A review of available information for the open coastal waters of the Manawatū-Wanganui Region

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Cover image: MODIS image of the lower North Island from the Aqua satellite, April 29, 2011. NASA Earth Observatory.

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Executive summary

The coastal marine area (CMA) of the Manawatu-Wanganui (Horizons) Region encompasses approximately 3,000 km^2 of Territorial Sea comprising distinct and separate western and eastern coastlines. Horizons Regional Council (HRC) manages the CMA in accordance with its combined Regional Policy Statement and Regional Plan (the One Plan), a key objective being to ensure that the natural character and ecosystem processes are maintained while still allowing activities and development.

Previously completed (e.g. Envirolink 1624-HZLC127) and current coastal projects focus on habitat mapping of the region's estuaries and provide further monitoring recommendation for these habitats. Coastal water quality monitoring is conducted at selected estuaries and beaches for State of Environment and contact recreation monitoring programmes but does not include sampling or habitat assessments beyond the intertidal areas. This is insufficient to fullfill the One Plan objectives. HRC has recognised that there is potential for pressures on the Region's coastal environment to increase and acknowledges that to ensure natural character and ecosystem processes are maintained, it first needs to know what and where they are. Thus, HRC seeks to establish a baseline inventory of what is currently known about the state of the coastal environment to inform State of the Environment (SoE) reporting and coastal resource management.

This report, funded through MBIE Envirolink Advice Grant 1817-HZLC140, presents a compilation of existing accessible baseline information and knowledge on the Horizon Region's coastal environment, supplemented with information for other regions where this provides an example of the types of information that could be provided for HRC if further funding was available. The focus is on the open coastal waters, beyond the Region's estuarine and intertidal zones, with the aim of assisting HRC to more fully evaluate its coastal environment and monitoring requirements.

An initial workshop with HRC established this report would summarise available information relevant to the Horizons CMA, including ocean physical data, sediment source tracking, primary production, zooplankton, marine benthic habitats, benthic invertebrates, threatened or vulnerable species (including corals and other sensitive marine environments, marine mammals, and seabirds), marine fish, commercial fishery catch and effort, and threats and hazards to the CMA.

The report establishes there is a wealth of physical oceanographic data available to draw upon to describe the ocean properties along Horizon's western CMA in the South Taranaki Bight (STB). These data have been used to compile and calibrate a sophisticated oceanographic model that describes ocean flows and sediment transport processes in the STB, including HRC's western CMA. Primary production in the STB, including HRC's western CMA, has also been been investigated and modelled in detail. There are some data available to describe the basic characteristics and dynamics of zooplankton communities in the STB, although few data have been collected from HRC's western CMA and none from the eastern CMA. There are no existing detailed maps of the distribution of seafloor sediments or biogenic habitats in HRC's eastern or western CMAs. NIWA's sampling intensity of marine invertebrates in Horizons CMA is low, but nonetheless a detailed summary and analysis of existing information may suggest the likely distribution of biogenic habitat forming species and the distribution of corals and other vulnerable species. Existing likelihood distribution models of a range of threatened or vulnerable seafloor species and marine mammals are available to be interrogated or are nearing completion. These could yield more detailed analysis of occurrence and distribution of these species within HRC's CMA. Likewise, existing likelihood models of reef fish and demersal fish distribution and abundance would yield detailed maps for many species occurring in HRC's western and eastern CMAs. Good information on the distribution of commercial fishing effort and catch in HRC's western CMA exists and is publicly available. There has been no similar compilation of fishing catch and effort for the eastern CMA. The relative importance of a wide range of anthropogenic threats to the types of marine habitats in HRC's CMA is broadly understood. Detailed assessments of these threats, including sea level rise, at specific localities within the CMAs have not been undertaken. The existing Marine Habitat Assessment Decision Support (MarHADS) tool has potential application to the Horizon's CMA by providing a mechanism to pull together a disparate range of information to undertake an overall assessment of marine habitat vulnerability and value.

The report identifies 16 significant information gaps and suggests a two-phase approach to filling those gaps. In the first phase, substantial additional information could be extracted from existing databases and models that was beyond the resources available in this project. This includes information on:

- ocean physical data in HRC's western CMA,
- patterns of primary production in the eastern CMA,
- derived continuous maps of seafloor sediment grain size and carbonate content for the eastern and western CMAs,
- seafloor biotic sampling information for both CMAs,
- selected threatened or vulnerable seafloor species and marine mammals, seabirds, reef and demersal fish for both CMAs, and
- commercial fishing in the eastern CMA.

Extraction of these existing data and accompanying expert interpretations should be the first priority as they would be relatively straight forward and cost effective to undertake, and provide an up-to-date summary of available information with which to set the subsequent gap filling priorities.

The second phase would involve commissioning of new data collection and interpretation. This work may need to be prioritised and spread over a number of years to be affordable. This phase includes (in no particular order):

- investigation of coastal processes along HRC's eastern CMA,
- building a library of reference source soils from different land-use within HRC catchments and applying the Compound Specific Stable Isotope (CSSI) method to identify the sources of terrigenous sediments deposited in HRC's CMAs,
- investigating the spatial and temporal variation in zooplankton communities within HRC's eastern CMA,
- multibeam swath mapping of the sea floor in both CMAs,
- undertaking spot ground truthing of putative seafloor habitats identified during swath mapping,
- assessing the impact of projected sea level rise on coastal habitats and infrastructure in HRC's eastern and western CMAs, and

- applying the MarHADS tool to the putative extremes of degradation for a selected habitat(s) occurring within HRC's eastern or western CMA.

We suggest that the first priorities for any new data collection in the second phase of work should relate to the source, fate and impact of terrigenous sediments entering HRC's western and eastern CMAs, and the likely impacts of sea level rise. However, there may be other priorities that warrant further discussion to identify those that best meet HRC's One Plan objectives. To lower overall costs, some of the Phase 2 work could be undertaken in collaboration with adjacent regional councils, where there would be a common interest in the knowledge gained.

1 Introduction

1.1 Background

The Manawatu-Wanganui (Horizons) Region's coastal marine area (CMA) encompasses approximately 3,000 km^2 of Territorial Sea comprised of distinct and separate western and eastern areas in the Tasman Sea and Pacific Ocean, respectively (Figure 1-1). The west coast spans approximately 120 km from Waiinu Beach in the north of the Region to Waikawa Beach in the south. This section of coastline is characterised by narrow sandy beaches backed by sea cliffs in the north, and sandy beaches backed by a dynamic dune system from Wanganui southwards. The Region's east coast is shorter in length, extending approximately 40 km from Cape Turnagain south to the Owahanga River mouth, and is characterised by rocky platforms backed by cobbled or sandy beaches dotted with boulders (Horizons One Plan, 2016).

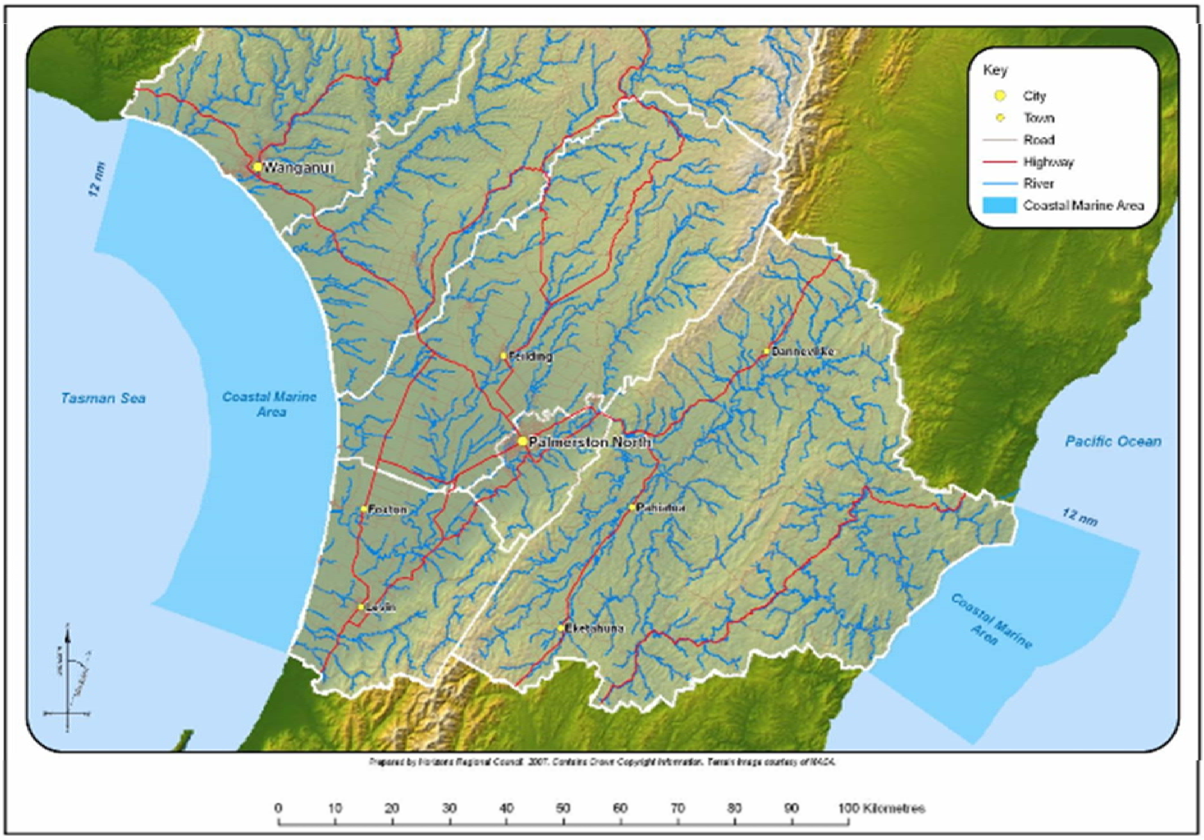


Figure 1-1: Coastal marine area for the Manawatu-Wanganui (Horizons) Region. (Reproduced from the One Plan 2014, p8-3).

To date there has been a low demand for activities in the CMA. Only 46 coastal permits were operative in 2005 and the area landward of Mean High Water Springs (MHWS) has not faced the same level of development pressure that has been experienced in most other regions of New Zealand (Horizons One Plan, 2016). However, Horizons Regional Council (HRC) has recognised that there is potential for pressures on the coastal environment to increase and therefore seeks to establish a baseline inventory of what is currently known about the state of the coastal environment to inform State of the Environment (SoE) reporting and coastal resource management. HRC has already implemented habitat mapping of the region's estuaries and has a programme in place for fine scale monitoring of these coastal habitats. Coastal water quality monitoring is also conducted by

HRC at selected estuaries and beaches for SoE and contact recreation monitoring programmes but this does not include sampling or habitat assessments beyond the intertidal areas.

This report, funded through MBIE Envirolink Advice Grant 1817-HZLC140, presents a compilation of existing accessible baseline information and knowledge on the Horizon Region's coastal environment, supplemented with information for other regions where this provides an example of the types of information that could be provided for the HRC if further funding was available. The focus is on the open coastal waters, beyond the Region's estuarine and intertidal zones, with the aim of assisting HRC to more fully evaluate its coastal environment and monitoring needs.

1.2 Approach

The project was structured into two parts to provide information for HRC's upcoming SoE report and advice on coastal resource management options:

1. An initial workshop to identify Horizons' knowledge gaps and coastal monitoring needs and match these with available information and expertise within NIWA.
2. A report summarising the information available describing the Region's open water coastal resources, identification of monitoring gaps, and recommendations for further research to advance Horizons' knowledge and understanding of the coastal environment.

1.3 Planning Context

Coastal resource management issues and rules for the Horizons Region are set out in the Horizons One Plan, a combined Regional Policy Statement and Regional Plan. Chapter 8 of the RPS provides an overview of the Region's coastal resources and lists three significant resource management issues for the Horizons CMA:

- <u>Issue 8-1: Integrated management of the coastal environment</u>
  Integration of different agencies' management frameworks across the landward boundary of the CMA is critical for the sustainable management of the coast and the protection of natural character. There is a need to recognise that activities landward of MHWS impact on the quality of the CMA. There are also some activities that should be managed in the same manner irrespective of their location within or outside of the CMA.

- <u>Issue 8-2: Appropriate protection, use and development in the CMA</u>
  Some activities rely on a coastal location to operate and need to be located in the CMA - for example, a port. Activities in the CMA, including aquaculture or renewable energy generation, have the potential to create benefits but also the potential to cause adverse effects, if not managed appropriately. Generally, the CMA is valued and enjoyed by people primarily for its natural character, open space, amenity, tikanga Māori and recreation values. In managing activities, it is important to ensure that these qualities of the coast are retained and that the integrity of natural coastal processes (such as waves, currents and sand movements) is provided for.

- <u>Issue 8-3: Water quality</u>
  Water quality affects the life-supporting capacity of the CMA as well as people's enjoyment of the CMA. The water entering the CMA from rivers, including streams, has a significant impact on the quality of water in the CMA.

A series of objectives, policies and methods are set out in the One Plan to address these issues (e.g., aquaculture activities in the CMA require the establishment of an aquaculture management area by way of a notified change to Chapter 18 of the One Plan; water quality is to be maintained or enhanced with the CMA divided into a Seawater Management Zone and various Estuary Water Management Subzones with water quality targets set in place under Schedule I as a guide for decision-makers). Method 8-4 (Coastal Information) has the aim to support the collection of further information on biology, coastal processes, historic heritage and significant sites and values in the CMA. The long term target under this method is to progesssively aim to improve the coastal information base. The outcomes and recommendations of this Enviroloink project are in exact alignment with this One Plan target, and following the recommendations in this report would align to the Council's goals.

The key objective in managing the CMA is to ensure that the natural character and ecosystem processes are maintained while still allowing activities and development. The RPS also recognises that most adverse effects in the CMA result from landward uses and development.

Chapter 18 (Activities in the Coastal Marine Area) of the One Plan sets out the rules for various activities that can be carried out in the CMA, including the status of activities in relation to resource consent requirements. Chapter 18, together with Schedule I and Chapters 11, 12 and 19 form the Regional Coastal Plan under the RMA. Activities addressed in Chapter 18 include occupation, structures, reclamations and drainage, disturbances, removal and deposition, water takes (incl. uses, damming and diversions), discharges, noise, and exotic and introduced plants. Schedule I (27 pp) addresses CMA Activities and Water Management. It includes maps of the west and east coast CMA and associated river mouths and estuary water management subzones (Part A), as well as tables of activity management areas in Part B.

Previously completed (e.g. Envirolink 1624-HZLC127) and current coastal projects focus on habitat mapping of the region's estuaries and provide further monitoring recommendation for these habitats. Coastal water quality monitoring is conducted at selected estuaries and beaches for State of Environment and contact recreation monitoring programmes, but does not include sampling or habitat assessments beyond the intertidal areas. This is insufficient to insufficient to fullfill the One Plan objective.

2 Workshop

A workshop was held at HRC on 25 August 2017. Attendees are listed in Table 2-1. HRC staff summarised Horizons' previous work in the CMA, the drivers stemming from the RPS and One Plan for the need for more comprehensive information on the marine environment, the lack of resources and expertise within HRC to provide this information, and hence the need for this project with NIWA. NIWA participants then provided an overview of the sorts of information that could be drawn upon to fill some of the information gaps in Horizons CMA, and provided examples of information gathering and collation undertaken for other parties. The workshop clarified that the NIWA report will:

1. Detail the availability of the following information, and where possible provide illustrative examples of:
   - Ocean physical data (wave climate, currents, temperature, salinity, suspended sediments, river inputs, etc.)
   - Primary productivity
   - Zooplankton sampling
   - Marine habitats
   - Benthic invertebrate species records
   - Distribution of threatened / vulnerable species (e.g. corals, marine mammals, seabirds)
   - Distribution of fish (reef, demersal, pelagic)
   - Distribution of fisheries effort and catch
   - Threats and hazards including sea level rise and relevant threat assessments.
2. Describe the Marine Habitat Assessment Decision Support (MarHADS) tool – prepared for councils under Envirolink – and potential application to the Horizons coastal area.
3. Identify gaps in knowledge and map out a phased approach to filling those gaps.

Table 2-1: Participants in Horizons/NIWA joint workshop, August 2017.

Name	Institution	Area of expertise or responsibility
Alison MacDiarmid	NIWA	Regional Manager – marine ecology, anthropogenic threats, risk assessment
Juliet Milne	NIWA	Resource Management Scientist – water quality, environmental monitoring, RMA, environmental assessment
Janine Kamke	Horizons	Water Quality Scientist
Abby Mathews	Horizons	Science and Innovation Manager
Jon Roygard	Horizons	Group Manager, Natural Resources and Partnerships

3 Available information

This section summarises available information relevant to the Horizons CMA, including ocean physical data, sediment source tracking, primary production, zooplankton, marine benthic habitats, benthic invertebrates, threatened or vulnerable species (including corals and other sensitive marine environments, marine mammals, and seabirds), marine fish, commercial fishery catch and effort, and threats and hazards.

3.1 Ocean physical data

Ocean physical data, able to characterize the ocean and coastal domain for the areas of interest, are available from a variety of sources; NIWA's Conductivity, Temperature and Depth (CTD) database, NIWA's oceanographic mooring database, International Argo Float data, NIWA Glider data along selected tracks, remote sensed data, and ship-based underway sampling/measurements using a variety of instruments. Wave data can also be hindcast for an area given knowledge of wind direction and strength, fetch, and seafloor bathymetry. Finally, these data can be used to construct and/or calibrate a computer model of the oceanography for a particular region that can yield a detailed understanding of water movement throughout the modelled area. Each of the above sources of information is described and illustrated below using examples prepared for different areas around New Zealand.

3.1.1 NIWA CTD data

This database typically comprises water temperature and salinity data from near surface to near bottom taken from a ship at a specific location or station on a particular date. Sampling is usually done once at each site, so provides a snapshot of the water column at that time. Some stations also collect oxygen, fluorescence (e.g. for chlorophyll-a determination), turbidity, and photosynthetically active radiation (PAR) data. Bottle samples may also be collected using the CTD instrument, and these will have been post-processed for analysis of nutrient content and other parameters. An example of CTD stations in the Bay of Plenty is provided in Figure 3-1.

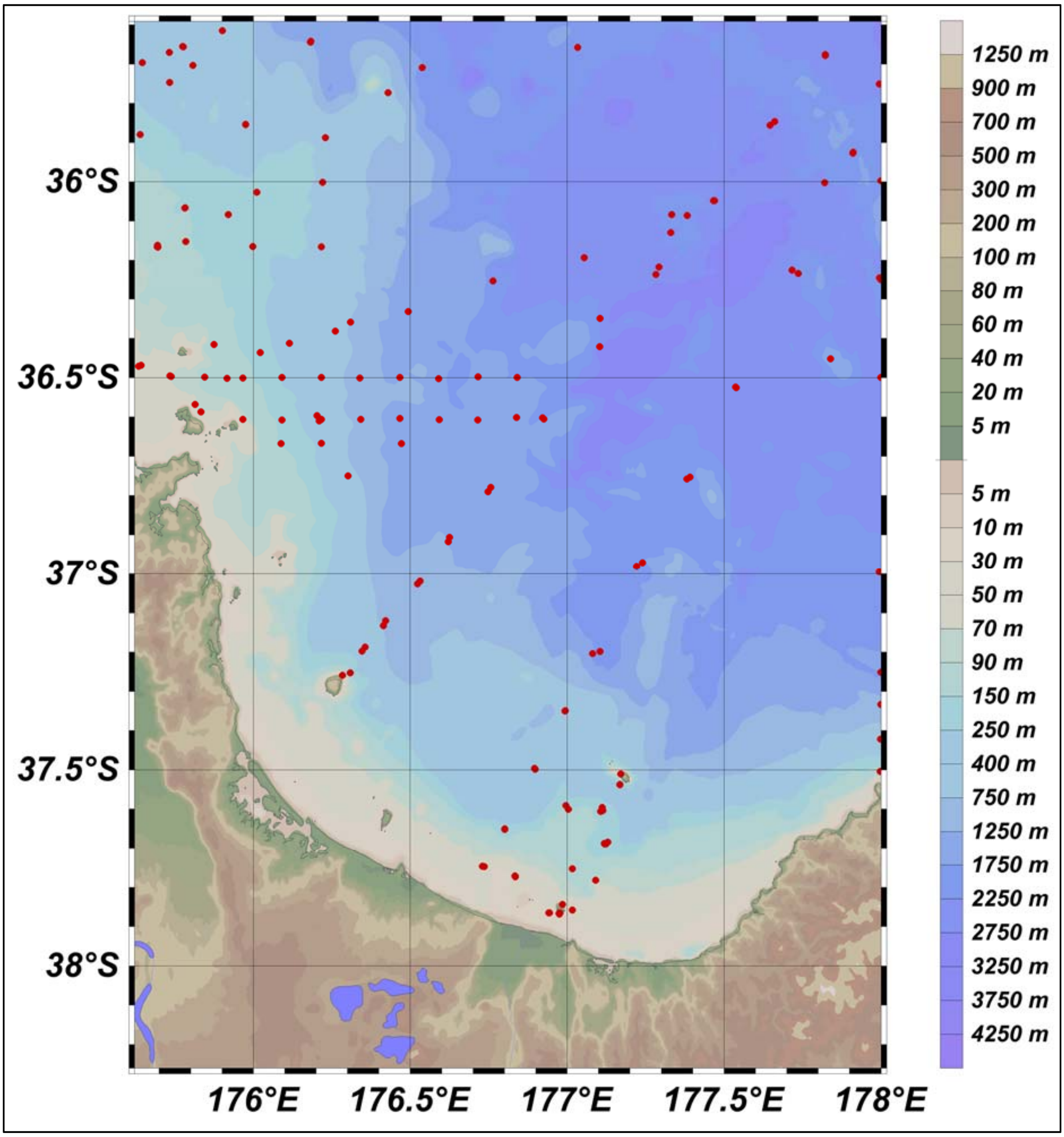


Figure 3-1: NIWA CTD sampling locations in the Bay of Plenty.

3.1.2 NIWA oceanographic mooring data

Typically, the mooring is deployed and left at the site for a specific period. In this case the mooring provides time dependent information at a specific site. Dependent on the mooring design, information on water temperature, salinity, current speeds and directions, and suspended sediment concentrations over the depths of the mooring are post-processed and archived. NIWA moorings deployed for Trans-Tasman Resources Ltd in the South Taranaki Bight (STB) have included a range of instruments at the sites indicated in Figure 3-2 and Figure 3-3. Details of instrument deployment are provided in Table 3-1 and Table 3-2. Full details of the approach and results are available in MacDonald et al. (2015 a and b).

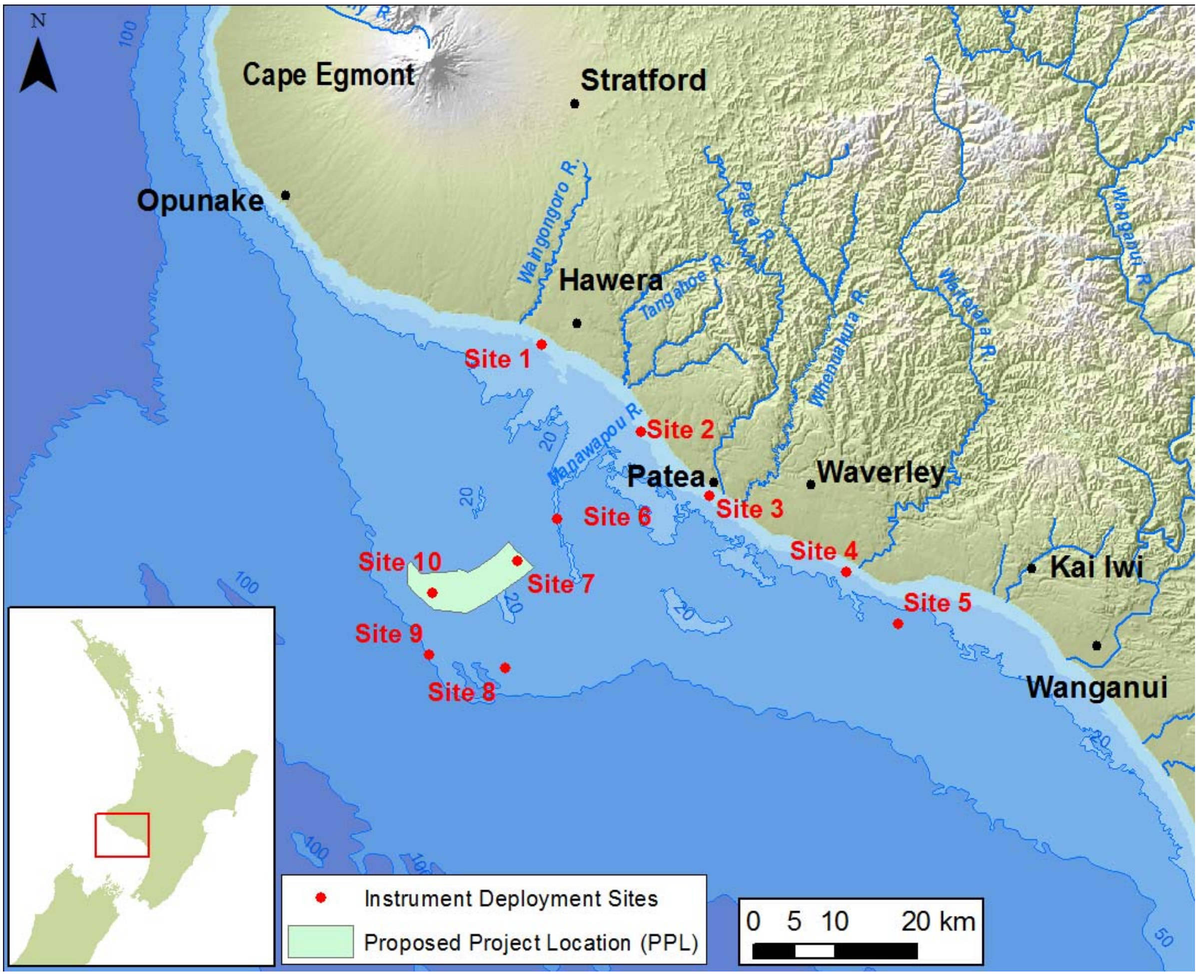


Figure 3-2: NIWA oceanographic mooring locations 1-10 in the South Taranaki Bight. From MacDonald et al. (2015).

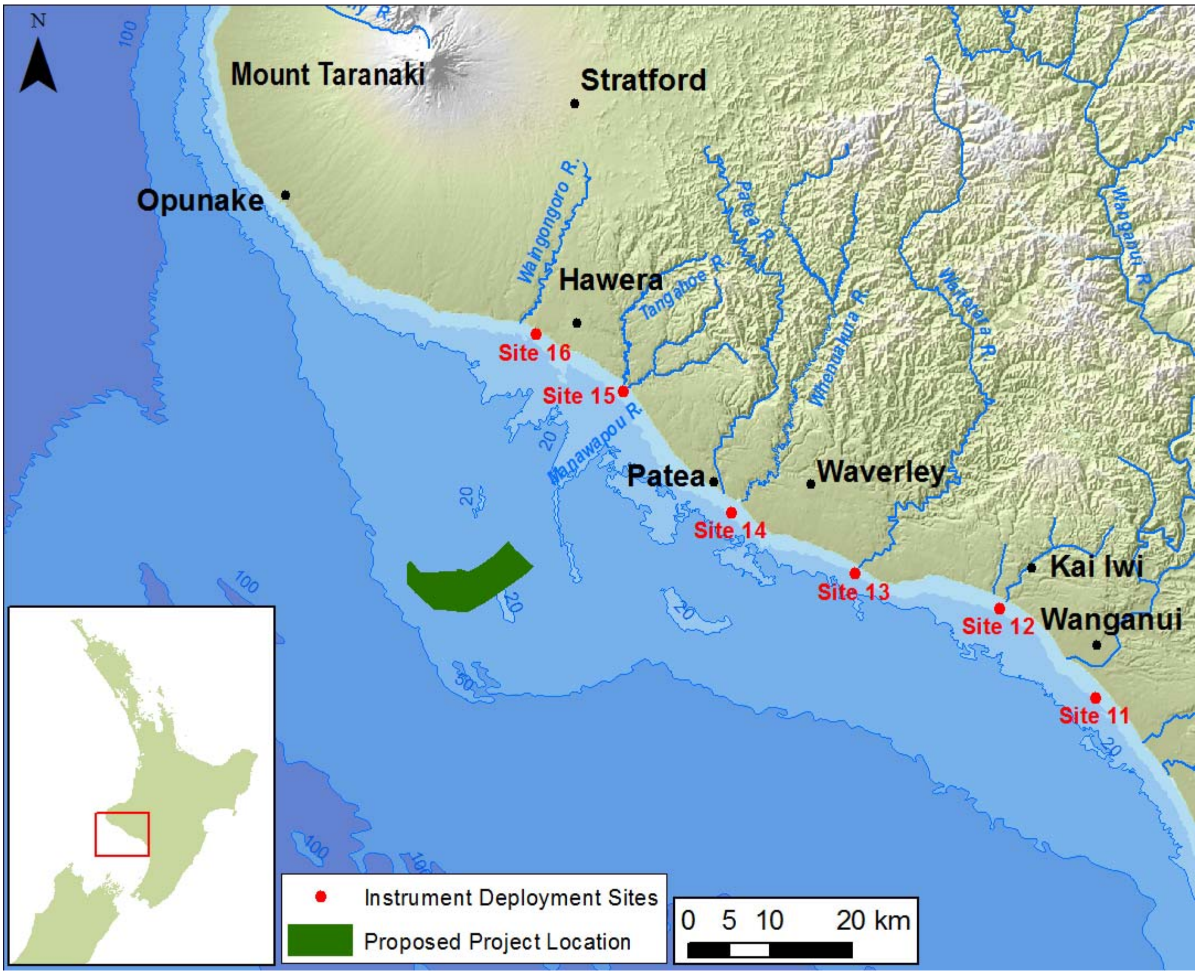


Figure 3-3: NIWA oceanographic mooring locations 11-16 in the South Taranaki Bight. From MacDonald et al. (2015b).

Current velocities in the STB were measured using Acoustic Doppler Current Profilers (ADCP). ADCPs measure currents in “bins” throughout the water column, thus providing the user with a velocity profile over the entire water column. ADCPs were deployed on the sea bed facing the water surface, which is known as a bottom-mounted upward-looking configuration. ADCP acoustic transducers were nominally positioned 0.4 m above the sea bed.

Table 3-1: Locations and deployment information for NIWA oceanographic moorings 1-10. D1: 06/09/2011 to 01/12/2011; D2: 08/12/2011 to 09/02/2012; D3: 24/04/2012 to 01/07/2012. *The WRB had sufficient memory and battery endurance to span the entire deployment period. SSC = suspended sediment concentration. From MacDonald et al. (2015a).

Site	Latitude (S)	Longitude (E)	Instrument (parameter measured)	Deployment period	Approximate water depth
1	39° 36.652	174° 13.459	DWG (waves)	D1 and D2	12
2	39° 42.286	174° 22.085	DWG (waves)	D1 and D2	15
3	39° 46.471	174° 28.114	DWG (waves)	D1 and D2	9-11
4	39° 51.333	174° 39.945	DWG (waves)	D1 and D2	11-13
5	39° 54.754	174° 44.498	ADCP (currents and waves) OBS (near-surface SSC)	D1 and D2	26
6	39° 48.179	174° 15.033	ADCP (currents and waves) ABS (*SSCs*) 2 x OBS (near-bed and near-surface SSC)	D1 and D2	23
7	39° 50.973	174° 11.625	ADCP (currents and waves) ABS (SSC) 2 x OBS (near-bed and near-surface SSC) Temperature and salinity	D1 and D2	31
8	39° 58.092	174° 10.788	ADCP (currents only) ABS (SSC) 2 x OBS (near-bed and near-surface SSC)	D3	45
9	39° 57.301	174° 4.158	WRB (waves) Temperature and salinity	D1* D1 and D2	>50
10	39° 53.166	174° 4.350	ADCP (currents only) ABS (SSC) 2 x OBS (near-bed and near-surface SSC) Temperature and salinity	D3	42

Significant wave height[1], mean spectral period and, where possible, mean direction of wave propagation were measured using three different instruments, these being (1) ADCPs, (2) DOBIE Wave Gauges (DWGs) and (3) a surface-following Datawell wave rider buoy (WRB). The ADCP calculates the three wave parameters from the current velocity measured in the bin closest to the sea surface. In contrast to the ADCP, which calculates wave parameters from current velocities measured close to the sea surface, the DWG calculates wave parameters from pressure fluctuations measured at the height of the instrument. Pressure fluctuations beneath waves attenuate with depth through the water column at a rate that depends on the wave frequency (where wave frequency is the inverse of wave period). The rate of attenuation is higher for high-frequency waves than it is for low-frequency waves. Therefore, not only will the total variance of the pressure spectrum at depth be less than the total variance of the pressure spectrum at the sea surface, but also the shape of the spectrum will be different, due to the relatively greater attenuation of the high-frequency (short-period) components. Care is required when comparing wave parameters from difference sources (e.g., field measurements and a wave model) to ensure that like terms are being compared. No

[1] Defined as the average of the top 33% (1/3) of wave heights over the measurement cycle.

information about wave direction can be derived from pressure measured at a single location. The Wave Rider Buoy floats on the water's surface and uses accelerometers to measure the 3-dimensional motion that results from the propagating wave train.

Table 3-2: Summary information about NIWA oceanographic moorings 11-16. All six moorings consisted of a DOBIE gauge equipped with a pressure sensor for measuring water level and an optical backscatter sensor (OBS, Seapoint Sensor Inc). The records at sites 13 and 15 ended earlier than anticipated because of an unexpected memory issue. From MacDonald et al. (2015b)

Site No.	Latitude (S)	Longitude (E)	Approximate distance from shoreline (m)	Time period (NZST)	Duration (days)	Depth below water surface (m)	Mean water depth (m)
11	39° 59.415	175° 01.689	1450	26/02/13 13:00 to 01/05/13 11:45	63	3.0	11.5
12	39° 53.631	174° 53.268	1250	26/02/13 14:00 to 01/05/13 13:45	63	3.0	11.5
13	39° 51.524	174° 40.782	960	26/02/13 15:00 to 20/04/13 16:00	53	3.0	11.5
14	39° 47.622	174° 30.056	1590	27/02/13 07:30 to 02/05/13 14:45	64	3.0	11.5
15	39° 39.728	174° 20.523	880	27/02/13 09:00 to 08/04/13 21:00	40	3.0	11.5
16	39° 35.994	174° 13.054	508	27/02/13 10:00 to 02/05/13 09:15	64	3.0	11.5

3.1.3 International Argo Float data

Argo Floats are deployed (by multiple countries) and left to sample the ocean autonomously. The floats sit at 1000 m water depth; then every 10 days they descend to 2000 m, then rise to the surface sampling water temperature and salinity; once at the surface the sampled information is transmitted via satellite to international Argo data centres and then is made available to researchers. The float then re-descends to 1000 m to repeat the cycle. The Horizon's western CMA is too shallow for Argo Floats to enter but the eastern CMA has deep water off shore providing an opportunity for Argo vertical profiles of the water column at different locations and times, dependent on their trajectories. An example of Argo Float sampling locations (153) in the Bay of Plenty is shown in Figure 3-4.

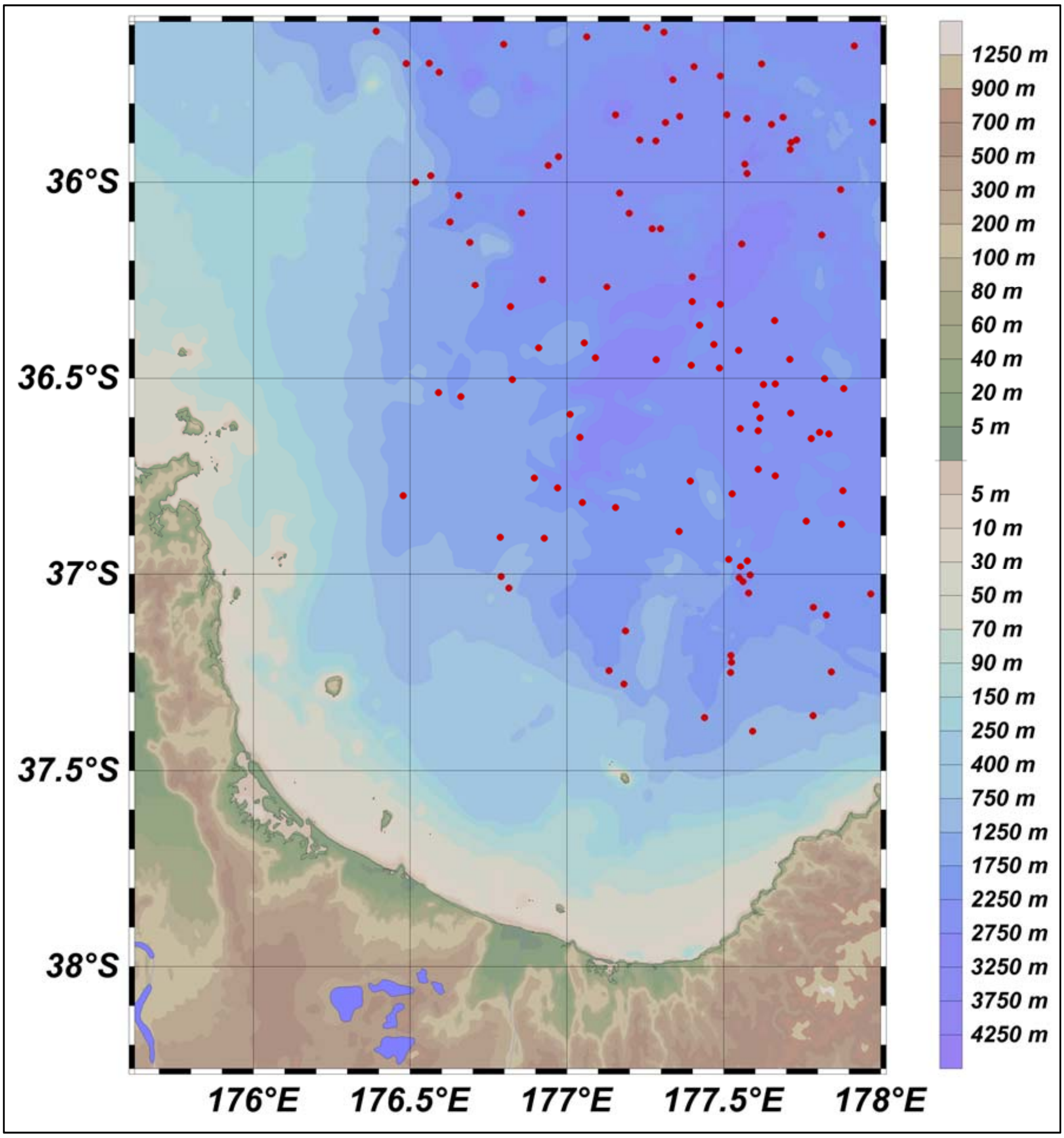


Figure 3-4: Argo Float data sampling locations in the Bay of Plenty.

3.1.4 Oceanographic glider data

Gliders are autonomous platforms sampling to a programmed depth as they dive along their glide path, then returning to the surface to determine and transmit their location before heading off in their next programmed direction. The gliders can typically dive to around 200 m, but provide data every four seconds so return a highly sampled image of the water that the that is passed through. For the example tracks shown (Figure 3-5), each glider took about three days to pass through the domain, returning approximately 10,000 records per day. Presently the glider sensors report water temperature, salinity, oxygen, fluorescence, turbidity, and PAR, providing a complementary data set to that of the CTD. No glider missions have yet sampled either HRC's eastern or western CMAs, but they provide a cost effective way of collecting relevant oceanographic information.

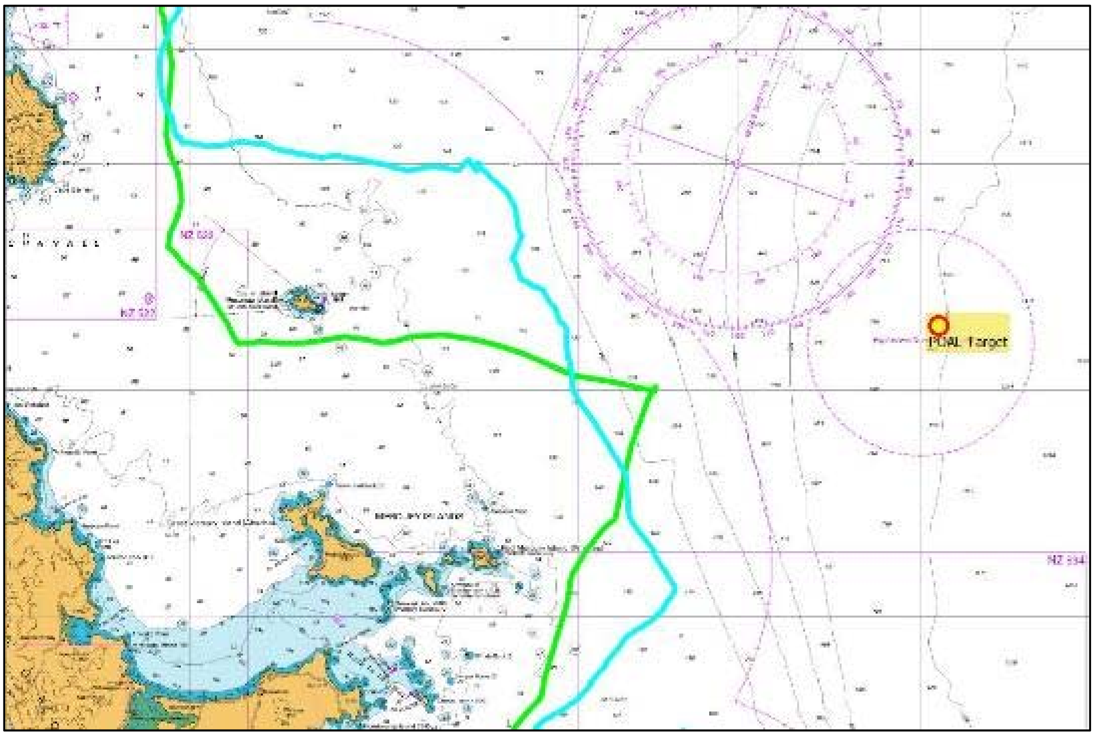


Figure 3-5: Oceanographic glider tracks for two missions off the east Coromandel coast.

3.1.5 Ship-based underway sampling

In March and May 2013, NIWA carried out two boat surveys in the South Taranaki Bight (STB) to assess the spatial variability in near shore water column optical variables and SSC. For the boat surveys, vertical profiles of various optical parameters were measured at intervals along a shore-normal transect (Figure 3-6) using a profiling instrument, Bio-Fish (ADM Electronik), which is a multiparameter system designed for the collection of various physical, chemical and biological variables (Table 3-3). Transects SP1-SP3 fall within the Horizon's western CMA. Full details of the approach and results are available in MacDonald et al. (2015b). No similar measurements are available for Horizon's eastern coastal waters.

Table 3-3: Summary of variables measured and instrumentation used during near-shore boat surveys carried out in the STB by NIWA in March and May 2013. From MacDonald et al. (2015b).

Optical variable	Symbol	Manufacturer/Instrument
Nephelometric turbidity	T_n	Seapoint./Optical Backscatter Sensor (OBS)
Light beam attenuation at 530 nm (green)	c_{530}	Wet labs/ C-Star transmissometer
Light beam attenuation at 650 nm (red)	c_{650}	Wet labs/ C-Star transmissometer
Downwelling irradiance	E_d	LI-COR/ PAR sensor
Conductivity, temperature, salinity	C, T and S	ADM Elektronik/Conductivity and Temp. sensor
Chlorophyll fluorescence	Chl-a	Wet labs/ Eco Triplet
Coloured dissolved organic matter fluorescence	CDOM	Wet labs/ Eco Triplet

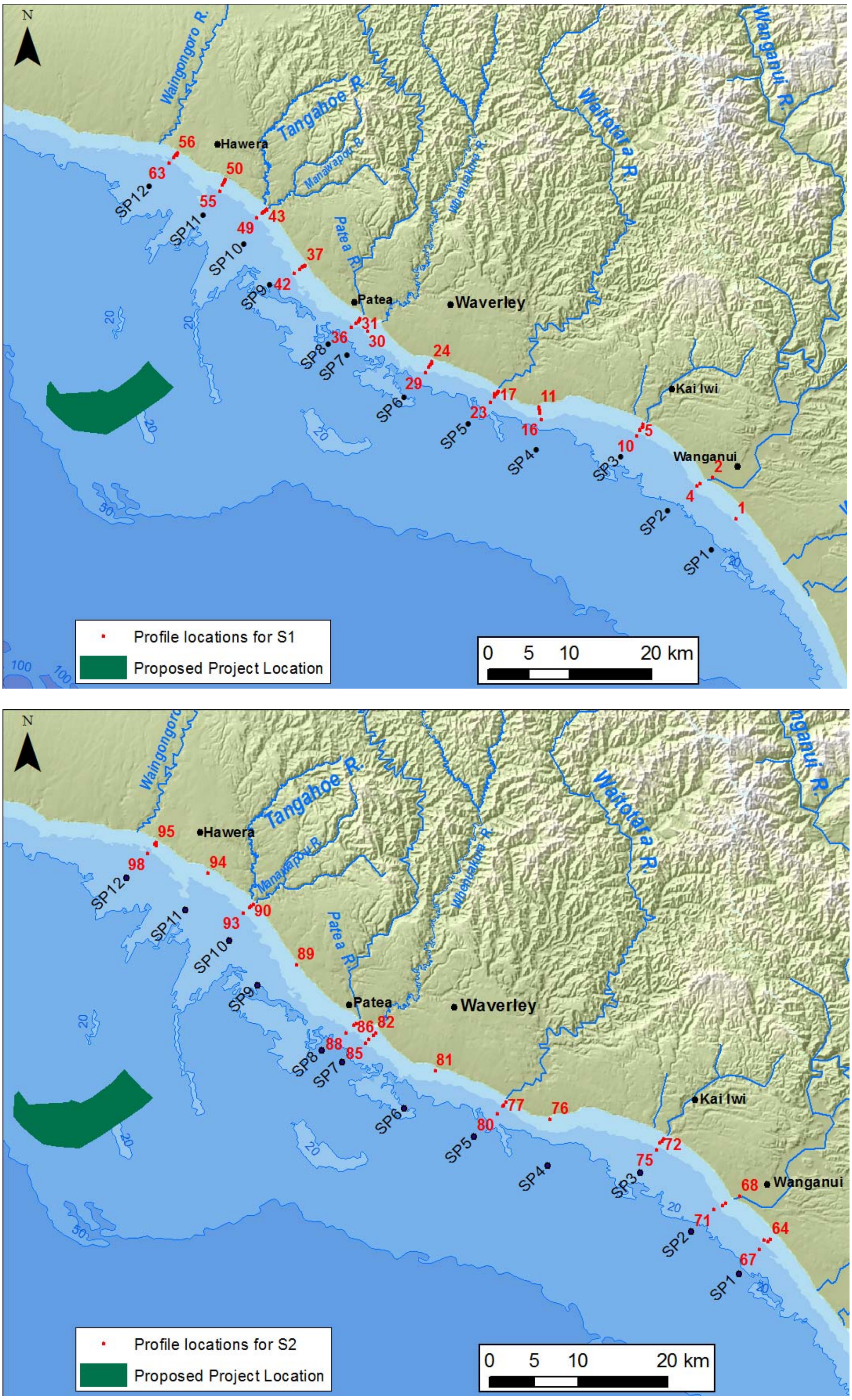


Figure 3-6: Locations of near-shore transects (SP1 – SP12) and profiles (in red) from NIWA's first (top panel) and second (bottom panel) nearshore boat surveys. From MacDonald et al. (2015b).

3.1.6 Waves

The wave energy flux across the 50 m isobath along the south-west flank of the North Island from a 20 year hindcast (Gorman et al. 2003a, Gorman et al. 2003b) is shown in Figure 3-7. The prevailing wave swell direction tends to be from the south-west; as such, the wave energy flux is typically higher in the north-west part of the domain than the more sheltered south-east. The wave energy fluxes are not normal to the coastline, with the shore-parallel flux typically toward the south-east along the northerly part of the shoreline, while the flux has a northerly component along the eastern shoreline. This flux influences the distribution of sediment entering the system via rivers. The significant wave height statistics from the hindcast show that the north of the region has a mean peak at around 1.5 m, but that heights in excess of 8 m also arise, especially in the winter months during storm events. In the relatively sheltered eastern part of the domain, the mean heights are around 1 m, and the maximum wave heights are generally less than 6 m or so. Wave periods are typically in the range 10–14 s.

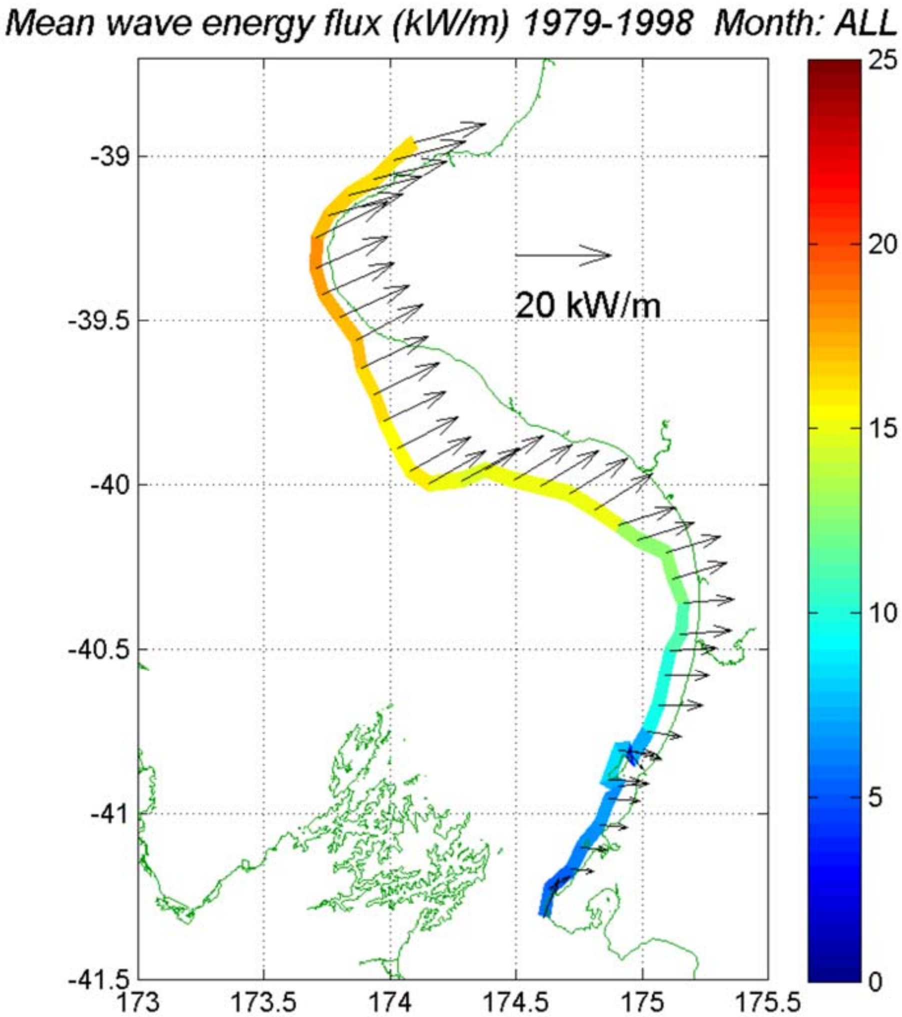


Figure 3-7: Spatial distribution of mean wave energy flux along the south-west flank of North Island. This is the distribution of the flux along the 50 m isobath averaged over the full 20-year hindcast record. The colour scale shows the mean of the magnitude of the energy flux, while the arrows show the vector averaged flux. Figure from MacDiarmid et al. (2015).

3.1.7 Currents

Tidal currents in the STB were summarised by MacDiarmid et al. (2015). These are typically strong in the STB, due to the difference in tidal phase between the western and eastern ends of Greater Cook Strait. Figure 3-8 shows tidal velocities from the NIWA tidal model (Goring 2001; Goring et al. 1997; Walters et al. 2001). The tidal flow amplitude exceeds 1 m/s in Cook Strait Narrows. Over Patea Shoals the tidal flows are around 0.4 m/s and are largely parallel to the shore. Similar data can be provided for Horizon's eastern CMA.

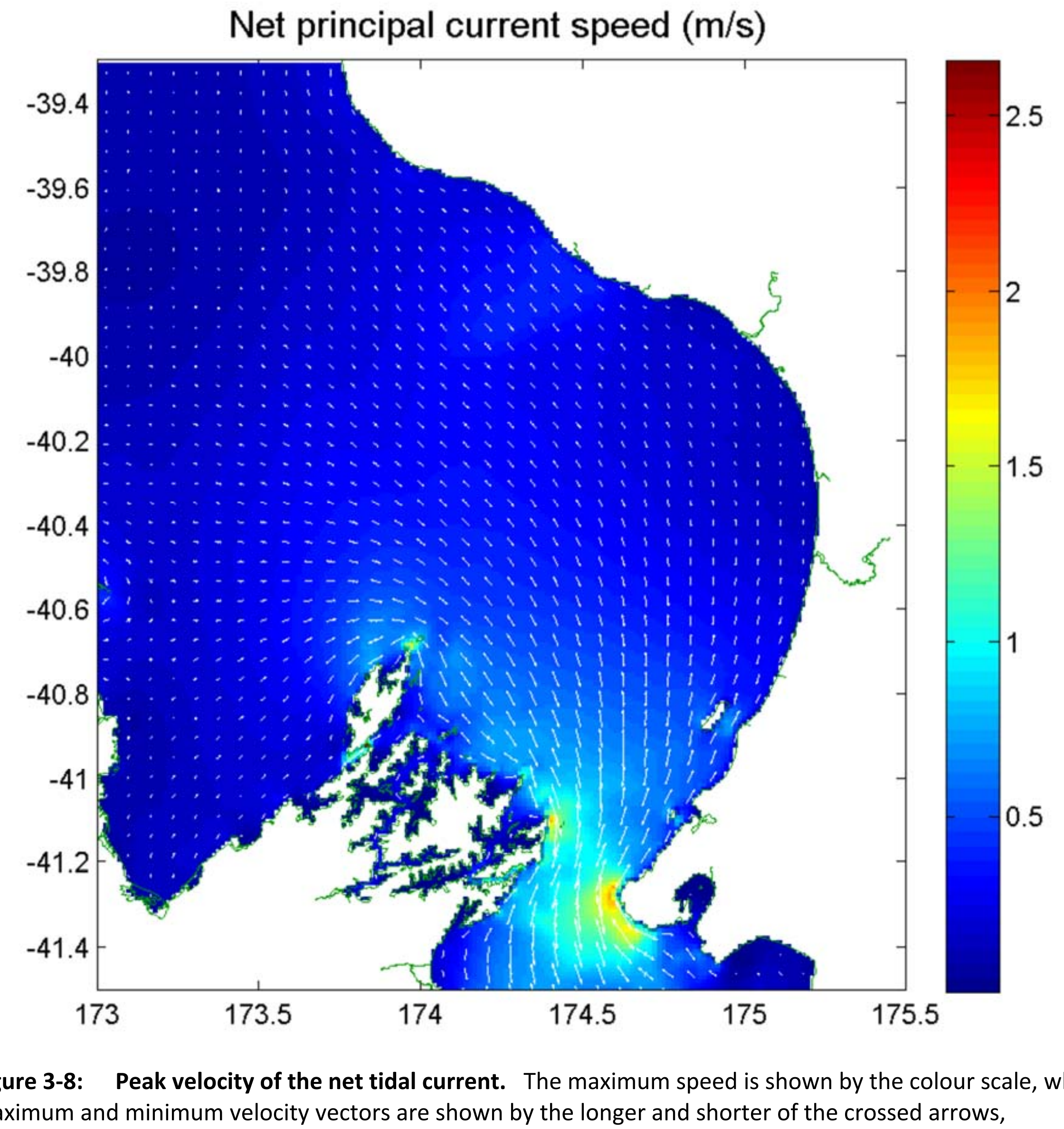


Figure 3-8: Peak velocity of the net tidal current. The maximum speed is shown by the colour scale, while maximum and minimum velocity vectors are shown by the longer and shorter of the crossed arrows, respectively. Figure from MacDiarmid et al. (2015).

3.1.8 Remote sensed data

Satellite imagery can provide a region-wide indication of the complexity of the processes occurring near the sea surface. For example, in Figure 3-9, near shore, plumes of sediment laden water can be seen spilling from the major river systems in the STB. Offshore, in the middle of the STB lies a large area of clearer water. The concentration of total suspended solids (TSS) in surface waters can be derived from satellite estimates of optical backscatter at wavelengths of 488 nm (Pinkerton and Gall

2015). TSS includes the inorganic suspended sediment, but also phytoplankton and suspended organic matter. Offshore, TSS is expected to exceed SSC, but near the shore the two quantities should be approximately equal as inorganic sediment dominates. For the STB, backscatter was derived from the NASA ocean colour satellite sensor, MODIS-Aqua, using measurements between 2002 and 2008. Data were processed using the Quasi-Analytical Algorithm with local modification derived from in situ bio-optical measurements (Pinkerton and Gall 2015). Offshore, TSS is low (<1 mg/L), but near shore TTS can reach higher levels, especially around river mouths (Figure 3-10).

Figure 3-9: Pseudo-true colour MODIS-Aqua satellite image of the South Taranaki Bight (29 April 2011). Data used courtesy of NASA, Goddard Space Flight Center, MODIS project.

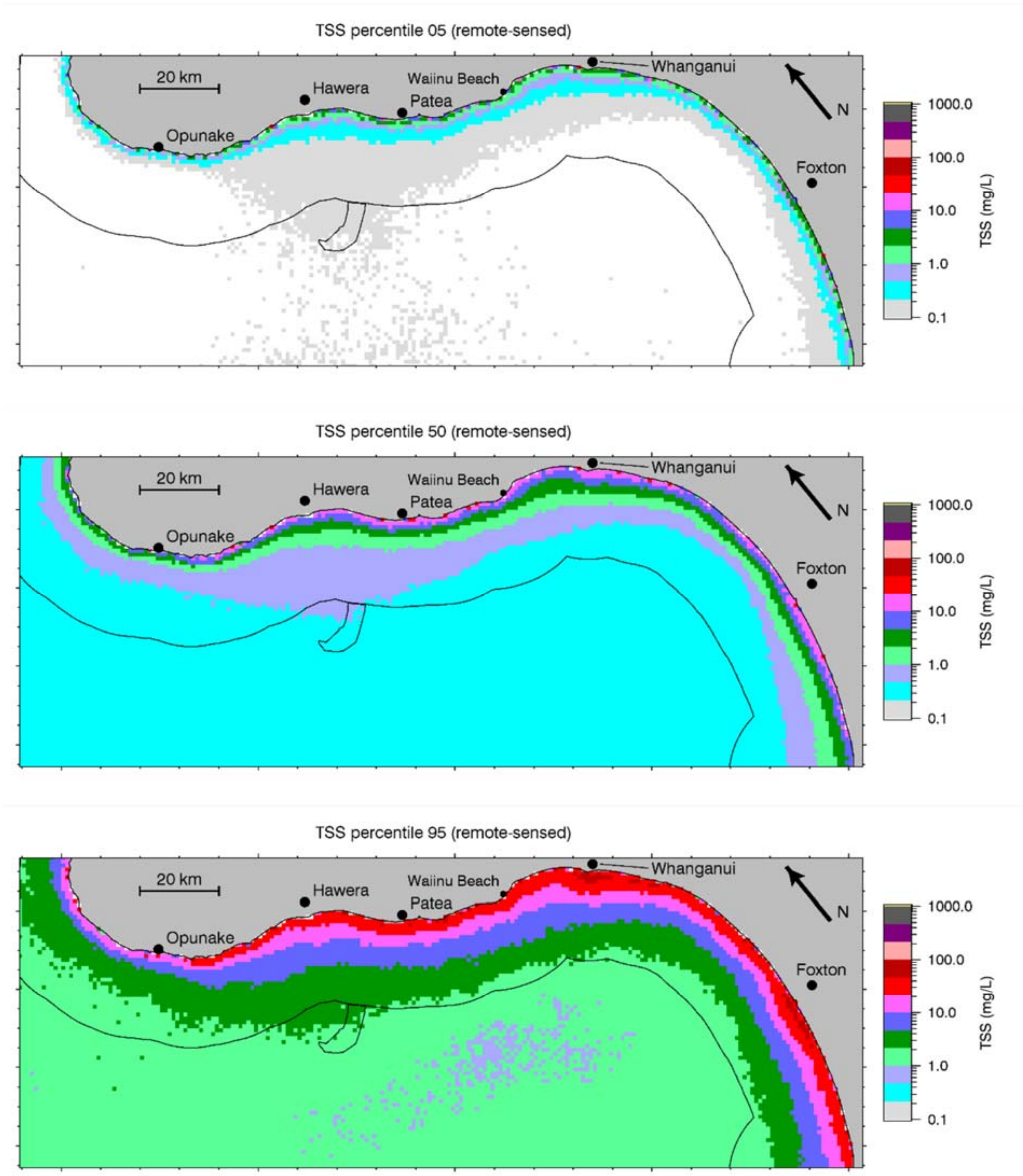


Figure 3-10: Remote sensed 5th percentile (top panel), median (50th percentile) (top panel) and 95th percentile (bottom panel) annual surface concentration of total suspended solids (TSS) in the STB. The black line indicates the outer limit to the Territorial Sea. TTR's proposed mining area is shown in the EEZ south of Hawera. From Hadfield and Macdonald (2015).

3.1.9 Oceanographic modelling

Computer modelling provides a way of assimilating and integrating a wide variety of marine physical data to predict the detail flow regimes and suspended sediments throughout the water column over an entire region. For the STB NIWA constructed a modelling system comprising a set of nested domains (Hadfield and Macdonald 2015). The outer domain covered Greater Cook Strait (Figure

3-11). The inner domain extended from Cape Egmont to just north of Kapiti Island, thus including the all of Horizons western coastal waters in the STB. The model was the Regional Ocean Modeling System or ROMS (Haidvogel et al. 2008), a widely accepted ocean/coastal model with optional embedded models of suspended-sediment and sediment-bed processes (Warner et al. 2008). Details of the model setup and calibration can be found in Hadfield and Macdonald (2015).

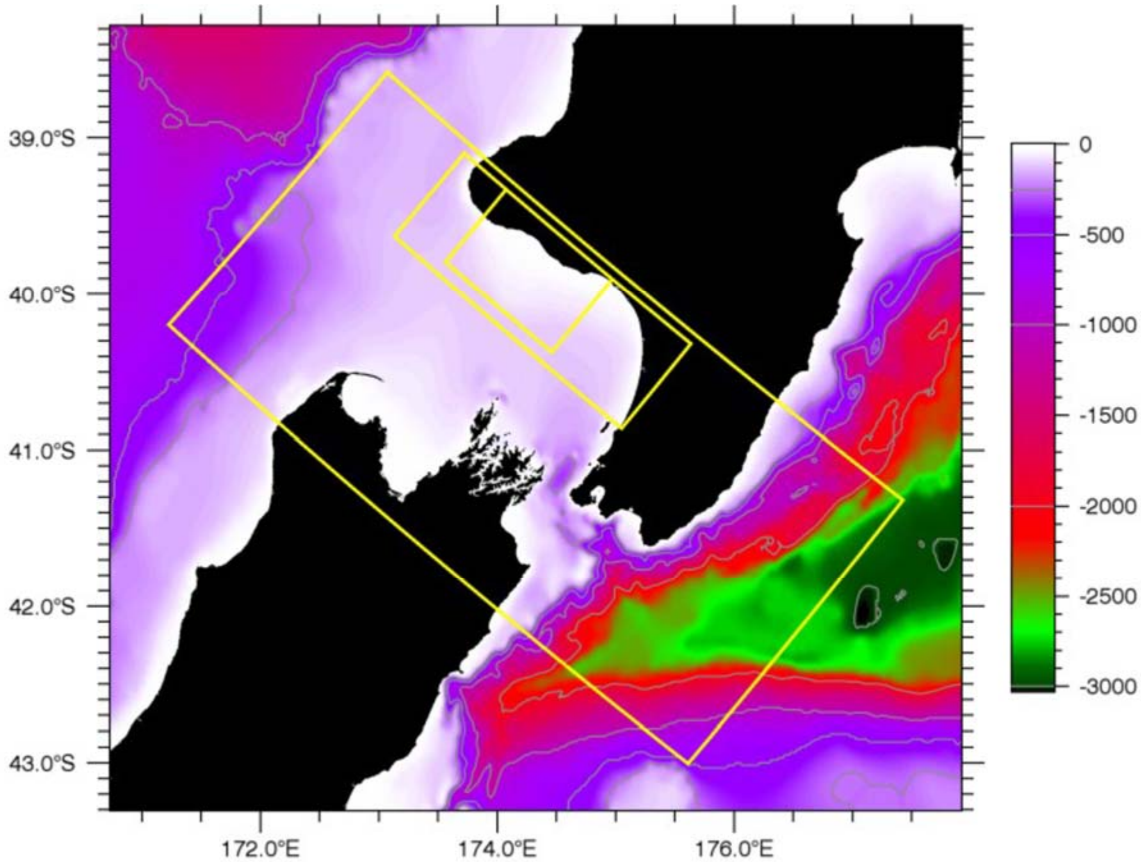


Figure 3-11: Nested ROMS model domains used in the South Taranaki Bight (depth in meters). From Hadfield and Macdonald (2015).

Figure 3-12 shows depth-average velocity vectors averaged over two years of a Cook Strait model run and similar data from the inner model from hadfield and MacDonald (2015). As they describe, "A continuous current can be seen entering Cook Strait from the south along the north-west coast of the South Island, then crossing the strait at its shallower, western end. The path of the current then follows the 50–100 m depth band to the South Taranaki coast, skirting the Patea Shoals. From there it follows the coast south past Manawatu, Horowhenua and Kapiti, through the Narrows and then northward along the Wairarapa coast. The existence of this current system has been known for several decades, but the details of its spatial pattern and temporal variability were not previously well described." An accurate representation of this current and its variability is important because it is expected to have a major influence on the transport of sediment entering the coastal zone from rivers and from the proposed iron sand extraction operation south of Hawera. Dynamic outputs from this model show the hourly variation in the current flows through the region and how storm and rain events impact suspended sediment concentrations, particularly near shore.

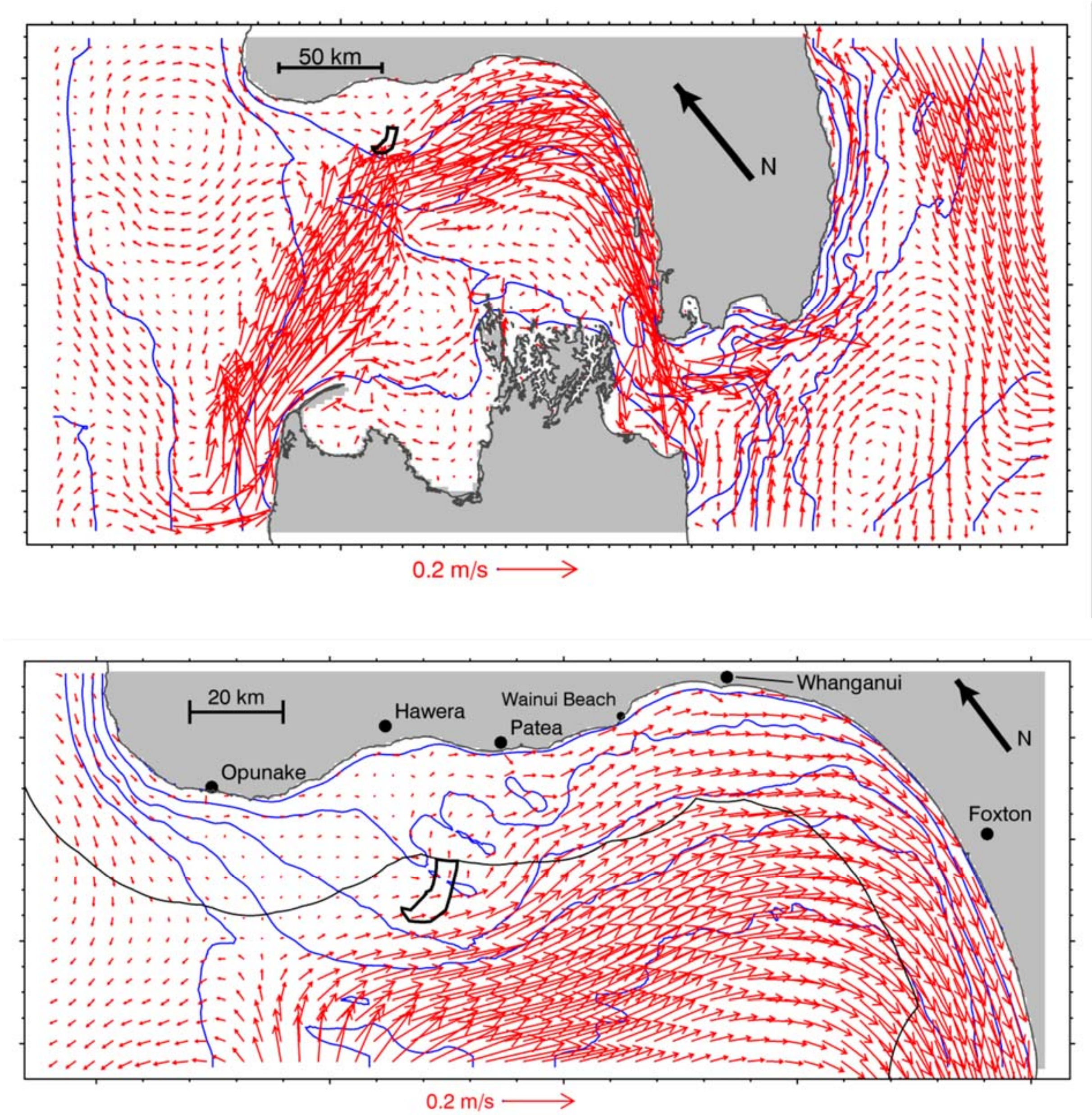


Figure 3-12: Time-averaged, depth-average velocity from the Cook Strait model (top panel) and the inner model (bottom panel). Velocity vectors are averaged over 730 days and shown at every 4th grid point. In the top panel depth contours in blue are at 50, 100, 250, 500, 1000 and 2000 m. In the bottom panel depth contours in blue are at 10, 25, 50, 75 and 100 m. The black line indicates the outer limit to the Territorial Sea. TTR's proposed mining area is shown in the EEZ south of Hawera. From Hadfield and Macdonald (2015).

Modelling by Hadfield and Macdonald (2015) indicates that the annual median, near-surface, background SSC is elevated adjacent to the coast, and this strip of elevated values is wider to the west of Whanganui than further south, where it is elevated mainly around river moths (top panel in Figure 3-13). The highest values are in excess of 20 mg/L (magenta) and occur near the mouths of the Manawatu and Whanganui Rivers. The model underestimates background SSC offshore (Hadfield and Macdonald 2015). In the lower part of the water column, due to frequent physical disturbance by waves and currents, median background levels of suspended sediments are typically greater than the median, near-surface background SSC by a factor of 10 or more (lower panel in Figure 3-13). The highest values are in excess of 200 mg/L (magenta) and occur near the mouth of the Whanganui

River and also near Hawera. Along the coast south of Whanganui to south of Foxton the near bottom median SSC is typically 10–50 mg/L (pink and red) but diminishes to less than 1 mg/l 10-15 km offshore.

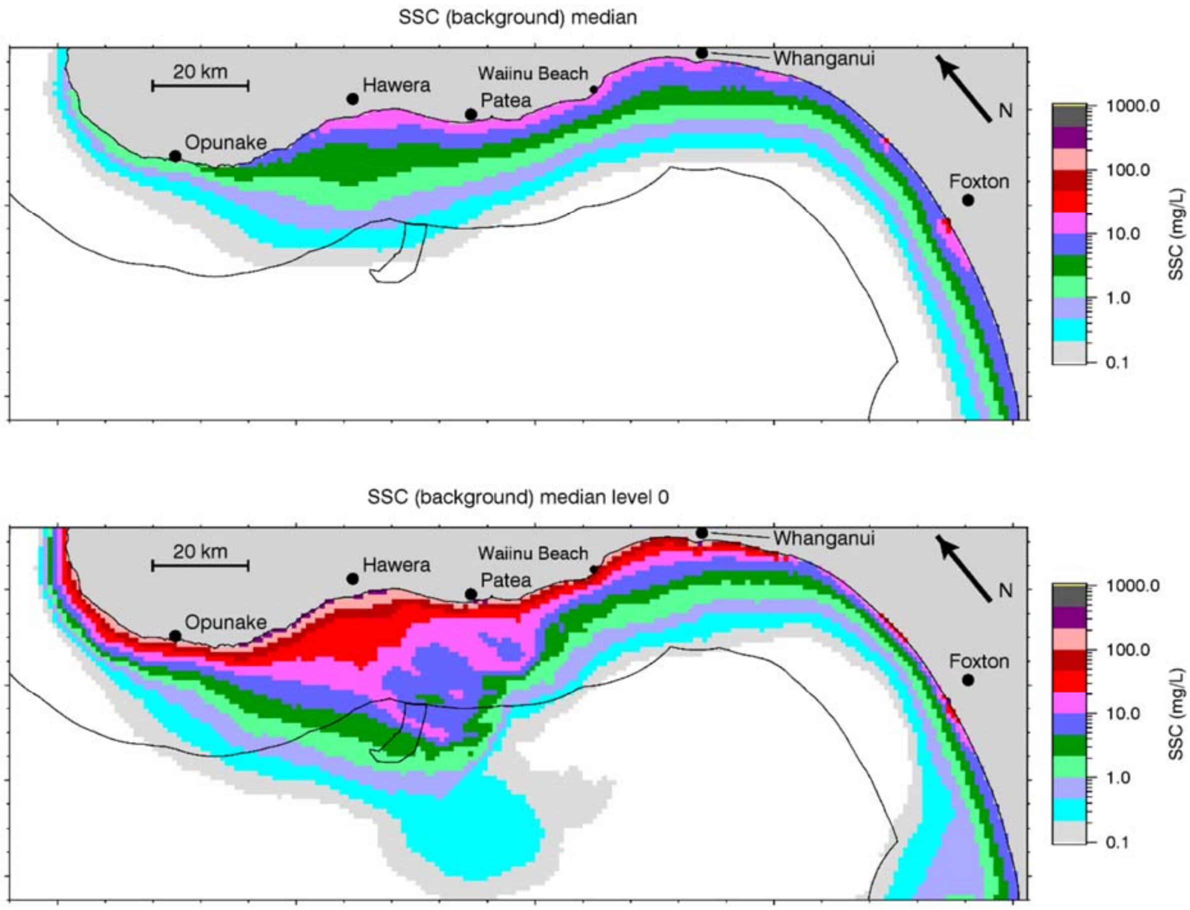


Figure 3-13: Annual median near-surface (top panel) and near-bottom (lower panel) background concentration of suspended sediment in the STB. The black line indicates the outer limit to the Territorial Sea. TTR's proposed mining area is shown in the EEZ south of Hawera. From Hadfield and Macdonald (2015).

3.2 Sources of sediment in the CMA

The sources of eroded soils and their relative contributions to coastal sediments are able to be determined using a Compound Specific Stable Isotope (CSSI) method developed by NIWA (Gibbs 2008). Handley et al. (2017) describe the application of this approach to sediments deposited in the Pelorus Sound, Marlborough. They indicate that "The CSSI method has been used in over 20 estuaries throughout New Zealand, tested in the Environment Court, has been elevated to the status of being usable as a compliance monitoring tool, and adopted by the international Atomic Energy Agency (IAEA) and Food and Agricultural Organisation (FAO) and used in over 40 overseas countries. The results are given as a "best estimate", within definable limits, of the proportional contribution of each potential source soil. Information obtained using this method will allow development of management strategies to alter land-use practices to reduce the sediment load to rivers and from land directly coupled to the coast, and thus, the impact on the aquatic ecosystem downstream in estuaries and in sheltered coastal waters."

The CSSI method uses compound-specific isotopic analysis of naturally occurring biomarkers (fatty acids) derived from plants to link source soils to land-use within a single catchment (Gibbs 2008). Identification relies on the evaluation of the sediment sample relative to a "library" of reference source soils from different land-use within the surrounding catchments. Selection of potential sources is geographically constrained by the requirement for a natural linkage between each source soil and the sediment site sampled (Handley et al. (2017).

As far as known, the CSSI method has not been used to identify the sources of terrigenous sediments deposited in HRC's CMA. However, HRC is currently undertaking a pilot study with Landcare using geochemical analysis to identify the sources of terrigenous sediments in the Orua catchment. These approaches are complementary.

3.3 Primary Production

Primary production in the STB, including Horizons western CMA, has been investigated in detail by Pinkerton and Gall (2015) using a combination of satellite remote sensed data, calibrated using in-situ measurements of photosynthetic pigments. This report should be consulted for a full explanation of measurements, calibration and interpretation. The resulting best estimate of spatial variation in chlorophyll-a concentration (mg/m3) is shown in Figure 3-14. Highest levels occur nearshore but levels of moderate primary production around 1 mg/m^3 occur over a wide area of the STB.

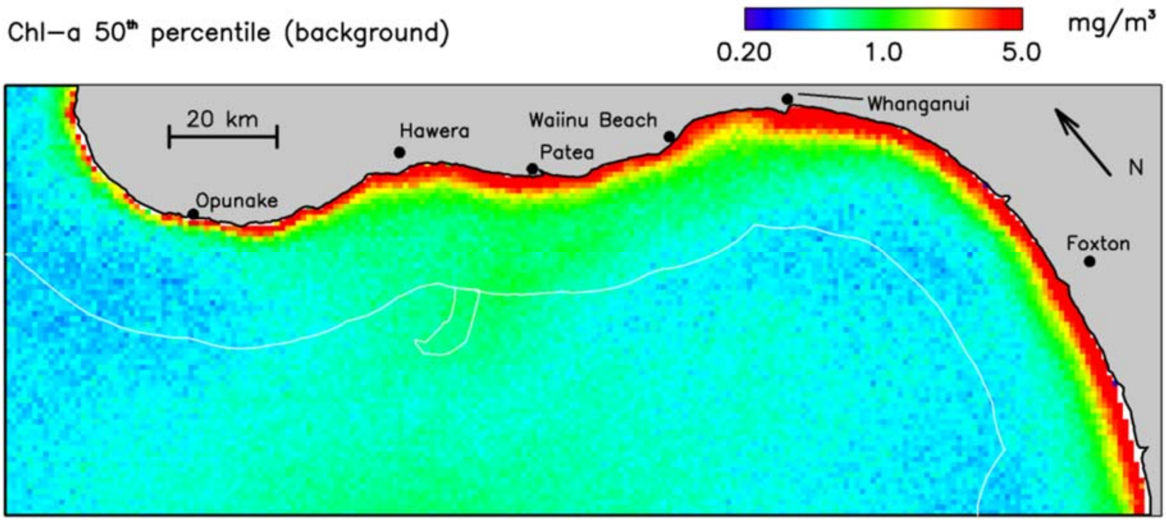


Figure 3-14: Annual median chlorophyll-a concentration (mg/m^3) in the STB. The white line indicates the outer limit to the Territorial Sea. TTR's proposed mining area is shown in the EEZ south of Hawera. From Pinkerton and Gall (2015).

There are no similar studies of remote sensed aspects of water quality for Horizon's eastern CMA although the relevant satellite data are routinely down-loaded and stored by NIWA.

3.4 Zooplankton

Zooplankton communities in the STB were well assessed in the 1970s and 1980s with 90 stations sampled over a period of 13 years (Figure 3-15) (Battaerd 1983, Bradford 1977, 1978, 1980, Bradford and Roberts 1978, Bradford et al. 1993). In mid-February 2015, NIWA sampled zooplankton communities from the sea surface to the sea floor, at 16-20 stations in the northern part of the STB (Figure 3-16, Figure 3-17), an area previously poorly sampled (MacDiarmid, Gall, Robinson et al. 2015). An overview of the functioning of zooplankton communities in the STB has been provided by Bradford-Grieve and Stevens (2013). No similar data are available for Horizon's eastern CMA.

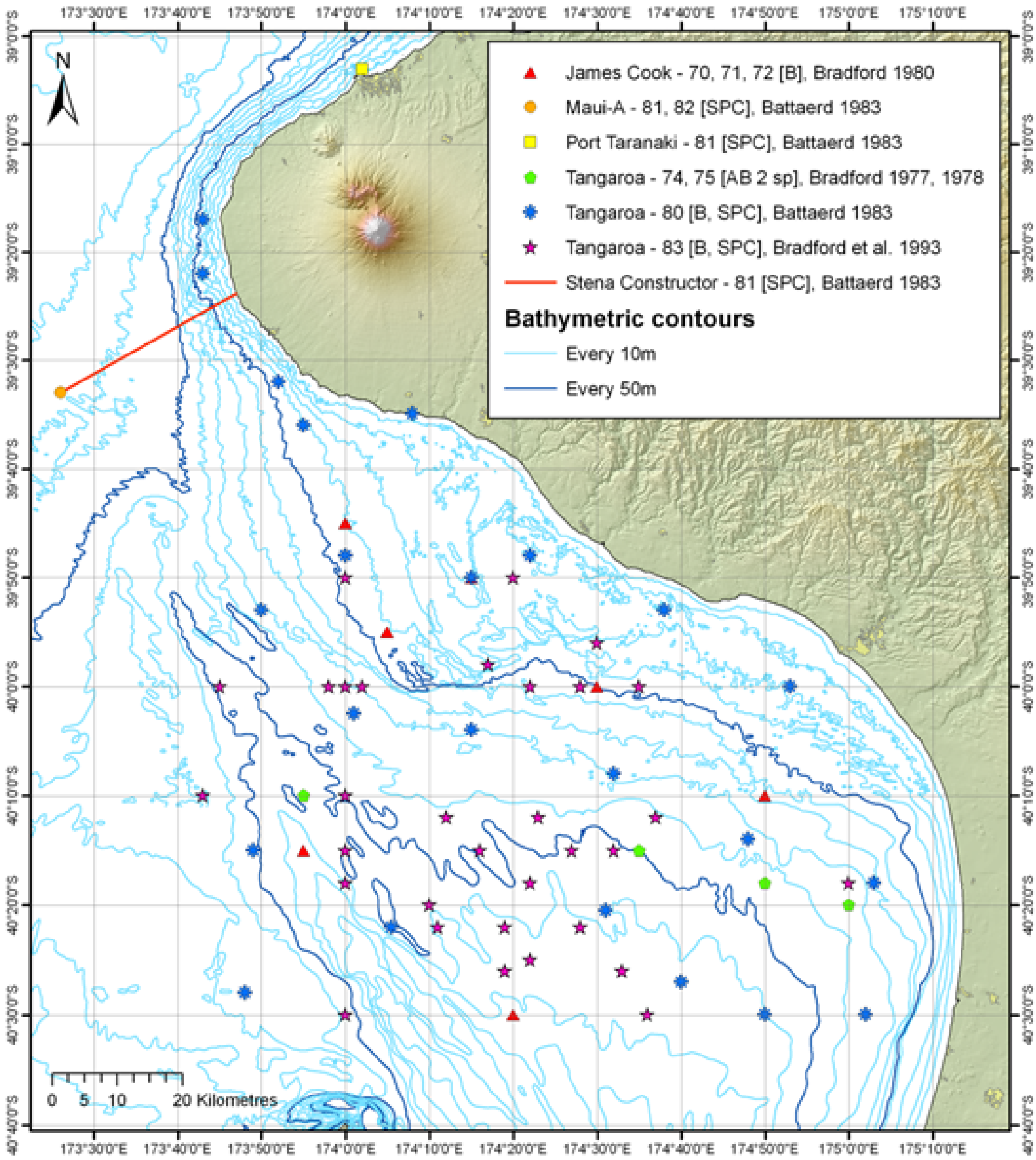
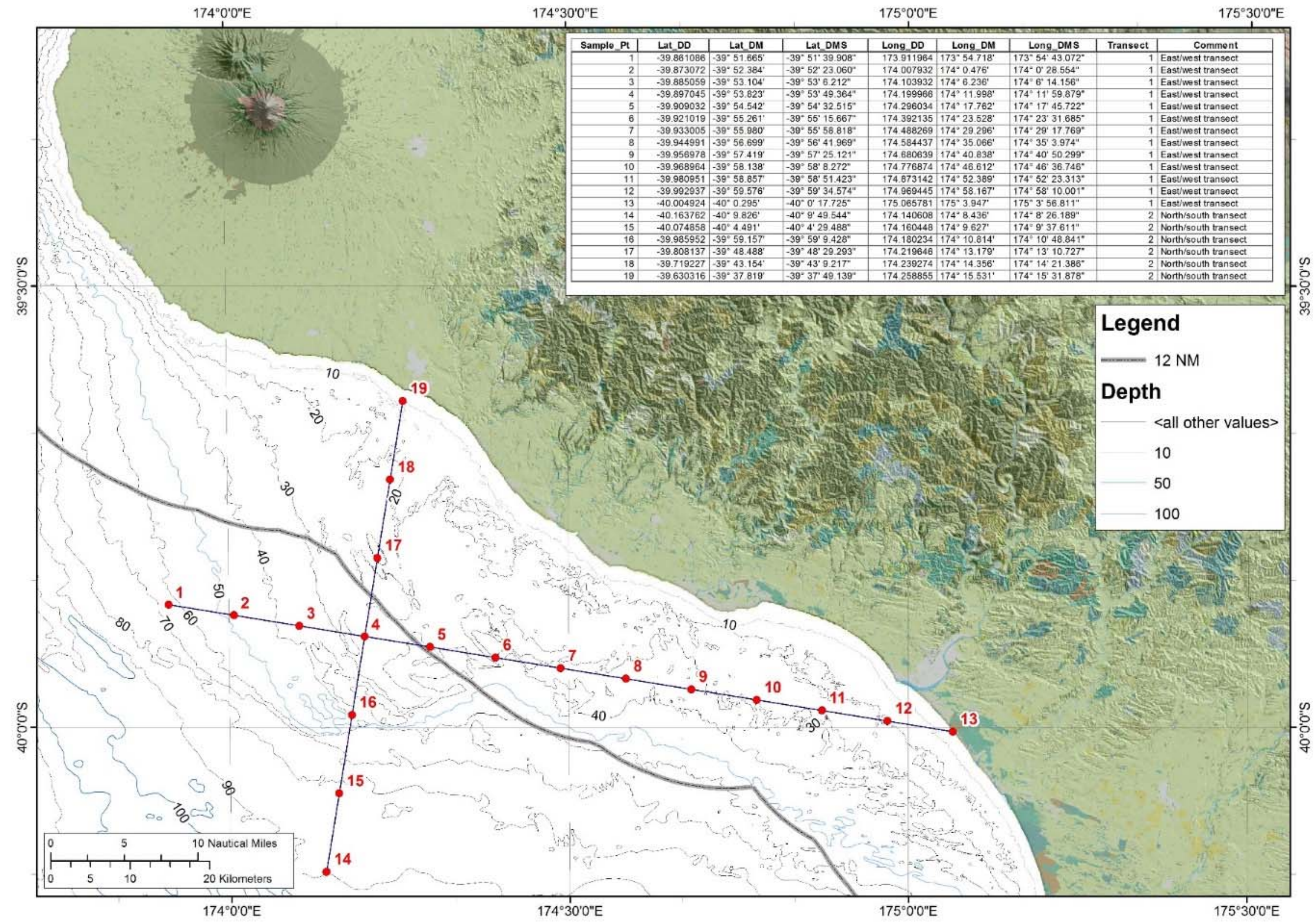


Figure 3-15: Locations in the South Taranaki Bight where meso-zooplankton sampling has been conducted. The legend shows the vessel or location, followed by the year of sampling and the reference. Codes refer to the types of samples that were collected where B=biomass, SPC=species composition, and AB 2 sp=abundance data for 2 individual copepod species. A total of 23 stations were sampled along a transect from Oaonui to the Maui-A gas platform (Stena Constructor). From Bradford-Grieve and Stevens (2013).



Sample_Pt	Lat_DD	Lat_DM	Lat_DMS	Long_DD	Long_DM	Long_DMS	Transect	Comment
1	-39.861086	-39° 51.665'	-39° 51' 39.908"	173.911964	173° 54.718'	173° 54' 43.072"	1	East/west transect
2	-39.873072	-39° 52.384'	-39° 52' 23.060"	174.007932	174° 0.476'	174° 0' 28.554"	1	East/west transect
3	-39.885059	-39° 53.104'	-39° 53' 6.212"	174.103932	174° 6.236'	174° 6' 14.156"	1	East/west transect
4	-39.897045	-39° 53.823'	-39° 53' 49.364"	174.199966	174° 11.998'	174° 11' 59.879"	1	East/west transect
5	-39.909032	-39° 54.542'	-39° 54' 32.515"	174.296034	174° 17.762'	174° 17' 45.722"	1	East/west transect
6	-39.921019	-39° 55.261'	-39° 55' 15.667"	174.392135	174° 23.528'	174° 23' 31.685"	1	East/west transect
7	-39.933005	-39° 55.980'	-39° 55' 58.818"	174.488269	174° 29.296'	174° 29' 17.769"	1	East/west transect
8	-39.944991	-39° 56.699'	-39° 56' 41.969"	174.584437	174° 35.066'	174° 35' 3.974"	1	East/west transect
9	-39.956978	-39° 57.419'	-39° 57' 25.121"	174.680639	174° 40.838'	174° 40' 50.299"	1	East/west transect
10	-39.968964	-39° 58.138'	-39° 58' 8.272"	174.776874	174° 46.612'	174° 46' 36.746"	1	East/west transect
11	-39.980951	-39° 58.857'	-39° 58' 51.423"	174.873142	174° 52.389'	174° 52' 23.313"	1	East/west transect
12	-39.992937	-39° 59.576'	-39° 59' 34.574"	174.969445	174° 58.167'	174° 58' 10.001"	1	East/west transect
13	-40.004924	-40° 0.295'	-40° 0' 17.725"	175.065781	175° 3.947'	175° 3' 56.811"	1	East/west transect
14	-40.163762	-40° 9.826'	-40° 9' 49.544"	174.140608	174° 8.436'	174° 8' 26.189"	2	North/south transect
15	-40.074858	-40° 4.491'	-40° 4' 29.488"	174.160448	174° 9.627'	174° 9' 37.611"	2	North/south transect
16	-39.985952	-39° 59.157'	-39° 59' 9.428"	174.180234	174° 10.814'	174° 10' 48.841"	2	North/south transect
17	-39.808137	-39° 48.488'	-39° 48' 29.293"	174.219646	174° 13.179'	174° 13' 10.727"	2	North/south transect
18	-39.719227	-39° 43.154'	-39° 43' 9.217"	174.239274	174° 14.356'	174° 14' 21.386"	2	North/south transect
19	-39.630316	-39° 37.819'	-39° 37' 49.139"	174.258855	174° 15.531'	174° 15' 31.878"	2	North/south transect

Figure 3-16: Stations in the northern South Taranaki Bight where meso-zooplankton and surface water sampling was conducted on the 17-18 February 2015. Note that due to time constraints station 13 was not sampled. From MacDiarmid, Gall, Robinson et al. (2015).

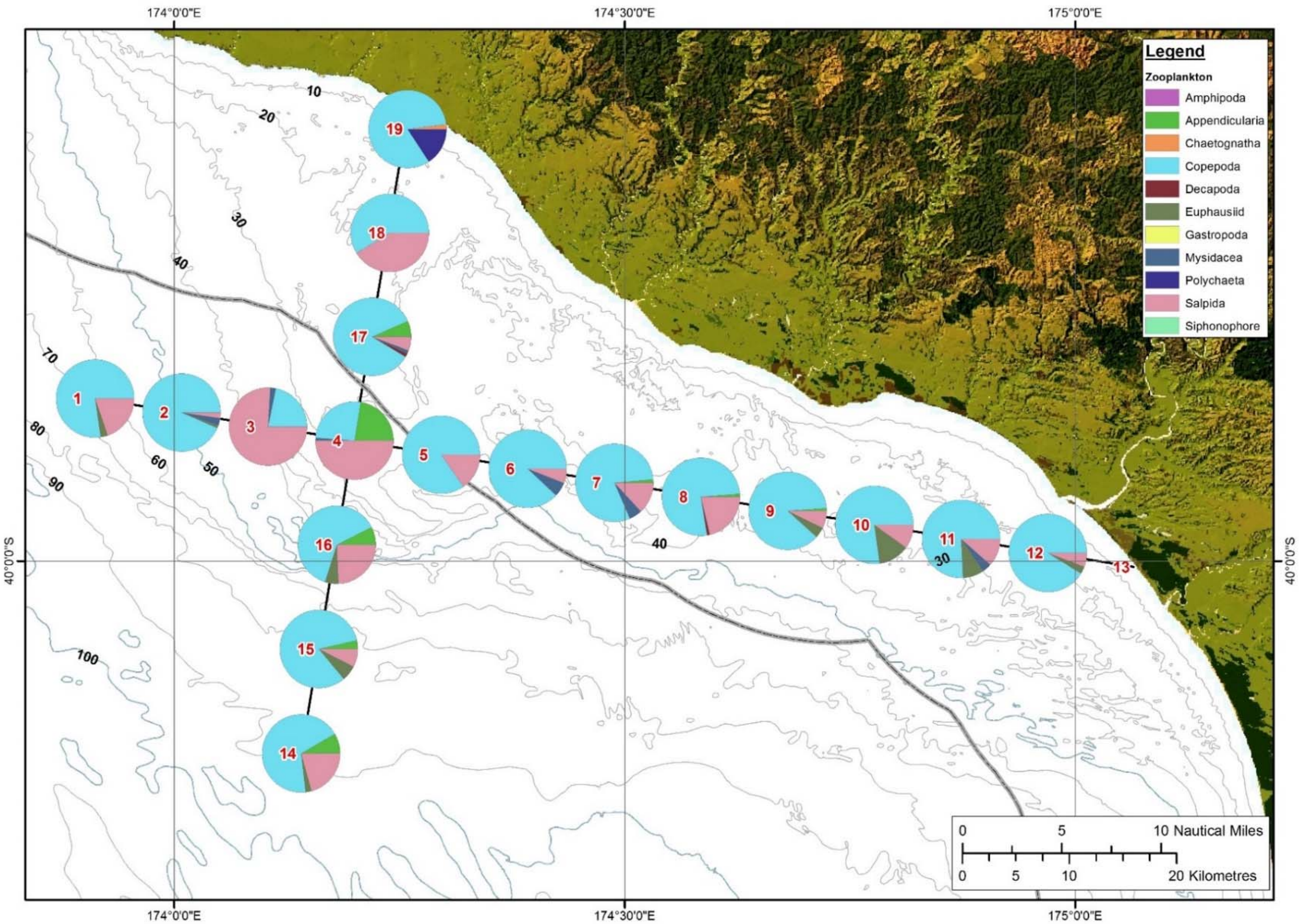


Figure 3-17: The broad taxonomic numerical composition of zooplankton samples taken in the northern STB, 17-18 February 2015. Marine benthic habitats

3.5.1 Seafloor sediments

NIWA has a large database of marine sediments sampled throughout the Territorial Sea and EEZ with an emphasis towards samples from shelf waters. Sediment samples typically have basic descriptive information and occasionally quantitative information on the % gravel, % sand and % mud and in some cases information about % carbonate and a description of the sediment and whether it contains volcanic material. A paper describing the distribution of these samples and derived continuous maps of grainsize (mud %, sand % and gravel %) and carbonate content using a kriging method in GIS based on the 12 nearest sampling points is in the late stages of preparation and is planned for publication in mid-2018 (Bostock in prep). An example of sample intensity and derived measures is provided for the Bay of Plenty Region in Figure 3-18 and Figure 3-19, respectively. These maps show that the near shore region is dominated by sand, with mud more common at the edge of the continental shelf and on the slope. There is some sand around the volcanic edifices in the bay, but most of the region offshore is volcanic gravel, with only minor mud and sand. The region is low in carbonate content, with the exception of one small area close to shore near Tauranga. Similar extracts can be made for Horizon's CMA.

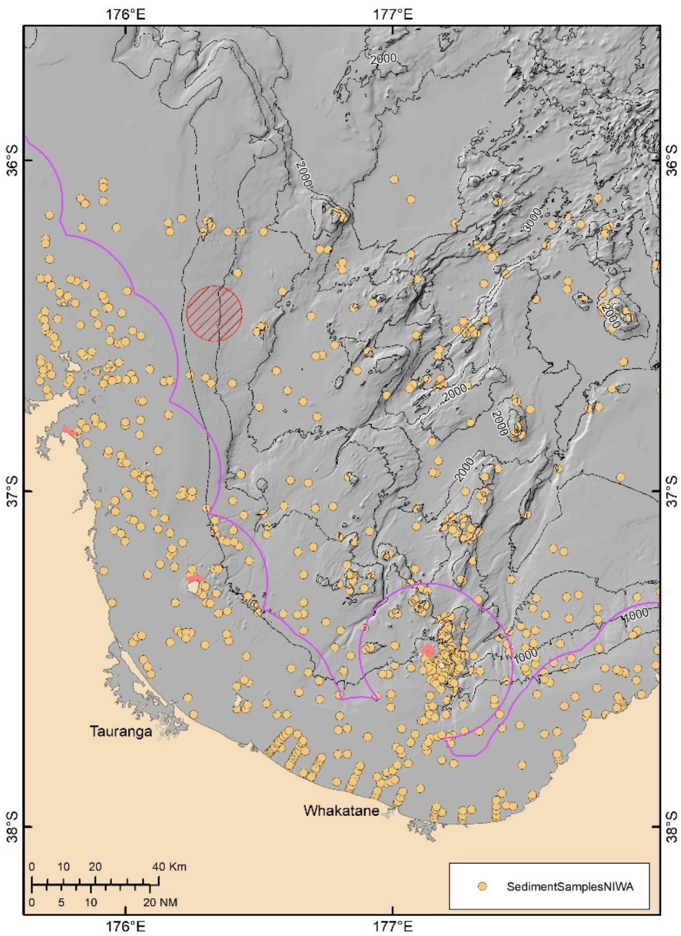


Figure 3-18: Seafloor sediment samples in the Bay of Plenty. The purple line indicates the 12 nautical-mile limit to the Territorial Sea, and black lines are bathymetric contours at 500 m, 1000 m, 2000 m and 3000 m below sea level. The three orange areas demarcate marine reserves. The red-hatched circle indicates an Explosives Dumping Ground. (NIWA unpublished data)

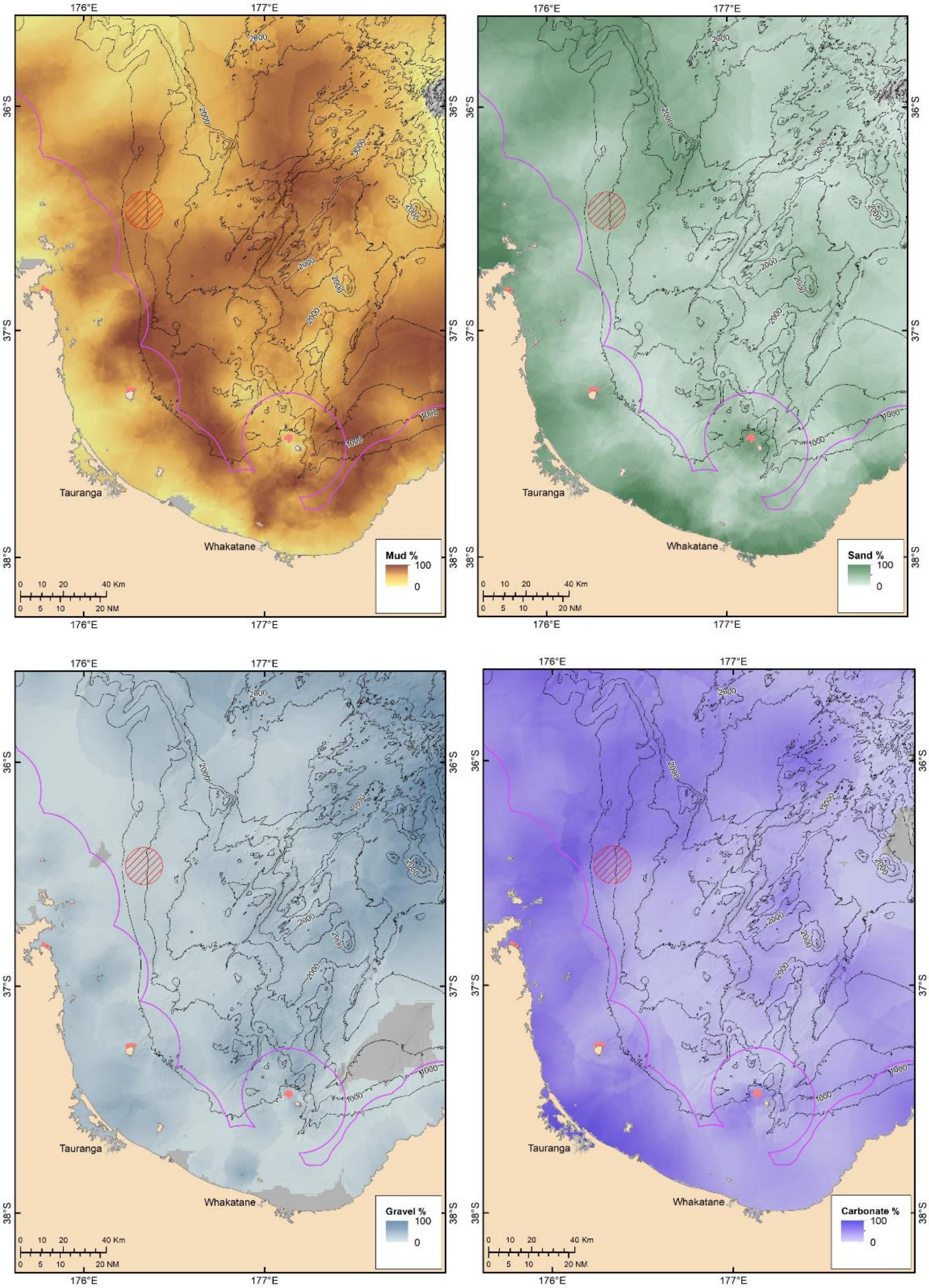


Figure 3-19: Distribution of mud, sand, gravel and carbonate in seafloor sediments in the Bay of Plenty. The map was produced using the data from the samples in Figure 3-18 and interpolating using a kriging method in GIS. The purple line indicates the 12 nautical-mile limit to the Territorial Sea, and black lines are bathymetric contours at 500 m, 1000 m, 2000 m and 3000 m below sea level. The three orange areas demarcate marine reserves. The red-hatched circle indicates an Explosives Dumping Ground. (NIWA unpublished data)

3.5.2 Biogenic habitats

Particular species, because of their three-dimensional structure, size and abundance, form a habitat for a wide range of other species. Tube dwelling polychaete worms, macroalgae, sea grass, sponges, bryozoans, and cold-water corals are all groups that can form so called biogenic habitats. Jones at al. (2016) surveyed fishermen for their local ecological knowledge (LEK) of the locations and extent of these sorts of seafloor habitats around New Zealand's coast. In Horizon's western CMA (Figure 3-20), Jones et al. (2016) identified a large area dominated by the large thick shelled dog cockle in the north off Whanganui, and further south offshore of the Manawatu River areas of horse mussels, sponges, and "coral" (possibly bryozoans). Intensive NIWA sampling on the Patea Bank provides a more detailed description of seafloor habitats to the west of Horizons CMA (Figure 3-21). Near-shore sampling by NIWA (Figure 3-22) provides information inshore of the LEK.

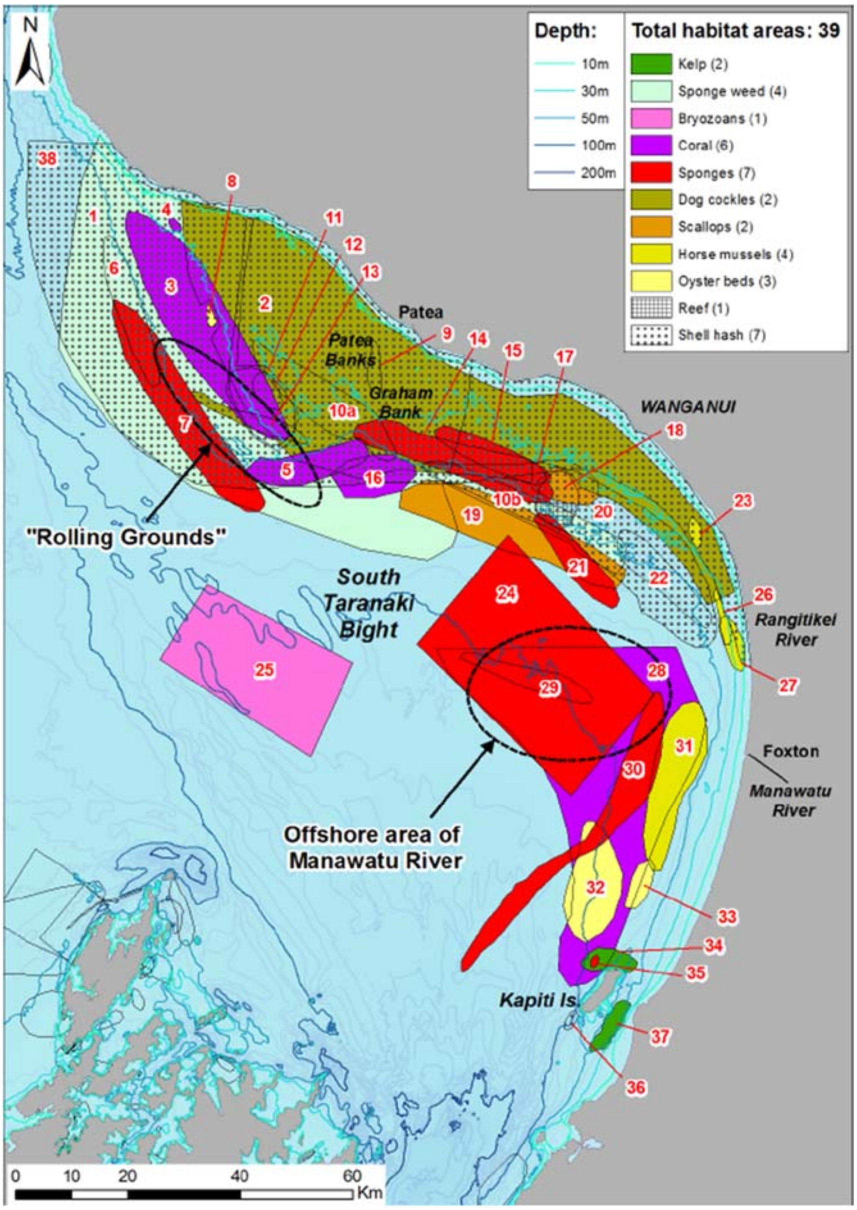


Figure 3-20: South Taranaki Bight Local Ecological Knowledge map. Each fisher-drawn area has been assigned a unique number, (red). Some key sites are circled and labelled as black text on white background. From Jones et al. (2016).

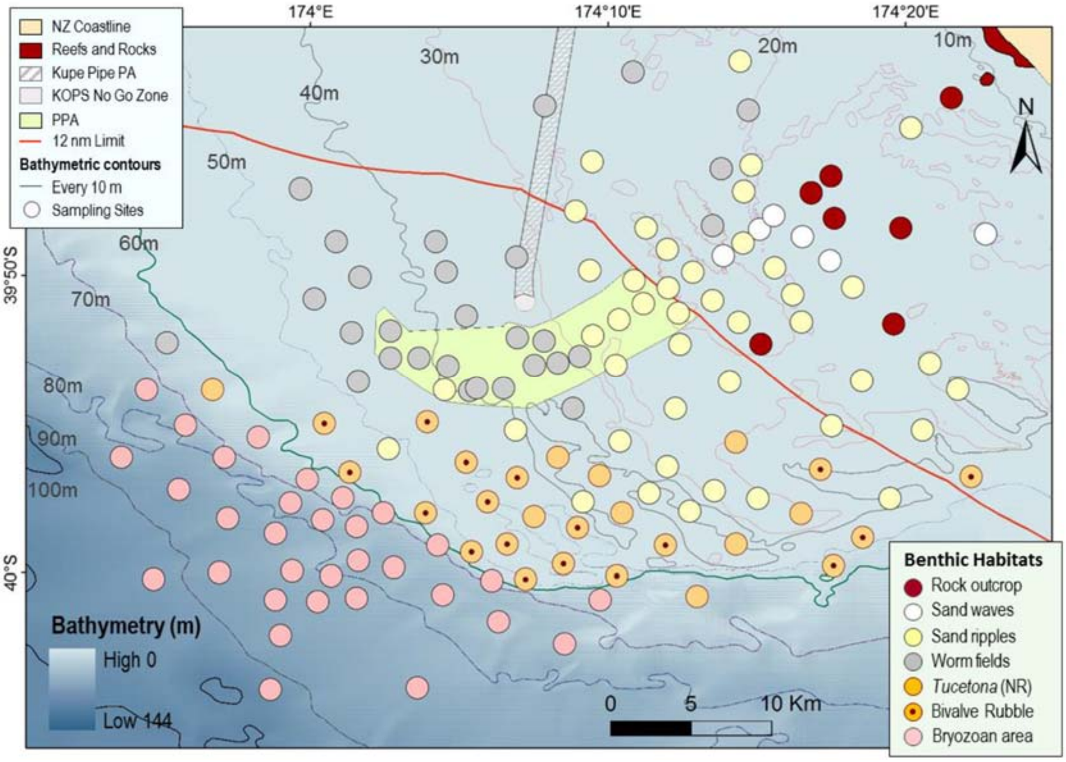


Figure 3-21: Seabed habitat types observed at each site within the Patea Shoals region, STB.
PPA = Proposed Project Area. Coloured circles represent survey sites; Tucetona (NR) = dog cockle sites with live *T. laticostata* but little to no shell debris (i.e. No Rubble). From Beaumont et al. (2015).

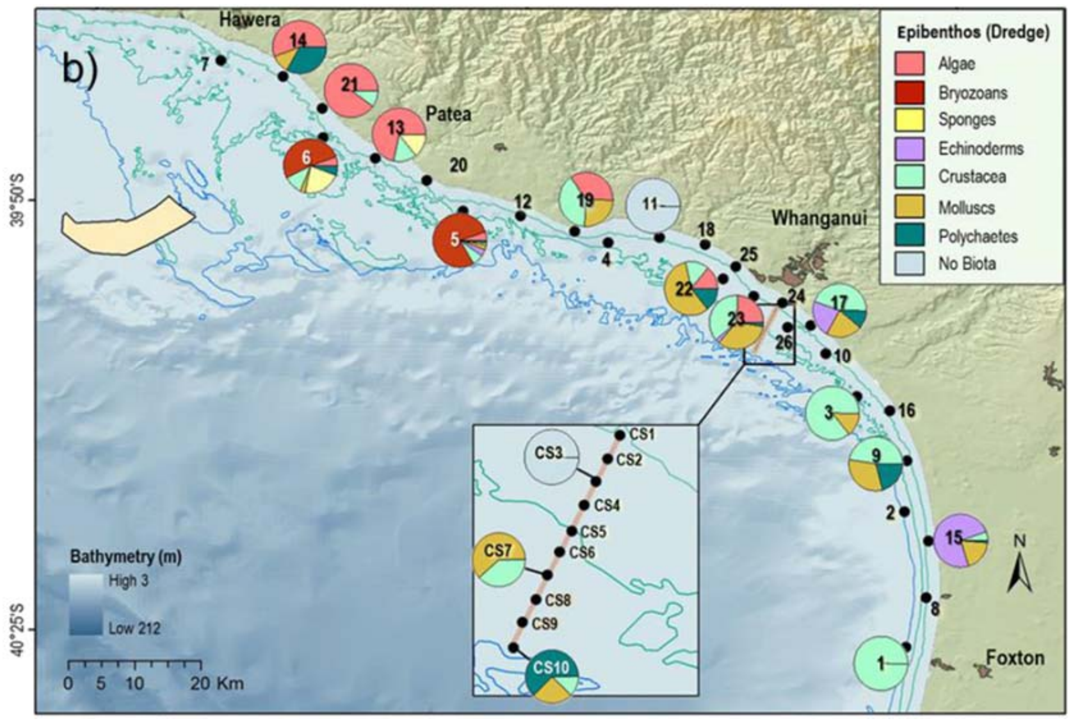


Figure 3-22: The proportion of major taxonomic groups of macrobenthos collected at dredge sites. TTR's proposed mining site south of Hawera is also shown. From Anderson et al. (2015).

3.6 Benthic invertebrates

NIWA's *Specify* database is a collation of benthic invertebrate specimens collected from New Zealand science programmes from 1950 to the present. Data consist of taxonomic identification, location, depth, and research voyage details. It should be noted, however, that these are qualitative rather than quantitative data. Generally, only a subset of specimens sampled at each site are recorded into *Specify,* often only "voucher" specimens or specimens of particular interest (i.e. new records for a site). Older surveys are also less well represented in the database than more recent ones. Despite these limitations, the database contains much useful information. *Specify* currently holds 118,698 registered catalogue items from 45,394 localities, and includes 7,856 species in 24 invertebrate phyla (Figure 3-23). The sampling intensity in Horizons CMA is low.

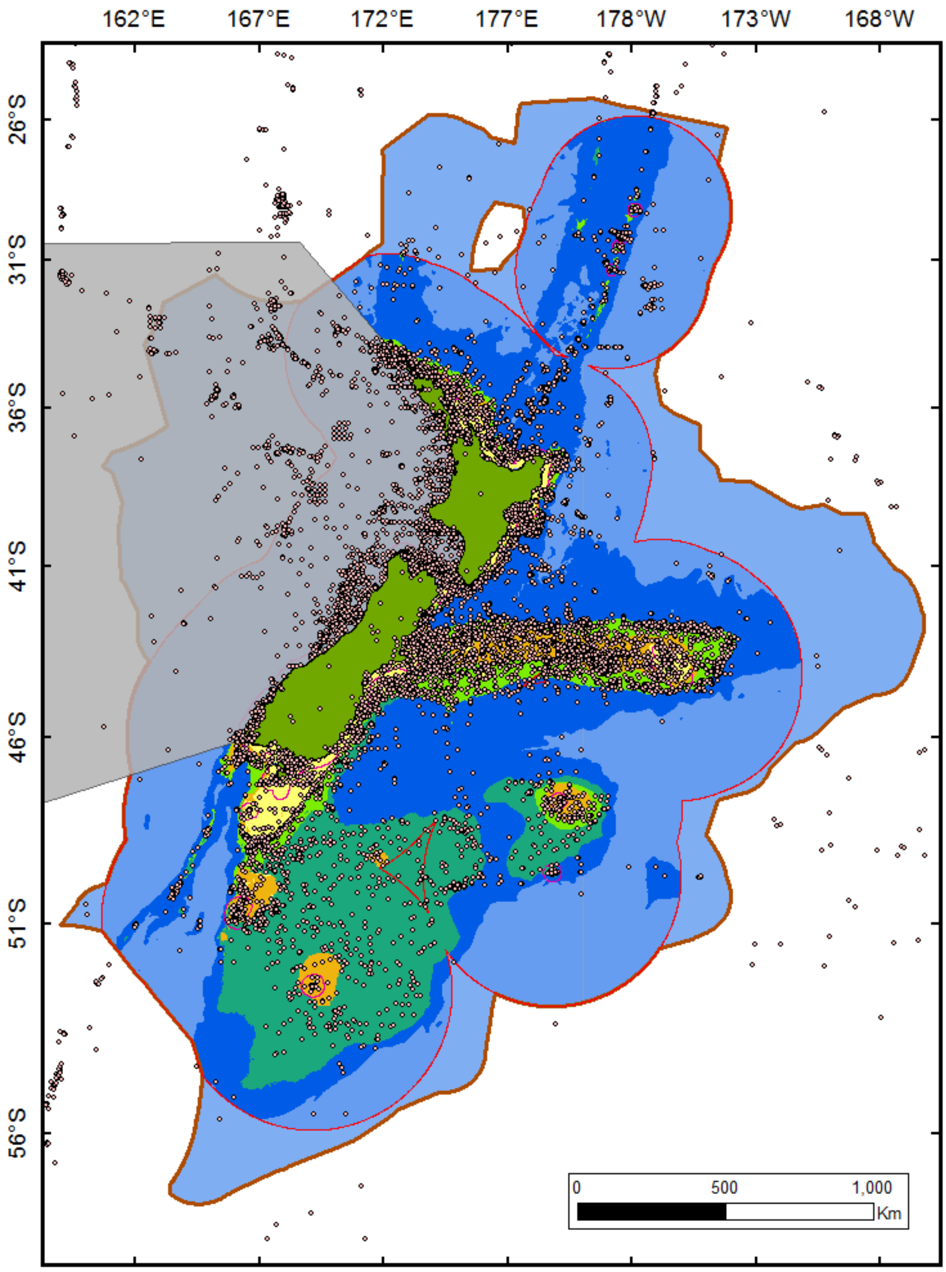


Figure 3-23: Location of invertebrate records from the NIWA *Specify* database. (NIWA)

3.7 Distribution of threatened or vulnerable species

3.7.1 Corals and other sensitive marine environments

Using data from NIWA's *Specify* database as well as verified (confirmed by coral taxonomists) fisheries-observer datasets and all available fisheries-observer coral data (non-verified), Anderson et al. (2016) modelled the distribution likelihoods based on environmental relationships for several groups of corals, sponges and echinoderms. These indicate the likelihood for several habitat-forming or vulnerable deep-seafloor groups to occur in the Horizons CMA (e.g. Figure 3-24 to Figure 3-26). These likelihoods are much greater in the eastern CMA where deep water corals, sponges, and other vulnerable species occur close to the coast.

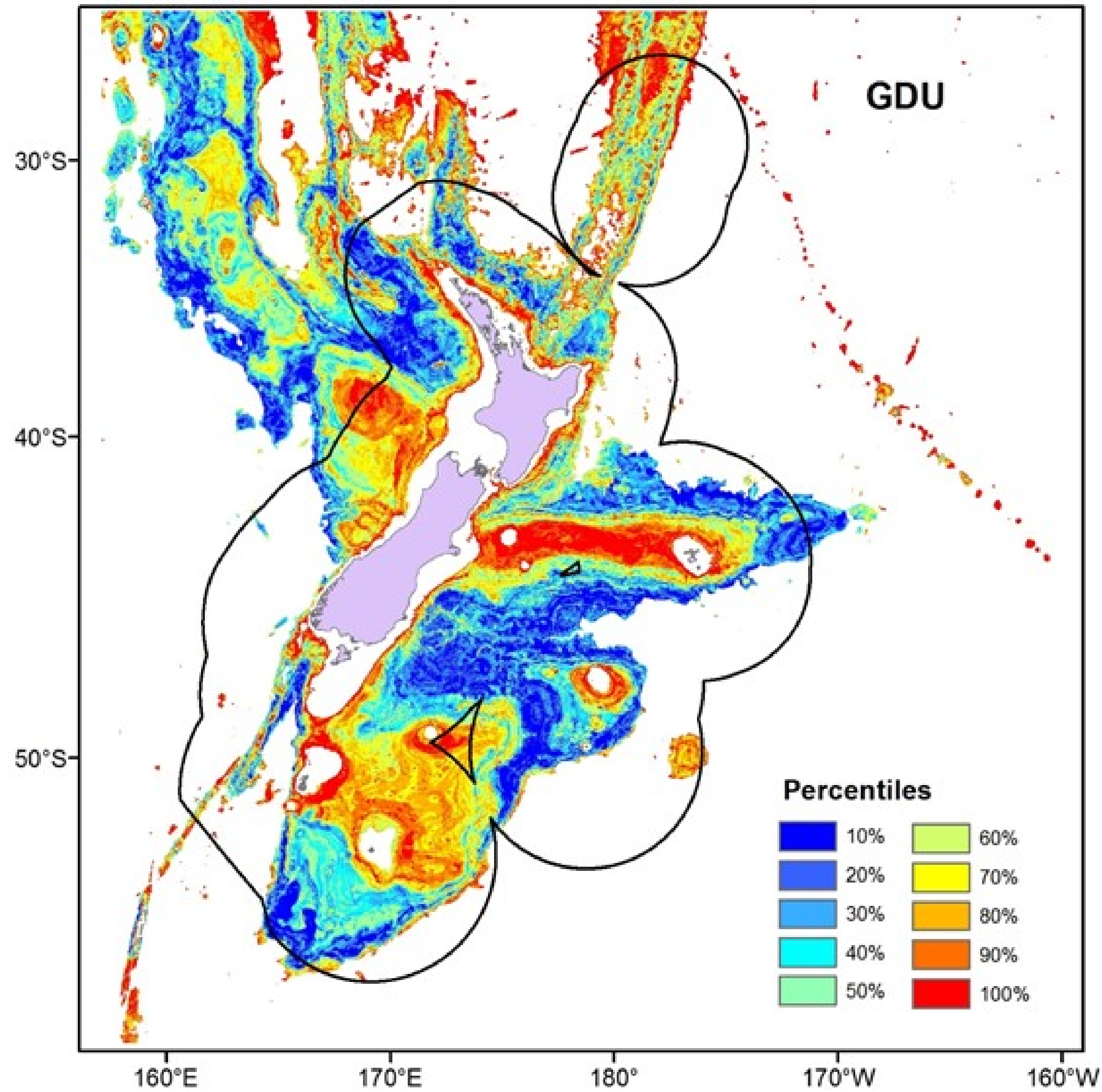


Figure 3-24: Predicted distribution of *Goniocorella dumosa*, a habitat-forming deep-sea coral and sensitive environment indicator taxon. Colours reflect probability deciles (habitat suitability values divided into equal-sized categories), where dark blue represents areas of low probability of presence and red indicates high probability. High predicted probabilities of suitable habitat for this species (red areas) occur along the eastern CMA. From Anderson et al. (2016).

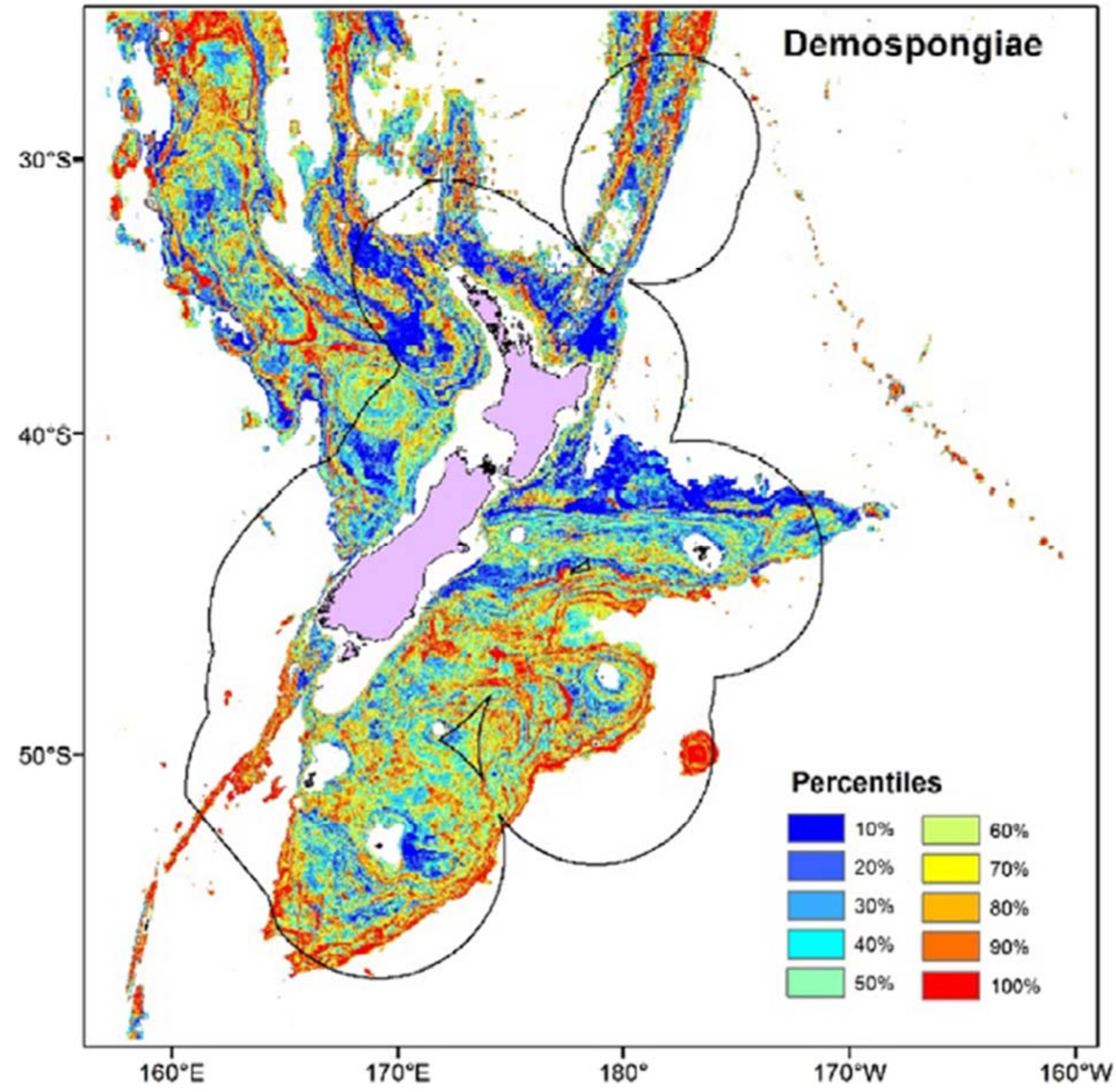


Figure 3-25: Predicted distribution of Demospongia, a habitat-forming group and sensitive environment indicator taxon. Colours reflect probability deciles (habitat suitability values divided into equal-sized categories), where dark blue represents areas of low probability of presence and red indicates high probability. Habitat suitability for this group is predicted to be moderate along the eastern CMA. From Anderson et al. (2016).

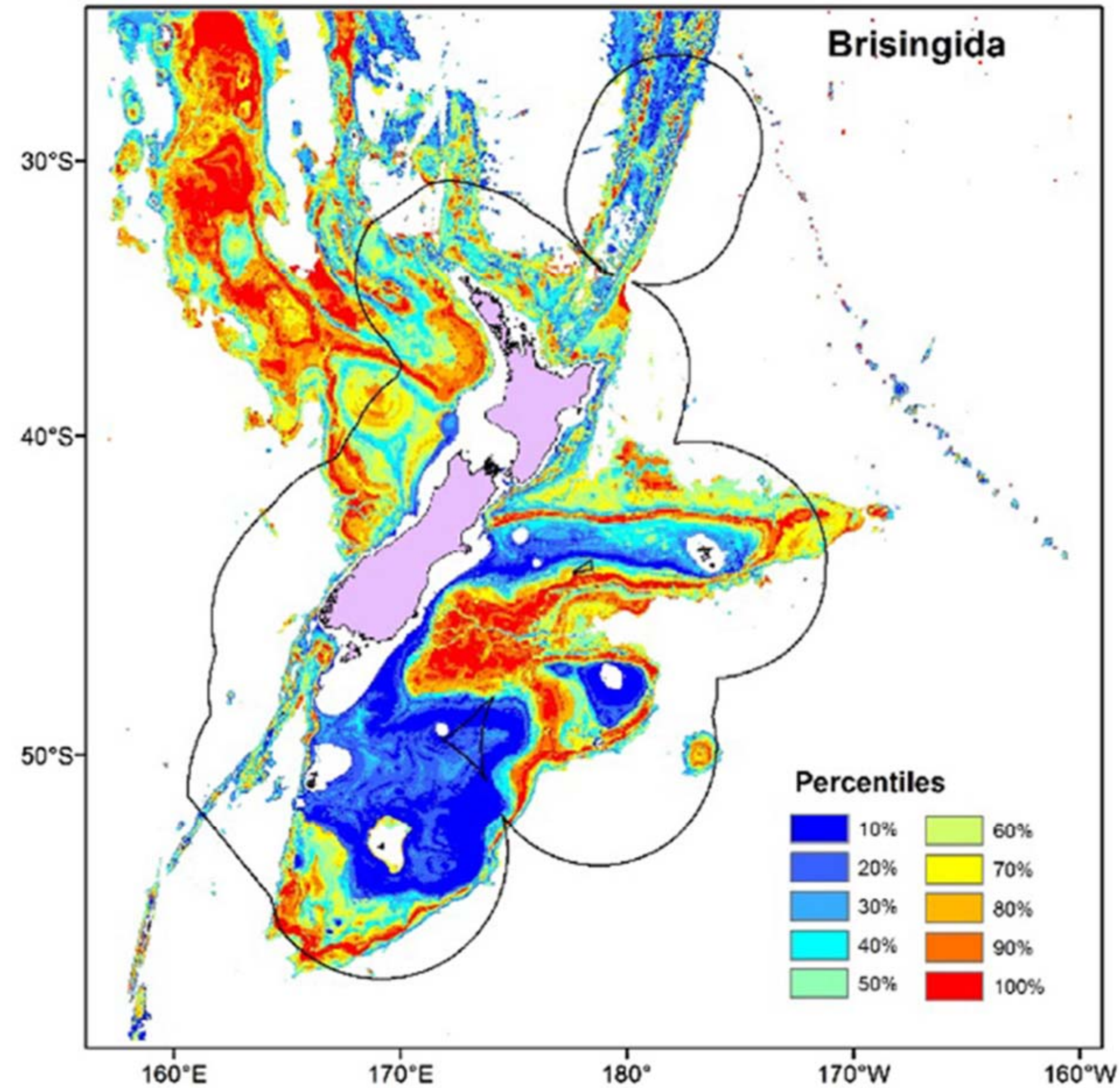


Figure 3-26: Predicted distribution Brisingid echinoderms, a sensitive environment indicator taxon. Colours reflect probability deciles (habitat suitability values divided into equal-sized categories), where dark blue represents areas of low probability of presence and red indicates high probability. The predicted probability of habitat suitability for this group along the eastern CMA is low. From Anderson et al. (2016).

3.7.2 Marine mammals

Summaries of incidental sights of whales and dolphins on the South Taranaki Bight have been provided in MacDiarmid et al. (2015) (Figure 3-27). These sightings are predominantly presence only data obtained from casual observers, not the presence-absence data that would normally be available from systematic sampling. Consequently, areas where there are no observations do not necessarily indicate an absence of marine mammals. Similarly, clusters of observations near human population centres or areas of high boating activity do not necessarily indicate favoured areas for marine mammals.

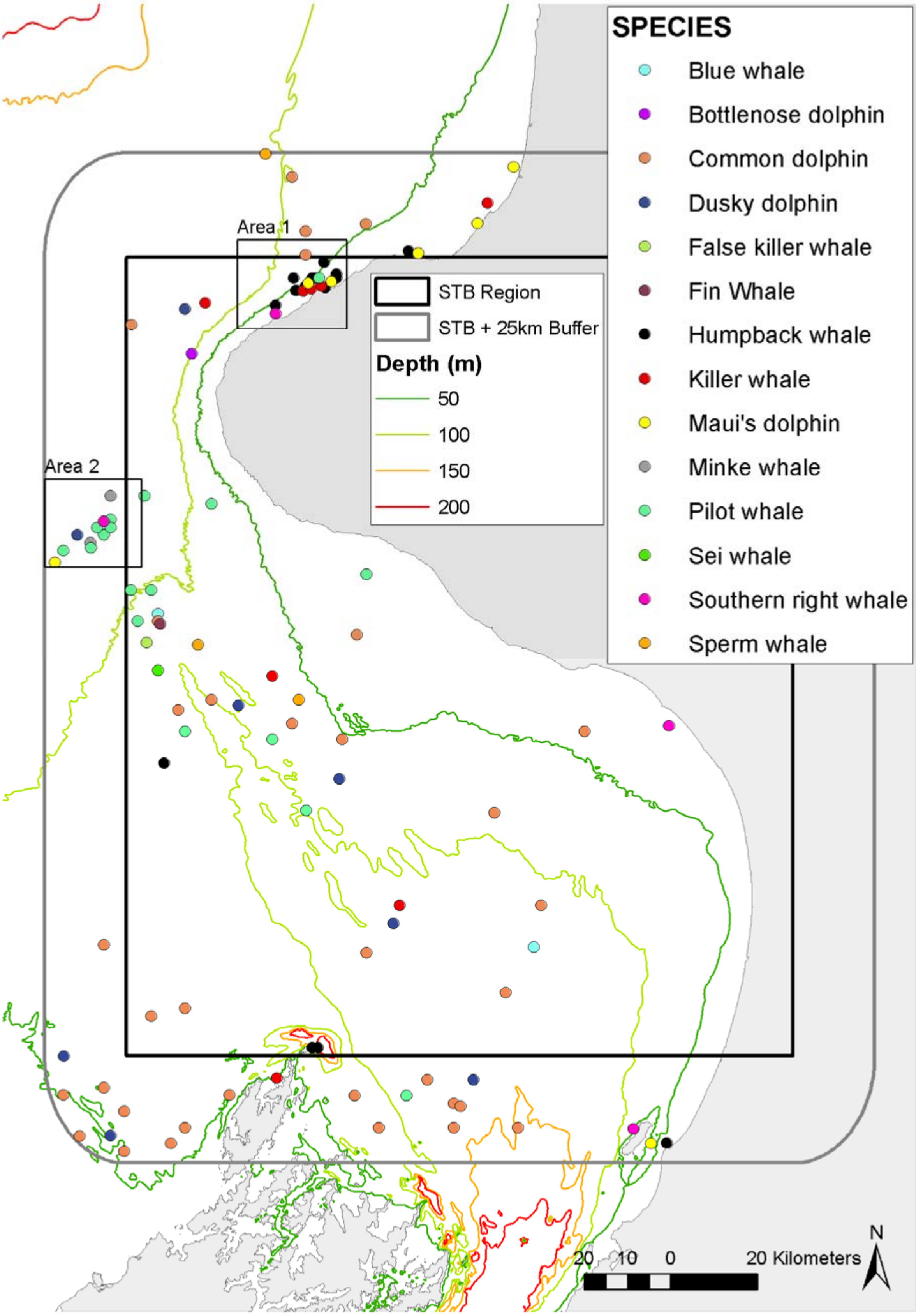


Figure 3-27: Distribution of marine mammal sighting locations, by species in the STB. Area 1 and Area 2 demarcate two areas of sighting concentrations. From MacDiarmid et al. (2015).

Incidental sightings data (Figure 3-28) combined with relevant environmental data (e.g., winter sea surface temperature, sea surface temperature gradient, sea surface primary productivity, the 95th percentile of annual average wave height that indicates extreme events, dissolved organic matter, suspended particulate matter, and tidal current velocity) have been used to model the probabilistic distribution of three marine mammal species (southern right whales –winter shelf distribution only, Hector's dolphins, killer whales) in New Zealand waters (Torres et al. 2015). This modelling indicates that the Horizons western and eastern CMAs are of low to moderate suitability for southern right whales during the calving season (Figure 3-29), and low suitability for Hector's dolphins (left panel in Figure 3-30). Horizons western CMA has low to moderate suitability for killer whales but the eastern CMA, especially around Cape Turnagain, is of moderate to high suitability for killer whales (right panel in Figure 3-30). Further modelling, currently underway by NIWA, will provide similar habitat suitability maps for another 15-20 whale and dolphin species for which there are sufficient sighting data.

Stranding data (e.g., Brabyn 1991) may also indicate the presence of a marine mammal species within a broader region, but cannot unequivocally indicate the usual occurrence of a species at a particular location.

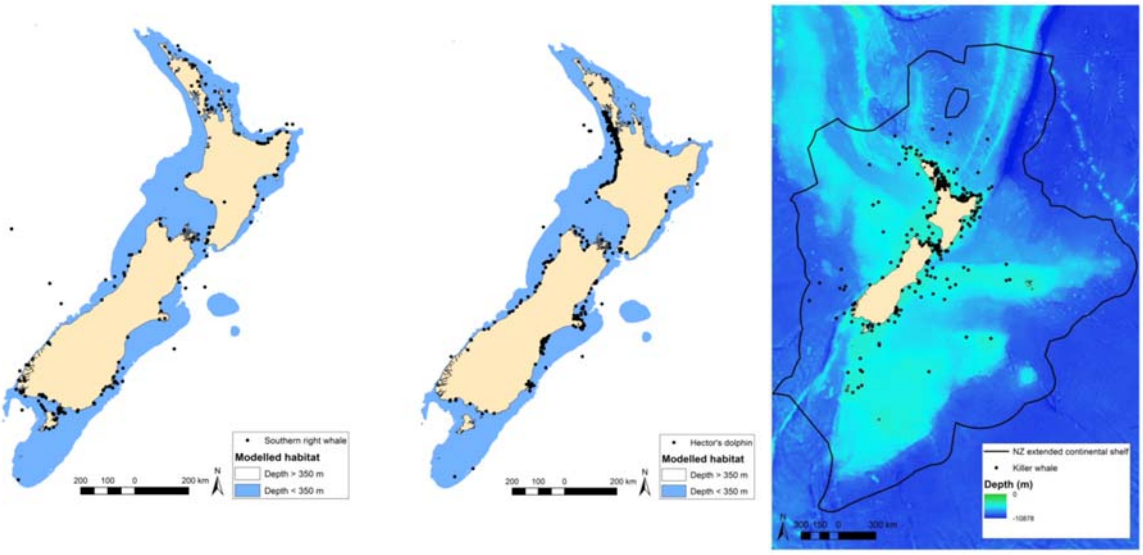


Figure 3-28: Distribution of incidental sightings of southern right whales (left panel), Hector's dolphins (middle panel), and killer whales (right panel) used in distribution models. The blue areas in the first two panels represent habitat less than 350 m that was used as the modelling extent. The black line in the right panel illustrates the extended continental shelf used as the extent for the killer whales model; regional bathymetry is illustrated. From Torres et al. (2015).

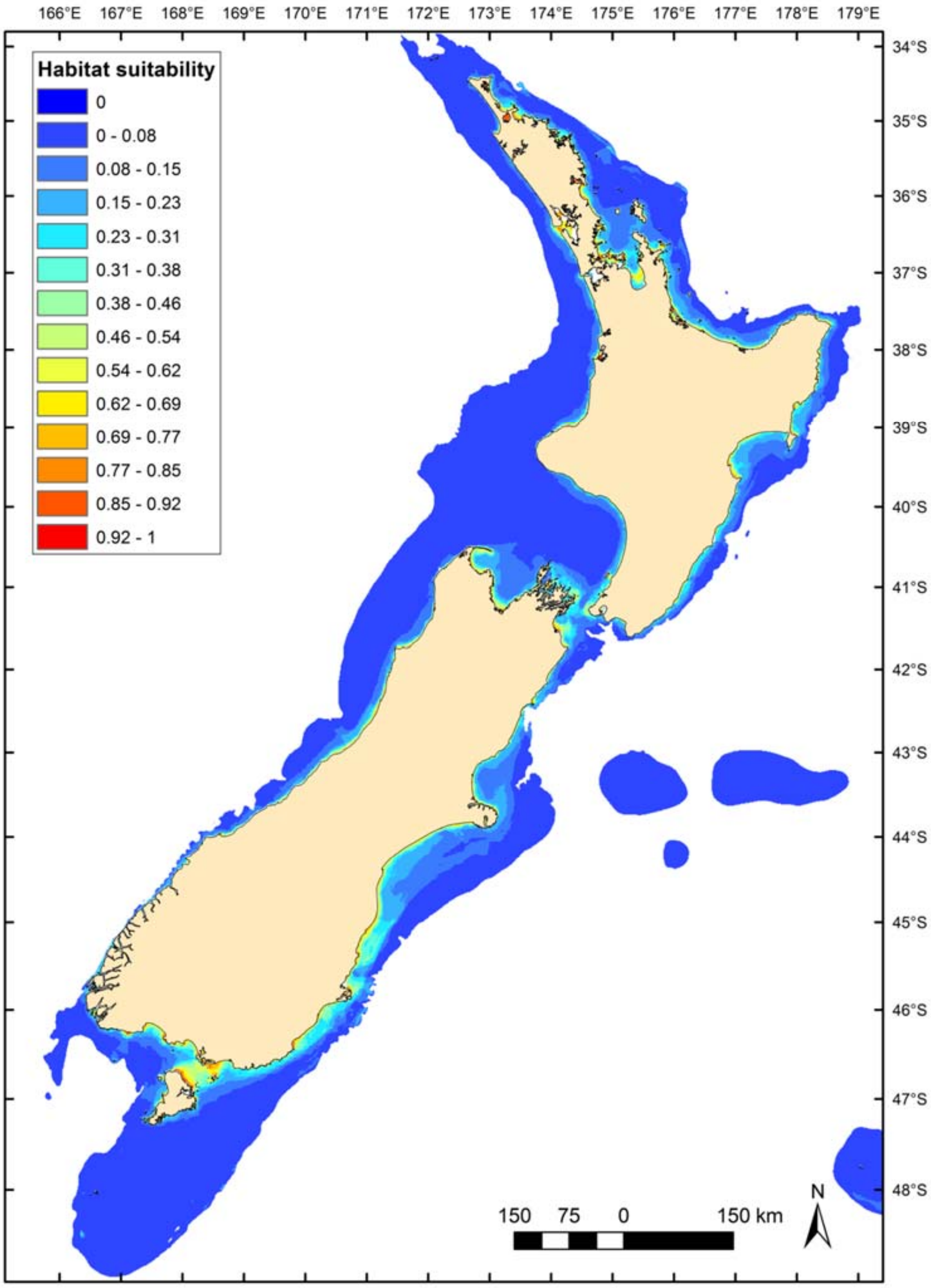


Figure 3-29: Winter habitat suitability predictions for southern right whales. Full extent of model within the 350 m isobaths of mainland New Zealand. Warm colours indicate the highest habitat suitability. From Torres et al. (2015).

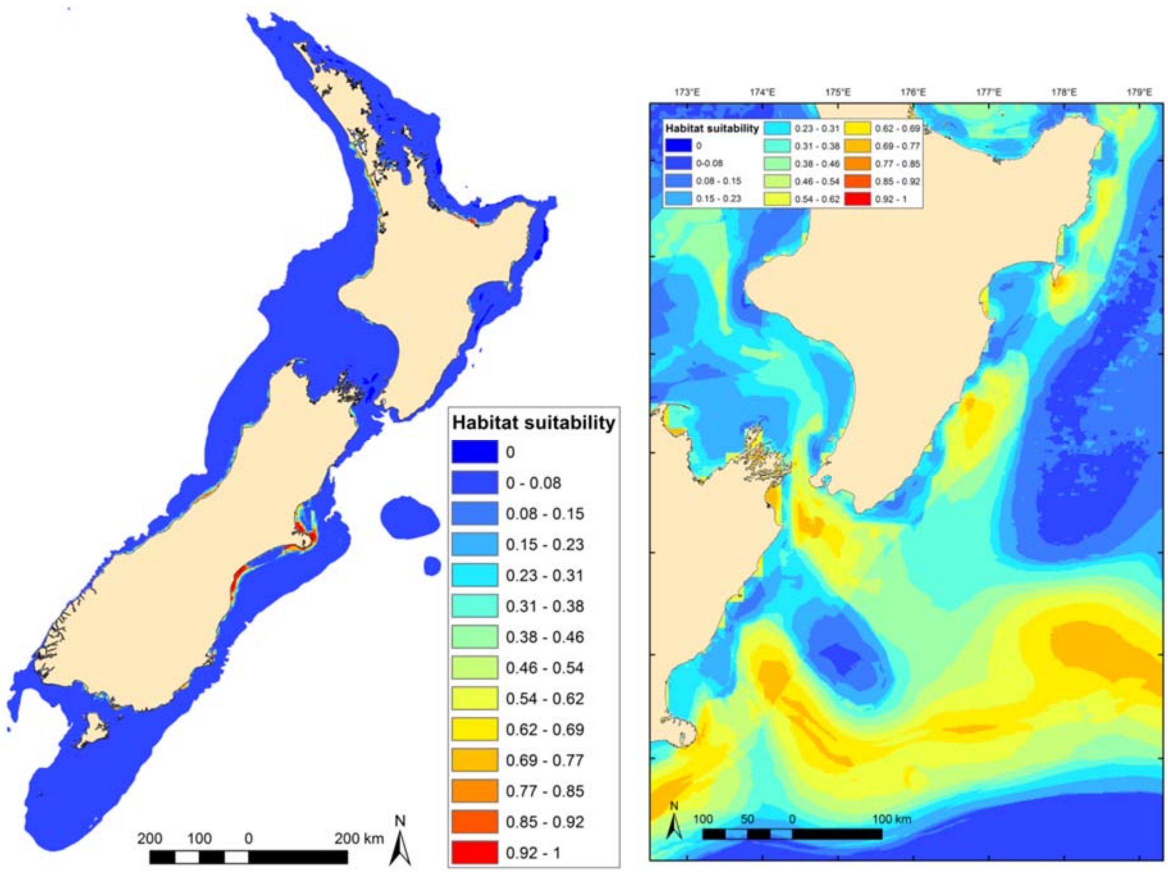


Figure 3-30: Habitat suitability predictions for Hector's dolphins (left panel) and killer whales (right panel). Predictions were derived from habitat use models with correction for the spatial bias in observations. Warm colours show the highest habitat suitability. From Torres et al. (2015).

3.7.3 Seabirds

The distribution of 38 species or species groups of seabirds as recorded by MPI Fisheries Observers are available from https://seabird-counts.dragonfly.co.nz/explore/counts/xsb/all-seabirds.html (e.g., Figure 3-31 and Figure 3-32) (Richard et al. 2011) and for 48 species from the National Aquatic Biodiversity Information System (NABIS). To the best of our knowledge, there have been no systematic, quantitative boat-based surveys of seabirds across the Horizons CMA. A list of seabirds that are likely to occur within the areas of interest could be compiled based primarily upon sightings data publicly available at the 'eBird' website (see http://ebird.org/content/newzealand/) and on New Zealand bird distribution data presented in Robertson et al. (2007).

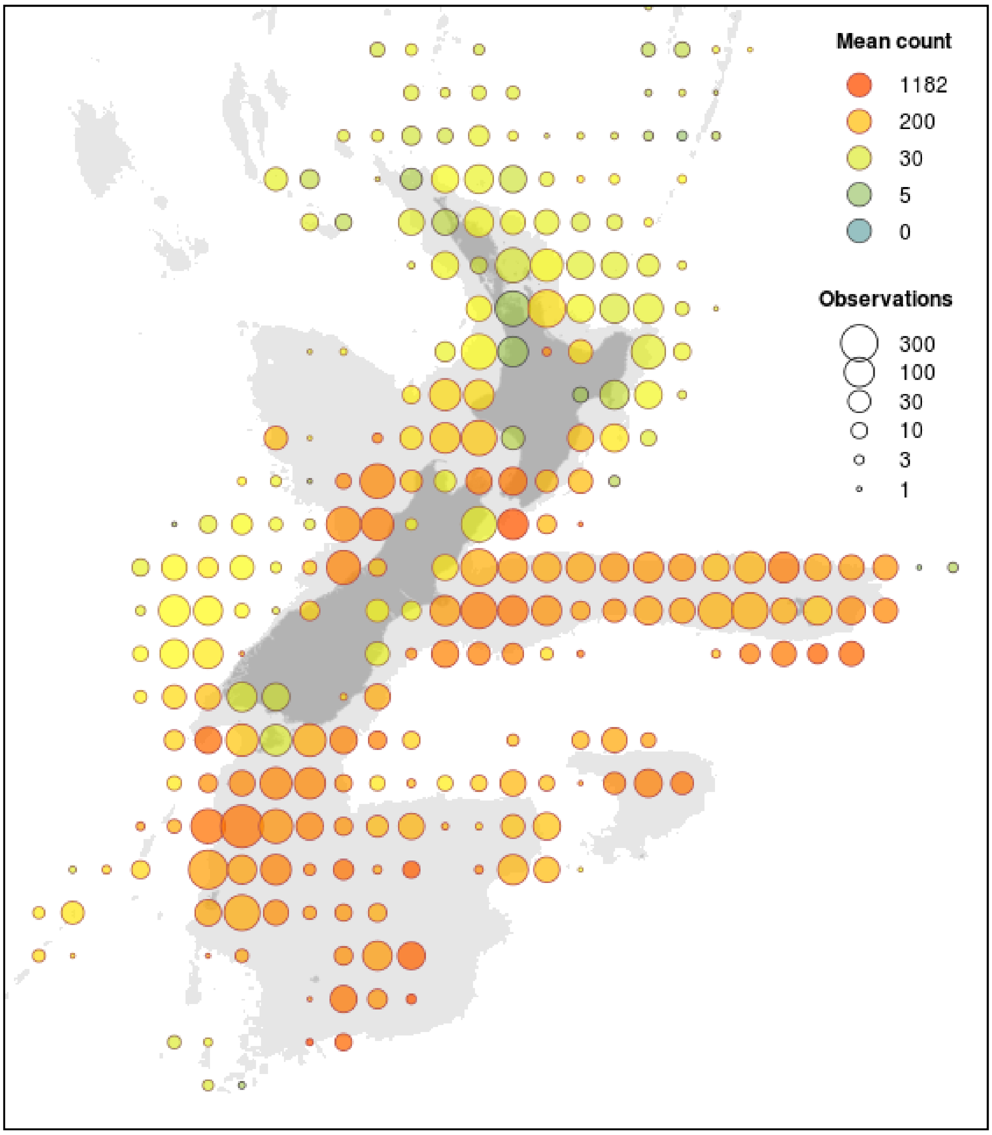


Figure 3-31: Mean number of all seabirds recorded around fishing vessels during counts by government observers. Counts are binned to 1° of longitude and latitude. The size of the circle indicates the number of observations, whereas the colour indicates the mean number of birds recorded during counts. Empty circles indicate that no birds were observed. The grey areas indicate water depths of less than 1000 m. Image from https://seabird-counts.dragonfly.co.nz/explore/counts/xsb/all-seabirds.html Richard et al. (2011).

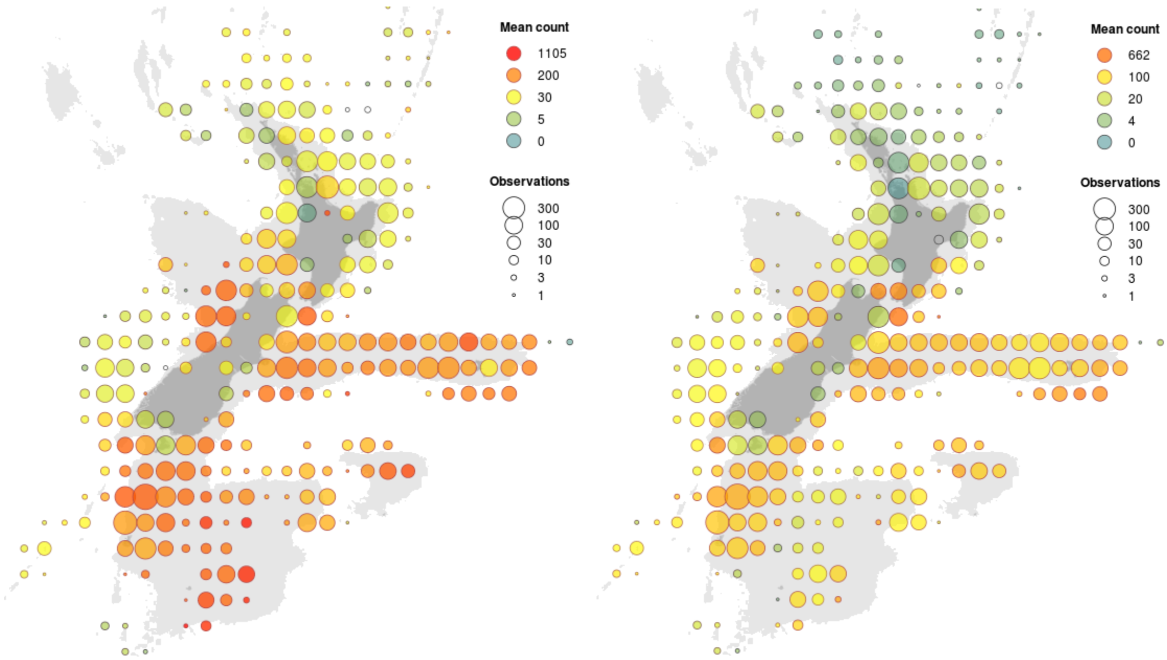


Figure 3-32: Mean number of all petrels (left panel) and all albatrosses (right panel) recorded around fishing vessels during counts by government observers. Counts are binned to 1° of longitude and latitude. The size of the circle indicates the number of observations, whereas the colour indicates the mean number of birds recorded during counts. Empty circles indicate that no birds were observed. The grey areas indicate water depths of less than 1000 m. Image from https://seabird-counts.dragonfly.co.nz/explore/counts/xsb/all-seabirds.html Richard et al. (2011).

3.8 Distribution of fish

3.8.1 Reef fish

The distribution and abundance of reef fish along the Horizons CMA has been modelled by Smith et al. (2013). Using underwater fish count data from surveys conducted around New Zealand, together with a set of environmental and geographical predictors, they describe the expected distribution, abundance and species richness of reef fish on all mainland and offshore island reefs to depths <50 m. Because the analysis was dependent on field count data, it ignores rare and/or cryptic species for which little or no count data were available and concentrates on 72 species for which there were adequate data.

Extracts from the model for specific reef fish species distributions and abundance, and species richness have been made for the Wellington Region (e.g., Figure 3-33). Similar model extracts can be made for the Horizons CMA.

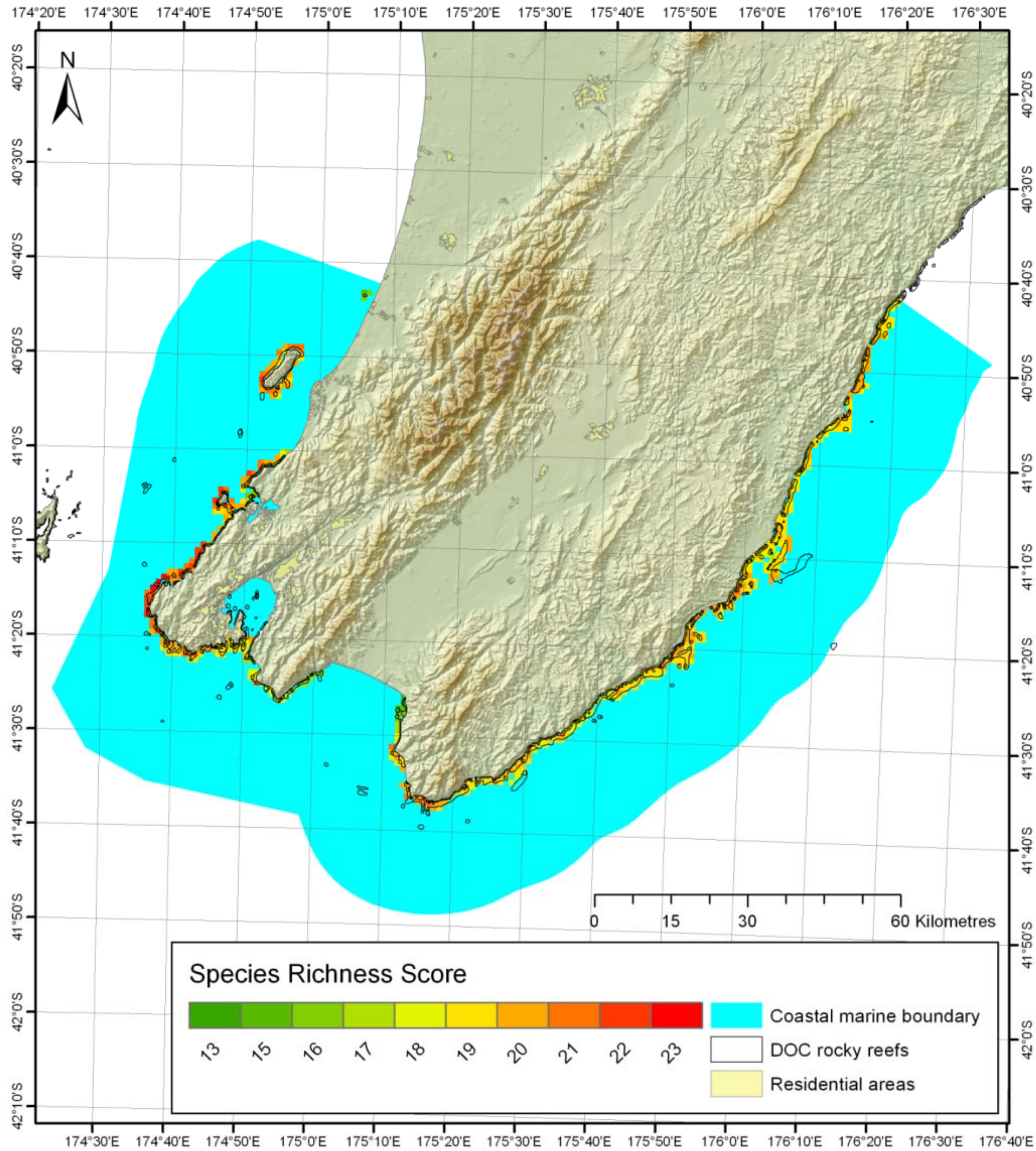


Figure 3-33: Predicted reef fish species richness in the Wellington region. Model output from Smith et al. (2013).

3.8.2 Demersal and pelagic fish

Bottom associated and pelagic fish species occur throughout the HRC CMA. Published modelling of demersal fish species richness (Leathwick et al. 2006a) indicates moderate fish diversity in the Horizon CMA (Figure 3-34). Modelled spatial likelihood occurrence and abundance data are available for 70 demersal and pelagic fish species New Zealand wide. An extract for one species, the leather jacket, is provided (Figure 3-35 and Figure 3-36). Similar extracts can be provided for all the modelled species occurring in Horizons CMA.

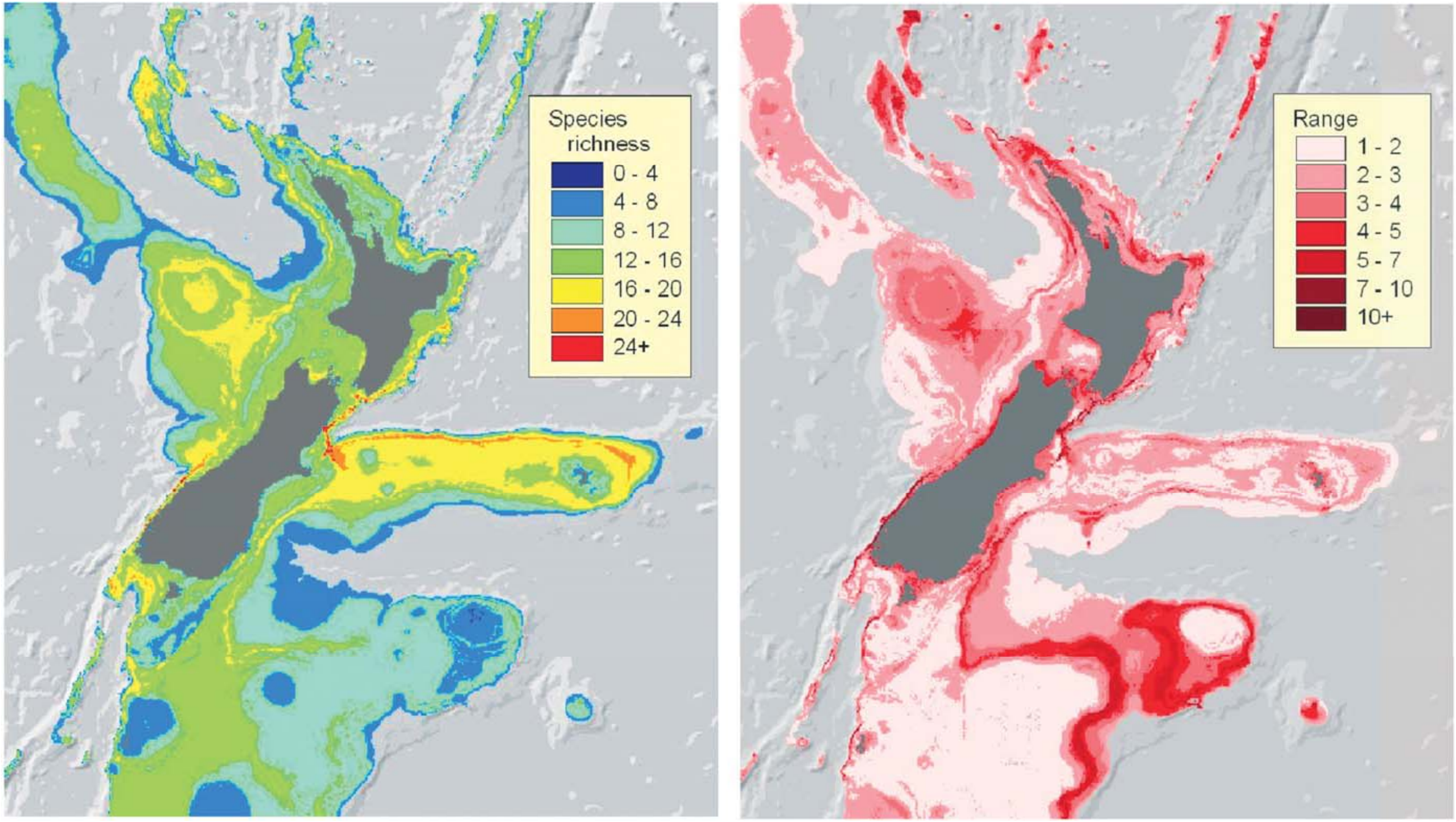


Figure 3-34: Demersal fish species richness. This was predicted from a Boosted Regression Tree model using environment and trawl characteristics as predictors, and fitted with a tree size of five. Confidence intervals were estimated from predictions made from 1000 models fitted to bootstrap samples of the trawl dataset. Left panel: predicted species richness. Right panel: range of the 5 to 95% confidence interval (From Leathwick et al. 2006a).

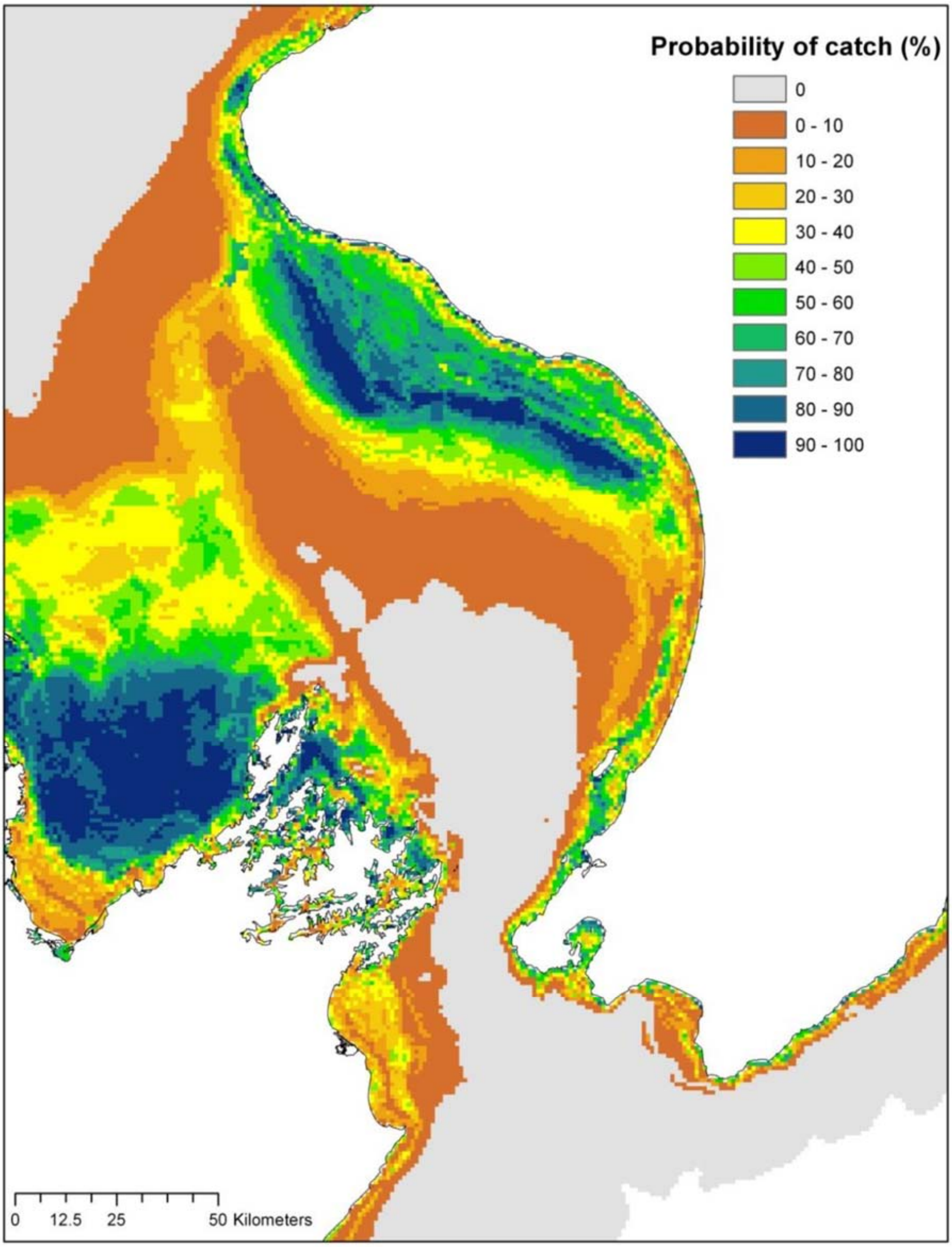


Figure 3-35: Probability of occurrence (%) of leatherjacket (*Parika scaber*) in a demersal trawl in the South Taranaki Bight region. From MacDiarmid et al. (2015)

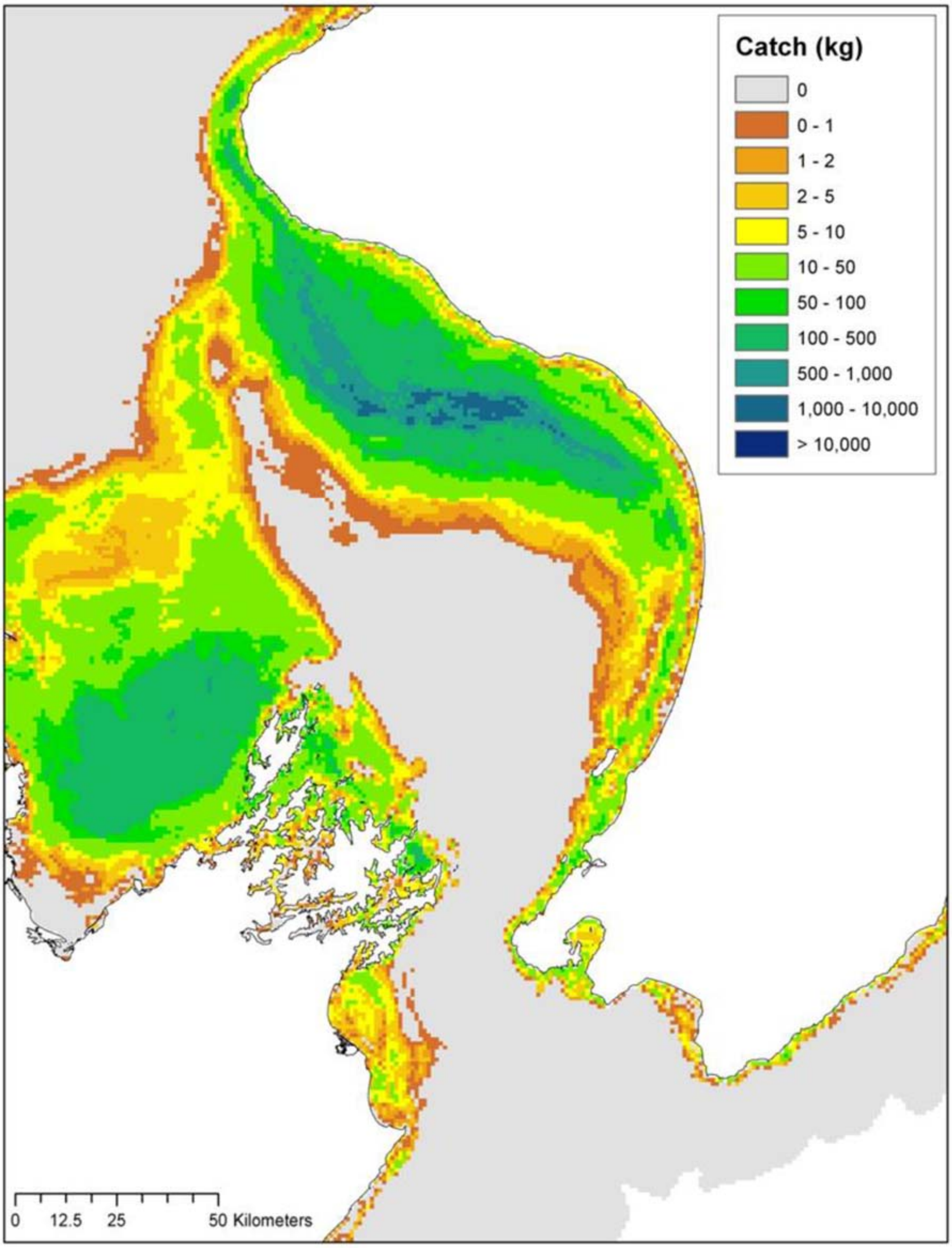


Figure 3-36: Predicted catch (kg) of leatherjacket (*Parika scaber*) in a demersal trawl in the South Taranaki Bight region. From MacDiarmid et al. (2015).

3.9 Distribution of commercial fisheries effort and catch

Commercial fisheries catch and effort data, daily processing data, and landings data are held in the Ministry for Primary Industries catch-effort database "warehou" administered by NIWA. These data can be requested to provide summaries of fisheries catch and effort on a spatial scale no smaller than 0.1° x 0.1° latitude and longitude respectively, so as to preserve commercially sensitive information. An example of such an extract is provided for the South Taranaki Bight showing the distribution of catch and effort in relation to TTR proposed mining activities (Figure 3-37) (MacDiarmid and Ballara 2016). Extracts can be made by fishing effort or fish species. Similar extracts could be prepared for the Horizons eastern CMA.

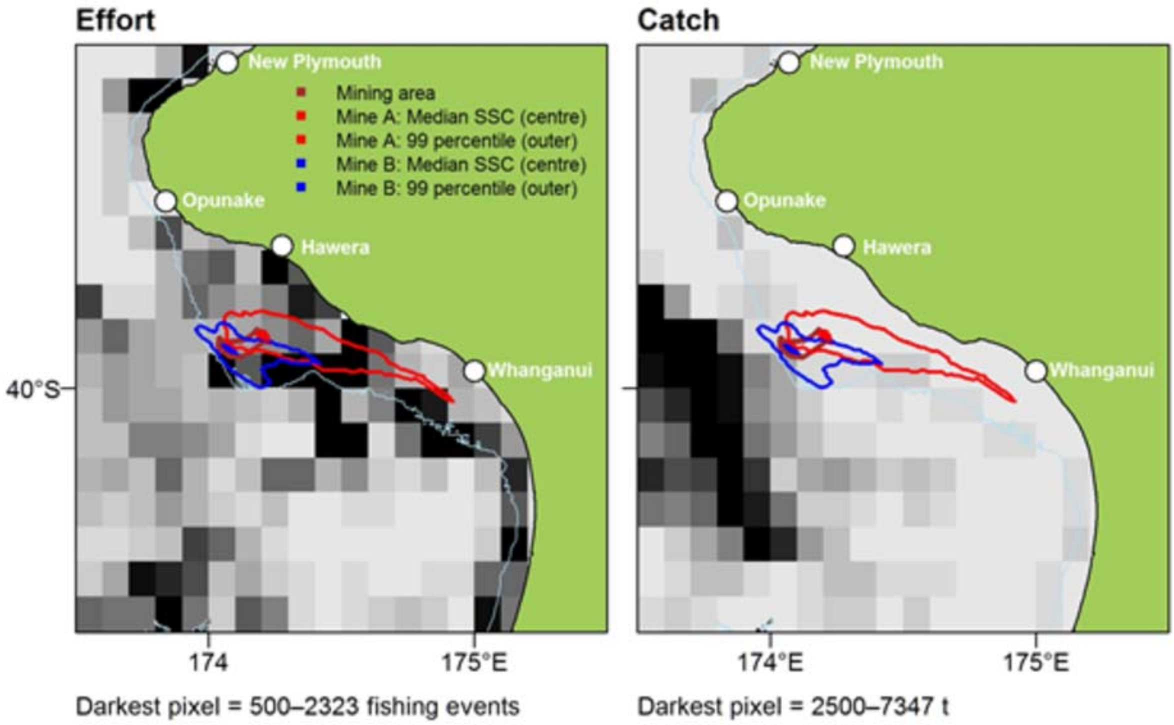


Figure 3-37: All commercial fishing methods - effort and catch where locational data were available from TCEPR, TCER, LTCER, LCER, and NCELR forms. Density plots showing the spread of commercial fishing effort (number of fishing events) and total catch within the study area between 1 October 2006 and 30 September 2015. Pixels are 0.1° x 0.1° rectangles. The light blue line represents the 50 m contour. Also shown is the proposed mining area, and the contours where SSC is above the threshold at which marine fish avoid sediments (2mg / l) 50% (median) and 1% (99th percentile) of the time when mining occurs at the innermost (A) and outermost (B) points of the mining area. (From MacDiarmid and Ballara 2016)

3.10 Threats and hazards

3.10.1 Assessment of anthropogenic threats

The impact of 65 human activities or threats on 62 types of marine habitats occurring in New Zealand's territorial seas and EEZ was assessed by MacDiarmid et al. (2012). This report, funded by the Ministry for Primary Industries (MPI), was written to provide an overall context for the various threats facing the marine environment, particularly threats falling within MPI's mandate, including 13 types of fishing, three consequences of aquaculture, and two types of biosecurity risk. Baird et al. (2011) reviewed and assessed some of these same threats, with a particular focus on how they related to marine protected areas and marine biodiversity in New Zealand.

The marine habitats assessed by MacDiarmid et al. (2012) ranged from saltmarsh in the high intertidal zone to abyssal plains on the deep ocean floor, including the range of habitats occurring in HRC's CMA. The study assessed the vulnerability of each habitat type to each particular threat. Each habitat-by-threat combination was given a vulnerability score based on the assessment by independent marine experts of five factors; the spatial scale, frequency and functional impact of the threat, as well as the susceptibility of the habitat to the threat and the recovery time of the habitat following disturbance by the threat. The experts also independently assessed their confidence in the quality of the information available to support their evaluation. The assessments from each expert were summarised to estimate the vulnerability of each habitat to each threat, the overall impact of each threat across all habitats, and the overall impact on each habitat from all threats.

MacDiarmid et al. (2012) found that, by a considerable margin, the highest scoring threat over all New Zealand marine habitats was ocean acidification. This is a consequence of higher CO_2 levels in the atmosphere increasingly being absorbed in the sea and forming carbonic acid, thereby altering the ocean's chemistry and making it more difficult for organisms to secrete carbonate structures such as shells and bones. The second highest scoring overall threat was ocean warming, with seven other threats deriving from global climate change ranking in the top 20.

Threats deriving from human activities occurring in catchments were among the highest scoring threats to coastal marine habitats (MacDiarmid et al. 2012). Foremost among those was levels of terrigenous sedimentation resulting from patterns of land-use. It was the third equal highest ranked threat over all habitats and was the highest ranked threat for five coastal habitats including harbour intertidal mud and sand, subtidal mud, seagrass meadows and kelp forest.

Seven of the top 20 threats were directly related to human activities in the marine environment, including fishing, non-indigenous species, coastal engineering, and aquaculture (MacDiarmid et al. 2012). The most important was bottom trawling, followed by dredging for shellfish.

As expected, the expert assessments indicated that the importance of particular threats varied among habitats. Across the approximately 27 types of marine habitats occurring in the Horizon's coastal areas – muds, sands, saltmarsh and shellfish beds in estuaries, and all habitats on exposed coasts and the shelf, as well as the water column – the top ecosystem threats in order of deceasing frequency were ocean acidification, bottom trawling, increased storminess, sedimentation, and reclamation.

It is important to note that the assessment of threats to habitats reported by MacDiarmid et al. (2012) was undertaken in a general or average sense, without taking into account the specific level of threat posed by activities occurring at a particular locality. Thus, the results summarised above must be interpreted cautiously, as they provide general New Zealand-wide indications of the relative vulnerability of marine habitats to anthropogenic threats. Other tools are available that provide more precise evaluation of the specific risks posed by threats occurring at a particular place. One such tool is the Marine Habitat Assessment Decision Support (MarHADS) tool, specifically designed for use by regional councils, which incorporates a local version of the habitat vulnerability assessment applied by MacDiarmid et al. (2012) on a national scale (see section 4).

In the five years since the report by MacDiarmid et al. (2012) was published, knowledge of the trends and the spatial and temporal variation in ocean acidification has grown (see Law et al. 2016). Growing knowledge of its effects on a range of New Zealand species has increased concerns for calcifying organisms such as shellfish, particularly their early life-history stages (see Law et al. 2017). Overall, ocean acidification is probably the major threat to the ecological well-being of marine habitats in New Zealand. This is because it is so pervasive, potentially affecting every habitat and a very wide range of marine organisms.

3.10.2 Sea level rise

Nothing detailed is known about the physical threats and hazards to Horizon's eastern or western coastal areas arising from sea level rise due to climate change. A current NIWA project, funded by the Deep South National Science Challenge, in mid-2018 will provide a high-level assessment of these threats and hazards.

3.10.3 Costal erosion and deposition

Knowledge of coastal stability in the South Taranaki Bight (SBT), including much of the Horizons western CMA, has been extensively investigated and summarised by MacDiarmid et al. (2010) and further updated by Hume et al. (2015a and b). These authors provide an assessment of the stability of the shoreline of the SBT extending 130 km from about Opunake to Waikawa Beach. They reviewed the historical and present-day rates of change in the position of the shoreline and temporal variations in sand storage on the beaches west of Whanganui, and investigated cross shore sediment exchange and longshore flux and sand transport.

Hume et al. (2015a) found that overall in the SBT, there was large variability in beach morphology between the sites surveyed west of Whanganui (Figure 3-38), erosion and accretion throughout the year, small net storage of sand on the beaches and large quantities of sand moving on and off and along the beaches and being exchanged within the beach systems. They found that with the exception of the sand stored in the transgressive dunes, sand storage on beaches west of Whanganui is rather transient in a system of highly connected sand storage units.

MacDiarmid et al. (2010) reviewed and summarised the stretch of coastline from the Whangaehu River to Waikawa Beach. While the shoreline of much of the SBT to just south of Whanganui historically has been subject to erosion, further south the coastline has been accreting or variable, particularly around river mouths where localised erosion can be a problem (Figure 3-39).

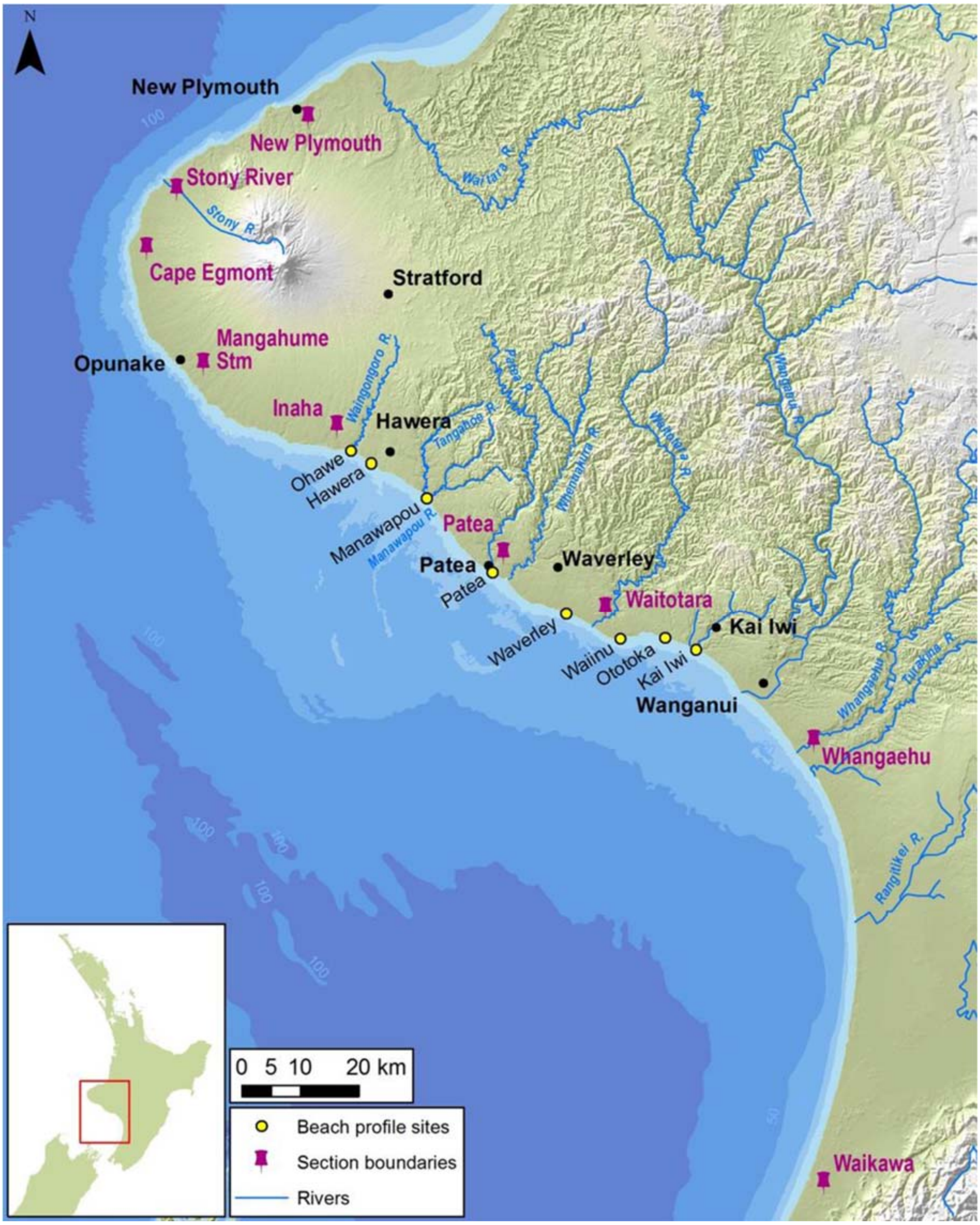


Figure 3-38: Study area and beaches surveyed (yellow dots). From Hume et al. (2015a).

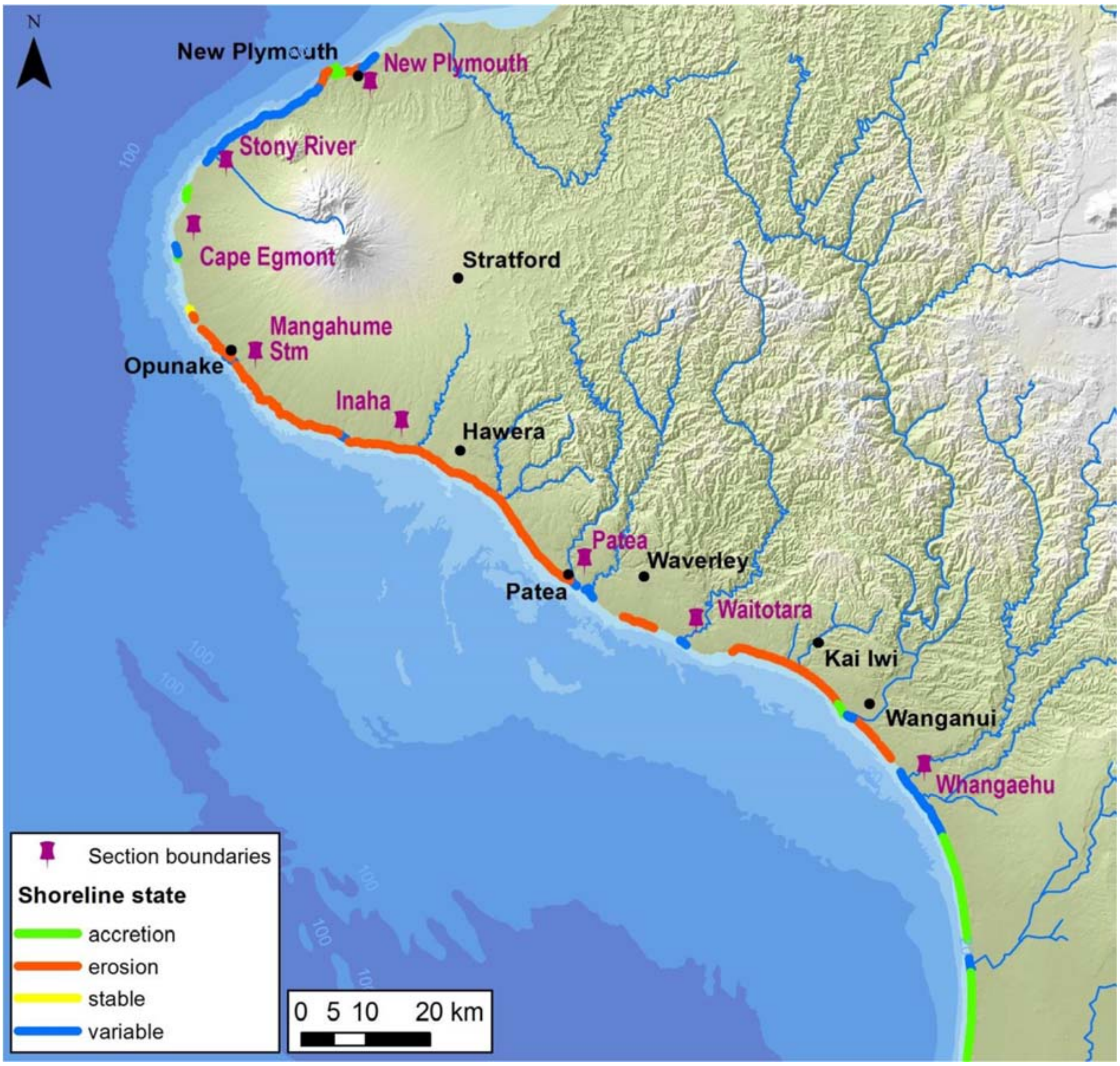


Figure 3-39: Shoreline stability in the South Taranaki Bight in historical times. Areas for which there are no data are left blank. From Hume et al. (2015).

4 The MarHADS tool and its potential application

Over the period 2008-2011 the Marine Habitat Assessment Decision Support (MarHADS) tool was jointly developed by NIWA and a team of regional council coastal scientists and planners to assist regional council resource managers and decision makers to critically assess the relative state and value of coastal habitats (MacDiarmid et al. 2011). It was envisaged by the participating councils that standardisation of the assessments through application of the tool would enable comparison of habitat values within and among regions, and at a national level. The Excel based tool incorporates five types of knowledge about marine habitats (Figure 4-1). These are:

1. The quantity of habitat – the actual and relative size of the habitat in question on local, regional, bioregional and national scales;

2. Habitat vulnerability – this includes likely threats, their scale and functional impact, as well as the resilience of the habitat to those specific threats, the recovery timescale once the threat is removed and the level of uncertainty in assessments of these factors given the state of knowledge about them;

3. The nationally threatened and at-risk species that may occur within particular habitats;

4. Habitat quality as assessed by the number of invasive species, water quality, sediment quality, the degree to which the expected biotic assemblage remains intact, and an overall assessment of the degree that expected ecosystem features and functions remain in operation; and

5. The level of regulatory, provisioning, and non-consumptive ecosystem goods and services provided by marine habitats.

In the first use of this tool, it was recommended that regional councils assess examples of each habitat type within their region that lie at, or near, the extremes of environmental pristineness and degradation. Habitats occurring within long-established marine reserves could provide one extreme; local knowledge could suggest the locations of the other extreme. These initial assessments would then provide immediate knowledge of the likely range of environmental characteristics for each habitat that would indicate its regional significance. As further assessments were undertaken the proportions of a habitat within a region that lie along this gradient would become increasingly apparent. Regular sharing of habitat assessments among councils would help to indicate the likely range of environmental characteristics for each habitat that would indicate its national significance. To date only the Auckland Council has used the MarHADS tool to assess any marine habitats (MacDiarmid et al. 2014), although the Department of Conservation, with NIWA's assistance, is in the process of applying the tool to assess the threats to its marine protected areas.

It was envisaged that regular upgrades to the tool would be necessary to take advantage of increases in the quality and quantity of ecological information available within New Zealand. In this way, the tool could increase in benefit in the future as well as provide immediate application. This first upgrade occurred in 2014 (MacDiarmid and Taylor 2014) with updates to the lists of non-indigenous marine species occurring at New Zealand ports, and threatened marine invertebrates (Freeman et al. 2014), shore birds and seabirds (Robertson et al. 2013), introduction of a mechanism to enable efficient summarising of scores across assessments, and implementation of a new method for a more automated system of updates to the tool.

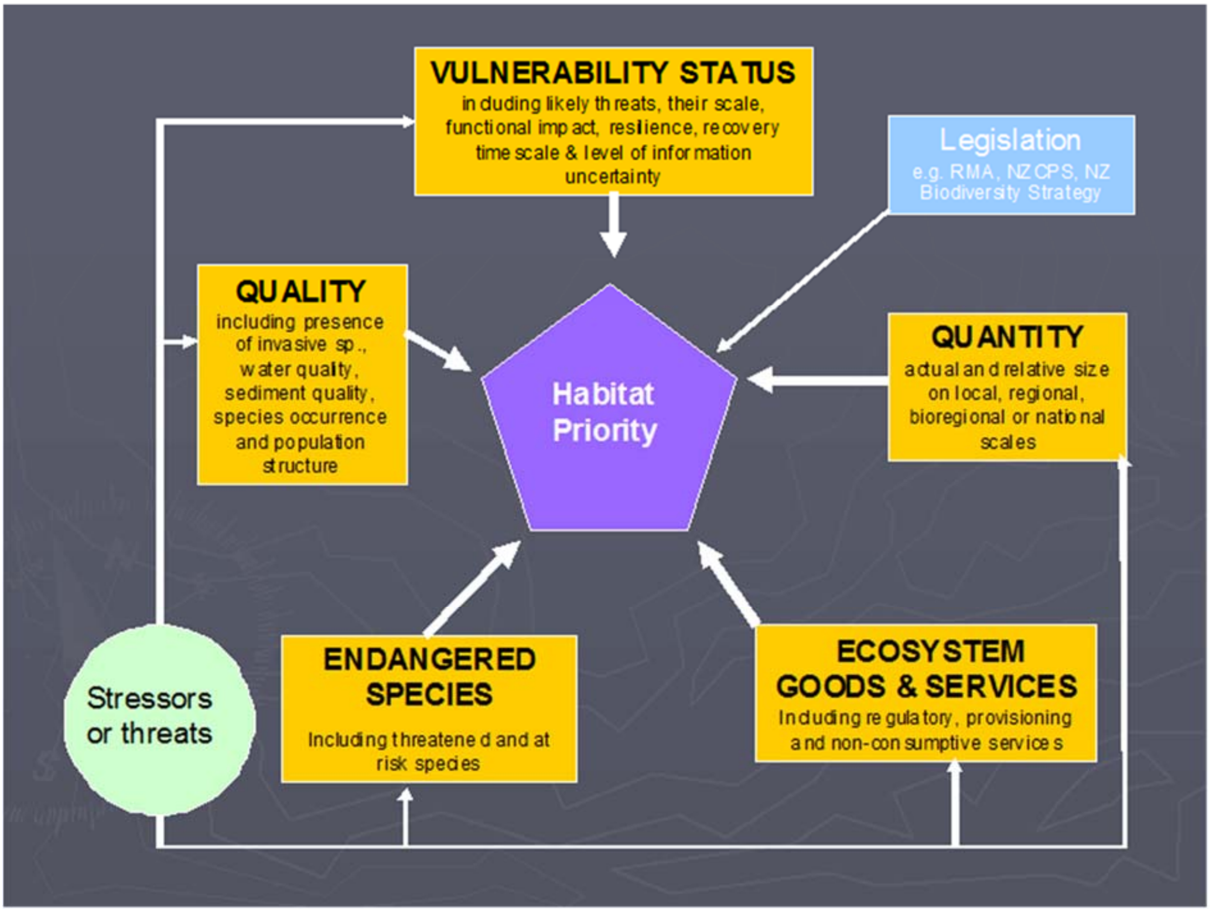


Figure 4-1: Conceptual view of the MarHADS tool indicating the five components used in assessing habitat significance.

To be effectively implemented the MarHADS tool requires a great deal of knowledge and information about particular habitats at identified localities. Knowledge is required about the spatial distribution of the environment being assessed, which in most cases is displayed in a habitat map. Knowledge of the likely threats to a habitat, their scale and functional impact, as well as the resilience of the habitat to those particular threats, and the recovery timescale once the threat is removed is required. Information is also needed about the presence of nationally threatened and at-risk species, the number of invasive species, water quality, sediment quality, the degree to which the expected biotic assemblage remains intact, and an overall assessment of the degree to which expected ecosystem features and functions remain in operation. Knowledge about the level of regulatory, provisioning, and non-consumptive ecosystem goods and services provided by the assessed habitats, although desirable, is not essential as national defaults for these values can be used, though these remain to be tested and compared against local information.

The amount of information required to properly implement the MarHADS tool is probably little different from that needed to effectively assess terrestrial or freshwater habitats. However, in marine areas the lack of even basic environmental information, such as a map of habitat distributions for a region, is commonplace. This is true for HRC's eastern and western CMA. Unfortunately, this lack of information about the extent of marine habitats, the distribution and abundance of most species, and the state of the marine environment is a general and serious problem nationwide that hampers efforts by every agency to effectively manage its marine estate and resources (MacDiarmid et al. 2012). The data requirements of the MarHADS tool underscores the need for more effort to overcome the deficit in information regarding New Zealand's marine environment.

MacDiarmid et al. (2014) made several recommendations for efficient and consistent use of the MarHADS tool. If these were put into operation results from assessments using this tool would be able to be incorporated into future revisions of Horizon's One Plan.

5 Knowledge gaps and approaches to filling them

In subsections 5.1 to 5.11 below we briefly identify gaps in knowledge in each of the subject areas from Sections 3 and 4, and list ways of filling these gaps, from (i) to (xv). Finally in section 5.12 we suggest which gaps should be filled first.

5.1 Ocean physical data

As described in subsection 3.1, there is a wealth of physical oceanographic data available to draw upon to describe the ocean properties along Horizon's western CMA in the South Taranaki Bight. These data have been used to compile and calibrate a sophisticated oceanographic model that describes ocean flows and sediment transport processes in the STB, including HRC's western CMA. This model could be interrogated to:

(i) provide HRC with a detailed description of the present state of natural coastal processes (such as waves, currents and sand movements),

(ii) determine the added scientific value of HRC deploying an offshore oceanographic buoy in its western CMA; and

(iii) address concerns and questions about the fate of terrigenous sediments carried into the CMA via the region's major river systems, for example.

Knowledge of the oceanographic environment along HRC's eastern CMA is much less advanced as there has been little directed research in this area. Given HRC's short stretch of coastline in this area, and its similarity to CMAs under the jurisdiction of the adjacent Hawke's Bay and Wellington Regional Councils, we suggest that:

(iv) depending on the priority placed on this information by HRC, there may be an opportunity for all three regional councils to collaborate to fund an investigation of coastal processes along the entire stretch of coast from Cape Kidnappers in the north to Cape Palliser in the south.

5.2 Sources of sediment in the CMA

A large volume of sediment enters HRC's CMA via rivers but it is unlikely that all sediment sources in the upstream catchments contribute equally to this volume. Knowledge of the relative contribution of sources of sediment will allow development of highly targeted management strategies to alter land-use practices to reduce the sediment load to rivers. As far as known, the CSSI method (refer subsection 3.2) has not been used to identify the sources of terrigenous sediments deposited in HRC's CMA. We suggest consideration is given to:

(v) building a library of reference source soils from different land-uses within HRC catchments and applying the CSSI method to identify the sources of terrigenous sediments deposited in HRC's CMA. This would complement HRC's current pilot study with Landcare using geochemical analysis to identify the sources of terrigenous sediments in the Orua catchment.

5.3 Primary production

Primary production in the STB, including HRC's western CMA, has been investigated in detail but there are no similar studies of remote sensed aspects of water quality for the eastern CMA although the relevant satellite data are routinely down-loaded and stored by NIWA. Given HRC's short stretch of coastline in this area, and its similarity to CMAs under the jurisdiction of the adjacent Hawke's Bay and Wellington Regional Councils, we suggest that:

(vi) depending on the priority placed on this information by HRC, there may be an opportunity for all three regional councils to collaborate to fund an investigation of the spatial and temporal variation in primary production along the entire stretch of coast from Cape Kidnappers to Cape Palliser.

5.4 Zooplankton

There are some data available to describe the basic characteristics and dynamics of zooplankton communities in the STB, although few data have been collected from HRC's western CMA, and none from the eastern CMA. Given HRC's short stretch of coastline on the east coast, and its similarity to CMAs under the jurisdiction of the adjacent Hawke's Bay and Wellington Regional Councils, we suggest that:

(vii) depending on the priority placed on this information by HRC, there may be an opportunity for all three regional councils to collaborate to fund an investigation of the spatial and temporal variation in zooplankton communities along the entire stretch of coast from Cape Kidnappers to Cape Palliser.

5.5 Marine benthic habitats

There are no existing detailed maps of the distribution of seafloor sediments or biogenic habitats in HRC's eastern or western CMAs. NIWA holds a large database of marine sediments sampled throughout the Territorial Sea and is presently developing derived continuous maps of grainsize (mud %, sand % and gravel %) and carbonate content for the whole of New Zealand. The distribution of biogenic habitats requires intensive (and expensive) sampling or photo-imaging of the seafloor, but multibeam swath mapping of the ocean floor can provide a first approximation of the distribution of presumed habitats, which later can be ground truthed by targeted (and cost effective) sampling or imaging. If HRC seek further information on marine benthic habitats in its open coastal waters, we suggest that they:

(viii) commission NIWA to derive continuous maps of grainsize (mud %, sand % and gravel %) and carbonate content for the eastern and western CMAs; and

(ix) secure funding to undertake multibeam swath mapping of the sea floor in first the western CMA, and second the eastern CMA.

5.6 Benthic invertebrates

NIWA's sampling intensity of marine invertebrates in Horizons CMA is low, but nonetheless a detailed summary and analysis of existing information may suggest the likely distribution of biogenic habitat forming species and the distribution of corals and other vulnerable species. If HRC seek further information on these aspects in its open coastal waters, we suggest that they:

(x) commission a detailed summary and analysis of existing seafloor biotic sampling information that may suggest the likely distribution of biogenic habitat forming species and the distribution of corals and other vulnerable species.

5.7 Distribution of threatened or vulnerable species

Existing likelihood distribution models of a range of threatened or vulnerable seafloor species and marine mammals are available to be interrogated or are nearing completion. These could yield more detailed analysis of occurrence and distribution of these species within HRC's CMA. Data on seabird distributions are too sparse at present to commission similar detailed maps, but summaries of existing published information could be compiled. If HRC seek further information on these aspects in its open coastal waters, we suggest that they:

(xi) commission interrogation of existing likelihood distribution models of threatened or vulnerable seafloor species and marine mammals to yield detailed analysis of occurrence and distribution of these species within HRC's CMA; and

(xii) commission compilation of a list of seabirds and their threat status that are likely to occur within HRC's eastern and western CMAs, based primarily upon publicly available sighting data and other published information.

5.8 Fish distribution

Existing likelihood models of reef fish and demersal fish distribution and abundance would yield detailed maps for many species occurring in HRC's western and eastern CMAs. If HRC seek further information on these aspects in its open coastal waters, we suggest that they:

(xiii) commission interrogation of existing likelihood models of reef fish and demersal fish distribution and abundance to yield detailed maps for modelled species occurring in HRC's western and eastern CMAs.

5.9 Distribution of commercial fisheries effort and catch

Good information on the distribution of commercial fishing effort and catch in HRC's western CMA exists and is publicly available. There has been no similar compilation of fishing catch and effort for the eastern CMA. If HRC seek further information on these aspects in its open coastal waters, we suggest that they:

(xiv) commission extraction and compilation of commercial fisheries catch and effort data for HRC's eastern CMA and produce maps to show fishing distribution by fishing method and main catch species.

5.10 Threats and hazards

The relative importance of a wide range of anthropogenic threats to the types of marine habitats in HRC's CMA is broadly understood. Nine of the top 20 threats to marine habitats derive from aspects of global climate change including ocean acidification, ocean warming, and sea level rise. Threats deriving from human activities occurring in catchments are also among the highest scoring threats to coastal marine habitats, particularly sedimentation. Detailed assessments of these threats, including sea level rise, at specific localities within the CMAs have not been undertaken. If HRC seek further information on these aspects in its open coastal waters, we suggest that they:

(xv) commission an assessment of the impact of projected sea level rise on coastal habitats and infrastructure in HRC's eastern and western CMAs.

5.11 Application of the MarHADS tool

The MarHADS tool has potential application to the Horizon's CMA by providing a mechanism to pull together a disparate range of information to undertake an overall assessment of marine habitat vulnerability and value. Its application could be staged by first undertaking assessments at the putative extremes of habitat degradation occurring within Horizon's eastern and western CMAs. Its usefulness could then be evaluated. If HRC seek further information on these aspects in its open coastal waters, we suggest that they:

(xvi) apply the MarHADS tool to the putative extremes of degradation for a selected habitat(s) occurring within Horizon's eastern or western CMA, to evaluate its wider applicability to assessing the vulnerability and value of marine habitats occurring in the region.

5.12 A phased approach to filling the knowledge gaps

While we have compiled in this report readily available information pertaining to the open water environments in HRC's CMA, there is substantial additional information that could be extracted from existing databases and models but was beyond the resources available in this relatively modestly funded project. This includes information on ocean physical data in HRC's western CMA, patterns of primary production in the eastern CMA, derived continuous maps of seafloor sediment grain size and carbonate content for the eastern and western CMAs, seafloor biotic sampling information for both CMAs, selected threatened or vulnerable seafloor species and marine mammals, seabirds, reef and demersal fish for both CMAs, and commercial fishing in the eastern CMA. We suggest that extraction of these existing data and accompanying expert interpretations should be the first priority as doing so would be relatively straight forward and cost effective, and provide an up-to-date summary of available information with which to set the subsequent gap filling priorities.

More expensive would be the commissioning of any new data collection and interpretation, and this may need to be spread over a number of years to be affordable. This includes, investigation of coastal processes along HRC's eastern CMA, building a library of reference source soils from different land-uses within the region's river catchments and applying the CSSI method to identify the sources of terrigenous sediments deposited in HRC's CMAs, investigating spatial and temporal variation in zooplankton communities within HRC's eastern CMA, multibeam swath mapping the sea floor in both CMAs, undertaking spot ground truthing of putative seafloor habitats identified during swath mapping, assessing the impact of projected sea level rise on coastal habitats and infrastructure in HRC's eastern and western CMAs, and applying the MarHADS tool to the putative extremes of degradation for a selected habitat(s) occurring within HRC's eastern or western CMA. Some of the work could be undertaken in collaboration with adjacent regional councils, where there would be a common interest in the knowledge gained. If a currently proposed Coastal Special Interest Group (C-SIG) Envirolink Tools project on preparing coastal maps from remote sensing data is approved, this provides an opportunity for HRC to add value to this project, and trial the outputs in its CMA. This may provide an opportunity for HRC to review its water quality monitoring programme and decide if sufficient data are being obtained to calibrate remote sensed data, or that the present programme needs to be increased in inrtensity or extended further offshore. These considerations were beyond the scope of this initial project.

We suggest that the first priorities for any new data collection in the second phase of work should relate to the source, fate and impact of terrigenous sediments entering HRC's western and eastern CMAs, and the likely impacts of sea level rise. Nevertheless, there may be other priorities that warrant further discussion to identify. Finally, we note that filling the knowledge gaps would be necessary to enable achievement of what HRC has set out to do in its One Plan.

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7 References

Anderson, T.; MacDiarmid, A.; Stewart, R. (2015). Benthic habitats, macrobenthos and surficial sediments of the nearshore South Taranaki Bight. NIWA Client Report No: NEL2013-012,

Anderson, O., Guinotte, J., Rowden, A., Tracey, D., Mackay, K. and Clark, M. (2016). Habitat suitability models for predicting the occurrence of vulnerable marine ecosystems in the seas around New Zealand. Deep-Sea Research Part I, 115: 265-292.

Baird, S.J. MacDiarmid, AB, Thompson, D. (2011) Review of threats to New Zealand's marine environment. NIWA Client Report No: WLG2011-35, 45 p

Battaerd, W.R. (1983). Zooplankton of the South Taranaki Bight. Report (Maui Development Environmental Study) No. 83-1. ix, 142 ill. 130 cm. p.

Beaumont, J.; Anderson, T.; MacDiarmid, A. (2015). Benthic flora and fauna of the Patea Shoals region South Taranaki Bight, NIWA Client Report No: WLG2012-55,

Brabyn, M.W. 1991: An analysis of the New Zealand whale stranding record. Science & Research series No. 29. Department of Conservation, Wellington

Bradford, J. M. (1977). Distribution of the pelagic copepod *Temora turbinata* in New Zealand coastal waters and possible trans-Tasman population continuity. *New Zealand Journal of Marine and Freshwater Research II:* 131-144.

Bradford, J. M. 1978: *Paracalanus indicus* Wolfenden and *Corycaeus aucklandicus* Kramer, two neritic pelagic copepods from New Zealand. *Journal of the Royal Society of New Zealand 8:* 133-141.

Bradford, J. M. (1980). New Zealand region, zooplankton biomass (0-200 m). New Zealand Oceanographic Institute chart, miscellaneous series 41.

Bradford, J.M.; Roberts, P.E. (1978). Distribution of reactive phosphorus and plankton in relation to upwelling and surface circulation around New Zealand. *New Zealand Journal of Marine and Freshwater Research 12*: 1-15.

Bradford, J.M.; Lapennas, P.P.; Murtagh, R.A.; Chang, F.H.; Wilkinson, V. (1986). Factors controlling summer phytoplankton production in greater Cook Strait, New Zealand. *New Zealand Journal of Marine and Freshwater Research 20*: 253-279.

Bradford-Grieve, J.M.; Murdoch, R.C.; Chapman, B.E. (1993). Composition of macrozooplankton assemblages associated with the formation and decay of pulses within an upwelling plume in greater Cook Strait, New Zealand. *New Zealand Journal of Marine and Freshwater Research 27*: 1-22.

Bradford-Grieve, J.; Stevens, C. (2013). Zooplankton and the processes supporting them in Greater Western Cook Strait. NIWA Client Report No: WLG2013-9, 22 p.

Freeman, D.; Schnabel, K.; Marshall, B.; Gordon, D.; Wing, S.; Tracey, D.; Hitchmough, R. (2014). Conservation status of New Zealand marine invertebrates, 2013. New Zealand Threat Classification Series X, Department of Conservation, XX p

Gibbs, M. (2008). Identifying source soils in contemporary estuarine sediments: a new compound specific isotope method. Estuaries and Coasts, 31: 344–359.

Goring, D. (2001). Computer models define tide variability. The Industrial Physicist 7(5): 14

Goring, D.K.; Walters, R.A.; Bell, R.G. (1997). "Modelling the propagation of tides around New Zealand." Presented at the Pacific Coasts and Ports '97, Christchurch, New Zealand, September 7-11, 1997.

Gorman, R.M.; Bryan, K.R.; Laing, A.K. (2003a). Wave hindcast for the New Zealand region: deep water wave climate. New Zealand Journal of Marine and Freshwater Research 37(3): 589-612.

Gorman, R.M.; Bryan, K.R.; Laing, A.K. (2003b). Wave hindcast for the New Zealand region: nearshore validation and coastal wave climate. New Zealand Journal of Marine and Freshwater Research 37(3): 567-588.

Hadfield, M.; Macdonald, H. (2015). Sediment plume modelling. NIWA Client Report No: WLG2015-22, 117 p.

Haidvogel, D. B., H. Arango, W. P. Budgell, B. D. Cornuelle, E. Curchitser, E. Di Lorenzo, K. Fennel, W. R. Geyer, A. J. Hermann, L. Lanerolle, J. Levin, J. C. McWilliams, A. J. Miller, A. M. Moore, T. M. Powell, A. F. Shchepetkin, C. R. Sherwood, R. P. Signell, J. C. Warner, and J. Wilkin (2008). Ocean forecasting in terrain-following coordinates: Formulation and skill assessment of the Regional Ocean Modeling System. Journal of Computational Physics,227, 3595-3624

Handley, S.; Gibbs, M. Swales, A.; Olsen, G.; Ovenden, R.; Bradley, A. (2017). A 1,000 year history of seabed change in Pelorus Sound/Te Hoiere, Marlborough. Prepared for Marlborough District Council, Ministry of Primary Industries, and the Marine Farming Association. NIWA Client Report No: 2016119NE, 136 p. https://www.marlborough.govt.nz/repository/libraries/id:1w1mps0ir17q9sgxanf9/hierarchy/Documents/Environment/Coastal/Scientific%20Investigations%20List/A_1000_year_history_of_seabed_change_in_Pelorus_Sound_Te_Hoiere.pdf

Hume, T.; Ovenden, R.; MacDonald, I. (2015a). Coastal stability in the South Taranaki Bight - Phase 1: Historical and present day shoreline change. NIWA Client Report No: HAM2012-083, 96 p.

Hume, T.; Gorman, R.; Green, M.; MacDonald, I. (2015b). Coastal stability in the South Taranaki Bight - Phase 2: Potential effects of offshore sand extraction on physical drivers and coastal stability NIWA Client Report No: HAM2013-082, 135 p.

Jones, E.G.; Morrison, M.A.; Davey, N.; Hartill, B.W.; Sutton, C. (2016). Biogenic habitats on New Zealand's continental shelf. Part I: Local Ecological Knowledge. New Zealand Aquatic Environment and Biodiversity Report No. 174. 95 p.

Law CS, Rickard GJ, Mikaloff-Fletcher SE, Pinkerton MH, Gorman R, Behrens E, Chiswell SM, Bostock HC, Anderson O, Currie K. 2016. The New Zealand EEZ and South West Pacific. Synthesis Report RA2, Marine Case Study. Climate Changes, Impacts and Implications (CCII) for New Zealand to 2100. MBIE contract C01X1225. 41pp.

Law CS, Bell JJ, Bostock HC, Cornwall CE, Cummings V, Currie K, Davy SK, Gammon M, Hepburn CD, Hurd CL, et al. 2017. Ocean acidification in New Zealand waters. New Zealand. Journal of Marine & Freshwater Research. doi:10.1080/00288330.2017.1374983.

MacDiarmid, A.; Anderson, O.; Beaumont, J.; Gorman, R.; Hancock, N.; Julian, K.; Schwarz, J.; Stevens, S.; Sturman, J.; Thompson, D.; Torres, L. (2010). South Taranaki Bight iron sand mining baseline environmental study. NIWA Client Report WLG2010-46, 391 p.

MacDiarmid AB, Taylor P, Carbines M, Hewitt J, Bolton-Ritchie L, Maharadz-Smith A, Townsend M, Thrush S, Walker J (2011). Marine Habitat Assessment Decision Support (MarHADS) Tool - Background and Operating Instructions. Produced for the NZ Regional Council Coastal Special Interest Group, Envirolink Contract NIWX0803, 25 pp.

MacDiarmid, AB, Andy McKenzie, James Sturman, Jenny Beaumont, Sara Mikaloff-Fletcher, John Dunne (2012). Assessment of anthropogenic threats to New Zealand marine habitats. New Zealand Aquatic Environment and Biodiversity Report 93: 255 p.

MacDiarmid, A.B; Stenton-Dozey, J.; Roulston, H. (2014). Testing and applying the MarHADS tool in the Auckland Council region. Prepared by NIWA for Auckland Council. Auckland Council Technical Report, TR2013/xxx

MacDiarmid, A.; Taylor, P. (2014). Marine Habitat Assessment Decision Support (MarHADS) Tool: Background and Operating Instructions – Revised. Project ARC14301, 38 p

MacDiarmid, A.; Ballara, S. (2016). South Taranaki Bight Commercial Fisheries: 1 October 2006 – 30 September 2015. NIWA Client Report No: WLG2016-28, 26 p.

MacDiarmid, A.; Anderson, O.; Sturman, J. (2015). South Taranaki Bight Fish and Fisheries NIWA Client Report No: WLG2012-13, 71 p.

MacDiarmid, A.; Gall, M.; Robinson, K.; Stewart, R.; Fenwick, M. (2015). Zooplankton communities and surface water quality in the South Taranaki Bight February 2015. NIWA Client Report No: WLG2015-25, 22 p.

MacDonald, I.; Budd, R.; Bremner, D.; Edhouse, S. (2015a). South Taranaki Bight Iron Sand Mining: Oceanographic measurements data report. NIWA Client Report No: HAM2012-147, 106 p.

MacDonald, I.; Gall, M.; Bremner, D. (2015b). Nearshore Optical Water Quality in the South Taranaki Bight. NIWA Client Report No: HAM2013-040, 88 p.

Pinkerton, M; Gall, M. (2015). Optical effects of proposed iron sand mining in the South Taranaki Bight region. NIWA Client Report No: WLG2015-26, 79 p.

Richard, Y.; Abraham, E.R.; Thompson, F.N.; Berkenbusch, K. (2011). Counts of seabirds around commercial fishing vessels within New Zealand waters. 30 pages. (Unpublished report prepared for the Department of Conservation, retrieved from https://seabird-counts.dragonfly.co.nz/seabirds-around-fishing-vessels.pdf, Nov 19, 2013.)"

Robertson, C.J.R.; Hyvönen, P.; Fraser, M.J.; Pickard, C.R. (2007). Atlas of bird distribution in New Zealand 1999-2004. The Ornithological Society of New Zealand.

Robertson, H.A.; Dowding, J.E.; Elliott, G.P.; Hitchmough, R.A.; Miskelly, C.M.; O'Donnell, C.F.J.; Powlesland, R.G.; Sagar, P.M.; Scofield, R.P.; Taylor, G.A. (2013). Conservation status of New Zealand birds, 2012. New Zealand Threat Classification Series 4, Department of Conservation, 26 p.

Smith, A.N.H.; Duffy, C.A.J.; Leathwick, J.R. 2013: Predicting the distribution and relative abundance of fishes on shallow subtidal reefs around New Zealand. Science for Conservation 323. Department of Conservation, Wellington. 25 p. + 2 supplements.

Torres, L.; Compton, T.; Fromant, A. (2015). Habitat models of southern right whales, Hector's dolphin, and killer whales in New Zealand. NIWA Client Report No: WLG2012-28, 59 p.

Walters, R.A.; Goring, D.G.; Bell, R.G. (2001). Ocean tides around New Zealand. New Zealand Journal of Marine and Freshwater Research 35: 567-579.

Warner, J.C.; Sherwood, C.R.; Signell, R.P.; Harris, C.K.; Arango, H.G. (2008). Development of a three-dimensional, regional, coupled wave, current, and sediment-transport model. Computers & Geosciences 34(10): 1284–1306.

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