NIWA
Taihoro Nukurangi

Spatial information to assess naturalness of marine habitats

Prepared for Ministry for the Environment

June 2025

Climate, Freshwater & Ocean Science

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NIWA CLIENT REPORT No: 2025132HN
Report date: June 2025
NIWA Project: MFE24208

Quality Assurance Statement		
	Reviewed by:	Vonda Cummings
	Formatting checked by:	Jo Downey
	Approved for release by:	Michael Bruce

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Executive summary

The marine environment is affected by a diverse range of activities that may result in physical damage or loss, pollution, or other changes that impact on habitats, species and ecosystems. In Aotearoa New Zealand, the spatial and temporal footprints of these activities are poorly understood, which limits the ability to assess the cumulative effects of these multiple stressors and hampers effective stressor management. This project progresses the central government programme of work on developing datasets representing the marine Key Ecological Areas criteria by collating datasets that can contribute to representing the Naturalness criterion, although additional steps are required to fully achieve this representation. For this project, Naturalness was defined as *'the degree to which an area is pristine and characterised by native species with an absence of perturbation by human activities and introduced or cultured species'.*

The key output of this project is exploration and acquisition of data available to represent different aspects of Naturalness. A series of layers was compiled to provide spatially-explicit representations of human activities on marine ecosystems (e.g., mineral extraction, shellfish aquaculture, shipping). Marine activities that impact on Naturalness were allocated to 56 categories of activities within 11 themes: 1) Coastal management activities; 2) Waste management activities; 3) Extraction of living resources; 4) Production of living resources; 5) Extraction (and disposal) of non-living resources; 6) Energy generation; 7) Transport; 8) Recreation and leisure; 9) Marine research; 10) Defence and national security; and 11) Other man-made structures. The comprehensive list of 56 activity categories was used to guide the prioritisation and acquisition of available data to represent each category, although data were not available to populate all activity categories. Datasets were then evaluated for their suitability to represent individual activities and their potential impacts on species, habitats and ecosystems. Further analyses to convert spatially-explicit layers of activities to spatially-explicit representations of their stressor footprint were explored and prioritised within the project budget based on data accessibility and comprehensiveness, and time required for data conversions. This has provided guidance on the next phase of the central government programme of work.

Over 55 geospatial layers were compiled for this project, with geospatial data available typically in point, polyline or polygon formats to represent the majority of the major stressors on marine ecosystems. New layers were developed to represent land-based sediment and nutrient inputs based on riverine sources to the coast, and for shipping and anchoring activities. The majority of gaps were identified for smaller localised consenting activities, typically managed by regional authorities, and for which no national database existed. Other gaps were due to emerging industries for which activity footprints do not yet exist. The next steps for converting activity footprints into stressor footprints are indicated, for example converting point records of activities to polygons, or determining timing and extent of activity footprints within broad scale licensed areas.

Anticipated pressures on habitats, species and ecosystems are summarised for each activity category. Alongside this project, evidence supporting existence of these pressures has been compiled in an aligned DOC-funded project that is linking activities to pressures that are likely to have negative impacts on biodiversity. Future work is required to link the pressures from these activities to species, habitats, and ecosystems, in order to develop a comprehensive spatially-explicit representation of Naturalness for Aotearoa New Zealand's marine system, including impacts from fisheries and climate-related stressors.

1 Introduction

1.1 Background

The marine environment is affected by a diverse range of activities, including land use, climate change, resource extraction and pollution (Halpern et al. 2008, MacDiarmid et al. 2011a, MacDiarmid et al. 2012), however the spatial and temporal footprint of these activities, and their associated impacts on marine ecosystems and biodiversity is poorly understood. The lack of information on the spatial distribution of stressors or 'stressor footprints' limits the ability to assess the cumulative effects of multiple stressors in marine ecosystems and hampers effective stressor management to maintain and/or recover ecological functioning and associated ecosystem services in degraded systems. Many exercises have mapped the spatial distribution, intensity, frequency and seasonality of potential stressors of different anthropogenic activities (i.e., the stressor footprint), and assessed the vulnerability of different biodiversity features to individual stressors to calculate cumulative impact scores (Ban et al. 2010, Halpern et al. 2014, MacDiarmid et al. 2011b). Enhancing the evidence base to describe existing and historical activities for New Zealand's marine ecosystems can support spatial management processes and management of cumulative effects, and inform development of new blue industries such as offshore renewable energy.

The Marine Protected Areas Science Advisory Group (MSAG), comprised of the Department of Conservation (DOC), Fisheries New Zealand (FNZ) and Ministry for the Environment (MfE), has supported ongoing development of the evidence base to support enhanced management of Aotearoa New Zealand's marine ecosystems. Criteria to identify Key Ecological Areas (KEA), largely based on the Convention on Biological Diversity (CBD) EBSA[1] criteria (Clark et al. 2014), were developed by the MSAG (Freeman et al. 2017). The KEA criteria are: 1) Vulnerability, Fragility, Sensitivity or Slow Recovery; (2) Uniqueness / Rarity / Endemism; (3) Special Importance for Life History Stages; (4) Importance for Threatened / Declining Species and Habitats; (5) Biological Primary Productivity; (6) Biological Diversity; (7) Naturalness; (8) Ecological Function; and (9) Ecological Services (Freeman et al. 2017).

Prior DOC funded projects contracted to NIWA have compiled ecological datasets that could be used to represent the nine KEA criteria (DOC investigation number 4735), which were then evaluated for comprehensiveness and uncertainty (DOC investigation number 4759) (Lundquist et al. 2020, Stephenson et al. 2018). The KEA criteria were also compared to the IUCN's framework (Key Biological Areas or 'KBAs') to determine if international methodologies for defining marine protected areas could be adapted to the KEA framework (DOC investigation number BIO205) (Stewart-Sinclair and Lundquist 2022). Other projects initially progressed the KEA criterion 6 Biological Diversity (DOC investigation numbers BIO332, BIO338) (Bennion et al. 2024c, Cook et al. 2023). Prior projects have also developed a web-based prototype application for analysing KEA criteria (DOC investigation number BIO237) (Bennion et al. 2022), and developed guidance for the use of decision-support tools for using KEA datasets to inform spatial planning and biodiversity conservation (DOC investigation number 4758) (Lundquist et al. 2021).

[1] EBSA: Ecologically or Biologically Significant Marine Areas.

1.2 Project context

Funded by MfE, this project further progresses the MSAG work programme by developing spatial layers that contribute towards the evidence base to evaluate the KEA criterion 7 Naturalness (Freeman et al. 2017).

MSAG defined the KEA Naturalness criterion as "*an area with a comparatively higher degree of naturalness resulting from a lack of or low level of human-induced disturbance or degradation*" (Freeman et al. 2017). Defining Naturalness allows identification of areas of biodiversity that are in better condition. Naturalness therefore describes a gradient from completely natural to completely artificial. Areas with higher states of Naturalness may include species and/or habitats that do not occur or are not represented in more degraded areas, allowing these areas to serve an important role as reference sites. Protecting areas in a higher state of naturalness reduces the need to rely on recovery from a degraded state, which may not be possible without targeted restorative efforts.

As part of the scoping of this project, three main purposes were identified for developing stressor footprints and assessing marine Naturalness:

A. to properly estimate and report on the ecological state of the marine environment to inform and evaluate marine ecosystem management,

B. to develop objective standards for marine conservation and management, and

C. to identify natural, intact marine ecosystems for focussed management.

Further development of the Naturalness criterion can be separated into a set of component parts. In combination, all components can be used to quantify impacts to biodiversity that can collectively provide a spatially explicit indication of Naturalness (Figure 1-1).

1. <u>Mapping of human activities that potentially impact on marine ecosystems.</u> This step is the key outcome of this project which provides a series of layers detailing the spatial (and where applicable, temporal) distribution of potentially impactful human activities that can contribute to representing the Naturalness criterion under the Key Ecological Areas framework. This project also identifies gaps and suggests next steps to fill these gaps.

2. <u>Generating stressor footprints derived from human activities.</u> Following acquisition of activity layers, these must be converted into spatially-explicit representations of stressor footprints derived from human activities (e.g., sedimentation and nutrient inputs or disturbances to the seafloor resulting from activities like land-use change, aquaculture, and dredging).

3. <u>Linking activities to pressures that are likely to have negative impacts on biodiversity</u>. Individual activities can result in one or more pressures on marine ecosystems, including hydrological changes, pollution and other chemical changes, physical loss, physical damage, other physical pressures and biological pressures. Note that DOC has initiated a multi-stage project to link human activities to marine pressures within a standardised Aotearoa New Zealand activities-pressure matrix (Douglas and Lundquist 2025). That project has initiated population of the matrix which describes the links, or relationships between human activities and their associated pressures. A further step is required to link

components of biological diversity to the activities and pressures. Identifying a list of species, habitats, and ecosystems for which pressures will be evaluated is part of this third step.

4. Combining multiple stressors to inform marine spatial planning. A final step is the development of a comprehensive spatially-explicit representation of the Naturalness criterion under the Key Ecological Areas framework. Stressor footprints for the fishing industry [e.g., Rowden et al. (2024)], and climate-change impacts are being developed separately, and are out of scope for this project. Outputs of these other stressors and the datasets compiled by this contract can be combined to provide a spatially-explicit indication of Naturalness. Spatial layers representing Naturalness can be incorporated into marine spatial planning process, and management actions can be linked to different activities to identify how they can be managed to avoid, remedy or minimise impacts of activities on biodiversity.

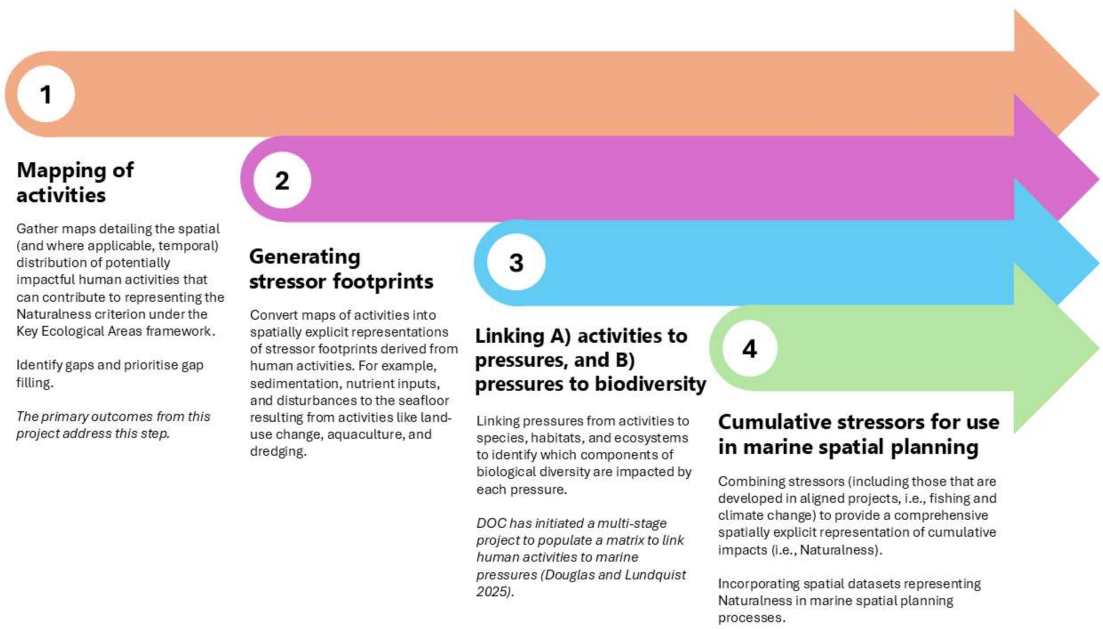

Figure 1-1: Roadmap detailing the steps involved in development of the Naturalness criterion. This project focuses on (1) mapping of activities. Other concurrent projects (Douglas and Lundquist 2025) are focused on progressing other steps, namely (3) linking activities to pressures.

1.3 Project aim

A Project Advisory Group, including members from the MSAG from MfE (Pierre Tellier, Michael Bates), FNZ (Karen Tunley) and DOC (Shane Geange), was established to oversee this project and ensure project outputs were fit-for-purpose and could be used to inform management decisions, as well as to coordinate across other MSAG projects. A larger Inter-Agency Working Group was also formed, and consisted of various central and regional government staff whose role was to provide feedback on priorities for acquisition of stressor datasets, and to serve as institutional contacts for acquiring datasets and other information relevant to the project. An Inter-Agency Working Group Workshop was held in August 2024 to present the scope of the project, and facilitate input from this working group.

Following discussions with the Project Advisory Group and at the Inter-Agency Working Group Workshop, the scope of the project was clarified. This further clarication considered the larger process of informing development of a spatially-explicit representation of Naturalness based on multiple overlapping activity layers (Figure 1-1).

The primary aim of this project is to compile geospatial maps of human activities on marine ecosystems (*Step 1. Mapping of human activities that potentially impact on marine ecosystems)*. A list of 56 activity categories, each described in this report, was used to guide the prioritisation and acquisition of available data to represent each category, although data was not available to populate all activity categories. Datasets were then evaluated for their suitability to represent individual activities and their potential impacts on species, habitats and ecosystems. Further analyses to convert spatially-explicit layers of activities to spatially-explicit representations of their stressor footprint were explored and prioritised within the project budget (*Step 2. Generating stressor footprints*) based on data accessibility and comprehensiveness, and time required for data conversions. Gaps and recommendations for filling remaining gaps to compile a comprehensive dataset of stressor footprints are discussed.

In addition, we briefly summarise anticipated pressures for each activity category relevant to Step 3 [*Linking A) activities to pressures, and B) pressures to biodiversity*]. An aligned DOC project has begun the process of linking activities to pressures on species, habitats and ecosystems and provides an evidence base to support these links (Douglas and Lundquist 2025). We also summarise potential approaches for combining the broader suite of stressor footprints, including fisheries and climate-related stressors that can be used to develop a comprehensive spatially-explicit representation of Naturalness to inform Step 4 (*Cumulative stressors for use in marine spatial planning*).

2 Identification of stressor datasets

2.1 Initial data scoping and engagement activities

2.1.1 Initial data scoping

Spatially-explicit marine stressor data were acquired from a diversity of sources as part of an initial data scoping exercise. As part of this project, all datasets and metadata were further assessed, sources confirmed, and datasets updated if additional information was available. Metadata were compiled to confirm date acquired, data source, and caveats and assumptions of each dataset.

The DOC-funded Key Ecological Area programme initially investigated which datasets were available to populate the key ecological criterion Naturalness (Lundquist et al. 2020, Stephenson et al. 2018). The first Key Ecological Areas data collection report included data on a pilot analysis of land-use impacts for New Zealand's 44 marine no-take reserves (Cook et al. in review), noting that this analysis could be extrapolated more broadly to the New Zealand coast. The metrics included: proportion of land-use and land-cover categories assumed to have larger impacts on sediment and nutrient transport to coastal zones (i.e., forestry, agricultural lands); maps of public conservation land as indicators of more natural areas; human population; and sediment and nutrient loading. Each metric was quantified relative to individual marine reserves. The report also collated information on the bottom fishing footprint and fishery metrics for commercial fishing from Catchmapper. While Catchmapper does include a recreational category, this reflects fish captured recreationally during commercial fishing trips (for instance, some handlining may take place recreationally between commercial events). However, Catchmapper does not include comprehensive mapping of recreational fishing effort and catch (Osborne 2018). Finally, the report also provided maps of existing spatial management areas such as marine reserves, benthic protection areas, depth refuges from fishing impacts, and other use restrictions as indicators of areas with higher levels of naturalness.

A follow up report on Key Ecological Areas datasets filled some additional gaps in the KEA Naturalness criterion (Lundquist et al. 2020). The proportion of land-use and land-cover categories was extrapolated to a national scale through creation of 10 km coastal polygons based on a smoothed outline of the New Zealand coast, and extending polygons out to the 12 nm territorial sea limit. These coastal polygons were selected to illustrate visual differences at regional scales within New Zealand between different stressors, noting that these polygons were simplistic representations of stressor locations. Within each coastal segment, the catchment area contributing to that segment was quantified based on the New Zealand River Environments Classification database (REC). Land-use and land-cover maps were intersected with catchment maps to estimate the proportion of land use categories contributing to each coastal polygon. This report also discussed data available to describe the distribution of shipping traffic from AIS (automated identification system required for vessels >20 m). Available data included 82 million ship positions for the period of 2009-2020, however AIS data extracts are costly, and were not collected for the 2020 project. An existing data extract for the Hauraki Gulf was used to showcase how the AIS data could be used to create maps of hotspots of fishing activity. Oil and gas exploration and existing infrastructure dataset were collated for publicly available LINZ data, including submarine pipelines. A final naturalness dataset for biosecurity was extracted from the Marine Biosecurity Porthole (https://marinebiosecurity.org.nz), with data extracts including point-location records of invasive marine invertebrates, fish and algae.

A contract from DOC to Visitors Solutions had compiled a large number of recreational use datasets (Visitor Solutions 2012), including point-location records and kernel density estimation (KDE) analyses of boat trailer registrations and other recreational vessel information, holiday home distributions, coastal business distributions, and other indicators of value for recreation such as nationally recognised surfing and diving locations, fishing clubs, and beaches.

Many of the layers from these contracts, as well as other geospatial layers representing administrative and management boundaries, and components of marine biodiversity, habitats, and ecosystems were combined together in the Te Ukaipo o Hinemoana online decision support tool (https://niwa.co.nz/te-ukaipo-o-hinemoana). This tool was developed by the Sustainable Seas project 1.2 Spatially Explicit Cumulative Effects Tools (SPEXCET) and has been maintained since June 2023 by NIWA internal funding provided by the Ministry of Business and Employment (MBIE; Strategic Science Investment Fund or SSIF). This tool was initially developed for the purpose of visualising the overlap of different stressor layers with marine ecosystem features to assist in the understanding of cumulative stressors. Datasets on marine activities and stressors were primarily at national scale, supplemented by regional data when available, and included:

- Resource extraction data – Sand extraction areas, petroleum wells and active permits, mineral active and applications and minerals extension of land.
- Dredging areas and dredge disposal areas.
- Offshore structures – Offshore platforms and sub-marine pipelines.
- Invasive and non-indigenous species location records.
- Coastal anthropogenic effects on the marine system, including urbanisation, coastal land-use, and freshwater influxes of sediment and nutrients.
- Marine farm data for multiple species.
- Land-use layers calculated for individual 10 km coastal polygons from shore to 12 nm, with land-based metrics calculated based on catchments with terminal segments within that segment of coast. Layers included land cover class, terrestrial protection, sediment and nutrient loads, population size, and sediment and nutrient loading.

2.1.2 Stakeholder engagement activities

Initial data scoping identified available spatial data representing stressors in the marine environment, which were presented to the Project Advisory Group, and then to an Inter-Agency Working Group to provide feedback on identified stressors, priorities for mapping, and additional datasets that could be acquired (see Appendix A for Inter-Agency Working Group Workshop agenda). The Project Advisory Group provided further guidance on refining the definition of Naturalness to inform further data acquisition.

A workshop attended by members of the Inter-Agency Working Group was held in person and online at NIWA Wellington, Greta Point on 14 August 2024. Initial discussions focused on the definition of Naturalness for the project, after which the project team reviewed datasets collated during the initial scoping exercises (Section 2.1.1). Attendees discussed additional stressor footprint datasets they were aware of and believed should be obtained or included in the project. Discussions also reflected on which stressors should be out of scope of the project (e.g., fishing and climate change).

Advice was sought from the project team on several overarching stressor data decisions, including the extent of maps (i.e., Exclusive Economic Zone or EEZ, or coastal/territorial sea scale), resolution of maps (i.e., 1 km grids), and data types (i.e., raster, polygon, point-location) that would be useful to compile. Approaches to combine data to make 'grouped stressor layers' were also discussed, and the usefulness of ensuring that combined stressor layers were also provided as individual components (e.g., shipping footprints available as both combined as well as differentiated into container, passenger, and recreational vehicles).

The working group also discussed what time periods would be mapped (i.e., historical and current footprints, temporal impacts of various stressors whether permanent or transient). Initially, discussions were held about how biological diversity information could be incorporated into analyses to examine biological responses to stressor footprints, however ultimately the advisory group took the decision to move these kinds of analyses to a future project, keeping the scope of this project on the compilation of spatial datasets of stressor footprints. Finally, the workshop attendees completed the workshop by discussing the long-term approach to bringing together these and other stressors to inform overall Naturalness. The group noted that a cumulative Naturalness map based only on the layers compiled for this project would be incomplete without fisheries and climate-related stressors.

A presentation of initial methods was provided on 19 September 2024 at a Fisheries NZ Aquatic environment Working Group (AEWG) / Biodiversity Research Advisory Group (BRAG) virtual meeting. A further presentation of the final outputs of the project was provided to AEWG/BRAG on 30 May 2025. The key feedback from participants in the first AEWG/BRAG workshop is summarised as follows:

- Naturalness is interesting and an intuitive concept, and it is useful to have both quantifiable component layers of individual stressors as well as stressor impacts summarised across domains, each contributing to a cumulative naturalness layer.
- Because this project is not acquiring layers on fisheries or climate change impacts, a cumulative naturalness layer based solely on layers acquired for this project would be incomplete.
- Naturalness is really a scale from 100% natural to 100% artificial. Most definitions of Naturalness imply that to be natural requires the exclusion of humans and human impacts, however, there are many existing broad scale impacts such as climate change, as well as historical impacts. Human activities impact on all marine ecosystems and no ecosystem could be considered 100% natural or fully intact.
- Members expressed interest in having the data layers made available for visualisation and download (aside from confidential layers), and there was support for a central data storage approach. Existing geospatial tools (e.g., DOC Marine Geoportal, NIWA/Sustainable Seas Te Ukaipo o Hinemoana geospatial tool) provide potential approaches for display and download of data layers, noting that any tool requires long term funding for updating and maintenance.
- Regional Councils are holders of a lot of layers but also carry out similar work in terms of biodiversity and significant areas and stressors, and there is a need to ensure these different efforts are aligned to ensure consistency and avoid replication of effort.

2.2 Working definition for Naturalness

Early in the project in discussions with the Project Advisory Board, and following discussions on the concept of Naturalness at the Inter-Agency Working Group Workshop and at the AEWG/BRAG meeting, it was determined that clarifying the definition of Naturalness would be useful to help in the scoping and identification of relevant activity layers to inform Naturalness. Discussions at the Inter-Agency Working Group Workshop also identified potential inconsistencies in whether or not activities contributed to Naturalness based on temporal features, for example the role of historical stressors (i.e., acoustic impacts of initial construction stages of marine infrastructure) and of future or potential stressors (i.e., oil spills that have not yet occurred).

The Project Advisory Board highlighted four main considerations of stressors that may affect Naturalness:

- Does the activity result in a meaningful impact?
- What is the temporal aspect of this activity – one-off vs continual/ongoing stressor?
- Does this stressor represent an existing or a future/potential impact of an activity (i.e., exploratory license versus active license)?
- Does this layer represent a risk of something happening that may not occur?

The Marine Protected Areas Science Advisory Group (MSAG) defined the KEA Naturalness criterion as an '*area with a comparatively higher degree of naturalness resulting from a lack of or low level of human-induced disturbance or degradation*' (Freeman et al. 2017). Naturalness was also determined to be directly associated with three other KEA criteria (Biological Diversity, Ecological Function, Ecological Services; Freeman et al. (2017)).

To inform a project-level definition of Naturalness, and to clarify how other national and global entities interpret Naturalness in a management and policy context, the project team then performed a review of national and international definitions and uses of Naturalness in marine ecosystem management (Table 2-1).

Table 2-1: Examples of national and international uses of the term Naturalness in marine ecosystem management.

Source	Description	Reference
New Zealand Key Ecological Areas criteria	Area with a comparatively higher degree of naturalness resulting from a lack of or low level of human-induced disturbance or degradation.	(Freeman et al. 2017)
IUCN Marine Protected Areas Guidelines	Protected areas should usually aim to maintain or, ideally, increase the degree of naturalness of the ecosystem being protected.	(Day et al. 2012)
World Commission on Protected Areas of IUCN – The World Conservation Union	Extent to which the area has been protected from, or has not been subject to, human-induced change.	(Kelleher 1999)

Source	Description	Reference
Ecological or biologically significant marine areas (Convention on Biological Diversity)	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation. Rationale: To protect areas with near natural structure, processes and functions; To maintain these areas as reference sites; To safeguard and enhance ecosystem resilience.	(Clark et al. 2014)
OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic	The area has a high degree of naturalness, with species and habitats/biotope types still in a very natural state as a result of the lack of human-induced disturbance or degradation.	(OSPAR 2006)
European Union's Marine Strategy Framework Directive (MSFD)	Good Environmental Status (GES) as "The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive". ▪ Descriptor 1: Biodiversity is maintained. ▪ Descriptor 2: Non-indigenous species do not adversely alter ecosystems. ▪ Descriptor 3: Populations of commercial fish and shellfish species are healthy. ▪ Descriptor 4: Food webs ensure long-term abundance and reproduction of species. ▪ Descriptor 5: Eutrophication is reduced. ▪ Descriptor 6: Sea floor integrity ensures the proper functioning of ecosystems. ▪ Descriptor 7: Permanent alteration of hydrographical conditions does not adversely affect ecosystems. ▪ Descriptor 8: Concentrations of contaminants give no pollution effects. ▪ Descriptor 9: Contaminants in seafood are at safe levels. ▪ Descriptor 10: Marine litter does not cause harm. ▪ Descriptor 11: Introduction of energy (including underwater noise) does not adversely affect the ecosystem.	(European Commission 2008)

Source	Description	Reference
New Zealand definition of Natural Character	Interpretations of naturalness: 1. Naturalness as that which is part of nature. 2. Naturalness includes humans and their activities. 3. Naturalness as a contrast to ‘artifactuality’. 4. Naturalness as historical independence from human actions. 5. Naturalness is where ecosystem processes occur without human intervention. 6. Naturalness that includes ecologically harmonious human influence or actions. 7. Naturalness only includes humans if they are in a closed system. 8. Naturalness as possession of features and properties found in an ‘ideal’ natural ecosystem. 9. Naturalness as similarity of biotic structure and composition, and physical/ecological processes compared with historical benchmarks.	(Froude et al. 2010)

This information was presented to the Project Advisory Board at an online meeting in September 2024, who then assessed available definitions and discussed components of naturalness as they relate to data compilation by this project. Primary components of Naturalness were determined to be: state (i.e., pristine or low level of degradation); absence of perturbation; and characterised by native species / species assemblages.

The original KEA Naturalness definition was thus adjusted to encompass the identified components, and the following project-level definition of Naturalness agreed upon:

> “*The degree to which an area is pristine and characterised by native species with an absence of perturbation by human activities and introduced or cultured species*.”

2.3 Data formats

Discussions with the Project Advisory Board and at the Inter-Agency Working Group Workshop also considered data formats for the stressor layers. Data guidance was as follows:

- Data should be provided in their raw format as well as any modelled versions (i.e., kernel density estimates, point records converted to raster grid formats).
- Individual components of a stressor should be retained when data layers were combined across multiple components (e.g., hotspots of invasive species occurrence records would include a summary layer as well as a level of individual occurrence points across all species).
- The scale of relevant pressures should include both the territorial sea (to 12 nm) as well as the Exclusive Economic Zone (EEZ).

- The temporal period should be confined to historical and current footprints, with metadata to confirm whether stressors were reoccurring or transient, and noting timing of occurrence for one-off stressors. Future and potential stressors or risk footprints (e.g., risk of oil spills) were determined to be out of scope. The DOC categorisation of stressors includes a number of activities that are not yet present in New Zealand, allowing for recognition of their potential occurrence, and ability to refine data layers should these new activities eventuate.

2.4 Refining the suite of marine pressures

In addition to the refined project definition of Naturalness, DOC provided a list of potential activities resulting from an internal review of Aotearoa New Zealand and international lists of marine activities and pressures, primarily based on the framework used by JNCC Pressures Activities Database (Robson et al. 2018), the MarHADs tool (MacDiarmid et al. 2011b), and assessments of anthropogenic threats to New Zealand marine habitats (Baird and Wood 2018; MacDiarmid et al. 2012). The DOC review had resulted in a categorised list of 65 activities and 35 pressures and their definitions, and was used to categorise the data layers acquired for this project. Definitions of each category of activity are based on definitions provided by DOC to maintain consistency across MSAG projects on Naturalness and pressures.

An aligned project (Douglas and Lundquist 2025) populated a matrix linking marine activities based on the DOC list with relevant pressures on elements of biodiversity and ecosystems, and evaluated evidence for each pressure-activity relationship. Activities were mapped to categories of 35 pressures across six themes: Hydrological changes (inshore/local); Pollution and other chemical changes; Physical loss; Physical damage; Other physical pressures; and Biological pressures. Some activities in the original list were merged into broader categories since impacts were similar and/or it was difficult to differentiate between impacts. Some merged activities were activities where different stages of activity development had been listed separately in the DOC list of activities such as construction, operation and maintenance, and decommissioning. We combined the different stages of activity development for activity categories for Renewable energy – offshore wind, Renewable energy – wave energy, and Marine hydrocarbon extraction (except for the exploration phase). Similarly different components of Submarine cables were also merged (pipeline laying, burial and protection, operations and maintenance, and decommissioning). Vessel moorings and vessel berths were also merged. The final activity list for this aligned DOC project was used to categorise activities that impact on naturalness for this MfE project, and included 56 categories of activities within 11 themes:

A. Coastal management activities.

B. Waste management activities.

C. Extraction of living resources.

D. Production of living resources.

E. Extraction (and disposal) of non-living resources.

F. Energy generation.

G. Transport.

H. Recreation and leisure.

I. Marine research.

J. Defence and national security.

K. Other man-made structures.

In the following sections (Sections 3-13), we describe and summarise the state of knowledge and next steps toward obtaining comprehensive geospatial datasets representing the stressor footprints from activities within each activity category.

3 Coastal management activities

Six types of activities were categorised as coastal management activities: 1) Coastal defence and land claim protection (including beach replenishment); 2) Coastal boat ramps, docks, ports and marinas; 3) Forestry; 4) Farming and Agriculture; 5) Strandline clearance; and 6) Reclamations and causeways. Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for each activity category (Table 3-1).

Evidence for links between coastal management activities and pressures on the marine environment has not yet been compiled within the aligned DOC project that linked human activities with pressures, and reviewed supporting evidence (Douglas and Lundquist 2025). Impacts on biodiversity within this activity category differ between those involving modification or infilling of land (Coastal defence and land claim protection; Coastal boat ramps, docks, ports and marinas; and Reclamations and causeways), and other activities within this broad category. Spatial maps of impacts of biodiversity are likely to directly overlap the spatial footprint of those activities involving modification or infilling of land, often with complete loss of habitats and associated species where these activities take place. For activities associated with point or non-point source pollution from upstream sources (Forestry; Farming and Agriculture), temporal and spatial footprints of activities are difficult to quantify. For all land-based activities, the quantity of stressors released and their transport will vary based on land-use, management practices used (i.e., fencing of streams, intensity of forestry practices), as well as typography, geology and hydrography that influences likelihood of erosion of sediments and nutrients and their transport to the coastal zone. Stressor footprints from land-based sources to coasts and estuaries accumulate over time, and include both low but constant inputs that contribute to gradual change, as well as large event-based inputs that may have more severe direct impacts on species and habitats (Thrush et al. 2004). Transport of sediment and nutrient stressors in the coastal zone is influenced primarily by tidal currents and regional hydrodynamics, storm-events, and seasonal variability that may result in stressor footprints being extended well beyond the river mouths where they enter the coastal zone (Gladstone-Gallagher et al. 2024, Leduc et al. 2024, Low et al. 2023). The impacts on biodiversity of strandline clearances are primarily localised where the activity occurs due to disturbance by machinery, though trophic impacts may be more widespread due to the removal of beach habitats and nutrient sources.

Table 3-1: Descriptions of layers compiled for the category Coastal management activities.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Coastal defence/beach nourishment	Artificial shorelines	one-off	<1 km	n/a	No	Regional authorities	Data extraction
	Beach renourishment	ongoing	<1 km	n/a	No	Regional authorities	Data extraction
Boat ramps, docks, ports & marinas	Ports/marinas/berths	one-off	1-10 km	Point records	Incomplete	This project/LINZ	Add missing ports/marinas; Convert to polygons; add information on number of berths
	Boatramps	one-off	<1 km	Polylines	Yes	LINZ	Validate against coastal imagery
Forestry	Land use: Exotic forest	ongoing	10-100 km	Land-use map, Proportion per 10 km segment	Yes	MfE	Temporal analysis
	Sediment load/yield	ongoing	>100 km	Point values for REC2 terminal segments, cumulative values per 10 km segment	Yes	This project	Coastal dispersal
	Sediment erosion	ongoing	>100 km	Point values for REC2 terminal segments	Yes	MfE	Coastal dispersal
Farming and Agriculture	Land use: Intensive agriculture	ongoing	10-100 km	Land-use map, Proportion per 10 km segment	Yes	MfE	Temporal analysis

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
	Sediment load/yield	ongoing	>100 km	Point values for REC2 terminal segments, cumulative values per 10 km segment	Yes	This project	Coastal dispersal
	Phosphorus loading	ongoing	>100 km	Point values for REC2 terminal segments, cumulative values per 10 km segment	Yes	This project	Coastal dispersal
	Nitrogen loading	ongoing	>100 km	Point values for REC2 terminal segments, cumulative values per 10 km segment	Yes	This project	Coastal dispersal
	Land use: Proportion of native cover; Proportion of area in formal protection	ongoing	>100 km	Land-use map, Proportion per 10 km segment	Yes	MfE	Temporal analysis
Strandline clearance		ongoing	<1 km	n/a	No	Regional authorities	Data extraction
Reclamations and causeways		one-off	<1 km	n/a	No	Regional authorities	Data extraction

3.1 Coastal defence and land claim protection (including beach replenishment)

3.1.1 Description

As defined by DOC, this activity category includes development and maintenance of coastal defences. It includes management of beaches, bunds, ditches/drainage, managed realignment sites, beach/sediment recharge or on-going sediment feeding (i.e., beach renourishment to combat erosion), management of vegetation, sand dune stabilisation, and also considers vessels, machinery, vehicles, and materials associated with each activity.

3.1.2 State of knowledge

This activity includes the majority of the marine ecosystem function groups that are categorised as 'Artificial Shorelines' with the IUCN Global Ecosystem Typology (Lundquist et al. 2024). Most are activities requiring consent under the Resource Management Act and are managed by regional authorities.

The Inter-Agency Working Group reflected that information on coastal infrastructure was available at regional scales through regional authorities. However, council databases typically included only publicly funded or maintained infrastructure, and information was unlikely to be available for activities on private land. The MBIE Endeavour Future Coasts programme was cited as a potential source of a national data layer, and further conversations with Futures Coasts scientists at NIWA confirmed that they had explored compiling such a layer but found that little information was available in a comprehensive state on artificial shorelines, and that it was beyond the scope of their research to compile such a layer. Some sub-sets of this dataset might be simpler to compile, for example, beach replenishment that would include individual consents, but also may not include information on exact timing and extent of replenishment activities.

3.1.3 Next steps

This dataset was not compiled here due to the effort required to compile data at a national scale, especially as activities comprised a large number of consent types that may differ in data availability between regions. At the project workshop, the Inter-Agency Working Group noted that there is a high likelihood that a majority of coastal development (i.e., that on private land) would not be available. However, it was noted that quantifying the extent of artificial shorelines would fill an important gap, as coastal structures are linked to coastal resilience (i.e., from storms, sea level rise and other coastal hazards). As a next step, regional authorities could prioritise compilation of a national database through identifying relevant coastal consents, and identifying and compiling spatial layers associated with such consents. Data gaps such as coastal defence on private land could be explored through remote sensing analyses. If available, this dataset would contribute to informing the quantification of stressors from coastal management activities. Such a layer could also be used in national reporting through populating the 'Artificial Shorelines' ecosystem functional group with the IUCN Global Ecosystem Typology and similar artificial ecosystem categories within a proposed national marine ecosystem typology based on the Coastal and Marine Ecological Classification Standard (CEMCS) (Lundquist et al. 2024).

3.2 Coastal boat ramps, docks, ports and marinas

3.2.1 Description

As defined by DOC, this activity category includes building, expanding, and upgrading coastal boat ramps, docks, berths, ports and marinas, and includes consideration of vessels, machinery, vehicles, and materials associated with each activity. This category overlaps with data layers in the Transport category relating to Shipping activities (see Section 9).

3.2.2 State of knowledge

Data on boat ramps had been compiled for the DOC project on recreational use and values of New Zealand's marine environment (Visitor Solutions 2012). A Sustainable Seas project (Cook et al. in review) converted this data layer to a geospatial layer with number of boat ramps per 10 km coastal polygon to aid in visualisation within the geospatial tool Te Ukaipo o Hinemoana. An updated layer was acquired from the LINZ national dataset 'NZ Boatramp Centrelines', noting that changes since that data acquisition appeared to be formatting rather than additional data points, and that the latest LINZ update of the layer was on 28 August 2012. Data were available from LINZ as polylines based on true length, including boat ramps <50 m in length. The dataset does not include a date stamp to inform when boat ramps were built, or any further information on maintenance or expansion. Thus, it is an indication of the presence of non-natural substrate as well as an indicator of potential impacts associated with the use of boat ramps (e.g., litter pollution, vessel oil leakage) (Figure 3-1).

Data on marinas were reported on by the DOC project on recreational use and values of New Zealand's marine environment (Visitor Solutions 2012) based on information from the Marina Operators Association, the Yellow Page Business Directory, and the Marine Industry Association. Data included name and location, but no further information on dates of construction, expansion or upgrades. The Visitor Solutions dataset on marinas was not able to be accessed for this project, but could be further explored, noting that it would require updating as marina expansions have occurred in some locations.

The Ministry for Primary Industries (MPI) lists fourteen international ports approved for international arrivals and shipping. These are: Northland, Auckland, Tauranga, Waikato (Taharoa), Gisborne, Napier, New Plymouth, Wellington, Picton, Nelson, Christchurch (Lyttelton), Timaru, Dunedin (Port Chalmers), and Invercargill (Bluff and Tiwai Point). LINZ nautical charts indicate more detailed locations of ports, however no shape file of the extent of ports was found. Major ports are also identified within the National Marine High Risk Site Surveillance (NMHRSS) programme of surveys targeted at the early detection of high-risk marine non-indigenous species, and point locations were generated for this project (Figure 3-1). Other sources suggest New Zealand has 30-50 ports, though smaller ports typically overlap with maps of marinas.

A dataset of berths was acquired from LINZ, which includes named or numbered berths at wharfs. The dataset appeared incomplete, consisting of individual berths at some but not all major ports (e.g., Tauranga, Wellington, Greymouth) (Figure 3-1).

3.2.3 Next steps

Data on boatramps was determined to be relatively complete and sufficient for the assessment of impacts of this activity, though some private boatramps may not be included. The dataset includes no information on building date, expansion or maintenance of the boat ramps and marinas to allow interpretation of any temporal impacts of construction. Updating the dataset to include temporal information would require extensive effort to track building and expansion dates of individual boat ramps and marinas, most of which have been present in some form for many decades.

The boat ramp dataset includes those on public land and is expected to include consented boat ramps on private land, though whether the boat ramp was on private or public land was not provided in the dataset. Ensuring that all private and public boat ramps are included would require visual assessment of satellite photos of New Zealand's coastline. It is likely that the existing dataset provides sufficient information to assess the relative impact of this activity.

An initial set of port locations was generated for this project, and could be further expanded to include all ports and marinas in New Zealand. Port and marina point locations should be converted to polygons to better represent the spatial footprint of these activities. Compiling information on the number of docks or berths associated with individual ports and marinas would be useful to provide an indication of the potential magnitude of impact associated with each port or marina.

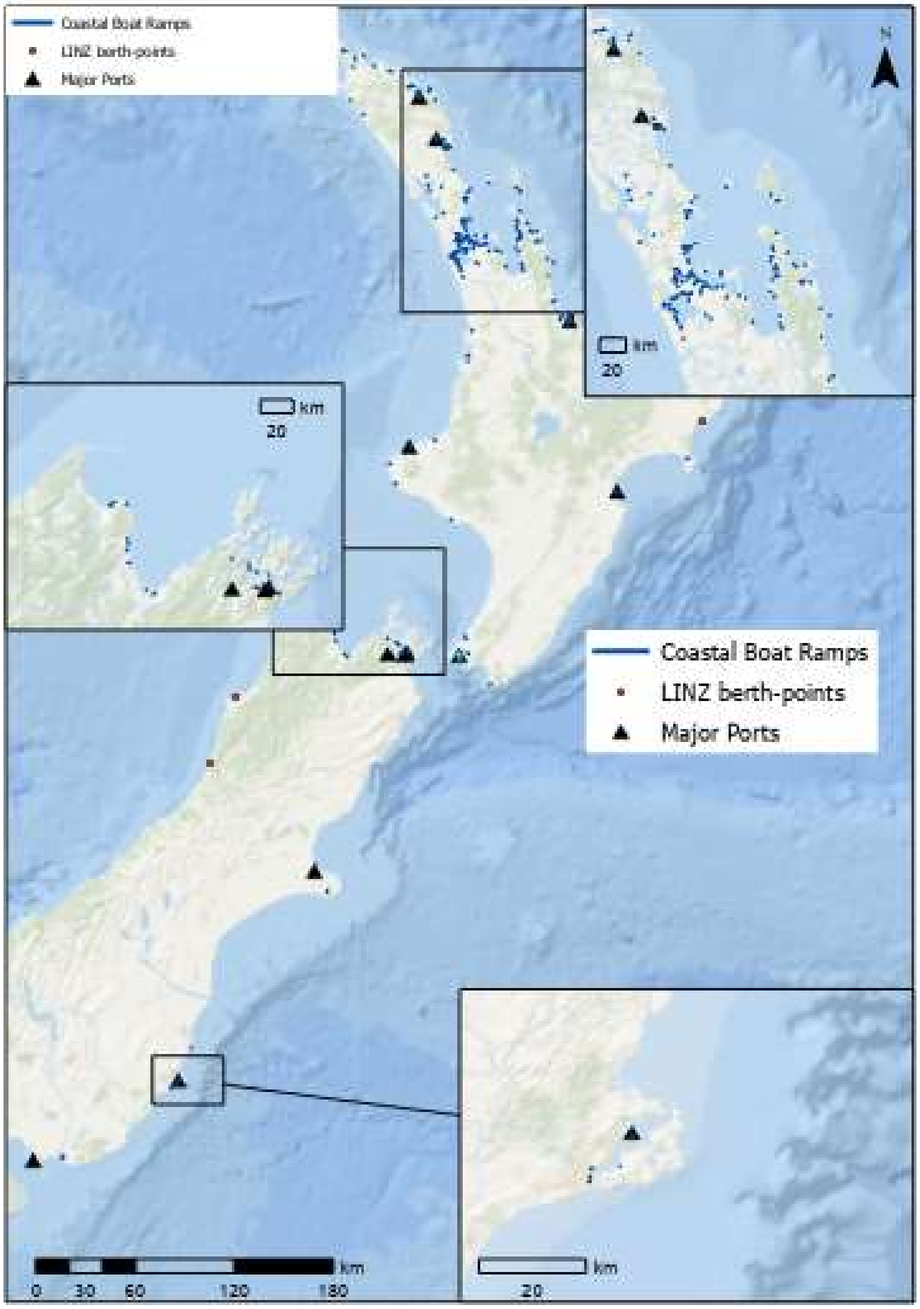

Figure 3-1: Boat ramps, ports, and berths. Data from LINZ for boat ramps and berths. Point locations for ports were generated for this project for 12 major ports surveyed by the National Marine High Risk Site Surveillance programme, noting this port and marina dataset is incomplete.

3.3 Forestry

3.3.1 Description

As defined by DOC, this activity category includes both (i) the effects of removing existing forests and (ii) afforestation (the planting of trees), and includes consideration of vessels, machinery, vehicles, and materials associated with each activity.

3.3.2 State of knowledge

Exotic forests in New Zealand (dominated by *Pinus radiata*) have a typical rotation time of 25-32 years (Ministry of Agriculture and Forestry 2010). Deforestation is associated with soil erosion, decreased water quality, and sedimentation impacts downstream in freshwater, estuarine and marine systems (Thrush et al. 2004). Smothering by sediment as well as changes in sediment grainsize toward increasingly muddy sediments and increasing turbidity are often attributed to sediment run-off from forestry (Leduc et al. 2024, Thrush et al. 2004). Sediment impacts have been demonstrated on estuarine and coastal soft sediment epifaunal and infaunal communities and on shallow subtidal rocky reefs, with suspension-feeding organisms being particularly sensitive.

Landcover is available for the New Zealand mainland, with two primary datasets representing land cover and land use at set time intervals. The New Zealand Land Cover Database (LCDB) provides the distribution of 33 'detailed' land cover categories at five 'snapshots' in time: 1996, 2001, 2008, 2012 and 2018. The latest version of the LCDB (version 5.0), created by Manaaki Whenua - Landcare Research with the support of MfE and other government agencies, was released in January 2020. LCDB classes have evolved over time. Prior iterations (LCDB v1, v2) differentiated Class 71 into seven additional categories: Afforestation, Afforestation (imaged, post LCDB1), Minor Shelterbelts, Major Shelterbelts, Pine Forest - Open Canopy, Pine Forest - Closed Canopy, and Other Exotic Forest, however the current LCDBv5 includes only two classes relevant to this activity being Class 71 (Exotic forest) and class 64 (Forest-Harvested) and does not provide sufficient information to assess potential disturbances from 'Afforestation' as per the description of the activity.

The LUCAS New Zealand Land Use Map includes twelve land-use classes at five snapshots in time corresponding to 1989, 2007, 2012, 2016, and 2020 (Ministry for the Environment 2012), and was last updated on 2 December 2024 (Figure 3-2). LUCAS classes relevant to this activity are 'Planted Forest- Pre 1990' and 'Post 1989 Forest'.

The DOC Evaluating KEAs report (Lundquist et al. 2020) extrapolated land-use and land-cover categories to a national scale through creation of 10 km coastal polygons based on a smoothed outline of the New Zealand coast, and extending polygons out to the 12 nm Territorial Sea limit (Figure 3-3); these 10 km coastal polygons were created to facilitate visualisation of regional differences in land-use. The catchment area for each coastal polygon was calculated using data for from the New Zealand River Environments Classification database (REC). The catchments of all rivers/streams that reached the coast within each polygon was summed to provide a unique catchment area associated with each polygon. The catchment area of each coastal polygon was intersected with the spatial polygons contained with the LUCAS database to calculate absolute area and proportional coverage of the land use categories for each catchment. Maps for coastal polygons were available from the DOC KEA project (Lundquist et al. 2020), and the proportion of forestry land-use was included within the content provided on the Te Ukaipo o Hinemoana geospatial tool (Figure 3-4).

Sediment loading was also available for coastal polygons using the same approach of quantifying sediment metrics based on the REC catchments, and included estimates of sediment loads based on all terminal REC segments within that 10 km coastal segments; these analyses were performed by the Sustainable Seas SPEXCET project (Cook et al. in review) using the CLUES (Catchment Land Use for Environmental Sustainability) model (https://niwa.co.nz/freshwater/clues-catchment-land-use-environmental-sustainability-model).

Participants at the Inter-Agency Working Group Workshop expressed dissatisfaction with the 10 km coastal polygons for quantifying land-use and sediment stressors, and suggested raw data would be more appropriate for assessing location of the source of these stressors. Thus, this project developed a new spatial layer of sediment loading. The CLUES software (Semadeni-Davies et al. 2015) was used to quantify sediment load (kilo-tonnes y^{-1}) and sediment yield (t ha^{-1} y^{-1}) for individual REC class 2 terminal segments (n = 593,517 individual segments). Sediment loads provide estimated annual sediment loads based on current catchment land-use, though they do not account for localised forestry inputs (Figure 3-5). Sediment yields provide sediment inputs relative to the contributing catchment area (Figure 3-6). CLUES can also be used to provide estimates of pre-European sediment loads, though these would require a separate analysis such as that used to estimate and compare historical and current sediment loads in the Hawke's Bay region in a Sustainable Seas case study (Lundquist et al. 2022).

Sediment loads are also available based on national sediment erosion maps (Hicks et al. 2000, Hicks et al. 2019) for LCDBv3 land-use classes (2008). These estimates are generally similar to the CLUES sediment maps with the exception of a few locations (e.g., Fiordland) where CLUES sediment estimates were very high, likely due to dependence of the CLUES model estimates on rainfall (Cook et al. in review). This sediment layer is also available on the DOC Coastal Sediment Source Portal (https://web.nz.dhigroup.com/CoastalSedimentSourcePortal/), and also includes future climate change estimates of sediment load. This approach could be used to generate sediment loads for other LCDB land-use snapshots (e.g., 1996, 2001, 2012, 2020) to allow changes across years to be explored.

As noted previously, it is difficult to quantify temporal and spatial footprints of activities associated with point or non-point source pollution, and the quantity of stressors released and their transport will vary based on land-use, management practices used (i.e., fencing of streams, intensity of forestry practices), as well as typography, geology and hydrography that influences likelihood of erosion of sediments and nutrients and their transport to the coastal zone. Stressor footprints from land-based sources accumulate over time, and include both low constant inputs and event-based inputs. Transport, deposition, and resuspension of sediments and nutrients in the coastal zone is influenced by tidal currents and regional hydrodynamics, storm-events, and seasonal variability that may result in stressor footprints being extended well beyond the river mouths where they enter the coastal zone. Sediment stressor footprints are difficult to map at a national scale due to this spatial and temporal variability.

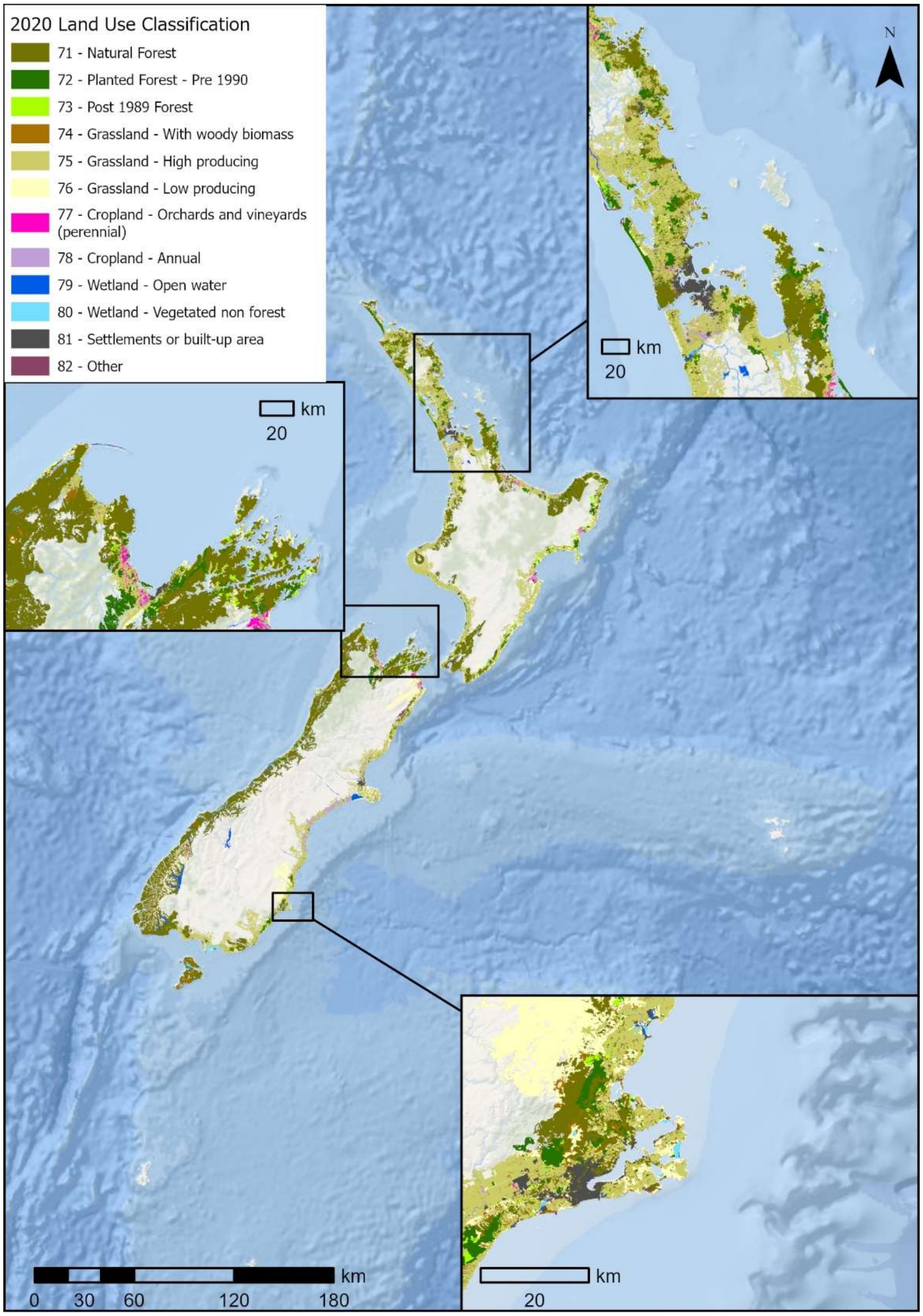

Figure 3-2: Land-use classes, clipped to coastal land within 30 km of the shoreline. Note land-use classes of wetland and open water are combined, and barren/other are not displayed on this map.

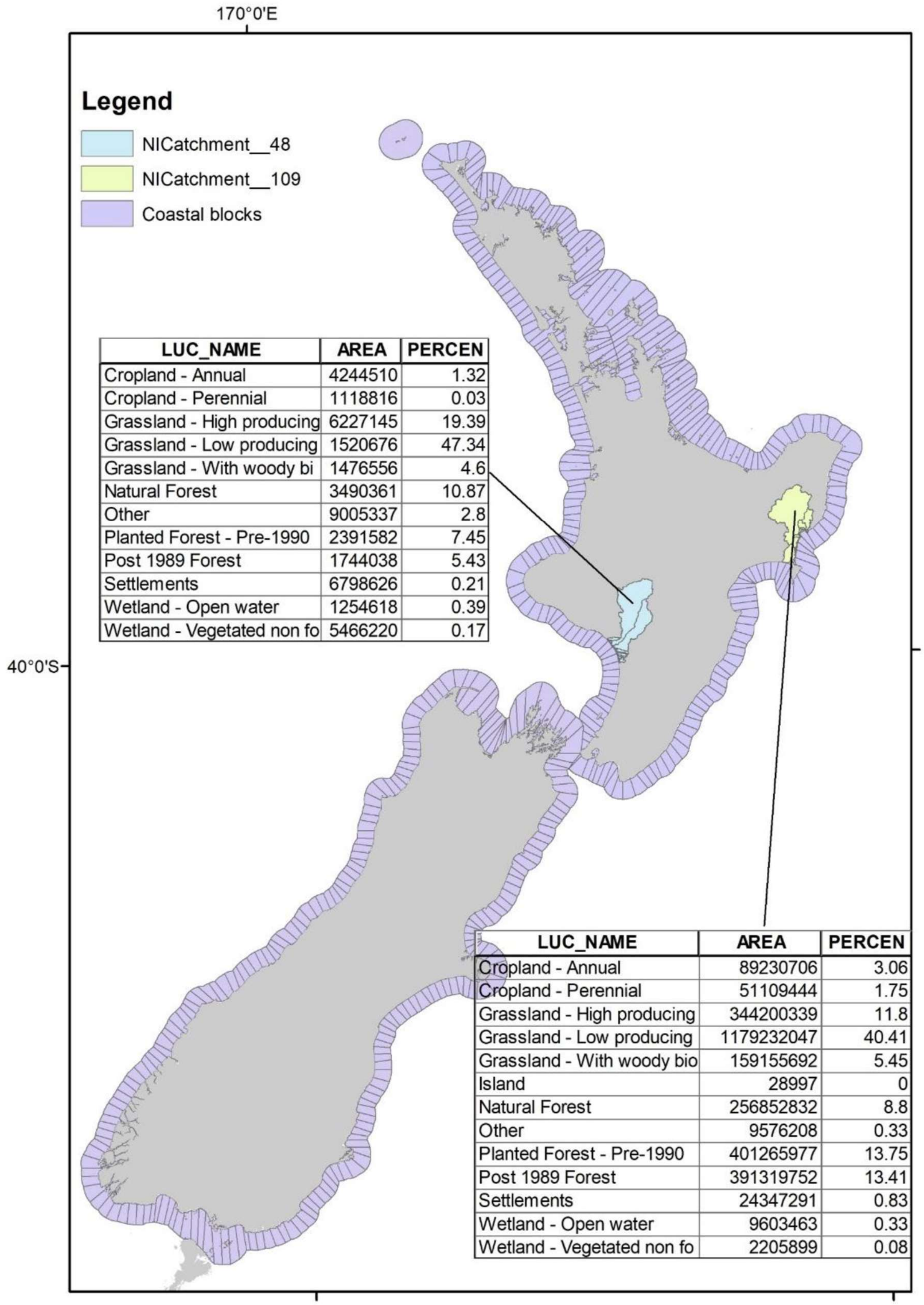

Figure 3-3: Example of proportion of LUCAS land-use classes attributed to individual catchments. Based on data available from Lundquist et al. (2020).

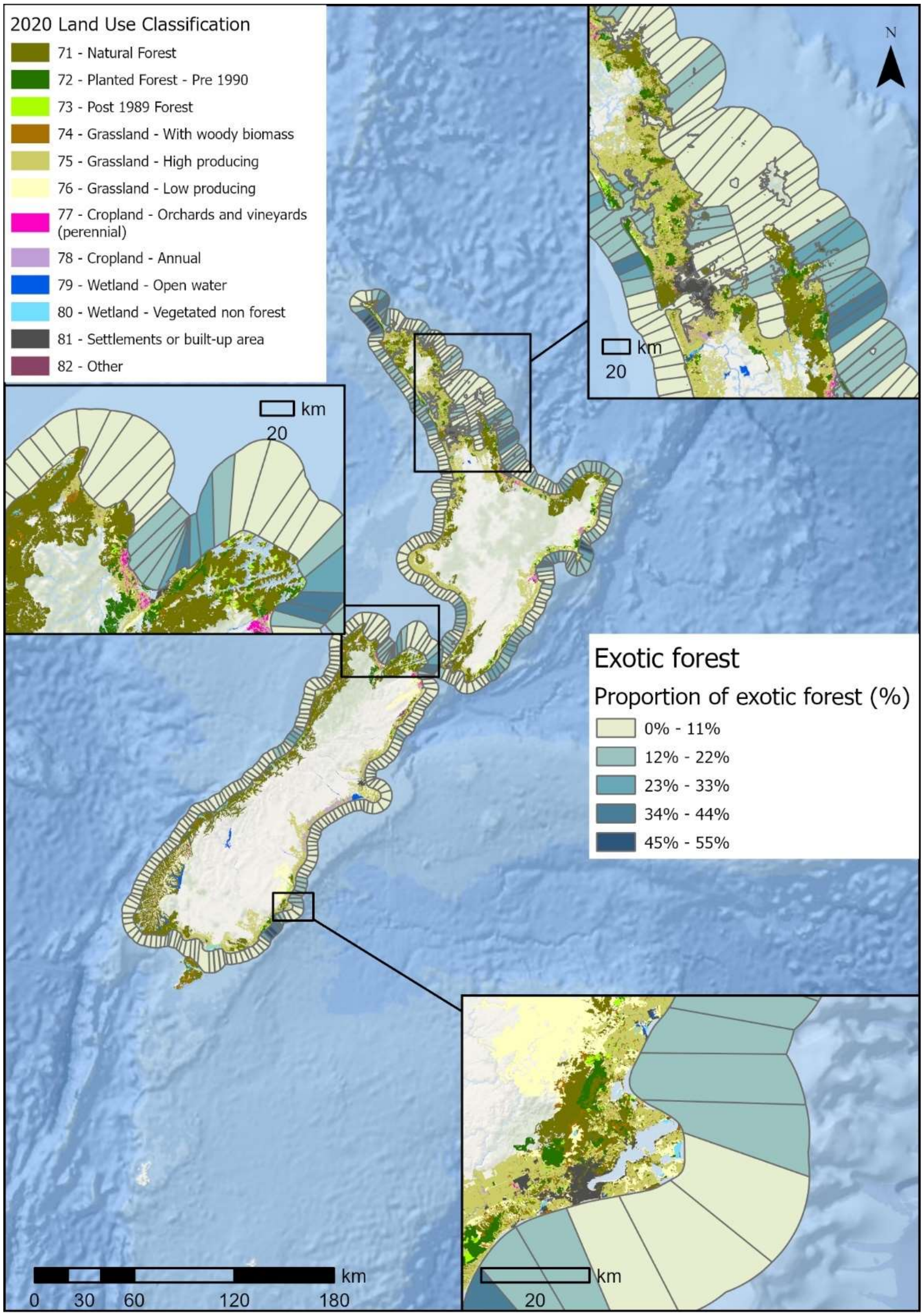

Figure 3-4: Proportion of exotic forest within catchments associated with 10 km coastal segments based on 2020 land-use classification. Land-use categories clipped to 30 km distance from the coastline. 10 km segments were extended to the territorial sea (12 nm) boundary, based on layer available acquired from the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana.

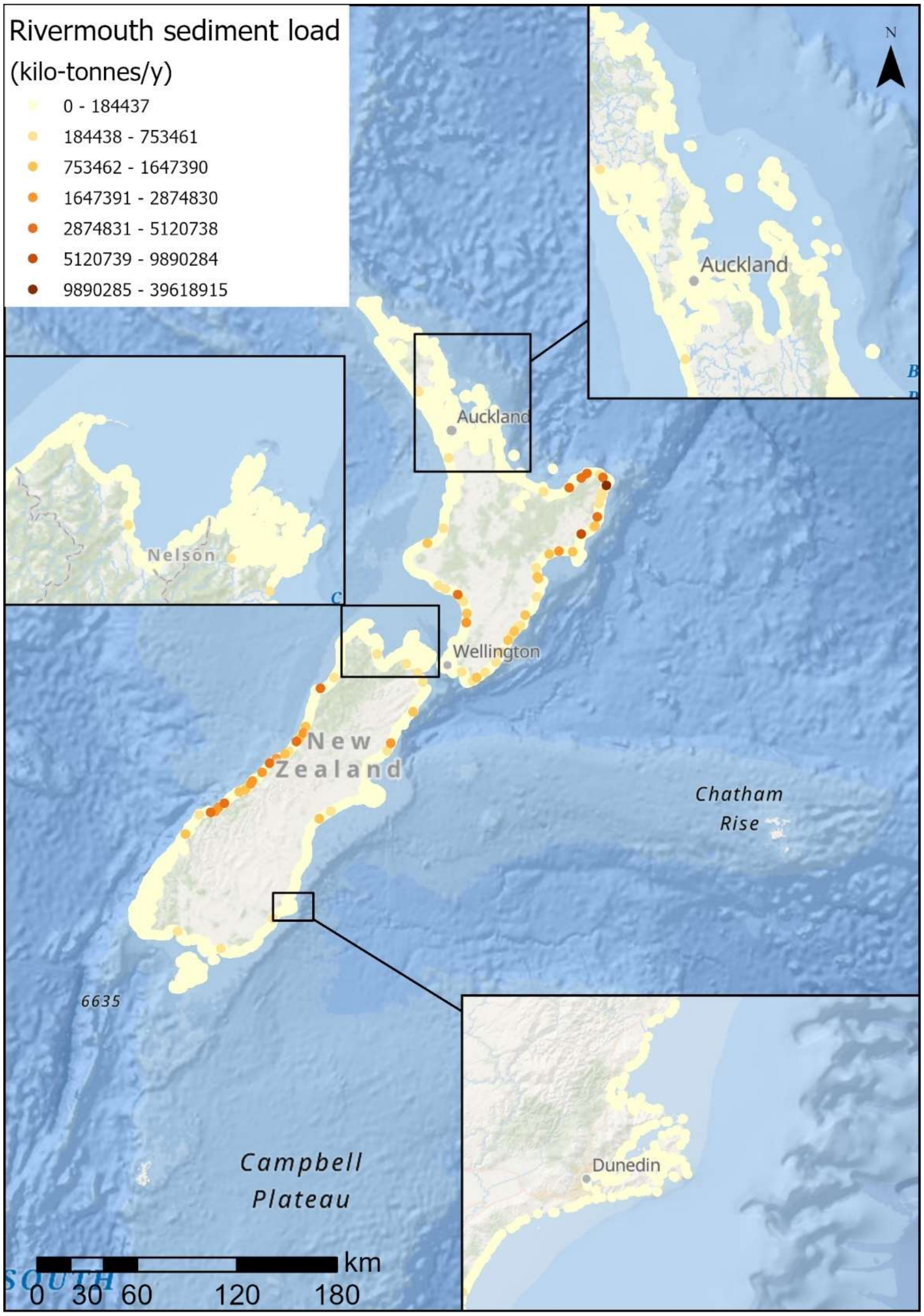

Figure 3-5: Sediment load (kilo-tonnes y^{-1}) for terminal segments of River Environments Class REC2 segments.

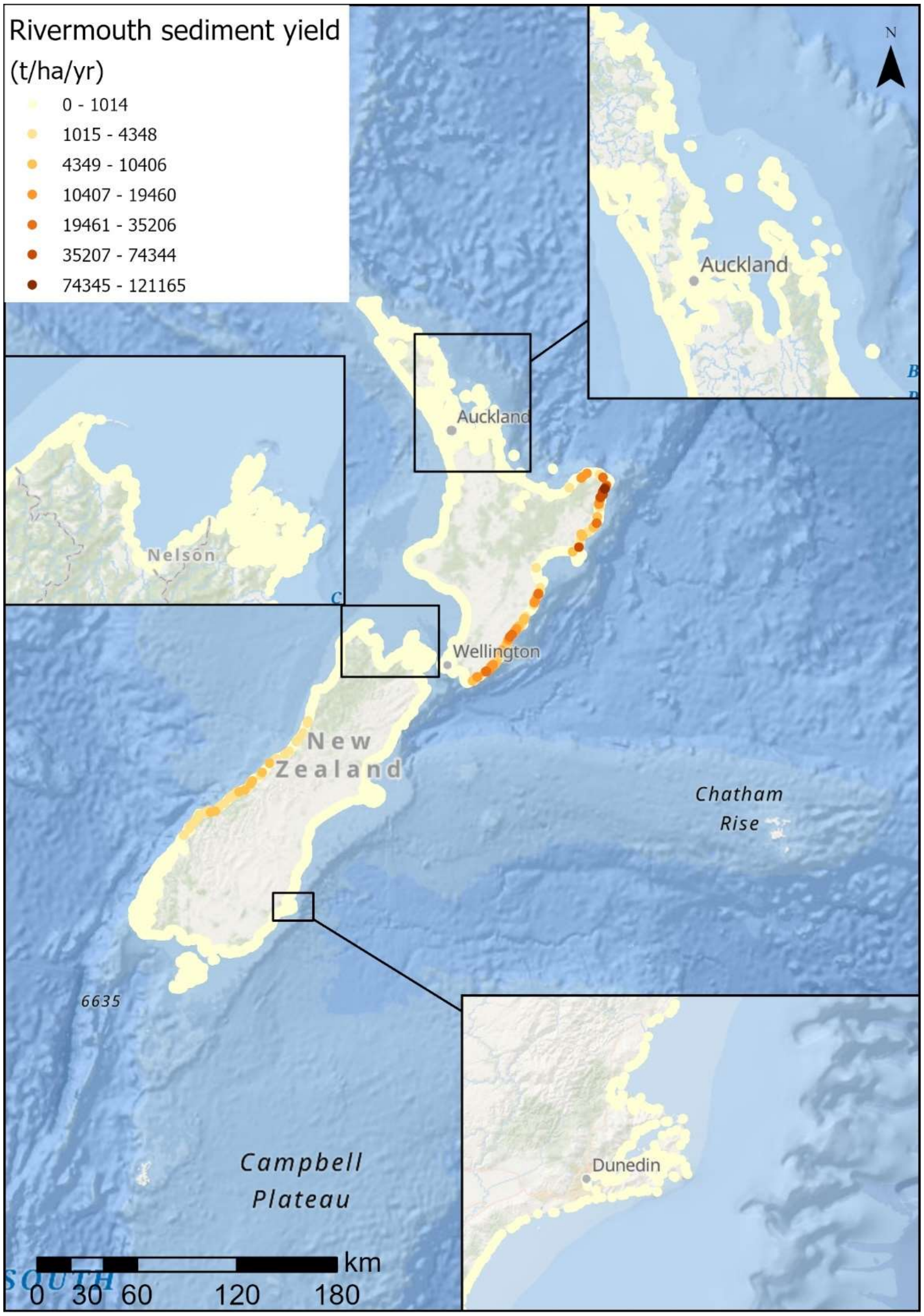

Figure 3-6: Sediment yield (t ha^{-1} y^{-1}) for terminal segments of River Environments Class 2 segments.

3.3.3 Next steps

Maps of land-use are only available for particular snapshots in time, and do not provide information on timing or extent of forestry activities within a forestry block. Thus, this dataset was determined to be robust for the represent of potential risk of stressors from land-use, however the dataset was assessed as being a poor representation of the true stressor footprint, as it did not include the temporal component of forestry activities. Forestry activities and timing were not easily acquired, but the forestry industry could be queried, and footprints of forestry activity generated. For decadal time scales, differences between snapshots within LCDB and LUCAS land classes in sediment load using either CLUES or the Hicks et al. (2019) approach could be quantified and used as a changes in spatial inputs of sediment over time, noting that these estimates would still not elucidate small-scale changes in sediment inputs due to forestry activities.

Estimated sediment loads and yields are based on all land-use classes, and do not specify the proportion of sediment load resulting from forestry land. Predicted future sediments loads at national and regional scales have also been quantified for future climate scenarios (Neverman et al. 2023); these layers are publicly available, but were not acquired for this project.

While the layers of sediment load and sediment yield creating for this project are a first step toward estimating stressor footprints related to land-based sediment inputs based on river mouth locations, they do not include transport of sediment from the river mouth. This transport and eventual deposition of sediment (and potential resuspension) on the seafloor is the more appropriate sediment footprint of this stressor as it is experienced by marine fauna and flora. Hydrodynamic models have been used in some case studies to estimate spatial and temporal patterns of sediment deposition (Leduc et al. 2024), however, these site-specific models are expensive to develop and validate, and were assessed as beyond the scope of this project. A number of potential simplifications of hydrodynamic approaches were discussed that could also be acquired to attempt to further refine sediment metrics: 1) using annual or seasonal mean current flows based on high resolution (5 km) outputs from the MBIE Endeavour Moana project; or 2) using metrics representing turbidity from the satellite remote sensing database NIWA Seas, Coasts and Estuaries, New Zealand (SCENZ) Ocean Colour ArcGIS Application (https://data-niwa.opendata.arcgis.com/documents/NIWA::niwa-scenz-ocean-colour-application/about). SCENZ includes weekly, monthly, seasonal and annual averages of ten metrics quantified from satellite remote sensing, available at a 500 m coastal grid. However, SCENZ data cannot be easily attributed to different land-use classes and represents 'total' sedimentation effects across all land use categories. Further work could explore spatial relationships between SCENZ variables and land-use specific loads at the river mouths. A recently funded MBIE Smart Idea to NIWA will explore approaches to quantifying sediment effects on seafloor primary production via satellite remote sensing (https://www.mbie.govt.nz/science-and-technology/science-and-innovation/funding-information-and-opportunities/investment-funds/endeavour-fund/currently-funded-smart-ideas/national-institute-of-water-and-atmospheric-research-limited-smart-ideas-funded-projects).

3.4 Farming and Agriculture

3.4.1 Description

As defined by DOC, this activity category includes the use of coastal areas for grazing of domestic animals (e.g., cows, sheep and horses) and drainage and fertilisation of coastal areas to improve grazing and agriculture, and includes consideration of vessels, machinery, vehicles, and materials associated with each activity.

3.4.2 State of knowledge

As per quantifying stressors related to forestry, the LCDB and LUCAS land class maps provide spatial representations of where these land-uses occur relative to coastal ecosystems. LCDBv5 classes relevant to this activity include Class 24 (Short-rotation Cropland), Class 26 (Vineyard), Class 27 (Orchard and Other Perennial Crops), Class 28 (High Producing Exotic Grassland), Class 31 (Low Producing Grassland), Class 41 (Tall Tussock Grassland) and Class 47 (Depleted Grassland). LUCAS land-use classes relevant to this activity include Cropland – Annual, Cropland - Orchards and Vineyards, Grassland - High Producing, Grassland - Low Producing, and Grassland- with woody biomass.

Following the same approach as for forestry, the DOC Evaluating KEAs report (Lundquist et al. 2020) extrapolated land-use and land-cover categories representing intensive agriculture to 10 km coastal polygons (Figure 3-7). Maps for coastal polygons were available from that project (Lundquist et al. 2020), and the proportion of intensive agriculture land-use was included within the content provided on the Te Ukaipo o Hinemoana geospatial tool.

Sediment loading was available as per the approach described for forestry, noting that the CLUES model and other estimates of sediment erosion are based on combined land-use maps and do not specify the proportion of sediment inputs contributed by each land-use class (Figure 3-5, Figure 3-6). Based on input at the Inter-Agency Working Group Workshop, this project also developed layers using CLUES (Semadeni-Davies et al. 2015), to provide estimates of nitrogen and phosphorus loading (kg y^{-1}) (Figure 3-8, Figure 3-9).

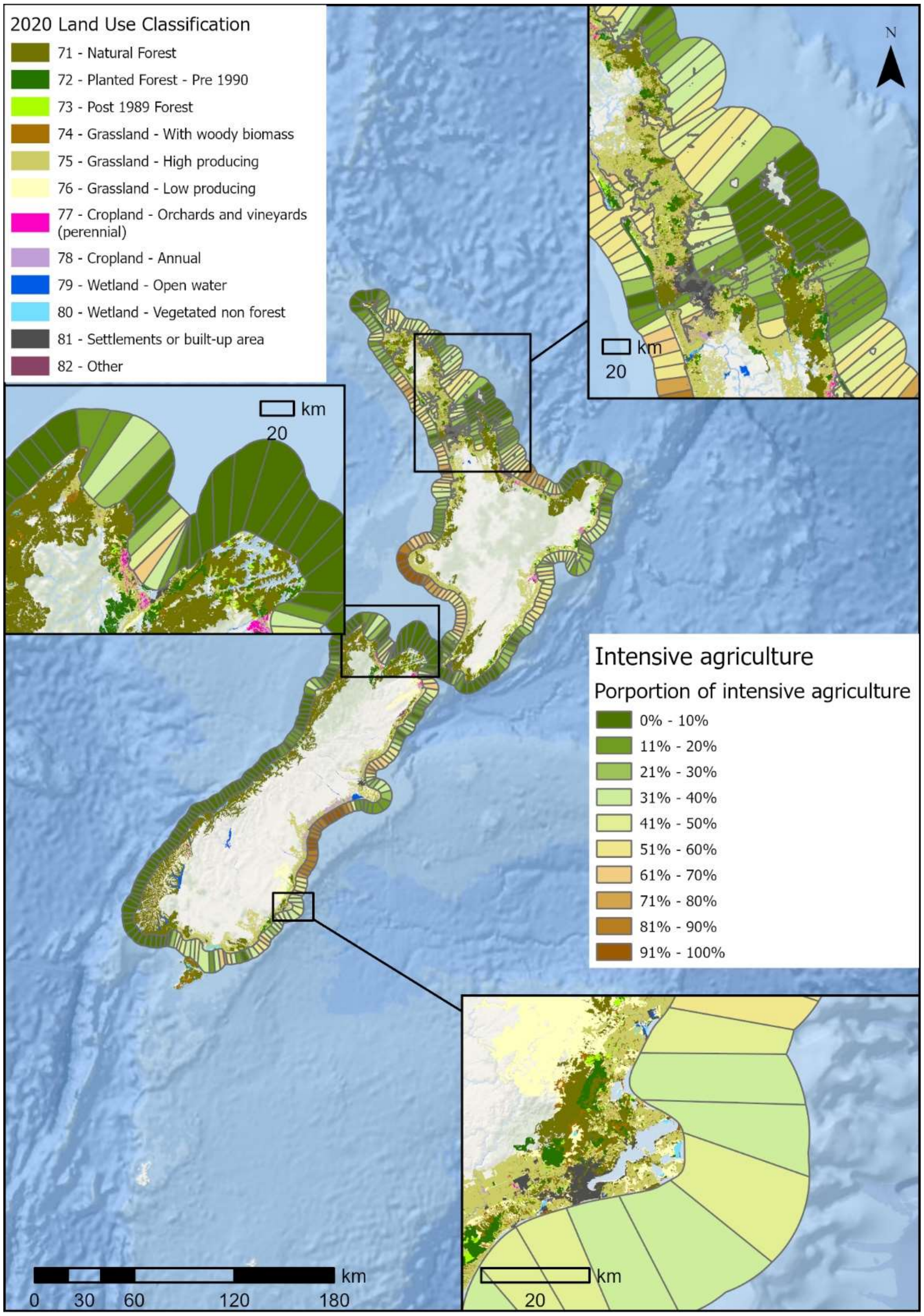

Figure 3-7: Proportion of intensive agriculture within catchments associated with 10 km coastal segments based on 2020 land-use classification. Land-use categories clipped to 30 km distance from the coastline. 10 km segments were extended to the territorial sea (12 nm) boundary, based on layer available acquired from the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana.

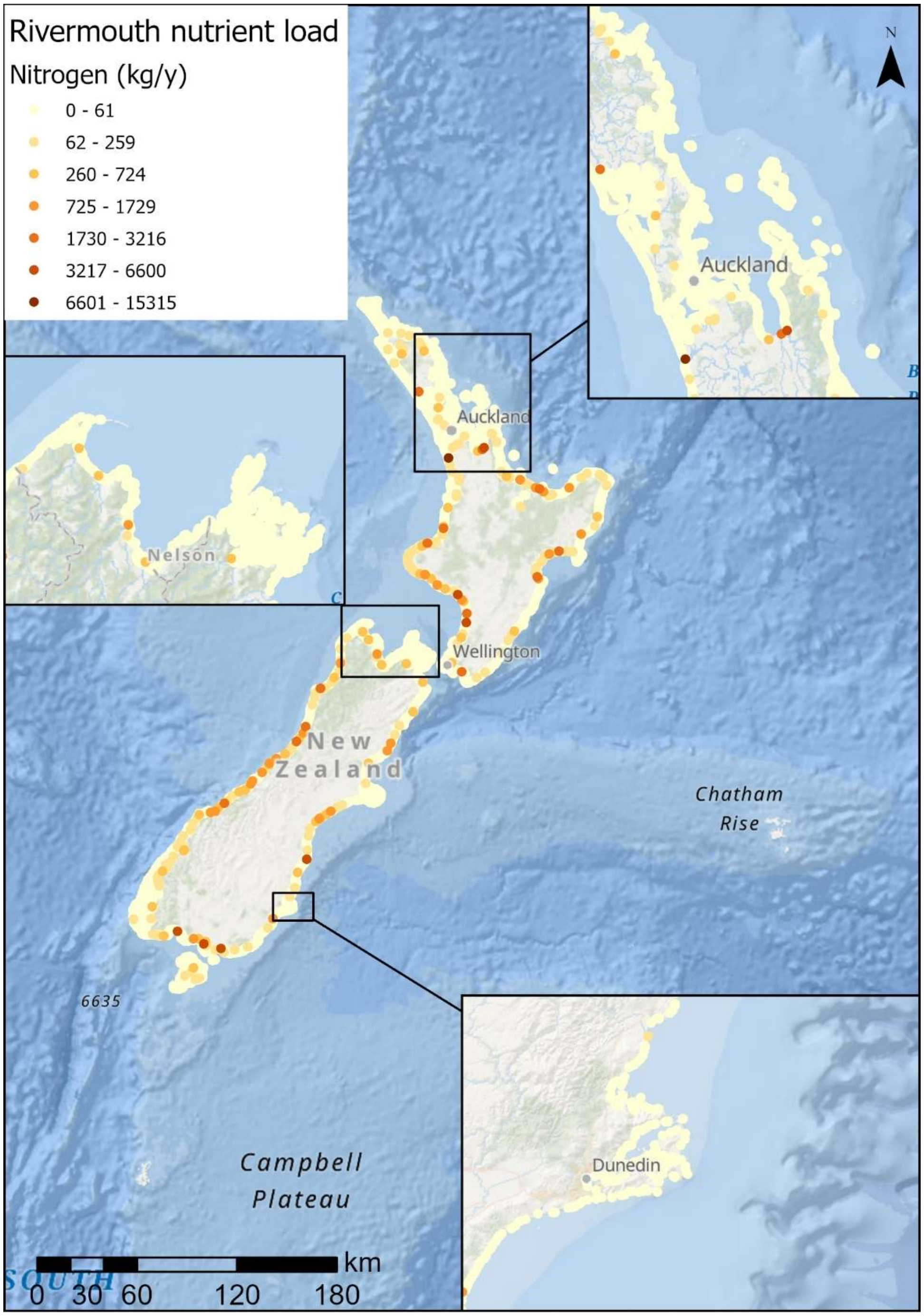

Figure 3-8: Nitrogen load (kg y^{-1}) for terminal segments of River Environments Class REC2 segments.

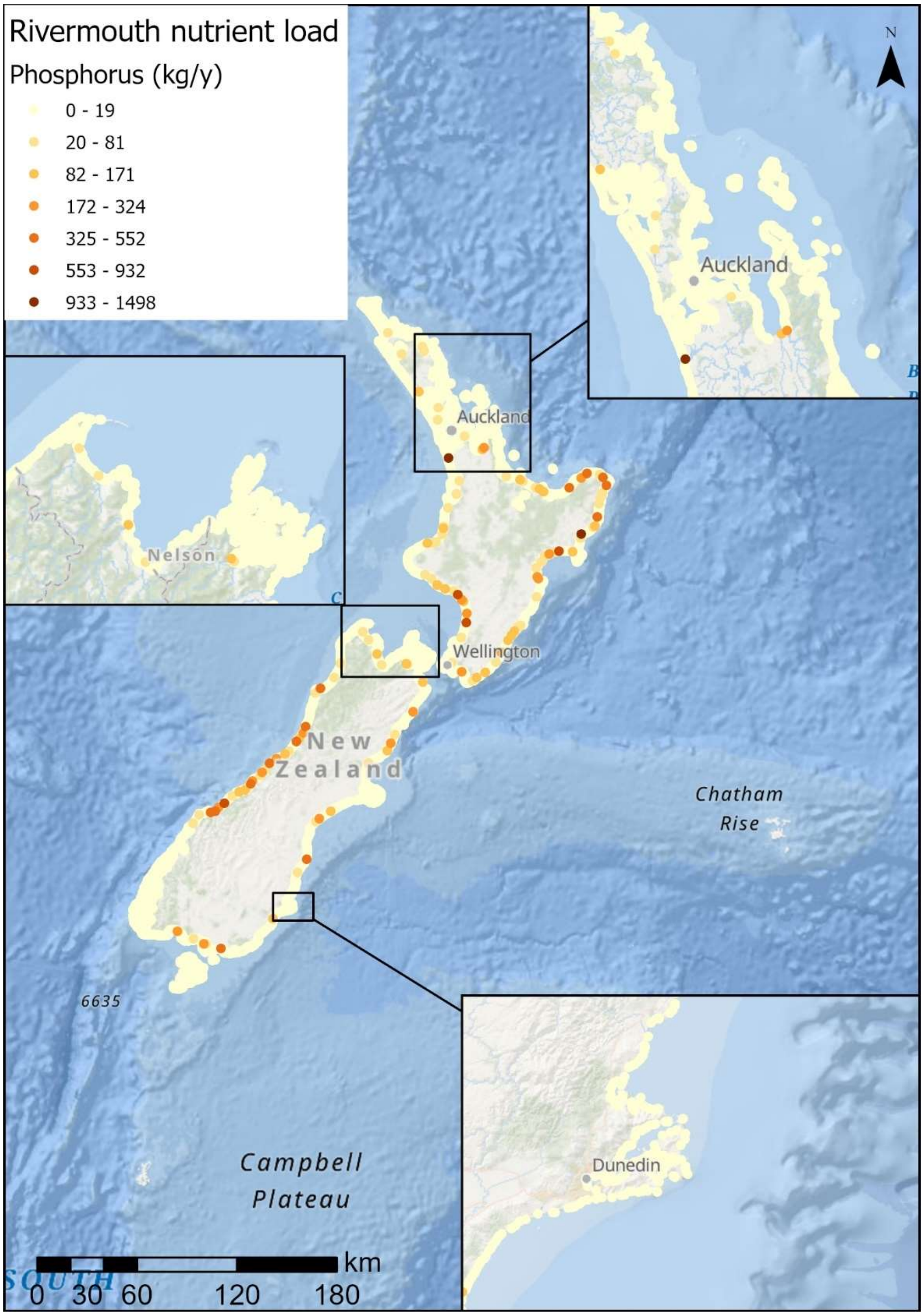

Figure 3-9: Phosphorus load (kg y^{-1}) for terminal segments of River Environments Class REC2 segments.

3.4.3 Next steps

Maps of land-use are only available for particular snapshots in time, and do not provide information on intensity of land-use or changes in land-use at small temporal scales (seasonal, annual). Thus, as with forestry, this dataset was determined to be robust for the represent of potential risk of stressors from farming and agricultural land-use, however the dataset was assessed as being a poor representation of the true stressor footprint. For decadal time scales, differences between snapshots within LCDB and LUCAS land classes could be quantified and used as a spatial estimate of changes in farming or agricultural sediment inputs, though estimates of differences in sediment loads based on different types of farming and agricultural use would need to be quantified relative to the localised typography, geology and hydrology.

Estimated sediment loads and yields are based on all land-use classes, and do not specify the proportion of sediment load resulting from farming and agricultural land. Predicted future sediments loads at national and regional scales have also been quantified for future climate scenarios (Hicks et al. 2019, Neverman et al. 2023); these layers are publicly available, but were not acquired for this project.

As per forestry sediment inputs, the layers of sediment and nutrient loads created for this project do not include transport of sediment beyond the river mouth, which is the more appropriate sediment footprint of this stressor as it is experienced by marine fauna and flora. Potential hydrodynamic approaches that could extrapolate nutrient stressor footprints in the coastal zone were discussed in the forestry section (Section 3.3).

3.5 Strandline clearance

3.5.1 Description

As defined by DOC, this activity category considers the removal the removal of natural debris, such as seaweed and driftwood, that accumulates along the high tide line on beaches. The process of clearing the strandline is often done to maintain the cleanliness and appearance of beaches, but it can also impact the local ecosystem, as the debris provides habitat and nutrients for various coastal species. This activity includes consideration of the associated vessels, machinery, vehicles, and materials required for clearing strandlines.

3.5.2 State of knowledge

Some harbours have well known seasonal challenges with nuisance macroalgal blooms, particularly sea lettuce (*Ulva* spp.) (Nelson et al. 2015). While there are reports in the media for a number of estuaries (e.g., Tauranga, Maketū, Avon-Heathcoate), no geospatial layers were found that described locations and regularity of strandline clearing. According to Bay of Plenty Regional Council, there are no restrictions on removal of nuisance algae (if it is not being used for sale), and sea lettuce has been advertised to the public for its use as garden compost. There are no requirements for monitoring harvest of beach strandlines. Seaweed farming is an emerging sector in New Zealand (Fisheries New Zealand 2023a), and permits are required for harvest or cultivation for commercial purposes, and described separately in Section 5.2 (Harvesting –seaweed and other sea-based food (e.g., pāua, kina, mussels, pūpū etc.). *Ulva* spp. is also being explored for its potential to remove excess levels of nutrients in Bay of Plenty harbours.

3.5.3 Next steps

This dataset was determined to be incomplete. Commercial harvest permits should be obtainable from FNZ and are addressed in Section 5.2 on harvesting of seaweed, however robust data on the temporal and spatial scale of the strandline removals from any clean up efforts by community groups are unlikely to exist.

Removal activities by regional authorities are likely to be recorded, and could be interrogated to see if information is provided on date and extent of clearings, as well as vehicle or machinery used as an indicator of the magnitude of disturbance. However, the activities are expected to have impacts at only local scales, and potential differ intra- and inter-annually in terms of extent. Regional authorities could interrogate local databases to determine what information exists to assess the frequency and extent of these activities to determine whether localised impacts on particular beaches could be severe.

3.6 Reclamations and causeways

3.6.1 Description

As defined by DOC, this activity considers reclaiming land from below the high-water mark to create new areas for quaysides, coastal defences, or port estates. This often involves building new walls or hard defences and filling in behind them to raise the land level. It also considers the vessels, machinery, vehicles, and materials needed for these activities.

3.6.2 State of knowledge

We consider coastal defence and other reclamation activities to overlap with the activities described in Section 3.1. For causeways, information on roads is available from LINZ within the database of national roads. The Sustainable Seas SPEXCET programme extracted data on roads and summarised roads near marine reserves (Cook et al. in review). This dataset includes both roads in a 10 km buffer near a marine reserve, as well as roads within a 1 km buffer inland from the coast in the catchment for each marine reserve.

3.6.3 Next steps

This dataset was determined to be mostly covered within Section 3.1, although note that this dataset was not compiled for this project due to the effort required to compile data at a national scale, and especially as activities comprised a large number of consent types that may differ in data availability between regions. In addition, there is a high likelihood that information on the majority of coastal development (i.e., that on private land) would not be available. For roads, the LINZ roads dataset is comprehensive. More detailed analyses of coastal roads could be progressed, for example, extrapolating motorways or other large thoroughfares, though differences in impact may be similar for both large and smaller paved roads as both may result in similar levels of coastal armouring.

4 Waste management activities

Seven types of activities were categorised as waste management activities: 1) Residential and urban wastewater (including storm water) discharges; 2) Sewage disposal; 3) Industrial and agricultural liquid discharges; 4) Waste disposal - munitions (chemical and conventional); 5) Dredge and spoil disposal; 6) Thermal effluent discharges; and 7) Rocket abandonment. Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for each activity category (Table 4-1). While not specified here, we also include a general activity of non-point source litter.

Impacts on biodiversity within this activity category include primarily pressures consisting of pollution and other chemical changes. Thermal effluent is also potentially associated with hydrological changes. Evidence for links between waste management activities and pressures on the marine environment has not yet been compiled within the aligned DOC project (linking human activities to marine pressures) as it was not among the initial subset of prioritised activities (Douglas and Lundquist 2025).

Table 4-1: Descriptions of layers compiled for the category Waste management activities.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Urban wastewater	Outfall pipes	ongoing	10-100 km	Polyline	Incomplete	LINZ/Regional authorities	Data extraction
	Human population	ongoing	10-100 km	Polygon	Yes	StatsNZ	Decadal update
	Land use: urban settlements	ongoing	10-100 km	Land-use map, Proportion per 10 km segment	Yes	MfE	Decadal update
Sewage disposal	Outfall pipes	ongoing	10-100 km	Polyline	Incomplete	LINZ/Regional authorities	Data extraction
Industrial/agricultural discharges	Point and non-point discharges	ongoing	10-100 km	Point	No	Regional authorities	Data extraction
Munitions disposal	Military - ammunition dumping	ongoing	10-100 km	Polygon	Yes	LINZ	Confidentiality
	Marine dumping grounds	ongoing	10-100 km	Polygon	Yes	EPA	Timing/extent
Dredge & spoil disposal	Dredge disposal areas	ongoing	10-100 km	Polygon	Yes	LINZ, EPA	Timing/extent
Thermal effluent discharges	Discharge consents	ongoing	10-100 km	Anecdotal point locations	Incomplete	Regional authorities	Timing/extent
Rocket abandonment	Rocket launch disposal area	risk	10-100 km	Polygon	Yes	LINZ/Rocket Lab	Clarify maps

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Litter - other	Landfills	risk	<1 km	Point	Yes	LINZ	Timing/extent
	Beach litter	ongoing	<1 km	Point	No	Environmental groups	Data extraction
	Seafloor litter (DTIS)	ongoing	>100 km	Point	Yes	NIWA	One-off analysis
	Litter (Trawl records)	ongoing	>100 km	Point	Yes	FNZ	Temporal analysis

4.1 Residential and urban wastewater (including storm water) discharges

4.1.1 Description

As defined by DOC, this activity category considers the construction, maintenance, and ongoing use of outfall pipes. These pipes could discharge liquids at varying temperatures, salinities, oxygen, nutrient concentrations. This category includes consideration of vessels/machinery/vehicles and materials associated with construction, maintenance operational usage of infrastructure

4.1.2 State of knowledge

LINZ provides maps of NZ drain centrelines (https://data.linz.govt.nz/layer/50262-nz-drain-centrelines-topo-150k/), which is defined as all channels containing surface water, however these are not specified as to what is transferred within particular outfall pipes, nor do the maps indicate ruptures causing wastewater spills. The LINZ Submarine pipeline layer also indicates whether pipes are for 'outfalls' in some cases, however this dataset is not as comprehensive as the drain centrelines layer.

A proxy for wastewater could be human population size, which is available through population mesh blocks based on NZ 5-year census data from StatsNZ. A meshblock is a defined geographic area, varying in size from part of a city block to large areas of rural land. Meshblocks are contiguous: each mesh block borders on another to form a network covering all of New Zealand, including coasts and inlets and extending out to New Zealand's Exclusive Economic Zone (EEZ). In the Sustainable Seas SPEXCET project, Cook et al. (in review) estimated human population impacts on marine reserves by extrapolating population mesh blocks based on NZ 5-year census data from 2012 obtained from StatsNZ. Geospatial population mesh blocks did not directly overlap on a standard grid or on the catchments identified for this analysis; rather mesh blocks were allocated proportionally based on overlap with distance-derived polygons (within 100 km) from marine reserve centroids, or with REC catchments.

Areas of high proportions of urban area could be another proxy for wastewater discharges. Following the same approach as for prior land-use datasets, LCDB or LUCAS land use and landcover datasets can be used to estimate the proportion of urban land, for example using the land-use class 'Settlements or built-up area' within the land-use classification (Figure 4-1).

4.1.3 Next steps

This dataset was determined to be incomplete but difficult to populate with a data layer representing a stressor footprint. A proxy layer of human population or urban land use is a potential surrogate, assuming that wastewater spills are strongly correlated with population size. However, wastewater discharges are likely due to a range of factors including natural disasters (e.g., earthquakes and Avon-Heathcote), and regional differences in weather (e.g., heavy rainfall events that may result in overflows) and resources allocated to upgrading existing systems. Regional authorities could explore how wastewater spills are typically recorded to inform appropriate spatial and temporal scale for populating this activity layer.

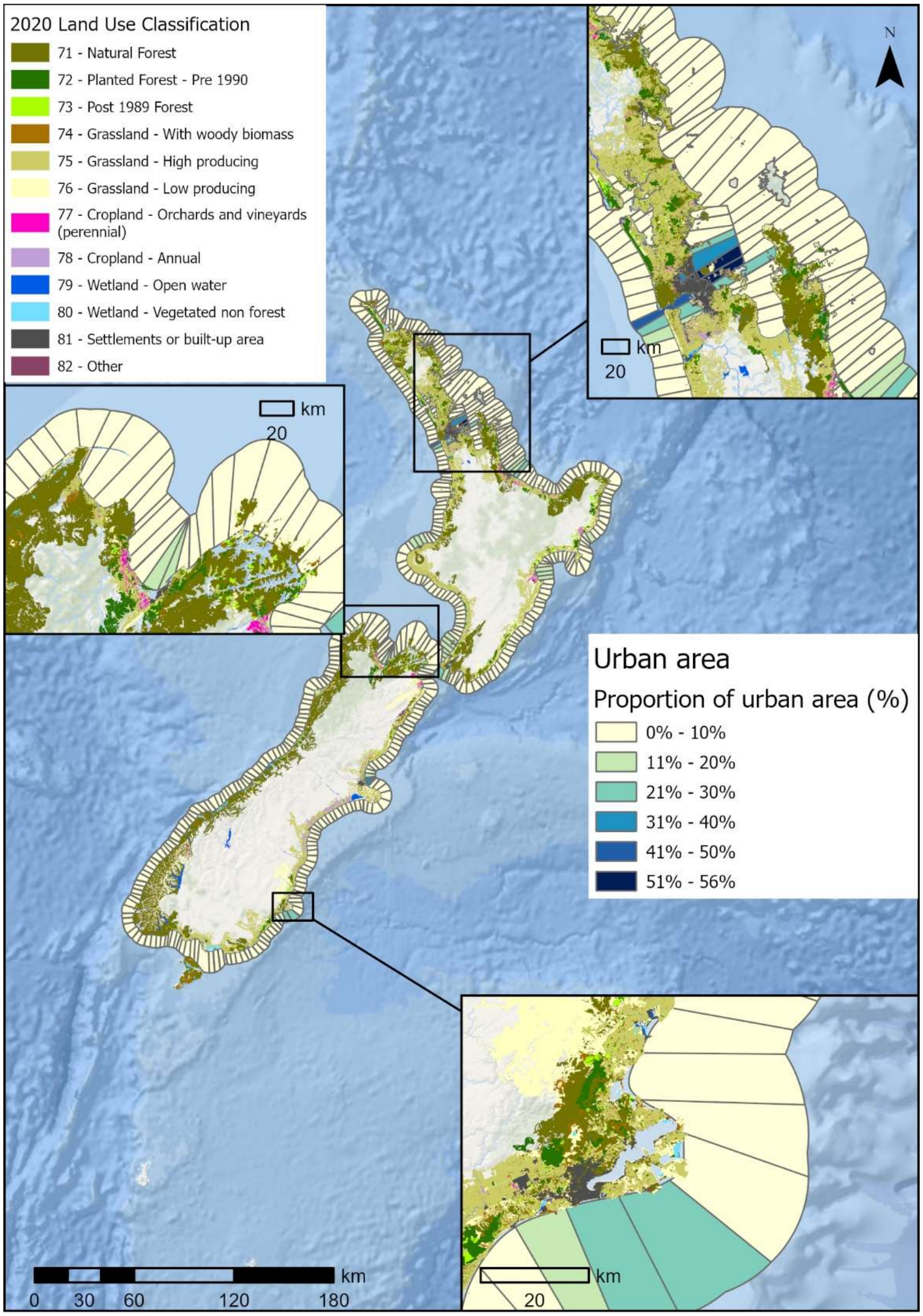

Figure 4-1: Proportion of urban area within catchments associated with 10 km coastal segments based on land-use. Land-use categories clipped to 30 km distance from the coastline. 10 km segments were extended to the territorial sea (12 nm) boundary, based on layer available acquired from the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana.

4.2 Sewage disposal

4.2.1 Description

As defined by DOC, this activity category includes the release of wastewater, which includes sewage, from sewage treatment facilities. This wastewater can be treated or untreated. It was noted by the project team that this category overlaps with Residential and Urban wastewater, which also includes outfalls.

4.2.2 State of knowledge

Spatial layers representing sewage disposal pipelines were not found, and potential data layers and proxies for sewage disposal are human population size and the proportion of urban areas. Wastewater network information is typically held by regional authorities, for example, Waikato District Council summarises its wastewater and sewage system as consisting of nine wastewater treatment plants, 78 wastewater pump stations, 292 km of reticulated wastewater pipelines, and 13,623 domestic and industrial property connections (https://www.waikatodistrict.govt.nz/services-facilities/water/wastewater/our-network). Sewage discharges to the coastal environment are typical known and can be individually mapped, for example the treated wastewater from the Whāingaroa / Raglan Wastewater Treatment Plan which is discharged daily on outgoing tide at a discharge point near the mouth of the harbour. The LINZ Submarine pipeline layer also indicates whether pipes are for 'sewage' in some cases, however this dataset is not as comprehensive as the drain centrelines layer.

4.2.3 Next steps

This dataset was not compiled for this project, as sspecific discharges from wastewater or sewage were not available at a national scale, would vary regionally, and would require significant effort to compile (as already noted in section 4.1.3 above). Proxies such as urban land-use and population size are likely to be highly correlated with this activity. Regional authorities could explore how sewage spills are typically recorded to inform appropriate spatial and temporal scale for populating this activity layer, and determine the appropriateness of proxy layers for this activity.

4.3 Industrial and agricultural liquid discharges

4.3.1 Description

As defined by DOC, this activity category includes the release of liquid waste products from industrial and agricultural activities into the marine environment. Discharges can contain chemical contaminants, organic matter and thermal pollution. These discharges can have significant environmental impacts if not properly managed.

4.3.2 State of knowledge

Discharges of contaminants require regional resource consents which are managed by regional authorities. While regional authorities maintain records, there is no national map of consents, nor how often discharges occur for a consent.

4.3.3 Next steps

This dataset was not compiled for this project, as it would require significant effort to compile at a national scale and would likely require geo-rectifying individual resource consent records, and confirming whether the consents were actively used.

Regional authorities could explore which consented activities are likely to have significant stressor impacts, and use this information to categorise and prioritise compilation of consents into a national layer of industrial and agricultural liquid discharges to enable quantification of these stressors.

4.4 Waste disposal - munitions (chemical and conventional)

4.4.1 Description

As defined by DOC, this activity category includes sites where military ordnance has been discarded. These sites can pose environmental and safety risks due to the potential for chemical leaching and unexploded ordnance. Significant quantities of munitions were disposed of in the ocean around New Zealand after World War II, with continued disposal of obsolete or surplus munitions in subsequent years. Known sites include the Hauraki Gulf and Wellington Harbour.

4.4.2 State of knowledge

One point location was available as a military zone within the LINZ dataset of Military practice area points, corresponding to an area in the eastern Hauraki Gulf. However, this area was noted as not containing military ordinance during the Hauraki Gulf marine spatial planning process (Bennion et al. 2023). Within its notice to mariners (https://www.linz.govt.nz/sites/default/files/doc/hydro_202425-almanac_ANTM-5_pdf.pdf), LINZ indicates locations of Firing Practice, Exercise and Submarine Safe Bottoming Areas. Locations were georeferenced based on WGS84 coordinates as provided in the LINZ almanac (Figure 4-2).

EPA provides spatial data on EPA NZ Authorised Dumping Zones through ArcGIS Online. These datasets relate to areas outlined in the EEZ and Continental Shelf Act and some specific disposal areas part of Marine Dumping Consents (Figure 4-2), though spatial layers are indicative only and do not provide information on extent of material or type of marine discharged, or where within the zone it was deposited.

4.4.3 Next steps

This dataset was determined to be a comprehensive indication of potential areas of ammunition disposal, however prior exploration of the Hauraki Gulf area as part of the FNZ Trawl Corridor practice indicated that the military did not consider this area to be an area of discarded military ordnance; it is also possible that this information is confidential to the military. It is unlikely that additional information will be available on the type or extent of munitions dumping, or when and if these dumping sites have been actively used. While EPA does hold data about the specifics of material dumped and discharged in the EEZ with EPA Authorised Dumping Zones, this information is recorded as part of our compliance monitoring function and is not in the public dataset. Its acquisition to inform stressor footprints could be explored further.

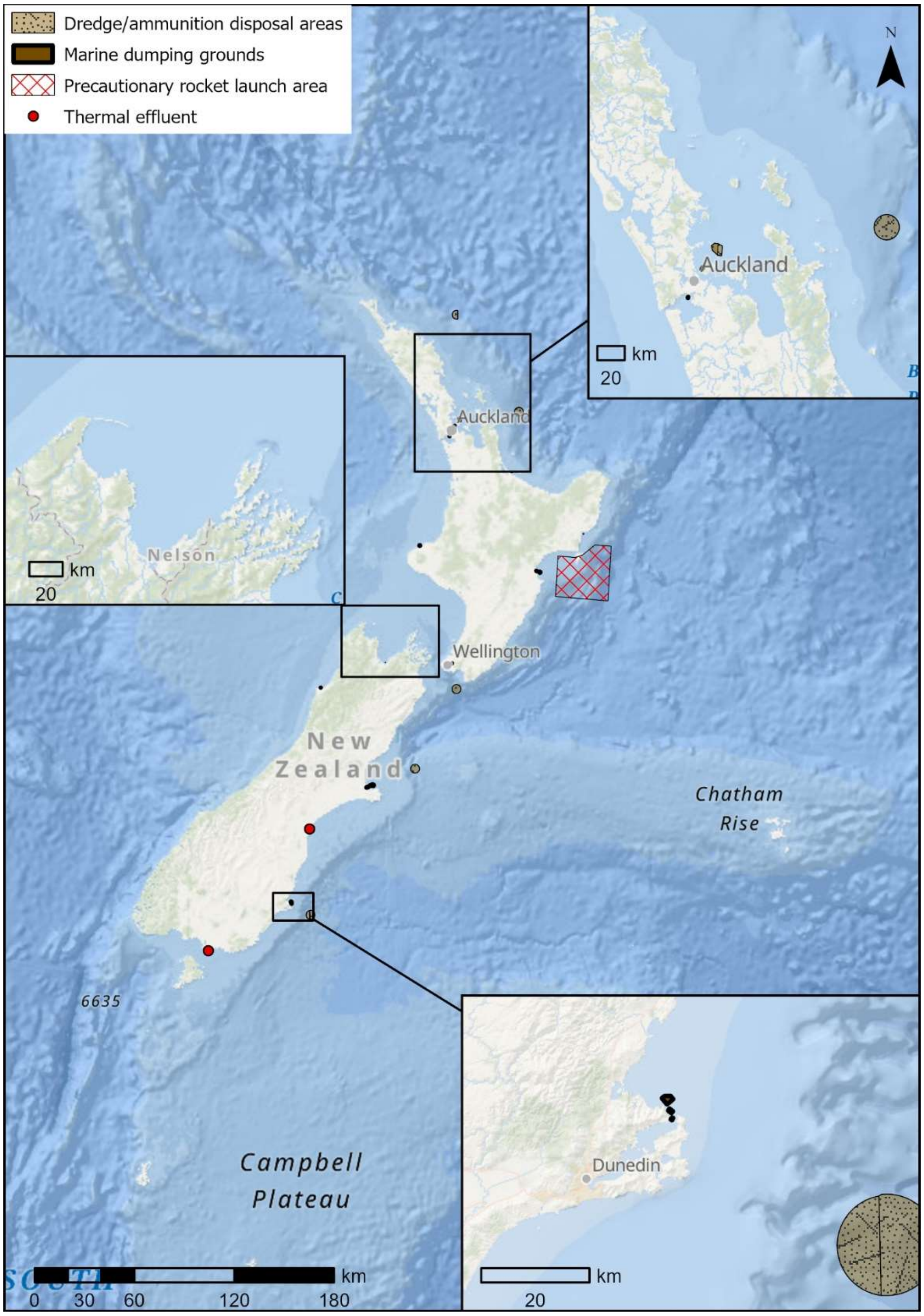

Figure 4-2: Waste management activities, including dredge and ammunition disposal areas, marine dumping grounds, precautionary rocket launch sites and locations of known thermal effluent.

4.5 Dredge and spoil disposal

4.5.1 Description

As defined by DOC, this activity category includes the disposal of dredged materials originating from the bottom of water bodies, like rivers, lakes and harbours.

4.5.2 State of knowledge

Most dredge disposal areas are linked to dredging of navigation channels such as those for Waitemata or Otago Harbours. Consents include permitted locations for dredge disposal, however, dates and amounts of disposal (i.e., the stressor footprint) were not able to be quantified (Figure 4-2). Offshore dumping is managed by the EPA with respect to their role within the EEZ and Continental Shelf Act, and geospatial layers are available on their website to indicate authorised dumping zones and disposal areas for marine dumping consents.

4.5.3 Next steps

This dataset was determined to be incomplete in terms of locations of disposal, as many major shipping ports did not have associated dredge disposal zones identified. The amount of dredge disposal and exact location of disposal was unlikely to be recorded at sufficient resolution to estimate the size of the stressor footprint. It was also expected that only small portions of permitted dredge disposal areas were likely to be impacted, and that dredge disposal occurred irregularly. Improving representation of the stressor footprint required quantification of dates of dredge disposal and amounts of disposal. Regional councils indicated that the dates of disposal could be identified based on timing of consent monitoring required following dredge disposal events. Further information on this activity could be compiled through extracting individual consent documents and following up with port authorities to determine time, location and extent of dredge disposal events. However, disposal zones for all major shipping ports should be able to be obtained reasonably easily.

4.6 Thermal effluent discharges

4.6.1 Description

As defined by DOC, this activity category includes the discharge of heated water or steam into the environment, typically into rivers, lakes, or oceans, after being used in the cooling processes, for example in thermal power stations and geothermal power plants.

4.6.2 State of knowledge

Thermal effluent discharges were identified based on expert input at the Inter-Agency Working Group Workshop, and point locations were generated to indicate the location of such sites (Figure 4-2). No information was available without interrogating resource consents to assess the amount of discharge of heated water, or the resulting change in temperature following water discharge.

4.6.3 Next steps

This dataset was determined to be difficult to update, though regional authorities could be contacted to provide any relevant consents with respect to thermal discharge.

4.7 Rocket abandonment

4.7.1 Description

As defined by DOC, this activity refers to the practice of disposing of rocket stages and other space debris in the ocean after they have been used. This is often done to minimise the risk of debris causing damage on land.

4.7.2 State of knowledge

The main rocket launch site in New Zealand (Mahia Peninsula) has a large zone that is noted as a precautionary area with respect to rocket launches (Figure 4-2). The total number and dates of rocket launches could be identified through communication with industry. Rocket Lab launches, particularly if unsuccessful, are typically reported by the media. Unsuccessful missions typically splash down in the ocean off the Mahia Peninsula and are retrieved by the company's recovery team. It is expected that the rocket launch area is more relevant as a safety zone during launches; no rocket abandonment has yet occurred in this zone.

4.7.3 Next steps

The rocket launch precautionary area was unlikely to correlate with abandoned rocket material. This area could be updated if future rocket launches are unsuccessful and rocket stages are not retrieved at the surface. We note that the Rocket Launch Areas (Mahia Peninsula) (Figure 4-3) is displayed differently by Rocket Lab (https://www.rocketlabusa.com/missions/launch-safety) compared to the shape file provided by LINZ, and the correct layer should be identified.

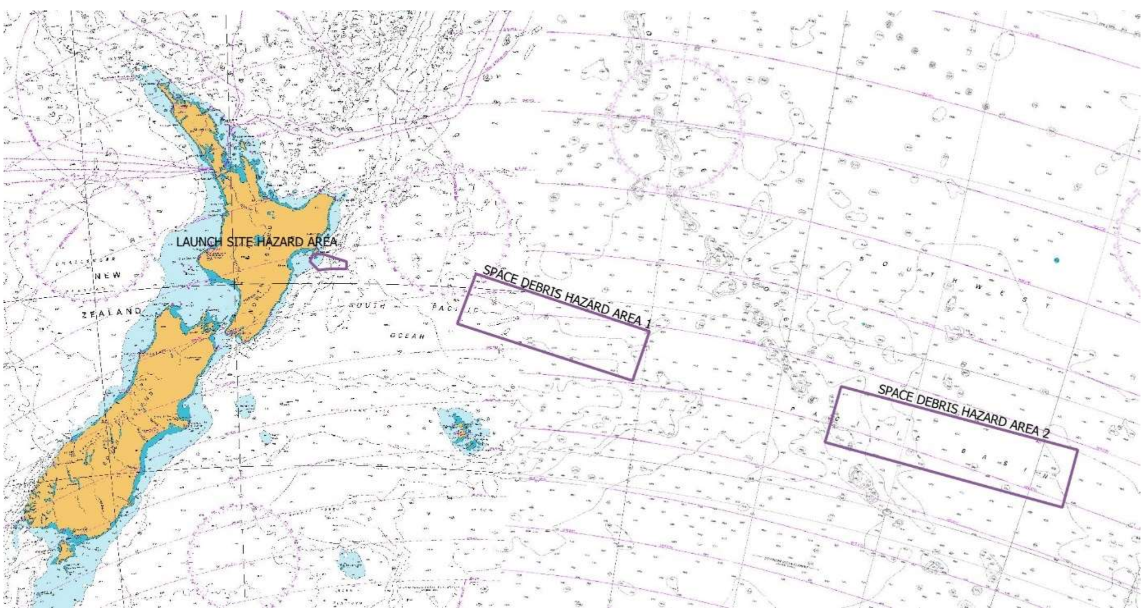

Figure 4-3: Rocket launch hazard areas as provided by Rocket Lab. Source: Rocket Lab.

4.8 Litter – coastal landfill sites and coastal non-point source litter

4.8.1 Description

This activity is not specifically listed within the waste management activities as defined by DOC, but here we describe datasets of landfill sites near the coast that could result in significant impacts with breaching of landfills during large storm events (e.g., as occurred in the West Coast Region of the South Island in 2019). General litter is indicated as a 'pressure' although it is difficult to locate the source of non-point source litter found on beaches and on the seafloor.

4.8.2 State of knowledge

Point locations representing landfill sites were available from LINZ (https://data.linz.govt.nz/layer/50294-nz-landfill-polygons-topo-150k/) and clipped to include landfills within 10 km of the coastline.

Marine debris has been the subject of scientific research in recent decades. Regional community clean up groups often record how much litter was collected by weight and volume, which could be used to indicate site-specific rates of rubbish accumulation. One study quantified marine debris at 41 beaches in the North and South Islands both by counts and by weight, with majority of items being classified as plastic, and classified as arriving via ocean-based (as opposed to land-based) sources (van Gool et al. 2021). Other community efforts include Litter Intelligence https://litterintelligence.org/) which is a long-term programme that collects litter data, and is led by New Zealand charity Sustainable Coastlines, working in collaboration with MfE, DOC and StatsNZ. Their website includes information on date of survey and weight of litter collected, noting that activities are located in major cities.

Litter has also been quantified on the seafloor based on data collated from 169,000 seafloor observations NIWA's Deep Towed Imaging System (DTIS) research trawl database, and identified using UNEP categories for litter (Behrens et al. 2021). Most observations of litter were off Northland and East Cape, and few observations of litter were on the Chatham Rise, though sampling effort was extensive in the Chatham Rise. Observations included 77% rope, 7% bottles, 5% plastic sheets, 4% fishing related, and 7% attributed to other categories (Behrens et al. 2021). The analysis did not include a systematic sampling design, however general patterns did indicate that plastic litter was more abundant near the coast, and that litter density decreased rapidly with distance from the coast (Behrens et al. 2021). Thirty-five percent of all fishing related litter and approximately 50% of all bottles and drink cans were found within 25 km of the coast. The analysis also noted other potential sources of litter data including camera surveys in Marlborough, NIWA scampi surveys, trawl surveys, plastic recordings from plankton recorders, river and streams, seabird gut contents, and sediment cores. Litter data from the fishery trawl database was also compiled, reflecting litter captured in fishing gear as reported by fisheries observers.

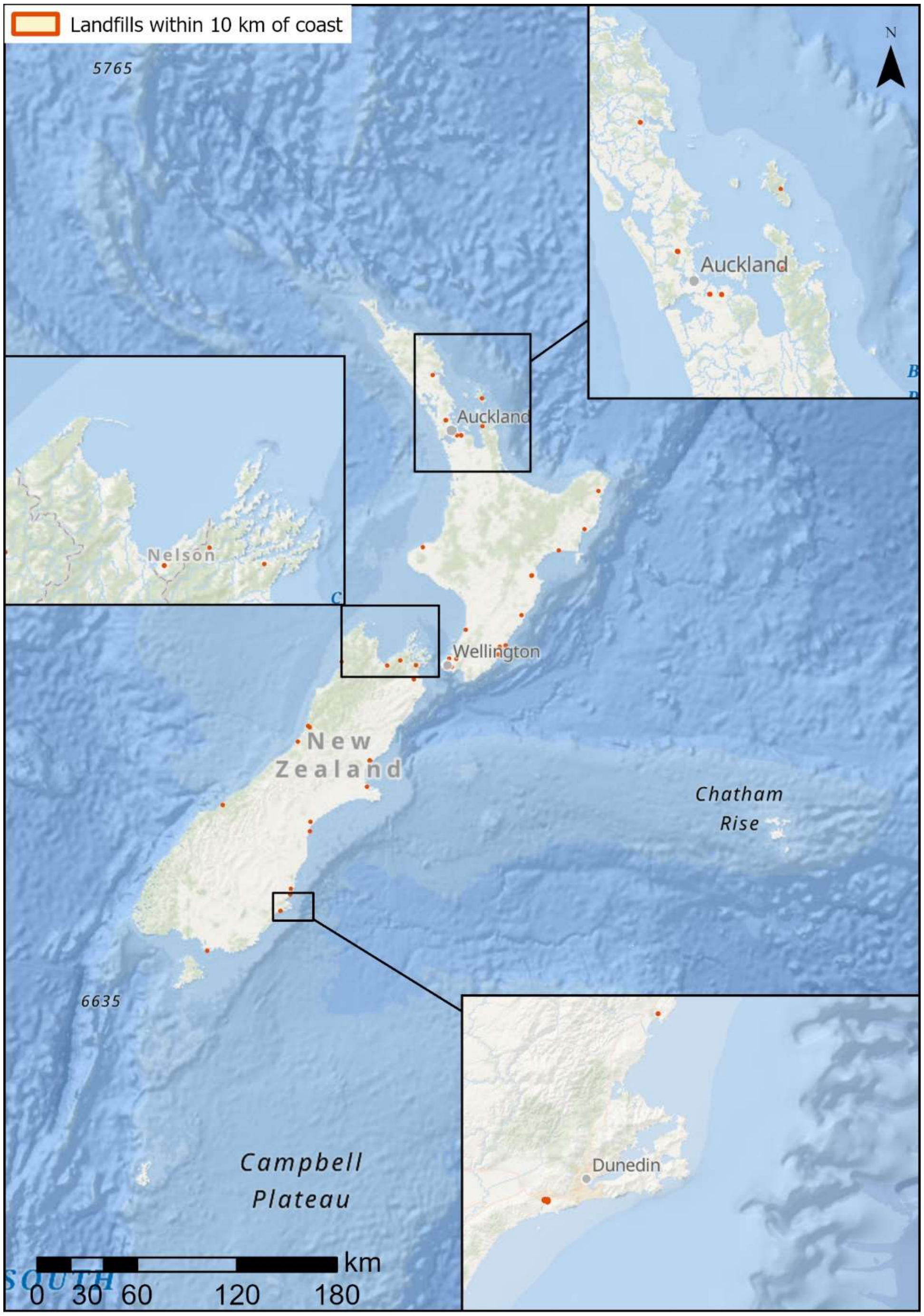

Figure 4-4: Landfills within 10 km of the New Zealand coast.

4.8.3 Next steps

Litter was correlated with proximity to the coast, such that human population density or urban land-use could be used as a proxy for litter sources. Minimal information is currently available to quantify the extent of litter or its impacts on marine ecosystems. Community groups could be interrogated to quantify beach clean up extent, and litter surveys (van Gool et al. 2021) could be repeated and expanded to provide comprehensive spatial coverage of litter.

5 Extraction of living resources

Twelve types of activities were categorised as activities reflecting extraction of living resources: 1) Fishing – bottom trawling; 2) Fishing – dredging; 3) Fishing – midwater trawling; 4) Fishing – traps (potting/creeling); 5) Fishing – spear fishing; 6) Fishing – set netting; 7) Fishing – lines; 8) Fishing - seines (encircling), excluding beach seining; 9) Fishing – beach seine; 10) Fishing - diving and snorkelling; 11) Harvesting – seaweed and other sea-based food (e.g., pāua, kina, kuku/kutai/kukutai (mussels), pūpū (cat's eye), etc.); and 12) Extraction of genetic resources e.g., bioprospecting and maerl (blue technology).

Fisheries activities were deemed to be out of scope for this project and updated layers were processed elsewhere in aligned contracts from Fisheries New Zealand to assess impacts of fishing on marine biodiversity, habitats and ecosystems. Evidence for links between waste management activities and pressures on the marine environment have not yet been compiled within the aligned DOC project (linking activities to pressures) as it was not among the initial subset of prioritised activities (Douglas and Lundquist 2025). Effects of fishing on marine species, habitats and ecosystems have been reviewed extensively elsewhere (Sciberras et al. 2018, Thrush and Dayton 2002).

For completeness, we present a brief summary of readily available data on the various categories of fishing (Section 5.1). We then, we provide a description and summarise the state of knowledge and next steps for the two additional activities in this category (Harvesting – seaweed and other sea-based food (e.g., paua, kina, mussels, pūpū etc.) and Extraction of genetic resources (e.g., bioprospecting and maerl (blue technology) in Sections 5.2 and 5.3, respectively (Table 5-1).

Table 5-1: Descriptions of layers compiled for the category Extraction of living resources.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Fishing – all methods					Out of scope	FNZ	
Harvesting – seaweed and other sea-based food (e.g., paua, kina, mussels, pūpū etc.)	Non-fish harvest layers	ongoing	< 1 km	n/a	No	FNZ	Emerging industry, customary
Extraction of genetic resources e.g. bioprospecting & maerl (blue technology)	Biopropecting and maerl industries	emerging	unknown	n/a	No	EPA	Emerging industry

5.1 Fishing – various methods

Data layers representing the bottom trawl footprint, commercial fishing (combined and individual methods), and recreational fishing were compiled as part of the Key Ecological Areas data compilation (Stephenson et al. 2018). Data on the bottom trawl footprint (swept area, tows per km) is available from Fisheries New Zealand and is regularly updated (MacGibbon & Mules 2023, MacGibbon et al. 2024). These data layers include information from both inshore and offshore fisheries, and can be further interrogated to provide information by year or by target fish stock. Heat maps and spatial estimates of commercial fishing (all trawl, line and potting methods; dredging effort) are available from the Fisheries New Zealand tool 'CatchMapper' (Osborne 2018). CatchMapper includes all commercially fished species and all fishing methods, although the spatial data reported for each fishing method varies and thus the ability to map effort footprints varies. Since the advent of electronic reporting and geospatial position reporting during the 2019/20 fishing year, fishing is mostly reported at an event level and location data is provided at a higher resolution often at frequent intervals during a fishing event. The mapping of effort for most fishing methods is more accurate for fishing years since 2019/20. Spatial data on recreational fishing is limited, with heat maps available based on a limited number of spatial and temporal surveys (Osborne 2018). Recreational catch surveys are the National Panel Surveys which are complemented by aerial surveys and boat ramp monitoring and interviews (Heinemann & Gray 2024, Maggs et al. 2024).

The fishing footprint is an estimate of how much seabed area has been contacted by bottom fishing gear, but it does not provide a measure of the impact of fishing on seabed communities. A recent FNZ project has used the trawl footprint information, in addition to other sources of information on impacts of contact by trawl gear on seabed fauna, to quantify the potential impacts to seabed communities and habitats (Rowden et al. 2024).

5.2 Harvesting – seaweed and other sea-based food (e.g., pāua, kina, mussels, pūpū etc.)

5.2.1 Description

As defined by DOC, this activity category includes the collection of marine organisms by hand, excluding diving and snorkelling, without the use of nets, traps, lines or other fishing gear. This technique is often used for collecting shellfish, seaweed, and other easily accessible marine resources.

5.2.2 State of knowledge

Attached bladder kelp *Macrocystis pyrifera* is part of New Zealand's quota management system, with two reporting areas (South-East (coast) and South-East (Chatham Rise)). Current landings are reported as attached kelp only, whereas prior to 2010, reported landings also included free-floating and beach-cast kelp. FNZ does not have quantitative estimates of either recreational or customary harvest of kelp, and the May 2024 Fisheries Assessment Plenary assumes both are negligible, and that commercial harvest is also low. Information in fisheries documents is provided as tonnage per management area, with no spatially-explicit information on catch location.

Beach cast harvesting (of *Ulva* spp.) from strandines (Fisheries New Zealand 2023a) was discussed in Section 3.5. Seaweed farming is an emerging industry in New Zealand, with most industry developments occurring in land-based facilities (e.g., for *Asparagopsis* spp.).

Customary harvest of shellfish is common, but poorly quantified. Daily catch limits apply, but over-exploitation is noted for many species at local scales where high recreational effort occurs (e.g., green-lipped mussels, pāua, cockles, pipi, etc.). Customary and recreational harvest components in commercial fisheries are typically provided as estimates but are not recorded in catch records.

5.2.3 Next steps

This dataset was determined to be incomplete, with limited information available on locations of seaweed harvest, or of amounts or weights of recreational and customary catch of seaweed and invertebrates. Culture-based seaweed aquaculture is an emerging industry in New Zealand (Fisheries New Zealand 2023a), and future expansion and potential impacts could be monitored. FNZ permits for harvesting of beach cast seaweed could be interrogated to assess timing and extent of harvest.

5.3 Extraction of genetic resources (e.g., bioprospecting and maerl (blue technology)

5.3.1 Description

As defined by DOC, this activity category includes bioprospecting which involves collecting natural materials and developing new products from useful organic compounds found in biological resources. It also considers the vessels, machinery, vehicles, and materials needed for these activities. Maerl extraction is common in Europe, but is not an existing marine industry in New Zealand.

5.3.2 State of knowledge

New Zealand's large EEZ offers opportunities for bioprospecting and discovery, however it was difficult to find comprehensive information on either locations for bioprospecting or collections targeted at live biological resources. We found a global database containing records of patents for new marine genetic resources from the deep-sea which including some records from the high seas outside New Zealand's EEZ, however we did not find spatial layers that included information inside New Zealand's EEZ (Zhivkoplias et al. 2024). We did not find information to clarify whether prospecting locations were public or private information.

5.3.3 Next steps

This dataset was determined to be incomplete, with this activity indicated as an emerging technology for which there is unlikely to be a current stressor footprint.

6 Production of living resources

Six types of activities were categorised as representing the production of living resources: 1) Aquaculture - finfish; 2) Aquaculture - shellfish; 3) Aquaculture – macroalgae; 4) Ocean fertilization; and 5) Translocations and transplanting. Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for each activity category. To minimise replication of content, we discuss the three aquaculture datasets together (Table 6-1).

Evidence for links between activities representing the production of living resources and pressures on the marine environment were compiled within the aligned DOC project that populated the matrix of activities and pressures that reviewed supporting evidence (Douglas and Lundquist 2025). Finfish, shellfish and macroalgal aquaculture had evidence linking them with similar pressures (refer to individual pressure definitions and supporting references in Douglas and Lundquist (2025). These pressures included: hydrological pressures (change to water flow, oxygen and pH; pollution and other chemical pressures such as contaminants, synthetic compounds, de-oxygenation of seafloor sediments, nutrient and organic enrichment); physical pressures (change in seafloor type, physical habitat structure, disturbance of surface and sub-surface sediments, suspended solids and siltation); biological pressures (introductions or spread of non-indigenous species and pathogens); and other pressures (changes to light regimes, increasing noise and potential for collisions with aquaculture structures and lines) (Douglas and Lundquist 2025).

Table 6-1: Descriptions of layers compiled for the category Production of living resources.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Aquaculture - fin-fish	Marine farms - finfish	ongoing	<1 km	Polygon	Yes	FNZ	Convert to active use
Aquaculture - shellfish	Marine farms (mussels, oysters)	ongoing	<1 km	Polygon	Yes	FNZ	Convert to active use
Aquaculture - fin-fish and Shellfish	Marine farm applications	ongoing	<1 km	Polygon	Yes	FNZ	Regular update
Aquaculture - fin-fish and Shellfish	Aquaculture Settlement Areas	ongoing	<1 km	Polygon	Yes	FNZ	Regular update
Aquaculture – macro-algae	Aquaculture – macro-algae	emerging	>100 km	n/a	No	FNZ	Emerging industry
Ocean fertilization	Ocean fertilization	emerging	<1 km	n/a	n/a	n/a	Emerging industry
Translocations and transplanting	Aquaculture spat collection	emerging	10-100 km	Point	Incomplete	FNZ	Convert to extent
	Active restoration sites	emerging	<1 km	Point	Incomplete	Regional authorities	Convert to extent

6.1 Aquaculture - finfish, shellfish and macroalgae

6.1.1 Description

As defined by DOC, the finfish aquaculture activity considers finfish grown in cages/nets suspended from surface structures or lines. The shellfish aquaculture activity considers shellfish (mussels, oysters) grown on racks or trestles in the intertidal or grown on ropes/nets suspended from surface structures or lines. The macroalgae aquaculture activity considers seaweed grown on ropes/nets suspended from surface structures or lines. Structures used in all three aquaculture/marine farming types may be anchored to the seabed. Aquaculture activities also include the vessels, machinery, vehicles, and materials needed for these activities. FNZ notes that in New Zealand, finfish are suspended from surface structure and not from lines, and tha tin New Zealand, all types of aquaculture are anchored to the seabed.

6.1.2 State of knowledge

The Sustainable Seas SPEXCET project extracted data representing marine farms from various sources, as compiled by MPI and last updated by SPEXCET in February 2022. These spatial layers were available on the Te Ukaipo o Hinemoana website, and include marine farms recorded by MPI as approved and active with permit issued (Figure 6-1). The marine farm dataset also includes marine farm applications and aquaculture settlement areas created under the Māori Commercial Aquaculture Claims Settlement Act. Regional council websites were suggested by experts as a preferred source for detailed information about specific farms, and the SPEXCET layer was validated against regional council layers prior to being published on the Te Ukaipo o Hinemoana website. The SPEXCET dataset includes the type of structure, the species group (finfish, shellfish, and seaweed farms, or combinations of these groups), the area it covers (ha), date permits were granted, and permit expiry date. We found only finfish and shellfish farms within the database. Data available from regional councils varied from high resolution aerial photography to simpler formats such as coordinates supplied by permit holder or digitised council records. Due to varying methods of data collection and recording by different councils, available data to describe aquaculture consent areas differed in temporal and spatial resolution between councils.

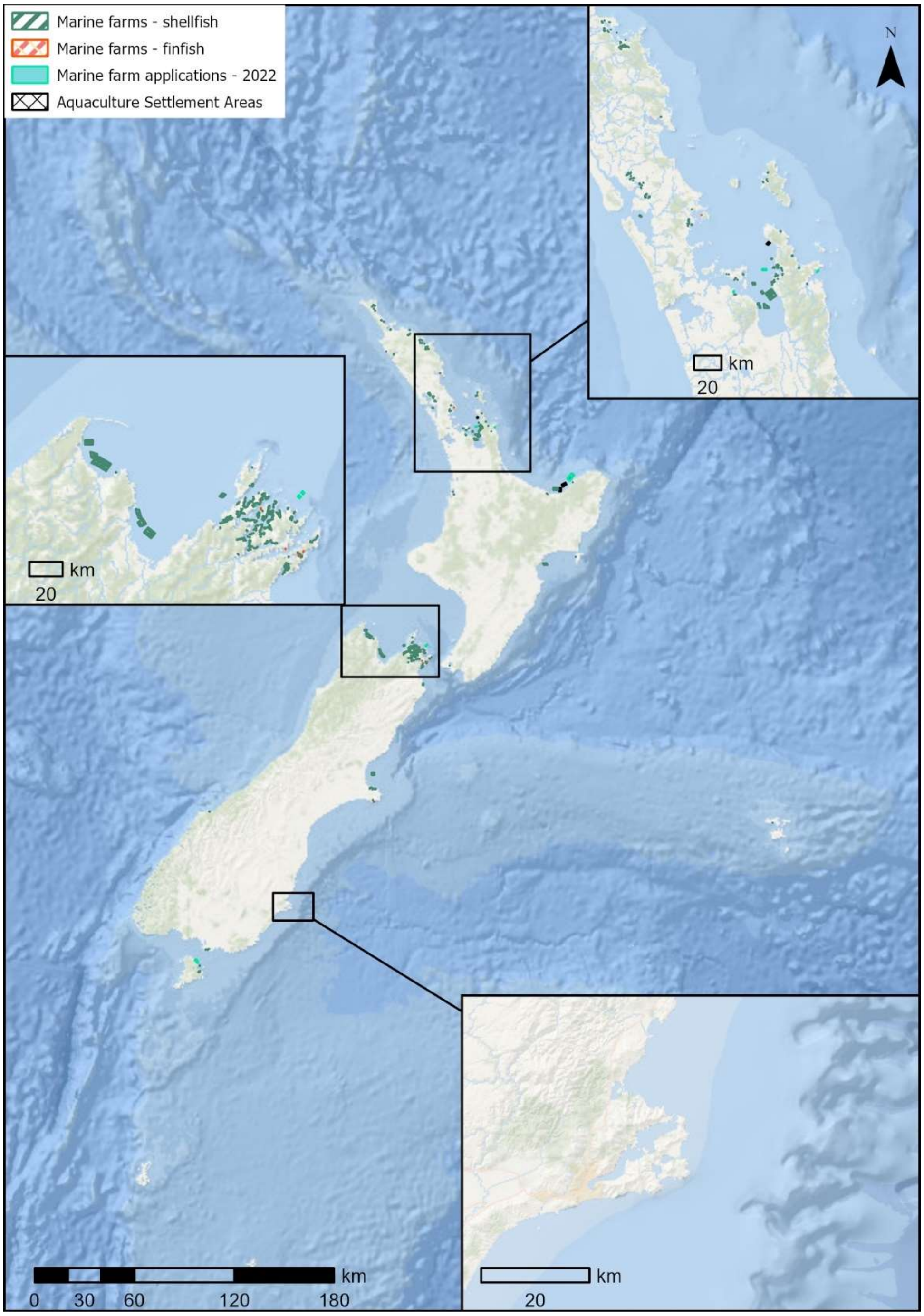

Figure 6-1: Locations of Marine farms for finfish culture and lined culture (mussels, oysters), Marine farm applications, and Aquaculture Settlement Areas. Based on layer available acquired from the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana.

6.1.3 Next steps

This dataset available on Te Ukaipo o Hinemoana was determined to be accurate at describing the locations of active permits, recognising that regular updates should occur through validation of the status of permits by MPI or on regional council websites. The layer displayed here was most recently updated in February 2022, and marine farm applications may have been granted or denied in subsequent years. As data includes the date of expiry of permits, this information could in future be used to guide rapid updating of the dataset to add new permits. Resource Management Act amendments in September 2024 extended the duration of all existing coastal permits for marine farms for 20 years.

The translation of the permit areas to a stressor footprint area was determined to be a slightly more complex process, as the existence of an active license does not always translate to active use of that license. Aquaculture consent areas may develop in stages as capital is acquired to increase the size of the farm, thus marine farms can include active licenses, applications, and aquaculture settlement areas. In some cases multiple areas in excess of the settlement obligation are set aside as ASAs to allow flexibility; if the space is optioned, it would be converted into a consented area, and thus ASAs do not reflect active stressors, rather they indicate future potential for aquaculture. Accordingly, the size of the stressor should be quantified based on the amount of each license area that is actively used. An example of ongoing development of an offshore mussel farm in the Bay of Plenty is given in Figure 6-2.

Figure 6-2: Example of associations between active permits, permit applications, and aquaculture settlement areas in some locations, with this example being of the Whakatohea mussel farm, Bay of Plenty. Red outlines indicate application, green outlines indicate licensed marine farm, and white outlines indicate aquaculture settlement areas.

We explored what would be required to quantify marine farm stressor footprints and validate the proportion of a consent area being actively used. One option is the use of aerial photography. In an example from Te Kouma Harbour, Coromandel Peninsula, suspended shellfish culture lines can be viewed within at least half of the licensed farm area, and other less obvious shaded areas may indicate the presence of shellfish racks (Figure 6-3). However, any subsurface suspended culture lines will not be as visible within an aerial photograph. In another example in Stewart Island, fishpens can be seen within some of the licensed areas. However, fishpens are moved regularly which is expected to influence the impact intensity relative to areas without farm rotation (Figure 6-3). Furthermore, just because a fishpen is visible, it is not necessarily stocked with fish.

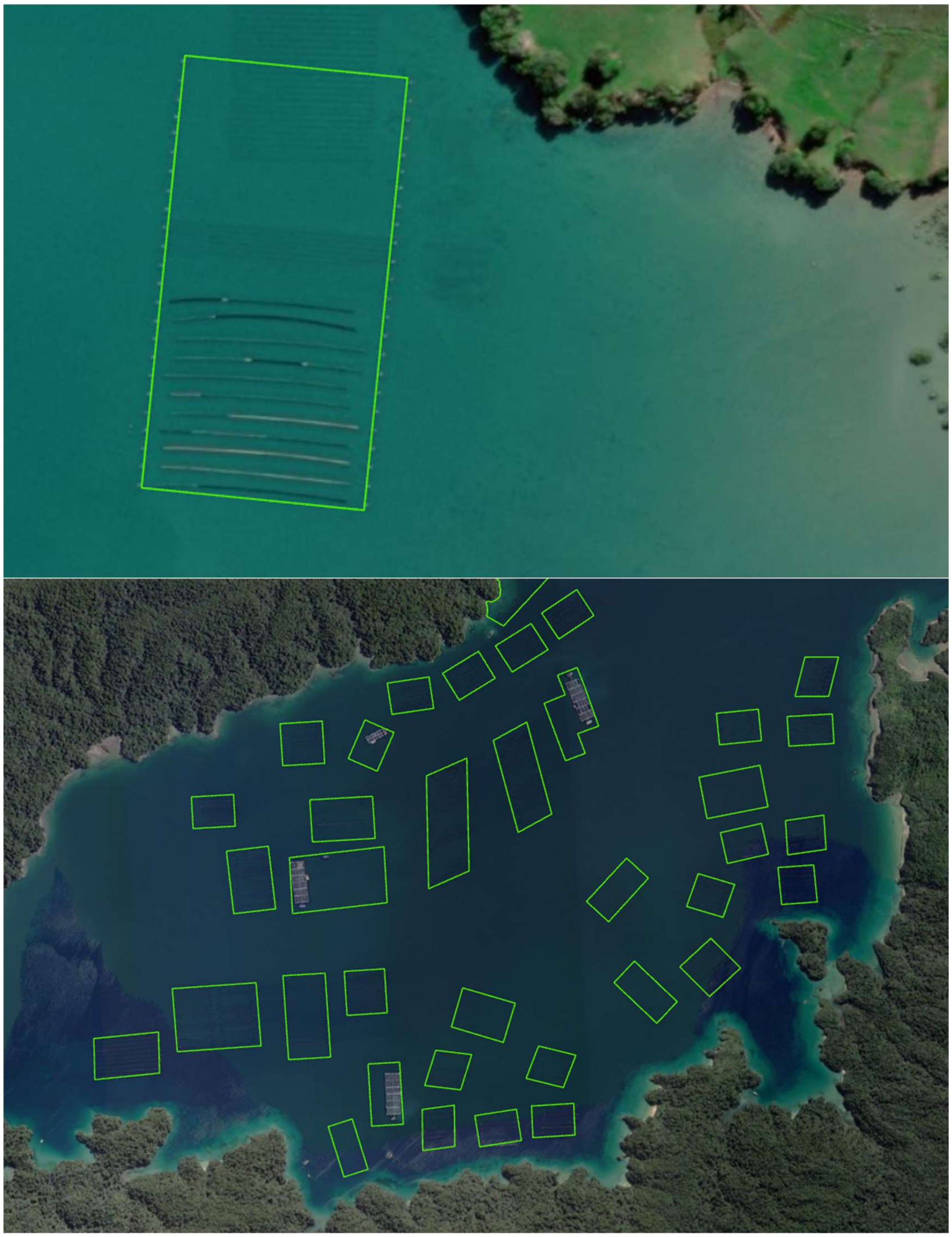

Figure 6-3: Example of validation of proportion of a marine farm being used to quantify the stressor footprint. Suspended shellfish culture lines, Te Kouma, Waikato (top); Salmon farms, Stewart Island (bottom). Green outlines indicate licensed marine farm areas.

Thus, while it seems feasible to use aerial photographs to convert marine farm polygons into stressor footprints based on active use of each polygon assessed, we found that this was not a simple exercise. Farms were not always visible on aerial photographs, different farm types or culture species were not easily discerned, farms may appear to be in use (e.g., presence of buoys on mussel farms) but may not be stocked, and farms could increase in size rapidly over the course of a few years, raising questions as to the required frequency of such evaluations. Furthermore, in some areas, fishpens are moved regularly which is expected to influence the impact intensity relative to areas without farm rotation.

Variability in these factors mean that use of aerial images may over- or under-estimate the marine farm stressor footprints. As the marine farm database includes >1000 marine farm polygons, it is feasible to perform this analysis. However, we suggest that an alternative and more cost-effective approach would be to assume a proportional use of farms based on their type and age since licensing. Regular updates of permits with MPI or regional council databases can confirm any newly granted permits, and expired permits.

The three types of marine farms are also associated with potentially different pressures on marine species, habitats and ecosystems, with finfish farms typically associated with larger pressures and longer lasting footprints following decommissioning of a farm. Additionally, open ocean or offshore aquaculture is emerging in New Zealand and there is currently little knowledge of the stressor impacts or footprint size in deeper coastal waters relative to existing nearshore aquaculture (Connor-McClean et al. 2020, Heasman et al. 2020, Mascorda Cabret al. 2021, Stenton-Dozey et al. 2021). Stressor footprints also likely differ between the two primary species of shellfish (oysters, green-lipped mussels), with oyster farms typically being nearshore and often intertidal, whereas mussel lines typically extend around seven metres deep therefore affecting a much larger portion of the water column with greater potential to have effects transferred outside the local footprint (Keeley et al. 2009 Keeley et al. 2009). Accumulation of shell material or sediment deposition to the seafloor may also vary based on depth and cultured species (Keeley et al. 2009).

6.2 Ocean fertilization

6.2.1 Description

As defined by DOC, this activity category includes adding nutrients (e.g., iron, nitrogen and/or phosphorous) to the ocean to stimulate the growth of phytoplankton and enhance marine productivity. It also considers the use of vessels to transport and disperse nutrients over targeted areas, and wave pumps and floating tubes that bring nutrient-rich deep water to the surface.

6.2.2 State of knowledge

This activity does not yet occur in New Zealand, though one of at least thirteen global scientific trials of ocean fertilization since 1990 occurred in the Southern Ocean (Boyd 2002, Wallace et al. 2010). Scientific studies to date have been short-term and of relatively small scale, and there is significant uncertainty as to how ocean fertilization might affect zooplankton, fish and seafloor biota, and the magnitude of carbon export to the deep ocean. Experiments have not been carried out at commercial scales.

6.2.3 Next steps

This dataset was determined to be complete, with no current stressor footprint, however, this layer should be updated if ocean fertilization activities commence at trial or commercial scales in New Zealand.

6.3 Translocations and transplanting

6.3.1 Description

As defined by DOC, this activity considers transplanting or translocating marine organisms to bolster local populations. Examples include replanting seagrass in areas where it has been lost or seeding shellfish beds to enhance and restore local populations. Artificial reefs are considered separately in Section 13.3.

6.3.2 State of knowledge

We consider this activity to include both restoration and rehabilitation activities, which can include translocations of live shell as well as repurposed dead shell, as well as translocations of mussel seed (juveniles) to support marine farms. The primary translocation activity in Aotearoa New Zealand is that of green-lipped mussel spat collection from Te Oneroa-a-Tōhe / Ninety Mile Beach, which has been the primary source of mussel spat since the 1970s. Tonnes of seaweed that contain spat are removed annually to support the commercial mussel industry. The Moana Endeavour project has performed models suggesting that the Ninety Mile Beach spat most likely are transported from mussel reefs off Ahipara, Tiriparepa / Scott Point and Hokianga. Mussel seed collection requires quota. Oyster spat historical came from Kaipara Harbour and was translocated to oyster farms in Mahurangi, Waitemata, and Coromandel Harbours, though hatchery production is now the primary source of oyster spat. Paua seed are spawned from wild-stock adults and can be released as juveniles to replenish the harvested stock.

The other main activity for which translocations and transplanting occurs is that of coastal restoration. FNZ has summarised and mapped point locations of key restoration initiatives for kelp and green-lipped mussels (Figure 6-4; Fisheries New Zealand (2023b)). Seagrass restoration has occurred in intertidal areas in Whangarei Harbour (e.g., Matheson et al. (2017) and around Nelson by the Restore the Meadows project (https://www.cawthron.org.nz/research/our-projects/seagrass-restoration/).

6.3.3 Next steps

This dataset was determined to be complete with respect to location of green-lipped mussel and kelp restoration activities. Mussel restoration has involved both translocations of live mussels and of empty, previously harvested mussel shells from vessels, resulting in small plots with added live or dead shell material typically less than 5 m x 5 m (Alder et al. 2021, 2022a,b, Benjamin et al. 2023). While initial impacts may include small scale smothering of sediment and anoxia, positive benefits include creation of habitat structure (Wilcox et al. 2017, 2018). The efforts have to date not resulted in large scale restoration of self-sustaining mussel reefs, but research is continuing to explore potential approaches to improve success rates (Fisheries New Zealand 2023a,b, Cummings et al. 2024). Restoration activities for seagrass have to date been small in scale, with minimal disturbance to sandflats and mudflats by community groups for seagrass efforts.

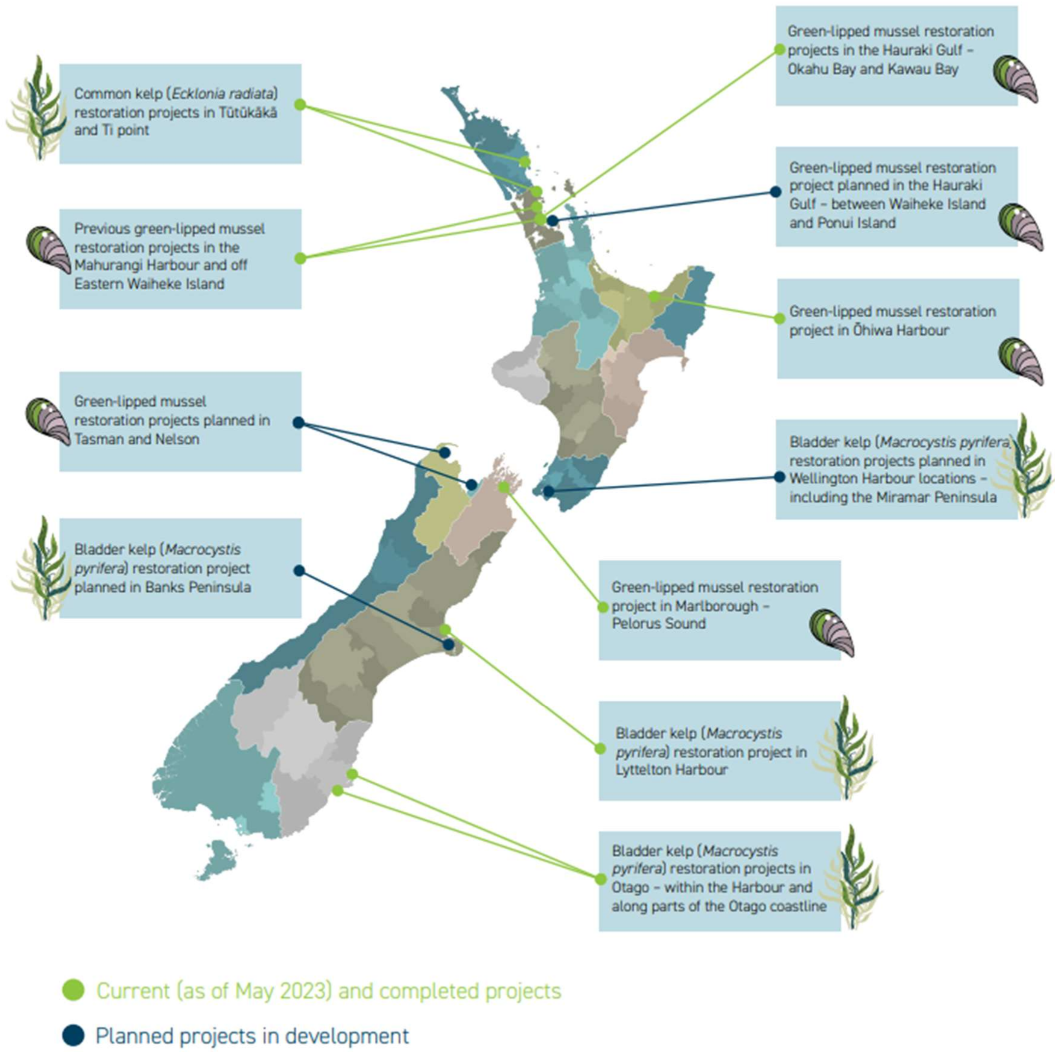

Figure 6-4: Map of kelp and green-lipped mussel restoration projects in New Zealand. Source: Fisheries New Zealand (Fisheries New Zealand 2023b).

7 Extraction (and disposal) of non-living resources

Five types of activities were categorised as activities representing the extraction (and disposal) of non-living resources: 1) Extraction – sand and gravel (aggregates); 2) Extraction – minerals; 3) Extraction – maintenance dredging; 4) Salvage operations; and 5) Extraction – water (abstraction). Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for each activity category (Table 7-1).

Evidence for links between the extraction (and disposal) of non-living resources and pressures on the marine environment were compiled within the aligned DOC project (linking activities to pressures, Douglas and Lundquist 2025). Primary pressures associated with extractive activities are physical damage, seabed disturbance, loss of habitat structure and changes in suspended sediment concentrations/levels. Evidence also suggests extractive activities are associated with chemical contamination, de-oxygenation, and nutrient and organic enrichment. Activities involving water extraction and disposal are associated with hydrological pressures such as changes to temperature, salinity and water flow (Douglas and Lundquist 2025).

Table 7-1: Descriptions of layers compiled for the category Extraction (and disposal) of non-living resources.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Extraction – sand and gravel	Sand extraction areas	ongoing	10-100 km	Polygon	Yes	EPA; Regional authorities	Rapid change occurring
Extraction – minerals	Active mineral permits	ongoing	10-100 km	Polygon	Yes	NZPAM	Agree buffer, extent used
Extraction – minerals	Mineral permit applications	ongoing	10-100 km	Polygon	Yes	NZPAM	Rapid change occurring
Extraction – maintenance dredging	Dredging areas	ongoing	10-100 km	Polygon	Incomplete	Regional authorities	Missing data; Extent and timing
Salvage operations	Salvage operations	ongoing	<1 km	Point	No	Regional authorities	Data extraction
Extraction – water (abstraction)		ongoing	1-10 km	Point	Incomplete	Regional authorities	Extent and timing
Translocations and transplanting	Aquaculture spat collection	ongoing	10-100 km	Point	Incomplete	FNZ	Convert to extent
	Active restoration sites	ongoing	<1 km	Point	Incomplete	Regional authorities	Convert to extent

7.1 Extraction – sand and gravel (aggregates)

7.1.1 Description

As defined by DOC, this activity category includes removing sand and gravel from the seabed for construction and beach replenishment, using suction dredges or grab samplers. This activity is associated with numerous vessel movements, sediment alteration and resuspension. This activity is associated with the dredge spoil disposal activity in Section 4.5, though here it refers to the extraction of dredge material, whereas previously it was referring to the disposal of material in a different area.

7.1.2 State of knowledge

Sand mining and extraction has been occurring along New Zealand's coastlines for over 100 years, but demand for sand has rapidly increased since 2000 due to its use in concrete production, glass and other construction materials (which are in high demand for urban development) and beach replenishment. Sand is now the most consumed resource in the world after water. Seafloor sand extraction is done in shallow depths (up to 25 m) via suction dredging and pumping sand onto barges, which causes damage to seafloor ecosystems and suspension of sediments. There are concerns over the ability of natural processes to replace much of what is removed. Mining of sand dunes can remove important coastal habitats, and sand removal both on land and at the seafloor raise growing concerns for weakening the resiliency of coastlines in the face of climate change and sea level rise.

Sand mining operations take place north of Auckland in the Kaipara Harbour, at Pākiri Beach since the 1940s, and from Kawhia Harbour (Taharoa Iron Sands). Over 380,000 cubic metres of sand per year was extracted from Kaipara and Pākiri combined, although the permit to extract up to 76,000 cubic metres annually from Pākiri expired in 2020. Offshore in the South Taranaki Bight, Trans Tasman Resources Limited (TTRL) made two unsuccessful applications in 2013 and 2015 (initially successful, then appealed) to the Environment Protection Authority (EPA) for marine consents to mine iron ore. A new consent under the Fast-Track Act is in process in Taranaki, which would allow extraction of up to 50 million tonnes of seabed material per year, over 20 years for the purpose of recovering up to approximately 5 million tonnes of vanadium-rich titanomagnetite concentrate. The consent also includes the return the de-ored material to the seabed, and monitoring of environmental recovery for up to 5 years post-extraction. The consent application by TTRL was lodged on 23 April 2025, and deemed complete on 15 May 2025 and is now listed as in process on the Fast-track Approvals Act (2024) website.

Digitised licensed areas for sand mining were compiled by the Sustainable Seas SPEXCET project based on known areas in the Hauraki Gulf and the Waikato Region (Figure 7-1). Many sand mining consents have expired since this dataset was first compiled, and consent applications for new areas are currently listed within Fast-Track legislation, including both coastal areas at the boundary between Auckland and Northland regions, and offshore in the South Taranaki Bight.

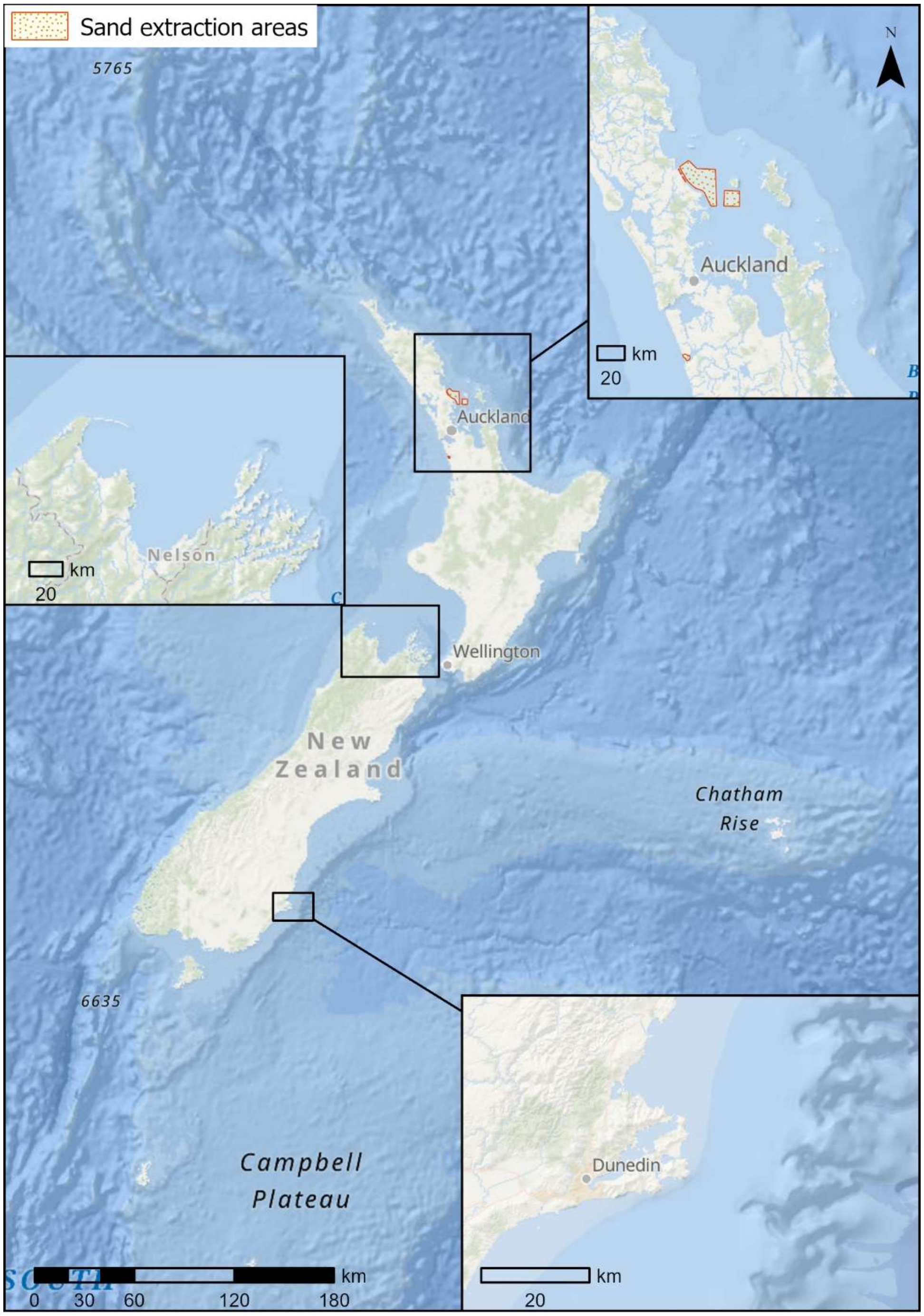

Figure 7-1: Sand extraction permits in New Zealand.

7.1.3 Next steps

This dataset was determined to be incomplete, with this activity in a rapid state of flux with the expiry of many long-term consents and many new applications in process. Boundary areas of permits are typically larger than active areas, and better information is required to extrapolate consent permits to stressor footprints. The extent of extraction and location within a consented area is likey to be confidential to industry. The active stressor footprint likely results in high levels of mortality and habitat degradation in soft sediment ecosystems, and extends beyond the area of extraction.

7.2 Extraction – minerals

7.2.1 Description

As defined by DOC, this activity considers the extraction of minerals from the seabed such as polymetallic nodules and includes the use of seafloor mining devices, riser and lifting systems and mining support vessels.

7.2.2 State of knowledge

A variety of types of minerals are potentially available for harvest offshore in New Zealand such as coal, gold, silver, copper, lead and zinc (from seafloor massive sulfides at vents in the Kermadec Arc and Colville Ridge) as well as iron sands (west coast of North Island), and phosphate (Chatham Rise).

Offshore mining is of concern for deep sea benthic communities, including those found at hydrothermal vents, seeps and seamounts. These species can be very slow growing and have demonstrated a lack of recovery from disturbances such as those created by fishing and mining which damage the sea floor habitat and suspend sediments (Clark et al. 2022). Exploration for potential mining sites can also be damaging to a variety of marine life beyond direct physical damage; depending on the technology used. For example seismic surveys create loud sounds that can be especially damaging to marine mammals, fishes, invertebrates and plankton.

Online maps were extracted from the New Zealand Petroleum and Minerals Geodata Map to show current minerals permits and applications in New Zealand. They are updated as required through the NZPAM permit registry system and GIS database. These maps also contain terrestrial mineral and mining information for coal and other minerals mined on land, and were clipped to include only permits and licenses in the marine area (Figure 7-2). A 'Reserved Area' layer (not shown) includes the Kermadec and Colville Arcs where permits for minerals will not be granted from 5 July 2021 to 4 July 2024 under section 28A of the Crown Minerals Act 1991, and which has been further extended for an additional 18 months to January 2026. This replaced a previous reservation that expired on 4 July 2021.

Minerals exploration permits give permit holders the exclusive right to explore for specified minerals in an area. Permitted activities may include literature reviews, drilling, bulk sampling and mine feasibility studies. Notable exploration permits are in the Taranaki Bight and offshore of the Coromandel Peninsula (Figure 7-2).

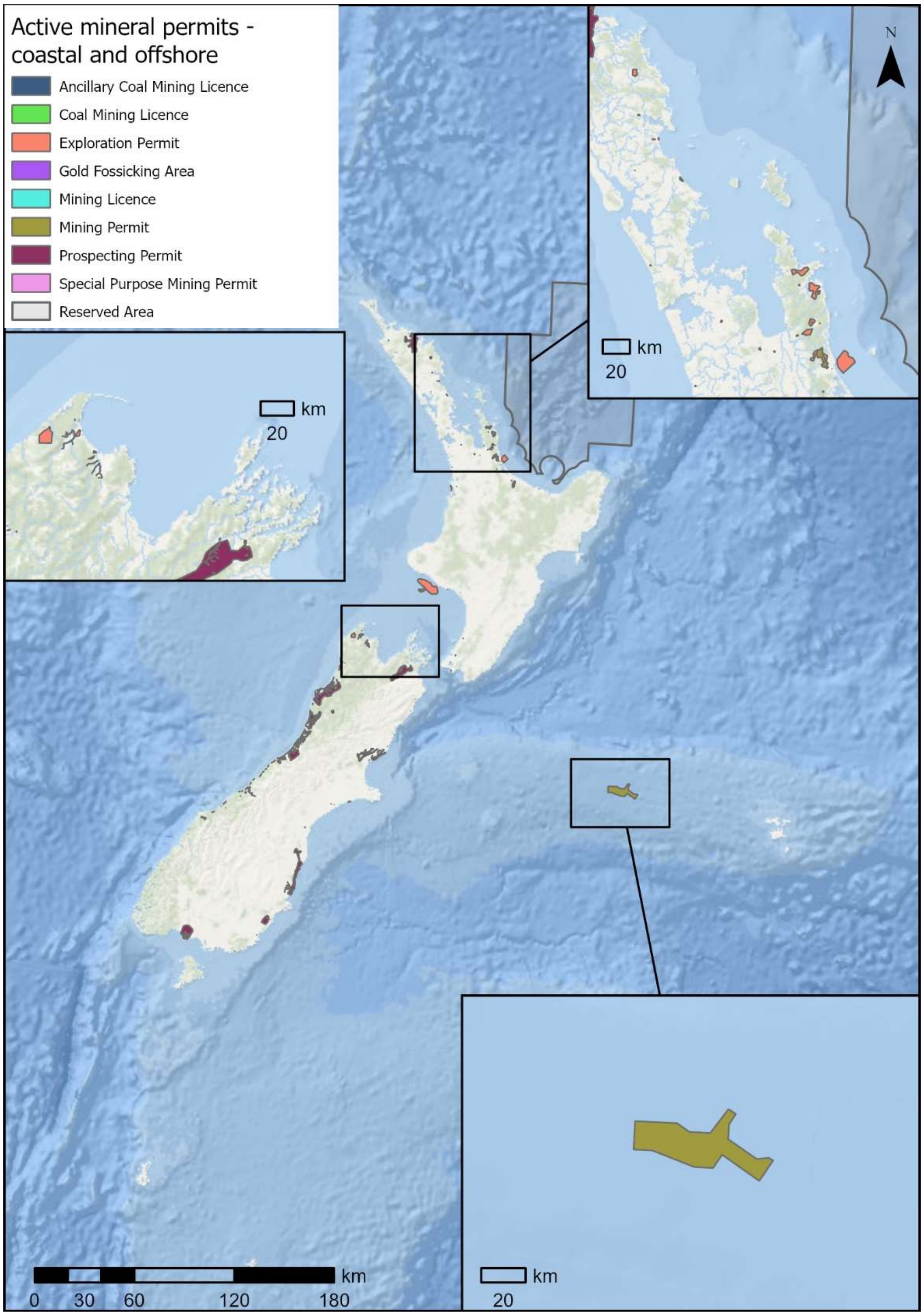

Figure 7-2: Mineral extraction permits and licenses in New Zealand; terrestrial permits are clipped to display coastal permits only.

7.2.3 Next steps

This dataset was determined to be up to date representing current permits and license areas for mineral exploration. However, details of use for these locations should be checked and verified, and any mineral exploration granted with Fast-Track legislation should be updated.

Various research projects (Sustainable Seas, MBIE ROBES) have quantified potential impacts of mineral mining on seafloor communities and can be used to estimate buffer zones for sediment transport and turbidity. The impact of activities carried out under permits for exploration are poorly known.

7.3 Extraction – maintenance dredging

7.3.1 Description

As defined by DOC, this activity includes the periodic or regular removal of material from previously dredged areas (e.g., berths, channels, marinas). The method of dredging may vary, and material may be removed for disposal elsewhere or be redistributed within the immediate area. This activity includes consideration of vessels/machinery/vehicles associated with activity. This activity is directly linked to dredge disposal (see Section 4.5).

7.3.2 State of knowledge

Most dredging is of navigation channels such as those for Waitemata or Otago Harbours. However many ports which are known to be dredged do not have areas indicated in this database, though they are likely identified in regional coastal plans. Areas of extraction are typically well known at a regional level, though dates and amounts of sediment removed may be poorly quantified (Figure 7-3).

7.3.3 Next steps

This dataset was determined to be complete in terms of locations of dredging, also indicating that navigation channels are typically areas of high disturbance and low naturalness. The amount of sediment removed was unlikely to be accurately recorded in terms of a true footprint or depth of sediment impact; regional council consent records could clarify the detail of information available. Regional authority or port authority records can also confirm dates of dredging, potentially based on timing of consent monitoring required following dredge disposal events. Updating this activity may require extraction of information from individual consent documents and following up with port authorities to determine time, location and extent of dredge events. Considering the stressor footprint to be equivalent to that of the main navigation channels is likely a sufficient proxy.

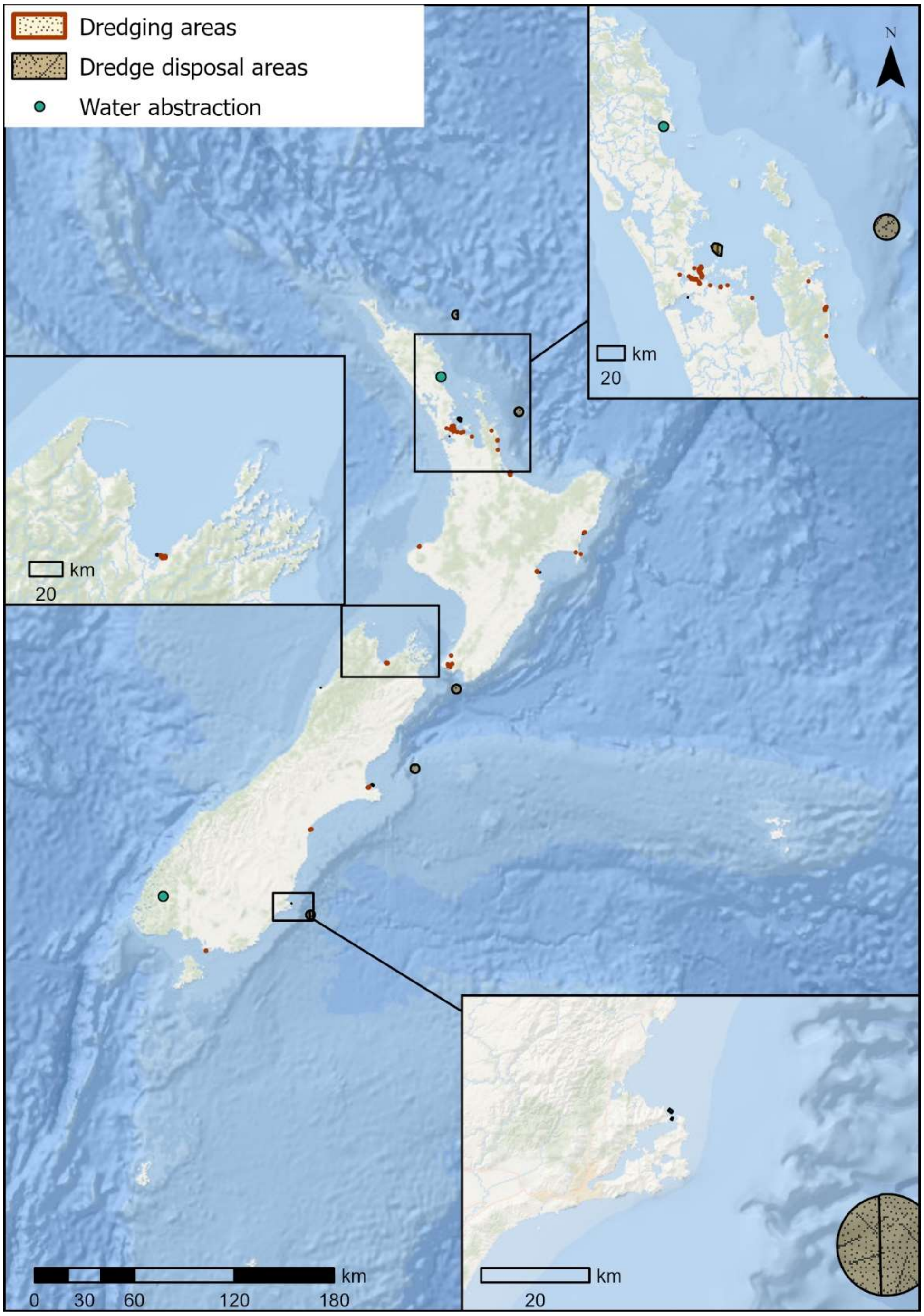

Figure 7-3: Dredging, dredge disposal and water extraction areas.

7.4 Salvage operations

7.4.1 Description

As defined by DOC, this activity category includes salvage of vessels or infrastructure, e.g., from oil and gas, wrecked on or near the coast. This activity considers the pressures associated with salvaging, including the removal of wrecked structures and associated activities caused by supporting vessels.

7.4.2 State of knowledge

While many marine salvage companies were found to exist in New Zealand, we did not find spatial layers representing significant marine salvage operations. One significant wreck (the Rena) was acknowledged as comprising a known salvage operation. Other wrecks (e.g., the Niagara) provide potential risks of oil leaks, and salvage operations have been proposed but not yet initiated. Most salvage operations are likely small scale, with impacts on the order of <10s of metres, and are poorly documented.

7.4.3 Next steps

This dataset was not compiled in this project due to lack of data found beyond large well known shipwrecks (e.g., the Niagara) which are unlikely to be salvaged. Wrecks are discussed in Section 13.4.

7.5 Extraction – water (abstraction)

7.5.1 Description

As defined by DOC, this activity category includes the temporary or permanent removal of water from the marine environment, for reasons such hydroelectric management and water cooling of power plants.

7.5.2 State of knowledge

No formal datasets were available to indicate locations or extents of water abstraction activities. Some sites (Marsden Point, Manapouri) were noted during the Inter-Agency Working Group Workshop or by Project Advisory Group members, and point records were created manually to identify these locations (Figure 7-3).

7.5.3 Next steps

This dataset was determined to be incomplete, as other locations could likely be identified that included water abstraction or changes in water flow that likely result in pressures on marine species, habitats and ecosystems. The dataset should be expanded to include the quantity and regularity/timing of water abstraction to allow quantification of the stressor footprint via potential change in hydrological features.

8 Energy generation

Four types of activities were categorised as energy generation activities: 1) Renewable energy – offshore wind construction/operation/maintenance/decommissioning (not including cables); 2) Renewable energy – wave energy construction/operation/maintenance/decommissioning (not including cables); 3) Marine hydrocarbon extraction - construction/operation/decommission (not including pipelines); and 4) Marine hydrocarbon extraction - exploration phase (not including pipelines). We combined some activities where different stages of activity development had been listed separately in the DOC list of activities such as construction, operation and maintenance, and decommissioning were combined for 1) Renewable energy – offshore wind, 2) Renewable energy – wave energy, and 3) Marine hydrocarbon extraction. We kept the exploration phase of 4) Marine hydrocarbon extraction listed separately due to the seismic and acoustic disturbances associated that were different to the pressures in the othe phases of the activity. Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for each activity category (Table 8-1).

Evidence for links between energy generation activities and pressures on the marine environment were compiled within the aligned DOC project (linking activities to pressures, Douglas and Lundquist 2025). Primary pressures associated with renewable energy development are anticipated based on overseas studies, as neither activity currently exists in New Zealand. All activities include construction, operation and maintenance of structures within their stages of activity development, which are associated with pressures of physical damage and loss of seafloor habitats and potential changes in hydrology within the localised activity site. Pressures associated with pollution and other chemicals are also associated with these activities, particularly with marine hydrocarbon extraction. Other physical pressures such as potential electromagnetic changes and underwater noise are anticipated during exploration phases as well as through pipelines associated with offshore structures. Pressures affecting megafauna (marine mammals, seabirds) include underwater noise, risk of collision, introduction of light, barriers to species' movement and migratory pathways.

Table 8-1: Descriptions of layers compiled for the category Energy generation.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Offshore wind construction	Offshore platforms	ongoing	10-100 km	Polygon	Indicative	MBIE	Emerging industry
Offshore wind operation and maintenance		ongoing	10-100 km	n/a	n/a	n/a	Emerging industry
Offshore wind decommissioning		ongoing	10-100 km	n/a	n/a	n/a	Emerging industry
Wave energy construction		ongoing	1-10 km	n/a	n/a	n/a	Emerging industry
Wave energy operation and maintenance		ongoing	1-10 km	n/a	n/a	n/a	Emerging industry
Wave energy decommissioning		ongoing	1-10 km	n/a	n/a	n/a	Emerging industry
Oil & gas exploration	Geophysical, seismic, sonar surveys	one-off	>100 km	Polygon; Polyline	Yes	NZPAM	Convert to footprint
Oil & gas construction	Active Petroleum permits	ongoing	1-10 km	Polygon	Yes	NZPAM	Timing/extent, buffer
Oil & gas operation and maintenance	Active Petroleum wells	ongoing	1-10 km	Point	Yes	NZPAM	Timing/extent, buffer
Oil & gas decommissioning		ongoing	1-10 km	Point; Polyline	Yes	NZPAM	Regular update

8.1 Renewable energy – offshore wind construction, operation and maintenance, and offshore wind decommissioning (not including cables)

8.1.1 Description

As defined by DOC, this activity includes seabed preparation (possibly dredging), cuttings/dredging disposal, piling, use of explosives, cutting, drilling, excavation of seabed close to foundations, anchoring, mooring, vessel movement, vessel discharges/emissions, installation of scour protection, introduction of artificial substrate, removal of structures/scour protection and associated habitat. The timeline between exploration and construction phases is likely to be about a decade. Submarine cables are discussed separately in Section 13.1.

8.1.2 State of knowledge

This activity does not currently exist in New Zealand; however, it is an emerging industry and MBIE has released guidance for the permitting and licensing process associated with this offshore renewable energy industry. Areas of interest have been identified in the Waikato west coast, Taranaki Bight and Foveaux Straight (Figure 8-1).

8.1.3 Next steps

This dataset was determined to be complete, but will require updating when the permitting process is initiated. Permit areas are anticipated to be 250 km^2, with details of structures (i.e., densities, water depth, height, whether fixed or floating) to be described in consent applications. Specific impacts to New Zealand flora and fauna are poorly known.

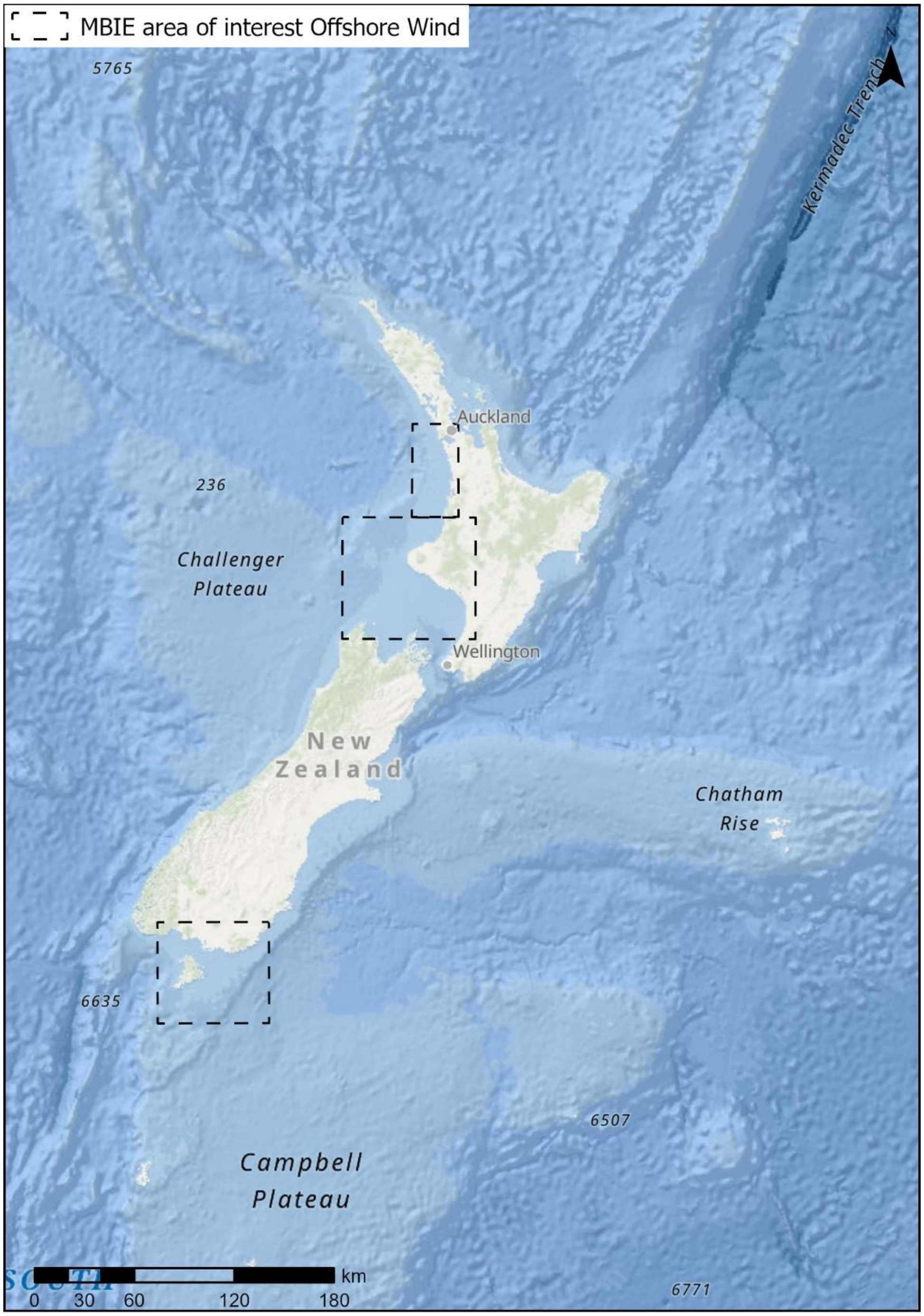

Figure 8-1: Areas identified for emerging industry in offshore renewable wind energy.

8.2 Renewable energy – wave energy construction, wave energy operation and maintenance, and wave energy decommissioning (not including cables)

8.2.1 Description

As defined by DOC, this activity includes seabed preparation (possibly dredging), cuttings/dredging disposal, piling, use of explosives, cutting, drilling, excavation of seabed close to foundations, vessel movement, vessel discharges/emissions, installation of scour protection, introduction of lighting, introduction of artificial substrate, operation of devices, removal of structures/cables and associated habitat. Submarine cables are discussed separately in Section 13.1.

8.2.2 State of knowledge

This activity is a potential emerging industry that does not currently exist in Aotearoa New Zealand. Computer models have estimated power output from tidal flows within Cook Strait and determined the best locations within the Strait and the size required for a tidal turbine farm that could generate 1000 megawatts of electricity (Vennell et al. 2015, Vennell et al. 2020). However, investment in tidal energy has not yet occurred.

8.2.3 Next steps

This dataset was determined to be complete, but will require updating if this industry commences. The likely location is Cook Strait.

8.3 Marine hydrocarbon extraction - construction, operation and maintenance, and decommissioning (not including pipelines)

8.3.1 Description

As defined by DOC, this activity includes the construction of oil and gas infrastructure in the marine environment including, but not limited to, the installation of rock dump to stabilise jack up rigs, cementing, introduction of other protection material such as concrete mattresses, matting and gravel, the temporary installation of infrastructure (such as pipelines, debris baskets, etc.), drilling wells and plugging and abandonment, accidental effects, vessel movement, installation of subsea infrastructure, etc. The operation and maintenance stage includes production and operation, with routine supply, return of wastes to shore, power generation, chemical use, produced water, and re-injection of reservoirs. Decommissioning potentially includes the plugging and abandonment of wells, removal of structures and associated habitat, use of explosives, cutting, drilling, disturbance of drill arisings and cuttings, placement of rock to cover remaining structures or to provide base for jack-up legs. All activity stages include operation by supporting vessels, vessel discharges, use of Remotely Operated Vehicles, lifting and jack-up rigs. Submarine pipelines are discussed separately in Section 13.1.

8.3.2 State of knowledge

Oil and gas infrastructure datasets were acquired from New Zealand Petroleum and Minerals database for the Sustainable Seas SPEXCET project and uploaded to the Te Ukaipo o Hinemoana geospatial tool. This dataset includes point records and polygons representing active petroleum wells, active permits, and petroleum permit applications (Figure 8-2). This is a mature extraction activity in New Zealand, with five producing fields in New Zealand's EEZ (Table 8-2) located in the

Taranaki region. Platforms are often connected to multiple wells (Table 8-2). Prospecting permits allow acquisition of geological and geophysical data collection but not drilling activities. Exploration permits are issued for up to 15 years to enable research into where commercially recoverable reserves of oil and gas may be, and can include sampling, aeromagnetic surveys, geological studies, seismic surveys and well drilling. Petroleum mining permits grant the holder rights to develop a discovered petroleum field to extract and produce petroleum, and permitted activities include extraction, separation, treatment and processing of petroleum.

Oil and gas infrastructure including platforms and pipelines introduce artificial structures and substrate and can result in point source pollution as well as destruction/disturbance of benthic communities. Once built, however, structures can function as artificial reefs, which can lead to greater abundances and diversity in a variety of marine life. Seafloor drilling damages the sea floor, contributes to sound pollution, and can result in devastating subsurface oil spills when blowouts occur. The potential values of decommissioned offshore infrastructure and platforms for industry, the community and the environment has been explored by Sustainable Seas (Lane 2018).

Table 8-2: Hydrocarbon producing fields in New Zealand. Updated, based on information compiled by Sustainable Seas (Lane 2018). *Note the Tui field has been decommissioned.

Producing Field	Māui A	Māui B	Tui*	Maari	Kupe	Pohokura
Water Depth (m)	108	108	120	100	34	30
Distance to shore (km)	35	50	55	80	30	4
Number of wells	14	12	4	Unmanned wellhead platform	5	9 (6 offshore, 3 onshore)
Pipeline infrastructure	2 x 35 km submarine pipelines	15 km submarine pipeline to Māui A	Floating Production Storage and Offloading vessel	Floating Production Storage and Offloading vessel	30 m submarine pipeline to shore	4 km submarine pipeline
Discovery (y)	1969	1969	2003	1983	1986	2000
Commencement of production (y)	1979	1992	2007	2009	2008	2004
Permit expiry (y)	27/6/2036	27/6/2036	24/11/2025*	1/12/2027	26/6/2031	7/10/2036

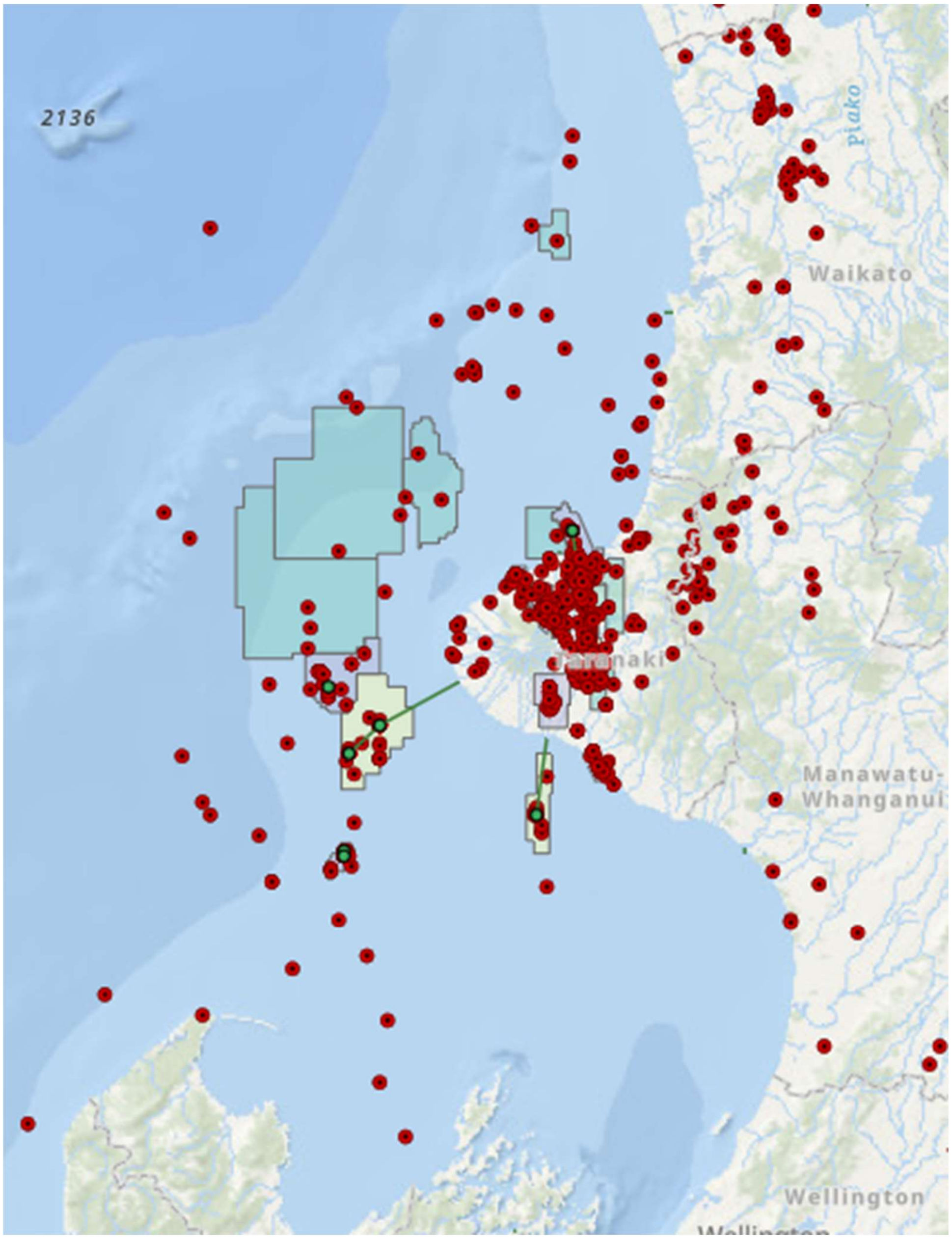

Figure 8-2: Locations of petroleum exploration permits (aqua polygons), petroleum mining licenses (yellow polygons), petroleum mining permits (purple polygons), and individual petroleum wells (red) in the Taranaki region. Based on layer acquired from NZPAM.

8.3.3 Next steps

This dataset (individual point records and polygons) was updated based on data extracts from the NZPAM Geospatial platform, and the dataset was clipped to include only coastal permits and wells.

Summary information on the extent of individual permits could be updated based on current operating capacity and decommissioning. Information from consent monitoring is confidential, provided to the Environmental Protection Agency, but if accessible, could be used to inform stressor footprints from this activity. Sustainable Seas reviewed the status of the main oil producing wells and the potential values and impacts of different decommissioning options (Lane 2018) that could also inform stressor footprint information based on decommissioning options and potential of structures serving as artificial reefs.

Information on decommissioning of the Tui oil field is available on the MBIE website (https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/minerals-and-petroleum/tui-project). The decommissioning of the Tui field was conducted in three main stages: 1) Demobilisation of the Floating Production Storage and Offloading (FPSO) vessel coupled with works to ensure that the subsea assets were left safe and secure (completed in May 2021); 2) removal of the subsea infrastructure (concluded in July 2022); and 3) plugging and abandonment of the wells (concluded in November 2023). Residual offshore work was completed in March 2024, however there are delays in completion of the decommissioning due to finalising the abandonment certification for one of the four wells.

8.4 Marine hydrocarbon extraction - exploration phase (not including pipelines)

8.4.1 Description

As defined by DOC, this activity includes searching for oil and natural gas deposits beneath the ocean floor using controlled-source electromagnetic surveys and exploratory drilling. Seismic surveys are also discussed in Section 11.3.

8.4.2 State of knowledge

Oil and gas infrastructure datasets were acquired from New Zealand Petroleum and Minerals database for the Sustainable Seas SPEXCET project and uploaded to the Te Ukaipo o Hinemoana geospatial tool. This dataset includes petroleum exploration permits (Figure 8-2) and locations of seismic surveys (2D and 3D), geophysical surveys and associated consents (Figure 8-3).

Exploration permits can include sampling, aeromagnetic surveys, geological studies, seismic surveys and well drilling. The primary stressors from this activity are from seismic surveys which use air guns to produce loud sounds that can have local impacts on a variety of species from plankton to invertebrates, fishes, and marine mammals, as well as low frequency sounds which can propagate thousands of kilometres from the source and result in significant alterations in behaviour, particularly in cetaceans. Geophysical surveys can include a variety of methods such as seismic, electrical, magnetic, radar and remote sensing techniques.

8.4.3 Next steps

This dataset was determined to be complete, however additional information could explore extracting temporal aspects of consents for seismic surveys and analysing data to assess their current or historical footprint. Geophysical surveys include information on individual surveys such as month and year, type of survey (e.g., airborne magnetics, radiometrics) and purpose (e.g., mineral exploration) to assist in defining stressor footprints within exploration polygons which are often large in areas. Seismic surveys include start and end dates of extensive surveys. Geophysical survey records include dates from 2007-2017. Seismic surveys (2D) include surveys from 2007-2017 and seismic surveys (3D) include surveys from 2009-2018.

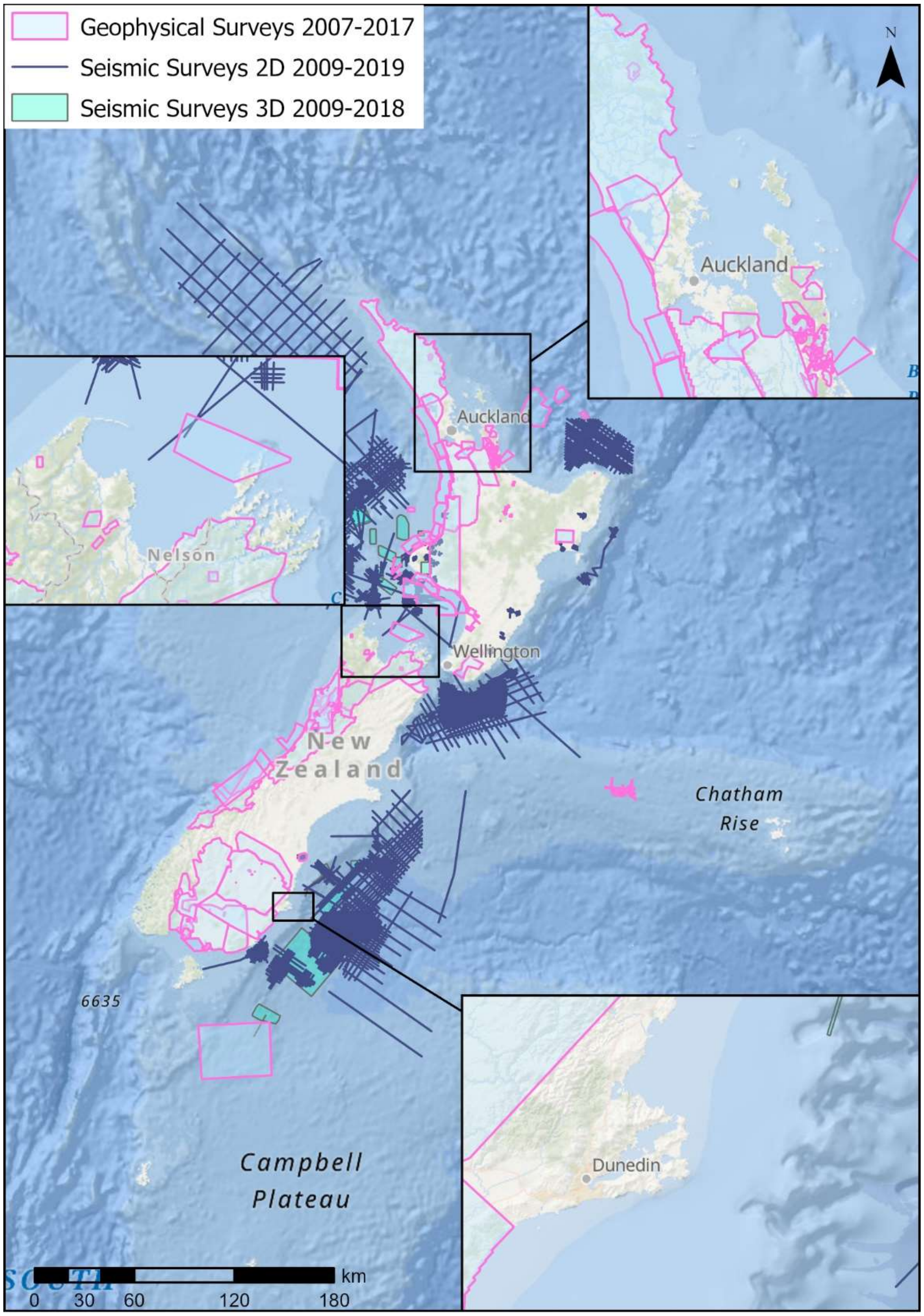

Figure 8-3: Locations of geophysical and seismic surveys associated with petroleum exploration permits. Based on layer acquired from the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana.

9 Transport

Four categories of activities were categorised as transport activities: 1) Shipping – port operations; 2) Vessel moorings (including small recreational vessels); 3) Anchoring; and 4) Shipping – general (at sea). Below, we provide a description and summarise the state of knowledge and next steps for each activity category (Table 9-1).

Evidence for links between transport activities and pressures on the marine environment were compiled within the within the aligned DOC project (linking activities to pressures, Douglas and Lundquist 2025). Primary pressures associated with transport were assessed as physical loss and damage to habitats associated with permanent ports and semi-permanent moorings and anchoring zones. Underwater noise and ship collisions, as well as biological pressures through introduction of non-indigenous organisms, were also key pressures for which evidence was summarised for this activity category (Douglas and Lundquist 2025).

Table 9-1: Descriptions of layers compiled for the category Transport.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Shipping – port operations	Port location	one-off	1-10 km	Incomplete	Yes	This project	Add missing data; Timing/extent
Shipping – port operations	Biosecurity risk - NIMS	ongoing	>100 km	Hotspot models; point records	Yes	This project	Regular update
Vessel berths and moorings	Mooring zones	ongoing	1-10 km	Polygon	Yes	LINZ/Regional councils	Data extraction
Vessel berths and moorings	Berths	ongoing	<1 km	Point	Yes	LINZ	Extent
Anchoring	Anchoring - AIS tracks	ongoing	<1 km	Point	Yes	This project	Temporal change
Shipping – general (at sea)	Shipping - AIS tracks	ongoing	>100 km	Point	Yes	This project	Regular update
Shipping – general (at sea)	Septic tanks/ballast water, scrubbers	ongoing	>100 km	Point	No	n/a	Anecdotal proxy
Shipping – general (at sea)	Lost fishing gear	ongoing	<1 km	Point	Incomplete	FNZ	Data extraction

9.1 Shipping – port operations

9.1.1 Description

As defined by DOC, this activity category includes trans-shipment of cargo, loading and unloading of vessels, landside handling, logistics and onward transportation, e.g., road, rail within the port estate. The activity also includes handling of hazardous cargo, and vessels/machinery/vehicles associated with the activity.

9.1.2 State of knowledge

Port facilities were described in Section 3.2. Point locations are available indicating both major and minor ports and marinas. Further information on stressor footprints of ports could be assessed through estimates of ship traffic or georeferencing of major port facilities. Indirect risks of shipping such as oil spills were determined to be out of scope as they were pressures that may not be realised.

An identified pressure from shipping is that of the transport of non-indigenous marine species (NIMS). Data were acquired for the Evaluating KEAs project (Lundquist et al. 2020) and were updated for this project. Data on presence records of non-indigenous marine species were acquired from the Marine Biosecurity Porthole (MBP) (https://marinebiosecurity.org.nz/). Analyses of point records were used to create hotspots (Figure 9-1). Priority non-indigenous marine species that are included in national state of the environment monitoring include the Asian paddle crab (*Charybdis (Charybdis) japonica*), the green tail or 'greasy-back' prawn, (*Metapenaeus bennettae*), the Mediterranean fanworm (*Sabella spallanzanii*), the Indo-Pacific ascidian (*Symplegma brakenhielmi*), the clubbed sea squirt (*Styela clava*), the Australian droplet tunicate (*Eudistoma elongatum*), the fragile clam (*Theora lubrica*), the Asian date mussel (*Arcuatula senhousia*), wakame (*Undaria pinnatifida*) and t macroalgae *Caulerpa brachypus* and *C. parvifolia* (Seaward and Inglis 2023).

Risks from individual species vary based on the likelihood of expansion and interactions with native species. Here we review a subset of monitored non-indigenous species and the diversity of species and habitats that may be impacted.

Arcuatula senhousia. The Asian date mussel is an intertidal and subtidal mussel native to the Pacific Ocean from Siberia to Singapore that can form dense mats on soft sediments and displace benthic communities, sometimes causing anoxic conditions from waste and decomposition (Figure 9-2).

Caulerpa spp. *Caulerpa brachypus* and *C. parvifolia* are two species of exotic *Caulerpa* that have been recently detected in New Zealand. These taxa are invasive green algae native to the Indo-Pacific that can outcompete and displace native species altering community composition (Figure 9-3).

Charybdis (Charybdis) japonica. The Asian paddle crab is an intertidal and subtidal estuarine swimming crab native to Southeast Asia that can outcompete native crabs and heavily consume important shellfish species (Figure 9-2).

Eudistoma elongatum. The Australian droplet tunicate or seasquirt is found along the waterline in muddy habitats and on man-made structures. It is native to Australia and can displace native species by forming dense colonies, smothering beaches, rocks and tide-pools as well as fouling boats and aquaculture equipment.

Sabella spallanzanii. The Mediterranean fanworm is native to the Mediterranean and Atlantic coast of Europe, and is usually found in subtidal areas on a variety of hard substrates. It can displace native species by forming dense colonies, decreasing plankton available for other filter feeders, and fouling aquaculture and other equipment (Figure 9-2).

Styela clava. The clubbed tunicate or seasquirt is a shallow subtidal tunicate living on hard substrates which is thought to be native to the northwest Pacific (Japan, Korea, Northern China, and Siberia). It can compete for space and food with native and aquaculture species and cause fouling problems on vessels, equipment and other structures (Figure 9-2).

Undaria pinnatifida. Wakame is a low intertidal and subtidal kelp native to Japan, where it is harvested for food. It can grow on a variety of hard structures in potentially thick forests that may displace native species and communities and cause fouling issues (Figure 9-3).

Presence records of NIMS obtained from the Marine Biosecurity Porthole are biased by survey locations, which tend to be focused near ports, harbours and marinas, but it offers the most comprehensive view of non-native species in New Zealand's marine environment. Port Biological Baseline Surveys (PBBS) were conducted in 2001 and 2007. National Marine High Risk Site Surveillance (NMHRSS) has occurred every six months at 12 of Aotearoa New Zealand's busiest ports, harbours and marinas (https://marinebiosecurity.org.nz/surveillance/). These surveys include a diverse suite of methods (crab condo lines, crab box trap lines, benthic sled tows, diver searches, and shore searches), and targets include 243-486 sampling locations per harbour per sampling time across the combination of gear types (Wood et al. 2022). Data on the MBP also include other verified records from published reviews, unpublished technical reports, biosecurity databases, museum records, regional councils, and submissions made to the Ministry for Primary Industries (MPI) for expert identification through the Marine Invasives Taxonomic Service (MITS). Key limitations of the NIMS dataset assembled for this project in describing the stressor footprint of non-indigenous species are:

- Primarily includes information gathered from NMHRSS.
- Data available for download are presence records only and do not include the collected information on abundance, density or spatial coverage.
- Presence records may be outdated (some data >10 years old).
- Sampling occurs every six months, during a summer and winter phase, to attempt to capture the species that exhibit seasonal fluctuations in abundance or presence or boom/bust cycles (e.g., *Arcuatula senhousia*, *Caulerpa* spp.). However, this data may be inaccurate if sampling does not occur during periods of presence or abundance. *Undaria pinnatifida* has a highly seasonal growth cycle involving summer senescence of sporophytes (especially in northern NZ where water is warmer). Therefore, port or other surveys conducted in summer may not be wholly representative of year-round presence or abundance.

9.1.3 Next steps

This dataset was determined to be biased, though likely representative of the broad pattern of invasive of non-indigenous marine species, as shipping vessels are their primary transport vectors.

As species vary in their impacts on native species and habitats, two components of stressor footprints are relevant: rate of spread, and likelihood of impact. The second component would require species-specific studies, which have been completed by regional councils and universities for a number of high risk NIMS.

To estimate rate of spread, the hotspot approach or a map of major shipping ports can showcase the primary risk and locations that typically have the largest stressor footprint from NIMS. However, carrying out surveys only at major ports means that colonisation events from recreational vessel transport that may occur at smaller ports or marinas are missed. For example *Caulerpa* spp. became locally established on Aotea Great Barrier for one or more years before it was detected. A number of other potential sources of records could be added to improve the spatial coverage of presence records, and also inform absence records, and many of these are already included the the Marine Biosecurity Porthole database on NIMS. These include:

- Surveillance data from aquaculture farms, including data potentially available from consent monitoring. *Undaria* and *Styela* are known to be associated with and spread by aquaculture activities (mussel farming). Potential datasets to explore include the Top of the South Marine Biosecurity Partnership (Marlborough District Council, MPI and the Marine Farming Association) which was formed to carry out surveillance (in addition to the routine NMHRSS sampling).
- Presence and abundance data from regional council estuarine monitoring.
- Other regional authority information on presence of NIMS, e.g., https://www.nrc.govt.nz/environment/weed-and-pest-control/marine-biosecurity/exotic-caulerpa/; spatial data on *Caulerpa* surveys: https://www.marinepests.nz/interactive-caulerpa-map; areas with Control Area Notices (CAN) for different species; regional council hull surveillance/compliance programs.
- Information from species-specific surveys performed by NIWA or universities, e.g., university theses on *Charybdis* in the Auckland region.
- Other global databases (e.g., OBIS) may also contain NIMS presence records.

Models of source locations could also be used to develop a stressor footprint. One approach mapped distance from ports as an indicator of risk (Inglis et al. 2006). This approach could be expanded through addition of recreational vessel areas such as marinas and mooring sites (Floerl et al. 2009), inclusion of aquaculture farms, and use of vessel movements and spatial networks (Hilliam et al. 2024) to inform incursion risks or likelihood of NIMS presence. For example, a New Zealand study used ballast water and biofouling declarations from actual vessel arrivals to develop statistical models to estimate relative likelihoods of entry of NIMS (Hatami et al. 2022).

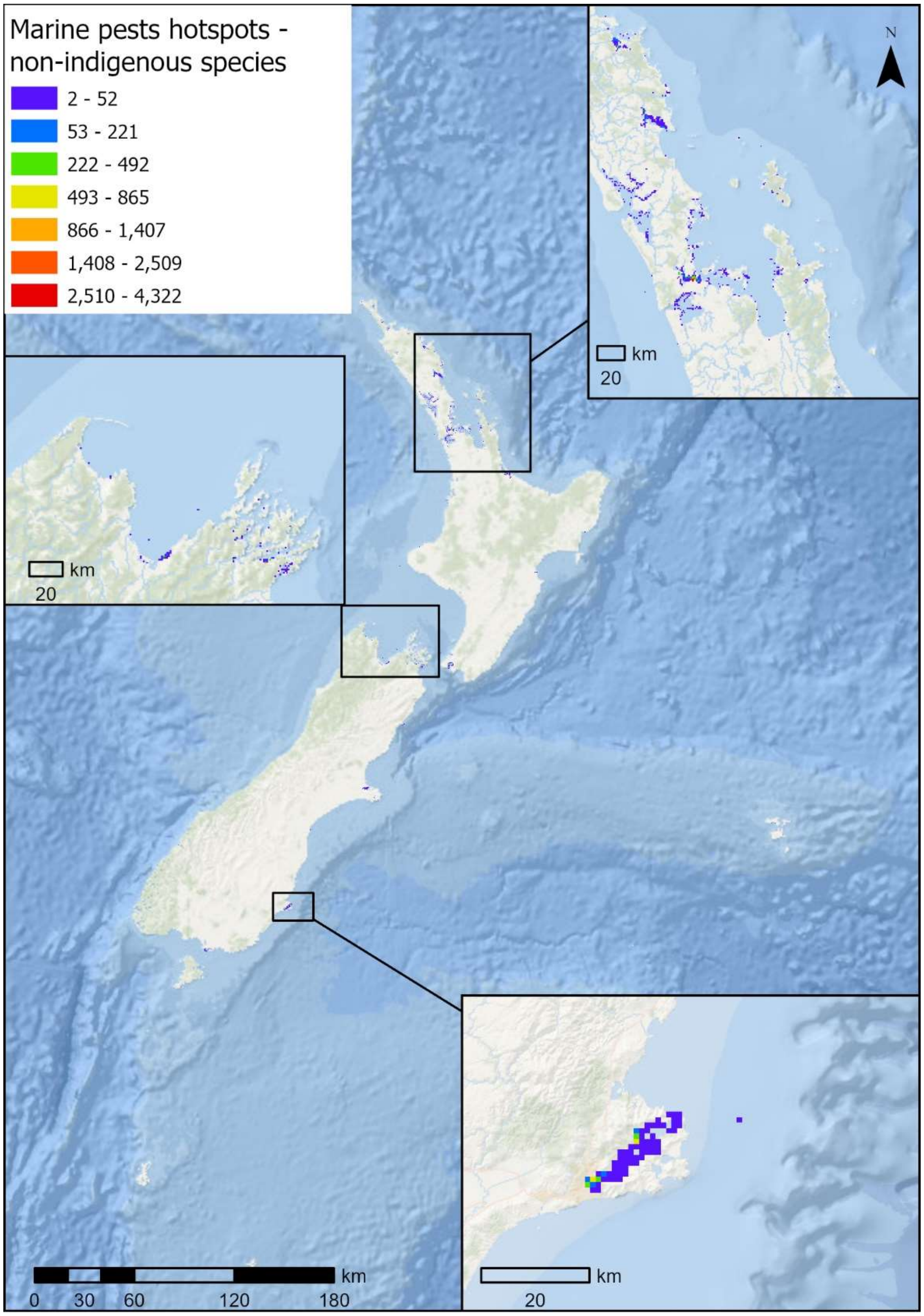

Figure 9-1: Hotspots of non-indigenous species point records from the Marine Biosecurity Porthole. Modelled layer based on data acquired for the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana in June 2023 from the Marine Biodiversity Porthole.

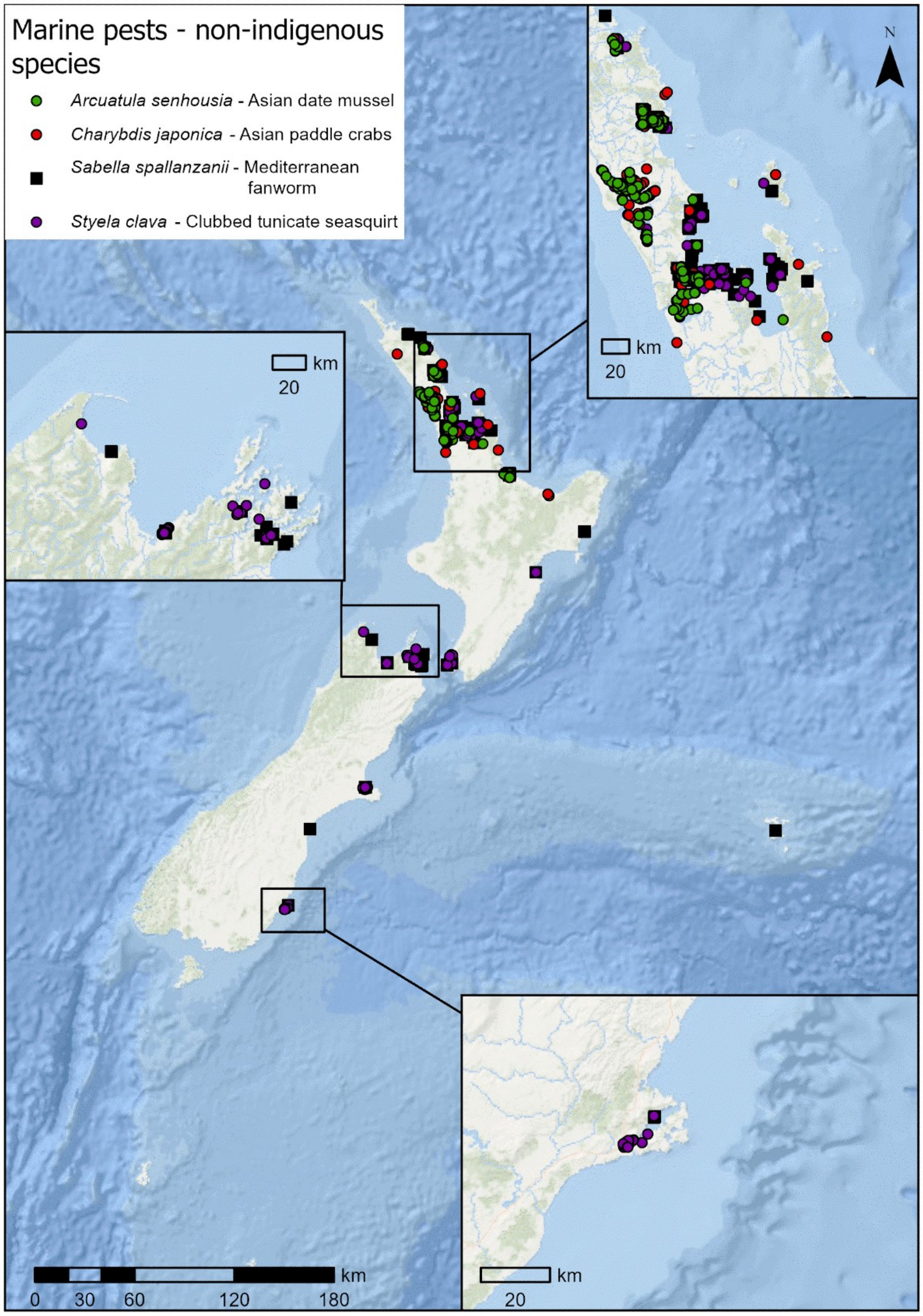

Figure 9-2: Selection of non-indigenous invertebrate point records from the Marine Biosecurity Porthole. Updated layer based on data acquired for the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana in June 2023 from the Marine Biodiversity Porthole.

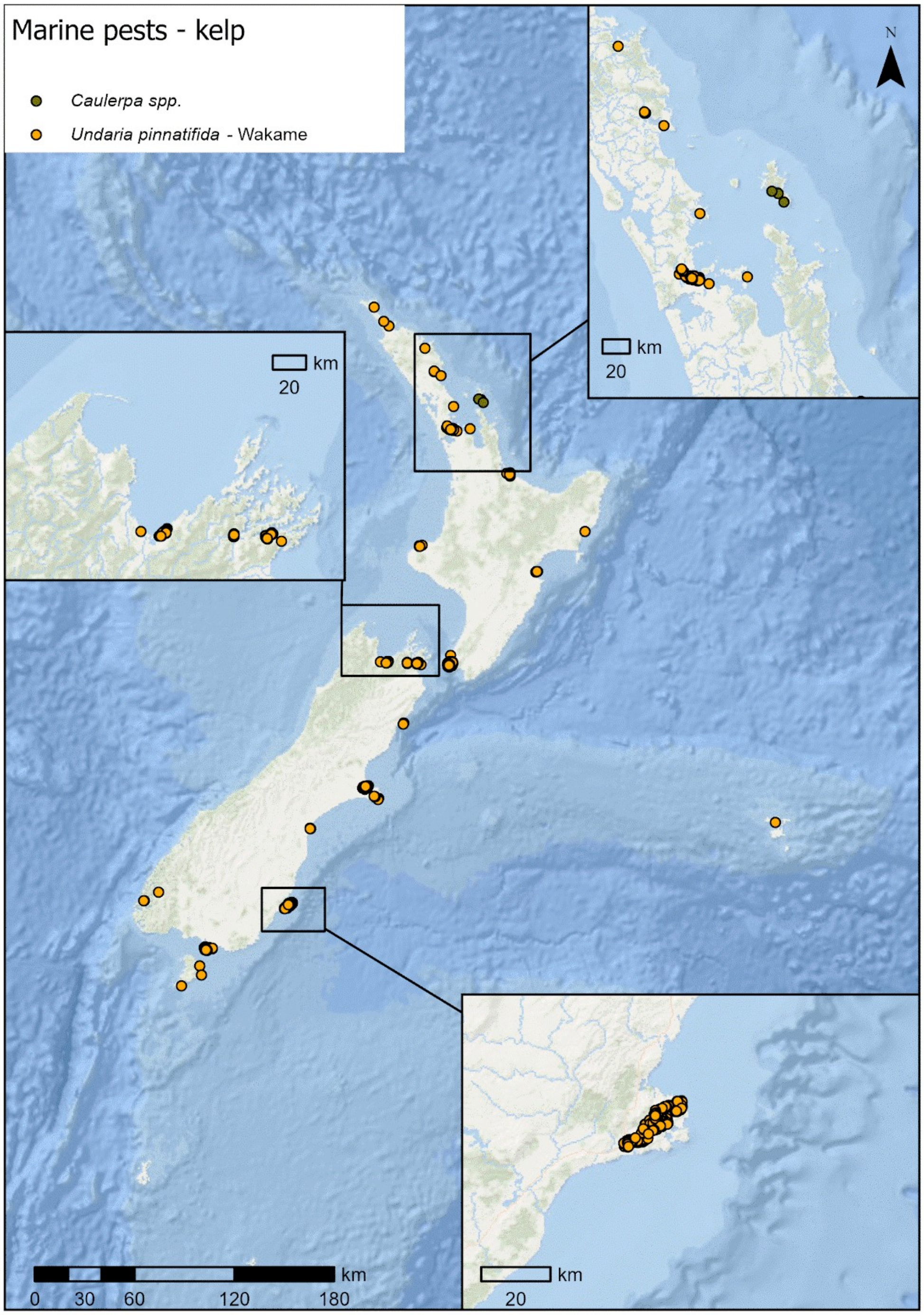

Figure 9-3: Selection of non-indigenous macroalgae point records from the Marine Biosecurity Porthole. Updated layer based on data acquired for the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana in June 2023 from the Marine Biodiversity Porthole.

9.2 Vessel berths and moorings (including small recreational vessels)

9.2.1 Description

As defined by DOC, this activity category includes the presence and use of berths and vessel moorings and the operational activities associated with mooring a vessel. A mooring is a temporary or permanent structure to which a vessel may be secured, e.g., swing mooring, trot, fore and aft mooring, pile mooring.

9.2.2 State of knowledge

Vessel berths and moorings are often located in or near marinas and ports (see Section 3.2). Moorings are typically managed at regional council levels; for example, Auckland Council provides information such as permanent moorings and permitted locations for mooring. There are 78 permanent Mooring Management Areas in the Auckland region.

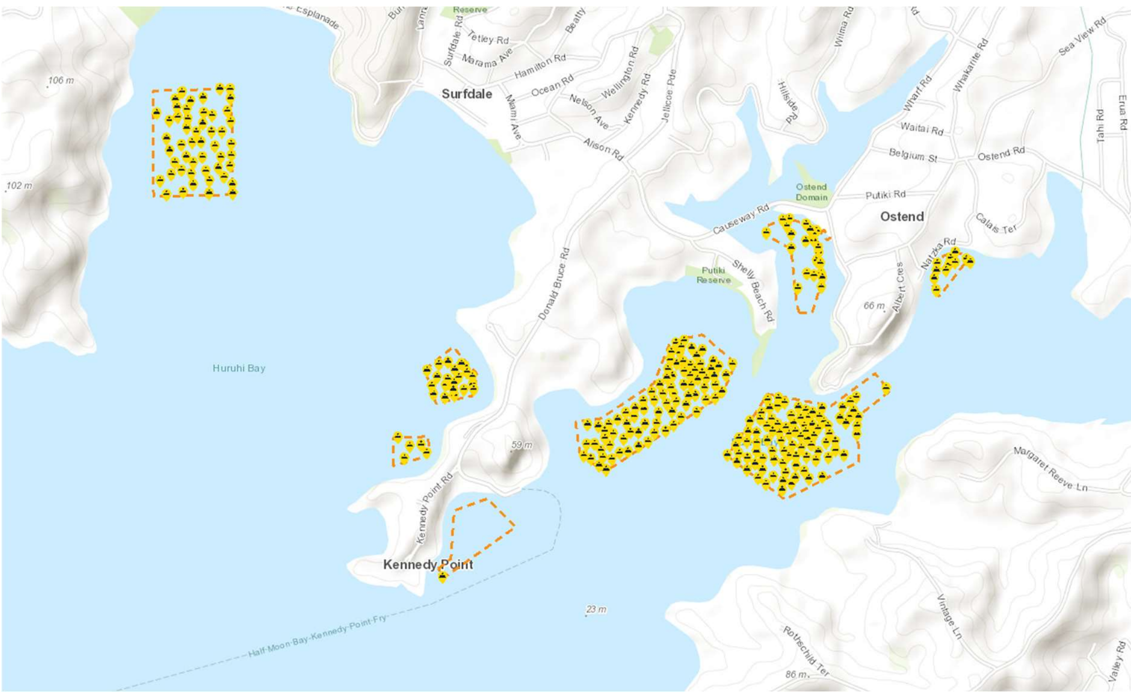

Figure 9-4: Example of mooring zones (orange dashed line) and individual registered moorings at Waiheke Island. Source: Auckland Transport Moorings map. https://mahere.at.govt.nz/portal/apps/webappviewer/index.html?id=c677de273d674c08a9572b741c1f9b75

Data representing mooring zones were investigated, with maps often available through regional councils, but acquisition of spatial data often requiring further follow up. LINZ has a national mooring/warping dataset ('Mooring/Warping facility points') which includes 96 point records and a berths dataset with 49 point records (Figure 9-5). Mooring zones are also typically detailed on navigational charts.

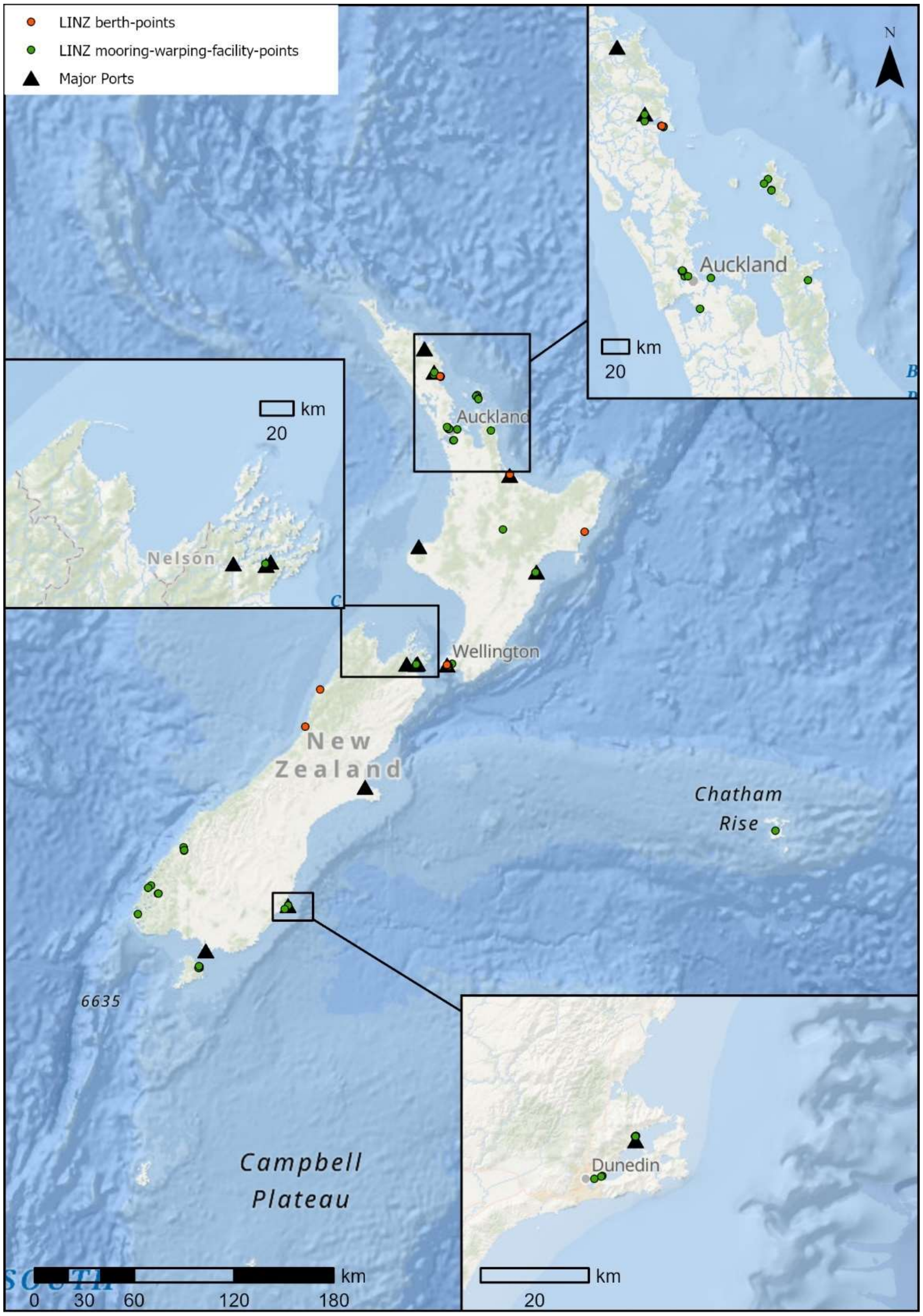

Figure 9-5: Ports, berths and mooring data available from national datasets. Source: LINZ and NMHRSS.

9.2.3 Next steps

This dataset was determined to be incomplete, and national and regional datasets should be compared and used to compile a comprehensive dataset on vessel berths and moorings.

9.3 Anchoring

9.3.1 Description

As defined by DOC, this activity category covers activity of anchoring generically as well as use of allocated anchorage areas where ships are permitted to anchor inside and outside harbours/ports. It also includes consideration of vessels when anchoring, anchored or weighing anchor.

9.3.2 State of knowledge

Most anchorages in New Zealand have been established over time through custom and practice, and are associated with ship anchoring while waiting to enter ports to discharge or load cargo, when sheltering from rough weather, or when conducting essential work that cannot be completed while underway. There is no national map of anchorage areas, though anecdotal information on commonly used areas could be acquired.

The MBIE Endeavour Smart Idea "Redesigning anchoring practices for a more sustainable shipping industry" (PI: Sally Watson, NIWA and University of Auckland) is researching anchoring practices, and surveying seafloor damage occurring during anchoring activity that can be used to inform this stressor footprint. That project is using Automated Identification System (AIS) shipping records to identify hotspots of anchoring activity, as well as converting anchoring activities into pressure footprints on the seafloor. AIS data for a four-year period (2021-2024) was purchased by the Smart Idea project, and the data used (in this project) to develop maps of anchoring activity footprints. Information was summarised for anchoring by large (>70 m) (Figure 9-6) and small (<70 m) vessels (Figure 9-7), as indications of damage from anchoring by commercial cargo vessels and smaller (primarily recreational) vessels, respectively. Anchoring activity hotspots show the extent of anchoring disturbance by large commercial vessels near major commercial ports (Figure 9-6), as well as the dispersed nature of anchoring activity. Anchoring activity for recreational vessels shows the extensive use of many sensitive areas by recreational vessels (e.g., the Marlborough Sounds; Figure 9-7).

A prior analysis of AIS data, limited to one 12 month period (July 2014 – June 2015), was contracted by LINZ and included information on anchorages (Riding et al. 2016).

9.3.3 Next steps

This newly acquired dataset was determined to be a good representation of anchoring activity by commercial and recreational vessels. Conversion of the activity maps to stressor footprints can be informed by research provided by the MBIE Endeavour Smart Idea, which is currently half way through its funding (October 2023 - September 2026). Anchorage hotspots determined from that project could be compared to the LINZ hydrographic risk report based on 2014-2015 data (Riding et al. 2016) to determine if there are changes in primary anchoring locations.

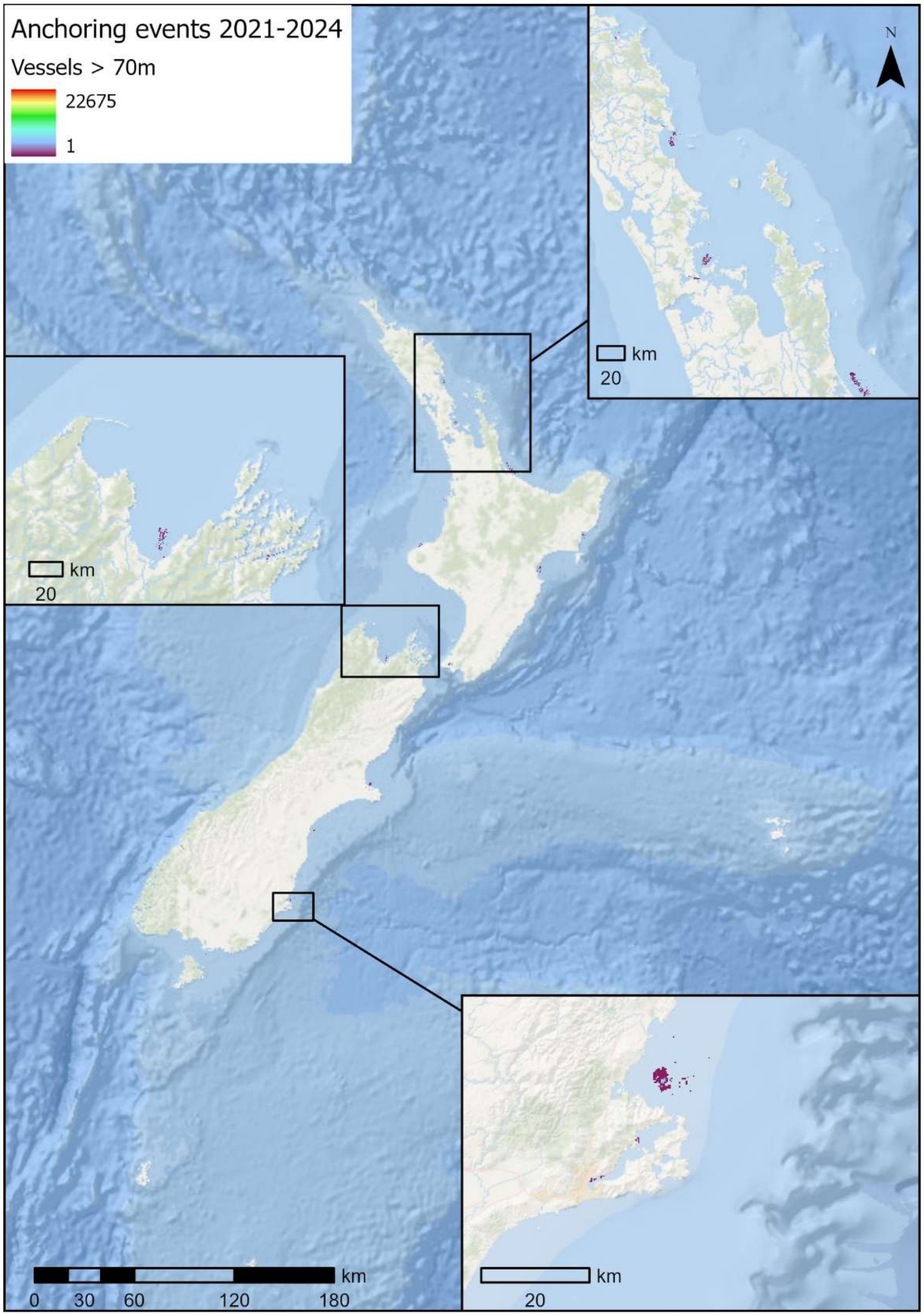

Figure 9-6: Anchoring events for vessels >70 m. Source: MBIE Endeavour Smart Idea, Sally Watson et al., NIWA, unpublished.

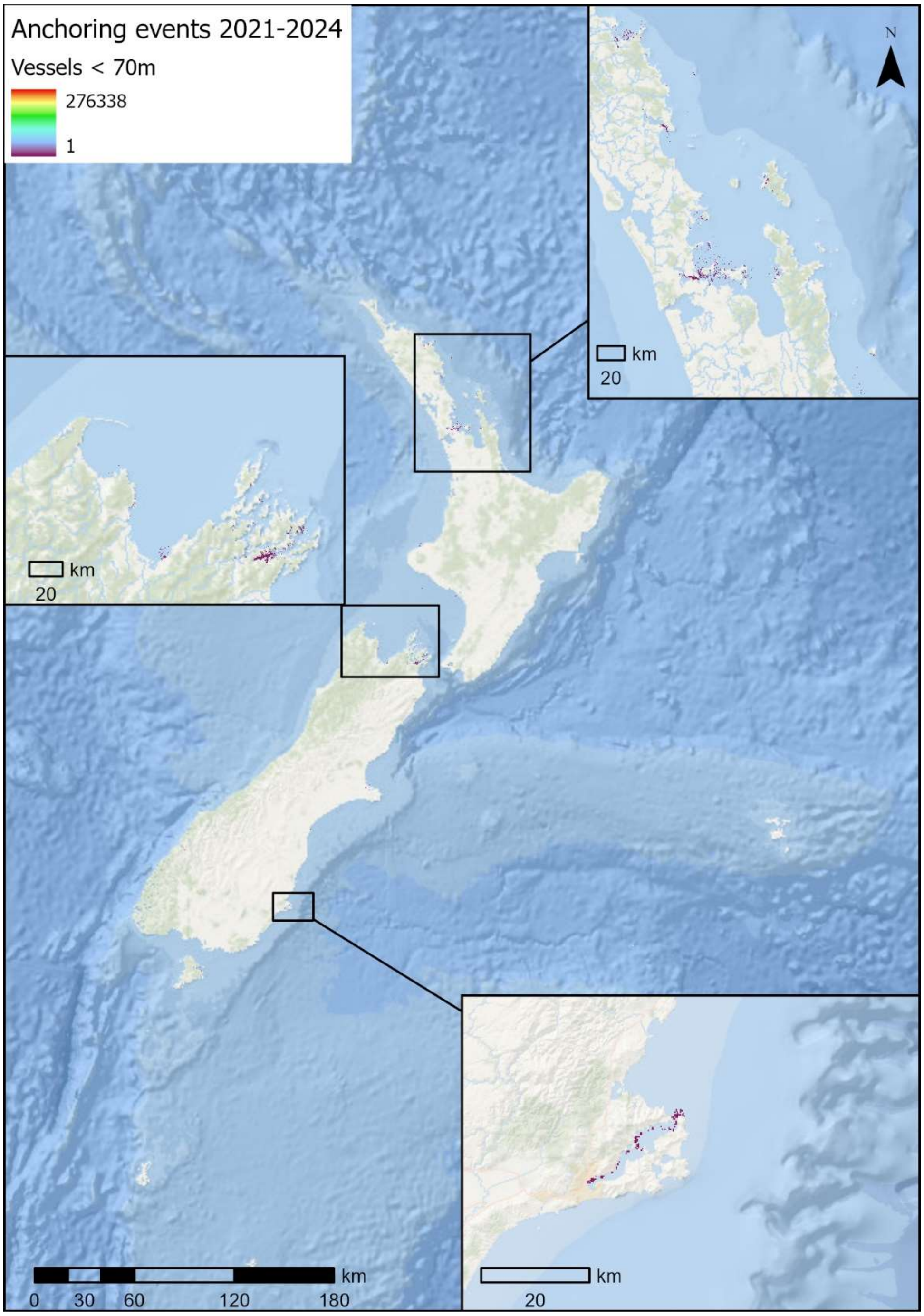

Figure 9-7: Anchoring events for vessels <70 m. Source: MBIE Endeavour Smart Idea, Sally Watson et al. NIWA, unpublished.

9.4 Shipping – general (at sea)

9.4.1 Description

As defined by DOC, this activity category includes movement of all commercial or 'non-recreation' vessels of all scales, from container ships, tankers and cruise liners to pilot vessels, tugs and small watercraft (including fishing vessels when not fishing). The activity also includes operational, incidental and accidental discharges/emissions from all types of vessels, including exhaust fumes, light pollution, wastes and wastewater, sewerage, oils, lubricants and chemicals, marine litter and other flotsam and jetsam. Anthropogenic noise pollution is likely the most significant stressor from shipping for a range of taxonomic groups.

9.4.2 State of knowledge

Shipping traffic

Data on the distribution of shipping traffic is available from AIS that are fitted to all modern commercial vessels. AIS data on locations of vessels is transmitted via satellite or VHF to shore stations and is held by third party, industry groups (e.g., Marine Traffic) and may be held in national databases administered by Maritime NZ (Riding et al. 2016). Data is available from the MarineTraffic: Global Ship Tracking Intelligence database (https://www.marinetraffic.com)/. This dataset includes live data on AIS tracks of vessels >20 m, as well as density maps available for purchase for nine types of vessels: passenger vessels, tugs and special craft, pleasure craft, fishing vessels, container ships, cargo vessels, LPG carriers, LNG carriers and tankers. Acquisition of AIS was explored within the Evaluating KEAs project (Lundquist et al. 2020) but was not acquired at the time due to the expense of AIS data extracts.

Populating a shipping dataset was prioritised by this project AIS extracts that were available for a four-year period (2021-2024) from the MBIE Smart Idea on Anchoring as discussed in the prior section to develop activity footprints for anchoring disturbance. The data extract was also available for analysis of shipping density, though the project team noted that this timeframe includes some anomalous years due to the COVID-19 pandemic, and may not be representative of typical shipping patterns.

A publicly available dataset was found and obtained, that originated from a partnership between the World Bank Group and the International Monetary Fund (IMF)'s World Seaborne Trade Monitoring System. The dataset contains density layers for six vessel types: 1) Commercial vessels; 2) Fishing vessels; 3) Oil and Gas [local transport activities associated with rigs and platforms]; 4) Passenger ships; 5) Leisure vessels; and 6) Global ship density layers of all ship categories combined. The raster layers were created using IMF's analysis of hourly AIS positions for the period from January 2015 to February 2021, for a grid cells with dimensions of 0.005 degree by 0.005 degree (approximately a 500 m x 500 m grid at the Equator). For this project, shipping records were extracted for commercial vessels (Figure 9-8), fishing vessels (Figure 9-9), leisure vessels (Figure 9-10), oil and gas vessels (Figure 9-11), and passenger vessels (Figure 9-12).

Unlike many ocean nations, New Zealand does not have a formal mandatory system of ship routing. Rather, New Zealand operates a Voluntary Code for Ships Carrying Oil and other Harmful Liquid Substances, which is in place to reduce the risk of incidents in New Zealand waters. Details are available from Maritime NZ. Some voluntary agreements have been put in place for managing collisions with cetaceans by reductions in ship speed near the Port of Auckland (Constantine et al. 2015).

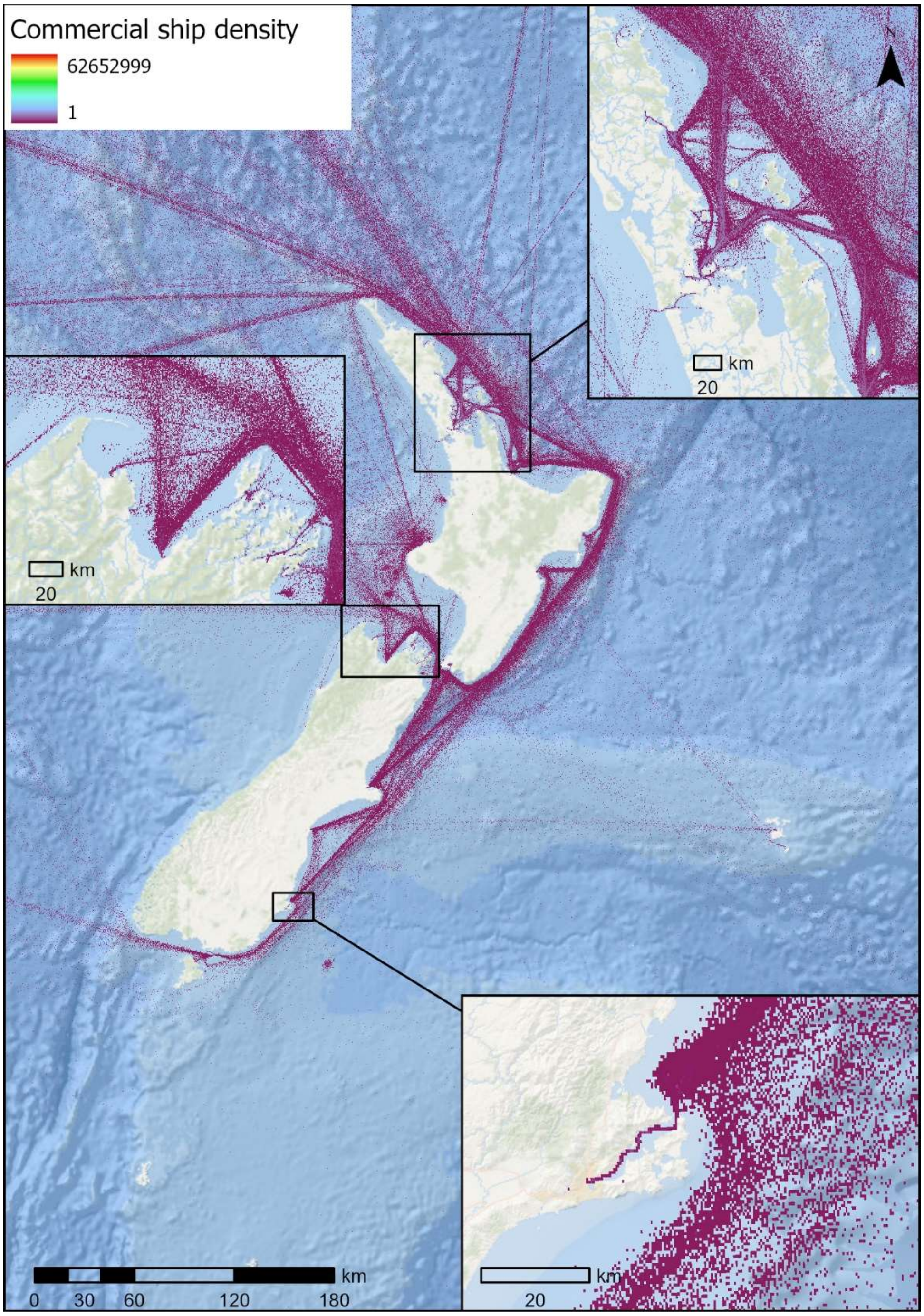

Figure 9-8: Shipping records from AIS tracking records for commercial vessels. Source: World Bank Group, obtained in partnership with the International Monetary Fund (IMF)'s World Seaborne Trade Monitoring System.

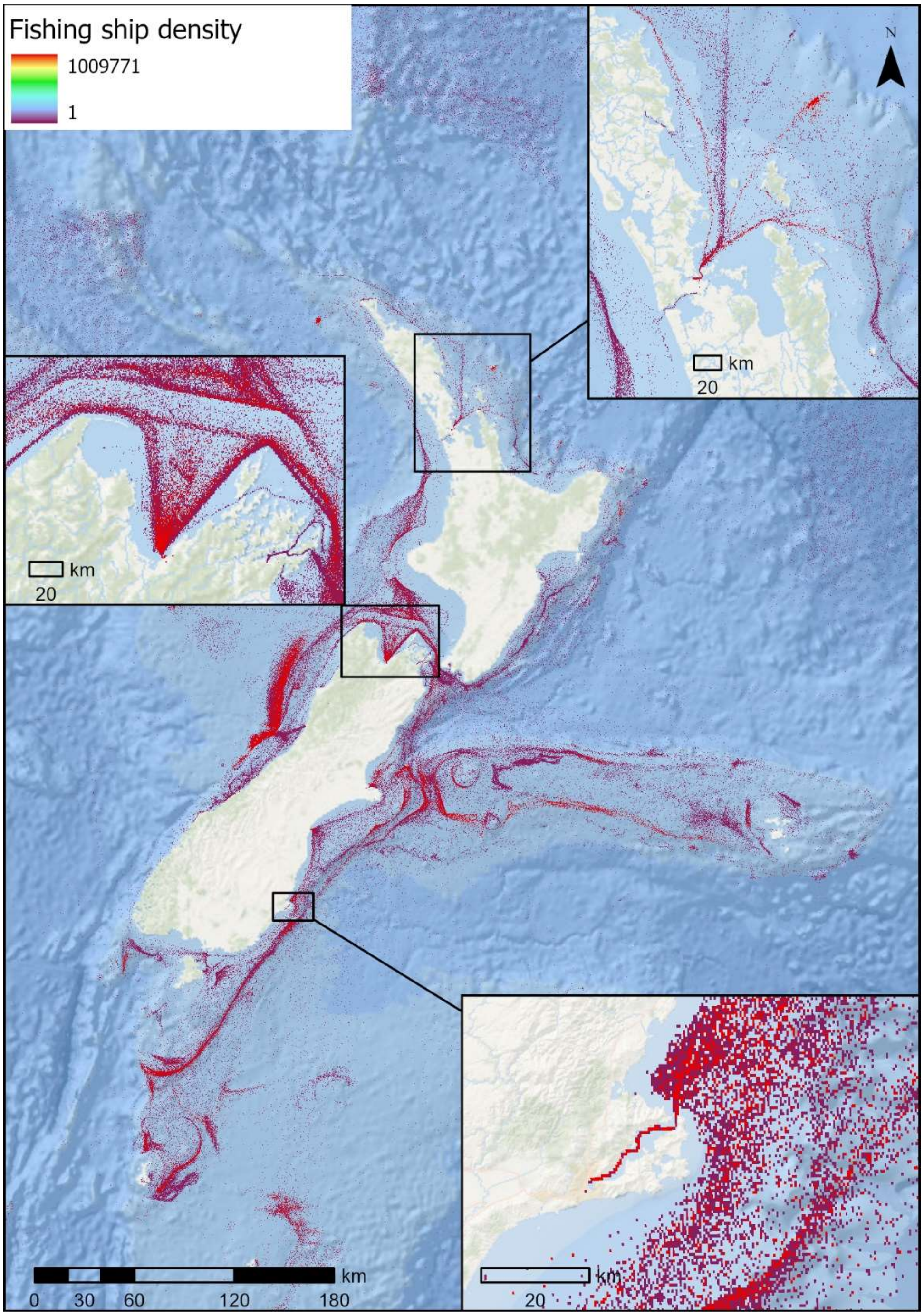

Figure 9-9: Shipping records from AIS tracking records for fishing vessels. Source: World Bank Group, obtained in partnership with the International Monetary Fund (IMF)'s World Seaborne Trade Monitoring System.

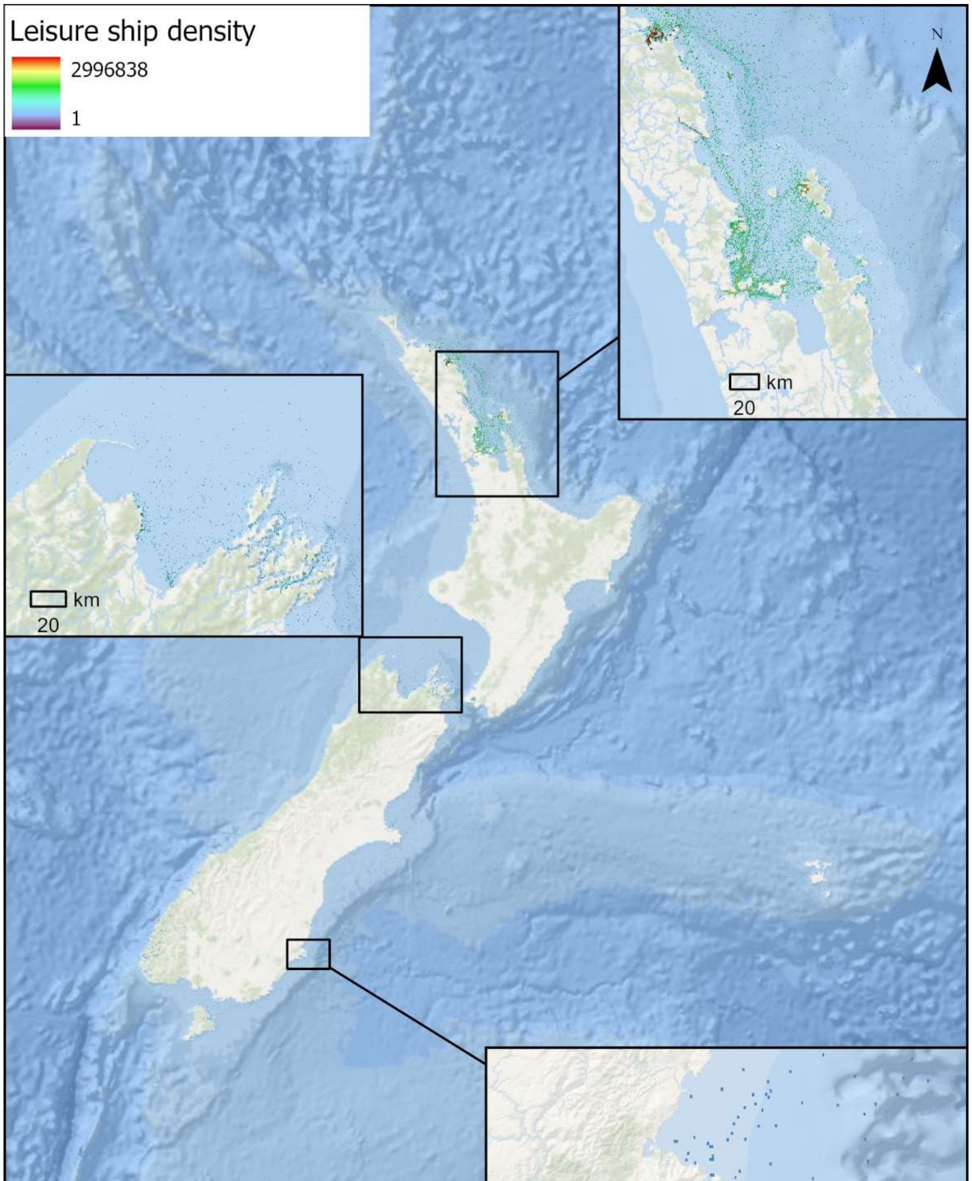

Figure 9-10: Shipping records from AIS tracking records for leisure vessels. Source: World Bank Group, obtained in partnership with the International Monetary Fund (IMF)'s World Seaborne Trade Monitoring System.

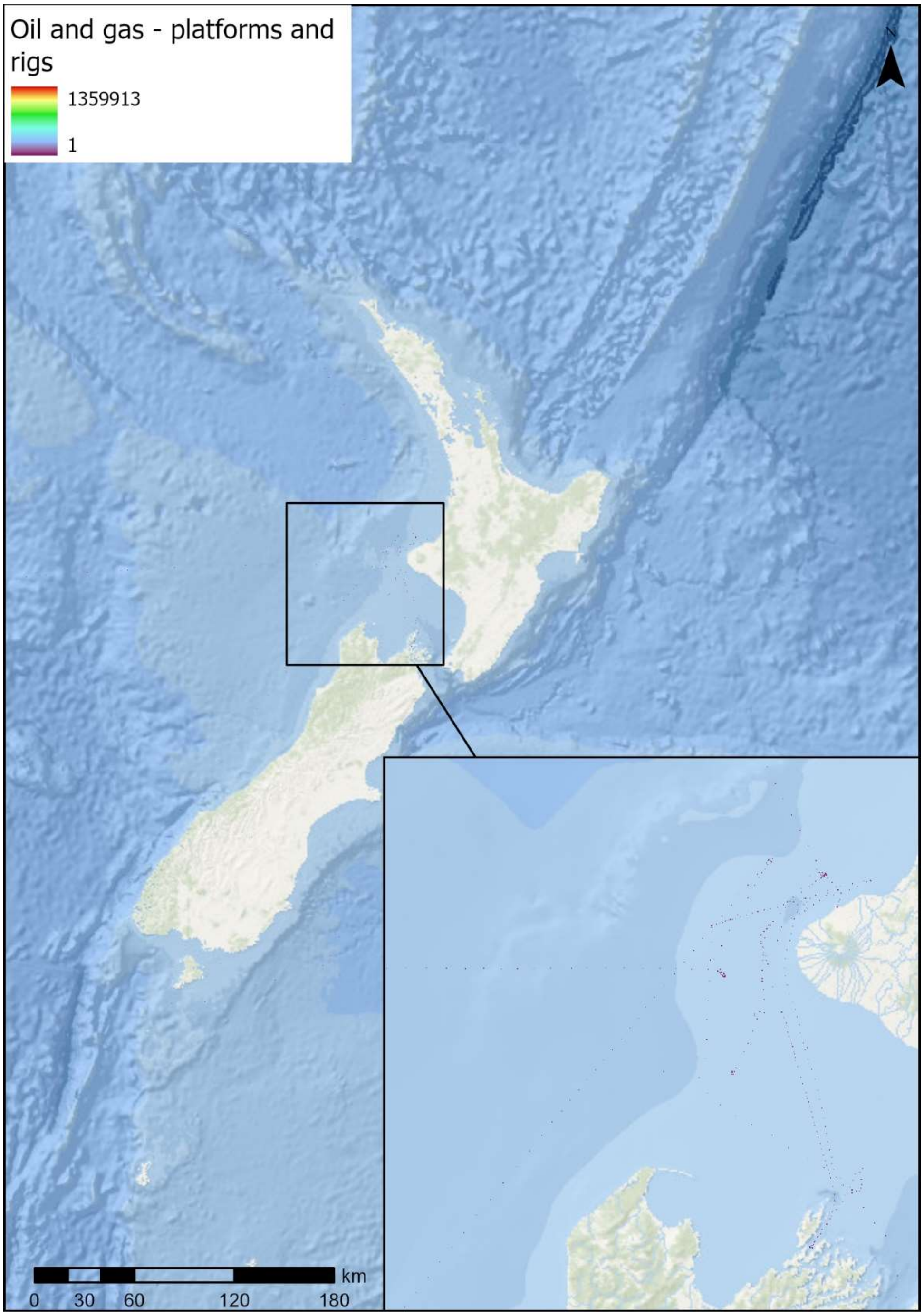

Figure 9-11: Shipping records from AIS tracking records for vessels associated with oil and gas platforms and rigs. Source: World Bank Group, obtained in partnership with the International Monetary Fund (IMF)'s World Seaborne Trade Monitoring System.

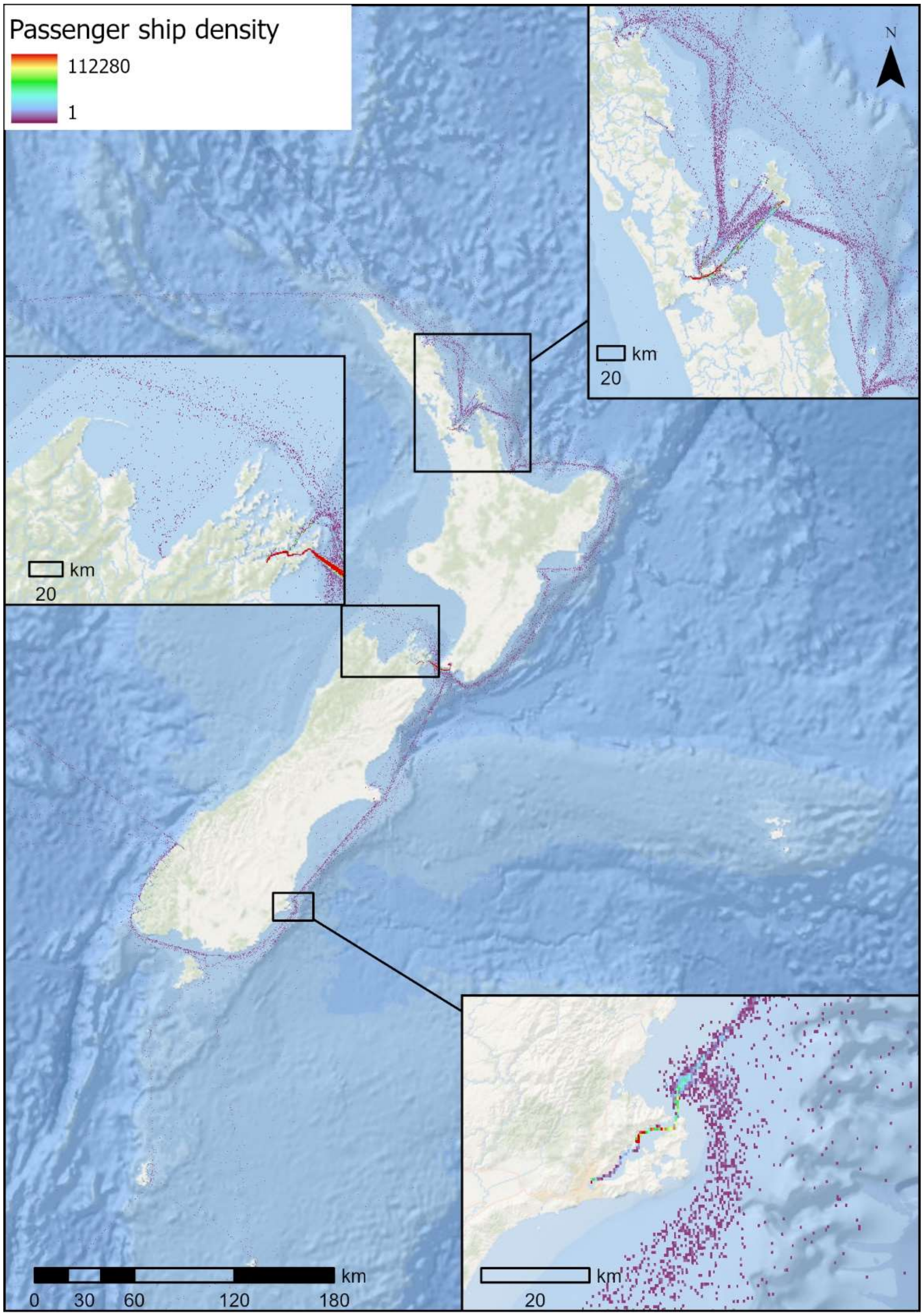

Figure 9-12: Shipping records from AIS tracking records for passenger vessels. Source: World Bank Group, obtained in partnership with the International Monetary Fund (IMF)'s World Seaborne Trade Monitoring System.

Shipping associated discharges

Ballast water regulations apply to all international entries to New Zealand waters and require discharge and/or treatment of all ballast water. Ships must record the time, date, volume and location of any ballast water discharge, and keep this information in the ship log for five years. While compliance is mandatory and may be checked upon entry into New Zealand waters, there is no database that holds the location of ballast water exchange. Individual ships would need to be interrogated to provide accurate data, though the Inter-Agency Working Group participants suggested that typical ballast water exchanges zones are known.

Waste disposal within the 12 nm limit is regulated by regional councils under the Resource Management Act (RMA). Waste disposal in the EEZ and Extended Continental Shelf are regulated by the EPA. Waste disposal on the high seas outside New Zealand's EEZ are regulated by the country under which a vessel is flagged. Garbage disposal restrictions apply within the Territorial Sea (to 12 nm). Food may be discharged beyond 3 nautical miles from shore if it is ground up, and vessel operators are prohibited from discharging cargo residues and cleaning agents if they are harmful to the marine environment. Lost fishing gear that poses a threat to the marine environment or is a navigation hazard must now be reported, in addition to recording these losses in the garbage record book or logbook. For sewage disposal, untreated sewage may not be discharged within 500 m from land, or in water less than 5 m deep; however, restrictions may vary based on regional council jurisdiction. There are fewer restrictions on the discharge of treated sewage. While actual discharge locations by recreational vessels are not required to be logged, the Inter-Agency Working Group participants suggested that typical disposal areas were often known to recreational users that complied with local regulations, and could potentially be used as a proxy for disposal stressor footprints.

9.4.3 Next steps

This dataset was determined to be complete with respect to the shipping footprint, and vessel type density maps were appropriate for assessing the stressor footprint. Data to further quantify shipping stressor footprints could be populated through risk analysis for particular species (e.g., cetaceans; (Constantine et al. 2015), but identifying specific biodiversity impacts were beyond the scope of this project. As per the project definition of Naturalness, datasets of potential risks of shipping such as oil spills were out of scope of this project as they were deemed to be activities that may never occur.

Data on discharges was of interest, but explorations did not find suitable datasets at regional or national scales. In the absence of official records of disposal locations for ballast water, sewage or rubbish, anecdotal evidence of primary locations of disposal near major centres were suggested as a potential proxy. It was noted at the Inter-Agency Working Group Workshop that there is a database on lost fishing gear, and Maritime NZ regulations confirm that lost fishing gear must be logged and reported. We did not find this dataset, but found categories of 'lost fishing gear' indicated within the fisheries TRAWL database including a category of Fishing (plastic and other).

10 Recreation and leisure

Four categories of activities were categorised as Recreation and leisure activities: 1) Coastal tourist sites (public beaches and resorts); 2) Ecotourism (whale watching, scuba diving etc); 3) Boating; and 4) Vehicle use on the foreshore. Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for each activity category (Table 10-1).

Evidence for links between Recreation and leisure activities and pressures on the marine environment has not yet been compiled within the aligned DOC project (linking activities to pressures) (Douglas and Lundquist 2025). Likely pressures associated with these activities include physical disturbance to habitats such as through dog walking and vehicles on beaches as well as disturbance to species that use these areas for roosting, feeding or nesting, and disturbance through vessel interactions with wildlife and through anchoring, vessel traffic and other associated activities discussed in other sections.

Table 10-1: Descriptions of layers compiled for the category Recreation & leisure.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Coastal tourist sites	Beach sites, surf beaches	ongoing	<1 km	Point	Incomplete	DOC/Visitor Solutions	Timing/extent
Ecotourism	Whale watch, dive sites	ongoing	1-10 km	Point	Complete	DOC/Visitor Solutions	Timing/extent, update providers
Boating	Recreational boat usage/anchoring	ongoing	>100 km	n/a	No	DOC/Visitor Solutions	Anecdotal proxy
Boating	Discharge areas	ongoing	>100 km	n/a	No	EPA/Regional authorities	Anecdotal proxy
Boating	Fishing clubs	ongoing	>100 km	Point	Complete	DOC/Visitor Solutions	Proxy
Boating	Recreational fishing effort	ongoing	>100 km	Raster	Complete	FNZ	Proxy
Vehicle use on the foreshore	Vehicle use	ongoing	<1 km	n/a	No	Regional authorities	Proxy from roads
	Roads	ongoing	<1 km	Polyline	Complete	LINZ	Proxy

10.1 Coastal tourist sites (public beaches and resorts)

10.1.1 Description

As defined by DOC, this activity category includes recreational activities where a vessel is not used, such as swimming, surfing and event type activities (e.g., beach clean-ups, festivals).

10.1.2 State of knowledge

Beach sites were assessed by a project funded by DOC on recreational use and values for the marine environment (Visitor Solutions 2012), including georeferencing of all beaches listed in various tourist guides, and a dataset for beaches that indicated presence of toilets, showers, carparks, picnic areas and other attributes. As part of the Sustainable Seas SPEXCET project, a dataset of carpark size associated with beaches was compiled as an indicator of beach popularity and use (Figure 10-1). The Visitor Solutions dataset also included georeferenced locations for surf life saving clubs, and recognised windsurfing and surf break areas.

10.1.3 Next steps

This dataset was determined to be incomplete. Beach use is seasonal, and no geospatial layer exists to assess stressor footprints from beach use. The beach carpark layer is a best proxy available to assess beach use. However, other activities associated with beach use, such as surfing and windsurfing, do not necessarily require carparks for access, and may be poorly represented by these proxy layers.

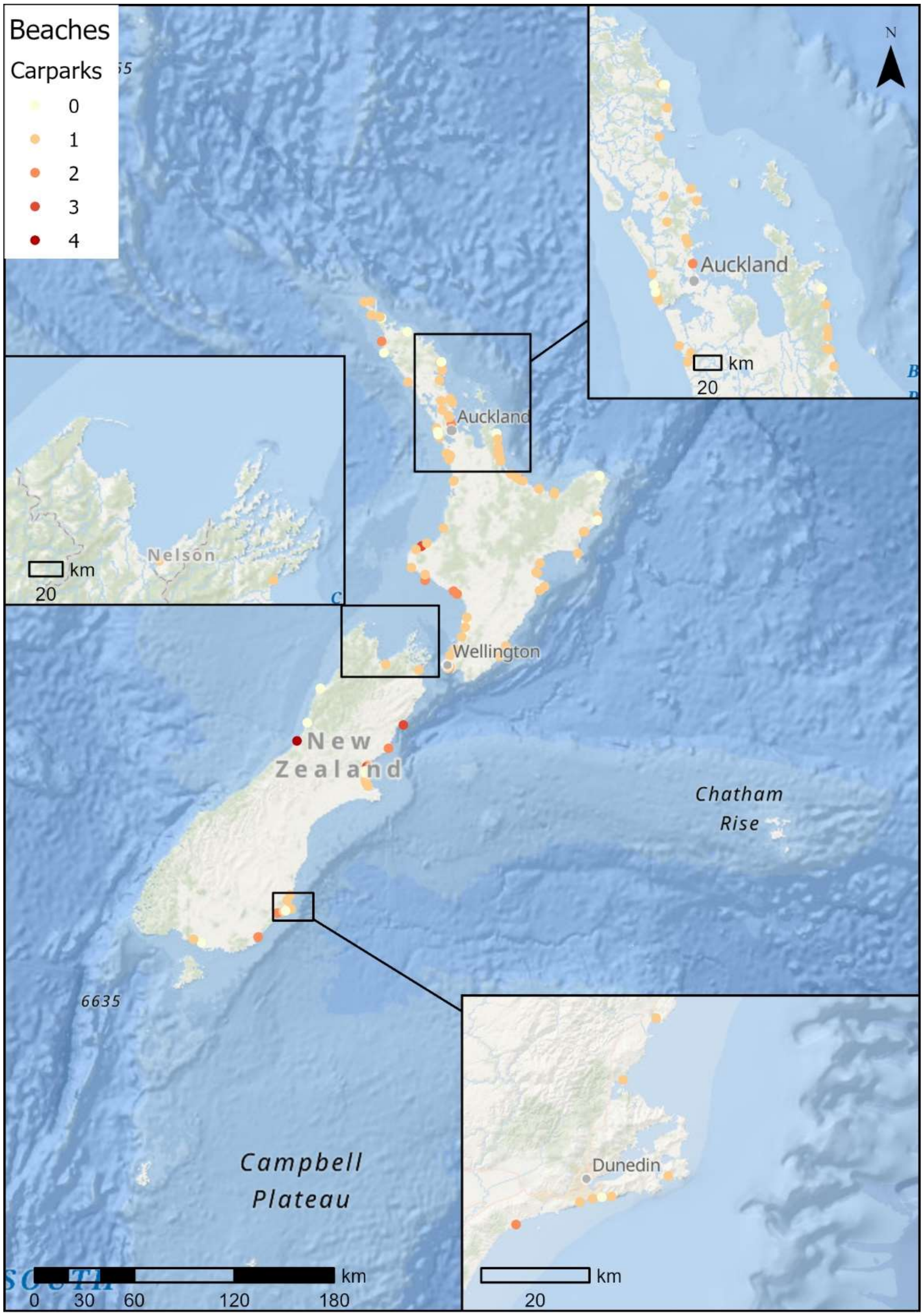

Figure 10-1: Beaches with extent of beach use indicated by carpark size. Based on layer acquired from Visitor Solutions (2012) for the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana.

10.2 Ecotourism (whale watching, scuba diving etc.)

10.2.1 Description

As defined by DOC, this activity category includes exploration and appreciation of marine environments while minimising environmental impact and promoting conservation. Examples include snorkelling and SCUBA diving, whale and dolphin watching, kayaking and paddle boarding, and marine biology tours. While recreational fishing is included within fishing activities (see Section 5), we also describe recreational fishing activities here, as it often occurs along with other eco-tourism activities.

10.2.2 State of knowledge

Ecotourism layers were acquired by a project funded by DOC on recreational use and values for the marine environment (Visitor Solutions 2012), including georeferencing of marine mammal tourism (not shown here), SCUBA diving sites (Figure 10-2) and SCUBA dive companies (not shown here).

10.2.3 Next steps

This dataset was determined to be sufficient for use in indicating locations of activities at a broad scale. Further details could be acquired on primary vessel routes used for marine mammal/whale watching activity and used to provide heatmaps of overlaps of vessels and marine mammals based on species distribution models, noting some surveys have occurred. It is likely that this information is provided as part of consent conditions for marine mammal ecotourism licenses.

Due to negative effects of high levels of vessel interactions (Curtin 2003), surveys of whale watch vessel interactions have been used to inform the total number of licenses granted to minimise disturbance to cetaceans by ecotourism. Other vessel interactions (e.g., cruise ships) can also result in negative interactions of eco-tourism/tourism on marine mammals. For example, a quadrupling of cruise ship visits and anchoring in Akaroa Harbour resulted in distributional shifts of Hector's dolphins to avoid cruise ship interactions (Carome et al. 2022).

As tourism providers were impacted by tourism during the pandemic, the number of whale watch operators should be updated, and surveys of their passenger size and number of weekly cruises, and how this varies seasonally, could be used to inform a stressor footprint.

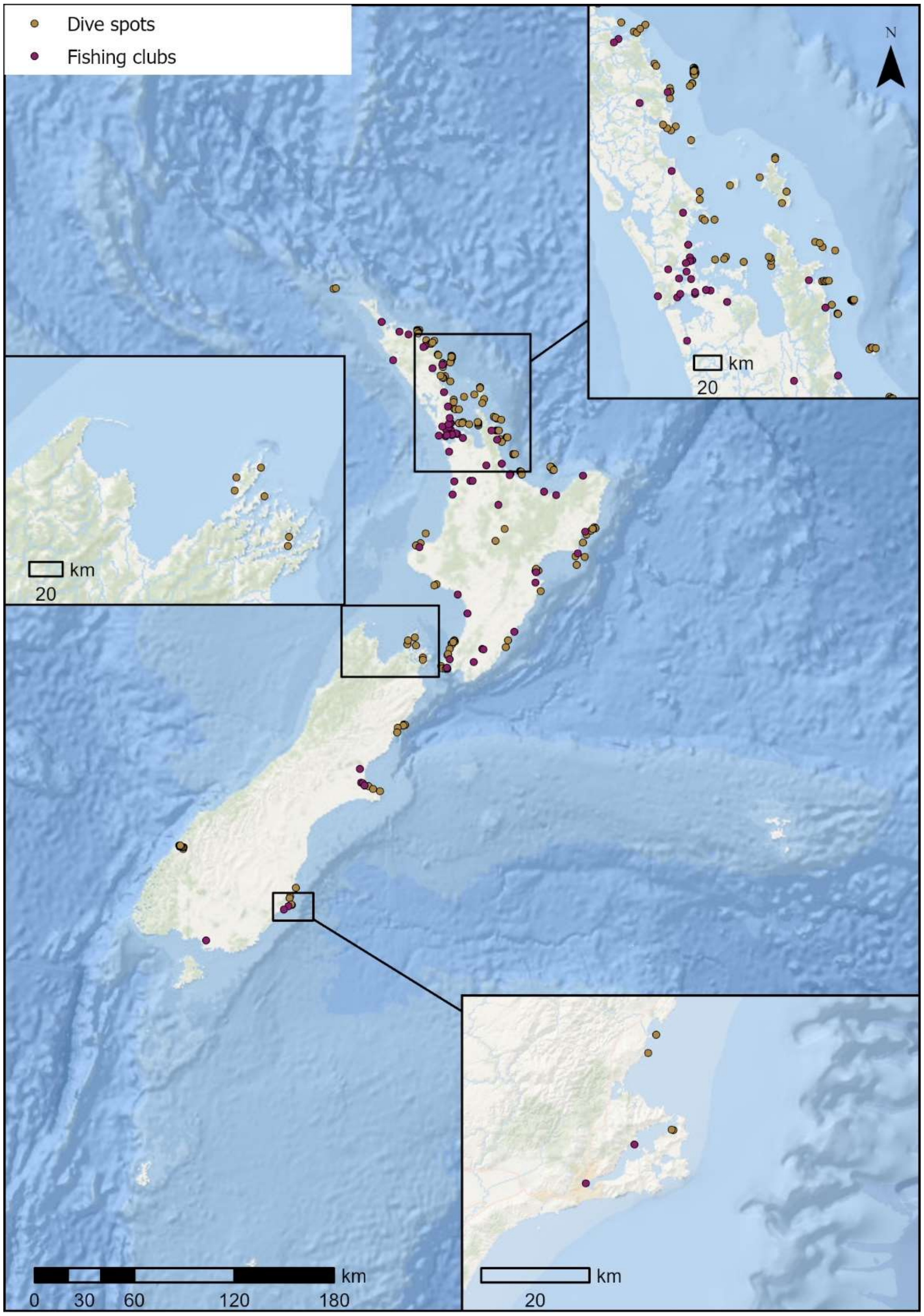

Figure 10-2: Dive spots and fishing clubs as indicators of recreational use. Based on layer acquired from the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana.

10.3 Boating

10.3.1 Description

As defined by DOC, this activity category includes recreating on a boat, and encompasses a wide range of activities, including cruising, sailing, motorboating, kayaking and canoeing, and yachting.

10.3.2 State of knowledge

Ecotourism layers were acquired by a project funded by DOC on recreational use and values for the marine environment (Visitor Solutions 2012), including georeferencing of fishing clubs (Figure 10-2), yacht clubs, boat trailer licenses, charter boats and other registered commercial vessels. Data points typically indicate popular coastal locations; boat licenses are correlated strongly with population size, indicating that they are not necessarily associated with local use of the coastal zone. Recreational fishing effort from two seasonal surveys was acquired from FNZ that provides spatial patterns of use by recreational vessels in the Hauraki Gulf and Top of the South regions (Figure 10-3).

10.3.3 Next steps

This dataset was determined to be incomplete, however limited information is available to represent recreational use and these datasets are the best available proxies.

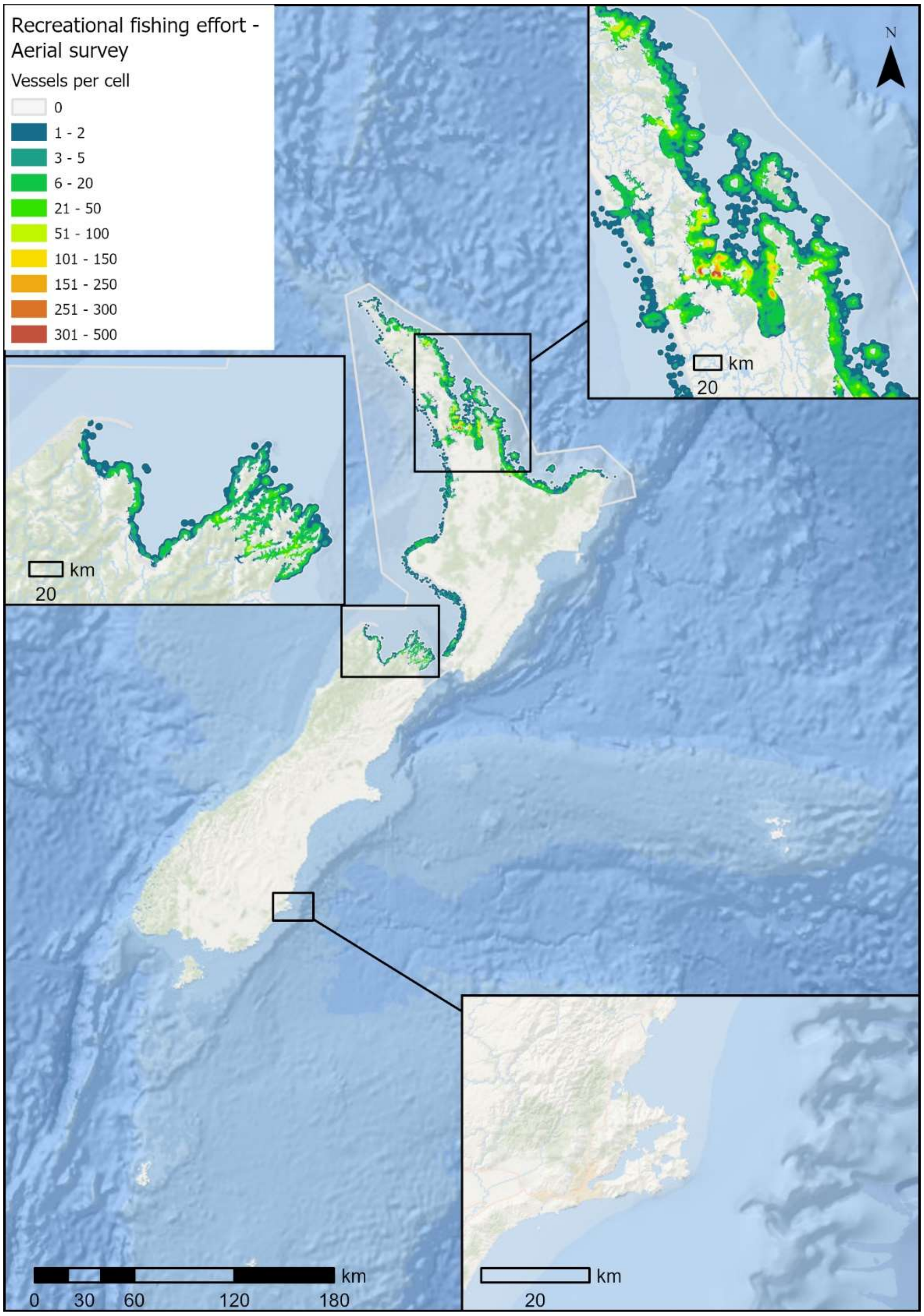

Figure 10-3: Recreational fishing use as indicators of recreational use. Based on layer acquired from FNZ for the Sustainable Seas geospatial tool Te Ukaipo o Hinemoana.

10.4 Vehicle use on the foreshore

10.4.1 Description

As defined by DOC, this activity category includes operation or parking of vehicles on the area of land that lies between the high and low tide marks along a coast. Vehicles can damage sensitive ecosystems, such as dunes and tidal flats, and disturb wildlife.

10.4.2 State of knowledge

Vehicle use on the foreshore is under the authority of regional councils, except for beaches within National Parks that are under the jurisdiction of the Department of Conservation.

Council maps will detail locations where vehicle use is prohibited within regional coastal plans, however no information was found that quantified vehicle use and disturbance in a geospatial layer. A recent study (Forest & Bird 2023) examined what public information and guidance was available, and rules, regulations or bylaws restricting or prohibiting the use of vehicles on beaches across local authorities. Unitary authorities may also have protective measures to regulate vehicle use on beaches (Figure 10-4).

10.4.3 Next steps

This dataset was determined to be incomplete, and the Forest & Bird (2023) exercise clarified that the information was typically not available, and that only one regional authority had staff whose specific role was to enforce vehicle regulations on beaches. The maps prepared by Forest & Bird (2023) indicate which authorities have sufficient regulations and enforcement, but for locations both with and without enforcement, there are no surveys that quantify vehicle use to inform a stressor footprint.

Figure 10-4: Map summarising regulations of vehicle use on beaches around Aotearoa New Zealand. Source: Forest & Bird (2023).

11 Marine research

Four categories of activities were categorised as marine research activities: 1) Physical sampling; 2) Remote sensing; 3) Seismic surveys; and 4) Sonar surveys. Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for each activity category (Table 11-1).

Potential pressures of marine species, habitat and ecosystems vary substantially between extractive activities like physical sampling (e.g., research trawls, grab samples, core samples), seismic and sonar surveys with acoustic pollution, and remote sensing activities that may have little impact on marine ecosystems. Evidence for links between coastal management activities and pressures on the marine environment have not yet been compiled within the aligned DOC project (linking activities to pressures, Douglas and Lundquist 2025).

Table 11-1: Descriptions of layers compiled for the category Marine research.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Physical sampling	Geophysical surveys (2007 - 2017)	one-off	>100 km	Polyline	Yes	EPA	Temporal impact, extent
Physical sampling	Scientific voyages/drilling	ongoing	>100 km	n/a	No	NIWA/Universities	Data extraction
Remote sensing	NIWA/University vessels	ongoing	>100 km	n/a	No	NIWA/Universities	Data extraction
Seismic surveys	Seismic surveys 3D (2009 - 2018)	one-off	>100 km	Polygon	Complete	NZPAM	Temporal impact, extent
Seismic surveys	Seismic surveys 2D (2009 - 2019)	one-off	>100 km	Polyline	Complete	NZPAM	Temporal impact, extent
Sonar surveys	LINZ seafloor mapping	one-off	>100 km	n/a	No	LINZ	Update indicative maps

11.1 Physical sampling

11.1.1 Description

As defined by DOC, this activity category includes physical sampling of the seabed, foreshore (intertidal) and/or water column in situ using a variety of marine survey techniques. It also considers the vessels, vehicles, and materials needed for these activities.

11.1.2 State of knowledge

Marine research activities have some requirements for reporting, with offshore activities regulated by the EPA. Scientific research that involves the collection of fauna, flora or sediment samples requires a collection permit from MPI, and reporting of location and quantity of samples on an annual basis. Scientific research in scientific reserves and marine reserves requires a permit, with similar reporting requirements to the Department of Conservation of any take of biological of physical specimens. Fisheries research trawls are available within the FNZ database hosted by NIWA and typically include counts and biomass of species collected.

11.1.3 Next steps

This dataset was determined to be incomplete, and was not compiled for this project due to extensive effort required to acquire and analyse data from different sources.

11.2 Remote sensing

11.2.1 Description

As defined by DOC, this activity category includes methods of obtaining data or images from a distance (e.g., from satellites, Autonomous Underwater Vehicles (AUV) or aircraft) and includes LIDAR. It also considers the vessels, vehicles, and materials needed for these activities.

11.2.2 State of knowledge

Airborne remote sensing includes both satellite and aircraft and drone surveys, including some used within the exploratory phases of extractive use permits (see Section 8.4). Vessel-based remote sensing primarily uses Remotely Operated Vehicles (ROVs), gliders or towed videos, supplemented by physical sampling for validation. NIWA maintains cruise records including survey locations from large vessel cruises on the Tangaroa, Kaharoa, and Kaharoa II. Video and still imagery is often analysed in the months to years after a voyage and is not always readily accessible.

11.2.3 Next steps

This dataset was determined to be incomplete, and was not compiled for this project due to extensive effort required to acquire and analyse data from different sources.

11.3 Seismic surveys

11.3.1 Description

As defined by DOC, this activity category includes any survey that uses airguns, including 2D/3D/4D and OBC (On Bottom Cabling) surveys and any similar techniques that use airguns. It also considers the vessels, vehicles, and materials needed for these activities.

11.3.2 State of knowledge

The majority of available data on seismic surveys were associated with hydrocarbon extraction in the exploration phase, which is reviewed in Section 8.4. Oil and gas infrastructure datasets were acquired from New Zealand Petroleum and Minerals (NZPAM) database for the Sustainable Seas SPEXCET project and uploaded to the Te Ukaipo o Hinemoana geospatial tool. This dataset includes locations of seismic surveys (2D and 3D), geophysical surveys and associated consents (Figure 8-3).

11.3.3 Next steps

This dataset was determined to be complete, though seismic surveys (2D) include dates from 2007-2017 and seismic surveys (3D) include surveys from 2009-2018. It should be confirmed if other seismic surveys have occurred since 2018, and whether these are available from NZPAM or other sources. Seismic surveys could be further analysed to assess their current or historical footprint, and to assess what proportion of exploration permits had been sampled. Information on individual surveys (e.g., month, year, survey tracks) could be used to define stressor footprints within exploration polygons, which are often large areas.

Sonar surveys are transient, and expected to be one-off stressor impacts, however vessels are often in a region for weeks to months to survey a region and which may have broader implications for migratory species impacted by acoustic pollution.

11.4 Sonar surveys

11.4.1 Description

As defined by DOC, this activity category includes the use of echo sounders underwater, for research or exploratory purposes as well as military purposes. It also considers the vessels, vehicles, and materials needed for these activities.

11.4.2 State of knowledge

Research vessels often use imaging systems like side-scan sonar or multi-beam ecosounders. Hydrographic survey coverage as part of LINZ's seafloor mapping programme is available from LINZ, with future survey and charting plans identified (https://www.linz.govt.nz/our-work/location-information/hydrographic-work-programme/hydrographic-survey). No information was found for other sources of sonar surveys such as military purposes.

11.4.3 Next steps

This dataset was determined to be incomplete, and was not compiled in this project due to the extensive effort required to acquire and analyse data from different sources to develop a stressor footprint. Sonar surveys are transient, and expected to be one-off stressor impacts through sound waves impacting fauna, however vessels are often in a region for weeks to months to survey a region which may have broader implications for migratory species impacted by acoustic pollution.

12 Defence and national security

One category of military activity was listed within the category of Defence and national security activities. Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for this activity category (Table 12-1).

Evidence for links between coastal management activities and pressures on the marine environment have not yet been compiled within the aligned DOC project (Activity pressure matrix evidence review) (Douglas and Lundquist 2025). A diversity of pressures is anticipated to be associated with military activities, including pressures such as vessel collisions, physical and acoustic disturbances.

Table 12-1: Descriptions of layers compiled for the category Defence and national security.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Military activities	Military operation zones	ongoing	>100 km	Polygon	Yes	LINZ	Confidential; temporal impact, extent
	Ammunition dumping areas	ongoing	>100 km	Polygon	Yes	LINZ	Confidential; temporal impact, extent

12.1 Military activities

12.1.1 Description

As defined by DOC, this activity category includes military exercises undertaken that involve the use of the sea surface (e.g., boats, surface explosions and surface target towing), water column (e.g., submarine use and diving) or seabed (e.g., installation and operation of seabed mounted equipment, seabed sampling and degaussing).

12.1.2 State of knowledge

Information was found online reflecting individual sites - for example, defence force weapon ranges in the Canterbury region, and military operations areas in the Kaipara Harbour. What appeared to be a comprehensive national layer of military operations areas was available from LINZ (Figure 12-1). Disposal sites for ammunition (as discussed in Section 4.4; Figure 4-2, Figure 12-1) were also acquired from the LINZ website.

12.1.3 Next steps

This dataset was determined to be complete, however it was unlikely that confidential information would be provided from the military to inform development of a stressor footprint layer to accurately describe spatial and temporal pressures within the large activity footprints.

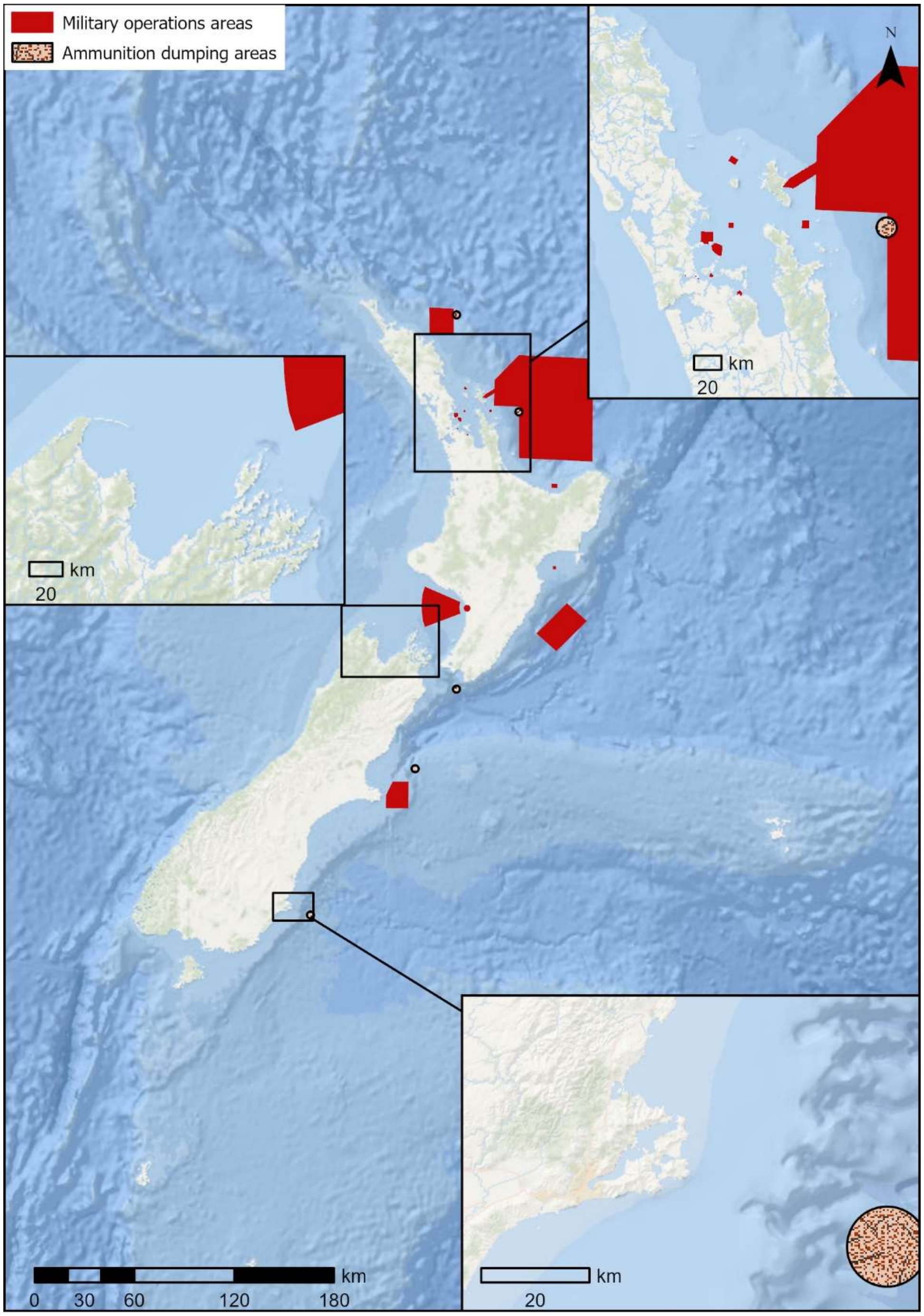

Figure 12-1: Military operations areas and ammunition dumping areas. Source: LINZ.

13 Other man-made structures

Four categories of activities were categorised as coastal management activities: 1) Submarine cables and pipelines - operations, maintenance, decommissioning; 2) Gas storage operations (carbon capture and natural gas storage); 3) Artificial reefs and other environmental structures; and 4) Cultural and heritage sites/structures (e.g., wrecks, archaeological sites etc.). Activities across the different stages of development of submarine cables were combined for this project. Below, we provide a description and summarise the state of knowledge and next steps for the dataset identified for each activity category (Table 13-1).

Evidence for links between coastal management activities and pressures on the marine environment were compiled within the aligned DOC project (linking activities to pressures, Douglas and Lundquist 2025). Primary pressures associated with this activity category were physical habitat loss and damage associated with construction phases, and electromagnetic and underwater noise impacts. Submarine cables, artificial reefs, and other structures, if left permanently, could serve as habitat-structure providers, and have positive impacts on marine biodiversity.

Table 13-1: Descriptions of layers compiled for the category Other man-made structures.

Activity	Data layers	Temporal scale of individual activities	Spatial scale of individual activities	Data format	Activity layer acquired	Source	Next steps to convert to stressor footprint
Submarine cable and pipeline laying, burial and protection	Submarine cable zones	ongoing	>100 km	Polygon/Polyline	Complete	LINZ, NZPAM	Buffer
Submarine cable and pipeline operations and maintenance	Submarine pipelines	ongoing	>100 km	Polygon/Polyline	Complete	LINZ, NZPAM	Regular update
Submarine cable and pipeline decommissioning	Submarine pipelines decommissioning	ongoing	<1 km	Polygon/Polyline	Complete	LINZ, NZPAM	Regular update
Gas storage operations (carbon capture & natural gas storage)	unknown	unknown	n/a	n/a	n/a	Emerging industry	Gas storage operations (carbon capture & natural gas storage)
Artificial reefs and other environmental structures	one-off	<1 km	Point	Point/Polygon	Incomplete	Regional authorities	Data extraction
Cultural & heritage sites/structures	Shipwrecks	ongoing	<1 km	Point	Yes	LINZ	Add missing wrecks
	Archeological sites	ongoing	<1 km	Point	No	NZ Archaeological Association	Available with subscription

13.1 Submarine cables and pipelines – laying, burial and protection; operations and maintenance; decommissioning

13.1.1 Description

As defined by DOC, this activity category includes the laying of cables and pipelines. Methods vary depending on the water depth and include laying either directly on the seabed, covered with material for protection, or buried. Seabed trench excavation through ploughing and hydraulic jetting is frequently used for burial. Protection can also be added where there is a reasonable risk of damage by rock placement on the seabed over the cable or pipeline. This activity also includes the retrieval or access of cables and pipelines for repairs or maintenance and their replacement following maintenance. The activity also includes vessel movement and anchoring during construction, operation and maintenance, and the removal or decommissioning of a cable or pipeline when it is no longer needed. When removal is deemed appropriate, cables and pipelines may be retrieved through grabbing and raising.

13.1.2 State of knowledge

Data on locations of submarine cables and pipelines were extracted from LINZ and from NZPAM databases (Figure 13-1). These datasets appear complete, and reflect telecommunications cables as well as submarine cables supporting hydrocarbon extraction. Stressor footprints for submarine cables include primarily the construction phase, with potential for cable zones to have positive benefits through reduction of other stressors because of restrictions on activities that might disturb the seafloor in the vicinity of buried cables.

13.1.3 Next steps

This dataset was determined to be mostly complete, noting that some hydrocarbon submarine cables should be removed from the database following recent decommissioning of the Tui oil field and its associated cables. Cable movement does happen, primarily associated with large seismic events, requiring further maintenance to repair cables, and potentially also resulting in localised disturbance where cables are impacted. These events could be noted in describing event-based footprints; understanding the magnitude of typical seasonal and annual movements in cables could also be used to identify a buffer zone of distance from a cable where scouring is likely to occur.

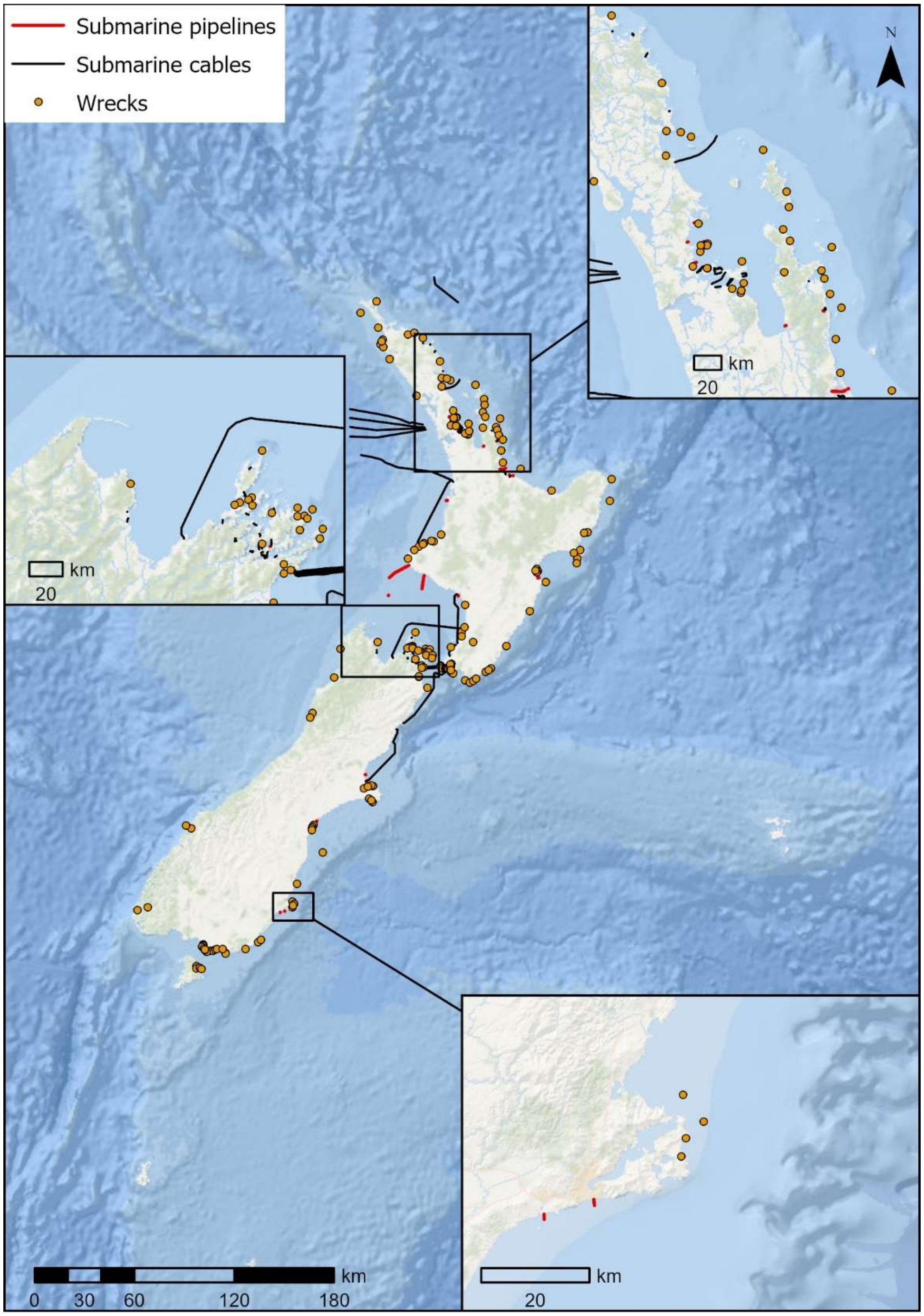

Figure 13-1: Other man-made structures including Submarine pipelines, Submarine cables, and Wrecks.
Source: LINZ and New Zealand Petroluem and Mining (NZPAM)

13.2 Gas storage operations (carbon capture and natural gas storage)

13.2.1 Description

As defined by DOC, this activity category includes gas injection into submarine storage sites, often referred to as subsea gas storage. It includes injecting gases like carbon dioxide (CO_2) or natural gas into geological formations beneath the seabed for both carbon capture and storage (CCS) and natural gas storage. It also considers the vessels, vehicles, machinery and materials needed for these activities

13.2.2 State of knowledge

This is an emerging industry that is not yet present in New Zealand.

13.2.3 Next steps

This dataset was determined to be non-existent and should be updated if this activity is permitted. An MBIE Endeavour Programme application was submitted by NIWA in the 2025 funding round to explore the potential of the industry for New Zealand, and if successful, could facilitate the industry's emergence.

13.3 Artificial reefs and other environmental structures

13.3.1 Description

As defined by DOC, this activity category includes human-made artificial reefs and other environmental structures that are placed underwater to promote marine life. They are specialised structures designed to mimic natural reef formations. They can be made from a variety of materials, including concrete, steel, tires, natural materials (e.g., rocks, shells), and can sometimes include sunken vessels. This activity also considers the vessels, vehicles, machinery and materials needed for the placement and maintenance of artificial reefs

13.3.2 State of knowledge

Artificial reefs are an emerging conservation measure in New Zealand. Evidence of artificial reef construction was found for the Hawke's Bay and Wellington regions through media articles and community group descriptions, but no spatial layers were available. Hawke's Bay artificial reefs were built through a partnership between Napier Port and LegaSea Hawke's Bay, a recreational fishing group, with the first reef located 1.4 km northeast of Pania Reef, and created from deposition of 15,000 tonnes of limestone. The second Hawke's Bay reef was created at the site of a shipwreck with additional deposition of 1400 tonnes of limestone. Limestone was repurposed from the dismantled wall at Napier Port. Construction of a third artificial reef was scheduled to commence in May 2024 in Wellington Harbour as part of the Petone to Ngauranga walking and cycling pathway and is described as consisting of 54 concrete pyramids on the western side of the harbour that will replace the natural rocky reef that will be lost during the building of the cycling and walking track. Mussel reef restoration (another form of artificial reef) is discussed in Section 6.3.

13.3.3 Next steps

This dataset was determined to be incomplete, with limited information available, mostly from media, on these artificial reefs. Regional councils should be contacted to confirm timing and extent of activities, and to confirm geospatial layers of the activities. In the case of the Wellington construction this activity would be associated directly with an activity involving land reclamation.

13.4 Cultural and heritage sites/structures (e.g., wrecks, archaeological sites etc.)

13.4.1 Description

As defined by DOC, this activity category includes the presence of wrecks and archaeological sites.

13.4.2 State of knowledge

Shipwrecks were compiled as part of the ecotourism layers acquired by a project funded by DOC on recreational use and values for the marine environment (Visitor Solutions 2012). An updated version was acquired from the LINZ 'Wreck' database (Figure 13-1). Some sites, such as the Rainbow Warrior wreck, have significant visitors due to its value as a SCUBA dive location.

Archaeological sites have been compiled by the NZ Archaeological Association (NZAA). Public maps of sites are available on their geospatial server (https://nzaa-archsite.hub.arcgis.com/pages/public-map) and include 1000s of locations primarily on New Zealand's coastline. Access to more precise locations, accuracy and known-extent polygons are available from the NZAA upon subscription, which was determined to be out of scope of this project.

13.4.3 Next steps

The shipwreck dataset was determined to be sufficient, though any new wrecks should be added. For example, we note that the Rena wreck on Astrolabe Reef in the Bay of Plenty is not included in this dataset. Archaeological sites could be further detailed and linked to those that are associated with high levels of eco-tourism.

14 Recommended approaches for cumulative biodiversity risk assessment

This project's aim was to develop spatial layers representing activity and stressor footprints. This is the first step within the broader programme of defining Naturalness which links pressures from human activities to impacts on species, habitats, and ecosystems. Figure 1-1 illustrates the broader process of informing the Key Ecological Areas Naturalness criterion, and the additional steps required to fully achieve this representation. An aligned DOC project (linking activities to pressures, Douglas and Lundquist 2025) has initiated work on Step 2 of this process, and is populating a pressure-biodiversity matrix to identify which components of biological diversity are impacted by each pressure.

The key output of this project (Step 1 in Figure 1-1) is the exploration and acquisition of data available to represent different aspects of Naturalness. A suite of layers providing spatially-explicit representations of stressor footprints derived from human activities (e.g., sedimentation and nutrient inputs, disturbances to the seafloor) was compiled.

To progress later steps in informing Naturalness (Figure 1-1), stressor layers will be integrated with biodiversity layers. The project team have collated spatial biodiversity data at the species, community, habitat, and ecosystem scales for past projects (e.g., Key Ecological Areas projects, Sustainable Seas National Science Challenge). Such data can be integrated into biodiversity impact assessments for each stressor footprint, and are reviewed here.

14.1.1 Biodiversity, habitat and ecosystem datasets

To inform a statistical approach to assessing biodiversity impacts, NIWA has created or collated data across these broad categories of biological diversity:

- Species distribution models:
  - Atlas of seabed biodiversity, containing 583 species distribution models of multiple taxa for the EEZ and coastal areas (Lundquist et al. 2020, Stephenson et al. 2023).
  - Cetacean species distribution models (30 species and species groups) (Stephenson et al. 2020).
  - Vulnerable marine ecosystem indicator taxa (Bennion et al. 2024a, Stephenson et al. 2024, Stephenson et al. 2021b).
  - Protected coral species and hotspots (Anderson et al. 2023).
  - Species distributions for two future climate scenarios (SSP3 - 7.0 and SSP2 - 4.5) and for two future periods (2050 – 2100) for ~ 60 species including biogenic habitat-forming invertebrates, other sponges, kelps, threatened macroalgae, corals, demersal fish and cetaceans) via DOC contract DOC25206: Species Distribution Models in future climate change scenarios: a management approach (Brough et al., 2025a).
  - Finer resolution species distribution models, at a local or regional scale, for certain areas around New Zealand's coastline (e.g., Bennion et al. (2024b)).

- Predicted seafloor invertebrate species richness: macroecological model of seafloor invertebrate species richness in New Zealand waters for the EEZ and coastal areas (Brough et al. 2025b).
- Species level point records of occurrence and abundance: Extensive in-house databases containing spatially-explicit occurrence records for thousands of marine taxa within the NIWA invertebrate database and macroalgae database (including data records held on behalf of Te Papa and Auckland Museum), NIWA extractions from OBIS and iNaturalist, and records in the trawl and cod databases that NIWA hosts and maintains on behalf of FNZ.
- Community level: Seafloor Community Classification (SSC) at the EEZ scale (Stephenson et al. 2021a) could be used as a proxy to infer unique community types for deepwater seafloor habitats where limited data is available.
- Habitat and ecosystems:
  - Collated habitat data for *Te Ukaipo o Hinemona* tool, including coastal and biogenic habitats and naturally uncommon ecosystems; many of these datasets were collated to support the DOC-funded Key Ecological Areas projects.
  - The development of layers representing Naturally uncommon marine ecosystems is currently being progressed under investigation in DOC investigation NOF-BIO-624.

14.1.2 Biodiversity impact assessment approaches

Many approaches are available for impact assessments and several approaches to quantify or qualify stressor impacts on biodiversity were presented to the Inter-Agency Working Group and the Project Advisory Group: 1) a statistical approach using modelled relationships between stressors and biodiversity; 2) spatial vulnerability of different biodiversity aspects – e.g., overlap of sensitive habitats or areas of high biodiversity with highly stressed areas; 3) expert-informed, trait-based impact assessments – utilising NIWA taxonomic experts and sub-contracted subject-based experts from the University of Auckland; and 4) a combination of these approaches depending on data scale and availability.

The most common approaches in marine ecosystems for assessing cumulative effects of multiple stressors are based on early approaches that synthesised datasets on anthropogenic drivers of ecological change (Halpern et al. 2014, Halpern et al. 2008). New Zealand applications of this approach quantified combined impacts on a suite of marine ecosystems through expert scoring procedures to assess the potential consequence of an activity, and the likelihood of that activity occurring (MacDiarmid et al. 2011b). These approaches provide rapid assessments; however, they are often criticised for over-weighting some future stressors (e.g., climate change) above existing stressors with high likelihood of negative impacts.

Other approaches have explored overlaps between activity layers and biodiversity features of interest, noting areas where conflicts arise that suggest management action is required to mitigate stressors from activities. Typical outputs of spatial decision support tools take this approach, developing prioritisations that minimise overlaps between conservation features and features associated with social or economic activities (Bennion et al. 2023, Lundquist et al. 2021, Rowden et al. 2019). These approaches can be performed using geospatial software or prioritisation algorithms to inform where stressors are most likely to impact on marine biodiversity features.

Species distribution model approaches can also be modified to include stressor layers, such that models are tuned with both environmental drivers and stressors, allowing predictions for both present, historical and future conditions of stressors/environmental conditions (e.g., fishing stressors or climate-related stressors) based on known correlations between biodiversity features and individual drivers (Brough et al. In review). These approaches are correlative, and rely on assumptions that species will not adapt in future as environmental conditions change, and that relationships between environmental drivers/stressors and biodiversity can be accurately characterised in these model approaches. These approaches are often criticised due to the lack of mechanistic inclusion of stressor responses, and data on biodiversity features are often represented by occurrence or habitat suitability rather than abundance. Other more complex models pair correlative and mechanistic approaches, allowing inclusion of biological interactions, life history stages and population dynamics to provide more realistic predictions of responses to one or more environmental stressors.

Climate change vulnerability assessments (CCVAs) (Brumby et al. 2024, Cummings et al. 2021, Foden et al. 2019) provide frameworks that are used to characterise the degree of risk faced by aquatic threatened species and ecosystems with respect to climate change stressors. The risk assessment provides a prioritisation that can be used to guide additional research and management (Brough et al. 2025a). The expert-driven framework provided by CCVAs could be adapted for a risk assessment of Naturalness. The approach provides a rapid assessment of vulnerability to climate change (or other stressors, based on the assessment of species traits under three vulnerability dimensions (Sensitivity, Exposure, Adaptive Capacity) under different climate change emissions scenarios and time periods. This approach has been tested on functional groups of marine invertebrates and macroalgae (Cook et al. 2024). In that project, CCVAs were carried out for 83 groups considering 33 traits, including exposure traits for predicted environmental change across two climate change scenarios SSP2 (4.5) and SSP3 (7.0) for two time periods (2050 and 2100). The taxon groupings included 8 bryozoans, 18 corals, 10 crustaceans, 12 echinoderms, 17 macroalgae, 10 molluscs and 8 sponges. Generally, it was found that the traits captured most of the vulnerabilities that benthic marine taxa face in the context of climate change. However, there were recommendations for the consideration of additional traits or updating existing trait definitions to provide more context and specificity for particular impacts, such as including additional information on life history stages, range shifts, sensitivity to other stressors, interactions with other species, habitat specialisation, exposure traits and adaptive capacity. Despite these recommended changes, the species experts involved in this project considered the framework was well suited for providing expert-driven risk assessments for marine species. With some additional considerations (e.g., review of the traits used to characterise risk), the CCVA framework could inform the expert-driven assessment of risk across a broad range of stressors from marine activities, and could be undertaken at various taxonomic levels to improve efficiencies (i.e., functional groups rather than species level assessments).

Some impact assessment approaches can draw from both statistical models, in addition to expert input, to account for a lack of data on species and habitat responses to impacts. For example, the relative benthic status (RBS) approach used for developing spatial datasets representing fishing impacts for specific species or morphotaxa (Pitcher et al. 2017) is often performed by drawing on expert input to derive values for depletion rates (*d*; how depleted a species or habitat is by a given magnitude of impact, usually a single trawl) and recovery rates (*r*; taxon-specific recovery rate after impact after a given amount of time) (Anderson et al. 2024). These flexible approaches highlight that despite limited data availability for some species, habitats and/impacts, it is still possible to conduct robust impact assessments.

There has been recent research funded by Sustainable Seas that has focussed on using stressor and ecological response footprints to inform cumulative effects and coastal ecosystem management (Low et al. 2023, Gladstone-Gallagher et al. 2023, 2024). To date this work has largely been theoretical, however progress has been made towards developing a spatial tool for estuary management (Lam-Gordillo et al., unpublished manuscript).

15 Discussion

15.1 General

This project has explored and acquired data available to represent different aspects of Naturalness, in order to properly estimate and report on the ecological state of the marine environment to inform and evaluate marine ecosystem management. The project scoped existing layers from research projects from central government, NIWA and Sustainable Seas that had acquired or developed layers providing spatially-explicit representations of human activities and of stressor footprints derived from human activities (e.g., sedimentation and nutrient inputs, disturbances to the seafloor), and developed new layers for those prioritised by the Project Advisory Group and Inter-Agency Working Group. On the roadmap to developing spatial datasets that represent Naturalness, this project therefore aimed to fulfil Step 1: mapping activities and identifying and prioritising gaps (Figure 1-1).

Marine activities that impact on Naturalness were allocated to 56 categories of activities within 11 themes: 1) Coastal management activities; 2) Waste management activities; 3) Extraction of living resources; 4) Production of living resources; 5) Extraction (and disposal) of non-living resources; 6) Energy generation; 7) Transport; 8) Recreation and leisure; 9) Marine research; 10) Defence and national security; and 11) Other man-made structures. The comprehensive list of 56 activity categories was used to guide the prioritisation and acquisition of available data to represent each category, although data was not available to populate all activity categories. Further analyses to convert spatially-explicit layers of activities to spatially-explicit representations of their stressor footprint were explored and prioritised within the project budget based on data accessibility and comprehensiveness, and time required for data conversions. Generating stressor footprints from activity maps would fulfil Step 2 (Generating stressor footprints) on the roadmap (Figure 1-1). Work which was concurrently running over the course of this project linked activities to pressures that are likely to have negative impacts on biodiversity (Douglas and Lundquist 2025), while future work is planned to link the pressures from these activities to species, habitats, and ecosystems. Combined, this linkage work would fulfil Step 3 (Linking activities to pressures, and pressures to biodiversity) on the Naturalness criterion roadmap (Figure 1-1). When the first three steps are complete, stressors could be combined (i.e., cumulative impacts) as suggested in Step 4 (Cumulative stressors for use in marine spatial planning) to develop a comprehensive spatially-explicit representation of Naturalness for New Zealand's marine system, including impacts from fisheries and climate-related stressors for use in marine spatial planning processes (Figure 1-1).

The information presented in and underpinning this report represents a significant increase in datasets with which to populate the KEA Naturalness criterion for the MSAG work programme. Activity categories were coordinated with aligned projects funded by DOC, thus ensuring consistency with respect to how activities were defined. The stepwise procedure introduced here provides guidance for the complex process required to develop a suite of layers representing Naturalness, including datasets of activities, evidence linking activities to potential pressures, and quantifying impacts of pressures on species, habitats and ecosystems.

Priorities for acquisition or development of geospatial activity layers in this project were assigned primarily based on two key criteria: 1) ease of obtaining accurate data; and 2) perceived importance within a comprehensive spatially-explicit representation of Naturalness (based on extent and/or magnitude of pressure produced by a given activity).

To progress this work towards a comprehensive spatially-explicit representation of Naturalness, acquisition of remaining activity datasets should now be 1) linked to pressures, then 2) said pressures should be linked to biodiversity, and 3) combined with impacts from fisheries and climate-related stressors (see steps in Naturalness criterion roadmap in (Figure 1-1).

15.2 Data limitations and considerations

The list of activities compiled here to represent potential impacts on marine ecosystems has been populated using best available data, and has noted a number of datasets for which proxies may be more suitable to provide sufficient information to develop stressor footprints. Proxy layers have been suggested where extensive effort would be required to acquire datasets to populate and describe activities in a geospatial format. Metadata has been provided, including sources and when datasets were last updated, to assist in maintaining an up-to-date database of marine stressor activities.

15.3 Long term data storage, maintenance and accessibility

Engagement with the Inter-Agency Working Group emphasised the desire for access to the layers compiled by this project. As part of aligned work by NIWA strategic science investment funding, and building on a prior project in Sustainable Seas (Phase II Project 1.2, Spatially Explicit Cumulative Effects tools; SPEXCET), a publicly accessible geospatial tool was created, entitled Te Ukaipo o Hinemoana (https://niwa.co.nz/te-ukaipo-o-hinemoana). While not an output of this project, we have updated many of the original layers on this geospatial tool to reflect layers compiled in this project. Regardless, long-term data storage and maintenance of these layers should be explored, given consideration to what types of features a suitable platform should deliver.

The tool has recently (April 2025) been migrated to ArcGIS Online. This tool provides visual access and links to sources to allow for access to raw data as well as metadata and basic descriptions of datasets, caveats and assumptions for their use. In addition, the DOC Marine Geoportal (https://doc-marine-data-deptconservation.hub.arcgis.com/) hosts many relevant biodiversity datasets resulting from the Key Ecological Areas programme, particularly individual species distribution model outputs.

16 Acknowledgements

We thank Pierre Tellier and Michael Bates for facilitating collaboration with the Ministry for the Environment, and Shane Geange and Karen Tunley for assistance with alignment across other Key Ecological Areas and stressor contracts, and feedback on the structure and content of this report. We thank members of the DOC-FNZ-MfE Project Advisory group for input and guidance on stressor prioritisation and acquisition of data layers, and for feedback on the structure and content of this report. We acknowledge the contributions of Judi Hewitt, Conrad Pilditch, and Inter-Agency Working Group participants from central and regional government who provided input on the concept of naturalness, and data layers that could be acquired. We also acknowledge Katie Cook who initiated the contract. We acknowledge members of the Fisheries New Zealand Aquatic Environments Working Group (AEWG) and Biodiversity Research Advisory Group (BRAG) for their input on presentations on methodology and outputs provided to the working groups. Finally, we thank Phil Heath and Kimberley Seaward for providing input to specific activity categories in the report, Jo Downey for editing this report and Vonda Cummings and Michael Bruce for reviewing its content.

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Appendix A Agenda of Inter-Agency Working Group workshop on naturalness

Date/time: 14 August 2025, 9am - 1pm

Location: Hybrid, with in person option at NIWA Wellington campus, Brodie Board room

Project background:

The Ministry for the Environment has recently awarded a contract to NIWA for a project entitled "Spatial information to assess naturalness in marine habitats". The purpose of the project is to develop spatial layers which map human-induced stressor footprints and quantify impacts to biodiversity. Collectively these spatial layers (and other stressors developed in aligned projects) inform a spatially explicit indication of naturalness (the degree to which an area is pristine and characterised by native species with an absence of perturbation by human activities and introduced or cultured species). As part of the project, NIWA will be interacting with an Inter-Agency working group to review datasets and approaches to be taken.

Participants:

Michael Bates (MfE), Pierre Tellier (MfE), Shane Geange (DOC), Karen Tunley (MPI), Rachel Corran (MfE), Paula Warren (DOC), Karen Bell (DOC), Greig Funnell (DOC), Andrew Baxter (DOC), Lyndsey Holland (DOC), Julia Moloney (EPA), Ruby Leverington (EPA), Abraham Growcott (FNZ), Jean Davis (FNZ), William Gibson (FNZ), Carolyn Lundquist (NIWA), Matt Bennion (NIWA), Tom Brough (NIWA), Eva Leunissen (NIWA), Nidhi Yogesh (NIWA); Apologies: Cassie Callard (FNZ)

Agenda topics

- Stressor footprints datasets
  - Stressor footprint datasets currently available to populate maps of those stressor footprints.
  - Stressors in/out of scope.
  - Gaps in data availability.
  - Priorities for further data acquisition.
- Overarching stressor data decisions
  - Extent of maps (i.e., EEZ, coastal scale), resolution of maps (i.e., 1 km grids), data type (i.e., raster, polygon, point).
  - Approach to combine data to make grouped stressor layers (for example, how to appropriately combine point records of multiple different non-native species to make a single 'invasive species' footprint layer).
  - What time periods will be mapped (i.e., historical and current footprints, temporal impacts of various stressors whether permanent or transient).
- Biological diversity to be assessed for 'stressor impacts'.

- Extent, resolution, and data type of maps relative to interactions with stressor layers.
- Discussion of potential approaches to quantify stressor impacts on biodiversity, including expert- informed qualitative biodiversity risk assessments.
- Prioritisation of biodiversity elements for stressor impact assessment (with respect to available budget).

- Further steps informing a naturalness layer
  - Long-term approach to bringing together these and other stressors to inform overall naturalness.