Evaluating Key Ecological Areas datasets for the New Zealand Marine Environment

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Prepared by:
Carolyn Lundquist, Fabrice Stephenson, Lisa McCartain, Stephanie Watson, Tom Brough, Wendy Nelson, Kate Neill, Tara Anderson, Owen Anderson, Richard Bulmer, Eleanor Gee, Matt Pinkerton, Ashley Rowden, David Thompson

For any information regarding this report please contact:

Carolyn Lundquist
Principal Scientist
Marine Ecology
+64-7-859 1866
carolyn.lundquist@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
PO Box 11115
Hamilton 3251
Phone +64 7 856 7026

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	Reviewed by:	Judi Hewitt
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Executive summary

The Department of Conservation (DOC) contracted NIWA to evaluate and assess the comprehensiveness of key ecological area (KEA) datasets prepared under DOC Investigation no. 4735, and newly available data, against the KEA criteria. These datasets were selected to satisfy one or more key ecological area criteria: 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 Productivity; 6) Biological Diversity; 7) Naturalness; 8) Ecological Function; and 9) Ecological Services. For each of nine key ecological area criteria, datasets were evaluated for their spatial and taxonomic comprehensiveness, uncertainty (particularly for modelled layers), and gaps. Input to the initial evaluation was provided by the Marine Science Advisory Group (MSAG) at a workshop with MSAG on 16 August 2019.

Following evaluation and identification of gaps, some new datasets were acquired, including relevant datasets produced subsequent to the publication of the Stephenson et al. (2018b) report, and datasets in development as part of concurrent MSAG projects. Additional datasets that could fill gaps in the key ecological areas' datasets, but were beyond the scope of the project, were also identified, as well as further analyses that could enhance the relevance of particular datasets to the objectives of this project.

This evaluation suggests that criteria that can be informed by taxon-based datasets are most comprehensive, and point records are available for most taxonomic groups. Data availability differs substantially between taxonomic groups, with extensive datasets available for cetaceans, fish, invertebrates, and macroalgae being large enough to support development of species occurrence models for a subset of species. The demersal fish data support the most robust models, and absence data (required for all models used) can be inferred from sampling locations where other species were observed. Models are less robust for invertebrate groups, with fewer available point records for species, and sample size sufficient only for analyses at the resolution of genera. Models of rocky reef taxa (fish and macroalgae) have some limitations as models are limited to areas which contain shallow marine reef habitats, and potential that they may be poorly represented by environmental variables at coarse resolutions. For modelled groups (benthic invertebrates, macroalgae) that include a variety of sampling methods, the interpretation of species absences is complex, such that an absence could mean a species was not at the locality, that not all species collected were recorded, or that it was not detectable due to the sampling gear used. An updated compilation of seabird and shorebird records, and seal and sea lions' records based on regional council significant ecological areas have substantially increased the data available for these taxonomic groups. Very little data is available to inform pelagic and deep-water (>2000 m) taxa and habitats.

Few datasets were available that apply to criteria of Biological Primary Productivity, Ecological Function, and Ecological Services, and many of the datasets were identified as proxies rather than true representations of these criteria. Datasets identified for each of these criteria often overlap with other criteria, requiring careful consideration of how these datasets are used in spatial prioritisation models. Datasets that provide information on habitat types that satisfy ecological criteria were often only available as point records, with spatial sampling biases. Many datasets are available to populate the Naturalness criterion; however, most provide only locations of an impact, but do not inform on how that particular layer impacts on marine biodiversity.

1 Introduction

As a contribution to a broader programme of work to develop an improved approach to the establishment of Marine Protected Areas (MPAs), DOC continues to progress the "key ecological areas" (KEA) project. This project contributes to identifying KEAs in geographical space with the potential for considering them as part of future protected area or for other management planning. This project (Investigation 4759) is a key deliverable under new biodiversity contingency funding allocated to the Department of Conservation as part of its 2018 budget (see https://www.doc.govt.nz/news/budget-2018/docs-budget-2018-explained/).

This project complements concurrent work that is developing a new broad-scale marine habitat classification system for New Zealand (Investigation 4757) and a spatial prioritisation exercise that is focussing on identifying biodiversity-optimised areas for consideration in marine protection planning (Investigation 4758). The key ecological areas (and the underlying component data layers, such as for biogenic habitats) will provide inputs into the wider prioritisation exercise.

This report evaluates the adequacy of, and expands, the key ecological area datasets prepared under DOC Investigation no. 4735 (Stephenson et al. 2018b) to support identification of priority areas for marine conservation. Key ecological area criteria were previously identified by MSAG (Table 1-1, Freeman et al. 2017, based on EBSA criteria (Clark et al. 2014), and include:

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.
9. Ecological Services.

Stephenson et al. (2018b) compiled 27 key ecological datasets following workshops with leading national biodiversity experts that identified existing datasets satisfying each of these key ecological area criteria. 'Confidence' of each dataset was briefly reviewed based on qualitative confidence scores related to data coverage and data gaps, biases, availability of quantitative uncertainty layers, and other limitations of each dataset relative to each criterion. Here, we provide a more detailed evaluation of the datasets collated for the nine KEA criteria to assess their utility and comprehensiveness in providing a robust spatial representation of each criteria with respect to its incorporation into marine conservation planning.

Table 1-1: Criteria for consideration of Key Ecological Areas for marine conservation planning in New Zealand. Criteria based on Freeman et al. (2017).

	Criterion	Definition	Rationale	New Zealand Examples
1	Vulnerability, fragility, sensitivity, or slow recovery.	Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.	In the absence of protection, associated biodiversity may not be able to persist.	Biogenic habitats, including bryozoan beds, sponge communities and coldwater corals. Low fecundity and, or high longevity (fish) species such as bramble sharks, hapuku, king tarakihi, orange roughy.
2	Uniqueness/rarity/endemism.	Area contains either (i) unique ("the only one of its kind", rare (occurs only in a few locations) or endemic species, populations or communities; and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanography features.	These areas contain biodiversity that is irreplaceable; non-representation in protected areas may result in loss or reduction in biodiversity or features. These areas contribute towards larger-scale biodiversity.	Hydrothermal vents; seeps; areas containing co-occurring geographically restricted species; biogenic habitats.
3	Special Importance for Life History Stages.	Areas that are required for a population to survive and thrive.	Species' particular requirements make some areas more suitable for carrying out life history stages.	Fish spawning or nursery grounds; pinniped breeding colonies; migratory corridors; sites where animals aggregate for feeding.
4	Importance for Threatened / Declining Species and Habitats.	Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.	Protection may enable recovery or persistence of these threatened / declining species or habitats.	Estuaries with populations of threatened shorebirds; foraging areas for marine mammals and seabirds.
5	Biological Primary Productivity.	Area containing species, populations or communities with comparatively higher natural biological productivity.	These areas can support enhanced growth and reproduction and support wider ecosystems.	Hydrothermal vents; frontal zones; areas of upwelling.
6	Biological Diversity.	Area contains comparatively higher diversity of ecosystems, habitats, communities or species, or has higher genetic diversity.	These areas are important for evolutionary processes, for species' and ecosystem resilience and contribute towards large-scale biodiversity.	Structurally complex communities such as deep-water sponge and coral communities; seamounts. Areas with high diversity of fish and invertebrate species.

	Criterion	Definition	Rationale	New Zealand Examples
7	Naturalness.	Area with a comparatively higher degree of naturalness as a result of the lack of or low level of human-induced disturbance or degradation.	Provides enhanced ability to protect biodiversity that is in better condition; reduces need to rely on recovery from degraded state (recovery may occur on a different trajectory); these areas may include species and/or habitats that do not occur or are not represented well in more degraded areas; important role as reference sites.	Remote areas; marine areas adjacent to protected terrestrial areas; areas not impacted by bottom trawling or invasive species.
8	Ecological Function.	Area containing species or habitats that have comparatively higher contributions to supporting how ecosystems function.	Some species, habitats or physical processes play particularly important roles in supporting how ecosystems function – their protection provides coincidental protection for a range of other species and wider ecosystem health.	Soft sediment habitats containing high densities of bioturbators; areas of high functional trait diversity; areas with functionally important mesopelagic communities (including myctophids).
9	Ecosystem services.	Area containing diversity of ecosystem services; and/or areas of particular importance for ecosystem services.	Provides for ability to protect species and habitats that provide particularly important services to humans. Provides ability to better contribute to CBD Aichi Target 11.	Areas containing dense populations of filter-feeding invertebrates; areas important for seafood provisioning. Areas important for supporting or regulating ecosystem services (e.g., areas of nutrient regeneration, biogenic habitat provision, carbon sequestration, sediment retention, gas balance, bioremediation of contaminants, storm protection) that underpin the delivery of provisioning or cultural ecosystem services.

Factors considered during key ecological areas dataset evaluations included:

- whether datasets cover all elements (e.g., all taxonomic groups, habitats) relevant to describing each KEA
- correlations between and within criteria, for example, a number of datasets are listed as relevant to multiple criteria, but may only be poorly associated with, or serve as a proxies for a particular criterion
- availability and/or assessment of uncertainty information in each dataset
- gaps in datasets needed to describe particular criteria
- appropriateness of thresholds applied to the data (e.g., for defining rarity), and
- consideration of additional measures or surrogates for naturalness.

Following evaluation and identification of gaps, some new datasets were acquired, including relevant datasets produced subsequent to the publication of the Stephenson et al. (2018b) report, and datasets in development as part of concurrent MSAG projects. The initial evaluation analysis was presented at a workshop with MSAG on 16 August 2019 (Appendix A). Additional datasets that could fill gaps in the key ecological areas' datasets were proposed and prioritised by MSAG at the workshop, and a number of these additional analyses and data acquisition steps were initiated. Other relevant datasets that were beyond scope of the project budget are identified here, as well as further analyses that could enhance the relevance of particular datasets to inform spatial prioritisations.

1.1 Aims and objectives

In this report, we evaluate the adequacy of the 27 datasets collated under the Key Ecological Areas Stage 1 contract, presenting:

- A summary report of discussion and recommendations from the workshop held with NIWA and MSAG in August 2019 (Appendix A).
- The evaluation of datasets across comprehensiveness, correlations, uncertainty, and gaps in datasets to inform particular criteria.
- Newly acquired datasets to fill gaps in the key ecological areas' information.
- Further recommendations on additional datasets that could be developed to fill remaining gaps in the key ecological areas' information.

To minimise repetition, the evaluation is structured sections representing the major Key Ecological Area criteria. In section 2, we present summaries by taxonomic groups, including those for which predictive modelling has occurred. These datasets typically inform four key ecological criteria: Biological Diversity, Uniqueness / Rarity / Endemism, Special Importance for Life History Stages, and Importance for Threatened / Declining Species and Habitats. In the sections 3 – 7, we discuss the evaluation of the five remaining key ecological areas criteria (Vulnerability, Fragility, Sensitivity or Slow Recovery, Biological Productivity, Naturalness, Ecological Function, and Ecological Services).

2 Criteria 2, 3, 4 & 6: Uniqueness, life history, threatened taxa/habitats and diversity

Here, we discuss new datasets specific to individual taxon grouping that relate to four key ecological criteria:

- Uniqueness / Rarity / Endemism (Criteria 2).
- Special Importance for Life History Stages (Criteria 3).
- Importance for Threatened / Declining Species and Habitats (Criteria 4).
- Biological Diversity (Criteria 6).

The August 2019 MSAG workshop identified large gains in the information available through both data acquisition and modelling of a more diverse set of species groups. Using funding across the three concurrent MSAG investigations (DOC Investigations 4757, 4758 (this investigation), and 4759), comprehensive predictive models were updated or developed for four taxonomic groups (demersal fish, reef fish, benthic invertebrates, macroalgae) following acquisition and cleaning of extensive taxonomic databases. These analyses include modelled species turnover and taxonomic classification groups (Investigation No. 4757), predicted models of species occurrence for species in each taxonomic group with adequate point records (Investigation No. 4759), uncertainty layers for species occurrence models (this investigation), and species richness layers to satisfy the Biological Diversity criteria (this investigation). For the modelled layers, some of these layers were available in the original key ecological areas datasets (demersal fish); others have either been updated (reef fish), their analysis extended (benthic invertebrates), or entirely new models have been developed (macroalgae). Uncertainty layers have also been developed for the species distribution models of these taxonomic datasets. Cetacean models were acquired for the original key ecological areas datasets, with models developed under funding by MPI and NIWA SSIF (Stephenson et al. 2020a, b).

The updated datasets produced for these major taxonomic groups inform all three concurrent MSAG investigations, providing information to support a new national marine habitat classification, updated and new species distribution models and uncertainty layers, and updated and new species richness (Biological Diversity) estimates. These datasets also provide new information to supplement present point records associated with threatened species.

Finally, while no models were developed for seabirds, shorebirds, seals and sea lions, significant ecological areas, identified by regional councils, were investigated resulting in substantial increases in point locations for these species.

Polygons or point records indicating coastal areas with significant ecological, natural or conservational value (referred to in this report as “areas of significant conservation value”, or ASCVs) were compiled for the initial key ecological areas project (summarised in section 3.2.1 of Stephenson et al. 2018b). These locations were identified to fulfil obligations under Policy 11 of the 2010 New Zealand Coastal Policy Statement (NZCPS) and Section 6(c) of the Resource Management Act. As a result, Unitary authorities (Regional and District Councils) have assessed and mapped coastal areas with significant ecological, natural or conservational value (ASCV) (for example Schedule of Significant Ecological Areas – Marine (Auckland Council); Schedule of Significant Coastal Areas (Canterbury)). The factors contributing to the selection of an ASCV are often reported in council coastal plans and include key ecological criteria such as importance for threatened or vulnerable species; rarity; diversity; uniqueness; and representativeness (reviewed in Fenwick et al. 2018).

At the August 2019 MSAG workshop, further exploration of data associated with these locations was prioritised, as typically councils have descriptive text associated with each location. As these descriptions often include direct reference to species observed at these locations, they were deemed to include a potentially valuable suite of additional records. Text descriptions were used to develop a database of site-specific information on key ecological areas criteria. Site-specific species information was also extracted and compiled from regional councils and other unitary authorities in New Zealand (Northland, Auckland, Waikato, Bay of Plenty, Manawatu-Whanganui (Horizons), Gisborne, Hawke's Bay, Taranaki, Greater Wellington, Tasman, Nelson, Marlborough, West Coast, Canterbury, Otago and Southland). Species-specific information primarily included seabirds, shorebirds, seals and sea lions, and was assumed to be based on expert assessments of sites. Additional detailed information from these regional council datasets are included under appropriate taxonomic or key ecological area criteria sections of the report.

As noted in Lundquist et al. (2019, 2020) and Thompson et al. (2019), ASCVs are most commonly identified for presence or life history stage requirements of birds and marine mammals; 54 of 80, 17 of 20, and 43 of 60 sites in the Waikato, Hawke's Bay, and West Coast were based on the presence of threatened species, respectively. Similarly, 11 of 80, 16 of 20 and 39 of 60 sites in the Waikato, Hawke's Bay, and West Coast were identified for Special Importance for Life History Stages. However, other ecological criteria were not comprehensively represented across all regions. Many criteria were inconsistently used to identify priority sites across different regional councils, for example 80% of sites identified in Hawke's Bay were deemed to have high Biological Diversity, whereas only 15% of West Coast sites were identified for diversity features. Some key ecological criteria were rarely used to identify significant sites for all regional councils, particularly criteria of Biological Productivity and ecosystem services.

For each taxonomic group, we summarise and discuss these available datasets, evaluating spatial comprehensiveness of records, biases in spatial sampling, adequacy of records, and other indicators of adequacy for use in marine conservation planning.

2.1 Marine mammals and reptiles

2.1.1 Summary

Table 2-1: Summary of marine mammal and reptile occurrence within NZ and core datasets provided in this report

	Cetaceans	Pinnipeds	Reptiles
Recognised species in NZ waters	48*	9*	8
Threatened species	7*	2*	5
Endemic species	2*	1*	0
Vagrant and migrant species	7*	5*	7
Point records (all datasets)	14513	218	58
Species with predictive models	30	0	0

*From Baker et al. 2019

Marine mammal and reptile data are available to populate all four species and taxon-specific key ecological criteria (Table 2-2). A total of 48 cetacean species (or recognised subspecies or types of cetaceans), nine seal and sea lion species, and eight marine reptile species have been documented in New Zealand's waters (Hitchmough et al. 2016, Baker et al. 2019).

Of the 57 marine mammals, 12 are described as non-resident (migrant or vagrant), and an additional 30 are described as data deficient, including 14 that were previously described in the 2009 assessment as non-resident migrant or vagrant (Baker et al. 2010, 2019). Marine mammal sighting records are compiled into a national database held by the Department of Conservation, which has been groomed, and includes >14,000 records comprising 30 species, subspecies or species complexes. These records have been used to develop national-scale species distribution models of 30 species, subspecies or species complexes, including 15 Boosted Regression Tree models for taxa with >50 sightings, and 15 Relative Environmental Suitability models for taxa with <50 sightings (Stephenson et al. 2020a, 2020b).

Seal and sea lion haul outs and colonies have been compiled from DOC, MPI (NABIS) and regional councils. Reptiles include primarily vagrant or migrant species, with only one (yellow-bellied sea snake) classified as resident, though observations of this species are rare. Recorded observations for marine reptiles are primarily from northern New Zealand and are not sufficient to support development of predictive models of species ranges. See supplementary material (S1) for details of the species relevant for each of the ecological criteria below.

Table 2-2: Summary of application of marine mammal and reptile datasets to key ecological area criteria.

Dataset	Uniqueness / Rarity / Endemism	Special Importance for Life History Stages	Importance for Threatened / Declining Species and Habitats	Biological Diversity
Species occurrence records: cetaceans	x	x	x	
Species occurrence records: Seal haul outs	x	x	x	
Species occurrence records: marine reptiles	x		x	
Species distribution models: cetaceans	x		x	
Species richness: cetaceans				x

2.1.2 Primary datasets

Species occurrence records: cetaceans

Compilation of this dataset began during the initial key ecological areas project (see section 3.5.4 in Stephenson et al. 2018b) and has since been completed and published (Stephenson et al. 2020a and b). At-sea cetacean sightings records (n = 14,513) include 30 cetacean species, subspecies and species complexes (blue whales (2), pilot whales (2), orca/killer whales (4)), covering 35 of the 48 assessed cetacean taxa in the New Zealand Threat Classification System (NZTCS) (Baker et al. 2019) (Figure 2-1). No records are available for the additional 13 cetacean taxa within the at-sea sightings database. Records were collected over the period 1970-2017 and collated from multiple databases: a privately held database from Martin Cawthorn (independent consultant); Centralised Observer Database (COD - an MPI database); databases held by National Institute of Water and Atmospheric Research (NIWA); OMV limited; and DOC. The data were further quality controlled to remove any errors prior to analyses (Stephenson et al. 2020a and b).

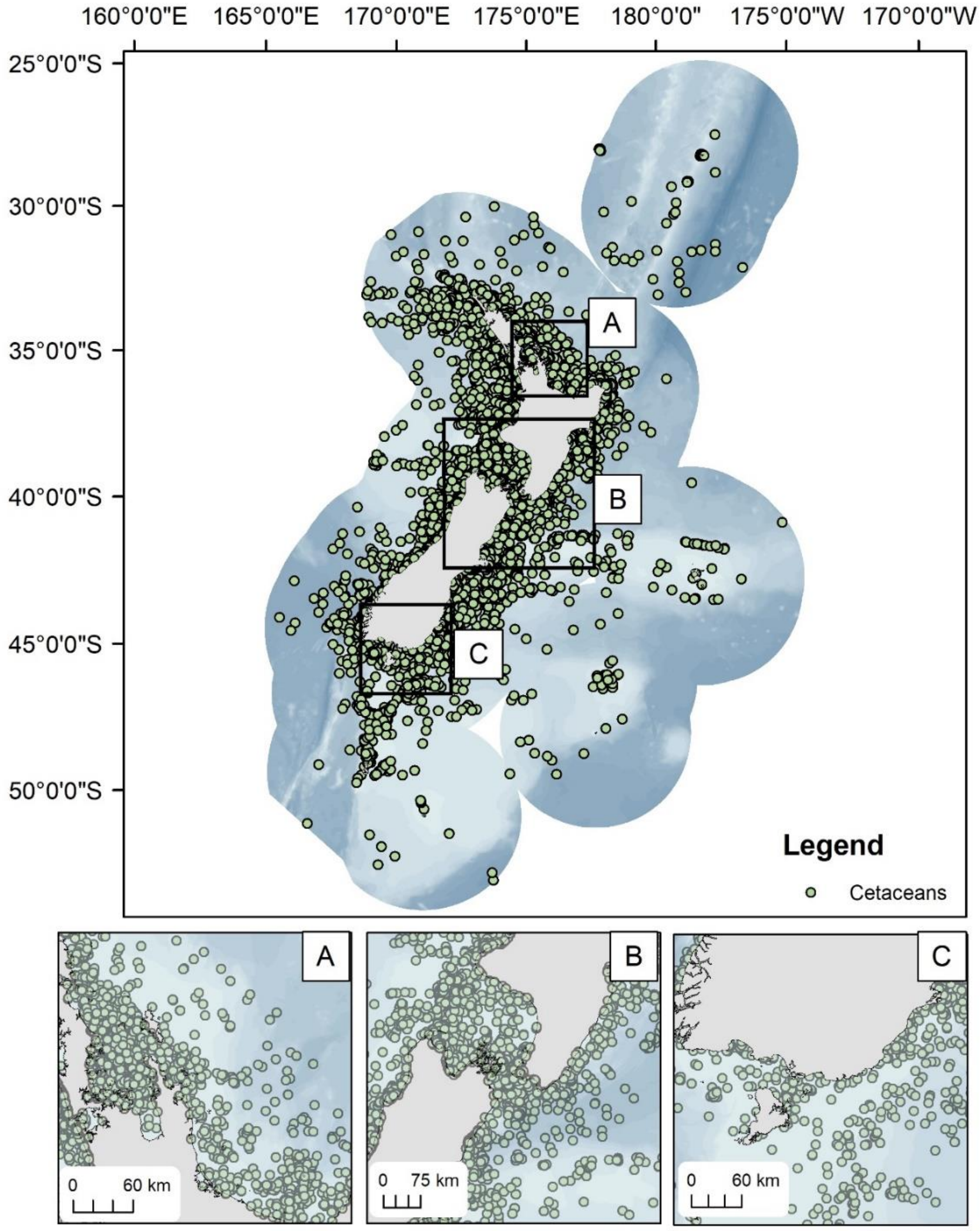


Figure 2-1: Locations of sightings records for 30 cetacean species.

Species occurrence records: seal haul outs

In New Zealand's waters there are nine species of seals. The original key ecological areas dataset included seal haul outs and colonies for three of these species (New Zealand sea lion, New Zealand fur seal, and southern elephant seal), including a 2018 update with the addition of 16 haul outs and 8 colonies completed by DOC experts (section 4.4.3 in Stephenson et al. 2018b). NABIS breeding colony layers (Figure 2-2), also available in the original key ecological areas compiled datasets, include 148 polygon records often over large areas of coastline.

NABIS layers do not identify individual colony sites, in contrast to other datasets which provide geospatial coordinates for particular intertidal locations. Further exploration of the NABIS dataset noted that large areas of coastline are attributed as breeding colonies of the southern elephant seal. Referring to the original reference material for these polygons which indicate most of the Otago coast (Oamaru to Nugget Point) as an 'occasional breeding colony', we found that this cited a personal communication in a report (Harcourt et al. 2002) which states that 'pups were frequently seen between Oamaru and Nugget Pt between 1965 and 1990 (pers. comm. C. Lalas), but no recent observations exist to confirm these. Expert communications suggest these polygons are out of date, and we recommend the exclusion of southern elephant seal breeding colonies on the mainland from this dataset.

The original key ecological areas compiled dataset has been further expanded to include regional council ASCV locations that identified a total of 45 locations for four species of seals or sea lions, including haul out sites and colonies (Table 2-3). Where available, coordinates for point locations of council ASCVs were acquired from either coastal plans or ArcGIS layers provided by the unitary body. 23 of these point locations as provided by regional council ASCVs were not part of the DOC or NABIS data of seal and sea lion haul outs and colonies updated in 2018, which focussed on haul outs and colonies identified by DOC field staff (Figure 2-2).

Table 2-3: Regional council records of seals and sea lions in ASCVs.

Species	Breeding	Breeding/haul out	Haul out	Present (unspecified)	Rare visitor	Total
Southern elephant seal			1	1		2
New Zealand sea lion				3		3
Leopard seal			1	1		2
New Zealand fur seal	6	5	16	10	1	38
Total	6	5	18	15	1	45

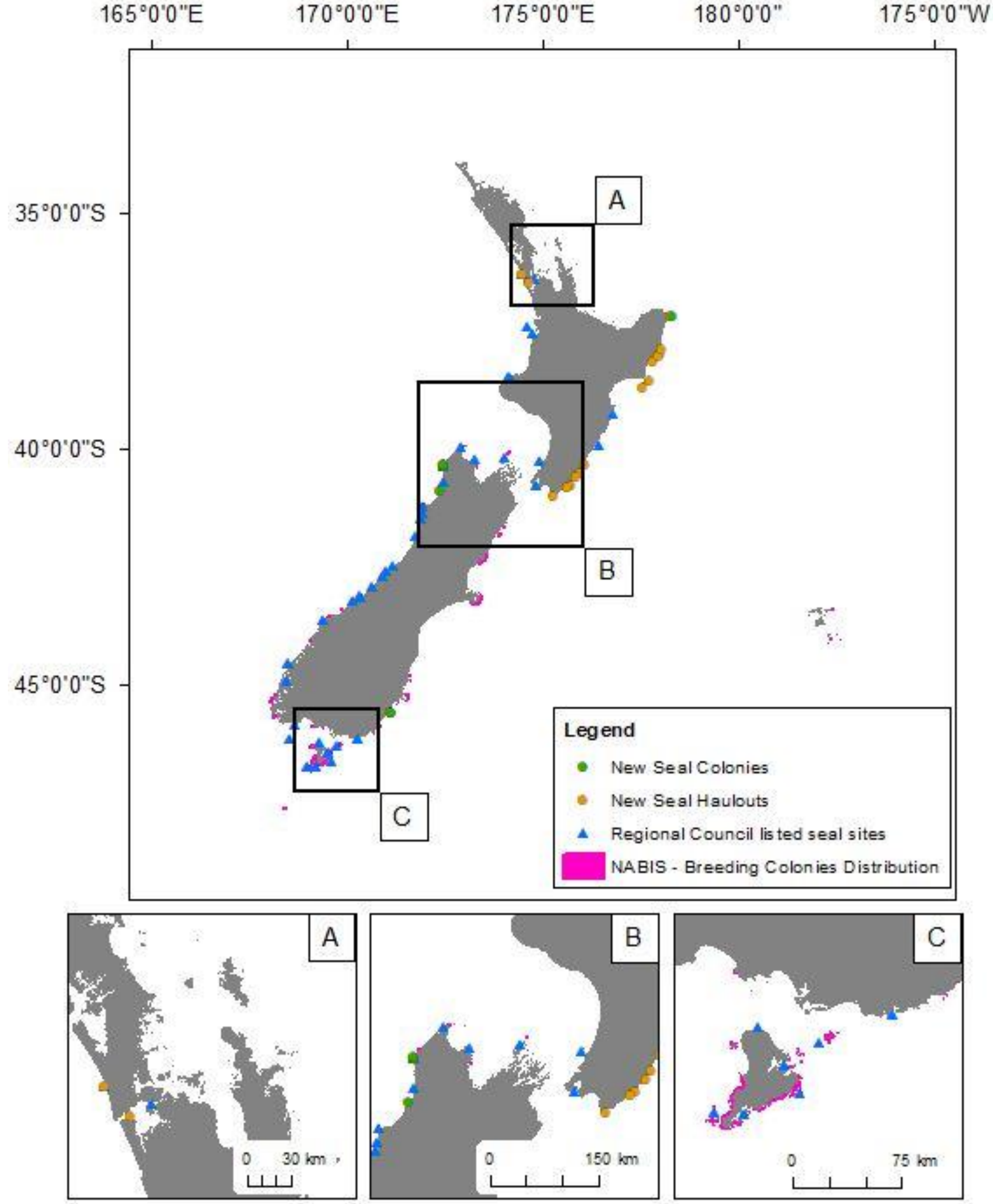


Figure 2-2: New Zealand seal and sea lion colonies and haul out sites.

Species occurrence records: marine reptiles

Reptiles include five sea turtle species and three sea kraits classified as "non-resident native species whose natural presence in New Zealand is either discontinuous (Migrant) or sporadic or temporary (Vagrant)" and one sea snake classified as a Resident (not threatened) with a "large, stable population" though the number of records imply that this species is uncommon (Hitchmough et al. 2016) (Table 2-4). Migrant taxa are defined as those that predictably and cyclically visit New Zealand as part of their normal life cycle (a minimum of 15 individuals known or presumed to visit per annum) but do not breed here, and Vagrant taxa as those whose occurrences, though natural, are sporadic and typically transitory, or migrants with fewer than 15 individuals visiting New Zealand per annum. No sea turtles or sea kraits, both of which require terrestrial habitats for breeding, are known to breed in New Zealand. The yellow-bellied sea snake breeds at sea, and is classified as a New Zealand resident.

As presented in section 3.5.4 of Stephenson et al. (2018b) based on data collated from Lundquist et al. (2015), OBIS records include observations of marine reptiles in New Zealand waters. A further download of OBIS records (download in March 2020, latest record from 2018) was undertaken, and data groomed to include only records from the New Zealand waters. The updated dataset includes 42 sea turtle records of all five recorded species of marine turtles, two records of one of the three sea krait species, and 14 records of the yellow-bellied sea snake. Records are nearly all from the North Island, with the majority being from Auckland and Northland.

Table 2-4: Marine reptiles observed in New Zealand.

Common name	*Scientific name*	NZ Status	Family	IUCN Status
Loggerhead turtle	*Caretta*	Vagrant	Cheloniidae	Vulnerable
Hawksbill turtle	*Eretmochelys imbricata*	Vagrant	Cheloniidae	Critically Endangered
Olive Ridley turtle	*Lepidochelys olivacea*	Vagrant	Cheloniidae	Vulnerable
Green turtle	*Chelonia mydas*	Migrant	Cheloniidae	Endangered
Leatherback turtle	*Dermochelys coriacea*	Migrant	Dermochelyidae	Vulnerable
Yellow-lipped sea krait	*Laticauda colubrina*	Vagrant	Laticaudidae	
Brown-lipped sea krait	*Laticauda laticaudata*	Vagrant	Laticaudidae	
New Caledonian sea krait	*Laticauda saintgironsi*	Vagrant	Laticaudidae	
Yellow-bellied sea-snake	*Pelamis platurus*	Not Threatened	Hydrophiidae	

2.1.3 Modelled datasets

Species distribution models

Species occurrences of 30 cetacean species, subspecies or species complexes were predicted using two modelling methods which combined the extensive at-sea sightings dataset (n > 14,000) with moderate-resolution (1 km^2) environmental data layers (Stephenson et al. 2020a). There were not sufficient data to model distribution for other marine mammals or reptiles known to inhabit NZ waters.

The choice of which modelling method was used was based on record numbers. For taxa with < 50 sightings (n = 15), Relative Environmental Suitability models (RES, as described in Kaschner et al. (2006)) were used, and for taxa with ≥ 50 sightings (n = 15), Bootstrapped Boosted Regression Tree models (BRT, as described in Elith et al. (2006)) were used. For the latter, spatially explicit uncertainty layers (standard deviation of the mean BRT predictions) were also produced. Winter and summer seasonal distributions for a subset of species were also predicted using BRT models (for those species with ≥ 300 sightings). Compilation of this dataset was begun during the initial key ecological areas project (see section 3.5.5 in Stephenson et al. 2018b) and has since been completed and published (Stephenson et al. 2020a,b).

2.1.4 Matching criteria

Criteria 2: Uniqueness / Rarity / Endemism

Of the marine mammals found in New Zealand, only Hector's dolphin and its subspecies Māui dolphin and the New Zealand sea lion are endemic to New Zealand. Predictive models of species occurrence using boosted regression trees are available for both cetacean subspecies based on 3,688 and 1,051 records in the national database, respectively. The false killer whale has been assessed by NZTCS as naturally uncommon, and a RES model is available for this species, which has 28 sightings records in the national database. A total of 3 additional locations from regional council ASCVs have been identified for the New Zealand sea lion. No marine reptiles found in New Zealand are categorised as endemic.

Criteria 3: Special Importance for Life History Stages

Little is known about the distribution and habitat use patterns of most cetaceans in the seas surrounding New Zealand, particularly with respect to life cycle requirement (see Rayment et al. 2015 for an exception), of both inshore and offshore species (Stephenson et al. 2020a). While some sea turtles use New Zealand waters as part of their regular visits within their migratory life cycle, there are no sea turtle breeding sites found in New Zealand.

A total of 23 additional locations from regional council ASCVs have been identified for the New Zealand sea lion and the New Zealand fur seal. Records for the southern elephant seal date to Harcourt et al. (2002), and include records until 1990 in Southland and Otago; it is unlikely that these are currently occupied. The leopard seal does not breed in New Zealand, but two haul out sites have been recorded in council datasets.

Criteria 4: Importance for Threatened / Declining Species and Habitats

Seven marine mammals (Bryde's whale, Māui dolphin, Hector's dolphin, orca, bottlenose dolphin, southern elephant seal and New Zealand sea lion) are classified as Threatened under the NZTCS (Baker et al. 2019), while 30 species of marine mammals are classified as Data Deficient. While the five sea turtles found in New Zealand are globally listed as vulnerable or endangered by IUCN, they are considered vagrant or migrant by NZTCS. BRT predictive models of species occurrence are available for all five threatened cetacean species. As reported in section 3.5.4 of Stephenson et al. (2018b), 4951 of the at-sea cetacean sightings records are of the five threatened cetacean species.

Of the seals and sea lions, two (southern elephant seal, New Zealand sea lion) are classified by NZTCS as Threatened and one, leopard seal, classified as At Risk - Naturally Uncommon. Note this species has recently been reassessed due to records suggesting a regular presence in New Zealand, but it is not thought to be facing imminent extinction (Baker et al. 2019). Of the remaining six, one (the New Zealand fur seal) is assessed as not threatened, and the other five are considered vagrant.

Criteria 6: Biological Diversity

Compilation of this dataset was begun during the initial key ecological areas project (see section 3.5.5 in Stephenson et al. 2018b) and has since been completed and published (Stephenson et al. 2020a). Cetacean species richness was estimated by stacking species distribution model predictions, and calculated as the sum of the occurrence probability predictions (ranging from 0 to 1) from individual models (15 BRT models and 15 RES models) (Ferrier & Guisan 2006; Calabrese et al. 2014). To reflect the lower prediction certainty associated with the coarser RES predictions, these were subjectively down-weighted by multiplying RES probability of occurrences by 0.25. For future applications the subjective weighting of RES layers could be further explored. The estimated distribution of cetacean richness therefore ranged from 0 to a theoretical maximum of 19 (Stephenson et al. 2020b) which was clipped to areas with adequate environmental coverage (Figure 2-3).

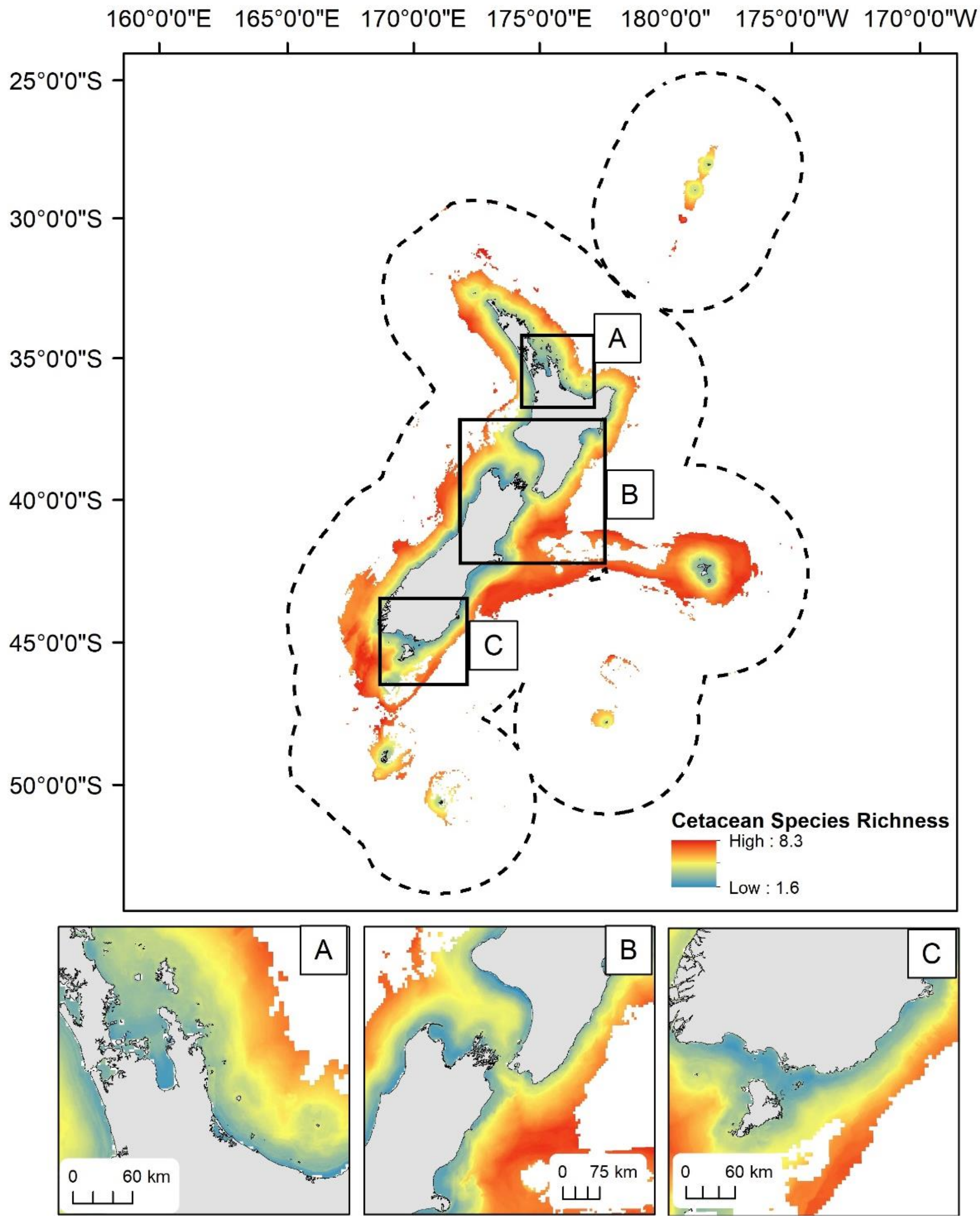


Figure 2-3: Species richness of New Zealand cetacean species based on weighted stacking of 30 models of species occurrences. Richness estimates are clipped to areas of adequate model environmental coverage (>0.05). Based on data presented in Stephenson et al. (2020b).

2.1.5 Data quality/spatial comprehensiveness

For cetaceans, as noted in Stephenson et al. (2020b), understanding of spatial distributions is challenged by the lack of comprehensive spatial coverage of sightings in the New Zealand EEZ (Figure 2-1). Predictive models of species occurrence have associated maps of environmental coverage that were calculated using the cetacean dataset as a whole. These maps depict the confidence that can be placed in the predictive models (Figure 2-4).

Coverage of the multi-dimensional environmental space (each environmental predictor representing a dimension) was calculated by obtaining values of each predictor for each presence sample of a certain taxa. A dataset of randomly generated absences, with associated environmental data, was generated in locations with no presences. Boosted Regression Trees (BRT) were used to model the relationship between presence/absence samples and the environmental predictors used in the SDMs. BRTs were constructed in the 'Dismo' package (Hijmans et al. 2017) and were fit using a Bernoulli error distribution, a learning rate that yielded > 2,000 trees and an interaction depth of 2. Based on the modelled probability of presences across the sampled range of environmental predictors, this model was used to predict a spatially explicit representation of the probability that the environmental characteristics of a site were represented by presence samples. Values of environmental coverage range from 0 (no sampling of environmental characteristics) to 1 (full sampling of environmental characteristics). To minimise unreliable model predictions due to poorly sampled environmental space, species richness estimates for cetaceans were predicted to sites where environmental coverage was 0.05 or higher (Stephenson et al. 2020).

For cetaceans, the environmental coverage layer suggests reasonable understanding in inshore waters and within proximity to offshore islands (Chathams, Kermadecs) but greater care should be taken in using predictions throughout much of the offshore region of New Zealand's EEZ. There are further biases resulting from the majority of sightings occurring in a limited number of coastal areas, driven by locations of field surveys, denser human populations or opportunistic tourism vessels, with a poor understanding of species distributions in other coastal areas. For some individual species (Hector's dolphin, Māui dolphin), regular surveys and population assessments are conducted due to their threatened status. Some taxa (particularly beaked whales) are particularly poorly known, with eight of nine species in the genus *Mesoplodon* having been assessed as Data Deficient.

Two types of species distribution models are available for New Zealand cetaceans. The more robust BRT models are available for only 15 cetacean taxa but do include uncertainty layers. These models have generally high predictive capacity (AUC range: 0.79 – 0.99) but large variation in the model deviance explained (0.16 – 0.88) (Stephenson et al. 2020a). While these models represent the current most robust approximations of cetacean species distributions, improvements require substantial investment in collection of additional data to fill spatial gaps in coverage, as well as gaps in understanding of temporal patterns of species distributions.

Cetacean species richness shows a pattern of lower richness estimates in inshore waters, reflecting a model bias toward offshore areas where species with large overlapping ranges occur (Stephenson et al. 2020b) (Figure 2-3). This pattern could be easily misinterpreted as implying low value of inshore waters for cetaceans; rather a large number of offshore species are often migrant or vagrant species. In addition, a number of inshore species (e.g., Hector's dolphin, Māui dolphin) have restricted ranges and limited overlap, which contributes to lower estimated inshore species richness.

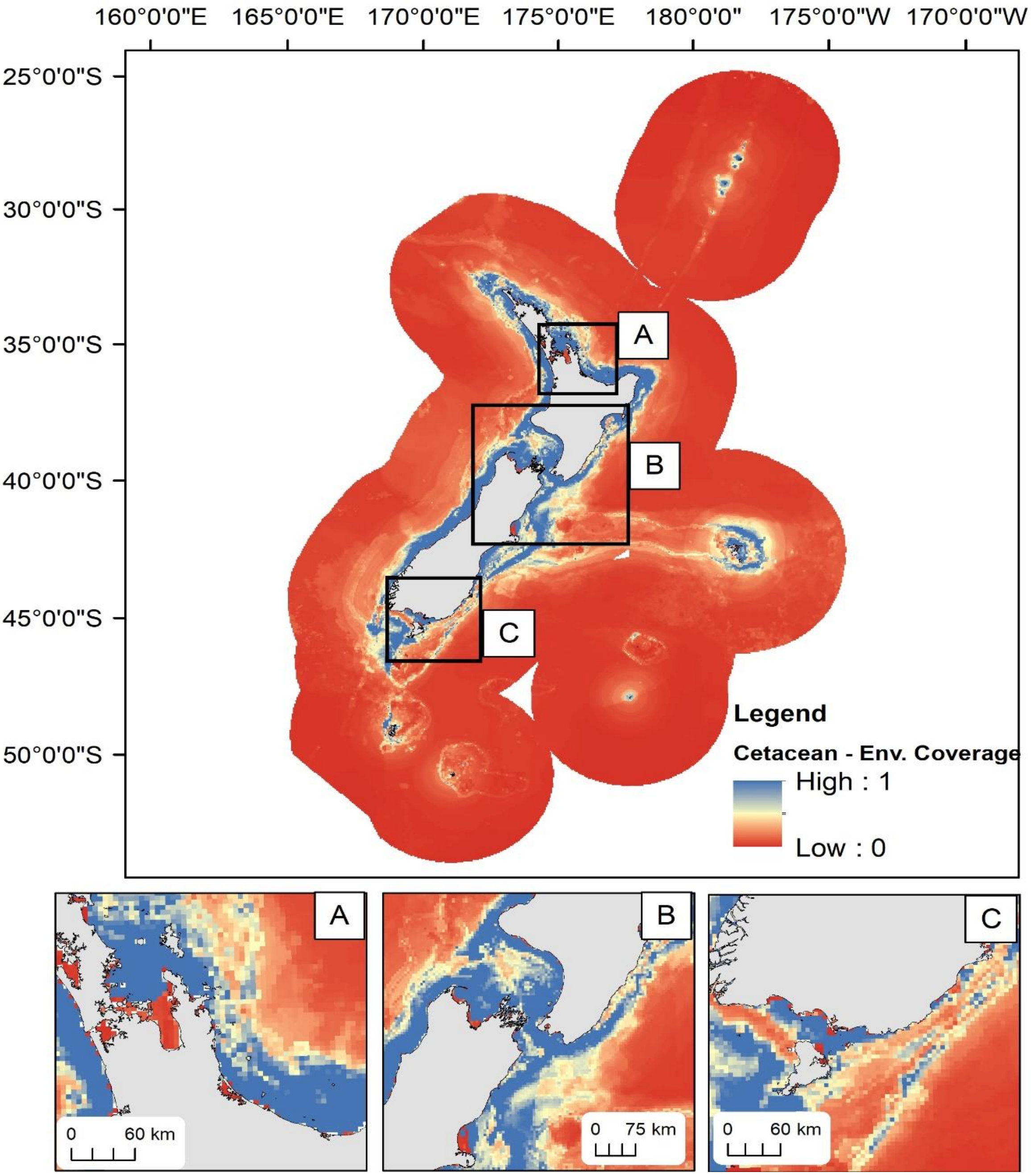


Figure 2-4: Predicted environmental coverage depicting the confidence that can be placed in cetacean predictive models. Scale ranges from low (i.e., no samples in the dataset with those environmental conditions) to high (i.e., many samples with those environmental conditions) within the New Zealand EEZ.

2.2 Seabirds and shorebirds

2.2.1 Summary

Table 2-5: Summary of seabird and shorebird occurrence within NZ and core datasets provided in this report.

	Seabirds and shorebirds
Recognised species in NZ waters	122*
Threatened species	55**
Endemic species	41*
Vagrant and migrant species	40*
Point records (all datasets)	572220
Species with predictive distributions	70

*From Gordon et al. 2010. **Based on Robertson et al. 2012 for native and endemic species only.

Table 2-6: Summary of application of seabird and shorebird datasets to key ecological area criteria.

Dataset	Uniqueness / Rarity / Endemism	Special Importance for Life History Stages	Importance for Threatened / Declining Species and Habitats	Biological Diversity
Species occurrence records: regional council datasets of bird presence and foraging/ breeding/ roosting in identified significant ecological areas	x	x	x	x
Species occurrence records from international databases: OBIS, GBIF/iNaturalist	x	x	x	x
Birdlife International/Forest & Bird Important Bird Areas and bird colonies		x	x	x
Seabird modelled distributions (Birdlife International/NatureServe)	x	x	x	x

The August 2019 MSAG workshop (Appendix A) highlighted the need to improve current seabird and shorebird data layers as existing layers are coarse and primarily include internationally important seabird colonies. Poor representation of shorebird species, for which New Zealand is an important part of the life cycle of dozens of migratory wading birds, was observed. As a result, this project explored new datasets, including extrapolating additional information on individual species presence from the Birdlife International Important Bird Areas (BirdLife International and Handbook of the Birds of the World 2019), downloading species records from international databases including iNaturalist and OBIS, and exploring regional council ASCVs for detailed information on presence of seabird and shorebirds, including presence of foraging, roosting or nesting species (Table 2-6). See supplementary material (S2) for details of the species relevant for each of the ecological criteria.

2.2.2 Primary datasets

Regional council significant sites

As discussed in section 2, New Zealand unitary authorities are required to identify areas of significant ecological, natural or conservational value within their jurisdictions. The importance of an area for coastal birds is one of the factors considered in the decision process and this information is often reported on within regional coastal/unitary plans. Where available, information on the distribution of coastal birds has been compiled across all councils. Whilst all councils mention the importance for birds and threatened species in these ASCVs, several do not provide species-specific information and thus have not been included in the dataset. Coordinates for point locations of council ASCVs have been pulled from either coastal plans or, if available, geospatial layers provided by the unitary authority. In addition to the council ASCV sites, species information and coordinates for six wetlands with international importance (RAMSAR sites) in New Zealand have also been compiled. Four of the six RAMSAR sites are coastal, whereas two (Whangamarino and Kopuatai) are inland wetlands (Figure 2-5). These data have been collated to create a map of all council significant areas and the bird species which are found within them. Information is summarised both by region and by individual taxa, and the geospatial database allows queries by individual bird species as well as geographic queries of how many bird species or bird records are found in particular regions (Table 2-7). A total of 1655 bird records were available within the ASCV dataset, which includes 93 seabird and shorebird species (Figure 2-5, Table 2-7).

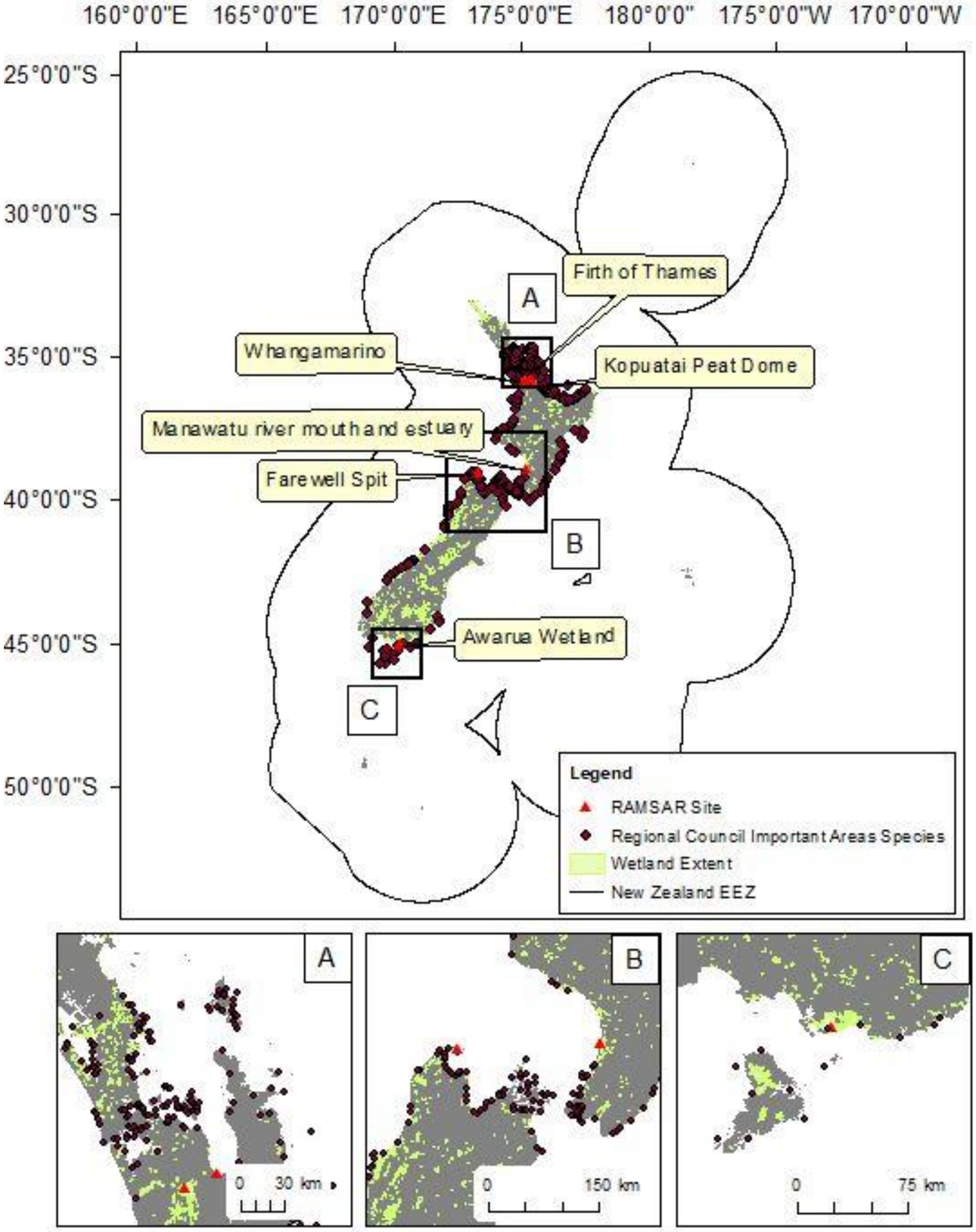


Figure 2-5: Seabird and shorebird point records from the regional council ASCVs and from international Ramsar wetlands. Data as per council datasets in December 2020.

Table 2-7: Number of council allocated ASCV's, within each region, which report the presence of New Zealand coastal/ seabird species. NC= Nationally critical, NT= Not threatened, NV= Nationally vulnerable, NE= Nationally endangered, D= declining, NU= Naturally uncommon, R= Recovering, Re=relict, Native=N, M=Migrant, V= Vagrant. Note Northland, Gisborne, Manawatu-Wanganui and Canterbury all report the presence of birds but are not species specific. For a list of bird species with scientific names please see appendix X. Note that councils often include birds that use the coastal environment, but would not typically be considered to be seabirds or shorebirds; we have included these to maintain consistency with council datasets.

Common Name	New Zealand Status	Conservation Status	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Environment Southland
Australasian bittern	Native	NC	-	15	5	28	-	6	6	-	0	6	2	0	0	-	0	0
Australasian shoveler	Native	NT	-	1	0	0	-	2	1	-	0	0	0	0	0	-	0	0
Banded dotterel	Endemic	NV	-	16	7	21	-	3	3	-	16	5	4	2	4	-	1	8
Banded rail	Native	D	-	38	6	34	-	1	0	-	0	17	3	6	0	-	0	0
Bar-tailed godwit	Native	D	-	1	10	0	-	2	0	-	4	0	0	0	1	-	0	1
Black billed gull	Endemic	NC	-	3	1	5	-	0	0	-	1	0	0	0	0	-	0	0
Black fronted dotterel	Native	NU	-	1	0	0	-	2	0	-	0	0	0	0	0	-	0	0
Black fronted tern	Endemic	NE	-	1	0	0	-	6	0	-	0	0	0	1	0	-	0	0
Black shag	Native	NU	-	0	0	16	-	1	0	-	29	0	0	0	0	-	0	0
Black stilt	Endemic	NC	-	2	3	3	-	0	0	-	0	0	0	2	0	-	0	0
Black swan	Native	NT	-	0	0	0	-	0	1	-	0	0	0	0	0	-	0	0
Black-winged petrel	Native	NT	-	0	0	0	-	1	0	-	0	0	0	0	0	-	0	0
Blue duck	Endemic	NV	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	1

Common Name	New Zealand Status	Conservation Status	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Environment Southland
Brown teal	Endemic	R	-	20	0	3	-	0	0	-	0	0	0	0	0	-	0	1
Buller's mollymawk	Endemic	NU	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	1
Caspian tern	Native	NV	-	27	3	27	-	6	2	-	10	3	0	5	0	-	1	0
Cattle egret	Native	M	-	0	0	0	-	0	0	-	0	1	0	0	0	-	0	0
Cook's Petrel	Endemic	Re	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	1
Curlew sandpiper	Native	V	-	1	0	0	-	0	0	-	0	0	0	0	0	-	0	0
Diving Petrel-Northern	Native	Re	-	3	3	0	-	0	0	-	0	0	0	5	0	-	0	0
Eastern bar-tailed godwit	Native	N	-	23	0	1	-	8	1	-	0	3	1	0	0	-	2	1
Eastern curlew	Native	V	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	1
Fairy Prion	Native	Re	-	0	0	0	-	0	0	-	0	0	0	4	4	-	0	0
Fiordland crested penguin	Endemic	NV	-	0	0	0	-	0	0	-	0	0	0	0	15	-	0	7
Flesh-footed shearwater	Native	NV	-	1	2	1	-	0	0	-	0	0	0	2	0	-	0	0
Fluttering shearwater	Endemic	Re	-	1	3	2	-	0	3	-	2	0	0	8	0	-	0	0
Grey duck	Native	NC	-	0	0	6	-	0	0	-	0	0	0	0	2	-	0	0
Grey faced petrel	Native	NT	-	4	0	0	-	0	3	-	0	0	0	0	0	-	0	0
Grey noddy	Native	NU	-	0	0	1	-	0	0	-	0	0	0	0	0	-	0	0

Common Name	New Zealand Status	Conservation Status	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Environment Southland
Grey teal	Native	NT	-	1	0	0	-	2	0	-	0	0	0	0	0	-	0	0
Grey warblers	Endemic	NT	-	1	0	0	-	0	0	-	0	0	0	0	0	-	0	0
Grey-tailed tattler	Native	V	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	1
Kaka	Endemic	R	-	1	0	3	-	0	0	-	0	0	0	0	0	-	0	0
Kakapo	Endemic	NC	-	1	0	0	-	0	0	-	0	0	0	0	0	-	0	1
Lesser knot	Native	NV	-	15	1	1	-	1	0	-	0	1	0	0	0	-	0	0
Little black shag	Native	NU	-	8	0	11	-	1	0	-	8	0	0	0	0	-	0	0
Little egrets	Native	V	-	1	0	1	-	0	0	-	0	0	0	0	0	-	0	0
Little Penguin	Native	D	-	7	4	11	1	1	7	1	10	3	0	6	10	-	0	1
Little shag	Native	NT	-	0	0	15	-	1	0	-	0	0	0	0	0	-	0	0
Long-tailed cuckoo	Endemic	NU	-	1	0	4	-	0	0	-	0	0	0	0	0	-	0	0
Marsh crake	Native	D	-	1	0	7	-	0	0	-	0	7	0	1	0	-	0	0
Mottled petrel	Endemic	Re	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	5
New Zealand Dabchick	Endemic	R	-	1	0	4	-	1	0	-	2	0	0	0	0	-	0	0
New Zealand dotterel	Endemic	R	-	34	0	2	-	1	3	-	1	0	0	1	0	-	0	6
New Zealand Fairy tern	Native	NC	-	5	0	6	-	0	0	-	0	0	0	0	0	-	0	0

Common Name	New Zealand Status	Conservation Status	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Environment Southland
New Zealand Falcon	Endemic	NE	-	0	0	5	-	0	0	-	0	0	0	0	0	-	0	0
New Zealand King shag	Endemic	D	-	0	0	0	-	0	0	-	0	0	0	7	0	-	0	0
New Zealand Pipit	Endemic	R	-	1	0	3	-	0	0	-	11	0	0	0	0	-	0	0
North Island Brown Kiwi	Endemic	D	-	1	0	4	-	0	0	-	0	0	0	0	0	-	0	0
North Island Fernbird	Endemic	D	-	15	0	37	-	1	0	-	1	0	0	0	0	-	0	0
North Island little shearwater	Native	R	-	0	3	0	-	0	0	-	0	0	0	0	0	-	0	0
North Island Weka	Endemic	R	-	0	0	8	-	0	0	-	0	0	0	0	0	-	0	0
Northern Diving Petrel	Native	Re	-	0	0	3	-	0	0	-	0	0	0	0	0	-	0	0
Northern New Zealand dotterel	Endemic	NV	-	6	18	38	-	0	0	-	0	0	0	0	0	-	0	0
Orange fronted parakeet	Endemic	NC	-	0	0	1	-	0	0	-	0	0	0	0	0	-	0	0
Pacific golden plover	Native	M	-	2	0	0	-	2	1	-	0	0	0	0	0	-	0	1
Paradise shelduck	Endemic	NT	-	1	0	0	-	0	0	-	0	0	0	0	0	-	0	0
Pied shag	Native	R	-	17	4	23	-	1	0	-	18	0	0	0	2	-	0	0
Pied stilt	Native	NT	-	14	0	20	-	2	0	-	14	0	0	0	0	-	1	0
Pukeko	Native	NT	-	4	0	0	-	0	0	-	0	0	0	0	0	-	0	0
Pycroft's petrel	Endemic	R	-	0	1	0	-	0	0	-	0	0	0	0	0	-	0	0

Common Name	New Zealand Status	Conservation Status	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Environment Southland
Red necked phalarope	Native	V	-	0	0	0	-	0	0	-	0	0	0	1	0	-	0	0
Red-billed gulls	Native	D	-	9	3	27	-	6	0	-	40	0	0	2	3	-	0	0
Red necked stint	Native	M	-	0	0	0	-	0	0	-	0	0	0	2	0	-	0	0
Reef heron	Native	NE	-	35	2	19	-	0	0	-	3	3	1	2	0	-	0	5
Royal spoonbill	Native	NU	-	2	0	5	-	1	2	-	4	6	1	1	0	-	0	1
Ruddy turnstone	Native	M	-	2	0	0	-	0	0	-	0	0	0	0	0	-	0	0
Sacred Kingfisher	Native	NT	-	7	0	0	-	0	0	-	0	0	0	0	0	-	0	1
Sanderling	Native	V	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	1
Sharp-tailed sand piper	Native	M	-	0	0	0	-	0	1	-	0	0	0	0	0	-	0	0
Shore plover	Endemic	NC	-	0	0	0	-	0	0	-	1	0	0	0	0	-	0	0
Sooty shearwater	Native	D	-	2	2	0	-	1	0	-	0	0	0	12	5	-	0	0
South Georgian Diving Petrel	Native	NC	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	1
South Island Fern bird	Endemic	D	-	0	0	0	-	0	0	-	0	13	0	1	0	-	3	0
South Island pied oystercatcher	Endemic	D	-	24	9	10	-	0	0	-	6	2	1	1	4	-	1	1
South Island Saddleback	Endemic	R	-	0	0	1	-	0	0	-	0	0	0	0	0	-	0	1
Southern Black backed gull	Native	NT	-	7	0	2	-	3	2	-	0	0	0	1	0	-	0	0

Common Name	New Zealand Status	Conservation Status	Northland	Auckland	Waikato	Bay of Plenty	Gisborne	Hawke's Bay	Taranaki	Manawatu-Wanganui	Wellington	Tasman	Nelson	Marlborough	West Coast	Canterbury	Otago	Environment Southland
Spotless crake	Native	D	-	6	1	15	-	4	1	-	0	1	0	0	0	-	0	0
Spotted shag	Endemic	NT	-	9	0	0	-	1	0	-	0	2	2	2	2	-	0	0
Stewart Island tokoeka	Endemic	NC	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	2
Stuart Island shags	Endemic	R	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	5
Tui	Endemic	NT	-	1	0	0	-	0	0	-	0	0	0	0	0	-	0	0
Variable Oyster catcher	Endemic	R	-	40	20	32	-	8	3	-	37	5	4	1	7	-	1	9
Welcome swallow	Native	NT	-	2	0	0	-	0	0	-	0	0	0	0	0	-	0	0
Westland Petrel	Endemic	NU	-	0	0	0	-	0	0	-	0	0	0	0	1	-	0	0
Whimbrel	Native	M	-	1	0	0	-	0	0	-	0	0	0	0	0	-	0	0
White heron	Native	NC	-	1	0	8	-	1	0	-	0	4	1	2	2	-	1	2
White- faced heron	Native	NT	-	8	0	0	-	0	0	-	0	0	0	0	0	-	0	0
White faced storm petrel	Native	Re	-	6	2	2	-	0	0	-	0	0	0	0	0	-	0	0
White fronted tern	Native	D	-	15	2	20	-	10	2	-	32	7	1	2	3	-	0	0
Wrybill	Endemic	NV	-	17	1	12	-	2	1	-	0	0	0	1	0	-	0	0
Yellow eyed penguin	Endemic	NE	-	0	0	0	-	0	0	-	0	0	0	0	0	-	0	8

iNaturalist/GBIF records

iNaturalist (iNaturalist.org) is a joint initiative of the California Academy of Sciences and the National Geographic Society providing a global platform for recording citizen scientist observations (iNaturalist.org 2020). Records uploaded to iNaturalist.org are provided weekly to the Global Biodiversity Information Facility (GBIF, https://www.gbif.org/) and are available within a subset of the GBIF database of iNaturalist Research-Grade Observations (i.e., quality checked). According to GBIF, "iNaturalist observations become candidates for Research Grade when they have a photo, date, and coordinates. They become Research Grade when the community agrees on an identification. If the community has multiple opinions on what taxon has been observed, iNaturalist chooses a taxon from all the proposed taxa (an implied ancestor taxa of the proposed taxa) that more than 2/3 of the voters agree with." Further information is provided on the iNaturalist website on the mathematical algorithm for applying a species name if multiple species names are suggested by the expert community.

A total of 56,961 bird records were available within the GBIF database of iNaturalist Research-Grade Observations, downloaded on 31 March 2020. These records were further groomed to exclude terrestrial species and naturalised/colonist species, or species with indeterminate taxonomic information. The final dataset included a total of 23,174 records of 184 seabird and shorebird species (Figure 2-6).

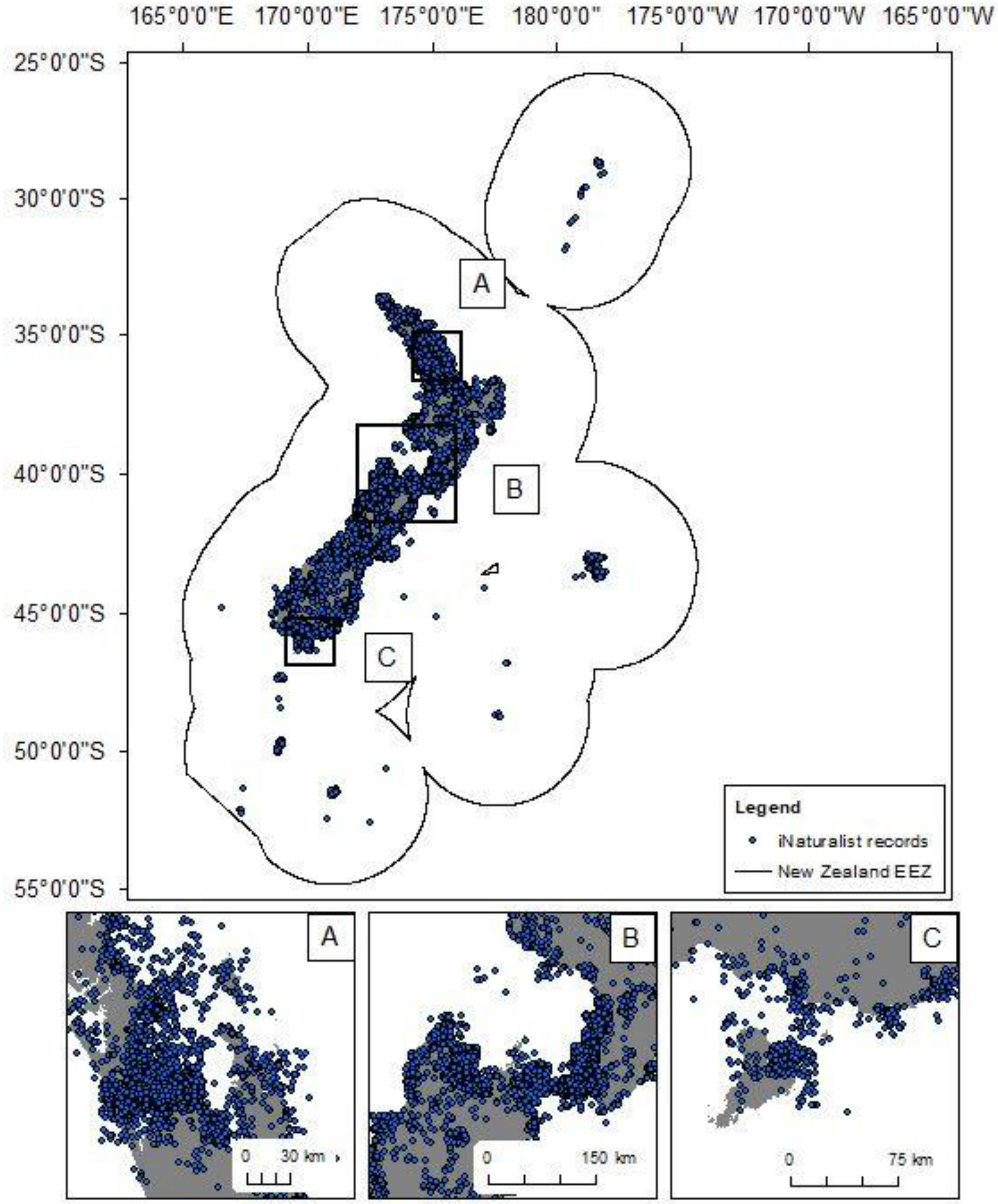


Figure 2-6: Seabird point records from the GBIF database of iNaturalist Research Grade Observations. Data downloaded on 31 March 2020

OBIS dataset

OBIS publishes datasets on marine species distribution in space and time. Datasets may be from field surveys (e.g., plankton, fishery trawl, benthic cores, whale and bird observations), specimen collections, and other taxonomic observations. OBIS originated as part of the information management component of the Census of Marine Life, and is now housed within the Intergovernmental Oceanographic Commission (IOC) of UNESCO, under its International Oceanographic Data and Information Exchange (IODE) programme. As of April 2020, over 58.9 million records had been uploaded into OBIS, including over 127,000 species and downloaded from 3,044 different international datasets or organisations (https://obis.org/). OBIS data include all groups of organisms that are associated with marine (including estuarine) habitats, i.e., marine vertebrates (fish, marine mammals, marine reptiles, etc.), marine invertebrates, marine bacteria, and marine plants (phytoplankton, macroalgae, seagrass, mangroves). OBIS preferably works through linkages with a number of regional nodes; the South Western Pacific Node is hosted by NIWA who manages all South Pacific regional database uploads. Other international databases (i.e., not part of the South Western Pacific Node) also contribute species records within the New Zealand EEZ. All data are open access, and responsibility for data quality, including updating records, is the responsibility of the data collector (Box 1). Data include only species name as taxonomic identification; all further taxonomic information is accessed via the World Register of Marine Species (WoRMS) database.

A total of 1,533,303 bird records were available within OBIS, downloaded on 4 April 2020 (updating previous datasets available from Lundquist et al. 2015). These records were further groomed to exclude terrestrial species and naturalised/colonist species, or species with indeterminate taxonomic information. The final dataset included a total of 572,058 records of 149 seabird and shorebird species (Figure 2-7).

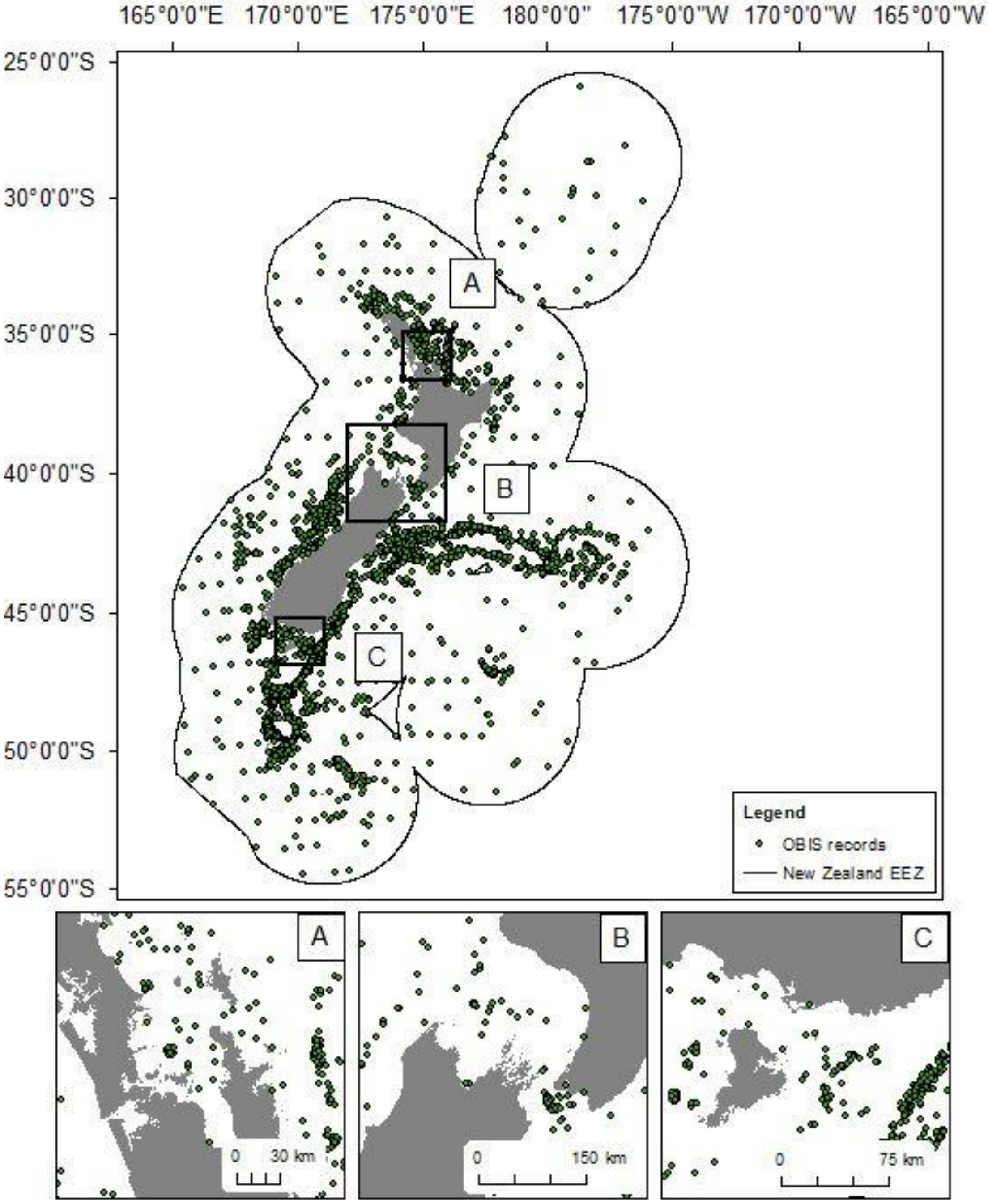


Figure 2-7: Seabird point records from the OBIS database. Data downloaded on 4 April 2020.

Birdlife International/Forest & Bird Important Bird Areas and bird colonies

The Birdlife International/Forest & Bird seabird colony distribution map is limited to seabirds, and does not include the distribution of many wading and cryptic coastal birds (BirdLife International and Handbook of the Birds of the World 2019, Forest & Bird 2014). The seabird colony distribution map and the Important Bird Area (IBA) polygons were acquired for the initial Key Ecological Areas project (Section 3.4.6 in Stephenson et al. 2018b). That dataset identifies the location of 162 New Zealand seabird colonies, and includes a simplistic distance-based extension of individual colonies to define IBAs. Further exploration of the data observed that information was available to identify individual species present at each colony. Data on the presence of 92 seabird species have now been extracted from Bird Life International (http://datazone.birdlife.org/site/search) and geospatially associated with all individual IBA seabird colonies (Figure 2-8). A number of offshore locations (i.e., not overlapping with offshore islands) were identified as proposed offshore marine IBAs, although not directly overlapping a bird colony (BirdLife International and Handbook of the Birds of the World 2019). The revised dataset now allows the user to a) find what bird species are present at a given IBA colony or b) search for colonies containing specific species. The number of species present at each site ranges from 1 to 16 (Antipodes island).

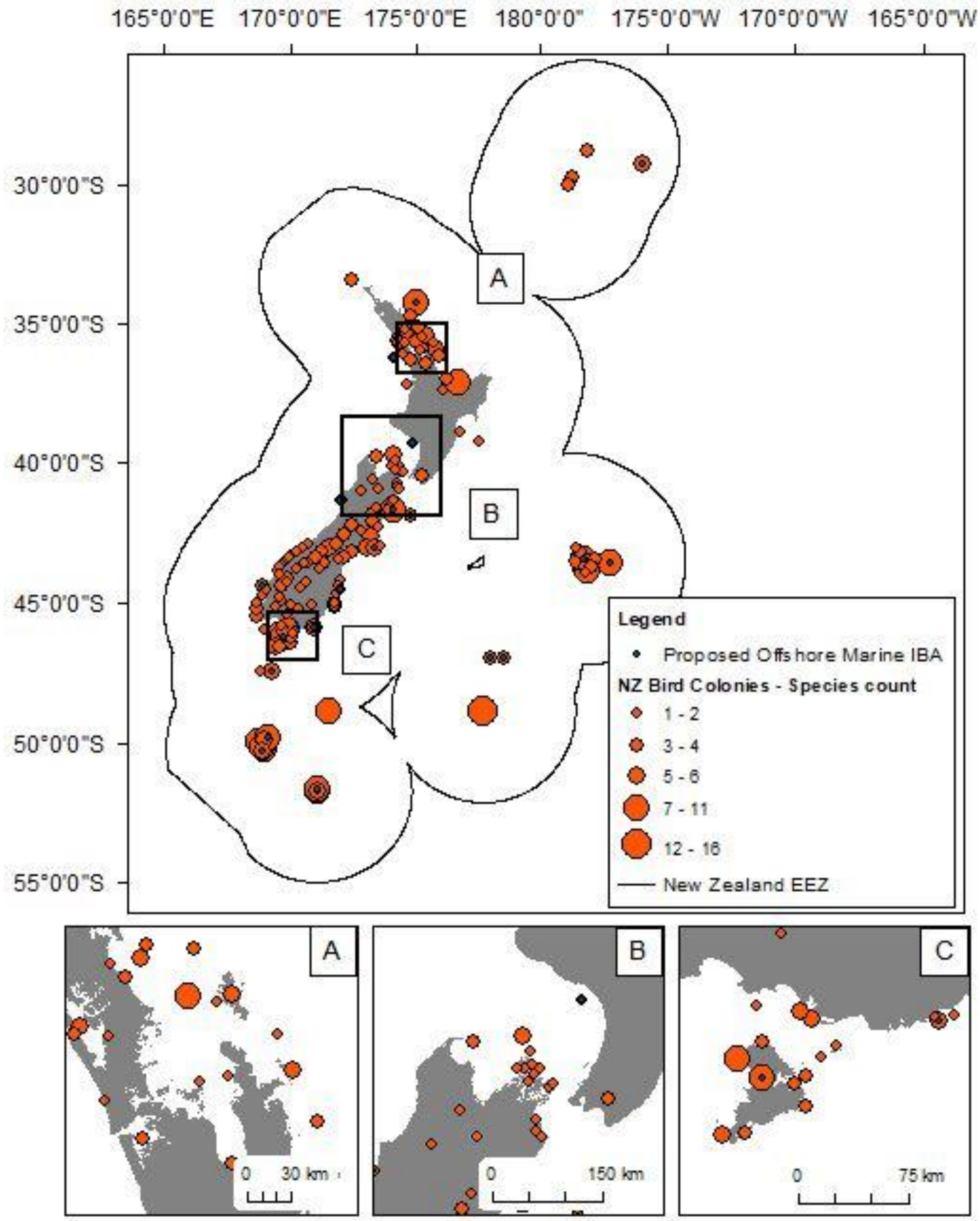


Figure 2-8: Locations of seabird colonies, ranked by the number of bird species using each colony site. Data acquired with permission (BirdLife International and Handbook of the Birds of the World 2019).

Species distribution models

Modelled distributions of annual averages of breeding, and non-breeding, at-sea distributions of 70 seabird species were acquired for the original Key Ecological Areas project (Section 3.3.9 in Stephenson et al. 2018b). These modelled distributions were categorised into 8 groups: albatrosses; diving petrels; procellariidae petrels; storm petrels; gulls, terns, skuas, and noddies; penguins; shags; and other seabirds (BirdLife International and Handbook of the Birds of the World 2019). It was noted that these modelled distributions showed bias toward location in fisheries areas, as most species records were from bycatch observer records. These models also incorporated NABIS annual distribution maps (90% and 100% confidence limits of the population range), and an exponential decay in value with distance from identified bird colonies.

2.2.3 Matching criteria - birds

Criteria 2: Uniqueness / Rarity / Endemism

Of the 258 total seabird and shorebird species (including some coastal birds found occasionally in saltmarsh or other coastal habitats noted in regional council ASCVs), 94 are endemic. Of the 122 seabirds described by Gordon et al. (2010), taxa of noted endemicity include 7 of the 12 albatross species (Diomedeidae), and a monotypic penguin genus (of the six penguin species which breed in NZ’s EEZ) (Gordon 2009).

Criteria 3: Special Importance for Life History Stages

The IBAs identify 92 seabird species with breeding colonies in New Zealand. Regional council datasets further identify sites used regularly for foraging and roosting by seabirds and international migratory wading shorebirds.

Criteria 4: Importance for Threatened / Declining Species and Habitats

As reported in Stephenson et al. (2018b), all of New Zealand’s seabirds and shorebirds have been assessed within the New Zealand Threatened Species Classification System and many are also listed as internationally threatened (Miskelly et al. 2008, Robertson et al. 2016). Updating the list of species from Stephenson et al. (2018b) to include all reported seabirds and shorebirds in the additional datasets collated by this project, 20 birds were assessed as nationally critical, 10 as nationally endangered, 21 as nationally vulnerable, 19 as declining, 19 as recovering, 16 as relict populations, and 31 as naturally uncommon.

Criteria 6: Biological Diversity

Species richness is available within the individual bird colony polygons and at individual regional council ASCV sites. Additional modelling or compilation of datasets could be undertaken to develop further maps of seabird diversity, such as the number of taxa per area.

2.2.4 Data quality/spatial comprehensiveness.

We have explored a number of new datasets on seabirds and shorebirds to provide a more comprehensive record of their occurrence in New Zealand. However, these datasets include a range of modelled distributions (from at-sea sightings by bycatch observers), colony sites, and known regional locations of regular occurrence, making their integration challenging (as observed in the 70 species modelled layers). Other datasets exist that we did not explore that may provide additional information on migratory shorebirds, for example from groups such as Birding New Zealand.

An identified challenge for the inclusion of seabirds and shorebirds in marine conservation planning is that these species often use terrestrial habitats for foraging, roosting, and nesting. Some seabirds range as far inland as alpine habitats, making it difficult to link these locations to a specific coastal location. Further discussion is warranted on how to best integrate these diverse datasets to provide best approximations of distributions of these species, particularly for species for which most records are 'terrestrial'. Differences in life history would be crucial in how individual seabirds and shorebirds are incorporated into key ecological area datasets, for example blue penguins with primarily coastal distributions, in contrast to black-billed gull and black-fronted term, which both include primarily terrestrial sightings (Figure 2-9).

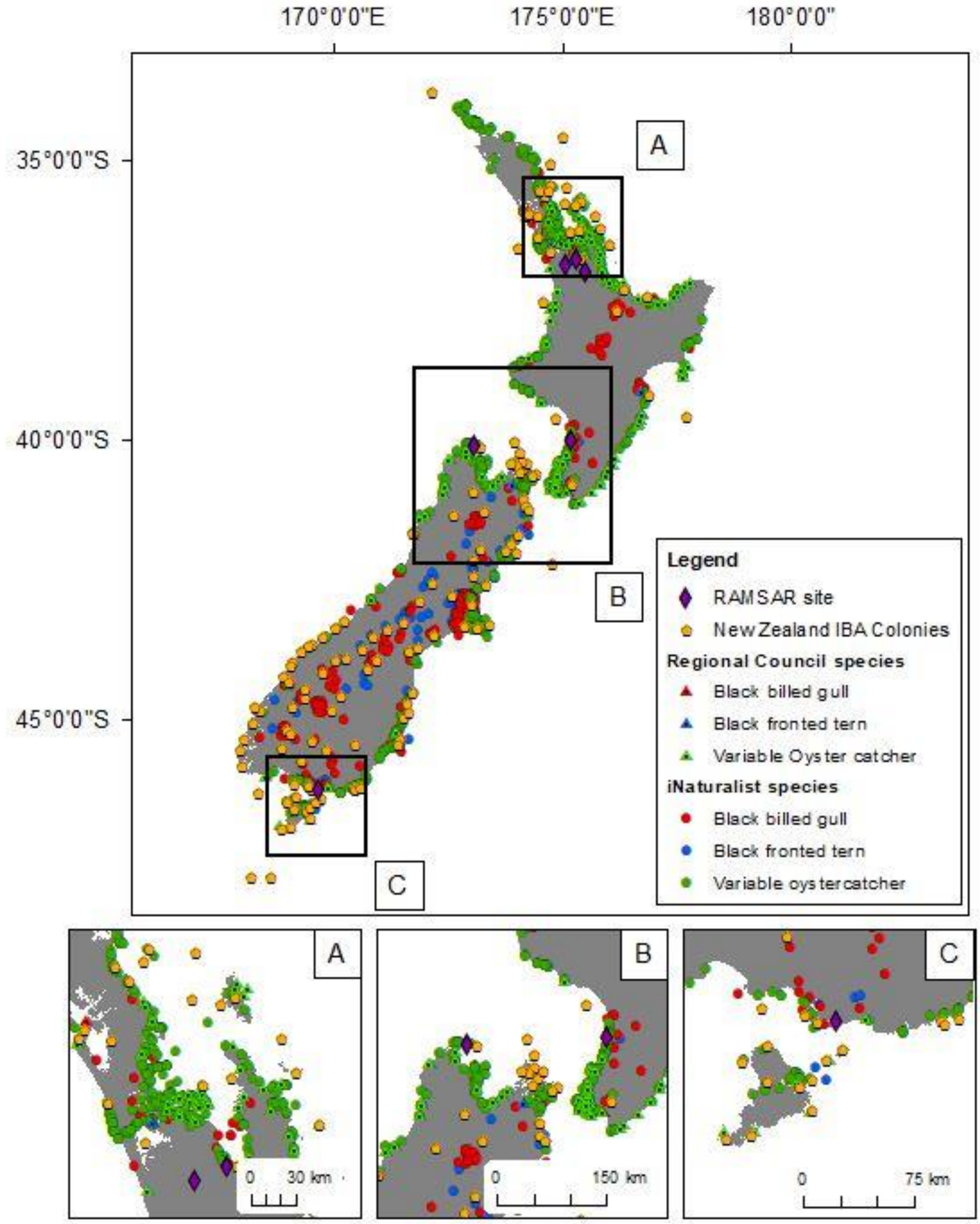


Figure 2-9: Observations of seabirds and seabird colonies for black-billed gull, black-fronted tern and variable oystercatcher.

2.3 Demersal fish

2.3.1 Summary

Table 2-8: Summary of demersal fish occurrence within NZ and core datasets provided in this report.

	Demersal fish
Recognised species in NZ waters	1313*
Threatened species	NA**
Endemic species	242*
Point records (all datasets)	391198
Species with predictive distributions	239

*From Gordon et al. 2010 for all marine fish. **No formal threat assessment for marine fish

Demersal fish data are available to populate all four species and taxon-specific key ecological criteria (Table 2-9). Demersal fish are one of the best known taxonomic groups in New Zealand, due to their importance for commercial fisheries. Significant effort has been put into surveys, the results of which are often contained in the Research TRAWL database which includes >390,000 records. Point records are available for most trawlable depths (<1600 m), though information on bathyal and abyssal areas are limited. There is some spatial bias due to this sampling effort focusing on key commercial fishing grounds such as the Chatham Rise. A groomed dataset of demersal fish observations of 317 species at 28,599 unique locations has been used to generate classification groups and species turnover, and species occurrence models for a subset of 239 species. While most demersal fish datasets were available from the original key ecological areas dataset, the classification groups and species distribution models have been updated through combined funding across the three concurrent MSAG investigations, and updated species occurrence models and associated uncertainty layers have been developed. These models include approximately 21% more species, due to new data collated in the fish records database.

Of the 1,313 recorded marine fish taxa in New Zealand including demersal, reef and pelagic species (Gordon et al. 2010), a large proportion are endemic (n = 242). A similar proportion (n = 47) of the 239 modelled demersal fish are endemic. A large proportion (20%) of the fish species assessed in the NZTCS were categorised as naturally uncommon. Key gaps in demersal fish datasets are a poor understanding of rare species, and point record datasets that have been prepared for taxa with various levels of rarity (e.g., taxa with only one unique record in New Zealand, taxa with 2-10 records). Classification groups have been developed as a further way to represent these groups when point records are insufficient to support development of robust species occurrence models (Stephenson et al. submitted). Abundance models were provided by Leathwick et al. (2006); however, current models include only species occurrence distributions. See supplementary material (S3) for details of the species relevant for each of the ecological criteria below.

Table 2-9: Summary of application of demersal fish datasets to key ecological area criteria.

	Uniqueness / Rarity / Endemism	Special Importance for Life History Stages	Importance for Threatened / Declining Species and Habitats	Biological Diversity
Species occurrence point records	x		x	
Freshwater fish point records		x	x	
Finfish spawning		x		
Species distribution models	x		x	
Species richness				x
Species turnover	x			x
Classification groups	x			x

2.3.2 Primary datasets

Species occurrence point records

Fish species occurrence records (n = 391,198) (including information on research cruise identifier, gear type, date, min and max depth of trawl, and GPS location) from 1979 – 2016 were extracted from the research trawl database 'TRAWL' (NIWA 2014, 2018). The data were groomed to only keep those records identified to species level, collected using bottom trawls and within the New Zealand EEZ (Figure 2-10). Species records were aggregated (to presence/absence) spatially to a 1 km^2 grid resolution (e.g., as in Stephenson et al. (2018b)). Records used in gradient forest models included observations of 317 species at 28,599 unique locations.

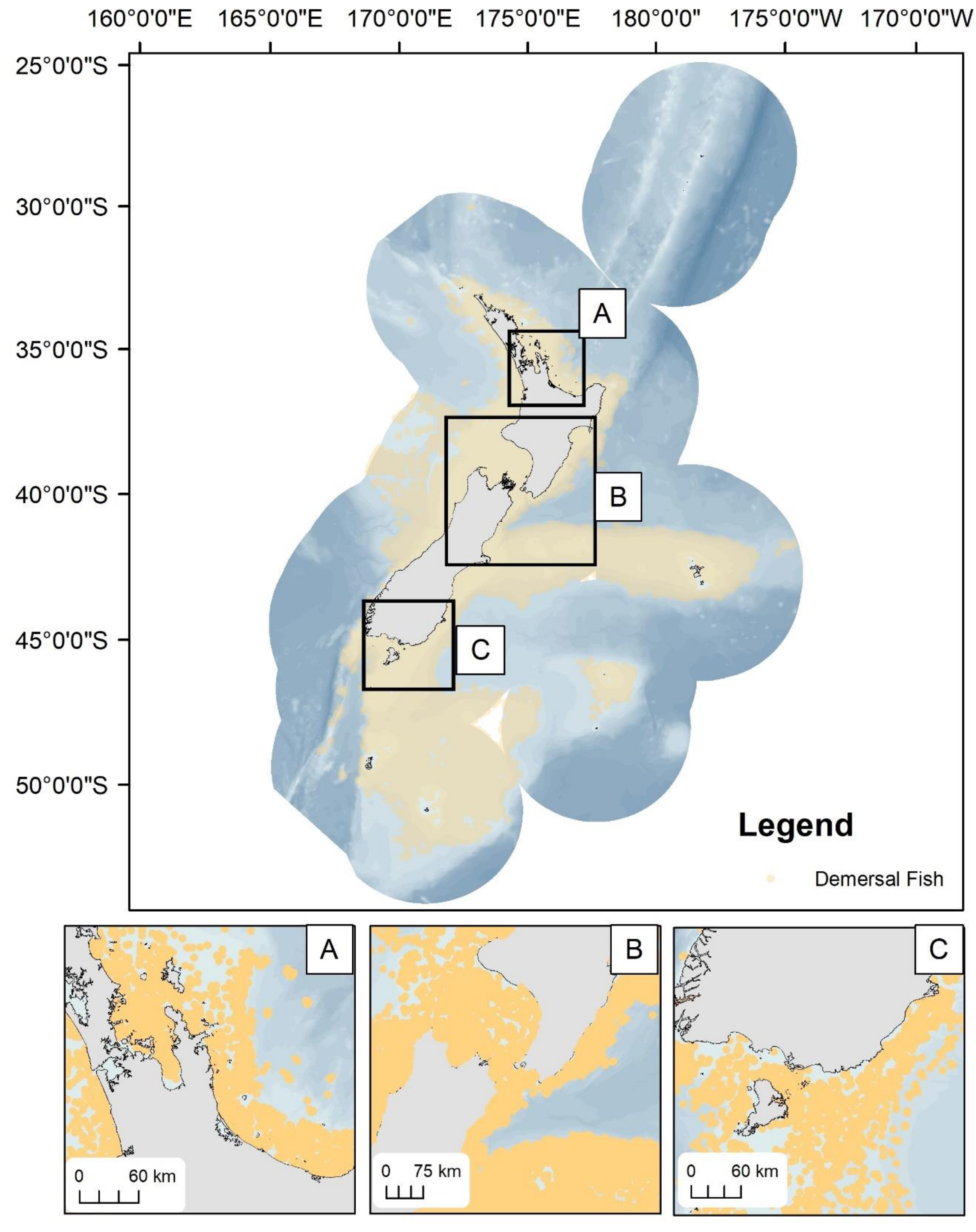


Figure 2-10: Locations of demersal fish records from the TRAWL database.

Finfish spawning

As presented in section 3.4.4 of Stephenson et al. (2018b), annual spawning distributions of 39 species were available from NABIS (2012). A further 'spawning hotspot' layer was created through summing each of the 39 annual spawning distributions (Stephenson et al. 2018b).

Freshwater fish database

At the August 2019 MSAG workshop, records of migratory fish species with 'marine or estuarine' life history stages were identified as a priority for acquisition. The New Zealand Freshwater Fish Database contains over 34,000 freshwater fish observations. Data stored include the location of sample sites, the fish species present, as well as information on their abundance, size, sampling methods and a physical description of each site. In recent years, data from the River Environment Classification (REC) has also been linked to the NZFFD, adding further environmental information to each NZFFD record. A total of 26 species codes (including three that were only identified to genus) were identified as species with migratory life cycles or marine species that were found upstream of estuaries in brackish waters. The data included ~74,000 point records including eels (anguillids), whitebait (galaxiids), mullets (*Aldrichetta forsteri*), triplefins, flounder, bullies, lamprey, and torrentfish (*Gobiomporphus cotidianus*, *G. huttoni*, *G. gobioides*, *Geotria australis*, *Cheimarrichthys fosteri*), smelt and other migratory fish (Figure 2-11). As the majority of these records are from inland streams and rivers, there is a need to further consider the most appropriate way to represent the distributions of these freshwater taxa with estuarine/marine life cycles.

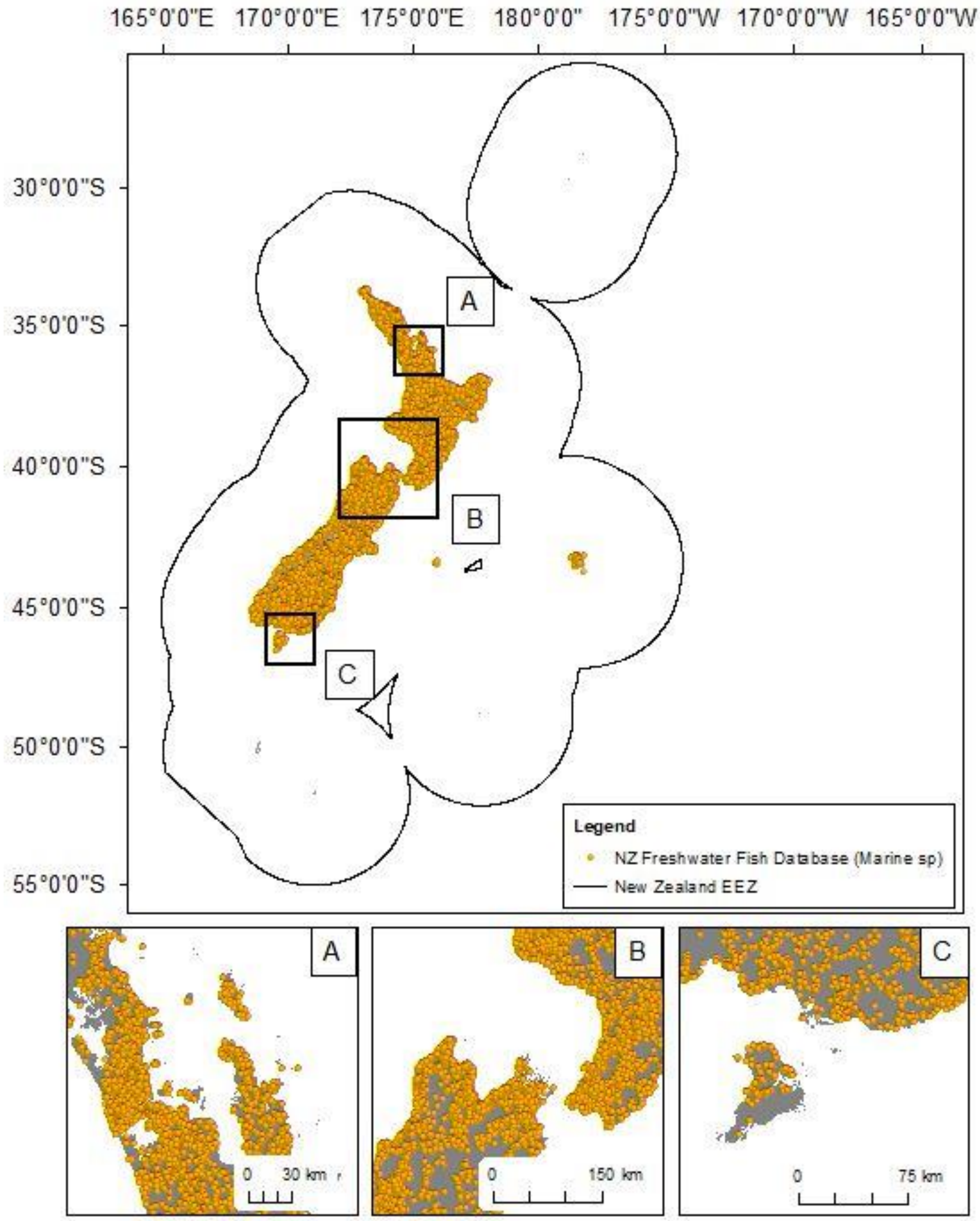


Figure 2-11: Locations of freshwater fish taxa with migratory life cycles from the New Zealand Freshwater Fish Database.

2.3.3 Modelled datasets

Species Distribution Models (SDMs)

Ensemble predictions from Boosted Regression Tree (BRT) and Random Forest (RF) species distribution models (Ensemble SDMs) were initially produced for 239 demersal fish taxa with > 50 unique spatial occurrences using species occurrence data (391,198 occurrences – described above) and 20 high-resolution (1 km^2) environmental data layers. Further expert validation of these models is in process to provide expert scores in addition to model fit metrics. This ensemble model approach limits dependence on a single model type or structural assumption and enables a more robust characterisation of the predicted spatial variation and uncertainty. Ensemble model AUC ranged from 0.83 (New Zealand smooth skate, *Dipturus innominatus*) to 0.99 (Big-spined boarfish, *Pentaceros decacanthus*) with a mean of 0.96. Detailed methodology of the ensemble approach is provided below, and applies to demersal fish, rocky reef fish, benthic invertebrate, and macroalgal modelled species distributions.

To estimate taxonomic distributions, BRT and RF models require locations of both presences (occurrence records) and absences. Here, we used 'target-group background data' (Phillips et al. 2009) as absences (referred to here as relative absence), i.e., a location where a different taxon to that being modelled was recorded (Stephenson et al. 2020c). Relative absences were generated for each taxon from occurrences within taxonomic groups (i.e. demersal fish relative absences were generated from demersal fish occurrence records). The location of relative absences was required to be at least 1 km from presence data and the number of absences was set to be equal to the number of presences (following best practice outlined in Aiello-Lammens et al. (2015) and Barbet-Massin et al. (2012)).

In most cases, the inclusion of many variables (e.g., all 20 + variables) was avoided because they generally only provide minimal improvement in predictive accuracy, and complicate interpretation of model outcomes (Leathwick et al. 2006). Several environmental variables showed some co-linearity within records for taxa groups however, although all levels of co-linearity were considered acceptable (Pearson correlation < 0.9) for tree-based machine learning methods (Elith et al. 2010; Dormann et al. 2013). In order to produce parsimonious models, an automated environmental variable selection was performed. In the first instance a RF model was fitted to the presence / relative absence data using the extended Forest package in R (Liaw and Wiener, 2002). This method accounts for any co-linearity in environmental predictor variables when determining the relative importance of each predictor variable in the model through the implementation of a conditional approach to variable importance calculation (Ellis et al. 2012). Only environmental variables with a relative influence > 5% were retained (Müller et al. 2013; Jouffray et al. 2019). This allowed environmental predictors that may have important localised importance, but with low overall importance, to be retained whilst removing any very low, or negatively contributing environmental variables (R Pitcher, pers. comm.). For each taxon, the 'final' environmental variables selected through this approach were also used in the BRT models.

BRT and RF models were bootstrapped 100 times for each taxon modelled. That is, a random 'training' sample of the presence-relative absence records was drawn without replacement. The bootstrapping process was repeated 100 times, and at each iteration, predictions were made to the 'evaluation' data, i.e. the remaining 25% of the presence data and relative absence data, allowing model fits (see **Ensemble Models** below for further details) to be examined both on the training and evaluation data. For taxa with < 100 unique sample locations, random 'training' sample of the presence-relative absence records was drawn with replacement which meant there was no ‘evaluation data’.

At each BRT and RF model iteration, geographic predictions were made using environmental predictor variables to a 1 km^2 grid. For each taxon, mean probability of occurrence and a spatially explicit measure of uncertainty (measured as the standard deviation of the mean (SD)) were calculated for each grid cell using the 100 bootstrapped layers. To avoid predictions into unsampled space (e.g., into deep areas with few biological samples), geographic predictions were clipped to areas with reasonable environmental coverage of samples (i.e. areas with environmental coverage scores > 0.05, as in Stephenson et al. 2020b).

Random Forest models

Random Forest models (Breiman 2001) fit an ensemble of regression (abundance data) or classification tree (presence/absence data) models describing the relationship between the distribution of an individual species and some set of environmental variables (Ellis et al. 2012). Following environmental predictor selection using an initial RF model, a second RF model was tuned using additional R routines based on methodologies previously applied to benthic invertebrate data (Rowden et al. 2017; Georgian et al. 2019) and demersal fish in the New Zealand region (Stephenson et al. 2018a).

Boosted Regression Tree models

BRT modelling combines many individual regression trees (models that relate a response to their predictors by recursive binary splits) and boosting (an adaptive method for combining many simple models to give improved predictive performance) to form a single ensemble model (Elith et al. 2008). Detailed descriptions of the BRT method are available in Ridgeway (2007) and Elith et al. (2008). All statistical analyses were undertaken in R (R Core Team 2013) using the ‘Dismo’ package (Hijmans et al. 2017). BRT models were fitted with a Bernoulli error distribution, a tree complexity of 2 -3, a learning rate between 0.01 – 0.0001 (with parameters selected so as to fit between 1000 and 3000 trees for each species’ model), a bag fraction of 0.6 and random 10-fold cross evaluation following recommendations from Elith et al. (2008) and Leathwick et al. (2006).

The BRT method has been widely used in ecological applications and has performed well in previous studies of invertebrate and fish distributions in New Zealand (e.g., Leathwick et al. 2006; Compton et al. 2013; Anderson et al. 2016b; Stephenson et al. 2020c).

Modelled datasets

BRT and RF model performance was evaluated using AUC (area under the Receiver Operating Characteristic curve) and True Skill Statistic (TSS, which takes into account Specificity and Sensitivity to provide an index ranging from -1 to +1, where +1 equals perfect agreement and -1 = no better than random, Allouche et al. (2006)). Model fit metrics were calculated using both the ‘training’ dataset and the ‘evaluation’ dataset (for those taxa > 100 unique sampling locations). The latter is considered a more robust and conservative method of evaluating goodness-of-fit of a model than using the same data with which the model was trained (Friedman et al. 2001).

Ensemble models

Ensemble models were produced for each taxon by taking weighted averages of the predictions from each model type, using methods adapted from Oppel et al. (2012); Anderson et al. (2016b); Rowden et al. (2017); Georgian et al. (2019). This adapted procedure derives a two-part weighting for each component of the ensemble model, taking equal contributions from the overall model performance (AUC value derived from the 'evaluation' data or the 'test' data for taxa < 100 unique sample locations) and the uncertainty measure (SD) in each cell, as follows:

$$W_{1BRT} = \frac{MPS_{BRT}}{MPS_{BRT}+MPS_{RF}} \text{ and } W_{1RF} = \frac{MPS_{RF}}{MPS_{BRT}+MPS_{RF}}$$

$$W_{2BRT} = 1 - \frac{SD_{BRT}}{SD_{BRT}+SD_{RF}} \text{ and } W_{2RF} = 1 - \frac{SD_{RF}}{SD_{BRT}+SD_{RF}}$$

$$W_{BRT} = \frac{W_{1BRT}+W_{2BRT}}{2} \text{ and } W_{RF} = \frac{W_{1RF}+W_{2RF}}{2}$$

$$X_{ENS} = X_{BRT} * W_{BRT} + X_{RF} * W_{RF}$$

$$SD_{ENS} = SD_{BRT} * W_{BRT} + SD_{RF} * W_{RF}$$

where MPS_{BRT} and MPS_{RF} are the model performance statistics; X_{BRT} and X_{RF} are the model predictions; SD_{BRT} and SD_{RF} are the bootstrap SDs; and X_{ENS} and SD_{ENS} are the weighted ensemble predictions and weighted SDs, respectively, from which maps of predicted species distribution and model uncertainty were produced.

Ensemble model performance was assessed using AUC and TSS by comparing ensemble model predictions to all the taxon's presence data and an equal number of randomly selected relative absence data. To ensure that the random selection of relative absence data did not provide misleading model performance metrics, this procedure was iterated 50 times and mean AUC and TSS score calculated for the ensemble model (Barbet-Massin et al. 2012). In addition, the Pearson's correlation between BRT and RF spatial predictions was calculated as a measure of model congruence (Anderson et al. 2016b).

Classification groups and species turnover

As presented in section 3.5.4 of Stephenson et al. (2018b), Gradient Forest (GF) models have been previously used to analyse and predict spatial patterns of 317 demersal fish species turnover (following methods described in Stephenson et al. (2020c)). GF models are less constrained by low sample number than individual species' distribution models (Pitcher et al. 2012). Demersal fish species with ≥ 10 occurrences were used for the analysis of species turnover. These models are in process of being updated as part of Investigation No. 4757 (Stephenson et al. in preparation).

Demersal fish species turnover was classified to produce species groups (inferred assemblages) at different levels of the classification hierarchy (30; 50; 100-group classifications, see section 3.5.4 of Stephenson et al. (2018b).

2.3.4 Matching criteria

Criteria 6: Biological Diversity

Species richness

Demersal fish richness was estimated by stacking the ensemble species distribution model predictions (S-SDM) for the 239 demersal fish species (Figure 2-12). Richness was calculated as the sum of the occurrence probability predictions (ranging from 0 to 1) (Ferrier and Guisan 2006, Calabrese et al. 2014). For demersal fish, environmental coverage was driven largely by depth, with very limited sampling at depths greater than 2000m. Thus, species richness layers for these taxa were clipped to areas shallower than 2000m. The estimated distribution of demersal fish richness, in areas with adequate environmental coverage (<2000m depth), ranged from 24 to a theoretical maximum of 84.

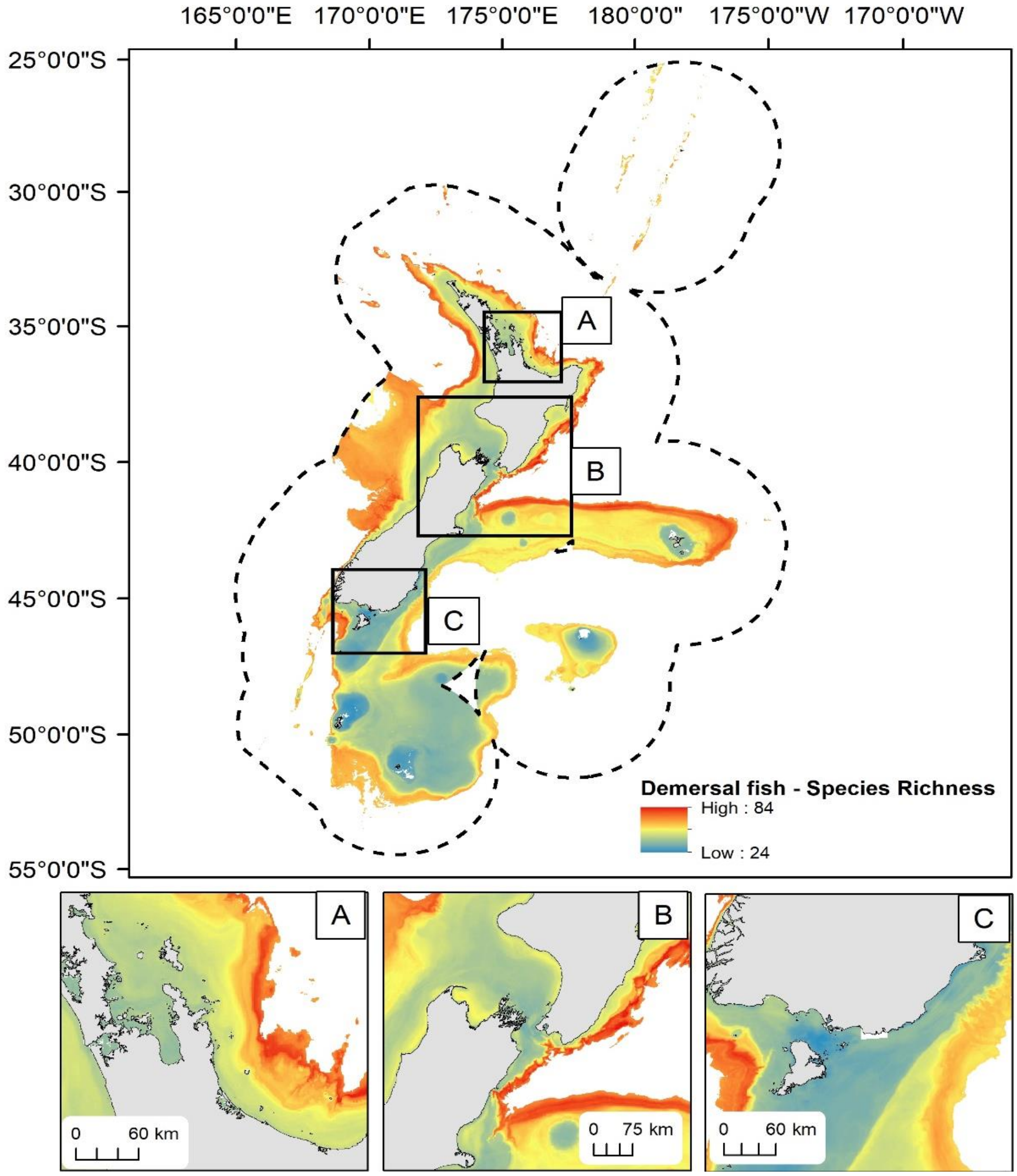


Figure 2-12: Demersal fish richness estimates (derived by stacking 239 bootstrapped SDMs). Richness estimates are clipped to areas of adequate model environmental coverage (<2000m depth).

Species turnover

A second aspect of Biological Diversity that was discussed at the August 2019 MSAG workshop was that of beta diversity. As presented in section 3.5.4 of Stephenson et al. (2018b), GF models provided estimates of species turnover for 317 species of demersal fish, applicable to this additional type of diversity. These models are in process of being developed as part of Investigation No. 4757 (Stephenson et al. in preparation).

Criteria 2: Uniqueness / Rarity / Endemism
Of the 1,313 recorded marine fish taxa in New Zealand including demersal, reef and pelagic species (Gordon et al. 2010), a large proportion are endemic (n = 242). Within the demersal fish point records database (section 2.3.2), there are 89,115 occurrence records and 76,826 unique locations representing 77 different endemic fish. Of the 317 demersal fish included in the GF models, 54 are endemic, whereas 47 of the 239 demersal fish for which species occurrence models were developed are endemic.

Point records for fish species that were identified as unique or rare were collated for the initial Key Ecological Areas project (Section 3.3.1 in Stephenson et al. 2018b). Unique taxa (n = 39) were identified as taxa with a single record from the New Zealand EEZ, and Rare taxa (n = 97) were identified as taxa with 2 – 10 records in the New Zealand EEZ.

Criteria 3: Special Importance for Life History Stages
For the original Key Ecological Areas project (Section 3.4.4 in Stephenson et al. 2018b), finfish spawning areas were compiled from NABIS (2012) for 39 commercially important finfish species, and a summed geospatial layer was created. These polygons are generally large, and often include entire regions but with limited information on specific areas with large embayments such as the Hauraki Gulf that are of particular important for finfish spawning.

Criteria 4: Importance for Threatened / Declining Species and Habitats
Only 218 of the fish species have been assessed in the NZTCS, with about 20% classified as 'Data deficient' and a further 20% as naturally uncommon.

For the original Key Ecological Areas project (Section 3.2.4 in Stephenson et al. 2018b), a geospatial dataset was compiled of point records of 32 chondrichthyan species that had been assessed as vulnerable in a qualitative risk assessment (Ford et al. 2015, 2018). This included a number of species listed in the Wildlife Act, though the point records include primarily deeper (>200 m) depths. Fish species listed in Schedule 7a of the Wildlife Act include:

- Carcharhiniformes (ground sharks); some species with records in the demersal fish database, with the exception of the Oceanic whitetip shark (*Carcharhinus longimanus*).
- Orectolobiformes (carpet sharks)— Whale shark (*Rhincodon typus*).
- Rajiformes (skates and rays); some species with records in the demersal fish database, with the exception of the manta ray (*Manta birostris*) and spinetail devil ray (spinetail mobula) (*Mobula japonica*).

- Osteichthyes (bony fishes)— Perciformes (perch-like fishes); some species with records (e.g., spotted grouper) are listed in the demersal fish database, with the exception of the giant grouper (Queensland grouper) (*Epinephelus lanceolatus*).

Point records for fish species that were identified as threatened in the NZTCS, primarily shark and ray species, were collated for the original Key Ecological Areas project (see Section 3.5.2 in Stephenson et al. 2018b). Records for a total of 49 species were collated into a geospatial point records layer.

2.3.5 Data quality/spatial comprehensiveness.

The most comprehensive datasets available for key ecological areas evaluations are for demersal fish. Approximately 20% of fish species have modelled species occurrence distributions complete with associated uncertainty layers. A remaining area for further exploration is in determining how well species occurrence models of demersal fish represent patterns of abundance of these species.

Point records are dominated by trawlable depths (<1600 m), and information on bathyal and abyssal areas are limited (Figure 2-13). There is further spatial bias due to locations of research trawl surveys which focus on key commercial fishing grounds such as the Chatham Rise.

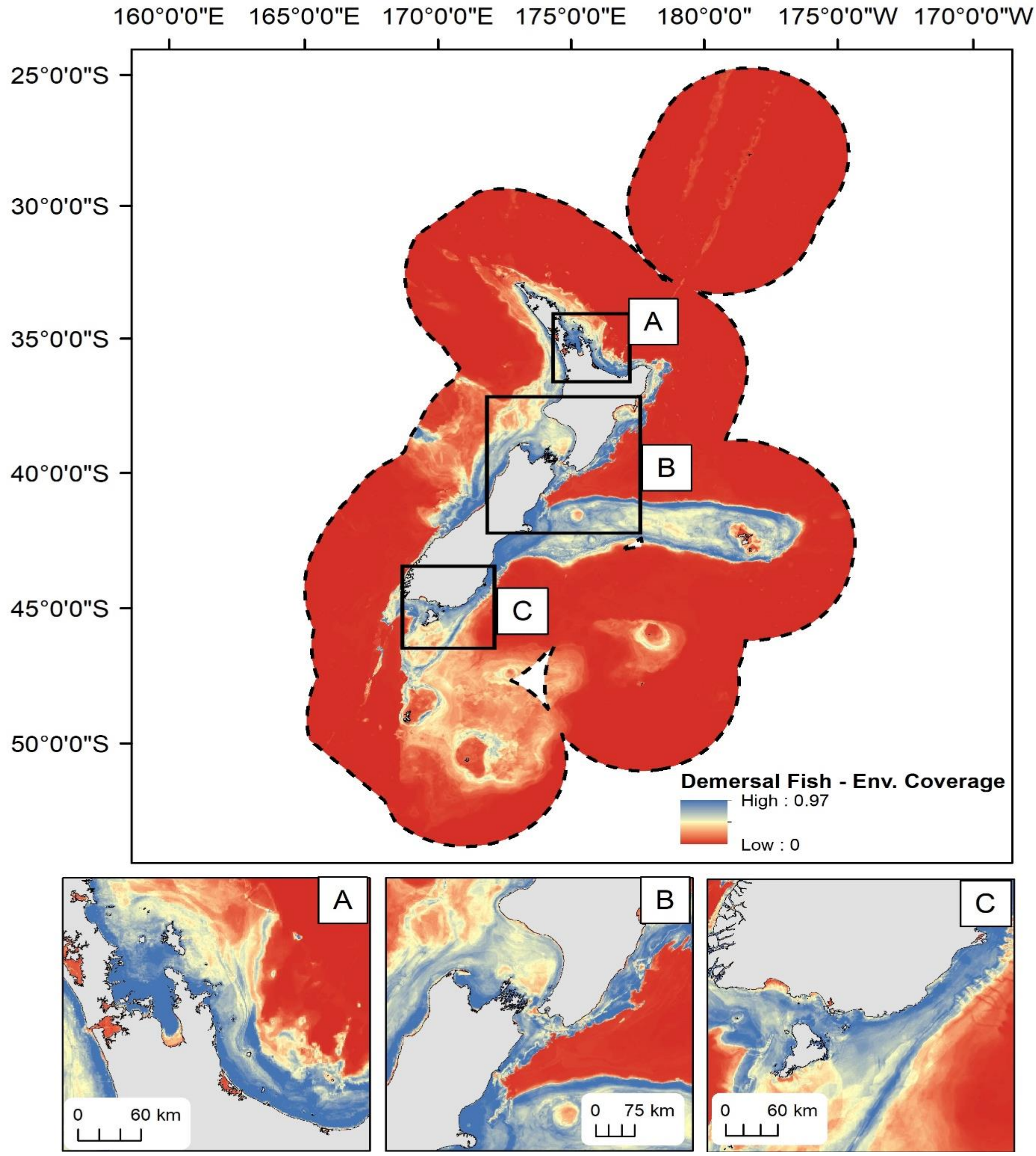


Figure 2-13: Predicted environmental coverage depicting the confidence that can be placed in demersal fish predictive models. Scale ranges from low (i.e., no samples in the dataset with those environmental conditions) to high (i.e., many samples with those environmental conditions) within the New Zealand EEZ.

Abundance models were provided by Leathwick et al. (2006) however current models include only species occurrence distributions.

While about 2/3 of fish species identified by Gordon et al. (2010) (including demersal, pelagic and rocky reef fish) do not have modelled species occurrence distributions, a larger portion have been included within demersal and rocky reef fish classification groups and species turnover models, allowing for representation of these rarer taxa. Geospatial datasets of unique, rare and endemic species records have also been compiled. Only 218 of the fish species have been assessed in the NZTCS, with about 20% classified as 'Data deficient' and a further 20% as naturally uncommon.

2.4 Rocky reef fish

2.4.1 Summary

Table 2-10: Summary of reef fish occurrence within NZ and core datasets provided in this report.

	Rocky reef fish
Recognised species in NZ waters	1313*
Threatened species	NA**
Endemic species	242*
Point records (all datasets)	467
Species with predictive distributions	51
Species also occurring in demersal fish model set	20

*From Gordon et al. 2010 for all marine fish. **No formal threat assessment for marine fish

Some rocky reef fish data are available to populate all four species and taxon-specific key ecological areas criteria (Table 2-11). Point records are limited to dataset of 467 records from 339 unique shallow subtidal rocky reef locations (aggregated to 250 m), though sampling methodology was identical for all records. There is some spatial bias due to depth as well as more exposed or remote coastal areas having lower sampling effort. A total of 72 rocky reef species occurrence models were previously available in the original key ecological areas dataset, but were determined to require updating. Revised species occurrence models and associated uncertainty layers were developed for 51 of these taxa, and utilised more robust statistical methodologies and updated sediment maps. However, these models include only species occurrence distributions, and not estimates of abundance. Models of classification groups were also developed.

Approximately 1/3 of the rocky reef fish with modelled distributions are endemic, with >7,000 records at >3,400 unique locations. Analyses of threatened species, life history stages, and uniqueness and rarity were compiled with demersal fish and discussed in combination with those fish groups. See supplementary material (S3) for details of the species relevant for each of the ecological criteria below.

Table 2-11: **Summary of application of rocky reef fish datasets to key ecological area criteria.**

Dataset	Uniqueness / Rarity / Endemism	Special Importance for Life History Stages	Importance for Threatened / Declining Species and Habitats	Biological Diversity
Species occurrence point records	x		x	
Species distribution models	x	x	x	
Species richness				x
Species turnover	x			x
Classification groups	x			x

2.4.2 Primary datasets

Rocky reef fish occurrence data

The relative abundance of reef fishes were obtained from 467 SCUBA dives made around the coast of New Zealand over an 18-year period from November 1986 to December 2004 (for detailed methodology see Smith et al. (2013)). The data were already groomed and all records were provided to species level identification, though only modelled distributions were compiled for the original key ecological areas project, and point records have been subsequently acquired to support updated modelling. Species records were aggregated (to presence/absence) spatially to a 250 m grid resolution and included observations of 160 species at 339 unique locations.

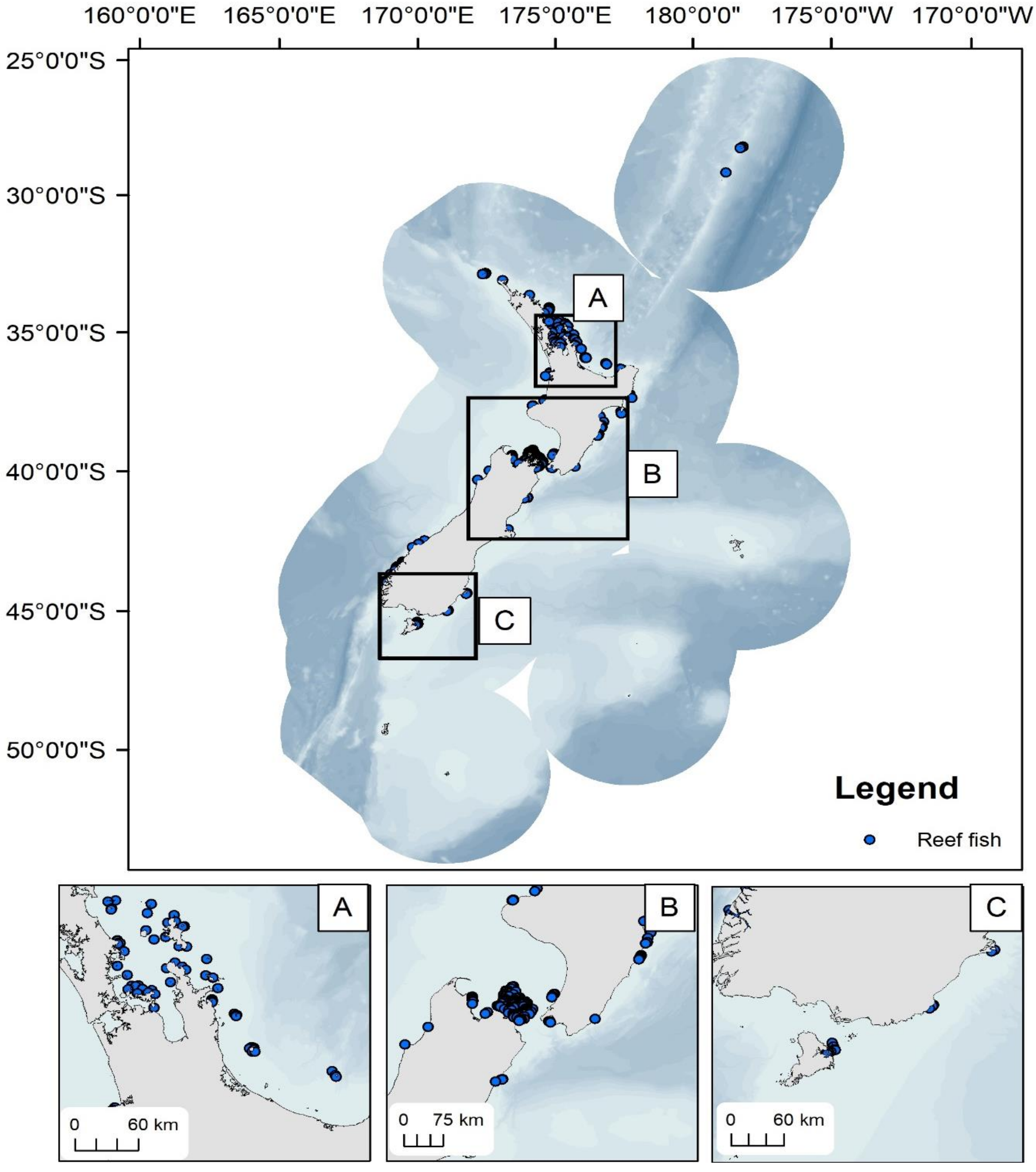


Figure 2-14: Locations of rocky reef fish records.

2.4.3 Modelled datasets

Species Distribution Models

While prior species distribution models were available for 72 reef fish (Smith et al. 2013) as acquired for Stephenson et al. (2018b), a MSAG priority was to have these models, and the datasets produced, updated using more robust statistical methodologies and updated environmental layers. Ensemble predictions from Boosted Regression Tree (BRT) and Random Forest (RF) species distribution models (Ensemble SDMs) were initially produced for 51 rocky reef fish taxa (those with ≥ 35 unique spatial occurrences) using species occurrence data and 20 high-resolution (250 m grid resolution) environmental data layers. These models include approximately 27% fewer species, as the statistical approaches used require larger datasets but are expected to provide more robust estimates of probability of occurrence. Example models are shown in Figure 2-15. Model parameterisations were the same as those used for demersal fish (described in section 2.3.3). Model predictions were limited to subtidal reefs (areas inferred from navigational charts, Smith et al. (2013)). Ensemble model AUC ranged from 0.93 (blue dot triplefin, *Notoclinops caerulepunctus*) to 0.99 (banded parrotfish, *Notolabrus fucicola*) with a mean of 0.97. Expert validation of these models is in process to provide expert scores in addition to model fit metrics. There is some overlap of demersal fish and rocky reef species occurrence models, with 20 taxa included in both datasets. Future work could explore whether relative environmental suitability models (see marine mammal section) could provide meaningful approximations of species distribution for reef fish taxa with limited records.

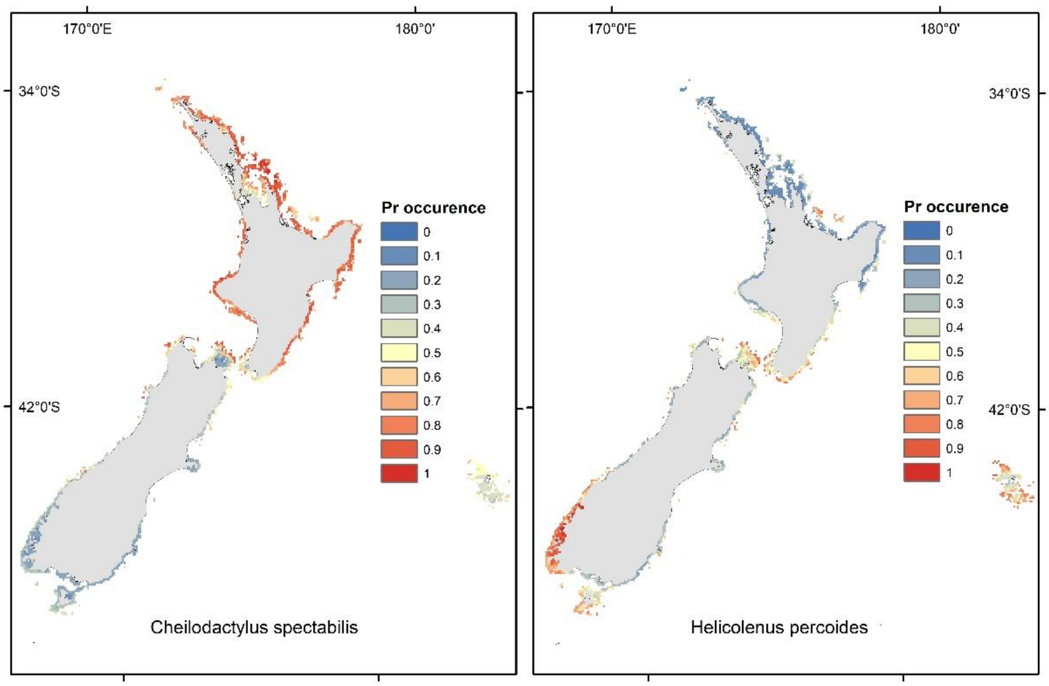


Figure 2-15: The predicted probability occurrence of red moki (*Cheilodactylus spectabilis*, left) and sea perch (*Helicolenus percoides*, right) on subtidal rocky reefs. SDM raster layers were aggregated to 5km grid resolution for easier visualisation.

Classification groups and species turnover

Gradient Forest (GF) models were used to analyse and predict spatial patterns of 92 rocky reef fish species turnover (following methods described in Stephenson et al. (2020c)) using the rocky reef fish presence/absence dataset (section 2.4.2) and high-resolution environmental data layers overlapping with subtidal rocky reefs (250 m grid resolution). GF models are less constrained by low sample number than individual species' distribution models (Pitcher et al. 2012). Rocky reef fish species with ≥ 10 occurrences were used for the analysis of species turnover. These models are in process of being developed as part of Investigation No. 4757 (Stephenson et al. in preparation).

2.4.4 Matching criteria

Criteria 6: Biological Diversity

Species richness.

Rocky reef fish richness was estimated by stacking the ensemble species distribution model predictions (S-SDM) for the 51 rocky reef fish species (Figure 2-16). Richness was calculated as the sum of the occurrence probability predictions (ranging from 0 to 1) (Ferrier & Guisan 2006; Calabrese et al. 2014). Estimated distribution of rocky reef fish richness, ranged from 9 to a theoretical maximum of 34. The maximum richness value is not the total number of species (51) for which SDMs are available as there are no sites where all species overlap in space. Values are 'theoretical' as richness is estimated based on species for which SDMs are available and are thus a relative rather than absolute measure of richness). Environmental coverage was not used to clip species richness layers for reef fish.

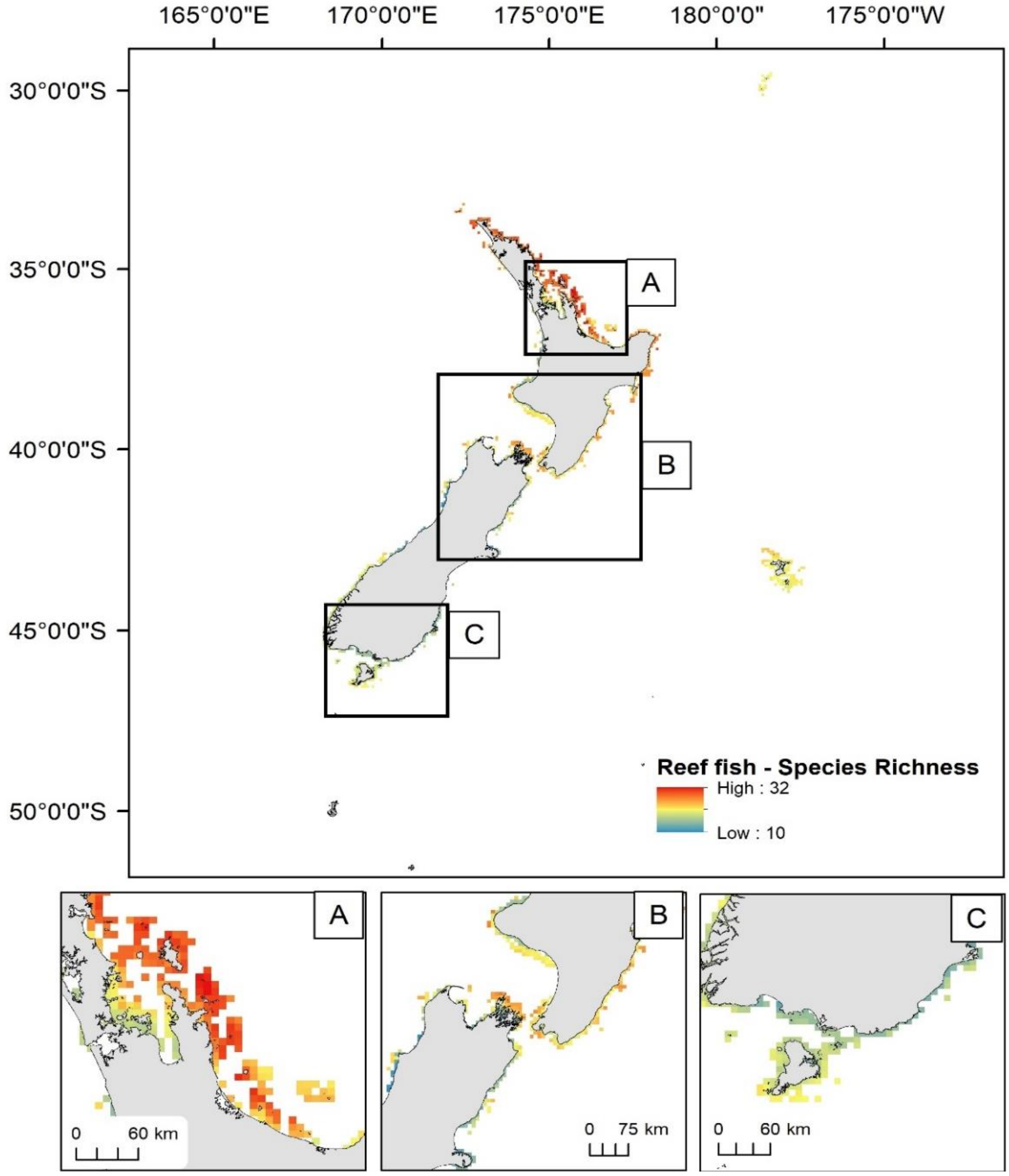


Figure 2-16: Rocky reef fish richness estimates (derived by stacking 52 bootstrapped SDMs Note model estimates are aggregated for visualisation, resulting in presentation of a lower range of species richness than available in the actual dataset.

Species turnover
A second aspect of Biological Diversity that was discussed at the August 2019 MSAG workshop was that of beta diversity. Models of species turnover are in process of being developed as part of Investigation No. 4757 (Stephenson et al. in preparation).

Criteria 2: Uniqueness / Rarity / Endemism
Of the 92 rocky reef fish included in the GF models, 27 are endemic, whereas 19 of the 51 rocky reef fish for which species occurrence models were developed are endemic. There are 7,360 occurrence records and 3,428 unique locations for these endemic rocky reef fish.

Criteria 3: Special Importance for Life History Stages
Finfish spawning distributions exist for 8 of the 51 reef fish for which species occurrence models have been developed, as described in the initial Key Ecological Areas project (Section 3.4.4 in Stephenson et al. 2018b).

Criteria 4: Importance for Threatened / Declining Species and Habitats
Threatened fish are discussed within the Demersal fish section 2.3.4 as detail was not available to separate out demersal, pelagic and rocky reef fish.

2.4.5 Data quality/spatial comprehensiveness

Sample coverage of New Zealand's EEZ for rocky reef fish is restricted to shallow subtidal reefs, with further limitations to more sheltered and accessible coastal sites (Figure 2-17). Rocky reef fish have high overlap with the demersal fish dataset, with approximately half of rocky reef modelled species being included in both fish datasets. All modelled species occurrence distributions have associated uncertainty layers. However, as with demersal fish, only predictions of species occurrences are available; predictive models of abundances have not been built. As for demersal fish, the classification groups and species turnover models allow for representation of rare taxa. Rocky reef taxa are included within geospatial datasets of unique, rare and endemic species fish records.

Point records are dominated by a limited number of sites (n = 339) and include only reefs within diving depths; no information is available for deeper reef fish communities. There is further spatial bias due to limitations on accessibility of exposed locations.

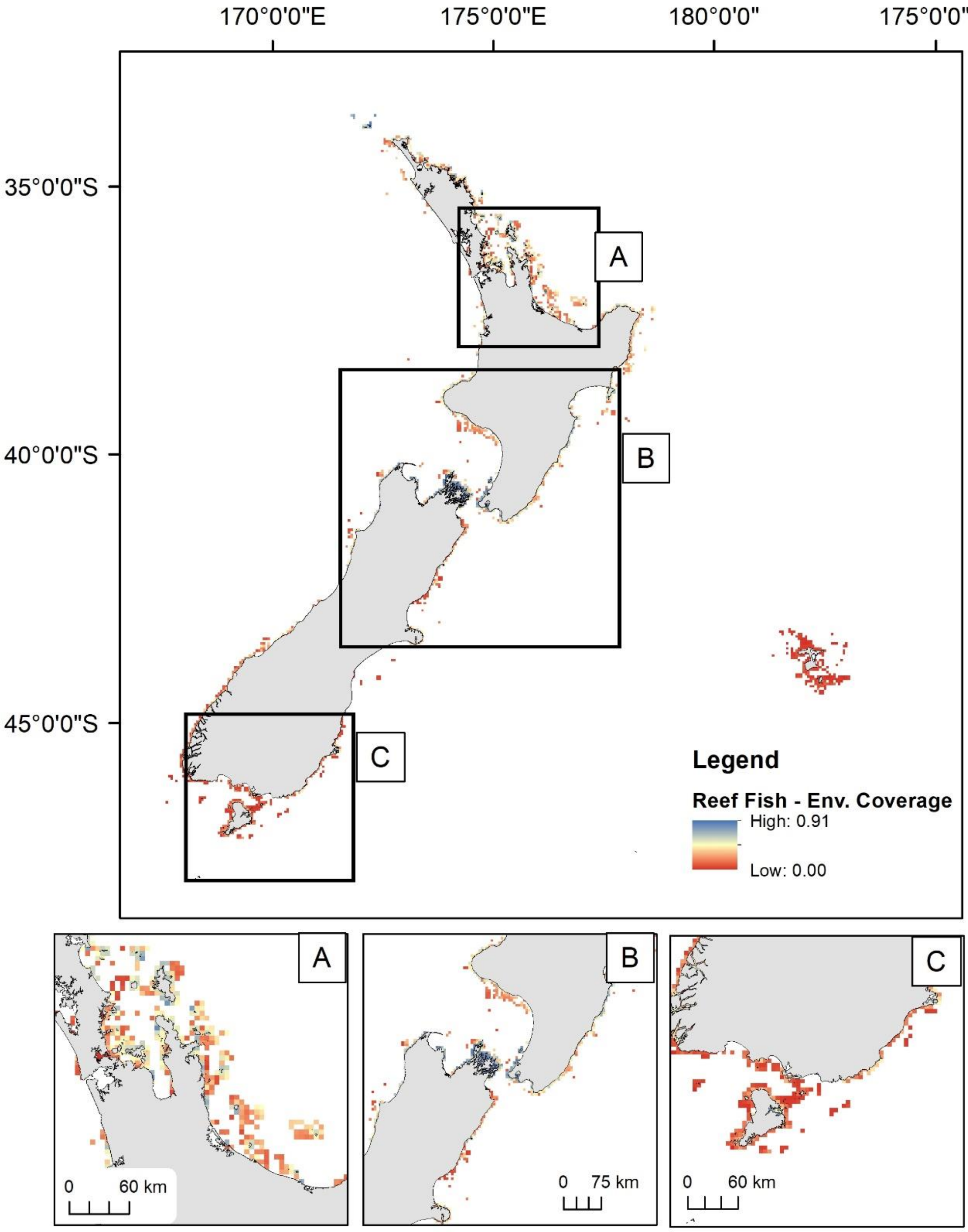


Figure 2-17: Predicted environmental coverage depicting the confidence that can be placed in reef fish predictive models. Scale ranges from low (i.e., no samples in the dataset with those environmental conditions) to high (i.e., many samples with those environmental conditions) within the New Zealand EEZ

2.5 Benthic invertebrates

2.5.1 Summary

Table 2-12: Summary of benthic invertebrate occurrence within NZ and core datasets provided in this report.

	Benthic invertebrates
Recognised species in NZ waters	10898*
Threatened species	33**
Endemic species	>6000*
Genera point records (all datasets)	127330***
Genera with predictive distributions	207***

*From Gordon et al. 2010 . **Formal threat assessment for only 307 benthic invertebrate species. *** Benthic invertebrate records pooled to genus level.

Benthic invertebrate data at the taxonomic scale of genera are available to populate all four species and taxon-specific key ecological criteria (Table 2-13). Use of invertebrate datasets is challenging due to multiple types of sampling gear used, and incomplete records of taxa found at each location. Point records are spatially biased to primarily trawlable depths (< 1600 m), though there are samples as shallow as the intertidal, and information on bathyal and abyssal areas is limited. While the original key ecological areas project included pilot models of benthic invertebrate classification groups and species richness, updating these models was undertaken through combined funding across the three concurrent MSAG investigations. Species occurrence models and associated uncertainty layers were also newly developed. Individual species records were generally insufficient, and instead species occurrence models were prepared based on genera. Models, as per other taxa, are limited to species occurrences, and are not estimates of abundance.

Gordon et al. (2010) identify > 6000 invertebrates (including all marine invertebrate taxa) as endemic to New Zealand. Only 307 of the marine invertebrate species have been assessed in the NZTCS, with 33 classified under various Threatened categories, 8 classified as Data deficient and a further 243 as Naturally Uncommon. Key gaps in invertebrate datasets are poor understanding of distributions of both common and rare species. Point record datasets have been prepared for taxa at various levels of rarity (e.g., taxa with only one unique record in New Zealand, taxa with 2-10 records).

Classification groups have been developed as a further way to represent these groups when point records are insufficient to support development of robust species occurrence models (Stephenson et al. submitted). See supplementary material (S4) for details of the genera relevant for each of the ecological criteria below

Table 2-13: **Summary of application of benthic invertebrate datasets to key ecological area criteria.**

Dataset	Uniqueness / Rarity / Endemism	Special Importance for Life History Stages	Importance for Threatened / Declining Species and Habitats	Biological Diversity
Species occurrence point records	x		x	
Species distribution models	x	x	x	
Species richness				x
Species turnover	x			x
Classification groups	x			x

2.5.2 Primary datasets

Species occurrence

Benthic invertebrate occurrence records (*n* = 127,330) (including GPS location, species name, collection date, and sampling gear used) from 1896 – 2019 were extracted from TRAWL (n = 56,841), NIWA invert (n = 59,144), Te Papa (n = 2943) and Auckland Museum (n = 8402) databases (Figure 2-18). Only those records that had been classified to at least genus level and included information on sampling gear were extracted. Each record included information on the date, GPS location, survey and collection method. Across the four databases, 208 different methods were used to sample benthic invertebrates. In order to account for both the large number of gear types recorded and the differences in sampling parameters, gear types were grouped into catchability categories (Table 2-14). Catchability was assumed to be influenced by gear size, deployment area and selectivity (Stephenson et al. 2018b). Following categorisation of gear types, four gear classes were retained for species distribution modelling: SMG (small size, medium deployment area, general selectivity), SSG (small size, small deployment area, general selectivity), MMG (medium size, medium deployment area, general selectivity) and LLG.LMG (Large size, medium and large deployment area, general selectivity). Gear class information was used to select representative absences for the modelled taxa, but samples from all gear types were combined for species occurrence models (see section 3 for further information). No taxa records collected using highly selective sampling methodology were retained as these reflected opportunistic sampling which were not deemed robust enough for species distribution modelling.

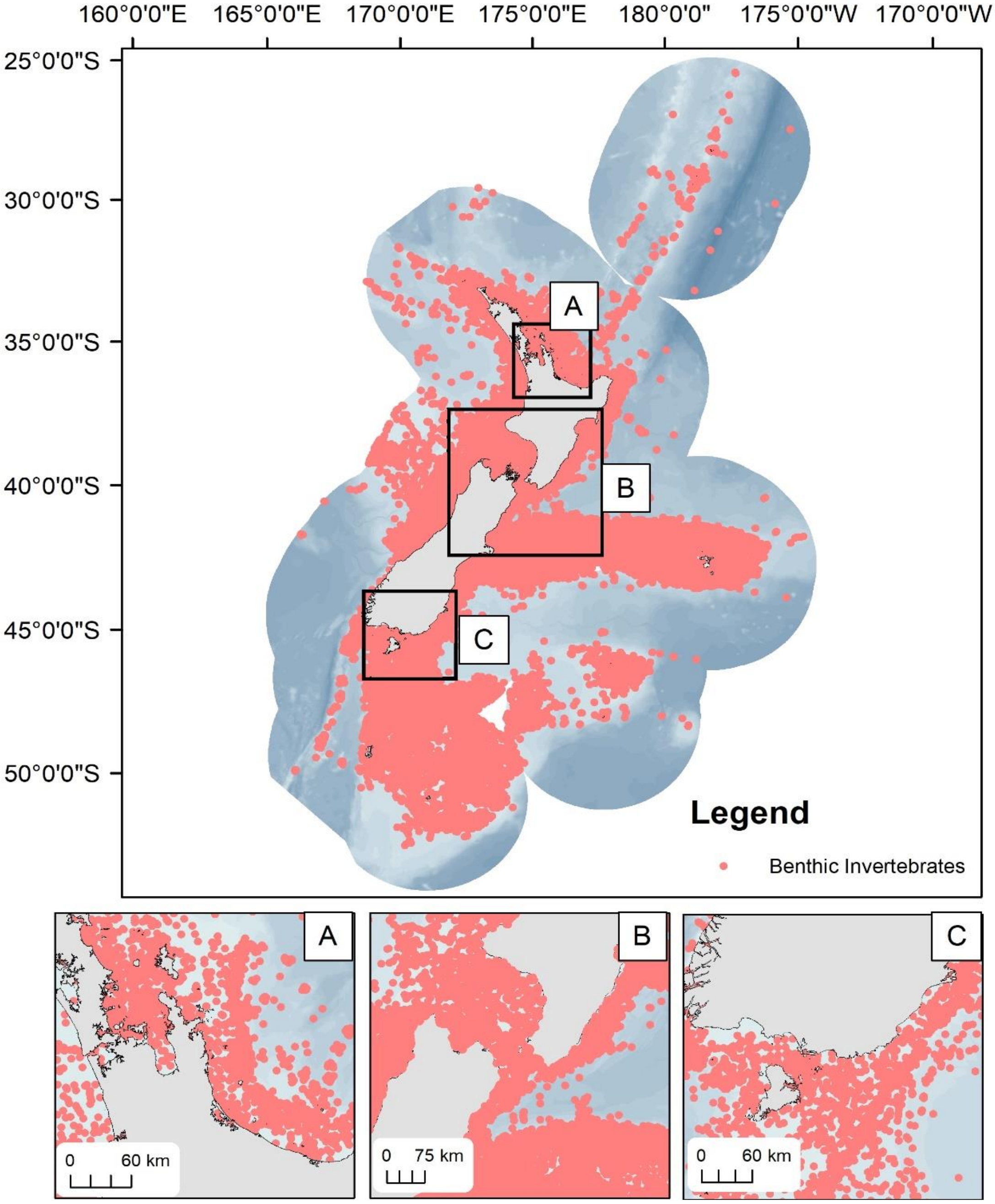


Figure 2-18: Locations of benthic invertebrate records.

Table 2-14: Sampling gear types corresponding to benthic invertebrate point records.

Type	Category	Description	Example
Gear size	Small	< 1m	Devonport dredge
	Medium	1-3m	Benthic sled
	Large	> 3m	Otter trawls
Deployment area	Small	< 1m	Box corer
	Medium	10 s – 100 s m	Beam trawls
	Large	> 1 km	Otter trawls
Selectivity	HS	Highly selective	Collected by hand
	G	General	Benthic sled

2.5.3 Modelled datasets

Species Distribution Models

Benthic invertebrate records were spatially aggregated to a 1 km grid resolution. Genus level records were used because this provided a greater number of unique locations than when aggregated to species level (33,187 vs 28,263). In addition, records identified to genera were more diverse at a genus level than species records at a genus level (3828 genera vs 3053 genera, respectively). That is, at a genus level, benthic invertebrate records were more inclusive across all benthic invertebrate taxa than records at a species level. To ensure distribution models were robust, only benthic invertebrate genera with ≥ 70 occurrences were retained for analysis. The final dataset included records of 207 benthic invertebrate taxa at 27,274 unique sampling locations.

Ensemble predictions from Boosted Regression Tree (BRT) and Random Forest (RF) species distribution models (Ensemble SDMs) were initially produced for 207 benthic invertebrate taxa with ≥ 70 unique spatial occurrences using species occurrence data (described above) and 20 high-resolution (1 km grid resolution) environmental data layers. Model parameterisations were the same as those used for demersal fish (described in section 2.3.3). In the case of benthic invertebrate records, the number and location of relative absences was generated within each gear class. Ensemble model AUC ranged from 0.86 (a genus of hermit crabs, *Lophopagurus*) to 0.99 (a genus of brittle stars, *Amphiophiura*) with a mean of 0.94. Expert validation of these models is in process to provide expert scores in addition to model fit metrics.

Classification groups and species turnover

While the initial key ecological areas dataset included pilot models of benthic invertebrate classification groups and species richness (section 3.3.7 in Stephenson et al. 2018b), updating of these models was undertaken through combined funding across the three concurrent MSAG investigations. Gradient Forest (GF) models were used to analyse and predict spatial patterns of 958 benthic invertebrate genera species turnover (following methods described in Stephenson et al.

(2018a, 2020c)) using the benthic invertebrate presence/absence dataset (section 2.5.2) and moderate-resolution environmental data layers (1 km^2 grid resolution). GF models are less constrained by low sample number than individual species' distribution models (Pitcher et al. 2012). Benthic invertebrate genera with ≥ 10 occurrences were used for the analysis of species turnover. These models are in process of being developed as part of Investigation No. 4757 (Stephenson et al. in preparation).

Estuarine invertebrate classification and species turnover
Additional models have been developed to summarise patterns of distribution of estuarine macrofauna, and will be presented in the report for Investigation No. 4757 (Stephenson et al. in preparation). In summary, the abundance of benthic invertebrates collected from estuaries was retrieved from the National Estuary Dataset (Clark et al. 2018) which was compiled as part of the MBIE-funded Oranga Taiao, Oranga Tanga (OTOT) programme. The dataset is comprised of primarily unitary authority intertidal estuarine monitoring data throughout New Zealand. The raw dataset includes data from 70 estuaries, 409 sites and 815 sampling events collected and analysed by a range of organisations. Samples were collected over a range of years from 2001 to 2016, and over a range of months. Environmental data used in this analysis included macrofaunal abundance data and paired physico/chemical sediment data, site exposure, sea surface temperature (SST) and salinity. Some methods (including taxonomic resolution and sediment processing) varied between datasets, and required further adjustment to enable analysis. Log-transformed abundance of estuarine benthic invertebrate taxa were used in our analysis.

Species compositional turnover of estuarine benthic invertebrates was estimated using bootstrapped GF models as described for other taxonomic groups. Predicted compositional turnover between samples was summarised using principle components analysis (PCA), and was summarised into 10 estuarine benthic invertebrate groups.

2.5.4 Matching criteria

Criteria 6: Biological Diversity

Species richness

While the original key ecological areas project produced pilot models of benthic invertebrate species richness (section 3.7.4 in Stephenson et al. 2018b), updating of these models was undertaken through combined funding across the three concurrent MSAG investigations. As per other modelled taxonomic groups, benthic invertebrate species richness was calculated by stacking the individual SDMs for the 207 genera and summing the probability of occurrence for each overlapping (individual genus) cell.). For benthic invertebrates, environmental coverage was driven largely by depth, with very limited sampling at depths greater than 2000m. Thus, species richness layers for these taxa were clipped to areas shallower than 2000m. The estimated distribution of benthic invertebrate richness ranged from 33 to a theoretical maximum of 101 (Figure 2-19). The maximum richness value is not the total number of genera (207) for which SDMs are available as there are no sites where all genera overlap in space. Values are 'theoretical' as richness is estimated based on species for which SDMs are available and are thus a relative rather than absolute measure of richness.

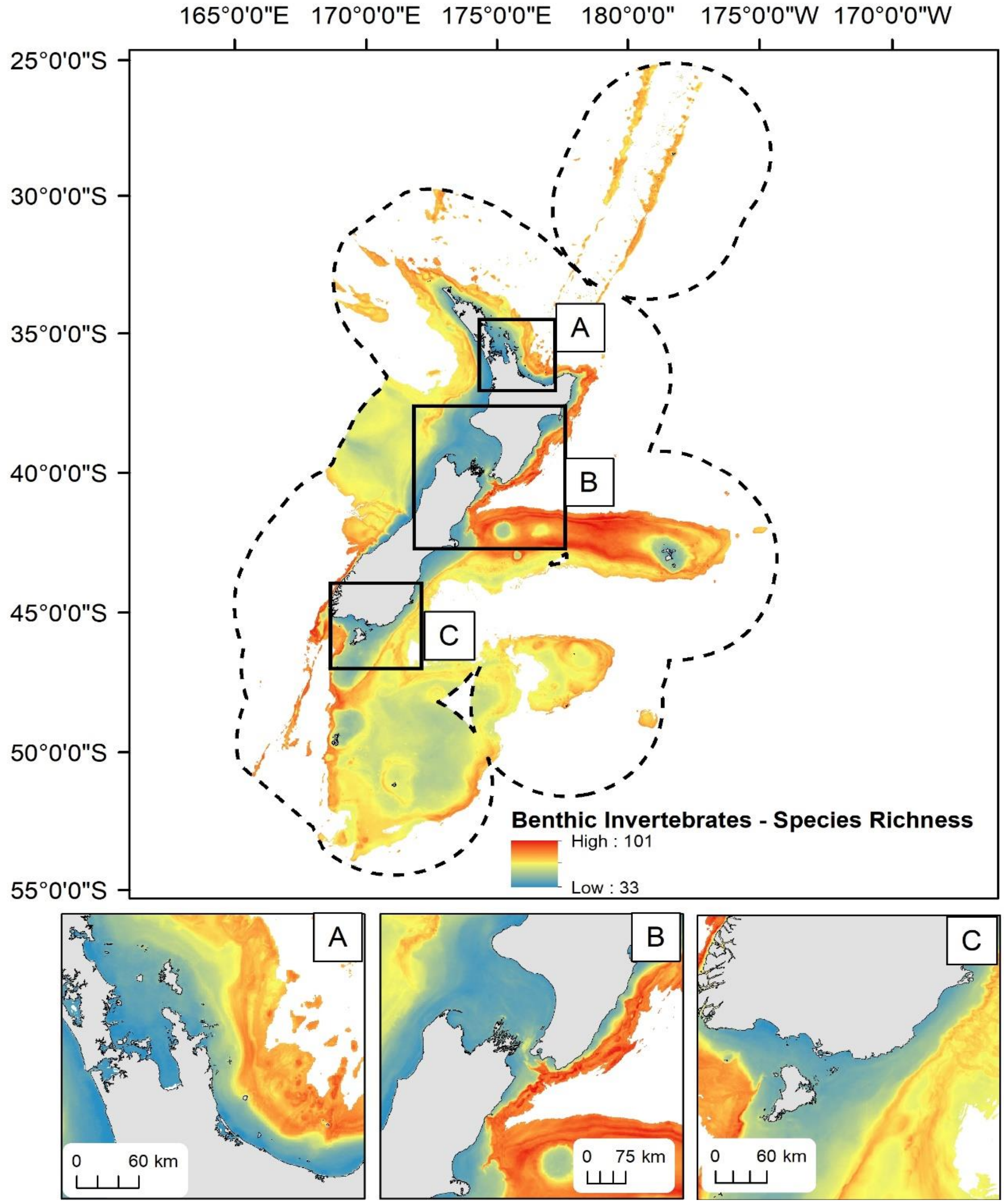


Figure 2-19: Benthic invertebrate richness estimates (derived by stacking 207 bootstrapped SDMs. Richness estimates are clipped to areas of adequate model environmental coverage (depths <2000m).

Species turnover
A second aspect of Biological Diversity that was discussed at the August 2019 MSAG workshop was that of beta diversity. Models of species turnover are in the process of being developed as part of Investigation No. 4757 (Stephenson et al. in preparation).

Criteria 2: Uniqueness / Rarity / Endemism

As noted in the initial Key Ecological Areas project (Section 3.3.2 in Stephenson et al. 2018b), geospatial datasets of point records were compiled for benthic invertebrates identified as Unique (taxa with a single record from the New Zealand EEZ), Rare (taxa with 2 – 10 records in the New Zealand EEZ) and Endemic (n = 1627 species, as per Gordon (2009)).

Of those marine invertebrates reviewed within the NZTCS (Freeman et al. 2010, 2014), 79% were classified as naturally uncommon, matching expectations seen globally for invertebrates with high proportions (30 – 60%) of rare taxa (Ellingsen et al. 2007).

Criteria 3: Special Importance for Life History Stages
Some information on spawning locations of squid species is known (Smith et al. 1987, Jackson 2001), but no robust information is available on invertebrate life history or locations that are of special importance for invertebrate life cycles.

Criteria 4: Importance for Threatened / Declining Species and Habitats
As noted in the original key ecological areas project (section 3.5.3 in Stephenson et al. 2018b), only 307 species (approximately 2.7% of known New Zealand marine invertebrates) have been assessed in the NZTCS (Freeman et al. 2010, 2014). 13.5% of those 307 marine invertebrates assessed were classified as Threatened.

2.5.5 Data quality/spatial comprehensiveness.

Invertebrate information is poor relative to marine vertebrate groups. Lack of information on invertebrate life history or locations that are of special importance for invertebrate life cycles and an incomplete assessment of threatened species means that these two key criteria cannot be assessed for benthic invertebrates. Our ability to calculate values for the other two criteria considered in the section (Biological Diversity and Uniqueness / Rarity / Endemism) is also limited. Sample coverage of New Zealand's EEZ is slightly more restricted than that of demersal fish (Figure 2-20). New models of both species turnover and species occurrences will improve our understanding, but these models are at a coarser taxonomic scale than for other taxonomic groups due to limitations in the taxonomy of point records, requiring modelling of genera instead of species, and challenges with comparing observations across multiple different types of sampling gear. Taxonomic records also are typically records of presence, and often only those taxa requiring taxonomic confirmation are recorded. In contrast, research trawls for demersal fish are typically performed using similar methods and gear, and all observed taxa are recorded, thus a lack of observation of a species can be used to infer absence.

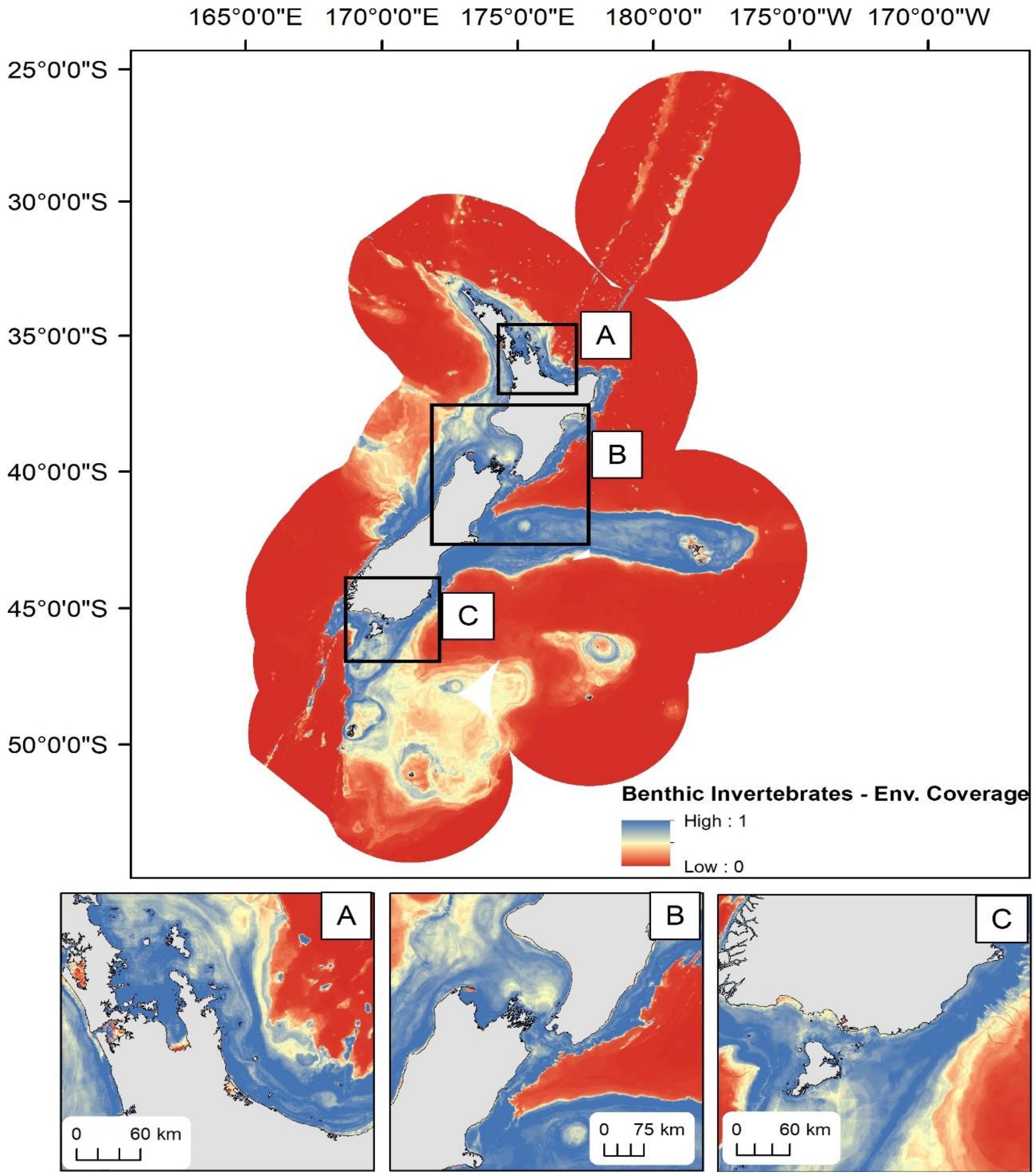


Figure 2-20: Predicted environmental coverage depicting the confidence that can be placed in benthic invertebrate predictive models. Scale ranges from low (i.e., no samples in the dataset with those environmental conditions) to high (i.e., many samples with those environmental conditions) within the New Zealand EEZ.

2.6 Macroalgae

2.6.1 Summary

Table 2-15: Summary of macroalgal occurrence within NZ and core datasets provided in this report.

	Macroalgae
Recognised species in NZ waters	1295*
Threatened species	7**
Endemic species	277*
Species point records (all datasets)	25324
Species with predictive distributions	88

*From Gordon et al. 2010 . **Nelson et al. 2019.

Table 2-16: Summary of application of macroalgal datasets to key ecological area criteria.

Dataset	Uniqueness / Rarity / Endemism	Special Importance for Life History Stages	Importance for Threatened / Declining Species and Habitats	Biological Diversity
Species occurrence records: macroalgae	x	x	x	
Species threat assessment: macroalgae	x		x	
***Durvillaea* long term monitoring**		x	x	
Species distribution models: macroalgae	x		x	
Species richness: macroalgae				x

New Zealand has a rich assemblage of macroalgae with extensive representation across the three main classes (Nelson et al. 2019a). However, there have been limited national-wide surveys for macroalgae, particularly in soft-sediments, although occurrence records can be pooled from many local-scale field surveys and records. The majority of these local datasets are representative of the more accessible parts of New Zealand's coastline, with limited coverage of deeper and offshore habitats. The datasets do, however, span the length of the New Zealand mainland. Most of the macroalgal records are based on observations without any strict measurement of survey effort or type. This means occurrence records are presence only, and thus introduce some bias into spatial analyses. All taxa have been assessed within the NZTCS since the completion of the initial key ecological areas project, though a majority are categorised as 'Data deficient'.

Limited records for macroalgae were compiled for the original key ecological areas project, primarily within the sensitive habitats point records (Anderson et al. 2019). As such, macroalgae were identified at the August 2019 MSAG workshop as a high priority for acquisition of further information. Compilations within this project included a groomed species occurrence database, species distribution models and uncertainty layers for 88 taxa, a species richness layer, and classification groups and species turnover layers (Table 2-16). A number of macroalgal habitats were also added to the list of potential vulnerable or sensitive habitats, including additional species within algal meadow habitats and rhodoliths, and new habitats of coralline turfs and crusts (see section 3.1). See supplementary material (S5) for details of the species relevant for each of the ecological criteria.

2.6.2 Matching criteria

Criteria 6: Biological Diversity

Species richness

As per preceding taxa, macroalgal species richness was calculated by stacking the individual SDMs for the 88 species and summing the probability of occurrence for each overlapping (individual species) cell. The estimated distribution of macroalgae richness, on subtidal rocky reefs, ranged from 20 to a theoretical maximum of 50 (Figure 2-21). The maximum richness value is not the total number of species (88) for which SDMs are available as there are no sites where all species overlap in space. Values are 'theoretical' as richness is estimated based on species for which SDMs are available and are thus a relative rather than absolute measure of richness.). Environmental coverage was not used to clip species richness layers for macroalgae.

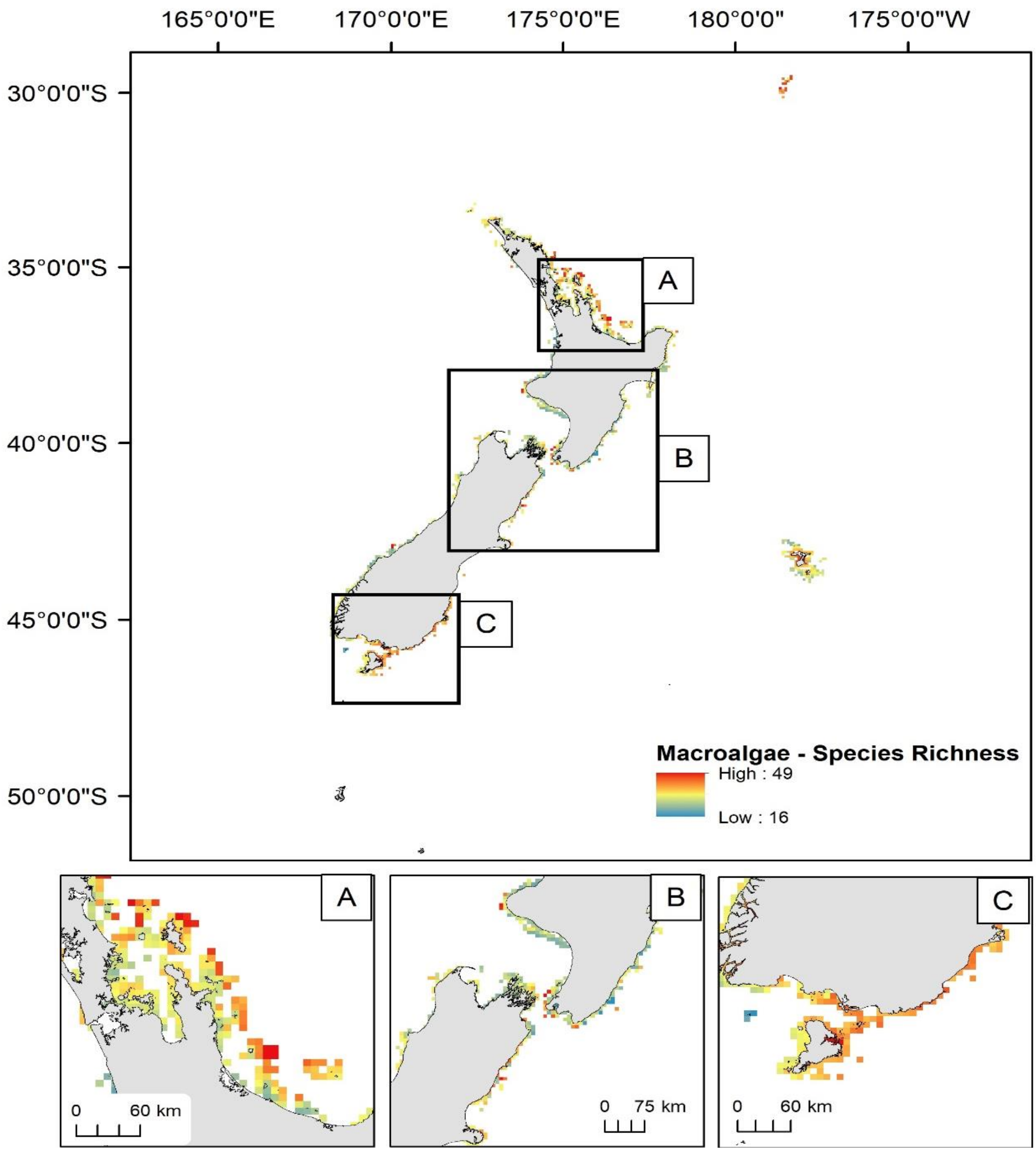


Figure 2-21: Macroalgal species richness estimates (derived by stacking 88 bootstrapped SDMs) for rocky reef areas shallower than 30m. Note model estimates are aggregated for visualisation, resulting in presentation of a lower range of species richness than available in the actual dataset.

Species turnover

A second aspect of Biological Diversity that was discussed at the August 2019 MSAG workshop was that of beta diversity. Models of species turnover are in process of being developed as part of Investigation No. 4757 (Stephenson et al. in preparation).

Criteria 2: Uniqueness / Rarity / Endemism

A total of 105 species of 938 species assessed in the NZTCS were classified as being “At risk, naturally uncommon” (Nelson et al. 2019a). A geospatial layer comprising point records for these species could be compiled, though the sparsity of records for these uncommon species suggests that it will be uninformative of patterns of rarity of this taxonomic group (see for example Figure 2-22 for threatened macroalgae). The endemism of most macroalgae taxa in New Zealand is poorly understood, with an estimate of 1/3 of the macroalgae being endemic (Gordon 2009).

Criteria 3: Special Importance for Life History Stages

Macroalgae that form biogenic habitats are known to be important for life history stages of some other species, but the extent of the dependence and/or obligate nature of these relationships, is largely unknown.

In general macroalgae require hard substrata for settlement of early life stages, and to support the growth of mature thalli. In macroalgae that have heteromorphic life histories the habitat requirements of the sporophytic and gametophytic life stages often differ significantly.

Criteria 4: Importance for Threatened / Declining Species and Habitats

Since the compilation of the original key ecological areas dataset, the conservation status of 938 New Zealand macroalga taxa has been assessed using the NZTCS (Nelson et al. 2019a). This assessment followed the protocols established by the Department of Conservation, namely using expert panels and assessing taxa following the criteria of Townsend et al. (2008).

Six species were determined to be “Nationally critical”, including *Dione arcuata*, *Gelidium johnstonii*, *Gigartina dilatata*, *Prasionema heeschiae* and two taxonomically unresolved species (*Gigartina* sp. C (WELT A016481; Bounty I.) and *Prasiola* sp. A (WELT A024286; Antipodes Is)). One species was categorised “Nationally endangered”, *Prasiola novaezelandiae*. Five species were considered to be “At Risk – declining” – two species of bull kelp, *Durvillaea antarctica*, *Durvillaea poha*, and their obligate epiphytes *Herpodiscus durvilleae* and *Pyrophyllon subtumens*, and also the giant kelp *Macrocystis pyrifera*. Of the 938 taxa assessed, 609 were categorised as “Data deficient” which means that they are unable to be assigned to “any particular category due to a lack of current information about their distribution and abundance”.

A database of point records for threatened macroalgae species was generated by extracting all locations for each threatened species from the macroalgal species occurrence database (Figure 2-22). Six species of threatened macroalgae were represented by records in the occurrence database: *Dione arcuata, Gigartina dilatata, Prasionema heeschiae, Gelidium johnstonii, Prasiola novaezelandiae, Gigartina* sp. C. There were 72 occurrences of these threatened species made between the years 1936 and 2013.

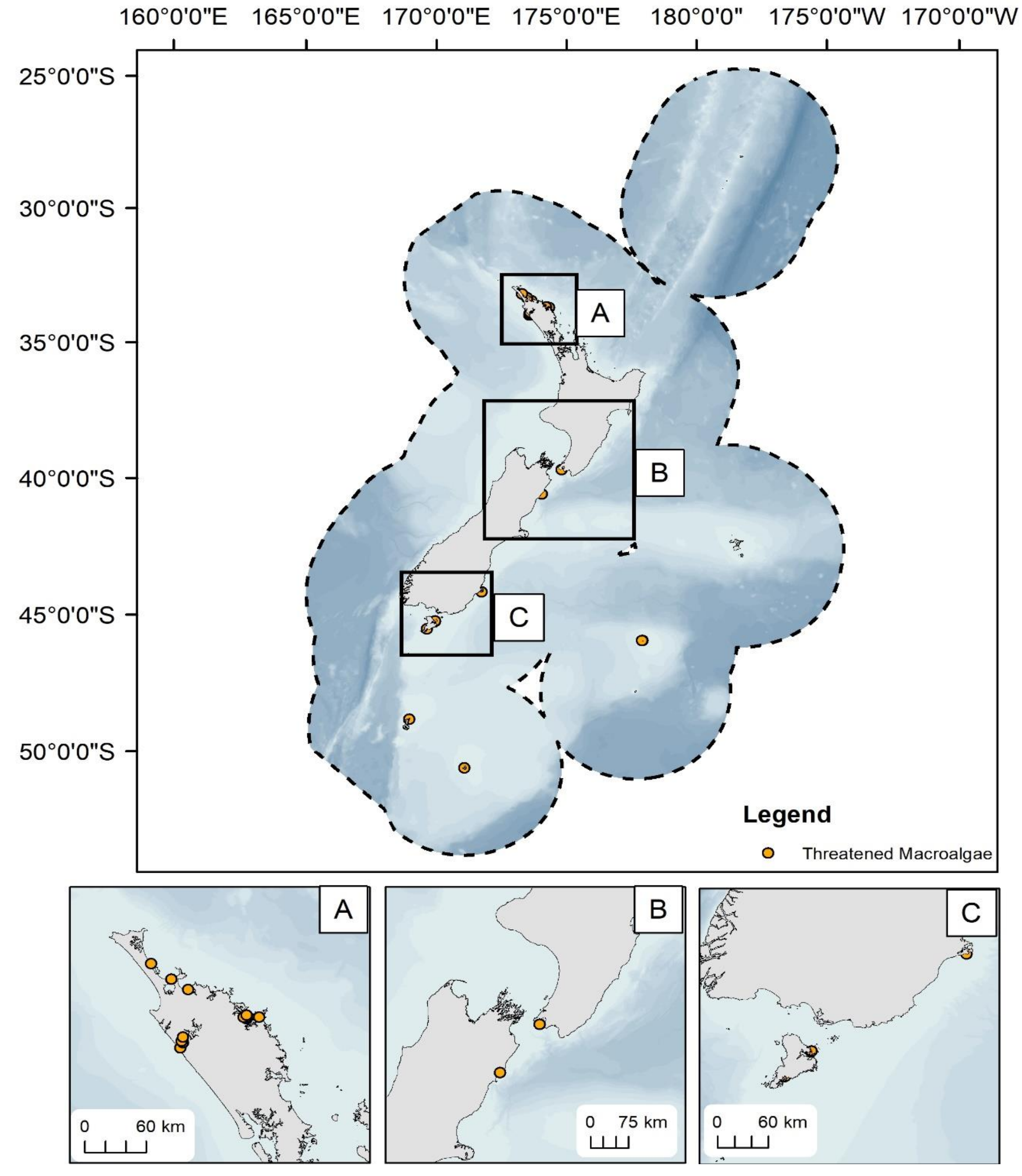


Figure 2-22: Point records of macroalgal species assessed as threatened in the NZTCS.

2.6.3 Datasets

Primary datasets

Species occurrences
Macroalgae occurrence records were extracted for herbarium specimens housed at Te Papa Tongarewa - Museum of New Zealand, Auckland Museum, and NIWA. The material in natural history collections and herbaria only provide presence data, establishing that the species was present at that locality when collected, and the interpretation of species absences is complex, i.e., the species may not have been at the locality, or was not collected, or not detected. A total of 824 species were represented in this dataset. Of these, 349 species were found at more than 10 unique locations (range 10 – 381), and were represented by between 12 and 524 occurrence records.

In addition, three observational datasets were included, representing 2,088 records. The first was based on citizen science observations of large brown algae, assembled as part of an MPI funded project (ZBD201406). These citizen science contributions were verified via photographs with observation records submitted to NatureWatch (now iNaturalist NZ). These observations extended the known/recorded distributions or filled in distributional gaps for a number of species (e.g., *Cystophora platylobium* - Kaikoura and Dunedin, *Cystophora retroflexa* - southern Hawkes Bay, *Cystophora scalaris* - East Cape, *Durvillaea poha* - Kaikoura and Stewart Island, *Hormosira banksii* - Wairarapa and north Otago, *Macrocystis pyrifera* - SE Otago). The second was extracted from dive logs contributed by Clinton Duffy (Department of Conservation, Auckland) of large brown seaweed observed around New Zealand between 1979 and 2007. The third was data collected by Shears & Babcock (2007) during their work on shallow subtidal reef communities.

The locations of all macroalgal data used in compiling the dataset for this project are given in Figure 2-23.

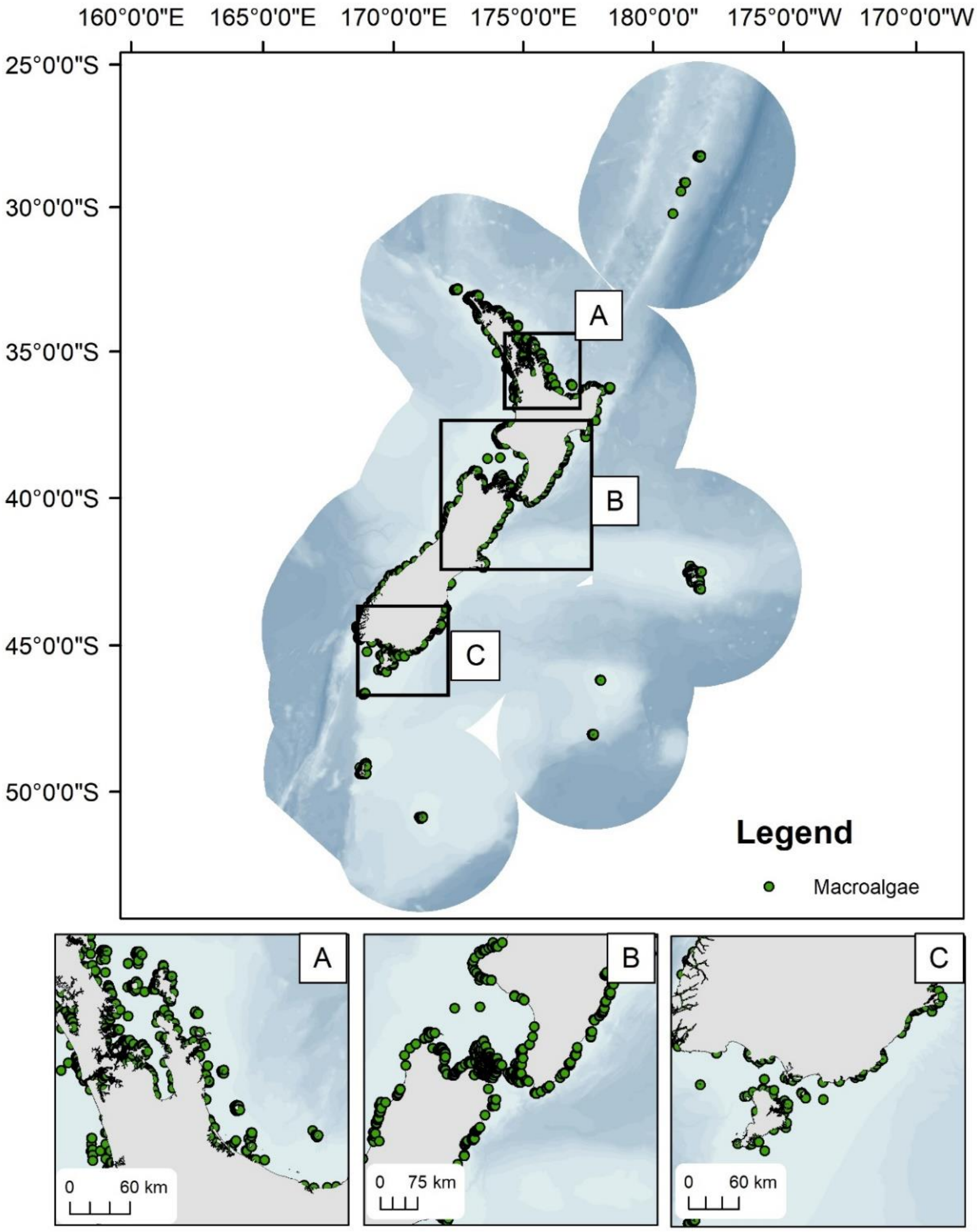


Figure 2-23: Locations of macroalgal records. Point records include data from herbaria housed at Te Papa Tongarewa - Museum of New Zealand, Auckland Museum, and NIWA, naturewatch, Duffy (2007) and Shears & Babcock (2007) datasets.

2.6.4 Modelled datasets

Species Distribution Models

Ensemble predictions from Boosted Regression Tree (BRT) and Random Forest (RF) species distribution models (Ensemble SDMs) were produced for 88 macroalgal taxa with ≥ 50 unique spatial locations using species occurrence data (described above) and 20 high-resolution (250 m grid resolution) environmental data layers. Model parameterisations were the same as those used for demersal fish (described in section 2.3.3). Macroalgal SDMs and uncertainty were predicted spatially to 250 m grid cells. However, as most macro-algal species are either reef or gravel associated, SDMs were only predicted to grid cells that contain these substrate types. SDMs for macroalgae were not clipped by environmental coverageEnsemble model AUC ranged from 0.87 (*Codium gracile*) to 0.98 (*Agarophyton chilense*) with a mean of 0.94. Expert validation of these models is in process to provide expert scores in addition to model fit metrics.

Classification groups
Gradient Forest (GF) models were used to analyse and predict spatial patterns of 349 macroalgal species turnover (following methods described in Stephenson et al. (2018a, 2020c)) using only the macroalgal presence/absence dataset (section 2.6.2) with high-resolution environmental data layers that overlapped with subtidal rocky reefs (250 m grid resolution). GF models are less constrained by low sample number than individual species distribution models (Pitcher et al. 2012). Macroalgal species with ≥ 10 occurrences were used for the analysis of species turnover. These models are in process of being developed as part of Investigation No. 4757 (Stephenson et al. in preparation).

2.6.5 Data quality/spatial comprehensiveness.

The macroalgae datasets include records from multiple databases, housed by several institutions, with often limited information on the origins of the records and/or survey information. Many records are the product of observations only (e.g., herbarium records) and therefore cannot be used to generate true absence data for spatial modelling. While records have been made by qualified personal, we cannot rule out that there may be some differences in species identification ability over the many people who contributed to these datasets over many decades. The records span the length of the New Zealand coastline; however many inaccessible and particularly exposed locations have limited records (Figure 2-24). Due to the long time frame over which occurrences have been logged, there is likely to be a mismatch between the environmental predictors (calculated for the last ca. 20 years) and many presence records. If environmental conditions have changed significantly over time, this will introduce some bias into the species distribution models and calculation of richness.

There are additional challenges when interpreting gaps in distributional records, particularly evaluating the representativeness of the records and intensity of collections (Figure 2-24). Nelson et al. (2013) summarised the range of biases that affect different aspects of natural history/herbarium collections, e.g., the position of access roads and settlements, particularly in the case of coastal collecting; seasonal biases arise for a number of reasons, not least of which is the impact of weather on access to coastlines; and the number of collections obtained from particular regions is frequently closely related to the location of active collectors. There are also biases as far as which species are collected. The remoteness of some areas means that collections are more assiduously made and preserved and, therefore, the flora of these regions may be more completely represented than other more accessible coastlines. Commonly occurring species are frequently under-collected and so their complete geographic range is not adequately represented in collections e.g., *Hormosira banksii*. Other species because of their size and /or the difficulty of getting access to populations e.g., *Durvillaea* spp. remain under-collected. Graham et al. (2004) consider that "non-representative sampling in environmental space remains the most difficult source of error to detect and correct". Further, changes in taxonomic nomenclature can challenge understanding of even large common macroalgae, for example, differentiation of *Durvillaea* species and the lack of historical records of *D. poha* as well as the problems of under-collection or lack of formally identified records given the large size of species in this genus.

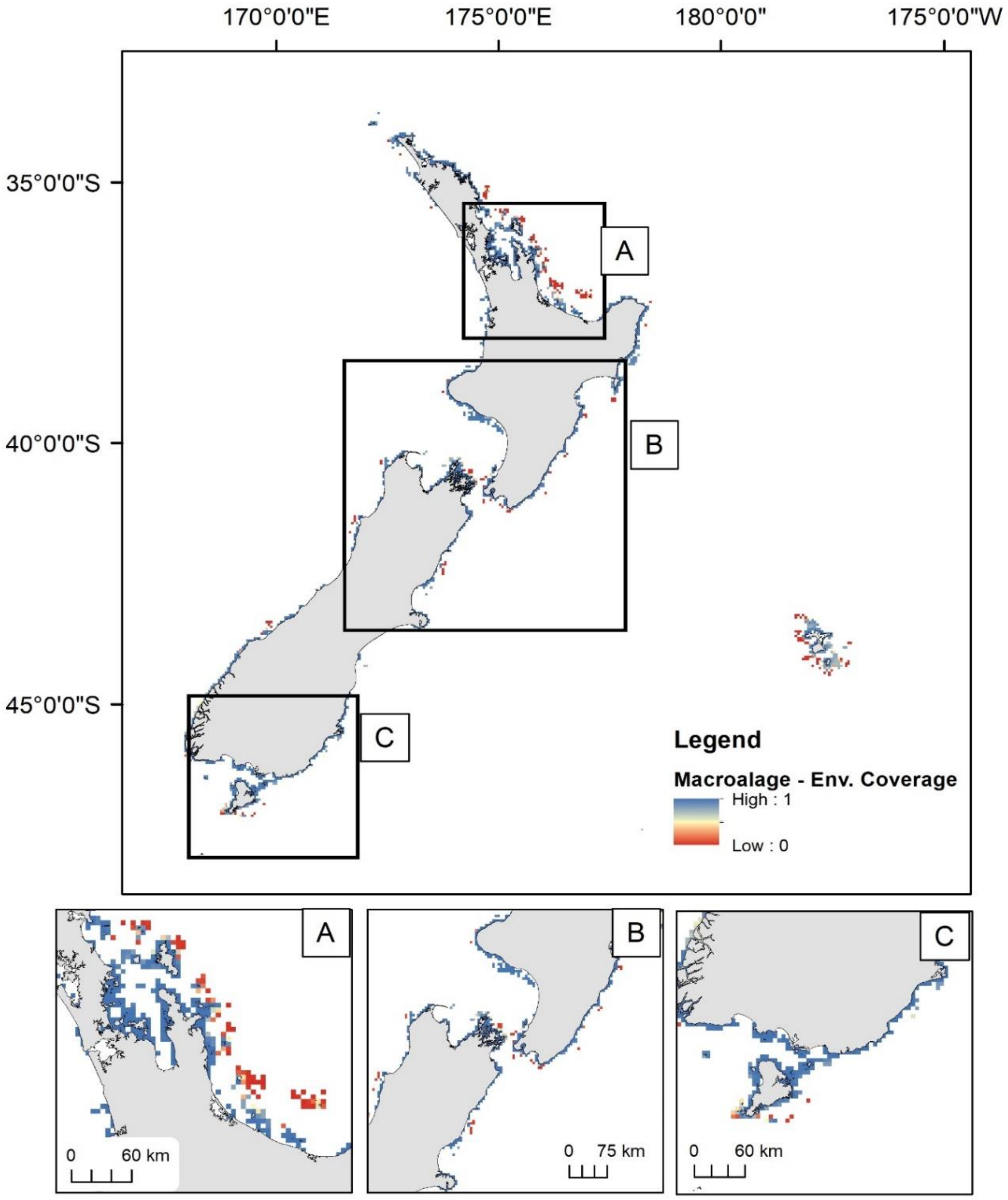


Figure 2-24: Predicted environmental coverage depicting the confidence that can be placed in macroalgal predictive models. Scale ranges from low (i.e., no samples in the dataset with those environmental conditions) to high (i.e., many samples with those environmental conditions) within the New Zealand EEZ.

2.7 Habitat datasets: Uniqueness / Rarity / Endemism (Criteria 2)

In addition to the taxonomic metrics informing this criterion as introduced for particular taxonomic groups in Section 2, data on a number of habitat types were also compiled for the original key ecological areas dataset including hydrothermal vents, cold seeps, and naturally uncommon habitats. A national seamount dataset was acquired to add to these unique habitat types, noting that most seamounts are already likely identified due to presence of features that fit the Vulnerability criteria described in the following section.

3 Criteria 1: Vulnerability, Fragility, Sensitivity or Slow Recovery

This criterion is defined as areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery. A number of datasets were acquired to inform this criterion in the original key ecological areas project, including sensitive habitats, regional council significant areas, vulnerable marine ecosystems, and vulnerable chondrichthyan species. Newly available records from the macroalgal herbaria dataset were prioritised to populate both previously defined and newly defined sensitive habitats. Newly revised Vulnerable Marine Ecosystem models were acquired to update available information on this dataset. Fish species (previously included due to assessment of slow recovery) were deemed to more appropriately belong within the threatened species criteria, as assessment of recovery potential was determined to be out of scope for fish species. While data were extracted from regional council significant areas, the data were inconsistently included across councils, and we opted to not create a new dataset due to the few available ASCV records.

3.1 Sensitive habitats: algal datasets

The original KEA project collated available data and information on sensitive habitats, including a diversity of biogenic habitats compiled for a Ministry for the Environment project (see Stephenson et al. 2018b (section 3.2.3 and section 3.9.1) and Anderson et al. (2019)). In addition to these datasets, the August 2019 MSAG workshop recommended two priorities for collating additional data on sensitive habitats: identifying additional taxa that could be included within the already identified sensitive habitat types, and identification and acquisition of data to inform new habitat categories. Particular emphasis was given to incorporating additional observations from the newly compiled large brown algae database (D'Archino et al. 2019) and a national database of herbarium records, neither of which was available during the Anderson et al. (2019) sensitive habitats project, or the original key ecological areas project (Stephenson et al. 2018b). The August 2019 MSAG workshop also prioritised the inclusion of a subset of the large brown algae dataset to describe potential declines in kelp forest species, as has been observed in Australia. Each sensitive habitat type is represented by a point feature layer showing the occurrence of component species of that habitat.

3.1.1 Large brown algae

Canopy-forming large brown algae are significant primary producers in addition to providing three dimensional habitat structures for fish, invertebrates, and other algae, and contributing to Ecological Function (reviewed in Anderson et al. 2019). D'Archino et al. (2019) assembled all available data (including previously acquired datasets) on the distribution of large brown algae around New Zealand.

The dataset was used to evaluate the use of large brown algae for monitoring change in coastal ecosystems, and their potential as national scale indicators of human-induced change in New Zealand's marine ecosystems.

As introduced in section 2.6.2, the large brown algae dataset includes citizen science observations of large brown algae, assembled as part of an MPI funded project (ZBD201406, D'Archino et al. 2019). These new observations of sensitive habitats included Laminariales and Fucales. The Laminariales include 3 native genera and 9 species (Lessoniaceae: *Ecklonia radiata*; *Lessonia adamsiae, L. brevifolia, L. tholiformis, L. variegata,* 3 undescribed species; Laminariaceae: *Macrocystis pyrifera*) and one introduced genus/species (*Undaria pinnatifida*). The Fucales include 10 genera (Durvillaeaceae: *Durvillaea* (5 species); Hormosiraceae: *Hormosira* (1 species); Notheiaceae: *Notheia*

(1 species - an obligate epiphyte, primarily found on *Hormosira*); Sargassaceae: *Cystophora* (4 species), *Carpophyllum* (4 species), *Landsburgia* (3 species), *Phyllotricha* (1 species), *Sargassum* (7 species); Seirococcaceae: *Marginariella* (3 species); and Xiphophoraceae: *Xiphophora* (2 species).

Large brown algae long term monitoring

While anecdotal evidence suggests declines in some regions of large brown algae, the August 2019 MSAG workshop prioritised further exploration of what evidence exists of these declines. D'Archino et al. (2019) summarised the results of surveys conducted in the East Otago Taiapure in 2009 and 2017. It was found that for the largest of the brown algae surveyed, *Undaria* increased significantly in density and geographic spread, while *Macrocystis pyrifera* and *Durvillaea antarctica* populations decreased.

Declines in *Durvillaea* populations have been observed in a number of sites in the South Island. D'Archino et al. (2019) report on a study in the East Otago Taiapure which found that the abundance of both adult and juvenile *Durvillaea antarctica* decreased 70% between surveys conducted in 2009 and 2017 while *Durvillaea willana* was observed very rarely during both survey years. In New Zealand the effects of sediments on settlement and post-settlement survival have been investigated for several key habitat-forming large brown macroalgae. Schiel et al. (2006) found that the attachment of sporelings to the substrate was disrupted by sediment, whereby "a light dusting of sediment" reduced *Durvillaea* zygote settlement by 71%, and a complete sediment cover prevented attachment altogether. Thomsen et al. (2019) documented the decline of *Durvillaea* spp. on the east coast of the South Island following a marine heatwave event in 2018. This heatwave resulted in the local extinction of all *Durvillaea* spp. across the northern rocky reefs of Bank's Peninsula (Pile Bay, Lyttelton), after which the invasive kelp *Undaria pinnatifida* recruited to these same reefs in high densities (Thomsen et al. 2019). For both *Durvillaea antarctica* and *D. poha*, the literature and herbarium records are likely to be incorrect (Fraser et al. 2012).

Although there are anecdotal accounts of changes in the distribution of *Macrocystis* in New Zealand, particularly in the northern portion of its range in the Marlborough Sounds, and also in offshore Otago sites, baseline data are very limited, and the extent of population and distributional declines remain unclear. Hay (1990) compared the distribution of *Macrocystis* at its northern limits as mapped by Rapson et al. (1942), with its distribution in the same region between 1984 and 1988. Hay postulated that the retraction in its distribution was linked to increases in sea surface temperature (SST), and particularly to extreme temperature events. Pirker (2002) investigated a number of aspects of the biology of *Macrocystis* in New Zealand and followed seasonal changes in several populations around Banks Peninsula.

Beds at Akaroa Harbour were found to exhibit strong seasonal canopy declines over the summer months, which was attributed to a combination of warmer water temperatures, nutrient limitation, and sediment inputs. In this study, the greatest biomass reductions were associated with boat ramp construction activities adjacent to the kelp bed, which delivered significant quantities of sediment that physically smothered the kelp canopy, covered the seafloor, and prevented kelp recruitment for over a year (Pirker 2002). In contrast to the summer declines reported by Pirker (2002), Fyfe et al. (1999) observed winter declines in populations of *Macrocystis* on the North Otago coast as a consequence of winter storms.

Algal meadows

Algal meadows have been identified in New Zealand in a number of places in the North, South and Stewart Islands, but remain poorly documented in terms of locations, extent, species present (Rowden et al. 2012, Anderson et al. 2019). The term "algal meadows" is applied to extensive beds of benthic macroalgae, typically growing in sheltered intertidal or subtidal soft sediment habitats, either anchored to the sediment, attached to other habitat formers such as emergent tubeworm beds, loosely attached to shell or shell fragments, cobbles or small stones, or unattached (reviewed in Anderson et al. 2019).

New records for algal meadow species were extracted from the herbarium database. These records included the species *Agarophyton* spp. – both *A. chilense* and *A. transtasmanicum* (formerly known as *Gracilaria*), *Adamsiella* spp., *Caulerpa flexilis*, *Crassiphycus proliferus* (formerly known as *Gracilaria truncata*), *Stenogramma interruptum*, *Rhodophyllis* spp., *Rhodymenia* spp., and species of Delesseriaceae e.g., *Schizoseris* spp., *Haraldiophyllum crispatum*).

Rhodolith beds
The location, extent, and ecosystem functioning of rhodolith beds in New Zealand remains poorly documented, with few records compiled for the original key ecological areas dataset. Rhodolith beds have been reported from Rangitahua/ Kermadec Islands, and at sites around the North and South Islands, and Stewart Island, but very little quantitative data are available either regionally or nationally. Information available about the distribution and ecology of rhodoliths in New Zealand is summarised in Nelson et al. (2019b) and Anderson et al. (2019). In the beds that have been investigated, high biodiversity of both macroalgae and fauna and a high number of rare species have been found associated with the beds (Neill et al. 2015, Nelson et al. 2019b).

Rhodolith records were also extracted from the new herbarium dataset. Data were extracted for rhodoliths belonging to three genera (*Lithothamnion, Sporolithon* and "*Lithophyllum"*), with two species commonly found in New Zealand. These are *Sporolithon* sp B NZC2375 sensu Twist et al. (2019), formerly referred to as *Sporolithon durum,* and *Lithothamnion crispatum* (Harvey et al. 2005, Farr et al. 2009). Records for three additional rhodolith species discovered at Rangitāhua/Kermadec Islands and belonging to three undescribed genera (two members of the Corallinales and one Sporolithales) were also extracted.

Coralline turfs and crusts
This newly specified sensitive habitat (i.e., not previously compiled in Anderson et al. (2019)) includes geniculate coralline algae with alternating segments that are calcified (intergenicula) and non-calcified (genicula). They are often referred to as articulated coralline algae and can form dense turfs over suitable substrates. There are four genera and 13 species currently recorded in New Zealand: *Amphiroa* J.V. Lamour (1 species), *Arthrocardia* Decne (3 species), *Corallina* L. (1 species), *Jania* J.V. Lamour (8 species) (Nelson et al. 2019b). Point records were extracted for these taxa from the new herbarium dataset.

On many rocky shores, turf-forming geniculate coralline algae are a major component of algal assemblages and extremely diverse and productive macrofaunal assemblages have been recorded within the structurally complex habitat provided by the densely packed fronds of coralline turf (e.g., Hicks 1971, Taylor 1998, Cowles et al. 2009). The physical structure of the coralline turf provides a refuge from desiccation, predation, and wave action. Coralline turf provided the best refuge for mobile invertebrates from fish predation in a variety of intertidal tidepool habitats tested by Coull & Wells (1983).

After examining the impacts of trampling on invertebrates inhabiting intertidal geniculate coralline algae, Brown & Taylor (1999) concluded that, in light of the abundance and importance of these invertebrates and their vulnerability to even low levels of trampling, effective marine protection in some places may need to address this through exclusion or restriction of access.

3.2 Sensitive habitats: calcareous tubeworm mounds

At the August 2019 MSAG workshop, participants discussed recent surveys as part of the MBIE Bottlenecks project, and prioritised acquisition of new records of *Galeolaria* tubeworm habitats. *Galeolaria* tubeworm habitats were until recently thought to be extremely rare, and restricted to only a few discrete locations in the South Island (i.e., Perano Shoals and Port Underwood, Marlborough Sounds and Paterson's Inlet, Stewart Island) (Anderson et al. 2019). Recent surveys in 2018, 2019 and 2020 (that are not yet available in the sensitive habitats dataset) have confirmed numerous new records of structural habitats created by this species within Queen Charlotte Sounds, Marlborough Sounds (HS51 and NIWA ground-truthing projects, MBIE Bottlenecks C01X1618), as well as newly discovered mounds in the Hauraki Gulf and Firth of Thames (MBIE Bottlenecks C01X1618). Data analysis from the HS51 and NIWA ground-truthing projects is in progress, and expected to be available by the end of 2020. Data from the MBIE Bottlenecks project has only recently been collected and has not yet fully been analysed; these records should be further acquired upon the conclusion of the MBIE project in 2021.

3.3 Vulnerable marine ecosystems

The initial key ecological areas dataset included published models of ten indicator taxa for Vulnerable Marine Ecosystems (section 3.2.2 in Stephenson et al. 2018b; Georgian et al. 2019), including four species of reef-forming scleractinian corals (*Enallopsammia rostrata*, *Solenosmilia variabilis*, *Goniocorella dumosa*, and *Madrepora oculata*); Demospongiae and Hexactinellida (sponges); Pennatulacea (sea pens); Antipatharia (black corals), Stylasteridae (hydrocorals) and the umbrella group *Alyconacea*.

These modelled layers have been recently updated (Anderson et al. submitted), and have been acquired for the key ecological areas dataset. The updated models incorporate additional coral presence records from recent commercial and research sampling surveys, and use regional environmental predictor layers for the current and future climate conditions based on NIWA's Earth System Model (ESM). More sophisticated habitat suitability modelling techniques were utilised to consider spatial autocorrelation in the sampling data, estimate precision of the predicted distributions, combine two model types (boosted regression trees and random forests), and assess model performance.

Models were produced for the four reef-forming scleractinian coral species, whereas all other layers represent models of taxa not previously available at the level of species or genera, including eight additional taxa. These are the gorgonian octocoral genera *Paragorgia* (bubblegum corals), *Primnoa* (primnoid seafans), *Corallium* (precious corals); and *Keratoisis* and *Lepidisis* (bamboo corals) combined; two antipatharian (black) coral genera, *Bathypathes* and *Leiopathes*; and two genera of stylasterid hydrocorals, *Errina* and *Stylaster*. Environmental predictors were derived primarily from outputs of the New Zealand Earth System Model but several fixed predictors, including revised and updated sediment data layers, seafloor slope, and seamount (as a categorical variable) were also considered. Model iterations considered two different environmental conditions (present-day and predicted conditions at the end of the 21st century), and included assessment of vulnerability to interactions with fishing gear.

4 Criteria 5: Biological Primary Productivity

This key ecological criterion had few datasets deemed to inform understanding of productivity. Primary producers (seagrass, mangroves, macroalgae, as presented in section 3.6.1 of Stephenson et al. 2018b) were represented in the original KEA project by point records for seagrass, kelp forests, and algal meadows, with polygons available for a limited number of regions. Many of these datasets lack metadata and are in process of being confirmed by DOC. Mangrove distributions are typically more comprehensive and are available for the four northern regions of the New Zealand North Island within the mangrove distributional range. Mangrove layers are expected to be reasonably up to date, though dates of datasets vary substantially between regions and occasionally within regions. Seagrass layers are unlikely to be up to date, with some records in the database being decades old, while in other locations, recent expansions of seagrass in the last decade (for example, an increase from <0.1 ha to >40 ha in Waitemata Harbour, Lundquist et al. 2018) at many locations on both the North and South Islands suggest this important biogenic habitat would benefit from a comprehensive national mapping strategy.

Three other layers were assessed in the original KEA project as applying to productivity generally: these were marine reef fish records, hydrothermal vents, and cold seeps (sections 3.6.2, 3.6.3, and 3.6.4 respectively in Stephenson et al. 2018b). At the August 2019 MSAG workshop, these datasets were deemed to be proxies (e.g., reef fish) or more suited to inform other criteria (Vulnerability, Fragility, Sensitivity or Slow Recovery).

4.1 Satellite data and derived products

Two spatially comprehensive layers representing primary productivity were compiled in the first KEA project (see Section 3.6.5 in Stephenson et al. 2018b): an offshore layer at 4 km resolution; and an inshore layer at 0.5 km resolution. The August 2019 MSAG workshop assessed both layers, and suggested the offshore layer of chlorophyll a concentration (as proxy for water column phytoplankton biomass) appeared representative of expected patterns of offshore productivity. However, there was substantial uncertainty with respect to the adequacy of the coastal phytoplankton layer, and there was interest in further development of this approach to improve the representation of primary productivity in coastal environments. Stephenson et al. (2018b) discussed the complexity of estimating chlorophyll a in coastal waters due to the intermittent presence of coloured material (sediment and other particulate matter) from land run off and benthic resuspension. Ongoing work on determining concentration of suspended particulate matter in the upper-water column, using proxies of particulate backscatter estimated from satellite imagery, are in development to improve these coastal productivity estimates (Matt Pinkerton, pers. comm.).

For offshore waters, discussion with remote-assessment experts identified a number of avenues of research to improve estimates of both spatial and temporal primary productivity that were beyond the scope of this project, but could be further explored to fill gaps in this criterion for offshore waters.

- Assessment of change in environmental properties as independent data layers in themselves. For example, the productivity criteria could include both average chlorophyll a and also the 20 year trend in chlorophyll a as two separate layers. Climate models indicate the potential for bioregional changes, and the inclusion of multiple productivity metrics would assist in quantifying bioregionalisations of change in productivity.

- Assessment of seasonal differences in primary productivity (whereas current layer are annual averages) through analyses that separate satellite data into seasonal layers (summer, winter, spring, autumn average chlorophyll a) in addition to the annual average. Trends in seasonal data could also be calculated.
- Additional satellite remote sensing products that are currently available and are relevant as proxies of primary productivity include incident light at the sea surface (PAR).
- Additional satellite remote sensing products that are in progress but not yet available include: (a) mixed layer depth (model derived, if/when a suitable high resolution coastal New Zealand model is available); (b) phytoplankton functional group distributions; (c) bentho-pelagic flux (a prototype product exists but requires further development); (d) regionally-tuned net primary production; and (e) phytoplankton functional type.

5 Criteria 7: Naturalness

A number of datasets were available to inform the 'naturalness' criterion from the original KEA project (section 3.8 in Stephenson et al. 2018b), including the bottom fishing footprint, fishery metrics for commercial and recreational fishing from Catchmapper (Osborne 2018), and maps of existing spatial management areas such as marine reserves, benthic protection areas, depth refuges from fishing impacts, and other use restrictions.

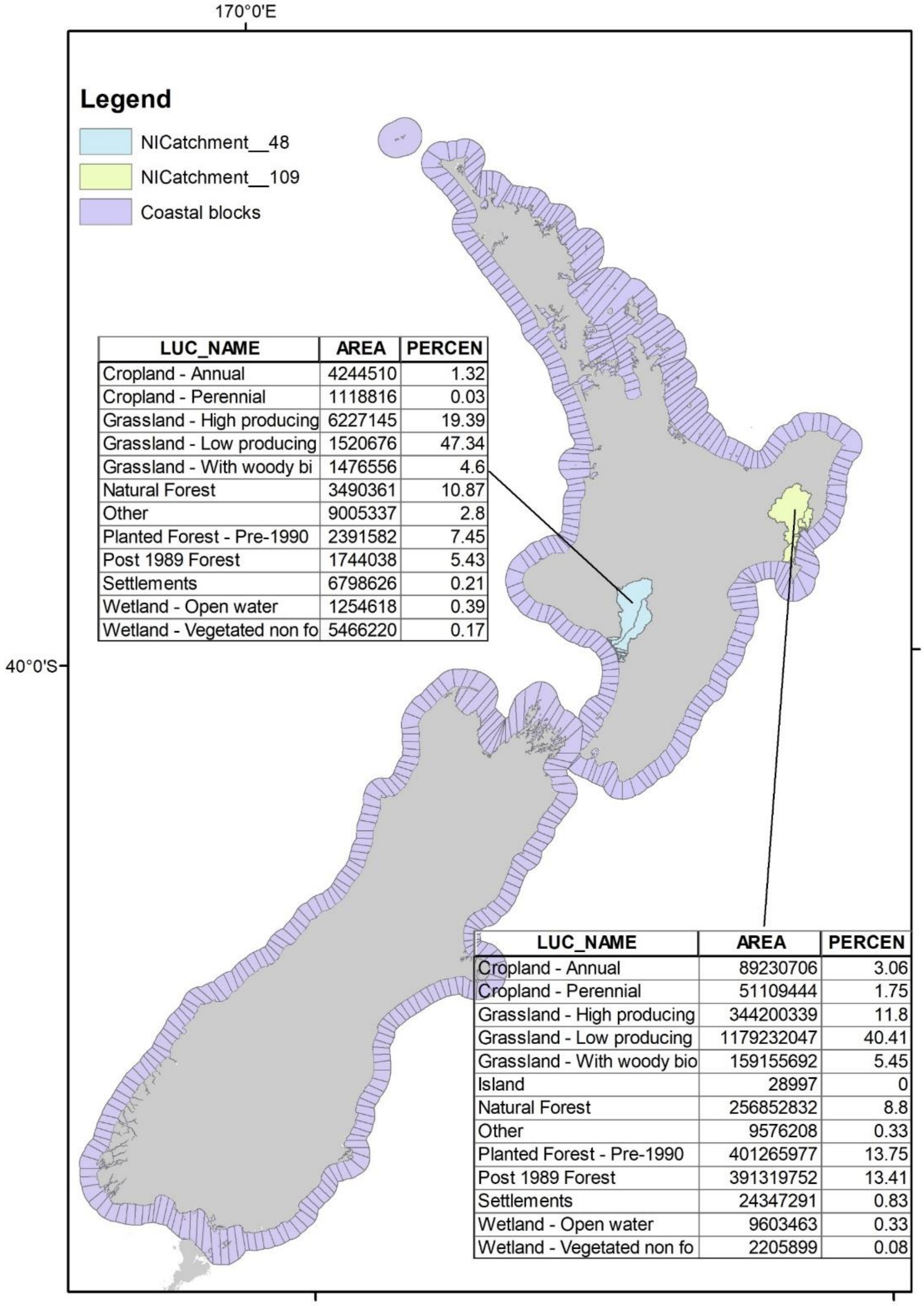
A pilot study to develop stressor layers based on land use and human population density was presented in section 3.8.4 of Stephenson et al. (2018b). A suggested pathway for development of this layer was investigated, but completion of this task was beyond the scope of the project. A number of other potential stressors that would reduce naturalness of marine ecosystems were explored, but would also need further development, including shipping, oil and gas and underwater cables, and invasive species.

A new FNZ project led by Ashley Rowden (NIWA) will quantify 'naturalness' of the seafloor in areas subject to benthic trawling; these datasets should be acquired for the key ecological areas project as soon as they are available.

5.1 Land use

Information on the potential impacts of land use practises on the coastal habitat is an important consideration for appraising 'naturalness'. A pilot exploration funded by NIWA SSIF that investigated land use impacts on 44 New Zealand marine reserves (Lundquist et al. unpublished manuscript), was acquired under the original KEA project. The pilot study calculated the absolute area and proportional representation of land-use categories, sediment and nutrient loading and erosion metrics within the catchment area of each MPA. Estimates of human population density within 100 km were also included to provide an indication of anthropogenic factors not captured by the preceding data sources (e.g., pollution, vessel traffic).

In this project, we began extrapolating the analyses of the pilot study of 44 marine reserves to the entire mainland NZ coast. All analyses were undertaken in ArcMap (v 10.6: ESRI). Firstly, 10 km coastal polygons were constructed based on a smoothed outline of the NZ coast; these polygons extended out to the 12 nm territorial sea limit. Secondly, 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 10 km of each polygon was summed to provide a unique catchment for each polygon. A spatial database of 11 land use categories was available from the LUCAS database (LCDB v4). The catchment area of each coastal polygon was intersected with the spatial polygons contained with the LUCAS database (Figure 5-1) to calculate absolute area and proportional coverage of the land use categories for each catchment. These data were then attached as attributes to each coastal polygon feature.



LUC_NAME	AREA	PERCEN
Cropland - Annual	4244510	1.32
Cropland - Perennial	1118816	0.03
Grassland - High producing	6227145	19.39
Grassland - Low producing	1520676	47.34
Grassland - With woody bi	1476556	4.6
Natural Forest	3490361	10.87
Other	9005337	2.8
Planted Forest - Pre-1990	2391582	7.45
Post 1989 Forest	1744038	5.43
Settlements	6798626	0.21
Wetland - Open water	1254618	0.39
Wetland - Vegetated non fo	5466220	0.17

LUC_NAME	AREA	PERCEN
Cropland - Annual	89230706	3.06
Cropland - Perennial	51109444	1.75
Grassland - High producing	344200339	11.8
Grassland - Low producing	1179232047	40.41
Grassland - With woody bio	159155692	5.45
Island	28997	0
Natural Forest	256852832	8.8
Other	9576208	0.33
Planted Forest - Pre-1990	401265977	13.75
Post 1989 Forest	391319752	13.41
Settlements	24347291	0.83
Wetland - Open water	9603463	0.33
Wetland - Vegetated non fo	2205899	0.08

Figure 5-1: Approach to extract information on land-use impacts for coastal polygons. Example showcasing land-use categories for catchments associated with each coastal polygon based on LUCAS (LCDB v4) database.

Further work is required to calculate nutrient and sediment loads, erosion metrics and population density for the coastal polygon areas. Additional analyses could relate spawning habitat of native freshwater fish to each coastal polygon. The analyses conducted in the NIWA pilot study (Lundquist et al. unpublished manuscript) included some manual selections of naturalness metrics that are not feasible with the large number of coastal polygons (compared to the original 44 marine reserves). There are several options to automate these processes that would significantly speed up extrapolating the full analysis to the entire coastline. Further, incorporation of an interpolation/smoothing factor between coastal polygons should be prioritised to represent the variable effects of catchments beyond the immediate land/sea interface.

5.2 Shipping

The distribution of shipping is an important measure of naturalness. Shipping is a significant source of noise in the ocean (Erbe et al. 2012) that has been implicated in population level consequence for a range of marine taxa (Rolland et al. 2012; Slabbekoorn et al. 2012). High vessel traffic also increases the likelihood of ship strike to marine megafauna (Kraus et al. 2005), and risk of collisions and contaminant spills.

Data on the distribution of shipping traffic is available from AIS (automated identification system) systems 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. Data for the period (2009 - 2020) is available for the entire EEZ and includes ca. 82 million ship positions. In order to view hotspots of shipping activity, a kernel density estimate can be applied to the point source records. An example of an AIS dataset for the Hauraki Gulf is presented in Figure 5-2. AIS data extracts are costly, and their acquisition was beyond the scope of the project.

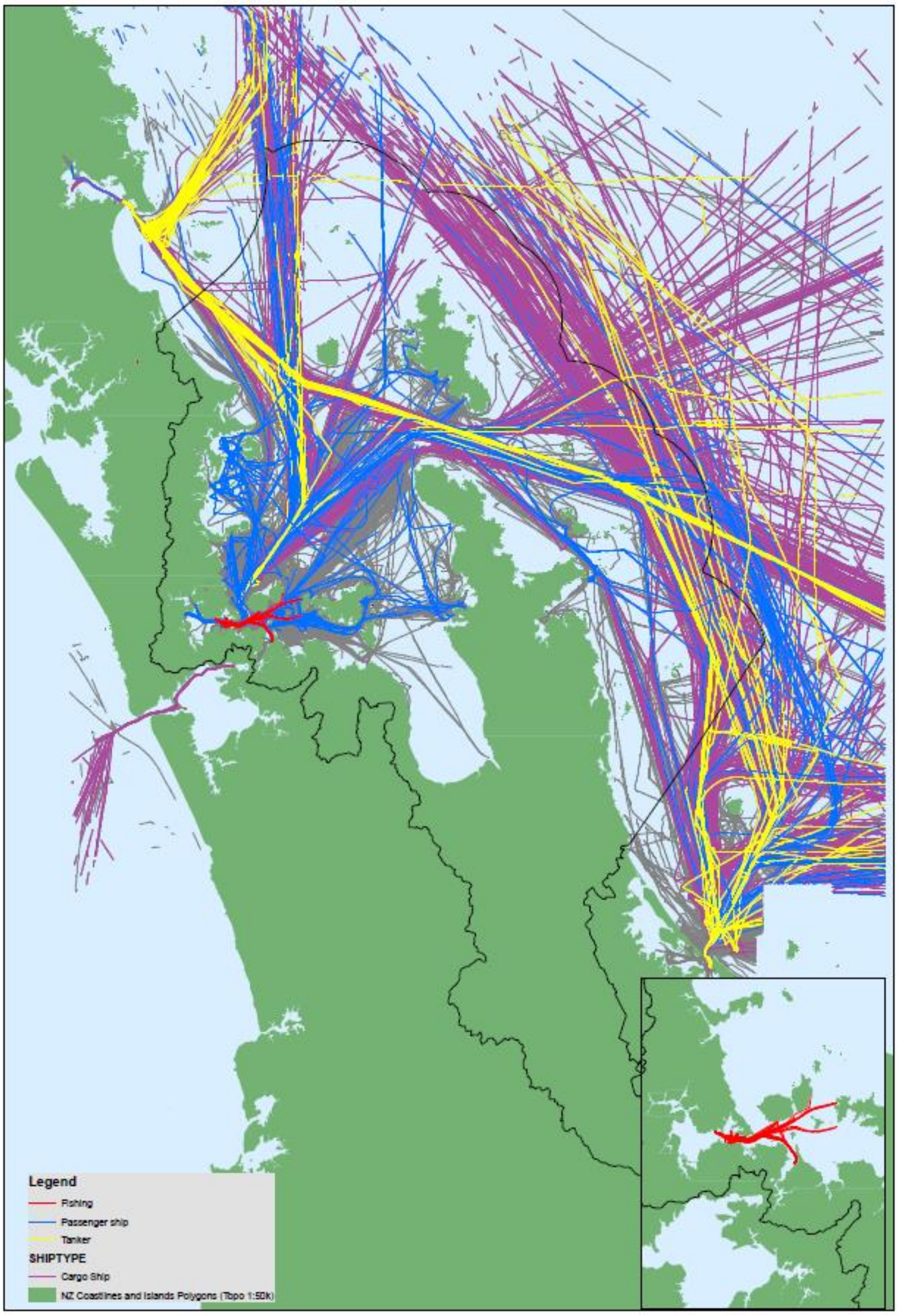


Figure 5-2: Example of satellite derived AIS shipping data acquired for the Tai Timu Tai Pari Hauraki Gulf Marine Spatial Plan.

5.3 Oil and Gas

Oil and gas exploration and existing infrastructure were indicated as a high priority layer for collation within the naturalness key ecological area criteria. Infrastructure including oil and gas platforms and pipelines introduce artificial substrate and can result in point source pollution – raising further considerations for marine spatial planning. The location of oil and gas infrastructure was accessed from the LINZ website (Figure 5-3). The feature layer is named “offshore-platform-points-hydro-190k-1350k”. Likewise, a feature layer detailing the location and extent of submarine pipelines was assessed via the LINZ website and is named “pipeline-submarine-on-land-polyline-hydro-190k-1350k”.

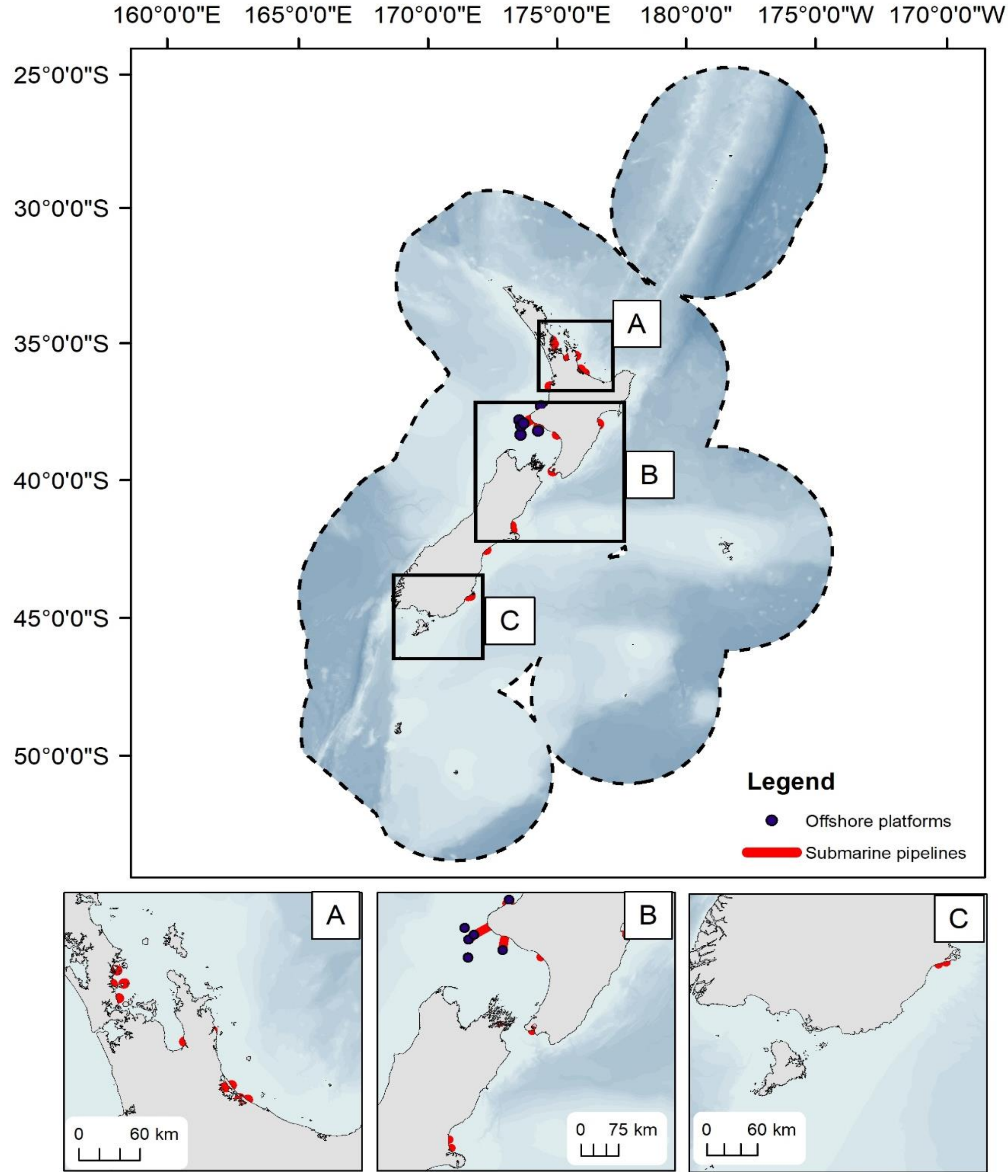


Figure 5-3: Offshore oil and gas platforms, and submarine pipelines.

5.4 Invasive species

A further indicator of naturalness that was prioritised for further investigation and data acquisition was marine invasive species records in the Marine Biosecurity Porthole (MBP) https://marinebiosecurity.org.nz/. Established marine pests that are monitored include, for example, the Asian paddle crab (*Charybdis japonica*), the Mediterranean fanworm (*Sabella spallanzanii*), the clubbed seasquirt (*Styela clava*), the Australian droplet tunicate, (*Eudistoma elongatum*), the Asian date mussel (*Arcuatula senhousia*) and wakame (*Undaria pinnatifida*).

Initial explorations were based on data collated for a University of Auckland PhD thesis (Nestor Robinson, unpublished data) which examined the distribution of the invasive macroalgae *Undaria pinnatifida* in New Zealand, one of the invasive species with the largest number of records. Point records for this species included 9,033 records from the MBP, and an additional 197 records from the Atlas of Living Australia (ALA) and 96 records from GBIF; OBIS records included only duplicates of records available from ALA or GBIF (Figure 5-4).

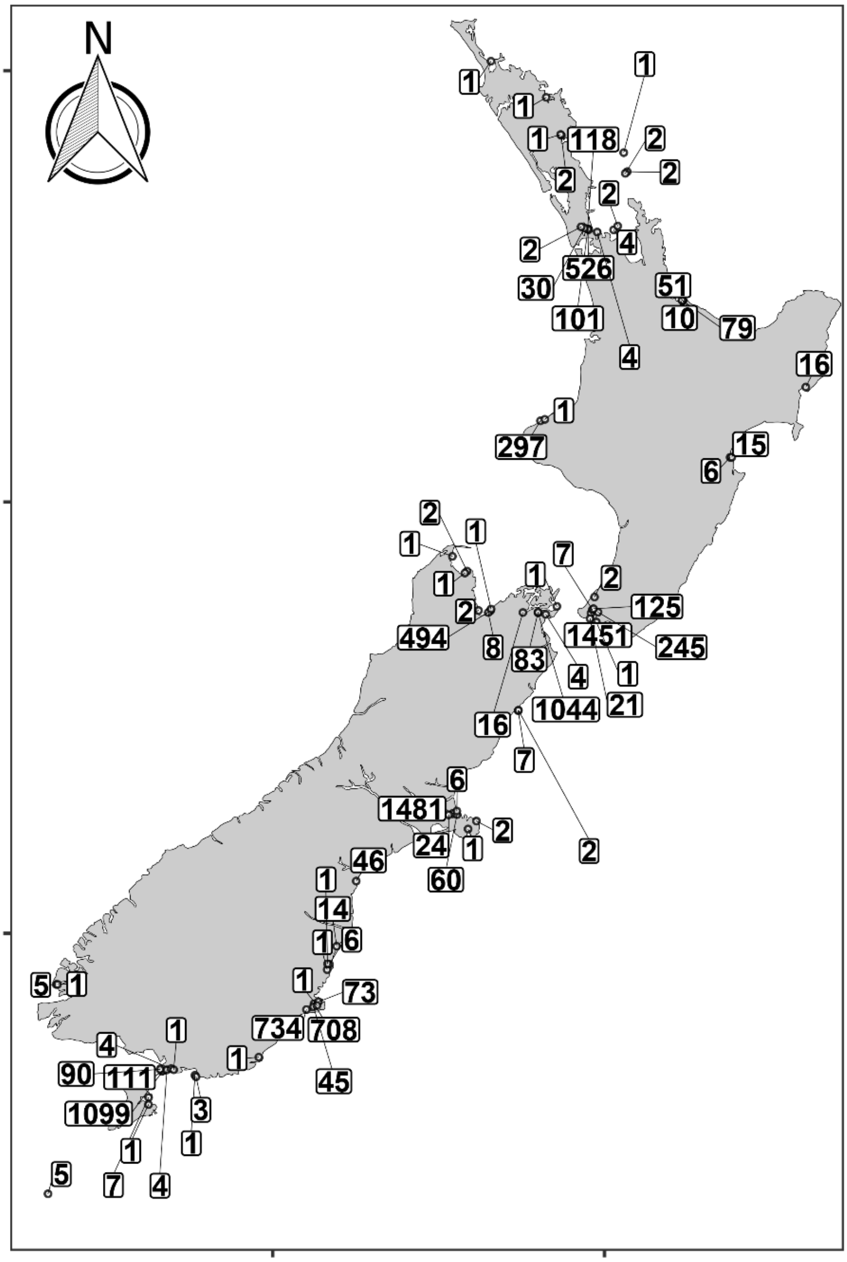


Figure 5-4: Sample of invasive species data from MITS. Point records for *Undaria pinnatifida* in New Zealand showing the number of presence records at each site. Unpublished data provided by Nestor Robinson, PhD Thesis under review at the University of Auckland.

The dataset illustrates extreme sampling biases in the MBP dataset, as most of the records are dominated by the regular port and harbour surveys. For example, five ports (i.e., Lyttelton, Wellington, Picton, Dunedin and Auckland) and one harbour (i.e., Bluff) contained far larger numbers of presence records (n= 1481, 1451, 1041, 734, 536, 1099; respectively). The full dataset (from multiple sources including MBP) included only 74 unique locations; 20 of these locations were ports and harbours sampled by MBP. As this dataset includes primarily port and harbour locations, we recommend that a simpler approach would be to use locations and numbers of ports, harbours, and aquaculture farms (also associated with high rates of marine bioinvasions) as a simpler indication of risk of marine invasive species.

6 Criteria 8: Ecological Function

The initial KEA project identified only two datasets that fit the Ecological Function criteria. The sensitive environments dataset (see section 3.2.3 and section 3.9.1 in Stephenson et al. 2018b; Anderson et al. 2019) was suggested to better suit the Vulnerability criteria, as the majority of habitat types were selected for that purpose, and the basic Ecological Functions provided by most biogenic habitats are poorly known and often inferred from overseas studies. As discussed earlier, the further extraction of information used to identify regional council significant ecological areas (section 2) showed that this criterion was not consistently assessed across regions. Instead these ASCVs were predominantly selected for the presence of threatened birds and marine mammals. A number of exploratory analyses were performed, as suggested at the August 2019 MSAG workshop, in order to fill gaps in layers available to inform this key ecological criterion.

While marine reef fish were identified as a potential dataset to inform Ecological Function of rocky reefs, further discussion at the MSAG workshop in August 2019 suggested that these metrics with respect to this taxonomic group were only a proxy of Ecological Function, and should not be used to inform this criteria.

6.1 Mesopelagic layer

Mesopelagic fishes are the most abundant group of marine fishes, dominating global fish biomass (Irigoien et al. 2014). The daily vertial migration of these taxa from deep water into shallow depths at night is a major biological pump resulting in signficantly enhanced carbon and nutrient sequestration to the deep ocean (Hernández-León et al. 2010). Mesopelagic fish sustain stocks of some of the world's most important commercial fish species (Gjøsaeter & Kawaguchi 1980) and are key prey for marine megafauna (Harcourt et al. 2002). Due to these traits, mesopelagic fish are central to pelagic and deep-sea ecosystem function. In New Zealand, our mesopelagic fish fauna are dominated by species of the family Myctophidae (latern fishes; O'Driscoll et al. 2009). Existing databases hold information on the occurrence of these valuable taxa.

A list of names for all species within the family Myctophidae was accessed from the online database FishBase (fishbase.org; Froese and Pauly 2019). FishBase records a present allocation of 247 species of myctophid across 33 genera. Myctophid occurrence records were extracted from the NIWA TRAWL database and from the OBIS Chordata database for the NZ EEZ.

A dataset of 1,440 point records of myctophids was generated representing 25 genera and 40 species. Most records were classified to genus level only. Records of the genera *Lampanyctus*, *Lampanyctodes* and *Diaphus* were the most well represented with 462, 217 and 197 records respectively. Myctophid occurrence records spanned the entire EEZ but were strongly clustered south of East Cape, particularly on the Chatham Rise (Figure 6-1).

The myctophid dataset provided in this project consists of point records only. Further, significant biases are likely associated with these point records given the distribution of sampling effort most likely to retain myctophids (e.g. high number of oblique tows on the Chatham Rise). Given the large number of observations and a pre-existing suite of high-quality, relevant environmental predictors (i.e., those used for SDMs above), SDMs could be fit for Myctophids, but it is likely the resultant layers would be spatially bias. Spatial modelling of mesopelagic abundance derived from hydro-acoustic datasets is currently progressing under NIWA SSIF funding (M. Pinkerton pers. comm), and thus may be available as a KEA dataset in the future. Such a dataset would be invaluable for understanding pelagic/deep sea ecosystem function throughout NZ waters.

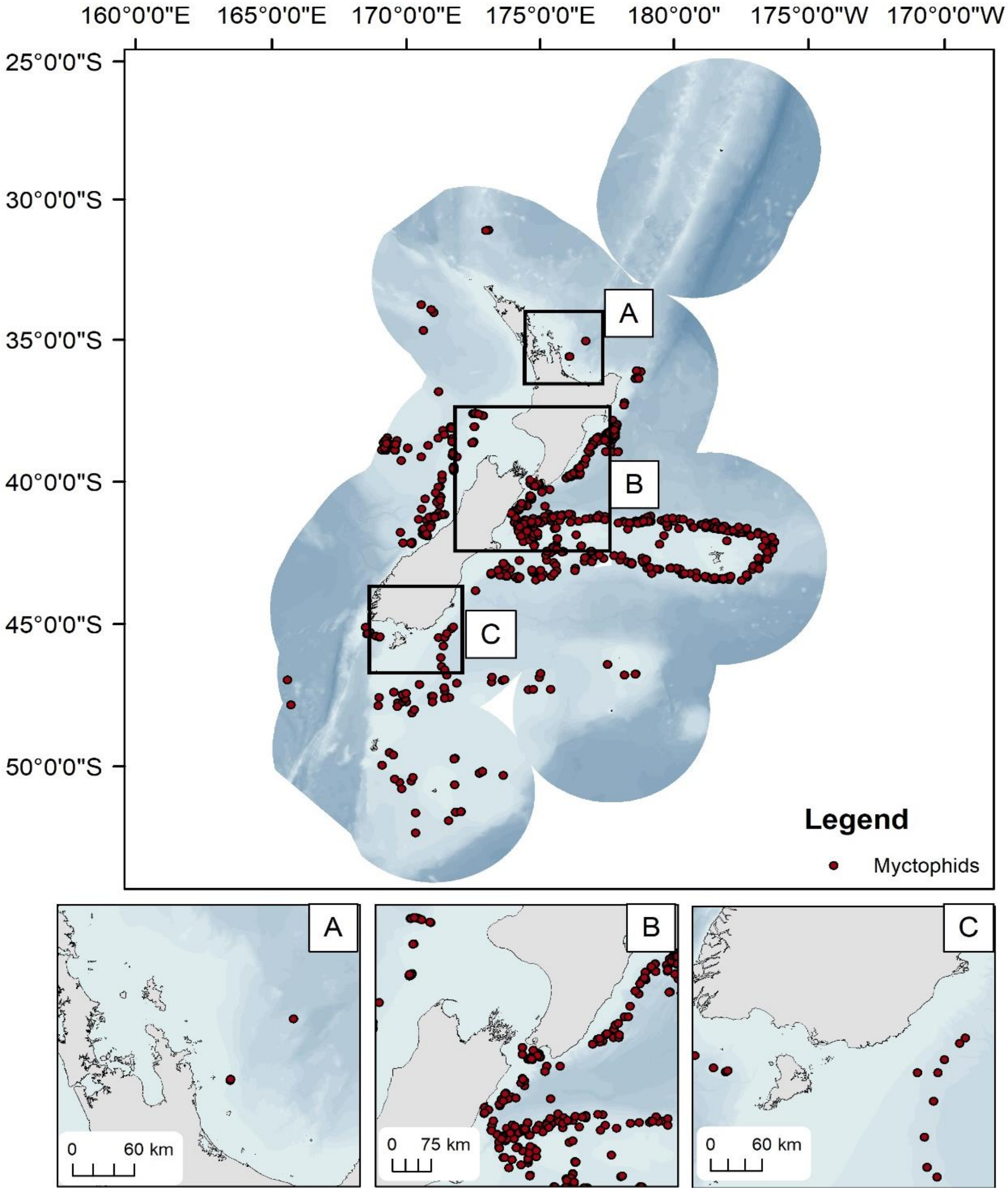


Figure 6-1: Myctophid layer extracted from TRAWL and OBIS databases. Based on 1,440 records representing 25 genera and 40 species.

6.2 Benthic invertebrate functional groups

An investigation of the potential to use benthic invertebrate functional groups as an indicator for this criterion was undertaken, as seafloor invertebrates are known to contribute to Ecological Functioning through sediment stabilisation, bioturbation, food provisioning, nutrient cycling and other substantive contributions to Ecological Function.

Genera with more than 50 occurrence records were matched against four NIWA databases with information on biological and/or functional traits for a wide range of benthic invertebrates in NZ waters. Five functional groups that represent ecosystem function were established. These were 1) upwards structure formers, 2) downwards structure formers, 3) substrate stabilisers, 4) substrate destabilisers, 5) bioturbators (see Table 6-1 for descriptions). A genus was included within a functional group if that genus was expected to exhibit that trait, guided by expert opinion. At this stage, genera that had previously been assigned to the above five functional groups were used. All occurrence records for each genus (with more than 50 occurrence records) contained within a functional group were extracted from the occurrence database and pooled into point record databases for each functional group. Limiting genera to those with more than 50 occurrences was based on the possibility of developing spatial models for these taxa, at the expense of excluding rare taxa (see section 9).

A total of 70,066 records were included in the functional group database, ranging from 4420 – 18801 occurrence records and 26 – 70 genera per functional group (Table 6-1, Figure 6-2 to Figure 6-6). Note that this is just an initial exploration of potential data to inform a further analysis. As the NIWA trait databases contain information on the biological traits that underlie the functional groups (e.g., size, mobility, position in the sediment), future work could use these databases to expand the allocation of the remaining genera. This expansion should include as many of the genera as possible (regardless of number of records) as some functional groups will be heavily comprised of rare genera.

Table 6-1: Point records of species occurrence of benthic invertebrate genera available to inform functional group analyses.

Functional group	Definition	n genera	Occurrence records
Upwards structure formers	Sedentary species or tubes that protrude from the sediment surface, providing a structure that other species can live on or within	60	13560
Downwards structure formers	Non-temporary burrows or holes that other species can live (or hide) in	40	14494
Substrate stabilisers	Sedentary species that live on the sediment surface, or species that armour the sediment surface	26	4420
Substrate destabilisers	Mobile species that move around on or dig holes through the sediment surface	48	18801
Bioturbators	Species that move particles or porewater by feeding or burrowing	70	18791

While point records of functional groups are of some use, it would be preferable to develop spatial layers that showcase the distribution of functional groups throughout New Zealand waters whilst including more rare taxa. This could involve density analyses, weighted by sampling effort, to remove biases associated with unequal sample effort. There are also interesting avenues to investigate whether models such as BRT or random forest can determine key habitat relationships between pooled functional group taxa and their environment. Establishing environmental drivers of functional group distributions may have important management implications and would allow the prediction of functional group occurrence into unsampled environmental space.

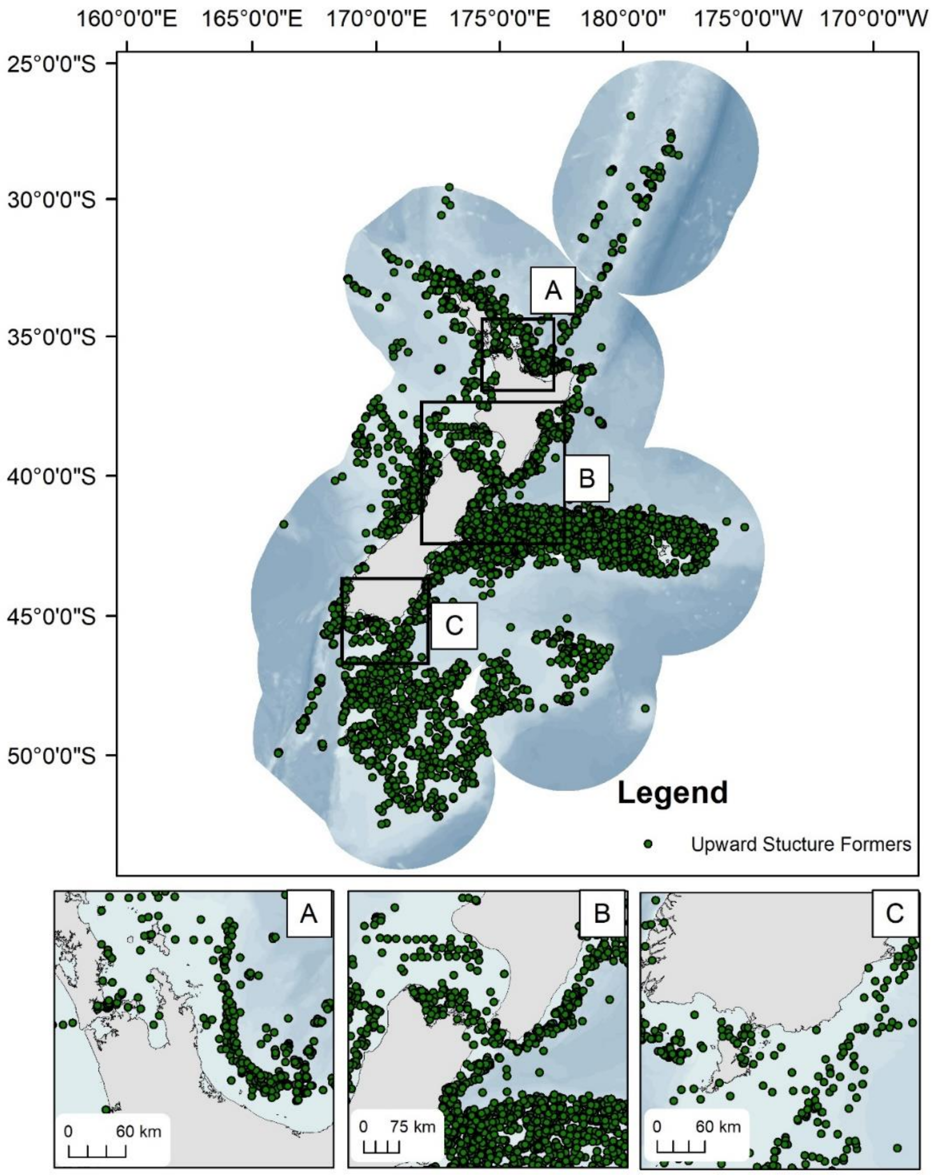


Figure 6-2: Point records of functional group upwards structure formers.

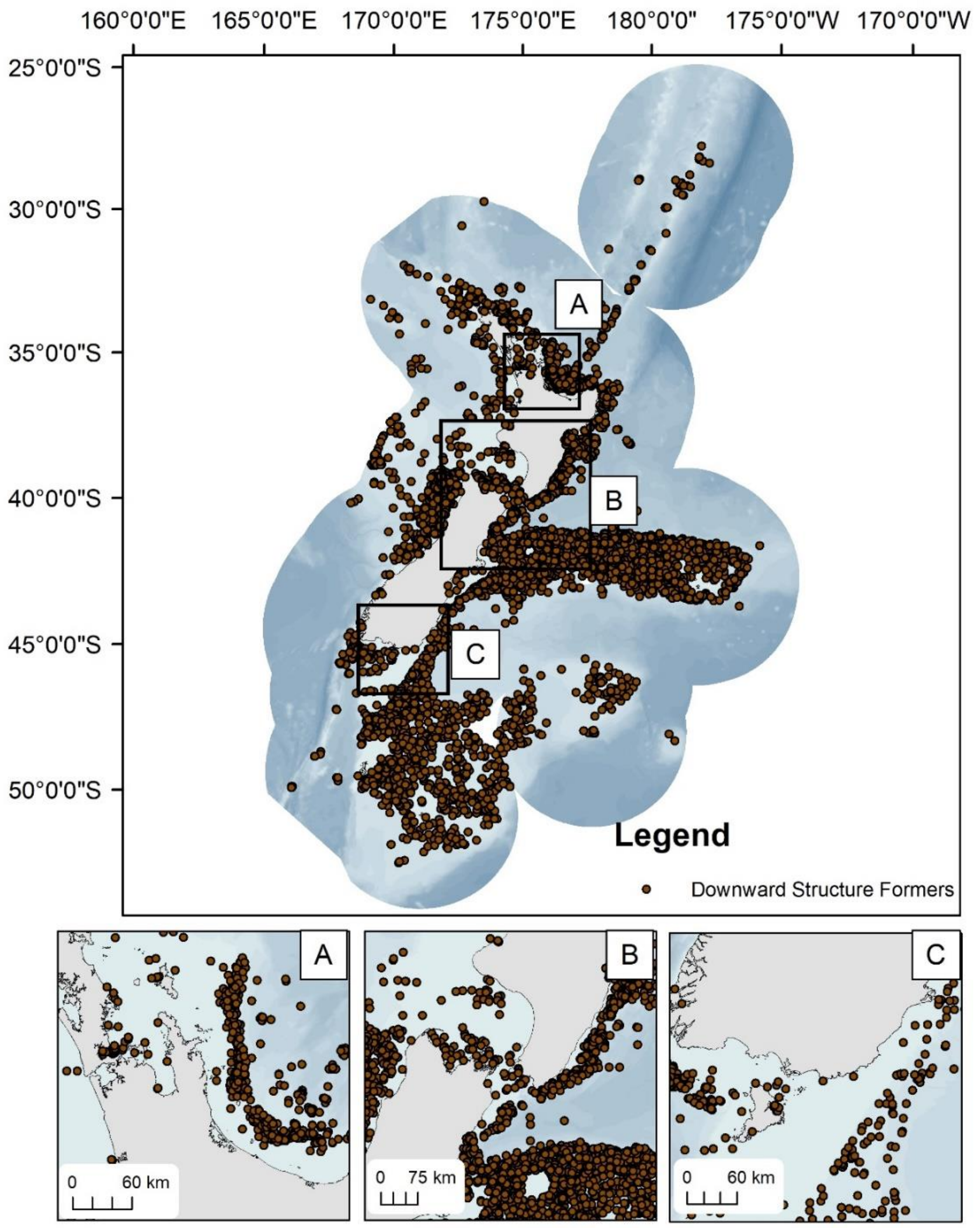


Figure 6-3: Point records of functional group downwards structure formers.

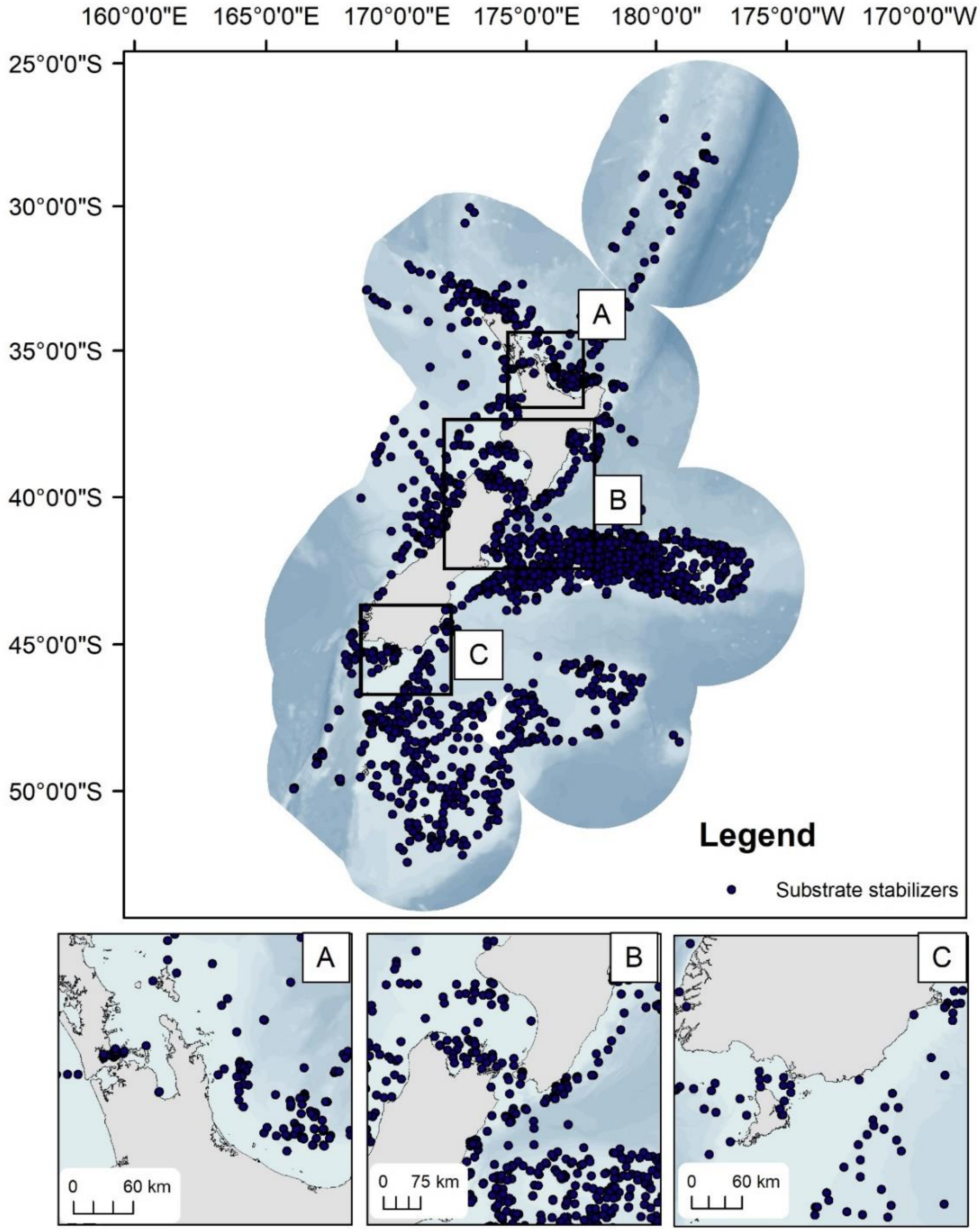


Figure 6-4: Point records of functional group substrate stabilisers.

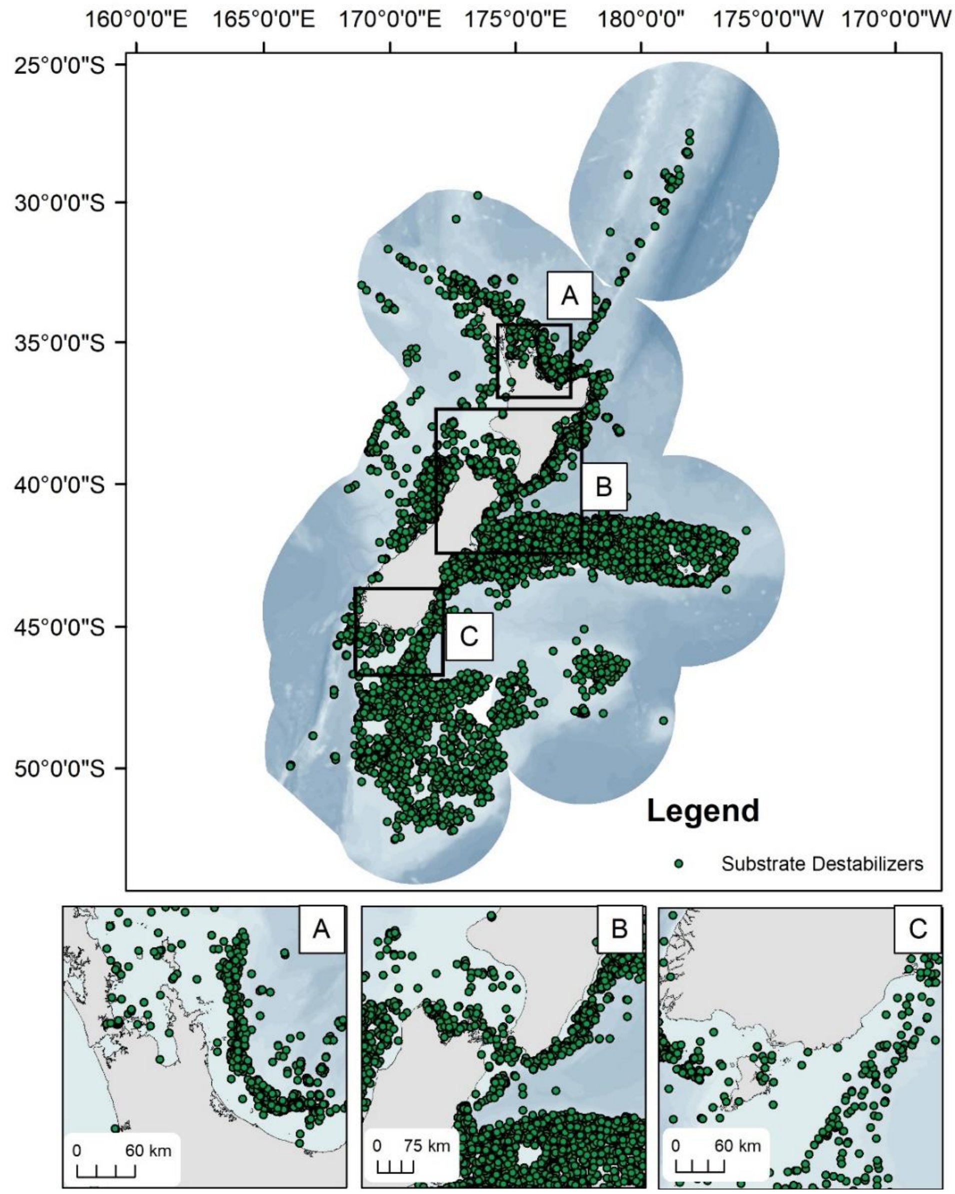


Figure 6-5: Point records of functional group substrate destabilisers.

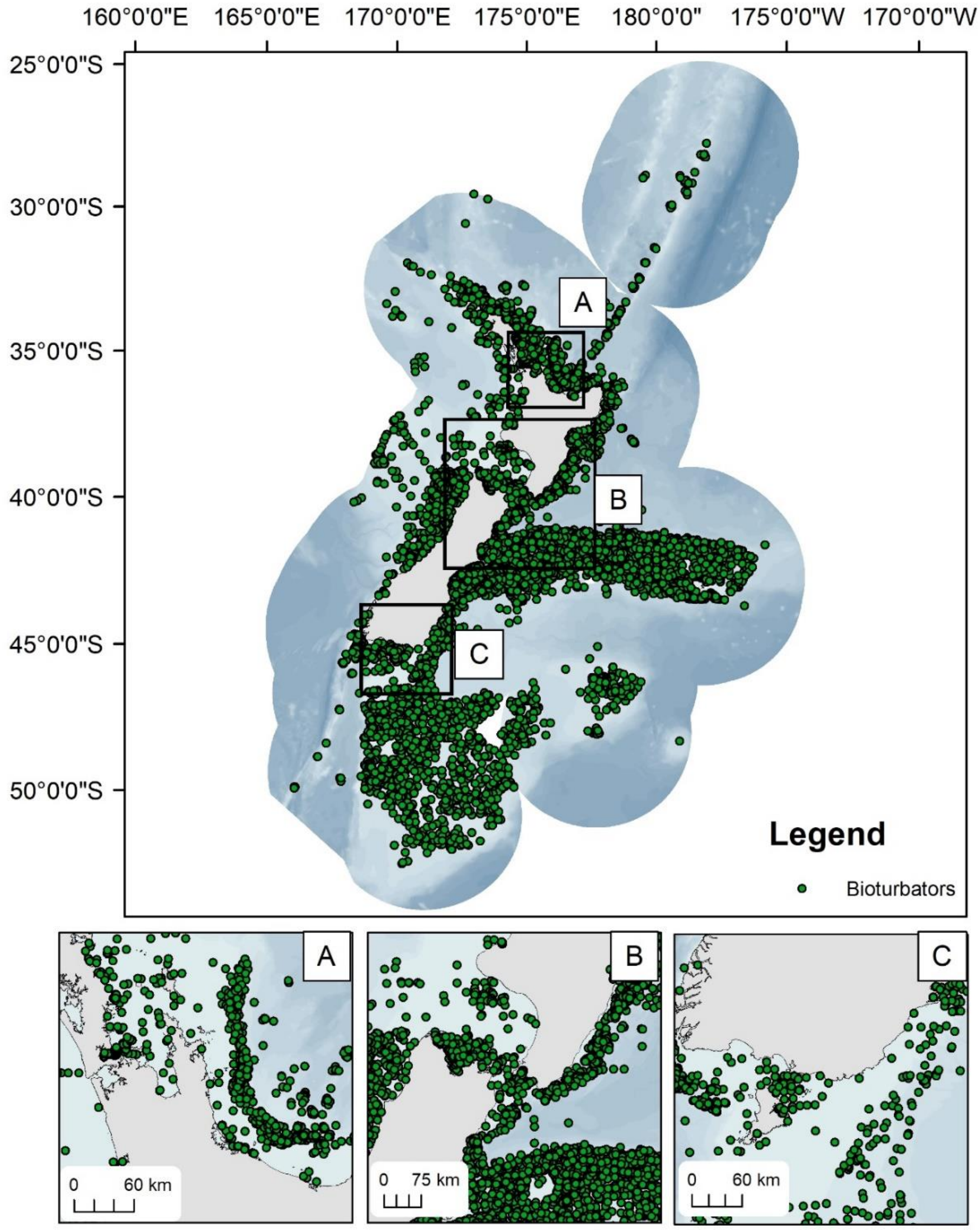


Figure 6-6: Point records of functional group bioturbators.

7 Criteria 9: Ecological Services

7.1 Summary

The original KEA project identified only three datasets available to inform the Ecological Services criteria. The biogenic habitat point records available from the sensitive environments dataset (see section 3.2.3 and section 3.9.1 in Stephenson et al. 2018b; Anderson et al. 2019) was one dataset selected to inform the Ecological Services of the provision of habitat structure. We hoped that the further extraction of information used to identify regional council ASCVs (section 2) would inform this criterion, but it was not consistently assessed across regions. A third available ecosystem services dataset that spatially mapped biogenic habitat using the Ecosystem Principles Approach (see section 3.10.2 in Stephenson et al. 2018b; Townsend et al. 2011) has since been empirically validated for its correlation with the presence of biogenic habitats (Townsend and Lohrer 2019).

While the initial key ecological areas project suggested that marine mammal and reptile data could be applied to the ecosystem services criteria, the MSAG workshop in August 2019 confirmed that the cultural or societal ecosystem services were out of scope, and that this criteria should be informed solely by supporting and regulatory ecosystem services.

7.2 Ecosystem Principles Approach

The Ecosystem Principles Approach is based on relationships between specific ecosystem services and environmental data and so may be particularly useful for areas where biological data is scarce. The approach has been validated for habitat provision in coastal areas (Townsend and Lohrer 2019), and further studies are investigating validation for shellfish provisioning (Rullens et al. 2019, in review) and denitrification potential (Lohrer et al. 2020). Primary productivity (one of the three original layers prepared by Townsend et al. 2014) is being further developed.

Mori (2017) provided pilot calculations of ecological ecosystem services for deep, offshore biodiversity, nutrient cycling, food provisioning (fisheries production), and carbon storage. Further validation through expert assessment of these principles, and their use in developing modelled layers for offshore marine ecosystems could assist in providing additional information to assess these often data poor regions.

7.3 InVEST

A number of global modelling platforms exist to support quantification of ecosystem services; Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) is one such tool for mapping the ecological and economic value of multiple ecosystem services at local and regional scales (Tallis et al. 2013). InVEST has been mostly used to map ES of terrestrial environments and freshwater, however modules have been developed for marine ecosystems that could be further explored for their use in filling gaps in the Ecological Services criteria. These include modules for ecosystem supporting services of habitat quality, habitat risk assessments, and marine water quality, and ecosystem services of blue carbon, unobstructed views (scenic quality provision), visitation, wave attenuation and erosion reduction, wave energy production, offshore wind energy production, marine finfish aquaculture production, and marine fishery production (Tallis et al. 2013). While many of these are relevant for broader marine spatial planning through the representation of human values for marine ecosystems (as they mainly focus on "goods" produced rather than supporting or regulating services), some of their modules are relevant here. Regardless, their exploration was beyond the scope of the project.

8 Discussion

Our evaluation suggests that New Zealand marine biodiversity, habitat and ecosystem datasets are best placed to inform criteria that are primarily relevant for taxonomic groups and can be tabulated for individual species (Uniqueness / Rarity / Endemism, Special Importance for Life History Stages, Importance for Threatened / Declining Species and Habitats, Biological Diversity) (Table 8-1). Data availability differs substantially between taxonomic groups, with extensive datasets available for cetaceans, fish, invertebrates, and macroalgae being large enough to support development of species occurrence models for a subset of species. The new compilation of seabird and shorebird data completed for this project suggests a plethora of available information that could be integrated to further inform spatial (and possibly temporal) distributions of this taxonomic group. The ongoing development of spatial layers through seabird spatial risk assessments (FNZ projects), may already have resulted in distribution layers that could be utilised for KEA mapping. The existence and availability of such layers should be explored.

Predictive models are less robust for invertebrate groups, with smaller available point records for species, and sample size sufficient primarily for analyses at the resolution of genera. For rocky reef taxa (fish and macroalgae) and invertebrats, there are limitations to using these approaches for these shallower marine habitats where environmental drivers may be poorly represented by coarse resolution (1 km^2) environmental variables. The availability of absence data, required for BRT and RF species distribution models, varies between taxonomic groups. For demersal fish with consistent sampling methods and location records that include all taxa observed, absence data can be inferred from sampling locations where other species were observed. For other modelled groups that compile point records from different sources and gear types, the interpretation of species absences is complex, such that an absence could mean a species was not at the locality, or that not all species collected were recorded, or that it was not detectable due to the sampling gear used.

Pelagic and deep water (bathyal, abyssal) ecosystems are poorly represented within the KEA datasets.

Table 8-1: Summary of evaluation of key ecological criteria across taxonomic and spatial comprehensiveness.

Criterion	Dataset description	Extent and resolution	Gaps and caveats
Vulnerability, Fragility, Sensitivity or Slow Recovery			
Sensitive habitats – macroalgae.	Point records of large brown algae, algal meadows, rhodolith beds, coralline turfs and crusts.	EEZ wide	Largely from herbarium records – presence only point records.
Sensitive habitats – bryozoans.	Species occurrence models (SDMs) of 11 taxa.	EEZ wide	

Criterion	Dataset description	Extent and resolution	Gaps and caveats
Sensitive habitats – other biogenic habitats.	Point records.	EEZ wide	Point records, spatial bias in coverage by region and to primarily trawlable depths or locations of survey effort. New records not yet available from MBIE Bottlenecks project.
Vulnerable marine ecosystems.	Raster layers of 12 VME taxa, updated from KEA1.	EEZ wide.	Robust species occurrence models including uncertainty; exploration of correlation between species occurrence and species abundance in process for MPI (SPRFMO).
Uniqueness / Rarity / Endemism			
Cetacean	Cetacean endemic (2) and rare species (1) – Point records and species occurrence models.	EEZ scale including offshore observations.	RES model for false killer whales based upon 28 points only.
Seals and sea lions	One endemic species (NZ sea lion) – point records of haul out and breeding colonies	Coastal locations, national scale.	May not be up to date as new colonies/haul outs established with expanding range of NZ sea lions.
Seabirds	Points records of endemic species.	EEZ wide but patchy.	Data pooled from many sources – integration not straightforward. Presence only data. Challenge of how to incorporate terrestrial habitat use.
Demersal fish	Point records of 54 and SDMs for 47 endemic species. Raster layers of species turnover and classification groups.	EEZ wide, rasters at 1 km resolution.	Records dominated by trawlable depths; species occurrence less certain beyond this. Correlation between species occurrence and abundance assumed, but not tested.
Rocky reef fish	Point records for 92 and SDMs for 19 endemic species.	Reef habitat in territorial sea and offshore islands.	Location of reef habitat not necessarily accurate. Sampling restricted to shallow reefs, bias towards sheltered sites. Poor coverage elsewhere.
Benthic invertebrates	Point records and SDMs of endemic species.	EEZ wide.	Records dominated by depths less than 2000 m. Models at genera scale, often including both endemic and non-endemic species.
Macroalgae	Point records and SDMs endemic species.	Reef habitat in territorial sea and offshore islands.	Location of reef habitat not necessarily accurate. Sampling restricted to shallow reefs, bias towards sheltered sites. Poor coverage elsewhere.

Criterion	Dataset description	Extent and resolution	Gaps and caveats
Seamounts	Point records.	EEZ wide.	Seamounts already identified due to overlap with vulnerability criteria.
Special Importance for Life History Stages			
Cetaceans			No information available to populate this criterion. Potential for modelling of seasonal spatial distributions and correlation with temporal variation in environmental drivers.
Seal and sea lions	NZ sea lion, fur seal and elephant seal breeding colonies. Point and polygon records.	Coastal locations, national scale.	May not be up to date as new colonies/haul outs established with expanding range of NZ sea lions and fur seals. 'Occasional' breeding colonies may not be accurate, particularly for historic records of southern elephant seal on the mainland.
Seabird	Location of breeding colonies for 92 species of seabird. Some foraging and roosting locations.	EEZ wide.	Data pooled from many sources – integration not straightforward. Presence only data, though likely mostly complete due to strong public interest.
Demersal fish	Fish spawning areas for 39 species, polygon layer.	Mainly territorial sea.	Polygons often represent large areas – coarse resolution. No spatial distributions available for juvenile distributions.
Freshwater fish	Freshwater fish species (26) point record and spawning locations.	Riverine habitat – North and South Island.	Mainly inland rivers and streams; no metric to assess relative importance of individual estuaries as spawning locations.
Rocky reef fish	Spawning locations for 8 species.	Mainly territorial sea.	Polygons often represent large areas – coarse resolution.
Invertebrates and macroalgae			No information available to populate this criterion.
Importance for Threatened / Declining Species and Habitats			
Cetaceans	Threatened species (5) point records and SDM raster layers.	EEZ wide, including offshore areas, 1 km resolution for SDMs.	Point records are spatially biased to areas with more survey effort. SDMs may not be accurate offshore due to lack of sightings. Large proportion of species at data deficient, and threatened status is unknown.

Criterion	Dataset description	Extent and resolution	Gaps and caveats
Seal and sea lions	Threatened species (2) haul out and breeding colony point and polygon records.	Coastal locations, national scale.	May not be up to date as new colonies/haul outs established with expanding range of NZ sea lions.
Reptiles	Internationally threatened sea turtles.	Point records, typically coastal.	Sparse point records; only one marine reptile (sea snake) is known to breed in New Zealand.
Seabirds	Threatened species point records.	EEZ wide.	Presence only data.
Macroalgae	Threatened species point records (n = 6).	Reef habitat in territorial sea and offshore islands.	Presence only data.
Biological Primary Productivity			
Coastal vegetation	Polygons for mangroves, limited polygons and mostly point records for seagrass, limited information for saltmarsh.	Coastal, national scale.	Inconsistencies of regional and temporal scale reporting. Few layers present at polygons. No spatial information for historical distributions (though anecdotal evidence of significant declines of seagrass and saltmarsh).
Satellite remote sensing primary productivity	Modelled layer.	EEZ wide at 1 km resolution; coastal at 400 m scale.	Poor understanding of coastal primary productivity and extrapolation of chlorophyll a when high levels of particulate matter.
Biological Diversity			
Cetaceans	Species richness raster layer created by stacking SDMS of 30 cetacean species.	EEZ wide, including offshore areas, 1 km resolution for SDMs.	Accuracy of underlying SDMs may be compromised by lack of sightings data – particularly offshore and for rare species. Use of layer should be guided by environmental coverage.
Seabirds	Species richness – within ASCV and IBA sites only.	Within regional council ASCV sites.	Point records, some sites with multiple species recorded.
Demersal fish	Species richness raster layer created by stacking SDMS of 241 fish species. Species turnover and classification group rasters.	EEZ wide at 1 km resolution.	Primarily trawlable depths, few deep records used to produce SDMs - use of layers should be guided by environmental coverage. Relative absences were generated from demersal fish occurrence records.

Criterion	Dataset description	Extent and resolution	Gaps and caveats
Rocky reef fish	Species richness raster layer created by stacking SDMS of 51 fish species. Species turnover and classification group rasters.	Reef habitat in territorial sea and offshore islands, 250 m resolution.	Location of reef habitat not necessarily accurate. Sampling restricted to shallow reefs, bias towards sheltered sites. Poor coverage elsewhere. Relative absences were generated from rocky reef fish occurrence records.
Benthic invertebrates	Species richness raster layer created by stacking SDMS of 207 invertebrate species. Species turnover and classification group rasters.	EEZ wide, rasters at 1 km resolution.	Primarily trawlable depths, few deep records used to produce SDMs - use of layers should be guided by environmental coverage. Coarse taxonomic scale (genera). Complex interpretation of absences due to differences in sampling gear.
Macroalgae	Species richness raster layer created by stacking SDMS of 88 species. Species turnover and classification group rasters.	Reef habitat in territorial sea and offshore islands, 250 m resolution.	Location of reef habitat not necessarily accurate. Sampling restricted to shallow reefs, bias towards sheltered sites. Poor coverage elsewhere. Complex interpretation of absences due to records being presence only herbaria specimens.
Naturalness			
Land use	Polygon layer summarising land use categories by adjacent catchment.	Territorial sea.	Currently no connection of catchments along coast, other land use effects (sediment/nutrient loads, erosion, population density etc) not included. Pathway forward identified to further quantifying this layer.
Oil and gas	Feature class layer denoting locations of offshore platforms and submarine pipelines.	Territorial sea.	Point records, lines. No assessment of impact or risk of their occurrence.
Invasive species	Presence of invasive marine species at 74 unique locations.	Coastal sea.	Strongly biased to survey locations (i.e., ports). No assessment of impact or risk to naturalness by species.
Fisheries metrics	Bottom fishing footprint, fishery metrics for commercial and recreational fishing.	EEZ wide.	Limited surveys and validation of recreational fishing to coastal areas; commercial fisheries metrics updated regularly. A naturalness layer to quantify degradation from bottom fishing impacts is under development.

Criterion	Dataset description	Extent and resolution	Gaps and caveats
Existing spatial management areas	Marine reserves, benthic protection areas, depth refuges from fishing impacts, and other use restrictions.	Polygons, EEZ wide.	Typically static areas/regulations.
Ecological Function			
Mesopelagic fish	Point records of 25 genera.	EEZ wide.	Initial exploration shows promise of modelling of this important mesopelagic group.
Benthic invertebrate functional groups.	Point records for genera classified into five function groups.	EEZ wide.	Not an exhaustive list of genera by group. More work required to link species and genera to functional groups.
Ecological Services			
Biogenic habitat provision.	Predictive models based on ecosystem principles approach.	Territorial Seas, national scale, rasters at 1 km resolution.	Empirically validated in northern New Zealand; dependent on environmental layers that may be poorly resolved in some regions.
Other ecosystem services.			No comprehensive spatial layers available in New Zealand.

Other key ecological area criteria are often parameterised by datasets at habitat or ecosystem scales, including Vulnerability, Fragility, Sensitivity or slow recovery, Biological Productivity, Ecological Function, and Ecological Services (Table 8-1). Most datasets identified in the original key ecological areas project for these criteria were deemed to be proxies, i.e., habitats that were associated with high Biological Productivity, but without metrics to assess relative contributions to these criteria. Most of the habitats identified with the Vulnerability criteria (particularly sensitive habitats) also inform other criteria, for example mangroves and seagrass inform Biological Productivity, Ecological Function, and Ecological Services. Most sensitive habitats are identified for their role in the provision of biogenic habitat structure, which contributes to Ecological Function and is also considered an ecological service. These sensitive habitats are also anecdotally associated with high Biological Diversity. Consideration should be given to the inclusion in any spatial prioritisations of datasets where they best suit key ecological area criteria, and minimisation of use for multiple criteria.

The limited information for the habitat specific criteria emphasise the key knowledge gap in New Zealand marine ecosystems of habitat distributions (and agreed definitions of habitat types), including distributions of biogenic habitats. While concurrent investigations will develop a new marine habitat classification based on the modelled taxonomic groups of demersal and rocky reef fish, benthic invertebrates and macroalgae, these habitat classifications are unlikely to provide information on the presence of biogenic habitats at scales appropriate for the designation of marine protection. Currently, the majority of information on biogenic habitats is of point records, with no comprehensive or strategic spatial surveying to fill gaps in our understanding. While a national scale biogenic habitat mapping exercise would be important for informing marine conservation planning, the thematic habitat classification (also in development within the parallel MSAG investigations) could further inform identification of relevant habitat types, including the often poorly differentiated infaunal soft sediment habitats that form the majority of the seafloor in New Zealand's EEZ.

Finally, there are large differences in the data available to populate the MSAG key ecological areas criteria. While most datasets were assigned to their most relevant criteria to avoid overlap or use of particular datasets as proxies for a number of ecological criteria, spatial prioritisations should consider how best to balance criteria about biodiversity versus those of ecological integrity and resilience. While biodiversity is often assumed to be correlated with increased ecosystem function, productivity and service provisioning, and resilience, these relationships may not always hold true.

9 Recommended additional datasets

Throughout this project, we have identified a range of additional datasets that could be acquired or developed to aid in the identification of key ecological areas. A list of these datasets and activities are provided under their relevant KEA criteria.

Criteria 2, 3, 4 & 6: Uniqueness, life history, threatened taxa and diversity

Explore alternative weighting for relative environmental suitability layers used in the generation of cetacean species richness.

Address spatial gaps in sampling coverage and gaps in the understanding of temporal patterns in cetacean species distributions. Note that it would require substantial investment to significantly improve the models.

Explore the utility of datasets housed by birding groups including Birding New Zealand for understanding the distribution of seabirds and shorebirds.

Investigate the availability of spatial layers on seabird distribution generated within national seabird spatial risk assessment projects.

Develop a spatial representation of seabird/shorebird diversity (e.g. species richness) – contingent on additional datasets that characterise distribution of these taxa.

Explore whether relative environmental suitability models (as per the marine mammal section) could provide meaningful approximations of distribution for other taxa with low numbers of presence records.

Criteria 1: Vulnerability, fragility, sensitivity or slow recovery

Investigate the availability of datasets gathered through MBIE bottlenecks project on the distribution of sensitive biogenic habitats, particularly calcareous tubeworm mounds.

Criteria 5: Biological productivity

Refine remote sensing datasets to provide better estimates of primary productivity in coastal water. These are currently under development within NIWA and may provide valuable additions to this criterion.

For offshore waters, investigate the several options (see page 82) for model development that may improve estimates of spatiotemporal primary productivity and fill gaps in this criterion for this poorly sampled habitat.

Criteria 7: Naturalness

Develop and refine a spatial layer representing land-use impacts on the territorial sea following the pilot study presented in this report, the land-use impacts on MPAs investigation (Lundquist et al. unpublished) and section 3.8.4 of Stephenson et al. (2018b).

Acquire and process AIS shipping datasets to construct a spatial layer representing the intensity of shipping traffic within NZ waters.

Explore datasets currently under development on the naturalness of the seafloor in areas subject to trawling (FNZ project led by Ashley Rowden, NIWA).

Investigate the applicability of datasets generated by the biosecurity project led by Graeme Inglis (NIWA) for providing information on the distribution of naturalness.

Criteria 8: Ecosystem function

Acquire or develop a spatial layer representing the distribution/abundance of mesopelagic fish (e.g. myctophids).

Expand the database of benthic invertebrate functional groups, and the genera represented by each group, to incorporate as many of the benthic invertebrate records that are currently available.

Develop spatial models (using KDe, SDM or similar) to illustrate an unbiased distribution of key benthic invertebrate functional groups. Understanding the environmental drivers of the abundance of functional groups would have important management implications.

Criteria 9: Ecological services

Acquire and validate the ecosystem services layers for deep offshore habitat in order to appraise its utility for informing ecological services of this poorly sampled habitat.

Investigate the utility of INVEST spatial layers on the distribution of ecological and economic values across multiple ecosystem services.

General

Investigate new datasets that can be used to fill the significant gaps on pelagic and deep-sea habitats.

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Appendix A Summary of Key Ecological Areas, Stage 2 Workshop

A.1 Agenda

Location: NIWA Wellington, Allen Boardroom

Date: 16 August 2019

Time: 9:30 am – 3:30 pm

Chairs: Debbie Freeman (DOC); Carolyn Lundquist (NIWA).

Participants: Shane Geange (DOC); Greig Funnell (via VC)(DOC); Amelia Smith (DOC); Karen Tunley (MPI); Pierre Tellier (MfE); Fabrice Stephenson (NIWA); Judi Hewitt (NIWA); Kate Neill (NIWA); Tamlin Jefferson (UoA).

Apologies: Ben Sharp (MPI); Constance Nutsford (MfE); Jade Maggs (MPI); Rich Ford (MPI).

Workshop objectives:

- To review and discuss key ecological area criteria and associated data layers, including the comprehensiveness and data quality/uncertainty of data layers compiled for each criteria.
- Identify and prioritise gaps in data layers to support further use of these criteria in identifying optimal areas for biodiversity conservation.
- Identification of biodiversity features in addition to the KEA and habitat mapping layers that should be included in the identification of optimal areas for biodiversity protection (contract 4758).

Agenda:

- Morning tea (from 900am in Allen Boardroom), VC logistics.
- Brief round table introductions.
- Project objectives for KEA stage 2, and how this fits into broader MSAG projects (Debbie, Carolyn).
- Discussion of key ecological area criteria and layers.
- Lunch at 12:30 pm.
- Further discussion as needed.
- Questions/thoughts from MSAG to NIWA (MSAG).
- Timeline and report logistics.

A.2 Introduction/Background

Amelia Smith briefly reported on how the KEA project could provide information that will inform upcoming MPA Policy, with the new policy potentially extending to the full EEZ (not just Territorial Sea), and thus requiring national strategies to incorporate optimisation across biodiversity targets, updating marine habitat classifications, and updating of KEA layers. MSA is well connected in this MPA policy group, with MPI and DOC jointly leading MPA policy reform.

The interim group (ISAG) was formed in 2016, and has since turned into a formal scientific advisory group (MSAG), which reports to marine directors of each organisation.

Information sharing across central government agencies (MfE, DOC, MPI) also occurs via the Marine Hub which supports joint briefing and coordination across agencies.

A.3 KEA Criteria Discussion

Each of the KEA criteria was then individually discussed across a suite of questions to guide prioritisation of additional data scoping. Data compiled under the KEA Stage 1 project were identified and used to guide discussions of gaps and priorities for further dataset acquisition.

General discussion of timing of acquiring of datasets, with most datasets to be acquired by contract milestone deadlines, but that some (particularly those dependent on data analyses for the Habitat Classification project, but also other projects developing useful data) may be added at a later date, due to availability of these datasets.

Key ecological area criteria as identified by MSAG (based on EBSA criteria):

- Vulnerability, Fragility, Sensitivity or Slow Recovery.
- Uniqueness / Rarity / Endemism.
- Special Importance for Life History Stages.
- Importance for Threatened / Declining Species and Habitats.
- Biological Productivity.
- Biological Diversity.
- Naturalness.
- Ecological Function.
- Ecological Services.

Guiding questions for discussion:

- Do datasets cover all elements (taxonomic groups, habitats) relevant to describing each KEA.
- Correlations between and within criteria, e.g., many datasets listed for multiple criteria.
- Availability and/or assessment of uncertainty in each dataset.

- How criteria could be represented within spatial planning software.
- Prioritisation of additional analyses, including newly available data.

A.3.1 Vulnerability, Fragility, Sensitivity or Slow Recovery

Definition: Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.

Rationale: In the absence of protection, associated biodiversity may not be able to persist.

Examples provided by MSAG: Biogenic habitats, including bryozoan beds, sponge communities and coldwater corals. Low fecundity and, or high longevity (fish) species such as bramble sharks, hapuku, king tarakihi, orange roughy

Regional council datasets on significant ecological areas**.** These were identified as a priority to cross check against KEA criteria. These include local data and are often covered in better detail than national datasets/modelled datasets.

Vulnerable species assessments. Sharks are the only taxonomic group for which a robust systematic assessment process has been performed across species group.

Slow to recover species. Discussion resulting in decision that these will not be included in KEA dataset, as this is dealt with through Fisheries NZ stock assessments (e.g., orange roughy) and through FNZ/DOC threat groups, and is thus is covered by other processes.

Biogenic habitats. Discussion of limitations of Sensitive Biogenic habitats layers (Anderson et al. MfE project) as they include primarily point records and are not systematic or continuous habitat layers and also show significant sampling effort bias due to limited spatial observations. Suggested to use as 'silent layers'.

Project team to explore other vulnerable habitats that may be available now since publication of the MfE report, such as rhodolith maps, coralline algae maps, algal meadows. Also to explore if data available from SPECIFY/OBIS to create layers for tube worms, coralline lattices, *Galeolaria* beds.

VME layers. These are currently being updated (DOC contract to NIWA, Owen Anderson lead), and should be available early 2020.

Seagrass and mangroves. Helen Kettles has compiled new/updated national layers for seagrass or mangroves as part of DOC estuaries programme. NIWA to contact Helen to obtain these, assuming that they include polygon layers from councils of these habitat types. Also to query if saltmarsh are included in these new layers.

General discussion of these types of layers (point records or those with sampling bias) resulting in decision for Zonation analyses that some layers can be used as 'Silent' layers – approach agreed as useful for layers to be reported on but not driving prioritisation due to limited observations, spatial biases. For others where there is need to bring in protection with limited points, e.g., black coral in Fiordland, a decision could be made to include point records that should be explored when scenarios are explored, and any biases to include vulnerable area data to be identified and assumptions clarified.

Biogenic habitat modelled layer. This layer is based on the Townsend et al. (2011) Ecosystem Principals Approach at national scale) and has been validated as a reasonable representation of biogenic habitats (and is published), however it is limited to the 12 nm limit. It can be used to represent where we think a habitat could be based on physical characteristics, though stressors (sediments, fishing) may result in these habitats not being found there. Also, to explore categorisation, as it is currently set up as bands of low to high value categories – lower end values are possibly more useful as indicators of low likelihood of biogenic structure, whereas mid to high categories may not be as useful to differentiate. The layer is also available as raw modelled values. It is a comprehensive layer covering the full inshore territorial seas to 12 nm, so does not have spatial biases, though its dependence on sediment as one of the driving layers means it is less accurate in areas with lower quality input data.

An offshore EPA model was developed, though is only to date published as a MSc thesis (Luca Mori, UoA MSc). Protect team to investigate using offshore, possibly cross checking with offshore point records.

A.3.2 Uniqueness / Rarity / Endemism

Definition: Area contains either (i) unique ("the only one of its kind", rare (occurs only in a few locations) or endemic species, populations or communities; and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphological or oceanography features.

Rationale: These areas contain biodiversity that is irreplaceable; non-representation in protected areas may result in loss or reduction in biodiversity or features. These areas contribute towards larger-scale biodiversity.

Examples: Hydrothermal vents; seeps; areas containing co-occurring geographically restricted species; biogenic habitats, vents/seeps, other deep sea features, seamount protected areas.

Demersal fish and benthic invertebrates. Turnover metrics of dissimilarity to indicate particularly unique classes. Will be provided by MSAG Habitat Classification project/layers.

Vents, Seeps, Seamounts. Multiple seamount datasets with endemism ranking that might be useful. Contact Ash/Malcolm and Tiff (MPI) re datasets of seamounts.

Naturally rare taxa. Could include the naturally rare species from NZTCS – but will be a lot of the taxa, as rare species are 50%+ for most marine groups. Could report as distribution of sampling effort? Chao effect bias model? Heatmap for uniqueness/rare/endemism?

A.3.3 Special Importance for Life History Stages

Definition: Areas that are required for a population to survive and thrive.

Rationale: Species' particular requirements make some areas more suitable for carrying out life history stages.

Examples provided by MSAG: Fish spawning or nursery grounds; pinniped breeding colonies; migratory corridors; sites where animals aggregate for feeding.

Sensitive environments. This layer (similarly a number of other layers) are double counted here. Consider how best to include in Zonation, i.e., create 'layers' for each criteria, or create layers for individual biodiversity features. Prioritisation project to explore both options.

Other habitats. Explore new or additional datasets to be extrapolated from large national datasets. Large brown algae. Coralline turfs and crusts. Rhodoliths.

Seabird distributions. Look into in more detail as multiple layers IBA, NABIS, eBird, global sightings, point records, banding. Lots of bird stuff is biased re bycatch data and showed biases of overlap with fisheries. Add new point records from regional council significant ecological areas. Seabird distributions – need to peel out roosting, feeding, nesting.

Seal breeding records. These have been recently updated. Cross check against regional council significant areas to make sure all are included.

Finfish spawning layer. Ian Tuck to double check (based on NABIS layers). Does not include juvenile areas, is based on expert knowledge and trawl samples. Can we add juvenile fish layers to this from AEBR report? Check if layers exist. Suggest to use summation map/hotspot layer of finfish spawning rather than individual polygons.

Marine reef fish. Surrogate for important rocky reef areas – to be explored in Habitat Classification project.

Migratory corridors. These are not defined for any species in NZ. Cetacean – none are explicitly defined. Cawthron – recent project, not yet completed. Lobster marches are anecdotal, not robust at national scale, DOC suggests to not include lobster migrations.

Freshwater fish. Explore anadromous/ catadromous/ diadromous species that would be good to include (due to marine life stage). Whitebait/eels typically included in regional council significance layers, could use NIWA freshwater point records to identify estuary mouths/rivers where these species occur (noting also that many are threatened species).

A.3.4 Importance for Threatened / Declining Species and Habitats

Definition: Area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.

Rationale: Protection may enable recovery or persistence of these threatened / declining species or habitats.

Examples provided by MSAG: Estuaries with populations of threatened shorebirds; foraging areas for marine mammals and seabirds

National threatened habitats. None of these are marine, though some are found adjacent to CMA. Also for some ‘known’ threatened habitats (e.g., green lip mussel reefs), the lack of marine habitat historical data (or lack thereof for baselines required to determine threshold to be considered nationally threatened) prevents most declining/threatened marine habitats from being included. Discussion of use of mātauranga to inform this, but outside scope of this project. Freshwater wetland marshes are included but does not appear to include coastal saltmarsh. Team to ask Helen Kettles what her new DOC estuary vegetation layers include.

Rare ecosystems. These areas are also land only but some potentially important for marine, e.g., saltmarsh, dunes, or for marine species. How far into foreshore do we go, e.g., for threatened bird roosting/nesting? Skinks? Project team to explore adding a metric of proximity to these, or clipping to coastline. How to include retracing/declining range/abundance that are only recently showing changes and won’t be in these national layers, e.g., the kelp *Durvillaea*.

Habitats - estuaries. Estuaries are not well represented in the KEA Stage 1 data, but are expected to be further explored in the habitat classification project.

Further discussion of threatened species that use terrestrial habitats. What is scope of threatened species? How can we represent terrestrial areas in Zonation, e.g., roosting/nesting/haul out areas inland for seabirds, shorebirds, marine mammals, skinks? Not sure if can be included at this stage but can come up with some ideas? Would be good to know which PAs are included on land as well as waterways.

Threatened species layers. Benthic invertebrates, fish have lots of unassessed species so layers may not be as robust as other threatened taxonomic groups that are comprehensively assessed (birds, mammals, reptiles). New macroalgae assessment/list to be provided by Kate/Wendy. Regardless these are point records and not spatially comprehensive, i.e., fish layers primarily from deeper research trawls so show bias toward 200m+ depths.

Seabirds. Can we make a guano layer? It is difficult to assess whether this would be useful with respect to other available seabird layers, but explore what we have in total for seabirds as well as fur seals, e.g., foraging, nesting, haul out, guano, etc. including areas (on land) that are important for threatened species. Lots of this detail is described in Regional council layers.

Cetacean layers (new). Use modelled layers and not just point records. Include all modelled layers (33 in total, with approx. a dozen being more robust BRT models, the rest being RES layers primarily for migratory/less common species. Suggest include all but down-weight the RES models that we don't think are resident.

Doublecheck Wildlife Act, iconic species database etc - make sure all species covered.

Doublecheck FAO criteria and inclusion of all FAO/VME taxonomic groups, e.g., criteria such as robust = slow growing.

A.3.5 Biological Productivity

Definition: Area containing species, populations or communities with comparatively higher natural Biological Productivity.

Rationale: These areas can support enhanced growth and reproduction, and support wider ecosystems.

Examples: Hydrothermal vents; frontal zones; areas of upwelling.

Discussion of underpinning question behind inclusion of this layer. Is goal primary, secondary or overall productivity? Productivity as supporting of biodiversity? Many of listed KEA layers are surrogates for biodiversity, e.g., sensitive environments, hydrothermal vents, cold seeps. Could keep it in biological criteria but maybe down-weight as feel uncomfortable not using it at all.

Primary productivity layer. Chlorophyll a used as surrogate. Inshore and offshore productivity – little confidence of expert group in coastal layer; offshore layer ok – however all are surface layers, not seafloor/whole of water column productivity. There isn't a single layer that will give productivity. Can use a few single measures to get an overview, Fabrice to follow up with Matt Pinkerton. Explore bentho-pelagic layer (Pinkerton) prototype used for climate change CCII project.

Areas of upwelling. Missing data for New Zealand on this. How do we identify where these areas are? They often come up with productivity anyway, as well as other measures already included so should be okay. Upwelling/fronts/eddies – gradient in zooplankton? Discuss with Matt P.

Ecosystem services productivity layers. Primary producer layers in NIWA EPA ecosystem services layers for the Hauraki Gulf, Drew Lohrer in process of updating these, but unlikely to be available in time, less confidence in the productivity compared to biogenic habitat layer. Team to confirm with Drew. Also note challenges identified in balancing macroalgae/mangrove/seagrass production with microphytobenthos and phytoplankton.

Freshwater inputs (but wary of sewage/land-use nutrients). There is CLUES output by river mouths, but no transport/direction once it reaches the ocean and is only land based.

Offshore islands with high nutrient transfer, see earlier conversation on guano.

Seabird or fish abundance as indicator of productivity. New demersal fish layers are occupancy layers and not abundance. Explore seabird – likely biases to fisheries hotspots with bycatch data providing most records.

How to incorporate concept of potential ramifications of 'lost productivity', e.g., *Durvillaea.*

A.3.6 Biological Diversity

Definition: Area contains comparatively higher diversity of ecosystems, habitats, communities or species, or has higher genetic diversity.

Rationale: These areas are important for evolutionary processes, for species' and ecosystem resilience and contribute towards large-scale biodiversity.

Examples provided by MSAG: Structurally complex communities such as deepwater sponge and coral communities; seamounts. Areas with high diversity of fish and invertebrate species.

Species richness layers. Available for benthic invertebrates, demersal fish, reef fish (to be updated?), cetaceans, macroalgae (to be completed in MSAG Habitat Classification project). Regional council important areas – explore adding point data for seabird/shorebird distributions.

Other aspects of diversity. Alpha, beta, and gamma diversity – species turnover can be calculated using beta diversity as heterogeneity, but need to think about scaling/area size. Beta diversity will be available for fish, invertebrates, macroalgae from habitat classification project.

Invertebrate species. New invertebrate beta diversity models ready early 2020, could also do individual habitat suitability/occurrence models for individual species or taxonomic groups.

Plankton/Pelagic groups. Most pelagic groups poorly covered by current KEA layers. Explore OBIS to see what information is available on mobile/pelagic groups. Habitat Classification project has discussed pelagic fish datasets. Ask Ho Chang (NIWA) re plankton.

Genetic, taxonomic distinctness. Will have to think about how to do this and whether there is time to do it. What about highly specious taxa in New Zealand, e.g., triplefins or some algal groups. Follow up to see if we can identify areas of particular adaptive radiation/speciose per genera/order. Phylogeny vs within species genetic diversity/adaptive potential. Probably too big of job to include, could be separate Zonation/Marxan analysis. Genetic breaks, metapopulation – there are some marine breaks identified – top west of South Island etc. If we could look at meta community stuff would be interesting for some of the layers. Dispersal barriers but seen as different to bioregions. Check out AraMoana project led by Massey, Libby Liggins – looking at all species, creating a genetic data standard for New Zealand.

A.3.7 Naturalness

Definition: 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: Provides enhanced ability to protect biodiversity that is in better condition; reduces need to rely on recovery from degraded state (recovery may occur on a different trajectory); these areas may include species and/or habitats that do not occur or are not represented well in more degraded areas; important role as reference sites

Examples: Remote areas; marine areas adjacent to protected terrestrial areas; areas not impacted by bottom trawling or invasive species.

Land use impacts. Neighbouring areas with differing land use including land protection, QEII covenants, national parks etc. Soil erosion Landcare layer. All explored under NIWA landuse impacts on MPA project. Exploratory analysis to extrapolate this analysis.

Fishing naturalness layer. New MPI project will do impact assessment looking at impact based on gear type etc. following the Roland Pitcher/CSIRO methodology, but won't be ready until end 2020. Add caveat to add at later date or in another project.

Recovery potential. Years since last trawled would be a good measure to have for this project. FNZ data will have inshore and offshore presented in new footprint. Considering adding this footprint layer. KEA project did compile trawl/dredge footprint/long lining. Layer would need regular updating based on new data. Explore.

Ship noise. Boat traffic. Shipping. Underwater noise. Oil and gas, infrastructure. Explore what exists that is comprehensive.

Invasive species. MBIE invasives project, MPI Biosecurity databases MITS records. Typically point records with port bias, not comprehensive. iNaturalist records of invasives? Marine farms and links with invasives/nutrients/shading/other impacts? Port/marina/boatramp from DOC Visitor Solutions as indicators of risk of invasive spread?

Submarine cables. Note these are also Type 2 marine protected areas. Layer exists, but unclear whether it is beneficial to biodiversity or a threat layer from cable impacts on seafloor.

Coastal hardening seawalls. Difficult layer to put together as inconsistent reporting by regions. Ask Graeme Inglis what is available.

A.3.8 Ecological Function

Definition: Area containing species or habitats that have comparatively higher contributions to supporting how ecosystems function.

Rationale: Some species, habitats or physical processes play particularly important roles in supporting how ecosystems function – their protection provides coincidental protection for a range of other species and wider ecosystem health

Examples: Soft sediment habitats containing high densities of bioturbators; areas of high functional trait diversity; areas with functionally important mesopelagic communities (including myctophids).

Hard concept to include spatially, possibly to incorporate later in optimisation?

<u>Myctophids as indicator of mesopelagic function</u>. Check if myctophids show up in Research Trawl demersal fish dataset. Explore creating myctophid layer using OBIS/fish dataset extractions.

<u>Keystone species</u>. Have these been identified and listed? DOC does not have a list/dataset for these though DOC matrix project lists some key species. Explore these though many are just species important for commercial, recreational, customary fishing. Most of others show up in sensitive habitats, threatened species etc.

<u>Marine reef fish</u>. They are listed in a few categories but might only be 3 or 4 species that are key drivers of the Ecological Function criteria from the whole group.

<u>Bioturbators</u>. Can group inverts into spatial representation of functional groups which may be useful. Team to follow up on using functional group approach sensu Lundquist et al. 2013 (AEBR) to cover bioturbators, filter feeders and other potential functional groups useful for key ecological functions.

<u>Habitats of value to fish</u>. AEBR 125 to be checked to see all are covered, anticipate high overlap with sensitive environments/biogenic habitats.

A.3.9 Ecological Services

Definition: Area containing diversity of ecosystem services; and/or areas of particular importance for ecosystem services.

Rationale: Provides for ability to protect species and habitats that provide particularly important services to humans. Provides ability to better contribute to CBD Aichi Target 11.

Examples: Areas containing dense populations of filter-feeding invertebrates; areas important for seafood provisioning. Areas important for supporting or regulating ecosystem services (e.g., areas of nutrient regeneration, biogenic habitat provision, carbon sequestration, sediment retention, gas balance, bioremediation of contaminants, storm protection) that underpin the delivery of provisioning or cultural ecosystem services.

Confirmation that KEA Stage 2 project is limited to biological ecosystem services only, not to include socioeconomic, cultural, other ecosystem services.

Useful for Aichi target 11 reporting on ecosystem services.

Discussion that there is a lot of overlap with over criteria being used as proxies or representing high ecosystem services delivery.

<u>Biogenic habitat provision</u>. High confidence modelled layer, but only coastal.

<u>Regional council important areas</u>. These are not systematic, individual polygon and point data only, typically not directly linked to ES but explore if any tick this criteria.

<u>Sensitive environments</u>. These layers come up in many other criteria, double count here and better suited elsewhere? Particular habitats that provide services, e.g., finfish spawning (better in life history, double count here?); biogenic mostly point/presence only records; mangrove/seagrass out

of date – replace with new DOC layers but could be useful for carbon sequestration. Large brown algae dataset also fits here in service delivery (productivity, habitat etc.).

Marine mammal and reptile sightings. Query as to why this was listed here in original KEA report – should we be considering only regulating/supporting services w.r.t. biodiversity vs provisioning, economic, societal, cultural services. Could be considered as 'biodiversity' value but then double count with the Biological Diversity criteria. Do not include in this category.

Carbon sequestration. Explore ways to do this as it is getting a lot of attention. Check INVEST (Stanford Uni Natural Capital Project) and UoA mangrove carbon student theses.

DOC Matrix approach. The report suggested list of habitats/species associated with particular ES delivery. Better if habitat map; only small number of these have complete spatial layers (e.g., most biogenic = point data). Explore Matrix list and see if all are covered, and cross checked with ES and other criteria.

Offshore Ecosystem Services layers as per UoA MSc by Luca Mori et al. Check which ES he quantified, and what further is required for this approach to be robust as work is not yet published but could be further explored to fill these offshore gaps through modelled layers based on EPA approach.

Discussion on quality (e.g., pollution, sewage leading to nutrient provision), and minimum threshold of habitat/species required to provide an ES, and challenges in interpreting service delivery with KEA data layers.

A.4 Priorities identified for initial exploration

Regional council significant ecological areas likely to apply across all KEA criteria. Priority.

Vulnerability, Fragility, Sensitivity or Slow Recovery

- Seagrass and mangrove (and saltmarsh?) layers from DOC estuaries dataset.
- New VME layers (DOC project to NIWA). Priority, but not available until 2020.
- New macroalgae layers. Available in 2020 from MSAG Habitat Classification project/layers.
- Project team to explore other vulnerable habitats that may be available now since publication of the MfE report, such as rhodolith maps, coralline algae maps – crusts and turfs, algal meadows. Also to explore if data available from SPECIFY/OBIS to create layers for tube worms, coralline lattices, *Galeolaria* beds.

Uniqueness / Rarity / Endemism

- Demersal fish and benthic invertebrates. Turnover metrics of dissimilarity to indicate particularly unique classes. Available in 2020 from MSAG Habitat Classification project/layers.
- Seamount datasets from Ash/Malcolm and Tiff (MPI).
- Naturally rare taxa. Explore but likely low priority to include the naturally rare species from NZTCS.

Special Importance for Life History Stages

- Regional council and other sensitive habitats as per above criteria.
- Seabird distributions. Explore how best to us multiple layers IBA, NABIS, eBird, global sightings, point records, banding. Add new point records from regional council significant ecological areas. Provide as individual layers of roosting, feeding, nesting.
- Seal breeding records. Cross check against regional council significant areas to make sure all are included.
- Finfish spawning layer. Ian Tuck to double check (based on NABIS layers). Does not include juvenile areas, is based on expert knowledge and trawl samples. MPI/Karen – can we add juveniles to this, or what data available in AEBR on juvenile fish.
- Marine reef fish. Surrogate for important rocky reef areas – to be explored in Habitat Classification project.
- Freshwater fish. Contact NIWA freshwater fish team to see what point records available to identify estuary mouths/rivers where these species occur.

Importance for Threatened / Declining Species and Habitats

- Threatened taxa. New macroalgal list of threatened taxa, and possibly new invertebrate NZTCS. Extrapolate point records from national databases.
- Terrestrial habitats. Explore metric for including land habitats used by marine species.
- Declining habitats. Explore what temporal records are available for kelp species with anecdotal evidence of retracting range.
- Estuaries. To be further explored in the MSAG habitat classification project.
- Seabirds. Collate multiple datasets as per life history criteria.
- Doublecheck Wildlife Act, Shark – Malcolm Francis, Wildlife Act, Iconic spp. to make sure all are covered.
- Doublecheck FAO criteria to make sure all criteria/taxa covered.

Biological Productivity

- Productivity layers and proxies such as upwelling. Explore bentho-pelagic layer (Pinkerton) prototype used for climate change CCII project.
- Ecosystem services productivity layers. Check status with Drew Lohrer.

Biological Diversity

- Species richness layers. Benthic invertebrates, demersal fish, reef fish, cetaceans, macroalgae to be completed/updated in MSAG Habitat Classification project.
- Regional council important areas. Explore adding point data for seabird/shorebird distributions.

- Invertebrate species. New invertebrate beta diversity models ready early 2020, could also do individual habitat suitability/occurrence models for individual species or taxonomic groups.
- Plankton/Pelagic groups. Most pelagic groups poorly covered by current KEA layers. Explore OBIS to see what information is available on mobile/pelagic groups. Ask Ho Chang (NIWA) re plankton dataset availability.
- Genetic, taxonomic distinctness. Explore if we can identify areas of particular adaptive radiation/phylogenetic diversity and of within species genetic diversity/adaptive potential. Check out IraMoana project led by Massey, Libby Liggins.

Naturalness

- Land use impacts from MPA Land-use project. Includes soil erosion, nutrients, population size, catchment land cover, proximity to land based protected areas.
- Fishing naturalness layer. From new MPI project, add at later date.
- Recovery potential. Years since last trawled.
- Ship noise. Boat traffic. Shipping. Underwater noise. Oil and gas, infrastructure. Explore what exists that is comprehensive.
- Invasive species. Explore what is available in MITS, other databases.
- Coastal hardening seawalls. Ask Graeme Inglis what is available.

Ecological Function

- Explore creating myctophid layer using OBIS/fish dataset extractions.
- DOC Matrix species/habitats – double check all included in KEA criteria.
- Use functional group approach to create bioturbators, filter feeders and other potential functional groups useful for key ecological functions.
- Habitats of value to fish. AEBR 125 to be checked to see all are covered, anticipate high overlap with sensitive environments/biogenic habitats.

Ecological Services

- Carbon sequestration. Explore use of InVEST model and NZ university theses.
- DOC Matrix. Check report of habitat/species associated with particular ES delivery to see if all are covered in KEA criteria.
- Explore EPA approach to offshore Ecosystem Services layers as per UoA MSc by Luca Mori et al. Check which ES he quantified, and what further is required for this approach to be robust as work is not yet published but could be further explored to fill these offshore gaps through modelled layers based on EPA approach.

Other discussions

- Build in redundancy value for uncertainty in lack of sampling areas.
- Get 'no data' areas the blunt way using OBIS no data to create a layer of gaps or create other layer to indicate data limitation uncertainty sensu Stephenson cetacean paper.
- New intertidal boundary layer (LINZ) – business case now, but years(?) until completed/updated.

A.5 Optimisation project discussion

Datasets to prepare for Zonation analysis:

Confirmed Albers Equal Area projection, raster format *.tif files suitable for Zonation data input layers.

Species richness and individual species layers available (demersal fish, reef fish, invertebrates, cetaceans, bryozoans, VME taxa).

Species of conservation concern – what additional layers only available as point data that need to be included.

Potential types of scenarios:

Marine Reserves (type 1, type 2), Seabed reserves, species sanctuaries – megafauna.

Compare common areas between layers, if covered by seabed then don't need to include somewhere else.

Compare scenarios with KEA [cumulative] criteria layers vs individual biodiversity features.

Compare scenarios with different types of biodiversity features.