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TASMAN COASTAL MARINE ENVIRONMENTS: EFFECTS OF ACTIVITIES

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Prepared for Tasman District Council

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EXCUTIVE SUMMARY

Tasman District Council (TDC) and Nelson City Council (NCC) are currently reviewing their regional coastal plans (RCPs). As part of this process, the councils are required to review the provisions that protect sites of significant indigenous biodiversity within the coastal environment. To support the RCP reviews and to give effect to Policy 11 and other policies in the New Zealand Coastal Policy Statement 2010 (NZCPS; Department of Conservation 2010), NCC and TDC want to gather information regarding the indigenous biodiversity values of the coastal environment and the effects of activities on those values, as well as develop a policy response for the RCPs. To this end, NCC and TDC have initiated a marine and coastal indigenous biodiversity project, with four stages (Stage 1: Literature and data review, Stage 2: Assessment, Stage 3: Management, and Stage 4: Maintenance).

Cawthron Institute (Cawthron) and three collaborators (Salt Ecology, National Institute of Water and Atmospheric Research [NIWA], and Davidson Environmental Ltd) were contracted to carry out Stage 1. This report is one of five (relating to seven topics) that represent the outputs from Stage 1:

- Bathymetry (Report 1)
- Hydrosystems (Report 1)
- Habitats (Report 2a)
- Indigenous biodiversity (Report 2a)
- Historical data (Report 2b, TDC only)
- Publicly available sites of significance to iwi (Report 3, TDC only)
- Effects of activities (Report 4, TDC only).

This, the fourth report in the series, considers effects of human activities on habitats and indigenous biodiversity and has been prepared for TDC only. In summary, the scope was to present information found during a literature and data search. Where available data was collated into a spatial data inventory with geographic information system (GIS) layers. Unavailable data and information gaps were also summarised. Our report also includes information on the potential relevance of the data to the NZCPS (Department of Conservation 2010) in relation to specified aspects of Policies 14, 19, 20 and 21. Considering the impacts of climate change was outside the scope of this report.

Main results:
Key details for mapped data relating to effects of activities on marine habitats and indigenous biodiversity in the Tasman Region are presented. This includes data format, description and source reference. Where data were available for inclusion in a spatial data inventory, layer names are also provided.

Nelson Bays marine ecosystems have been heavily modified by a wide range of anthropogenic effects and activities, commencing with early human colonisation and land-

use change, which has accelerated in scale and extent over the last century with more recent terrestrial and marine developments. Land-use change and ongoing soil disturbance have created the pervasive and widespread release of sediment (including nutrients and contaminants), which have been dispersed widely throughout the bays by tidal and wind driven waves and currents. In the bays, decades of trawling and dredging have modified the once heterogeneous soft sediment habitats by removing, killing or burying much of the historical biogenic or living habitats (shellfish, bryozoan, sponge, macro- and microalgal beds). Homogenised soft sediment habitats now contain increased proportions of fine silt, and it is likely that increasing turbidity from suspended fine sediments is impinging on any remaining historical habitats. Moreover, the current state of the marine environment has reduced the ability for lost habitats to recover (smothering, choking, shading). Large scale impacts relate to the NZCPS Policy 14 (potential to reduce success of restoration / rehabilitation) and Policy 21 (enhancement of water quality). At smaller scales that have been mapped, habitats are also affected by marine farming of shellfish, point source pollution, dredge spoil disposal, anchoring, and channel dredging.

Along the coastal margins, dunelands, sheltered estuaries and tidal flats, and seagrass and saltmarsh habitats have been reduced in historic extent by activities such as sand extraction, land reclamations, dredging and channelisation. These habitats and their associated wildlife suffer from ongoing effects of, for example, sedimentation and disturbance from vehicles, people and dogs (NZCPS, Policies 20 and 19 respectively).

There are data gaps for additional effects of activities in the Tasman Region including, for example, the effects of climate change, emerging contaminants such as pharmaceuticals and pesticides, and underwater noise pollution. Limited data are also currently available for plastic or litter pollution. Setting priorities for filling research gaps and future work are discussed in the report.

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1. INTRODUCTION

1.1. Context

Tasman District Council (TDC) and Nelson City Council (NCC) are currently reviewing their regional coastal plans (RCPs). As part of this process, the councils are required to review the provisions that protect sites of significant indigenous biodiversity within the coastal environment.

To support the RCP reviews and to give effect to Policy 11 and other policies in the New Zealand Coastal Policy Statement 2010 (NZCPS; Department of Conservation 2010), TDC and NCC want to gather information regarding the indigenous biodiversity values of the coastal environment and the effects of activities on those values, as well as develop a policy response for the RCPs. To this end, NCC and TDC have initiated a marine and coastal indigenous biodiversity project, with the following four stages.

Stage 1: Literature and data review – collate existing marine and coastal indigenous biodiversity information, including spatial data; categorise the existing literature and data against the requirements of Policy 11 (NZCPS); and prepare reports based on the gathered data. The scope of the project includes assessing the quality of the literature and data and identifying any gaps in information. As part of the review, some information relevant to only TDC is reported and mapped for use in separate NZCPS work streams.

Stage 2: Assessment – determine the assessment criteria to identify sites of significance and assess the sites against these criteria, with the assistance of an expert panel and an iwi working group established by NCC and TDC. Field investigations may be required as part of this stage.

Stage 3: Management – determine locations for management, activities significantly affecting the sites of significance, and methods of protection.

Stage 4: Maintenance – add and assess new information as it becomes available. The project will continue and evolve beyond Stages 1–3.

Cawthron Institute (Cawthron) and three collaborators (Salt Ecology, National Institute of Water and Atmospheric Research [NIWA] and Davidson Environmental Ltd) were contracted to carry out Stage 1. The report is one of five that represent the outputs from Stage 1. We understand that Stages 2, 3 and 4 will follow on from this.

1.2. Stage 1 reports

The Stage 1 literature and data review is organised into seven topics that are presented in five reports:

- Bathymetry (Report 1)
- Hydrosystems (Report 1)
- Habitats (Report 2a)
- Indigenous biodiversity (Report 2a)
- Historical data (Report 2b; TDC only)
- Publicly available sites of significance to iwi (Report 3; TDC only)
- Effects of activities (Report 4; TDC only).

Key reference information for data sources, reports and publications is provided in each of the above reports.

1.3. This report and its associated spatial layers

This, the fourth report in the series, considers effects of human activities on habitats and indigenous biodiversity and has been prepared for the Tasman Region only. This report summarises information found in the literature, including data in the form of spatial geographic information system (GIS) layers collated where possible into a spatial data inventory and provided to TDC as an output of the overall project (Appendix 1). The following key effects of human activities (where available information allows) are included as sections in this report:

- Sediment load, smothering, resuspension
- Benthic disturbance
- Recreational fishing
- Fish passage
- Aquaculture
- Terrestrial nutrients
- Dredge spoil
- Land-based contaminants
- State of environment (SOE) estuarine monitoring
- Mapua Fruitgrowers Chemical Company (FCC) contaminated site
- Disease, parasites, pests
- Algal blooms and ‘slime’ events
- Wildlife disturbance
- Sand extraction and relocation

- Vehicle disturbance to seabed
- Disturbance from vessel moorings and anchoring
- Marine biosecurity

Climate change is an overarching threat for marine habitats and indigenous biodiversity; however, considering climate change impacts (e.g. marine heatwaves, ocean acidification and more frequent storm events) was outside the scope of our report. Other information sources may provide further details on key activities, stressors and monitoring for Nelson Bays (e.g. Newcombe and Cornelisen 2014). Furthermore, a high-level assessment of threats that followed a consistent approach across data layers was undertaken in the Habitats and Indigenous Biodiversity report (Report 2a, Berthelsen et al. 2023b) for this project.

Our report also includes information on the potential relevance of the NZCPS (Department of Conservation 2010) in relation to:

- policy areas with opportunities for restoration or rehabilitation as identified in Policy 14 NZCPS
- areas where restrictions on public access may be necessary for the purposes set out in Policy 19(3)(a-d)
- areas where control of vehicles on beaches could be required for the purposes set out in Policy 20(1)(a)(b)(d)(f)(g)
- areas where the quality of water has deteriorated so that it is having a significant adverse effect on ecosystems, natural habitats, or water-based recreational activities or is restricting existing uses as set out in Policy 21.

Refer to Appendix 2 for full NZCPS policy details.

Key reference information for data is provided in the data sources (Tables 1 to 28) and the References section. Information gaps and recommendations for future work are also summarised (Section 3).

2. DATA SOURCES

This section on data sources contains a descriptive summary, key information (tabulated) and selected maps for the available and unavailable data.

2.1. Mapped data

Data sources are provided in the text below. Available (i.e. mapped) data, tabulated in white (i.e. no coloured background) were obtained and collated into our spatial data inventory (Appendix 1). Unavailable (i.e. unmapped) data that were not obtained in a spatial or digitised format are tabulated in grey. In some cases (e.g. where little information was known), unavailable data were only referenced in the report text rather than tabulated.

2.1.1. Sediment load, smothering and resuspension

Sediment load from catchments

Sediment accumulation rates, estimated from a sediment core collected offshore from Whariwharangi Bay in 2010, are now approximately 11 times the baseline, pre-human levels (Handley et al. 2020a). Changes in sedimentation have been attributed to anthropogenic terrestrial disturbance (Māori land clearance, traditional horticulture) and later, land-use intensification (land clearance, farming, silviculture, agriculture, roading). Following the pre-human baseline levels, a 10–15% increase in sediment silt content was measured from replicate cores collected at Separation Point (Handley et al. 2020b).

Land-based sediment has been reported as one of the most important stressors, including both suspended sediment and deposition effects, and associated decreases in water clarity (Morrison et al. 2009). As little as 26 mg l^{-1} of sediment fed continuously to sponges, oysters and mussels adversely affected their health after 13 days (Schwarz et al. 2006). Suspended sediments were also conjectured to have serious consequences at the ecosystem level from indirect effects through reduced epifaunal abundance, as epifauna are responsible for about 80% of the flow of energy and materials through rocky reef animal communities (Taylor and Cole 1994). Schwarz et al. (2006) thought that it was likely that epifaunal density reductions will have knock-on effects throughout the rocky reef food webs, both downwards through reduced epifaunal grazing on seaweeds and algal epiphytes, and upwards through reduced availability of food for small fishes. Increased sediment inputs can profoundly alter the structure and function of estuarine ecosystems and reduce their values, with event size and frequency both affecting the time it takes for coastal and estuarine habitats to recover (Thrush et al. 2004). Repeated deposition of thinner layers of fine sediment as little as 3 mm has been shown to do more damage than single small events causing alterations to macrobenthic community structure (Lohrer et al. 2004). However, catastrophic loss of marine resident fauna has also been measured after being smothered by 20 mm of terrestrial sediment, with fauna failing to recover completely for experiments lasting 212–603 days (Thrush et al. 2004).

Negative effects of fine sediment in Nelson Bays are likely to be widespread and pervasive. Effects have been recorded for bryozoans (Grange 2003), shellfish (Michael et al. 2015), phytoplankton production (especially at the seabed, e.g. Gillespie et al. 2000), seaweeds, seagrass and saltmarsh communities (see Berthelsen et al. 2023b; appendix 4). Handley et al. (2020b) found that resuspended sediment from benthic disturbance accounted for more of the variation in shellfish death assemblages sampled at Separation Point than sediment variables (deposition, changes in grainsize).

The biggest contributor to the average annual suspended sediment load to Tasman Bay / Te Tai-o-Aorere (hereafter Tasman Bay) and Golden Bay / Mohua (hereafter Golden Bay) is the Motueka River (41% of the total load delivered to the bays), with significant contributions from Waimea (13%), Aorere (12%), Wainui (9%) and Tākaka catchments (8%) (Hicks et al. 2011). Under large flood conditions, river plumes from Tasman Bay can extend into Golden Bay, and considerable amounts of sediment are also delivered to Golden Bay by the Aorere River and to a lesser extent the Tākaka River (Hicks et al. 2011; Tuckey et al. 2006) (Figure 1; Figure 2). Key information on sediment load data is provided in Tables 1 to 3.

Table 1. Key details for data (unmapped in our study) relating to tidal circulation in Tasman and Golden Bays: implications for river plume behaviour. Information includes data source and format, description and relevance to NZCPS.

Data source and format	Tuckey BJ, Gibbs MT, Knight BR, Gillespie P. 2006. Tidal circulation in Tasman and Golden Bays: implications for river plume behaviour. New Zealand Journal of Marine and Freshwater Research. 40(2):305–324. http://www.scopus.com/scopus/inward/record.url?eid=2-s2.0-33746478651&partnerID=40&rel=R6.0.0
Description	Simulated tidal residual circulation, validated model simulations of the fate of the plumes from the major rivers in Tasman Bay / Golden Bay.
Relevance to NZCPS	Policy 14(vi) potential to reduce success of restoration or rehabilitation. Policy 21(a)–(c).

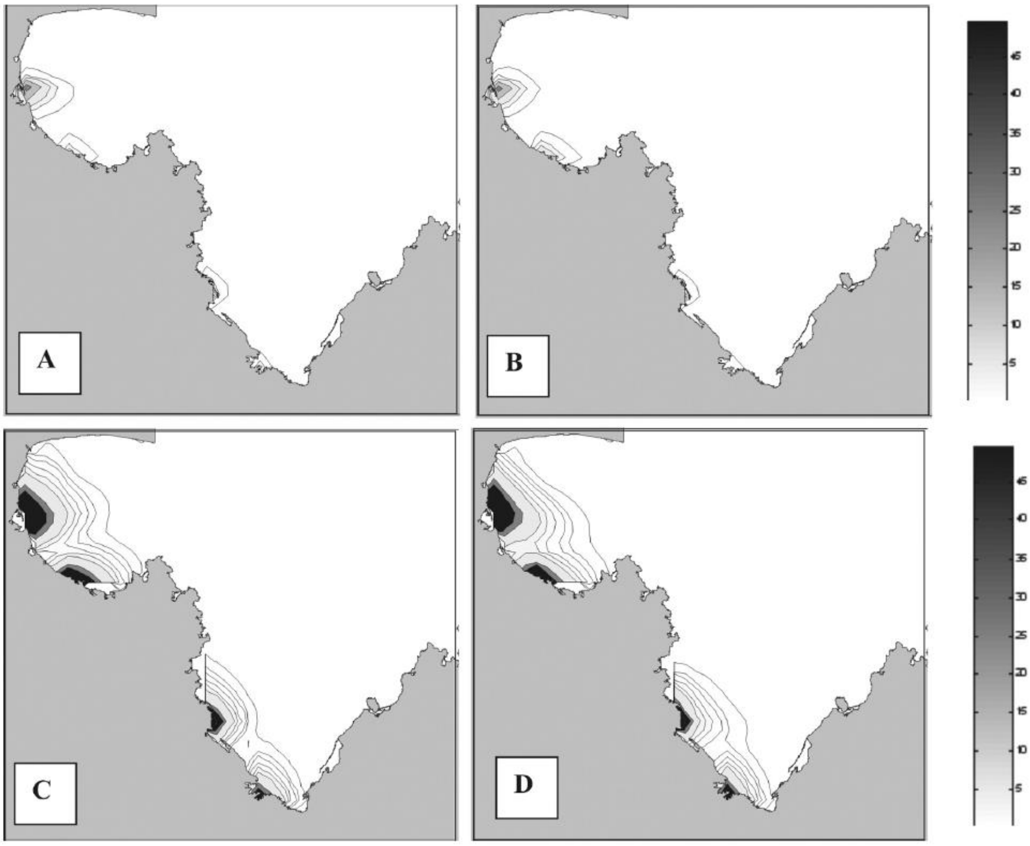

Figure 1. A, B, Surface water concentrations (mg l^{-1}) of suspended sediments (20 µm grain size) after 10 days flood river flow conditions forced with no wind (left frame) and a 10 knot northerly wind (right frame). C, D, Bottom bed concentrations (g m^{-2}) of depositional sediment (20 µm grain size) after 10 days flood river flow conditions forced with no wind (left frame) and a 10 knot northerly wind (right frame). Source: Tuckey et al. (2006).

Table 2. Key details for data (unmapped in our study) relating to suspended sediment yields from New Zealand rivers. Information includes data source and format, description and relevance to NZCPS.

Data source and format	Hicks M, Shankar U, McKerchar A, Basher L, Lynn I, Page M, Jessen M. 2011. Suspended sediment yields from New Zealand rivers. Journal of Hydrology (NZ). 50(1):81–142.
Description	Modelled river suspended yield estimates based on precipitation and erosion estimates, and land use.
Relevance to NZCPS	Policy 14(c)(vi). Policy 21(a)–(c),(e) suspended sediment and associated contaminants have potential to harm biodiversity.

Table 3. Key details for data (unmapped in our study) relating to sediment generation and delivery to Tasman and Golden Bays. Information includes data source and format, description and relevance to NZCPS.

Data source and format	Basher L, Hicks M. 2012. Sediment generation and delivery to Tasman and Golden Bays. Landcare Research Client Report prepared for NIWA, Appendix 1. In: Michael KP, Handley S, Williams JR, Tuck ID, Gillespie PA, Cornelisen C, Basher L, Chang FH, Brown SN, Zeldis J. 2015. A summary of information and expert opinion to help rebuild shellfish fisheries in Golden and Tasman Bays. NIWA Information Series No. 84. GIS maps of distribution of average annual specific suspended sediment yield (t km^{-2} y^{-1}) for catchments contributing to Tasman and Golden Bays, derived from Suspended Yield Estimator.
Description	Distribution of average annual specific suspended sediment yield (t km^{-2} y^{-1}) for catchments contributing to Tasman and Golden Bays, derived from Suspended Yield Estimator.
Relevance to NZCPS	Policy 14(c)(vi) potential to reduce success of restoration or rehabilitation. Policy 21(a)–(c),(e).

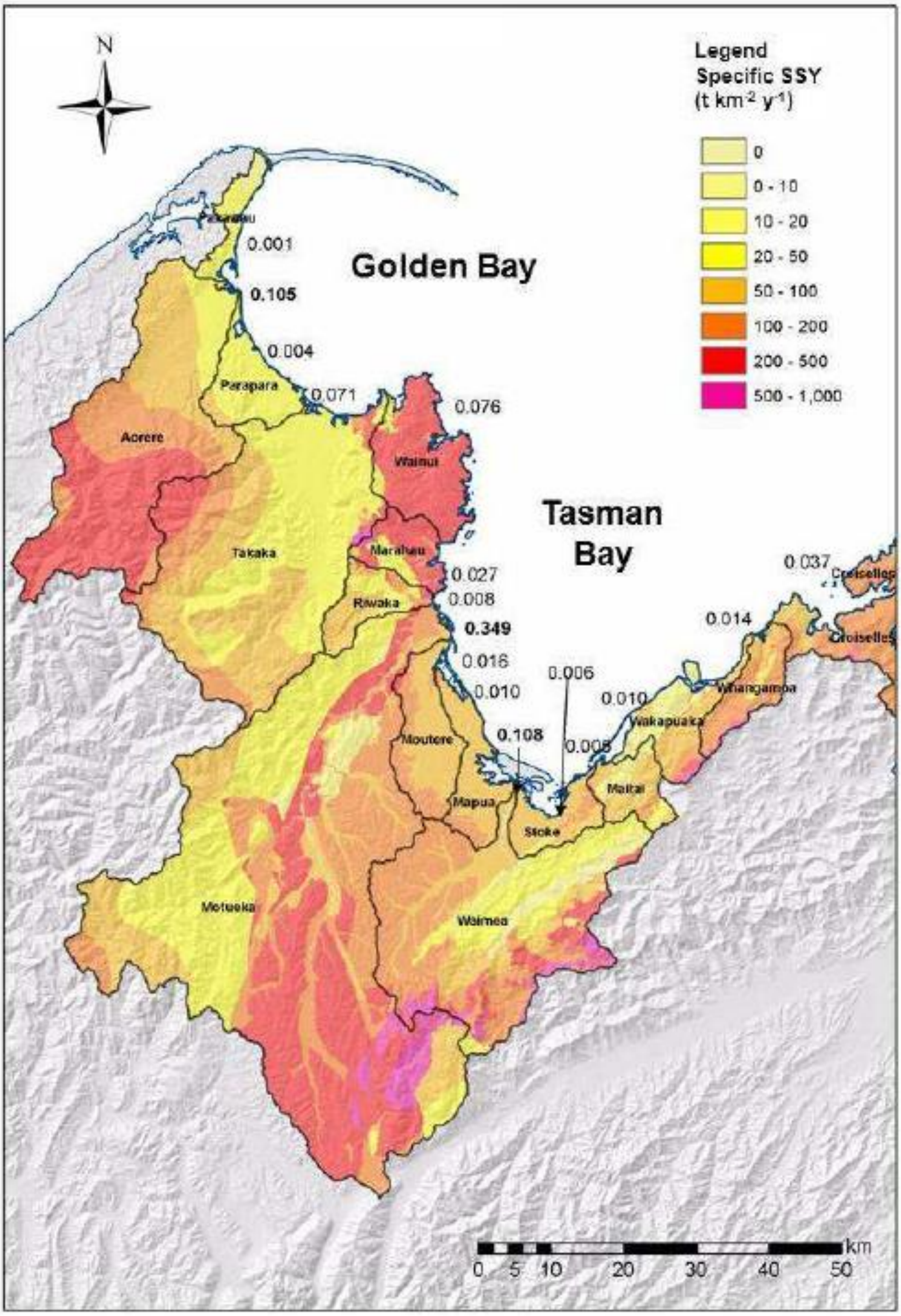

Figure 2. Distribution of average annual specific suspended sediment yield (t km^{-2} y^{-1}) for catchments contributing to Tasman and Golden Bays, derived from Suspended Yield Estimator. The total annual load (Mt) is shown for each contributing catchment. Source: Michael et al. (2015); appendix 1, figure 1.

Marine sediments

Marine sediments in Tasman and Golden Bays are dominated by silt and were mapped by Mitchell (1987) (Figure 3; Table 4) and revised by Bostock et al. (2019) (Figure 4; Table 5). The latter datasets are available through https://nzodn.nz/, but have not been downloaded into our spatial data inventory.

Table 4. Key details for data (mapped in our study) relating to Tasman sediments: surficial sediment granulometry. Information includes data source and format, description and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	Marine sediments
Layer name	NIWA_NZCOS_Tasman_Sediments
Data source and format	Mitchell JS. 1987. Tasman sediments. Coastal chart series 1:200 000. Sediments, 1 map. Surficial sediment granulometry.
Description	Tasman sediments: surficial sediment granulometry.
Relevance to NZCPS	Policy 14(c)(vi) potential to reduce success of restoration or rehabilitation.

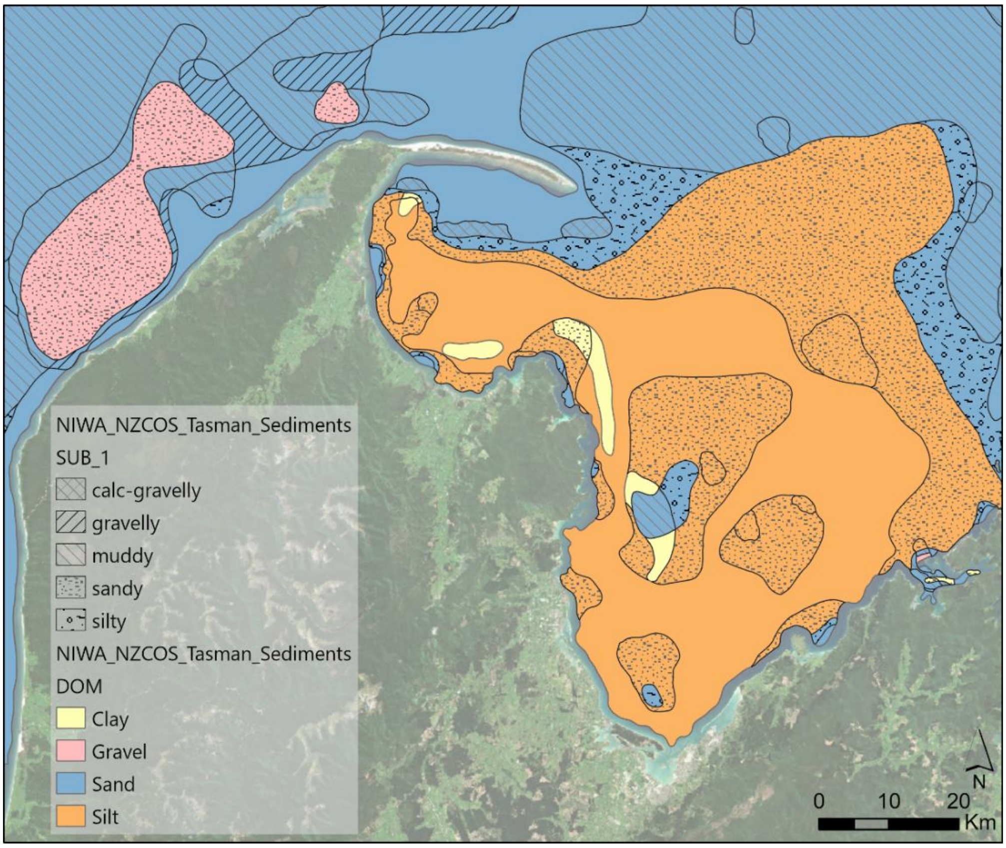

Figure 3. Sediments of Tasman and Golden Bays. Data source: Bradford-Grieve et al. (1994); Michael et al. (2015); Mitchell (1987); van der Linden (1969). Both DOM (dominant) and SUB_1 (first level subdominant) sediment types are displayed. Aerial imagery credit: NZ Imagery map service (Eagle Technology, Land Information New Zealand).

Table 5. Key details for data (unmapped in our study) relating to distribution of surficial sediments in the ocean around New Zealand. Information includes data source and format, description and relevance to NZCPS.

Data source and format	Bostock H, Jenkins C, Mackay K, Carter L, Nodder S, Orpin A, Pallentin A, Wysoczanski R. 2019. Distribution of surficial sediments in the ocean around New Zealand / Aotearoa. Part B: continental shelf. New Zealand Journal of Geology and Geophysics 62(1):24–45. Surficial sediment granulometry distribution on the continental shelf (0–150 m water depth) of New Zealand based on a new database – nzSEABED https://nzodn.nz/
Description	Surficial sediment granulometry distribution on the continental shelf (0–150 m water depth) of New Zealand based on a new database – nzSEABED.
Relevance to NZCPS	Policy 14(c)(vi) potential to reduce success of restoration or rehabilitation.

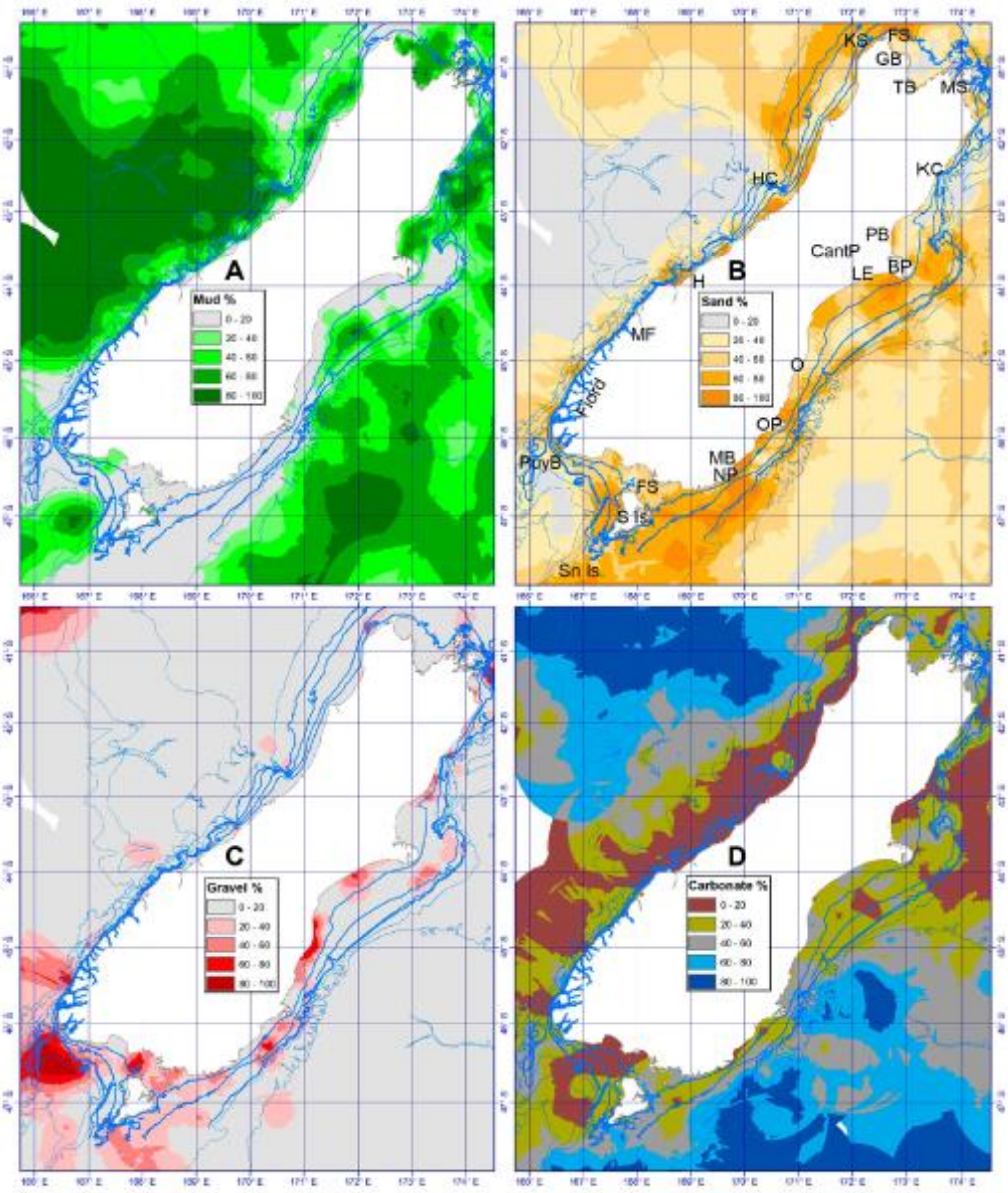

Figure 4. Map of the surficial sediments of the South Island continental shelf. A, Mud %. B, Sand %. C, Gravel %. D, Carbonate %. Station locations are not shown as they obscure the information in regions that are densely sampled. Place names are labelled: KC – Kaikōura Canyon, CantP – Canterbury Plains, PB – Pegasus Bay, BP – Banks Peninsula, LE – Lake Ellesmere / Te Waihora, O – Oamaru, OP – Otago Peninsula, MB – Molyneux Bay, NP – Nugget Point, FS – Foveaux Strait, S Is. – Stewart Island / Rakiura, Sn Is. – Snares Islands / Tini Heke, PuyB – Puysegur Bank, Fiord – Fiordland, MF – Milford Sound / Piopiotahi, HC – Hokitika Canyon, KS – Kahurangi Shoals, FS – Farewell Spit, GB – Golden Bay / Mohua, TB – Tasman Bay / Te Tai-o-Aorere. Source: Bostock et al. (2019).

Sediment smothering

Major storm events often result in major sediment deposition into marine environments, particularly estuaries. Davidson (2018) investigated three estuaries following a major cyclonic storm. Two estuaries had modified catchments (Kaiteriteri and Otūwhero) (Figures 5 and 6), while one had a natural catchment (Rākauroa / Torrent Bay). All three estuaries had comparable Separation Point granite geologies and relatively steep topography. Unlike estuaries spread across the plains of Tasman and Golden Bays, these Abel Tasman estuaries are naturally dominated by coarse substratum composed of granule, coarse, medium and fine sands. Mud is naturally uncommon, with mud habitat occupying only 7% of the estuaries within the Abel Tasman National Park (Davidson 1991). Davidson (2018) recorded smothering of coarse substratum and herb fields by a layer of silt and clay.

Figure 5. Layer of silt and clay over the base layer of coarse substrata in Otūwhero Inlet. Source: Davidson (2018).

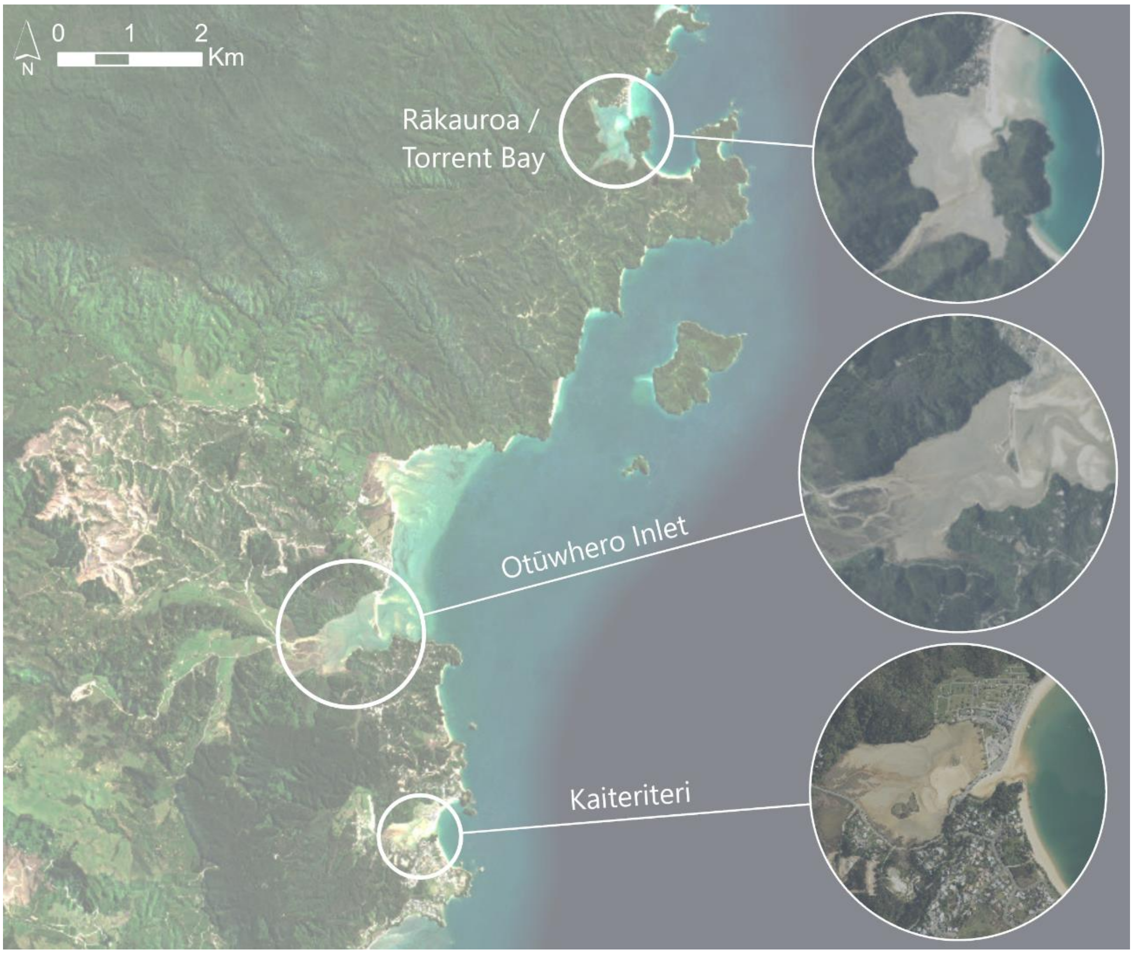

Figure 6. Estuaries investigated after a major weather event. Adapted from: Davidson (2018). Background aerial imagery is credited to the NZ Imagery map service (Eagle Technology, Land Information New Zealand).

Sediment resuspension

Resuspended sediments can contribute up to 90% of suspended solids in Tasman Bay (Gibbs 2001) and approximately 70% of sediment deposits in the inner Pelorus Sound / Te Hoiere (Swales et al. 2021). Sediment can be resuspended from natural climate and waves, affecting turbulence in the benthic boundary layer and high velocities below the thermocline associated with internal seiches (Gibbs 2001). Mean and maximum wave heights have been modelled; for example, approximately 12 km north of Whariwharangi Bay was estimated to be 0.62 m and 1.65 m, respectively (Gorman et al. 2003; Zeldis et al. 2011a) (Table 6). Specific model outputs have been generated for commercial clients (including TDC) and can be made available on request.

Table 6. Key details for data (unmapped in our study) relating to modelled wave hindcast for New Zealand. Information includes data source and format, description and relevance to NZCPS.

Data source and format	Gorman RM, Bryan KR, Laing AK. 2003. Wave hindcast for the New Zealand region: nearshore validation and coastal wave climate. New Zealand Journal of Marine and Freshwater Research. 37:567–588. Modelled wave hindcast for New Zealand (99 percentiles plotted in Zeldis et al. (2011b).
Description	Modelled wave hindcast for New Zealand.
Relevance to NZCPS	Not applicable.

2.1.2. Benthic disturbance

Bottom-contact trawling and dredge fisheries resuspend sediment, remove vulnerable fauna (e.g. long-lived biogenic communities), homogenise sediments (reducing shell gravels) and assemblages, and break down biogenic habitats (Handley et al. 2014; Saxton 1980). Trawling in Nelson Bays is extensive, with most areas affected (e.g. see figure 12 in Tuck et al. 2017). Trawl location data are outlined in Tables 7 to 11. These were generally considered commercially sensitive by Fisheries New Zealand, except for the nationwide dataset in Table 7, which was found to be publicly available online.

Table 7. Key details for data (mapped in our study) relating to trawl fishing intensity. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	BENTHIC DISTURBANCE
Layer name	MPI_TrawlFishingIntensity_2007_2017
Data format and details	ArcGIS Map Service, added via ArcGIS Online.
Description	Description from source: The distribution of commercial trawl catch is estimated for trawl fishing events reported in statutory catch and effort returns for the period 1 October 2007 to 30 September 2019. The location of trawl fishing events is reported by start or start and end coordinates precise to 1 nautical mile. The total catch of all species from each fishing event is spread uniformly over a polygon of space estimated to be occupied by that fishing. Trawl fishing polygons are derived from the length and width of the door-spread for the duration of the tow. The path of each tow is taken as a straight line between start and end coordinates where these are reported, or between start and estimated end coordinates. Where not required to

Group name	BENTHIC DISTURBANCE
	report end coordinates (as is the case for most inshore trawling), tow end points are derived using the direction of the next tow start position or the direction of the landing point for the last tow of the day. Catch intensity (kg/ha) is mapped to a square kilometre grid for all fishing events and summed. The data is aggregated into grid squares of between 1 and 2,500 km^2 as required to give 12-year annual averages of data from at least three permit holders. Catch per unit area values are classified into 10 intensity classes. The Ministry for Primary Industries (MPI) has high confidence in the data on catch quantities used to create these data, but the spatial distributions of those catches are only approximate and should be used with caution, especially at large map scales (maps of small spatial extent). Nevertheless, the aggregation of a large number of fishing events tends to provide consistent patterns that have passed scrutiny when tested with groups of fishers. Grid squares with less than three permit holders present have been removed to ensure the data remains confidential.
Source reference	Information from source: the data has been approved for public release by the data owner, Team Manager and Fisheries Data Management as permit holders. Catch values have been aggregated to ensure the data remains confidential and to align with MPI's commitment to promote open data. Please contact the data owner for any questions in relation to the release of this data (RDM@mpi.govt.nz). The custodian for this data is the Spatial Intelligence team (Spatial.Intelligence@mpi.govt.nz). The data were created to provide a generalised context and are not guaranteed to be 100% accurate. All values and locations displayed within these datasets are based on the best available information at the time of creation. Where accurate location information is lacking, fishing events have been aggregated to broader areas such as a fishery statistical area, or where an informed assumption can be made, to a subset of a statistical area (e.g. rocky areas within a statistical area for paua fishing events). Legal Constraints: Any hard copies produced should display the following text: Disclaimer: This map and all information accompanying it (the Map) is intended to be used as a guide only, in conjunction with other data sources and methods, and should only be used for reference purposes. The information shown in this Map is based on a summary of data obtained from various sources. While all reasonable measures have been taken to ensure the accuracy of the Map, MPI: (a) gives no warranty or representation in relation to the accuracy, completeness, reliability or fitness for purpose of the Map; and (b) accepts no liability whatsoever in relation to any loss, damage or other costs relating to any person 's use of the Map, including but not limited to any compilations, derivative works or modifications of the Map. Crown copyright. This map is subject to Crown copyright administered by MPI. The data is also displayed on the MPI website as the trawl fishing intensity map: https://tiles.arcgis.com/tiles/28amRQMPTiEvaF1p/arcgis/rest/services/MPI_TrawlFishingIntensity_2007_2017/MapServer
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation.

Table 8. Key details for data (unmapped in our study) relating to fishing trawl path estimates and line density interpolations. Information includes data source and format, description and relevance to NZCPS.

Data source and format	Tuck I, Hewitt J, Handley S, Willis T, Carter M, Hadfield M, Gorman R, Cairney D, Brown S, Palmer A. 2011. Assessing the effects of fishing on soft sediment habitat, fauna and processes. Progress Report for Ministry of Fisheries Project: BEN2007-01. Trawl path estimates and line density interpolations (figure 12, p. 23 in Tuck et al. 2017).
Description	Trawl path estimates and line density interpolations.
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation.

Table 9. Key details for data (mapped in our study) relating to effects of fishing on benthic habitats. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	BENTHIC DISTURBANCE
Layer name	NelsonBays_EffectsOfFishingOnBenthicHabitats
Data format and details	Point feature class.
Description	Assessment of the effects of fishing on soft sediment habitat, fauna and process in the Nelson Bays: survey locations only. Variables measured: sediment texture, organic matter, infaunal abundance and diversity, cover and complexity of biogenic habitat, fishing effort. Side-scan sonar was used to identify evidence of trawling and dredging.
Source reference	Tuck et al. (2017); https://fs.fish.govt.nz/Doc/24252/AEBR-178-Effects-of-fishing-on-soft-sediment-habitat.pdf.ashx
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation.

The spatial analysis of bottom-contacting trawl effort by commercial trawlers within the New Zealand Territorial Sea and the 200 nautical mile Exclusive Economic Zone (EEZ+TS), in waters open to trawling down to 1600 m depths, is presented in Baird and Mules (2021) for different time periods (Table 10).

Table 10. Key details for data (unmapped in our study) relating to fishing trawl and dredge path estimates. Information includes data source and format, description and relevance to NZCPS.

Data source and format	Baird S; Mules R. 2021. Extent of bottom contact by commercial trawling and dredging in New Zealand waters, 1989–90 to 2018–19. New Zealand Aquatic Environment and Biodiversity Report No. 260. Trawl and dredge path estimates (figures 3 and 4, p. 14; figure 6, p. 16).
Description	Trawl and dredge path estimates.
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation.

A study comparing the benthos inside and outside the Separation Point Power Fishing Exclusion Zone showed effects attributed to fishing reduced species diversity and the prevalence of large-bodied animals, with concomitant reductions in biomass and productivity (Handley et al. 2014) (Table 11). During a national-scale effects of fishing study carried out by the Ministry for Primary Industries (MPI), a Nelson Bays case study estimated the effects of benthic disturbance attributed to fishing were 19% of the measured variation (dedicated benthic study) where it caused reductions in epifaunal biomass (Tuck et al. 2011). Both substrate destabilisers (surface dwelling, mobile, deposit feeding species) and emergent epifauna (long-lived, sedentary, habitat forming species) were negatively correlated with fishing effort metrics, suggesting that the abundance within these groups may be reduced by up to 50% in areas fished 2–3 times per year (on average). Separate analysis of trawl survey benthic bycatch communities identified significant effects of waves, currents, depth, temperature and sediment parameters accounted for almost 70% of the total variance, as compared with terms for both scallop dredge and trawl effort that accounted for almost 10%.

A palaeoecological study that compared shell remains from sediment cores inside and outside the Separation Point Power Fishing Exclusion Zone found that historic legacy effects, ongoing sedimentation and fishing disturbance have synergistically modified the sediment characteristics from ‘natural’ baseline conditions (Handley et al. 2020b). Cultigen artefacts (taro, kumara) introduced by Māori corroborated transport of early human sediment and contaminants to offshore coring sites. Analysis of modern surficial sediments showed that fishing disturbance, with magnitude of effects estimated at approximately 20%, accounted for the greatest variation as compared with other sediment variables (15.3% variation), which included sediment accumulation and changes in grain size.

The greatest ecological change since the 1960s is thought to have been the removal of filter-feeding animals such as green-lipped mussels, oysters and scallops, as well as other invertebrates (Michael et al. 2015). These reported changes, however, did not include prior habitat degradation, especially of bryozoan habitats that were formally considered important juvenile fish nurseries. This removal has greatly reduced the filtration capacity and the ability to remove sediment and phytoplankton from the water of the bays, which likely affect biogeochemical pathways. The functions provided by biogenic habitats included armouring soft sediment from erosion and resuspension, increasing water clarity through filtration to allow light to reach the seabed, and the transfer of nutrients to the seafloor that enhance plant growth (e.g. microalgal diatoms, red algae and seagrass). These and other benthic animals historically modified the structure of sediments through the addition of calcium carbonate (Handley et al. 2014).

Table 11. Key details for data (mapped in our study) relating to Separation Point benthic effects of bottom fishing. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	BENTHIC DISTURBANCE
Layer name	SeparationPoint_BenthicEffectsOfBottomFishing
Data format and details	Point feature class.
Description	Seabed survey to understand the extent of fishing impacts in soft sediment ecosystems: survey locations only. Seabed variables measured inside and outside the Separation Point exclusion zone: sediment texture, sediment chlorophyll, biogenic cover, infaunal abundance, diversity, biomass and productivity. Side-scan sonar used to identify evidence of trawling and dredging.
Source reference	Handley et al. (2014); http://dx.doi.org/10.1016/j.seares.2013.11.005
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation.

2.1.3. Recreational fishing

Recreational fishing can impact the environment in various ways depending on the fishing type, location and intensity. Data on recreational fishing are included in our spatial data inventory. See Table 12 for key details on data.

Table 12. Key details for data (mapped in our study) relating to threats to aerial fishing survey. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	RECREATIONAL FISHING
Layer name	Aerial Fishing Survey
Data format and details	Feature Service Feature Class, added via ArcGIS Online.
Description	Aerial survey of recreational fishing pressure.
Source reference	https://maps.mpi.govt.nz/wss/service/ags-relay/arcgis1/guest/arcgis/rest/services/MARINE/MARINE_RecreationalSurveys/MapServer
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation.

2.1.4. Fish passage

Barriers to fish passage are a key threat to fish that need to travel up- or down-stream. See Table 13 for key details on data.

Table 13. Key details for data (mapped in our study) relating to fish passage sites. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	FISH PASSAGE
Layer name	a. FishPassageSites_TDC_CoastalEnvironment b. For full national dataset, including Nelson City Council (NCC) region, see: https://fishpassage.niwa.co.nz
Data format and details	a. Point feature class, supplied by Tasman District Council (TDC) and symbolised based on barrier type. b. Data not included but link provided.
Description	a. Fish passage dataset (points) provided by TDC and subset to the Coastal Environment by Cawthron. Data includes identifiers (StreamName, RiverSystem) and fish passage assessment data (BarrierType, Restriction). Note that URL links to reports do not function, but see national dataset for more information and reports. b. Details of FPAT (from website): the Fish Passage Assessment Tool has been developed to provide an easy to use, practical tool for recording instream structures and assessing their likely impact on fish movements. Data is collected using the Fish Passage Assessment Survey available in the NIWA Citizen Science app. A User Guide for the Fish Passage Assessment Survey is available on NIWA's website. The information collected using the app is automatically uploaded to a national fish passage database. Development of this tool was funded by MBIE through Envirolink Tools contract C01X1609. The data available on the Fish Passage Assessment Tool webpage (https://fishpassage.niwa.co.nz) are licensed under the CC-BY 4.0 licence, and users should read and understand the terms of this licence. Note that while NIWA endeavours to ensure the validity and reliability of the FPAT data, users should note that the data has been collected from a wide range of sources, has not been quality controlled and may be corrected, updated, changed or withdrawn at any time without notification. Users use the data at their own risk and NIWA disclaims and waives all liability for the use of or reliance on the data.
Source reference	https://fishpassage.niwa.co.nz/
Relevance to NZCPS	Policy 14(a),(b?),(c, iii,v,ix) potential to reduce success of restoration or rehabilitation.

2.1.5. Aquaculture

Mussel farms produce debris that falls to the seabed, namely faeces, pseudofaeces and mussel shells, as well as intact mussels and fouling algae and marine invertebrates (Cole and Grange 1996; Handley and Forrest 2013; Keeley et al. 2009). The amount that reaches the seabed and the extent of the 'footprint' is dependent on water column depth, current speed and direction, the weight of the debris and farming practices. This debris (biodeposits) has the potential to affect the stability of epifauna and infauna communities, and such disturbance may have ramifications further up the food web. For shellfish farms, the benthos and associated epibenthic species have been shown to recover within approximately 11 years (Davidson and Richards 2014). Benthic effects of mussel farms are well researched and often lead to higher macrofaunal abundance and diversity beneath farms. Mussel farm areas also offer respite from fishing damage, e.g. from trawling. The locations of marine farming areas and the consent monitoring sites for marine farms are presented in Report 2a (Berthelsen et al. 2023b). Data for aquaculture management areas and seabed and water column monitoring are outlined in Tables 14 to 16.

Table 14. Key details for data (mapped in our study) relating to aquaculture management areas and sites. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	AQUACULTURE: Marine farms and Aquaculture Management Areas (AMAs)
Layer name	a. TDC_TRMPAquacultureManagementAreas; b. TDC_TRMPAquacultureSites; c. MARINE FARMS – MPI
Data format and details	a. Polygons, supplied by Tasman District Council (TDC) as Feature classes. b. Polygons, supplied by TDC as Feature classes. c. ArcGIS Map Service.
Description	Boundary polygons for marine farms and aquaculture management areas (AMA) in Tasman and Golden Bays. Represents areas of potential impacts on natural character and outstanding natural landscapes and features. Also considered a potential threat to water column and benthic habitats, depending on monitoring results.
Source reference	a. Supplied by TDC. b. Supplied by TDC. c. https://maps.mpi.govt.nz/wss/service/arcgis1/guest/MARINE/MARINE_Aquaculture_Marine_Farms/MapServer. Note that the MPI dataset does not align with the TDC dataset in some cases. Assume TDC data is more accurate / up to date.
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Also may relate to Policy 21 (a)–(c),(e).

Table 15. Key details for data (mapped in our study) relating to aquaculture seabed and benthic monitoring. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	AQUACULTURE: Benthic monitoring
Layer name	a. AMA1_SubzoneA_SeabedMonitoring b. AMA1_SubzoneC_SeabedMonitoring c. AMA2_BenthicMonitoringStations_2022 d. AMA3_Seabed_Monitoring
Data format and details	Point feature classes, supplied by Cawthron or, for layer a) digitised from georeferenced report figure map.
Description	Ecological (seabed) monitoring stations or baseline monitoring for marine farms and aquaculture management subzones in the Nelson and Tasman regions: a. AMA1, subzone (a) b. AMA1, subzone (c) c. AMA2, subzones (p) and (q) d. AMA3, subzones (i), (j) and (k) Survey locations only, see individual layer metadata for specific descriptions and reports for data. Sampling methodologies differ but generally consist of grab samples and quadrat photos of sediment at farm and reference stations. Variables measured in grab samples include apparent redox discontinuity layer, redox potential, sediment texture, total organic matter, infaunal abundance and diversity, total free sulphides, nitrogen and phosphorus. Conspicuous epifauna quantitatively described from quadrat photos. Side-scan sonar images obtained for parts of seabed within AMA 1a. Organic enrichment stage (Enrichment stage: Keeley et al. 2012) of seabed assessed in some surveys.
Source reference	Watts and Grange (2015); Page et al. (2021); Major and McMullin (2021a, 2021b); McMullin (2022).
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation.

Table 16. Key details for data (mapped in our study) relating to aquaculture water quality monitoring. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	AQUACULTURE: Water quality monitoring
Layer name	a. AMA3_WaterColumn_MonitoringStations_2022 b. AMA3_WaterColumn_MonitoringSites_2016 c. AMA2_WaterColumn_MonitoringStations_2022 d. AMA2_WaterColumn_Monitoring_2017 e. AMA1_WaterColumn_MonitoringStations
Data format and details	Point feature classes, supplied by Cawthron.
Description	Water column sampling conducted at in-farm and reference sites for AMAs 1, 2 and 3 in Tasman and Golden Bays. Included to represent potential impacts of reduced water quality on habitats and biodiversity, depending on monitoring results. Variables measured differ among locations (see reports for methodologies and layer metadata for descriptions), but collectively include: total nitrogen, dissolved inorganic nitrogen, nitrate, ammonia, total phosphorus, dissolved reactive phosphorus (analysis of water samples), conductivity, temperature and depth profiles (CTD sonde), dissolved oxygen, photo-active radiation, chlorophyll-*a* and turbidity profiles (CTD sonde), chlorophyll-*a* by fluorometer, chlorophyll-*a* and phytoplankton species identity and abundance (analysis of water samples), current speed and direction (ADCP).
Source reference	Newcombe (2016); McMullin, Berthelsen, Smeaton and Jary (2022a, 2022b); McMullin, Smeaton and Jary (2022). Note that follow up monitoring is planned for autumn or spring 2023.
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Policy 21(a)–(c),(e).

2.1.6. Terrestrial nutrients

Nutrient loadings from land were considered minor as compared with nutrients transported into Nelson Bays from offshore upwelling from the West Coast via Cook Strait (Zeldis 2008; Chiswell et al. 2017). The flux of dissolved inorganic nitrogen (DIN) from rivers contributed about 12% for Golden Bay and 9% for Tasman Bay of the total DIN supplied to both bays, with the remainder coming from oceanic supply. The estimated average annual total nitrogen (TN) loading rate between 2005 and 2009 from the Motueka River catchment (613 tonnes) is only approximately 20% of the annual loss of nitrogen based on extrapolated literature values for denitrification rates in Tasman Bay (Gillespie, Forrest, et al. 2011). Gillespie, Forrest, et al. (2011)

considered there was little potential for resulting dysfunctional river plume ecosystem enrichment effects to occur. Also refer to Sections 2.1.8 to 2.1.10 for further information on nutrient enrichment in the Tasman Region in relation to land-based contaminants, SOE estuarine monitoring and the Mapua Fruitgrowers Chemical Company (FCC) contaminated site.

2.1.7. Dredge spoil

The effects of dredge spoil disposal on contaminant concentrations and benthic macrofauna were examined at a shallow marine disposal site used for approximately 20 years from 1974 (Roberts and Forrest 1999) (Figure 7). The site had received approximately 50,000 m^3 yr^{-1} of maintenance dredging material annually from the Port of Nelson. Port sediments were contaminated to varying degrees with some trace metals, organochlorine pesticides, polychlorinated biphenyls and polycyclic aromatic hydrocarbons. The sediments showed mildly elevated toxicity in laboratory bioassays, and their macrofauna was dominated by small-bodied polychaetes. Despite this, there was very little indication of impact in the spoil disposal area. The disposal area spoil spreading zone and control sites were all similar in terms of sediment contaminants, sediment toxicity, neogastropod imposex and macrofauna. The lack of discernible impact is probably because of the dynamic sedimentary environment in the disposal area, which disperses dumped dredgings and mixes them with ambient sediment. Most recent monitoring reports in relation to dredge spoil include Cameron (2017) (refer Table 17) and Sneddon (2023).

Table 17. Key details for data (mapped in our study) relating to dredge spoil ground monitoring. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	DREDGE SPOIL
Layer name	PortNelson_DredgeSpoilGroundMonitoring
Data format and details	Point feature class.
Description	Seabed monitoring stations within the Port Nelson dredge spoil ground and reference stations: survey locations only. Dataset from core samples and quadrat photos of sediment at six stations in and around the spoil ground and three reference stations. Variables measured in sediment samples: apparent redox discontinuity layer, sediment texture, total organic matter, contaminants (trace metals, PAHs and organotins), infaunal abundance and whelks.
Source reference	Spatial data supplied by Cawthron; Cameron (2017).
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Policy 21(a)–(c),(e).

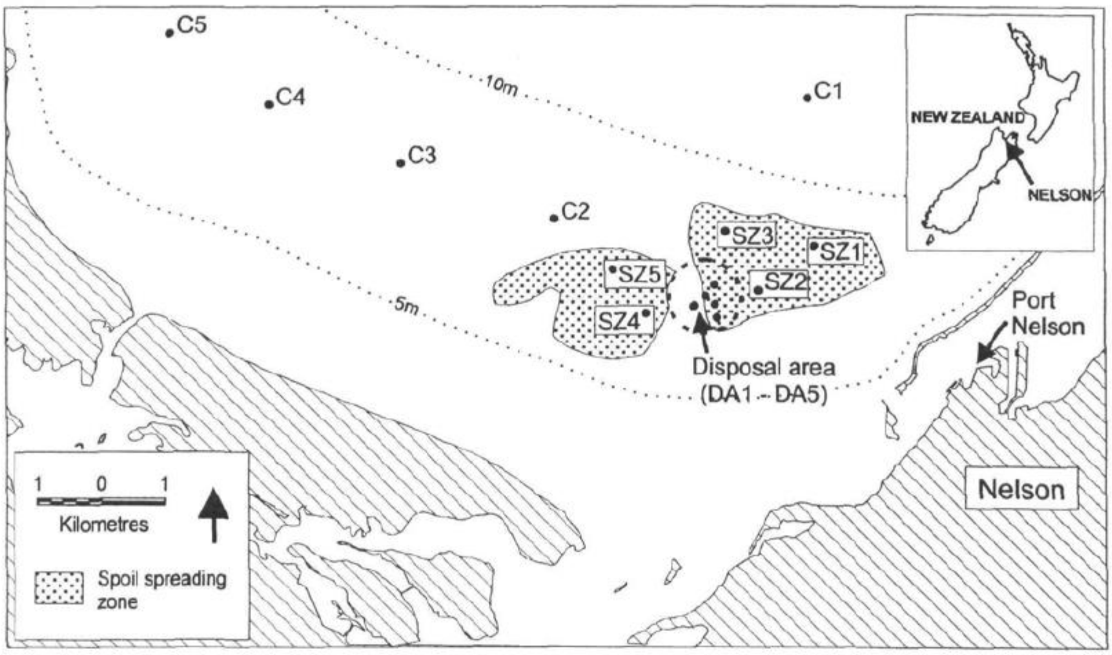

Figure 7. Location of the spoil disposal area in Port Nelson, New Zealand and sampling sites in Tasman Bay. Spoil spreading zone is based on Kettell and Barnett's (1986) map of net sediment accretion. The 5 m and 10 m depth contours are shown (dotted lines). Source: Roberts and Forrest (1999).

2.1.8. Land-based contaminants

A range of human activities can cause land-based contaminants to enter the marine environment.

Stormwater represents a potential contamination source for the coastal environment. To represent this, we have included in our spatial data inventory the stormwater network from Top of the South Maps, along with a sub-set of features considered relevant by TDC. Stormwater can also enter the coastal environment via diffuse pathways, over land or in groundwater. Monitoring data for stormwater (water quality and sediments) are likely held by TDC in report format, but these were not provided for this report.

Wastewater also represents a potential source of contamination to the coastal environment, either as treated effluent or as emergency or accidental overflows; for example, relevant data include those related to monitoring of the Bell Island Treatment Plant (WWTP) (Table 18), and there are also others (for example, in Motueka and Golden Bay). It is possible that TDC also holds information about emergency overflow incidents. Wastewater features have been included in the spatial data inventory from Top of the South Maps, but these require filtering to sub-set relevant types. Refer to Table 19 for stormwater and wastewater infrastructure data.

Table 18. Key details for data (mapped in our study) relating to Bell Island Wastewater Treatment Plant (WWTP) benthic monitoring and mussel and water quality monitoring. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	LAND-BASED CONTAMINANTS: Wastewater Treatment Plant monitoring
Layer name	a. Bell Island WWTP benthic monitoring b. BellIsland_MusselMonitoring_WaterQuality
Data format and details	Point feature class, supplied by Cawthron.
Description	a. Mussel (and water quality) monitoring survey stations (locations only, see reports for data) – coastal effects of the Bell Island regional sewerage discharge. Monitoring for faecal coliform bacteria, temperature, total suspended solids (TSS), chlorophyll-*a*, salinity, dissolved oxygen (DO), photosynthetically active radiation (PAR) and composition and abundance of phytoplankton.
Source reference	a. Morrisey (2022). b. Campos and Morrisey (2022).
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Policy 21(a)–(c),(e).

Table 19. Key details for data (mapped in our study) relating to stormwater and wastewater infrastructure. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	LAND-BASED CONTAMINANTS: Stormwater & wastewater infrastructure
Layer name	a. Top of the South Maps: Services – Wastewater Features (unfiltered); Services – Stormwater Features (unfiltered); Services – Stormwater Drains b. TDC_SDE_StormwaterSurfaceFeatures_Selection
Data format and details	a. Map service layer, see source / reference. b. Point feature class, sub-set and supplied by Tasman District Council (TDC).
Description	a. Stormwater and wastewater point features and stormwater drains (lines) for TDC and Nelson City Council (NCC) regions, included here to represent potential impacts of reduced water (and sediment) quality on habitats and biodiversity. Data should be filtered by councils to sub-set relevant feature types (outfalls, others?). b. Sub-set of TDC stormwater surface features dataset, filtered (by TDC) to represent potential inputs to marine / coastal environment. Features include floodgates, inlet / outlet structures, pipe outlets and soak pits.
Source reference	a. Added as a map service layer via URL: https://www.topofthesouthmaps.co.nz/ArcGIS/services/TopoftheSouthMaps/MapServer/WFSServer b. Supplied by TDC. Monitoring reports for stormwater (water quality, sediment quality) and some other features may be held by councils. These were requested but not received for this project.
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Policy 21(a)–(c),(e).

Embryonic stages of bivalves are particularly sensitive to pollutants (Michael et al. 2015). Heavy metal analysis of scallops from Tasman Bay has shown elevated cadmium levels in their stomachs, but cadmium does not accumulate in other parts of the body (Nielsen and Nathan 1975). Cadmium was thought to originate from aerial top-dressing of superphosphate fertiliser, which can get washed into waterways (Bradford-Grieve et al. 1994; Nielsen and Nathan 1975). It is not known whether the source of this heavy metal is the land or the sea. An approximate 50 km^2 area around the mouth of the Motueka River is contaminated by heavy metals (nickel and chromium), which likely originate from the plume and can be traced back to a natural upper catchment mineral belt (Forrest et al. 2007). Concentrations strongly exceeded sediment quality thresholds for probable ecological effects. Although the Motueka plume appears to influence sediment chemistry up to 6 km from the Motueka River mouth, analysis of shellfish did not reveal any evidence of direct terrestrial or riverine influence (Forrest et al. 2007).

A survey of agricultural chemicals between 1986 and 1988 identified Azinphos-CH3 in the Nelson / Marlborough area, which was used as a non-selective pesticide (Bradford-Grieve et al. 1994). It was phased out for use in Aotearoa New Zealand by 2014. There is a register of known and possible contaminated sites kept by TDC (and NCC), many of which are situated on private land. As landowners are liable for any contamination on their property, even if the contamination was caused by a previous owner, site information is sensitive, and as a result, councils are reluctant to release information on non-public sites (Michael et al. 2015).
Key details for data relating to TDC Hazardous Activities and Industries List (HAILS) are outlined in Table 20. Spatial data for HAIL sites are held by councils but were not supplied for this project.

Table 20. Key details for data (unavailable for mapping in our study) relating to TDC Hazardous Activities and Industries List (HAILS). Information includes data source and format, description and relevance to NZCPS.

Data source and format	TDC Hazardous Activities and Industries List (HAILS): https://www.tasman.govt.nz/my-region/environment/environmental-management/land/hail-sites/
Description	TDC Hazardous Activities and Industries List (HAILS).
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation; 14(c)(vi)(x). Policy 21(a)–(c),(e).

In addition to suspended sediment contamination from land, faecal contamination affects contact recreation and shellfish gathering. Land Air Water Aotearoa (LAWA) provide a web-based tool for the public to check water quality (Figure 8; Table 21). Frequent issues have been recorded at Motupipi and Pōhara, and contamination from the Aorere River has affected shellfish farming and cockle harvests (pers. comm. Ben Knight, Cawthron).

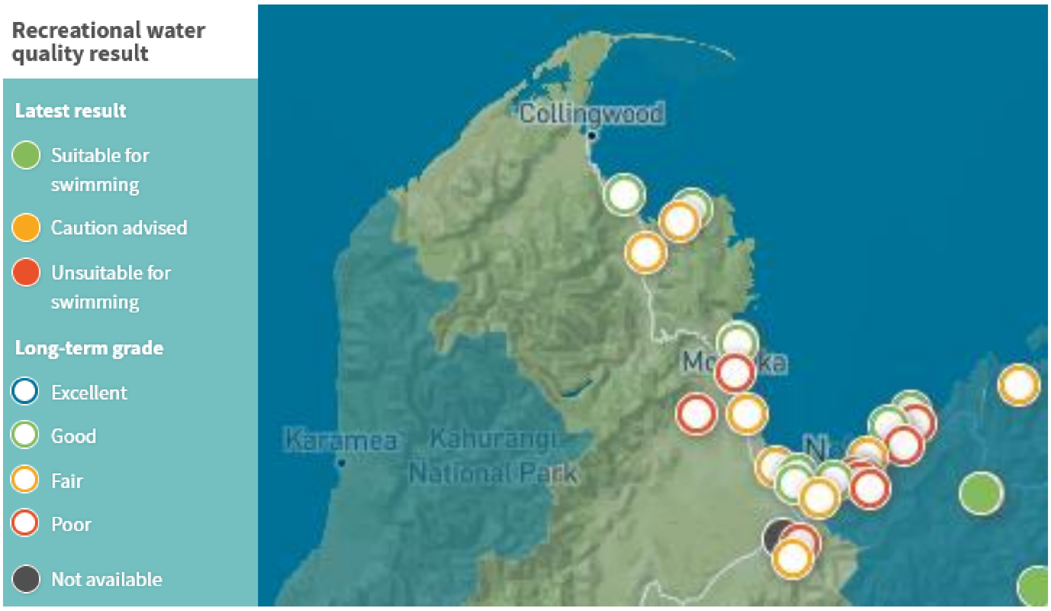

Figure 8. LAWA interactive web tool. Screenshot showing recreational water quality monitoring sites, with example results and grades. Source: https://www.lawa.org.nz/explore-data/swimming/

Table 21. Key details for data (mapped in our study) relating to LAWA coastal and river monitoring sites. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	LAND-BASED CONTAMINANTS: Land Air Water Aotearoa (LAWA) monitoring sites
Layer name	a. LAWAsites_CoastalMonitoring Sites, b. LAWAsites_RiverWaterQualityMonitoring Sites
Data format and details	Point feature classes.
Description	a. Coastal (Can I swim here?) monitoring sites in the Nelson & Tasman regions. b. A selection of River Water Quality monitoring sites, in or near the Nelson and Tasman coastal environments. The following parameters are measured at these sites: *E. coli*, total suspended solids (TSS), water clarity and nutrients (nitrogen and phosphorus species).
Source reference	Spatial data (monitoring site points) extracted from LAWA database by Cawthron. a. https://www.lawa.org.nz/explore-data/swimming b. https://www.lawa.org.nz/explore-data/nelson-region/river-quality/ and https://www.lawa.org.nz/explore-data/tasman-region/river-quality Monitoring sites only. Data can be downloaded from the LAWA website: https://www.lawa.org.nz/download-data
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Policy 21(a)-(c),(e).

Davidson and Freeman (2013) investigated contaminant levels from four subtidal sediments sites and five invertebrate sites (four species) along the Abel Tasman coast. For sediment, apart from nickel, all levels were well below the Australia and New Zealand Environment and Conservation Council (ANZECC) low trigger levels. Nickel levels were above the low trigger level standard for all but two of the samples. Naturally high concentrations of heavy metals (nickel, chromium, and copper) enter the sea via the Motueka River. These metals come from the weathering of ultramafic rock in the Red Hills and settle onto the seafloor in the river plume area of Tasman Bay.[1] Two sites had cadmium exceedances in horse mussel flesh and one unidentified bivalve. The cadmium levels in sediments were below ANZECC standards. Zinc samples were mostly around 10–30 mg/kg; however, the unidentified bivalve from Tonga Quarry had a value of 50 mg/kg. A similar result was recorded

[1] Note: metals may also be discharged from erosion of ultramafic rock formations within other catchments, including the Maitai and Waimea catchments (e.g. Gibbs and Woodward 2018).

from the same shellfish for nickel, with all other values remaining at relatively low levels.

Coastal water quality is also monitored by the NIWA and TASCAM monitoring buoys, key details for which are outlined in Table 22.

Table 22. Key details for data (mapped in our study) relating to NIWA and TASCAM monitoring buoys. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	LAND-BASED CONTAMINANTS: monitoring buoys
Layer name	a. NIWAbuoy_GoldenBay, b. TASCAMbuoy_TasmanBay
Data format and details	Point feature classes.
Description	a. Point location of buoy in Golden Bay. The NIWA buoy comprises an array of meteorological and oceanographic instruments, which return sea-surface and air temperature, barometric pressure and solar radiation data to NIWA databases in near real-time. It has been in operation in Golden Bay since May 2007. During summer 2019–2020 it was bought ashore and completely refitted. b. Point location of buoy in Tasman Bay. TASCAM records long-term information on simple but significant parameters such as temperature, salinity, turbidity (sediment) and chlorophyll – all indicators of the quality and productivity of our coastal waters. Wind speed and direction and barometric pressure are also recorded. Tascam was installed in 2011. Cawthron owns and maintains two TASCAM buoys, which helps ensure a continuous dataset. While one buoy is deployed the other can undergo maintenance and calibration.
Source reference	a. Data are available at: https://www.tasman.govt.nz/my-region/environment/environmental-data/tidal-data/metbuoy b. Data may be viewed via: https://tools.cawthron.org.nz/tascam
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Policy 21(a)–(c),(e).

2.1.9. SOE estuarine environment monitoring

Since 2002, broadscale and fine-scale estuary surveys have been undertaken for SOE monitoring purposes in the largest of the estuaries present in the Tasman (and Nelson) Region; these surveys have generally followed the National Estuary Monitoring Protocol (NEMP) (Robertson et al. 2002) and subsequent extensions.

NEMP monitoring is primarily designed to detect and understand broad changes in estuaries over time and determine the effects of catchment influences, especially those contributing to the input of nutrients, muddy sediments and indicators of sediment contamination, e.g. heavy metals. Excessive nutrient and fine sediment inputs are a primary driver of estuary eutrophication symptoms, such as prolific macroalgal (seaweed) growth, and can contribute to poor sediment condition, e.g. sediment anoxia and increased organic content. Sediment contaminants can have adverse impacts on estuary plants and animals.

SOE monitoring to date has included the following larger estuaries in the Tasman region: Whanganui / Westhaven, Ruataniwha, Motupipi, Motueka Delta, Moutere and Waimea.[2] Estuaries in the Nelson Region include: Waimea, Nelson Haven, Delaware and Kokorua. The habitats described below are included in Report 2a (Berthelsen et al. 2023b), with key monitoring data now also reported for LAWA in the current report (Table 23). Although our report focuses on the Tasman Region, we have included information on Nelson estuaries here for completeness. Briefly, recent key SOE results and associated stressors for estuaries include:

Kokorua: A previous broadscale survey in 2015 and fine-scale monitoring in 2015, 2018, 2019 and 2020 identified excessive sediment muddiness as a key issue, particularly in the upper estuary arms; in contrast, the central and lower estuary arms are in relatively good condition (Scott-Simmonds et al. 2023 [forthcoming]). Overall, most condition indicators within Kokorua Inlet were rated 'very good' to 'good', reflecting large areas of remaining salt marsh, low nutrient enrichment and limited habitat modification. However, excessive fine sediment deposition remains an issue, with both mud extent and sedimentation rated 'poor'. The impacts of exotic forest harvesting, the most likely source of recent sediment inputs to the estuary, were evident.

Delaware Bay: The results and associated condition ratings of fine-scale monitoring (NEMP) in 2021 showed that, notwithstanding the issue of muddy sediment inputs (recognising increased exotic forest harvesting), the Delaware Inlet was in a reasonably healthy condition (Forrest and Stevens 2021a). This assessment was supported by a recent 'broadscale' habitat assessment (Stevens and Forrest 2019a) and was consistent with the 2009 report (Gillespie, Clement, et al. 2011), which stated that the Delaware study sites were 'within a range typical for relatively undisturbed to slightly enriched or productive estuarine conditions'. However, this condition appears to have changed markedly due to large-scale sediment inundation following a storm event on 18 August 2022 when 232 mm of

[2] See: https://www.tasman.govt.nz/my-council/key-documents/more/environment-reserves-and-open-space/environmental-monitoring-reports/?path=Other/Environment/Environmental%20Monitoring%20Reports/Coastal/Estuaries

rain fell in 36 hours at Hira. The flood waters and associated sediment loading buried many habitats, including cockle beds, in the estuary (pers. observ. Sean Handley; Stevens and Roberts 2022).

Nelson Haven: Overall, results indicate the main tidal flats of Nelson Haven are in a relatively healthy condition despite considerable historic modification of estuary margins, loss of salt marsh and wetland habitats, the development of a port and marina, and the removal of about 70% of the natural forest cover from the catchment (Forrest and Stevens 2021b). Improvements in ecological condition documented in wide-scale monitoring in 2019 (Stevens and Forrest 2019b) included a reduction in mud-dominated substrate and an increase in seagrass. However, these improvements appear to have been compromised by an increase in sediment load compared to the estimated natural state load. In addition, muddy sediment inputs (e.g. from urban subdivision and forest harvest) have been recognised as the main ongoing threat to the Haven (Forrest and Stevens 2021b). A sediment source tracing study identified that native forest and mature pine forest plantations produce very little sediment (Gibbs and Woodward 2017). However, forestry harvesting produces substantial amounts of sediment in the longer term. There is a period of 6 years when soil and slope protection is low; this period occurs between 2 years, when the replacement crop begins to reinforce the soil, and 8 years after harvesting, when all reinforcement effects of harvesting have disappeared (O'Loughlin and Watson 1979). Although pine forest is estimated to occupy 26% of the Maitai watershed, only a small proportion of that forest is harvested at any time, emphasising the requirement for implementation of an appropriate management strategy to reduce sediment yield during harvesting. Bank erosion is a major source of fine sediment. This material progressively moves downstream as a bedload, which then merges with other sediment to become an amorphous sediment source in the lower reaches of the river. Management strategies should identify and require mitigation to target the sources of bank erosion sediment.

Waimea (Waimeha) Inlet: Fine-scale assessments showed that the National Benthic Health Model (BHM) rated the impact from mud on Waimea Inlet macrofauna as 'moderate' to 'high' compared with other intertidal estuarine sites across New Zealand (Forrest et al. 2021). However, the overall impression provided by the suite of indicators and their associated health ratings is that the main tidal flats of Waimea Inlet are in a reasonably healthy state, retaining many areas of very significant ecological value (Stevens et al. 2020a). This is despite extensive historical habitat modification (impacts to estuary margins, loss of salt marsh habitat, and land development in the catchment), significantly reduced habitat diversity, and large areas of mud-dominated sediments. However, the key broadscale habitat stressors that threaten these values are the prevalence of mud-dominated substrate, the persistence of localised dense macroalgal beds and high enrichment conditions, and the pressures on salt marsh near the estuary margin from drainage and reclamation. Salt marsh losses are likely to increase in future in response to sea-level rise due to the current limited capacity for landward migration. There is a risk that the slow incremental degradation of sediments will exceed the mud tolerance of key species, whose populations could eventually decline, causing flow on effects to the wider ecosystem. Recent studies have highlighted agricultural land uses and exotic forest harvest as being key historic or ongoing contributors of sediment to the Waimea Inlet (Gibbs and Woodward 2018).

Moutere Inlet: Fine-scale monitoring has identified that soft sediment habitats in some parts of the Moutere estuary may reach a point at which the mud tolerance of key species (e.g. cockles, wedge shells) is exceeded, leading to a population decline (Forrest et al. 2022). Such an outcome could have flow on effects to the wider ecosystem, such as reducing important prey items for birds and fish. Elsewhere in the estuary, broadscale habitat mapping in 2019 (Stevens et al. 2020b) revealed areas that were very muddy and showed symptoms of high nutrient and organic enrichment. These included locations with excessive growths of opportunistic macroalgae species that can thrive in enriched muddy habitats. A recent study has highlighted that activity associated with exotic forestry land use (in particular, forest harvest with a 90% contribution; Gibbs and Woodward 2018) is a key contributor of sediment to the Moutere Inlet.

Ruataniwha estuary: Fine-scale monitoring in Ruataniwha estuary in 2016/2017 showed that the various physical and chemical indicators, NZ Hybrid AMBI scores and macroinvertebrate taxa analyses all indicated a muddiness issue in the upper estuary. In addition, poor sediment oxygenation and the consequent shift towards a more mud tolerant community indicate that the estuary condition has deteriorated since it was last monitored in 2001 (Robertson et al. 2017). Previous broadscale monitoring (Stevens and Robertson 2015) identified excessive muddiness as an issue in the estuary.

Whanganui (Westhaven) Inlet: 2015 fine-scale monitoring showed that overall there is currently a ‘HIGH’ risk of adverse impacts to the estuary ecology occurring because of the high sediment mud content, a ‘LOW’ or ‘MODERATE’ risk from organic and nutrient enrichment, and a ‘LOW’ risk from toxicants (Robertson and Stevens 2016). Despite the high mud content, the estuary had a diverse macroinvertebrate community typical of seagrass covered tidal flats. In contrast, a broadscale study of changes in seagrass extent between 1948 and 2021 showed beds were relatively stable between 1948 and 2013 before undergoing a very rapid decline (Stevens et al. 2022). Overall, 718 ha of high cover (> 50%) seagrass has been lost from the estuary since 1948, with most of the losses (531 ha, 74%) occurring in the 8 years between 2013 and 2021. The significant loss of seagrass in the last decade likely represented one of largest recent losses of seagrass recorded in Aotearoa New Zealand. The cause of the decline was postulated to be triggered by climate change: intense marine heat waves, which are known to cause acute and dramatic die-offs of seagrass meadows, were recorded in the summers of 2015/16, 2016/17 and 2018/19. Secondary impacts from the remobilisation of fine sediment following seagrass die-off were also likely. Regardless of the specific drivers of change, the loss of such a large area of high value habitat is of significant concern, particularly as it may signal that seagrass beds in other parts of the region and Aotearoa New Zealand are potentially vulnerable to rapid change.

Additional summary information on vulnerability assessment for TDC estuaries can be found in Report 1 of this project (Berthelsen et al. 2023c).

Table 23. Key details for data (mapped in our study) relating to state of the environment estuarine environmental monitoring – LAWA sites. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	State of the Environment (SOE) Estuarine Environment monitoring
Layer name	LAWAsites_EstuarineMonitoringSites
Data format and details	Point feature class.
Description	Estuarine monitoring sites in Nelson City Council (NCC) and Tasman District Council (TDC) estuaries. Data for Estuary Health Indicator (estuary macrofauna score) and Estuary Stressors (mud content, contaminants) are updated regularly by LAWA.
Source reference	Spatial data (monitoring site points) https://www.lawa.org.nz/explore-data/nelson-region/estuaries/, https://www.lawa.org.nz/explore-data/tasman-region/estuaries/ Monitoring sites only. Data can be downloaded from the LAWA website: https://www.lawa.org.nz/download-data
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Policy 19: Access to sites dependant on walking access, with potential for restrictions to protect habitats etc. (a)–(j). Policy 20: Access to sites dependant on vehicle access, with potential for restrictions to protect habitats etc. (a)–(g). Policy 21: Enhance or restore water quality (a)–(c), or protect / mitigate effects of cultural importance (e).

2.1.10. Mapua FCC contaminated site

Fruitgrowers Chemical Company (FCC) formerly operated an agrichemicals factory on a site in the small settlement of Mapua, 15 km west of Nelson. The site has the

Mapua Channel and the Waimea Inlet on two boundaries. The former use of the land left a legacy of contaminated soil, marine sediment and groundwater on and adjacent to the site (PDP 2009). The major contaminants of concern were organochlorine pesticides, which include DDT, DDD and DDE (collectively known as DDX), and aldrin, dieldrin and lindane (collectively known as ADL). A decision was made to remediate the site to prevent further effects on the marine environment and to restore the site to a usable condition. Following initial trials, works commenced in October 2004 and were completed in early 2008.

By 2009, it was considered that 'remediation to the extent practicable' had been broadly achieved in the marine foreshore areas (PDP 2009). It is clear that the remediation in these areas has not been successful in meeting the Soil Acceptance Criteria (SAC) for both DDX and ADL. However, redeposition of non-complying sediment from the surrounding marine environment probably meant that compliance with the SACs could not be achieved within the foreshore surface sediments. In addition, recontamination of the deeper backfill material has occurred during the remediation works. The mechanism(s) for this are not clear, but site run-off is probably a major contributor. Apart from the localised effects on the marine ecosystem, the effects of the residual sediment contamination on other receptors are not likely to be significant. However, it is probable there will be localised effects on the foreshore ecosystem at the point of discharge of the groundwater. Algal growth shows excess nutrients in the discharge, although the potential effects on the wider marine ecosystem are not expected to be significant because of dilution.

Remediation of groundwater could be considered to deal with local effects, but such consideration is premature (PDP 2009). Further monitoring is required to better assess the significance of the local effects. Remediation should only be considered if unacceptable effects are confirmed and such effects cannot be managed via other means. Remediation of groundwater would be expensive and the outcomes potentially uncertain; moreover, the work would need to continue for many years.

Remediation at the former FCC site in Mapua is the most heavily studied area adjacent to the marine environment at the top of the South Island. Soils at the site and two areas of foreshore were included in the remediation between 2004 and 2008. Moderate levels of nutrient enrichment were detected in the marine environment east and west of the site, resulting in anaerobic conditions or changes in community composition, perhaps in response to the nutrient enrichment. Present levels of pesticides in marine sediments have not resulted in a decrease in the invertebrate community diversity or abundance. Levels of chemicals in cockles were comparable to other areas of New Zealand considered representative of contaminated sites (i.e. close to large cities or development). Levels in cockles were below the United States and Canadian limits for the protection of human health. Levels of chemicals in mudflat snails were elevated west of the FCC shore, but levels fluctuated both down and up during 2009, 2010 and 2011; the elevated levels did not correspond to an increase in contaminant levels at the site, with the reasons unknown. Recommendations for future monitoring include the west FCC stream, where there is potential for recontamination in the central and upper area of this stream. Based on ongoing variability in contaminant levels at the site, continued monitoring of mudflat snail, cockle and top shells has been recommended.

Following the completion of the remediation project, marine sediment and selected species adjacent to the former FCC were regularly sampled by Davidson et al. (2010, 2011, 2012, 2016) with samples also collected by TDC staff in 2013, 2014 and 2015. From 2018 onwards, contaminants in sediment and selected marine species have been collected on three occasions (Davidson 2018; Davidson et al. 2019, 2022) (Table 24). Over the duration of the 13-year study (2010–2022), a decline in contaminant levels has been documented. In 2022, all but one surface and four deep sites met the SAC for ADL. For DDX, five shallow and most deep sites exceeded the SAC; however, levels continued to show a decline compared to 2010. Invertebrate contaminant levels showed a declining trend over the duration of the study.

Table 24. Key details for data (mapped in our study) relating to Mapua FCC contaminated site. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	Mapua FCC (FruitGrowersChemicalCompany) contaminated site
Layer name	a. MapuaFCC_InvertebrateSamplingSites b. MapuaFCC_SedimentSamplingSites
Data format and details	Point feature classes.
Description	Mapua Fruit Growers Chemical Company a) invertebrate sampling sites and b) sediment sampling sites (only site locations, no data included).
Source reference	Spatial data provided by Rob Davidson; Davidson et al. (2022).
Relevance to NZCPS	Policy 14: Potential to reduce success of restoration or rehabilitation. Policy 21(a)–(c),(e).

2.1.11. Disease, parasites and pests

Many diseases, parasites and pests have been identified in Golden Bay and Tasman Bay shellfish, some at high prevalence and intensity of infection (Michael et al. 2015). The effects of shellfish diseases have not been assessed in Nelson Bays, and the effects of environmental change and fishing activity on scallop and oyster disease mortality is unknown. Shellfish health is monitored at marine farms in the Tasman region (e.g. Major and McMullin 2021a, 2021b).

2.1.12. Algal blooms and 'slime' events

Slime events have been a recurring feature of Nelson Bays and other harbours around Aotearoa New Zealand since the 1860s (Ayson 1908; Hurley 1982). Slime events occurred in the Nelson Bays in the 1860s and 1901, 1960–62 and 1981. The pre-1981 events reportedly caused fish and shellfish mortalities, and in some areas, oysters (up to 80% mortality) and green-lipped mussels were affected more than scallops.

There were both spatial and temporal differences in the distribution of slime within the bays and the effects. Strong northwest winds (La Niña) and warmer seawater temperatures in the bays have been implicated in facilitating these blooms (Hurley 1982). Among a number of species of plankton cultured from samples of the 1981 'Tasman Bay slime', the colonial, non-motile, mucilage producing algae (*Phaeocystis pouchetti*) was identified as the most likely cause of the bloom. The bloom was first detected in July and continued through to November (Mackenzie et al. unpublished MS, cited in Bradford-Grieve et al. 1994).

Also refer to Section 2.1.9 (SOE estuarine environment monitoring) for further information on macroalgal blooms in estuaries.

2.1.13. Wildlife disturbance

Disturbance can cause adverse effects on indigenous taxa that are listed as threatened or at risk in the New Zealand Threat Classification System. Nine species of shorebird recorded from Tasman District are included in the current list (see Melville and Schuckard 2013; appendix 3). Shorebirds around the coasts of Tasman District are subject to a variety of direct and indirect threats, including disturbance, habitat loss and degradation, aquaculture and fisheries, pollution, exotic organisms, climate change and sea-level rise. These potential threats may impact on birds that are roosting, nesting or foraging, and the nature of these threats is further explained in Schuckard and Melville (2013). Relevant controls in the NZCPS, the Tasman Resource Management Plan (TRMP), the Conservation Act and the Reserves Act are also listed and discussed in Melville and Schuckard (2013). Areas of international significance are shown in Figure 9. Report 2a (Berthelsen et al. 2023a; appendix 4) provides key details for mapped data relating to sites of international importance for shorebirds in Tasman District. This includes layer names, data source and format, description and relevance to NZCPS. Note that the layer name relates directly to that in the spatial data inventory (see Appendix 1).

Figure 9. Sites of international importance for shorebirds in the Tasman District. Adapted from: Melville and Schuckard (2013), figure 1. Background aerial imagery is credited to the NZ Imagery map service (Eagle Technology, Land Information New Zealand).

Melville and Schuckard (2013) outlined the effects of selected activities on shorebirds in the Tasman District:

> Disturbance to high-tide [shorebird] roosts throughout the year is considered the most immediate threat facing these birds in this region. The next highest threat in Tasman District is disturbance to banded dotterel and variable oystercatcher breeding areas. Following the direct disturbance of birds, habitat degradation or destruction of high-tide roosting areas, breeding areas and feeding areas are the next most important threats (in that order). Dogs and people walking into important shorebird areas are significant threats in Tasman, as in many parts of the world. However, other threats including

> horse-riders, vehicles, marine craft, and aircraft, while coastal erosion and sea-level rise are also important in Tasman. A range of management methods including signage/education, dog control bylaws, and restricting public access are considered with advantages and disadvantages listed for each. It is recommended that the TRMP be reviewed to expand the rules regarding the effects of vehicles and craft (including hovercraft) to include disturbance that is likely to displace shorebirds from an area temporarily or long term. Schedule 25D of the Plan also needs revising to include the seven additional internationally significant sites: Westhaven (Whanganui Inlet), Pākawau, Totara Avenue / Collingwood, Rototai, Motueka Sandspit, West Waimea Inlet and East Waimea Inlet. Management actions are recommended specifically for each of the internationally-important shorebird areas in Tasman. (Melville and Schuckard 2013)

2.1.14. Sand extraction and relocation

The relocation of sand occurs at Kaiteriteri Beach (RM130673) and has occurred at Mārahau Beach (Davidson and Richards 2004a, 2004b, 2005; Figure 10; Table 25). These activities have the potential to impact on infaunal communities and disturb wildlife. Davidson and Richards (2005) reported on a 2-year study monitoring the impact of removing sand from the southern beach to replenish sand further north on the same beach. Ten sites were sampled for invertebrates and the area was habitat mapped. A total of 92 surface quadrats were sampled and 92 core samples were collected.

Davidson and Richards (2005) reported the following:

> A comparison of biological data collected from the initial pre-activity survey and the first post-activity survey showed no major changes that could be attributed to impacts from the sand extraction and deposition activities. Particular species did exhibit differences in abundance between the sample events, however, these changes were also often also recorded from the control sites suggesting that these changes were natural fluctuations.

Figure 10. Sampling sites (teal dots) in relation to sand extraction and deposition areas (indicative locations and extents shown in red) at Mārahau Beach. Adapted from: Davidson and Richards (2005). Background aerial imagery is credited to the NZ Imagery map service (Eagle Technology, Land Information New Zealand).

Table 25. Key details for data (mapped in our study) relating to sand extraction and deposition areas at Mārahau Beach. Information includes group and layer names, data format and details, description, source reference and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	SAND EXTRACTION AND RELOCATION
Layer name	Marahau_SandExtraction_SamplingSites
Data format and details	Point feature class generated from site coordinates supplied by Rob Davidson.
Description	Monitoring sites at which invertebrates were sampled during a 2-year study of the impact of sand removal and deposition at Mārahau Beach.
Source reference	Davidson and Richards (2005).
Relevance to NZCPS	Policy 11(a)(iv),(v),(b)(i),(ii),(iii),(iv),(v). Policy 20(1)–(3).

2.1.15. Vehicle disturbance to seabed

On 12 October 2010, TDC granted two 10-year consents for vehicle access and sand deposition at Mārahau in relation to a vehicle access way that enables various operators to launch and retrieve boats (RM100513, RM100144). As part of the consents, TDC applied monitoring conditions. The vehicle access way (i.e. between the ramp and where boats are launched and retrieved) is shown in (Figures 11, 12) (Davidson 2016). These data are outlined in Table 26. Although seagrass beds have declined over time in areas near the access way, damage is minimised by provision of the accessway, and it is monitored by DOC. Information on vehicle disturbance is also included in Natural Character Threats data included in Report 2a (Berthelsen et al. 2023a).

Table 26. Key details for data (unmapped in our study) relating to review of biological monitoring and protocols in relation to the vehicle access way across the Mārahau sand flats. Information includes data source and format, description and relevance to NZCPS.

Data source and format	Davidson RJ. 2016. Review of biological monitoring and protocols in relation to the vehicle access way across the Marahau sand-flats (2011 to 2016): 45. Also, non-notified consents RM100513, RM100144. Google Earth™ image, low resolution map (Figure 2 8, Figure 2 9).
Description	Review of biological monitoring and protocols in relation to the vehicle access way across the Mārahau sand flats.
Relevance to NZCPS	Policy 11(a)(iv),(v),(b)(i),(ii),(iii),(iv),(v). Policy 20(1)–(3).

Figure 11. Vehicle access way across Mārahau sand flats (red arrow). Aerial taken 21 January 2013. Source: Davidson (2016).

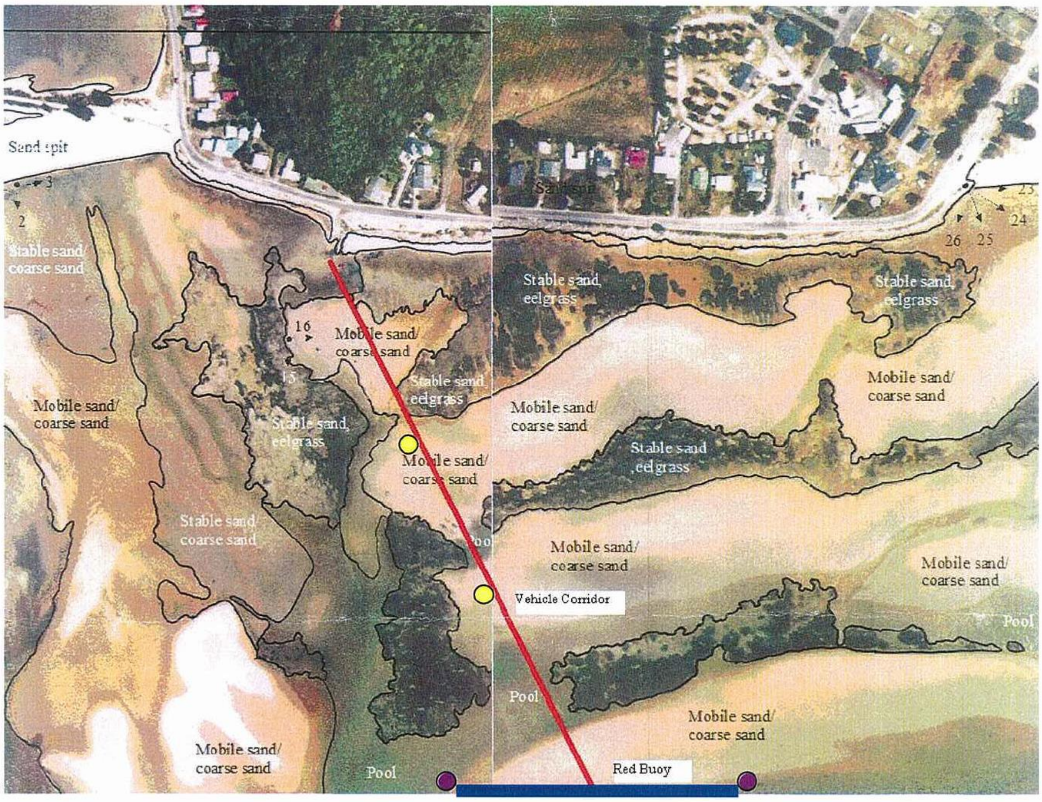

Figure 12. Plan A – Location of access corridor and mobile sand deposits. Source: non-notified consents RM100513, RM100144.

A launching access way in Whanganui Inlet is also present, but no monitoring has occurred (pers. comm. R. Davidson).

There is a track crossing the Waimea Inlet to Jackett Island; used periodically, this track is visible on Google Earth™ (pers. comm. L. Stevens, Salt Ecology; Figure 13). The vehicle (a 6-wheel 'Argo') crosses mostly sand and gravel, so its impact is relatively minor. There was some localised vehicle tracking evident along the inner-estuary upper-shore of Jackett Island, which was last observed during broadscale mapping carried out in 2019.

Figure 13. Uncontrolled access track across the Waimea Inlet to Jackett Island.

Disturbance by vehicles is also noted for habitats including seagrass, saltmarsh, rocky reef, and shell habitats in locations such as Westhaven, Mārahau, Kaiteriteri and Motueuka Sandspit at the general threat level (see Berthelsen et al. 2023a; appendix 4).

2.1.16. Disturbance from vessel moorings and anchoring

Two types of mooring are used in intertidal and subtidal locations.

Pole moorings

Pole moorings are usually long poles driven into the benthos that hold vessels in place. Vessels rise and fall with the tide; however, the vessels point of contact with the substratum is restricted to relatively small areas due to pole support and tethering. Physical disturbance appears limited to the small area where the keel or hull contacts the substratum. Davidson (2015) reported shell debris and organisms sometimes accumulate under vessels and have presumably become dislodged or been removed from the hull over time.

Swing moorings

Traditional swing moorings hold vessels at the bow via one or two anchors or blocks. Swing moorings can impact the seabed up to 5–10 m from a mooring block depending on the structure and depth (e.g. Sneddon 2010). For example, Davidson's (2015) study of the effects from moorings in Waikawa Bay, Marlborough did not represent a more than minor ecological impact to soft sediment because of:

- the small benthic areas affected relative to the amount of similar soft sediment habitat in the wider area
- the relatively depauperate epibiotic communities over much of the area proposed for the swing mooring zones, especially those in water depths greater than 7 m
- the absence of significant biogenic structures; and the resilient sediment infauna assemblages characterised by relatively high mobility, short generation times and high rates of recruitment and migration.

Impacts from moorings in the Tasman Region maybe similar to those above where benthic habitats are also similar (i.e. a sheltered mud benthos with a depauperate epibenthic community).

In the Tasman Region there are many sheltered subtidal embayments characterised by mud substrata. However, some sheltered harbours, estuaries and coastal embayments do support biological features of importance (e.g. tubeworm beds, horse mussel beds and shellfish beds). Refer to Report 2a (Berthelsen et al. 2023a; appendix 4) for relevant spatial information on these habitats or species for the Tasman (and Nelson) Region. A report by Davidson (2015) recommended that 'in areas that support sensitive or vulnerable habitats or species, moorings can be either excluded, removed or if permitted, adopt a structure or system that results in little or low impact'.

TDC and NCC are currently working on designating mooring zones for ships in Tasman Bay (pers. comm. Dan Cairney, TDC Harbour master).

Estuarine mooring zones

Davidson's (2015) report made recommendations for moorings zones in: Mangarākau wharf mooring area (Whanganui Inlet), Milnthorpe mooring area (Parapara Estuary), Ligar mooring area (Ligar Inlet / Tata Estuary), Boundary and Glasgow Bays (Abel Tasman National Park), Otūwhero Inlet (Abel Tasman coast, Mārahau), Kaiteriteri (Abel Tasman coast), Stephens Bay (Abel Tasman coast), Tapu Bay (Abel Tasman coast), Moutere delta (Tasman Bay), Moutere Inlet marina (Tasman Bay), Mapua Channel and Grossi Point (Waimea Inlet) (Davidson 2015). A Mooring Area layer was included in the TRMP through Plan Change 72 – Moorings and Coastal Structures, and made operative on 22 July 2022. The layer identifies the location of 11 Mooring Areas, which are subject to specific rules in the TRMP, which provide for the activity and occupation of the coastal marine area for the purpose of mooring (Table 27).

Table 27. Key details for mapped data relating to mooring areas located between Waimea Inlet and Whanganui Inlet. Information includes layer names, data source and format, description and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	Disturbance from vessel moorings
Layer name	TRMP_MooringAreas
Data source and format	Feature class (polygons) supplied by Tasman District Council (TDC) from Tasman Resource Management Plan (TRMP); Plan Change 72.
Description	The Mooring Area layer was included in the TRMP through Plan Change 72 – Moorings and Coastal Structures and made operative on 22 July 2022. The layer identifies the location of 11 Mooring Areas, which are subject to specific rules in the TRMP, which provide for the activity and occupation of the coastal marine area for the purpose of mooring, as a permitted activity, subject to the mooring owner holding a Mooring Licence issued under the Chapter 5a of the Tasman District Council Consolidated Moorings Bylaw 2023 by the Harbourmaster. Within the Mooring Areas, there are likely to be a number of moorings of which the location may not be specifically recorded. Some moorings within the Mooring Areas will hold a resource consent and the consented location of these moorings can be found under the TDC Resource Consent layer.
Relevance to NZCPS	Policy 14(c)(vii),(ix).

Anchoring

Anchoring by vessels can damage the seafloor and organisms that live on or within it. Davidson and Freeman (2013) described damage to a sensitive rhodolith bed from recreational anchor deployment along the Abel Tasman coast. TDC recently commissioned a survey of benthic habitats within the vicinity of proposed anchoring areas (Crossett and Clark 2023 [forthcoming]). Some data obtained from this survey (e.g. for horse mussel beds [layer name HorseMussels_TasmanBay]) were included in data layers associated with Report 2a (Berthelsen et al. 2023a; appendix 4).

2.1.17. Marine biosecurity

MPI have developed a Marine Biosecurity Porthole web tool that can be used to search for non-indigenous species incursions (including their biosecurity status) in the Nelson Region (Figure 14; Table 28).

Table 28. Key details for mapped data relating to the Marine Biosecurity Porthole. Information includes layer names, data source and format, description and relevance to NZCPS. Group and layer names relate directly to those in the spatial data inventory (see Appendix 1).

Group name	MARINE BIOSECURITY
Layer name	Marine Biosecurity Porthole: https://marinebiosecurity.org.nz/search-for-species
Data format and details	Data not included, but link supplied.
Description	The Marine Biosecurity Porthole contains the most complete source of information on the national distribution of non-native marine species in Aotearoa New Zealand. Distribution records in the portal come from four principal sources: Port Biological Baseline Surveys (including indigenous species); National Marine High Risk Site Surveillance; Marine Invasive Taxonomic Service; Other verified observations of non-native marine species.
Source reference	Link to portal: https://marinebiosecurity.org.nz/search-for-species; Report: Seaward et al. (2015).
Relevance to NCPS	Policy 14(c)(ii).

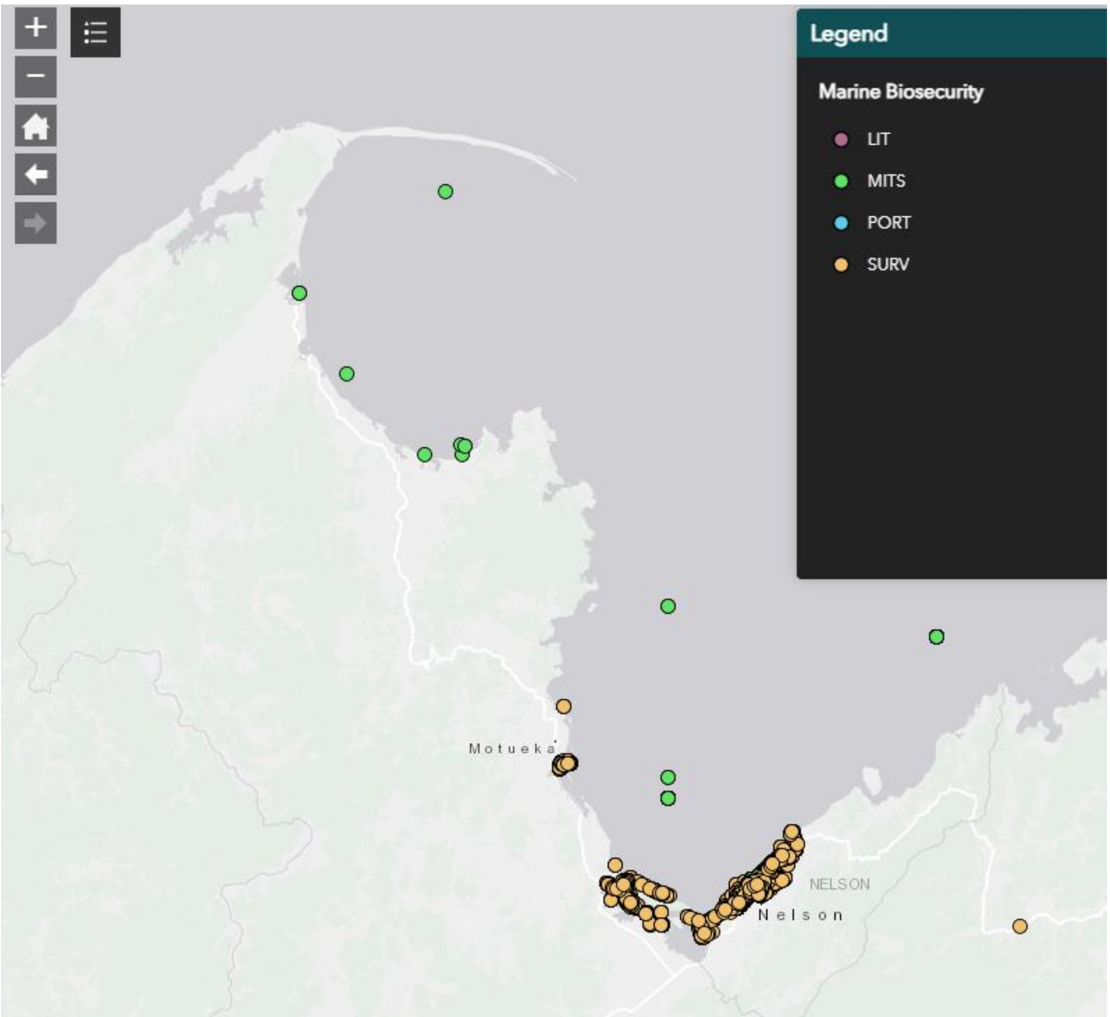

Figure 14. Marine Biosecurity Porthole interactive web tool. Screenshot showing records of non-native marine species in Tasman and Golden Bays from various sources: Marine Invasive Taxonomic Service (MITS, green dots), National Marine High Risk Site Surveillance (SURV, yellow dots) and Port Biological Baseline Surveys (PORT, blue dots at Port Nelson concealed by SURV). Source: https://www.marinebiosecurity.org.nz/search-for-species/.

3. INFORMATION GAPS AND RECOMMENDATIONS FOR FUTURE WORK

Information gaps and recommendations for future work in relation to effects of human activities on the marine environment (Tasman Region) are summarised below. These are provided at a high level and are not exhaustive.

3.1. Sediment load from catchments

An example of a knowledge gap for catchment sediment loads relates to the spatial extent of diffuse key stressors, including fine sediments, once they are discharged from riverine sources. The use of sediment source tracing techniques (e.g. Gibbs and Woodward 2017, 2018) could potentially be used to understand the extent of sediment contaminants in Nelson Bays. Existing soils source libraries could thus be used to map the spatial extent of effects stemming from land-based disturbance.

3.2. Benthic disturbance

An example of future work relating to effects of activities that will fill a data gap is the compilation of an initial inventory of the organic carbon stocks in marine sediments around Aotearoa New Zealand. This could potentially enable investigation of the potential impacts of bottom trawling and other anthropogenic activities upon the release of this sediment carbon into the water column. A report on this subject is expected to be released later this year (2023).

3.3. Terrestrial nutrients and contaminants

The erosion and transport of fine sediment has the potential to contribute to diffuse nutrient effects or aid the transport of contaminants. This is because small particles of clay that include metal ions can bind with contaminants or nutrients such as phosphorus. Those contaminants or nutrients can be locked up by the clay particles and then be transported and deposited onto the seabed. Under anaerobic conditions, phosphorous can be released again, potentially fueling algal production of unknown extent. The potential spatial extent of diffuse nutrient or contaminant effects could be evaluated if chemical analyses were combined with a soil-source sediment mapping study (see 3.1 above).

The following list summarises other data gaps in respect to land-based contaminants:

- Reference nutrient, trace metal and bacterial loading data for intermittent wastewater / stormwater discharges

- Baseflow / high-flow characterisation of nutrient, trace metal, oil and grease and bacterial data for river / stream discharges
- Pollution source apportionment / quantification tools
- Baseline characterisation of water quality effects of port / harbour / fishing activities, including commercial and recreational vessel discharges
- Integrated water quality monitoring using satellite and *in situ* buoy data to describe baseline conditions / contamination hot spots
- Trend analysis and mapping of water quality monitoring data to identify critical activities, sensitive receptors and tipping points
- Eutrophication (and sedimentation) vulnerability assessment, e.g. still to be completed for some estuaries (refer to SOE monitoring section below).
- Emerging contaminants such as pharmaceuticals and pesticides (e.g. fate, transport, transformation, effects of chemical mixtures).
- Review of impacts of marine litter including as habitat and vector for pathogen dispersal.

Further background on plastics

Microplastic particle (< 5 mm) waste are a potential contaminant of significance to aquatic and human health, with 710 million tons of plastic waste estimated to enter the world's marine environment by 2040 (Jambeck 2015; Lau et al. 2020). Microplastics can impact benthic communities and microbial functions and have been shown to affect the ability for microbes to process carbon and other nutrients (Seeley et al. 2020), potentially contributing to heavy metal build-up. The bioaccumulation of microplastics by filter-feeders like mussels could potentially pose risks for human health (Barboza et al. 2018; Chamas et al. 2020; Huang et al. 2021; Ugwu et al. 2021). Little is known about the quantity, fate or dispersion of microplastics in Aotearoa New Zealand (Tremblay et al. 2020) and therefore also in Nelson Bays. A study comparing microplastic particle concentration between Picton and a site approximately 30 km away in the Long Island - Kokomohua Marine Reserve, Queen Charlotte Sound found distal sites had four times the microplastic accumulation as compared to near the coastal township (Ribó et al. 2023 [forthcoming]). Differences in the spatial and temporal accumulation of microplastics were also identified. A media article reported that local residents have expressed concern about pollution of microplastics and debris washed ashore from mussel farming in Golden Bay (Stuff 2020[3]). An ocean plastic simulator has also been recently developed for Aotearoa New Zealand to track plastic particles in the ocean (https://ocean-plastic-simulator.cawthron.org.nz/). This tool could be used in the future to understand the movements of floating macroplastics in the Tasman Region. The Aotearoa Impacts and Mitigation of Microplastics (AIM²) is a national research programme that aims to

[3] https://www.stuff.co.nz/environment/122767725/golden-bay-residents-survey-reveals-negative-effects-from-mussel-boat-noise

determine the impacts of microplastics in Aotearoa New Zealand. Some of this research is being carried out in the Nelson Region.[4]

3.4. SOE estuarine monitoring

There are various information gaps for threats to estuaries in the Tasman (and Nelson) Region.

No assessments of ecological vulnerability are known to have been undertaken for the estuaries in Abel Tasman National Park, and the most recent habitat mapping data are from 1991 (see Davidson 1992). Changes in habitat features are almost certain to have occurred in the interim. The previous assessments of ecological vulnerability undertaken in 2012 for Tasman (Robertson and Stevens 2012), and 2017 for Nelson (Stevens and Robertson 2017), were limited in scope and did not include all estuaries in the regions. Improvements to assessment criteria have subsequently been made to reduce subjectivity and improve consistency in the assessment of estuary state and identification of pressures (e.g. Roberts et al. 2022). Reviewing the assessment criteria and pressures to key estuaries is recommended.

Fine sediment stands out as a key stressor noted in most of the reviewed SOE monitoring sites (see Section 2.1.9). Existing soil source libraries (e.g. Gibbs and Woodward 2017, 2018) could be used to monitor compliance of land-based management measures implemented within catchments in response to recommendations in those reports. For example, the CSSI method is being used for compliance monitoring in the Whangamarino wetland following an Environment Court Decision.[5]

3.5. Disease, parasites and pests

There is a poor understanding of disease, parasites and pests of habitat-forming species, including shellfish, and their relationship with historic declines (see Berthelsen et al. 2023a). There is, therefore, wide scope to monitor remnant populations or use sacrificial 'sentinel' animals to understand the role of disease, parasites and pests. This work could also include exploring relationships between stressors such as climate change, sedimentation and sediment resuspension to understand the resilience to diseases, especially for habitat-forming species.

[4] AIM2 microplastics project on Vimeo: https://vimeo.com/658398203
[5] Environment Court Decision No. [2018] NZEnvC 202 – Whangamarino Wetland

3.6. Marine biosecurity

An example of an information gap, beyond Marine High Risk Surveillance sites (e.g. Port Nelson and Mapua), is the limited understanding of the spatial extent and temporal spread over time of invasive species incursions (e.g. *Styela clava*). This information could be valuable in understanding how species and habitats might be changing in response to invasive species, and the rate and extent of their spread.

3.7. Underwater noise pollution

All marine mammals are potentially vulnerable to disturbance by anthropogenic noise (e.g. Croll et al. 2001; Nedwell and Howell 2004; Nowacek et al. 2007). Significant noise levels may arise from construction such as piledriving, explosive or seismic work, ramming, drilling and dredging operations. Although short-term, these may be damaging to marine mammals in the area (Madsen et al. 2006). A study of the exposure to underwater broadband sound fields resembling offshore shipping and construction activities were found to alter sediment-dwelling invertebrate contributions to fluid and particle transport – key processes in mediating benthic nutrient cycling (Solan et al. 2016). Noise-associated changes in behaviour of some functionally important species depends on the class of broadband sound (continuous or impulsive). How noise pollution is affecting marine biota in the Tasman Region is a data gap of unknown extent.

3.8. Climate change

There are data gaps for additional effects of activities in the Tasman Region including, for example, the effects of climate change (impacts are ongoing and are predicted to increase in the future). Further consideration of this is outside the scope of our report.

3.9. Setting priorities for filling research gaps and future work

To address the widespread modification of marine ecosystems in Nelson Bays impacted by a wide range of anthropogenic effects and activities, a 'Conservation by Design' project is currently underway, led by The Nature Conservancy, which is working on behalf of the Kotahitanga mō te Taiao Alliance (KMTT, May 2023) and includes Te Tauihu Councils. High-level outcomes of this project currently prioritise habitat restoration or rehabilitation initiatives around the focal point of shellfish. Shellfish are an important group throughout Te Tauihu for their role as keystone species that provide biogenic habitat, water filtration, sediment binding and sustenance to the ecosystem. The project has also highlighted the need to better understand the scale and sources of the key threats to marine ecosystems in Te Tauihu and the options for mitigating these threats, particularly with regards to shellfish. For example, threats such as sedimentation relate to impacts on remnant habitats (Policy 11) or those that might affect the success of restoration or rehabilitation (Policies 14, 21). The progress of this project will be important in determining priorities, identifying knowledge gaps, and determining restoration or rehabilitation actions on land and in Nelson Bays.

4. APPENDICES

Appendix 1. Tasman and Nelson coastal marine environments: spatial data inventory

Spatial data layers for the overall project (including those relevant to effects of activities) are supplied as part of an ArcGIS Pro project package (spatial data inventory, TasmanNelsonCoastalEnvironment_SpatialData.ppkx). Datasets available in spatial format were imported to an ArcGIS Pro (version 3.0.1) project (.apr) and presented in the Effects of Activities map. In the map's contents panel (shown in Figure A.1), group layers and sub-groups can be expanded to view and turn on or off individual data layers. Key details for mapped data are outlined in tables (presenting available, i.e. 'mapped' data, tabulated in white) in the report text and are appended to data layers as metadata, accessible through layer properties. These include group and individual layer names (as they appear in the spatial data inventory), data format, details, description and source reference.

Data layers collated for the other reports in this overall project are also included in the spatial data inventory and are presented in a series maps associated with each report (Berthelsen et al. 2023a, 2023b, 2023c; Handley et al 2023). The ArcGIS Pro project was packaged to form the project package (TasmanNelsonCoastalEnvironment_SpatialData.ppkx) and its associated geodatabases, which include all the data layers.

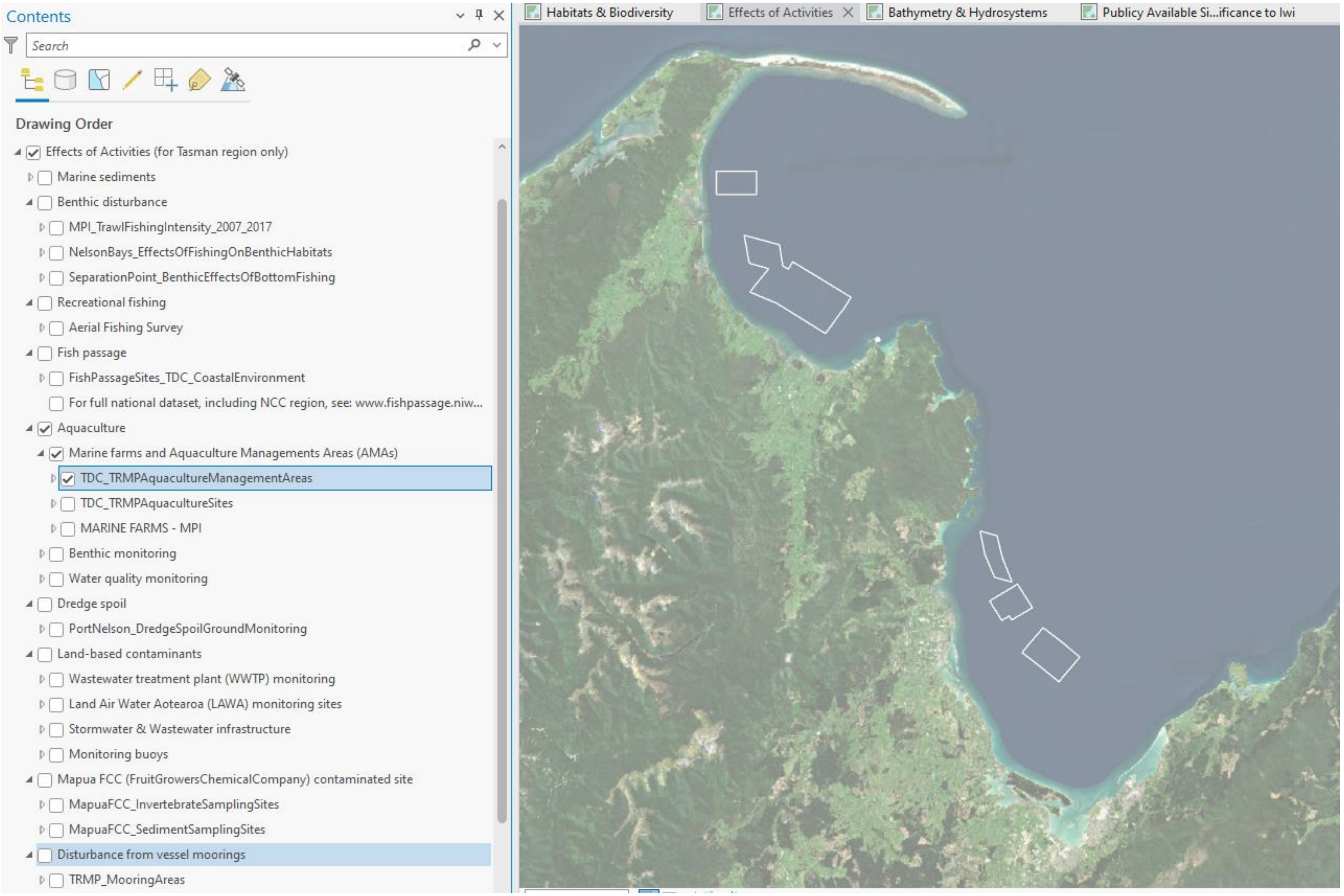

Figure A1. Screenshot of our ArcGIS Pro project package to demonstrate the layout to package users.

Appendix 2. New Zealand Coastal Policy Statement: policies relevant to this report (on effects of human activities)

Policy 14 Restoration of natural character

Promote restoration or rehabilitation of the natural character of the coastal environment, including by:

(a) identifying areas and opportunities for restoration or rehabilitation;

(b) providing policies, rules and other methods directed at restoration or rehabilitation in regional policy statements, and plans;

(c) where practicable, imposing or reviewing restoration or rehabilitation conditions on resource consents and designations, including for the continuation of activities; and recognising that where degraded areas of the coastal environment require restoration or rehabilitation, possible approaches include:

(i) restoring indigenous habitats and ecosystems, using local genetic stock where practicable; or

(ii) encouraging natural regeneration of indigenous species, recognising the need for effective weed and animal pest management; or

(iii) creating or enhancing habitat for indigenous species; or

(iv) rehabilitating dunes and other natural coastal features or processes, including saline wetlands and intertidal saltmarsh; or

(v) restoring and protecting riparian and intertidal margins; or

(vi) reducing or eliminating discharges of contaminants; or

(vii) removing redundant structures and materials that have been assessed to have minimal heritage or amenity values and when the removal is authorised by required permits, including an archaeological authority under the Historic Places Act 1993; or

(viii) restoring cultural landscape features; or

(ix) redesign of structures that interfere with ecosystem processes; or

(x) decommissioning or restoring historic landfill and other contaminated sites which are, or have the potential to, leach material into the coastal marine area.

Policy 19 Walking access

(3) Only impose a restriction on public walking access to, along or adjacent to the coastal marine area where such a restriction is necessary:

(a) to protect threatened indigenous species; or

(b) to protect dunes, estuaries and other sensitive natural areas or habitats; or

(c) to protect sites and activities of cultural value to Māori; or

(d) to protect historic heritage.

Policy 20 Vehicle access

(1) Control use of vehicles, apart from emergency vehicles, on beaches, foreshore, seabed and adjacent public land where:

(a) damage to dune or other geological systems and processes; or

(b) harm to ecological systems or to indigenous flora and fauna, for example marine mammal and bird habitats or breeding areas and shellfish beds; or
(c) danger to other beach users; or
(d) disturbance of the peaceful enjoyment of the beach environment; or
(e) damage to historic heritage; or
(f) damage to the habitats of fisheries resources of significance to customary, commercial or recreational users; or
(g) damage to sites of significance to tangata whenua;
might result.

Policy 21 Enhancement of water quality
Where the quality of water in the coastal environment has deteriorated so that it is having a significant adverse effect on ecosystems, natural habitats, or water based recreational activities, or is restricting existing uses, such as aquaculture, shellfish gathering, and cultural activities, give priority to improving that quality by:
(a) identifying such areas of coastal water and water bodies and including them in plans;
(b) including provisions in plans to address improving water quality in the areas identified above;
(c) where practicable, restoring water quality to at least a state that can support such activities and ecosystems and natural habitats;
(d) requiring that stock are excluded from the coastal marine area, adjoining intertidal areas and other water bodies and riparian margins in the coastal environment, within a prescribed time frame; and
(e) engaging with tangata whenua to identify areas of coastal waters where they have particular interest, for example in cultural sites, wāhi tapu, other taonga, and values such as mauri, and remedying, or, where remediation is not practicable, mitigating adverse effects on these areas and values.

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