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Mapping the Values of New Zealand's Coastal Waters. 4. A Meta-analysis of Environmental Values.

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Abstract

Previous work by Beaumont *et al.* (2008) generated a spatially explicit database of marine environmental value of the New Zealand coastline. This database comprised 14 attributes of marine environmental value derived from 200 unique layers of environmental information ranging from species occurrences and diversity indices to marine mammal breeding areas and habitat distribution.

The present study is a meta-analysis of the outputs from Beaumont *et al.* (2008). Using a ranking system to ensure data initially valued over different ranges could be meaningfully compared, 29 summary maps were created. These identify the overall trends in the spatial distributions of the attribute values for each dataset and identify areas of coincidence among high-value attributes of the indigenous coastal marine environment.

Many coincident hotspots of biological and habitat diversity have been identified within this meta-analysis. The east coast of Northland, the Kaipara Harbour, southwest Fiordland, Stewart Island and the Chatham Islands all stand out as being particularly diverse with respect to both habitat and biological diversity.

It should be noted that this meta-analysis is only as accurate as the available data and care should be taken when consulting these summary maps.

Key words:

Measures of environmental value
Spatially-explicit database
Coastal, shelf and estuarine habitats
Diversity indices
Habitat distributions

1 Introduction

New Zealand's coastal environment is inhabited by an estimated 65,000 species, many of which are unique to New Zealand making it a hotspot for marine diversity worldwide (Arnold 2004; MacDiarmid 2007; Gordon in press). These species and their associated ecosystems deliver a wide range of environmental services to New Zealand including the basic productivity that sustains considerable fishing, aquaculture and tourism industries.

In 2008 NIWA carried out a study (Environmental Value Mapping project) to assess the perceived value of New Zealand's coastal marine environment for MAFBNZ as part of a wider project to assess the social, economic, cultural and environmental values of the New Zealand coastal area (Beaumont et al. 2008). This resulted in a spatially explicit database comprising Geographic Information System (GIS) layers representing eight subcomponents, in which a total of 14 attributes of marine environmental value were presented. Information included in the database ranged from species occurrences and diversity indices to habitat distributions and marine mammal breeding areas. The 26 datasets and their associated attribute values comprise approximately 200 unique GIS layers.

In response to a MAFBNZ request, a meta-analysis of these data has been undertaken. The aims of the present study were to summarise the spatial distribution of attribute values and to determine areas of coincidence among high-value attributes.

1.1 OVERALL OBJECTIVE

To determine the perceived environmental values of New Zealand's marine environment.

1.2 SPECIFIC OBJECTIVES

- Summarise the overall trends in the spatial distributions of the attribute values for each dataset.
- Undertake a GIS analysis identifying areas of coincidence among high-value attributes.

2 Methods

2.1 STUDY AREA

The study area included the entire coastline and estuarine region of New Zealand (the North, South, Stewart and outlying islands) as well as the Three Kings, Kermadec, Chatham and sub-Antarctic Islands. The marine habitats most likely to be impacted by incursion events and therefore of interest to BNZ were the coastal and shelf systems. As a result, the outer limit of the study area was 12 nm offshore or a depth of 250 m to include all the relevant coastal and shelf areas.

In order to map the measures of marine environmental value around New Zealand it was necessary to divide this area into smaller units (Beaumont *et al.* 2008). The study area was

initially divided into 300 roughly equal “coastal cells”. However, the taxon-specific datasets used in this study had very patchy distributions and as a result many coastal cells had few or no records associated with them. In data-sparse parts of the coastline it was therefore necessary to join neighbouring coastal cells together into "coastal areas" to enable analyses on these datasets to take place (Beaumont *et al.* 2008). In this way all coastal cells could have a value assigned to them.

2.2 SUBCOMPONENT AND DATASET SELECTION

Five subcomponents and 21 datasets were chosen for use in the meta-analysis (Table 1). The subcomponents, data sources and methodologies used to derive the values mapped within each subcomponent are described in detail in Beaumont *et al*. (2008).

Table 1 Subcomponents used in the meta-analysis and their associated data sources, data owners, data type and the values mapped

Environmental value subcomponent	Data sources within each subcomponent	Data owners	Data type	Values mapped for each dataset
Taxon-Specific Diversity	1 Sponge dataset	NIWA	Numerical presence	Total species
	2 Bryozoan dataset (OBIS)	NIWA	Numerical presence	Species richness
	3 Polychaete dataset (OBIS)	NWIA	Numerical presence	Average Taxonomic
	4 Mollusc dataset	Te Papa	Numerical presence	Distinctness (ATD)
	5 Echinoderm dataset (OBIS)	NIWA	Numerical presence	Variation in ATD
	6 Arthropod dataset (OBIS)	NIWA	Numerical presence	Species rarity
	7 Algal database (KEmu)	Te Papa	Numerical presence	Species composition
	8 Diadromous fish dataset (FBIS)	NIWA	Predicted probability of catch	
	9 OSNZ Wader bird counts	OSNZ	Raw counts	
	10 Rocky reef fish dataset	DoC	Numerical counts	Species richness
At risk or threatened species	11 NZ Threat Classification system	DoC	Presence and absence / threat category	Species distributions
Habitat area within NZ region	12 Intertidal rocky reef	LINZ	Shapefiles	Habitat distributions (using normalised and non-normalised data) Proportion of habitat with each coastal cell
	13 Subtidal rocky reef	DoC	Shapefiles	
	14 Seagrass data	NIWA	Expert knowledge	
	15 Mangrove data	NIWA	Shapefiles	
	16 Biogenic reefs dataset	WWF	TIF files	
	17 MEC Physical habitat categories	NIWA	Shapefiles	
	18Derived value: habitat diversity		Ratio	Derived value (ratio of cell length and coastline length)
Primary Productivity	19 MEC V2 (chlorophyll data)	NIWA	Shapefiles	Mean concentrations
Marine Mammal Distribution	20 Te Ara/NABIS bird and mammal distribution data	Te Ara	TIF files	Distribution maps
	21 Incidental cetacean sighting	Martin Cawthorn	Numerical presence	

Abbreviations used: National Institute of Water and Atmospheric Research (NIWA), Ornithological Society of New Zealand (OSNZ), Ministry for Culture and Heritage (Te Ara), Museum of New Zealand (Te Papa), Department of Conservation (DoC), Biosecurity New Zealand (BNZ), Land Information New Zealand (LINZ), World Wildlife Fund New Zealand (WWF), Ministry of Fisheries (MFISH), Ocean Biogeographic Information System (OBIS), Freshwater Biodata Information System (FBIS), Marnie Biodiversity and Biosecurity Database (BIODS), Te Papa’s database system (KEmu).

2.2.1 Datasets not included in the meta-analysis

2.2.1.1 Overall biodiversity

With the exception of the rocky reef fish dataset, the overall biodiversity data were not used in this meta-analysis. This was to avoid double counting as many of the taxa modelled in the

rocky reef invertebrate and vertical rocky wall communities datasets were represented within the taxon-specific datasets. Raw data from taxon-specific datasets were used in preference to the modelled data (e.g. rocky reef invertebrate data) because the modelled data have not yet been ground-truthed for reliability. It was therefore assumed that raw data would be the more reliable of the two datasets for the purpose of creating summary maps.

2.2.1.2 Non-indigenous species

Many non-indigenous species are known to be present around the New Zealand coastline, however, comprehensive data on the distribution of these species were only available for the major ports around the NZ coastline (Beaumont *et al.* 2008). To use such patchy data would introduce a bias into the meta-analysis. In addition, it is the potential effect of these species on the environmental "values" at each locality that is of ultimate interest to MAFBNZ. To include these data in the meta-analysis would obscure the underlying value of New Zealand's indigenous coastal marine ecosystem.

2.2.1.3 Area of MPAs, sanctuaries and restrictions

These datasets have already been summarised in Beaumont *et al.* (2008). These summary maps should be used alongside this meta-analysis to give information on area restrictions and the presence of sanctuaries and MPAs for areas of interest along the New Zealand coastline.

2.3 SUMMARY MAPS

In order to be able to compare and summarise datasets with great differences in assigned values and scales, a ranking system was used. For each dataset, attribute values in all cells and coastal areas were assigned a rank of 0 to 10, using automated IF functions within Microsoft excel spreadsheets. A rank of zero was assigned for cells with zero values, a rank of one for cells with the lowest 10% of positive values, while a rank of ten was assigned to values in the top 10% of the range, with intermediate values in between (i.e. values were broken down into deciles for rank value assignments). This ranking procedure gave all datasets equal representation to enable summary maps to be created from mean values across all attributes for each dataset or subcomponent.

Summary maps created using the datasets detailed in Table 1 are outlined in Table 2. First-stage summary maps combine all the information available for each dataset (e.g. total species, species richness, ATD, variation in ATD, species rarity and species composition for the taxon-specific diversity data). Information in these first-stage summary maps was combined within each subcomponent to create second-stage summary maps. These second-stage summary maps were combined to create third-stage summary maps of all biological data and all habitat data. A final-stage summary map was created to combine both biological and habitat data.

Table 2 Summary maps created within the scope of this report

Environmental value subcomponent	First-stage summary maps	Second-stage summary maps	Third-stage summary maps	Final-stage summary map
Taxon-specific Diversity	1) Summary: Sponges 2) Summary: Bryozoan 3) Summary: Polychaetes 4) Summary: Molluscs 5) Summary: Echinoderms 6) Summary: Arthropods 7) Summary: Algae 8) Summary: Wading birds 9) Summary: Diadromous fish 10) Summary: Rocky reef fish	24) Total taxon-specific diversity (maps 1-10)	27) Combined biological data map: Summary of biological data including taxon-specific diversity, at risk or threatened species and marine mammals (maps 1-15)	29) Overall summary map: All data – biological and habitat (maps 1-23).
At risk or Threatened species	11) Threatened Species: Invertebrates 12) Threatened Species: Birds	25) Total threatened species (maps 11-12)		
Marine Mammals	13) Summary: Total dolphins 14) Summary: Total whales 15) Summary: Total seals	26) Total marine mammals (maps 13-15)		
Habitat within New Zealand	16) Habitat: Intertidal reefs 17) Habitat: Subtidal reefs 18) Habitat: Biogenic reefs 19) Habitat: Seagrass 20) Habitat: Mangroves 21) Habitat: MEC physical categories 22) Habitat: Diversity		28) Combined habitat data map: Summary of habitat data including the 5 discreet habitats, the MEC physical categories, habitat diversity and primary productivity (maps 16-23)	
Primary Productivity	23) Primary productivity			

2.4 VALUATION METHODS FOR BIOLOGICAL DATA

2.4.1 Taxon-specific diversity

These datasets are discussed in detail in Beaumont *et al.* (2008). The taxon-specific datasets comprise: 1) Sponges, 2) Bryozoa, 3) Polychaetes, 4) Molluscs, 5) Echinoderms, 6) Arthropods, 7) Algae, 8) Diadromous fish and 9) Wading birds. The only overall diversity dataset included this analysis is dataset 10) Rocky reef fish.

First-stage summary maps were initially made for each dataset by ranking each attribute of environmental value from 0 to 10 and calculating a mean value for each coastal cell. All attributes are described in detail in Beaumont *et al*. (2008). A second-stage summary layer was then created by taking a mean value of each of the ten datasets for each coastal cell.

It is important to note that where data were not available, coastal cells were joined together into coastal areas and a value was estimated for cells without records. These summary maps should be used in conjunction with maps of total records and coastal areas to better understand where assumptions have been made.

The following attributes were used in the meta-analysis for the nine taxon-specific diversity datasets:

2.4.1.1 Species richness

Species richness is a measure of the number of species present within a defined area. Species richness is sampling-effort dependent (e.g. Ugland *et al.* 2003; Colwell *et al.* 2004; Beaumont *et al.* 2008). In order to assign a meaningful estimate of species richness to each coastal cell it was necessary to take into account the great variation in sampling density between cells. EstimateS software (Colwell 2006) was used to create individual-based Coleman's rarefaction curves for datasets 1 to 7.

The value represented in the data layer is, therefore, not an actual value of species richness, but a value representing the difference in species discovery rate to that expected from the rarefaction curve (for all of New Zealand). A positive value indicates a cell or coastal area with a higher than expected species discovery rate and a negative value indicates a cell with a lower than expected value. A zero value indicates an "as expected" species discovery rate.

The ranking system assigned to species richness (discovery rate) in the meta-analysis gave a rank of "5" for a "zero" or "as expected" species richness with higher ranks (up to 10) for positive values and low ranks (1 to 4) for negative values.

2.4.1.2 Average Taxonomic Distinctness (ATD)

ATD is a measure of the relatedness of the species within a sample. ATD was calculated on the relatedness of species using taxonomic information from Order to Species (or Order to Genus in the case of polychaetes) using the multivariate software package PRIMER (Clarke and Warwick 2001a).

Values of ATD for each coastal cell or coastal area were ranked between 0 to 10. A high ATD value was assigned a rank of 10 and a low ATD value was assigned a rank of 0.

2.4.1.3 Variation in ATD (VarATD)

This is a measure of the variance in the pairwise path lengths used to calculate ATD (Clarke and Warwick 2001b) and reflects the unevenness of the taxonomic tree within a sample or, in this case, within a coastal area.

As for ATD, values of Variation in ATD were ranked from 0 to 10 with 10 assigned to high values of VarATD.

2.4.1.4 Species rarity

Rarity, in terms of distribution, was assessed for all taxon-specific datasets (except dataset 8; see below) in order to highlight coastal cells or areas around New Zealand that are particularly important with respect to rare species (in terms of distribution) of each taxonomic group. A rare species for the mapping environmental study was defined as a species that occurs in just one coastal area around the New Zealand coastline (Beaumont *et al.* 2008).

Rarity was presented as both a raw value and normalised by the proportion of the total number of records in each coastal area. The non-normalised value was used for meta-analysis.

As for ATD and VarATD attributes, rarity was ranked on a scale of 0 to 10, with 10 assigned to cells with a high number of rare species and 0 for cells with no rare species.

2.4.1.5 Species composition

Species composition is a measure of the similarity of biological communities, calculated using PRIMER software (Beaumont *et al.* 2008). This measure enables the identification of those cells or areas around New Zealand with unusual or unique species compositions.

A high mean resemblance value represents a coastal area that is very similar to many other coastal areas in terms of species composition. Conversely, the smaller the mean resemblance value the more distinct the species composition. As such, species composition was ranked from 0 to 10, with 10 assigned to cells with a distinct species composition (i.e. a low mean resemblance value), and cells with a common species composition (i.e. a high mean resemblance value) assigned a lower rank. This ensured that those coastal cells or areas with unusual or unique species compositions are ranked highly.

2.4.2 Overall diversity datasets (rocky reef fish data (dataset 10))

The model outputs within this dataset were presented as mean species richness per coastal cell based on a 1 km x 1 km grid (Smith 2008). For the meta-analysis, these mean values were ranked from 0 to 10 with 10 assigned to cells with a high mean species richness and a low rank assigned to a low species richness.

2.4.3 At risk or threatened species

Information on the distribution of at risk and threatened species around the New Zealand coastline was sourced from the New Zealand Department of Conservation's Threat Classification System (dataset 15), and from data held jointly by the Ministry for Culture and Heritage (Te Ara) and the Ministry of Fisheries (dataset 16). These data include all the information currently held on the distribution of the nationally critical, nationally endangered or nationally vulnerable species.

Values of the number of species or the presence (or area) of a taxon/species within a cell were ranked from 0 to 10. A rank of zero was assigned to those cells where the taxon/species was not known to be present. A rank of 10 was assigned to those cells which contained high numbers or a large proportion of the area that a species/taxon was known to inhabit. Summary maps were created to show:

- the number of threatened species of invertebrate per cell or coastal area (first-stage);
- the number of threatened species of birds per cell or coastal area (first-stage);
- the number of invertebrate and birds for cell or coastal areas (second-stage).

2.4.4 Marine mammals

Information on the distributions of marine mammals (whales, dolphins and pinnipeds) was sourced from the Ministry of Culture and Heritage (Te Ara; dataset 16) and incidental cetacean sighting data (dataset 25).

These two sources of data were combined to create summary maps of marine mammal distribution. In order not to double count, the incidental cetacean sightings data (dataset 25) were used as the main dataset. The Te Ara dataset (dataset 16) was used to indicate species presence in coastal cells not covered by sightings data or for species that were not included in dataset 25. Where the Te Ara data were included, the 100% range of the species was used.

First-stage summary maps were created using presence/absence data for each species in each coastal cell to show the total distribution of whales, the total distribution of dolphins, the total distribution of seals and a second-stage summary map to show the total distribution of all cetaceans for which data were available.

2.5 VALUATION METHODS FOR HABITAT AREA WITHIN NZ REGION DATASETS

A mean value of all the habitat types, including the number of Marine Environmental Classification (MEC) categories, habitat diversity proxy and primary production for each cell was calculated to create a first-stage summary map to highlight important cells with respect to

these habitat types around the New Zealand coastline. The ranking system used for each data type is described below. These data were combined to create a third-stage summary map for habitat distribution.

2.5.1 Habitat distribution

Five habitat distribution datasets were available within this subcomponent: 17) Intertidal rocky reefs, 18) Subtidal rocky reefs, 19) Seagrass beds, 20) Mangroves, 21) Biogenic reefs. Data were available as the proportion of the New Zealand total shelf area of each habitat within each coastal cell. These data were ranked from 0 to 10 for each cell. A zero value indicates that habitat was not present and a rank of 10 was assigned to those cells with the greatest area of that habitat within New Zealand.

2.5.2 Marine Environmental Classification (MEC) physical habitat categories

The number of physical habitat categories, as described by the MEC, was calculated for each coastal cell around New Zealand. This value (number of physical habitats) was ranked from 0 to 10, with a rank of 10 assigned to those cells with the highest number of habitat categories.

2.5.3 Derived value: Habitat diversity index

This derived value is a ratio of straight-line distance between intersection points of coastline and coastal cell boundary versus the actual length of the coastline within each coastal cell. This value was used as a proxy for habitat diversity and was ranked from 0 to 10. A rank of 10 was assigned to those cells with a low ratio (a high inferred habitat diversity – i.e. complex coastlines) and a low value was assigned to those cells with a high ratio (a low inferred habitat diversity – i.e. straight coastlines).

2.5.4 Primary production dataset

Primary productivity was derived from MEC chlorophyll data (dataset 23), in which mean annual near-surface chlorophyll-*a* concentrations were generated from satellite imagery. Chlorophyll-*a* concentration is a good proxy for local levels of primary production that drives the food chain.

These data were also ranked 0 to 10 for each coastal cell, with a high rank (10) assigned to those cells with a high mean annual near-surface chlorophyll-*a* concentration and a low rank for those cells with low concentrations.

3 Results

3.1 FIRST-STAGE SUMMARY MAPS: BIOLOGICAL DATA

3.1.1 Taxon-specific diversity

Data layers representing ecological indices and the number of species were combined in order to give a measure of diversity for each dataset. It is important to note that where data were not available, coastal cells were joined together into coastal areas to enable a value to be estimated for cells without records. These summary maps should be used in conjunction with maps of total records and coastal areas to better understand where assumptions have been made.

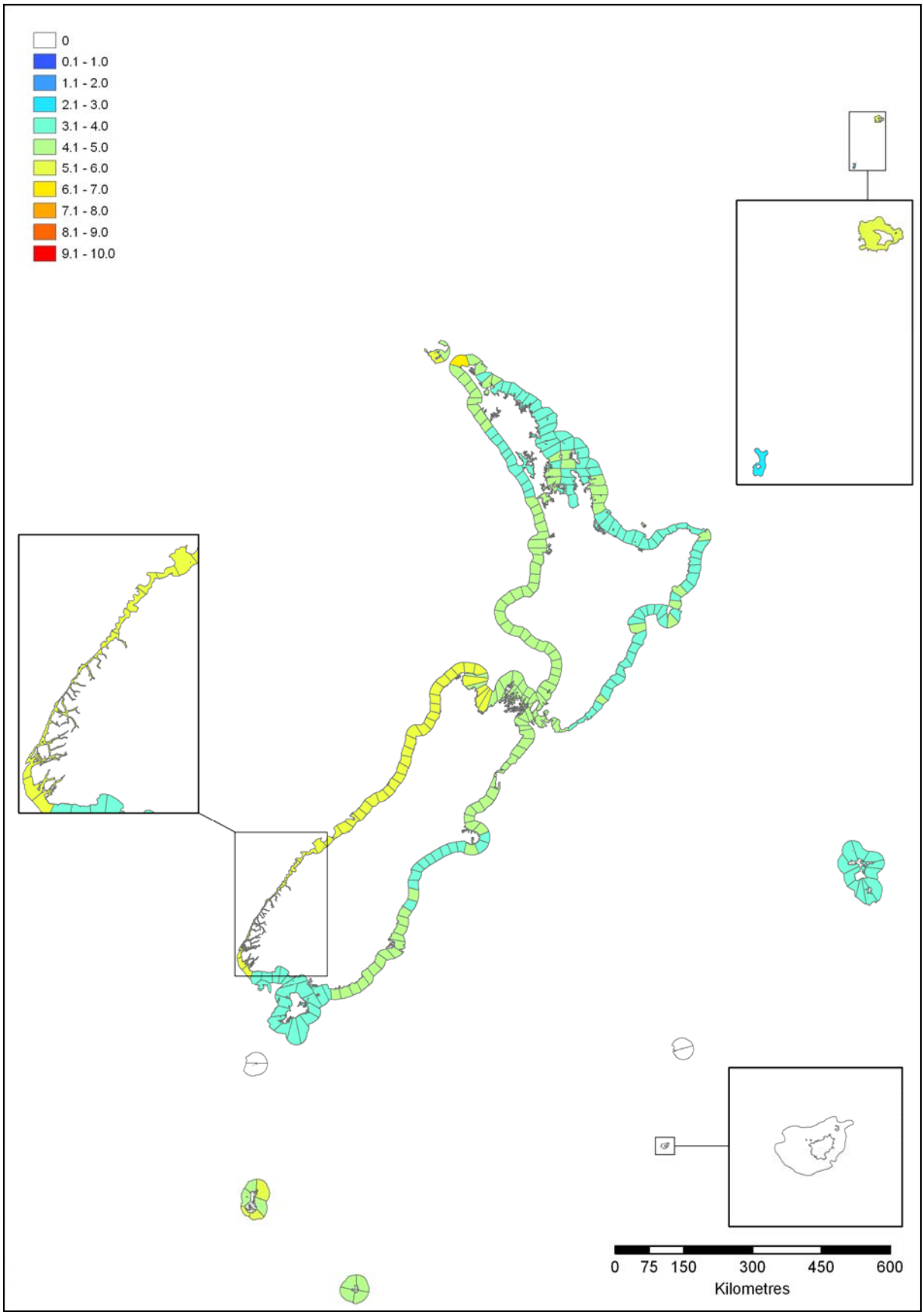
3.1.1.1 Sponge

Six attributes of sponge diversity were summarised: Total species, Species richness, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species Composition (Figure 1). These data were generated from approximately 3,100 raw data records.

The northern tip of New Zealand, between Cape Reinga and North Cape, had the highest mean rank of all the cells around New Zealand and is, therefore, potentially an important area for sponge diversity (Figure 1). Other important areas are the west coast of the South Island from Nelson to Fiordland inclusive and the Kermadec, Three Kings and Auckland Islands.

Data were not available for the Snares, Bounty and Antipodes Islands.

Figure 1 First-stage summary map: Taxon-specific diversity: Sponges. Mean rank of six biological attributes.



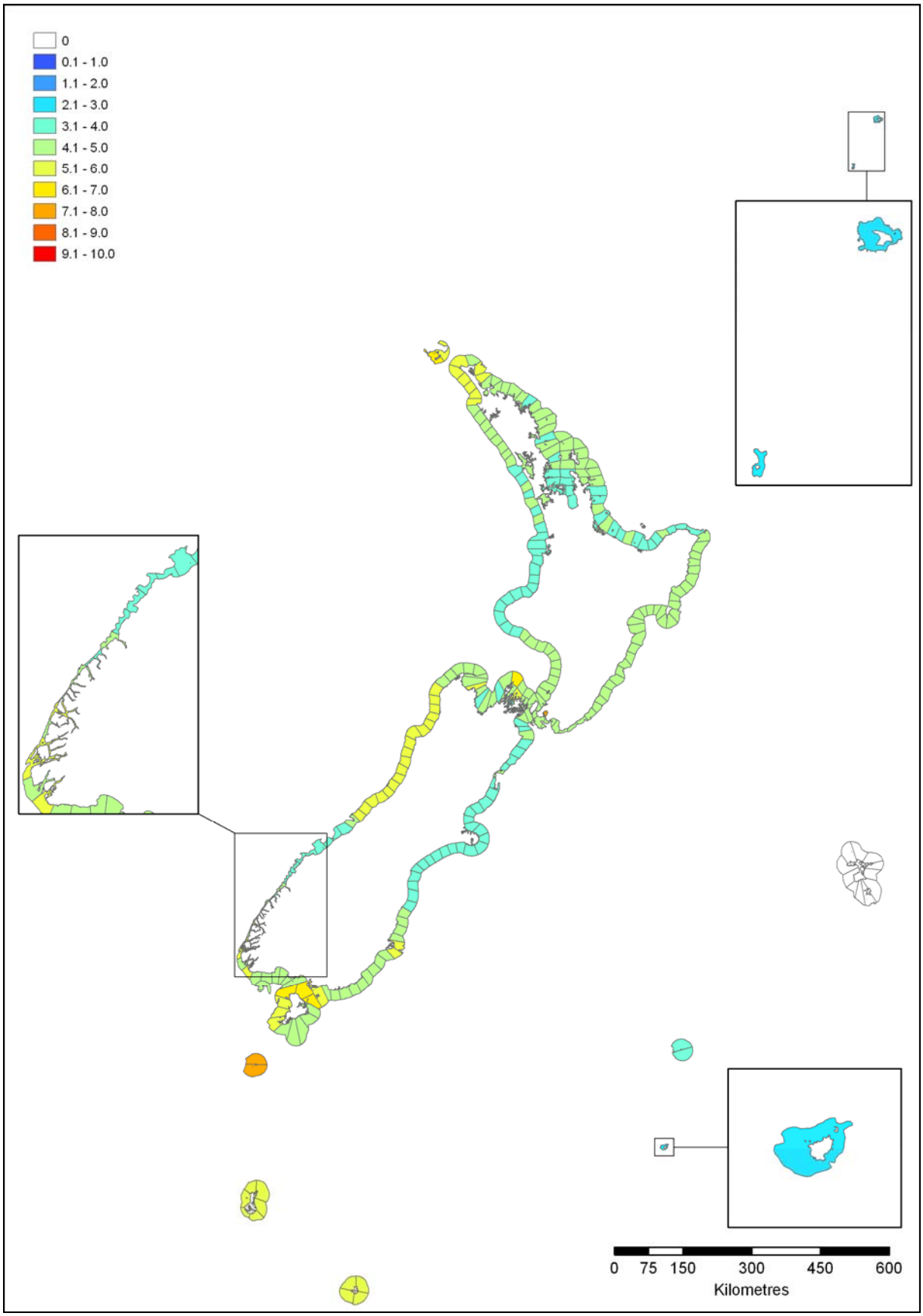
3.1.1.2 Bryozoans

Six attributes of bryozoan diversity were summarised: Total species, Species richness, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species Composition (Figure 2). These data were generated from approximately 4,500 raw data records.

Snares Island had the highest rank of all the coastal cells around New Zealand, showing this to be the most important area for bryozoans from the available data. The Three King Islands, Cape Stevenson in Marlborough Sounds and Foveaux Strait were also highly ranked. The west coast of the South Island from Westport to Gillespies Point and the northern tip of the North Island also have relatively high ranks.

Data were not available at the Chatham Islands.

Figure 2 First-stage summary map: Taxon-specific diversity: Bryozoans. Mean rank of six biological attributes.



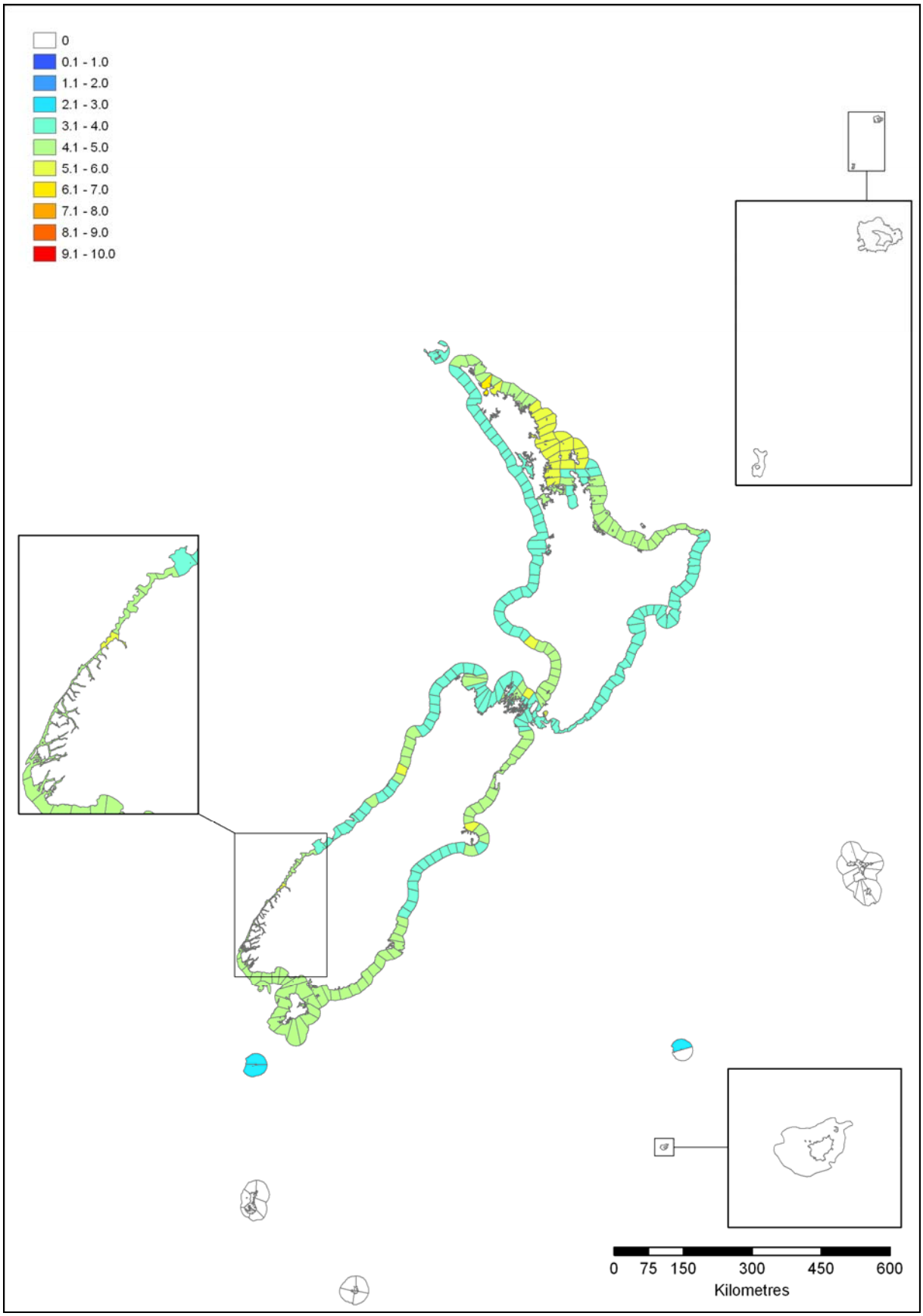
3.1.1.3 Polychaetes

Six attributes of polychaete diversity were summarised: Total species, Species richness, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species Composition (Figure 3). These data were generated from approximately 3,900 raw data records.

Ragnaunu Harbour, on the northeast coast of Northland, is highlighted as being interesting with respect to polychaete diversity. Other apparently important areas include the Hauraki Gulf up to Cape Brett, southern Taranaki, Marlborough Sounds, northern Bank Peninsula and Greymouth. The Snares and Bounty Islands have a particularly low rank.

Data were not available for Kermadec, Chatham, Auckland, Campbell and Antipodes Islands.

Figure 3 First-stage summary map: Taxon-specific diversity: Polychaetes. Mean rank of six biological attributes.

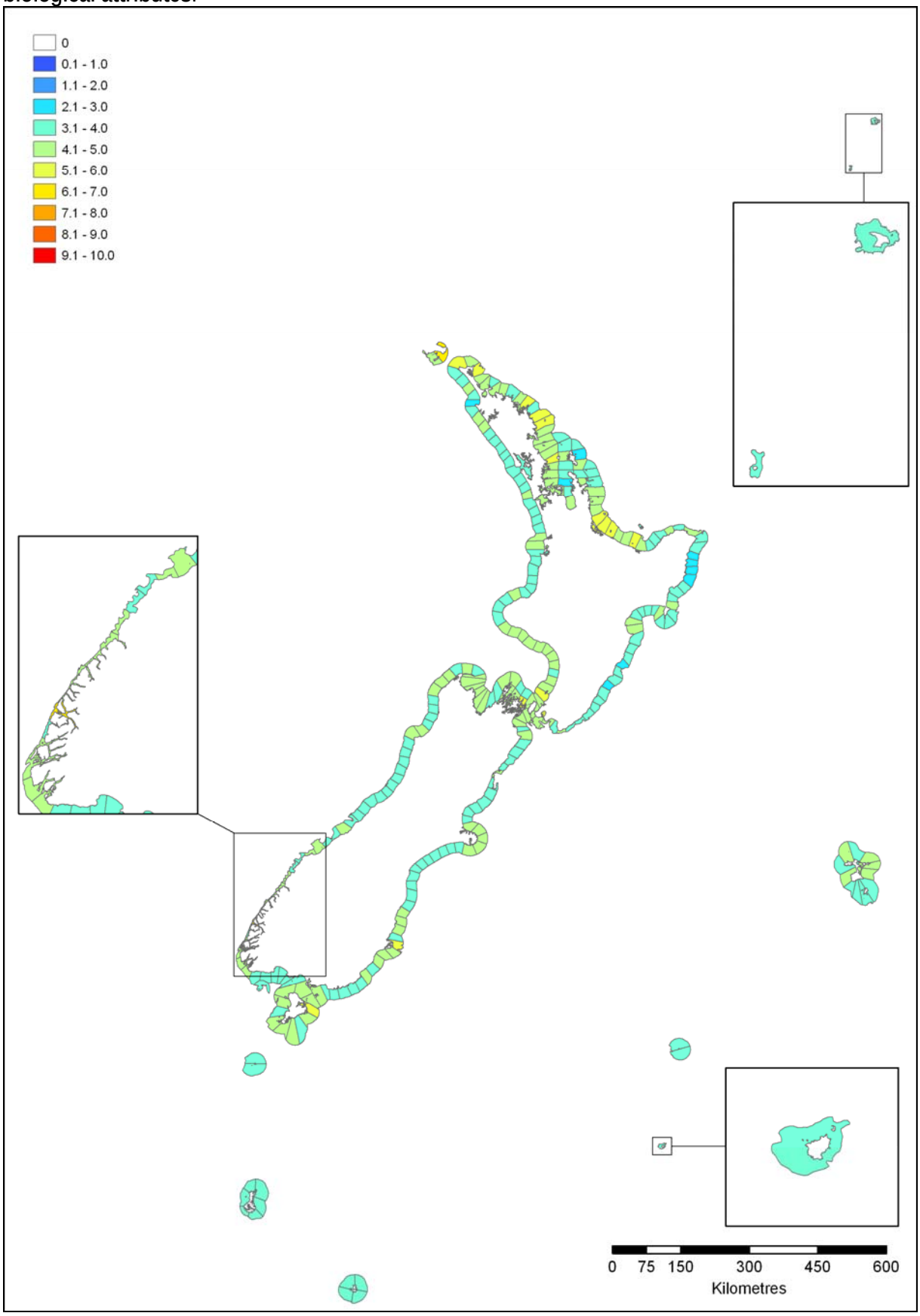


3.1.1.4 Molluscs

Six attributes of mollusc diversity were summarised: Total species, Species richness, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species Composition (Figure 4). These data were generated from approximately 34,600 raw data records.

The Three Kings Islands and many areas along the east coast of Northland stand out as potentially important areas with respect to mollusc diversity, as do the Otago Peninsula, eastern Stewart Island and central Fiordland. The east coast of the North Island appears to be ranked below most of the rest of New Zealand.

Figure 4 First-stage summary map: Taxon-specific diversity: Molluscs. Mean rank of six biological attributes.



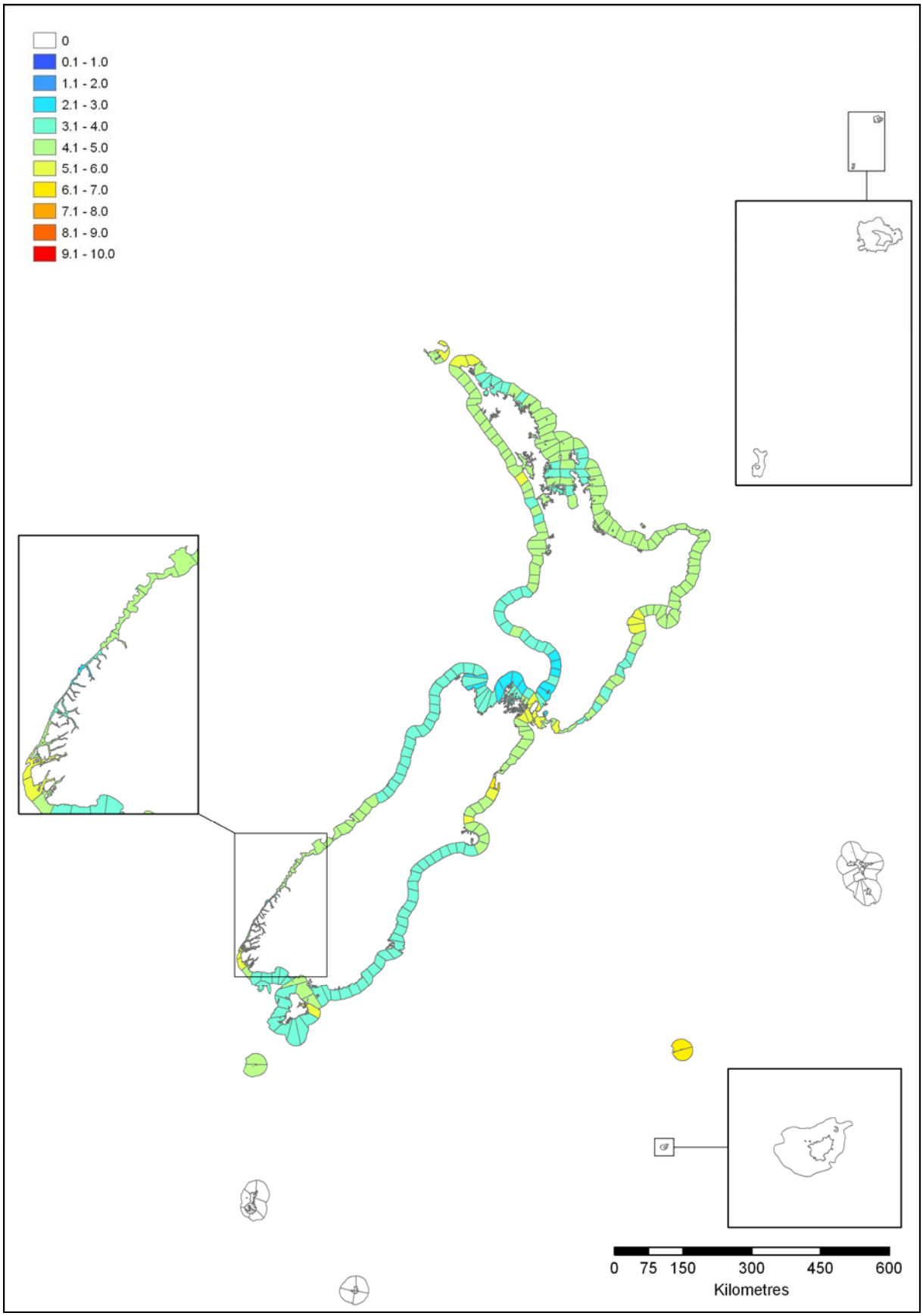
3.1.1.5 Echinoderms

Six attributes of echinoderm diversity were summarised: Total species, Species richness, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species Composition (Figure 5). These data were generated from 1,733 raw data records.

The Kaikoura Peninsula and Bounty Islands are highlighted as having the highest ranked values around New Zealand, closely followed by the Three Kings, Cape Reinga to North Cape area, southern Kaipara Harbour, Hawke Bay, Cook Strait, north of the Banks Peninsula, eastern Stewart Island, and southern Fiordland. The Nelson area, Marlborough Sounds and Kapiti coast appear to be particularly poor with respect to echinoderm diversity.

Data were not available for Auckland, Campbell, Antipodes, Chatham and Kermadec Island.

Figure 5 First-stage summary map: Taxon-specific diversity: Echinoderms. Mean rank of six biological attributes.



3.1.1.6 Arthropods

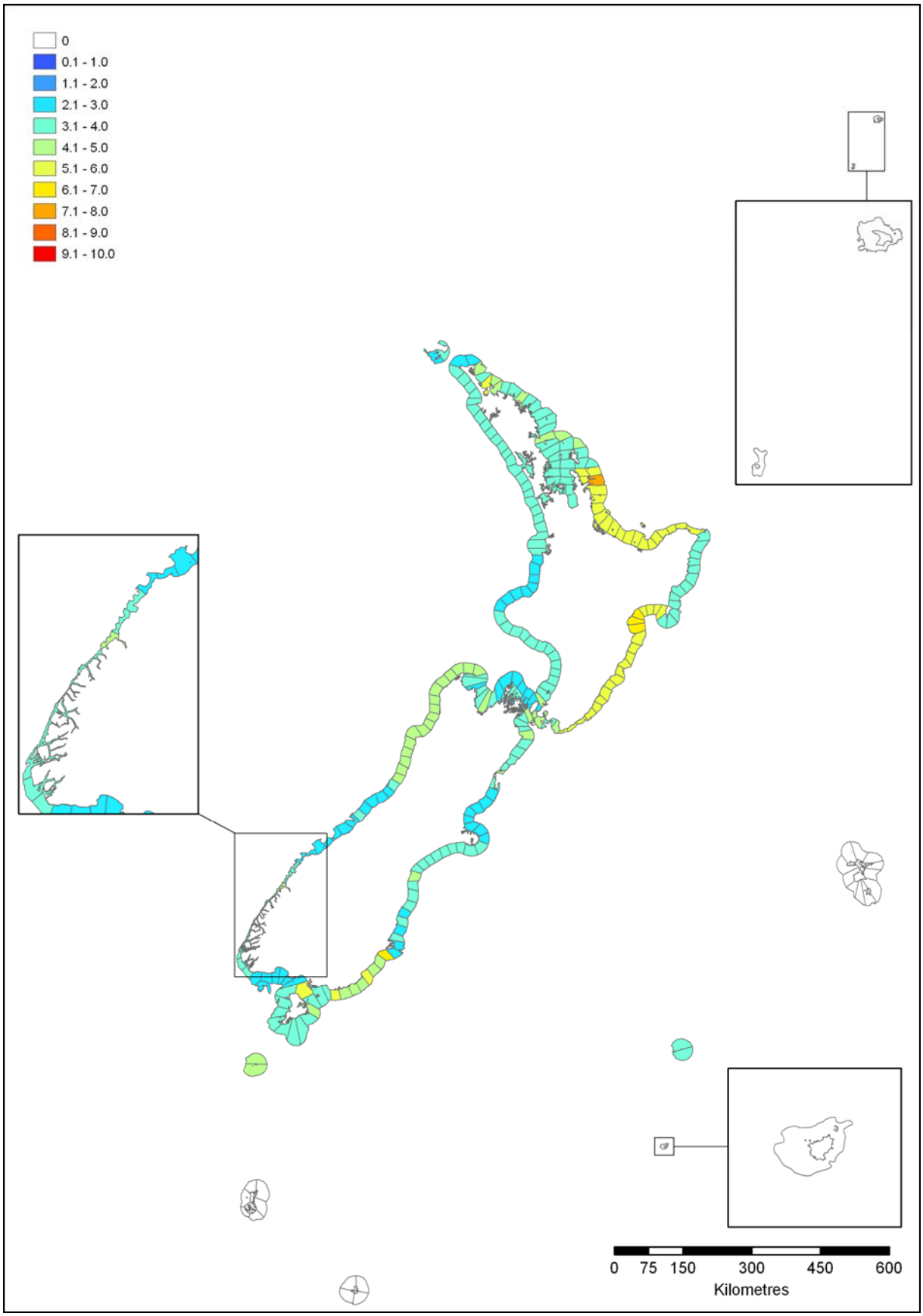
Six attributes of arthropod diversity were summarised: Total species, Species richness, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species Composition (Figure 6). These data were generated from approximately 1,400 raw data records.

Large areas of the east coast of the North Island stand out as being potentially important for arthropod diversity: the Bay of Plenty from the northeast coast of the Coromandel Peninsula to East Cape – especially around the Mercury Islands off the eastern Coromandel Peninsula, and the area from Hawke Bay to Cape Palliser. Rangaunu Harbour in the far northeast of Northland is also highly ranked.

There were fewer areas with highly ranked values in the South Island. These included the southern Otago Peninsula, parts of the Catlins coastline and Bluff.

Data were not available for Auckland, Campbell, Antipodes, Chatham and Kermadec Islands.

Figure 6 First-stage summary map: Taxon-specific diversity: Arthropods. Mean rank of six biological attributes.

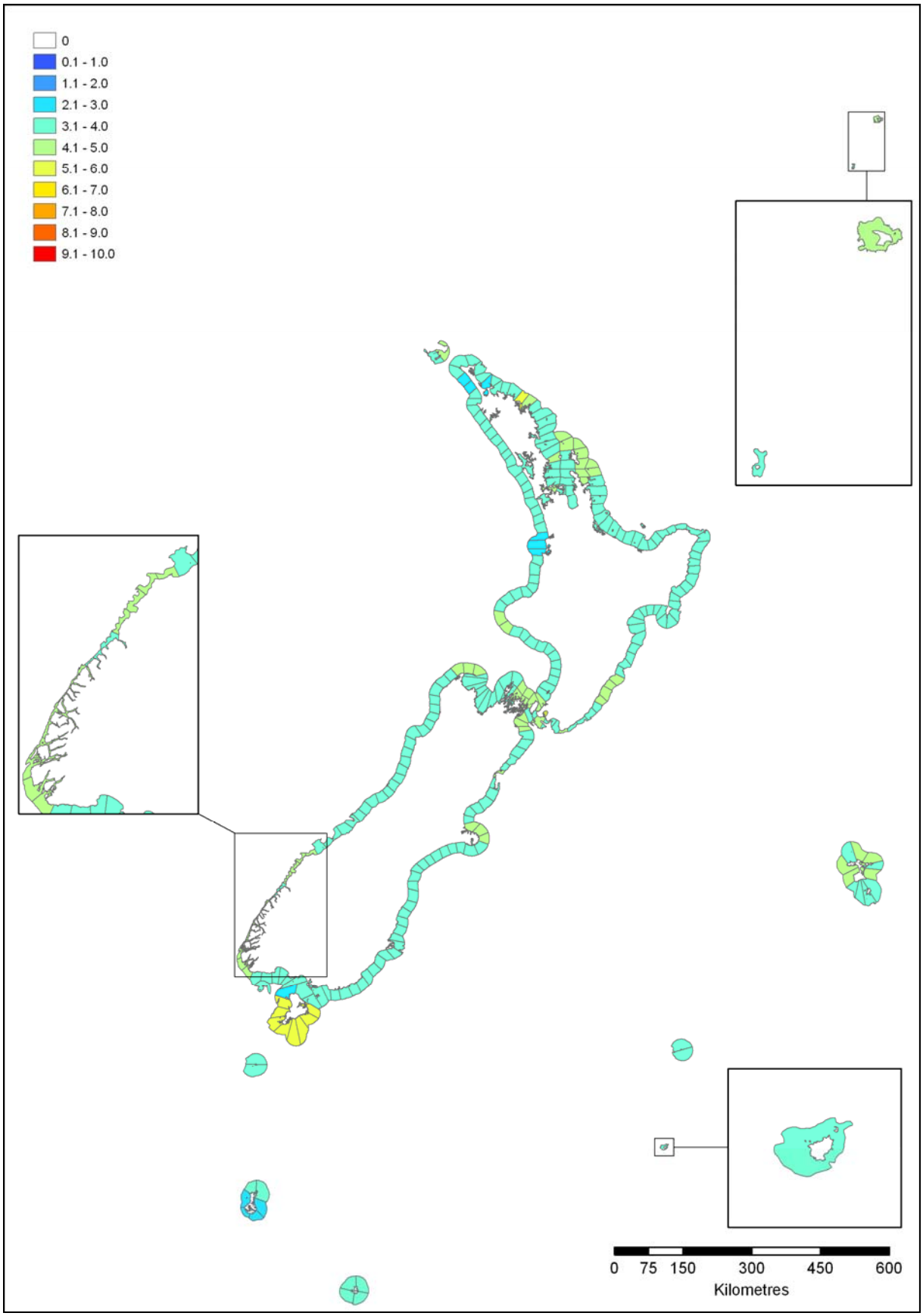


3.1.1.7 Algae

Six attributes of algal diversity were summarised: Total species, Species richness, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species Composition (Figure 7). These data were generated from 15,175 raw data records.

Algal communities are quite homogenous around New Zealand, with the highest values present in Stewart Island and Bay of Islands. Areas with particularly low values are the Raglan area on the west coast of the North Island, Ninety Mile beach on the west coast of Northland, the northwest coast of Stewart Island and the southern Auckland Islands.

Figure 7 First-stage summary map: Taxon-specific diversity: Algae. Mean rank of six biological attributes.



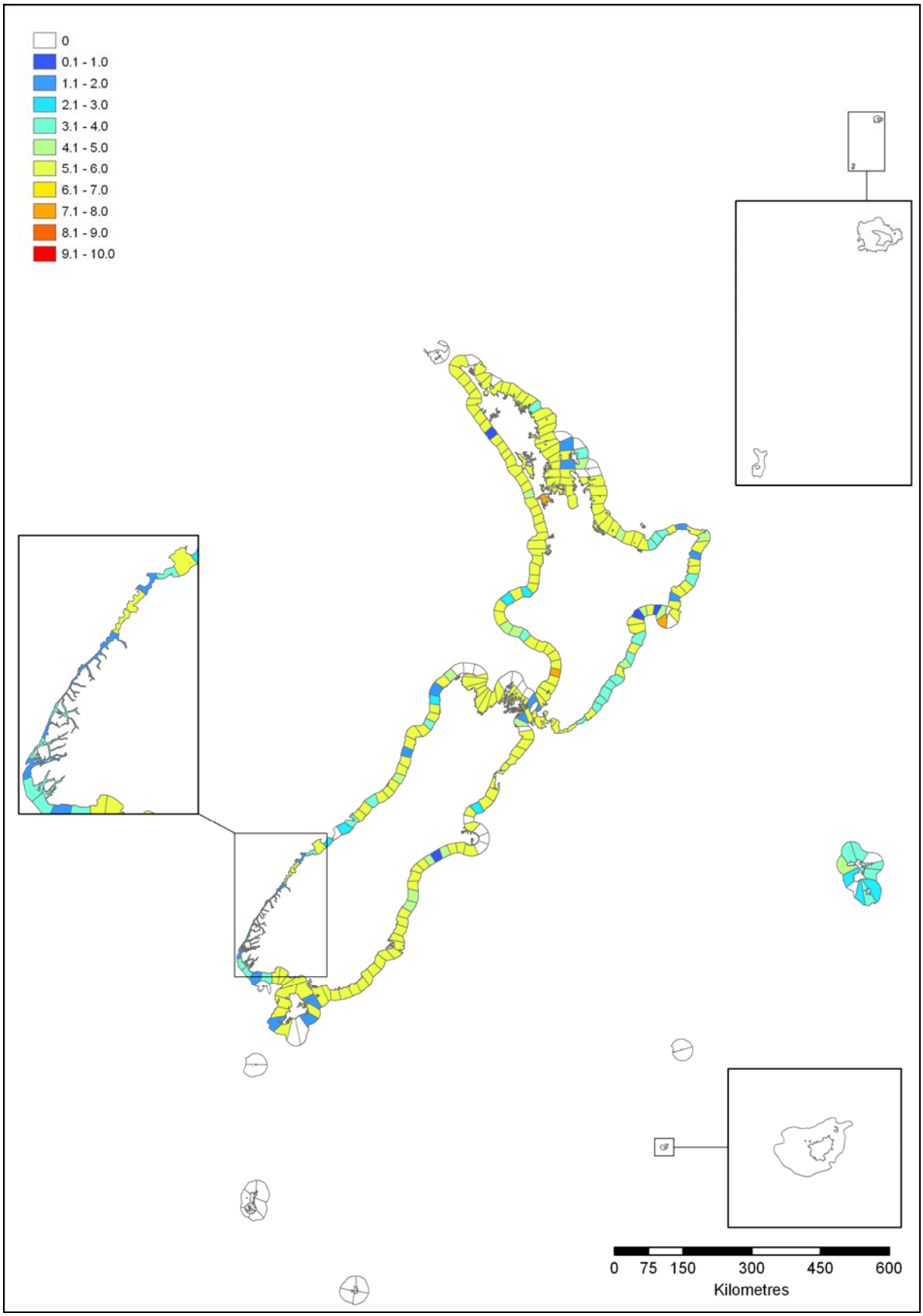
3.1.1.8 Wading birds

Five attributes of wading bird diversity were summarised: Total species, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species composition (Figure 8). These data were generated from approximately 3200 raw data records.

The Ornithological Society of New Zealand (OSNZ) carries out a regular survey of wading birds in 150 estuaries nationwide. In contrast to many of the invertebrate summary maps, the summary map for wading birds shows much of the New Zealand coastline to have high values suggesting that much of the New Zealand coastline supports a relatively high diversity of wading birds. Areas with particularly high values include the Manukau Harbour, around the Mahia Peninsula and along the Foxton coast. Fiordland, the southeast coast of the North Island and the Chatham Islands have areas of low wading bird diversity.

Data were not available for the Snares, Auckland, Campbell, Antipodes, Bounty and Kermadec Islands.

Figure 8 First-stage summary map: Taxon-specific diversity: Wading Birds. Mean rank of five biological attributes.



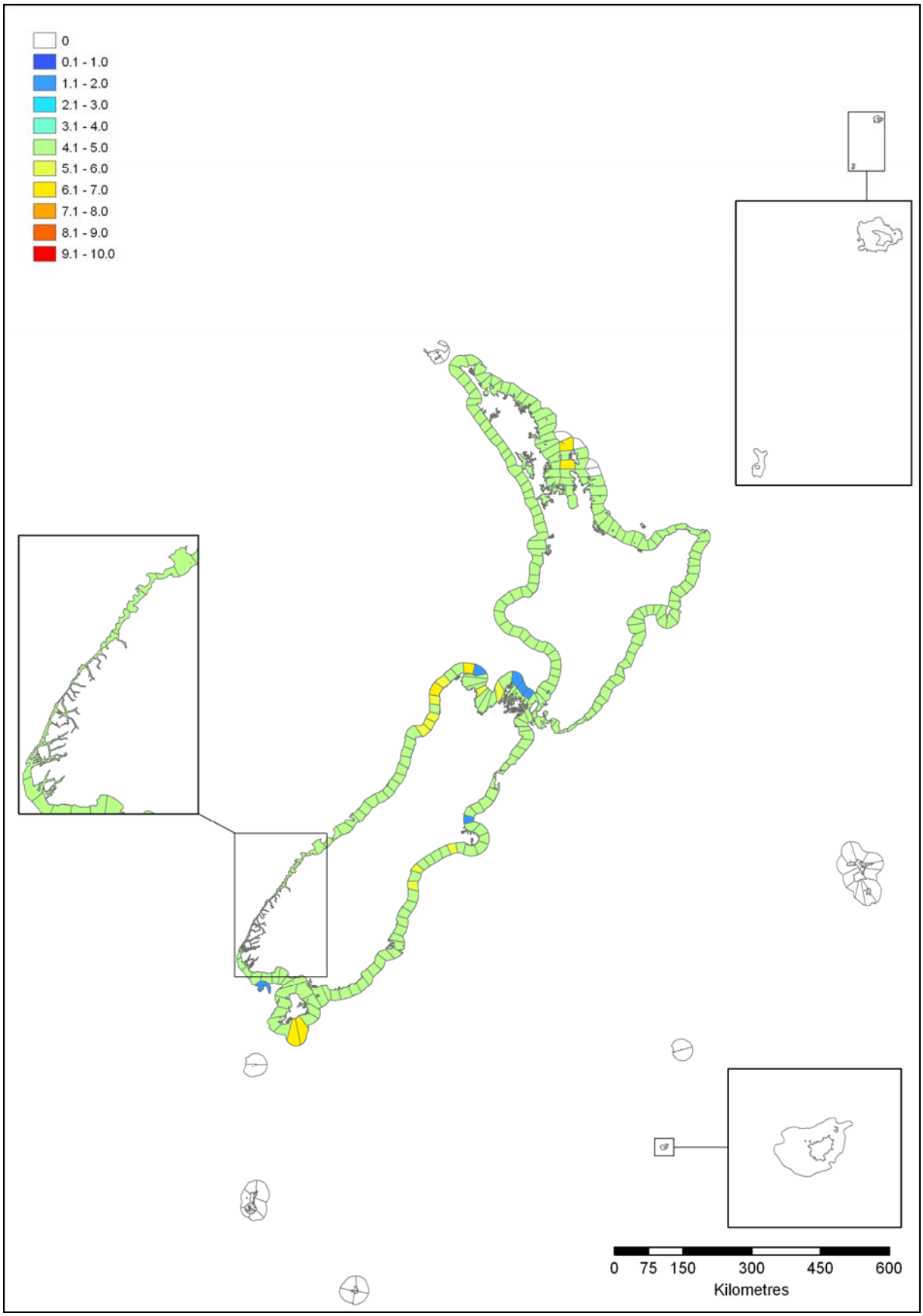
3.1.1.9 Diadromous fish

Five attributes of modelled diadromous fish diversity were summarised: Total species, Average Taxonomic Distinctness (ATD), Variation in ATD, Species rarity and Species composition (Figure 9).

Diadromous fish are homogeneously distributed around New Zealand with respect to species presence. Areas of note include southeastern Stewart Island, and northwestern South Island as well as a few areas between Otago and Banks Peninsulas and Great Barrier Island in the North Island.

No data were available for the offshore islands.

Figure 9 First-stage summary map: Taxon-specific diversity: Diadromous Fish. Mean rank of five biological attributes.



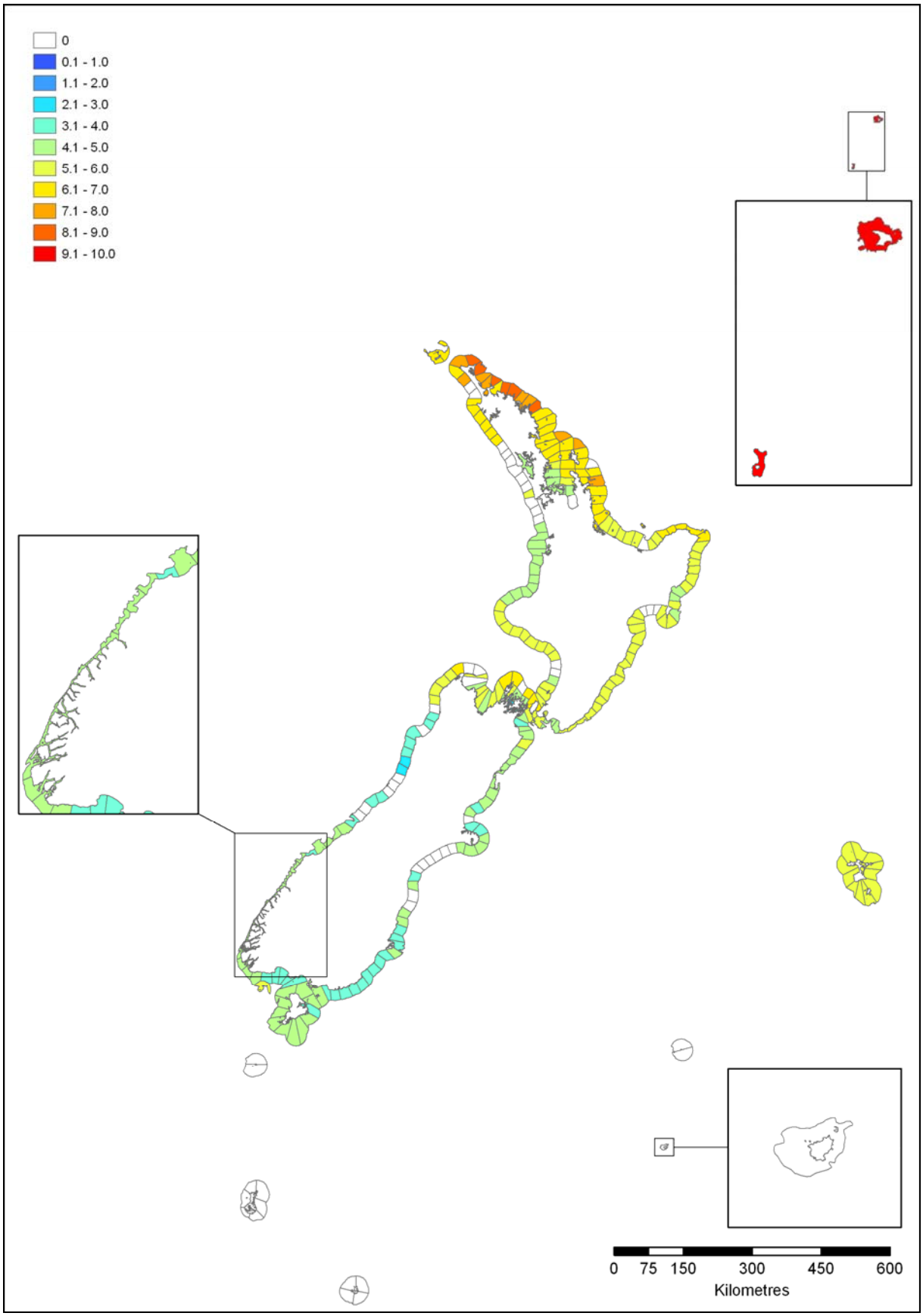
3.1.2 Overall diversity (Rocky reef fish)

The rocky reef fish dataset, collected by Clinton Duffy (Department of Conservation) over many years, covers 400 sites nationally where transect counts of fish have been assigned into logarithmic abundance classes for 20 to 40 species of fish per site. Although the number of sites is high there are gaps in national coverage. The MEC has been used to model the distributions of reef fish species based on physical correlates to provide interpolated data nationally.

A strong latitudinal gradient is apparent (Figure 10), with greater diversity in the north of New Zealand and lower diversity in the south. The highest ranked cells are in the Kermadec region and the lowest ranked cells are on the west coast of the South Island. The highest ranking area in the South Island is the north coast, from the Marlborough Sounds to the west coast. Solander Island, to the west of Stewart Island, stands out as having the highest rank in the southern part of the South Island.

Data were not available for Snares, Auckland, Campbell, Antipodes and Bounty Islands.

Figure 10 First-stage summary map: Taxon-specific diversity: Rocky Reef Fish. Ranked values of modelled species richness.



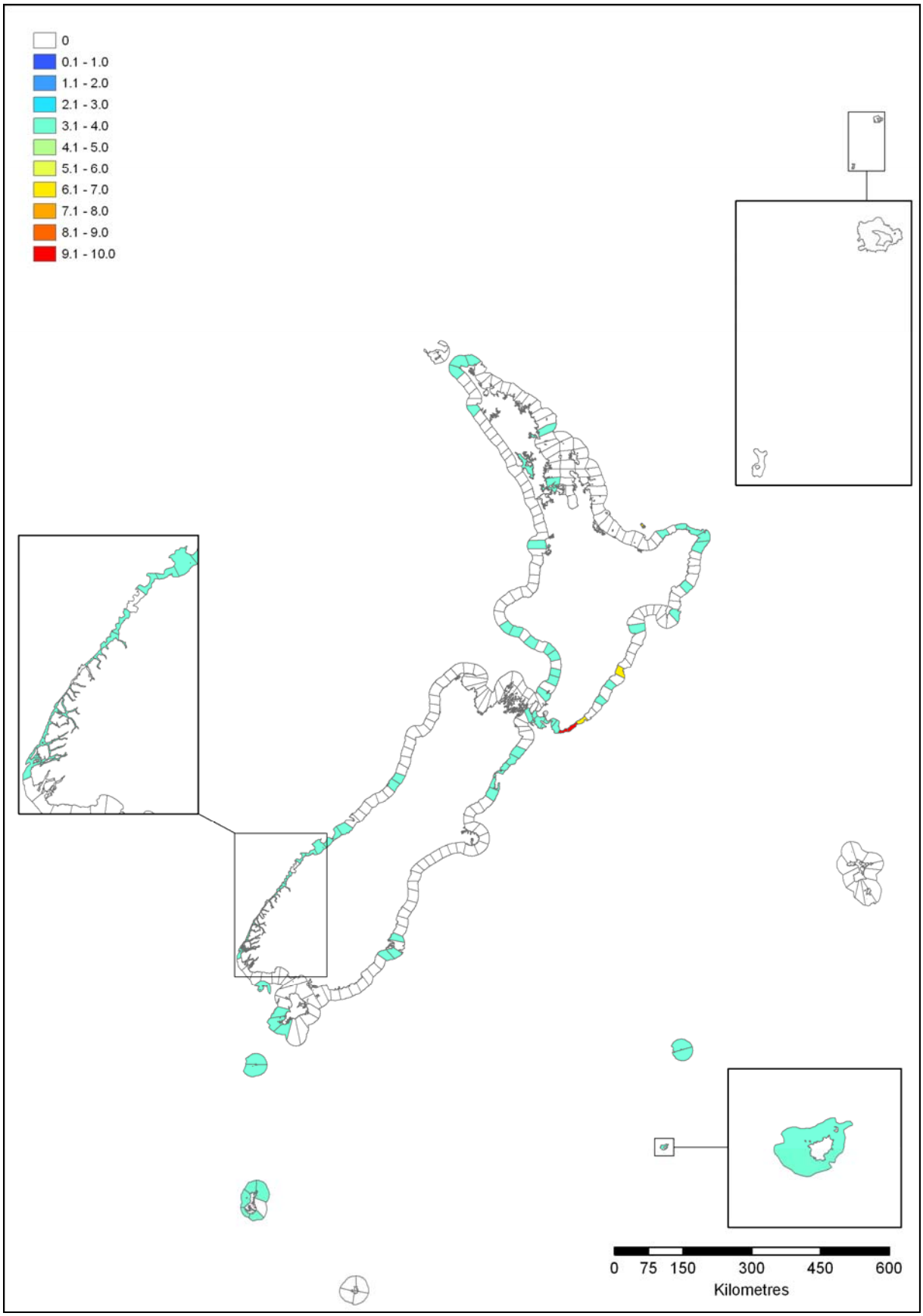
3.1.3 At risk or threatened species

3.1.3.1 Invertebrates

The distribution of at risk or threatened invertebrate species around New Zealand was mapped, ranked according to the number of these species within each coastal cell (Figure 11). Coastal cells containing moderate numbers of at risk or threatened species are found throughout the New Zealand coastline. However, three coastal cells around the southeastern coast of the North Island stand out as having particularly high numbers of these species: to the east of Cape Palliser and in the vicinity of Cape Turnagain.

Threatened invertebrates are not known to occur along much of the New Zealand coastline.

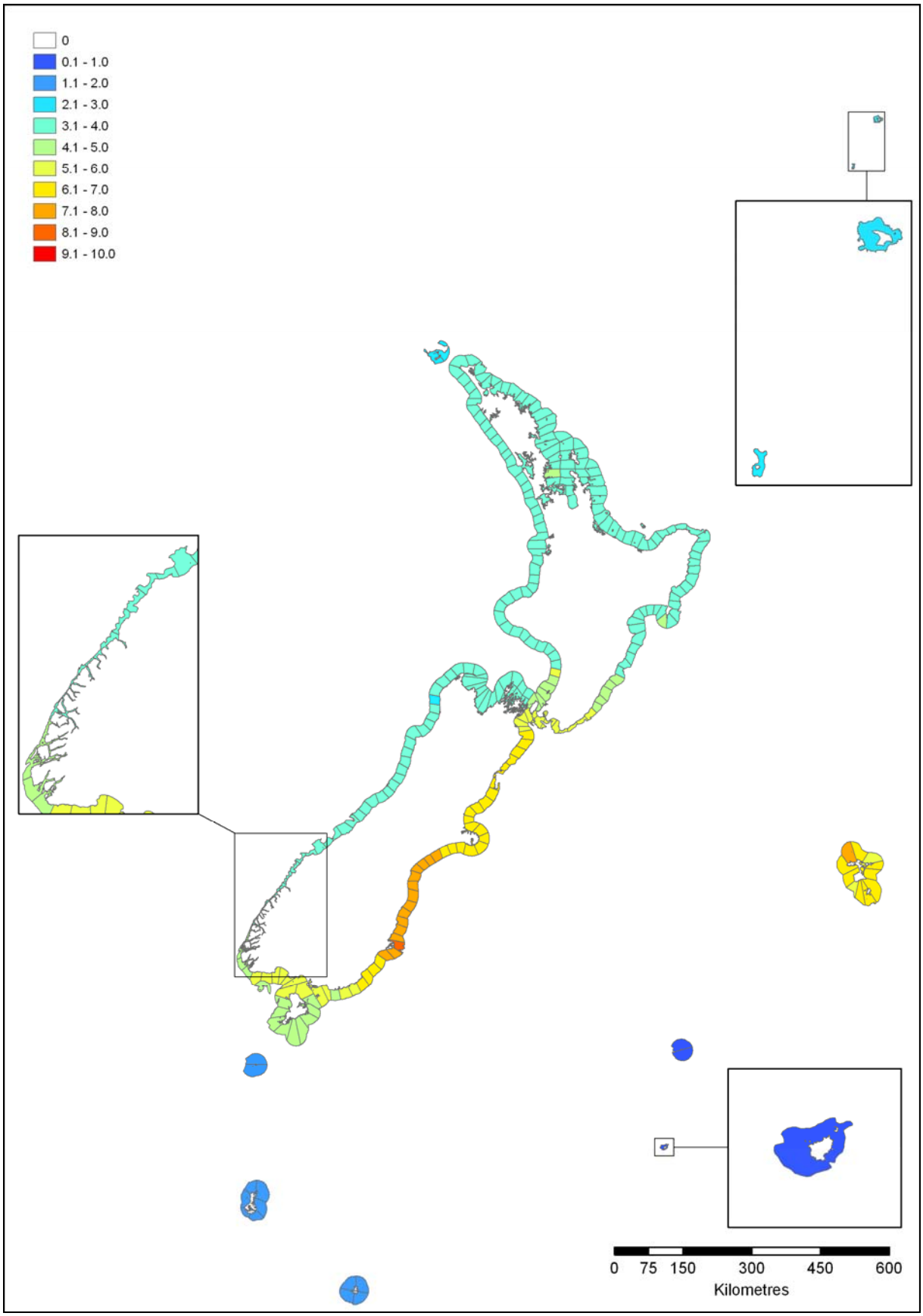
Figure 11 First-stage summary map: At risk or threatened species: Invertebrates. The number of at risk or threatened invertebrate species per coastal cell is displayed as a ranked value.



3.1.3.2 Birds

The distribution of nationally threatened bird species around New Zealand was mapped, ranked according to the number of these species present within each coastal cell (Figure 12). The south and east coast of the South Island and the south and southeastern coast of the North Island as well as the Chatham Islands stand out as being important with respect to the presence of nationally threatened bird species. In particular, the northern tip of the Chathams and the area from the Otago Peninsula north towards Banks Peninsula had particularly high values. Interestingly the offshore islands, with the exception of the Chathams, including the Three Kings and Kermadec Islands, as well as the sub-Antarctic islands, have particularly low ranks with respect to the number of threatened bird species recorded at these sites.

Figure 12 First-stage summary map: At risk or threatened species: Birds. The number of at risk or threatened bird species per coastal cell is displayed as a ranked value.



3.1.4 Subcomponent: Marine mammal distribution

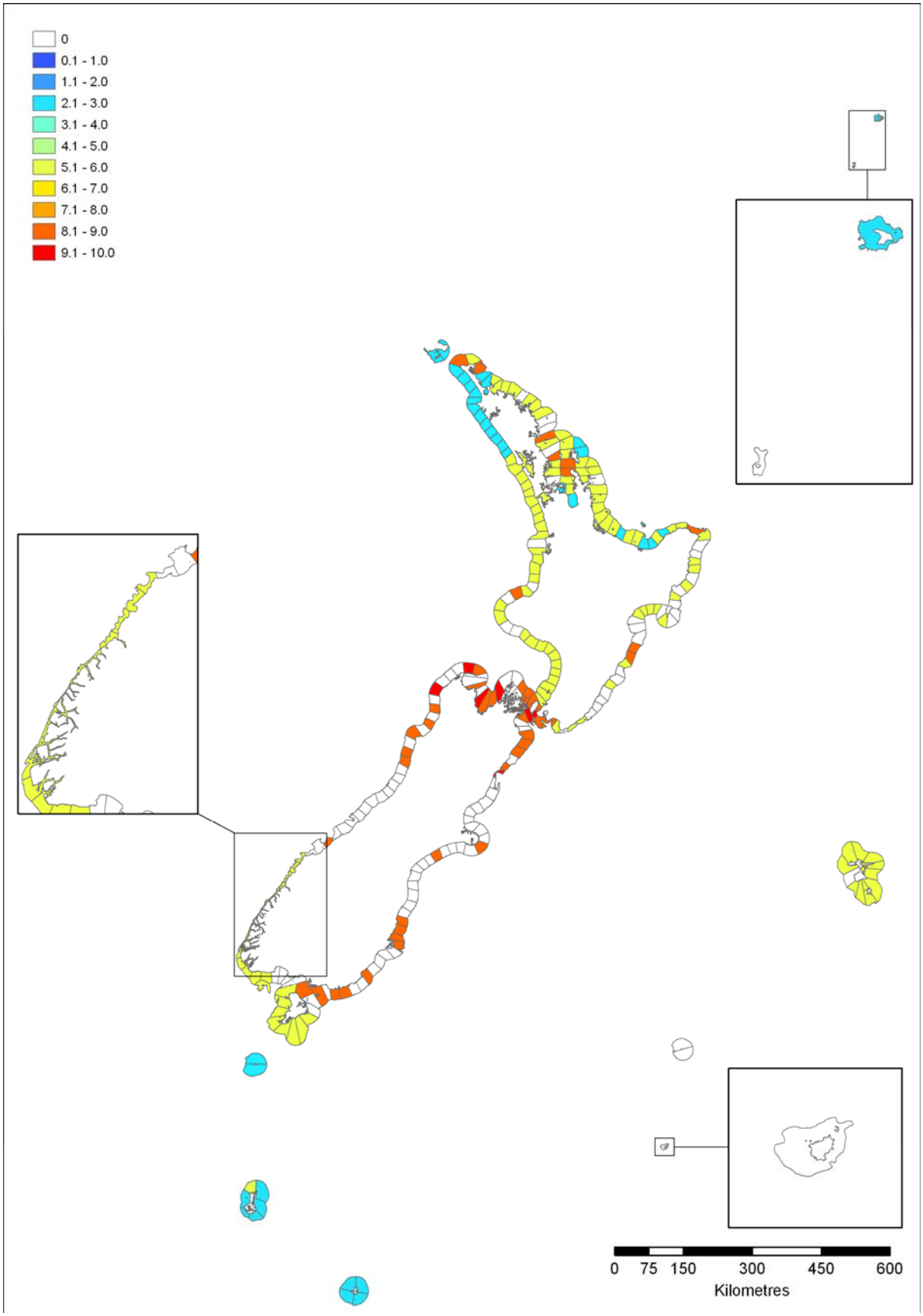
3.1.4.1 Dolphins

The distribution of the sightings of seven species of dolphins and toothed whales around the New Zealand coastline was mapped (Figure 13). Species included were the bottlenose (*Tursiops truncatus*), common (*Delphinus delphis*), Hector's (*Cephalorhynchus hectori*), dusky (*Lagenorhychus obscurus*), Maui's (*Cephalorhynchus hectori maui*) dolphins and killer (*Orcinas orca*) and pilot (*Globicephala* spp.) whales. The data were ranked according to the number of species present within each coastal cell.

Dolphins have been sighted around much of the New Zealand coastline. This is particularly true of the North Island and the northern and southern South Island. They have also been seen at many of the offshore islands. Areas with particularly high numbers of dolphin species known to be present include the Spirits Bay area and North Cape, parts of the Hauraki Gulf, East Cape, Cook Strait and much of the northern coast of the South Island, Banks Peninsula, Otago and parts of the Catlins coast and Foveaux Strait. Stewart Island, Fiordland, the Kapiti Coast, Taranaki Bight and much of the west and northeastern coasts of the North Island and the Chatham Islands also have relatively high numbers of dolphin species.

Low numbers of dolphin species are known to be present around the northwestern coast of the North Island and many of the offshore islands (with the exception of the Chatham Islands). There were no records of dolphins around much of the west and east coasts of the South Island, and much of the east coast of the North Island. It is not known whether this is a true representation of the distribution of dolphins or whether they are present but have not been recorded.

Figure 13 First-stage summary map: Total dolphin sightings distribution. The number of dolphin species sighted per coastal cell is displayed as a ranked value.

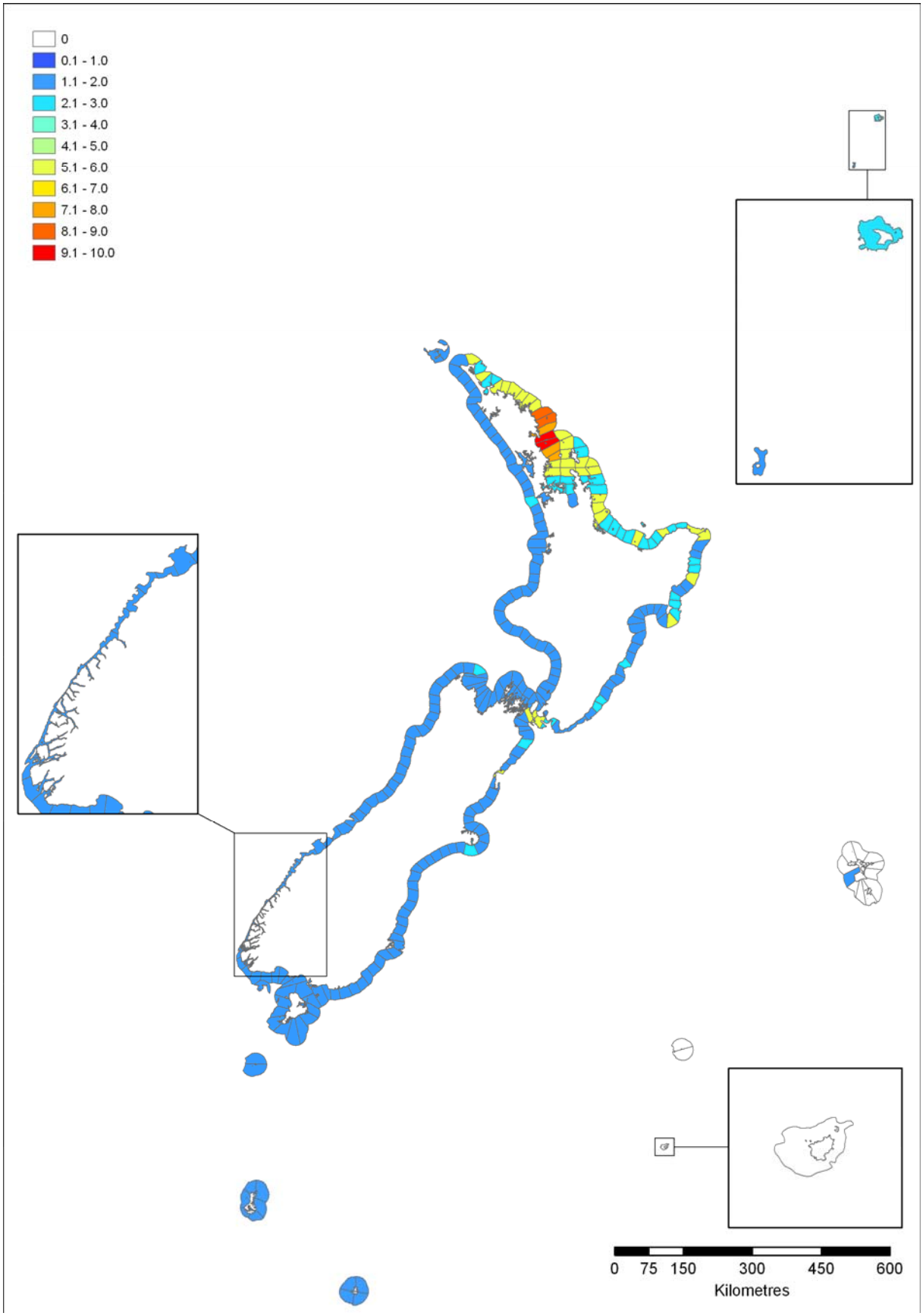


3.1.4.2 Whales

The distribution of nine species of whale around the New Zealand coastline based on sightings records was mapped (Figure 14). Species included in the analysis were the blue (*Balaenoptera musculus*), beaked (Families Ziphiidae, Mesoplodon and Hyperoodon), Bryde's (*Balanoptera edeni*), fin (*Balanoptera physalus*), humpback (*Megaptera novaeangliae*), minke (*Balanoptera acutorostrata*), southern right (*Eubalaena australis*), sei (*Balanoptera borealis*), and sperm (*Physeter macrocephalus*) whales. The data are ranked according to the number of species present within each coastal cell.

Whales have been observed around all of the New Zealand coastline and most of the offshore islands. However, the greatest number of species of whales has been observed on the northeast coast of the North Island, to the north of the Hauraki Gulf, in the vicinity of the Poor Knights and Hen and Chicken's islands. However, moderate numbers of whale species were also recorded across the entire northeastern coast of the North Island as well as Cook Strait and the Kaikoura coastline.

Figure 14 First-stage summary map: Total whales sightings distribution. The number of whale species sighted per coastal cell is displayed as a ranked value.

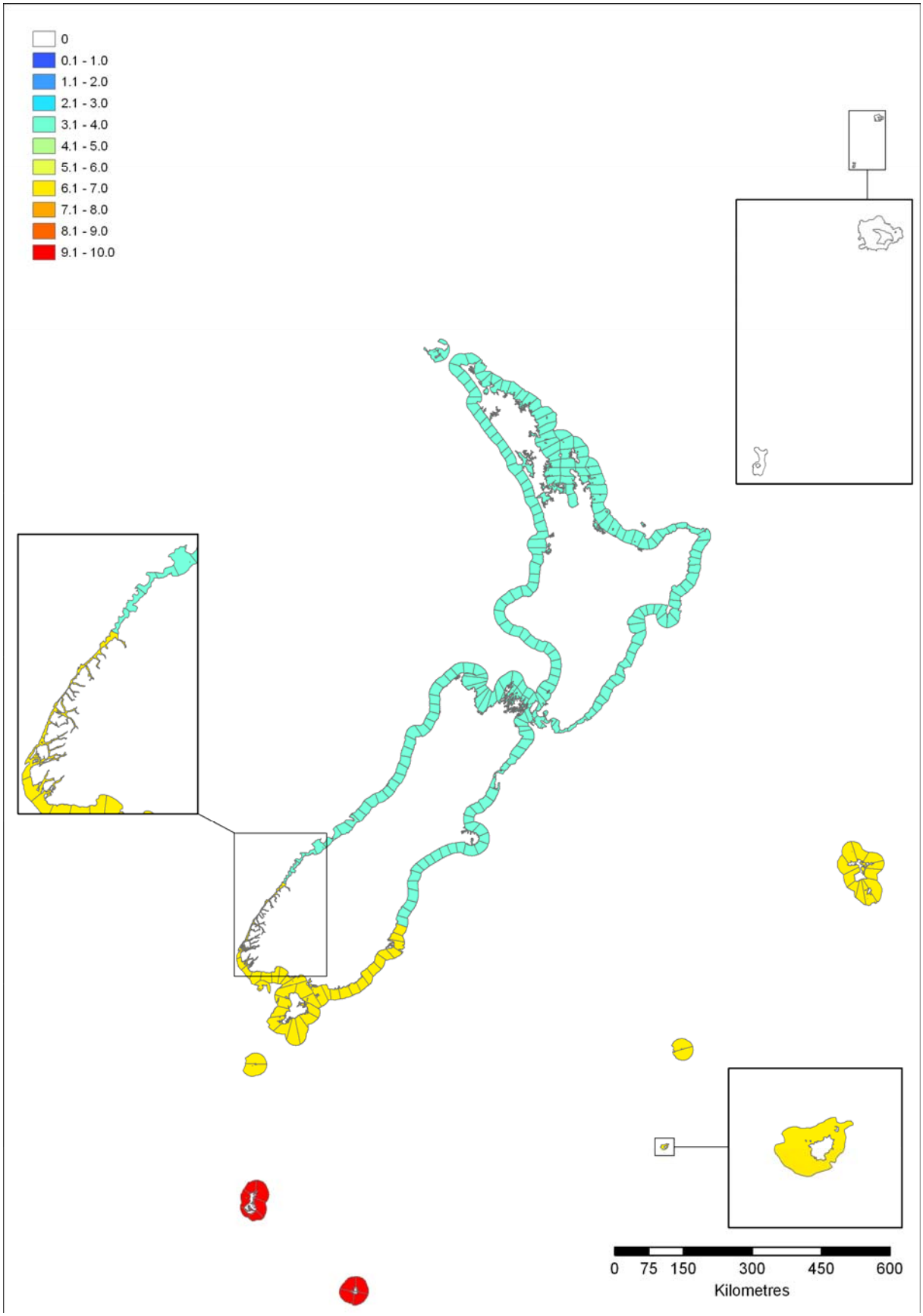


3.1.4.3 Seals

The distribution of pinnipeds around the New Zealand coastline was mapped (Figure 15). Species included in the analysis were the New Zealand fur seal (*Arctocephalus forsteri*), the New Zealand sea lion (*Phocarctos hookeri*) and the southern elephant seal (*Mirounga leonina*). The ranked values reflect the number of species within each coastal cell.

Seals are present all around the New Zealand coastline, with the exception of the Kermadec Islands. Only one species (the New Zealand fur seal) is present throughout the North Island and the northern half of the South Island. Two species (the New Zealand fur seal and New Zealand sea lion) are present in the southern half of the South Island, south of Otago and Fiordland, and around Stewart, Snares, Antipodes, Bounty and Chatham Islands. All three species of seal are known to be present in the Auckland and Campbell Islands.

Figure 15 First-stage summary map: Total pinniped sightings distribution. The number of species sighted per coastal cell is displayed as a ranked value.



3.2 FIRST-STAGE SUMMARY MAPS: HABITAT DATA

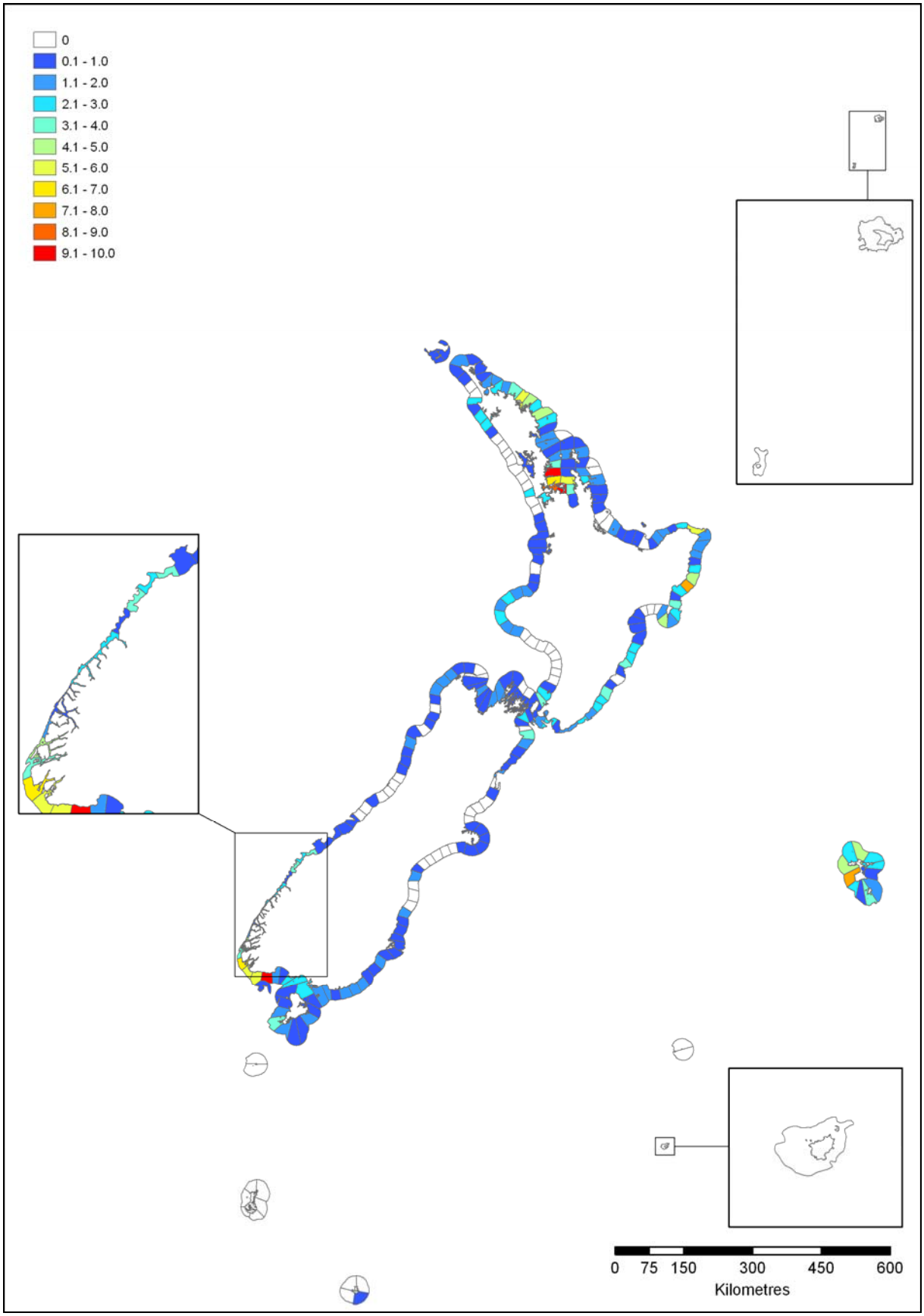
Data layers showing the distribution of key marine habitats (mangrove, seagrass, biogenic reefs etc.) were created to show the area of habitat per coastal cell as a proportion of the total area of that habitat in New Zealand. It is important to note that some habitat maps, such as those of seagrass and biogenic reefs, were created using expert knowledge and reflect the best information available rather than being accurate on a fine scale.

3.2.1 Intertidal rocky reef

Intertidal reefs are rocky areas of the coastline extending between spring low water and up to the spring high tide mark. They include many different habitats based on exposure and aspect and host a wide range of organisms including algae, crustaceans, molluscs and polychaete worms.

The area of intertidal rocky reef per coastal cell was mapped as a proportion of the total area of this habitat in New Zealand (Figure 16). The Hauraki Gulf, the northeast coast of Northland, the east coast of the North Island (near Gisborne), the southwest tip of the South Island and the west coast of the Chatham Islands are all important areas with respect to the distribution of intertidal rocky reefs. Interestingly, large areas of both the North Island and South Island coastlines are devoid of intertidal rocky reefs.

Figure 16 First-stage summary map: Habitat: Intertidal rocky reef. Ranked value of the area of intertidal rocky reef per coastal cell as a proportion of the total area of this habitat in New Zealand.

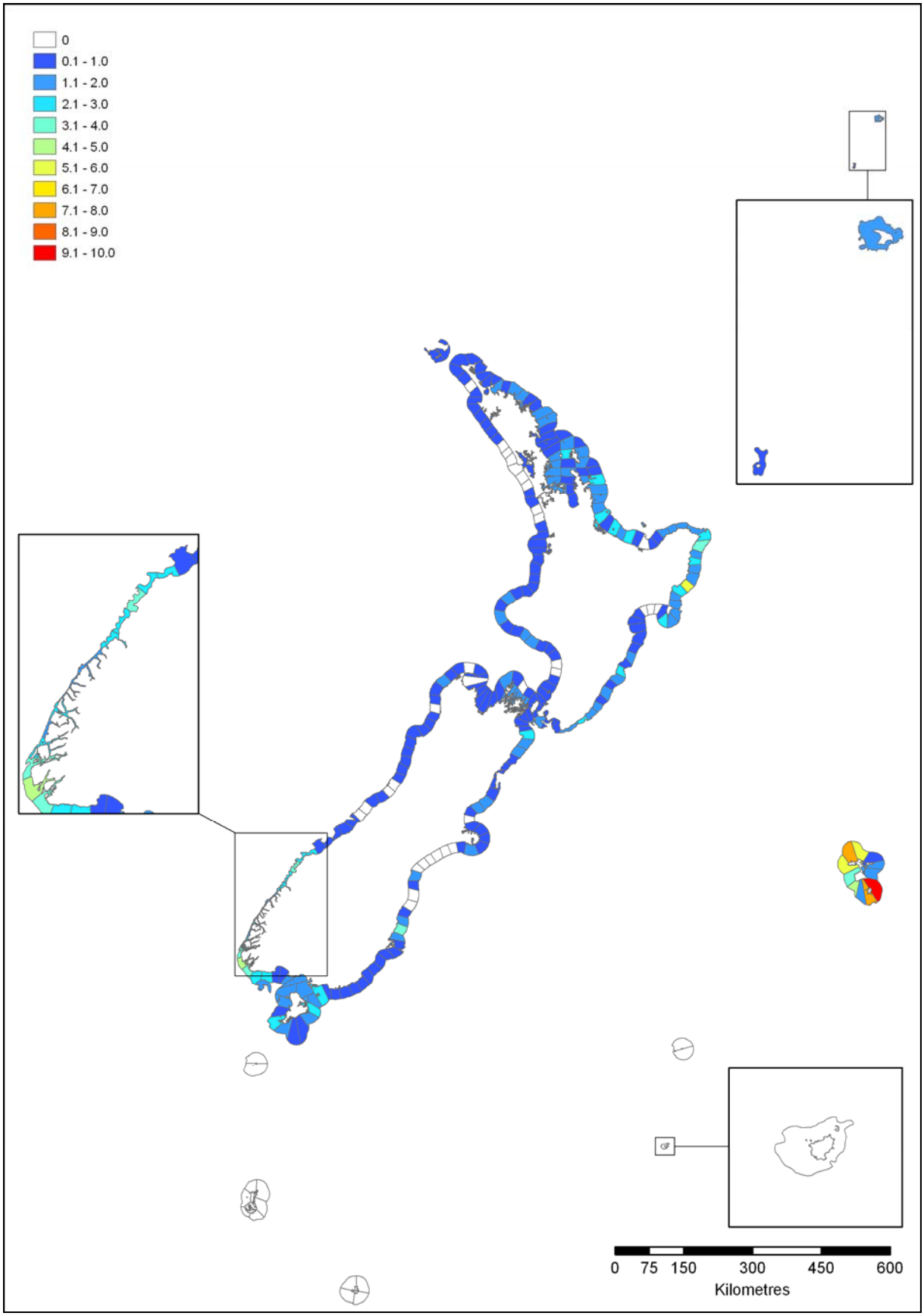


3.2.2 Subtidal rocky reef

Shallow subtidal rocky reefs, to a maximum depth of 50 m, have been mapped by the Department of Conservation using historic hydrographical data. The area of subtidal rocky reef per coastal cell was mapped as a proportion of the total area of this habitat in New Zealand (Figure 17).

Many parts of the New Zealand coastline contain some subtidal rocky reef habitat. However, Fiordland, East Cape and the Chatham Islands stand out as being particularly important areas with respect to the distribution of subtidal rocky reef habitat. As with the intertidal rocky reefs, there are large areas devoid of subtidal rocky reefs: particularly on the west coast of the North Island in the vicinity of the Kaipara Harbour, the east coast of the South Island to the south of Banks Peninsula and patches on the west coast of the South Island.

Figure 17 First-stage summary map: Habitat: Subtidal rocky reef. Ranked value of the area of subtidal rocky reef per coastal cell as a proportion of the total area of this habitat in New Zealand.

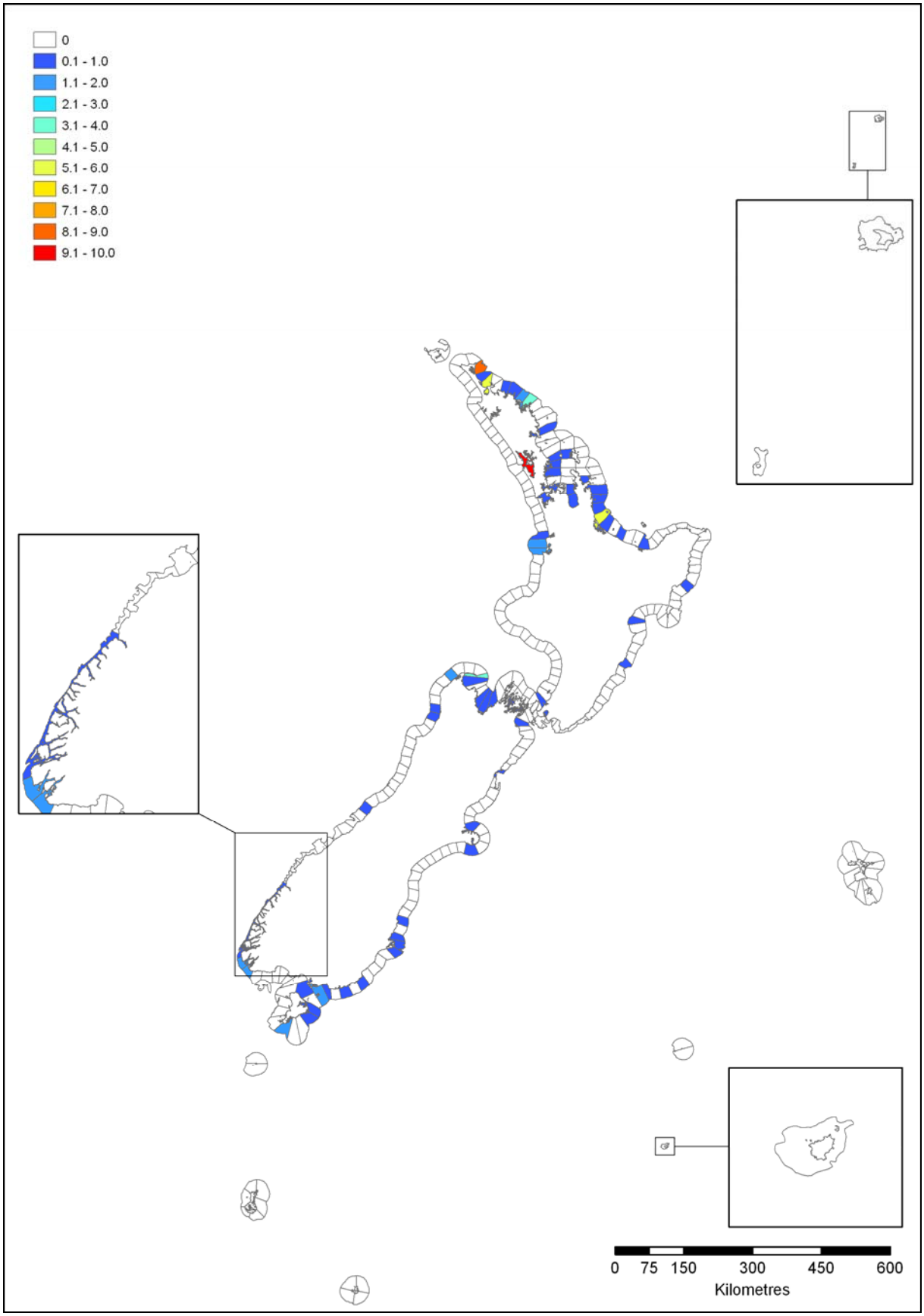


3.2.3 Seagrass

Seagrasses are aquatic flowering plants that form meadows in marine and brackish water. In New Zealand only one species, *Zostera capricorni*, occurs, which grows mainly in the intertidal zone. Seagrass beds provide feeding and nursery habitat for a range of fish and invertebrates, trap and stabilise bottom sediment, create primary productivity and recycle nutrients. Seagrass is a fragile habitat which can be damaged by coastal development and pollution (Rowden *et al.* 2007).

The distribution of seagrass in coastal cells around the New Zealand coastline was mapped as a proportion of the total area of this habitat in New Zealand (Figure 18). The distribution of seagrass is patchy and often associated with harbours, with many areas devoid of seagrass beds. Important areas with respect to seagrass habitat are the Kaipara Harbour, Parengarenga Harbour and Rangaunu Bay on the northeast coast of Northland and Tauranga in the Bay of Plenty in the North Island and Farewell Spit in the South Island.

Figure 18 First-stage summary map: Habitat: Seagrass. Ranked value of the distribution of seagrass in coastal cells around the New Zealand coastline as a proportion of the total area of this habitat in New Zealand.



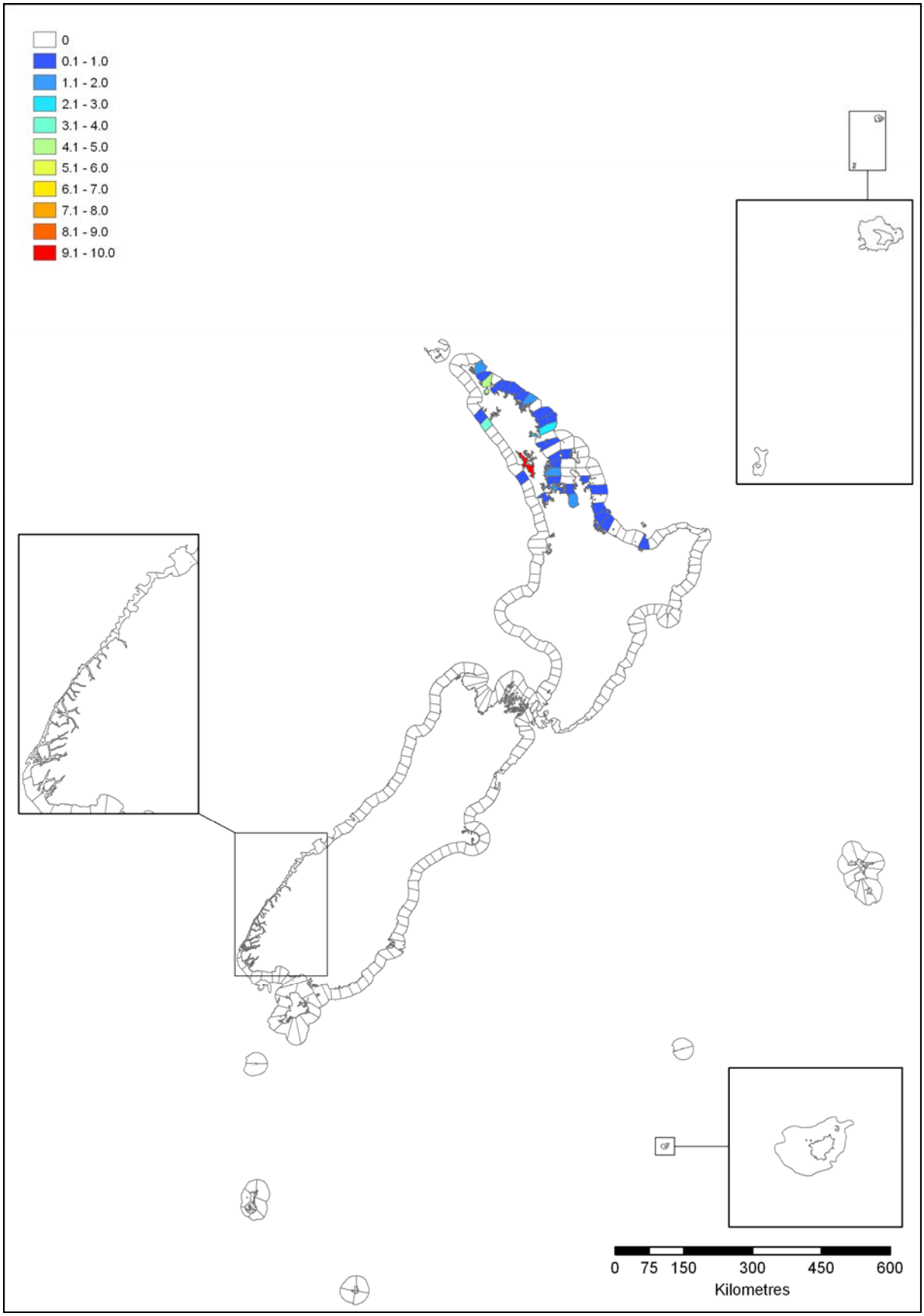
3.2.4 Mangroves

Mangroves are aquatic flowering plants that generally occur in tropics and sub-tropics. *Avicennia marina* is the only species which occurs in New Zealand and can be found in the shallow water of harbours and estuaries in the northern half of the North Island. Mangroves protect the coast by trapping sediment and offer habitat for many native species of birds, insect, shellfish, snails and crabs (Rowden *et al.* 2007).

The distribution of mangrove forest as a proportion of the total area of this habitat in New Zealand within each coastal cell was mapped (Figure 19). Kaipara Harbour is the most important area with respect to mangroves in New Zealand. High values were also present in Parengarenga Harbour, Rangaunu Bay, Bay of Islands, Whangarei Harbour and Hauraki Gulf. Ohiwa Harbour in Bay of Plenty represents the southernmost extent for the mangroves in New Zealand.

Mangroves are absent in the northernmost locations at the Three Kings and Kermadec Islands.

Figure 19 First-stage summary map: Habitat: Mangroves. Ranked value of the distribution of mangrove forest as a proportion of the total area of this habitat in New Zealand within each coastal cell.

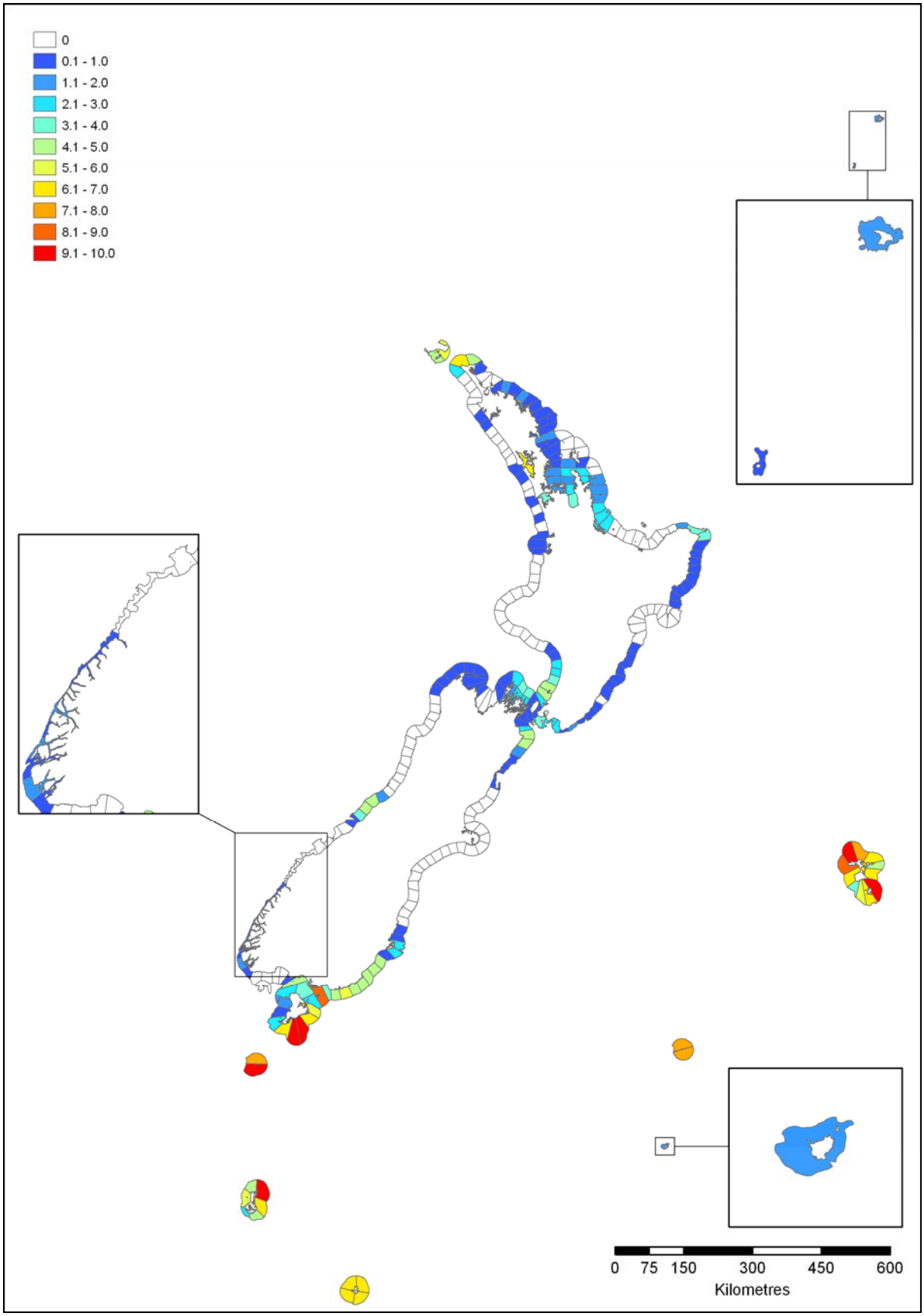


3.2.5 Biogenic reefs

Biogenic reefs are a highly specialized habitat, often occurring in areas of strong water movement. Reefs are made from colonial tube worms, sponges, corals, bryozoans, or coralline algae and can form extensive areas of three dimensional structures up to 2 m tall. Structures such as horse-mussel beds are also classed as biogenic reefs (Holt *et al.* 1998).

The distribution of known biogenic reefs in New Zealand coastal area is patchy, but primarily found in the far south of New Zealand on the Catlins coast and Stewart Island; in the middle of New Zealand from Kaikoura across to the northwest tip of the South Island, Cook Strait, and Kapiti Coast and Wairarapa Coast on the North Island, East Cape and the east coast of Northland (Figure 20). However, the sub-Antarctic Islands, Stewart Island and the Chatham Islands are the areas with the highest ranks, supporting the greatest proportions of biogenic reef habitat in New Zealand.

Figure 20 First-stage summary map: Habitat: Biogenic reefs. Ranked value of the distribution of biogenic reefs as a proportion of the total area of this habitat in New Zealand within each coastal cell.

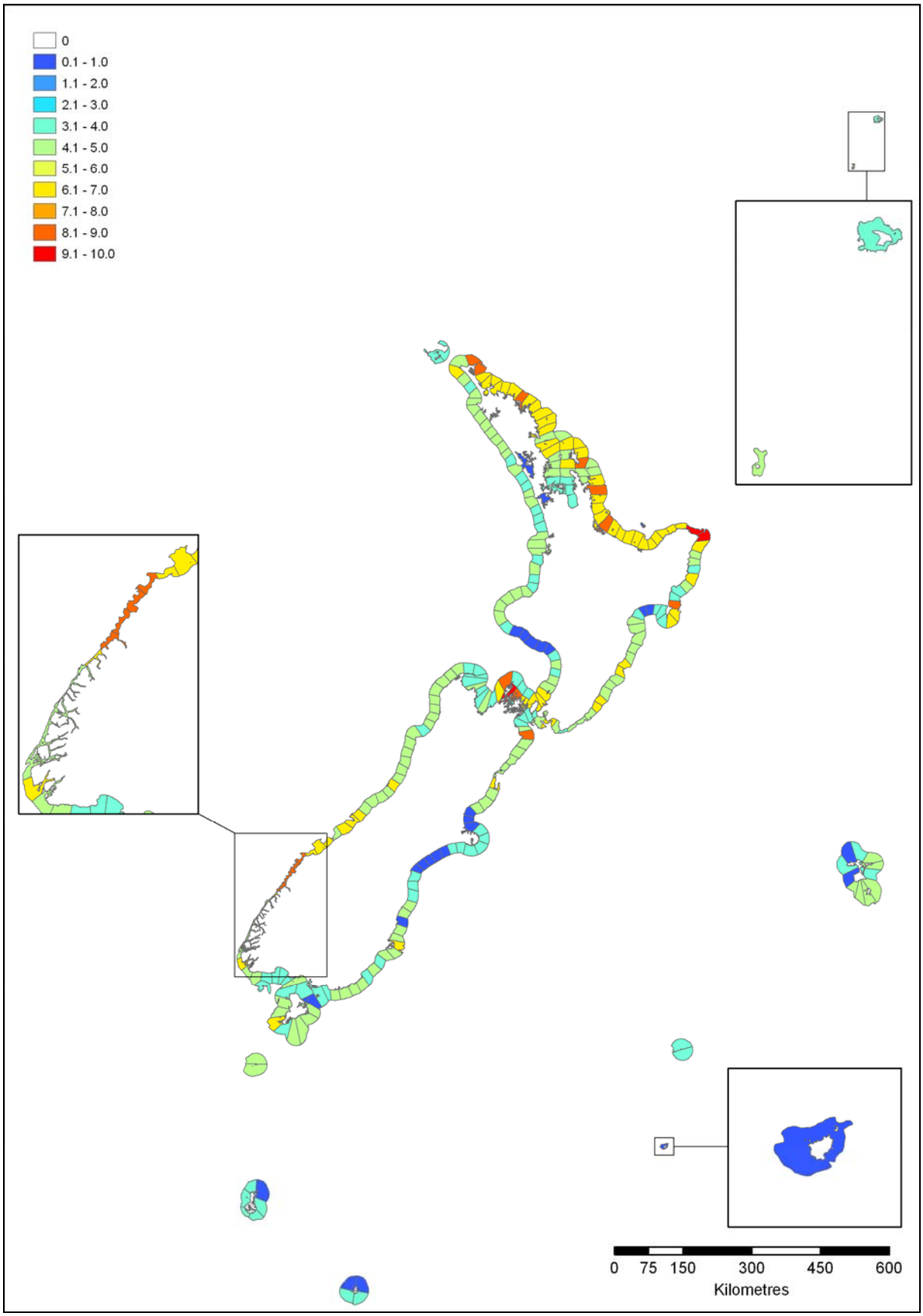


3.2.6 MEC physical habitat categories

The Marine Environmental Classification (MEC) system used nine environmental variables to define up to 290 classes of physical habitat in the New Zealand Exclusive Economic Zone. The number of physical habitat categories in each coastal cell around New Zealand was mapped, using a ranking scale, in Figure 21. A high rank (10) was assigned to those cells with high numbers of habitat categories (i.e. high diversity of environmental conditions) and a low rank (1) was assigned to those coastal cells with low numbers of habitat categories (i.e. a low diversity of environmental conditions).

The northeast coast of the North Island, from East Cape to North Cape, is highly ranked with respect to the number of physical habitat categories per coastal cell (Figure 21). The North Cape, Bay of Islands, Great Barrier Island, Coromandel Peninsula, Tauranga and East Cape have particularly high values. In the South Island, the Marlborough Sounds, Cape Campbell and northern Fiordland are also highly ranked. Areas with a more uniform physical environment, with a low rank with respect to the number of physical habitat categories per coastal cell, include the east coast of the South Island, particularly to the south and north of Banks Peninsula, the South Taranaki Bight, areas of Hawke Bay, the Kaipara and Manukau Harbours, the northeast coast of Stewart Island and many of the offshore islands (Auckland, Campbell, Antipodes and Chatham Islands).

Figure 21 First-stage summary map: Habitat: MEC Physical Habitat Categories. Ranked value of the number of habitat categories present within each coastal cell.



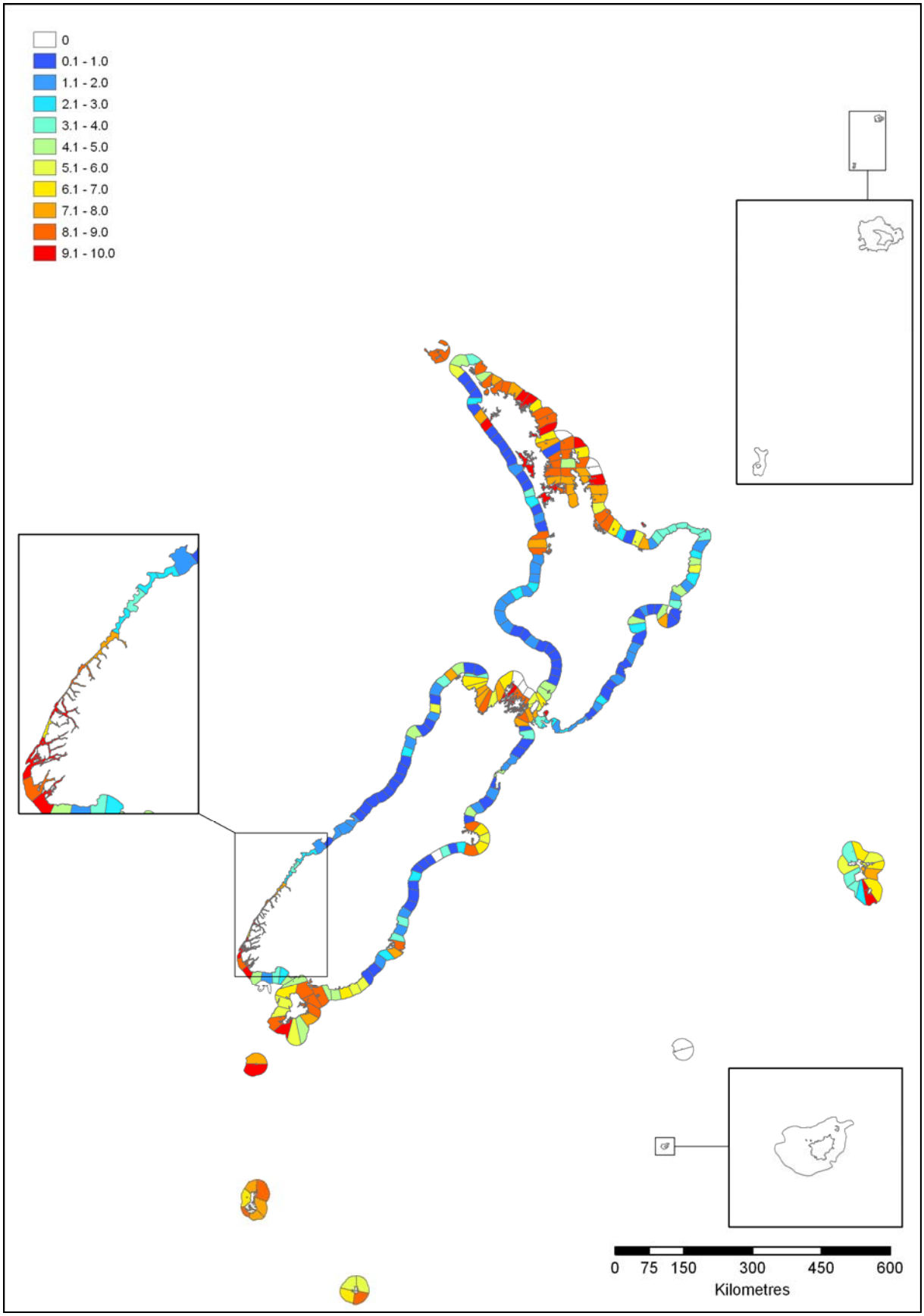
3.2.7 Habitat diversity index

This derived value is a proxy for habitat diversity, generated using the ratio between the actual length of coastline per cell and the straight-line length of the coastal cell. Coastal cells with a low ratio (i.e. a much longer actual length than straight-line length; a complex coastline profile) were assigned a high rank. Therefore coastal cells ranked highly on the summary map (Figure 22) are those with a complex coastline where it is expected that there will be a high diversity of habitat types (e.g. exposed rocky headland, sandy/muddy sheltered bays, narrow channels with high tidal flows etc.). Coastal cells with a high ratio (i.e. a similar actual and straight-line length) were assigned low ranks. It is expected that these sections of the coastline will have a relatively uniform physical environment.

The east coast of Northland, the Three Kings islands and many of the harbours in the Northland area (e.g. Manukau, Kaipara, Raglan) of the North Island were ranked particularly highly with respect to habitat diversity (Figure 22). In the South Island, the Marlborough Sounds, Abel Tasman and Golden Bay area, Banks Peninsula, Otago Peninsula, Stewart Island and Fiordland all stand out with high values of habitat diversity. The offshore islands for which data were available also have highly diverse coastlines.

Large areas of both the east and west coasts of both North and South Island appear to have very low values of habitat diversity.

Figure 22 First-stage summary map: Habitat: Habitat diversity index (derived value). Ranked value of the ratio between the actual length of coastline per cell and the straight-line length of the coastal cell. A high ranked value represents a low ratio (high predicted habitat diversity).

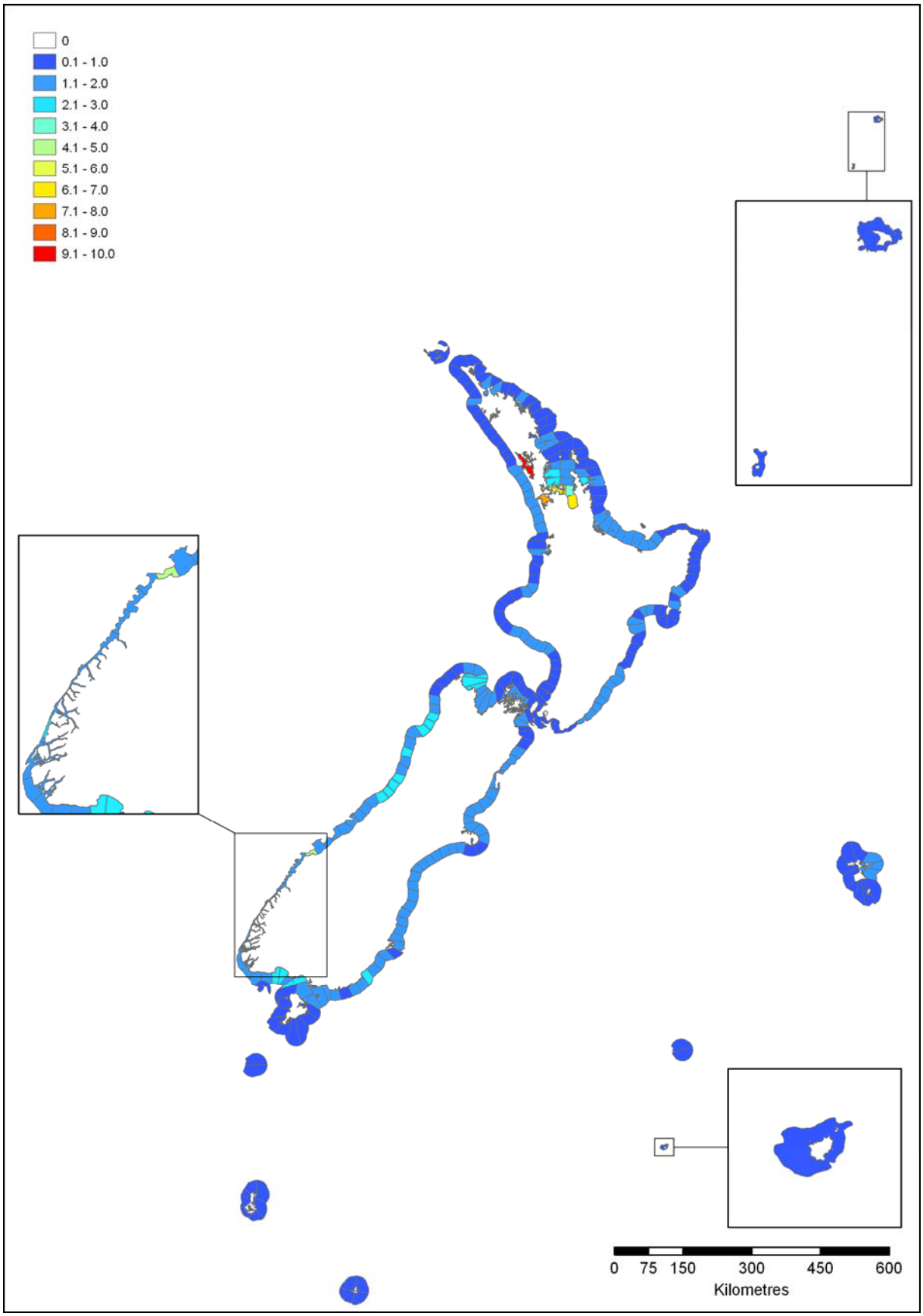


3.2.8 Primary production: Chlorophyll-*a*

Mean annual near-surface chlorophyll-*a* concentrations, generated by SeaWIFS satellite imagery, used here as a proxy to quantify local primary production, the driver of the food chain, in coastal cells around New Zealand.

The distribution of mean annual chlorophyll-*a* concentrations around New Zealand was mapped (Figure 23). As with the other summary maps, the mean values were ranked from 1 to 10. Coastal cells with a high mean annual chlorophyll-*a* concentration were assigned a high rank (10) and those with a low mean annual concentration assigned a low rank (1). Primary production is relatively constant around the New Zealand coastline with the exception of the Kaipara and Manukau Harbours and southern Hauraki Gulf which have very high mean annual concentrations.

Figure 23 First-stage summary map: Habitat: Primary productivity. Ranked value of mean annual concentration of Chlorophyll-*a* per m^3.



3.3 SECOND-STAGE SUMMARY MAPS: BIOLOGICAL DATA

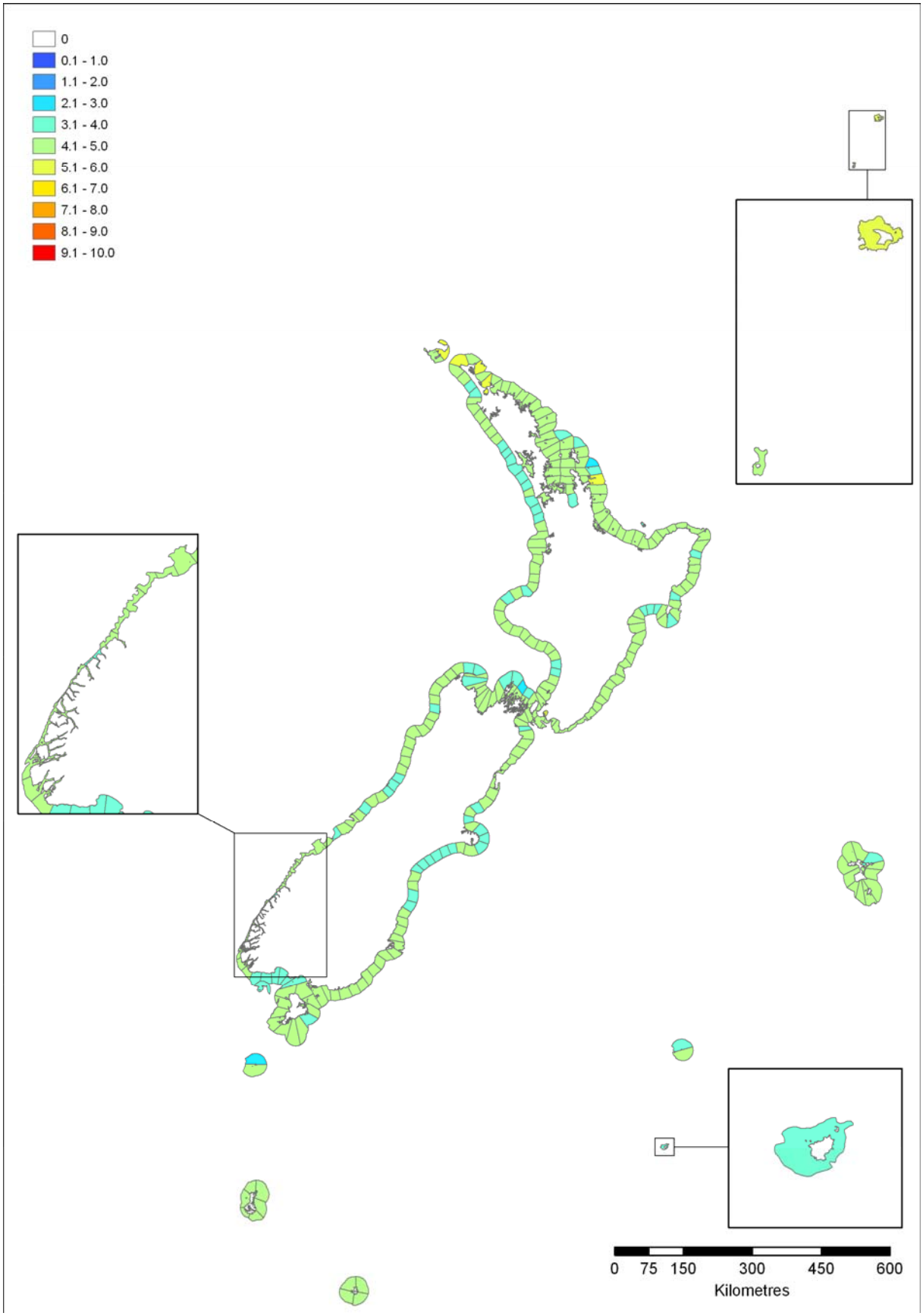
3.3.1 Summary map: Taxon-specific diversity

This second-stage summary map (Figure 24) combines all ten taxon-specific diversity summary maps (Figures 1 to 10). Taxa included in this summary are: sponges, bryozoans, polychaetes, molluscs, echinoderms, arthropods, algae, diadromous fish, wading birds and rocky reef fish. The values mapped are the mean ranks of the ten taxa in each coastal cell.

Mean values of diversity are relatively homogeneous around the New Zealand coastline (Figure 24). The Kermadec Islands, Three Kings Islands, North Cape area and a coastal cell on the east coast of the Coromandel Peninsula that includes the Mercury Islands all have relatively high mean ranks, suggesting that these areas are potentially important with respect to taxon-specific diversity. Areas with particularly low values include the south coast of the South Island, Golden Bay area, Farewell Spit, offshore from the Marlborough Sounds and the east coast of the South Island in the Banks Peninsula region. In the North Island, the northwest coast near the Kaipara Harbour appears to be particularly low with respect to taxon-specific diversity.

It should be noted that these summary values are mean ranks of a suite of diversity measures calculated from presence data from a variety of data sources. There are inherent problems associated with calculating diversity metrics from presence-only data and these are discussed in Section 4.

Figure 24 Second-stage summary map: Taxon-specific diversity.

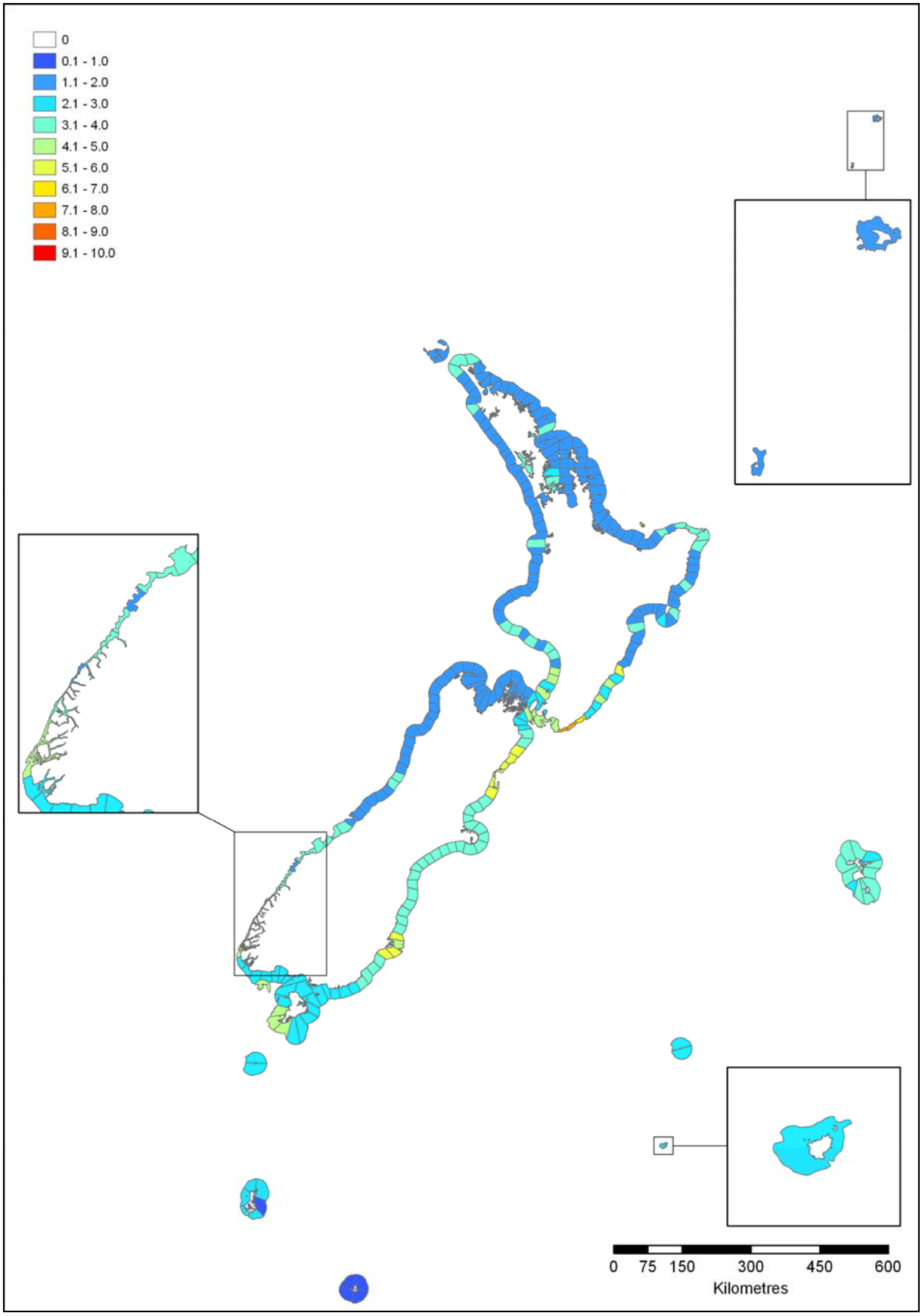


3.3.2 Summary map: At risk or threatened species

The mean ranks of the number of threatened birds and threatened invertebrate species per coastal cell were mapped (Figure 25, and see also Figures 11 and 12). Note that the ranking scale was generated using data on the presence of species rather than abundance data.

Many parts of the New Zealand coastline are important for at risk or threatened birds and invertebrates (Figure 25). Specifically, the east coast of the South Island in the Kaikoura and Otago regions and in the North Island Cape Palliser and sections of the east coast between Cape Palliser and Hawke Bay are highlighted as being particularly important areas. Stewart Island, Fiordland, the Chatham Islands, the east coast of the South Island, the Kapiti Coast, Wairarapa coast, East Cape, North Cape, Hauraki Gulf, Kaipara Harbour and the Bay of Islands are also relatively important areas.

Figure 25 Second-stage summary map: At risk or threatened species (Birds and Invertebrates).

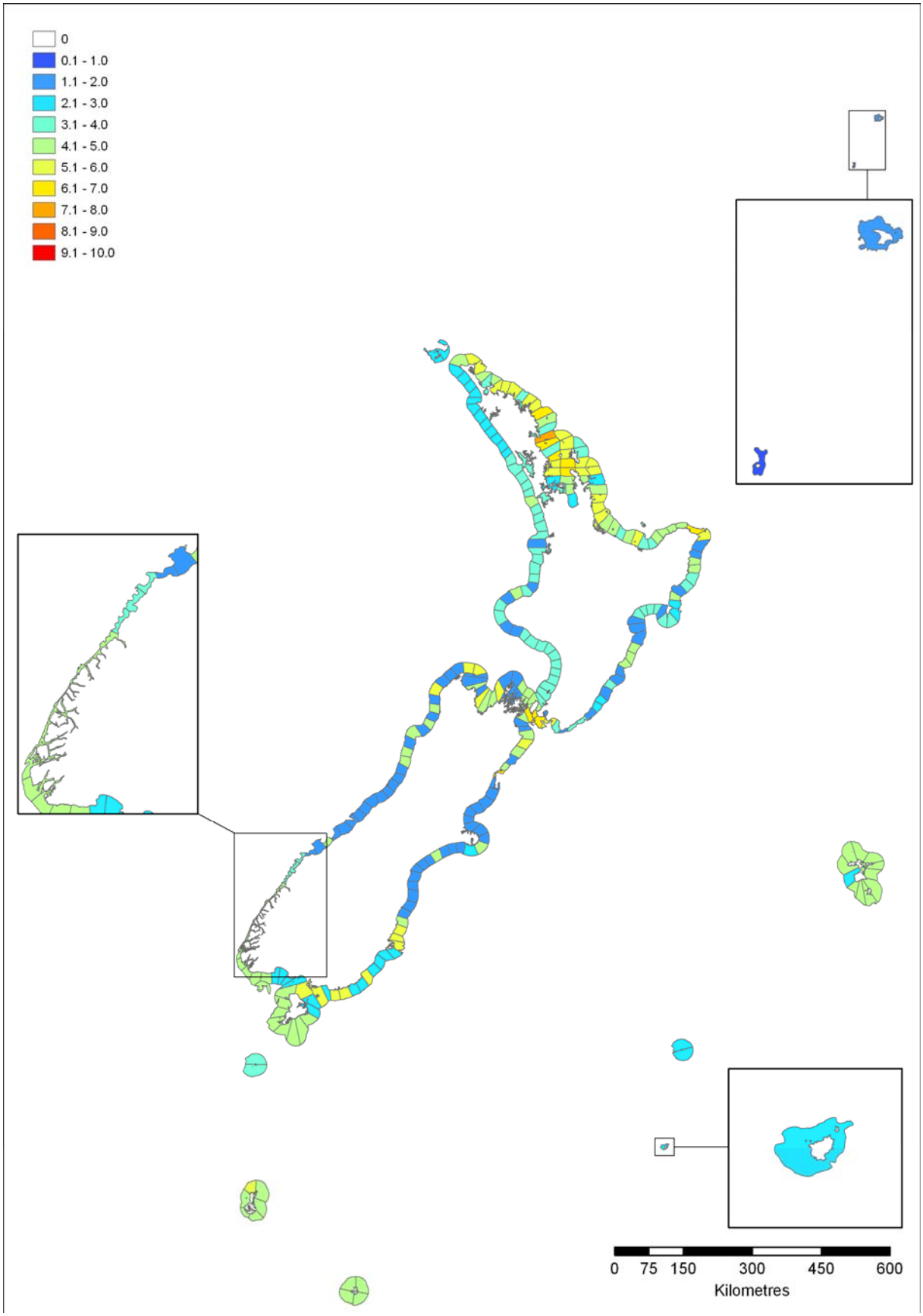


3.3.3 Summary map: Marine mammals

The mean ranks of the number of dolphins, whales and seals sighted per coastal cell (see Figures 13, 14 and 15) was mapped (Figure 26). Note that the ranking scale was generated using data on the presence of species rather than abundance data.

Marine mammals are present throughout the New Zealand coastal area, including offshore islands (Figure 26). Areas highlighted as being important for marine mammals overall (in terms of numbers of species of each of dolphin, whale and seal) include the east coast of Northland, especially around Bream Head, the Bay of Plenty and East Cape, Cook Strait, Nelson/Abel Tasman area, the northwest tip of the South Island, the Kaikoura coastline, and the Otago and Catlins coasts. Fiordland, Stewart Island, Auckland, Campbell and Chatham Islands, and the southeastern coast of the North Island all have moderately high values.

Figure 26 Second-stage summary map: Marine mammal distribution.



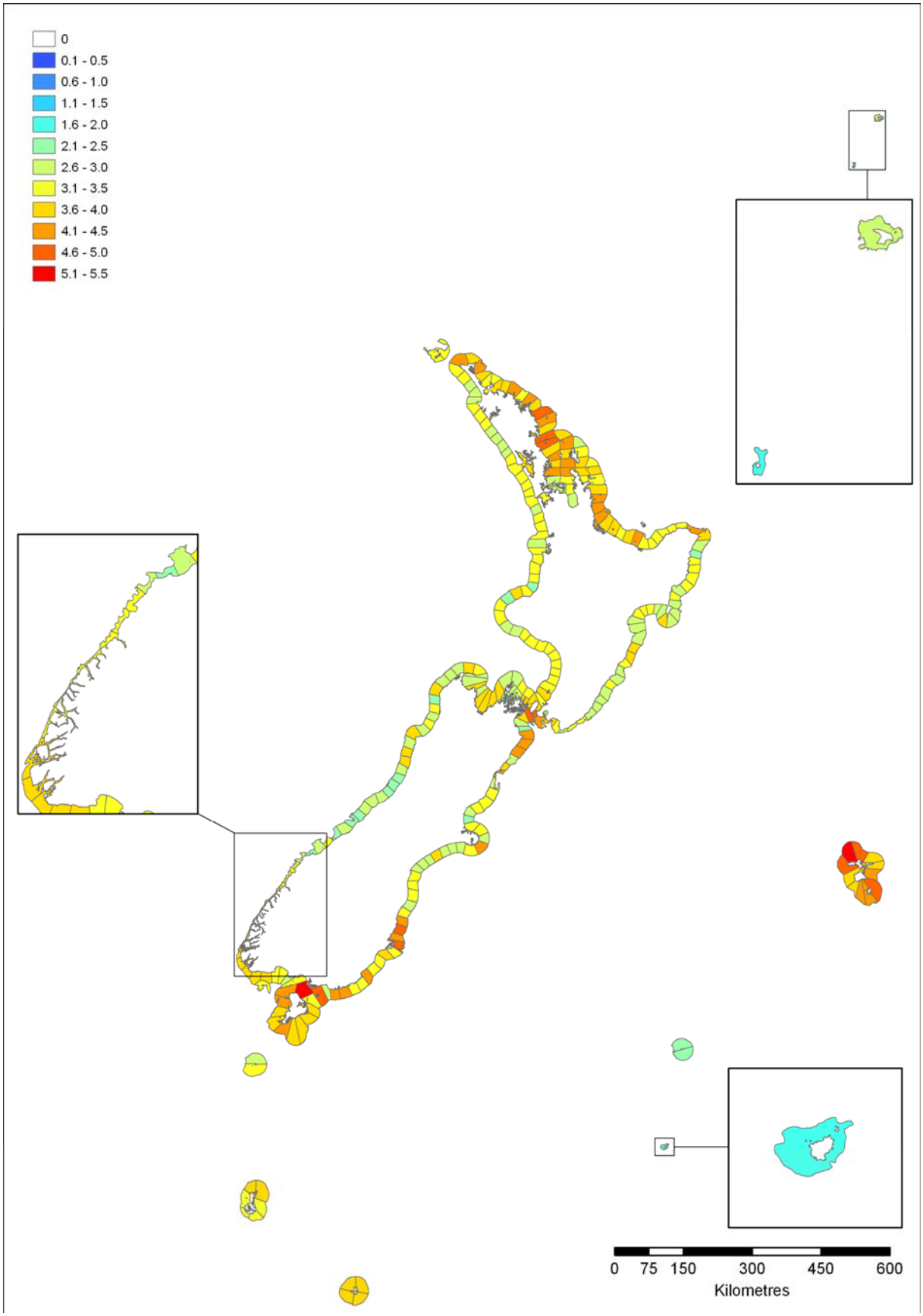
3.4 THIRD-STAGE SUMMARY MAPS: COMBINED BIOLOGICAL DATA

Figure 27 combines the data from each of the 10 taxon-specific diversity datasets (Figures 1 to 10) with the summary maps for marine mammals and at risk and threatened species (Figures 25 and 26) to give an overall indication of the importance of individual coastal cells with respect to overall biological diversity.

Mean values of the ranks for each of these datasets have been calculated for each coastal cell (Figure 27). Mean ranks are relatively homogeneous throughout New Zealand. However, there are areas which stand out as being particularly important. These areas include North Cape and the east coast of Northland, the northwestern Bay of Plenty, Cook Strait and Kaikoura coast, Banks Peninsula, the Otago and Catlins coast, Foveaux Strait and the Chatham Islands. Fiordland, the Kaipara Harbour, Stewart Island, Nelson and the Auckland and Campbell Islands are also highly ranked.

It is surprising that the Kermadec Islands, known for their unusual marine life, do not stand out as being particularly important within this summary map. As discussed previously, there are inherent problems associated with using non-standardised data types, particularly presence-only data, when determining diversity metrics. As such, these summary maps depict the available data and should be used in conjunction with the individual layers to indicate the confidence in the estimates made.

Figure 27 Third-stage summary map: Combined biological data. Taxon-specific diversity, at risk and threatened birds and invertebrates and marine mammal distribution. Mean rank of 10 biological datasets.

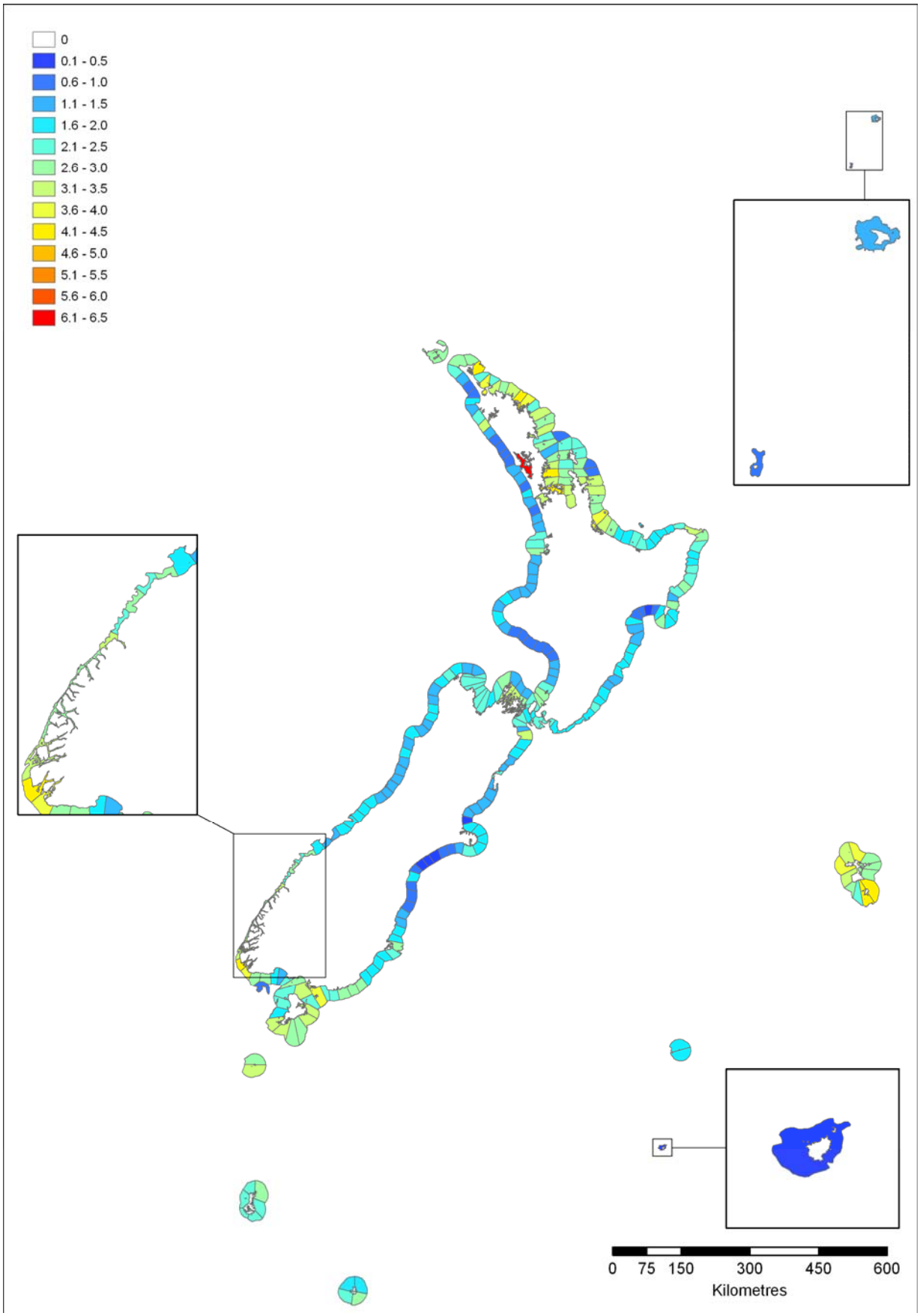


3.5 THIRD-STAGE SUMMARY MAPS: COMBINED HABITAT DATA

Figure 28 combines information from eight previously described datasets: seagrass, mangroves, intertidal rocky reefs, subtidal rocky reefs and biogenic reefs, chlorophyll-*a* concentration, MEC physical habitat categories and the habitat diversity index (Figures 16 to 23). Values plotted in the summary map are mean ranks of each of the above datasets for each coastal cell. A high value, therefore, represents an area potentially important with respect to habitat types: either containing a high number of different types of habitat or a large proportion of a specific type of habitat.

As with the third-stage combined biological data map, the values in the third-stage combined habitat data map are relatively homogeneous throughout New Zealand. However, the east coast of Northland, North Cape, the Kaipara Harbour, the east coast of the Coromandel Peninsula, East Cape, Cook Strait, Otago Peninsula, Foveaux Strait, Fiordland, Stewart Island and the Chatham Islands all stand out as having high values (Figure 28). Regions with particularly low values include the Antipodes and Bounty Islands, the Kermadec Islands, the west coasts of both North and South Islands (excluding Fiordland and the Kaipara Harbour), the east coast of the South Island and Hawke Bay and the Wairarapa coast in the North Island.

Figure 28 Third-stage summary map: Combined habitat data. Mean rank of eight habitat datasets.

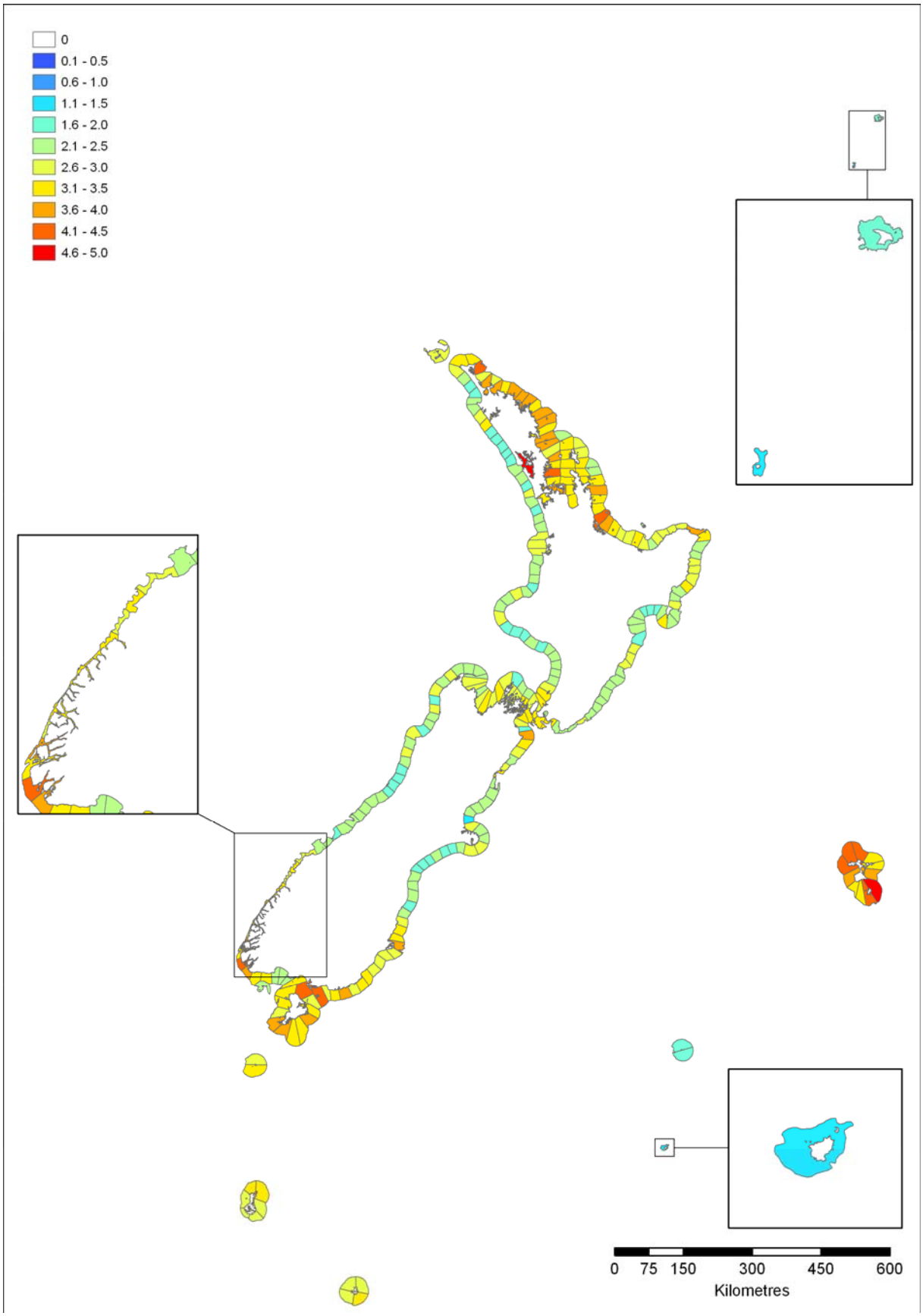


3.6 FINAL-STAGE SUMMARY MAP: ALL DATA (BIOLOGICAL AND HABITAT)

Figure 29 combines all information from both biological and habitat datasets, highlighting important areas of the New Zealand coastline with respect to both habitat and biological diversity.

Many parts of the northern North Island and the southern South Island are ranked highly; in particular the Kaipara Harbour, Parengarenga Harbour at the northern tip of New Zealand, the Kawau area of the Hauraki Gulf, Tauranga, Foveaux Strait and southern Fiordland. The Chatham Islands are also highly ranked. Other key areas include the northeastern coast of the North Island from North Cape to East Cape, Cook Strait, the Otago and Catlins coast, Fiordland and Nelson. Areas that stand out as being of overall low importance are the Canterbury Bight and much of the middle of the east and west coasts of the South Island, Hawke Bay, the Taranaki Bight and much of the west coast of the North Island and the Antipodes, Bounty and Kermadec Islands.

Figure 29 Final-stage summary map: All data. Mean ranked value of all available datasets.



3.7 RELATIONSHIP BETWEEN HABITAT AND BIOLOGICAL DIVERSITY

To identify the relationship between habitat and biological diversity around the New Zealand coastline, linear regression plots were made of habitat rank versus biological rank for each coastal cell (Figure 30) and habitat diversity index versus biological rank for each coastal cell (Figure 31). Both regressions show a weak positive relationship (r^2 = 0.1933 and 0.0628 respectively).

Figure 30 Linear regression showing the relationship between habitat and biological diversity.

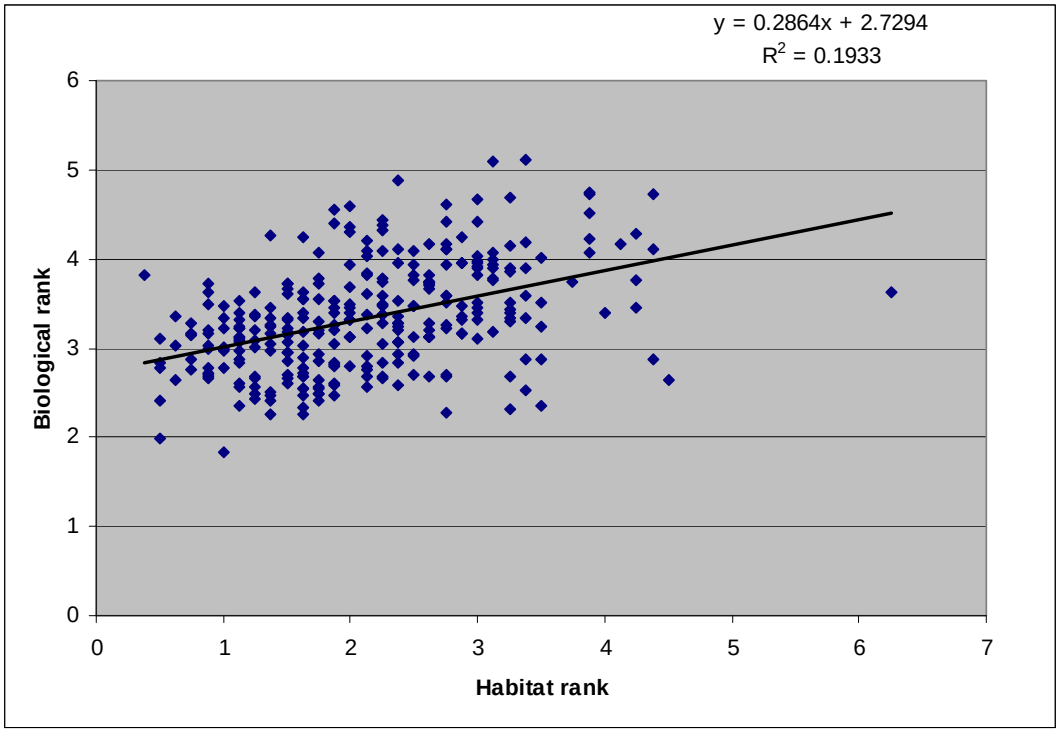
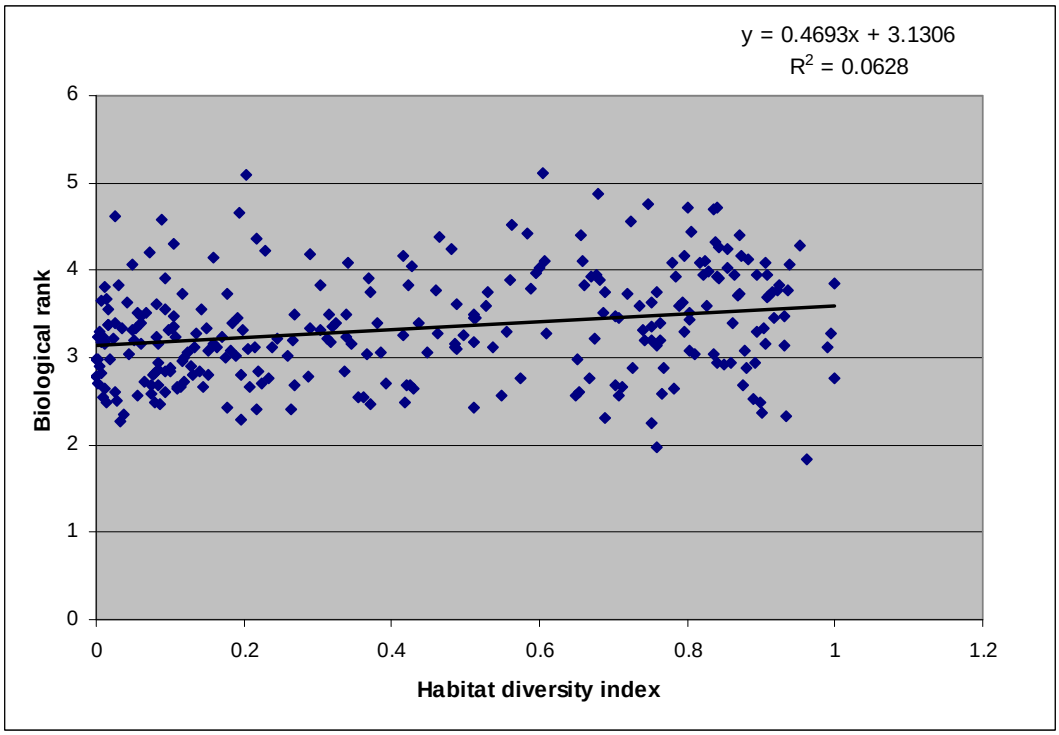


Figure 31 Linear regression showing the relationship between the habitat diversity index and biological diversity.



4 Discussion

The use of a ranking system enabled summary maps to be made of biological data, habitat data and an overall summary map of all data, thus identifying coincident hot- and cold- spots of habitat and biological diversity within the available data.

Biological hotspots for taxon-specific diversity include the Kermadec Islands, Three Kings Islands, North Cape area and the eastern coast of the Coromandel Peninsula including the Mercury Islands. At risk or threatened invertebrate and bird hotspots include the Kaikoura and Otago regions and the south eastern tip of the North Island. Marine mammal hotspots include Bream Head and the eastern Northland coastline, East Cape, Cook Strait, Nelson/Abel Tasman, the northwest tip of the South Island, the Kaikoura coastline and the Otago and Catlins coasts.

Biological coldspots for taxon-specific diversity include the northwest coast of the North Island, near Kaipara Harbour, the south coast of the South Island, Golden Bay and Farewell Spit, offshore from the Marlborough Sounds and the east coast of the South Island in the Banks Peninsula region. At risk or threatened invertebrate and bird coldspots include large areas of the northwestern coastline of the South Island, and much of the north of the North Island as well as the Kermadec Islands and Campbell Islands. Much of the east and west coasts of both the South and North Islands as well as the Bounty, Antipodes and Kermadec Islands appear to be poor with respect to marine mammals generally, though some areas are important for a specific species (e.g. the West Coast of the South Island is important for New Zealand fur seals).

When all these biological datasets were combined into one summary map, the co-incident hotspots for biological diversity highlighted include North Cape, the east coast of Northland and the northwestern Bay of Plenty in the North Island. In the South Island, hotspots include the Kaikoura coast, Banks Peninsula area, Otago and Catlins coasts and Foveaux Strait. Cook Strait and the Chatham Islands are also highlighted as hotspots. Fiordland, the Kaipara Harbour, Stewart Island, Nelson and the Auckland and Campbell Islands are also highly ranked. Areas of coincident low values (coldspots) include large areas of the west coast of the South Island and many of the offshore islands (Kermadecs, Bounty and Antipodes Islands).

Coincident high values (hotspots) with respect to habitat include the east coast of Northland, North Cape, the Kaipara Harbour, the east coast of the Coromandel Peninsula, East Cape, Cook Strait, the Otago Peninsula, Foveaux Strait, Fiordland, Stewart Island and the Chatham Islands. Coincident low values (coldspots) with respect to habitat include the Antipodes and Bounty Islands, the Kermadec Islands, the west coasts of both North and South Islands (with the exception of Fiordland and the Kaipara Harbour), the east coast of the South Island and Hawke Bay and the Wairarapa coast in the North Island.

There appeared to be many coincident hot and cold spots between the habitat and biological data summaries, so it was not surprising that a positive relationship, if only weak, was found between values of habitat and biological data. Therefore, when habitat and biological data were combined to create an overall summary map of all data, the trends reflected those seen for individual summary maps. In summary, many parts of northern coastline of the North Island were ranked very highly, including the Kaipara Harbour, Parengarenga Harbour at the northern tip of New Zealand, the Bay of Islands area, the inner Hauraki Gulf, particularly in the vicinity of Kawau, and northwestern Bay of Plenty, as well as Foveaux Strait, the Otago Peninsula, southwest Fiordland, Stewart Island and the Chatham Islands.

The offshore islands around New Zealand, particularly the Kermadecs, Bounty and Antipodes Islands, had surprisingly low overall values in the second-stage, third-stage and overall summary maps. While it is possible that these low values are a true reflection of the marine ecosystem in some of these areas, it is more likely that these low values are a consequence of the type of information used within this meta-analysis to generate these summary layers. The marine ecosystem around the coastline of the Kermadec Islands, for example, supports New Zealand's only tropical coral reef systems. However, while this coral habitat was included in the analysis as a biogenic reef, it was not included as a habitat in its own right and so does not gain extra weighting within the meta-analysis for being a unique habitat. The habitat diversity value of many of the offshore islands within this study, calculated using measures such as the number of MEC physical habitat categories and number of known habitats (seagrass, rocky reef, mangrove etc.) was relatively low and so these habitats, despite their often unique qualities, were not highly represented within the summary layers. The Kermadec Islands are also known to support a fish community that differs from much of New Zealand as a result of the presence of many tropical species. While this area would have been ranked highly within the species composition index, within the taxon-specific diversity metrics, the uniqueness of these species would not have resulted in high ranked values in most of the other diversity indices. This lack of recognition of "uniqueness" may have resulted in many areas within the New Zealand coastal zone being under-represented within the summary layers of this meta-analysis.

With the exception of the rocky reef fish dataset and the summary map of seal distributions around New Zealand, there does not appear to be a relationship between latitudinal gradient and ranked values around the New Zealand coastline. However, very often northern and southern extremes of each of the North and South Islands were ranked particularly highly. This may be a consequence of the interaction of strong oceanic currents and shelter from oceanic swells provided by the presence of islands and/or a highly complex coastline.

4.1 DATA LIMITATIONS

There are limitations with the data available within this study that should be noted (Beaumont *et al.* 2008). The summary layers created within the meta-analysis were often generated using diversity metrics derived from patchily-distributed presence-only data. This is particularly true of the taxon-specific diversity datasets which contained historical/museum records i.e. presence at a location rather than presence/absence data. This made generating estimates of many diversity indices problematic, particularly that of species richness.

For many datasets, it was necessary to join poorly populated coastal cells to neighbouring cells to form "coastal areas" in order to have enough data records to enable diversity metrics to be calculated (Beaumont *et al.* 2008). In all cases, the total number of records per coastal cell for each taxon has been included in the original database, together with a data layer detailing which coastal cells have been joined into coastal areas. These data layers should be used to determine the confidence in the value assigned to each coastal cell or area. For example, the confidence in the value assigned to a coastal cell with 200 records is far greater than for that of a coastal cell which had one original record and has been joined to six neighbouring coastal cells in order to generate a value.

It is not only the biological data that should be interpreted carefully. With the exception of the intertidal rocky reef layer, where data on the distribution of the habitat was generated from aerial photography, all habitat layers are a best estimate of distributions. Data sources ranged from digitised hydrographic faring sheets (subtidal rocky reef layer) to personal communications on the existence of small habitat patches. Distributions of many biogenic

habitats (seagrass, mangroves, biogenic reefs) are also known to have temporal variation. As such, the fine-scale accuracy of habitats is only as good as the available data and cannot be relied upon.

It is therefore stressed that the summary maps created are a best estimate of the coastal habitats and biodiversity around New Zealand using the available data.

4.1.1 Intellectual property

All derived values and raw data have been provided to MAFBNZ with the exception of the raw data for the algal, mollusc and wading bird datasets. The intellectual property rights for these remain with Te Papa (algal and mollusc data), and the Ornithological Society of New Zealand (wading bird data).

4.2 RECOMMENDATIONS

The values that have been mapped are an estimate using the data available. It is strongly recommended that these data are ground-truthed in the near future through the use of a standardised sampling regime at key locations around the New Zealand coastline. These key locations should include areas with a range of diversity values (high, low and medium values) as well as areas lacking in data.

5 Acknowledgements

We would like to acknowledge all those who have contributed to this project. In particular thanks go to the data providers; Anne-Laure Verdier and James Sturman at NIWA for creating the data layers within GIS; and MAFBNZ for commissioning this meta-analysis.

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