds[1]: Introduced weed cover is 20-100% and exceeds that of any other growth form or bare ground.

Reedland: Reed cover is 20-100% and exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata*, and *Baumea articulata*.

Lichenfield: Lichen cover is 20-100% and exceeds that of any other growth form or bare ground.

Cushionfield: Cushion plant cover is 20-100% and exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Rushland: Rush cover (excluding tussock-rushes) is 20-100% and exceeds that of any other growth form or bare ground. A tall, grass-like, often hollow-stemmed plant. Includes some species of *Juncus* and all species of *Apodasmia (Leptocarpus)*.

Herbfield: Herb cover is 20-100% and exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Seagrass meadows: Seagrasses are the sole marine representatives of Angiospermae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrate. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries and are mapped.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain chlorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope. Macroalgal density, biomass and entrainment are classified and mapped.

Note NEMP classes of Forest and Scrub are considered terrestrial and have been included in the terrestrial Land Cover Data Base (LCDB) classifications.

[1]Additions to the NEMP classification.

SUBSTRATE (physical and zoogenic habitat)

Sediment texture is subjectively classified as: firm if you sink 0-2 cm, soft if you sink 2-5cm, very soft if you sink >5cm, or mobile - characterised by a rippled surface layer.

Artificial substrate: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates. Commonly sub-grouped into artificial: substrates (seawalls, bunds etc), boulder, cobble, gravel, or sand.

Rock field: Land in which the area of basement rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Boulder field: Land in which the area of unconsolidated boulders (>200mm diam.) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Cobble field: Land in which the area of unconsolidated cobbles (>20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Sand: Granular beach sand with a low mud content 0-10%. No conspicuous fines evident when sediment is disturbed.

Sand/Shell: Granular beach sand and shell with a low mud content 0-10%. No conspicuous fines evident.

Muddy sand (Moderate mud content): Sand/mud mixture dominated by sand, but has an elevated mud fraction (i.e. >10-25%). Granular when rubbed between the fingers, but with a smoother consistency than sand with a low mud fraction. Generally firm to walk on.

Muddy sand (HIgh mud content): Sand/mud mixture dominated by sand, but has an elevated mud fraction (i.e. >25-50%). Granular when rubbed between the fingers, but with a much smoother consistency than muddy sand with a moderate mud fraction. Often soft to walk on.

Sandy mud (Very high mud content): Mud/sand mixture dominated by mud (i.e. >50%-90% mud). Sediment rubbed between the fingers is primarily smooth/silken but retains a granular component. Sediments generally very soft and only firm if dried out or another component, e.g. gravel, prevents sinking.

Mud (>90% mud content): Mud dominated substrate (i.e. >90% mud). Smooth/silken when rubbed between the fingers. Sediments generally only firm if dried out or another component, e.g. gravel, prevents sinking.

Cockle bed /Mussel reef/ Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells

Table of modified NEMP substrate classes and list of Landcare Land Cover Database (LCDB5) classes.

Consolidated substrate			Code
Bedrock		Rock field "solid bedrock"	RF
Coarse Unconsolidated Substrate (>2mm)			
Boulder/ Cobble/ Gravel	>256mm to 4.1m	Boulder field "bigger than your head"	BF
	64 to <256mm	Cobble field "hand to head sized"	CF
	2 to <64mm	Gravel field "smaller than palm of hand"	GF
	2 to <64mm	Shell "smaller than palm of hand"	Shel
Fine Unconsolidated Substrate (<2mm)			
Sand (S)	Low mud (0-10%)	Mobile sand	mS
		Firm shell/sand	fSS
		Firm sand	fS
		Soft sand	sS
Muddy Sand (MS)	Moderate mud (>10-25%)	Mobile muddy sand	mMS10
		Firm muddy shell/sand	fSS10
		Firm muddy sand	fMS10
		Soft muddy sand	sMS10
	High mud (>25-50%)	Mobile muddy sand	mMS25
		Firm muddy shell/sand	fMSS25
		Firm muddy sand	fMS25
		Soft muddy sand	sMS25
Sandy Mud (SM)	Very high mud (>50-90%)	Firm sandy mud	fSM
		Soft sandy mud	sSM
		Very soft sandy mud	vsSM
Mud (M)	Very high mud (>90%)	Firm mud	fM90
		Soft mud	sM90
		Very soft mud	vsM90
Zootic (living)			
		Cocklebed	CKLE
		Mussel reef	MUSS
		Oyster reef	OYST
		Tubeworm reef	TUBE
Artificial Substrate			
		Substrate (brg, bund, ramp, walk, wall, whf)	aS
		Boulder field	aS BF
		Cobble field	aS CF
		Gravel field	aS GF
		Sand field	aS SF

Artificial Surfaces

1 Built-up Area (settlement)
2 Urban Parkland/Open Space
5 Transport Infrastructure
6 Surface Mines and Dumps

Bare or Lightly Vegetated Surfaces

10 Sand and Gravel
12 Landslide
16 Gravel and Rock

Water Bodies

20 Lake or Pond
21 River

Cropland

30 Short-rotation Cropland
33 Orchard Vineyard & Other Perennial Crops

Grassland, Sedge and Saltmarsh

40 High Producing Exotic Grassland
41 Low Producing Grassland
45 Herbaceous Freshwater Vegetation
46 Herbaceous Saline Vegetation

Scrub and Shrubland

47 Flaxland
50 Fernland
51 Gorse and/or Broom
52 Manuka and/or Kanuka
54 Broadleaved Indigenous Hardwoods
56 Mixed Exotic Shrubland
58 Matagouri or Grey Scrub

Forest

64 Forest - Harvested
68 Deciduous Hardwoods
69 Indigenous Forest
71 Exotic Forest

APPENDIX 4. EVA WEIGHTINGS

Category	Weighting				Average	FINAL weighting
	Roberts KL	Forrest BM	Stevens LM	Wade O		
Ecological Values						
Area of estuary (ha) ** Area of intertidal	0.2	0.2	0.2	0.2	0.2	0.2
Habitat Intactness	1.0	0.8	1.0	1.0	1.0	1.0
Seagrass (extent; % of intertidal area)	1.0	1.0	1.0	0.8	1.0	1.0
Salt marsh (extent; % of intertidal area)	1.0	1.0	1.0	0.8	1.0	1.0
Mangroves (extent; % of intertidal area)	1.0	1.0	1.0	0.8	1.0	1.0
Intertidal shellfish beds (indigenous)	1.0	1.0	1.0	0.8	1.0	1.0
Biogenic reef	1.0	1.0	1.0	1.0	1.0	1.0
Species of conservation significance	0.6	0.8	0.6	0.8	0.7	0.8
Protected status (within or adjacent to estuary i.e. terrestrial or marine)	0.6	0.6	0.8	0.8	0.7	0.8
Pressures						
Catchment Land Use - % Indigenous Vegetation Cover	1.0	1.0	1.0	1.0	1.0	1.0
Catchment Land Use - % Exotic Forest	1.0	1.0	1.0	0.8	1.0	1.0
Catchment Land Use - % High producing grassland	1.0	0.8	1.0	0.8	0.9	1.0
Catchment Land Use - % Urban & industrial development	0.6	0.6	0.6	0.8	0.7	0.6
Catchment Land Use - % Horticulture	0.6	0.6	0.6	0.6	0.6	0.6
Nutrient Load Thresholds (macroalgae)	1.0	1.0	1.0	0.8	1.0	1.0
Sedimentation rate (CSR:NSR ratio*) *CSR = Current sedimentation rate, NSR = natural sedimentation rate	1.0	1.0	1.0	1.0	1.0	1.0
Grazing animals in estuary and margin	0.8	0.8	0.8	0.8	0.8	0.8
Altered Hydrology	0.8	0.8	1.0	0.8	0.9	0.8
Fish passage	0.8	1.0	0.6	0.8	0.8	0.8
Chemical contaminants - marine	0.6	0.6	0.6	0.4	0.6	0.6
Chemical contaminants - terrestrial	0.4	0.4	0.4	0.4	0.4	0.4
Marine oil spill risk	0.8	0.8	0.8	0.8	0.8	0.8
Introduced marine species	0.4	0.4	0.4	0.4	0.4	0.4
Phytoplankton blooms	0.2	0.2	0.2	0.2	0.2	0.2

Category	Weighting				Average	FINAL weighting
	Roberts KL	Forrest BM	Stevens LM	Wade O		
Pressures continued.						
Pathogens	0.2	0.2	0.2	0.2	0.2	0.2
Direct Human use - Non-commercial use	0.6	0.6	0.4	0.4	0.5	0.6
Direct Human use - Commercial marine species harvest/aquaculture	0.4	0.6	0.4	0.4	0.5	0.4
Direct human access - Level of protection to prevent disturbance of wildlife.	0.6	0.6	0.6	0.4	0.6	0.6
Salt Marsh pressures (Number of recorded pressures)	1.0	1.0	1.0	0.8	1.0	1.0
Seagrass pressures (Number of recorded pressures)	1.0	1.0	1.0	0.8	1.0	1.0
Suceptibility						
Estimated Physical Susceptibility	1.0	1.0	1.0	0.8	1.0	1.0
Mixing status (i.e. well mixed, partially mixed, stratified)	0.8	0.8	0.8	0.8	0.8	0.8
Likelihood catchment pressures within <10 years	1.0	1.0	1.0	1.0	1.0	1.0
Likelihood contaminants (chemical & biological) within < 10 years	0.6	0.6	0.6	0.6	0.6	0.6
Likelihood human use pressures increase within < 10 years	1.0	1.0	1.0	1.0	1.0	1.0
Likelihood catchment pressures within >10 years	0.6	0.8	0.8	0.6	0.7	0.8
Likelihood contaminants (chemical & biological) within >10 years	0.4	0.4	0.4	0.6	0.5	0.4
Likelihood human use pressures increase within >10 years	0.6	0.6	0.6	0.6	0.6	0.6
Adaptive capacity of estuary to sea level rise	0.8	0.8	1.0	1.0	0.9	1.0
Coastal vulnerability Index - Coastal erosion and sea level rise	0.8	0.8	0.8	1.0	0.9	0.8
Climate adaptation and resilience	Under development					
Condition						
Estimated historical salt marsh extent (% of historical remaining)	0.8	0.8	0.8	0.8	0.8	0.8
Proportion (%) of current salt marsh degraded	1.0	1.0	1.0	1.0	1.0	1.0
% Seagrass decline from estimated baseline	0.8	0.8	0.8	0.8	0.8	0.8
Proportion (%) of current seagrass degraded	1.0	1.0	1.0	1.0	1.0	1.0
Diversity of substrate types	0.6	0.6	0.4	0.4	0.5	0.6
Predicted sedimentation rate (mm/y)	0.8	0.8	0.8	0.6	0.8	0.8
Mud extent (% intertidal)	1.0	1.0	1.0	0.8	1.0	1.0
Opportunistic macroalgae extent (% intertidal)	1.0	1.0	1.0	0.8	1.0	1.0
Phytoplankton (ug/L)	0.6	0.6	0.6	0.4	0.6	0.6
High Enrichment Conditions (Ha or % intertidal area)	1.0	1.0	1.0	1.0	1.0	1.0
Existing presence of invasive species in the estuary	0.8	0.8	0.6	0.6	0.7	0.8
Reclamation and/or drainage (Percentage of area affected)	1.0	0.8	0.8	0.8	0.9	0.8
Shoreline length modified/ disturbed	0.6	0.8	1.0	0.8	0.8	0.8
Hardening of estuary margin (e.g. artificial rock wall, earth bund)	0.6	0.8	0.6	0.8	0.7	0.8
200m terrestrial margin (Densely vegetated)	0.4	0.4	0.2	0.4	0.4	0.4

APPENDIX 5. OPPORTUNISTIC MACROALGAL BLOOMING TOOL

The UK-WFD (Water Framework Directive) Opportunistic Macroalgal Blooming Tool (OMBT) (WFD-UKTAG 2014) is a comprehensive 5-part multi-metric index approach suitable for characterising the different types of estuaries and related macroalgal issues found in NZ. The tool allows simple adjustment of underpinning threshold values to calibrate it to the observed relationships between macroalgal condition and the ecological response of different estuary types. It incorporates sediment entrained macroalgae, a key indicator of estuary degradation, and addresses limitations associated with percentage cover estimates that do not incorporate biomass e.g. where high cover but low biomass are not resulting in significantly degraded sediment conditions. It is supported by extensive studies of the macroalgal condition in relation to ecological responses in a wide range of estuaries.

The 5-part multi-metric OMBT, modified for NZ estuary types, is presented in the WFD-UKTAG (2014) with additions described in Plew et al. (2020), and is paraphrased below. It is based on macroalgal growth within the Available Intertidal Habitat (AIH) - the estuary area between high and low water spring tide able to support opportunistic macroalgal growth. Suitable areas are considered to consist of *mud, muddy sand, sandy mud, sand, stony mud and mussel beds.* Areas which are judged unsuitable for algal blooms, e.g. channels and channel edges subject to constant scouring, need to be excluded from the AIH. The following measures are then taken:

1. Percentage cover of the available intertidal habitat (AIH).

The percent cover of opportunistic macroalgal within the AIH is assessed. While a range of methods are described, visual rating by experienced ecologists, with independent validation of results is a reliable and rapid method. All areas within the AIH where macroalgal cover >5% are mapped spatially.

2. Total extent of area covered by algal mats (affected area (AA)) or affected area as a percentage of the AIH (AA/AIH, %).

The affected area represents the total area of macroalgal cover in hectares. In large water bodies, small patches of macroalgal coverage relative to the estuary size would result in the total percent cover across the AIH remaining within the 'high' or 'good' status. While the affected area may be relatively small when compared to estuary size the total area covered could actually be quite substantial and could still affect the surrounding and underlying communities (WFD-UKTAG 2014). In order to account for this, the OMBT included an additional metric; the affected area as a percentage of the AIH (i.e. (AA/AIH)*100). This helps to scale the area of impact to the size of the waterbody. In the final assessment the lower of the two metrics (the AA or percentage AA/AIH) is used, i.e. whichever reflects the worse-case scenario.

3. Biomass of AIH ($g.m^{-2}$).

Assessment of the spatial extent of the algal bed alone will not indicate the level of risk to a water body. For example, a very thin (low biomass) layer covering over 75% of a shore might have little impact on underlying sediments and fauna. The influence of biomass is therefore incorporated. Biomass is calculated as a mean for (i) the whole of the AIH and (ii) for the Affected Areas. The potential use of maximum biomass was rejected, as it could falsely classify a water body by giving undue weighting to a small, localised blooming problem. Algae growing on the surface of the sediment are collected for biomass assessment, thoroughly rinsed to remove sediment and invertebrate fauna, hand squeezed until water stops running, and the wet weight of algae recorded. For quality assurance of the percentage cover estimates, two independent readings should be within ±5%. A photograph should be taken of every quadrat for inter-calibration and cross-checking of percent cover determination. For both procedures the accuracy should be demonstrated with the use of quality assurance checks and procedures.

4. Biomass of AA ($g.m^{-2}$).

Mean biomass of the Affected Area (AA), with the AA defined as the total area with macroalgal cover >5%.

5. Presence of Entrained Algae (% of quadrats).

Algae are considered as entrained in muddy sediment when they are found growing >3cm deep within muddy sediments. The persistence of algae within sediments provides both a means for over-wintering of algal spores and a source of nutrients within the sediments. Build-up of weed within sediments therefore implies that blooms can become self-regenerating given the right conditions (Raffaelli et al. 1989). Absence of weed within the sediments lessens the likelihood of bloom persistence, while its presence gives greater opportunity for nutrient exchange with sediments. Consequently, the presence of

opportunistic macroalgae growing within the surface sediment was included in the tool. All the metrics are equally weighted and combined within the multi-metric, in order to best describe the changes in the nature and degree of opportunistic macroalgae growth on sedimentary shores due to nutrient pressure.

TIMING

The OMBT has been developed to classify data over the maximum growing season so sampling should target the peak bloom in summer (Dec-March). However, peak timing may vary among water bodies, so local knowledge is required to identify the maximum growth period. Sampling is not recommended outside the summer period due to seasonal variations that could affect the outcome of the tool and possibly lead to misclassification, e.g. blooms may become disrupted by stormy autumn weather and often die back in winter. Sampling should be carried out during spring low tides in order to access the maximum area of the AIH.

SUITABLE LOCATIONS

The OMBT is suitable for use in estuaries and coastal waters which have intertidal areas of soft sedimentary substratum (i.e. areas of AIH for opportunistic macroalgal growth). The tool is not currently used for assessing intermittently closed and open estuaries (ICOEs) due to the particular challenges in setting suitable reference conditions for these water bodies.

DERIVATION OF THRESHOLD VALUES

Published and unpublished literature, along with expert opinion, was used to derive critical threshold values suitable for defining quality status classes (Table A1).

REFERENCE THRESHOLDS

A UK Department of the Environment, Transport and the Regions (DETR) expert workshop suggested reference levels of <5% cover of AIH of climax and opportunistic species for high quality sites (DETR, 2001). In line with this approach, the WFD adopted <5% cover of opportunistic macroalgae in the AIH as equivalent to High status. From the WFD North East Atlantic intercalibration phase 1 results, German research into large sized water bodies revealed that areas over 50ha may often show signs of adverse effects, however if the overall area was less than 1/5th of this, adverse effects were not seen so the High/Good boundary was set at 10ha. In all cases a reference of 0% cover for truly un-impacted areas was assumed. Note: opportunistic algae may occur even in pristine water bodies as part of natural community functioning. The proposal of reference conditions for levels of biomass took a similar approach, considering existing guidelines and suggestions from DETR (2001), with a tentative reference level of <100g/m^2 wet weight. This reference level was used for both the average biomass over the affected area and the average biomass over the AIH. As with area measurements a reference of zero was assumed. An ideal of no entrainment (i.e. no quadrats revealing entrained macroalgae) was assumed to be reference for un-impacted waters. After some empirical testing in a number of UK water bodies a High / Good boundary of 1% of quadrats was set.

CLASS THRESHOLDS FOR PERCENT COVER

High/Good boundary set at 5%. Based on the finding that a symptom of the potential start of eutrophication is when: (i) 25% of the available intertidal habitat has opportunistic macroalgae and (ii) at least 25% of the sediment (i.e. 25% in a quadrat) is covered (Comprehensive Studies Task Team (DETR, 2001)). This implies that an overall cover of the AIH of 6.25% (25*25%) represents the start of a potential problem.

Good / Moderate boundary set at 15%. True problem areas often have a >60% cover within the affected area of 25% of the water body (Wither 2003). This equates to

Table A1. The final face value thresholds and metrics for levels of the ecological quality status. These thresholds have been recently revised for New Zealand (see Table A3).

ECOLOGICAL QUALITY RATING (EQR)	High[1]	Good	Moderate	Poor	Bad
	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	≥0.2 - <0.4	0.0 - <0.2
% cover on Available Intertidal Habitat (AIH)	0 - ≤5	>5 - ≤15	>15 -≤25	>25 - ≤75	>75 - 100
Affected Area (AA) [>5% macroalgae] (ha)[2]	≥0 - 10	≥10 - 50	≥50 - 100	≥100 - 250	≥250
AA/AIH (%)*	≥0 - 5	≥5 - 15	≥15 - 50	≥50 - 75	≥75 - 100
Average biomass (g.m^{-2}) of AIH[3]	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000
Average biomass (g.m^{-2}) of AA[3]	≥0 - 100	≥100 - 500	≥500 - 1000	≥1000 - 3000	≥3000
% algae entrained >3cm deep	≥0 - 1	≥1 - 5	≥5 - 20	≥20 - 50	≥50 - 100

*Only the lower EQR of the 2 metrics, AA or AA/AIH should be used in the final EQR calculation.

15% overall cover of the AIH (i.e. 25% of the water body covered with algal mats at a density of 60%).

Poor/Bad boundary is set at >75%. The Environment Agency has considered >75% cover as seriously affecting an area (Foden et al. 2010).

CLASS THRESHOLDS FOR BIOMASS

Class boundaries for biomass values were derived from DETR (2001) recommendations that <500g.m^{-2} wet weight was an acceptable level above the reference level of <100g.m^{-2} wet weight. In Good status only slight deviation from High status is permitted so 500g.m^{-2} represents the Good/Moderate boundary. Moderate quality status requires moderate signs of distortion and significantly greater deviation from High status to be observed. The presence of >500gm^{-2} but less than 1,000g.m^{-2} would lead to a classification of Moderate quality status at best but would depend on the percentage of the AIH covered. >1kg.m^{-2} wet weight causes significant harmful effects on biota (DETR 2001, Lowthion et al. 1985, Hull 1987, Wither 2003). **Thresholds applied in the current study are described and presented in Table A3.**

THRESHOLDS FOR ENTRAINED ALGAE

Empirical studies testing a number of scales were undertaken on a number of impacted waters. Seriously impacted waters have a very high percentage (>75%) of the beds showing entrainment (Poor / Bad boundary). Entrainment was felt to be an early warning sign of potential eutrophication problems so a tight High /Good standard of 1% was selected (this allows for the odd change in a quadrat or error to be taken into account). Consequently, the Good / Moderate boundary was set at 5% where (assuming sufficient quadrats were taken) it would be clear that entrainment and potential over wintering of macroalgae had started.

EQR CALCULATION

Each metric in the OMBT has equal weighting and is combined to produce the **Ecological Quality Rating** score (EQR).

The face value metrics work on a sliding scale to enable an accurate metric EQR value to be calculated; an average of these values is then used to establish the final water body level EQR and classification status. The EQR determining the final water body classification ranges between a value of zero to one and is converted to a Quality Status by using the categories in Table A1. The EQR calculation process is as follows:

1. Calculation of the face value (e.g. percentage cover of AIH) for each metric. To calculate the individual metric face values:

- Percentage cover of AIH (%) = (Total % Cover / AIH) x 100 - where Total % cover = Sum of [(patch size) / 100] x average % cover for patch
- Affected Area, AA (ha) = Sum of all patch sizes (with macroalgal cover >5%).
- Biomass of AIH (g.m^{-2}) = Total biomass / AIH - where Total biomass = Sum of (patch size x average biomass for the patch)
- Biomass of Affected Area (g.m^{-2}) = Total biomass / AA - where Total biomass = Sum of (patch size x average biomass for the patch)
- Presence of Entrained Algae = (No. quadrats with entrained algae / total no. of quadrats) x 100
- Size of AA in relation to AIH (%) = (AA/AIH) x 100

2. Normalisation and rescaling to convert the face value to an equidistant index score (0-1 value) for each index (Table A2).

The face values are converted to an equidistant EQR scale to allow combination of the metrics. These steps have been mathematically combined in the following equation:

*Final Equidistant Index score = Upper Equidistant range value – ([Face Value - Upper Face value range] * (Equidistant class range / Face Value Class Range)).*

Table A2 gives the critical values at each class range required for the above equation. The first three numeric columns contain the face values (FV) for the range of the index in question, the last three numeric columns contain the values of the equidistant 0-1 scale and are the same for each index. The face value class range is derived by subtracting the upper face value of the range from the lower face value of the range. Note: the table is "simplified" with rounded numbers for display purposes. The face values in each class band may have greater than (>) or less than (<) symbols associated with them, for calculation a value of <5 is given a value of 4.999'.

The final EQR score is calculated as the average of equidistant metric scores.

A spreadsheet calculator is available to download from the UK WFD website to undertake the calculation of EQR scores.

Table A2. Values for the normalisation and re-scaling of face values to EQR metric.

Metric	Quality status	Face value ranges			Equidistant class range values		
		Lower face value range (measurements towards the "Bad" end of this class range)	Upper face value range (measurements towards the "High" end of this class range)	Face Value Class Range	Lower 0-1 Equidistant range value	Upper 0-1 Equidistant range value	Equidistant Class Range
% Cover of Available Intertidal Habitat (AIH)	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.999	≥0.6	<0.8	0.2
	Moderate	≤25	>15	9.999	≥0.4	<0.6	0.2
	Poor	≤75	>25	49.999	≥0.2	<0.4	0.2
	Bad	100	>75	24.999	0	<0.2	0.2
Average Biomass of AIH ($g.m^{-2}$)	High	≤100	0	100	≥0.8	1	0.2
	Good	≤500	>100	399.999	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.999	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.999	≥0.2	<0.4	0.2
	Bad	≤6000	>3000	2999.999	0	<0.2	0.2
Average Biomass of Affected Area (AA) ($g.m^{-2}$)	High	≤100	0	100	≥0.8	1	0.2
	Good	≤500	>100	399.999	≥0.6	<0.8	0.2
	Moderate	≤1000	>500	499.999	≥0.4	<0.6	0.2
	Poor	≤3000	>1000	1999.999	≥0.2	<0.4	0.2
	Bad	≤6000	>3000	2999.999	0	<0.2	0.2
Affected Area (Ha)*	High	≤10	0	100	≥0.8	1	0.2
	Good	≤50	>10	39.999	≥0.6	<0.8	0.2
	Moderate	≤100	>50	49.999	≥0.4	<0.6	0.2
	Poor	≤250	>100	149.999	≥0.2	<0.4	0.2
	Bad	≤6000	>250	5749.999	0	<0.2	0.2
AA/AIH (%)*	High	≤5	0	5	≥0.8	1	0.2
	Good	≤15	>5	9.999	≥0.6	<0.8	0.2
	Moderate	≤50	>15	34.999	≥0.4	<0.6	0.2
	Poor	≤75	>50	24.999	≥0.2	<0.4	0.2
	Bad	100	>75	27.999	0	<0.2	0.2
% Entrained Algae	High	≤1	0	1	≥0.0	1	0.2
	Good	≤5	>1	3.999	≥0.2	<0.0	0.2
	Moderate	≤20	>5	14.999	≥0.4	<0.2	0.2
	Poor	≤50	>20	29.999	≥0.6	<0.4	0.2
	Bad	100	>50	49.999	1	<0.6	0.2

*Only the lower EQR of the 2 metrics, AA or AA/AIH should be used in the final EQR calculation.

CHANGES TO BIOMASS THRESHOLDS IN NEW ZEALAND

- Biomass thresholds included in the OMBT were lowered for use in NZ by Plew et al. (2020) based on unpublished data from >25 shallow well-flushed intertidal NZ estuaries (Robertson et al. 2016b) and the results from similar estuaries in California. Sutula et al. (2014) reported that in eight Californian estuaries, macroalgal biomass of 1450g.m^{-2} wet weight, total organic carbon of 1.1% and sediment total nitrogen of 0.1% were thresholds associated with anoxic conditions near the surface (aRPD < 10 mm). Green et al. (2014) reported significant and rapid negative effects on benthic invertebrate abundance and species richness at macroalgal abundances as low as 840–930g.m^{-2} wet weight in two Californian estuaries. McLaughlin et al. (2014) reviewed Californian biomass thresholds and found the elimination of surface deposit feeders in the range of 700–800g.m^{-2}. As the Californian results were consistent with NZ findings, the latter thresholds were used to lower the OMBT good/moderate threshold from ≤500 to ≤200g.m^{-2}, the moderate/poor threshold from ≤1000 to ≤500gm^{-2} and the poor/bad threshold from >3000 to >1450g.m^{-2}. These thresholds are considered to provide an early warning of nutrient related impacts in NZ prior to the establishment of adverse enrichment conditions that are likely difficult to reverse.

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Table A3. Revised final face value thresholds and metrics for levels of the ecological quality status used in the current assessment.

ECOLOGICAL QUALITY RATING (EQR)	High[1]	Good	Moderate	Poor	Bad
	≥0.8 - 1.0	≥0.6 - <0.8	≥0.4 - <0.6	≥0.2 - <0.4	0.0 - <0.2
% cover on Available Intertidal Habitat (AIH)	0 - ≤5	>5 - ≤15	>15 -≤25	>25 - ≤75	>75 - 100
Affected Area (AA) [>5% macroalgae] (ha)[2]	≥0 - 10	≥10 - 50	≥50 - 100	≥100 - 250	≥250
AA/AIH (%)*	≥0 - 5	≥5 - 15	≥15 - 50	≥50 - 75	≥75 - 100
Average biomass (g.m^{-2}) of AIH[3]	≥0 - 100	≥100 - 200	≥200 - 500	≥500 - 1450	≥1450
Average biomass (g.m^{-2}) of AA[3]	≥0 - 100	≥100 - 200	≥200 - 500	≥500 - 1450	≥1450
% algae entrained >3cm deep	≥0 - 1	≥1 - 5	≥5 - 20	≥20 - 50	≥50 - 100

*Only the lower EQR of the 2 metrics, AA or AA/AIH should be used in the final EQR calculation.

APPENDIX 6. SEDIMENT PLATE COORDINATES

Site Name	Plate Number	Easting (NZTM)	Northing (NZTM)
Havelock A	1	1664438	5430967
Havelock A	2	1664436	5430967
Havelock A	3	1664434	5430968
Havelock A	4	1664431	5430969
Havelock B	1	1664844	5430850
Havelock B	2	1664845	5430852
Havelock B	3	1664846	5430853
Havelock B	4	1664849	5430855
Havelock C	1	1664290	5430909
Havelock C	2	1664288	5430908
Havelock C	3	1664285	5430909
Havelock C	4	1664283	5430909
Havelock D	1	1664972	5430865
Havelock D	2	1664974	5430867
Havelock D	3	1664975	5430868
Havelock D	4	1664978	5430870
Havelock E	1	1663862	5430725
Havelock E	2	1663890	5430725
Havelock E	3	1663888	5430724
Havelock E	4	1663886	5430724
Havelock F	1	1664014	5430692
Havelock F	2	1664013	5430693
Havelock F	3	1664009	5430693
Havelock F	4	1664008	5430693
Mahikipawa Arm - Transect	1	1670108	5428564
Mahikipawa Arm - Transect	2	1670550	5429038
Mahikipawa Arm - Transect	3	1670135	5428661
Mahikipawa Arm - Transect	4	1670161	5428757
Mahikipawa Arm - Transect	5	1670189	5428854
Mahikipawa Arm - Transect	6	1670218	5428951
Mahikipawa Arm - Transect	7	1670242	5429046
Mahikipawa Arm - Transect	8	1670271	5429141
Mahikipawa Arm - Transect	9	1670364	5429108
Mahikipawa Arm - Transect	10	1670457	5429072
Kaiuma Site A - Transect	1	1666440	5434747
Kaiuma Site A - Transect	2	1666469	5434733
Kaiuma Site A - Transect	3	1666508	5434709
Kaiuma Site A - Transect	4	1666544	5434692
Kaiuma Site A - Transect	5	1666585	5434667
Kaiuma Site B	1	1667010	5434079
Kaiuma Site B	2	1667008	5434082
Kaiuma Site B	3	1667007	5434086
Kaiuma Site B	4	1667005	5434086
Kaiuma Site C - Transect	1	1666607	5434423
Kaiuma Site C - Transect	2	1666636	5434419
Kaiuma Site C - Transect	3	1666666	5434417
Kaiuma Site C - Transect	4	1666696	5434415
Ohinetaha (Mahau) - Transect	1	1677663	5435957
Ohinetaha (Mahau) - Transect	2	1677572	5435915
Ohinetaha (Mahau) - Transect	3	1677526	5435893
Ohinetaha (Mahau) - Transect	4	1677545	5435849
Ohinetaha (Mahau) - Transect	5	1677564	5435800
Ohinetaha (Mahau) - Transect	6	1677619	5435936
Keneperu - Transect	1	1694074	5441733
Keneperu - Transect	2	1693971	5441714
Keneperu - Transect	3	1693894	5441658
Keneperu - Transect	4	1693816	5441597
Keneperu - Transect	5	1693861	5441509
Whangarae A	1	1651851	5450138
Whangarae A	2	1651856	5450136
Whangarae A	3	1651865	5450131
Whangarae A	4	1651867	5450129
Whangarae B	1	1652168	5449780
Whangarae B	2	1652173	5449779
Whangarae B	3	1652182	5449778
Whangarae B	4	1652186	5449778
Smylies Arm - Transect	1	1669837	5475398
Smylies Arm - Transect	2	1669818	5475407
Smylies Arm - Transect	3	1669799	5475413
Smylies Arm - Transect	4	1669779	5475422

SALT
ECOLOGY