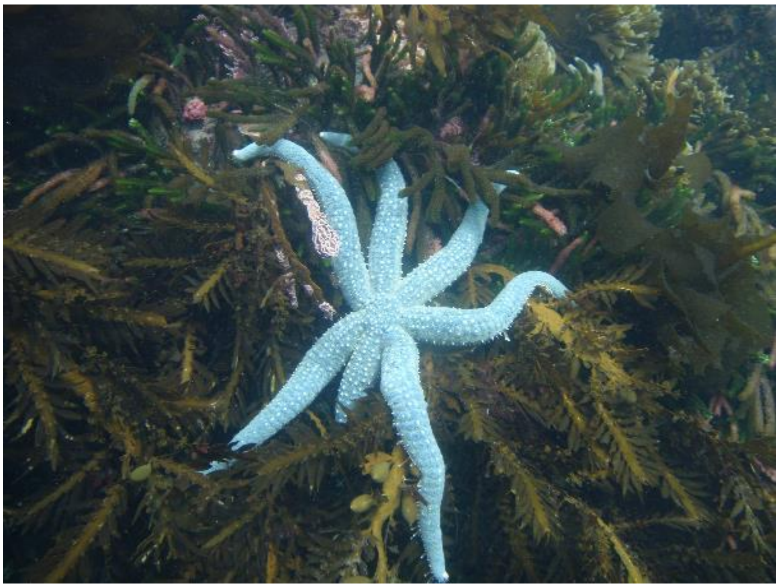
Technical Report 18

NIWA – Ecological Character Report

Ecological characterisation of Lyall Bay, Wellington

Prepared for Wellington International Airport Ltd

March 2016



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Cover image: The seastar *Astrostole scabra* on a reef along Transect E, Pete Notman, NIWA

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Executive summary

Wellington International Airport Limited (WIAL) proposes to extend its runway southwards into Lyall Bay (Huetepara) to achieve a minimum Take Off Runway Available (TORA) of 2300 metres. WIAL engaged NIWA to undertake a snapshot ecological assessment to characterise the Lyall Bay ecosystem, including water colour and clarity, plankton, and seafloor communities, over spring 2014 – and to characterise seabirds, marine mammals, fish, and fisheries over longer periods using existing data. Companion NIWA technical reports are Pritchard et al. (2015) on coastal hydrodynamics and sediment processes and Depree et al. (2015) on marine sediments and contamination.

The deployment of a mooring in Lyall Bay provided an assessment of the dynamics in optical water quality and estimates of total suspended sediment from turbidity over the spring month of September 2014. The deployment captured calm periods and several storm events, with corresponding reduction in visibility range and euphotic zone depth.

Plankton characteristics (phytoplankton and zooplankton abundance and species composition, chlorophyll-a concentrations) in Lyall Bay were typical of those in the Greater Cook Strait region, reflecting tidal mixing, upwelling, and stratified water conditions.

Sediments in Lyall Bay, due to its southern exposure, are dominated by well sorted fine sand. Gravels occurred only along the eastern margin.

Low particulate organic carbon (POC) values in Lyall Bay reflect the predominance of fine sandy sediments, the low biological infaunal biomass and the high levels of re-mobilisation of these surficial sediments by waves and tides. The overall low particulate nitrogen content and moderately high carbon to nitrogen ratios in surficial sediments, especially along the easternmost side of Lyall Bay in the area of the proposed runway extension, reflect the overall low contributions of organic matter to these sandy sediments.

The highly mobile nature of the surficial sandy sediments in Lyall Bay, and resulting low chlorophyll-a content, suggests that microphytobenthic activity is not a dominant factor on the seafloor. None of the three dinoflagellate cyst types found in seafloor sediments in Lyall Bay were produced by any of the harmful species previously identified in ports and harbours of New Zealand.

The soft-sediment seafloor communities assessed in Lyall Bay are typical of those found along Wellington's south coast. There is low overall abundance and species richness of epi- and macro-infaunal communities, most likely reflecting the exposed nature of this environment. Video imagery suggests that ghost shrimp, *Biffarius filholi,* comprise the bulk of the macro-infaunal biomass in the shallow half of Lyall Bay.

Meiofauna was the most abundant component of the soft sediment community in Lyall Bay with densities close to the average values reported for this type of habitat. The community was dominated by nematodes and harpacticoid copepods, and somewhat unusually, by kinorynchs and tardigrades at some sites. Monitoring the meiofaunal community would provide an ecologically meaningful indicator of the environmental conditions present at the seabed and would provide a means to gauge recovery following disturbance through comparisons with baseline data.

Apart from the areas of artificial substrates, especially in the intertidal and shallow subtidal zones, the rocky reef communities assessed in Lyall Bay are typical of shallow reef habitats along the Wellington south coast. They support a rich and diverse range of brown, red and green macroalgae which not only are key contributors to coastal ecosystems through the energy captured via

photosynthesis, but they also provide highly structured three-dimensional habitats critical for other grazing and predatory reef species, some of which are valuable food organisms such as paua, kina and rock lobsters, as well as a range of reef fish. Compared to a longer-term, wider area, survey of intertidal rocky reef communities on Wellington's south coast, the intertidal rocky reef communities in Lyall Bay sampled during this study can be expected to reflect the annual average for this site.

Lyall Bay has a moderately diverse reef fish fauna with only 27 of the 72 species modelled New Zealand-wide, predicted to occur on reefs within SCUBA diving depth range. None of the modelled species are nationally threatened. There was good agreement between the reef fish species observed by divers during algae and invertebrate counts and the modelled species predicted to be most common in Lyall Bay.

Adults of 44 species of demersal fish are predicted to occur in Lyall Bay, though 21 species are predicted be rare here, and another 12 species are predicted to be uncommon. Just 11 modelled species were predicted to be common in Lyall Bay.

Of the New Zealand total of seabird species at least 26% occur in the Cook Strait region, while for marine mammals at least 17% occur in the region. However, only a relatively small sub-set of seabird and marine mammal species occurring in Cook Strait have been recorded in Lyall Bay close to the southern end of the airport and there is little, if any, evidence to suggest these areas are important for seabirds and marine mammals, either as breeding sites or feeding zones. While blue penguins breed along the south coast of Wellington including the Moa Point area, it is unlikely this species breeds in the rock wall to the south of the airport as the exposure to wave action here would be relatively high.

In conclusion, Lyall Bay is the largest embayment along Wellington's southern coast line. It comprises three main habitats; the water column pelagic environment, sandy seafloor sediments in the main part of the bay, and rocky reefs around the bay's eastern and western margins. The fauna and flora associated with these habitats in the area potentially affected by the proposed airport extension are typical of that in adjacent habitats in Lyall Bay, which in turn are typical of those along Wellington's south coast. The potentially affected areas in Lyall Bay are not critical habitat for any threatened or rare species.

The only commercial fisheries known to operate near Lyall Bay are rock lobster potting and set netting for butterfish, and these are confined to the headlands at Moa Point on the east and Te Raekaihau Point, adjacent to the Te Taputeranga Marine Reserve boundary, on the west.

In contrast, recreational fishing does occur in the area potentially affected by the proposed airport extension. Rod and line fishing from the shore frequently occurs in Lyall Bay, particularly from the existing breakwater at the south-west corner of the existing runway, and hand-gathering of paua, kina, and rock lobsters occurs from the reefs at the southern end of the runway. Recreational set netting, probably for butterfish, occurs around the south-eastern entrance to Lyall Bay south of the airport.

1 Introduction

Wellington International Airport Limited (WIAL) operates on a constrained footprint in the coastal suburb of Rongotai. The airport has a single 1945 m Take-Off Runway Available (TORA), with 90 m safety areas at each end of the runway. WIAL proposes to extend the runway southwards into Lyall Bay (Huetepara) to achieve a minimum TORA of 2300 metres. This will require construction of a runway platform over reclaimed land (AECOM 2015).

Coastal environmental information is required primarily to support applications for coastal permits and consents and Notices of Requirement (NOR) for the Airport runway upgrade. WIAL engaged NIWA to provide reports on the coastal hydrodynamics and sediment processes (Pritchard et al. 2015), marine sediments and contamination (Depree et al. 2015), and marine ecology of Lyall Bay. This report focuses on the marine ecology of Lyall Bay within the context of the broader Wellington south coast and Cook Strait marine environment. As there was limited time available to conduct the ecological assessment, a snapshot approach was undertaken to characterise the Lyall Bay ecosystem, including water colour and clarity, plankton, and subtidal soft sediment and rocky reef communities occurring in the vicinity of the proposed extension, over spring 2014. Seabirds, marine mammals, fish, and fisheries were characterised over longer periods using existing data. This was sufficient to characterise the Lyall Bay ecosystem, set the findings in a broader regional ecological context, and enable the potential ecological impact of the proposed runway extension to be assessed (see James et al. 2015).

2 Methods

2.1 Water optical quality

2.1.1 Optical water quality parameters

The 'natural' state of optical water quality in Lyall Bay provides background context to the potential impacts of suspended particulate matter (SPM; quantified as total suspended solids, TSS) from the proposed airport extension. Optical water quality parameters of interest are its colour and clarity. In an ecological and environmental context, clarity is arguably more relevant and has two important aspects that respond in differing ways to changing optical properties: light penetration and visual clarity (Davies-Colley and Smith 2001).

Light penetration is quantified by the diffuse downward light attenuation coefficient (K_d), which determines the quantity and quality of light at a given depth. A convenient index of light penetration is the euphotic zone depth (z_{eu}), defined as the depth at which photosynthetically available radiation (PAR, 400-700 nm) is reduced to 1 % of surface values [$z_{eu} = \ln(100)/ K_d = 4.6/ K_d$] (Kirk 2011).

Visual clarity has historically been measured in the vertical direction as the disappearance distance of a black-and-white Secchi disk (z_{SD}), related to the ambient light conditions, K_d and beam attenuation (c). However, the horizontal visibility of a black target or disk viewed underwater (y_{BD}) is theoretically superior as an index of visibility in water, being directly related to the beam attenuation coefficient near the peak sensitivity of the human eye (~ 550 nm; green light) : $y_{BD} = 4.8/c550$ (Davies-Colley, RJ 1988). This 'robust' index of underwater visibility (Zaneveld and Pegau 2003) provides a useful index of the visual field of prey and predator organisms in water, and can be used to estimate beam attenuation or, vice-versa, visibility can be calculated if c is known.

Water **turbidity** (cloudiness) is a property of light scattering by suspended fine sediment, mainly from the 2-63 um diameter size range (Davies-Colley, R. J. and Smith 2001). Scattering properties vary greatly due to the nature of particles (size, shape, type – organic/inorganic). Turbidity can only be considered a relative index of scattering due to differences in optical design from manufacturers (e.g. angles of scattering, wavelengths of light used), of an arbitrary standard, typically formazin (Davies-Colley, R. J. and Smith 2001). However, optical backscatter sensors (OBS) that measure turbidity *in-situ* have found extensive use in monitoring TSS, due to their continuous operation, wide dynamic range and relative in-expensiveness compared with other sensors (Downing 2006). Therefore, turbidity sensors relate (in part) to light penetration and visual clarity, when TSS is dominant in the water column, but requires location and time specific calibration, as these relationships will vary with particle characteristics.

Other light-attenuating components (LAC) are phytoplankton - quantified by the concentration of the main photosynthetic pigment, Chlorophyll-a (Chla), and Coloured Dissolved Organic Matter (CDOM) - quantified by its absorption at 340 or 440 nm. Together with TSS, the concentrations and proportions of these LACs determine the optical properties of waters.

An optical mooring was used at the entrance to Lyall Bay to capture dynamics in optical water quality parameters across a range of natural conditions (calm to storm events) over a 34 day period. On-site sampling, a synoptic survey and laboratory suspended sediment calibrations were used to calibrate mooring parameters and develop relationships between the variables.

2.1.2 On-site sampling and synoptic survey

The optical mooring site (Figure 2-1) was sampled at the time of mooring deployment and recovery and other opportune moments during the deployment period, for: vertical visibility, using a black and white Secchi Disk (z_{SD}); and surface water colour, matched to Munsell Standards. Water samples were taken with a 10 L Niskin water sampler from two depths (top and bottom) corresponding to the depths of the moored sensors.

Water samples were transferred into carboys for subsequent courier delivery (chilled) within 24 hours to NIWA's Hamilton laboratory for analysis of: Turbidity (Method APHA 2130B - Standard Methods for the Examination of Water and Wastewater, 21st Edition, 2005); TSS, and its organic (OSS) and inorganic (ISS) fractions (Method APHA 2540D); Chl*a* concentration (Method APHA 10200H); and CDOM absorption at 340 nm (Davies-Colley 1992).

A spatial survey at the 11 other sites (Figure 2-1) was made after mooring deployment using the same types of sensors as on the mooring (see below - turbidity, beam attenuation and PAR) attached to a vertical profiling conductivity, temperature, depth probe (CTD; Biofish, ADM). The vertical profiles assist in developing relationships between optical parameters and evaluate spatial gradients.

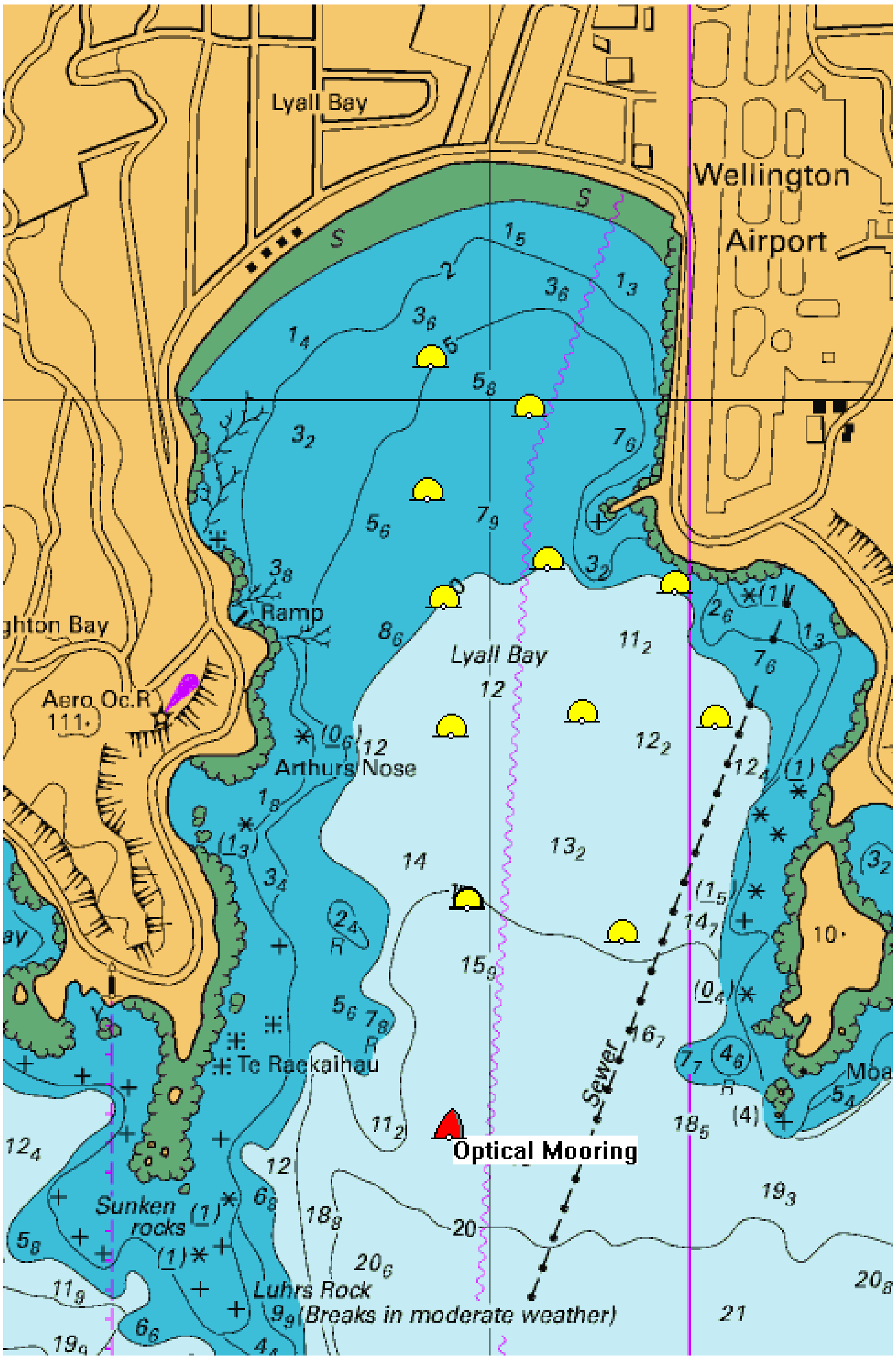

Figure 2-1: Location of optical mooring and synoptic survey sites. The optical mooring (red) is the outer most site in relation to other synoptic sites (yellow).

2.1.3 Laboratory suspended sediment relationships

Opportunities were limited for on-site water collections, and visits were biased toward relatively calm conditions. Laboratory suspended sediment calibrations were undertaken to calibrate turbidity and beam attenuation sensors (see below) across a range expected during mooring deployment. Data from a turbidity sensor with different configuration properties (XYLEM/YSI EXO sonde, infra-red 895 nm, 90 degree scatter) was also used to determine response differences between turbidity sensor types and monitor readings in real-time.

About 20 kg of benthic sediment (muddy-silty-sand) was collected from several sites across Lyall Bay to provide an adequate representation of the sediments likely to be lifted into the water column during wave events and 'measured' by the different sensors. A 200 L black barrel of filtered (< 0.5 μ) seawater was prepared days prior and allowed to equilibrate to room temperature to minimize bubble formation on surfaces during the experiment. Turbidity and beam attenuation sensors to be used on the optical mooring (see below) were placed in the barrel for calibration prior to deployment. A slurry of sediment was made with filtered (0.5 μ) seawater (to remove suspended sediments and phytoplankton). Fine suspended sediments from the slurry were added to the tank to provide turbidity loadings in steps of about 5 FTU. Two large bilge pumps in the bottom of the tank were used to ensure even and continual mixing. Turbidity was monitored on each addition until the desired turbidity was reach and stable. Sensor measurements were recorded on sampling intervals (about 1 min) planned for mooring deployment. After each measurement a water sample (1 L) was collected for laboratory analysis (Turbidity, TSS, ISS and OSS), to develop TSS-turbidity and beam attenuation relationships.

2.1.4 Optical mooring

The sub-surface mooring was deployed on the 4th Sept. at the entrance to Lyall Bay (-41.34877 S, 174.79878 E) in about 20 m of water (Figure 2-1). The mooring was designed (Figure 2-2) to withstand 5 m swells at Lowest Astronomical Tide (with the top portion 5 m below the surface), and instrumentation packages with sensors were positioned to sample upper (9 m) and lower (18 m) parts of the water column. Turbidity sensors (Seapoint, 895 nm IR, 15-150 degree scatter) and beam transmissometers (Wetlabs, C-Star, 530 nm, 10 cm path-length) were integrated into DOBIE wave gauges (NIWA) for power and logging. DOBIE wave gauges are equipped with an accurate pressure sensor and were configured for high frequency burst sampling over the 4 gain settings of the Seapoint turbidity sensors, sampling for about 3 min at 15 min intervals. Aquatech turbidity instruments (Seapoint sensors integrated into a small self-powered, logging units) were deployed alongside DOBIEs for redundancy and comparison. These auto-gaining instruments sample at 15 min intervals for a 1 min period. Downwelling PAR irradiance light sensors (Odyssey) were placed at the main instrument packages and about 4 m above, integrating over 15 min (top) and 30 min (bottom) periods for estimates of the downwelling light attenuation (K_d) in each part of the water column. All optical sensors were fitted with Hydro-wipers (ZebraTech) to minimise bio-fouling. The mooring was recovered about a month later on the 8th Oct.

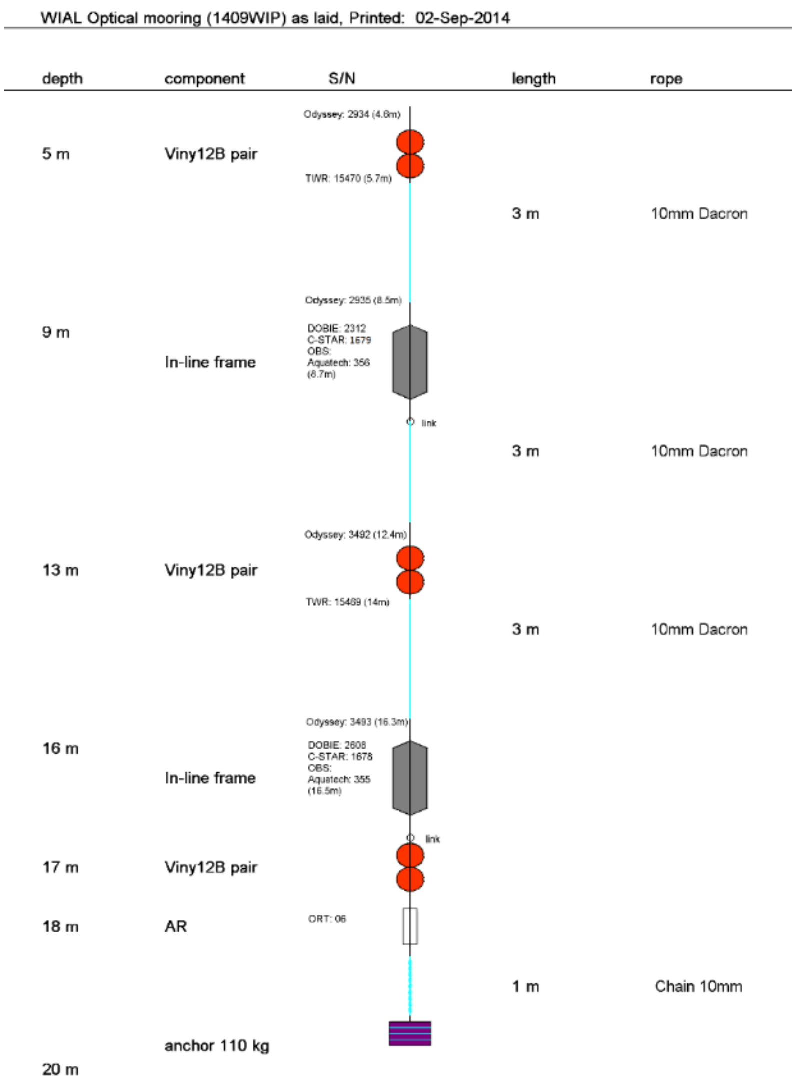

Figure 2-2: The optical mooring design. This diagram illustrates the positions (depths) of optical water quality sensors. S/N = serial number.

2.2 Plankton

2.2.1 Phytoplankton sampling

Surface water samples (150 ml) were collected from the inner (Sites 1 and 6), mid (Sites 3 and 7) and outer (Sites 5 and 9) parts of Lyall Bay (Figure 2-3), on 15 September 2014, and preserved with 1 % acidified Lugol's iodine solution. These samples were stored in dim light until cells were identified and counted. All samples of living material were collected under NIWA's special permit (505) with the Ministry for Primary Industries (MPI).

Subsamples (minimum 10 mls) were first transferred to sedimentation chambers. Identification of phytoplankton taxa and cell enumeration in Lugol's iodine samples were made using a Nikon Diaphot-TMD inverted light microscope after settling in the sedimentation chambers for at least 24 hours (Chang and Gall 1998). Taxonomic identification followed Hustedt (1958), Cassie (1963), Hasle

(1969), Taylor (1976), Hasle and Syvertsen (1997) and Steidinger and Tangen (1997). At least 100 cells in total (up to 400 cells) were counted at 100x magnification for diatoms, dinoflagellates and flagellates.

Figure 2-3: Zoo and phytoplankton sampling sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

2.2.3 Zooplankton

Zooplankton communities in Lyall Bay were characterised on 15 September 2014 by completing a grid of six zooplankton net casts in the inner (Sites 1 and 6) , mid (Sites 3 and 7) and outer (Sites 5 and 9) parts of Lyall Bay using a 570 mm diameter WP2 drop-net with 200 µm mesh (Figure 2-3). Samples were preserved in 10% formalin and sent to NIWA's Christchurch laboratory for analysis by a zooplankton identification expert. The data were graphically displayed to show spatial trends in zooplankton community composition and the abundance of key groups within Lyall Bay. All samples of living material were collected under NIWA's special permit (505) with the MPI.

2.3 Soft-sediment habitats and communities

Communities occurring on and in the sandy sediments in Lyall Bay were characterised using seafloor imaging, epibenthic sled tows and sediment coring. All samples of living material were collected under NIWA's special permit (505) with the MPI.

2.3.1 Seafloor imaging

Soft-sediment habitats in Lyall Bay were characterised along transects at 13 sites (Figure 2-4) using photographs and video obtained with NIWA's CoastCam2 towed imaging system (Figure 2-5). The camera frame, which weighs approximately 50 kg, was suspended on a 9 mm diameter cable from the NIWA inshore vessel R.V. Ikatere. Camera tows were made in water depths of 5 – 16 metres with an optimal tow speed of 0.5 – 0.8 knot. The target altitude of the camera frame is around one to two metres off the seafloor. However, during this survey, poor water clarity/visibility meant that the camera frame had to be flown closer than 1 metre to the seafloor. This resulted in less than optimal image exposure for some of the images and video.

The CoastCam2 is equipped with 2x Canon 580EXII flashguns via a Canon ST2 Speedlight transmitter using ETTL to determine the appropriate flash levels. Both flashguns and the still camera are powered by separate extension battery packs located inside pressure housings. CoastCam Video footage was obtained via a Sony SR12 camcorder recording at 1080i HD. The Camera was positioned in the frame to view the sea floor at an angle of 70 degrees looking forward. Lighting for the Sony SR12 was provided by a single 24 volt, 80 Watt, 5500 Lumen, 6000K colour temperature depth rate LED lamp with a 30^{o} beam pattern. Both the stills camera and video camera had scaling lasers set at 200 mm apart to enable sizes of any features/organisms to be determined.

Post survey, the video was observed by one trained analyst (Stewart) and positional data established by matching the camera times to data from the vessels navigational plotter. Substrate types were determined while reviewing footage and notes were made of conspicuous invertebrates, fish and flora. Objects less 3 cm in length viewed on video could not be identified with any certainty.

Figure 2-4: Location of Coastcam deployments in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

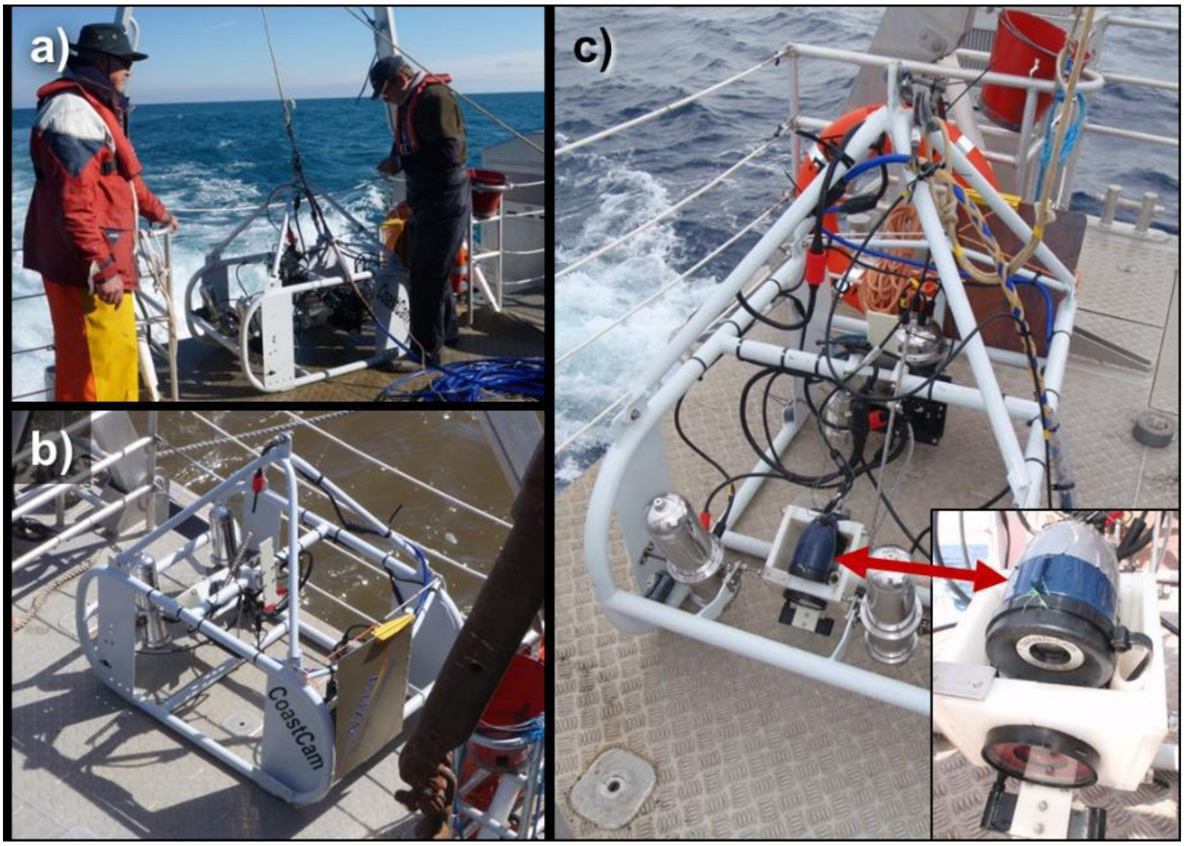

Figure 2-5: NIWA CoastCam imaging system used to survey soft sediment habitats in Lyall Bay.

2.3.2 Epibenthic sampling

Epi-fauna and -flora (fauna and flora living on or at the surface of the seabed) was characterised at 13 sites in Lyall Bay with one epibenthic dredge per site (Figure 2-6). Sites were sampled using NIWA's small (35.5 cm wide by 16 cm high) Oklemann dredge with a 3 mm aluminium mesh grate (Figure 2-7). Each deployment was from the stern of *Ikatere* withthe dredge towed along the seabed at 2 knots for 2 minutes, using a length of 10 mm Kevlar rope at least three times the water depth, covering a linear distance of approximately 120 m. Dredge track and distance were recorded using the vessels navigational plotter. Dredge tows were positioned on the same transects used for the camera imaging survey (described above).

Upon retrieval, the contents of the dredge net was emptied into a labelled plastic container, which was later transferred to the laboratory and immediately chilled. The dredge was always rinsed between deployments to prevent sample contamination between sites. The following day specimens from each catch were carefully separated into broad taxonomic groups (e.g., brittle stars, sea-stars, algae, worms, and crustaceans). Specimens were then preserved in either 99% ethanol (e.g., most taxa), 4% buffered formalin (e.g., algae and worms), or frozen (e.g., bivalves and gastropods) for identification to species or operational taxonomic unit (OTUs) by experts. Once identified, specimens were archived in NIWA's National Marine Invertebrate Collection at Greta Point, Wellington.

<u>Statistical analyses</u>

Analyses of univariate (abundance) and multivariate variables (community structure) were conducted using statistical routines in the software package PRIMER v6 (Clarke and Gorley 2006).

Multivariate analyses of epibenthic community structure were based on similarity matrices built using Bray-Curtis similarity of log (X+1)-transformed abundance data (Clarke et al. 2006). This transformation was used to decrease the influence of the numerically dominant species on patterns of community structure. The SIMPROF routine in PRIMER was used to identify any natural groupings in the dataset (P set at 0.05 and 0.1).

Relationships between environmental variables (i.e. water depth, sediment chl*a* and phaeopigment concentrations, nitrogen and carbon content, and %gravel, sand, silt, and clay particles – see section 2.3.3) and epibenthic abundance, diversity, and community structure were investigated using Distance-based Linear Models (DistLMs) in PERMANOVA+ (Anderson et al. 2008). The community structure similarity matrix was built as described above, whereas abundance and diversity similarity matrices were built using Euclidean distance of untransformed data (Anderson et al. 2008).

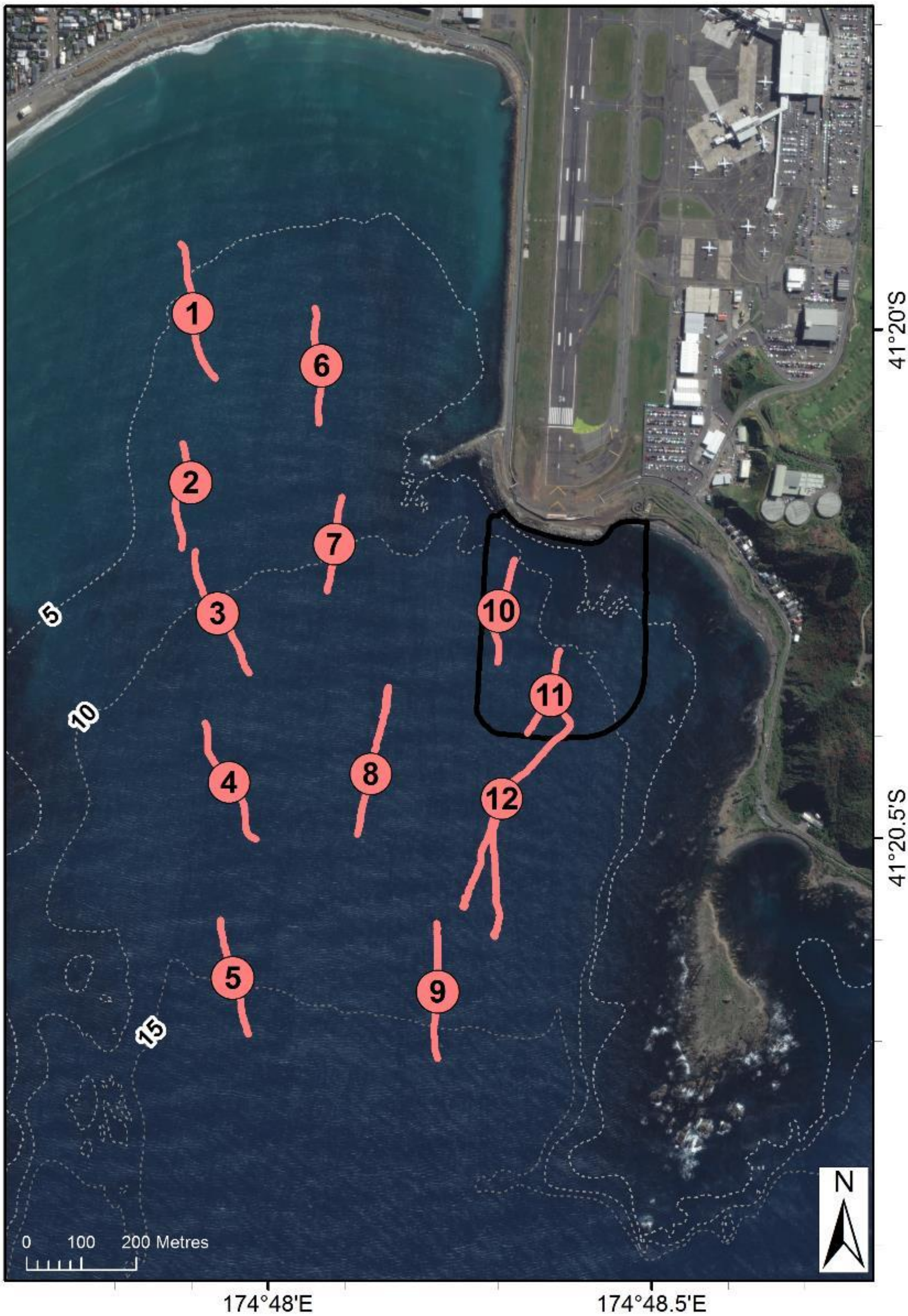

Figure 2-6: Location of epibenthic dredge tows in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

Figure 2-7: Okklemann dredge on Ikatere used for sampling epibenthic habitats in Lyall Bay.

2.3.3 Infaunal sampling

Field sampling

Seabed sediments and the associated infauna were sampled from 13 sites in Lyall Bay (Figure 2-8). Sites were positioned on each transect occupied during the camera imaging survey and dredge tows (described above). At each site, three cores were obtained using NIWA's KC Denmark HAPS corer (Figure 2-9a); one for sampling macrofauna (> 0.5 mm), another for meiofauna (< 0.5 mm), and one for sampling sediment characteristics (i.e., concentrations of Chl*a*, phaeopigment (phaeo), particulate nitrogen (PN), and particulate organic carbon (POC)). Sediment grain size was also determined on each of the macrofauna and meiofauna cores. The HAPS corer has a base frame of 80 x 80 cm, is 156 cm high and weighs 170 kg. It was deployed by winch off the stern of the research vessel. Each core was 13 cm diameter, with a maximum depth of 31 cm. The three cores at each site were separated by about 5-10 m.

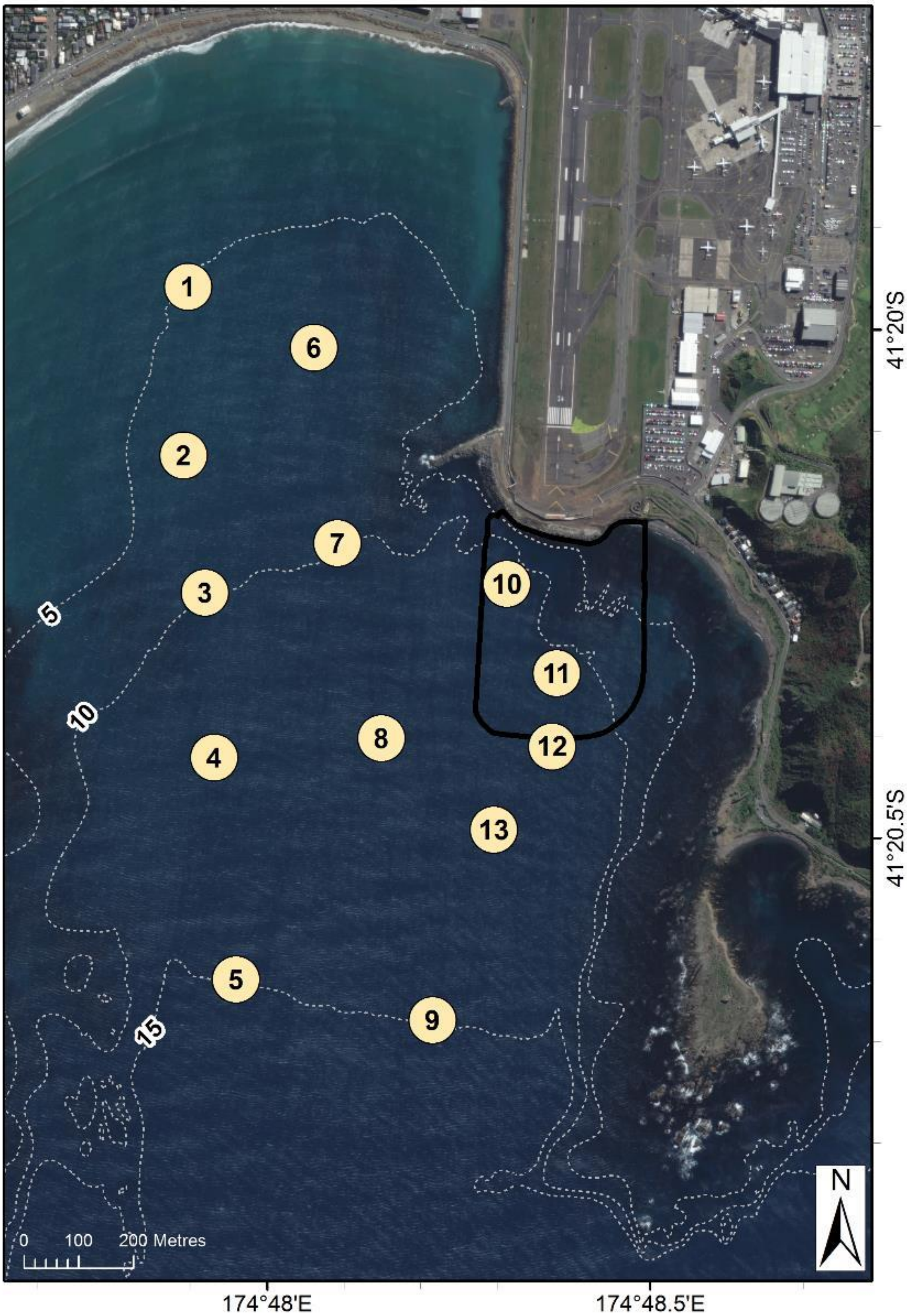

Figure 2-8: Location of coring sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

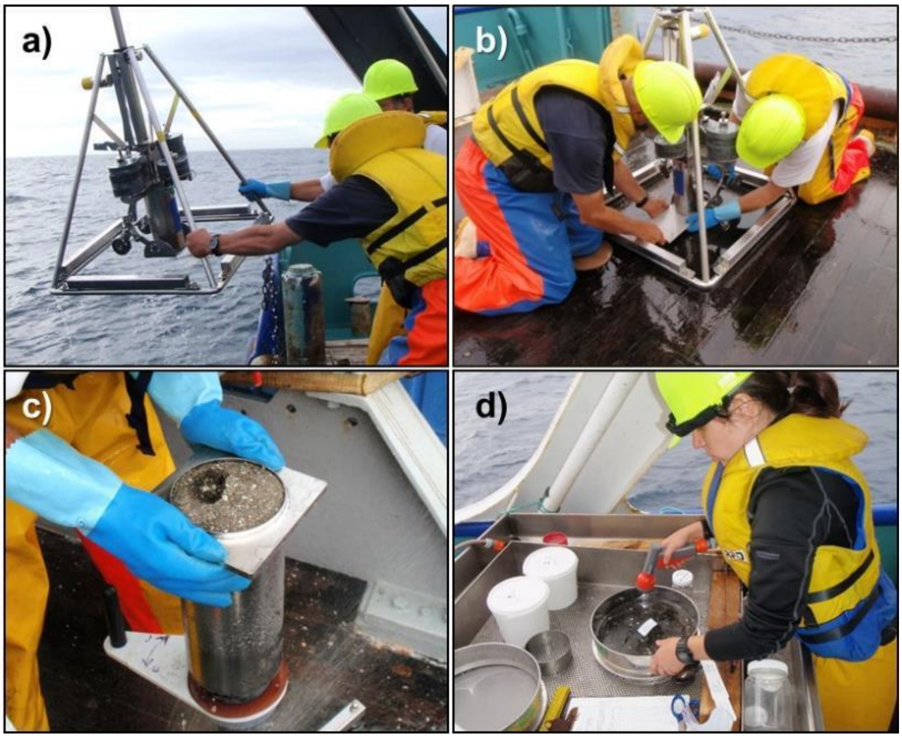

Figure 2-9: Sediment and infaunal sampling using NIWA's KC Denmark HAPS corer.

Upon retrieval of the HAPS corer safely back onto the deck of the vessel, a metal plate was positioned beneath the core cylinder, the core was then carefully removed and transferred to a piston press to extrude the sediment core from its cylinder (Figure 2-9 b and c). Cores for different sample types were processed differently.

Macrofauna core. Any pooled water on the surface of the sediment was syphoned onto a 500 μm mesh sieve and any retained organisms were put into a labelled bottle and preserved appropriately. The surface of the sediment was then photographed with a sample label, before taking a 19 mm x 5 cm deep subsample using a syringe core for sediment grain size analysis. This subsample was placed into a labelled zip-lock bag and kept cool and dark. The remaining top 5 cm of sediment was placed in a labelled bucket. The next 5 cm (5 - 10 cm) of sediment was placed directly into a labelled bucket. The next 5 cm (10 – 15 cm) of sediment was placed directly into a labelled bucket. Buckets were kept cool and in the shade onboard and were processed quickly once back onshore.

Meiofaunal core. A photo was taken of the surface of each core, before taking a 29 mm diameter, 5 cm deep, syringe core sample for meiofaunal analysis. This sediment sample was placed into a bottle and preserved with 4% buffered formalin and rose-bengal solution. A 19 mm diameter x 5 mm deep syringe core sample was also taken, for sediment grain size analysis. This sample was placed in a labelled zip-lock bag and kept cool and dark. The remaining sediment within the core tube was discarded.

Sediment core. The top 5 cm of each sediment core was placed into a labelled ziplock bag and kept in dark and cool before being frozen on return to shore and sent to NIWA's Hamilton laboratories for analysis (see below).

Laboratory analysis

Sediment analyses

Sediment samples were transferred (chilled) to NIWA's water quality laboratory in Hamilton, where it was homogenised and subsampled for analysis of POC, PN, Chl*a* and phaeo following ISA9000 protocols. POC and PN subsamples were acidified with 0.2 M sulphuric acid to remove carbonates and then %POC and %PN determined using catalytic combustion (900 °C) in a CHN analyser (CE Instruments NC2500), with an estimated machine precision of 2% (Sandilands and Mudroch 1983). Chla and phaeo concentrations in were determined in freeze dried sediments using standard extraction with 95% Ethanol and spectrometric measurement (Method APHA 10200H).

Grain-size distributions (i.e., %gravel, sand, silt, and clay) for sediment samples from the macro-and meiofaunal cores were quantified using a Beckman Coulter LS 13 320 Dual Wavelength Laser Particle Size Analyser, as this method provides higher efficiency, accuracy, resolution and repeatability than the more traditional stacked sieve methods. As the laser sizer is limited to grains <2 mm, the proportion of coarser grained sediments (i.e, gravel) per site was determined using dry sieve stacks.

Dinoflagellate cysts

To determine the presence of toxic algal cysts in the surficial sediment, subsamples used for grain-size analysis were mixed with filtered seawater to obtain a water slurry and then sonicated for 2 minutes to dislodge detritus particles. The water slurry was screened through a 60 µm sieve and collected on to a 20 µm sieve and the remaining fraction was panned to remove denser sand grains and larger detritus particles. Dinoflagellate cysts were examined using an inverted Nikon Diaphot light microscope. Identification of cysts follows Matsuoka and Fukuyo (2000) and literature detailed by Bolch and Hallegraeff (1990).

Macrofauna

All macrofauna (>500 µm) were post-processed from each vertical sediment layer in the laboratory. First, macrofauna were extracted from the surface sediments by carefully washing all the sediments through a 500 µm sieve. Material finer than this (<500 µm fraction) was discarded. The macrofauna was then sorted sequentially from the retained sediments under a dissecting microscope and grouped into coarse taxonomic groups (e.g. amphipods, copepods, polychaetes, bryozoans, molluscs, algae, etc.) and preserved in either 4 % buffered formalin (e.g. polychaete worms) or ethanol (e.g. most other taxa). Biological specimens from each taxonomic group (e.g. amphipods, copepods, polychaetes, bryozoans, molluscs, algae, etc.) were then transferred to taxonomic specialists for identification to species or operational taxonomic unit (OTU's – i.e. lowest taxonomic level possible), enumeration and the description of any new species.

Meiofauna

Sediment samples were washed through a 1 mm mesh to exclude macrofaunal organisms and through a 45 µm mesh to retain meiofaunal organisms. The material retained on the 45 mm sieve was transferred to a 500 ml glass cylinder and water was added to the 400 ml mark. The top of the cylinder was sealed before inverting four times to re-suspend all of the sediment and associated organisms. The cylinder was then left undisturbed for 25 seconds to allow sediment particles to settle, then the overlying water was poured over a 45 µm mesh. The material retained on the mesh was washed into a container. The cylinder was filled again with water to the 400 ml mark and the procedure was repeated four more times. The efficacy of this decantation method was tested by counting the number of meiofaunal organisms left in the sample after extraction in the first sample. The extraction efficiency was estimated to be 95%. Although some calcareous foraminiferans (singlecelled organisms with heavy shells) were observed in the samples, they are not efficiently extracted by decantation and their abundance was therefore not quantified.

The abundance of meiofaunal taxa was quantified by inspection of the samples in a Bogorov tray using a stereomicroscope (45× magnification). Some representative specimens were picked out of the sample, transferred to glycerol, and mounted onto slides to confirm identifications and obtain digital images at high magnification (400-1000×, Somerfield and Warwick 1996). Some of the soft-bodied taxa could not be identified with certainty due to damage and were therefore categorised as "unknown worms"; this category may include a number of soft-bodied taxa such as turbellarians, gastrotrichs, gnathstomulids and nemerteans.

Statistical analyses

Analyses of univariate (abundance, taxa diversity) and multivariate variables (community structure) were conducted using statistical routines in the software package PRIMER v6 (Clarke and Gorley 2006).

Abundance of macrofauna was expressed as numbers per 177 cm^2. The abundance of meiofauna was expressed as number of individuals per 10 cm^2, and taxa diversity as the total number of meiofaunal taxa identified in each sample. Univariate and multivariate meiofaunal data were plotted onto a map of the study area to illustrate spatial patterns.

Multivariate analyses of macrofaunal community structure and meiofaunal community structure were based on similarity matrices built using Bray-Curtis similarity of log (X+1)-transformed abundance data (excluding the "unknown worms" category in the meiofaunal) (Clarke et al. 2006). This transformation was used to decrease the influence of the numerically dominant species on patterns of community structure. The SIMPROF routine in PRIMER was used to identify any natural groupings in the dataset (P set at 0.05 and 0.1). Where required, the taxa contributing most to within-group similarity were identified using a similarity percentage routine (SIMPER).

Relationships between environmental variables (i.e. water depth, chl*a* and phae concentrations, PN and POC content, and %gravel, sand, silt, and clay particles) and faunal abundance, diversity, and community structure were investigated using Distance-based Linear Models (DistLMs) in PERMANOVA+ (Anderson et al. 2008). The community structure similarity matrix was built as described above, whereas abundance and diversity similarity matrices were built using Euclidean distance of untransformed data (Anderson et al. 2008).

2.4 Rocky reef communities

2.4.1 Phase 1 field sampling and analysis

The communities of marine algae and invertebrates on rocky reefs in Lyall Bay were characterised in 0.5 x 0.5 m (0.25 m^2) quadrats placed at intervals along transects that ran from the high intertidal to the deepest extent of the reef. Transects were delineated using fibre-glass measuring tape(s). Because of dangerous access to the intertidal zone at the end of the runway, only two transects were located within the proposed reclamation/runway extension area, one was located at the southern base of the existing breakwater, and three others were located on adjacent and nearby rocky reefs in Lyall Bay (Figure 2-10 and Table 2-1). The field work was completed over the period 10-16 October 2014. All samples of living material were collected under NIWA's special permit (505) with the MPI.

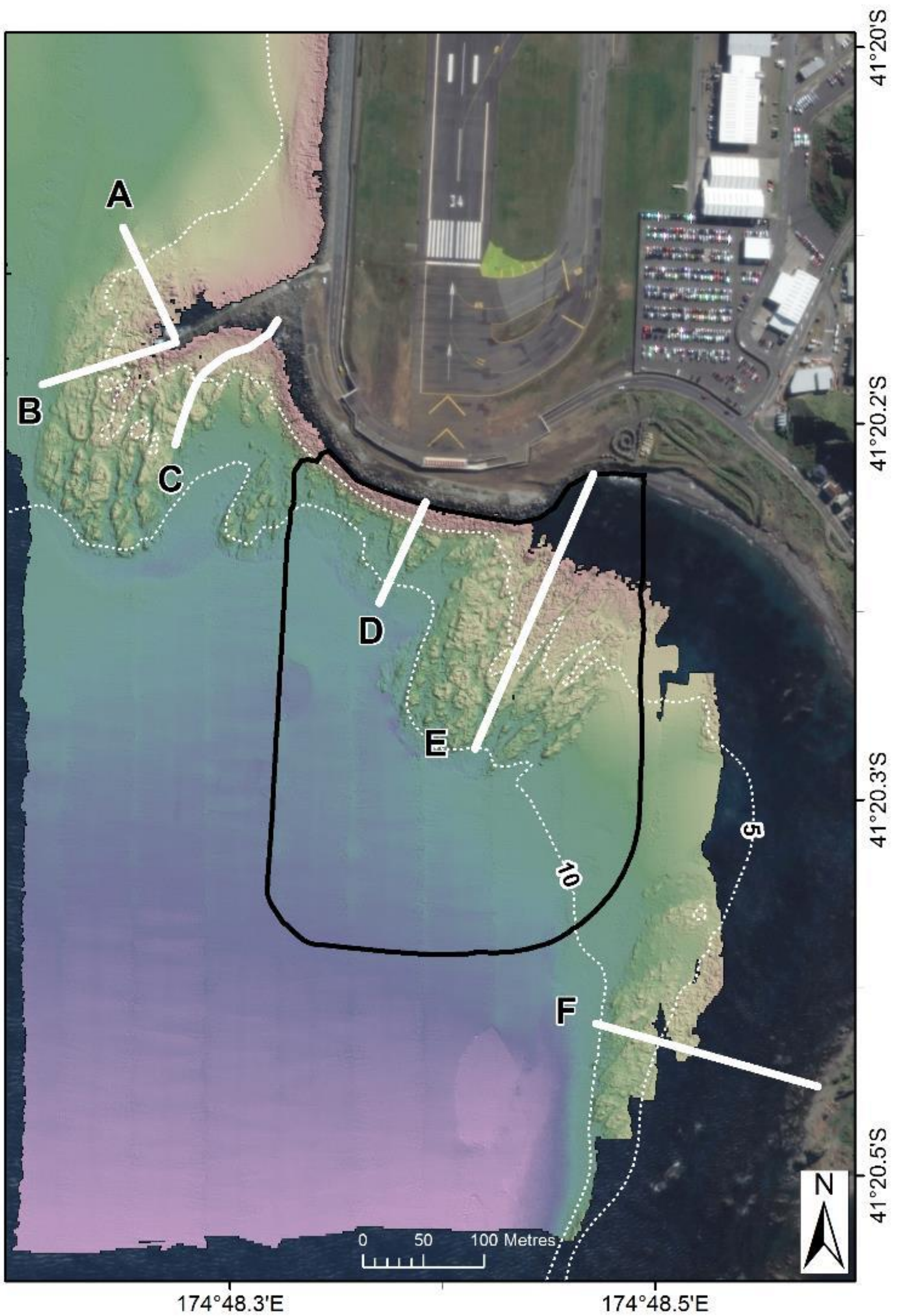

Figure 2-10: Composite aerial image and seafloor swath map of part of Lyall Bay adjacent to the proposed runway showing the location of rocky reef transects A-F. The proposed extension to the runway is outlined in black. The 5 and 10 m depth contours are indicated by white dashed lines.

Table 2-1: Summary of rocky reef transects undertaken in Lyall Bay.

Transect	Location	Intertidal vertical extent (m)	Sub-tidal depth range (m)	Sub-tidal transect length (m)
A	North breakwater	2.7	1 – 8.6	100
B	West breakwater	2.5	0.3-9.9	140
C	South breakwater, west of runway	2.2	0.3-10.9	120
D	South of runway in proposed reclaimed zone	Not assessed	0.2-11	90
E	South – east runway in proposed reclaimed zone	2.7	0.2-11.9	195
F	South- east shoreline off Moa Point road	2.4	0.3-11.3	180

Sub-tidal quadrats

Divers experienced in identifying marine species quantified the abundance of flora and fauna in each quadrat along the sub-tidal segment of each transect (Figure 2-11). The spacing of quadrats was two metres apart for the first 10 m, then three metre intervals for the next 15 m, and thereafter every five metres until the seaward reef edge was reached (Figure 2-12). In each quadrat, depth, substrate type, and the general relief (either vertical, partial slope or flat) were noted. For motile invertebrates (gastropods, decapod crustaceans, echinoderms and wandering anemones) all individuals in each quadrat were counted. Sessile encrusting fauna including ascidians, sponges, hydroids and bryozoans were assessed by percent cover within the quadrat.

The algae communities within each quadrat were also assessed by percent cover (Figure 2-13). In luxuriant kelp forests the percent cover for each quadrat often exceeded 100% due to the presence of several canopy layers. Specimens were retained for further identification in the laboratory. For analysis, brown, red and green algae were separately placed into different morphological groups (Table 2-2).

Figure 2-11: Divers commence the sub-tidal transect F in the shallows.

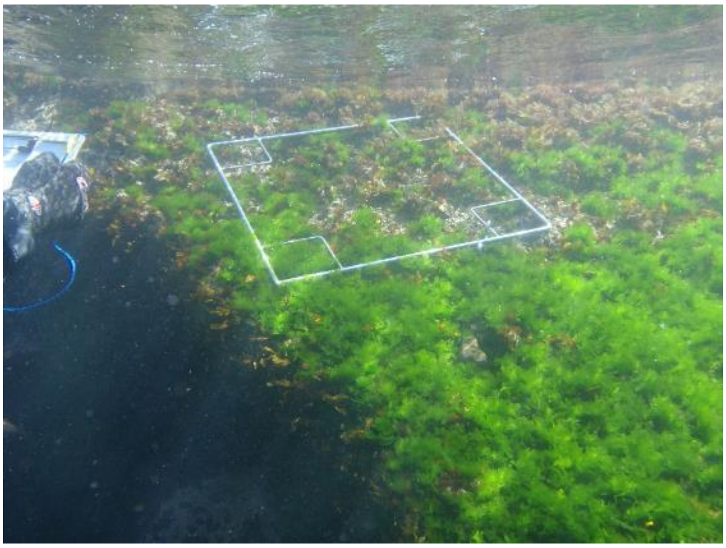

Figure 2-12: 50 x 50 cm quadrat in shallow sub-tidal zone of transect E.

Figure 2-13: Diver recording flora and fauna within a sub-tidal quadrat.

Table 2-2: Morphological groupings of brown, red and green marine macro-algae.

Brown algae	Red algae	Green algae
Large strap	Strap bladed	Thin flat sheet
Small strap	Coarse branched	Tubular form
Coarse branched	Fine branched	Flat encrusting
Flat and leathery	Fine flat sheet	Fine branched
Fine branched	Thin bladder	Coarse branched
Thin and flat	Red crust/turf	
Crusts	Non-geniculate coralline	
Filamentous		
Film / Diatoms		

Intertidal quadrats

The intertidal segment of rocky reef transects were an extension of the sub-tidal dive transects. Two experienced NIWA staff, including a marine algae expert, quantified the abundance of flora and fauna in each 0.5 m x 0.5 m segment by flipping a 0.25 m^2 quadrat end over end. The start point was as close as possible to where the divers commenced in the low intertidal zone, usually in a water depth of around 20-30 cm. The intertidal transect then continued directly shoreward perpendicular to the shoreline (Figure 2-14). This resulted in a single continuous transect which varied in length and height above sea level dependent on the shoreline topography. The upper shoreward limit was always well above the extreme high water mark in the zone where the blue-banded periwinkle *(Austrolittorina antipodium)* abundance diminished (Figure 2-15). Intertidal transects were completed within one hour of low water during a period of 0.4 m tides with a slight southerly swell of less than one metre. Because of dangerous topography the intertidal portion of Transect D could not be surveyed.

Each quadrat was recorded as being either 'dry' or 'wet', and in the case of a rock pool the water depth was noted. Details of substrate type such as: bedrock, concrete block, cobbles, gravel etc, and the general relief, either vertical, partial slope or flat, were also documented. As in the subtidal transects, total counts per quadrat were made of motile invertebrates such as limpets, chitons, snails and whelks. The numbers of sessile encrusting fauna including barnacles and mussels were assessed by counting the numbers occurring in a part of the quadrat and then estimating the total in the quadrat based on percent cover (Figure 2-16). The algae in intertidal quadrats were assessed by percent cover and for analysis placed into morphological groups as for the subtidal algae (Table 2-2). Specimens of interest were retained for further identification in the laboratory.

Figure 2-14: Location of Transect E over concrete slabs in the upper intertidal zone.

Figure 2-15: Section of intertidal quadrat on a concrete slab, Transect E, towards the upper limit of small *Austrolittorina antipodium* (blue-banded periwinkles).

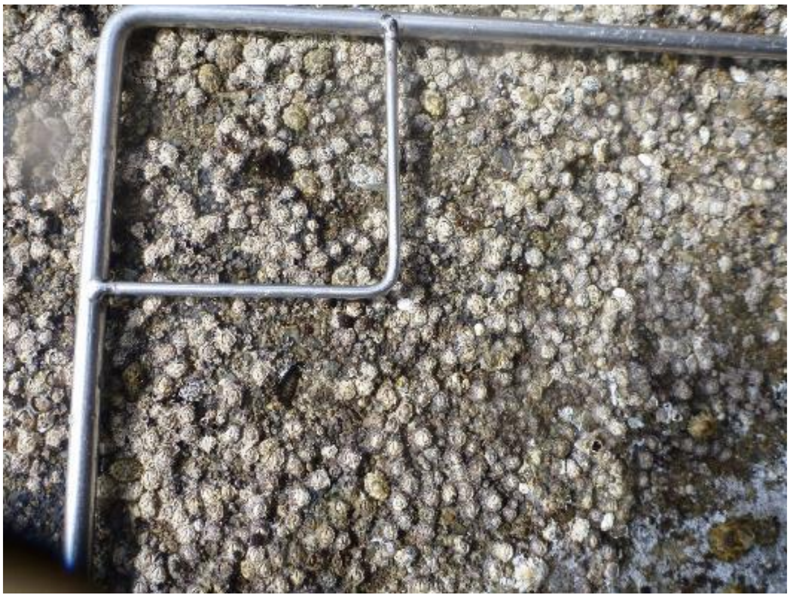

Figure 2-16: Part of quadrat on Transect B showing nearly 100% cover of barnacles and several limpets.

Analysis and display of rocky reef transects

For analysis and graphical display the information in adjacent quadrats was analysed in two intertidal and six subtidal zones as illustrated in Figure 2-17. These zones for each transect are shown in Figure 2-18.

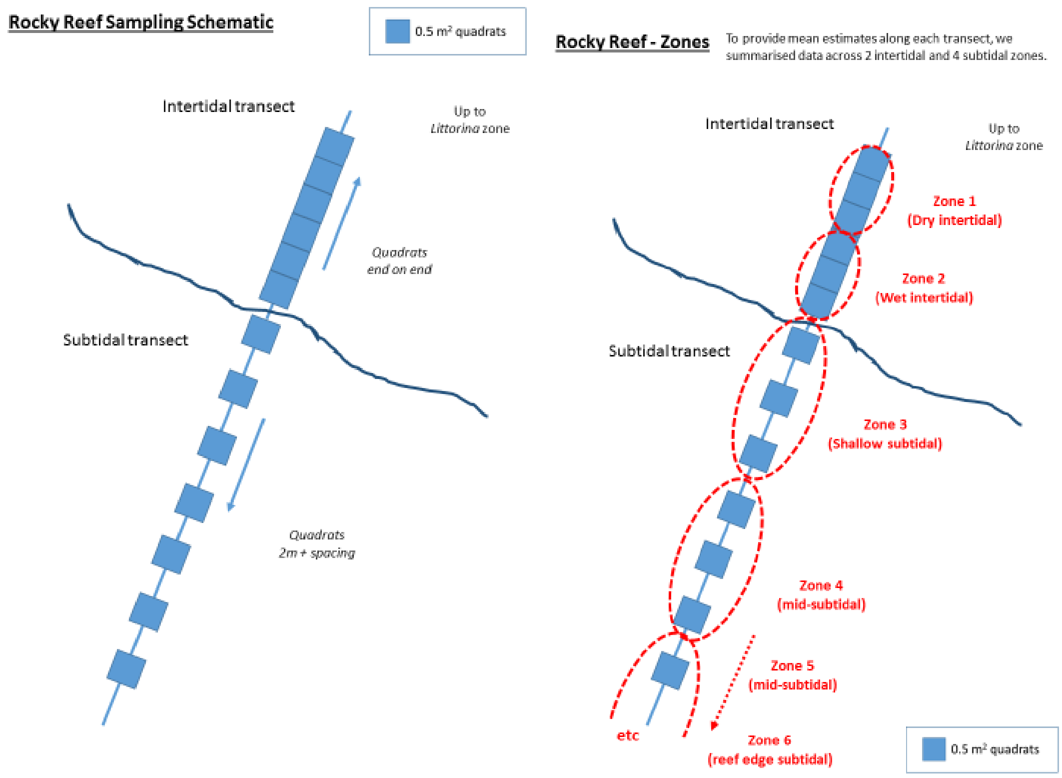

Figure 2-17: Cartoon of a rocky reef transects indicating its division into six zones (two intertidal, four subtidal) for analysis.

Canonical Correlation plots for the %cover taxa (macroalgae and sessile subtidal invertebrates) at the zone level were undertaken in SAS. To equalise variances, %habitat data and %cover taxa data were both square root transformed. Taxa were included in the analyses where they occurred in more than 15% of all zones. This totalled 36 transect by zone combinations (i.e. 6 transects * 4 or 6 zones per transect [NB: transect D only had 4 subtidal zones; no intertidal zones). Similarly, Canonical Correlation plots for the count taxa (intertidal and motile subtidal invertebrates) were undertaken at the zone level. To equalise variances habitat data were square root transformed but count taxa data were root (**0.25) transformed. Taxa were included in the analysis where they occurred in more than 10% of all zones to ensure that less abundant motile species such as sea urchins and chitons were included. As above there were 36 transect by zone combinations.

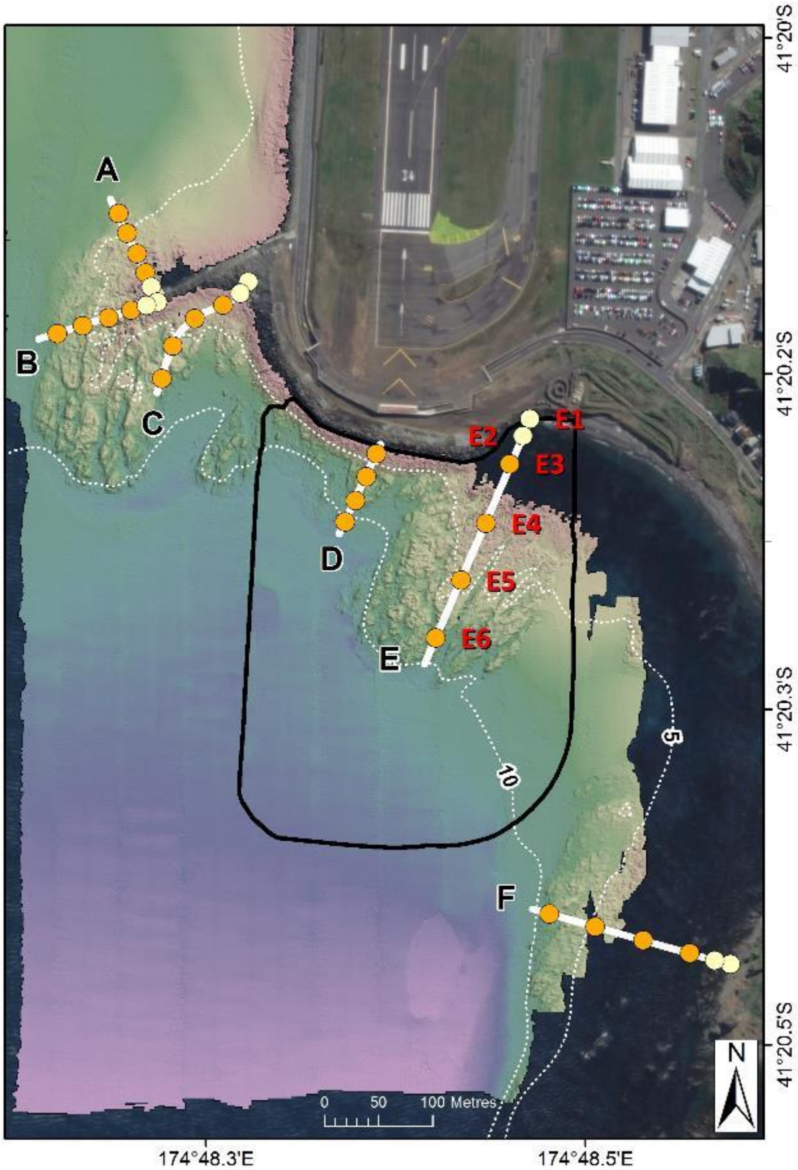

Figure 2-18: Map of the rocky reef transects in Lyall Bay indicating their division into six zones for analysis. Zones 1-6 are labelled for Transect E only. The proposed extension to the runway is outlined in black. The 5 and 10 m depth contours are indicated by white dashed lines.

2.4.2 Phase 2 sampling and analysis

During the intertidal and subtidal reef surveys a 'Bangiales' type filamentous algae, and an unnamed species of a red macro-algae were found, respectively, on intertidal and subtidal rocks at the southern end of the runway. As these species were unlikely to occur only on these reefs, genetic sequencing and further field work was undertaken in December 2014 to confirm their identity and south coast distributions. The intertidal search extended to all reefs fringing Lyall Bay and on both sides of Moa Point. Subtidal searches included reefs south of the existing runway towards Moa Point, artificial reefs on the western side of the runway north of the breakwater, and reefs on the western side of Lyall Bay. The red macro-algal was sequenced by NIWA staff using the 'Zuccarello genetics laboratory' at Victoria University of Wellington, while the samples of the undescribed filamentous algae were sequenced by Dr Judy Sutherland of Auckland University.

2.5 Reef fish

The results of a previous study (Smith et al. 2013) that estimated (modelled) expected reef fish abundance around New Zealand from surveys conducted nationwide, together with a set of environmental and geographical predictors, were used to describe the expected distribution, abundance and species richness of reef fish along Wellington's south coast. The original study ignored rare and/or cryptic species for which little or no count data were available. The predicted distributions and relative abundance of fishes were produced by Smith et al. (2013) by applying boosted regression trees (BRT) (an ensemble method for fitting statistical models) to diver surveys of fish abundance, using environmental and geographic variables as predictors. Model predictions were produced as a grid of 1 km^2 cells.

The original fish count data collected by Smith et al. (2013) consisted of relative abundance recorded by divers on a 5-level abundance scale (0 = absent; 1 = 1; 2 = 2-10; 3 = 11-100; 4 = greater than 100 individuals of a species observed per dive) at 467 sites throughout New Zealand, including Wellington's south coast.

The 15 environmental variables used by Smith et al. (2013) consisted of a range of measures available at high spatial resolution including temperature, salinity, dissolved organic matter, tidal current, wind fetch, distance from coast and several variables defining the characteristics of each dive. BRTs were used to predict the abundance of each species in a 1 km^2 grid for 9,605 grid squares having shallow (< 50 m depth) rocky reefs. The most important variable for explaining variation in fish abundance was sea surface temperature, followed by average fetch and salinity. On average, 64% of the variation in reef fish abundance was explained by Smith et al's models.

The model prediction for each fish species produced by Smith et al. (2013) was re-plotted in a Geographical Information System for the region covered by the present study. These predicted distribution maps provide an easily interpreted, visual summary of the parts of the study area inhabited by each species, and its relative abundance (at a coarse level) in the inhabited areas. The number of species predicted to occur within 1 km^2 grid squares was calculated as an indication of the spatial distribution of species richness in the region.

Divers conducting rocky reef surveys (Section 2.4) also noted all species of reef fish encountered. This species list was used to ensure that all relevant model data were extracted and presented.

2.6 Demersal and pelagic fish

The distribution and abundance of demersal (bottom-associated) and pelagic (open water) fish in Lyall Bay and along Wellington's south coast was summarised using an existing predictive demersal fish habitat use model (Leathwick et al. 2006 a and b) based on research trawl surveys and associated environmental data collected over an 18 year period (1979-1997).

There have been many research bottom-trawl surveys around New Zealand that have sought to determine the distribution and abundance of demersal fish. However, interpreting the raw abundance data from these surveys is difficult because they were collected using different vessels and fishing gear, in different seasons, and at different depths. Therefore, the predicted distributions and catch levels from existing statistical models using a statistical implementation of BRTs were used. This method uses stochastic gradient boosting to fit a model, enabling sophisticated regression analyses of complex responses, optimised for high predictive performance. This method differs from conventional regression in that rather than fitting a single "best" model, it fits an ensemble or "committee" of simple regression tree models that are then combined to form predictions. Further details of the modelling methods are provided in Leathwick et al. (2006 a and b). These models were used to predict both the probability of capture and catch (kg/trawl) of each fish species under standardised trawl conditions. For each species, maps showing its predicted distribution and abundance along Wellington's south coast, including Lyall Bay, were provided on a grid scale of 1 km^2.

The strength of the predicted fish distributions and abundances is that they are based on an enormous data set, containing 21,000 research demersal trawls from throughout New Zealand. This provides confidence that the model will provide reliable long-term patterns of demersal and pelagic fish distribution and abundance in the Wellington region. Short-term sampling for demersal fish cannot hope to replicate such an intense effort, would be expensive to undertake, and would be socially unacceptable in 'urban' waters.

2.7 Fisheries

Catch and effort information for commercial fishing activities in and around Cook Strait, Wellington Harbour and the Wellington South Coast (Figure 2-19) were summarised for the last five fishing years. The objectives were to (i) summarise catch and effort data by fishing methods and target species; (ii) characterise seasonal trends in effort in the main fisheries; and (iii) characterise spatial patterns in catch and effort in the main fisheries.

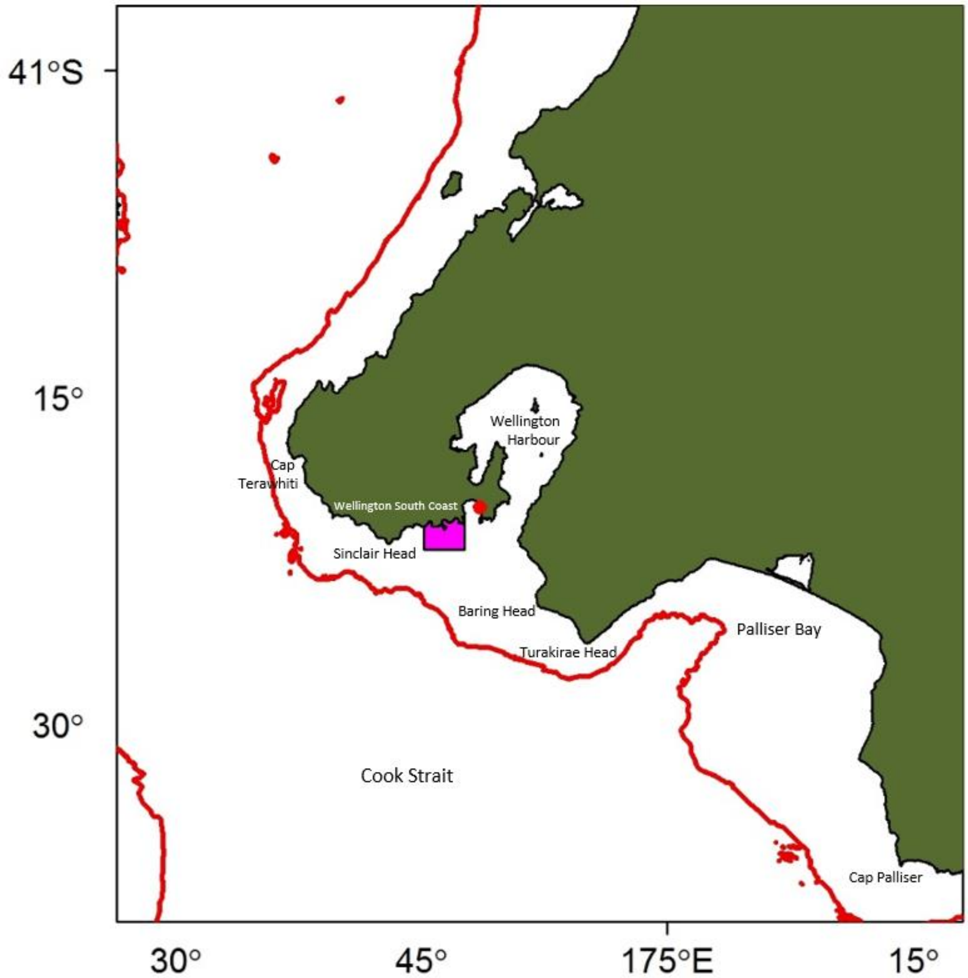

Figure 2-19: Map of the fisheries study area. The red line represents the 100 m depth contour. The red dot shows the approximate location of Wellington International Airport (WIA). The area in magenta is the Taputeranga Marine Reserve.

Catch and effort data from all commercial fishing activities within Cook Strait statistical area 16 (and part of 17) and rock lobster statistical area 915 (Figure 2-20) were obtained from the MPI in September 2014. Data were extracted for the 5 year period from 1 October 2008 (beginning of the 2008/09 fishing year) through to August 2014 (incomplete data from the 2013/14 fishing year). Data extraction involved checking the eel statistical area 'AM' and paua statistical area 'P237' for catch reports or commercial fishing activities; this was negative in both cases (no eel or paua commercial fishing occurred in these areas since 1 October 2008).

The resulting data extract included a large proportion (36%) of fishing events reported in catch effort landing return (CEL) forms without fine scale spatial information (i.e. spatial resolution limited to statistical areas). These data were assumed to represent coastal fishing activities and were summarised separately.

The remainder of the data included fishing activities extending well beyond the Wellington South Coast, into offshore areas of Cook Strait. To ensure that commercial fisheries data were summarised on a scale relevant to the proposed airport runway extension, inshore and offshore activities were distinguished by depth stratum (based on the 100 m depth contour), and characterised separately.

All data were summarised according to the standard fishing year which extends from 1 October to 30 September.

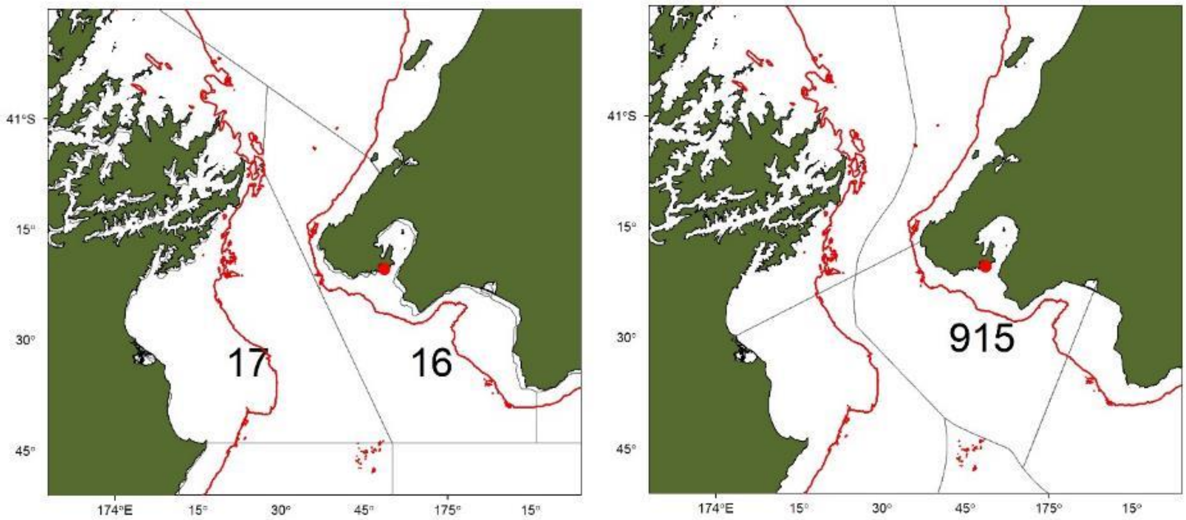

Figure 2-20: Maps of Cook Strait showing the boundaries of statistical areas 16 and 17 (left) and rock lobster statistical area 915 (right) (in grey). Shown are the approximate location of WIA (red dot); and the 100m depth contour (red line).

Recreational and customary fisheries along Wellington's south coast, including Lyall Bay, were summarised from existing information, particularly results from the Wellington south coast recreational fishing survey conducted in 1998 and 1999 (Bell and Associates 2000). There were no more recent data available.

2.8 Seabirds and marine mammals

There have been no systematic and quantitative surveys undertaken to record seabird and marine mammal species' abundance, and how this varies temporally (for example, seasonally) and spatially, within the Cook Strait region. Our knowledge of species occurrence in Cook Strait is based largely upon ad hoc sightings (for example, information contained in the cetacean sightings database maintained by the Department of Conservation; but see also Bartle (1974, 1975)), and for some seabird species the results of studies employing miniaturised electronic tracking devices (for example Walker and Elliott 2006, Landers et al. 2011). All available information was reviewed and collated to provide summaries of the occurrence of seabird, shore birds and cetaceans along Wellington's south coast including Lyall Bay.

3 Results

3.1 Water optical quality

3.1.1 On-site sampling and synoptic survey

Onsite collections were made during mooring deployment, mooring recovery and twice in between (Table 3-1). Due to the exposed nature of Lyall Bay, site visits could only be made under calm conditions and data are therefore biased toward these relatively optically clear times.

Optical properties from the synoptic survey vertical profiles (water column average) provide context for the mooring site in comparison to other sites within the bay and enabled relationships between parameters to be established (Figure 3-1).

Table 3-1: On-site collections made during the period the optical mooring was deployed. Collections include: Secchi depth (z_{SD}, m), Munsell colour match (Hue, Value, Chroma), water depth, and laboratory analysis of Turbidity (NTUlab), Chlorophyll-a (Chla, mg L^{-1}), CDOM absorption (A340, m^{-1}), Total (T), Organic (O), and Inorganic (I) Suspended Sediments (SS, mg L^{-1}), and percentage (P) OSS. Data missing (-).

Date	z_{SD}	Munsell	Depth	NTUlab	Chla	A340	TSS	OSS	ISS	OSSP
04-Sep-2014	8.5	5BG 7/6	5	0.59	1.45	0.011	-	-	-	-
			15	0.45	1.85	0.009	-	-	-	-
17-Sep-2014	5.5	10BG 5/6	5	0.82	-	-	0.68	0.12	0.56	18
			15	0.93	-	-	1.10	0.07	1.03	6
01-Oct-2014	11.5	5BG 5/6	5	0.70	0.43	0.003	0.59	0.28	0.31	47
			15	0.30	0.36	0.004	0.46	0.14	0.32	30
08-Oct-2014	5.0	5G 5/6	5	1.40	0.45	0.004	1.67	0.31	1.36	19
			15	2.20	0.40	0.003	2.90	0.22	2.68	8

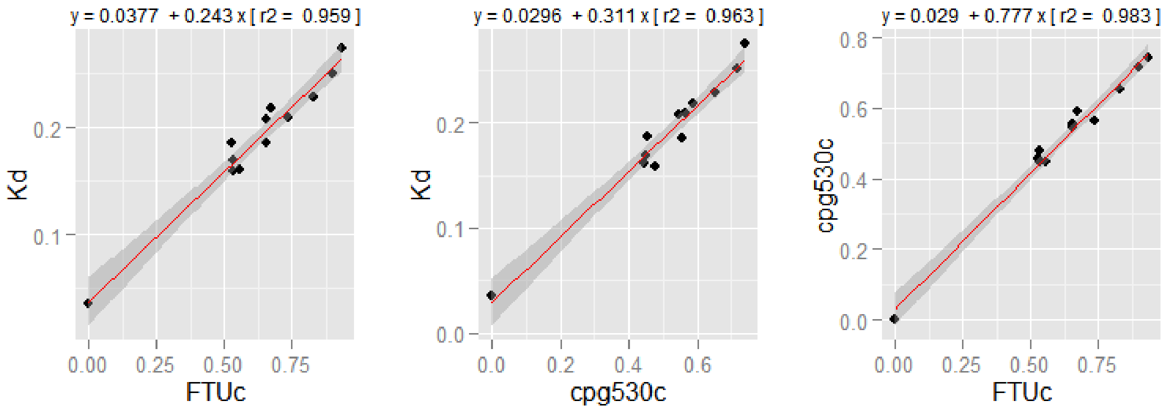

Figure 3-1: Synoptic survey relationships between optical water column parameters of interest. Downwelling light attenuation of PAR (Kd); Turbidity (FTUc); and green beam attenuation (cpg530c). The mooring site is the lowest non-zero value. Values for pure water were used in fits (zero for FTUc and cpg530c). A pure water Kd for PAR of 0.035 m^{-1} was used from (Morel et al. 2007).

3.1.2 Laboratory suspended sediment relationships

As anticipated, the relationship between turbidity and TSS determined in the laboratory varied depending on 'type' of turbidity sensors (Figure 3-2). When forced through zero, the following general relationships hold:

(1) TSS (mg L^{-1}) = 1.53FTU (r^2=0.99) [Seapoint sensors]
(2) TSS (mg L^{-1}) = 3.17FNU (r^2=0.99) [EXOsonde sensors]
(3) TSS (mg L^{-1}) = 2.43NTU (r^2=0.99) [Lab sensor]

The first equation was used to estimate TSS from Seapoint sensor mooring records. The other equations could be used if those sensors are used for monitoring, however, the differences between sensor types highlights the in-accuracy of using sensor specific turbidity units without carefully establishing their specific relationships to TSS.

Different turbulent velocities influence the suspended particle size distribution (PSD). It can be assumed that there has not been selective settling of larger particles (change in PSD over time) as the TSS to Turbidity relationships are linear (Figure 3-2). If larger particles were settling during the experiment, the PSD would shift toward smaller particles with a greater turbidity response per unit mass (i.e. non-linear and curving over with further additions).

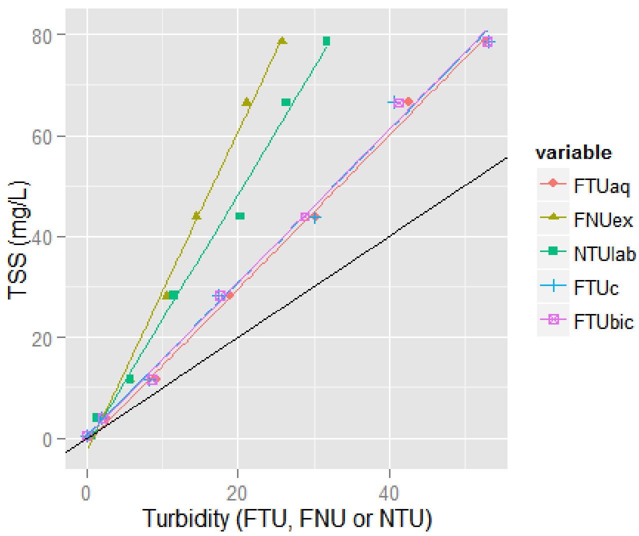

Figure 3-2: Laboratory suspended sediment calibrations for a range of turbidity sensors. Lab (NTUlab - green) and XYLEM/YSI EXOsonde (FNUex - brown) sensors are 90 degree scattering of white and IR (895 nm) light respectively. Seapoint sensors on Aquatek (aq – red), DOBIE (c - blue) and Biofish (bic -purple), collect IR light scattering between 15 and 150 degrees. The black line is the 1:1 relationship.

3.1.3 Optical mooring

Turbidity, beam attenuation and light attenuation all increased with increasing wave height over the deployment period (Figure 3-3). These temporal increases in suspended sediment (estimated from laboratory calibrations), decreases horizontal visibility and euphotic zone depth (Figure 3-4). Turbidity near the seafloor was slightly higher than those nearer to the surface, particularly during high wave events, evident in corresponding differences between depths for other parameters. The slight 'grading' of TSS probably reflects the combined effect of the sediment bed as the main source of turbidity due to wave erosion and settlement of suspended particles.

Statistical summaries across the water column (averaged over depths) provide an overview for the mooring deployment period (Table 3-2). Our spring sampling covered several calm periods (< 0.5 m waves) and energetic events (> 2 m wave heights and up to 5.25 m). Suspended sediment ranged from about 0.2 to 40 mg L^{-1}, corresponding to visibility from an exceptional 32 m to a poor 1 m and euphotic zone depths from 51 to 8 m, respectively.

Table 3-2: Summary statistics from mooring records. Physical properties (maximum wave height), optical properties (turbidity, beam attenuation (cpg530c) and light attenuation (Kd)). TSS was calculated from tank mass-loading calibrations (Figure 2). Optical water quality parameters (visual clarity (yBD) and euphotic zone depth (zeu)) were calculated from equations outlined in section 2.1.1.

Variable	Units	N	Mean	SD	Median	Min	Max
Waves	(m)	4972	0.79	0.67	0.57	0.08	5.25
FTUaq	(FTU)	4972	1.83	2.00	1.11	0.11	24.49
cpg530c	(m^{-1})	4972	0.76	0.64	0.55	0.09	4.92
Kd	(m^{-1})	2224	0.24	0.09	0.21	0.09	0.61
TSS	(mg L^{-1})	4972	2.81	3.06	1.69	0.17	37.47
yBD	(m)	4972	8.68	4.87	7.93	0.96	31.99
zeu	(m)	2224	21.67	6.82	21.83	7.60	51.36

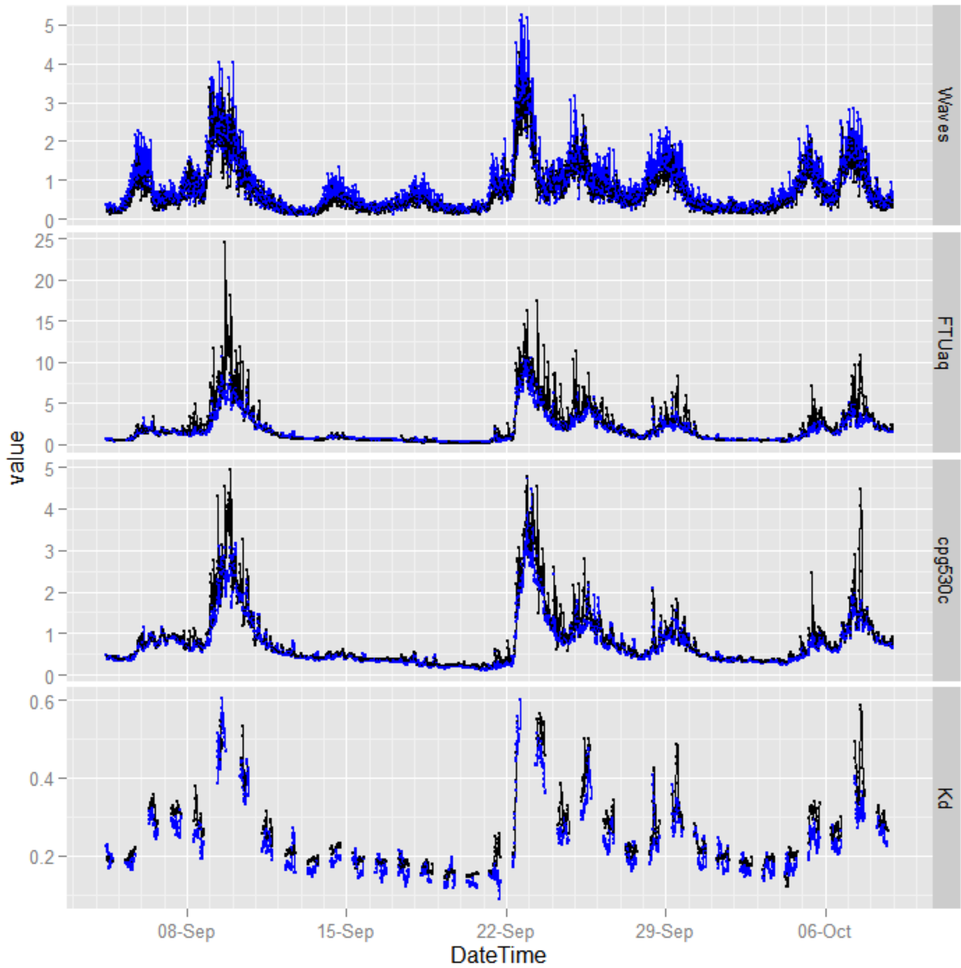

Figure 3-3: Optical property responses to wave heights in Lyall Bay from the upper (blue) and lower (black) parts of the optical mooring. Data provided are wave height (m) and optical properties including Aquatech turbidity (FTUaq), beam attenuation (cpg530c m^{-1}) and light attenuation (Kd, m^{-1}).

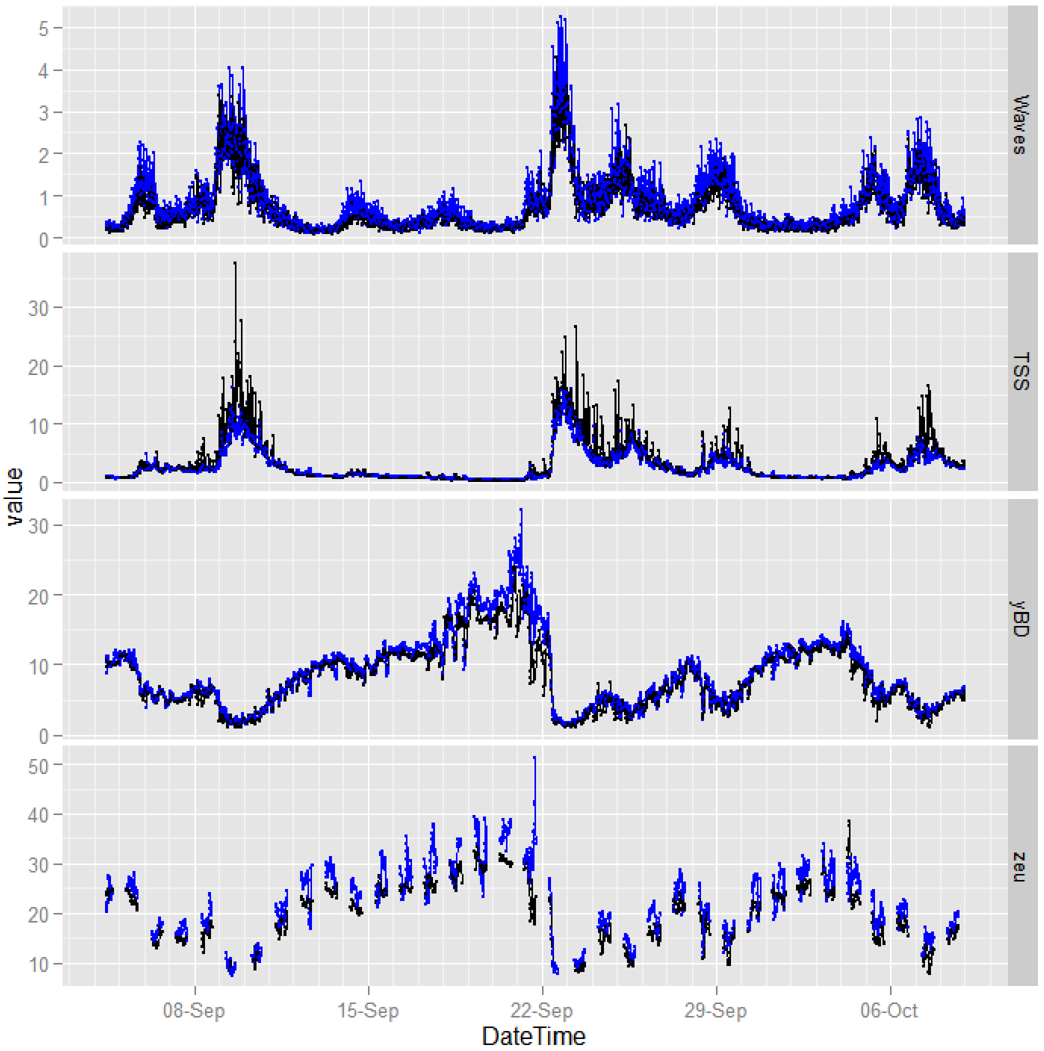

Figure 3-4: Estimates of total suspended sediment (TSS) and optical water quality parameters from the upper (blue) and lower (black) parts of the optical mooring in response to wave height in Lyall Bay. TSS (mg L^{-1}). Optical water quality parameters include the visibility index (yBD, m), and euphotic zone depth (zeu, m). yBD = 4.8/(cpg530c + c550w); c550w = 0.0579; zeu=4.6/Kd. Mooring records from the top (blue) and bottom (black).

3.1.4 Comparison of optical parameters from laboratory, synoptic survey and mooring records

To determine changes in mass-specific attenuation characteristics, changes in optical parameter relationships from laboratory, synoptic survey and mooring records (upper panels in Figure 3-5), and in temporal detail from mooring records as mass-specific (turbidity derived) parameters (Figure 3-6) were compared. Smaller-sized particles would be expected to dominate during the synoptic survey (on mooring deployment) and other calm wave conditions - high slopes (upper panels in Figure 3-5) and high mass-specific values when TSS is low (Figure 3-6). Laboratory calibrations appear to display small-medium-sized particle characteristics with intermediate slopes. When considering all mooring records, slopes are lower (upper panels in Figure 3-5), indicating the presence of larger particles in the water column, particularly during storm events which are more likely to re-suspend sand and perhaps aggregates of finer materials (Figure 3-6). However, changes in dominance and proportions of the LAC's (TSS, Chl*a* and CDOM) can also account for relationship changes as they effect turbidity, beam attenuation and downwelling light attenuation in differing ways. In Log-Log space deviations from linear regression are more clearly evident (lower panels in Figure 3-5) and may point toward either a multi-linear regression model, or an alternative non-linear regression fit (e.g. power law or Tanh functions which account for changing slopes in various ranges).

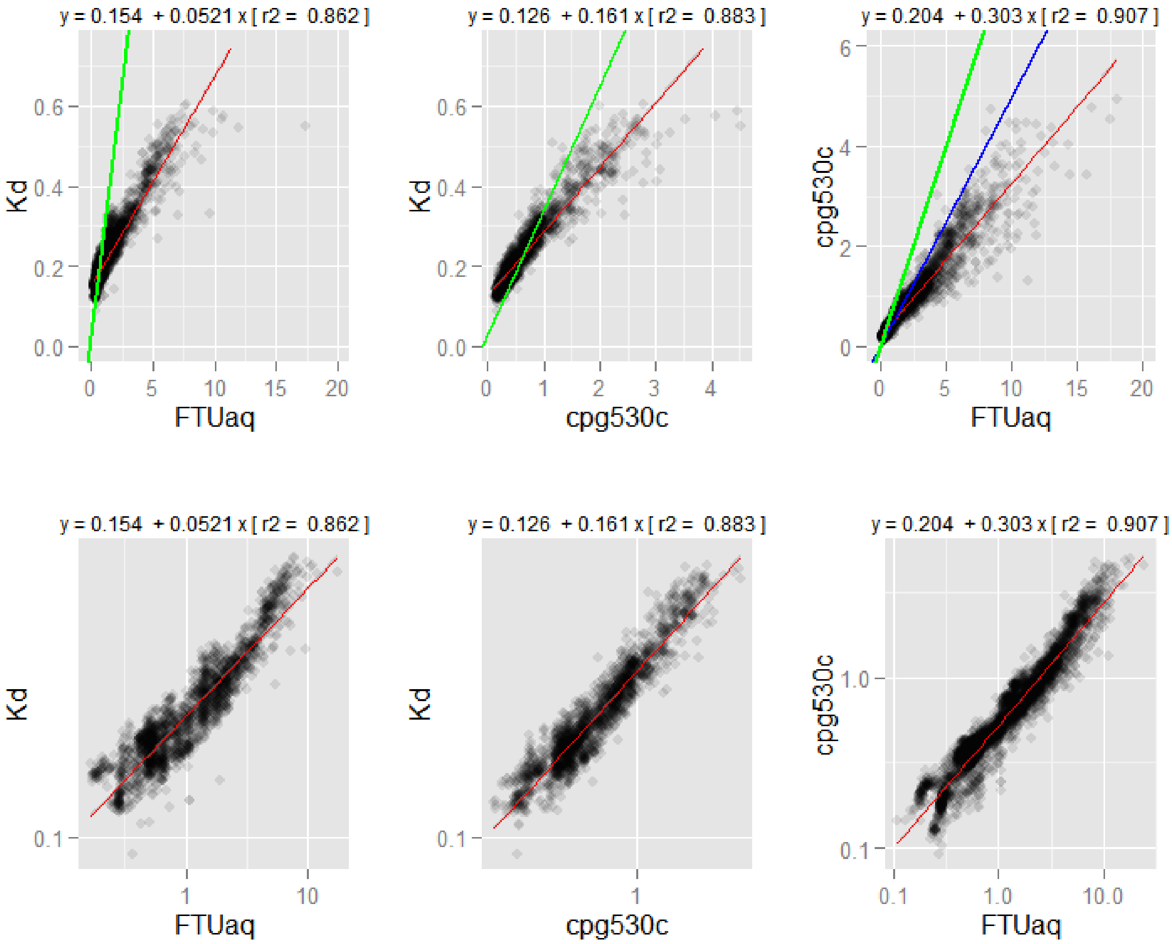

Figure 3-5: Optical parameter inter-relationships from mooring records in comparison to laboratory calibration and synoptic survey results. Linear space (upper panels) and log-log space (lower panels) relationships for all mooring data (black points and red regression line), synoptic survey (green line) and laboratory calibration (blue line).

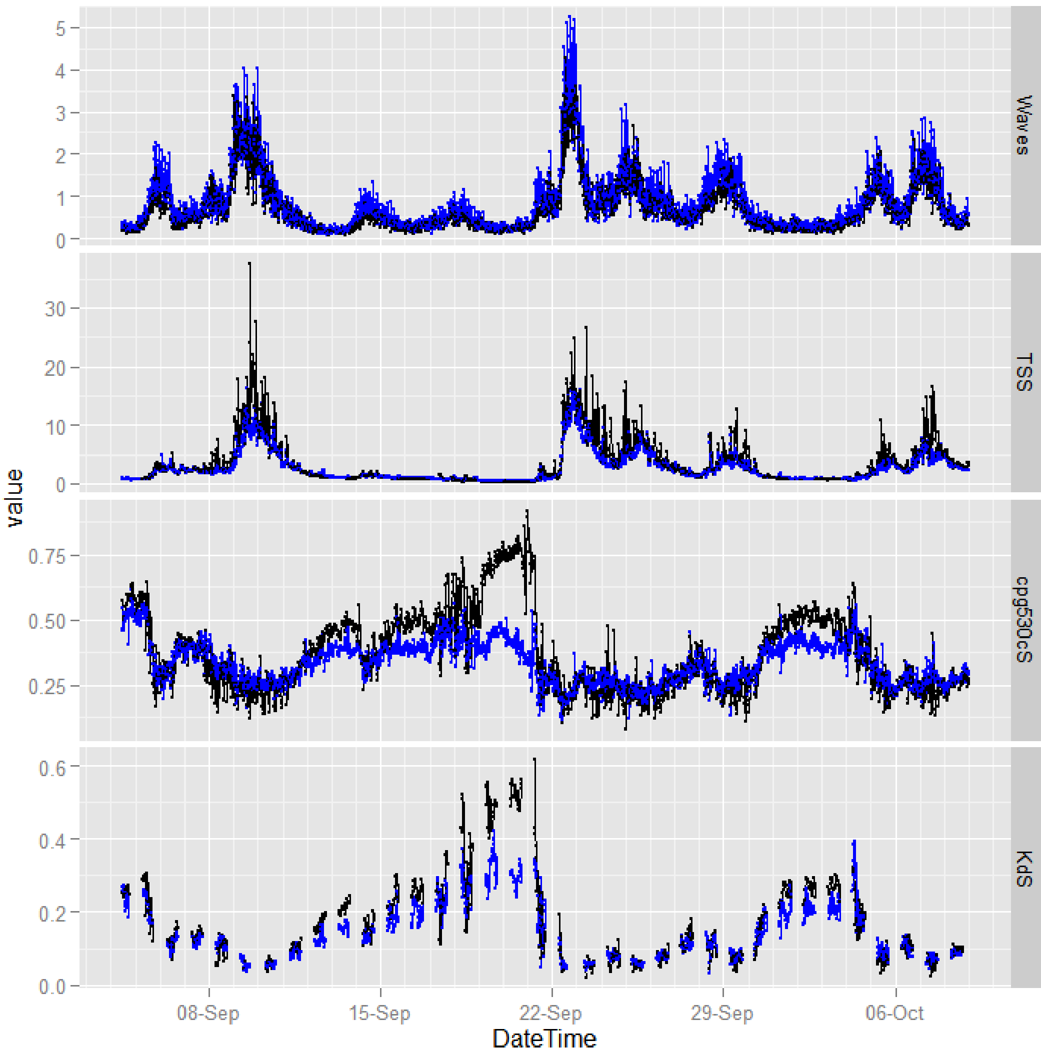

Figure 3-6: Mass-specific optical properties from the records for the upper (blue) and lower (black) parts of the optical mooring. Estimates are based on turbidity mass-specific (S) optical properties of beam attenuation cpg530cS ($m^2\ g^{-1}$) and downwelling light attenuation KdS ($m^2\ g^{-1}$). Changes in ratios indicate changes in particle characteristics (type, shape, size). Elevated wave height entrains benthic sediments into the water column, reducing optical properties per unit mass.

3.2 Plankton

3.2.1 Phytoplankton species composition and cell abundance

Three classes of phytoplankton, viz., Bacillariophyceae, Dinophyceae and Cryptophyceae, of approx. 30 species were recorded from six samples collected from Lyall Bay on 15 September 2014 (Table 3-3). The greatest diversity of phytoplankton (20 taxa) and the highest cell densities were found in the inshore station (#1; Figure 2-3). Fewer species were found at Stations #3, 7 and 9 (17 , 11 and 14 taxa, respectively), and the least at Stations #5 and #6 (8 and 9 taxa respectively).

Of the three classes, diatoms (Bacillariophyceae) were the most diverse, with 24 species recorded (Table 3-3). Seventeen of these species were centric while 7 were pennate diatoms. Dinoflagellates ranked second in diversity with 5 species. The number of thecate dinoflagellate (3 taxa) was slightly more than those of athecate species (2 taxa). Cryptomonad, however, was the least with one species identified.

The chain-forming diatom, *Thalassiosira hylina* (Grun.) Gran was found to be the dominant species. Cell concentration of *T. hylina* was greatest at Station #1 in the inshore water (13.5 x 103 cells per litre), with *Chaetoceros socialis* Lauder (5.9 x 103 cells per litre) and *Lauderia annulata* Cleve (4.4 x 103 cells per litre) as subdominant (Table 3-3). Cell concentrations of both dinoflagellates (up to 0.4 x 103 cells per litre) and cryptomonad (up to 0.8 x 103 cells per litre) found during the same period were generally very low.

Table 3-3: Phytoplankton taxa and concentrations (x 1,000 cells per litre) recorded at six stations in Lyall Bay, Wellington.

	Station					
Taxa	#1	#3	#5	#6	#7	#9
Class Bacillariophyceae						
Centric						
Bidulphia mobiliensis	-	-	-	-	0.3	0.3
Bidulphia sinensis	-	-	-	-	0.1	0.1
Chaetoceros affinis	0.4	-	-	3.3	0.4	-
Chaetoceros convolutus	-	-	-	-	0.5	-
Chaetoceros curvisetus	0.5	2.8	-	1.6	1.6	1.3
Chaetoceros decipiens	3.2	5.2	-	-	-	-
Chaetoceros socialis	5.9	2.8	0.4	3.5	1.7	5.1
Chaetoceros spp.	2	0.5	4.8	7.9	1.6	0.5
Corerthron criophillum	0.1	-	-	-	-	-
Cosinodiscus sp.	0.6	0.2	0.5	-	-	0.1
Detonula sp.	3.6	0.9	-	0.3	-	0.8
Ditylum brighwellii	-	0.1	-	-	-	-
Guinardia flaccida	-	-	-	-	-	0.3
Lauderia annulata	4.4	2.1	1.9	2.5	1.9	3.7
Rhizosolenia setigera	-	-	-	-	-	-
Thalassiosira decipiens	0.8	-	-	-	0.3	3.3
Thalassiosira hylina	13.5	5.2	4.7	3.7	4.5	3.6
Pennate						
Asterionella glacialis	0.4	-	0.5	-	-	-
Diploneis sp.	-	0.1	-	-	-	-
Navicula sp.	0.3	-	-	-	-	-
Nitzschia sp.	-	0.1	-	-	-	-
Pleurosigma sp.	0.1	-	-	-	-	-
Pseudonitzschia australis	-	-	-	-	-	0.9
Thalassionema nitzschioides	-	0.3	-	-	-	-
Class Dinophyceae						
Non-thecate						
Gymnodinium sp.	0.4	0.1	0.5	0.1		0.1
Gyrodinium sp.	0.3	0.1	-	-	-	-
Thecate						
Protoperidinium sp.	0.1	0.1	-	-	-	-
Oxytoxum sp.	0.1	-	-	-	-	-
Scrippsiella trichoidea	0.1	0.1	-	-	-	-
Class Cryptophyceae						
Cryptomonas sp.	0.8	0.4	0.1	0.1	0.1	0.1
Total	37.6	21.1	13.4	23	13	20.2

3.2.2 Zooplankton

The abundance of zooplankton was highest in the inner and mid parts of Lyall Bay where densities reached 889 individuals per m^3 and lowest in the outer parts of the bay where densities were as low as 119 individuals per m^3 (left panel in Figure 3-9). However, species richness was lowest inshore with 23-26 species occurring, while 28-37 species occurred at mid and outer bay sites (right panel in Figure 3-9). In total, 49 species of zooplankton were sampled within Lyall Bay.

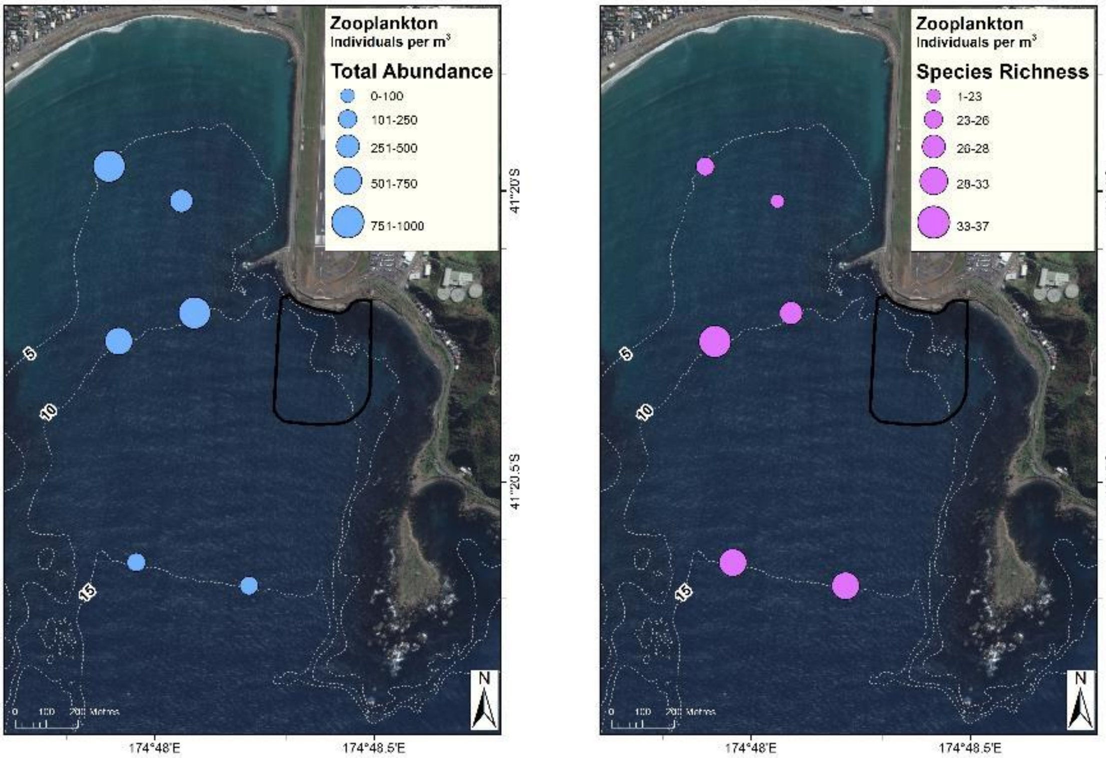

Figure 3-9: Abundance (numbers per m^3) (left panel) and species richness (right panel) of zooplankton sampled at six sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

Copepods were the dominant zooplankton taxa at all sites, comprising between 76% and 83% of all individuals (Figure 3-10). The other 20 classes of zooplankton each made up less than 5% of all individuals.

Of the copepods, the dominant group were two species in the genus *Paracalanus* which overall comprised 73% of the copepods but was most abundant in the inner and mid parts of Lyall Bay (Figure 3-11). *Euterpina acutifrons* comprised 9% of the copepods and was most abundant in the inner and mid parts of the bay, occurring in very low densities at the outermost sample sites. *Oithona* sp. comprised just 5% of the copepod fauna and was most abundant in the outer part of the bay. Copepod larvae comprised 5% of the copepod fauna and were most abundant in inner and mid parts of the bay (Figure 3-11).

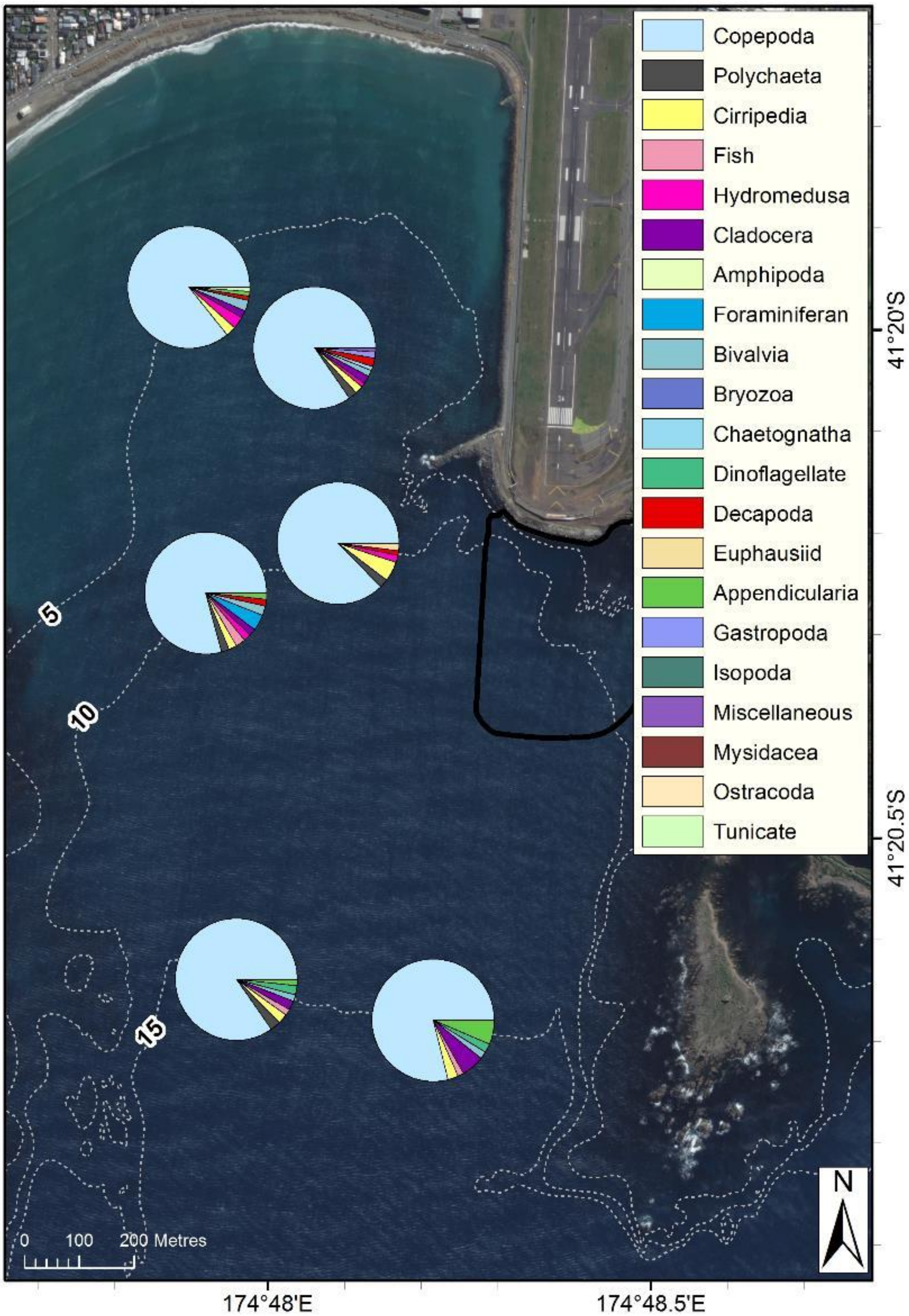

Figure 3-10: Percentage composition of the zooplankton community sampled at six sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

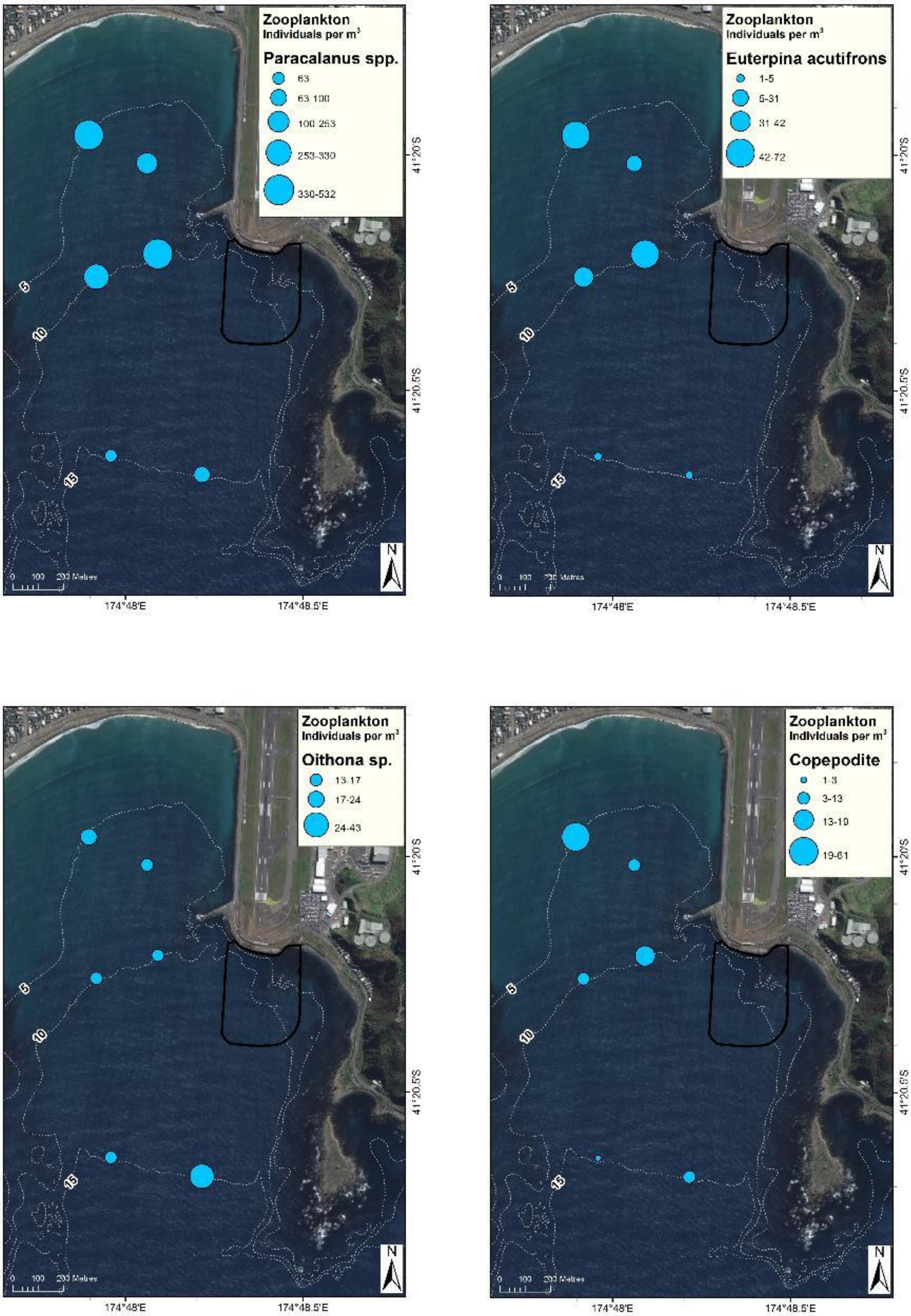

Figure 3-11: The abundance of the different copepod species at sampling sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

3.3 Soft sediment habitats and communities

3.3.1 Seafloor imaging

Nine seafloor habitats were identified in Lyall Bay from the imaging transects (Figure 3-12). The predominant habitat observed at all sites from video and still imagery was 'rippled sand' which is typical of shallow sediments of high energy coastlines. However, differences occurred across sites in terms of the level of bioturbation of the sandy seafloor.

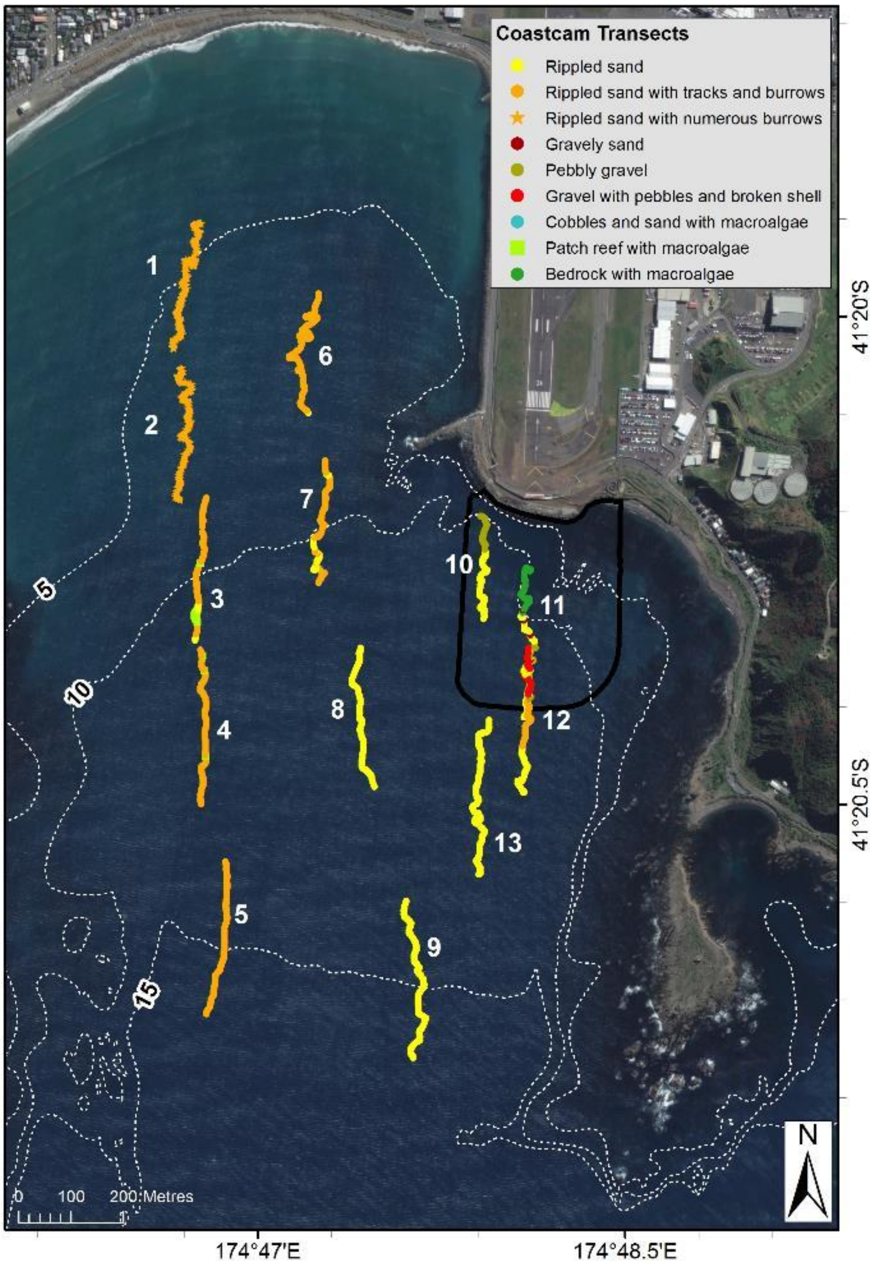

Figure 3-12: The distribution of habitat types along each seafloor imaging transect in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

Numerous small burrows of infaunal invertebrates occurred along the inshore transects (sites 1 and 2) in depths of five to eight metres (Figure 3-13). The shape and form of these burrows is consistent with those inhabited by ghost shrimps (Thalassinidea), most probably *Biffarius filholi* which was captured in cores from several sites including Site 1 (see section 3.3.4). Other camera transects in Lyall Bay revealed rippled sand with varying prevalence of larger burrows and surface 'tracks' (Figure 3-14). These are most likely to have been a result of several motile invertebrate species including pagurids (hermit crabs), various gastropods (snails) or seastars (Figure 3-15). The abundance of these animals observed on still images and video footage was very low throughout the study area (Table 3-4) and this was supported by similarly low catches in the dredge.

Figure 3-13: Numerous small burrows in rippled sand at Site 1 in Lyall Bay. The image area is approximately 0.24 m^2.

Figure 3-14: Surface tracks by motile invertebrates on rippled sand.

Two large starfish *Astrostole scabra* were the largest invertebrates observed, and both were noted at the deeper site 5 (Figure 3-15). They are a common predatory species found throughout New Zealand but usually occur on shallow reefs.

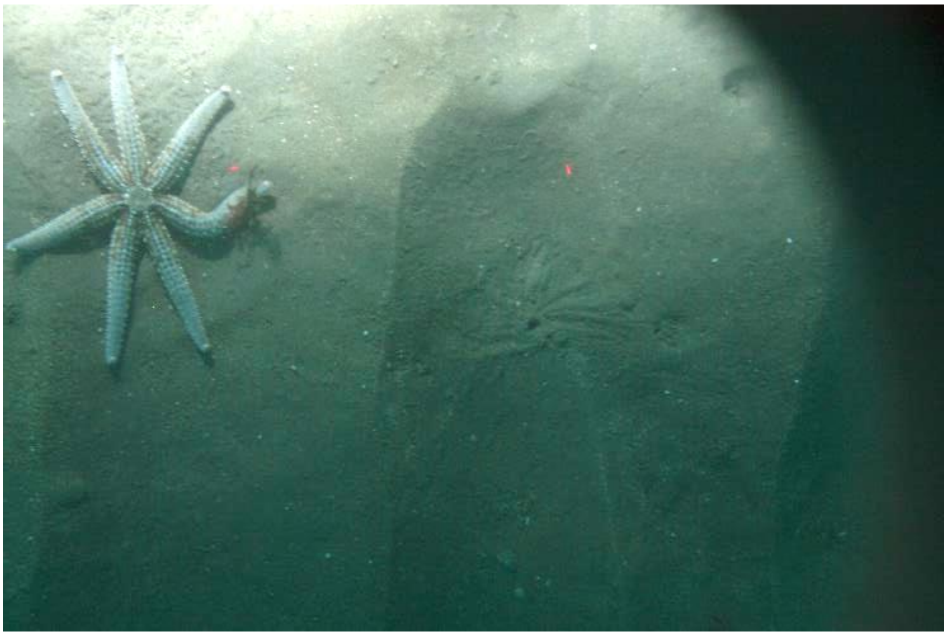

Figure 3-15: *Astrostole scabra*, a large predatory starfish at Site 5.

Small patch reefs (< 2 m^2) were observed in isolated areas along camera transects at sites 3 and 4 in the centre of Lyall Bay, at depths of around 10- 13 metres. They were conspicuous by the presence of macroalgae holdfasts attached to low-lying bedrock as opposed to unattached drifts of algae that were commonly seen at all locations. The two main algal species observed on these patch reefs were the very common laminarians; *Ecklonia radiata* and *Macrocystis pyrifera,* or bladder kelp. On one occasion the algal grazing urchin (kina) *Evechinus chloroticus* was observed attached to kelp fronds.

The only fish observed with the camera proved to be two small opalfish; *Hermerocoetes monopterygius* along transect 5 at a depth of 16 metres on a rippled sandy seafloor. They prey on crabs and shrimps which would also be associated with this habitat. It must be noted that the occurrence of fish is likely to be under represented in this towed imaging survey. The camera frame was 'flown' very close to the seafloor in shallow water making it likely that some fish species would have avoided the camera as it approached due to its bulk, underwater noise and presence of floodlights.

A distinct change to gravel with pebbles was observed at the northern end of the transect at site 10, about 80 m off the end of the existing runway. This gravel habitat continued in close proximity to the runway seawall when the deployment concluded about two boat lengths from the wall itself.

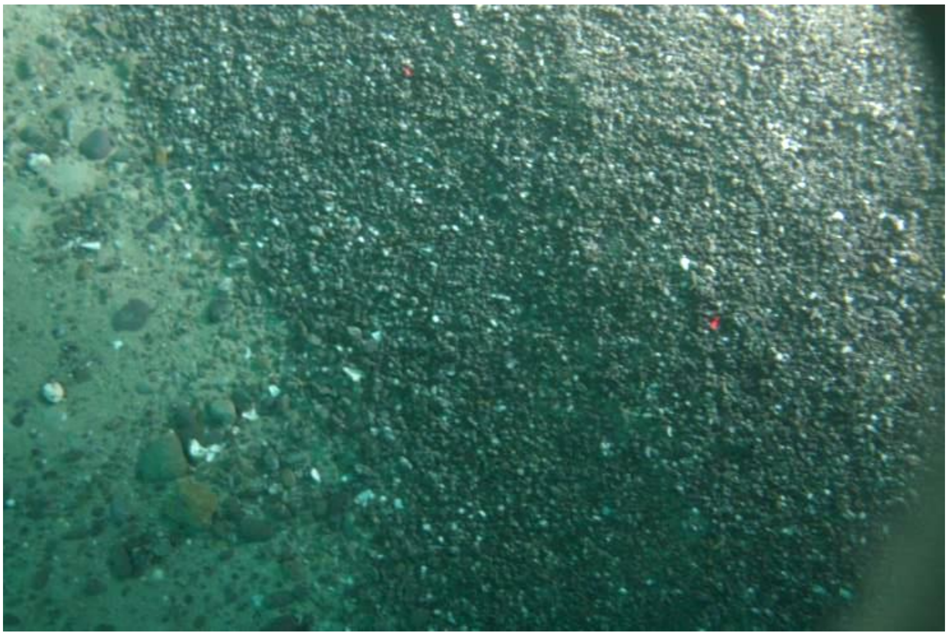

Figure 3-16: Distinct boundary change from sand to gravel/pebble substrate at the north end of transect 10.

The two eastern-most camera transects (at sites 11 and 12) which overlapped each other, were directly off the end of the existing runway in a south to north direction (Figure 3-12). At the deeper southern end the seafloor was characterised by rippled sand but this changed into a mix of cobbles, pebbles and gravels half way along. The northern shallow end consisted of a mix of bedrock, boulders and cobbles, with gravel and sand patches between (Figure 3-17). Canopy forming macroalgae species were dominant, including *Ecklonia radiata, Carpophyllum maschalocarpa* and *Lessonia variegata.* Sub-canopy species observed were a diverse mix of red algae and smaller browns. Occasional paua, *Haliotis iris,* and banded wrasse, *Notolabrus fucicola,* a very common reef fish were seen on video footage.

Figure 3-17: Bedrock, boulder and macroalgae habitat with sand and gravel patches along Site 12.

Table 3-4: The depth range, habitat, fauna, and flora observed along each seafloor imaging transect.

Transect	Depth range (m)	Habitat	Epi-fauna and -flora observed
1	5.5–6.3	Rippled sand with numerous burrows	
2	6.7-8.4	Rippled sand with numerous burrows	Asteroid x 1 (starfish)
3	8.5–12.7	Rippled sand with tracks and fewer burrows. Several isolated patch reefs (< 2m^2) with macro-algae were present	Gastropod x 1 (snail) Pagurid x 1 (Hermit crab)
4	12.7-14	Rippled sand with tracks and fewer burrows. Several isolated patch reefs (< 2m^2).	Gastropod x 1 (snail) Macro-algae on patch reefs
5	14.8-17.3	Rippled sand with tracks and fewer burrows with some shell fragments.	Asteroid x 1 (starfish) Opalfish x 2
6	7.9-9	Rippled sand with burrows	Pagurid x 1 (Hermit crab)
7	9.9-12	Rippled sand with some tracks and burrows	Gastropod x 2 (snail) Pagurid x 1 (Hermit crab) Asteroid x 1 (starfish)
8	11.5-12.9	Rippled sand	Pagurid x 2 (Hermit crab)
9	13.9-16.3	Rippled sand	Gastropod x 2 (snail) Pagurid x 1 (Hermit crab) Bryozoan clump x2 (lace coral)
10	10-11.5	Rippled sand then gravel and pebbles inshore	Gastropod x 2 (snail), Pagurid x 1 (Hermit crab). Some macro-algae
11	9-13.1	Mix of rippled sand, gravel, pebbles, cobbles, boulders and bedrock	Paua x4, gastropod x 1, asteroid x1, pagurid x1, kina, sponges, Rich diversity of macro-algae on rocks. Banded wrasse x 2
12	11.5-13.6	Rippled sand, with some tracks and burrows leading to gravel and pebbles	Gastropod x 1, Bryozoan clump x1
13	12.7-14.4	Rippled sand	Gastropod x 1

3.3.2 Sediment characteristics

The particulate organic carbon (POC) content of surficial sediments in Lyall Bay is low, with %POC ranging from 0.1 to 0.3% (Table 3-5). The highest values of 0.2-0.3% are found in sediments of the shallow (~10 m depth), easternmost side of the bay off the southern end of the present runway in the area of the proposed runway extension (sites 10, 11 and 12) (upper left panel in Figure 3-18). Particulate nitrogen content (%PN) is very low (i.e., at or below detection limits) and is generally invariant across the bay at 0.02% (Table 3-5).

Since %PN does not vary significantly across the bay, molar C:N ratios reflect variations in the %POC content of the surficial sediments. C:N ratios vary from 5.25 to 17.49 (Table 3-5). The highest ratios are found at sites 10, 11 and 12 in the area of the proposed runway extension on the eastern side of

Lyall Bay (upper right panel in Figure 3-18). At other sites, C:N ratios typically range from 5 to 8, with no obvious spatially coherent patterns.

Table 3-5: Concentration and ratios of Chlorophyll-a (Chla), Phaeophytin (Phaeo), Particulate Nitrogen (PN) and Particulate Organic Carbon (POC) in surficial sediment samples in Lyall Bay. The detection limit of Chlorophyll-a and Phaeophytin is 0.1 µg/g, PN is 0.02%, and POC is 0.01%.

Site	Collection date	Chla (µg/g)	Phaeo (µg/g)	Chl:Phaeo	Chla/(Chla + Phaeo)	% PN	% POC	Molar C:N
1	27/08/2014	0.75	0.43	1.74	0.64	0.02	0.11	6.41
2	27/08/2014	1.33	0.44	3.02	0.75	0.03	0.21	8.16
3	27/08/2014	0.75	0.54	1.39	0.58	0.02	0.11	6.41
4	27/08/2014	0.55	0.50	1.10	0.52	<0.02	0.14	8.16
5	27/08/2014	0.46	0.68	0.68	0.40	0.02	0.14	8.16
6	28/08/2014	0.94	0.61	1.54	0.61	0.02	0.15	8.75
7	28/08/2014	0.56	0.38	1.47	0.60	0.02	0.10	5.83
8	28/08/2014	0.60	0.27	2.22	0.69	0.02	0.12	7.00
9	27/08/2014	0.67	0.25	2.68	0.73	0.02	0.09	5.25
10	28/08/2014	0.51	0.32	1.59	0.61	0.02	0.24	13.99
11	28/08/2014	0.38	0.54	0.70	0.41	0.02	0.24	13.99
12	28/08/2014	0.22	0.16	1.40	0.58	0.02	0.30	17.49
13	28/08/2014	0.45	0.42	1.07	0.52	0.02	0.10	5.83
	Mean	0.63	0.43	1.6	0.6	0.02	0.16	8.88
	Standard deviation	0.28	0.15	0.7	0.1	0.00	0.07	3.82

Sediment Chla contents are low, ranging from 0.2 to 1.3 µg/g, with an area of higher values (0.6-1.3 µg/g) extending throughout the central part of Lyall Bay and lower values (0.2-0.5 µg/g) along the eastern side of the bay in the vicinity of the proposed runway extension (Table 3-5 and lower right panel in Figure 3-18). The data suggest a mid-bay high in Chla content at sites 2 and 6 between the 5 and 10 m bathymetric contours.

In contrast, sediment phaeopigments (i.e., non-photosynthetic degradation products of chlorophyll pigments, including Chla) did not vary substantially across Lyall Bay, with a range of 0.2 to 0.7 µg/g, and at most sites were exceeded by Chla concentrations (exceptions were sites 5 and 11). The ratio of Chla to total chloropigments (i.e., Chla plus total phaeopigments) in the surficial sediments did not vary markedly across the bay, ranging from 0.40 to 0.75, with no obvious spatial trends (Table 3-5 and lower left panel in Figure 3-18).

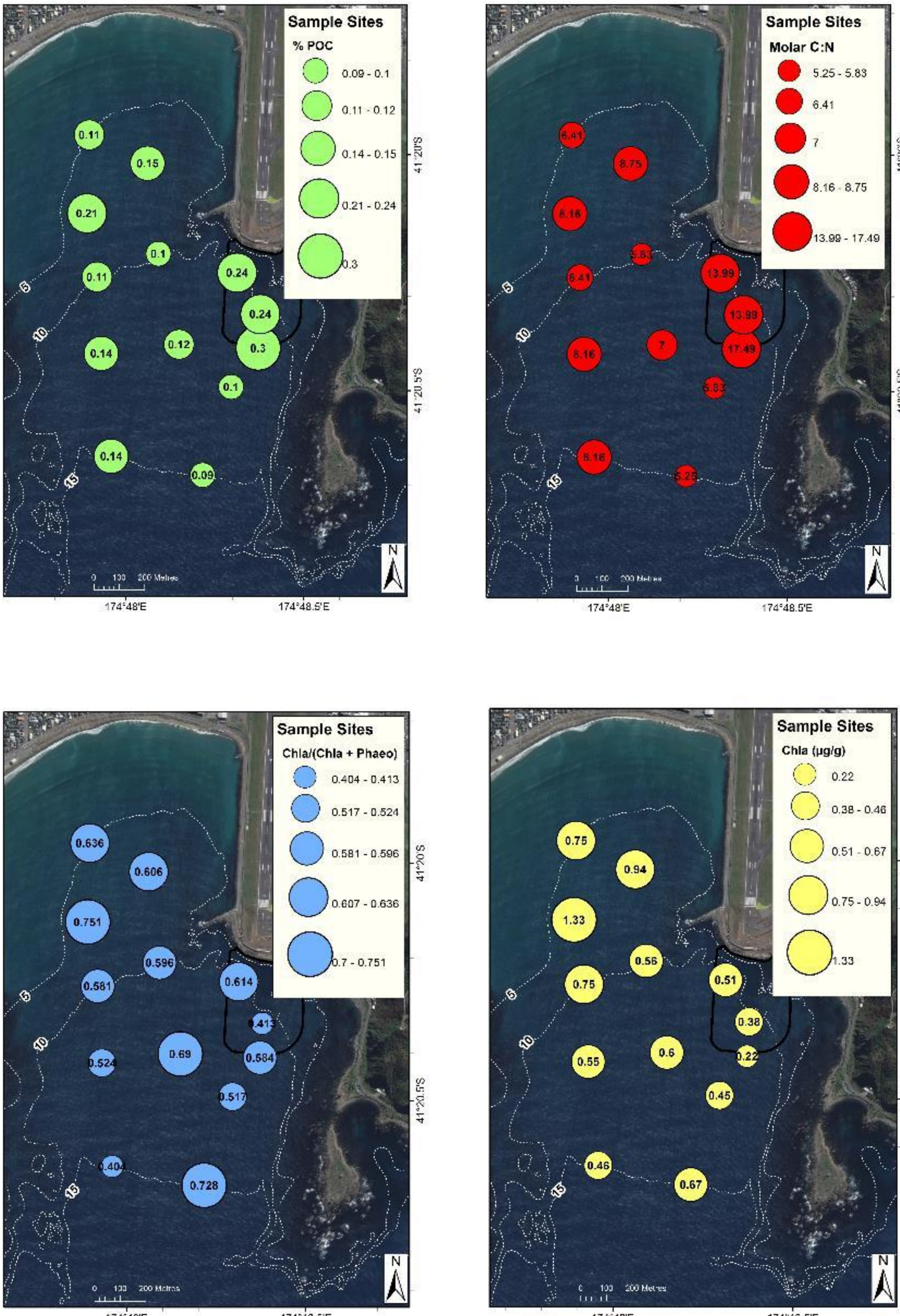

Figure 3-18: The distribution of key surficial sediment parameters in Lyall Bay. Clockwise from top left: % particulate organic carbon (POC), molar C:N ratio, Chlorophyll-a (Chla), and the ratio of Chlorophyll-a to the total of Chla plus phaeopigments.

The surficial sands were dominated by moderate to very well sorted fine sands with a very low percentage of silts at all sample sites. The exceptions were site 10, which was composed of very-course sand with a fine-gravel component, and site 12 which was composed of fine-sand with fine gravel component (Figure 3-19).

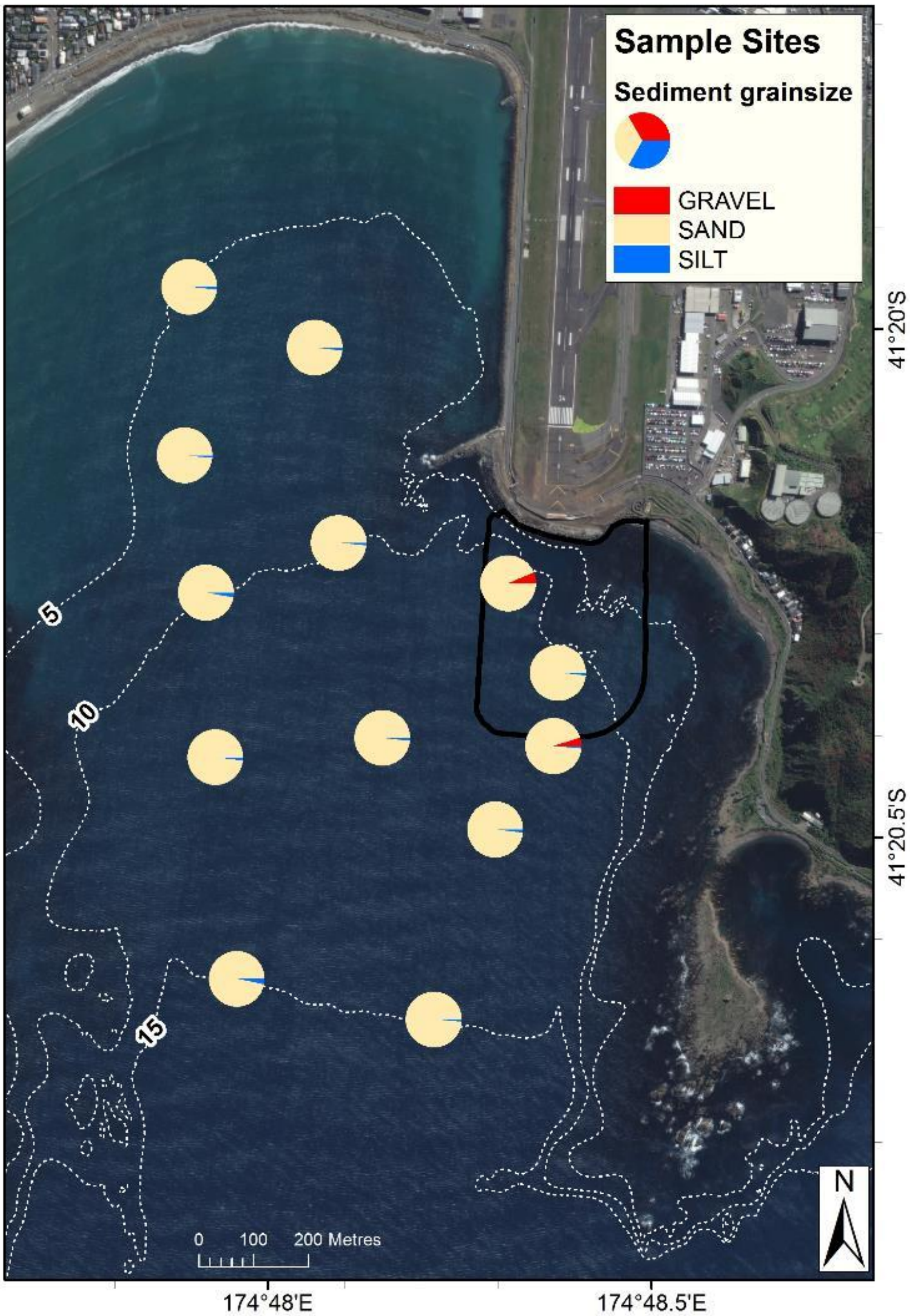

Figure 3-19: Surficial sediment grain size composition (%) at sample sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

3.3.3 Epibenthos

The epifauna in Lyall Bay was depauperate with a total of only 34 specimens of 13 species captured in the dredge tows along the 13 transects. There was no obvious geographical pattern in total abundance (left panel in Figure 3-20). No epifauna was captured at two sites and at four further sites only one individual of any species was captured. The highest number of individuals captured in a single dredge tow was seven. Consequently at five sites only a single class of organisms occurred, each comprising a single species (left panel in Figure 3-21). The gastropod *Amalda australis* was the most widely distributed, occurring at six sites, followed by the shrimp *Tenagomysis* sp. 1 at four sites, and an undescribed ophiuroid in the Family Ampiuridae at three sites (right panel in Figure 3-22).

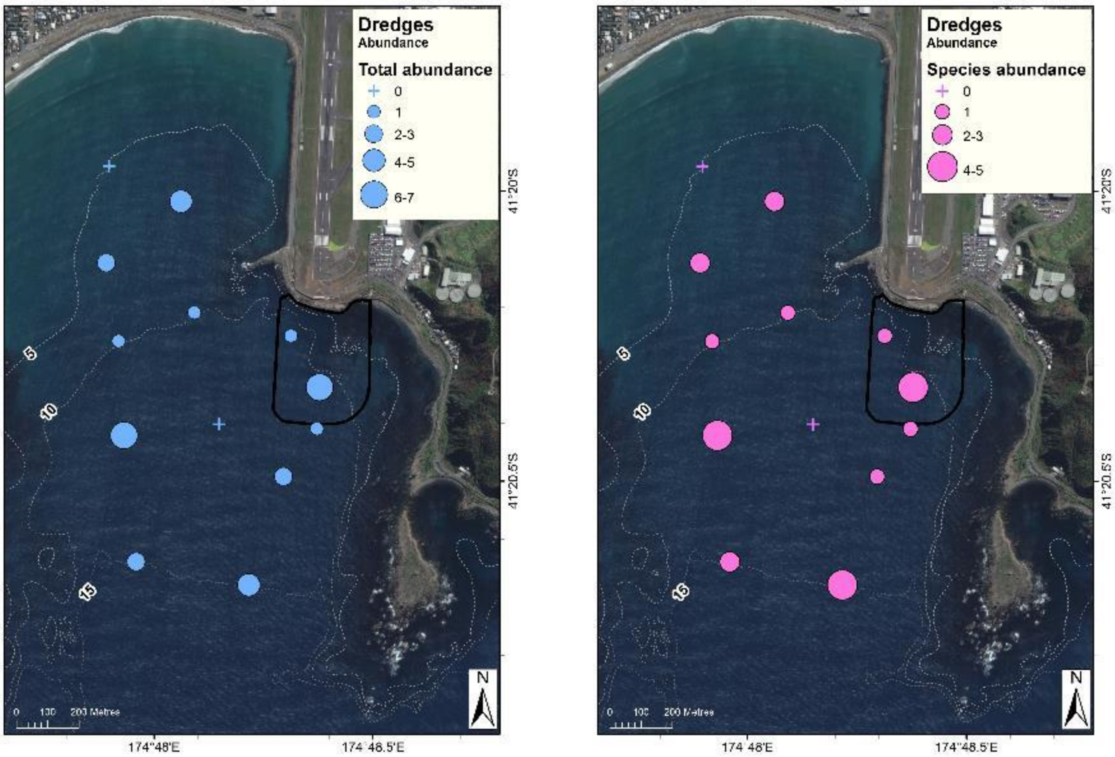

Figure 3-20: Total abundance (left panel) and number of species (right panel) of epibenthic fauna at 13 sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. Sites where no epifauna was captured are indicated by crosses.

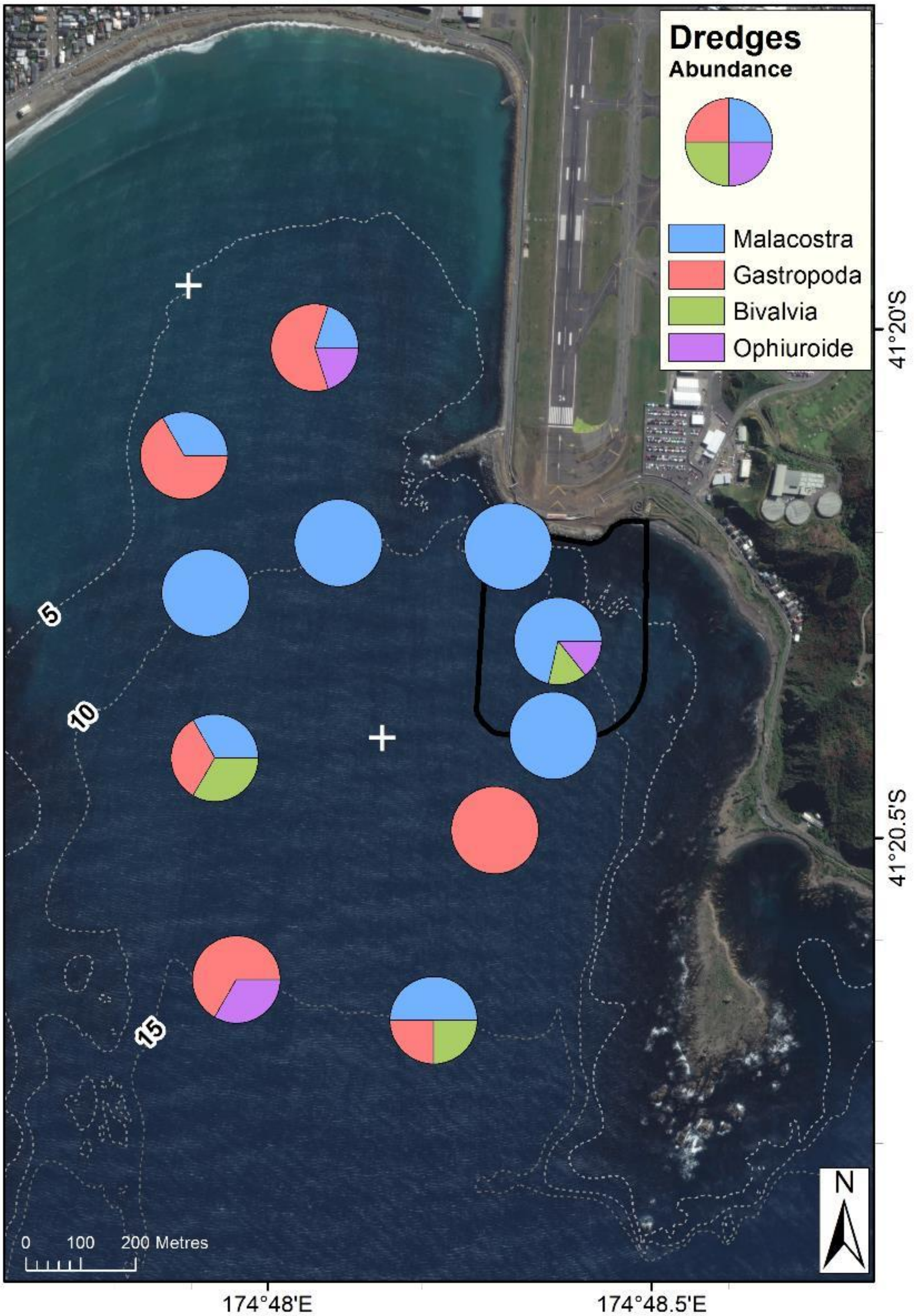

Figure 3-21: Composition of epibenthic fauna collected in dredge tows along 13 transects in Lyall Bay, by broad taxonomic class. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. Sites where no epifauna was captured are indicated by crosses.

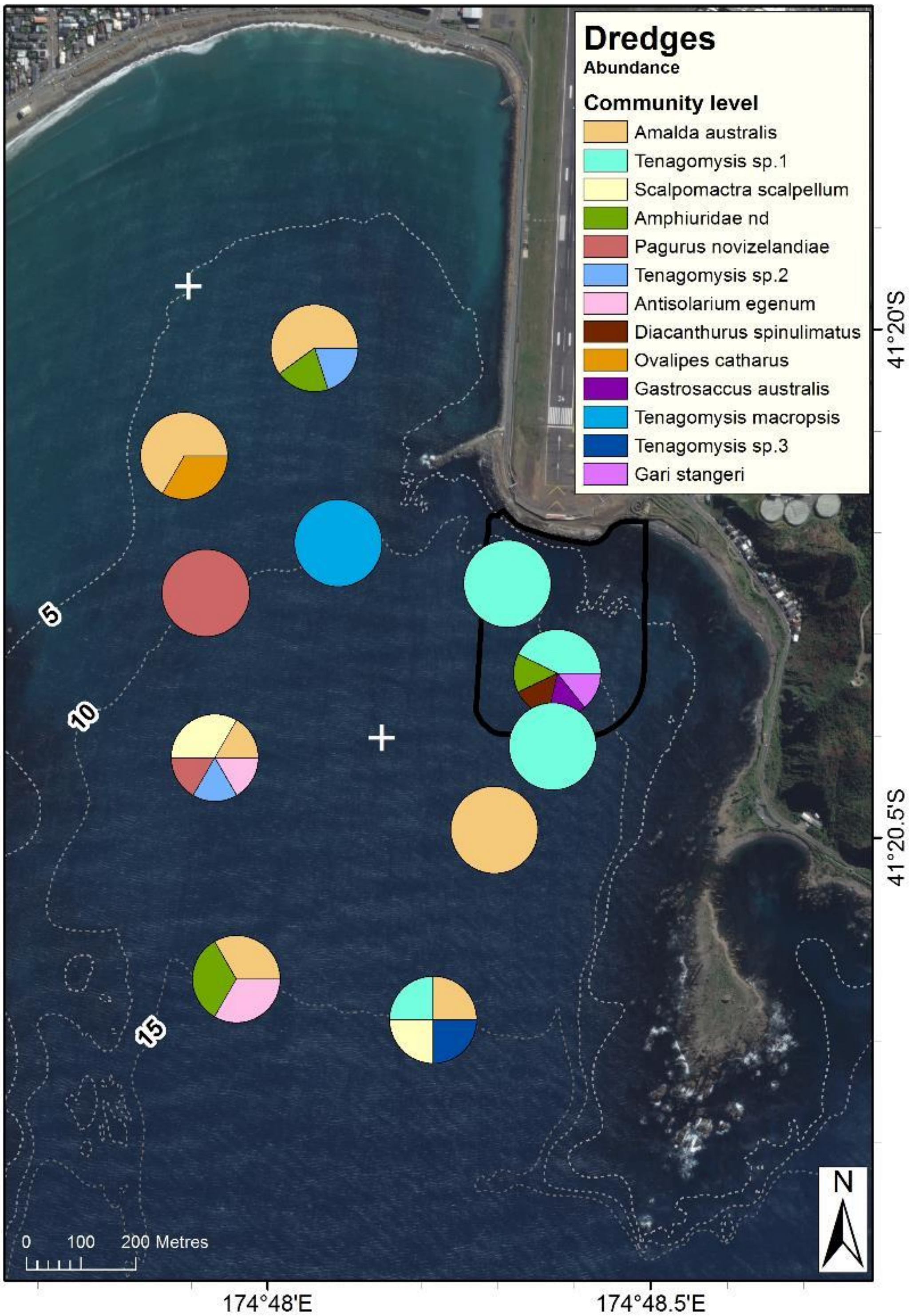

Figure 3-22: Composition of epibenthic fauna collected in dredge tows along 13 transects in Lyall Bay, by species. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines. Sites where no epifauna was captured are indicated by crosses.

The absence of epifaunal specimens at two sites, the occurrence of only one individual at a further four sites, and low overall catches suggests that the statistical analyses of the epifaunal communities must be interpreted cautiously.

Multivariate analyses of epifaunal community structure using the SIMPROF routine in PRIMER could not identify any significant clustering of sample sites at either the 5% or 10% significance levels.

A distance-based linear model (DISTLM) within PERMANOVA+ for PRIMER-E (Anderson et al. 2008) tests how much of the total variation each predictor (environmental) variable explains. Sequential tests within DISTLM (Table 3-6) indicated that the environmental variables accounted for 89% of the total variation in total abundance of epifauna but no one environmental variable was significant. Sequential tests within DISTLM (Table 3-6) indicated that the environmental variables explained about 70% of the total variation in species specific abundance, and showed that the %gravel at each site was the main and only significant driver of the variation in epifauna assemblages, explaining almost 25% of the overall variation ($p<0.05$). Figure 3-23 is a visual representation of the DISTLM analysis. The two axes explain 47.6% of total variation (compared with 70% variation explained by the DISTLM). The vector plot can be interpreted as the effect of a given predictor variable (the longer the vector the bigger the effect).

Table 3-6: DistLM sequential test results showing correlation between predictor variables and epifaunal total and species abundance. Values in bold* are statistically significant. SS = sum of squares. Sites 1 and 8 were removed from the analysis because of zero catches.

Variable	SS(trace)	Pseudo-F	P	R^2	Proportion of variance
Total abundance					
% sand	3276.8	3.6962	0.089	0.31602	0.31602
% gravel	127.42	0.12806	0.875	0.32831	0.012288
Phaeo (µg/g)	1212.2	1.2644	0.315	0.44521	0.11691
Chla (µg/g)	151.84	0.13555	0.846	0.45986	0.014644
POC %	993.39	0.86242	0.407	0.55566	0.05802
% silt	414.71	0.29674	0.673	0.59565	0.039995
Depth (m)	3010.5	5.0926	0.129	0.88598	0.29033
Species abundance					
% gravel	9088.6	2.9439	**0.019***	0.24648	0.24648
Phaeopigment (µg/g)	3255.6	1.0618	0.412	0.33477	0.088289
% sand	2072.2	0.64591	0.719	0.39096	0.056197
POC %	1681.6	0.48564	0.833	0.43657	0.045604
% silt	1026.9	0.26	0.933	0.46442	0.02785
Chlorophyll-a (µg/g)	2936.9	0.69877	0.593	0.54407	0.079648
Depth (m)	5676.2	1.5292	0.265	0.698	0.15394

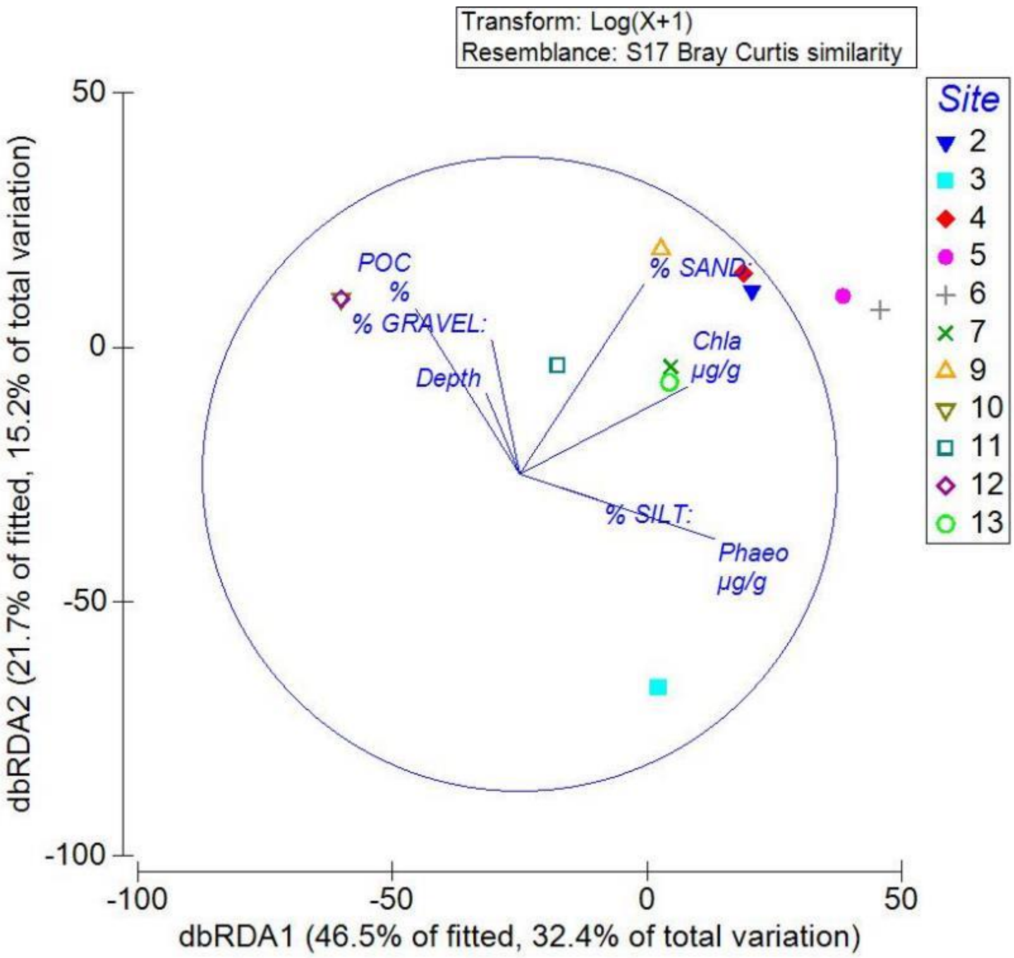

Figure 3-23: dbRDA plot of the epifaunal species abundance data. Sites 1 and 8 were removed from the analysis because of zero catches.

3.3.4 Macro-infauna

A total of 226 macro-infauna individuals were collected across all 13 sites/cores from the top 5 cm of the sediment (51% of all individuals from all layers of all cores), with a maximum of 38 individuals in the top segment of any one core (at site 12). In the 5-10 cm layer a total of 161 individuals (36.8% of all specimens from all layers of all cores) were captured, with a maximum of 47 individuals found in this layer (at site 11). At only eight sites did the corer sample to a depth of 15 cm yielding just 51 specimens (11.6% of all specimens from all layers of all cores). Henceforth, macro-infaunal figures and analyses apply only to the upper 5 cm layer.

There was no obvious geographical pattern in the abundance of macro-infauna in the upper 5 cm layer of sediment in Lyall Bay (left panel in Figure 3-24). The overall number of species captured across the upper layer of all cores was 43 with between four and 13 species occurring in any single core (right panel in Figure 3-24).

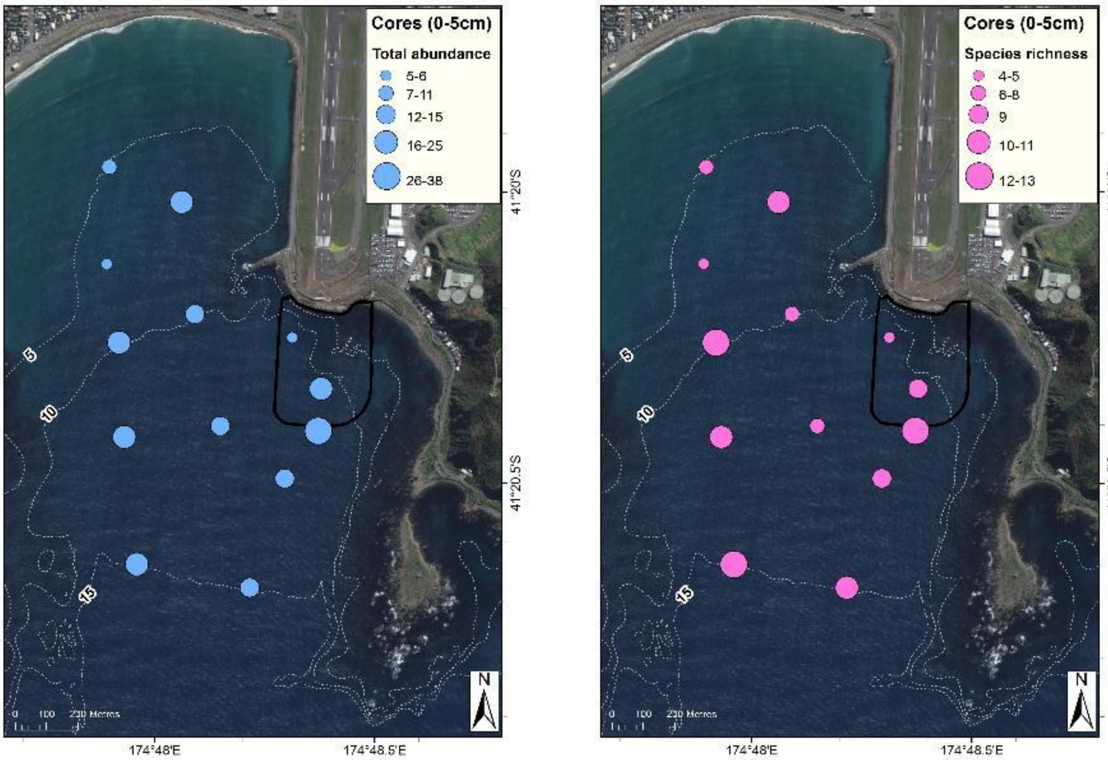

Figure 3-24: Total abundance (left panel) and number of species (right panel) of macro-infauna in the upper 5 cm of sediment at 13 sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

The macro-infauna in Lyall Bay comprised 25 species, including polychaete worms, decapod crustaceans, snails, bivalve shellfish, ophiuroids (snake stars) and nematodes (Figure 3-25). Polychaete worms were the dominant component of the macro-infauna, comprising 41% of all macrofaunal specimens overall, and were the most important component at 10 of the 13 sites (Figure 3-25). Key polychaete species were an undescribed species in the genus *Paraonella* (42% of polychaetes), an undescribed species in the genus *Aricidea* (13% of polychaetes), the widespread *Macroclymenella stewartensis* (11% of polychaetes), and an undescribed species in the genus *Aglaophamus* (10% of polychaetes) (Figure 3-26). Gammarid amphipods also occurred at every site, comprising 31% of the macroinfauna overall. Other key macro-infaunal groups were isopods, comprising 10% of the macroinfauna, and decapod crustaceans, specifically *Biffarius filholi*, a ghost shrimp of the family Callianassidae. *Biffarius* is endemic to New Zealand, grows up to 60 mm long (Poore 2010), and comprised almost 7% of macrofaunal specimens (Figure 3-25 and Figure 3-26). The numerous small burrows observed in seafloor images at sites 1-7 were very likely made by this species (see Figure 3-13).

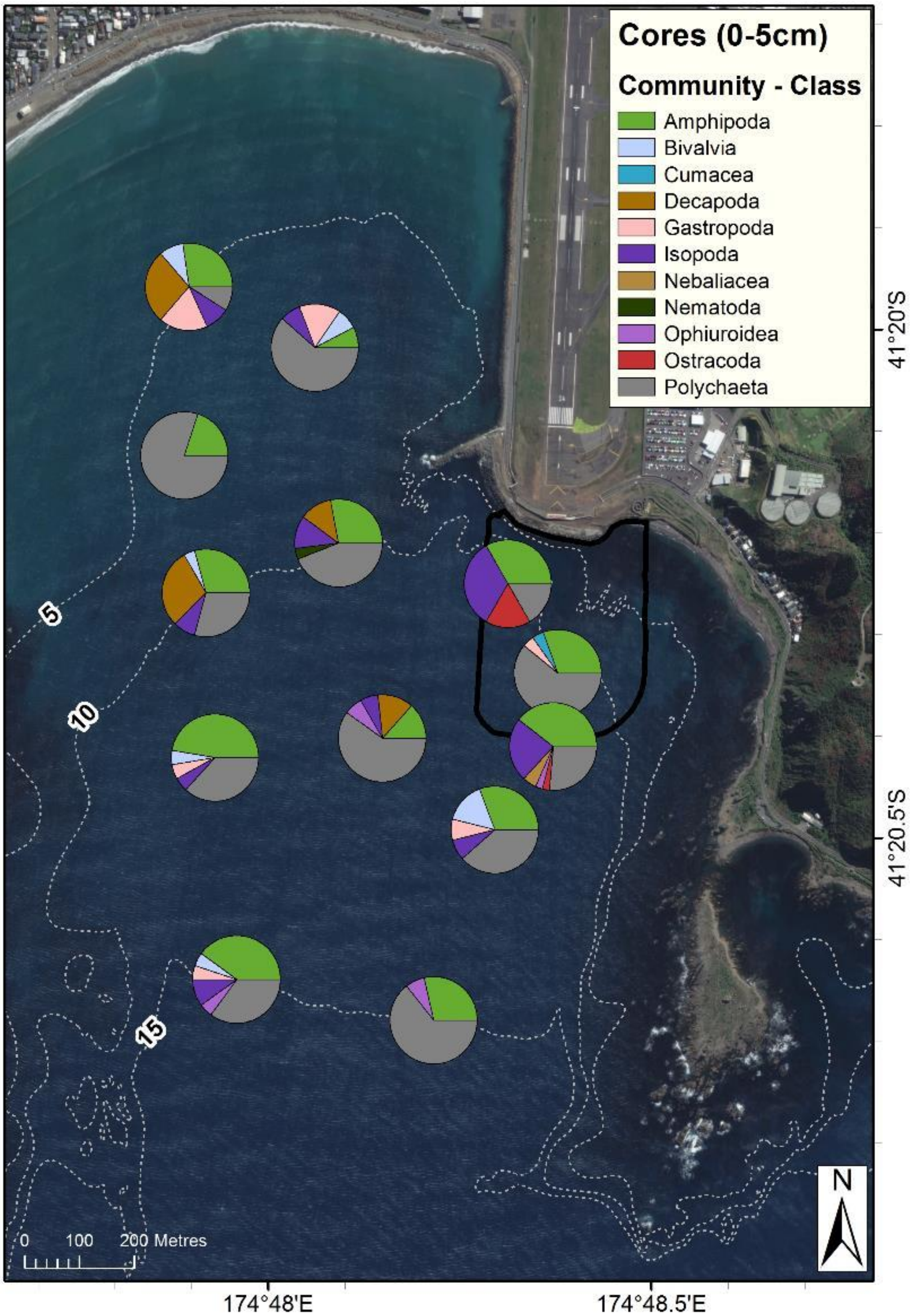

Figure 3-25: Composition of macro-infauna by broad taxonomic class in the upper 5 cm of sediment at 13 sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

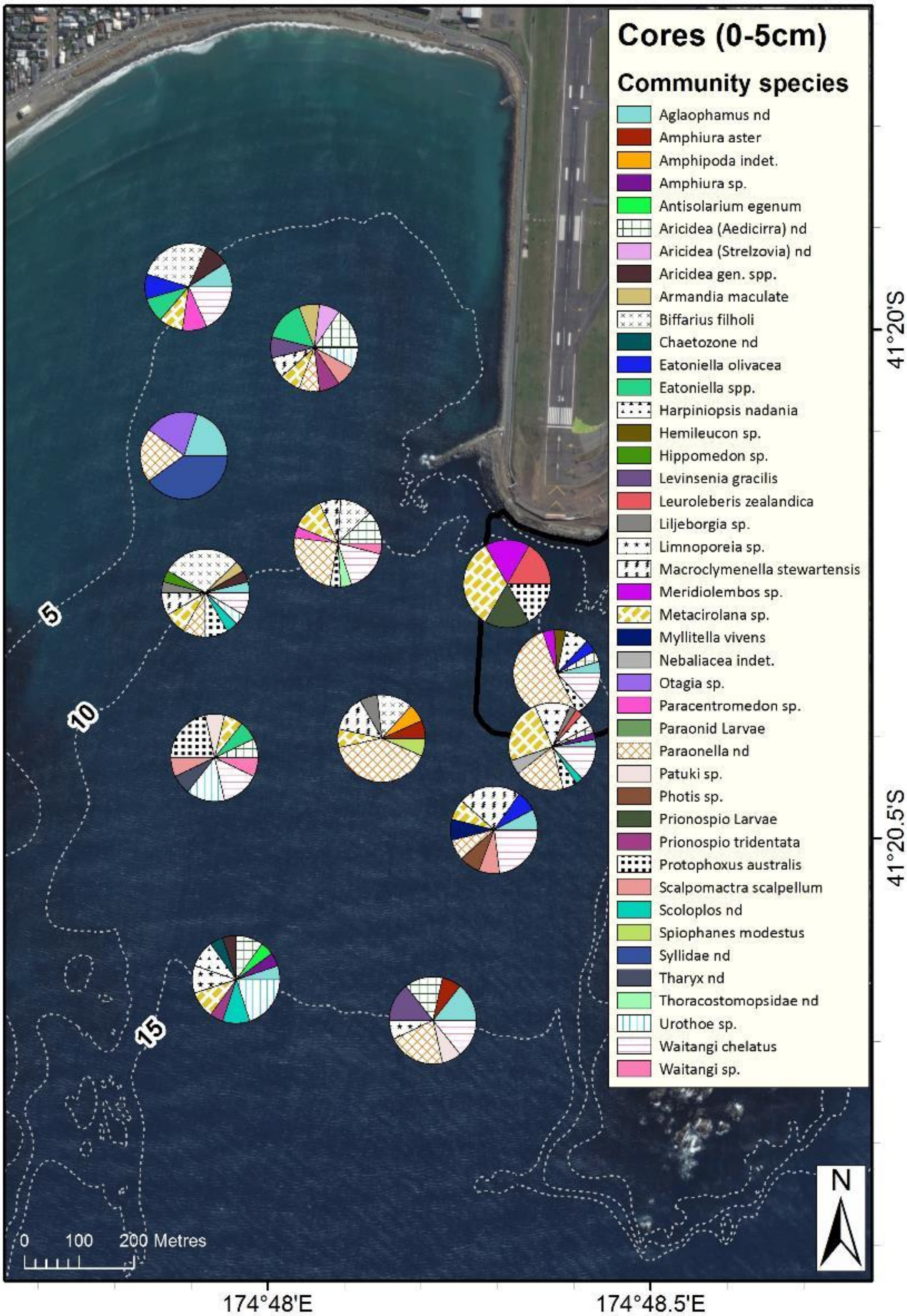

Figure 3-26: Composition of macro-infauna by species in the upper 5 cm of sediment at 13 sites in Lyall Bay. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

Multivariate analyses of macro-infauna community structure using the SIMPROF routine in PRIMER could not identify any significant clustering of sample sites at either the 5% or 10% significance levels.

A distance-based linear model (DISTLM) within PERMANOVA+ for PRIMER-E (Anderson et al. 2008) tests how much of the total variation each predictor (environmental) variable explains. Sequential tests within DISTLM (Table 3-7) indicated that the environmental variables accounted for 80% of the total variation in total abundance of macro-infauna but no one environmental variable was significant. Sequential tests within DISTLM (Table 3-7) explained about two-thirds of the total variation in taxon specific abundance and showed that the %sand at each site was the main and only significant driver of the variation in macro-infauna assemblages. Figure 3-27 is a visual representation of the DISTLM analysis for the species abundance data. The two axes explain 32.8 % of total variation (compared with 65 % variation explained by the DISTLM). The vector plot can be interpreted as the effect of a given predictor variable (the longer the vector the bigger the effect).

Table 3-7: DistLM sequential test results showing correlation between predictor variables and macro-infaunal total and species abundance. Values in bold* are statistically significant. SS = sum of squares.

Variable	SS(trace)	Pseudo-F	P	R^2	Proportion of variance
Total abundance					
Chla (µg/g)	1632.6	3.0157	0.087	0.21517	0.21517
% silt	1234.2	2.6144	0.119	0.37783	0.16266
POC %	1004.9	2.4338	0.139	0.51026	0.13244
% gravel	767.76	2.0833	0.163	0.61144	0.10118
Depth (m)	110.6	0.27284	0.622	0.62602	0.014577
% sand	769.95	2.2342	0.179	0.72749	0.10147
Phaeo (µg/g)	615.08	2.1171	0.179	0.80855	0.081062
Species abundance					
% sand	4696.7	1.8299	**0.01***	0.14263	0.14263
POC %	3647.3	1.4836	0.111	0.25339	0.11076
% gravel	3069.1	1.2838	0.234	0.3466	0.093205
Depth (m)	3143.7	1.3689	0.217	0.44207	0.095469
Chlorophyll-a (µg/g)	3193.1	1.4725	0.177	0.53904	0.096969
% silt	1847.9	0.83171	0.559	0.59515	0.056119
Phaeopigment (µg/g)	2065	0.91648	0.502	0.65787	0.062712

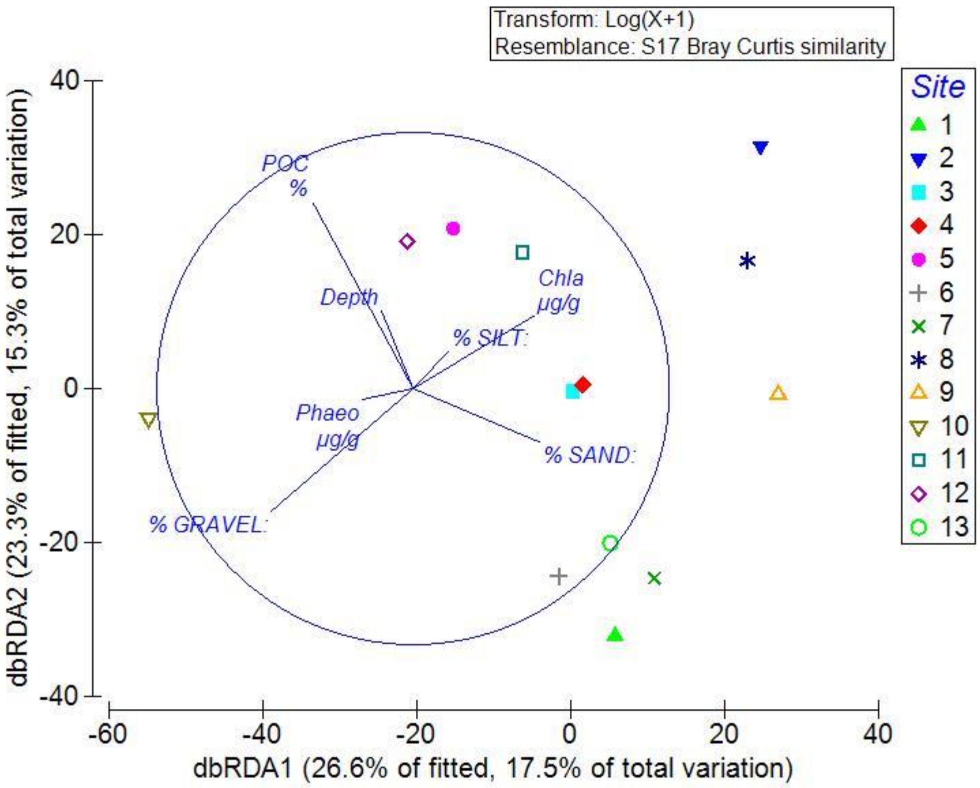

Figure 3-27: dbRDA plot of the macro-infaunal species abundance data.

3.3.5 Dinoflagellate cysts

Several cysts were found in sediment samples collected from a small number of sites, i.e., Site 1, 2, 6, 7 and 8. A total of three cyst types were identified. These were produced by three harmless dinoflagellate species, *Protoperidinium* cf. *punctulatum*, *Protoperidinium* sp., and *Scrippsisiella trochoidea* (Table 3-8).

Table 3-8: Dinoflagellate cysts found in sediment samples collected from Lyall Bay, Wellington.

	Station							
Taxa	#1	#2	#3	#4	#5	#6	#7	#8
Protoperdinium cf. *punctulatum*	-	+	-	-	-	-	+	-
Protoperdinium sp.	-	-	-	-	-	+	-	+
Scrippsiella trochoidea	+	-	-	-	-	-	-	-

3.3.6 Meiofauna

A total of 13 meiofaunal taxa were identified from the study sites (Table 3-9, Figure 3-28). Nematodes were the most abundant taxon (83% of total), followed by harpacticoid copepods (4%), kinorynchs (3%), tardigrades (3%), and nauplii (2%). All other taxa represented ≤ 1% of total meiofaunal abundance. Meiofaunal diversity did not vary substantially among sites (8-9 taxa 10 cm^{-2}).

Total meiofaunal abundance ranged from 250 to 1535 ind. 10 cm^{-2}, and was highest (>1000 ind. 10 cm^{-2}) at sites 6, 7, 8, 11, and 13 on the eastern side of the study area (Table 3-9). Site 10 was characterised by the lowest abundance (250 ind. 10 cm^{-2}); this site was situated on the north-eastern part of the study area close to the site with the highest abundance (site 11). Spatial trends in the abundance of meiofaunal taxa were most obvious for kinorynchs and tardigrades, which showed contrasting distributions; kinorynchs were most abundant in the western and central part of the study area, whereas tardigrades reached high densities at three of the eastern sites (Figure 3-29).

Table 3-9: Meiofaunal abundance (individuals 10 cm-2) at the study sites.

Site	1	2	3	4	5	6	7	8	9	10	11	12	13
Station	1	6	9	13	16	23	26	29	20	33	44	40	37
Nematodes	598	737	740	540	680	1070	1069	1019	786	120	1346	792	1086
Harpacticoids	109	30	45	55	8	35	38	26	24	62	36	41	39
Kinorynchs	55	48	85	71	3	24	56	27	41	2	11	3	2
Tardigrades	5	2	5	6	20	12	12	5	24	8	50	67	153
Nauplii	6	18	26	17	30	20	11	3	17	29	20	14	26
Turbellarians	3	5	15	0	15	11	2	5	8	2	17	5	29
Gastrotrichs	11	12	3	6	6	2	8	3	8	2	33	5	2
Ostracods	3	5	12	9	2	11	15	8	6	20	0	0	9
Polychaetes	0	2	0	5	0	2	9	6	5	0	2	3	5
Isopods	0	0	0	0	0	0	0	0	0	8	0	0	0
Amphipods	0	0	0	0	0	0	0	0	0	0	2	0	0
Bivalves	0	0	0	0	5	0	0	0	0	0	0	0	0
Acari	2	0	0	0	0	0	0	0	0	0	0	0	0
Total	818	881	940	731	786	1237	1248	1119	937	250	1535	960	1352

Figure 3-28: Light micrographs showing general appearance of a (A) tardigrade, (B) kinorynch, (C) harpacticoid copepod, and (D) nematode (family Draconematidae). Scale bar: A = 30 μm, B = 40 μm, C = 100 μm, D = 60 μm.

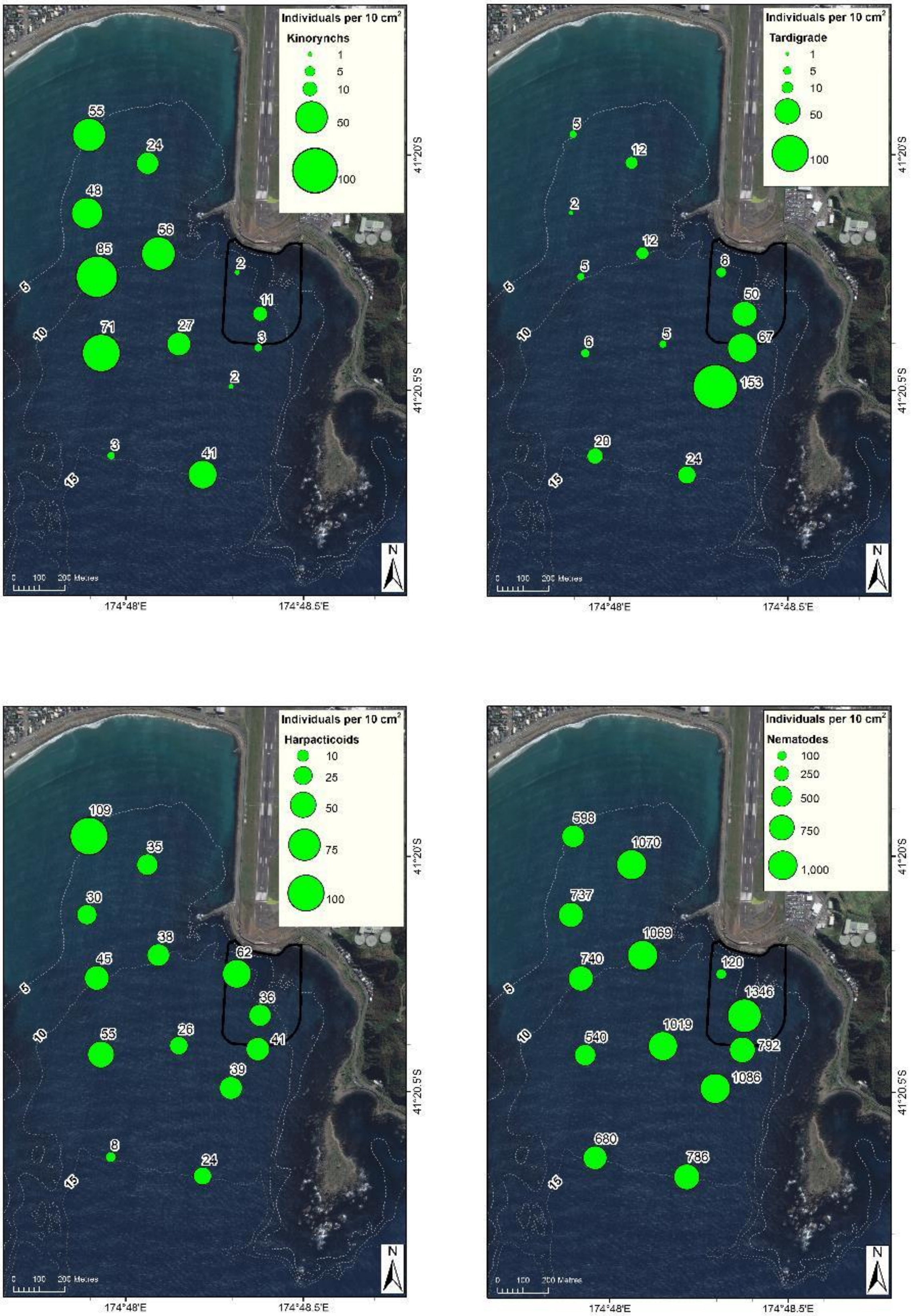

Figure 3-29: Abundance of key meiofaunal groups at sites sampled in Lyall Bay, Wellington south coast. In each panel the numbers of organisms sampled at each site is indicated.

SIMPROF results differed depending on the significance level chosen (P = 0.05 or 0.1). When using P = 0.05, all samples were grouped together, except for site 10, which was left ungrouped. When using P = 0.1, two communities were identified: one community comprising sites 5, 11, 12, and 13 (Community *a*; located in the south-eastern part of the study area), and another community (Community *b*) comprising all other sites except site 10 (which was left ungrouped) (Figure 3-30, Figure 3-31). Community *a* was characterised by high abundance of tardigrades, turbellarians, and gastrotrichs, whereas Community *b* was mainly characterised by the high abundance of kinorynchs and ostracods (Table 3-10). Site 10 was characterised by the lowest meiofaunal abundance, and was dominated by nematodes, harpacticoid copepods, nauplii, and ostracods.

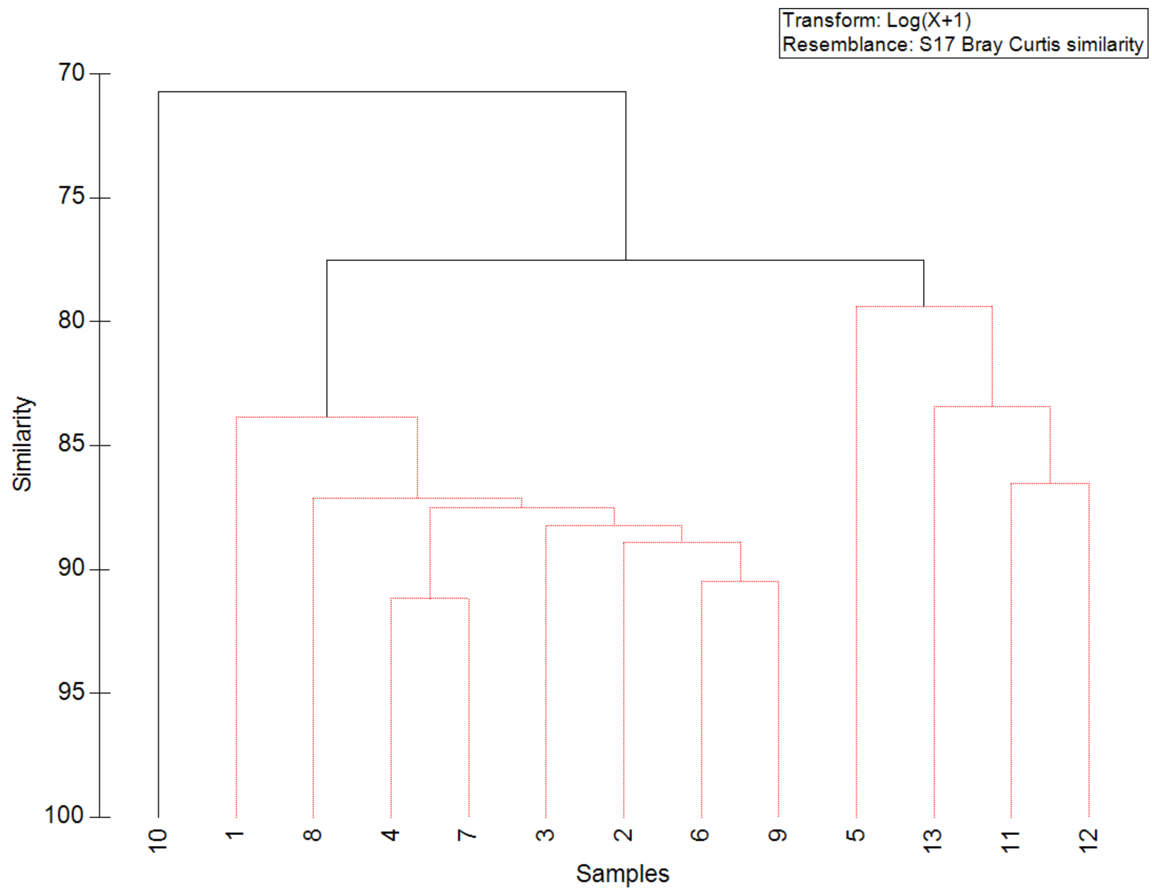

Figure 3-30: Cluster diagram showing the two communities (red lines) identified by SIMPROF analysis (P = 0.1). Site 10 (on the left) is left ungrouped.

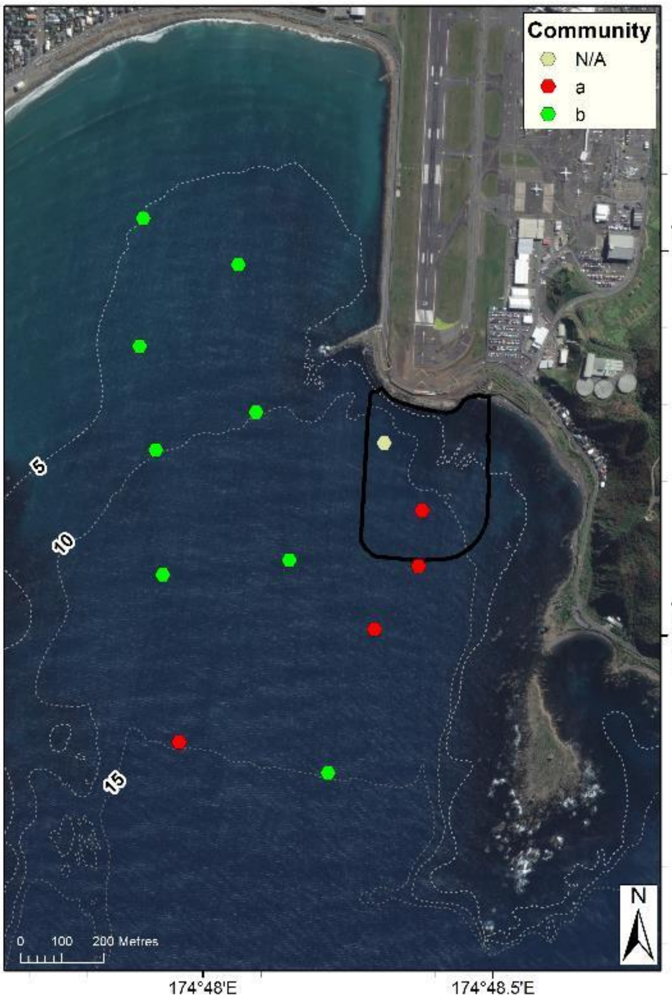

Figure 3-31: Distribution of the two meiofaunal community types identified in Lyall Bay.

Table 3-10: Results of SIMPER analysis showing the taxa responsible for the dissimilarity between Communities a and b identified by SIMPROF analysis. Av.Abund = average abundance (number of individuals 10 cm-2), Av.Diss = average dissimilarity, Diss/SD = dissimilarity divided by the standard deviation, Contrib% = percentage contribution to overall dissimilarity, Cum.% = cumulative percentage contribution to dissimilarity.

	Community a	Community b				
Species	Av.Abund	Av.Abund	Av.Diss	Diss/SD	Contrib%	Cum.%
Kinorynchs	5	51	4.9	3.36	21.78	21.78
Tardigrades	73	9	4.26	2.11	18.95	40.72
Ostracods	3	9	2.8	1.77	12.45	53.17
Turbellarians	17	6	2.37	1.43	10.54	63.71
Gastrotrichs	12	6	1.79	1.41	7.96	71.67
Polychaetes	3	3	1.55	1.32	6.89	78.57
Harpacticoids	32	45	1.43	1	6.38	84.94
Nauplii	23	15	1.34	1.1	5.95	90.89

Meiofauna abundance and community structure were significantly correlated with %sand (Table 3-11, Figure 3-32). None of the other predictor variables were significant correlated with meiofaunal abundance or community structure (Table 3-11). Note that two predictor variables were not used in the final analyses: nitrogen content and %clay (because all values were the same or below detection limits) and %gravel (which was strongly negatively correlated with %sand, r = 0.95).

Table 3-11: DistLM results showing correlation between predictor variables and meiofaunal abundance and community structure. Values in bold are statistically significant. SS = sum of squares.

	SS(trace)	Pseudo-F	P	R^2
Abundance				
chl *a*	4238	0.0844	0.759	0.0076
phaeo	13154	0.2662	0.638	0.0236
%C	17079	0.3482	0.575	0.0307
% Sand	231000	7.8005	**0.015**	0.4149
% Silt	0.61584	0.0122	0.999	<0.0001
Community structure				
chl *a*	365	1.7671	0.153	0.1384
phaeo	194	0.8711	0.516	0.0734
%C	243	1.1187	0.367	0.0923
% Sand	501	2.5816	**0.046**	0.1900
% Silt	244	1.1195	0.366	0.0924

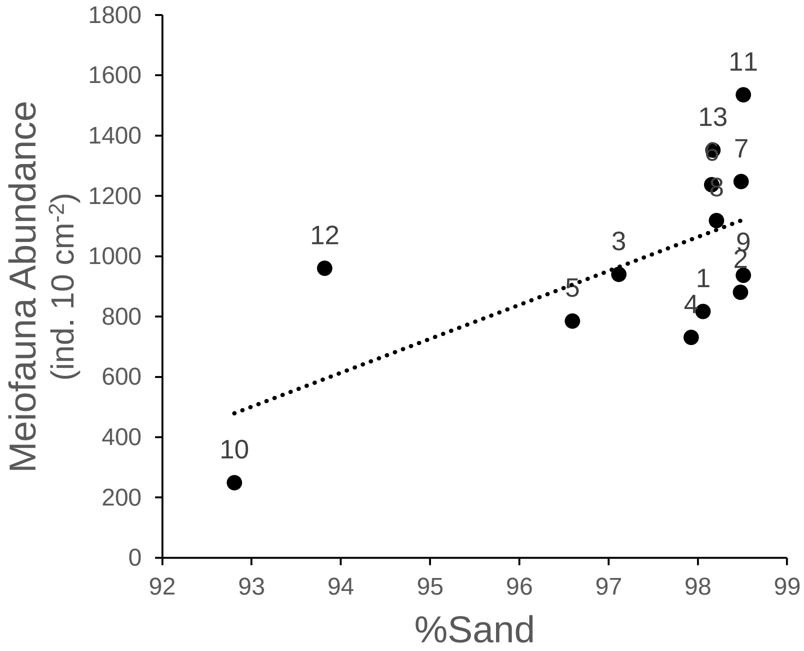

Figure 3-32: Relationship between the percentage of sand in seafloor sediments and meiofauna abundance in the Lyall Bay study area. Labels indicate site numbers.

3.4 Rocky reef communities

3.4.1 Phase 1 field sampling

The reefs sampled in Lyall Bay comprised a variety of natural and artificial substrates (Figure 3-33). Artificial substrates dominated in the intertidal zone on all transects except transect F (Figure 3-34). Large concrete tetrapods (labelled concrete blocks in the figure) were common on the upper part of transects A-D. Large concrete lumps in the shape of sacks also occurred on some transects. On transect E smaller concrete tiles occurred. On the middle and outer part of transects and on all of transect F natural bedrock, boulders, and cobbles occurred. Sand occurred around the margins of all reefs.

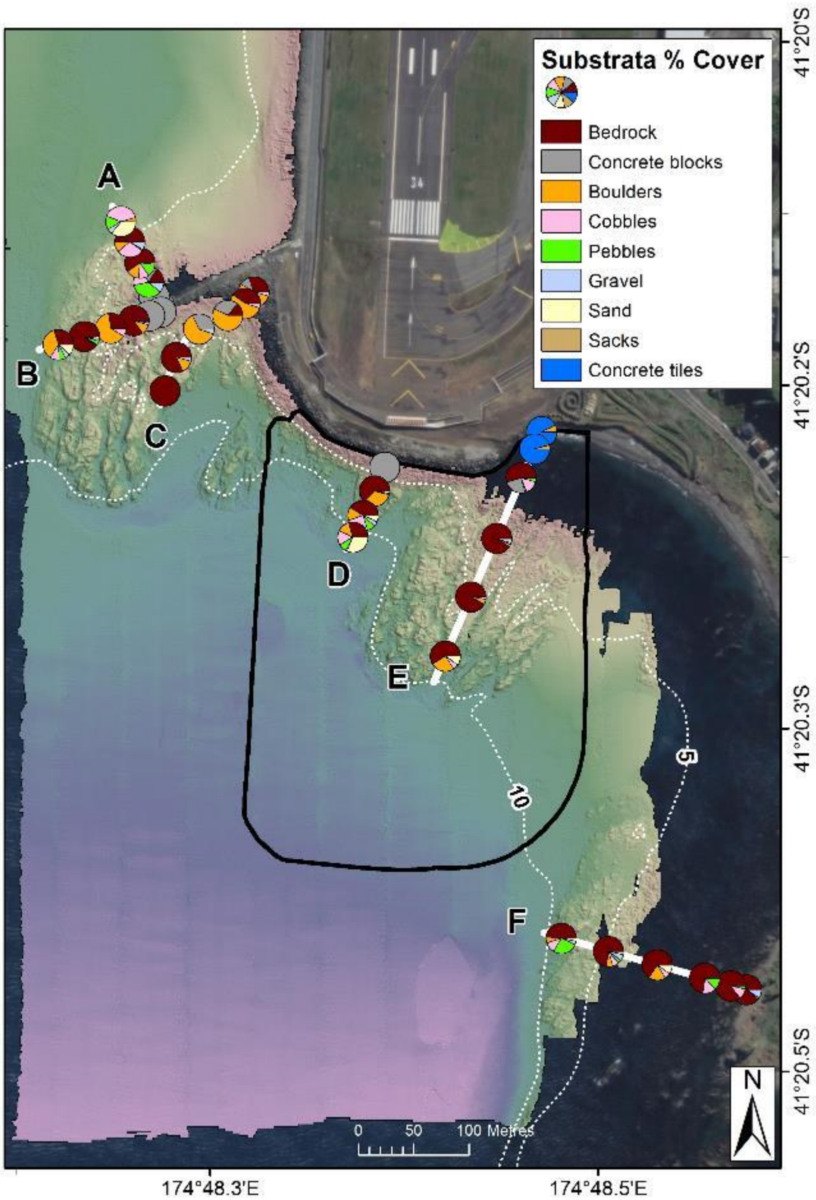

Figure 3-33: Substrate types encountered in different zones in rocky reef transects A-F. The proposed extension to the runway is outlined in black. Depth contours are indicated by white dashed lines.

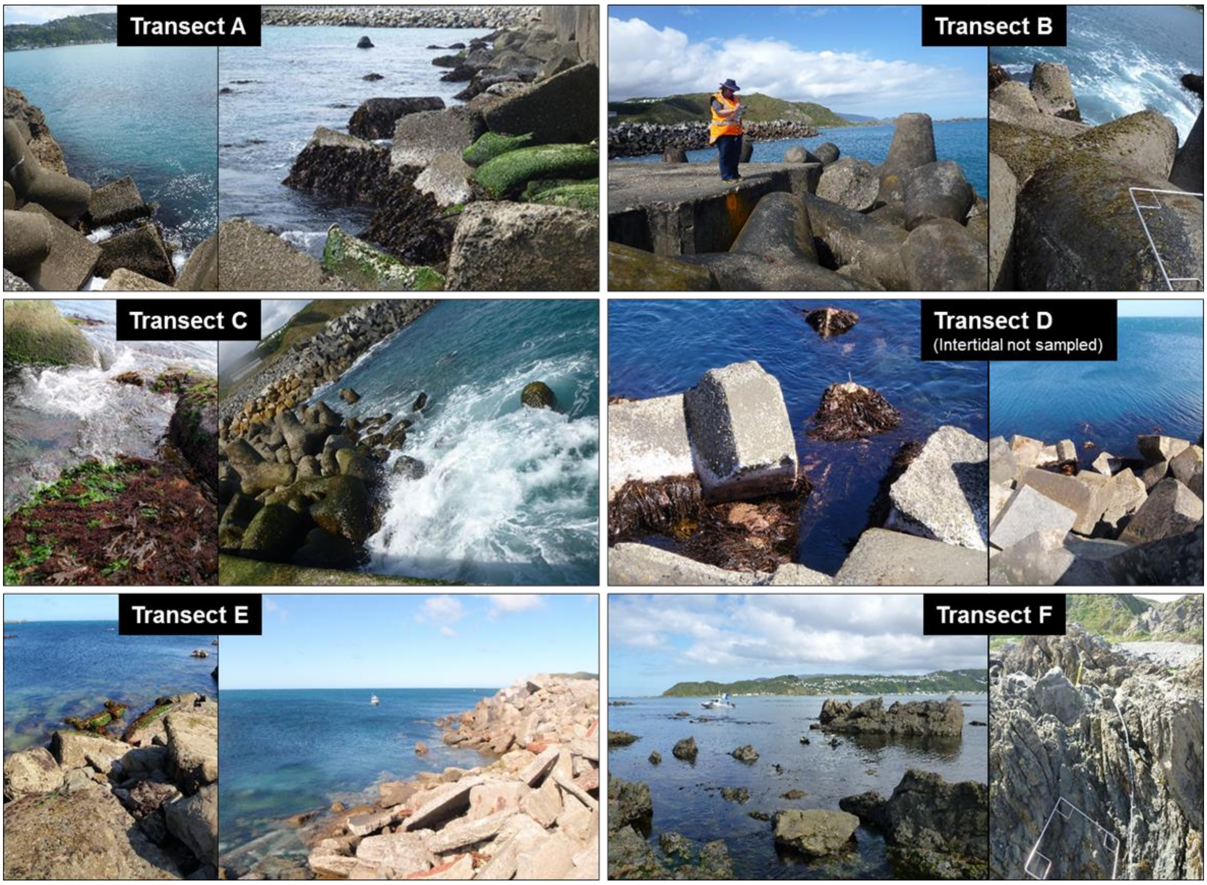

Figure 3-34: Still photos of rocky reef transects A-F showing the profile and substratum composition of the intertidal zones. Photographs by Rob Stewart, NIWA.

The distribution of brown, green, and red algae, and sessile invertebrates by zone for each transect is shown in Figure 3-37. The full list of species counted is provided in Appendix A.

Algae:

Green algae were the least common and were of two main types. Sheets of tubular 'Ulva' type algae occurred in the intertidal and shallow subtidal zones (Figure 3-35d and i, and left panel in Figure 3-38), particularly on the artificial substrates, while species of *Caulerpa* occurred only in the subtidal zones of each transect (except transect C), and were particularly common along the subtidal extent of transect F (Figure 3-36b). Brown and red algae were both common on each transect (Figure 3-37) but the morphological forms and species compositions varied by zone.

In the shallow subtidal canopy branching species in the genera *Carpophyllum* and *Cystophora* were common (upper left panel in Figure 3-39), along with subcanopy species such as *Zonaria aureomarginata* (upper right panel in Figure 3-39). Large strap-like canopy-forming species such as *Lessonia variegata* (Figure 3-36k) and *Macrocystis pyrifera* occurred along the length of the subtidal parts of all transects, except transect D (lower left panel in Figure 3-39). Canopy forming brown algal species such as *Ecklonia radiata* (Figure 3-36j) with flat leathery blades were most common on the mid and outer zones of transects (lower right panel in Figure 3-39).

Crusting and turfing red algae occurred intertidally (Figure 3-35a) and subtidally, except on transect D (upper left panel in Figure 3-40). Finely branched morphological types of red algae (Figure 3-36 g, h, and i) occurred along the length of all transects and were most abundant on transect D (upper right panel in Figure 3-40). Non-geniculate coralline algae occurred on all transects and were most common in the mid and lower zones (lower left panel in Figure 3-40). Strap-like red algae were most common towards the deeper parts of the reefs (lower right panel in Figure 3-40).

Figure 3-35: Examples of rocky reef intertidal habitats and biota. Photographs by Rob Stewart, NIWA.

Sessile invertebrates:

Sessile invertebrates such as sponges, bryozoans, and ascidians occurred subtidally on all the reef transects and comprised a maximum of 35% cover on the substrate by zone (upper left panel in Figure 3-41). Bryozoans were particularly common in zone 4 on transect C but otherwise were a small proportion of the subtidal sessile invertebrates (upper right panel in Figure 3-41). Sponges were more widespread occurring in the mid or lower parts of all transects where they comprised a maximum of 18% cover (lower left panel in Figure 3-41). Ascidians were also widespread and most abundant on transects A and B off the breakwater (lower right panel in Figure 3-41).

Over forty other invertebrate species were counted along the six rocky reef transects but most occurred at low densities. The most common species intertidally were barnacles of various species, the small periwinkle *Austrolittorina antipodum*, and limpet species occurring on every transect (at densities of up to 287, 86, and 12 individuals per 0.25 m^2, respectively; Figure 3-35 and Figure 3-42). Subtidally, the sea urchin or kina *Evechinus chloroticus*, occurred in very low densities on transects A, E, and F (lower right panel in Figure 3-42). Paua (*Haliotis iris*) and rock lobsters (*Jasus edwardsii*) were uncommon (see examples in Figure 3-36).

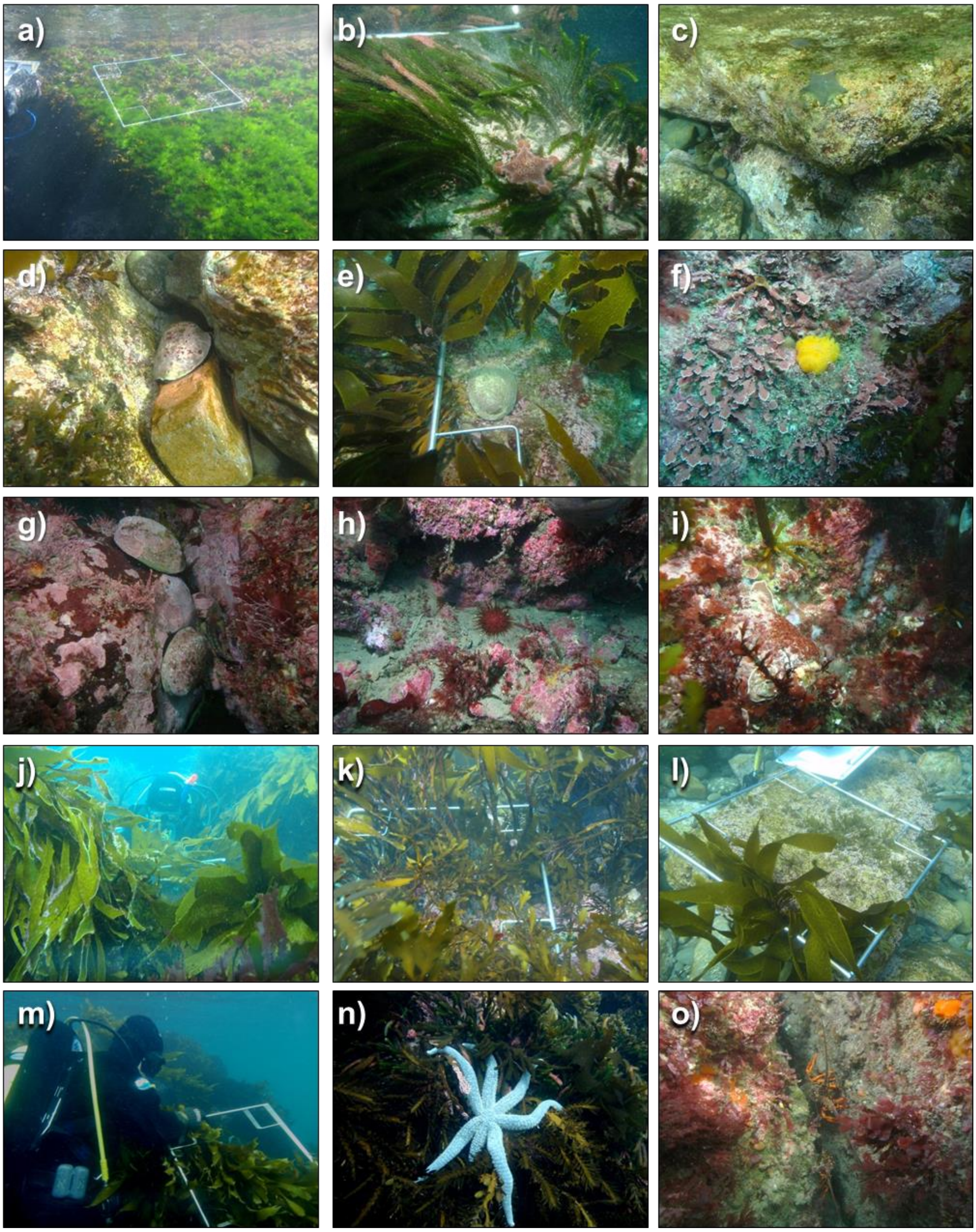

Figure 3-36: Examples of rocky reef subtidal habitats and biota. Underwater photographs by Pete Notman, NIWA.

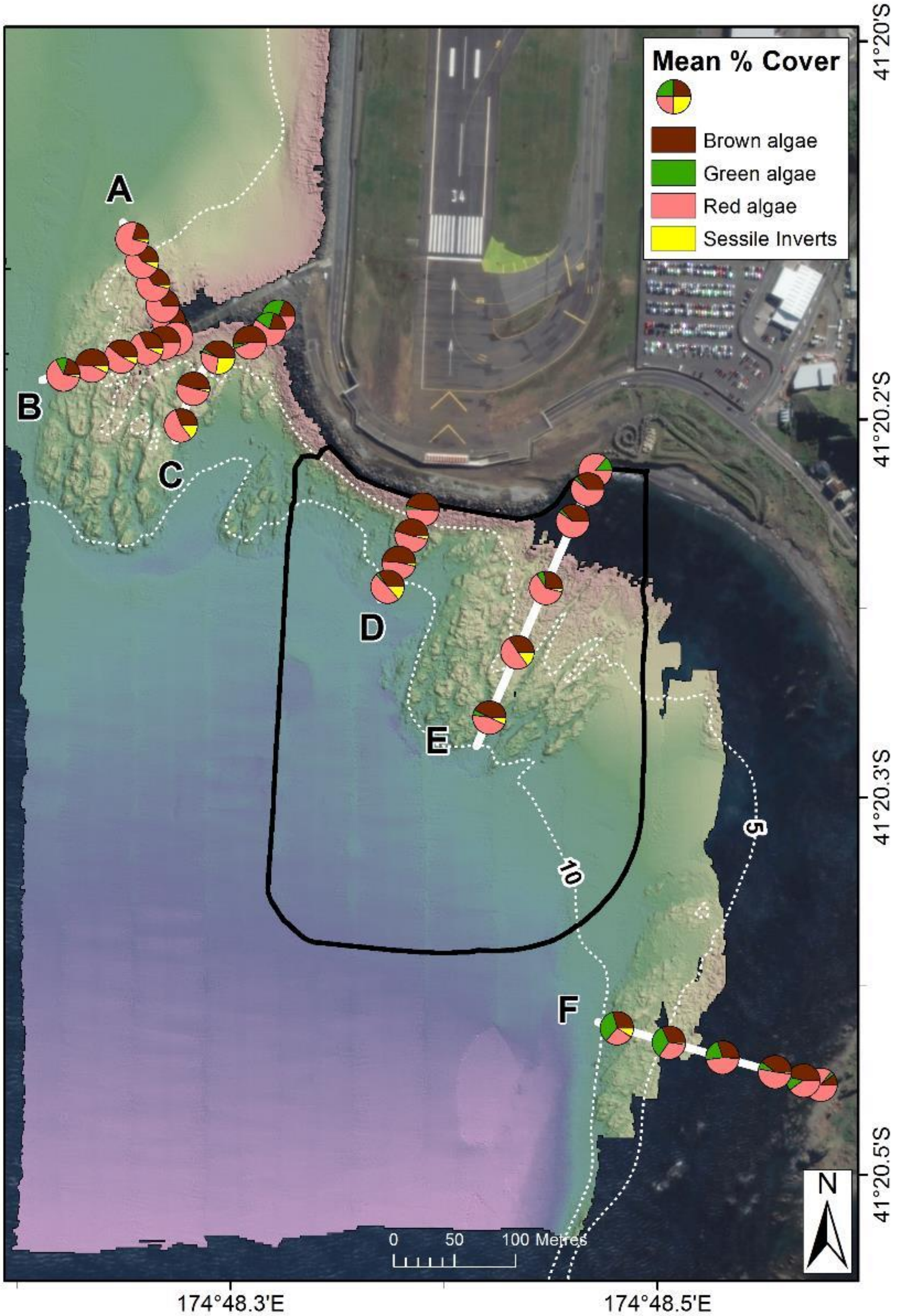

Figure 3-37: The percentage cover of brown, green and red algae, and encrusting sessile fauna in different zones on rocky reef transects A-F. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

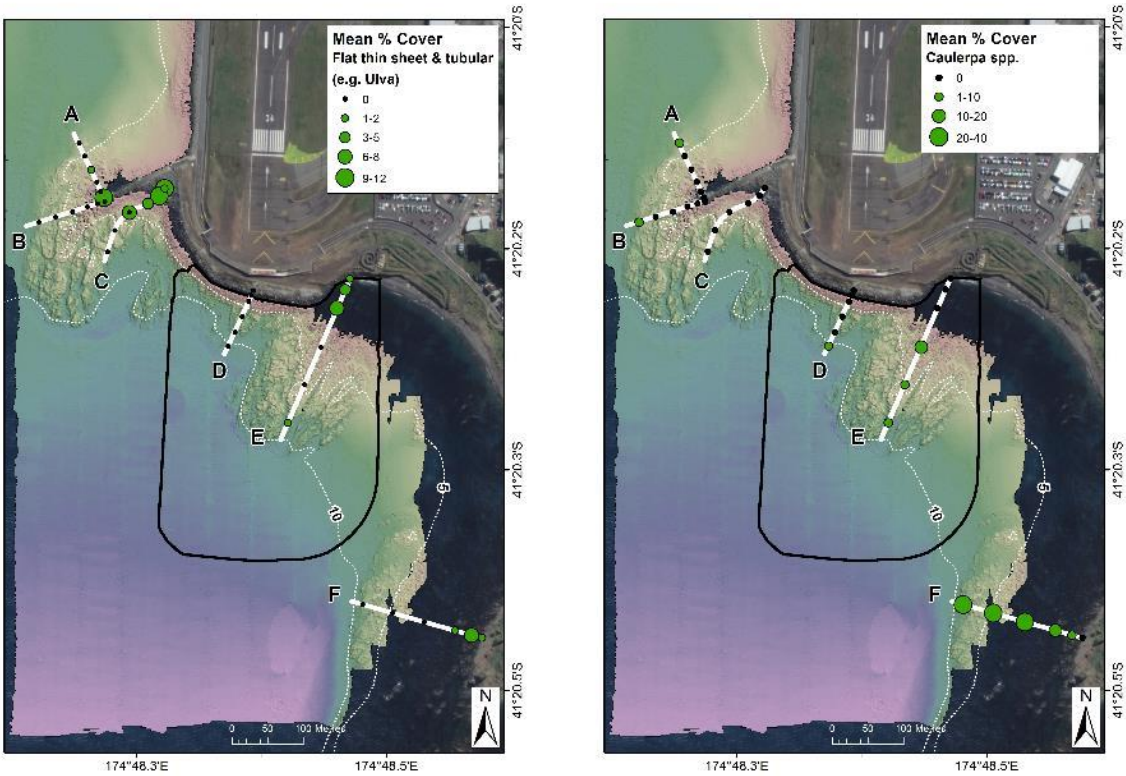

Figure 3-38: The percentage cover of two different morphological types of green algae in zones along rocky reef transects A-F. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

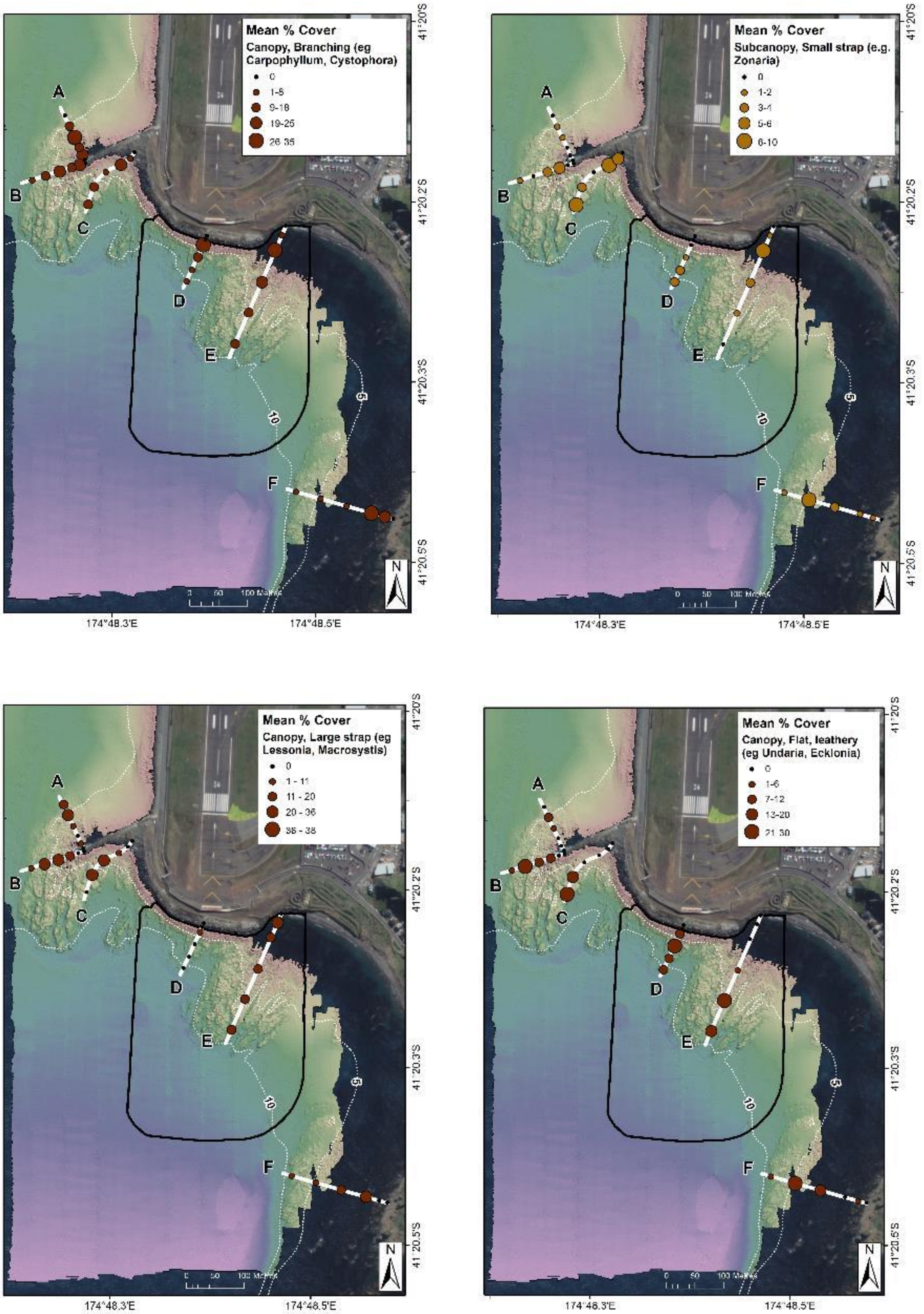

Figure 3-39: The percentage cover of four different morphological types of brown algae in zones along rocky reef transects A-F. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

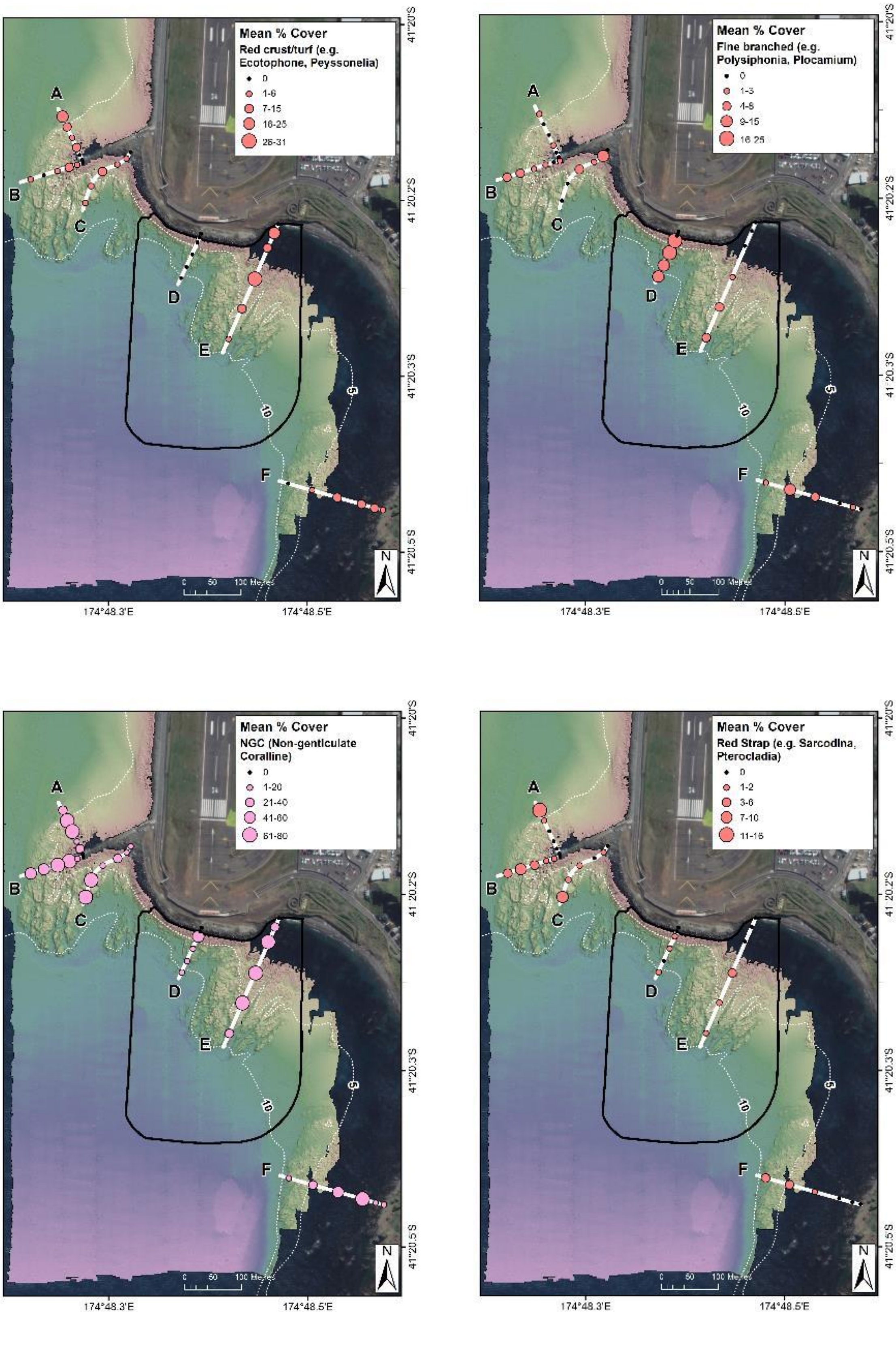

Figure 3-40: The percentage cover of four different morphological types of red algae in zones along rocky reef transects A-F. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

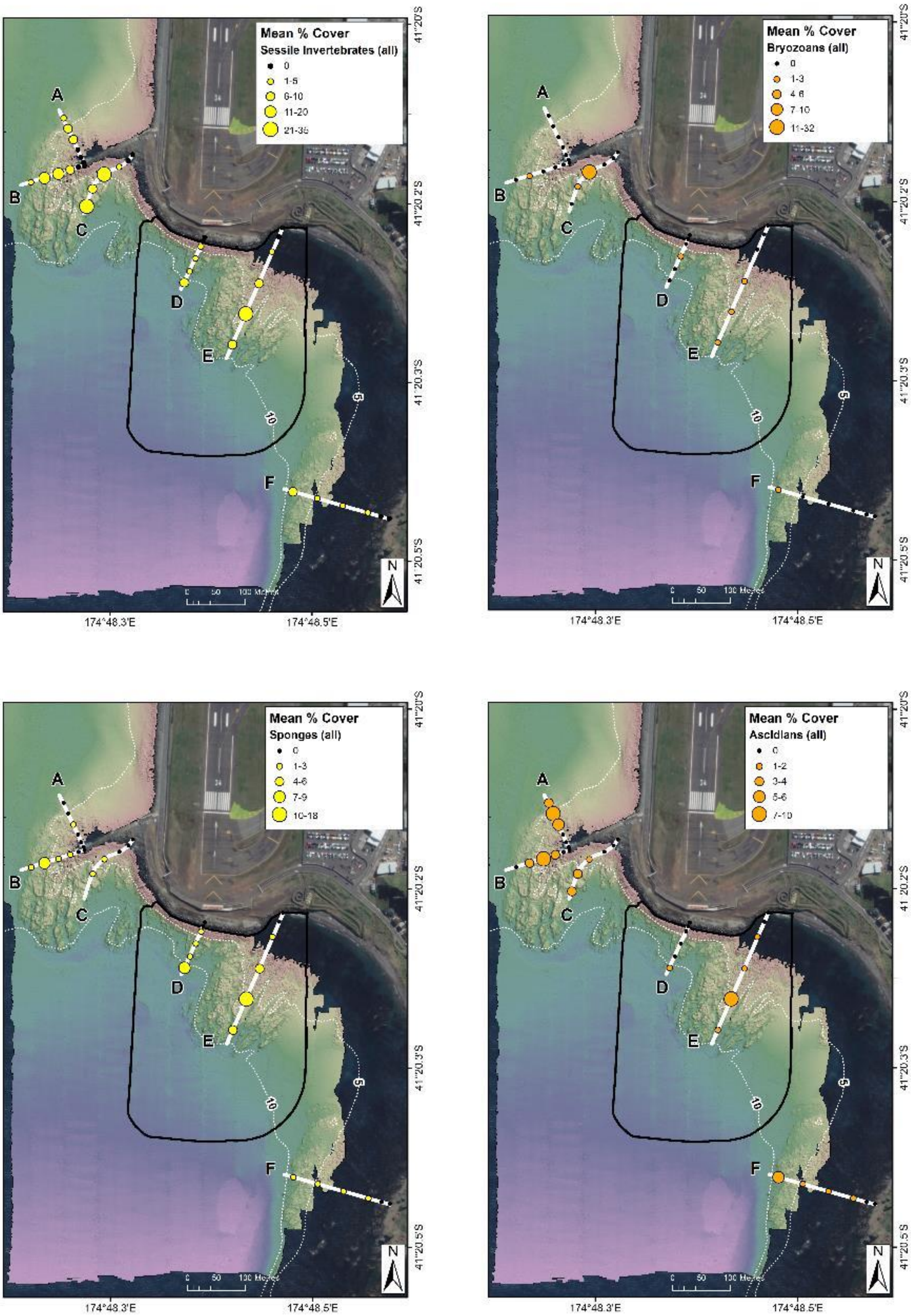

Figure 3-41: The percentage cover of (clockwise from top left panel) all encrusting invertebrates, bryozoans, ascidians, and sponges in zones along rocky reef transects A-F. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

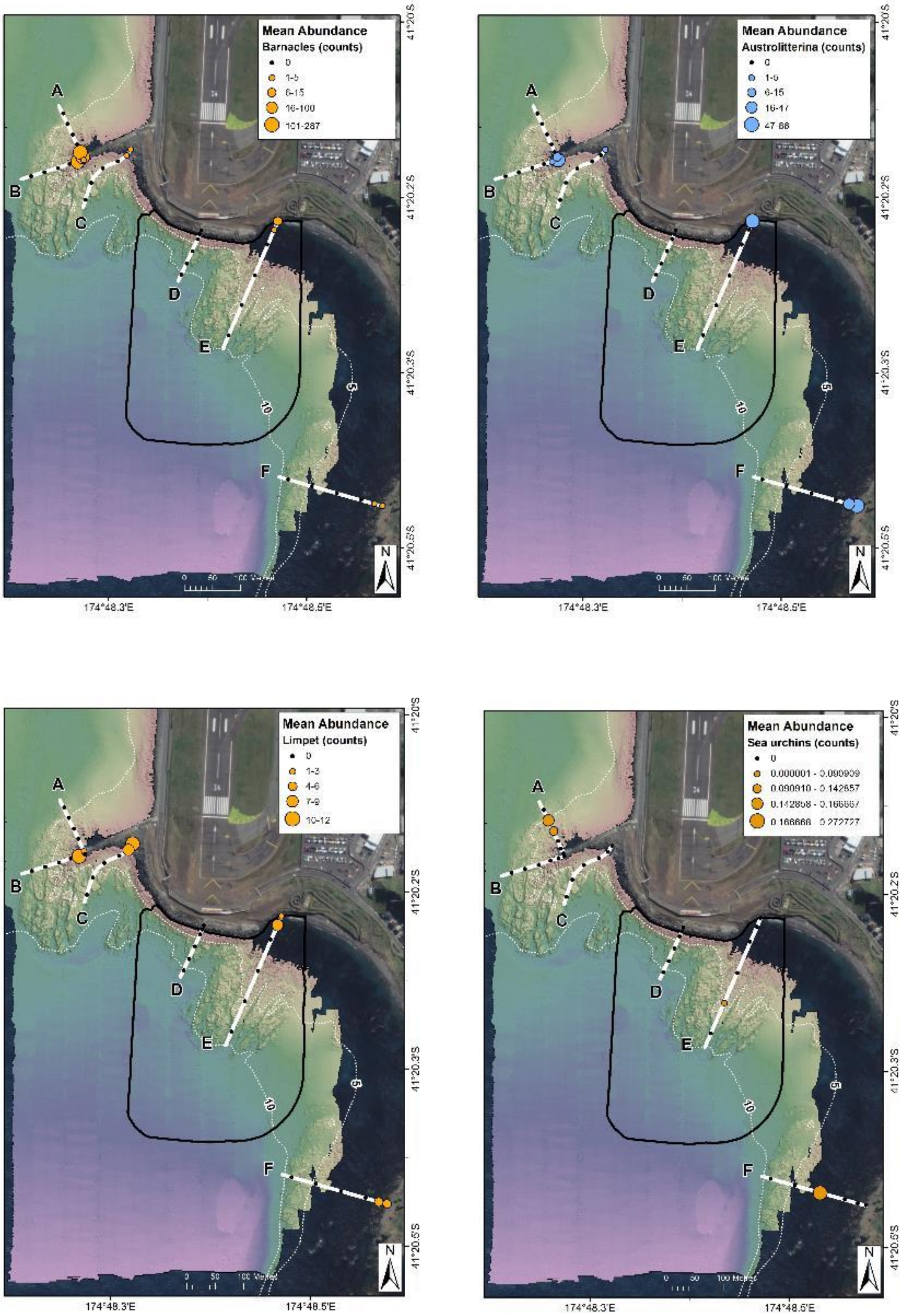

Figure 3-42: The abundance of (clockwise from top left panel) barnacles, *Austrolitterina*, sea urchins, and limpets in zones along rocky reef transects A-F. Abundance is expressed as numbers per m^2. The proposed extension to the runway is outlined in black. The 5, 10, and 15 m depth contours are indicated by white dashed lines.

3.4.2 Phase 1 statistical analyses

Canonical Correlation plots for a) groupings of % cover taxa (macroalgae and subtidal sessile invertebrates such as sponges, bryozoans, and ascidians) across zones and transects and b) groupings of % cover taxa across reef substrates are provided in Figure 3-43. Together the two axes explain only 23% of the overall variation in community composition, but this is sufficient to clearly separate the intertidal and subtidal zones (Figure 3-43a). Axis 1 (CV1) explains the depth pattern (i.e., intertidal versus subtidal), both in the type of substrate and in the biota associated with these depths. The intertidal habitats comprised mostly artificial concrete structures (blocks, bags, or aggregate sheet/blocks), (see Figure 3-33) supporting varying amounts of *Ulva* (Green) and/or *Pyropia* (red) algal cover (see upper left panels in Figure 3-38 and Figure 3-40). In contrast, in the subtidal, bedrock was common across most of the transects and zones, supporting canopy kelps, as well as subcanopy brown algae (Figure 3-39), non-genticulate coralline red algae (Figure 3-40) and sponges, including species of *Tethya* (Figure 3-41). In contrast, to subtidal bedrock habitats, broken rubble habitats (cobbles-gravel-sand) supported more red algae (i.e. branching and strappy red algae) and bryozoans.

Canonical Correlation plots for the count taxa (intertidal and motile subtidal invertebrates) at the zone level and on different reef substrates are provided in Figure 3-44. Together the two axes explain only 25% of the overall variation but this is sufficient to clearly separate the intertidal and subtidal zones. Again Axis 1 (CV1) explains the depth pattern, both in the type of substrate and the biota associated with these depths. The analyses clearly indicate that subtidal substrata generally cluster together with no distinct communities of animals between subtidal reef vs broken habitat, probably reflecting the generally low numbers of motile invertebrates through all subtidal substrata types. Paua were associated with both natural bedrock and artificial block as both occur in the immediate subtidal where paua are most abundant. The intertidal concrete structures (blocks, bags, or aggregate sheet/blocks) were dominated by the periwinkle *Austrolitterina antipodum*, snails, limpets, chitons and barnacles. Sack and Block artificial substrata which had rougher surfaces had more barnacles and snails, while the flatter aggregate sheets (Agblock) had fewer barnacles and more chitons which prefer smother surfaces.

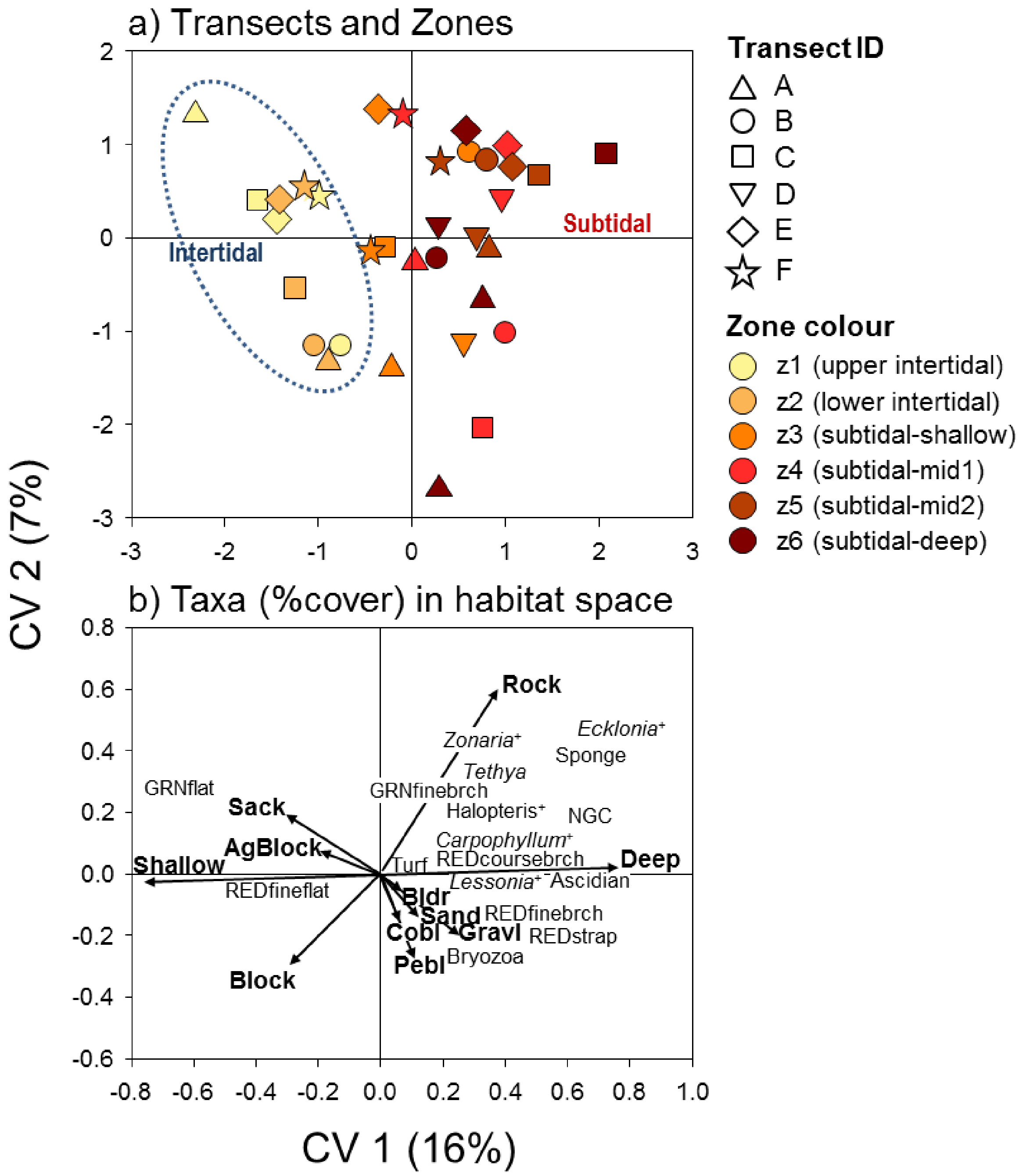

Figure 3-43: Canonical Correlation of % cover taxa on reefs in Lyall Bay. a) Transects and zones, coded by symbols (transects) and colours (zones) [36 combinations], and b) % cover of species/taxa plotted in habitat space (%cover of substrata). Abbreviations: Habitat variables: Depth = 0-5m (shallow=0m, deep=5m); Rock = Bedrock; Block = Concrete Block; Agblock = Concrete Conglomerate; Bldr = Boulder; Cobl = Cobble; Pebl = Pebble; Gravl = Gravel; Sand = Sand; Sack = Sack Material. Taxa types: Carpophyllum+ = BROWN coarse branched; Ecklonia+ = BROWN flat leathery; Lessonia+ = BROWN large strap; Zonaria+ = BROWN small strap; Halopteris+ = BROWN fine branched; NGC = RED Non geniculate coralline; CorallineTurf = RED turfing corallines; REDfinebrch = RED fine branched; REDstrap = RED strap form; Pyropia= RED fine flat sheet; REDcoarsebrch = RED coarse branched; Ulva= GREEN flat sheet thin ; GRNfinebrch = GREEN fine branched ; Sponge = Sponge; Tethya = Tethya golf ball sponge; Bryozoa = Bryozoan; Ascidian = Ascidian.

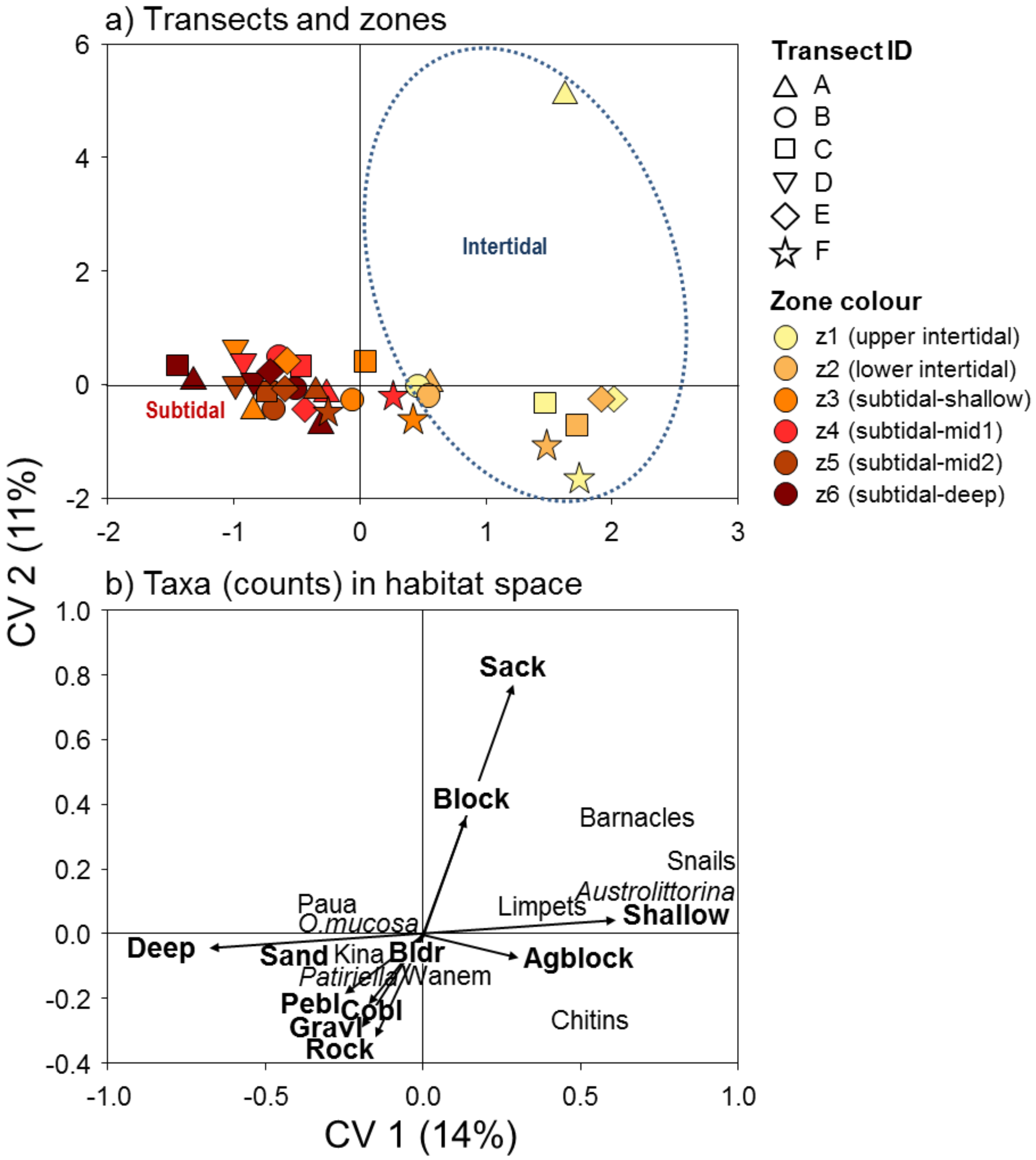

Figure 3-44: Canonical Correlation of intertidal and motile subtidal invertebrates (counts) on reefs in Lyall Bay. a) Transects and zones, coded by symbols (transects) and colours (zones) [36 combinations], and b) animal counts plotted in habitat space (%cover of substrata). Abbreviations: Habitat variables: Depth = 0-5m (shallow=0m, deep=5m); Rock = Bedrock; Block = Concrete Block; Agblock = Concrete Conglomerate; Bldr = Boulder; Cobl = Cobble; Pebl = Pebble; Gravl = Gravel; Sand = Sand; Sack = Sack Material. Taxa types: Austrolittorina = Austrolittorina spp; Barnacles = Barnacle spp; Chitins = Chitin spp; Kina = Evechinus chloroticus; Limpets = Limpets; O.mucosa = Oulactis mucosa; Patiriella = Patiriella sp; Paua = Haliotis iris; snails = generic snails; Wanem = Wandering anemone.

3.4.3 Phase 2 field sampling and analysis

During the Phase 1 reef surveys a 'Bangiales' type filamentous alga, and an undescribed species of a red macroalga were found on intertidal and subtidal rocks, respectively, at the southern end of the runway (Figure 3-45, Figure 3-46). The subtidal red algae belongs to an undescribed genus in the

Kallyemeniacae and has not been previously collected in the Wellington region. These species were unlikely to occur only on these reefs and genetic sequencing and further field work was undertaken in December 2014 to confirm the identity and south coast distribution of these species.

No additional specimens of filamentous Bangiales were found in the vicinity of Moa Point or the western reefs of Lyall Bay, but intertidal populations were found on boulders at the extreme western end of Lyall Bay beach. Samples were taken and sub-samples retained for sequencing. The sequencing revealed that these specimens, and the specimens originally collected on reefs at the end of the runway, were an undescribed species of algae known as '*Bangia* BMW' which has been previously collected from the Wellington region.

[*Note: the terms filamentous Bangiales and "Bangia" are used interchangeably - these algae belong to genetically distinct clades that are currently unnamed. Dr Wendy Nelson and NIWA colleagues are in the process with international colleagues of naming the new genera. New Zealand filamentous Bangiales belong to at least 5 genetically distinct clades. Two of these are restricted to New Zealand (Dione and Minerva) - and three remain unnamed. They are not able to be distinguished on the basis of morphological or anatomical characters.]*

The subtidal red macroalga first noted in transect E south of the airport runway in the initial sampling was not located on any of the additional reefs searched, but genetic sequencing indicates this algae is a member of the Kallyemeniacae and has been found on the Otago coastline previously. The additional subtidal searches did yield samples of a member of the Delesseriaceae previously not known from the Wellington area (an undescribed species of *Schizoseris*).

Figure 3-45: Previously undescribed filamentous 'Bangiales' type alga in the splash zone on concrete structures along transect C. Left is the general view showing extensive coverage of this algae. Right is a close up. Genetic sequencing confirms that this alga is a member of the Bangiales but the clade to which it belongs has not yet been determined.

Figure 3-46: Unnamed species of red foliose alga in the Family Kallyemeniacae found along transect E. This alga has not been previously recorded from the Wellington region.

3.5 Reef fish

3.5.1 Observations during reef transects

Ten species of reef fish were observed by divers during underwater counts of algae and invertebrates (Table 3-12). The most abundant species were spotties and banded wrasse which occurred on all transects. The least abundant species observed was marblefish where single individuals were seen on two transects.

Table 3-12: Abundances of reef fish noted along the subtidal sections of rocky reef transects A-F. Note that on the count scale used 0 = absent, 1 = single (1 individual seen per 1 h dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100).

	Transects					
Species	**A**	**B**	**C**	**D**	**E**	**F**
Spotty	3	3	3	3	4	4
Banded wrasse	2	3	3	3	3	3
Scarlet wrasse	0	0	2	0	2	2
Blue moki	0	3	2	0	2	0
Blue cod	2	2	2	2	2	2
Variable triple-fin	3	3	3	0	3	3
Yellow-black triple-fin	0	0	0	0	2	3
Blue eyed triple-fin	0	0	0	2	0	2
Butterfish	0	0	0	2	0	2
Marblefish	0	1	0	1	0	0

3.5.2 Modeled distributions

A total of thirty-one species of reef fish are predicted to be encountered in underwater dives on rocky reef habitats along Wellington's south coast. Maps of the modeled distributions of each species are provided in Appendix B. A few species, such as goatfish and sweep, while occurring in the north-western part of the Wellington region, are predicted to not occur on the reefs on Wellington's southern coast (Figure 3-47).

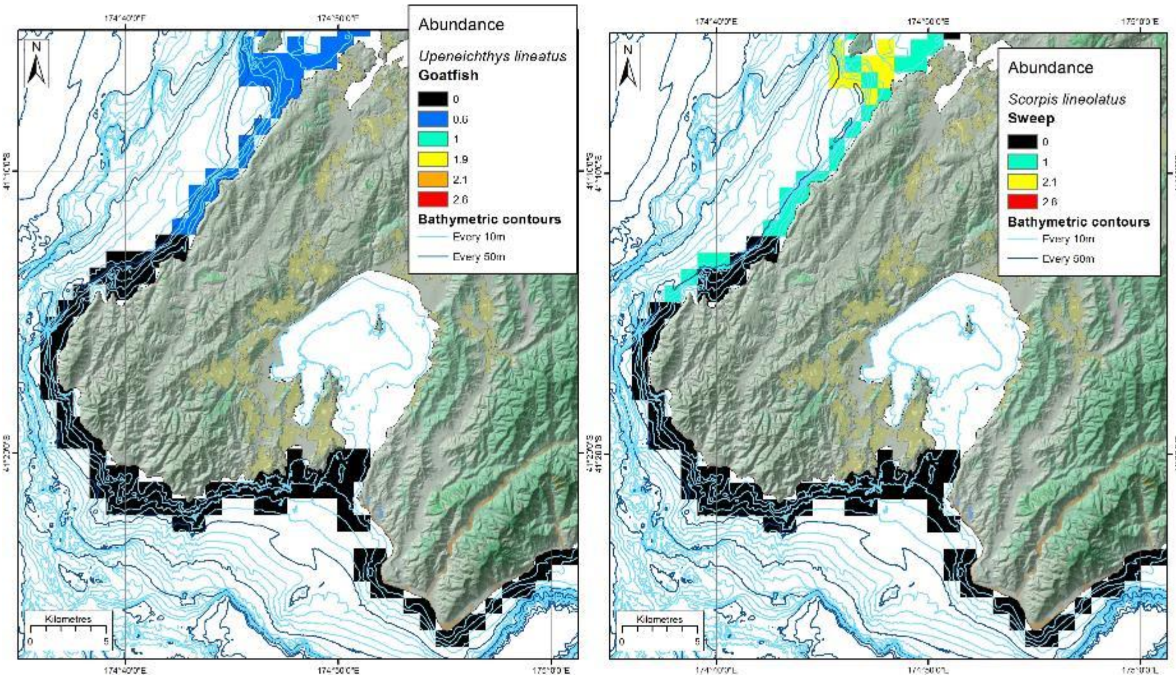

Figure 3-47: Modeled distributions of goatfish and sweep on reefs in the Wellington region. Data are estimated abundance in 1 km^2 grid squares. Note that on the scale provided 0 = absent, 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). Model output provided courtesy of the Department of Conservation (DOC) which owns the original fish survey data and funded the original modelling undertaken by Smith et al. (2013).

Reef fish species richness in the region is highest on the western entrance to Cook Strait where up to 23 species may be encountered in a 1 hour long underwater dive (Figure 3-48). In the shallow inner part of Lyall Bay and in the outer deeper parts of the bay 19 reef fish species may be expected to be encountered during a 1 hour dive though the species may differ with a total of 27 reef fish species occurring in the bay. In order of increasing abundance these 27 species include blue dot triple fin, common conger eel, Yaldwyns's triplefin, leather jacket, sea perch, rock cod, scaly head triplefin, scarlet wrasse, variable triplefin, spectacled triplefin, red moki, butterfish, red-banded perch, yellow-black triplefin, banded triplefin, blue moki, marble fish, blue-eyed triplefin, common triplefin, common roughy, tarakihi, blue cod, banded wrasse, oblique-swimming triplefin, butterfly perch, and spotty.

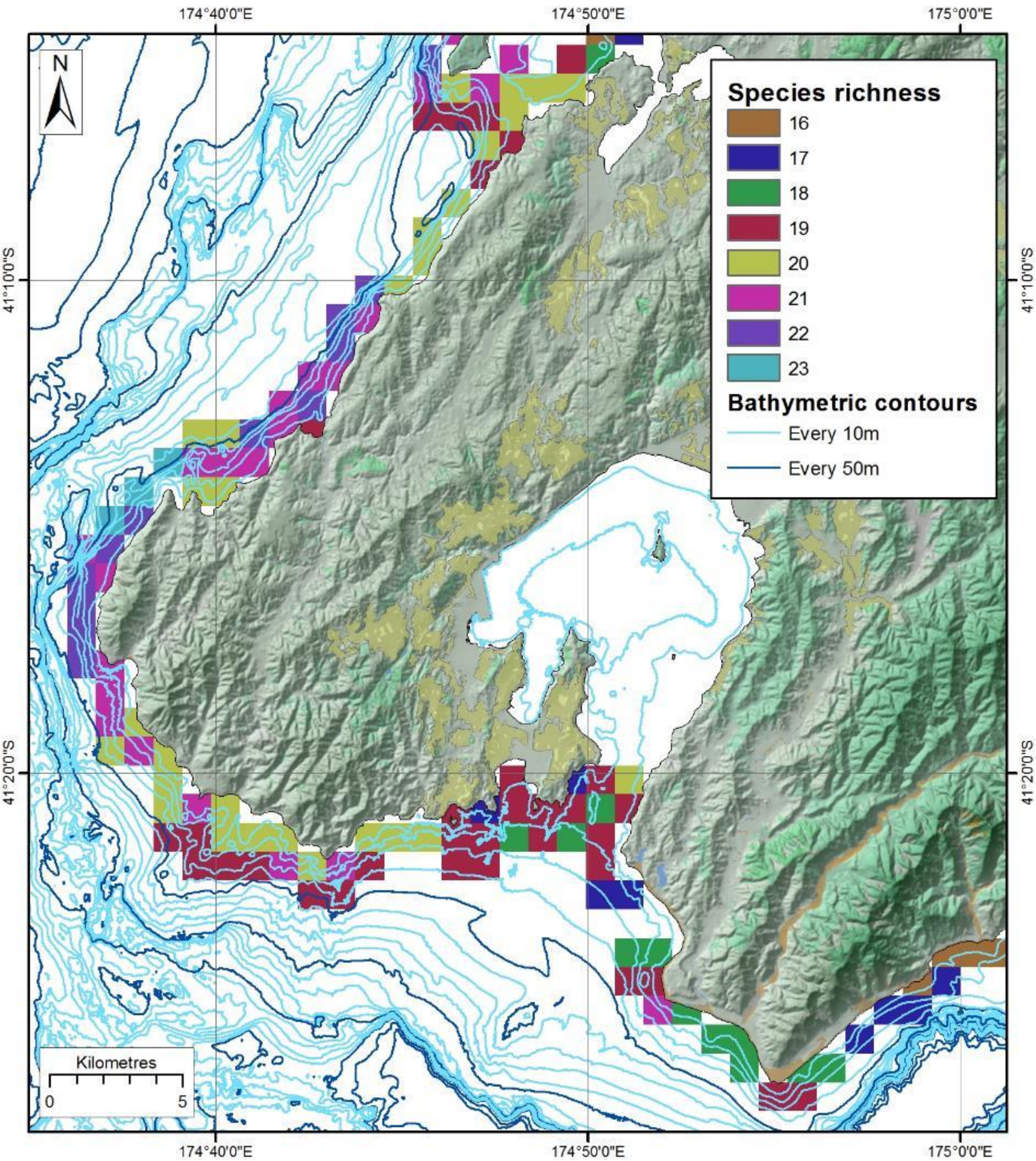

Figure 3-48: Modeled numbers of reef fish species occurring on reefs in the Wellington region. Model output provided courtesy of the Department of Conservation (DOC) which owns the original fish survey data and funded the original modelling undertaken by Smith et al. (2013).

Some of the less abundant species, such blue dot triplefin, occur only in the outer part of the bay and are not expected to occur in the vicinity of airport runway. Others, such as the common conger eel, are expected to occur in the inner part of Lyall Bay and not on the deeper reefs in the outer part of the Bay (upper panels in Figure 3-49). Other more common species, such as tarakihi, blue cod, banded wrasse, and spotties, are ubiquitous occurring on reefs in all parts of Lyall Bay and along the entire south coast (lower panels in Figure 3-49).

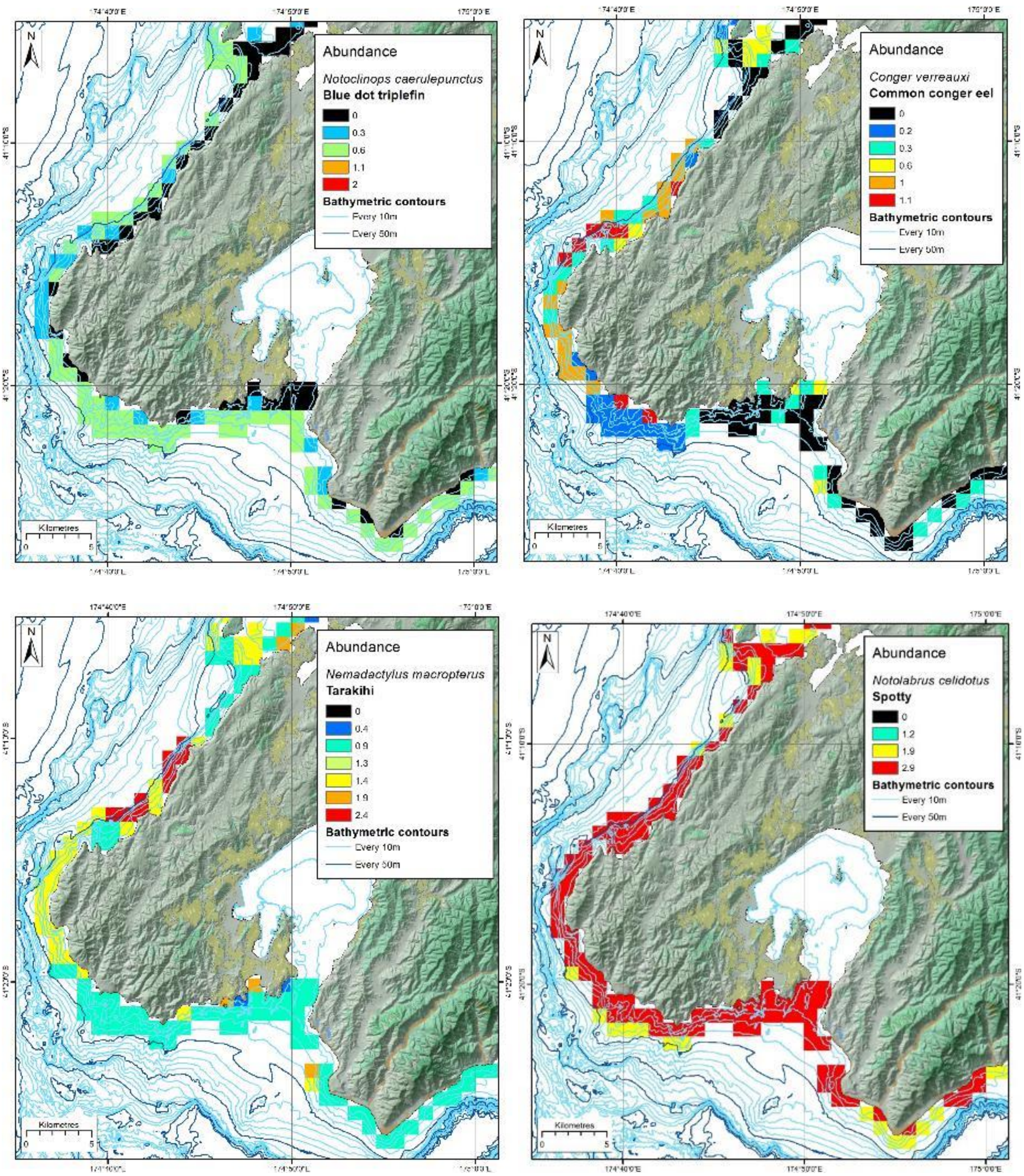

Figure 3-49: Modeled distributions of blue-dot triplefin, common conger eel, tarakihi and spotty on reefs in the Wellington region. Data are estimated abundance in 1 km2 grid squares. Note that on the scale provided 0 = absent, 1 = single (1 individual seen per 1 hr dive), 2 = few (2 – 10), 3 = many (11 – 100) and 4 = abundant (> 100). Model output provided courtesy of the Department of Conservation (DOC) which owns the original fish survey data and funded the original modelling undertaken by Smith et al. (2013).

3.6 Demersal and pelagic fish

Fifty species of demersal and pelagic fish species are predicted to occur in the Wellington region (Appendix B). Of these, 44 species are predicted to occur in Lyall Bay. Twenty-one species are rare with less than a 10% probability of occurrence in Lyall Bay. These include anchovy, crested bellowsfish, eagle ray, elephant fish, blue mackerel, frostfish, hake, hapuka, John dory, Murphy's mackerel, kahawai, kingfish, ahuru, porcupine fish, redbait, red mullet, silver dory, snapper, spotted stargazer, silverside, and trevally.

Twelve species are uncommon with a 10-50% probability of occurrence in Lyall Bay. These include carpet shark, NZ sole, gurnard, hoki, horse mackerel, golden mackerel, ling, scaly gurnard, school shark, sand flounder, sea perch, and rig. Eleven common species with a greater than 50% probability of occurrence in Lyall Bay include barracouta, blue cod, leatherjacket, lemon sole, red cod, spiny dogfish, spotty, silver warehou, tarakihi, common warehou, and witch. Illustrative distributions of rare, uncommon and common species in Lyall Bay are provided in Figure 3-50.

The 26 least abundant species in Lyall Bay with catch rates less than 10 kg per hour of trawling include anchovy, crested bellows fish, eagle ray, elephant fish, blue mackerel, frostfish, hake, NZ sole, hapuka, hoki, horse mackerel, John dory, kahawai, kingfish, ahuru, porcupine fish, redbait, ling, red mullet, silver dory, scaly gurnard, sea perch, spotted stargazer, rig, silverside, trevally, tarakihi, and witch.

Thirteen species in Lyall Bay are moderately abundant with catch rates of 10-50 kg per hour of trawling including blue cod, carpet shark, gurnard, Murphy's mackerel, golden mackerel, leatherjacket, lemon sole, school shark, sand flounder, snapper, spotty, silver warehou, and common warehou.

Three species in Lyall Bay are abundant with catch rates >50 kg per hour of trawling including barracouta, red cod, and spiny dogfish. Of these species spiny dogfish is predicted to be the most abundant in Lyall Bay with catch rates equivalent to 500-1000 kg per hour in a standard research bottom trawl. Illustrative distributions of rare, uncommon and common species in Lyall Bay are provided in Figure 3-51.

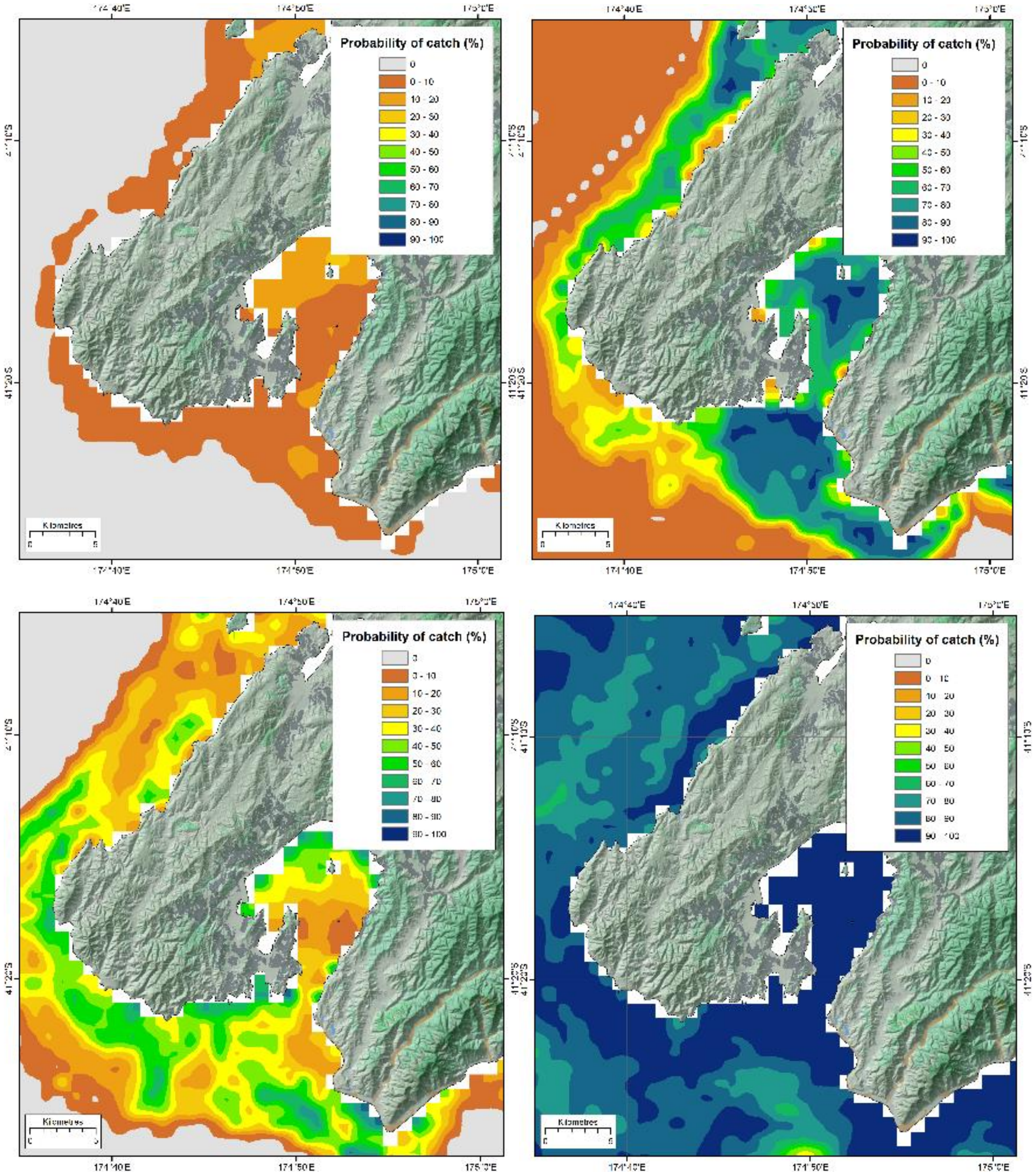

Figure 3-50: Probability of occurrence (%) in the Wellington region of representative rare, uncommon, and common demersal or pelagic fish species in Lyall Bay. Top left panel, a rare species, anchovy. Top right panel, an uncommon species, gurnard. Bottom left panel, a common species, blue cod. Bottom right panel, the most common demersal fish species in Lyall Bay, spiny dogfish.

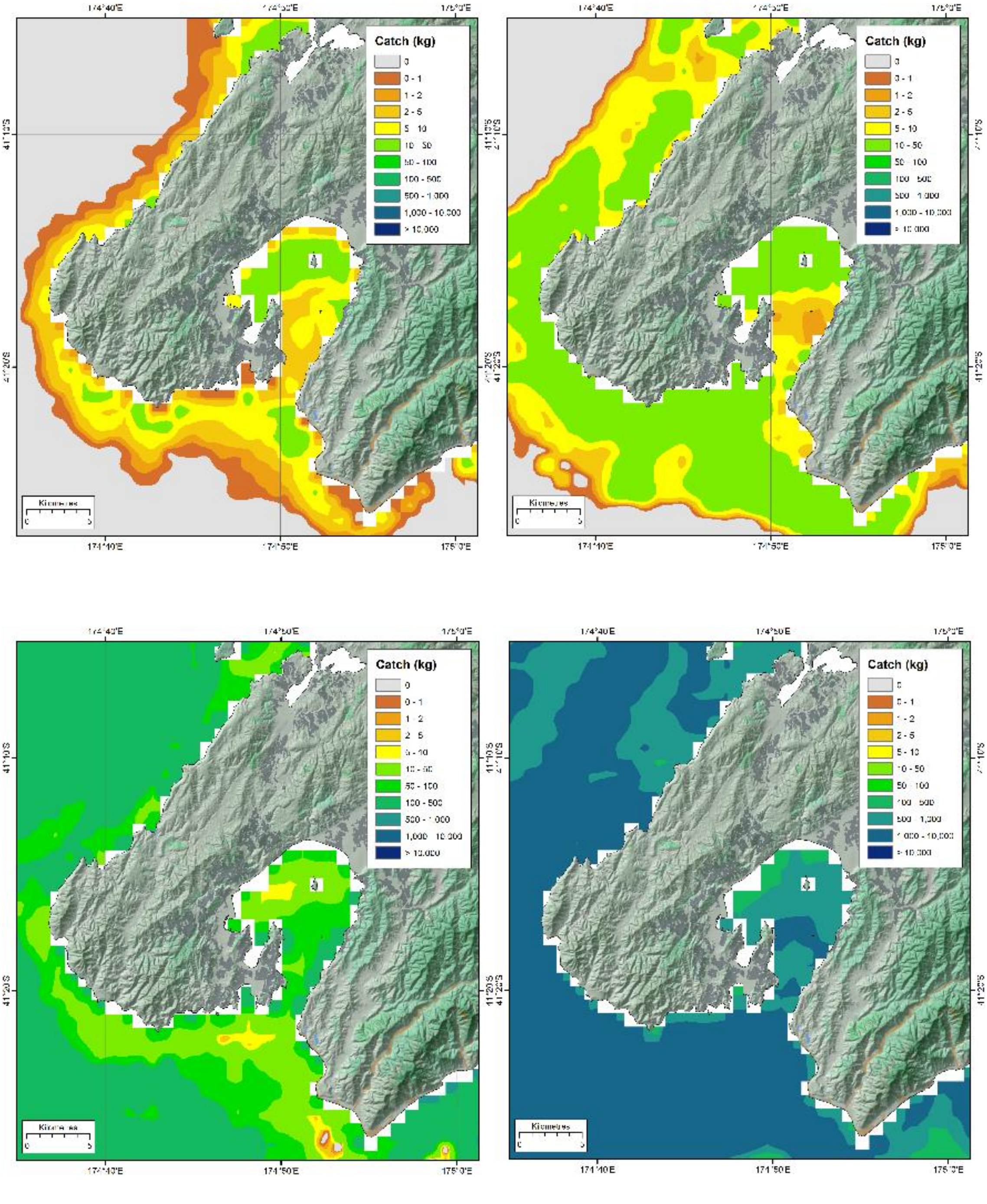

Figure 3-51: Catch (kg per hour) in the Wellington region of least abundant, moderately abundant, and abundant demersal or pelagic fish species in Lyall Bay. Top left panel, a least abundant species, kahawai. Top right panel, a moderately abundant species, blue cod. Bottom left panel, an abundant species, red cod. Bottom right panel, the most abundant demersal fish species in Lyall Bay, spiny dogfish.

3.7 Fisheries

3.7.1 Summary of coastal (CEL) commercial catch and effort information

A total of 7423 fishing events were reported in CEL forms without geographic coordinates from 1 October 2008 to 29 August 2014 (Table 3-13). Total effort was evenly split between statistical area 16 and rock lobster statistical area 915. However, numbers of fishing events in Area 16 increased in 2011/12 and 2012/13 relative to earlier years, while numbers of fishing events in Area 915 were reduced by nearly half as a result of rock lobster quota reductions in quota management area CRA4 in 2010/11 (MPI 2013).

Table 3-13: Number of coastal (CEL) fishing events by fishing year (1 Oct-30 Sep) and statistical area in the Wellington region. *Incomplete data (October 1 2013 to August 29 2014)

Fishing year	Statistical Area 16	Statistical Area 915
2008/09	583	708
2009/10	581	855
2010/11	657	782
2011/12	748	474
2012/13	830	472
2013/14*	465	268
Total	3864	3559

Fishing methods

Rock lobster potting was the most common fishing method, accounting for half (48%) of all fishing events over the study period (Table 3-14). Note that the fishing year for rock lobster runs from 1 April to 31 March. Herein, data were summarised according to the standard fishing year (1 October to 30 September) to facilitate comparisons among fisheries. Rock lobster potting effort was reduced in 2011/12 and subsequent years following quota reductions in CRA4 (MPI 2013). Set netting was the second-most common fishing method, generally accounting for 25% of the effort on an annual basis and 29% over the entire study period. Set netting effort was higher beginning in 2010/11 (≥ 400 fishing events) compared to earlier years (≤ 378 fishing events). The third most common fishing method was drop/dahn lines, which peaked in 2012/13 with 224 fishing events and explained 13% of total effort. Rock lobster potting, set netting and drop/dahn lines yielded total catches of 312 t, 281 t and 271 t over the study period, respectively.

Handlining, crab potting, cod potting and bottom longlining explained between 1% and 4% of all fishing events. Bottom longlining contributed the highest catch (47.2 t), followed by crab potting (31 t), cod potting (25 t) and commercial handlining (5 t). Other methods (hand gathering, diving, trolling, Danish seining, fish traps) accounted for less than 1% of the overall effort. The total catch from diving (5.6 t) however, exceeded that of handlining. Diving effort peaked in 2009/10 and 2010/11.

Table 3-14: Number of CEL fishing events by fishing year (1 Oct-30 Sep) and method, % of overall effort, and total catch by fishing method over the study period. Data are ordered by decreasing total number of fishing events. *Incomplete data (October 1 2013 to August 29 2014)

	No. fishing events								
	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014*	Total	% Effort	Total catch (t)
Rock lobster potting	709	851	779	475	469	269	3552	47.9	311.7
Set netting	333	378	400	426	415	169	2121	28.6	281.2
Drop/Dahn Lines	136	127	179	152	224	153	971	13.1	270.8
Handlining	21	20	10	105	71	48	275	3.7	5.1
Crab potting	3	13	12	24	84	39	175	2.4	31.1
Cod potting	28	21	33	31	30	30	173	2.3	25.4
Bottom longlining	54	13	12	7	5	0	91	1.2	47.2
Hand gathering	0	0	0	0	4	21	25	0.3	0.9
Diving	0	10	10	1	0	2	23	0.3	5.6
Trolling	1	2	3	1	0	2	9	0.1	0.4
Danish seining	5	0	0	0	0	0	5	0.1	0.4
Fish traps	0	1	1	0	0	0	2	<0.1	0.2
Eel potting	1	0	0	0	0	0	1	<0.1	0.1

Target species

Catch and effort data by target species are shown for the three main commercial fishing activities (rock lobster potting, set netting and drop/dahn line) in Table 3-15. Incomplete data from 2013/14 were excluded. Rock lobster was clearly the dominant target species and rock lobster target effort accounted for most of the catch in coastal fisheries over the study period. Set netting fisheries targeted a diverse array of species, however dominated by butterfish. Flatfishes (as a species group) was the second most important target. Set netting for common warehou, moki and sand flounder increased in recent years. In contrast, effort targeting red cod, kahawai, elephant fish and yellow-eyed mullet was generally lower compared to 2008/09 and 2009/10. Drop/Dahn lines effort mainly targeted hapuku and bass, followed by ling, bluenose and school shark. School shark target effort was higher than ling and/or bluenose target only in 2008/09 and 2009/10.

Seasonal patterns

Seasonal variations in the main coastal fisheries over the last five years are presented in Figure 3-52. Effort from all methods was higher in mid-winter (July-August) and mid-summer (January-February) and lower during autumn (March-May). Set netting effort was generally consistent among seasons. In the rock lobster fishery, effort peaked in August and January and was minimal in autumn. Drop/Dahn lines effort was higher in late-summer and autumn and lower during spring (September-October).

Table 3-15: Summary of commercial fishing activities within the coastal (CEL) dataset. Number of fishing events by fishing year (1 Oct-30 Sep) and target species, and total catch by target species for the main commercial fishing activities. Only target species which contributed a minimum catch of ≥ 1 t over the study period are shown. Data are ordered by fishing method and decreasing total catch.

Method	Target species	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	Total catch (t)
Rock lobster potting							
	Rock lobster	707	850	778	474	469	277.7
	Blue cod	2	1	0	0	0	0.4
Set netting							
	Butterfish	85	160	179	176	160	114.2
	Flatfishes	111	98	94	88	95	41.3
	Common warehou	4	7	8	41	45	35.1
	Moki	6	17	36	40	21	28.2
	Red cod	63	45	33	35	26	21.3
	Kahawai	26	28	20	15	12	13.8
	Sand flounder	0	1	16	21	47	3.2
	Elephant fish	18	4	6	5	2	2.4
	Yellow-eyed mullet	10	13	1	3	2	1.2
Drop/Dahn lines							
	Hapuku and Bass	89	107	112	128	143	163.7
	Ling	14	2	8	14	37	21.6
	Bluenose	17	8	5	4	25	19.3
	School shark	15	10	7	3	11	14.5
	Hapuku	1	0	0	2	3	1.7

Fine scale spatial information on commercial fishing activities for rock lobster in Statistical Area 915 were collected prior to the establishment of the Taputeranga marine reserve in 2008, which displaced considerable potting effort and annual catches of approximately 7.5 tonnes mainly to the eastern side of the marine reserve boundary at Princess Bay (Daryl Sykes, pers. com.). At present, there is intensive commercial fishing for rock lobster from Lyall Bay eastwards to Barrett's Reef, through Fitzroy Bay then past the Orongorongo stream to Turakirae Head and into western Palliser Bay (Daryl Sykes, pers. com.).

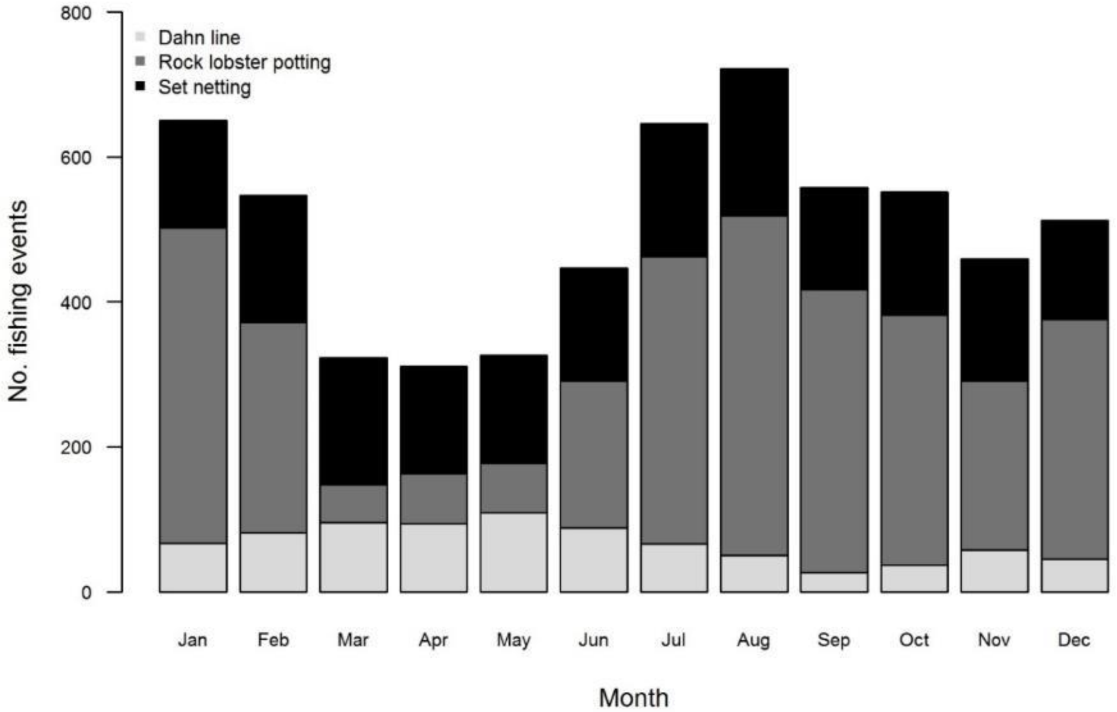

Figure 3-52: Monthly variations in effort in the main commercial fisheries in the coastal (CEL) dataset, from 2008/09 to 2012/13 fishing years. Monthly fishing effort is estimated as the as the number of fishing events.

3.7.2 Summary of catch and effort information for inshore (< 100 m depth) and offshore (≥ 100 m depth) commercial fishing activities within the study area

Fishing methods

In addition to the CEL data, 2789 inshore fishing events (fishing depth < 100 m) were reported (with geographic position data) in the study area from 1 October 2008 to 9 July 2014. Bottom trawl was the most common fishing method, accounting for more than half (56%) of fishing events and the majority of the catch (Table 3-16). Most of the remaining effort (42% of fishing events) was accounted for by set netting. Total catch from set netting was more than three times lower than the total catch from bottom trawling. Other methods (midwater trawl, bottom longlining and handlining) each accounted for 1% or less of the overall effort. However catches from midwater trawling activities were high and exceeded 200 t during the study period.

Table 3-16: Number of fishing events by fishing year (1 Oct-30 Sep), depth stratum and methods, % of overall effort, and total catch by fishing method. Data are ordered by decreasing total number of fishing events over the study period. *Incomplete data (October 1 2013 to July 9 2014)

Depth stratum	Fishing method	Number of fishing events						Total	% Effort	Total catch (t)
		2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014*			
Inshore (< 100 m)										
	Bottom trawl	189	257	253	271	324	275	1569	56.3	1219.9
	Set netting	242	170	184	188	197	189	1170	42.0	355.8
	Midwater trawl	2	12	7	4	3	5	33	1.2	242.7
	Bottom longlining	0	1	4	1	2	8	16	0.6	3.1
	Handlining	0	0	0	0	0	1	1	<0.1	<1
Offshore (≥ 100 m)										
	Midwater trawl	1259	1244	1086	1323	1350	1067	7329	69.4	75365.4
	Bottom trawl	493	383	376	395	509	464	2620	24.8	6204.2
	Bottom longlining	44	44	152	70	123	128	561	5.3	325.3
	Drop/Dahn lines	0	0	0	0	13	17	30	0.3	6.0
	Trot lines	8	0	0	6	10	4	28	0.3	6.3

A total of 10 568 offshore fishing events (fishing depth ≥ 100 m) were reported (with geographic position data) from 1 October 2008 to 9 August 2014. Midwater trawl was the main offshore fishing method, consistently explaining more than half of the fishing events on an annual basis and 69% of the total effort (Table 3-16). Total catch from offshore midwater trawls was equivalent to 75 365 t over the study period. Bottom trawl was the second most important fishing method (25% of all fishing events), followed by bottom longlining (5% of all fishing events). These fishing activities yielded total catches of 6 204 t and 325 t, respectively. Bottom longlining effort has been higher since 2010/11 compared to earlier (2008/09 and 2009/10) fishing years. Drop/Dahn lines and trot lines contributed limited catch and effort in offshore areas. Fishing activities using drop/Dahn lines were only reported over the last two years.

Target species

Catch and effort information by target species was tabulated for the main fishing methods in each of the depth stratum. Incomplete data from the 2013/14 fishing year were excluded.

Bottom trawl fisheries targeted a wide diversity of species. Inshore (< 100 m depth) bottom trawling primarily targeted common warehou (total 602 fishing events), followed by gurnard (319) and tarakihi (223) (Table 3-17). These fisheries yielded total catches of 475 t, 229 t and 144 t over the past five years, respectively. Barracouta, moki and trevally were next in importance, with total catches ranging between 24 t and 41 t. More fishing events targeted barracouta, moki and trevally in 2012/13. The total catch of flatfishes was 21 t, with no effort in 2010/11. Other target fisheries contributed total catches of 5 t or less. Emerging target species in recent years included lemon sole, New Zealand sole, ghost shark and to some extent, silver warehou. Inshore bottom trawling for red cod was not observed since 2010/11.

Table 3-17: Bottom trawling catch and effort by fishing year (1 Oct-30 Sep), depth stratum and target species, and total catch (t) by target species. Only target species that contributed a minimum catch of ≥ 1 t over the study period are shown. Data are ordered by decreasing total catch over the study period.

		Number of fishing events						
Depth Stratum	Target species	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	Total effort	Total catch (t)
Inshore (< 100 m depth)								
	Common warehou	102	97	147	130	126	602	474.7
	Gurnard	30	96	60	71	62	319	229.0
	Tarakihi	38	37	30	54	64	223	143.7
	Barracouta	2	0	4	4	9	19	41.3
	Moki	7	3	6	9	14	39	25.1
	Trevally	3	6	0	0	20	29	23.9
	Flatfishes	6	16	0	2	11	35	20.8
	Lemon sole	0	0	0	0	12	12	5.5
	New Zealand sole	0	0	0	0	3	3	2.5
	Silver warehou	0	0	2	0	1	3	2.0
	Red cod	1	0	1	0	0	2	1.2
	Ghost shark	0	0	0	1	1	2	1.0
Offshore (≥ 100 m depth)								
	Hoki	215	110	78	58	129	590	3501.8
	Tarakihi	184	188	188	246	252	1058	923.0
	Common warehou	38	26	42	36	62	204	181.9
	Ling	26	25	15	11	3	80	102.2
	Ghost shark	6	14	7	8	12	47	77.6
	Barracouta	2	0	10	2	6	20	57.1
	Moki	11	10	17	19	15	72	48.5
	School shark	9	1	3	3	0	16	39.5
	Cardinal fish	0	5	2	0	2	9	38.5
	Red cod	1	0	7	9	4	21	33.6
	Silver warehou	0	2	0	0	21	23	33.4
	Gemfish	0	0	2	2	0	4	4.1
	John dory	1	2	3	0	1	7	4.0
	Flatfishes	0	0	0	0	2	2	1.5
	Giant stargazer	0	0	0	1	0	1	1.1

Offshore bottom trawling mainly targeted tarakihi (total 1 058 fishing events), followed by hoki (590) and common warehou (204). The hoki fishery yielded a total catch of 3 502 t, compared to 923 t for tarakihi and 182 t for common warehou. Ling target effort ranked in fourth place but gradually decreased over the study period, for a total catch of about 100 t. More offshore bottom trawling events targeted ghost shark (total 47), Moki (72), red cod (21) and silver warehou (23) compared to inshore. Barracouta target effort in offshore areas yielded a higher total catch. In both depth strata, tarakihi target effort was higher in 2011/12 and 2012/13 compared to earlier years. Species targeted only in offshore (≥ 100 m depth) bottom trawling fisheries included ling, school shark, cardinal fish, gemfish, john dory and giant stargazer. Species targeted only in inshore (< 100 m depth) bottom trawling fisheries were gurnard, trevally and lemon and New Zealand sole.

Midwater trawling mainly targeted hoki in both inshore and offshore areas (Table 3-18). No other species were targeted inshore. Limited effort targeted moki and alfonsino and longfined beryx in offshore areas prior to the 2011/12 fishing year. Inshore fishing for hoki was higher in 2009/10 and 2010/11, while offshore fishing was higher over the last two fishing years (2011/12 and 2012/13). The total catch of hoki in offshore areas (66 505 t) was more than 300 times higher than inshore (204 t).

Table 3-18: Midwater trawling catch and effort by fishing year (1 Oct-30 Sep), depth stratum and target species, and total catch (t) by target species. Only target species that contributed a minimum catch of ≥ 1 t over the study period are shown. Data are ordered by decreasing total catch over the study period.

		Number of fishing events						
Depth stratum	Target species	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	Total effort	Total catch (t)
Inshore (< 100 m)								
	Hoki	2	12	7	4	3	28	204.4
Offshore (≥ 100 m)								
	Hoki	1257	1243	1085	1323	1350	6258	66505.2
	Moki	1	1	1	0	0	3	22.9
	Alfonsino and longfined beryx	1	0	0	0	0	1	9.2

Set netting activities were important within the inshore (< 100 m) depth stratum and mainly targeted butterfish (381 fishing events), followed by flatfishes (219), common warehou (203) and moki (143) (Table 3-19). Common warehou and moki effort yielded higher (> 100 t) total catches over the study period, compared to 55 t for butterfish. Rig and school shark target effort were generally limited and contributed total catches of less than 2 t. Effort targeting common warehou and moki was higher in 2011/12 and 2012/13, whereas a smaller number of fishing events targeted flatfishes.

Offshore bottom longlining mainly targeted ling, with a total catch of 194 t over the study period (Table 3-20). Other target species included hapuku, bass, bluenose and school shark. More effort targeted “hapuku and bass” than just “hapuku” and both had a higher number of fishing events in 2012/13 compared to earlier years. Bluenose effort was higher in 2009/10 and 2010/11. School shark target effort was reported only from 2010/11 onwards.

Table 3-19: Set net catch and effort by fishing year (1 Oct-30 Sep) and target species and total catch (t) by species within the inshore (< 100 m) depth stratum. Only target species which contributed a minimum catch of ≥ 1 t over the study period are shown. Data are ordered by decreasing total catch over the study period.

	Number of fishing events						
Target species	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	Total effort	Total catch (t)
Common warehou	40	11	24	52	76	203	116.4
Moki	17	14	33	41	38	143	115.6
Butterfish	124	83	55	63	56	381	55.2
Flatfishes	55	54	58	27	25	219	7.4
Rig	0	1	8	2	2	13	1.9
School shark	0	1	1	0	0	2	1.2

Table 3-20: Bottom longline catch and effort by year (1 Oct-30 Sep) and target species, and total catch (t) by species within the offshore (≥ 100 m) stratum. Only target species which contributed a minimum catch of ≥ 1 t over the study period are shown. Data are ordered by decreasing total catch over the study period.

	Number of fishing events						
Target species	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	Total effort	Total catch (t)
Ling	41	22	115	49	61	288	194.0
Hapuku and bass	2	6	15	5	25	53	29.2
Hapuku	0	1	3	8	29	41	14.2
Bluenose	1	14	16	3	2	36	10.4
School shark	0	0	3	4	5	12	5.8

Seasonal patterns

Total effort from the main fishing activities within the inshore (< 100 m) depth stratum was highest in mid-summer (December-January) and to a lesser extent in mid-winter (June and August) (Figure 3-53). Bottom trawling and set netting effort were observed throughout the year. Set netting effort peaked in August and was lower during autumn (March-April). Bottom trawling effort was highest in December-January. Midwater trawling contributed limited effort in inshore areas, essentially in June-July and December.

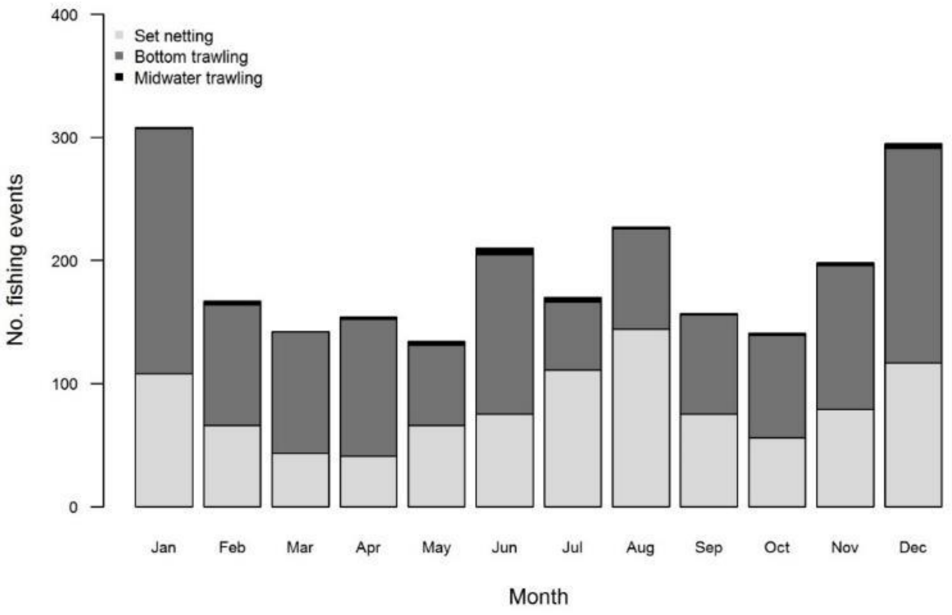

Figure 3-53: Monthly variations in numbers of fishing events (left) in the main inshore (< 100 m depth stratum) commercial fishery, from 2008/09 to 2012/13.

Marked seasonal variations in effort characterised the offshore (≥ 100 m) depth stratum (Figure 3-54). Total effort peaked in mid-winter (July through to September) and was lowest in the spring. Midwater trawl activities dominated the fishery during winter months, corresponding to the hoki spawning fishery season in Cook Strait. Bottom trawl effort was lower from June to October and generally stable the remainder of the year. Bottom longline effort peaked in autumn/early winter (April-June) and again in the spring and summer (September-January).

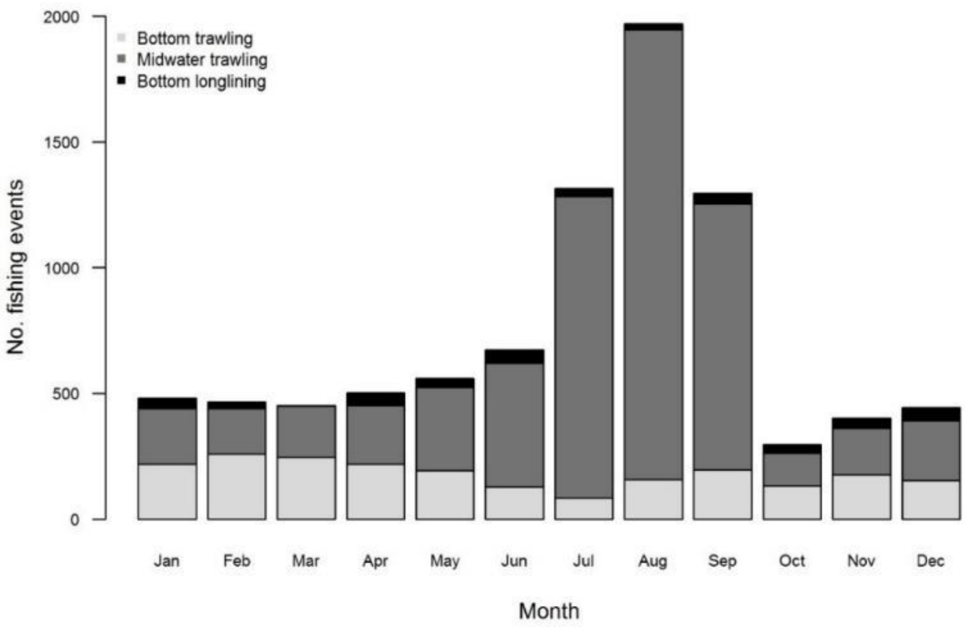

Figure 3-54: Monthly variations in effort in the main offshore (≥ 100 m depth stratum) commercial fishing activities, from 1 October 2008 to 30 September 2013.

Spatial patterns

Spatial patterns in catch and effort were characterised for the four main fishing methods: bottom and midwater trawling, set netting and bottom longlining, for the period ranging from 1 October 2008 to 30 September 2013.

Bottom trawling effort was widespread throughout the study area and concentrated within Palliser Bay (localities named in Figure 2-19), across the entrance from Wellington Harbour (between the 50 m and 100 m depth contours), and in offshore areas of Cook Strait at depths ≥ 100 m (Figure 3-55). High effort levels were also observed near the 100 m depth contour on the west coast. Offshore effort yielded higher catches.

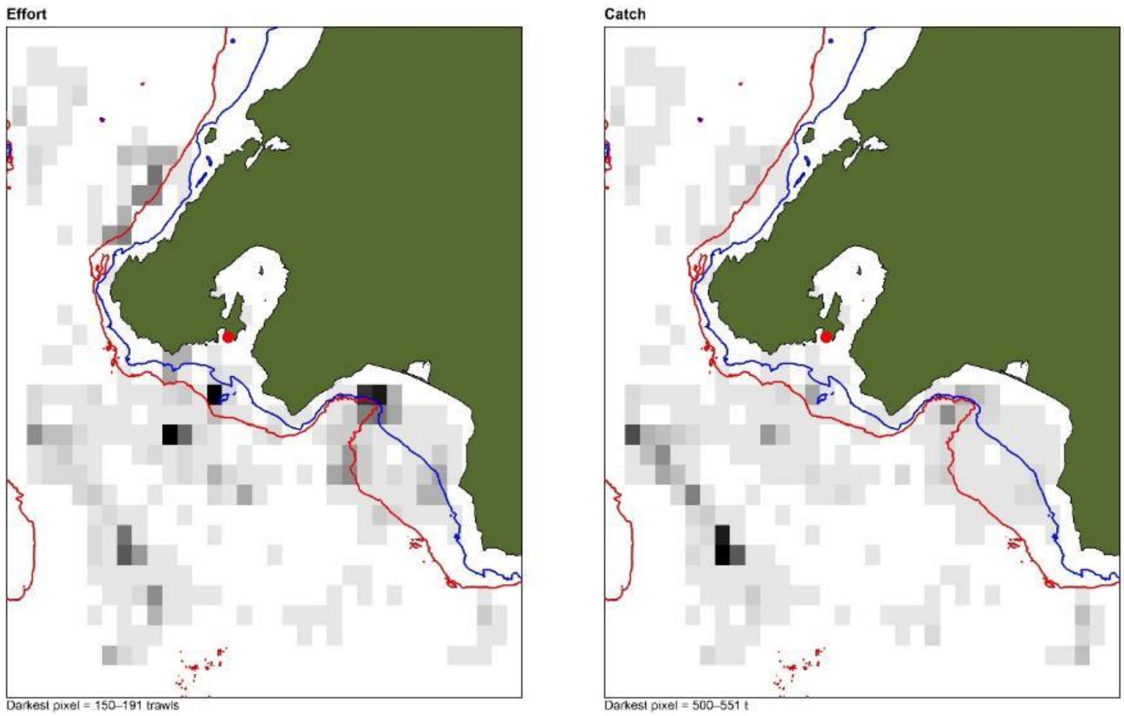

Figure 3-55: Bottom trawling catch and effort in the study area, from October 1, 2008 to September 30, 2013. Pixels are 0.025° x 0.025° rectangles. The red and blue lines represent the 100 m and 50 m depth contours, respectively. The red dot corresponds to the WIA approximate location.

Midwater trawling mainly occurred in offshore areas at depths greater than 100 m (Figure 3-56). Both catch and effort were higher offshore (i.e. towards the middle of Cook Strait), although high numbers of trawls and relatively high catches were also observed near the 100 m depth contour across the entrance from Wellington Harbour.

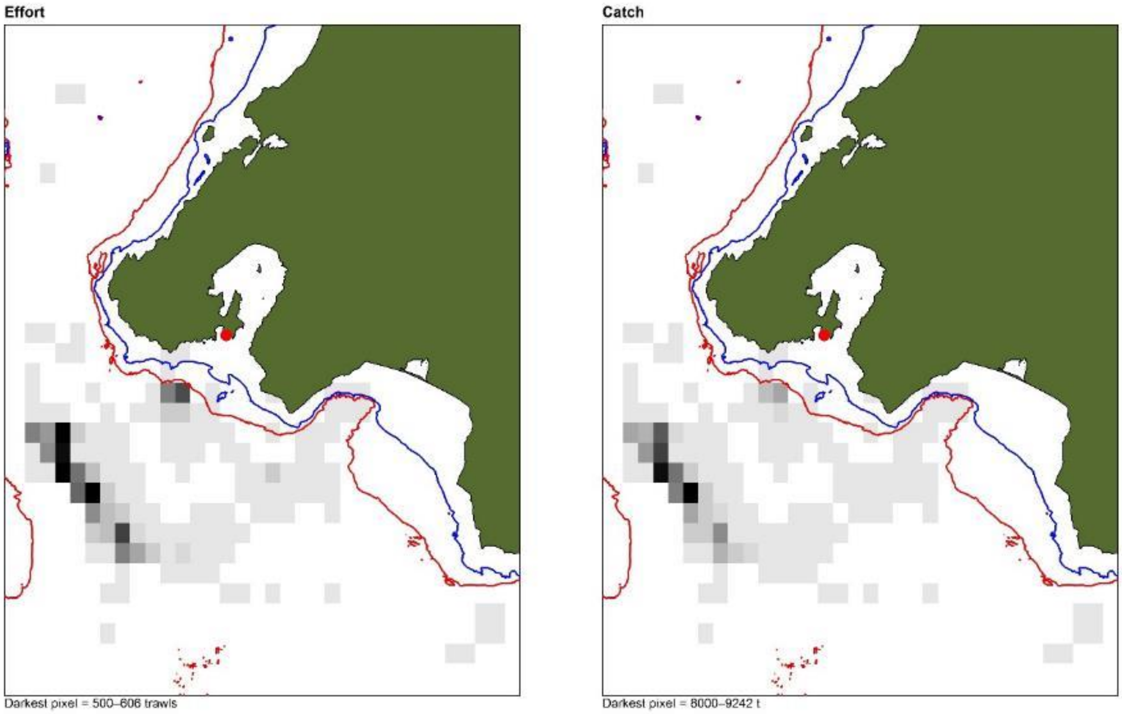

Figure 3-56: Midwater trawling catch and effort in the study area, from October 1, 2008 to September 30, 2013. Pixels are 0.025° x 0.025° rectangles. The red and blue lines represent the 100 m and 50 m depth contours, respectively. The red dot corresponds to the WIA approximate location.

Set netting activities were concentrated inshore (< 100 m depth) and often within the 50 m depth contour (Figure 3-57). Higher numbers of sets were observed within Wellington Harbour, on the west end of Palliser Bay, and on the Wellington South Coast between Sinclair Head and Cape Terawhiti. Catches were highest in Palliser Bay and relatively high on the Wellington south coast.

Bottom longlining occurred throughout the study area mainly at depths ≥100 m (Figure 3-58). Higher effort was observed near the 50 m and 100 m depth contours in western Palliser Bay, offshore from Cape Palliser, on the west coast and in the middle of Cook Strait. Higher catches were achieved in offshore-most areas of Cook Strait.

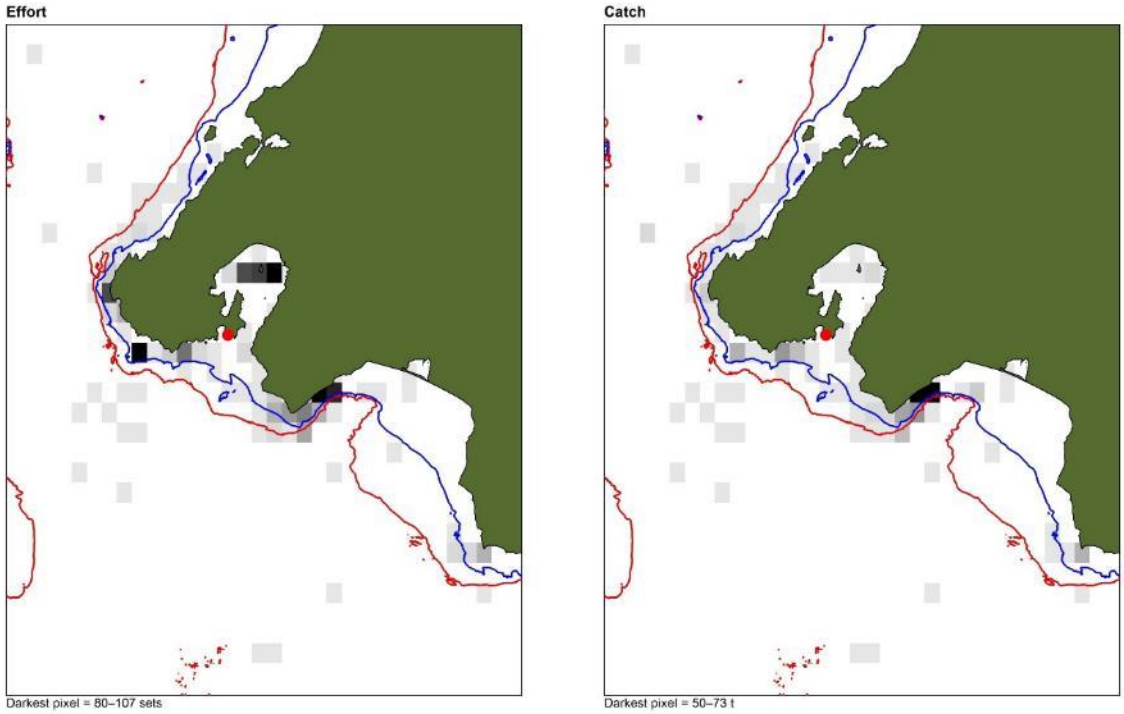

Figure 3-57: Set netting catch and effort in the study area, from October 1, 2008 to September 30, 2013. The red and blue lines represent the 100 m and 50 m depth contours, respectively. The red dot corresponds to the WIA approximate location.

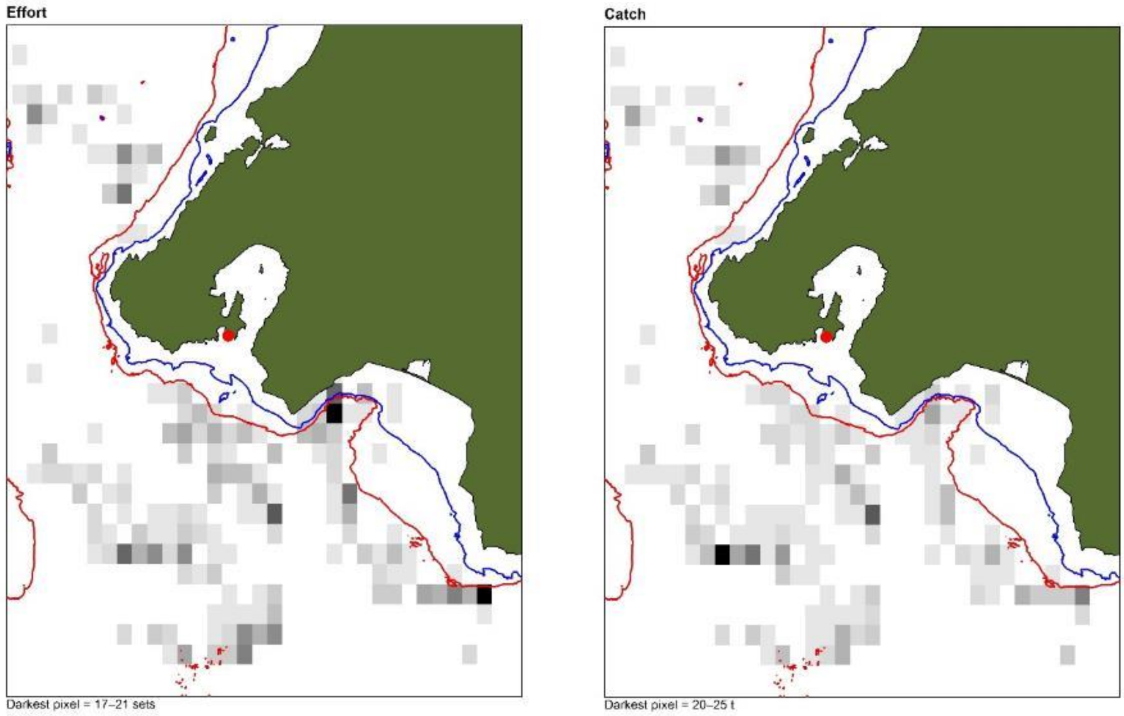

Figure 3-58: Bottom longline catch and effort in the study area, from October 1, 2008 to September 30, 2013. Pixels are 0.025° x 0.025° rectangles. The red and blue lines represent the 100 m and 50 m depth contours, respectively. The red dot corresponds to the WIA approximate location.

3.7.3 Recreational Fishing

In December 1998, Bell and Associates (2000) interviewed people fishing around Wellington's south coast, as well as members of fishing clubs and dive clubs and asked them to keep a diary of their fishing activities for a 12 month period. Over 350 fishers were interviewed and agreed to keep a diary yielding fishing histories for 2230 fishing trips. The data analysed by Bell and Associates (2000) indicate that over that period blue cod was the main species targeted (31% of 174 trips) in the area from Sinclair Head to Baring Head and including Lyall Bay. Other species targeted in this area were tarakihi, kahawai, Jock Stewart, paua, rock lobsters, butterfish, blue moki. The main fishing method employed in this area (40%) was rod and line from a private boat for an average period of 3.4 hours per trip though maps of fishing intensity indicated little fishing effort in Lyall Bay itself. Similarly no diving or potting effort was recorded in Lyall Bay. In contrast rod and line fishing from the shore was popular in Lyall Bay and there was some set netting effort, probably for butterfish, around its south-eastern entrance south of the airport.

During the intertidal and subtidal reef field work by NIWA staff, several groups of recreational fishers were observed snorkelling for paua, kina, and rock lobsters in the region adjacent to, and including the area of the proposed runway extension.

Live and dead bait line-fishing targeting pelagic fish species, such as kahawai and kingfish, appears to be a common practise off the existing breakwater to the south-west of the existing runway (personal observation, Rob Stewart, NIWA, February 2015).

3.8 Seabirds and marine mammals

3.8.1 Seabirds

A summary of the seabird and shorebird species likely to occur in Cook Strait, together with New Zealand threat classifications is provided in Table 3-21. Taxa identified are those that are likely to occur in Cook Strait on a regular basis, on an annual basis, with no temporal (seasonal) component. The list is unlikely to represent the full extent of taxa that could occur or have occurred in the Cook Strait area.

While the list of species occurring in the region is relatively large, a much reduced assemblage of species is likely to occur regularly within Lyall Bay and towards the south of the existing airport. This smaller group will likely comprise blue penguin, which breeds along the South coast of Wellington, fluttering shearwater, gulls, terns, shags, reef and white-faced herons and variable oystercatcher (Figure 3-59) (see Robertson 1992). It is very unlikely, however, that any of these species nest along the rock wall immediately to the south of the airport. Blue penguins breed nearby, in the Moa Point area for example.

Table 3-21: Species of seabirds and shorebirds occurring in Cook Strait. The list is based on sightings reported at http://ebird.org/ebird/newzealand/, and the corresponding New Zealand conservation status as reported by Robertson et al. (2013).

Common Name	Latin Name	New Zealand Conservation Status
Seabirds		
Blue penguin	*Eudyptula minor iredalei*	At Risk – Declining
Antipodean albatross	*Diomedea antipodensis antipodensis*	Threatened – Nationally Critical
Gibson’s albatross	*Diomedea antipodensis gibsoni*	Threatened – Nationally Critical
Southern royal albatross	*Diomedea epomophora*	At Risk – Naturally Uncommon
Northern royal albatross	*Diomedea sanfordi*	At Risk – Naturally Uncommon
Southern Buller’s albatross	*Thalassarche bulleri bulleri*	At Risk – Naturally Uncommon
Chatham albatross	*Thalassarche eremita*	At Risk – Naturally Uncommon
Salvin’s albatross	*Thalassarche salvini*	Threatened – Nationally Critical
Campbell albatross	*Thalassarche impavida*	At Risk – Naturally Uncommon
Black-browed albatross	*Thalassarche melanophrys*	Coloniser
White-capped albatross	*Thalassarche steadi*	At Risk - Declining
Cape petrel	*Daption capense*	At Risk – Naturally Uncommon
Northern giant petrel	*Macronectes halli*	At Risk – Naturally Uncommon
Southern giant petrel	*Macronectes giganteus*	Migrant
Antarctic prion	*Pachyptila desolata*	At Risk – Naturally Uncommon
Fairy prion	*Pachyptila turtur*	At Risk - Relict
Broad-billed prion	*Pachyptila vittata*	At Risk - Relict
White-chinned petrel	*Procellaria aequinoctialis*	At Risk – Declining
Westland petrel	*Procellaria westlandica*	At Risk – Naturally Uncommon
Cook’s petrel	*Pterodroma cookii*	At Risk - Relict
Mottled petrel	*Pterodroma inexpectata*	At Risk - Relict
Grey-faced petrel	*Pterodroma macroptera gouldi*	Not Threatened
Buller’s shearwater	*Puffinus bulleri*	At Risk – Naturally Uncommon
Flesh-footed shearwater	*Puffinus carneipes*	Threatened – Nationally Vulnerable
Fluttering shearwater	*Puffinus gavia*	At Risk - Relict
Sooty shearwater	*Puffinus griseus*	At Risk – Declining
Hutton’s shearwater	*Puffinus huttoni*	At Risk – Declining
Common diving petrel	*Pelecanoides urinatrix*	At Risk - Relict
White-faced storm petrel	*Pelagodroma marina*	At Risk - Relict
Black shag	*Phalacrocorax carbo*	At Risk – Naturally Uncommon
Little shag	*Phalacrocorax melanoleucos*	Not Threatened
Spotted shag	*Stictocarbo punctatus*	Not Threatened
Pied shag	*Phalacrocorax varius varius*	Threatened – Nationally Vulnerable

Little black shag	*Phalacrocorax sulcirostris*	At Risk – Naturally Uncommon
Australasian gannet	*Morus serrator*	Not Threatened
Arctic skua	*Stercorarius parasiticus*	Migrant
Black-backed gull	*Larus dominicanus*	Not Threatened
Red-billed gull	*Larus novaehollandiae*	Threatened – Nationally Vulnerable
Black-billed gull	*Larus bulleri*	Threatened – Nationally Critical
Black-fronted tern	*Chlidonias albostriatus*	Threatened – Nationally Endangered
Caspian tern	*Hydroprogne caspia*	Threatened – Nationally Vulnerable
White-fronted tern	*Sterna striata*	At Risk – Declining
Shorebirds		
Reef heron	*Egretta sacra sacra*	Threatened – Nationally Endangered
White-faced heron	*Egretta novaehollandiae*	Not Threatened
Banded dotterel	*Charadrius bicinctus bicinctus*	Threatened – Nationally Vulnerable
South Island pied oystercatcher	*Haematopus finschi*	At Risk – Declining
Variable oystercatcher	*Haematopus unicolor*	At Risk – Recovering
Spur-winged plover	*Vanellus miles novaehollandiae*	Not Threatened

Figure 3-59: Variable oystercatcher (*Haematopus unicolor*) on rocks at the end of the runway. Photo by Rob Stewart, NIWA.

3.8.2 Marine mammals

Table 3-22 summarises the conservation status of key marine mammal species occurring in the Cook Strait region, and Figure 3-61 illustrates location information for cetaceans within the Wellington area held in the DoC cetacean sighting database. Again, the list of taxa included in Table 3-22 is not exhaustive, additional species have occasionally been sighted in Cook Strait, for example sei whale *Balaenoptera borealis*. It is clear from Figure 3-61 that killer whales and common dolphins (see Figure

3-60) have occurred within Lyall Bay and close to the south of the existing airport. Further, bottlenose dolphins, Hector's dolphins, humpback whales, and southern right whales have all occurred within, or close to the entrance of, Wellington Harbour. New Zealand fur seals are occasionally sighted in the waters of Lyall Bay or hauled up on rocks around its margins. Their nearest regular haul out area is at Red Rocks at Sinclair Head which is occupied by seals from May to October. There is no evidence that Lyall Bay or the area to the south of the airport are particularly important for marine mammals. Notwithstanding that groups of common dolphins and killer whales, as well as solitary southern right whales occur here from time to time, marine mammal use of these areas could best be described as sporadic.

Figure 3-60: Common dolphins (*Delphinus delphis*) sighted adjacent to the existing runway in Lyall Bay during survey work. Photograph by Rob Stewart, NIWA.

Table 3-22: Most commonly sighted species of marine mammals occurring in Cook Strait. This list is based primarily on ad hoc sightings data maintained in the Department of Conservation cetacean sightings database. The corresponding New Zealand conservation status is as reported by Baker et al. (2010).

Common Name	Latin Name	New Zealand Conservation Status
New Zealand fur seal	*Arctocephalus forsteri*	Not Threatened
Killer whale	*Orcinus orca*	Threatened – Nationally Critical
Hector's dolphin	*Cephalorhynchus hectori hectori*	Threatened – Nationally Endangered
Bottlenose dolphin	*Tursiops truncatus*	Threatened – Nationally Endangered
Common dolphin	*Delphinus delphis*	Not Threatened
Sperm whale	*Physeter macrocephalus*	Not Threatened
Blue whale	*Balaenoptera musculus*	Migrant
Humpback whale	*Megaptera novaeangliae*	Migrant
Southern right whale	*Eubalaena australis*	Threatened – Nationally Endangered

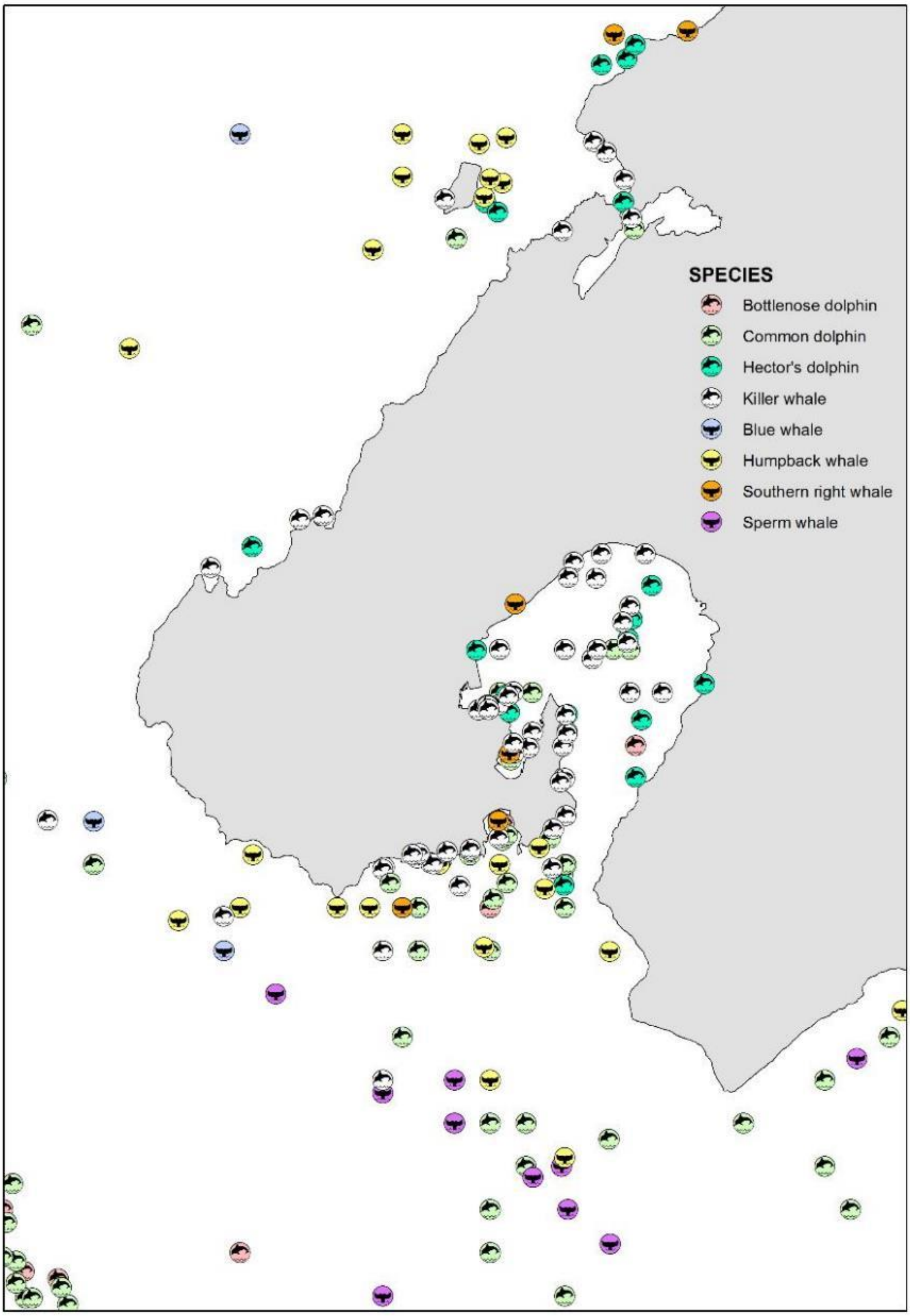

Figure 3-61: The distribution of sightings of the most common eight cetacean taxa in the Wellington area. Data are held in the Department of Conservation cetacean sighting database.

4 Discussion

4.1 Optical water quality in Lyall Bay

The deployment of a mooring in Lyall Bay has provided an assessment of the dynamics in optical water quality and estimates of TSS from turbidity over the spring month of September 2014. The deployment captured calm periods (waves < 0.25 m) and several storm events (waves up to about 5 m), with corresponding reduction in visibility range (from about 20-30 m down to < 1 m) and euphotic zone depth (about 40-50 m to < 10 m). Water colour during calm periods is typical of clear coastal waters with a blue-green hue, from the presence of low concentrations of phytoplankton and low CDOM. Although measures of water colour were not made during storm events, the increased concentration of benthic sediments resuspended during these periods is likely to shift the waters in Lyall Bay to a browner colour (green-yellow hues), more typical of river plumes.

Other seasons of the year will differ in environmental conditions (e.g. ambient light, photosynthesis, and climate), concentrations of the light-attenuating components (LAC's - TSS, Chl*a* and CDOM) and their effect on optical water quality. The dynamic seasonality of light and photosynthesis on coastal phytoplankton biomass and primary production are well known (e.g. Cloern 1996, Kirk 2011). Furthermore, seasonal dynamics in weather patterns and its effect on water column hydro-dynamic properties will also play an important role in observations. Sampling over the first month of spring 2014 (September) represents a snapshot of optical water quality properties and LAC conditions.

The accuracy of TSS estimates from mooring turbidity depends on how well this relationship holds for conditions *in-situ*. The Seapoint turbidity sensors used on the mooring measure the scattering of infra-red light across a range of angles (15-150 degrees), a component of attenuation (absorption and scattering of PAR wavelengths of incident radiation across all angles). Sensor IR (895 nm) light targets particles of mineral/inorganic origin, where there is little or no influence from organic particles (Downing 2006). As the particle size distribution (PSD) greatly influences the mass-specific attenuation cross-section (Davies-Colley and Smith 2001), it is likely that the TSS-turbidity relationship (slope) will also change with PSD. The PSD will be dependent on wave energy and environmental turbulence stirring up benthic sediment into the water column (Stokes law - settling velocity differences with particle diameter). As changes in water column PSD across the mooring deployment period from turbulence dynamics are expected, estimates of TSS derived from turbidity measurements will vary, particularly for low and high (extreme) concentrations.

Optical parameter inter-relationships from mooring records in comparison to laboratory calibration and synoptic survey results in Figure 3-5 may be useful as a broad semi-quantitative guide to effects of 'mineral' turbidity (or TSS with conversion from laboratory calibration equation) on optical water quality properties within Lyall Bay. However, as suggested by the range of slopes (upper panels in Figure 3-5), care must be taken to extrapolate these relationships to material from other sources and times. There is no reason to expect that any fine suspended sediment from airport construction will have the same particle optics (and same TSS to c, turbidity, visibility, light penetration relationships) as material entrained from bed sediments in and near Lyall Bay. Therefore, in consideration to optical water quality, TSS estimation and measurement of mass specific optical properties should both be undertaken.

For an assessment of the potential optical effects (impacts) on the optical water quality of Lyall Bay during construction of the proposed airport extension, knowledge of the PSD of the introduced suspended sediment, its size-mass-specific intrinsic optical properties would be required with the ‘background’ properties discussed above. A hydrodynamic sediment transport model with the ability to provide water column concentrations of TSS, and their size ranges, would provide details for the hydro-optical modelling required to estimate water column optical properties. An example of a hydro-optical model, is HydroLight/Ecolight-S (Sequioa Scientific, Inc.), a radiative transfer numerical model which computes optical water quality properties of interest (Mobley 2011). Optical modelling would be challenging due to the likely changes in nature and aggregation (flocculation) of sediments mobilised by construction.

4.2 Phytoplankton

Virtually all of the 30 species found in this survey were harmless, cosmopolitan species, similar to those previously reported by Cassie (1961) and Chang and Mullan (in press) in Wellington Harbour. The only potentially harmful species that was recorded here is *Pseudochattonella australis* Frenguelli (Moestrup et al. 2014). But only a small number of cells (0.9 x 10^3 cells per litre) of this species was recorded, and at only one site (site 9; Table 3-3).

The numerical domination of diatoms over other groups, both in terms of species and concentrations in samples collected from Lyall Bay in September 2014, is indicative of a spring diatom bloom. As the three chain-forming species, *Thalasssiosira hylina*, *Chaetoceros socialis* and *Lauderia annulata*, all showed moderate cell concentrations as well as high proportions of cells either in relatively short chains or in solitary form, they were likely to be at the end of the spring bloom.

The study of phytoplankton undertaken in Lyall Bay was necessarily a short snap-shot and had no temporal sampling on the order of days, months, seasons, or years. Considerable variation in the concentration and species composition of the phytoplankton community in Lyall Bay is to be expected over longer time scales with spring peaks and winter lows in Chla concentration (Crawford 1947, Bradford et al 1986, Tam 2012). Lyall Bay is open to Cook Strait and is regularly flushed by weak tidal and strong northerly and southerly wind driven currents (Pritchard et al. 2015). Thus the phytoplankton community in Lyall Bay will reflect that of the broader coastal phytoplankton community in Cook Strait which is subject to tidal mixing, upwelling, and stratified water conditions, as well as zooplankton grazing pressure (Bradford et al. 1986).

4.3 Zooplankton

The zooplankton communities sampled in Lyall Bay in spring 2014 are typical of inshore coastal waters around the North Island (Bradford 1980). Similar communities have been sampled in the Greater Cook Strait region (Battaerd 1983, Bradford 1978, 1980, Bradford et al. 1986). Typically these are dominated by calanoid copepods, especially *Paracalanus* species inshore and *Oithona similis* further offshore. As noted for phytoplankton above, considerable variation in the zooplankton community characteristics in Lyall Bay are expected over longer time scales (Crawford 1947, Bradford et al 1986), and will reflect that of the broader coastal zooplankton community in Cook Strait (Bradford et al. 1986).

4.4 Soft sediment habitats of Lyall Bay

4.4.1 Sediment environmental parameters

Lyall Bay is the largest embayment along Wellington’s southern coast line and, not unexpectedly due to its southern exposure, the sediments are dominated by well sorted fine sand. Gravels occurred only along the eastern margin and where they dominated were not well sampled using the HAPS corer.

Molar C:N ratios reflect the lability, or reactiveness, of organic matter in the sediments and the degree to which organic matter has been degraded (e.g., Lancelot and Billen, 1985). For suspended marine particulate matter, derived from phytoplankton, values above 6.6 (Redfield ratio, Redfield et al., 1963) indicate preferential loss of nitrogen-rich organic compounds, such as amino acids (proteins). Macroalgae (seaweeds) typically have higher C:N ratios (i.e., greater than 20, Meyers and Teranes, 2001). Similarly, high values of the ratio of Chla to total chloropigments suggests greater amounts of "fresh" pigment contributions to the total phytopigment pool in the sediments.

In Lyall Bay, the overall low PN content and moderately high C:N ratios, especially along the easternmost side of the bay in the area of the proposed runway extension (Table 3-5), reflects the overall low contributions of organic matter to the predominantly sandy sediments in general. In some sandy shallow estuarine systems, organic carbon contents can be reasonably high (i.e., 1.8 ± 0.7%; Pratt et al., 2014), but the low POC values in Lyall Bay reflect the predominance of fine sandy sediments (Figure 3-18), the low biological infaunal biomass (Section 3.3.6) and the high levels of re-mobilisation of these surficial sediments by waves and tides (e.g., Carter and Lewis, 1995). The higher C:N ratios of 14.0-17.5 on the eastern side of the bay may also reflect a macroalgal contribution to the sedimentary organic pool in the sediments.

The Chla content in the sediments of Lyall Bay reflect primary deposited material from phytoplankton in the overlying water column (Section 3.2.1), *in situ* microphytobenthic activity, and/or contributions from macroalgae on the fringing rocky reefs (see Section 3.4) (e.g., Redfield et al., 1963; Pomeroy et al., 1981; Evrard et al., 2012). In most mud-dominated systems, such as estuaries, degradation products (phaeopigments) often dominate over primary pigments, such as Chla (i.e., 4-40% Chla in total phytopigment pool; Pratt et al., 2014). This is opposite to the observations found in Lyall Bay where Chla predominates over phaeopigments. This suggests relatively low levels of biological and chemical activity in the bay (e.g., grazing, defaecation, bioturbation, oxidation, degradation), especially since all of the sites are likely to be within the photic zone, which would further reduce the chlorophyll-a preserved in the sediments (e.g., MacIntyre et al., 1996). Not unexpectedly, the Chla concentrations in Lyall Bay are very low compared to sheltered sandy shallow water systems (e.g., Cook et al., 2007) and especially where microphytobenthos are thought to enhance sediment stability (e.g., Miller et al., 1996). The highly mobile nature of the surficial sandy sediments in Lyall Bay, and resulting low Chla contents, suggest that microphytobenthic activity is not a dominant factor in the bay.

4.4.2 Dinoflagellate cysts

All three cyst types recorded in the survey are similar to those previously identified types found in the Marlborough Sounds (Baldwin 1987) and Wellington Harbour (Chang et al. 2008; Chang unpublished results). None were cysts produced by any of the harmful species previously identified in ports and harbours of New Zealand (Chang et al. 2008).

4.4.3 Epifauna

The epifaunal communities sampled in Lyall Bay were particularly low in overall abundance and species richness compared to those typically encountered in sandy substrates in sheltered harbours of similar depth (e.g. Mead et al 2005) and deeper sandy habitats on exposed coasts (e.g. Beaumont et al. 2013). In thirteen dredge tows totalling 1.56 km or 550 m^2 only 34 specimens of 13 species were captured. This is most likely due to the regularity and magnitude of wave events that sweep the seafloor removing organisms that are not buried or strongly attached. Interestingly, the occurrence of gravels at some sites had a significant effect on community structure, perhaps by providing stronger attachment for some epifaunal species during southerly storm events.

4.4.4 Macro-infauna

Macro-infauna, those species >0.5 mm living in the sediment, were not abundant in Lyall Bay with a total catch of just 226 individuals across the upper 5 cm of all 13 cores and a maximum of 38 individuals in this segment of any one core. These densities are about half those typically encountered in sandy substrates in more sheltered harbours of similar depth and deeper sandy habitats (e.g. Probert and Anderson 1986, Mead et al 2005, Paavo 2011, Beaumont et al. 2013) but are similar to another study carried out on Wellington's south coast (Smith et al. 2011). As with the epifauna, this low abundance is most likely due to the regularity and magnitude of wave events that sweep the seafloor removing organisms that are not deeply buried or strongly attached. From this perspective it should be noted that the typical depth (up to 65 cm) and complexity of burrows dug by the ghost shrimp *Biffarius filholi* (Morton and Miller 1968) suggests that this species was dramatically under-sampled by the HAPS corer that penetrated to a maximum depth of 30cm. The density of burrow entrances of this species observed in the seafloor imaging, all likely to be currently in use (because a southerly storm that generated 3 m waves in the bay the week prior to sampling will have obliterated any non-active burrows), suggests that in the shallow half of Lyall Bay this species may comprise the bulk of the macro-infaunal biomass.

4.4.5 Meiofauna

Comparison with similar habitats in other parts of the world

The abundance of meiofauna in subtidal sands can vary substantially depending on local conditions; abundances ranging from 40 to 12,000 individuals 10 cm^{-2} have been reported, with values averaging about 1000 ind. 10 cm^{-2} (see review by Coull 1988). The meiofaunal abundances reported here for the Lyall Bay study area are close to the average values reported for this type of habitat.

Nematodes typically dominate the meiofauna, and harpacticoids are usually second in abundance (Giere, 2009). Although nematodes dominated in all of the samples analysed, harpaticoid copepods were the second most abundant group in only 3 of the 13 samples we analysed. Kinorynchs and tardigrades were the second most abundant group in 6 and 3 of the samples analysed respectively. Kinorynch abundance in shallow water samples is usually in the range of 10-20 individuals 10 cm^{-2} (Giere 2009); in contrast, kinorynch abundance exceeded 40 individuals 10 cm^{-2} in six of the 13 samples analysed. Very little is known about the ecology of kinorynchs, and the reasons for their unusually high abundance in Lyall Bay are not clear. Several studies have shown this group to be sensitive to organic pollution (e.g., Mirto et al. 2012), but other factors, such as physical disturbance due to currents and sediment granulometry, are also likely to influence their distribution.

The high abundance of tardigrades (50-153 individuals 10 cm^{-2}) in three of the samples analysed is also unusual (Giere 2009), although densities of more than 500 individuals 10 cm^{-2} have been reported elsewhere (D'Addabo et al. 2007). Marine tardigrades are usually small (<250 μm in length) and are able to hold on to sediment particles even in highly disturbed sediments (Giere 2009). Their high abundance in community a may be indicative of high velocity/extreme hydrodynamic conditions favouring taxa able to withstand strong currents.

Comparison with published data from Wellington region and New Zealand

A number of meiofaunal studies have been conducted in the Wellington region, but most focused exclusively on the distribution of harpacticoid copepods in intertidal areas or living among seaweeds (e.g., Hicks 1992, Iwasaki 1993). Only two studies provide information about the distribution of other meiofaunal groups (Coull and Wells 1981; Hicks 1989).

The first of these studies compared the abundance and community structure of intertidal meiofauna at three sites (Waiwhetu Stream, Hutt River estuary, and Pauahatanui Inlet) differing in pollution levels (high pollution, low pollution, and unpolluted, respectively). Meiofaunal densities at the high pollution site was very low (<150 ind. 10 cm^{-2}), whereas densities at the low pollution and unpolluted sites were relatively high (150-660 and 350-690 ind. 10 cm^{-2}, respectively) (Coull and Wells 1981). The authors noted that kinorynchs were only present at the unpolluted site, and that this taxon is generally almost exclusively restricted to fine, clean sediments. The meiofaunal densities observed at the Lyall Bay study sites are broadly similar or higher than the densities observed by Coull and Wells (1981) at their unpolluted sites (including Pauahatanui Inlet). The presence of relatively high densities of kinorynchs and other meiofauna at the Lyall Bay study sites (particularly in the western area) would therefore suggest that the sediments there are unpolluted.

The second study, which focused on the density of intertidal meiofauna in sandy sediments of Pauahatanui Inlet, found high densities of nematodes and harpaticoid copepods, which, combined, exceeded 3000 ind. 10 cm^{-2} (other taxa were not included; Hicks 1989). The meiofaunal densities observed at the Lyall Bay study sites are markedly lower.

Comparing the meiofaunal densities between these studies, however, is complicated by the fact that comparison is made between an exposed subtidal area (Lyall Bay) and a sheltered intertidal area (Pauahatanui Inlet). Another study conducted in Martins Bay near Auckland, a subtidal open coast sandy area similar to Lyall Bay, found a mean meiofaunal density of 1050 ind. 10 cm^{-2} (Warwick et al. 1997), which is very similar to the mean density of meiofauna in the present study.

Overall, the density and composition of meiofauna at the Lyall Bay study area are consistent with published data from unpolluted coastal sites in New Zealand and elsewhere.

Nematodes

The meiofaunal community at site 10 was the most depauperate. The presence of draconematid nematodes at that site (a group characterised by modified ambulatory setae normally associated with coarse gravelly sediment) is consistent with extreme hydrodynamic conditions that may prevent the development of a more abundant meiofaunal community.

The presence of nematodes of the subfamily Stilbonematinae, a group of nematodes normally associated with sandy sediments with high organic matter input, suggests relatively high food availability at some of the Lyall Bay study sites although the POC measurements (see Figure 3-18) suggest that food availability in seafloor sediments is low.

Relationship with environmental parameters

Sediments were relatively homogeneous among sites, with sand content ranging from 93 to 99%. Most of the variation in sediment characteristics was due to the presence of gravel at some of the sites (i.e., sites 10 and 12, which were characterised by the lowest sand content). This relatively limited variation in sediment granulometry was linked with variation in both meiofaunal abundance and community structure. This relationship may reflect differences in hydrodynamic conditions and/or food availability among sites, both of which are important factors affecting the distribution of meiofauna (Giere 2009).

Meiofauna as indicators of ecological change

Meiofauna was the most abundant component of the soft sediment community in Lyall Bay, and exhibited some level of heterogeneity in community structure across the study sites. Some of this heterogeneity was associated with variation in the physical characteristics of the sediment, which was linked with differences in the abundance of some taxa such as tardigrades and kinorynchs. Monitoring the abundance of these taxa, as well as the rest of the meiofaunal community, would therefore provide an ecologically meaningful indicator of the environmental conditions present at the seabed (Sherman and Coull 1980, Kennedy and Jacoby 1999, Schratzberger et al. 2000). More specifically, changes in the abundance and structure of the meiofaunal community in the vicinity of the extension will provide an indication of whether changes in currents and/or sedimentation regime are impacting the organisms at the seabed, and would provide a means to gauge recovery following disturbance through comparisons with baseline data. Monitoring would provide information on environmental conditions integrated over periods of weeks to months (i.e., the range of life-cycle duration of meiofauna; Giere 2009).

4.5 Rocky reef communities

Apart from the occurrence of artificial substrates, especially in the intertidal and shallow subtidal zones, the rocky reef communities assessed in Lyall Bay are typical of shallow reef habitats along the Wellington south coast (e.g., Gardner 2008, Tam 2012). They support a rich and diverse range of brown, red and green macroalgae which not only are key contributors to coastal ecosystems through the energy captured via photosynthesis, but also provide highly structured three-dimensional habitats critical for other grazing and predatory reef species, some of which are valuable food organisms such as paua, kina and rock lobsters, as well as a range of reef fish. Lacking on the reefs surveyed were extensive beds of mussels. This is typical of Wellington’s south coast (Tam 2012).

A wider area survey of intertidal reefs along Wellington’s south coast over a period of two years (Tam 2012) found that three biodiversity indices (Shannon diversity index (H’), richness (S), and evenness (J’)) all varied significantly by site and season, with differences among sites much less than differences among seasons. The three indices at Moa Point (the closest sampling point to the runway extension) all peaked in winter, with lowest values in summer and spring values midway. Thus the intertidal rocky reef communities sampled during spring in this study can be expected to reflect the annual average for this site.

4.6 Reef fish

Lyall Bay has a moderately diverse reef fish fauna, with only 27 of the 72 species modelled by Smith et al. (2013) New Zealand-wide predicted to occur on reefs within SCUBA diving depth range (<30 m). None of the modelled species are nationally threatened (Hitchmough et al. 2007, Townsend et al. 2008). There was good agreement between the reef fish species observed by divers during algae and invertebrate counts and the modelled species predicted to be most common in Lyall Bay.

Despite their potential utility, Smith et al. (2013) pointed out that the reef fish abundance predictions have a number of limitations. These include problems with counting fishes underwater (e.g., some species are attracted to divers and others are repelled, while small cryptic species are rarely observed, e.g., Willis and Anderson 2003), depth limitations (most dives were to less than 30 m depth), coarse spatial resolution (1 km^2) relative to the scale of habitat variation known to affect reef fish abundance (a few metres to tens of metres), and use of surrogate variables that may be inappropriate for reef fishes (e.g. wind fetch instead of wave exposure). It should be noted that the modelled reef fish distributions, abundances and diversity only applies to rocky reef habitats. Some species, such as leather jackets and tarakihi, also occur over open habitats. The distributions of these species in these habitats were modelled separately. Nonetheless, NIWA considers that the information from Smith et al. (2013) provides an appropriate basis for subsequent consideration of potential effects associated with the proposed extension of the airport runway into Lyall Bay.

4.7 Demersal and pelagic fish species

Adults of 44 species of demersal fish are predicted to occur in Lyall Bay, though 21 species are predicted be rare with less than a 10% probability of occurrence, and another 12 species are predicted to be uncommon with a 10-50% probability of occurrence. Just 11 modelled species were predicted to be common. Leathwick et al. (2006a) indicated that over a broad region of shelf waters around the southern half of the North Island demersal fish species richness is predicted to be a moderate 12-16 species per standard research bottom trawl with 95% confidence limits ranging from + 1-4 species. This compares with the northern flank of the Chatham Rise and continental slopes along the north-eastern flank of South Island and south-eastern flank of North Island that have predicted richness in excess of 20 species per tow. Leathwick et al. (2006a) stated that depth, temperature, and salinity were the main predictors of species abundance, but noted that generally species richness also increased with increasing Chla concentration.

There are a number of strengths and limitations to these predicted distributions and abundances. The modelling is performed on research trawl data collected over a span of 26 years from 1979 to 2006 so that inter-annual variations or trends in demersal fish abundance and distributions are not apparent. Although effort from trawl surveys throughout the EEZ is included in the modelling, there are seasonal distribution biases that could confound the predictions, given that some species migrate. The predicted distributions and abundances only apply to habitats able to be bottom trawled; they do not apply to rocky reef habitats, for example. The strength of the predicted fish distributions and abundances is that they are based on an enormous data set, containing 21,000 research demersal trawls from throughout New Zealand, including the Wellington region. This provides confidence that the model provides reliable long term patterns of demersal and pelagic fish distribution and abundance around Wellington's south coast.

4.8 Fisheries

4.8.1 Commercial fisheries

The broader Wellington region supports important and diverse commercial fishing activities, including coastal and inshore fisheries for rock lobster, butterfish, gurnard, common warehou, moki and tarakihi, which individually contributed total catches ≥ 100 t over the last five years. Other important commercial fisheries for hoki, ling, hapuku, bass and bluenose, predominantly occur in offshore areas of Cook Strait at depths ≥ 100 m.

In terms of total effort, the most important commercial fisheries in the last five years were 1) offshore midwater trawl and bottom trawl fisheries for hoki; 2) rock lobster potting; 3) coastal and inshore set netting for butterfish; and 4) inshore bottom trawling for common warehou, tarakihi and gurnard.

Set netting effort in coastal fisheries has increased in recent years, following quota reductions (and reduced effort) in the rock lobster fishery. Unfortunately, limited spatial information was available to determine coastal fisheries 'hotspots'. However, the only commercial fisheries known to operate near Lyall Bay are rock lobster potting and set netting for butterfish, and these are confined to the headlands at Moa Point in the east and Te Raekaihau Point, adjacent to the Te Taputeranga Marine Reserve boundary in the west.

Inshore (< 100 m depth) set netting effort was concentrated within Wellington Harbour, along the Wellington South Coast, and at the western end of Palliser Bay but does not occur in Lyall Bay. These fisheries increasingly targeted common warehou and moki in recent years. Inshore bottom trawling effort was concentrated between the 50 m and 100 m depth contours across the entrance from Wellington Harbour and in Palliser Bay but not in Lyall Bay. Bottom trawl fisheries are the most diversified in terms of target species, both inshore and offshore.

All coastal, inshore and offshore fisheries within the Wellington region operate throughout the year. Marked seasonal variations in effort mainly occur as a result of the winter spawning fishery for hoki in Cook Strait and a break in potting for rock lobsters in autumn when females moult and mate. Coastal and inshore commercial fishing activities tend to peak in mid-summer and mid-winter. Lower effort was observed during autumn (from March to May) and in October.

4.8.2 Recreational fisheries

Only one study has explicitly documented recreational fishing along Wellington's south coast (Bell and Associates 2000). This found that rod and line fishing from the shore was most popular in Lyall Bay and there was some set netting effort, probably for butterfish, around its south-eastern entrance south of the airport (Bell and Associates 2000). While other forms of recreational fishing including rod and line fishing from boats, potting, and diving were documented along the south coast in the area from Sinclair Head to Baring Head, maps of their intensity indicated little effort in Lyall Bay itself (Bell and Associates 2000).

The NIWA observations of hand-gathering of paua and kina from reefs in Lyall Bay by several parties of recreational fishers suggests this is likely to be a persistent activity in this area.

It should be noted that the report by Bell and Associates (2000) was compiled before the Taputeranga Marine Reserve was put in place. Subsequently there is likely to have been displacement of recreational fishing activities, particularly rod and line fishing from private boats and from the shore, and diving, to adjacent coast lines as these were the main fishing activities in the area now protected.

4.9 Seabirds and Marine Mammals

New Zealand supports the most diverse seabird assemblage on Earth. Of approximately 359 seabird taxa worldwide, 161 (45%) have been recorded in New Zealand. Even when considering those taxa that breed in New Zealand, the total remains relatively high at 95 (60%). Of these, 31 taxa (33% of breeding taxa) are classified as 'threatened' (that is, either 'nationally critical', 'nationally endangered' or 'nationally vulnerable' by the New Zealand threat classification system: Robertson et al. 2013), and a further 51 taxa (54% of breeding taxa) are classified as 'at risk' (that is, either 'declining', 'recovering', 'relict' or 'naturally uncommon': Robertson et al. 2013).

Diversity among marine mammals is similarly high within New Zealand: 54 taxa have been recorded here, representing 43% of a worldwide total of approximately 125 taxa. Only eight (15%) taxa are classified as ‘threatened’ and no taxa are classified as ‘at risk’ (Baker et al. 2010). However, Baker et al. (2010) classified 13 (24%) taxa as ‘data deficient’ reflecting the paucity of basic information for some taxa within this group.

Of the New Zealand total of seabird species at least 26% occur in the Cook Strait region, while for marine mammals at least 17% occur in the region. However, only a relatively small sub-set of seabird and marine mammal species occurring in Cook Strait have been recorded in Lyall Bay close to the southern end of the airport and there is little, if any, evidence to suggest these areas are important for seabirds and marine mammals, either as breeding sites or feeding zones. While blue penguins breed along the south coast of Wellington including the Moa Point area, it is unlikely this species breeds in the rock wall to the south of the airport – exposure to wave action here would be relatively high.

5 Conclusions

Lyall Bay is the largest embayment along Wellington’s southern coast line. It comprises three main habitats; the water column pelagic environment, sandy seafloor sediments in the main part of the bay, and rocky reefs around the bay’s eastern and western margins. The fauna and flora associated with these habitats in the area potentially affected by the proposed airport extension are typical of that in adjacent habitats in Lyall Bay, which in turn are typical of those along Wellington’s south coast. The potentially affected habitats in Lyall Bay are not critical habitat for any threatened or rare species.

The only commercial fisheries known to operate near Lyall Bay are rock lobster potting and set netting for butterfish, and these are confined to the headlands at the entrance to the bay. In contrast, recreational fishing does occur in the area potentially affected by the proposed airport extension.

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Appendix A Rocky reef species from Lyall Bay

Ochrophyta (Brown algae) species

Structural form	Family	Genus	Species	Inter-tidal presence	Sub-tidal presence
Large strap	Durvillaeaceae	*Durvillaea*	*antartica*	yes	yes
Large strap	Lessoniaceae	*Lessonia*	*variegata*	yes	yes
Large strap	Laminariaceae	*Macrocystis*	*pyrifera*		yes
Small strap	Dictyotaceae	*Zonaria*	*aureomarginata*	yes	yes
Small strap	Dictyotaceae	*Dictyota*	*kunthii*	yes	yes
Small strap	Dictyotaceae	*Distromium*	*skottsbergii*	yes	yes
Small strap	Scytosiphonaceae	*Petalonia*	*binghamiae*	yes	yes
Coarse branched	Sargassaceae	*Carpophyllum*	*flexuosum*		yes
Coarse branched	Sargassaceae	*Carpophyllum*	*maschalocarpum*	yes	yes
Coarse branched	Sargassaceae	*Cystophora*	*retroflexa*	yes	yes
Coarse branched	Sargassaceae	*Cystophora*	*scalaris*	yes	yes
Coarse branched	Sargassaceae	*Landsburgia*	*quercifolia*		yes
Flat and leathery	Lessoniaceae	*Ecklonia*	*radiata*		yes
Flat and leathery	Alariaceae	*Undaria*	*pinnatifida*	yes	yes
Finely branched	Sporochnaceae	*Carpomitra*	*costata*	yes	yes
Finely branched	Stypocaulaceae	*Halopteris spp.*		yes	yes
Finely branched	Scytothamnaceae	*Scytothamnus spp*		yes	
Thin and flat	Scytosiphonaceae	*Colpomenia spp.*		yes	
Crusts	Ralfsiales	*Ralfia spp.*		yes	
Filamentous	Ectocarpales	*Ectocarpus spp*		yes	
Film / Diatoms	various	*various*		yes	

Chlorophyta (Green algae) species

Structural form	Family	Genus	Species	Inter-tidal presence	Sub-tidal presence
Thin flat sheet	Ulvaceae	*Ulva*	*pertusa*	yes	yes
Tubular form	Ulvaceae	*Ulva*	*compressa*	yes	
Flat encrusting	Codiaceae	*Codium*	*dimorphum*	yes	
Fine branched	Caulerpaceae	*Caulerpa*	*brownii*	yes	yes
Coarse branched	Caulerpaceae	*Caulerpa*	*germinata*	yes	yes

Rhodophyta (Red algae) species

Structural form	Family	Genus	Species	Inter-tidal presence	Sub-tidal presence
Strap bladed	Sarcodiaceae	*Sarcodia*	*grandifolia*		
Strap bladed	Rhodomelaceae	*Cladhymenia*	*coronata*	yes	yes
Strap bladed	Rhodomelaceae	*Adamsiella spp*			
Strap bladed	Phyllophoraceae	*Stenogramma*	*interruptum*		
Strap bladed	Rhodymeniaceae	*Rhodymenia spp.*			
Strap bladed	Cystocloniaceae	*Crasedocarpus*	*erosus*		
Strap bladed	Halymeniaceae	*Pachymenia*	*dichotoma*		
Strap bladed	Delesseriaceae	*Hymenena spp.*			
Coarse branched	Callithamniaceae	*Euptilota*	*formosissima*		
Coarse branched	Champiaceae	*Champia spp.*			
Coarse branched	Pterocladiaceae	*Pterocladia*	*lucida*		
Coarse branched	Gigartinaceae	*Gigartina spp.*			
Fine branched	Rhodomelaceae	*Polysiphonia*	*decipiens*		
Fine branched	Plocamiaceae	*Plocamium spp.*			
Fine branched	Bangiaceae	*Bangia spp*		yes	
Fine branched	Rhodomelaceae	*Lophurella*	*caespitosa*		
Fine flat sheet	Bangiaceae	*Pyropia spp.*		yes	
Fine flat sheet	Kallymeniaceae	Psaromenia	*berggrenii*		
Thin bladder	Nemastomaceae	*Catenellopsis*	*oligarthra*		
Red crust/turf	Kallymeniaceae	*Ectophora*	*depressa*		
Red crust/turf	Peyssonneliaceae	*Peyssonnelia spp.*			
Red crust/turf	Corallinaceae	*Arthrocardia*	*anceps*	yes	yes
Red crust/turf	Wrangeliaceae	*Spongoclonium*	*pastorale*		
Non-geniculate coralline	Corallinaceae	Various spp. (pink paint*)*		yes	yes

Bryozoans

Sample number	Transect	Bryozoan family	Genus	Species
A			*Elzerina*	*binderi*
A, C	D		*Bicrisia*	*edwardsiana*
B, C	E, D	Versiculariidae	*Amathia*	*wilsoni*
B, C	E, D	Candidae	*Bugulopsis*	*monotrypa*
B	E	Calloporidae	*Corbulella*	*corbula*
B, C	E, D	Chaperidae	*Chaperia sp.*	
B, C	E, D		*Calwellia*	*bicornis*
B	E		*Claviporella*	*eurita*
B	E	Bugulidae	*Dimetopia*	*cornuta*
C	D		*Orthoscuticle*	*fissurata*
C	D	Margarettidae	*Margaretta*	*barbata*
C	D		*Scalicella*	*Crystallina*
C	D	Candidae	*Emma*	*rotunda*
C	D	Candidae	*Emma*	*triangula*
C	D	Celleporidae	*Osthimosia sp.*	
C	D	Catenicellidae	*Costaticella*	*bicupsis*

Molluscs from inter-tidal transects; presence by quadrat number

Quadrat reference	Mollusca family	Genus	Species	Common name	Described by	Status	Abundance
A1	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
A2	Chitonidae	*Sypharochitin*	*pelliserpentis*	Snakeskin chitin	Quoy and Gaimard, 1835		common
A5	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
A12	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
A13	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
B2	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
B3	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
C1a	Mytilidae	*Mytilus*	*galloprovincialis*	Blue mussel	Lamarck, 1819		common
C1b	Mytilidae	*Aulacomya*	*maoriana*	Ribbed mussel	Iredale, 1915	endemic	common
C1c	Lottiidae	*Patelloida*	*cortica*	Ribbed limpet	Hutton, 1880	endemic	common
C2	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
C7a	Trochidae	*Diloma*	*aethiops*	Spotted black top shell	Gmelin, 1791	endemic	common
C7b	Trochidae	*Diloma*	*zelandica*	Top shell	Quoy and Gaimard, 1834	endemic	common
C8a	Trochidae	*Diloma*	*zelandica*	Top shell	Quoy and Gaimard, 1834	endemic	common
C8b	Nacellidae	*Cellana*	*radians*	Radiate limpet	Gmelin, 1791	endemic	common
C8c	Lottiidae	*Patelloida*	*cortica*	Ribbed limpet	Hutton, 1880	endemic	common
C9	Trochidae	*Diloma*	*zelandica*	Top shell	Quoy and Gaimard, 1834	endemic	common
C11a	Trochidae	*Diloma*	*aethiops*	Spotted black top shell	Gmelin, 1791	endemic	common

C11b	Trochidae	*Diloma*	*zelandica*	Top shell	Quoy and Gaimard, 1834	endemic	common
C12	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
C13a	Mytilidae	*Mytilus*	*galloprovincialis*	Blue mussel	Lamarck, 1819		common
C13b	Littorinidae	*Risellopsis*	*varia*	Crevice snail	Hutton, 1873	endemic	Fairly common
C13c	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
C13d	Nacellidae	*Cellana*	*Stellifera?*	Stellate limpet	Gmelin, 1791	endemic	Fairly common
C15a	Trochidae	*Diloma*	*zelandica*	Top shell	Quoy and Gaimard, 1834	endemic	common
C15b	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
C15c	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
C18	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
E23a	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
E23b	Littorinidae	*Austrolittorina*	*cincta*	Brown periwinkle	Quoy and Gaimard, 1833	endemic	Fairly common
E22	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
E19a	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
E19b	Littorinidae	*Austrolittorina*	*cincta*	Brown periwinkle	Quoy and Gaimard, 1833	endemic	Fairly common
E17a	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
E17b	Littorinidae	*Austrolittorina*	*cincta*	Brown periwinkle	Quoy and Gaimard, 1833	endemic	Fairly common
E15	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
E14	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
E13a	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
E13b	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common

E11a	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
E11b	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
E10a	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
E10a	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
E9a	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
E9b	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
E9c	Trochidae	*Diloma*	*aethiops*	Spotted black top shell	Gmelin, 1791	endemic	common
E9d	Muricidae	*Haustrum*	*haustorium*	Brown rock shell	Gmelin, 1791	endemic	common
E8a	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
E8b	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
E8c	Nacellidae	*Cellana*	*radians*	Radiate limpet	Gmelin, 1791	endemic	common
E7a	Nacellidae	*Cellana*	*radians*	Radiate limpet	Gmelin, 1791	endemic	common
E7b	Lottiidae	*Radiacmea*	*inconspicua*		Gray, 1843	endemic	Fairly common
F28a	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
F28b	Littorinidae	*Austrolittorina*	*cincta*	Brown periwinkle	Quoy and Gaimard, 1833	endemic	Fairly common
F26a	Chitonida	*Sypharochitin*	*pelliserpentis*	Snakeskin chitin	Quoy and Gaimard, 1835		common
F26b	Nacellidae	*Cellana*	*radians*	Radiate limpet	Gmelin, 1791	endemic	common
F25	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
F24a	Trochidae	*Diloma*	*aethiops*	Spotted black top shell	Gmelin, 1791	endemic	common
F24b	Trochidae	*Diloma*	*zelandica*	Top shell	Quoy and Gaimard, 1834	endemic	common
F22	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common

F18	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
F16a	Littorinidae	*Austrolittorina*	*antipodium*	Blue banded periwinkle	Philippi, 1847	endemic	common
F16b	Muricidae	*Haustrum*	*scobinum*	Oyster borer	Quoy and Gaimard, 1833	endemic	common
F12a	Trochidae	*Diloma*	*aethiops*	Spotted black top shell	Gmelin, 1791	endemic	common
F12b	Turbinidae	*Lunella*	*smaragdus*	Cats eye / Pupu	Gmelin, 1791	endemic	common
F12c	Buccinidae	*Cominella*	*maculosa*	Spotted whelk	Martyn, 1784	endemic	common
F11a	Trochidae	*Diloma*	*aethiops*	Spotted black top shell	Gmelin, 1791	endemic	common
F11b	Turbinidae	*Lunella*	*smaragdus*	Cats eye / Pupu	Gmelin, 1791	endemic	common
F11c	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
F10a	Nacellidae	*Cellana*	*ornata*	Ornate limpet	Dillwyn, 1817	endemic	common
F10b	Nacellidae	*Cellana*	*denticulata*	Limpet	Martyn, 1784	endemic	common
F6	Trochidae	*Diloma*	*aethiops*	Spotted black top shell	Gmelin, 1791	endemic	common
F1	Haliotidae	*Haliotis*	*iris*	Black foot paua	Gmelin, 1791	endemic	common
F0	Haliotidae	*Haliotis*	*iris*	Black foot paua	Gmelin, 1791	endemic	common

Appendix B Modelled reef fish abundance and distribution

The following xx figures for individual reef fish species are arranged by increasing order of maximum abundance in the mapped region. Note that on the scale provided 0 = absent, 1 = single (1 individual likely to be seen per 1 hour dive), 2 = few (2-10), 3 = many (11-100, and 4 – abundant (>100). Model output provided courtesy of the Department of Conservation which undertook the original field sampling and funded the modelling. See Smith et al. (2013) for details of the surveys and modelling.

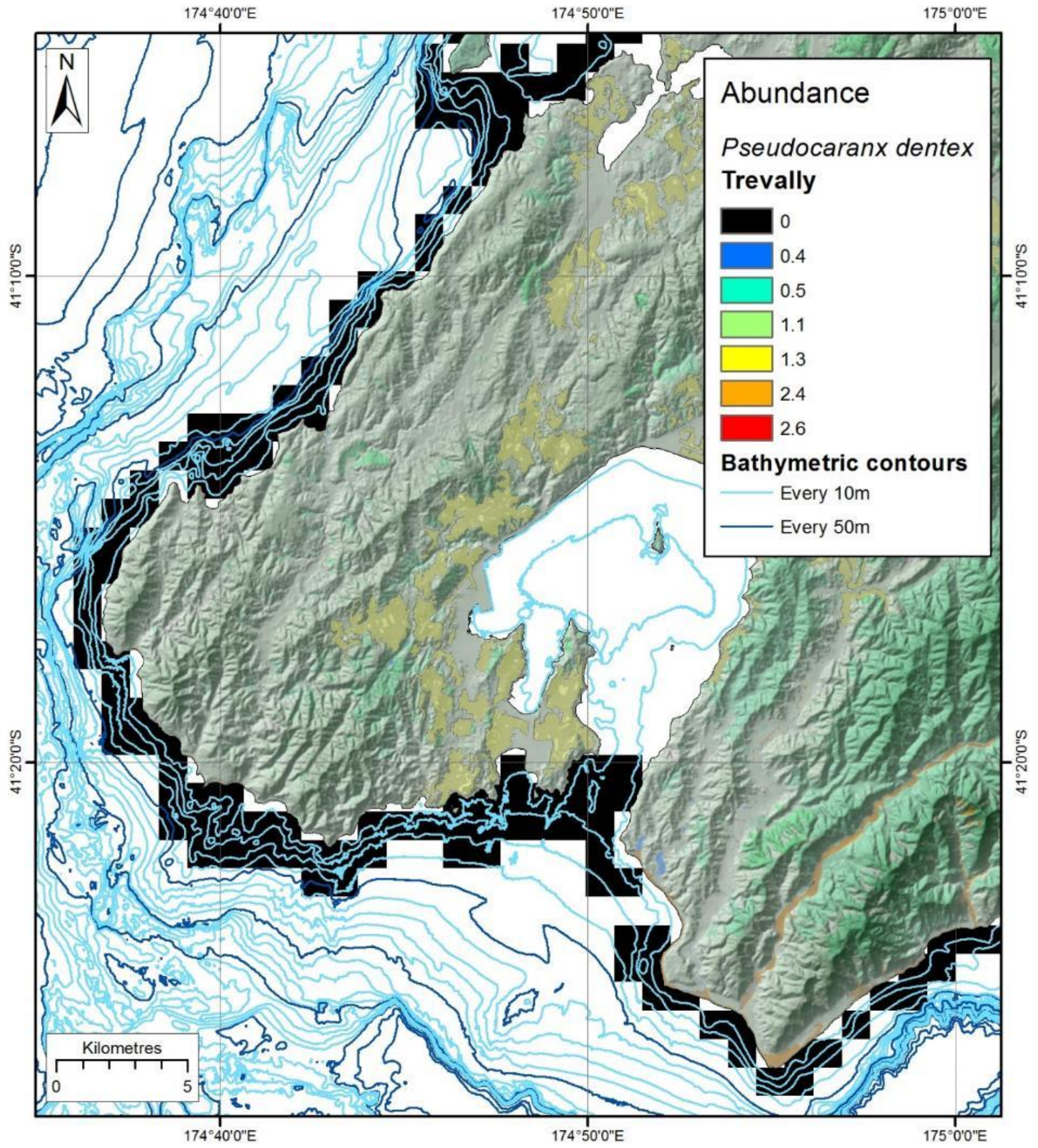


Figure 10-1: Modelled distribution and abundance of trevally on Wellington subtidal reefs.

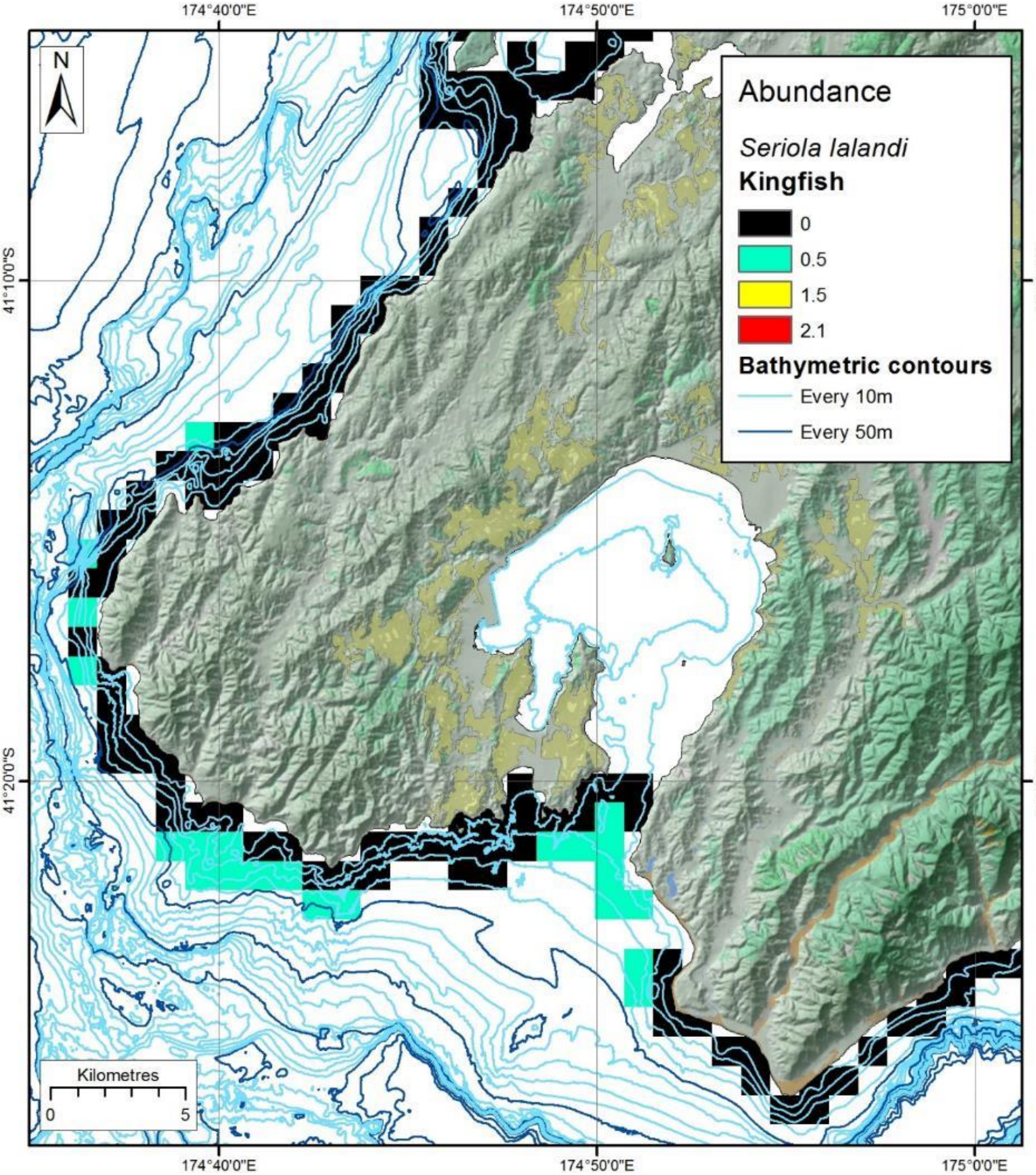

174°40'0"E
174°50'0"E
175°0'0"E
41°10'0"S
41°20'0"S
N
Abundance
Seriola lalandi
Kingfish
0
0.5
1.5
2.1
Bathymetric contours
Every 10m
Every 50m
Kilometres
0
5

Figure 10-2: Modelled distribution and abundance of kingfish on Wellington subtidal reefs.

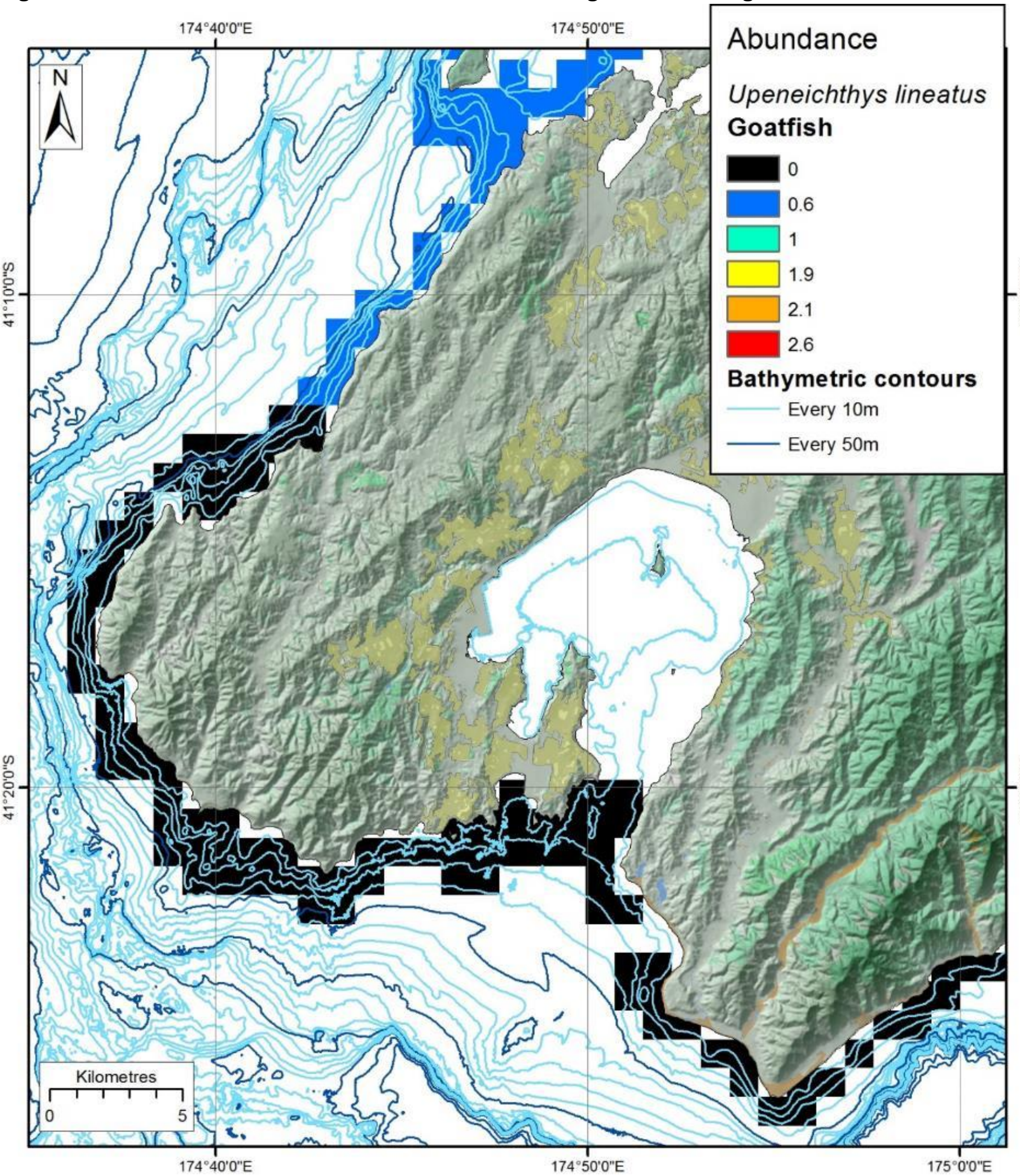


Figure 10-3: Modelled distribution and abundance of goatfish on Wellington subtidal reefs.

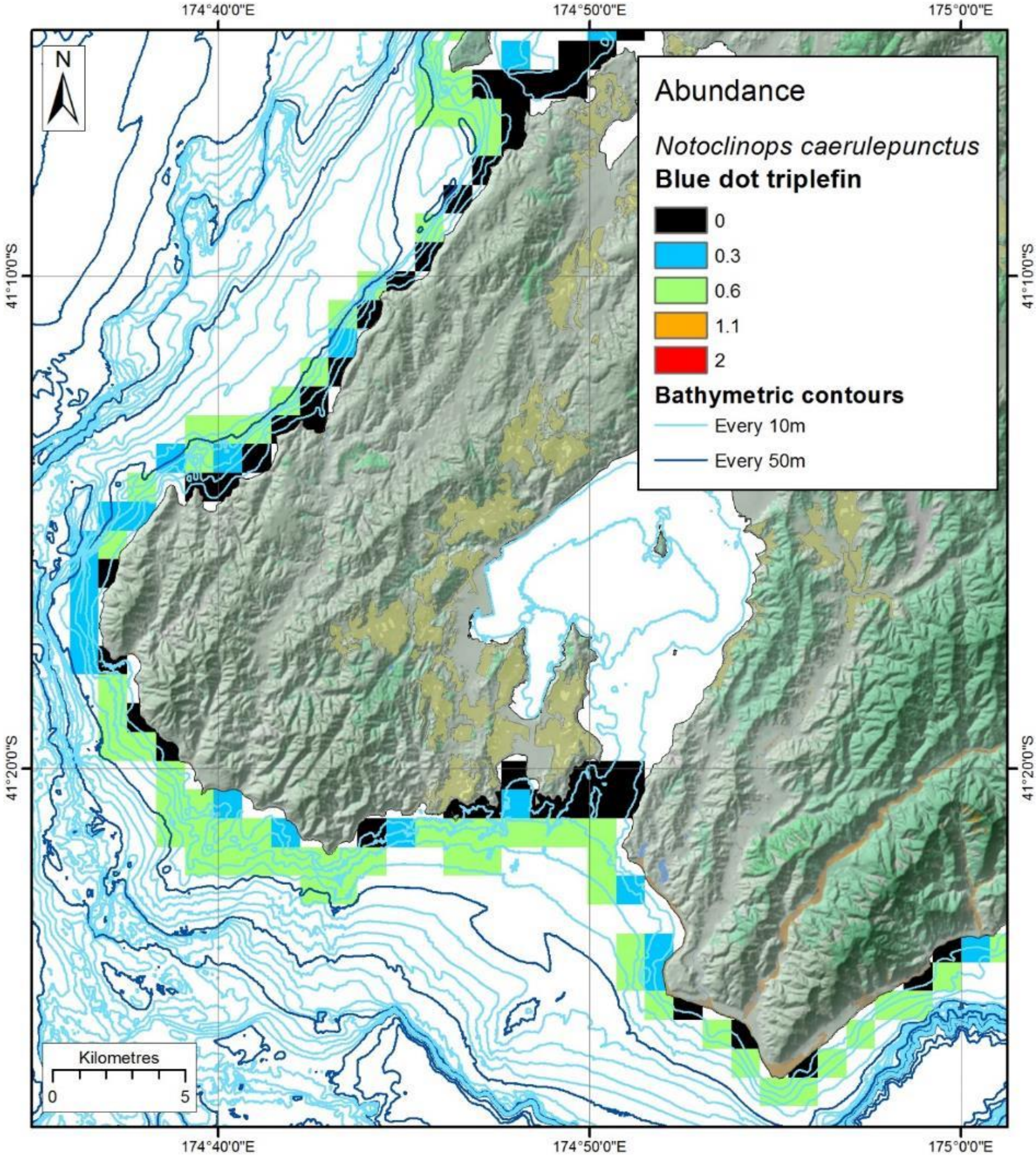


Figure 10-4: Modelled distribution and abundance of blue dot triplefin on Wellington subtidal reefs.

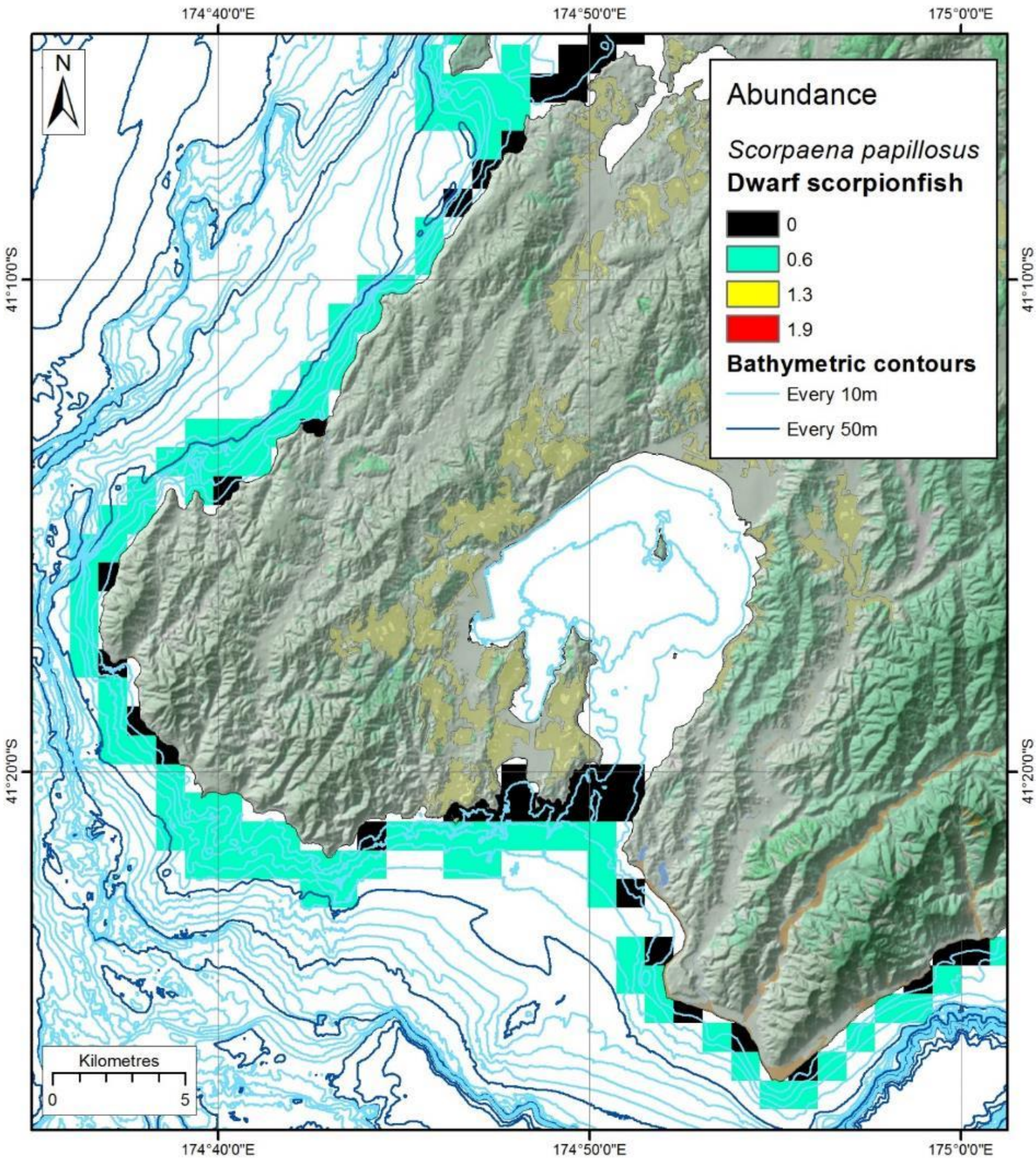


Figure 10-5: Modelled distribution and abundance of dwarf scorpionfish on Wellington subtidal reefs.

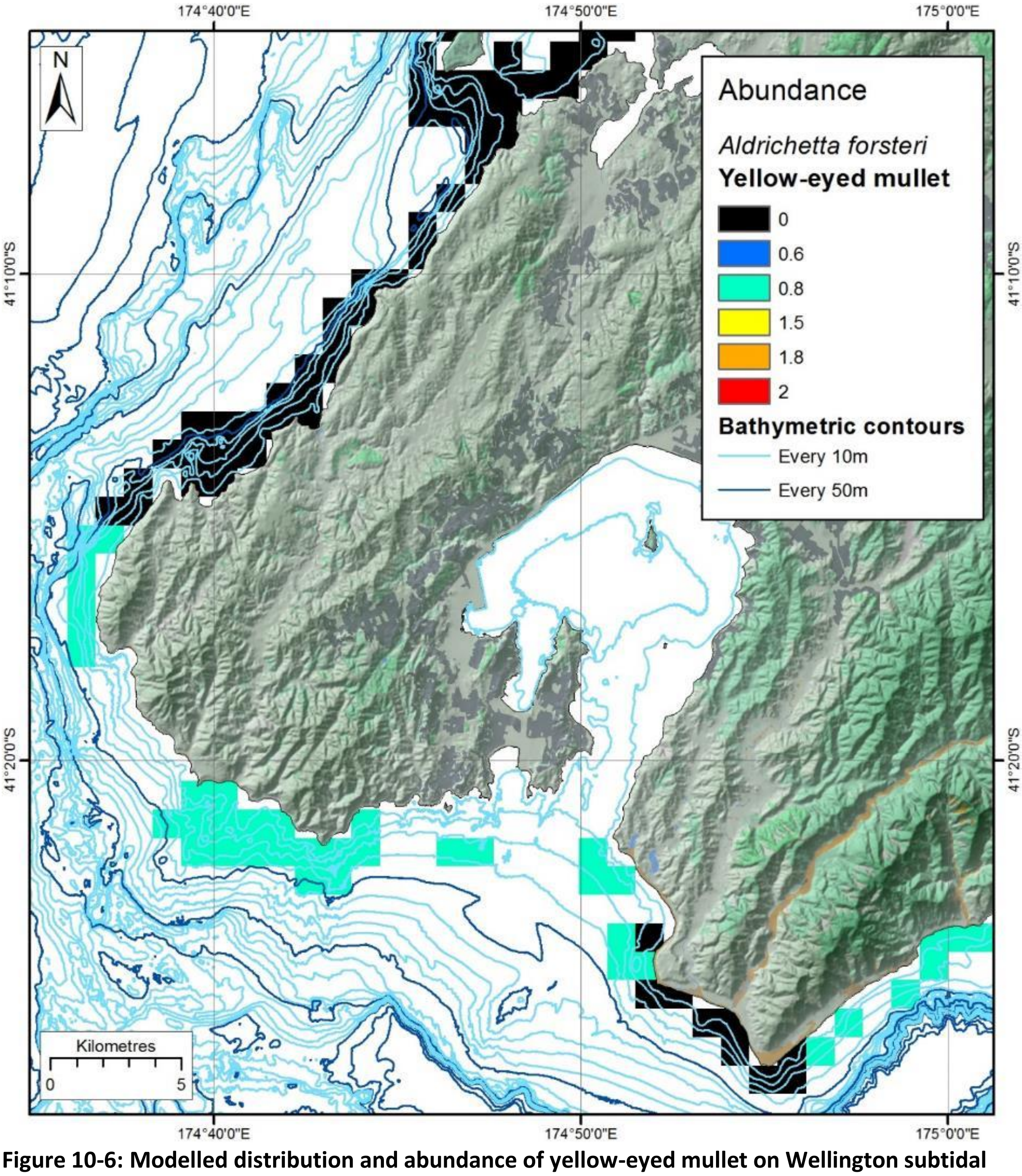


Figure 10-6: Modelled distribution and abundance of yellow-eyed mullet on Wellington subtidal reefs.

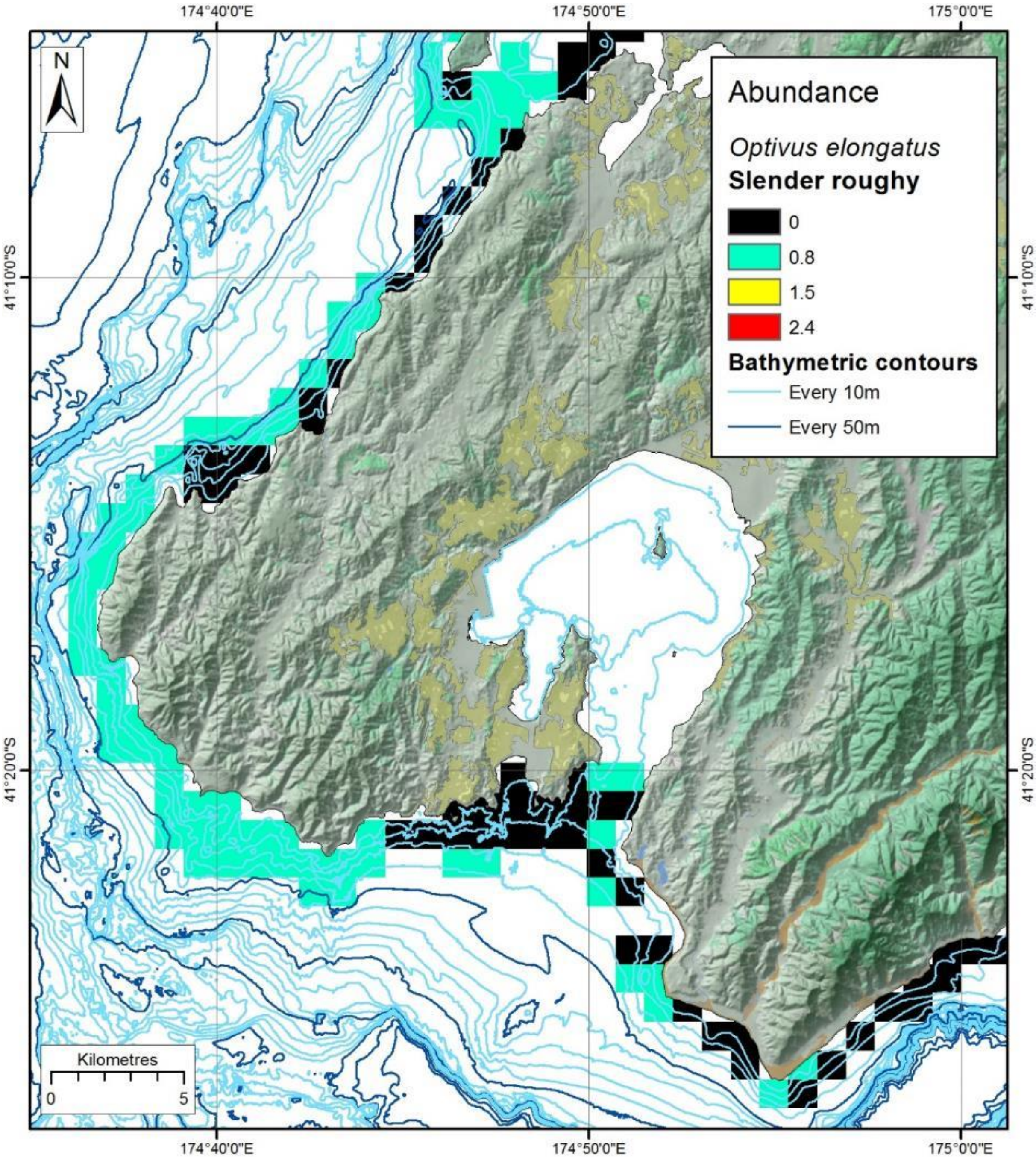


Figure 10-7: Modelled distribution and abundance of slender roughy on Wellington subtidal reefs**.**

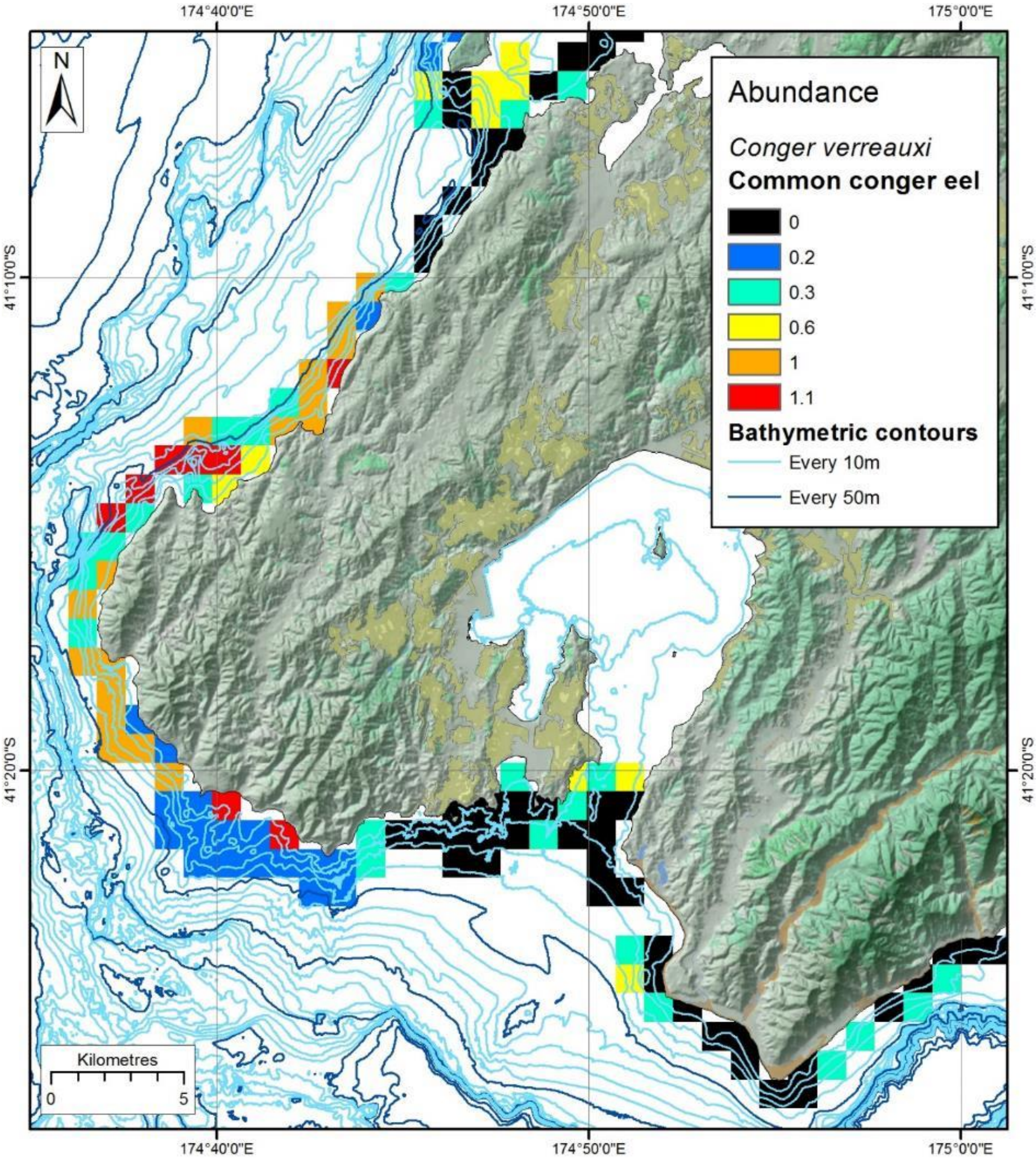


Figure 10-8: Modelled distribution and abundance of conger eel on Wellington subtidal reefs.

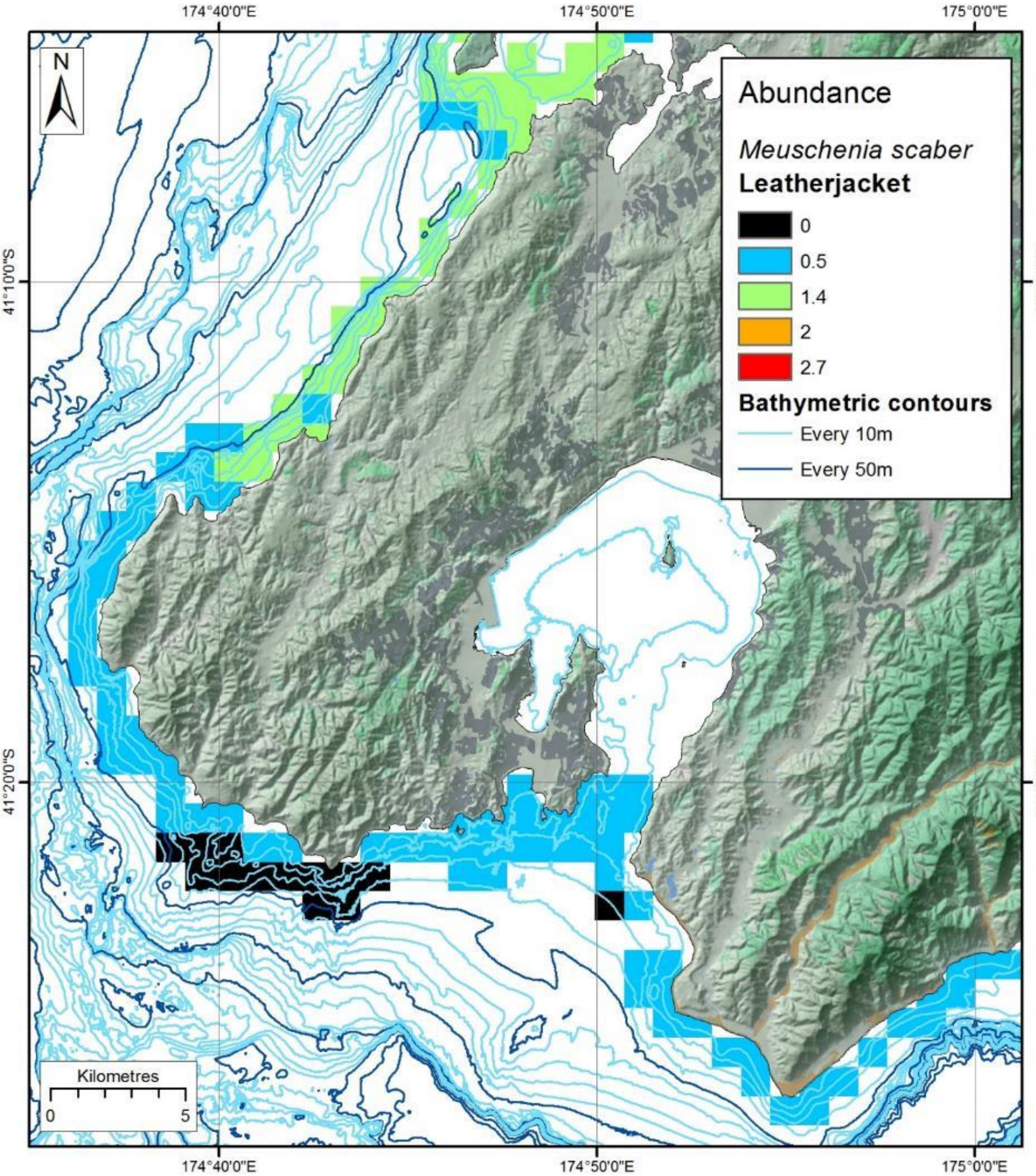


Figure 10-9: Modelled distribution and abundance of leatherjacket on Wellington subtidal reefs.

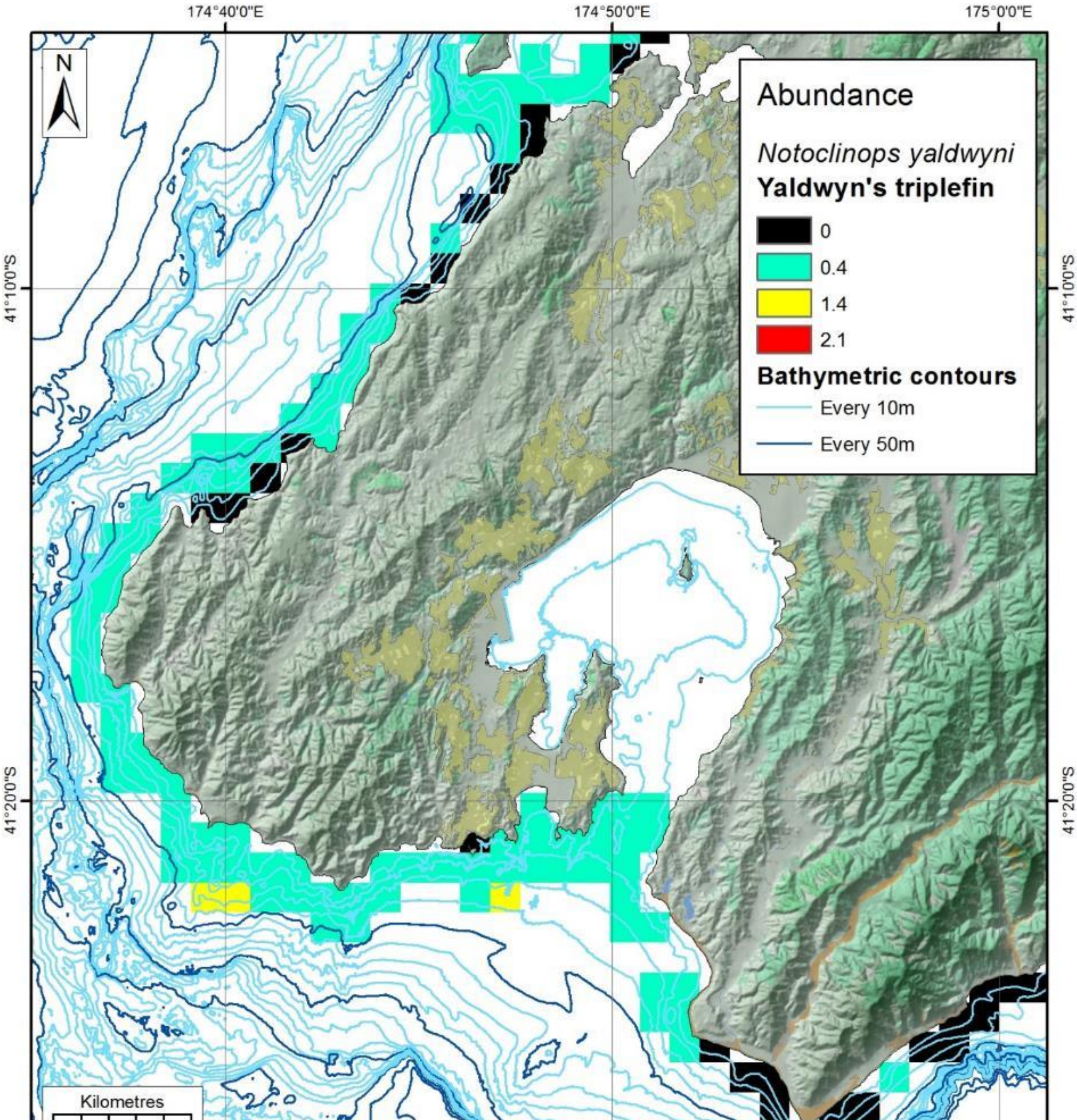


Figure 10-10: Modelled distribution and abundance of Yaldwyn's triplefin on Wellington subtidal reefs.

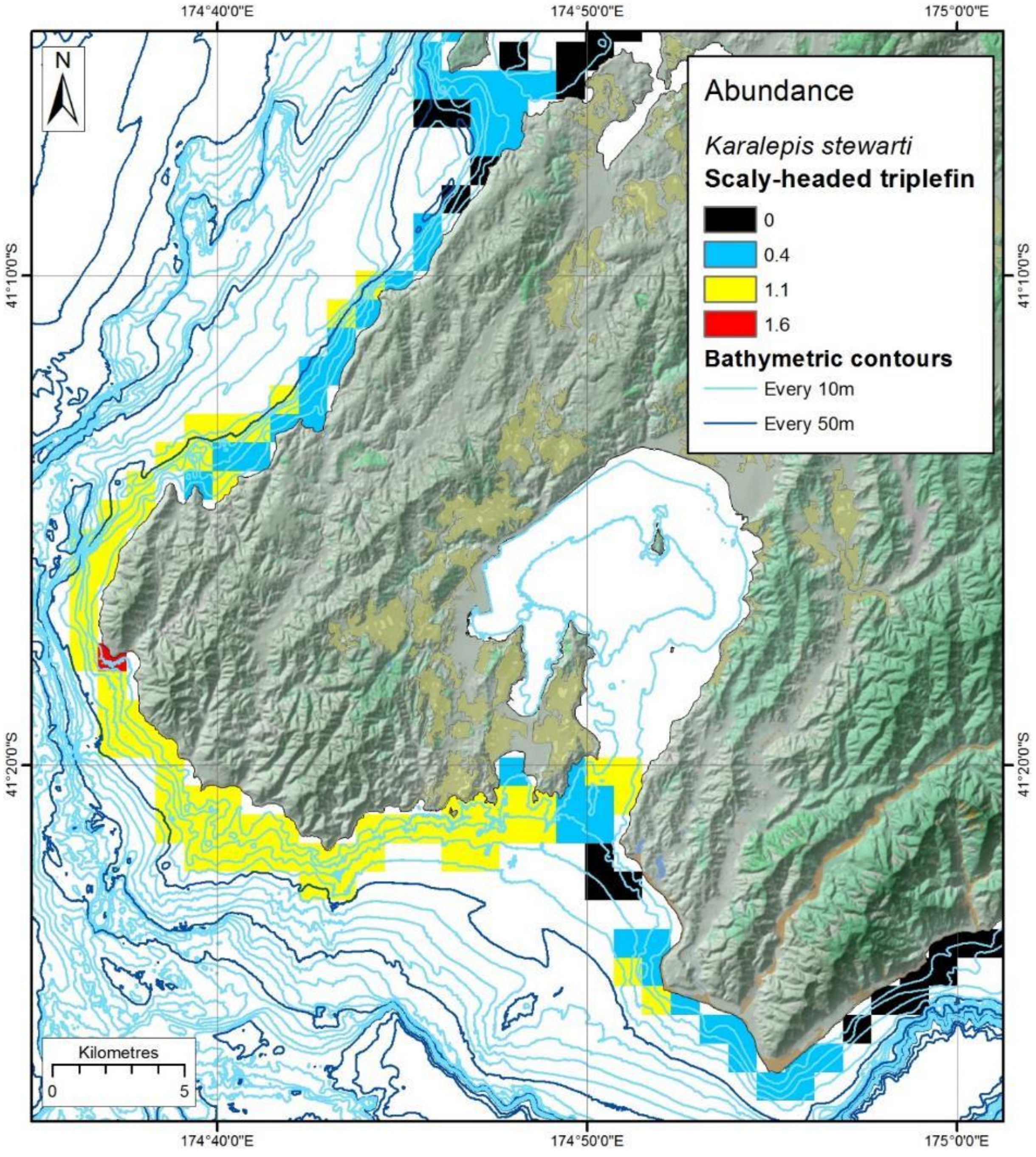


Figure 10-11: Modelled distribution and abundance of scaly-headed triplefin on Wellington subtidal reefs.

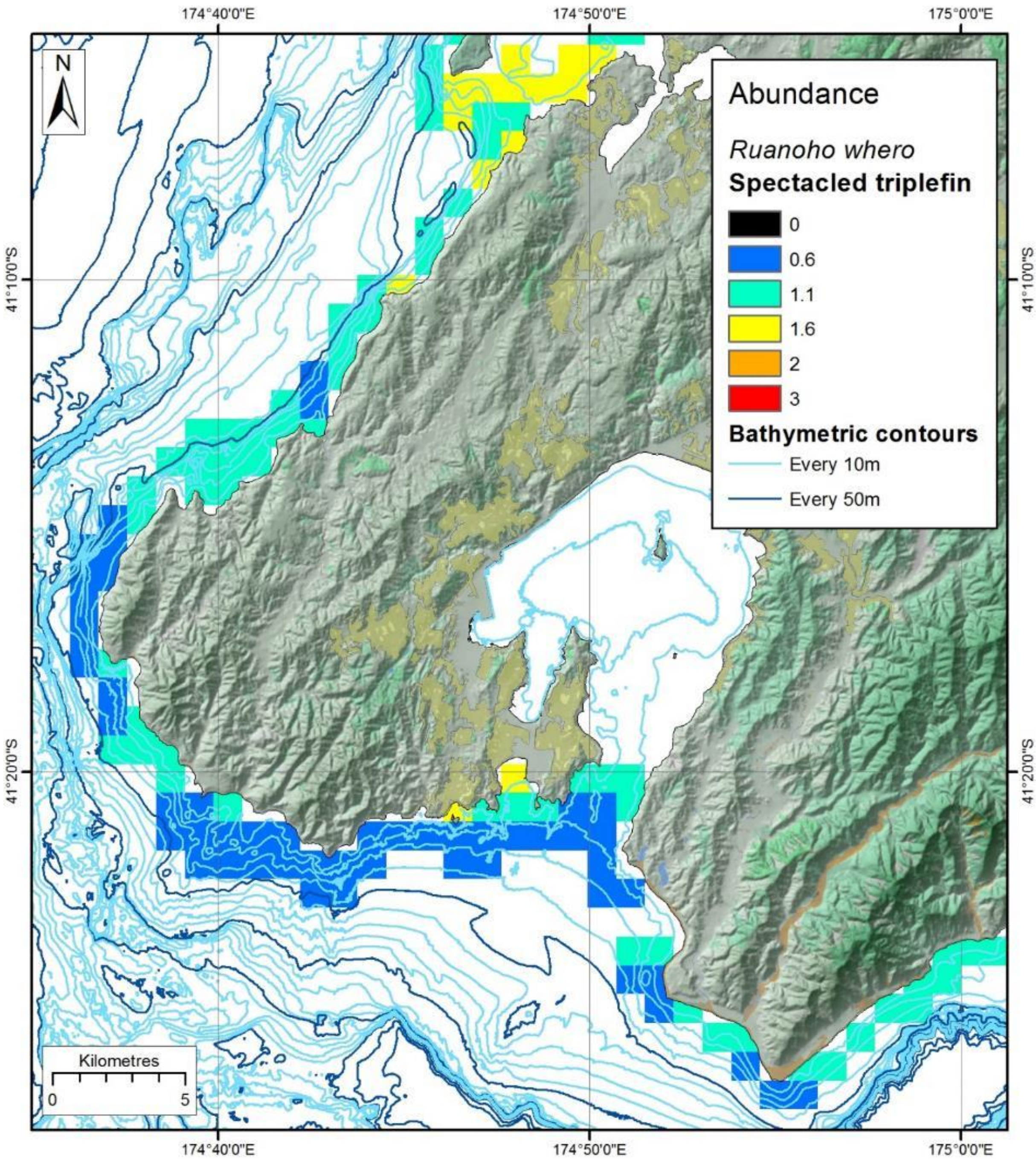


Figure 10-12: Modelled distribution and abundance of spectacled triplefin on Wellington subtidal reefs.

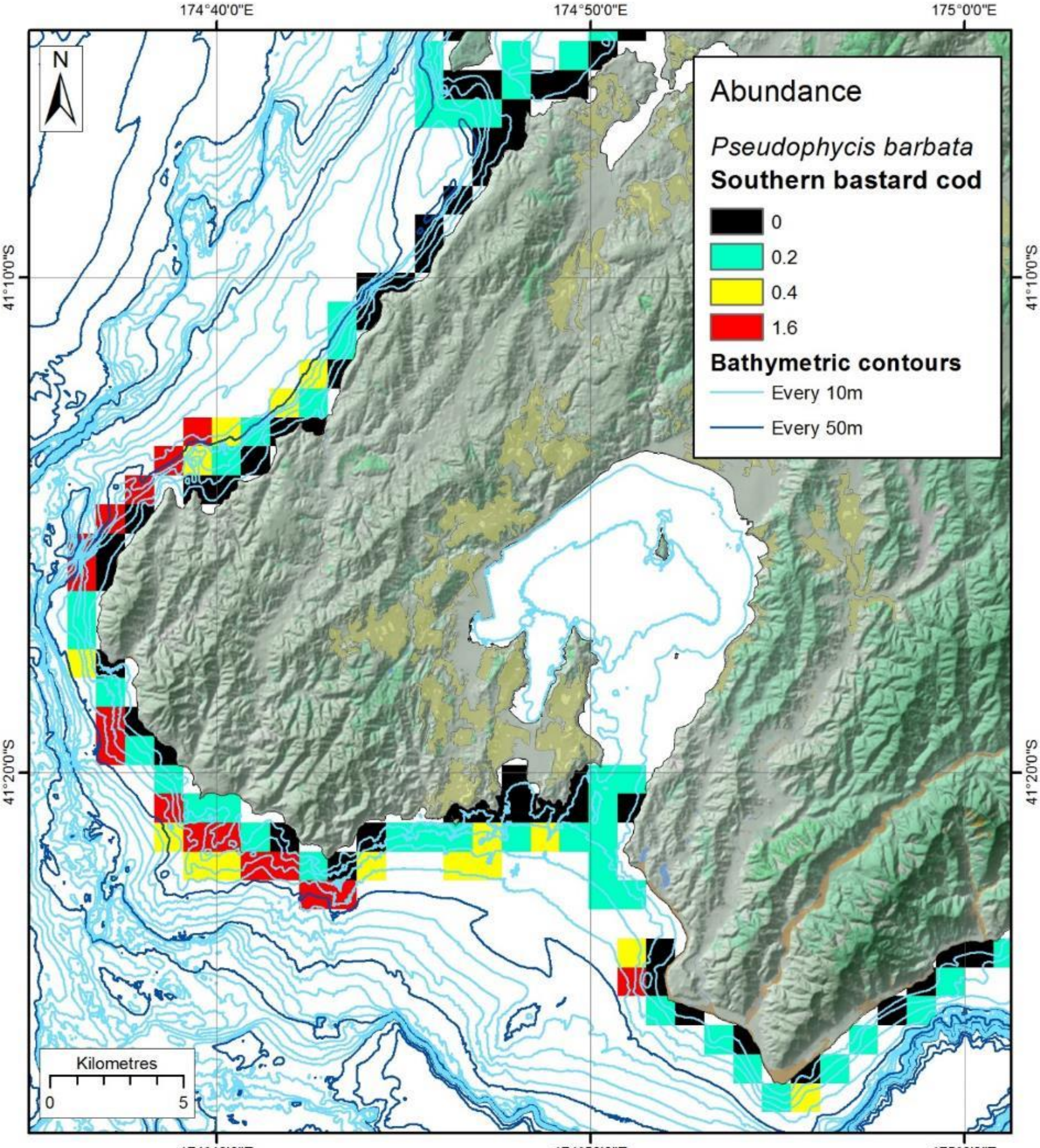


Figure 10-13: Modelled distribution and abundance of southern bastard cod on Wellington subtidal reefs.

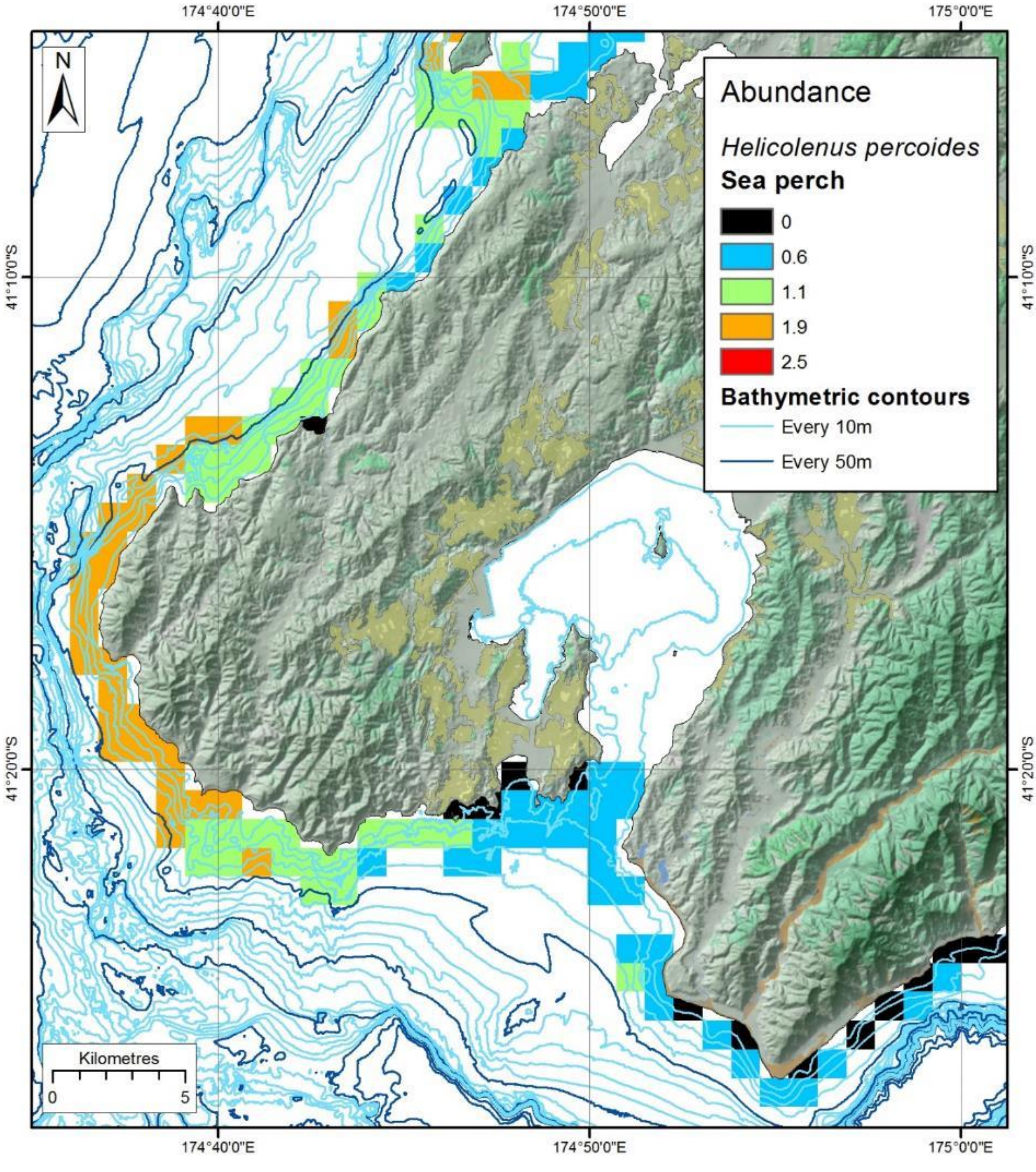
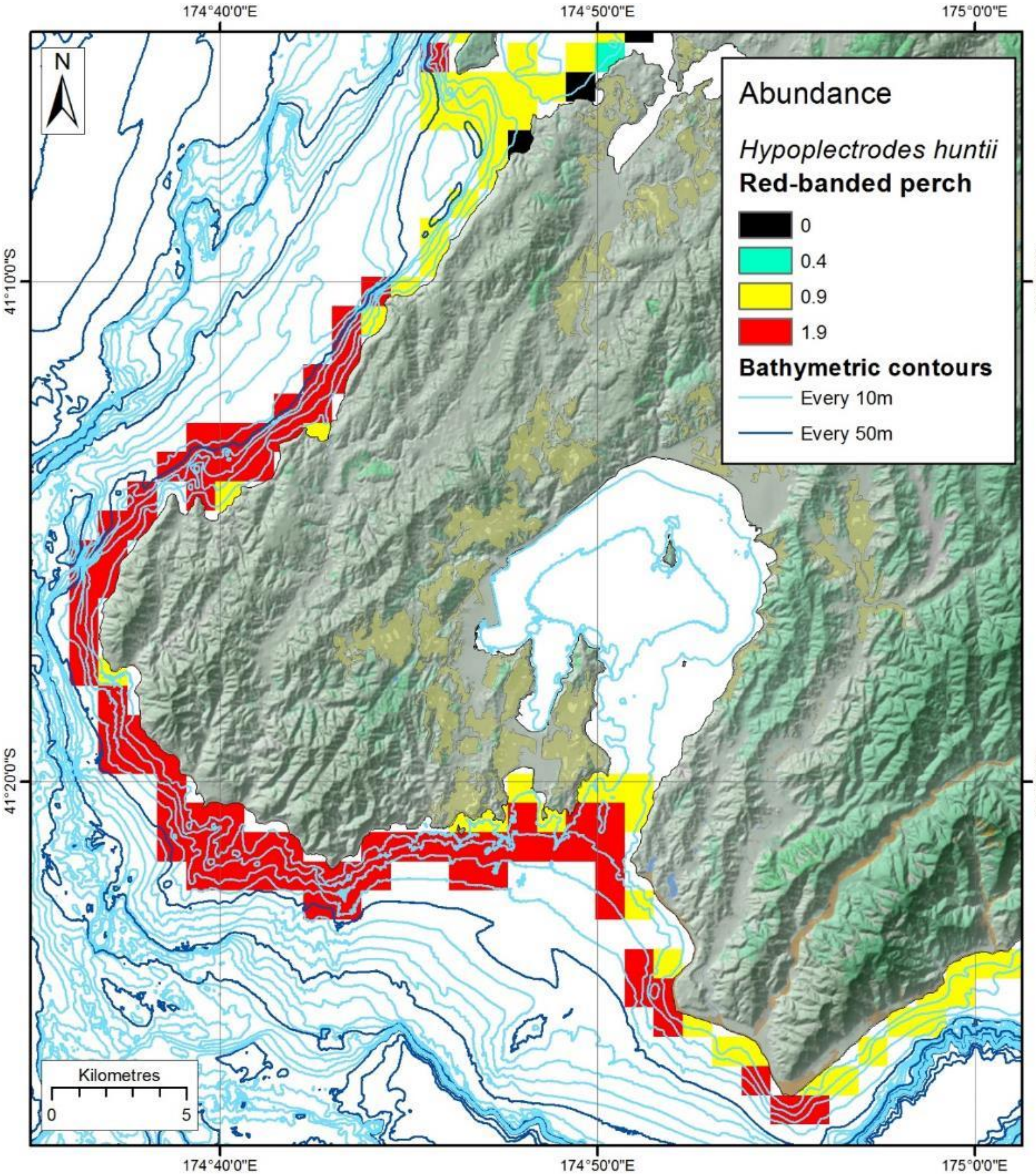


Figure 10-14: Modelled distribution and abundance of sea perch on Wellington subtidal reefs.



174°40'0"E
174°50'0"E
175°0'0"E
41°10'0"S
41°20'0"S
N
Abundance
Hypoplectrodes huntii
Red-banded perch
0
0.4
0.9
1.9
Bathymetric contours
Every 10m
Every 50m
Kilometres
0
5

Figure 10-15: Modelled distribution and abundance of red-banded perch on Wellington subtidal reefs.

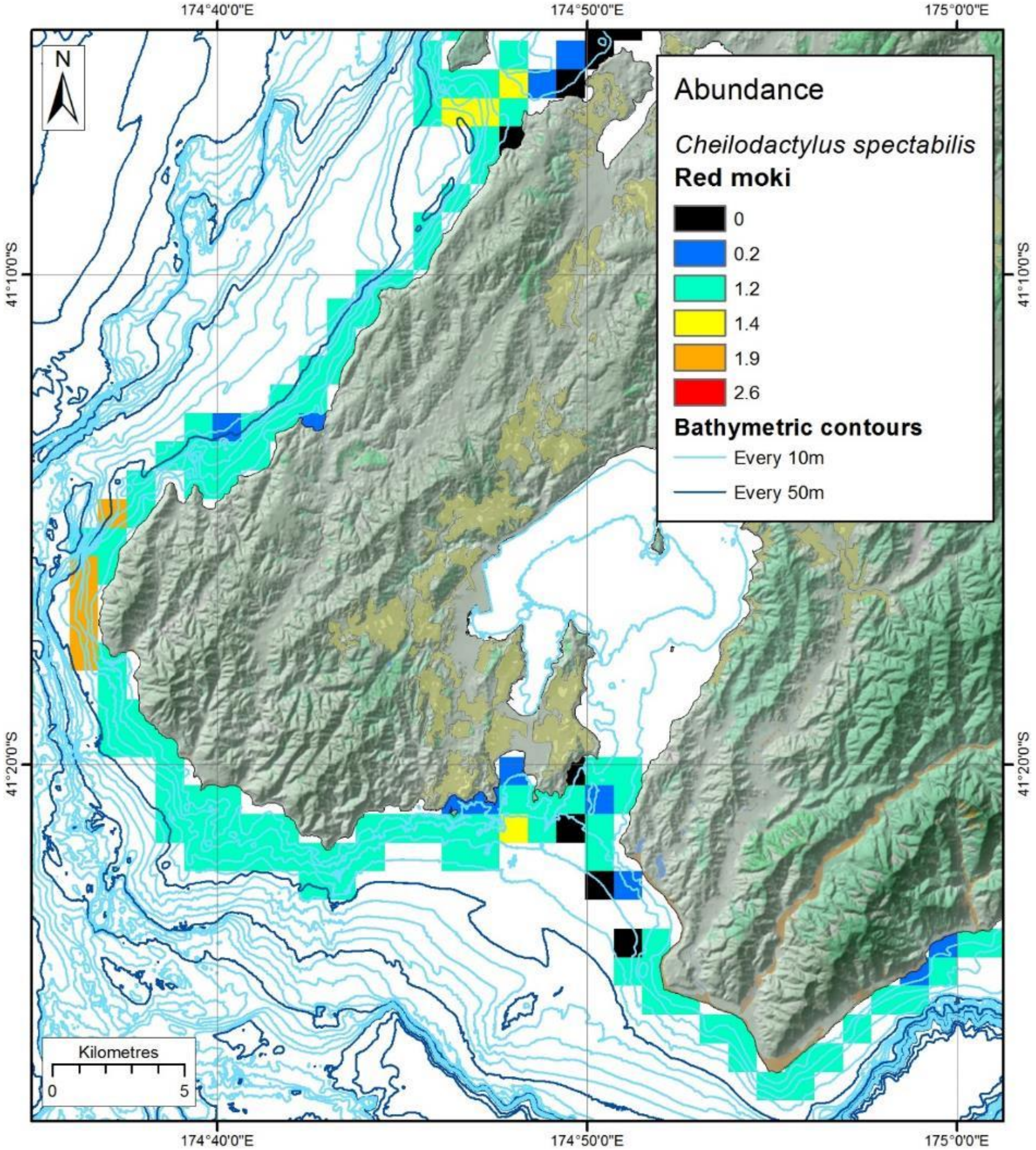


Figure 10-16: Modelled distribution and abundance of red moki on Wellington subtidal reefs.

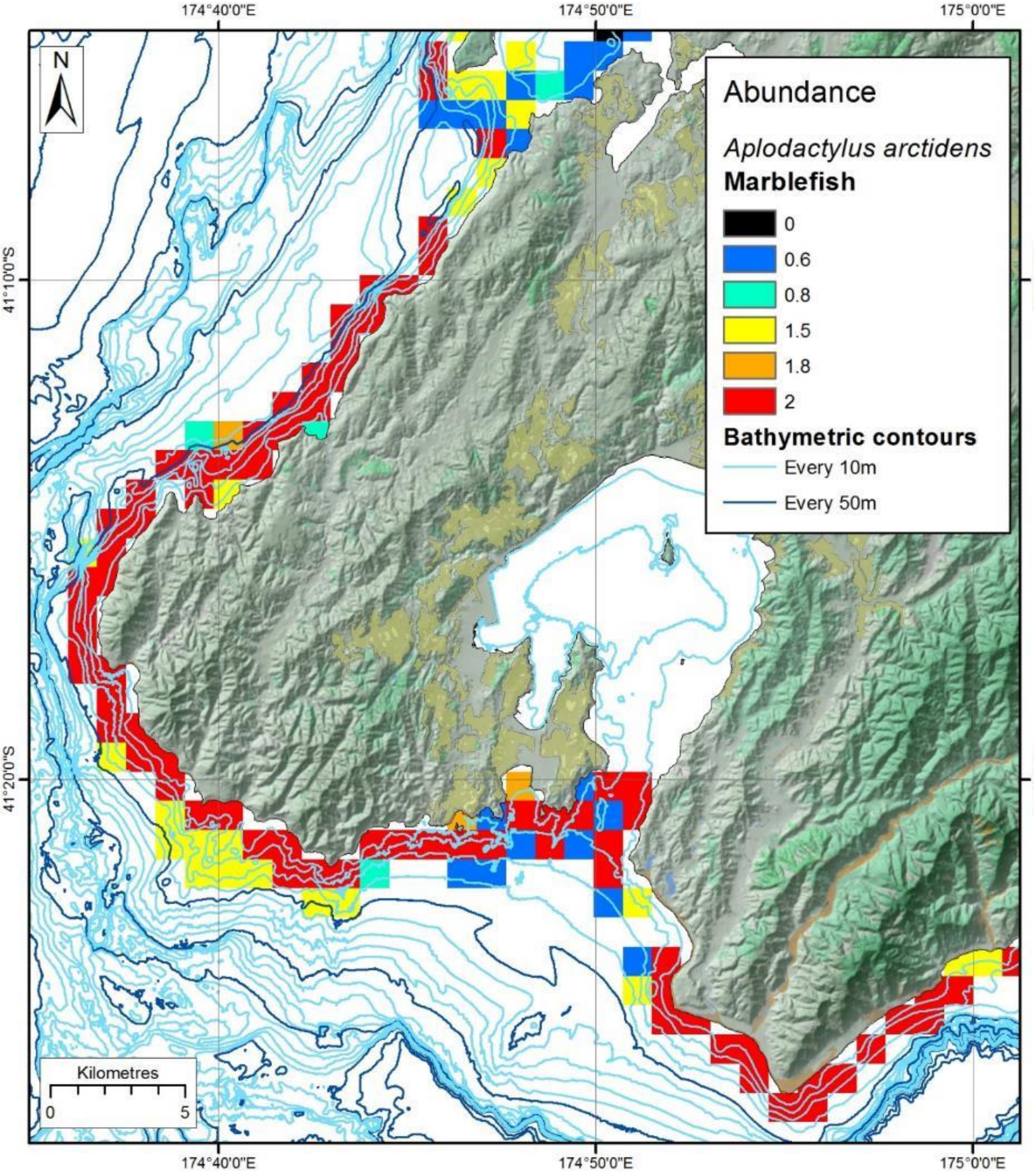


Figure 10-17: Modelled distribution and abundance of marblefish on Wellington subtidal reefs.

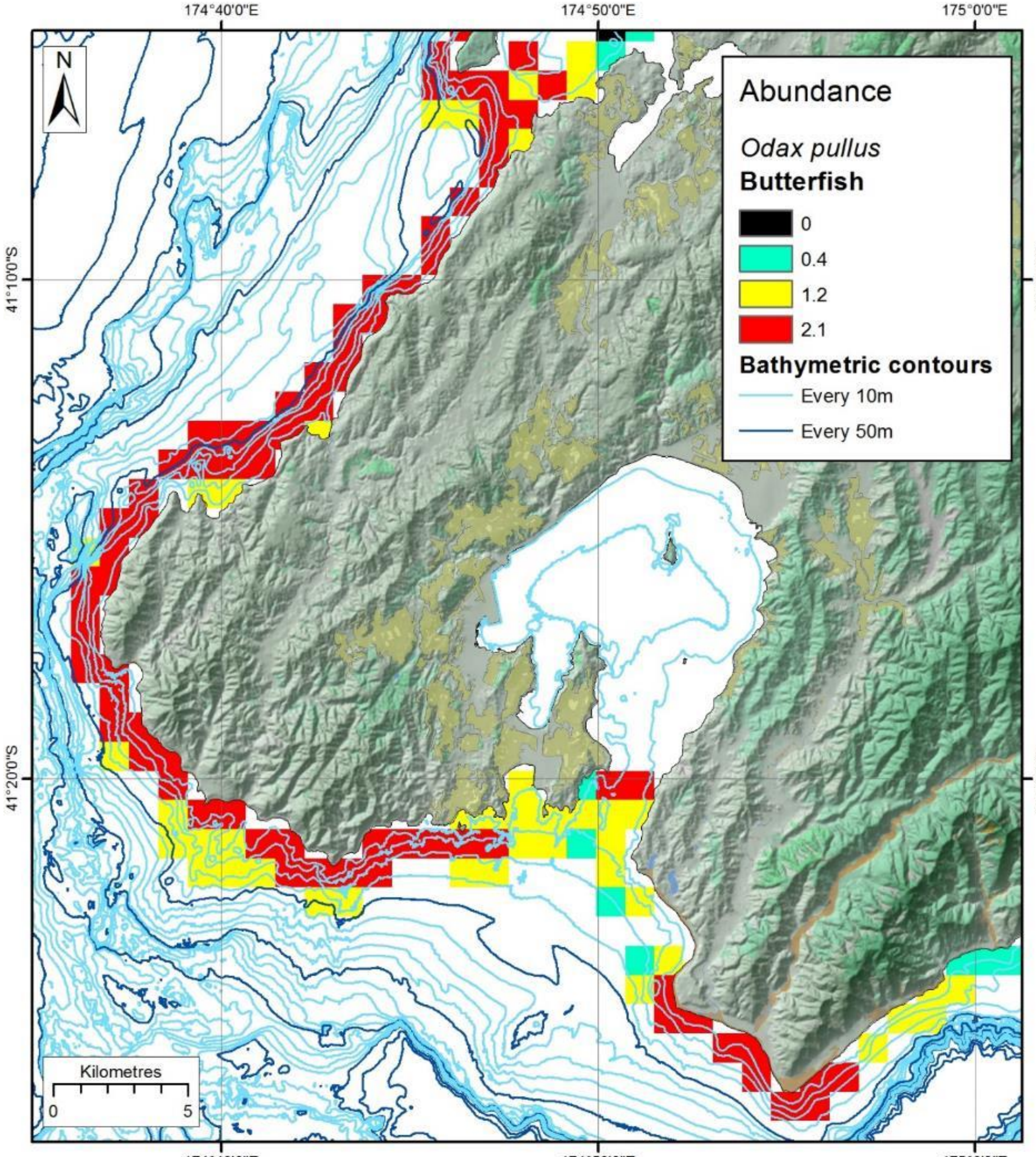
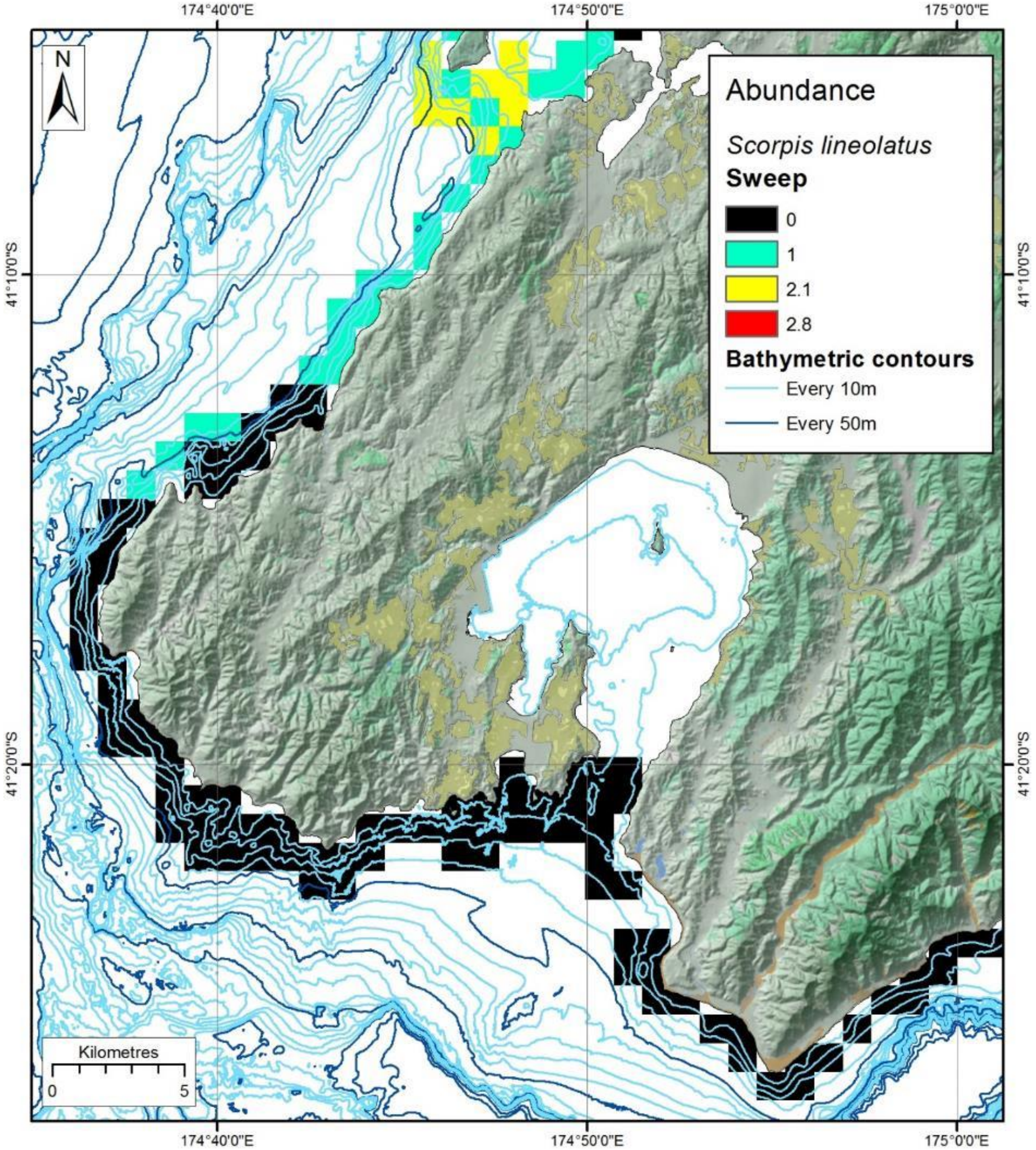


Figure 10-18: Modelled distribution and abundance of butterfish on Wellington subtidal reefs.



174°40'0"E
174°50'0"E
175°0'0"E
41°10'0"S
41°20'0"S
N
Abundance
Scorpis lineolatus
Sweep
0
1
2.1
2.8
Bathymetric contours
Every 10m
Every 50m
Kilometres
0
5

Figure 10-19: Modelled distribution and abundance of sweep on Wellington subtidal reefs.

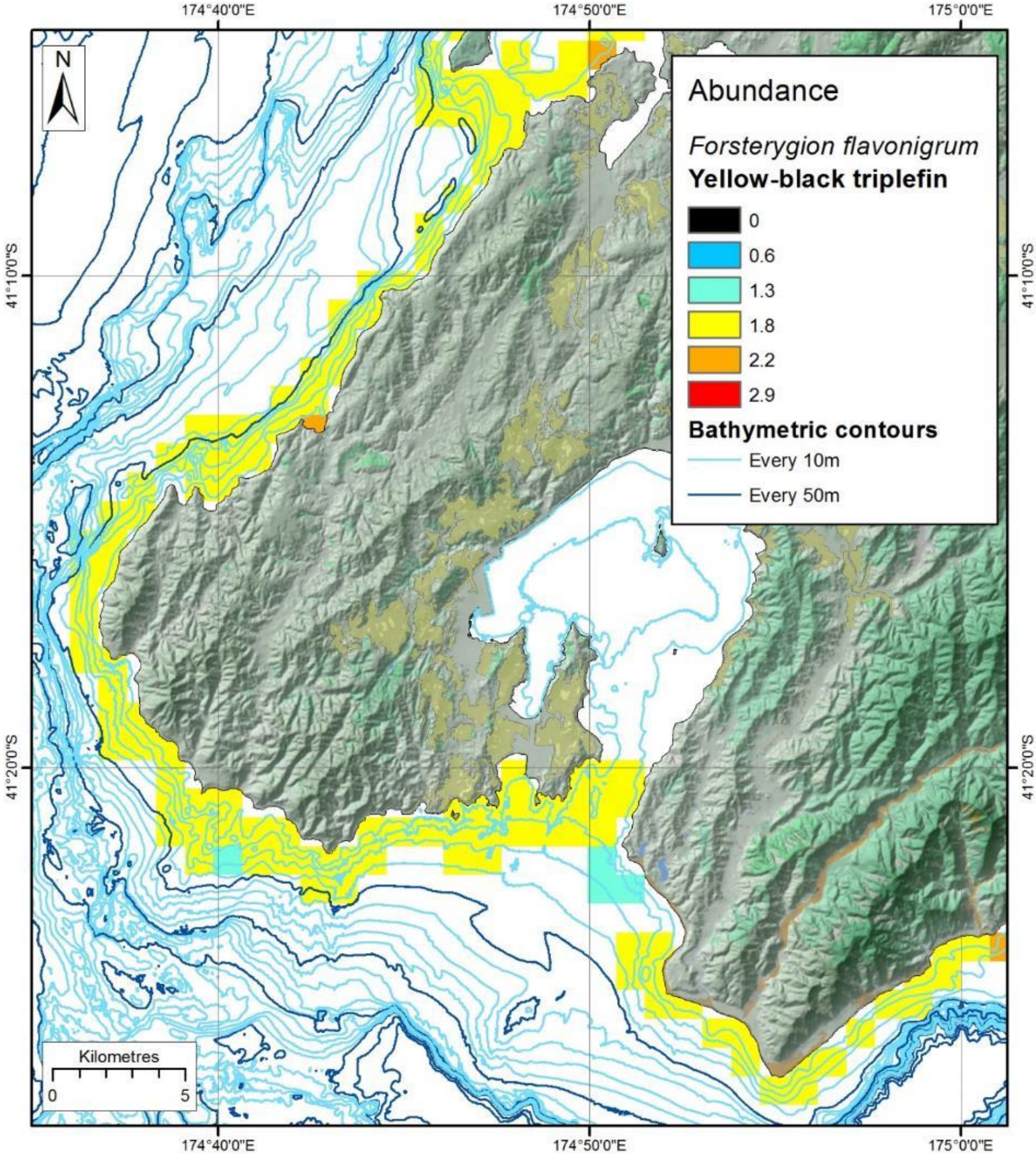


Figure 10-20: Modelled distribution and abundance of yellow-black triplefin on Wellington subtidal reefs.

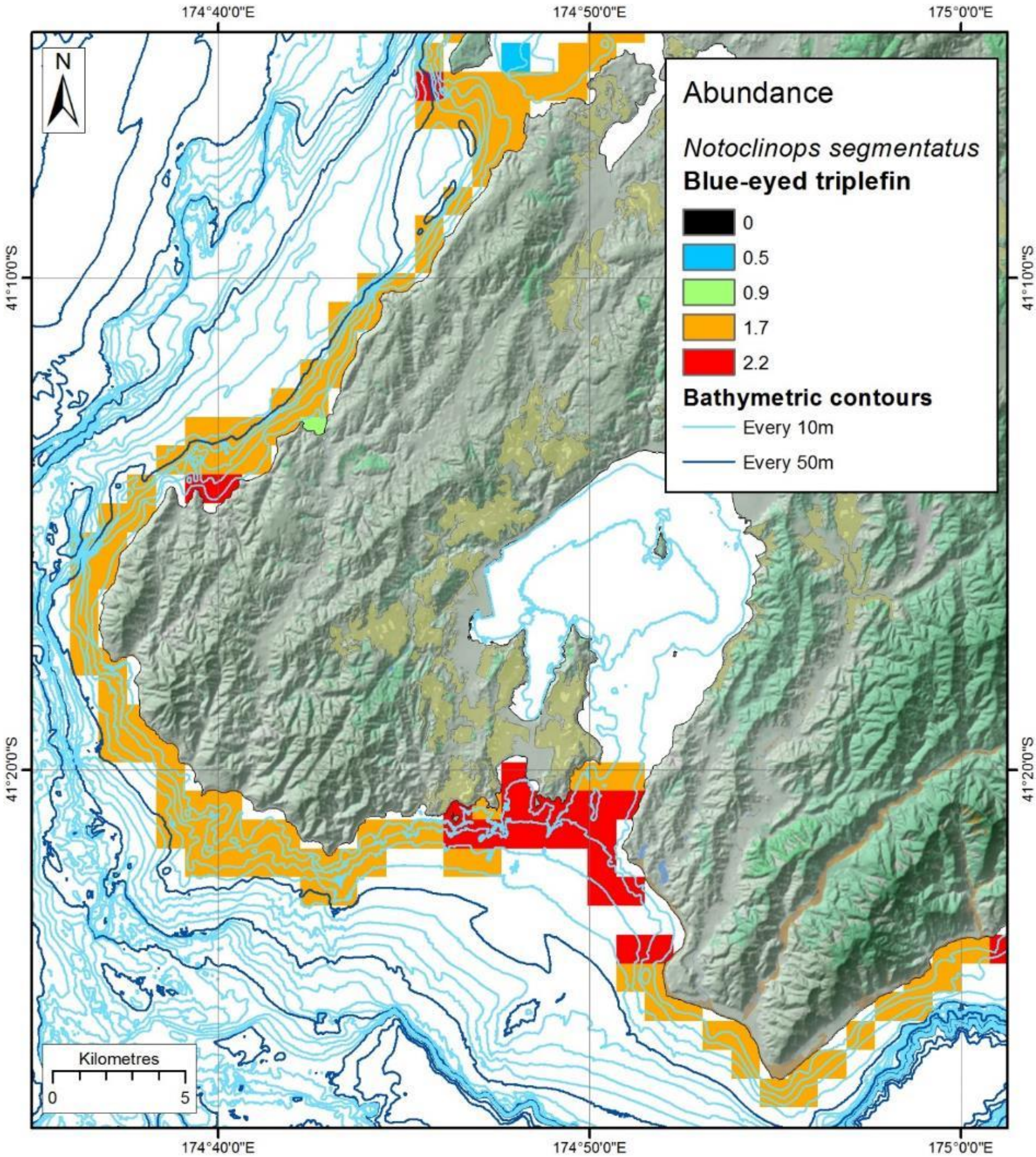


Figure 10-21: Modelled distribution and abundance of blue-eyed triplefin on Wellington subtidal reefs.

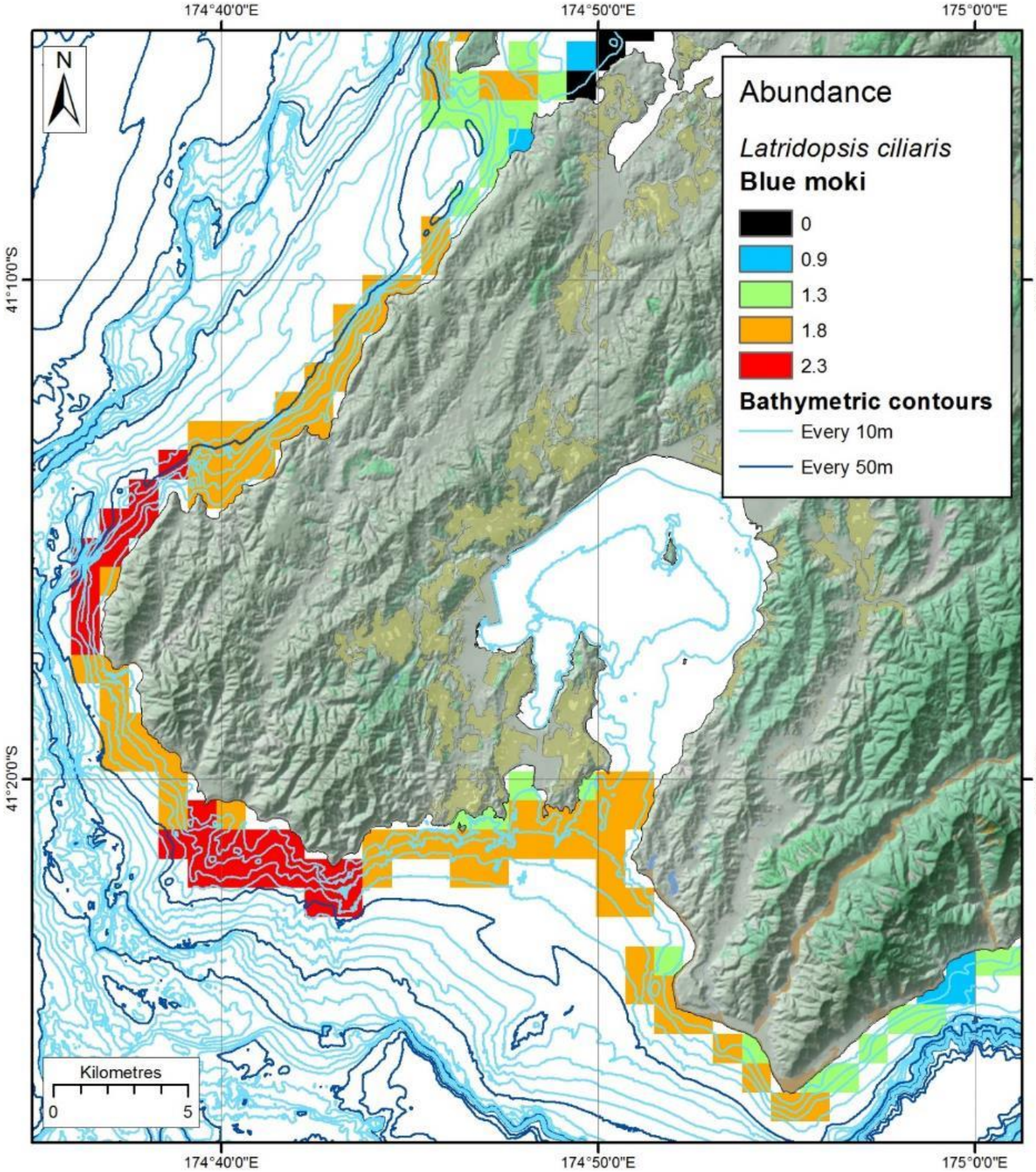


Figure 10-22: Modelled distribution and abundance of blue moki on Wellington subtidal reefs.

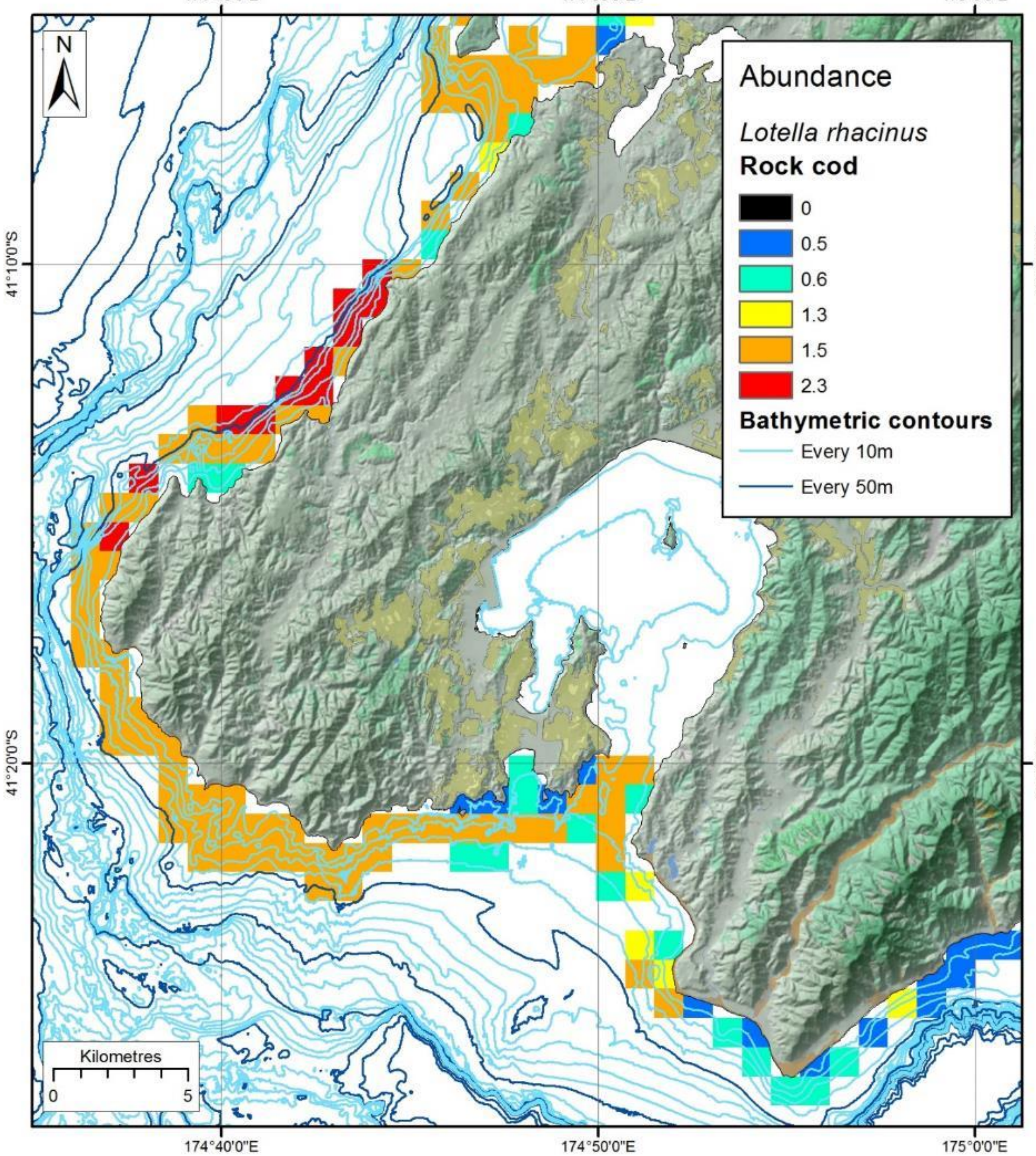


Figure 10-23: Modelled distribution and abundance of rock cod on Wellington subtidal reefs.

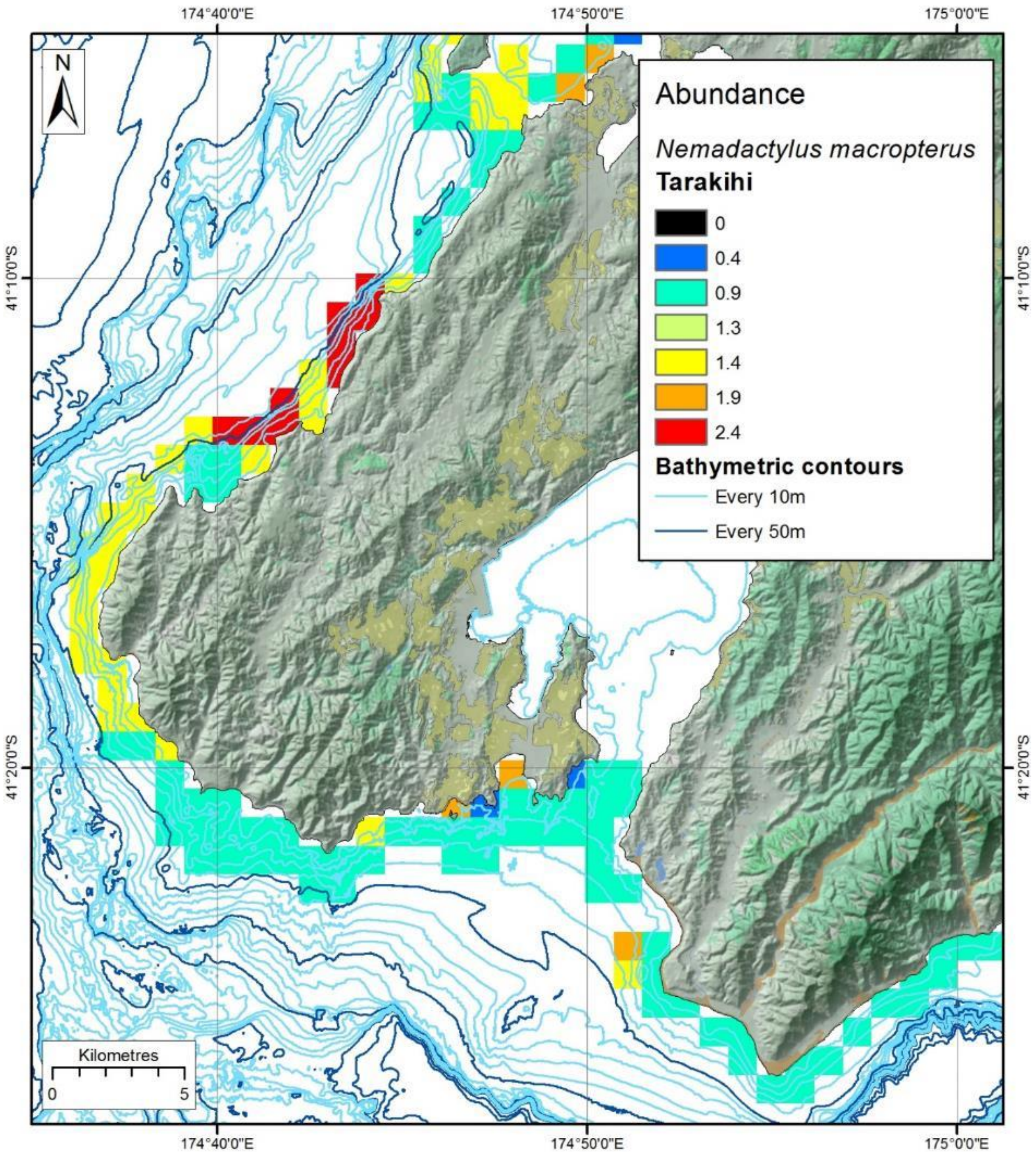


Figure 10-24: Modelled distribution and abundance of tarakihi on Wellington subtidal reefs.

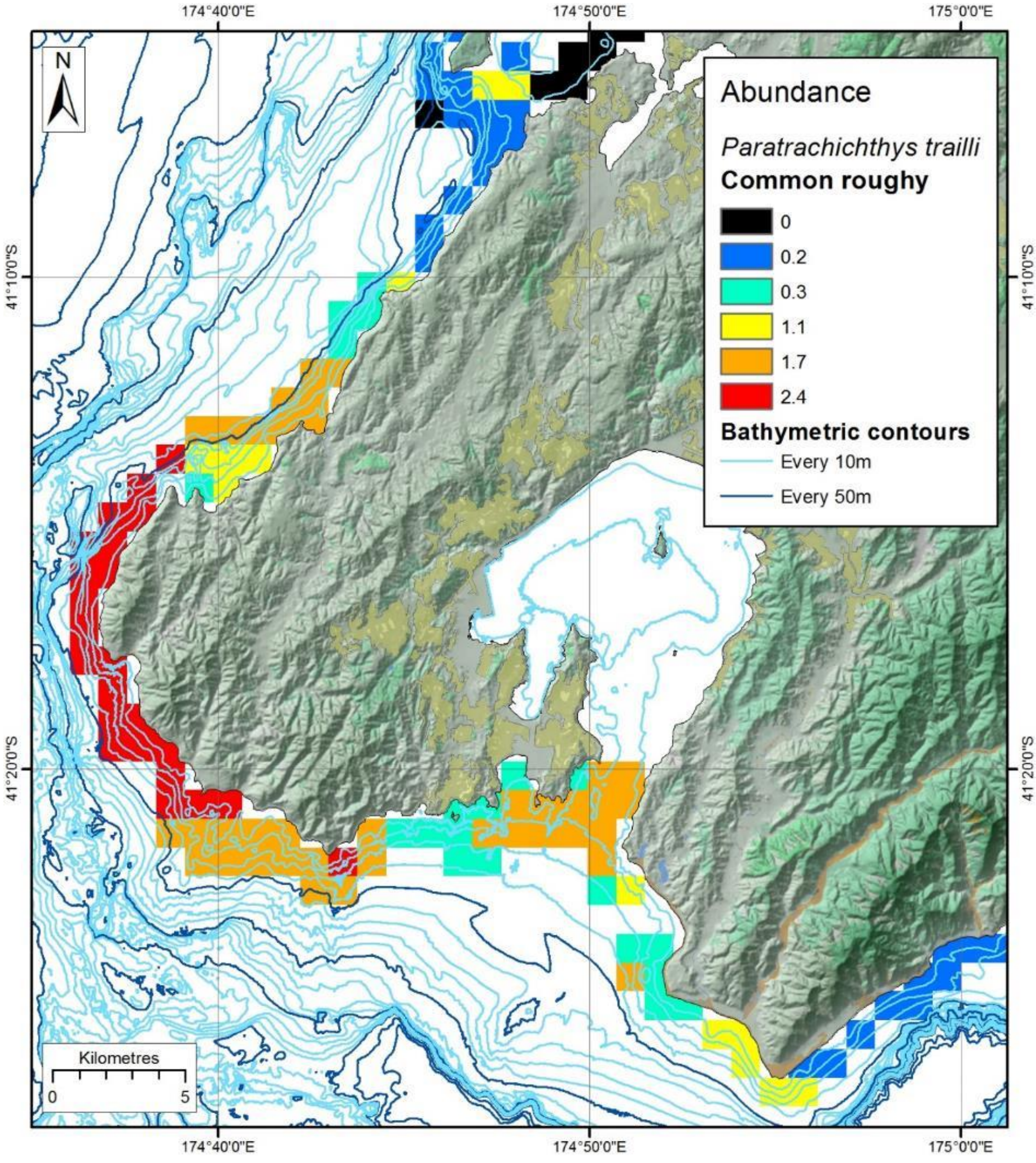


Figure 10-25: Modelled distribution and abundance of common roughy on Wellington subtidal reefs.

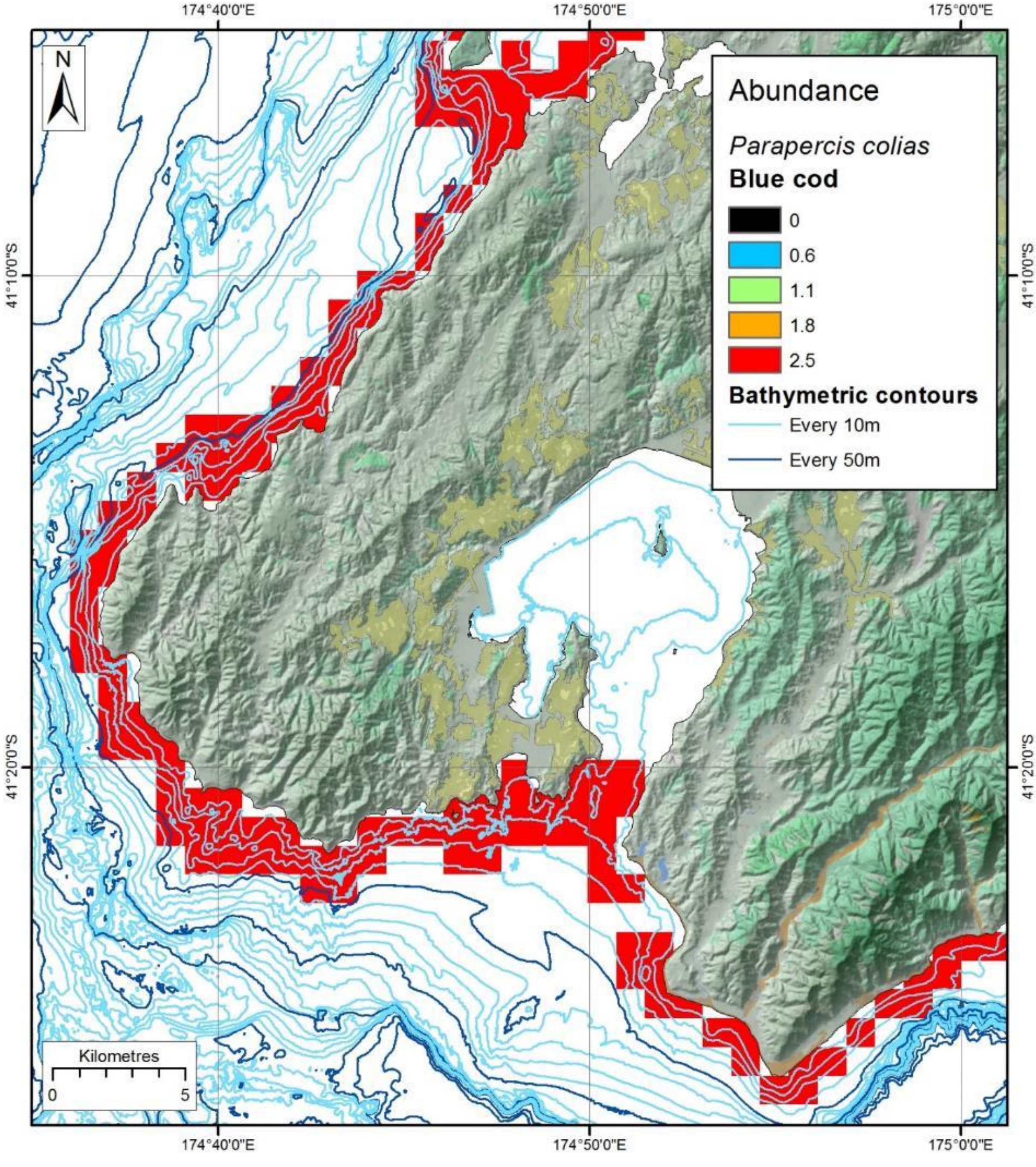


Figure 10-26: Modelled distribution and abundance of blue cod on Wellington subtidal reefs.

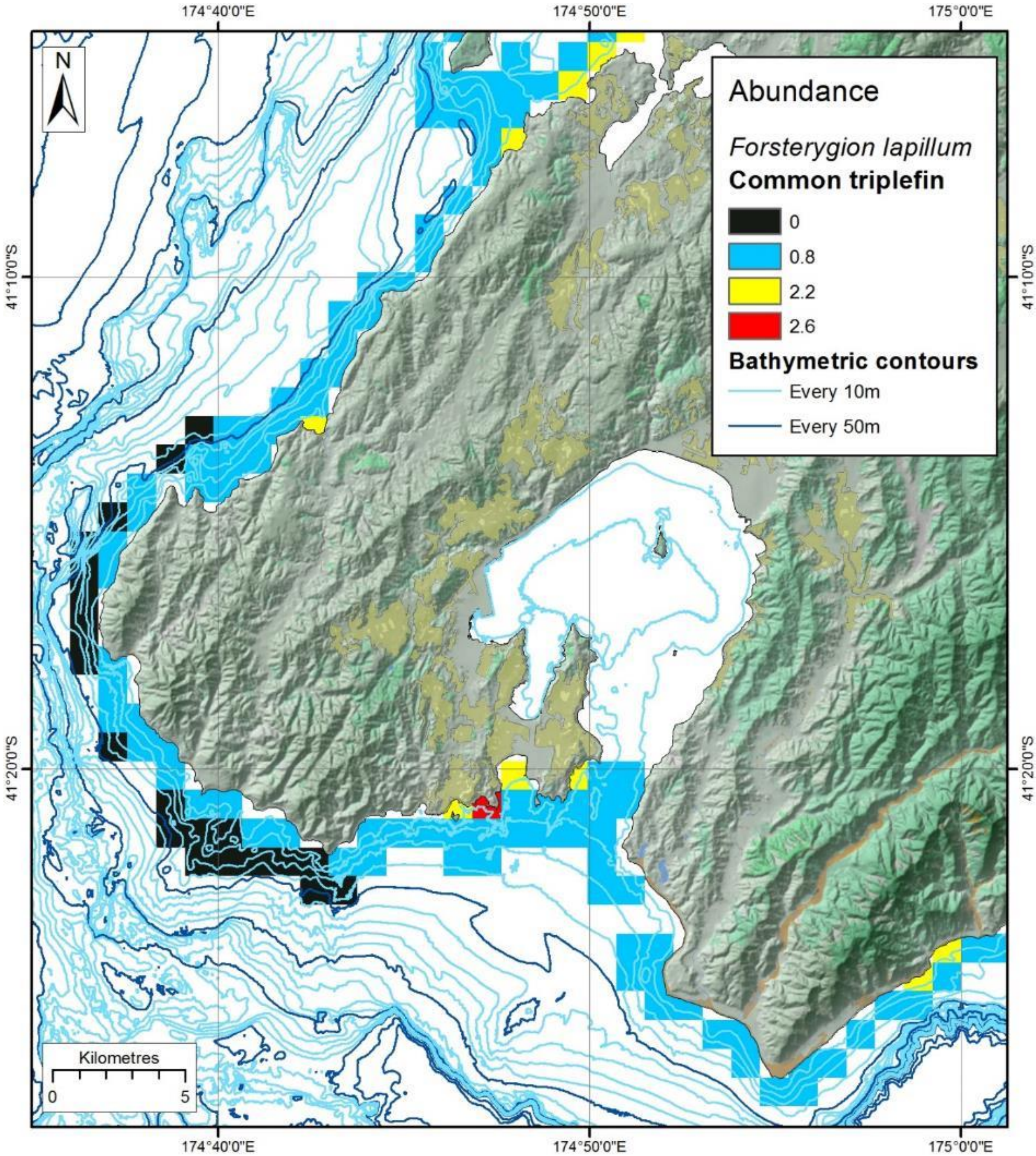


Figure 10-27: Modelled distribution and abundance of common triplefin on Wellington subtidal reefs.

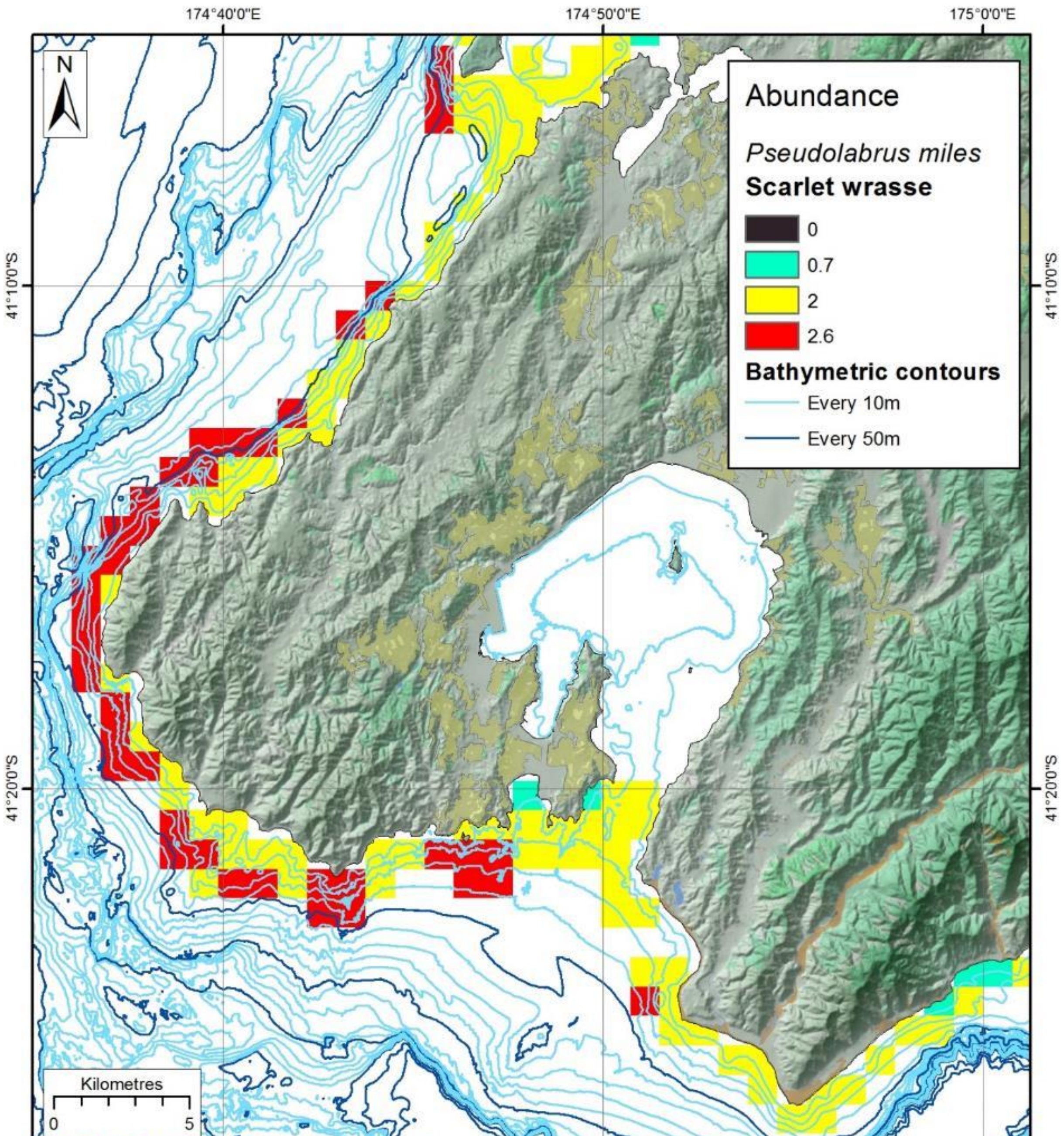
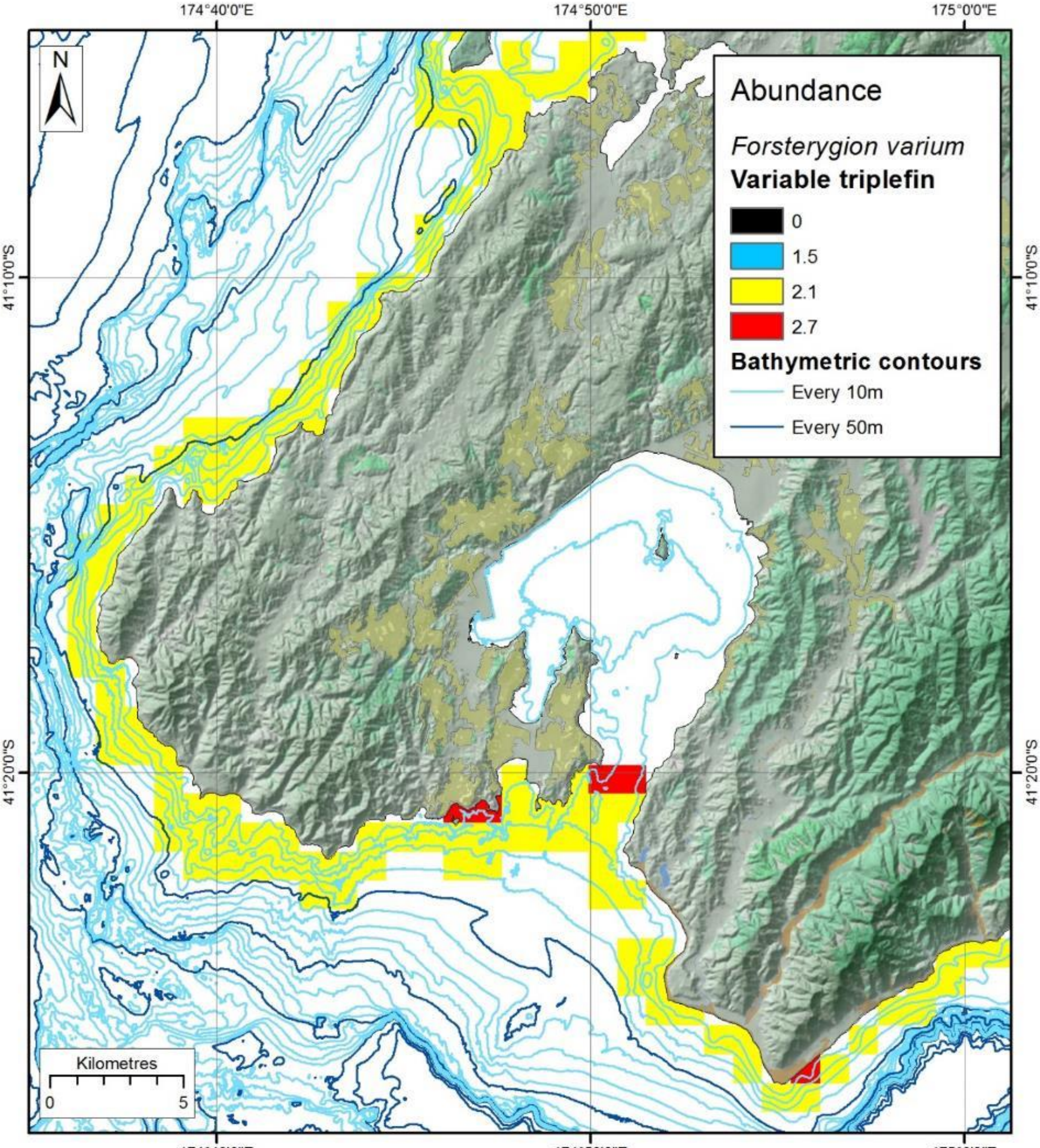


Figure 10-28: Modelled distribution and abundance of scarlet wrasse on Wellington subtidal reefs.



174°40'0"E
174°50'0"E
175°0'0"E
41°10'0"S
41°20'0"S
N
Abundance
Forsterygion varium
Variable triplefin
0
1.5
2.1
2.7
Bathymetric contours
Every 10m
Every 50m
Kilometres
0
5

Figure 10-29: Modelled distribution and abundance of variable triplefin on Wellington subtidal reefs.

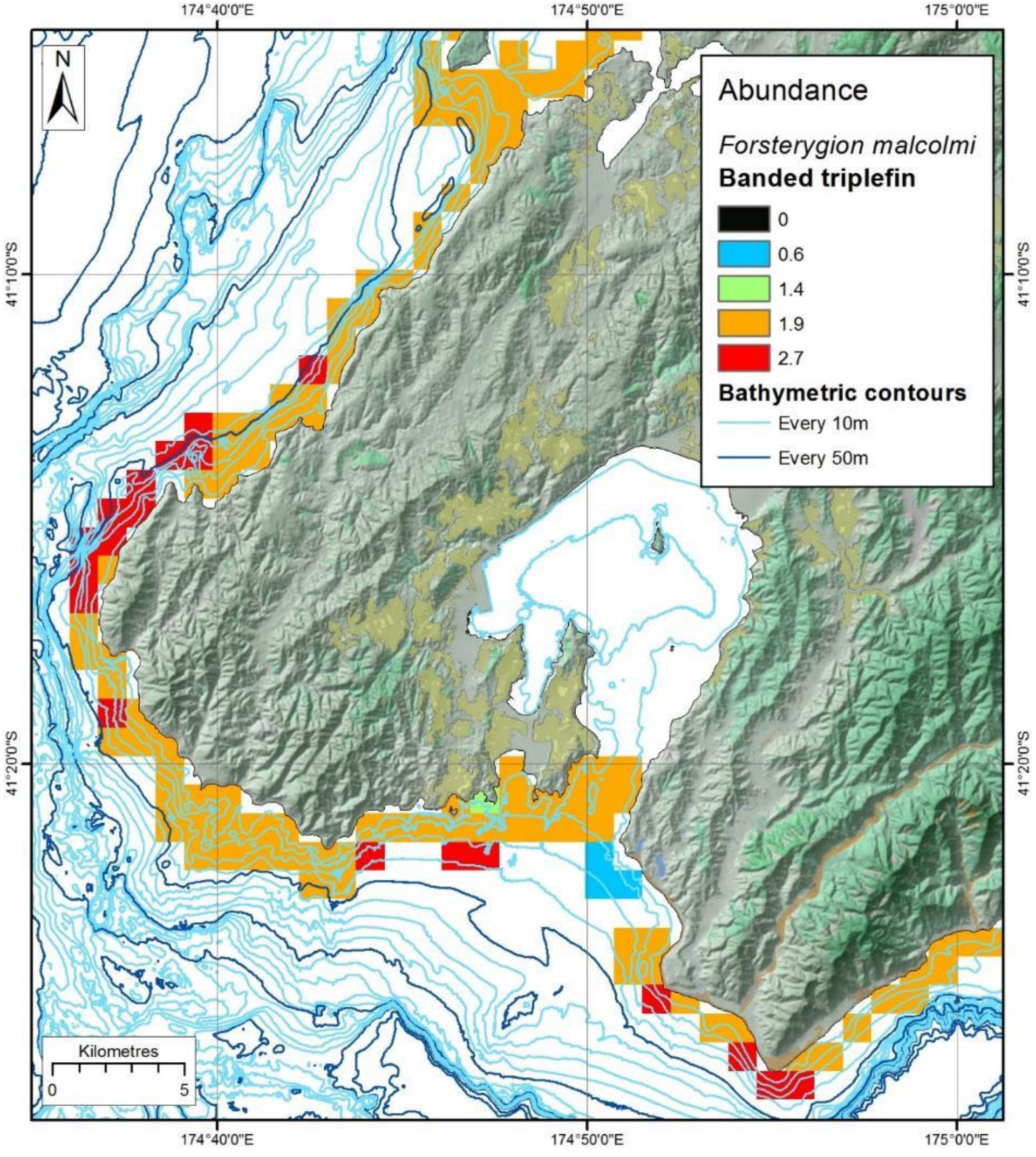


Figure 10-30: Modelled distribution and abundance of banded triplefin on Wellington subtidal reefs.

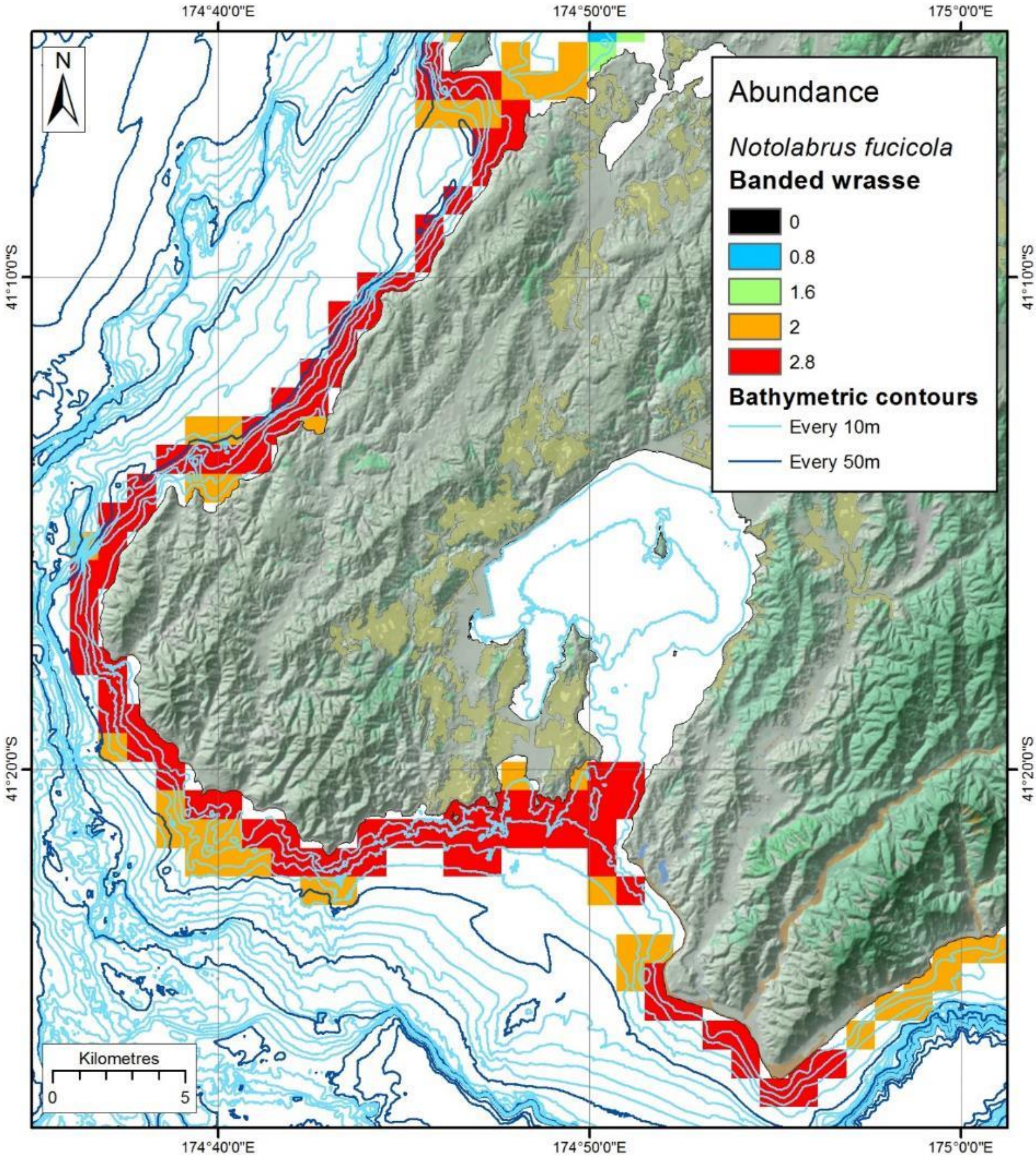


Figure 10-31: Modelled distribution and abundance of banded wrasse on Wellington subtidal reefs.

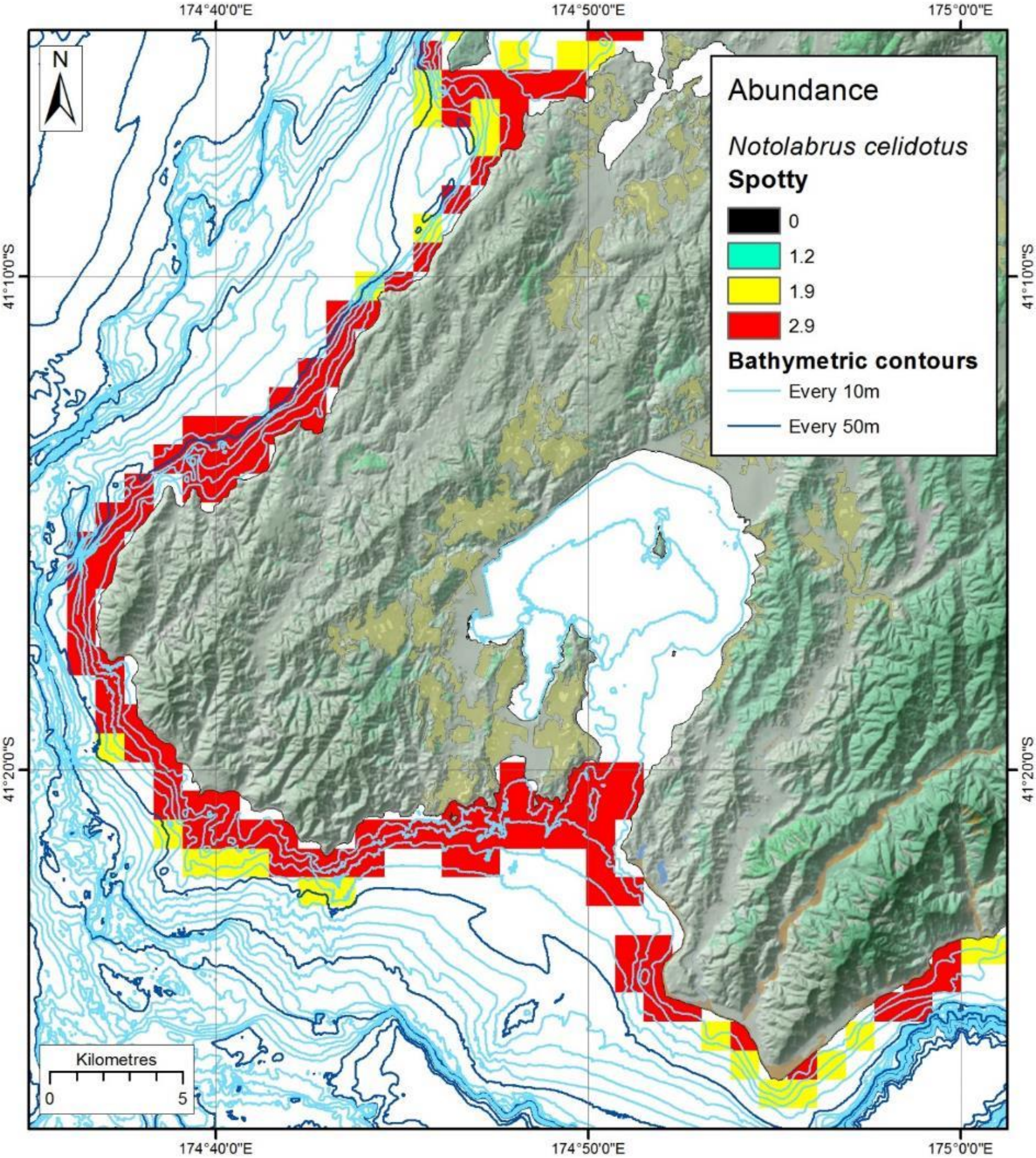


Figure 10-32: Modelled distribution and abundance of spotty on Wellington subtidal reefs.

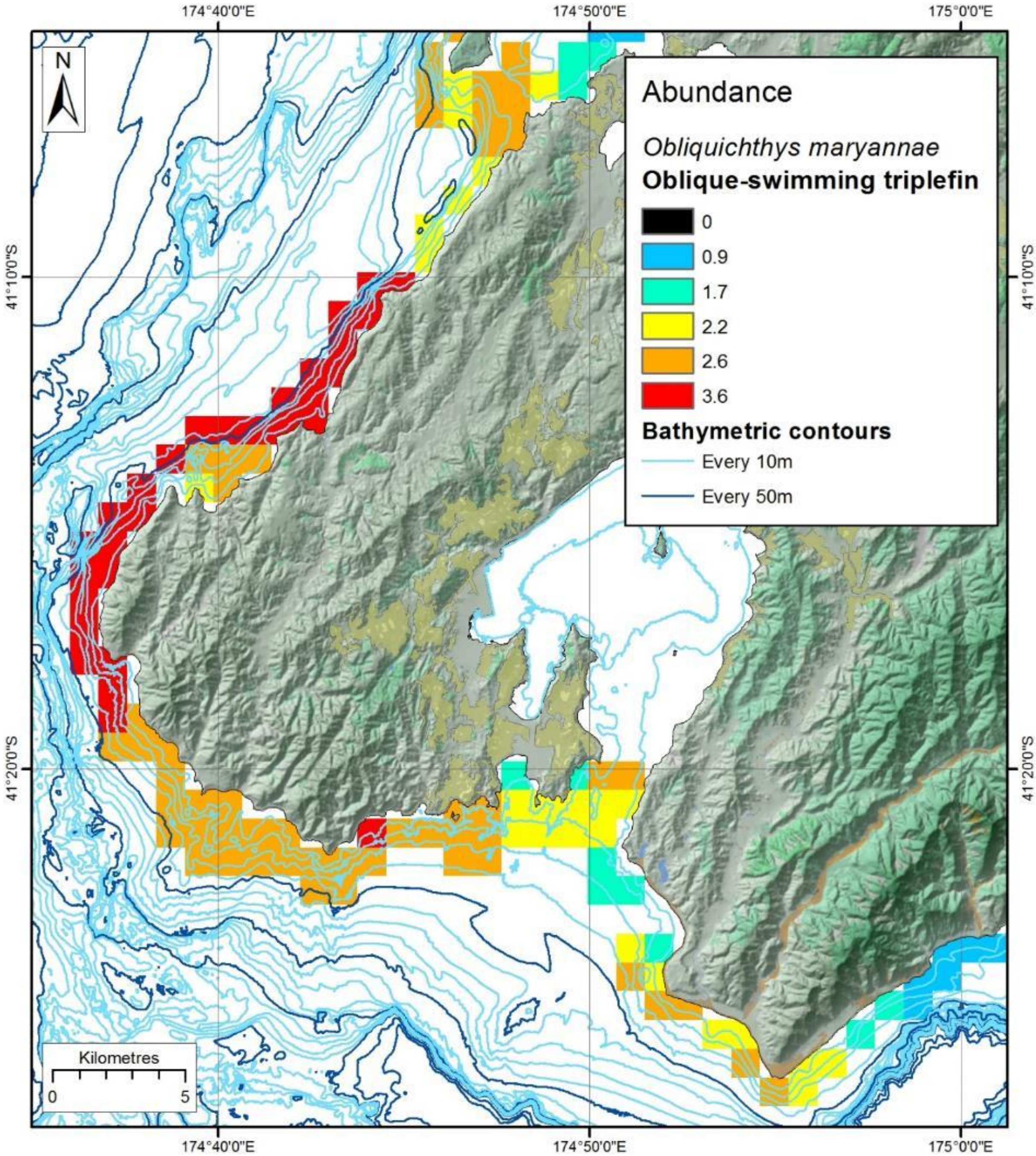


Figure 10-33: Modelled distribution and abundance of oblique-swimming triplefin on Wellington subtidal reefs.

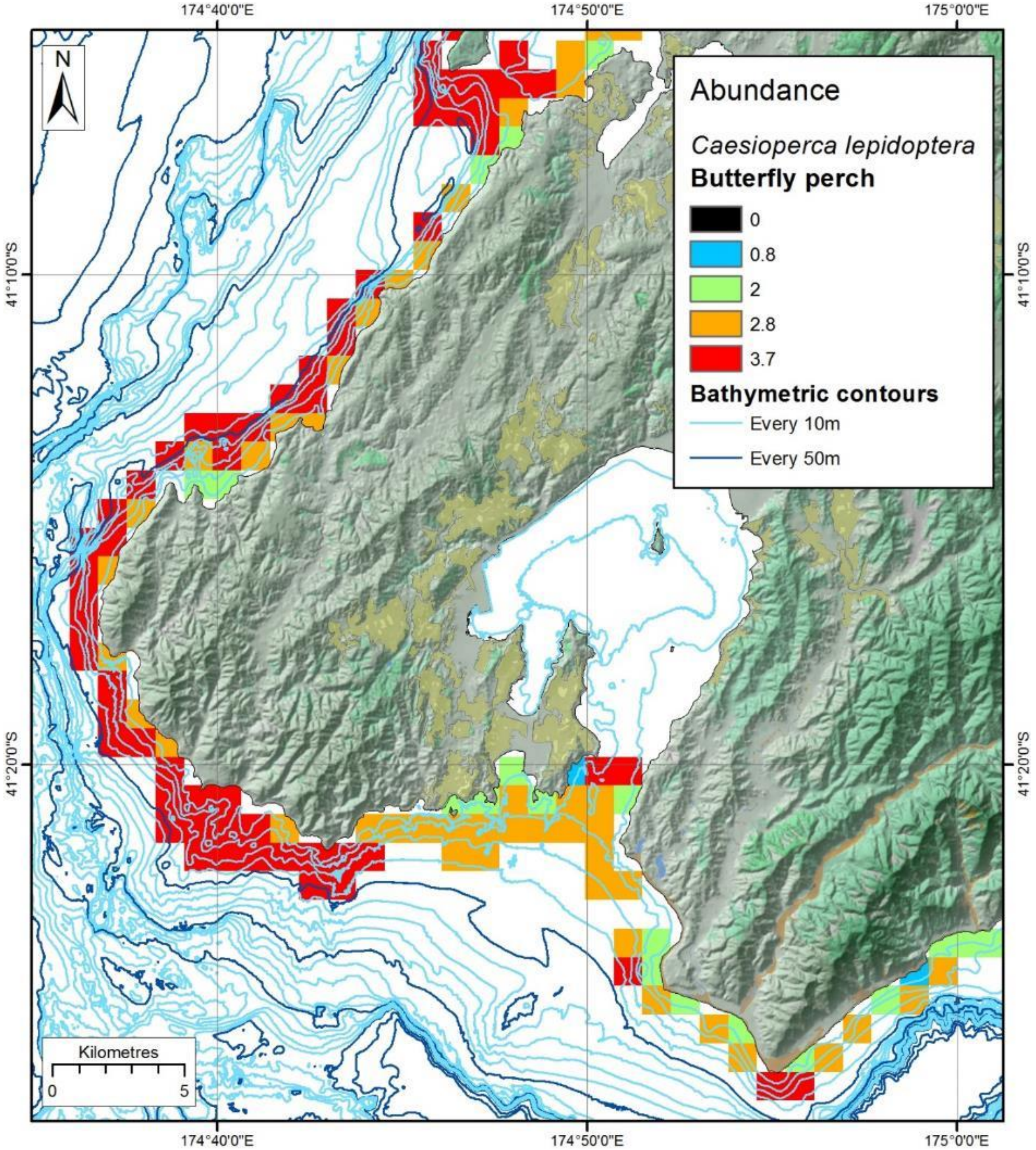


Figure 10-34: Modelled distribution and abundance of butterfly perch on Wellington subtidal reefs.

Appendix C Demersal (bottom associated) fish: modelled probability of catch (%)

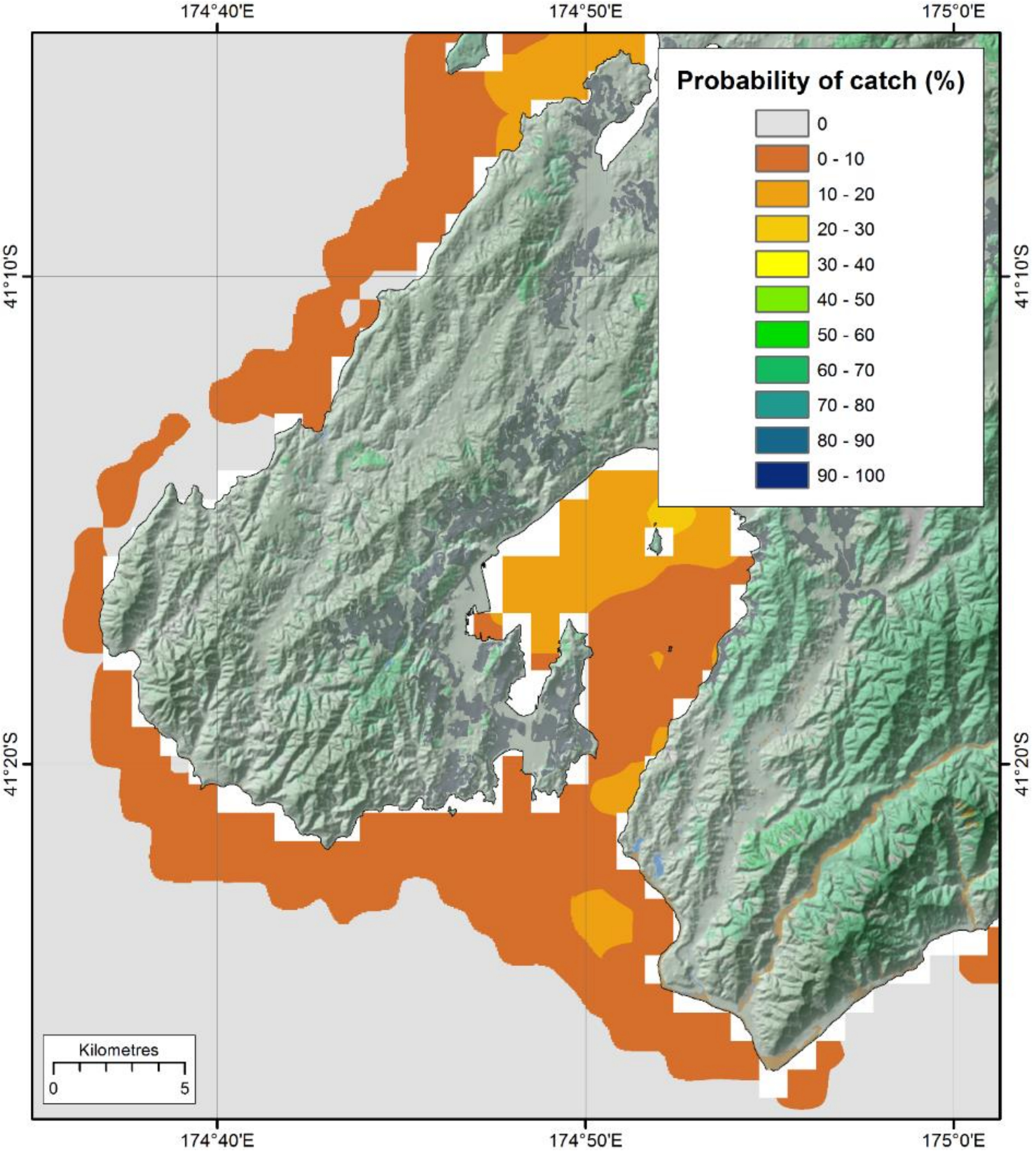


Figure 11-35: Probability of occurrence (%) of anchovy (*Engraulis australis*) in a demersal trawl in the Wellington region.

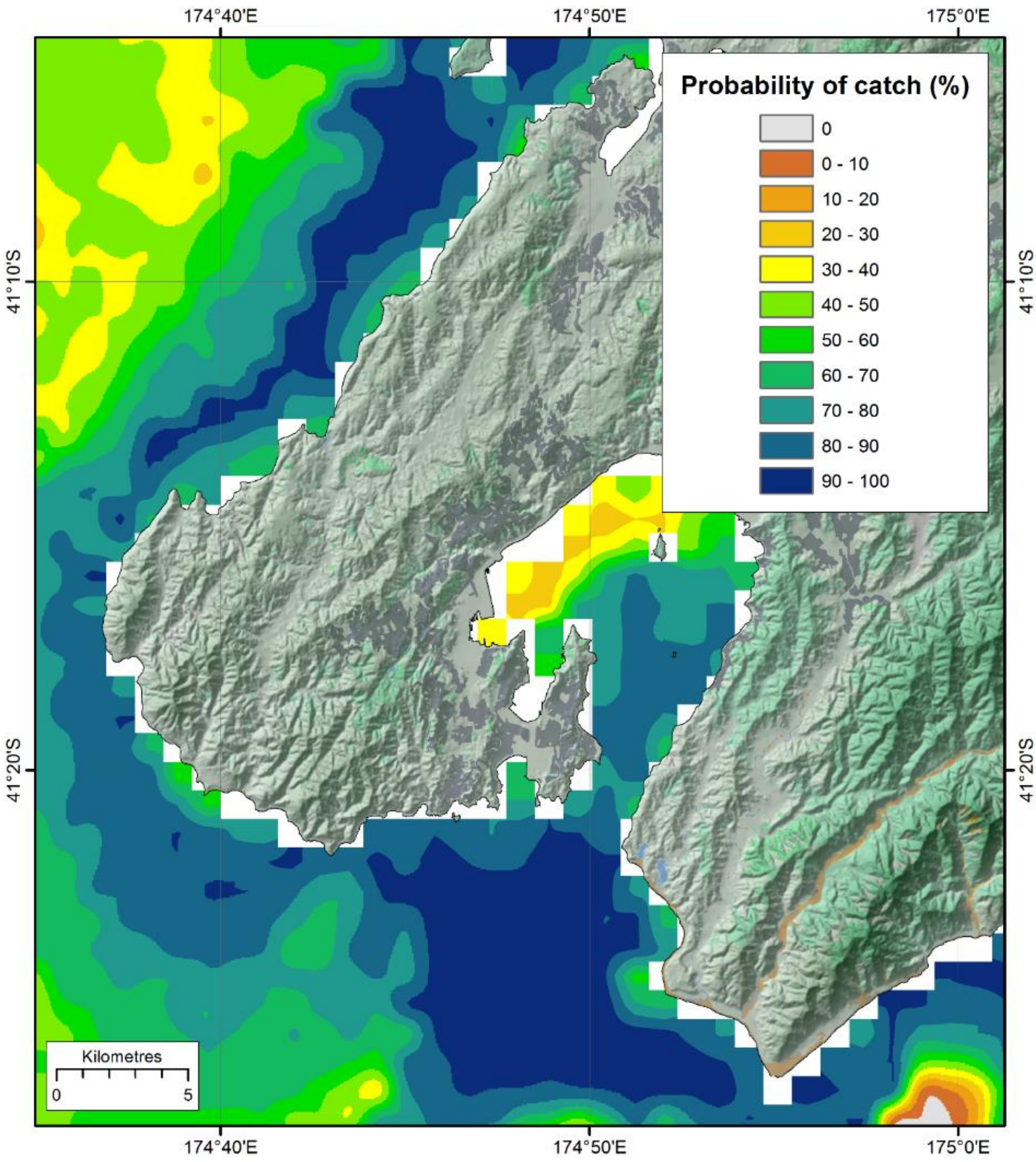


Figure 11-36: Probability of occurrence (%) of barracouta (*Thyrsites atun*) in a demersal trawl in the Wellington region.

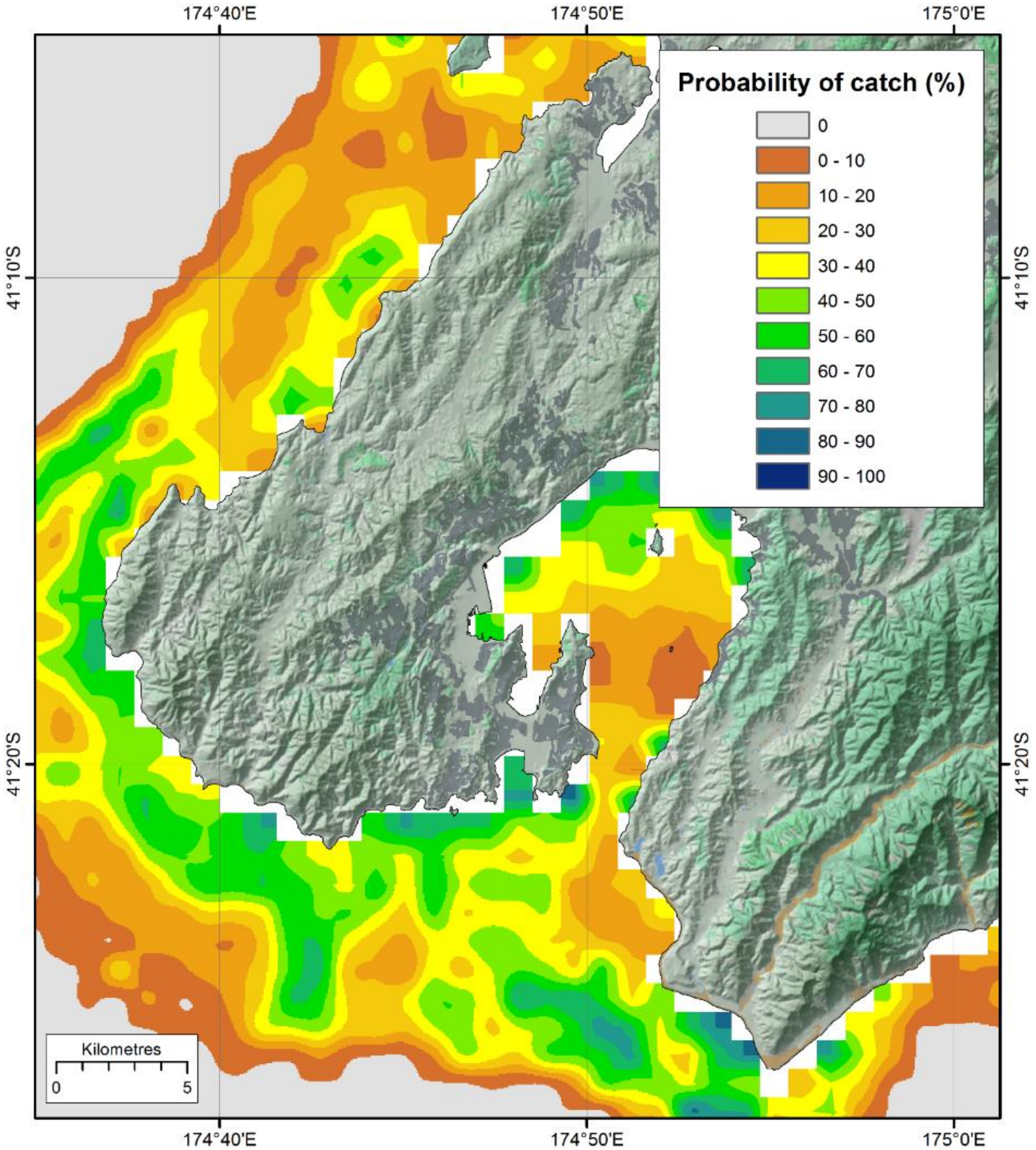


Figure 11-37: Probability of occurrence (%) of blue cod (*Parapercis colias*) in a demersal trawl in the Wellington region.

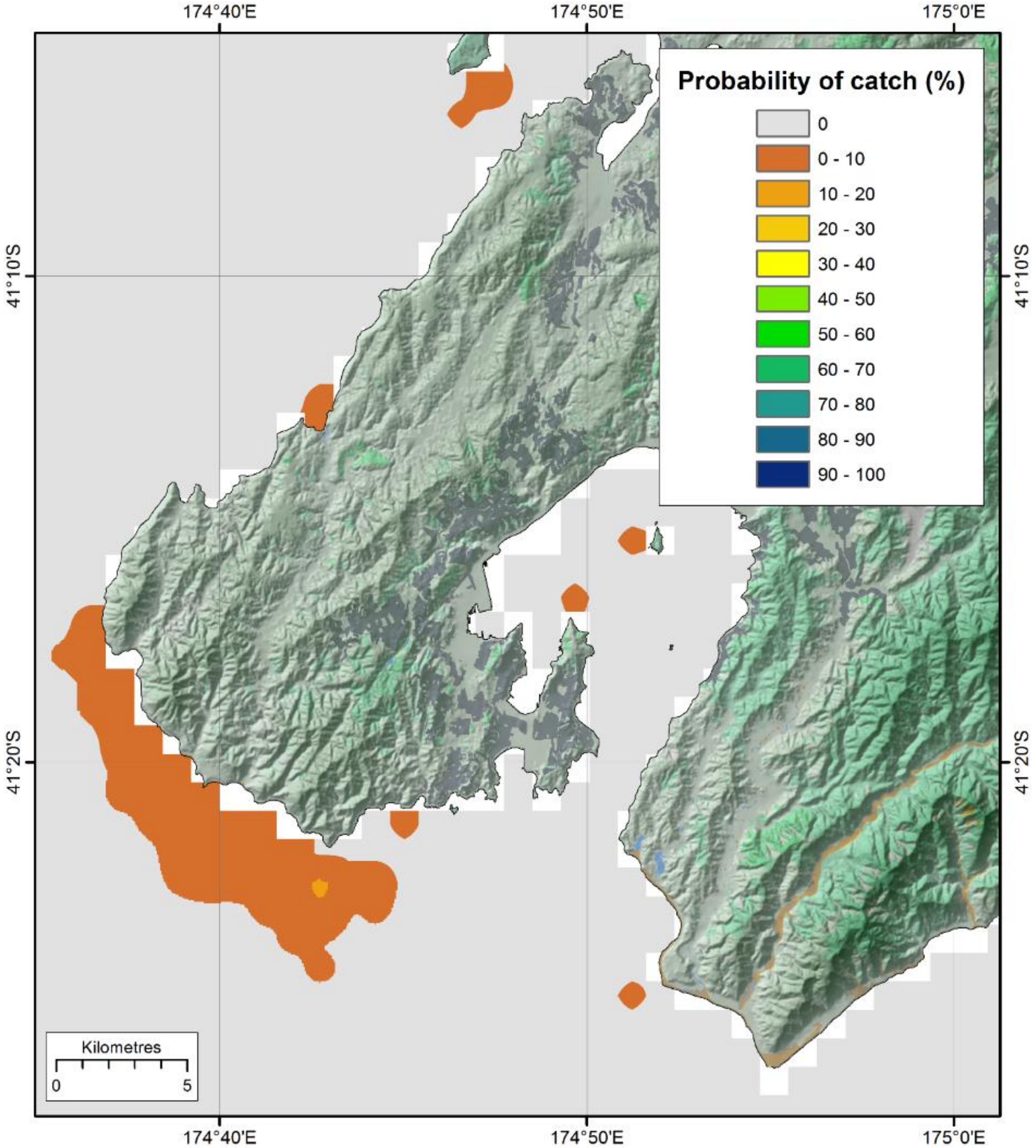


Figure 7-38: Probability of occurrence (%) of short-tailed black ray (*Dasyatis brevicaudata*) in a demersal trawl in the Wellington region.

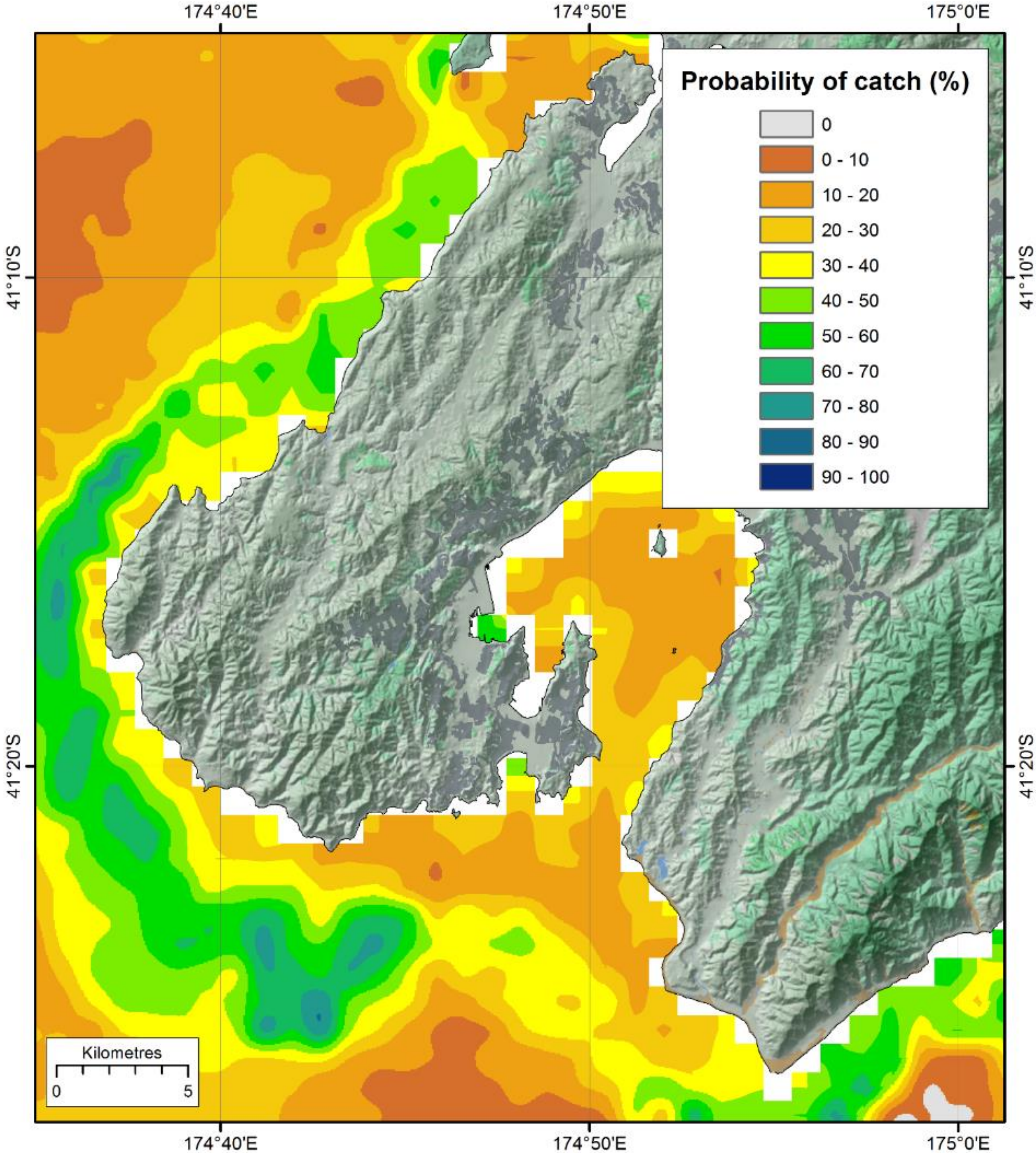


Figure 11-39: Probability of occurrence (%) of carpet shark (*Cephaloscyllium isabellum*) in a demersal trawl in the Wellington region.

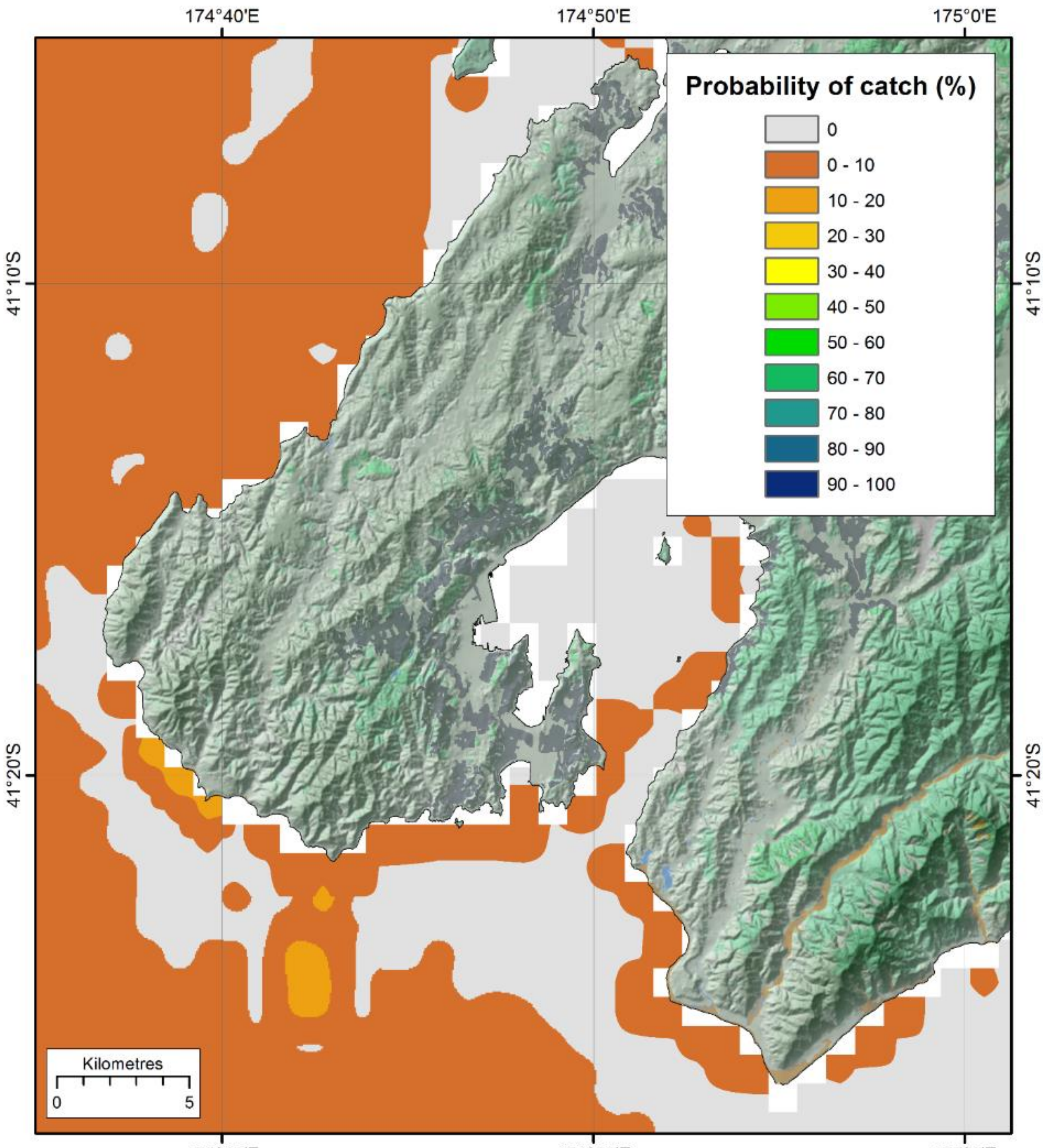


Figure 11-40: Probability of occurrence (%) of crested bellowsfish (*Notopogon lillei*) in a demersal trawl in the Wellington region.

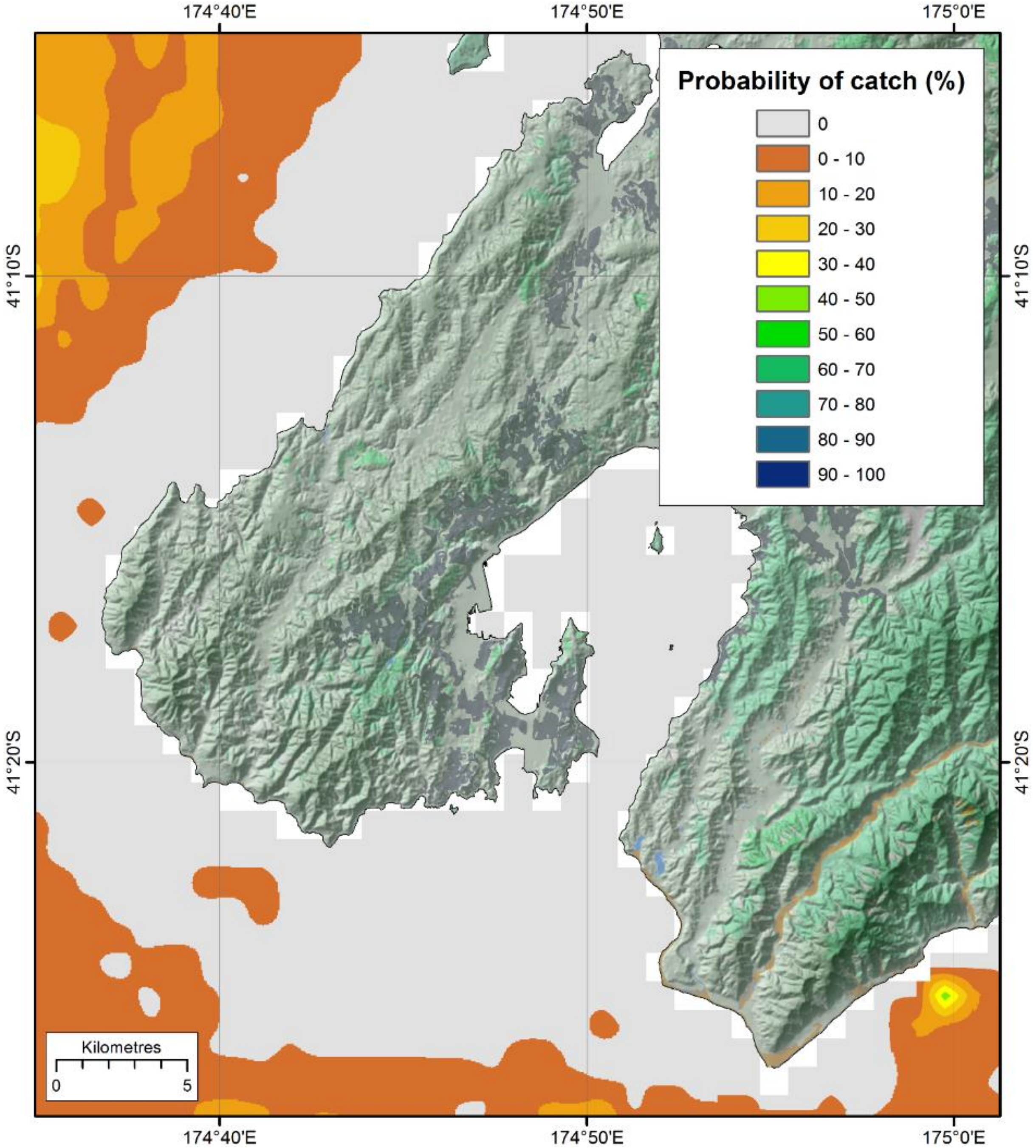


Figure 11-41: Probability of occurrence (%) of cucumber fish (*Chlorophthalmus nigripinnis*) in a demersal trawl in the Wellington region.

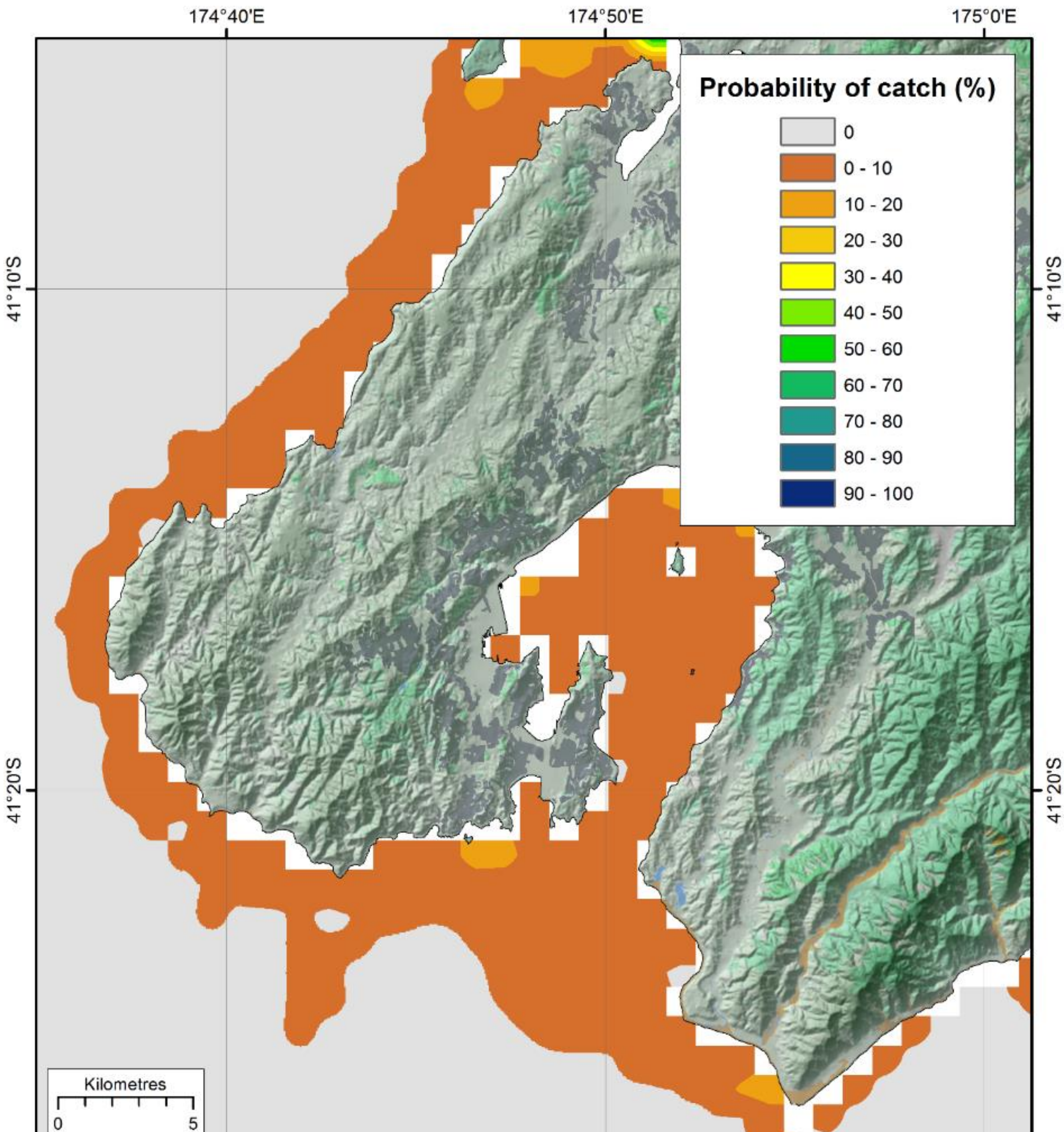


Figure 11-42: Probability of occurrence (%) of eagle Ray (*Myliobatis tenuicaudatus*) in a demersal trawl in the Wellington region.

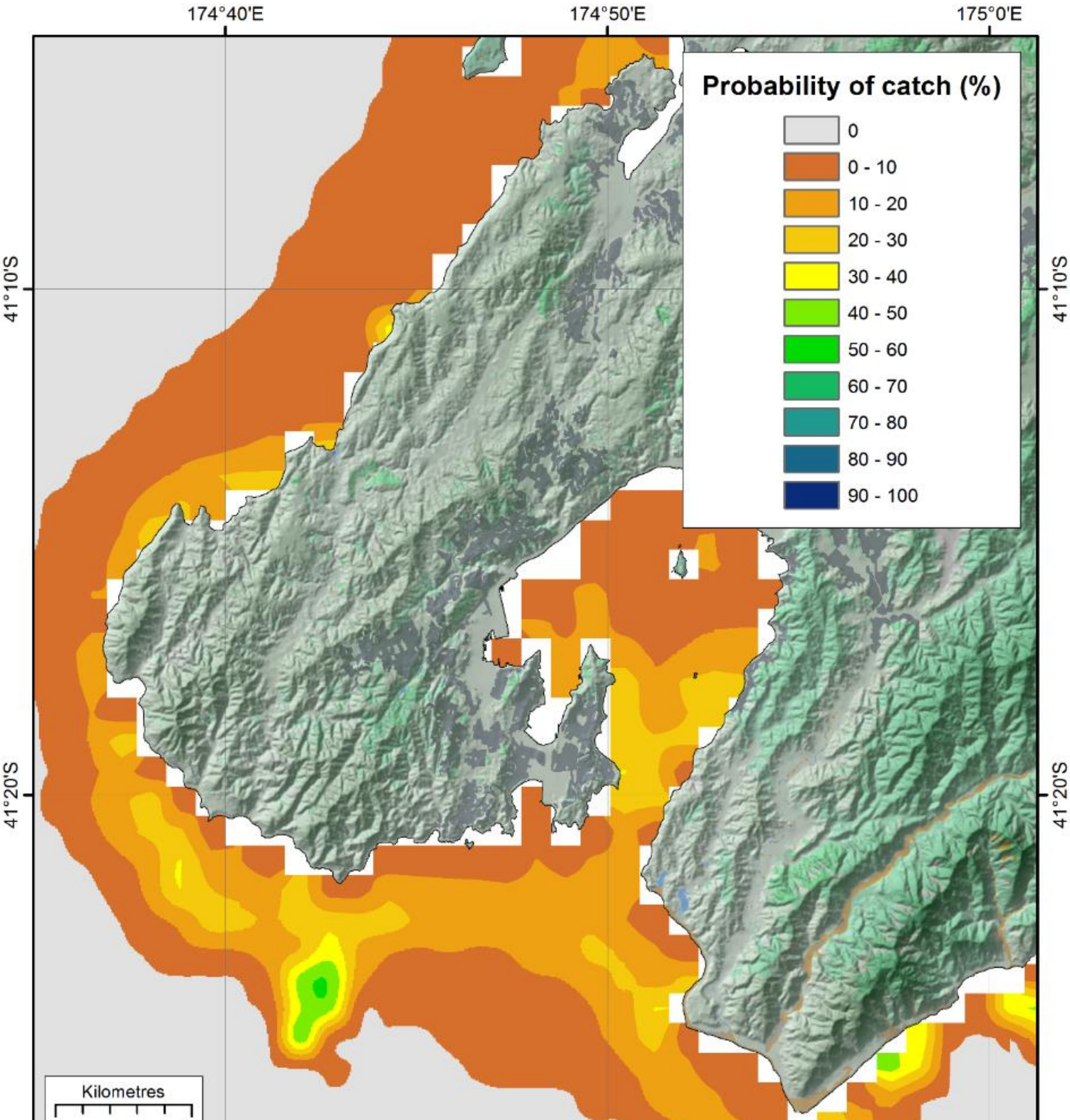


Figure 11-43: Probability of occurrence (%) of elephant fish (*Callorhinchus milii*) in a demersal trawl in the Wellington region.

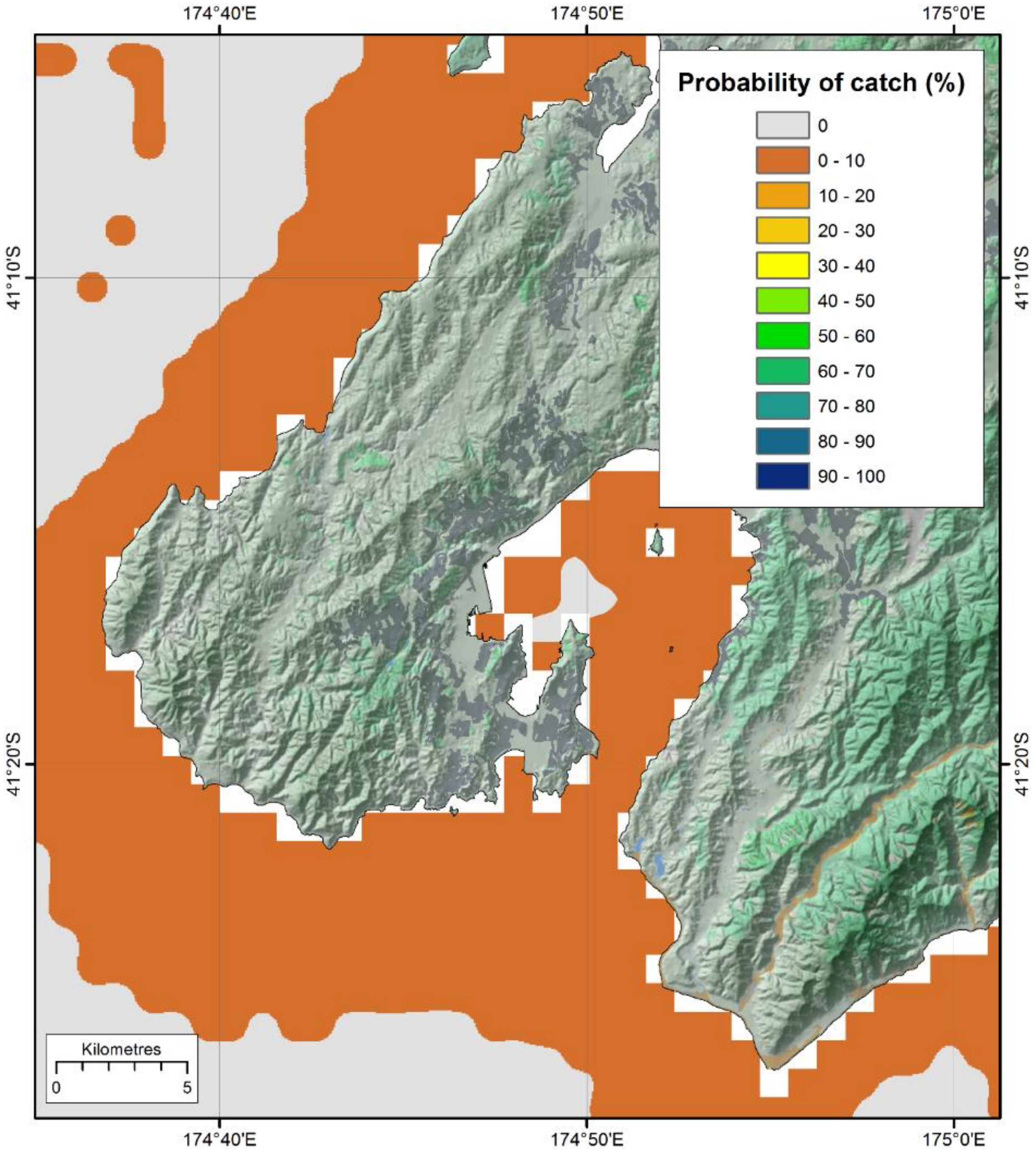


Figure 11-44: Probability of occurrence (%) of blue mackerel (*Scomber australasicus*) in a demersal trawl in the Wellington region.

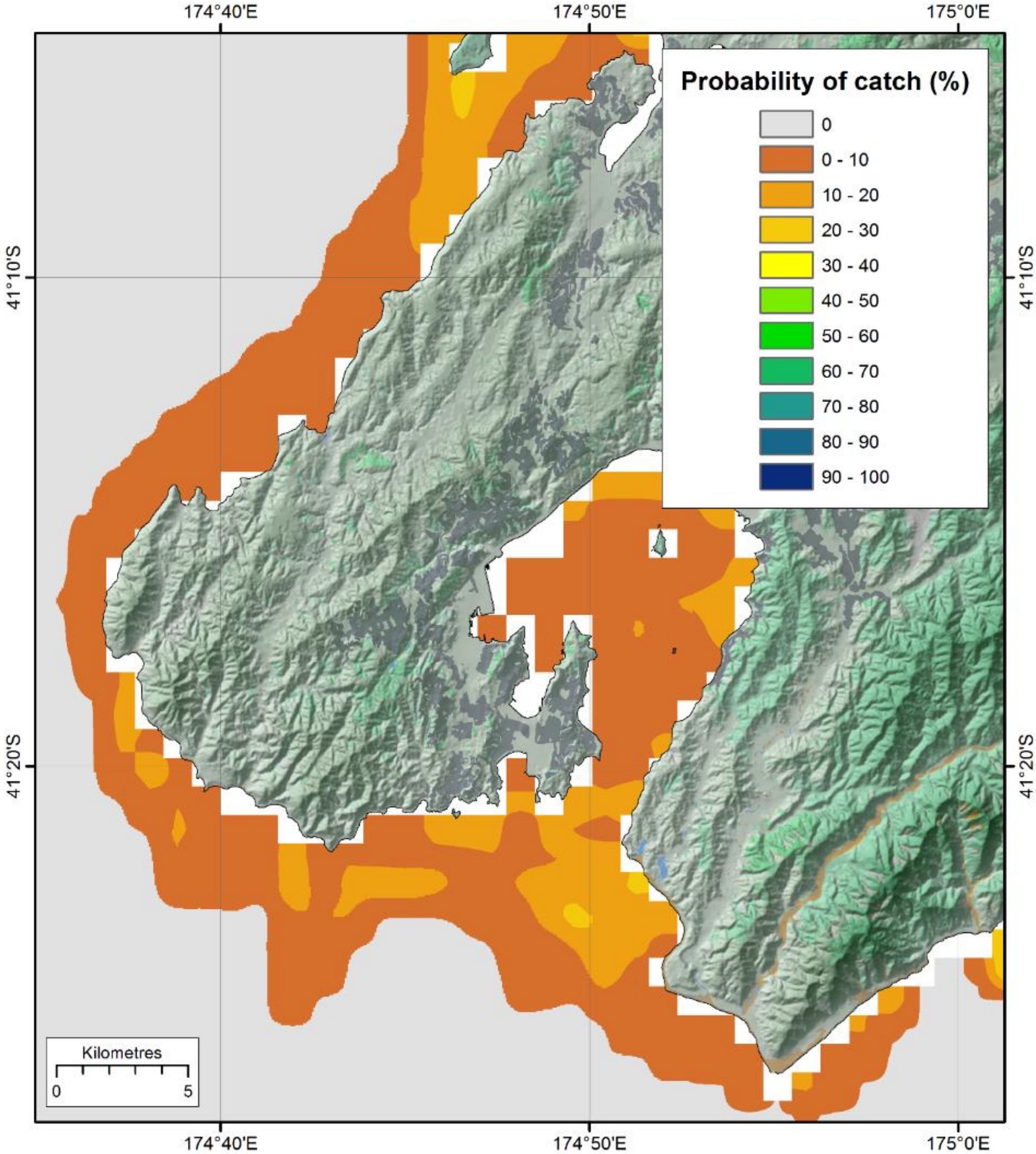


Figure 11-45: Probability of occurrence (%) of N.Z. sole (*Peltorhamphus novaezeelandiae*) in a demersal trawl in the Wellington region.

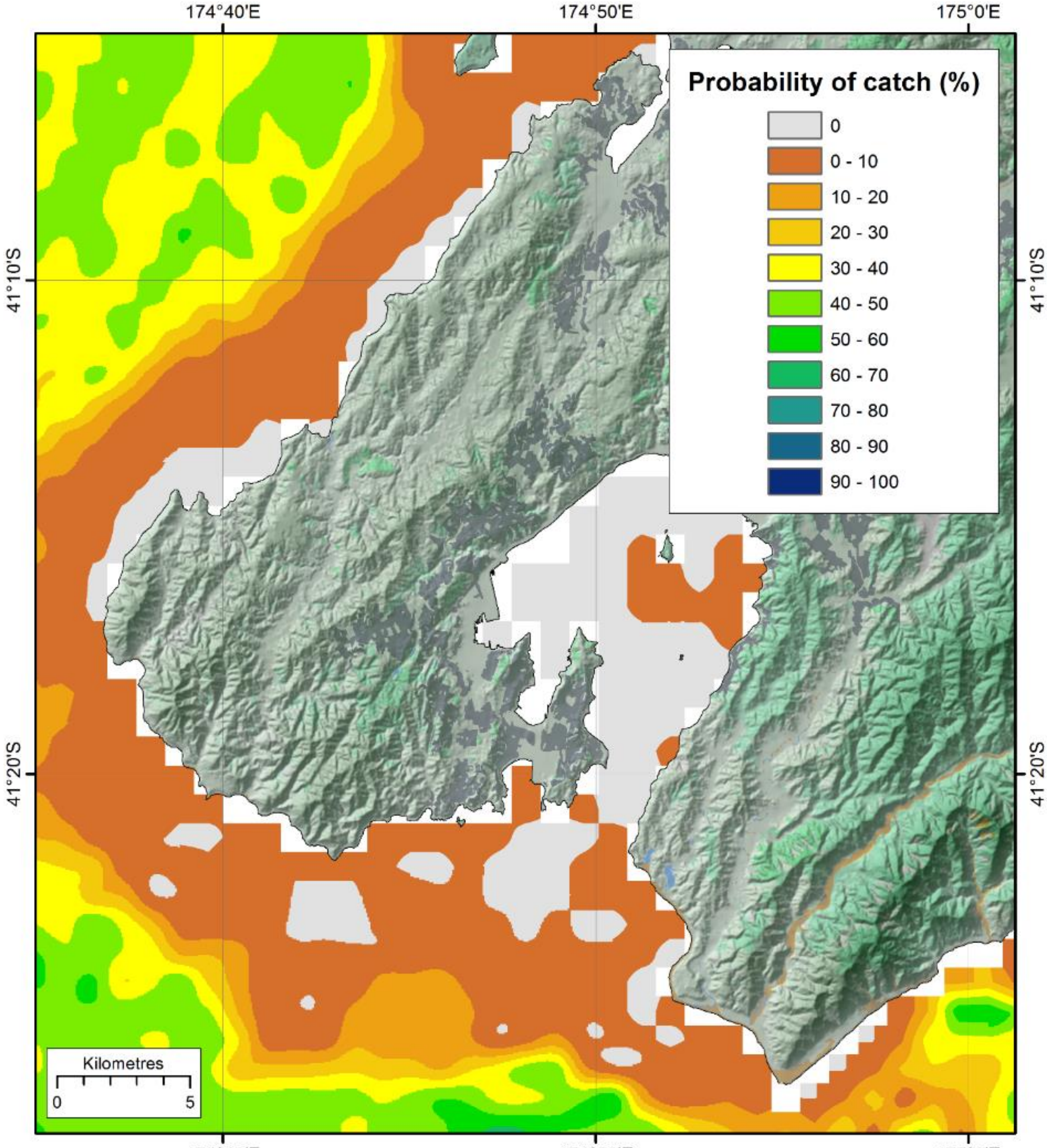


Figure 11-46: Probability of occurrence (%) of frostfish (*Lepidopus caudatus*) in a demersal trawl in the Wellington region.

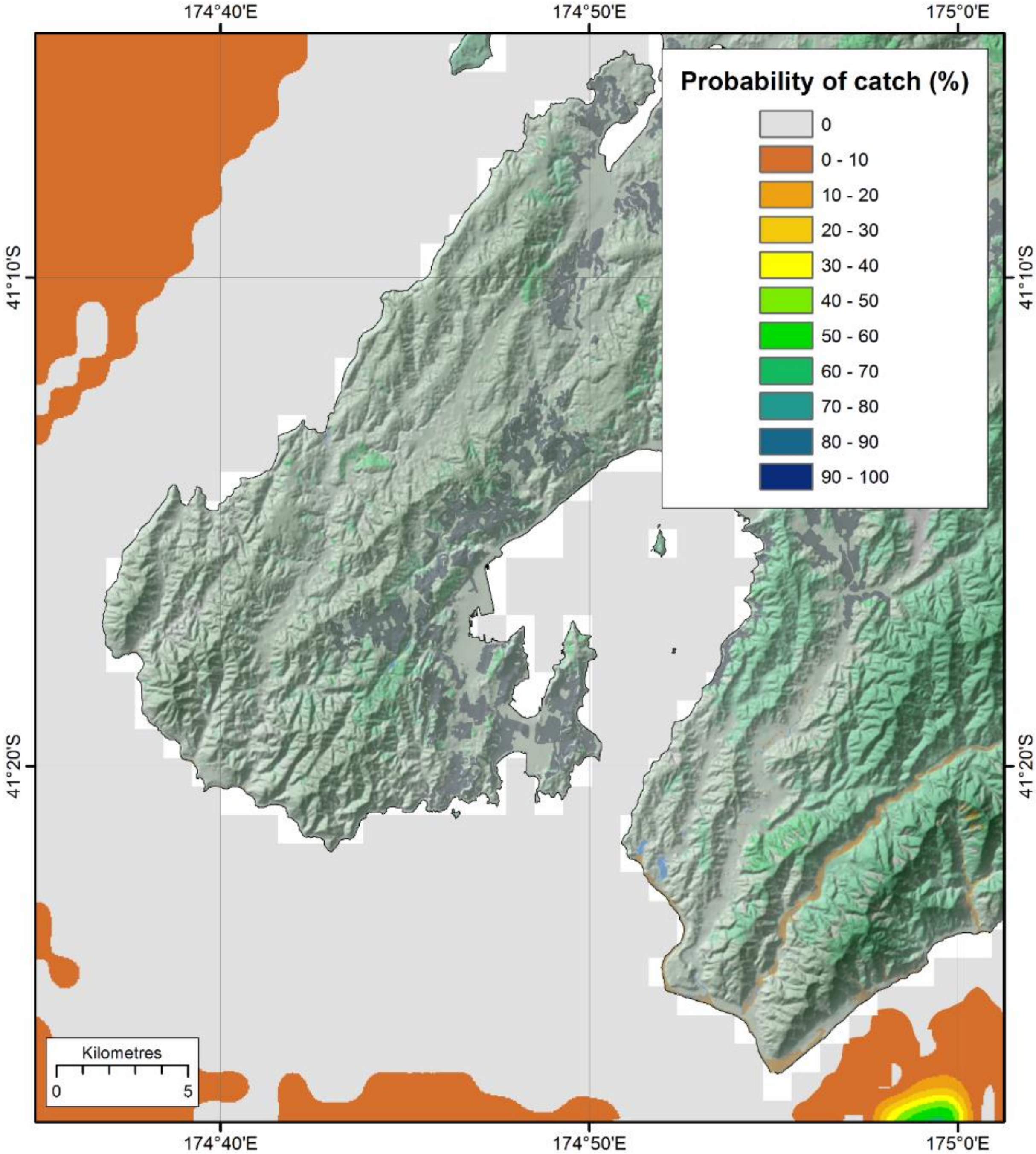


Figure 11-47: Probability of occurrence (%) of pale ghost shark (*Hydrolagus bemisi*) in a demersal trawl in the Wellington region.

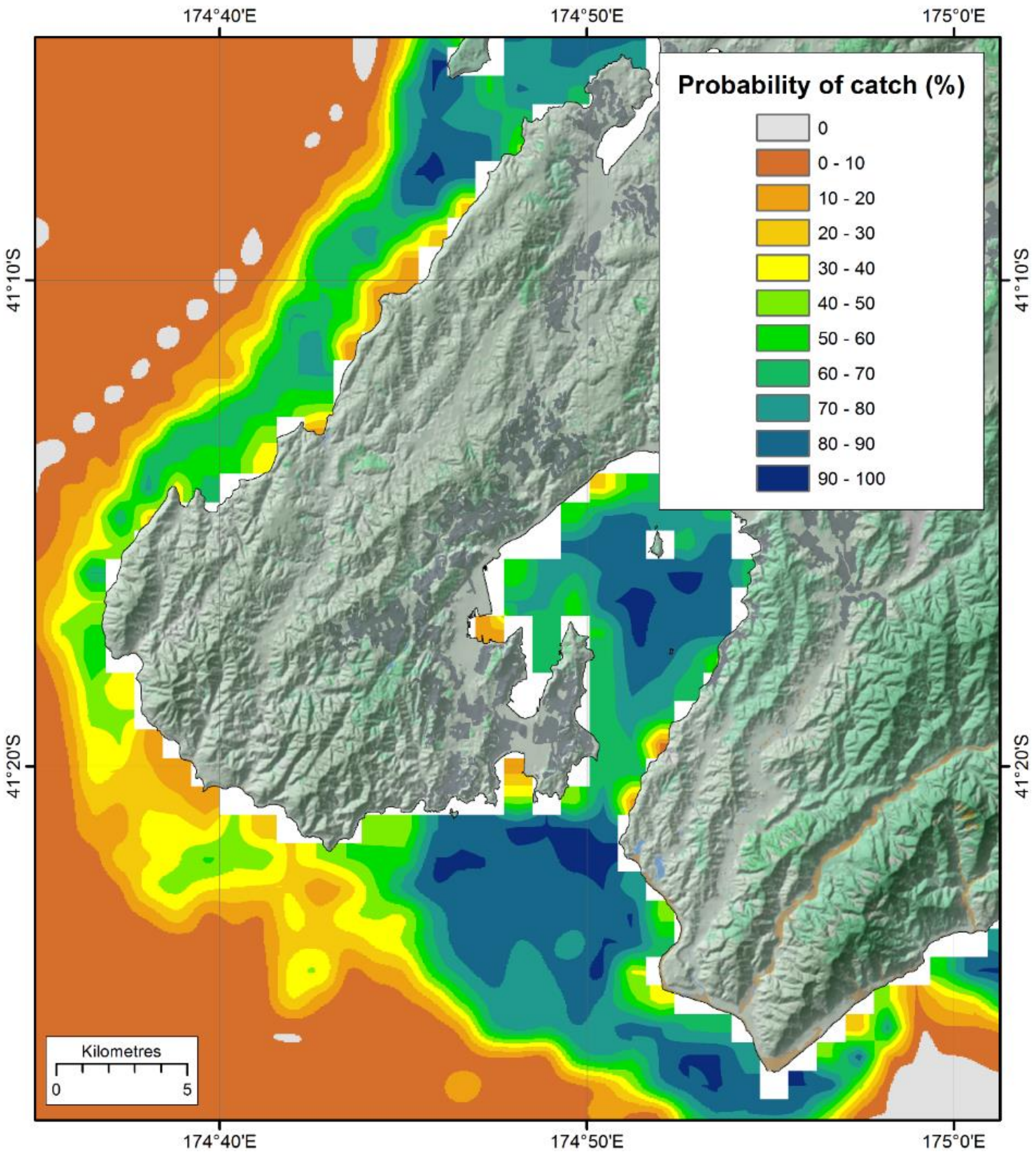


Figure 11-48: Probability of occurrence (%) of gurnard (*Chelidonichthys kumu*) in a demersal trawl in the Wellington region.

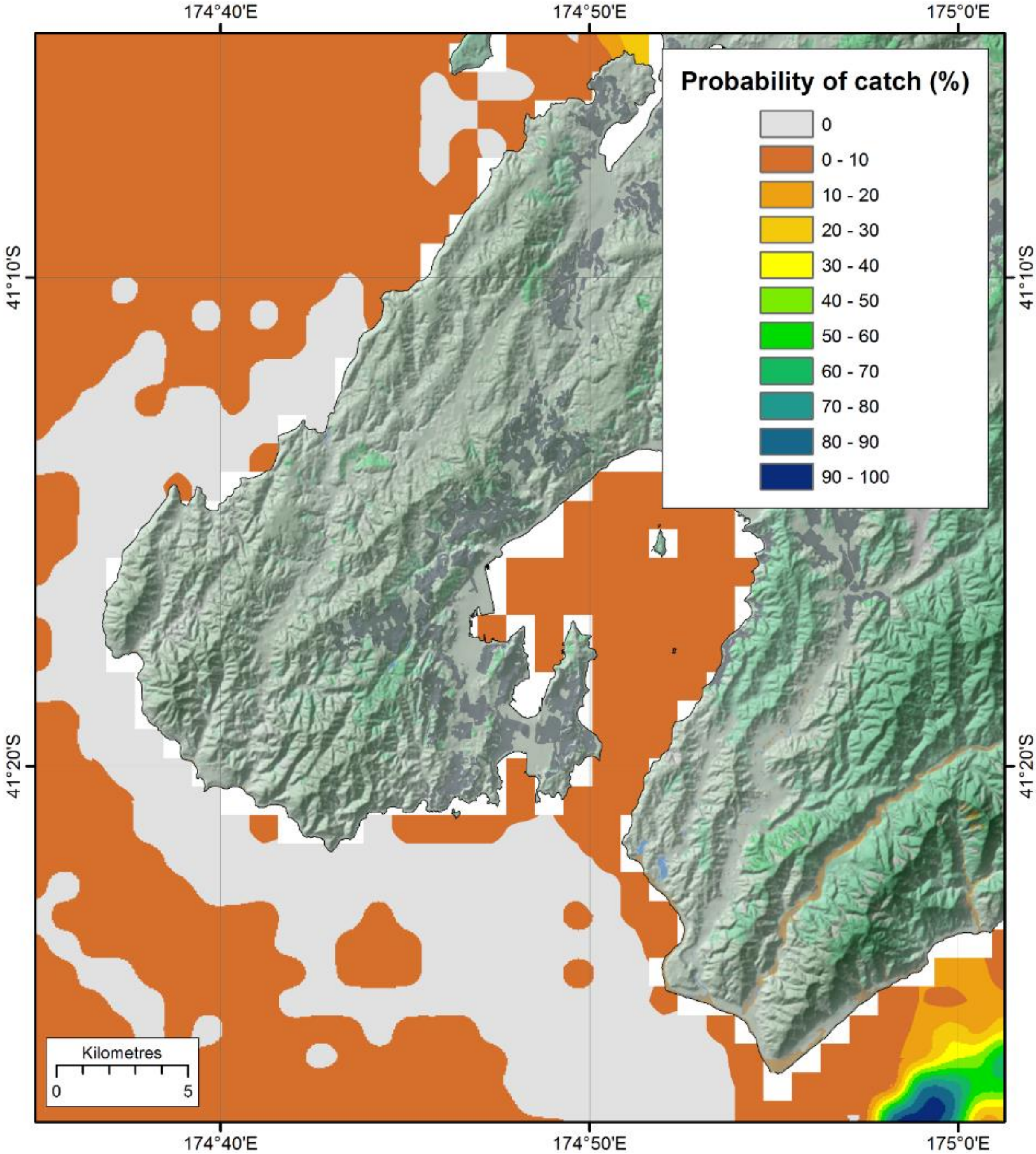


Figure 11-49: Probability of occurrence (%) of hake (*Merluccius australis*) in a demersal trawl in the Wellington region.

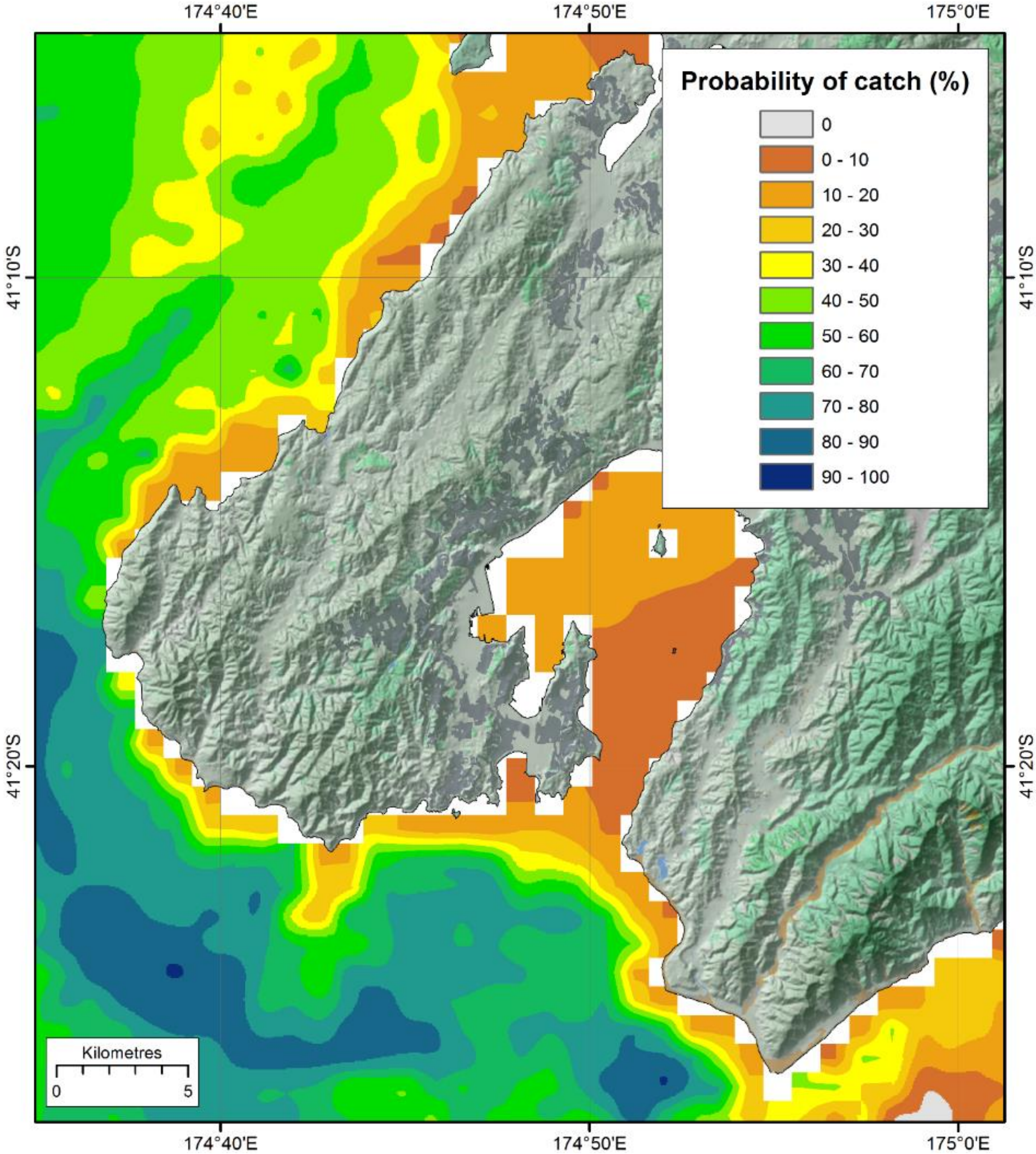


Figure 11-50: Probability of occurrence (%) of hapuka (*Polyprion oxygeneios*) in a demersal trawl in the Wellington region.

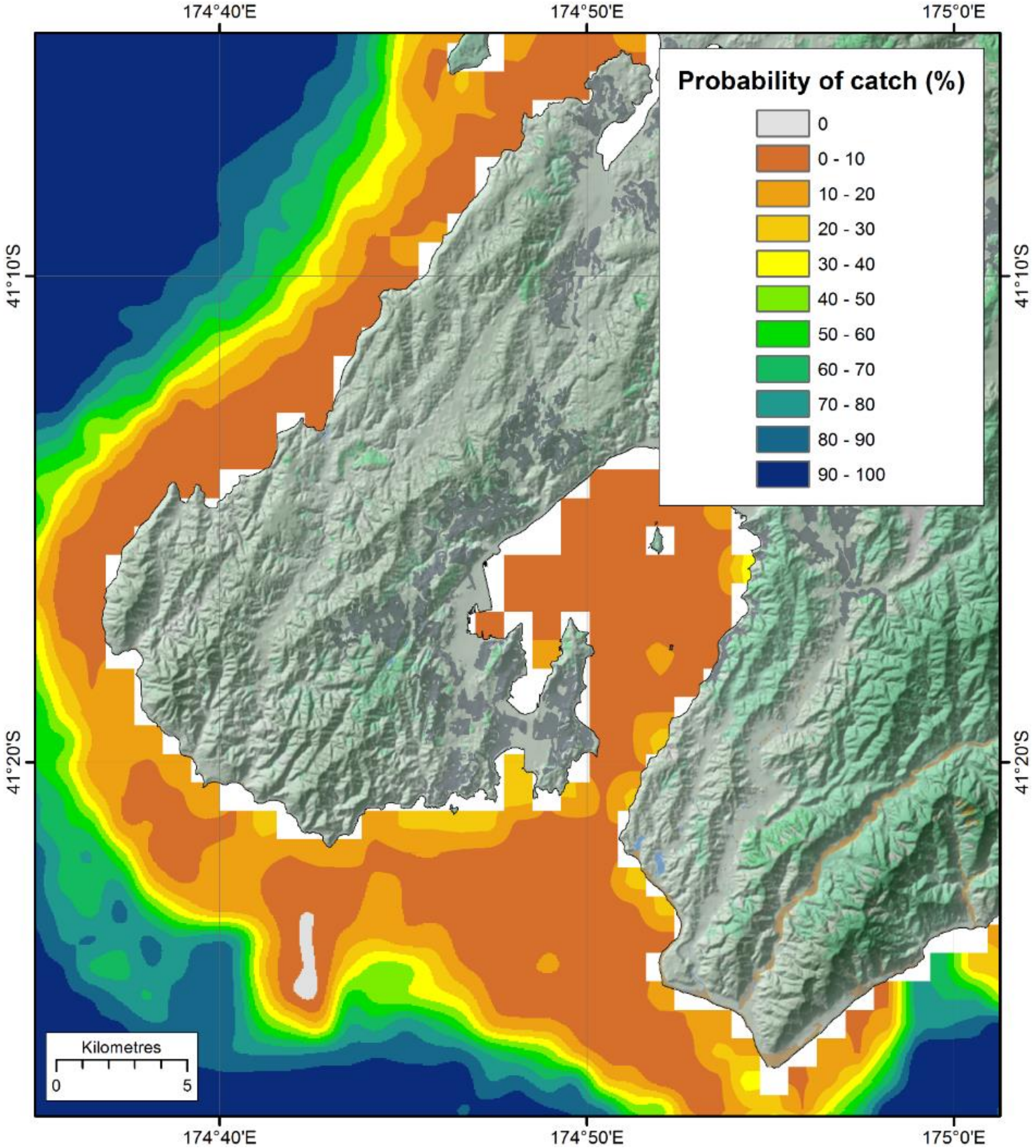


Figure 11-51: Probability of occurrence (%) of hoki (*Macruronus novaezelandiae*) in a demersal trawl in the Wellington region.

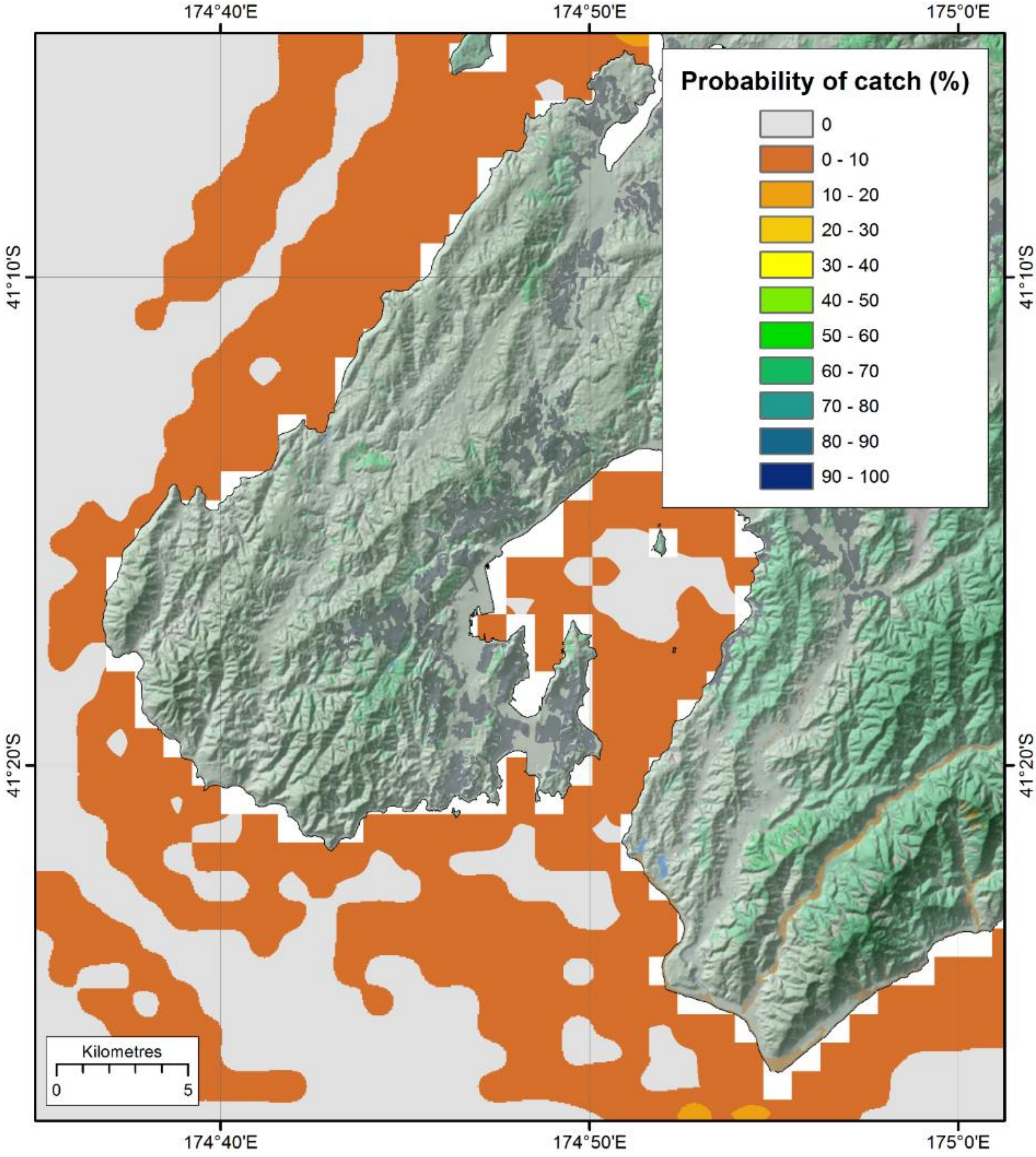


Figure 11-52: Probability of occurrence (%) of John dory (*Zeus faber*) in a demersal trawl in the Wellington region.

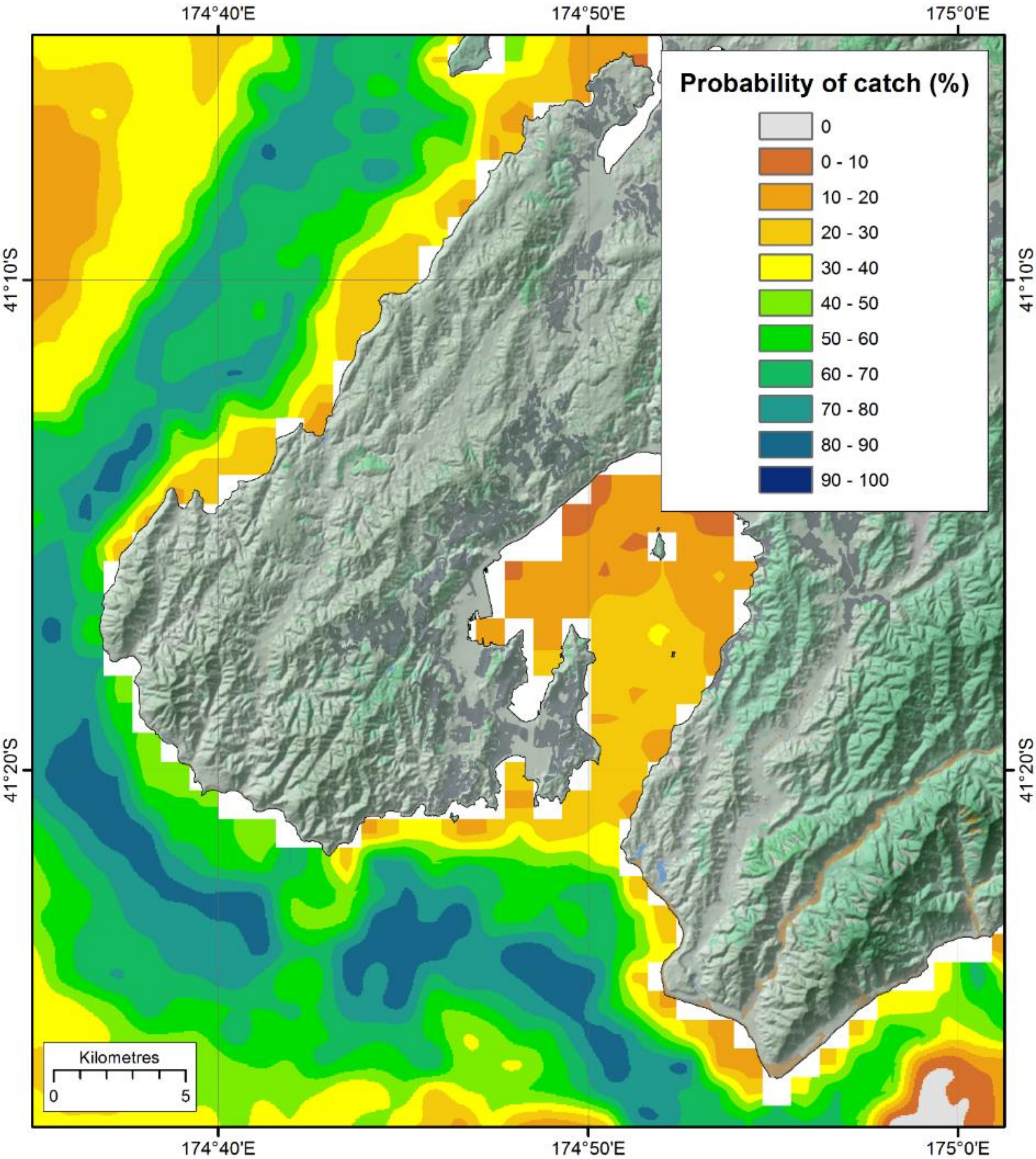


Figure 11-53: Probability of occurrence (%) of horse mackerel (*Trachurus declivis*) in a demersal trawl in the Wellington region.

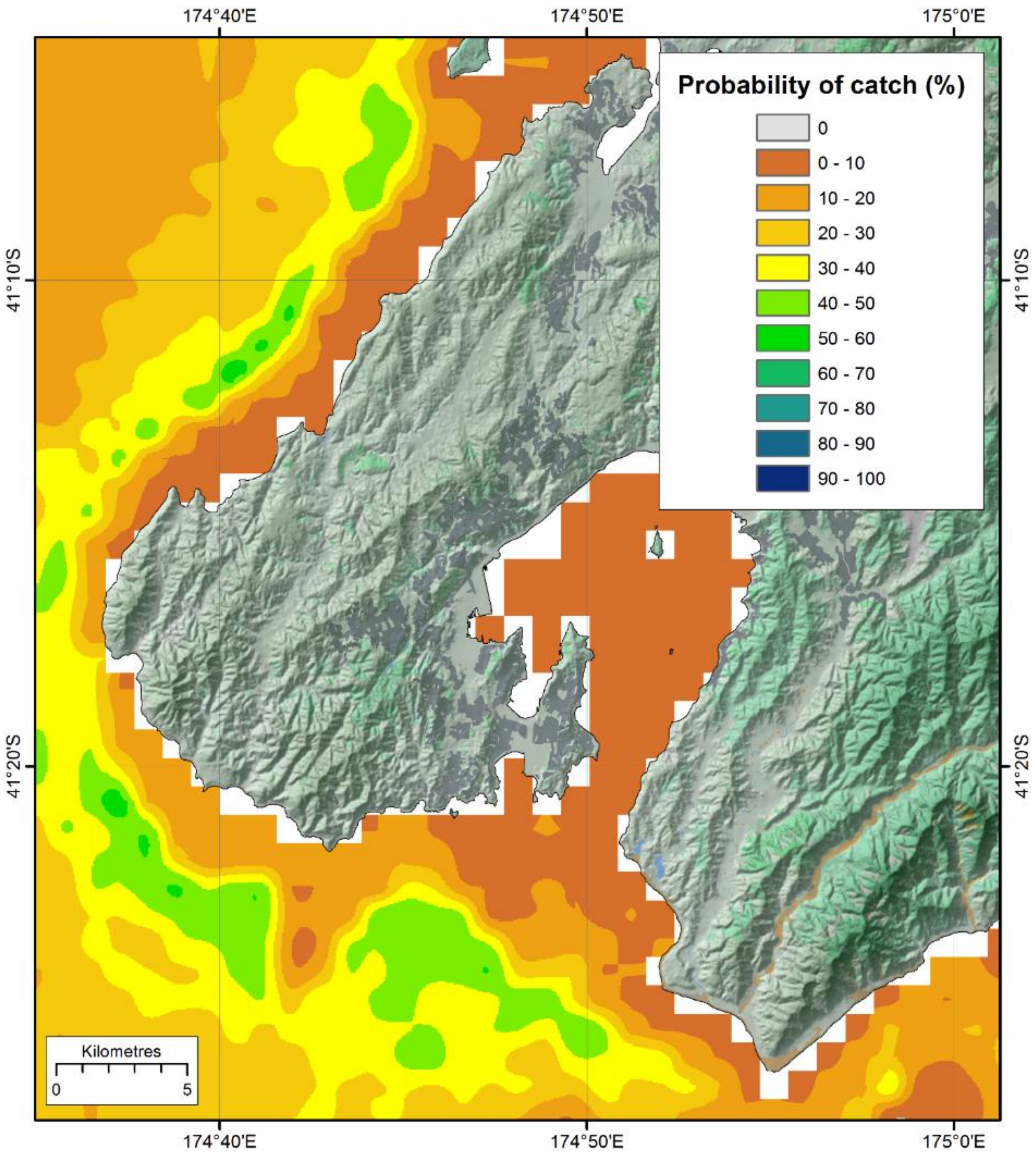


Figure 11-54: Probability of occurrence (%) of Murphys mackerel (*Trachurus symmertricus murphyi*) in a demersal trawl in the Wellington region.

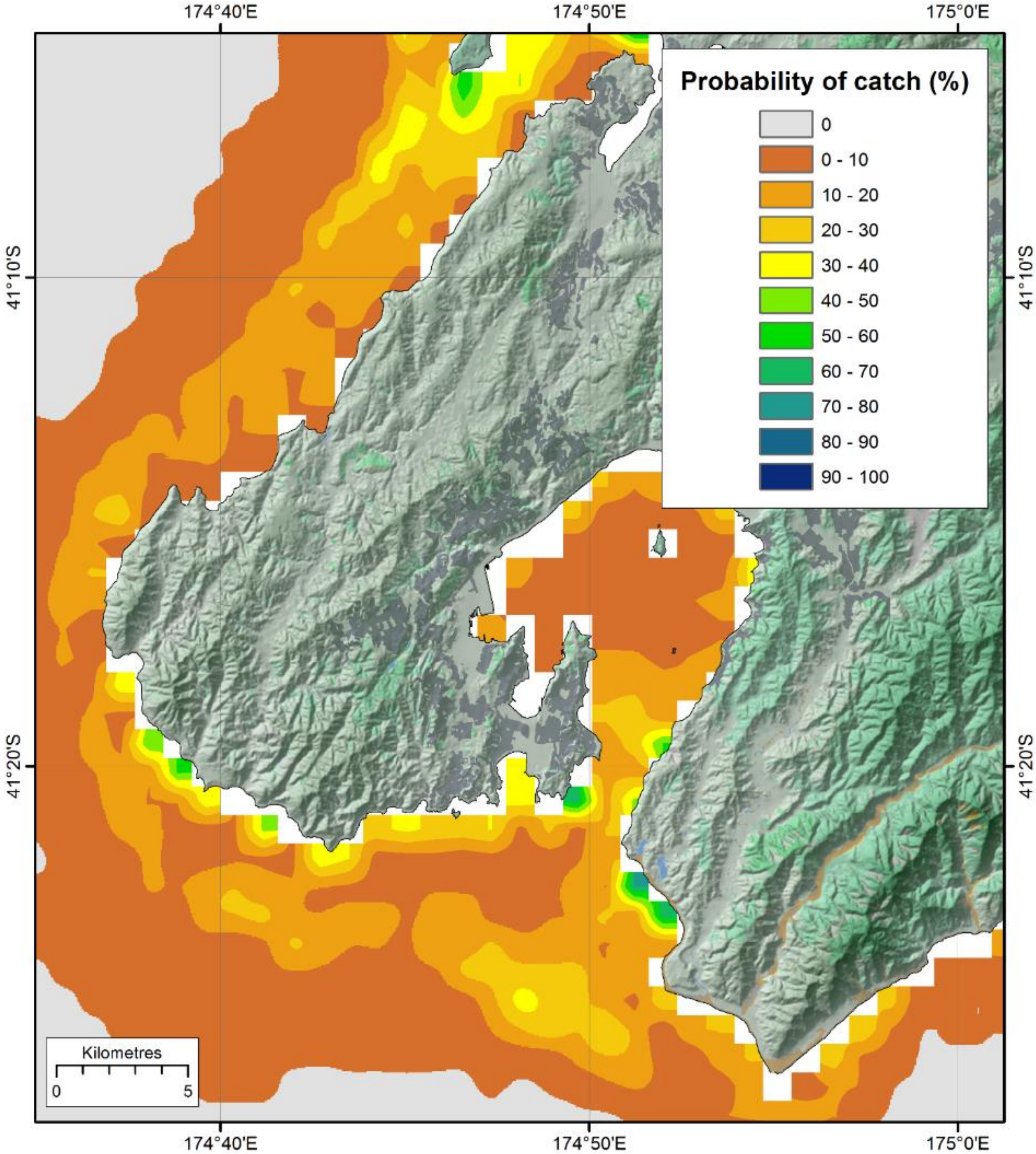


Figure 11-55: Probability of occurrence (%) of golden mackerel (*Trachurus novaezelandiae*) in a demersal trawl in the Wellington region.

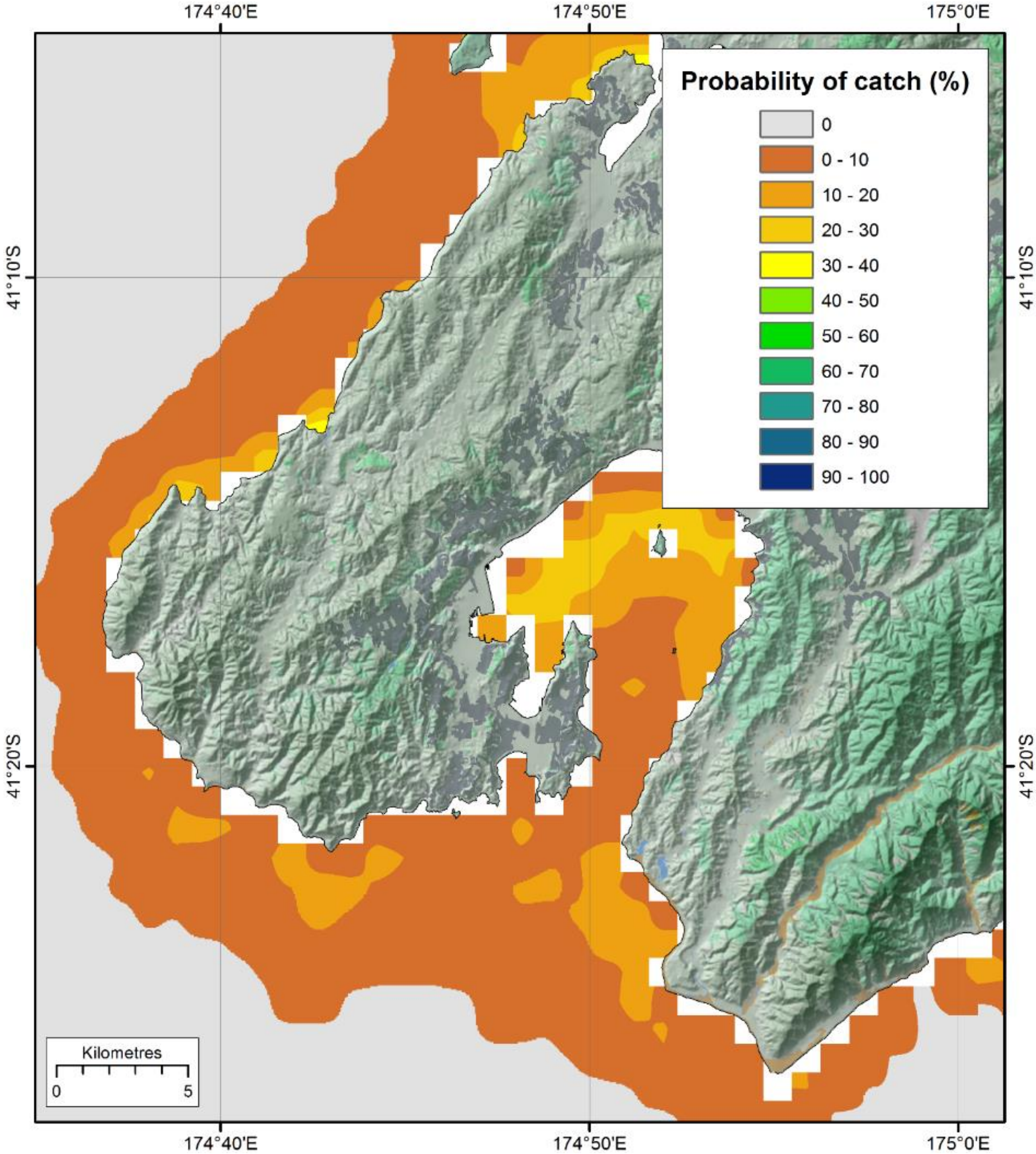


Figure 11-56: Probability of occurrence (%) of kahawai (*Arripis trutta*) in a demersal trawl in the Wellington region.

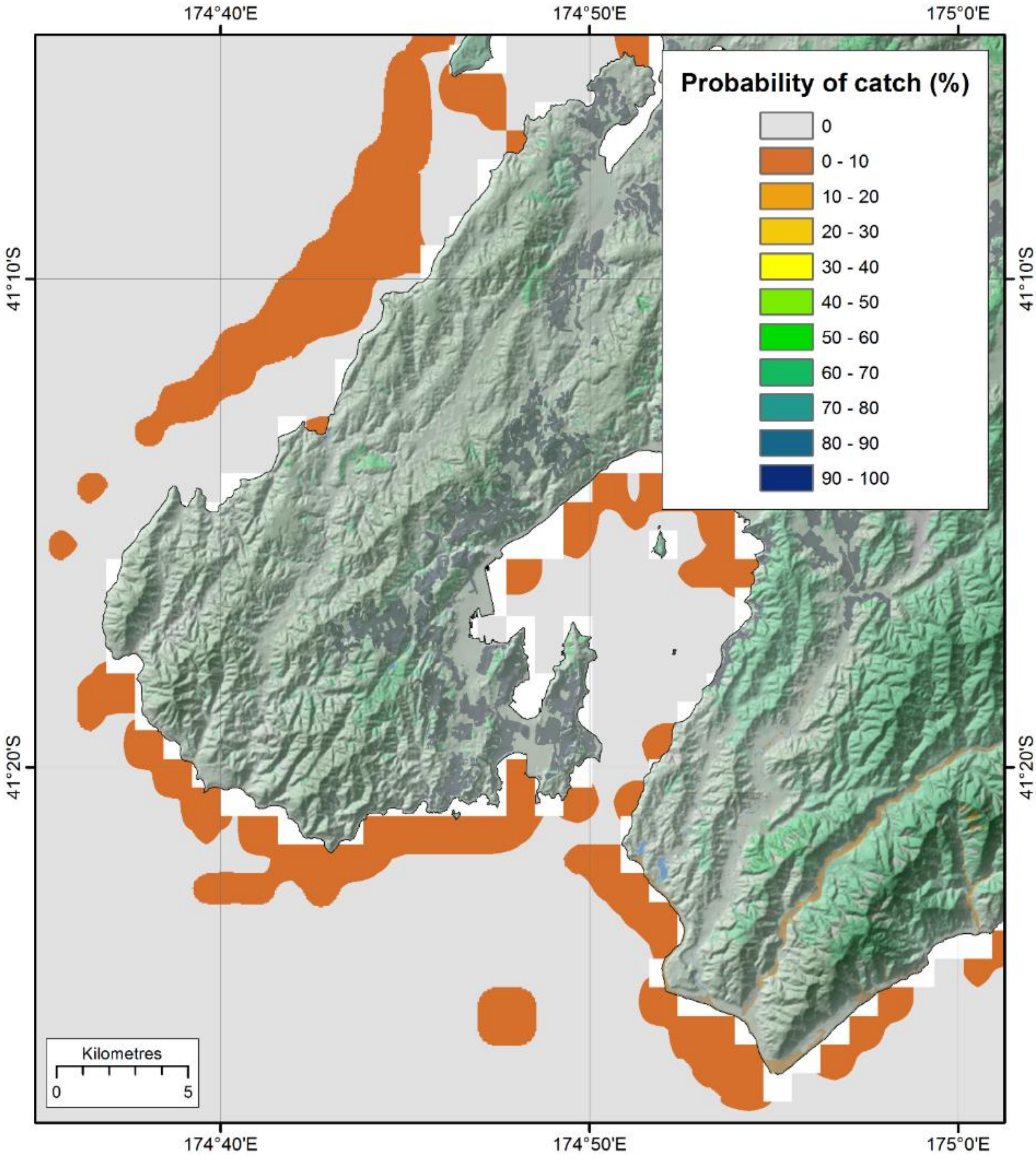


Figure 11-57: Probability of occurrence (%) of kingfish (*Seriola lalandi*) in a demersal trawl in the Wellington region.

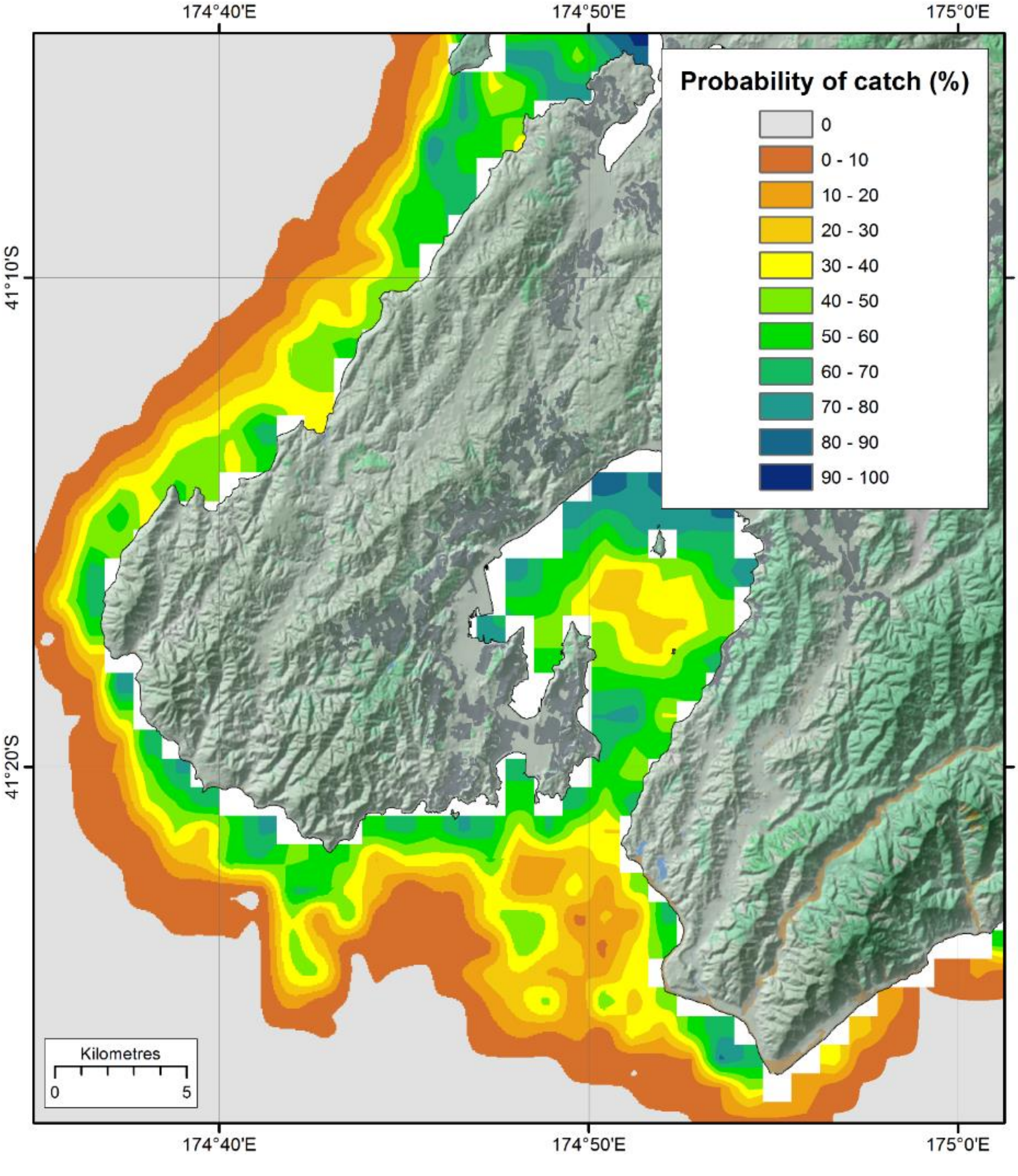


Figure 11-58: Probability of occurrence (%) of leatherjacket (*Meuschenia scaber*) in a demersal trawl in the Wellington region.

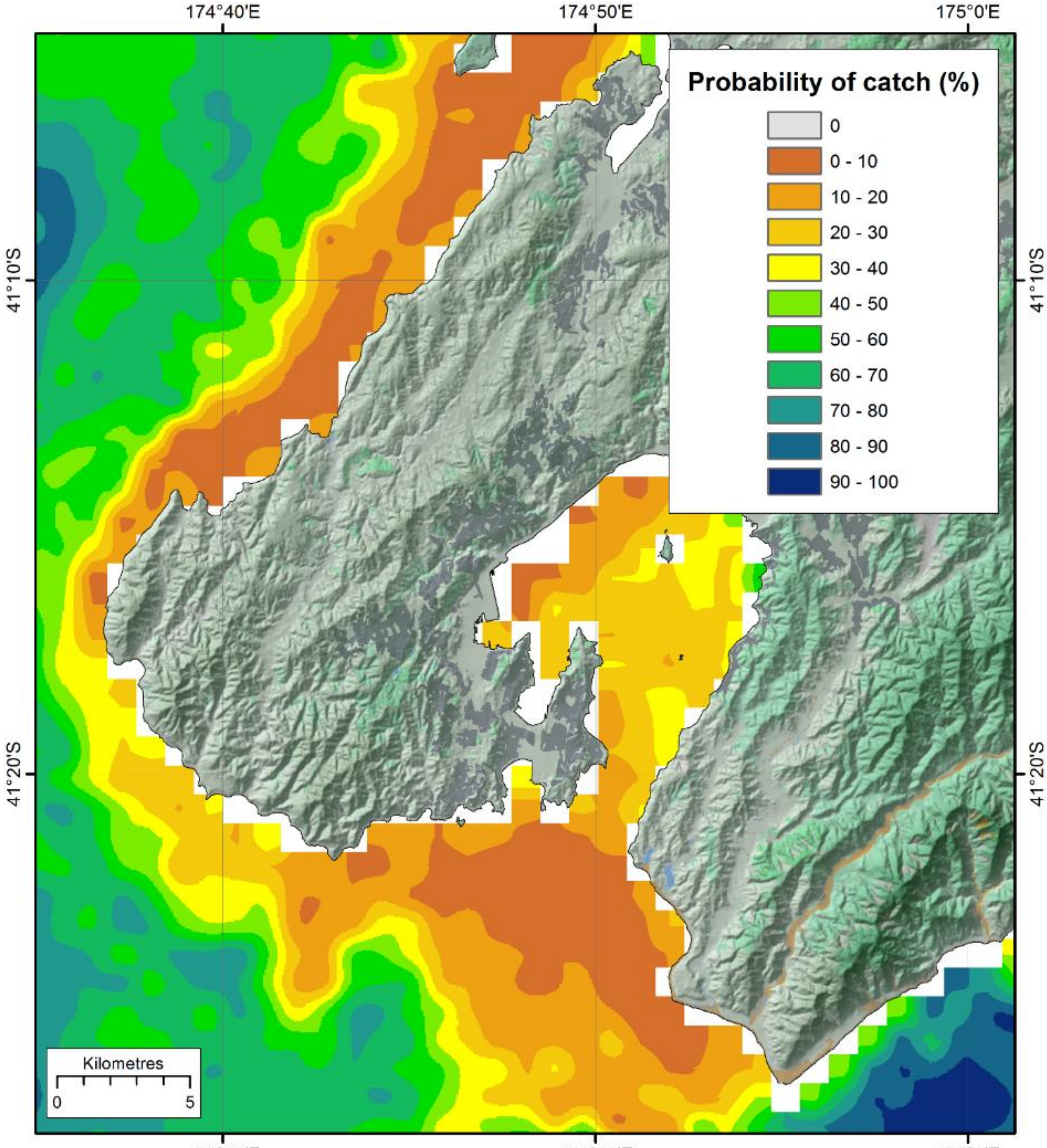


Figure 11-59: Probability of occurrence (%) of ling (*Genypterus blacodes*) in a demersal trawl in the Wellington region.

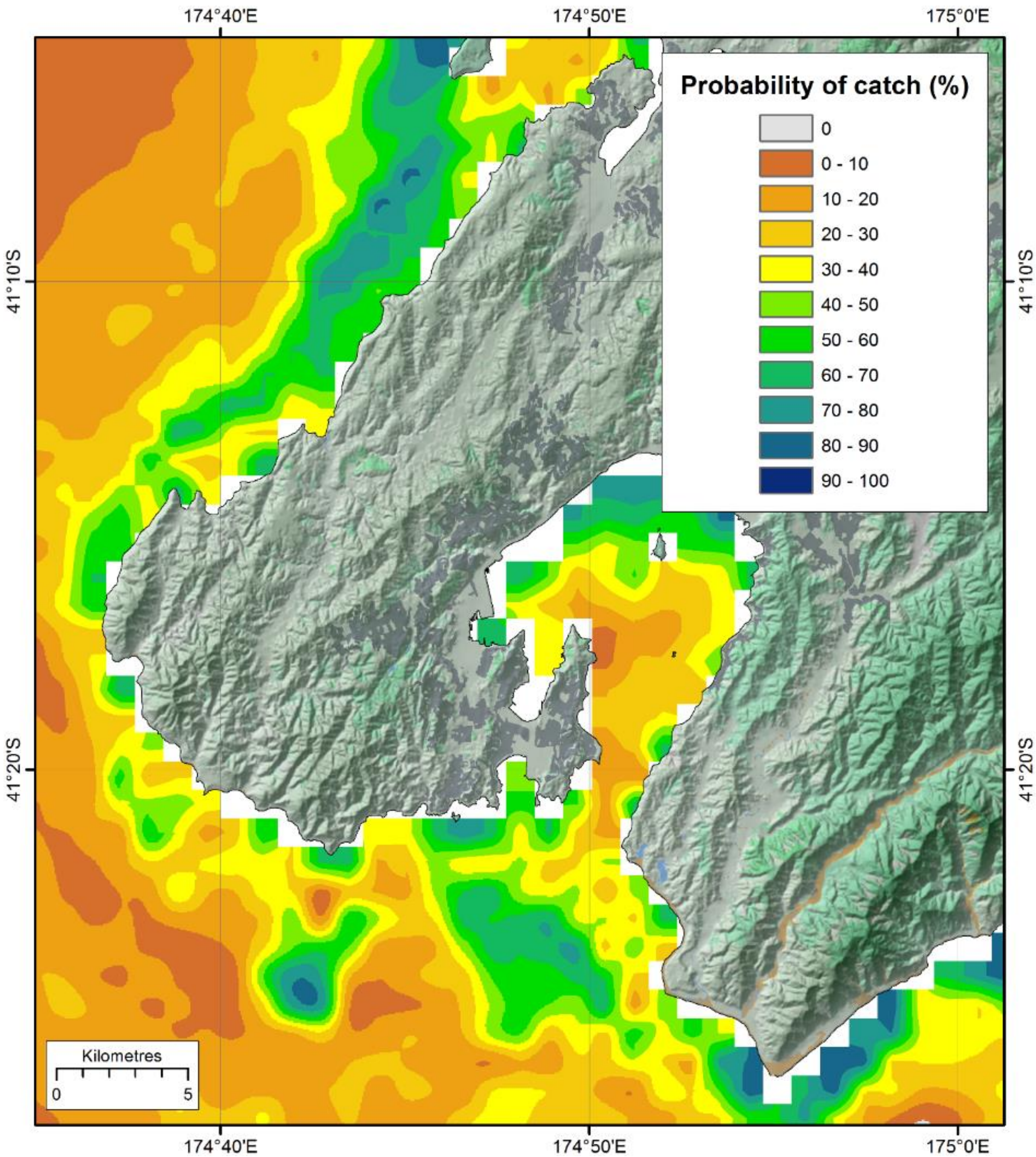


Figure 11-60: Probability of occurrence (%) of lemon sole (*Pelotretis flavilatus*) in a demersal trawl in the Wellington region.

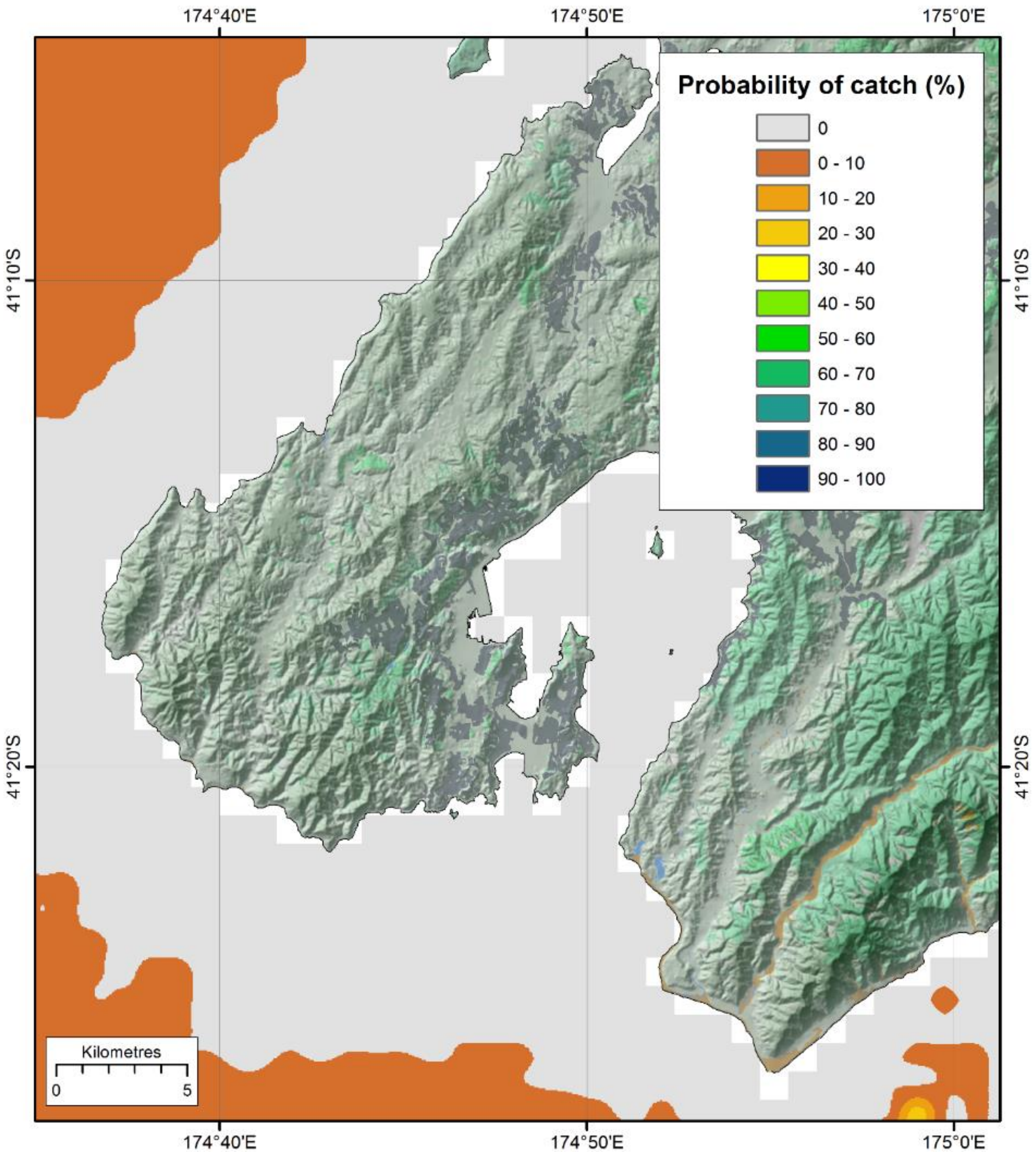


Figure 11-61: Probability of occurrence (%) of northern spiny dogfish (*Squalus griffini*) in a demersal trawl in the Wellington region.

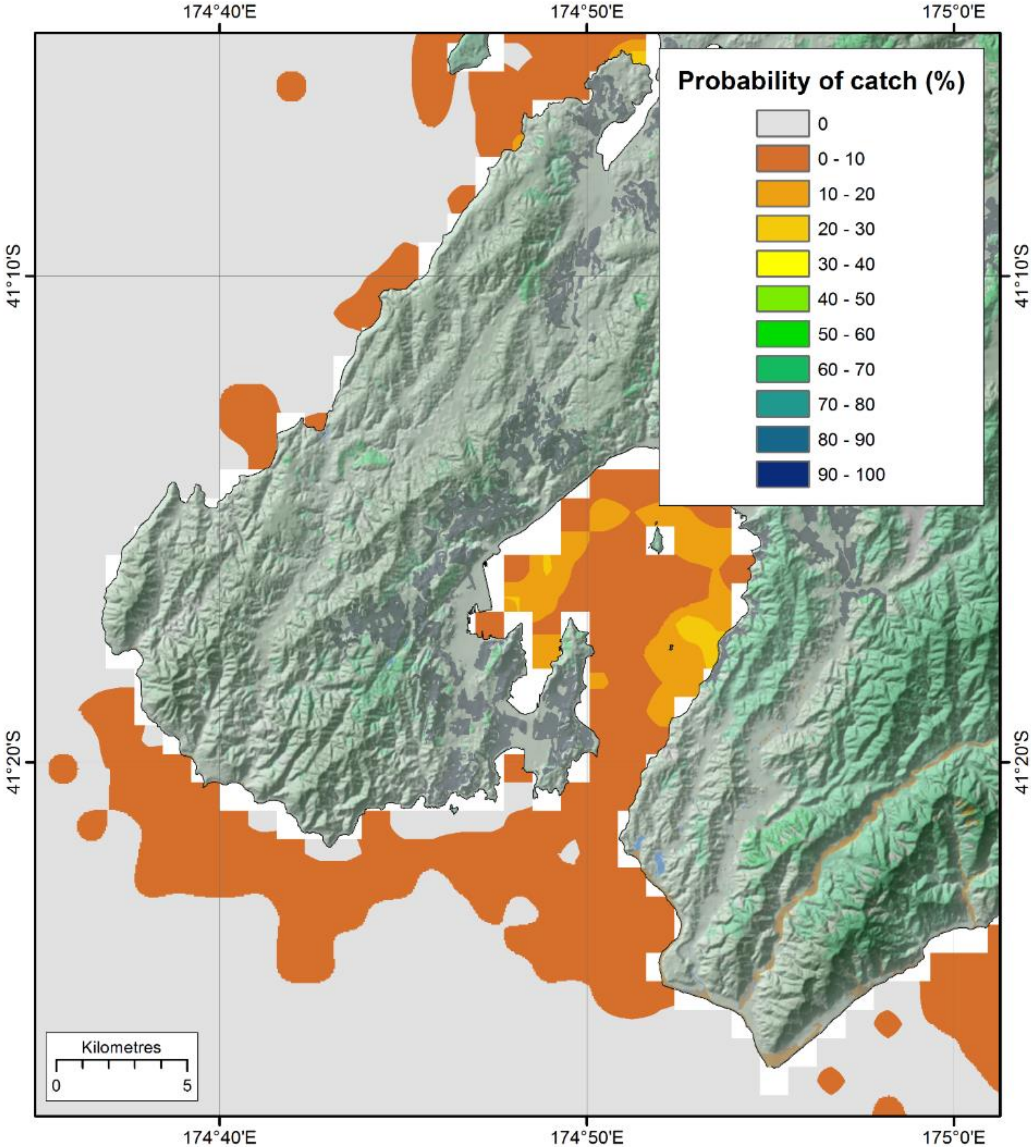


Figure 11-62: Probability of occurrence (%) of ahuru (*Auchenoceros punctatus*) in a demersal trawl in the Wellington region.

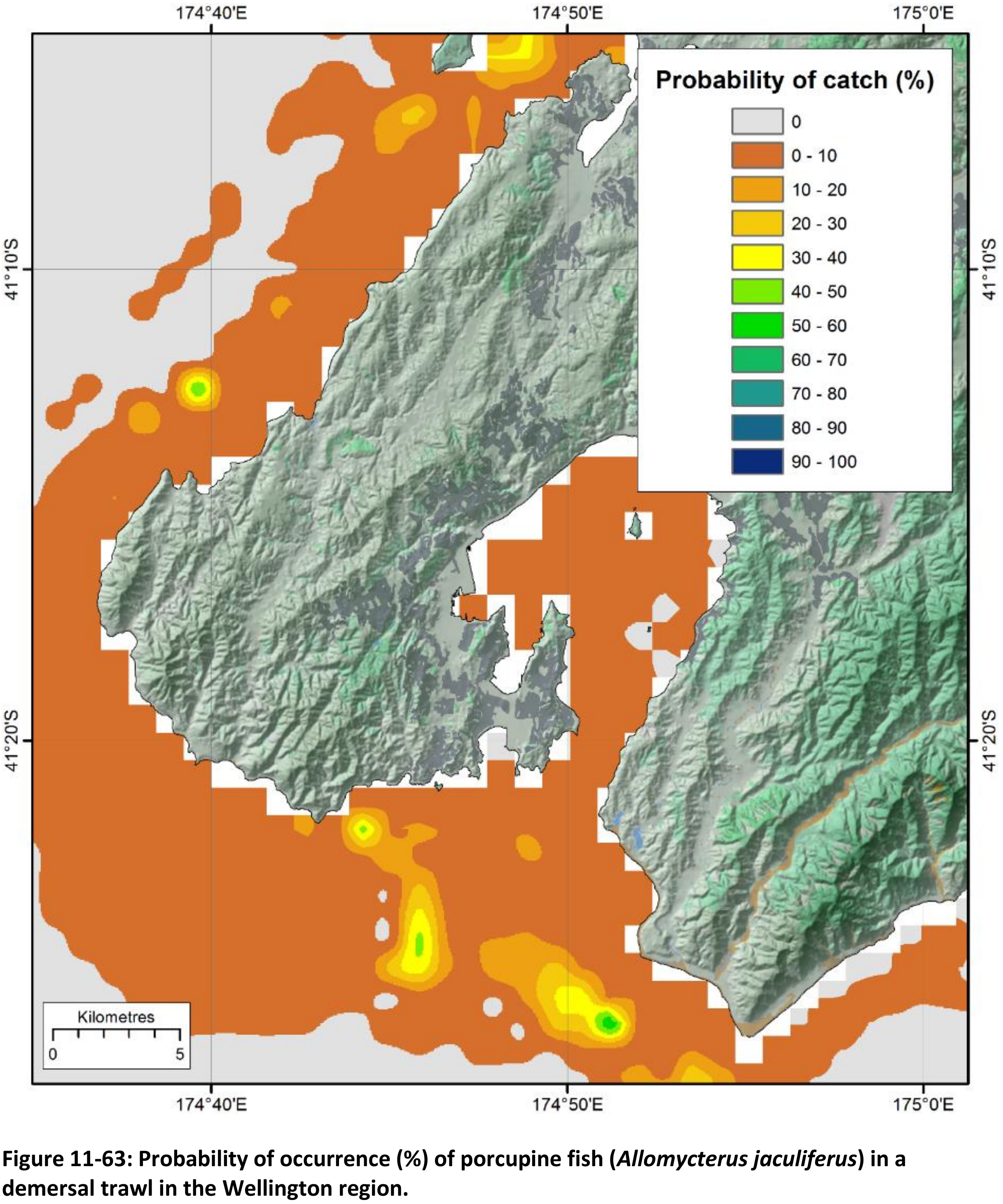


Figure 11-63: Probability of occurrence (%) of porcupine fish (*Allomycterus jaculiferus*) in a demersal trawl in the Wellington region.

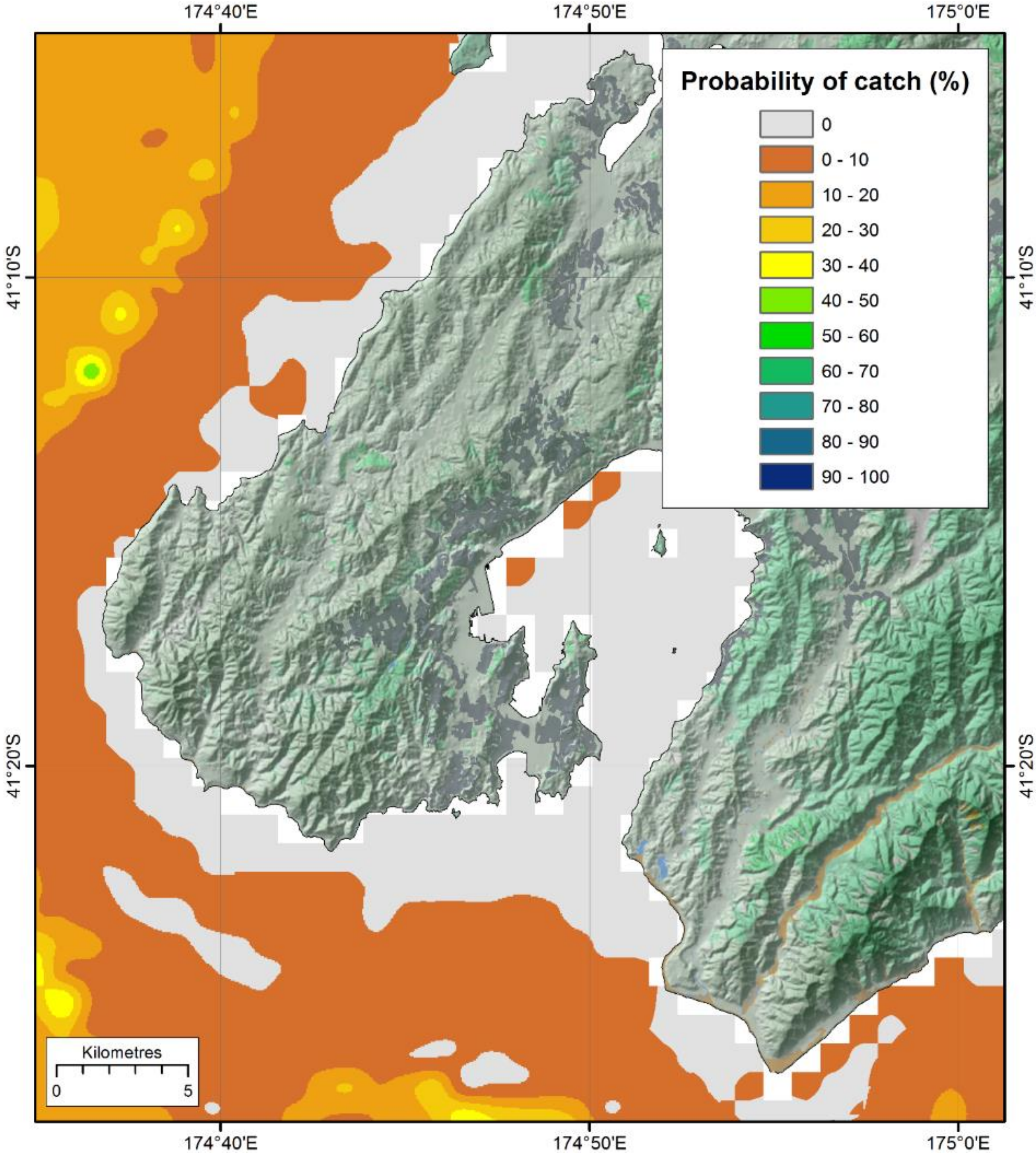


Figure 11-64: Probability of occurrence (%) of Ray's bream (*Brama brama*) in a demersal trawl in the Wellington region.

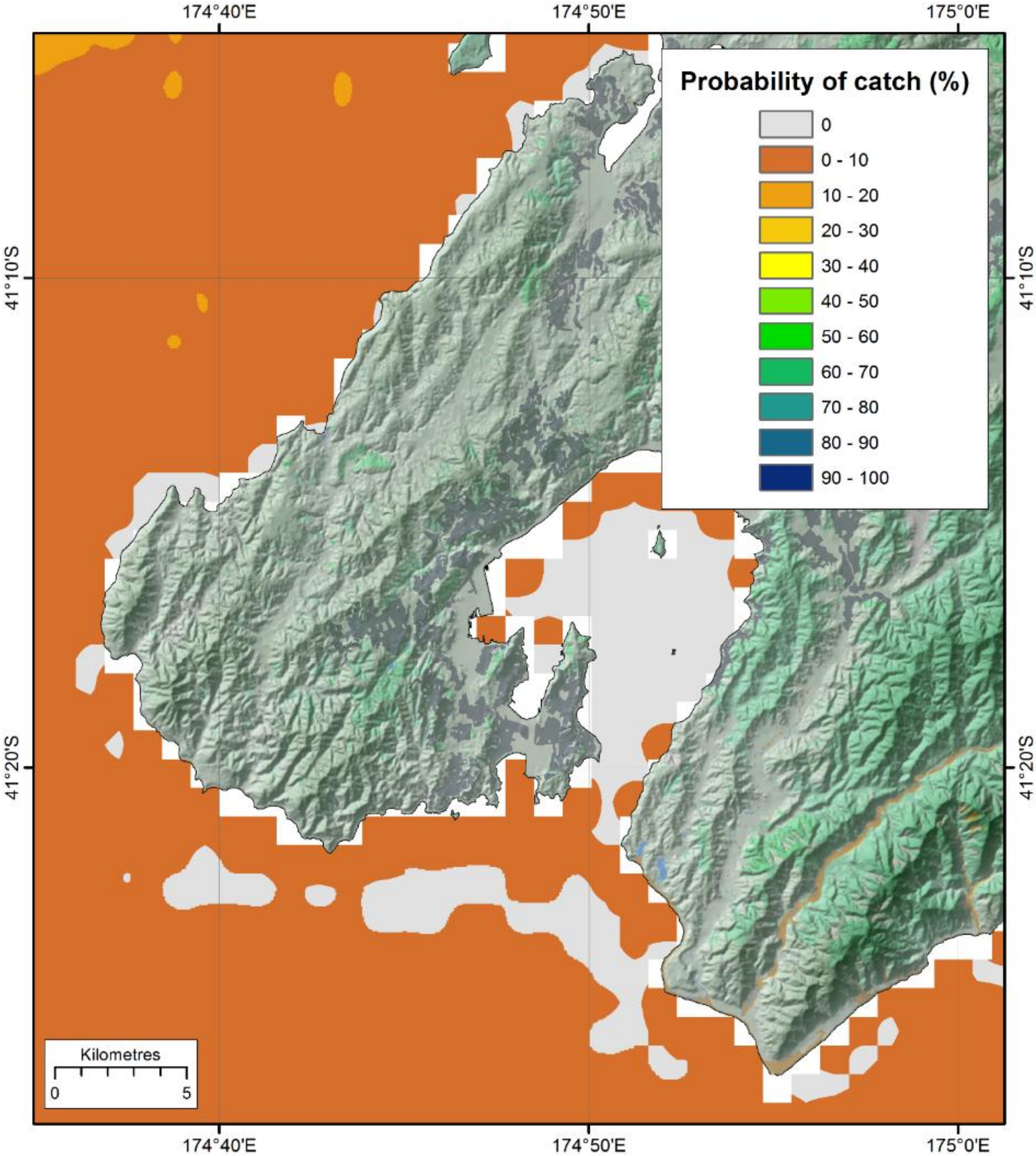


Figure 11-65: Probability of occurrence (%) of redbait (*Emmelichthys nitidus*) in a demersal trawl in the Wellington region.

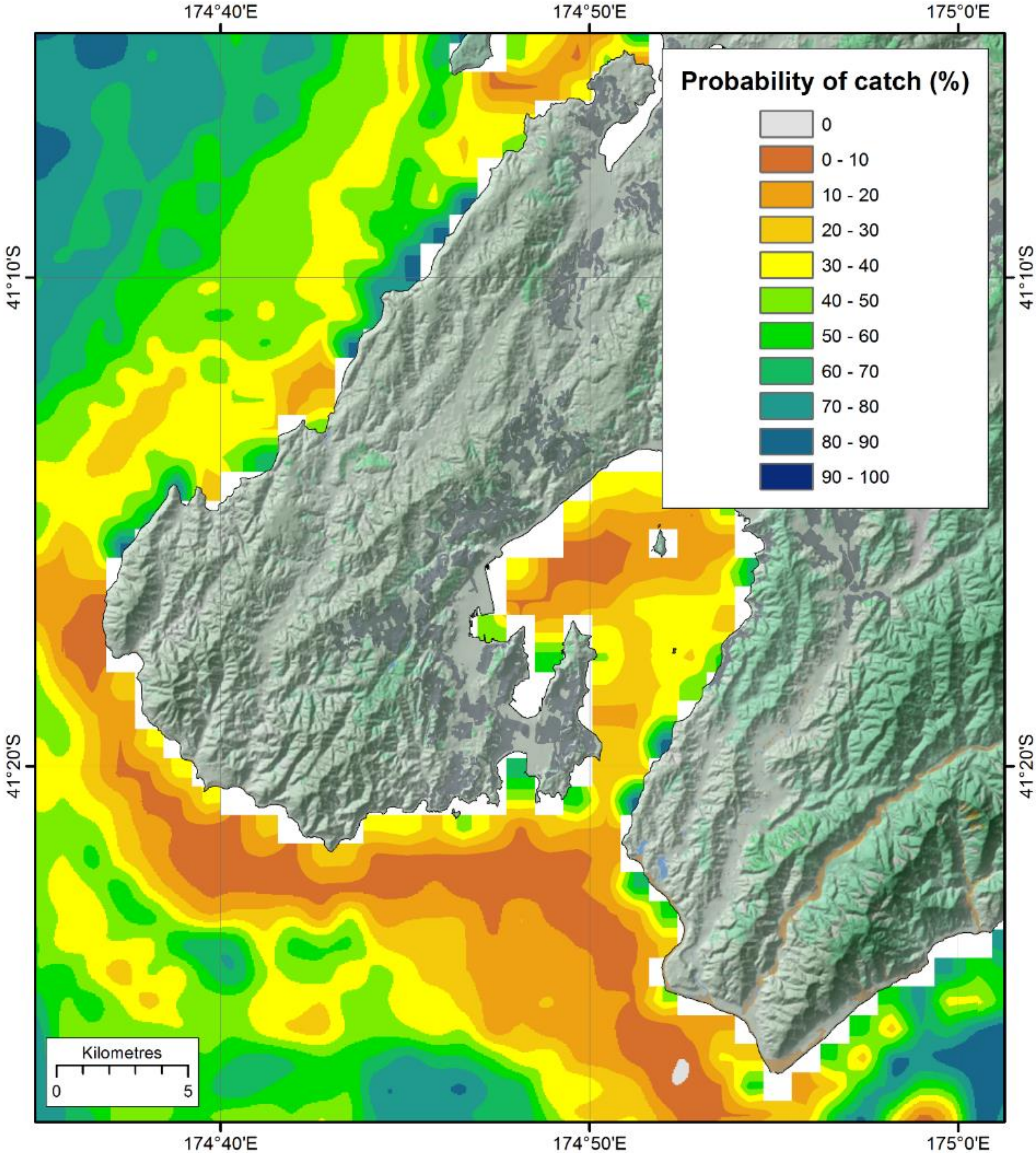


Figure 11-66: Probability of occurrence (%) of red cod (*Pseudophycis bachus*) in a demersal trawl in the Wellington region.

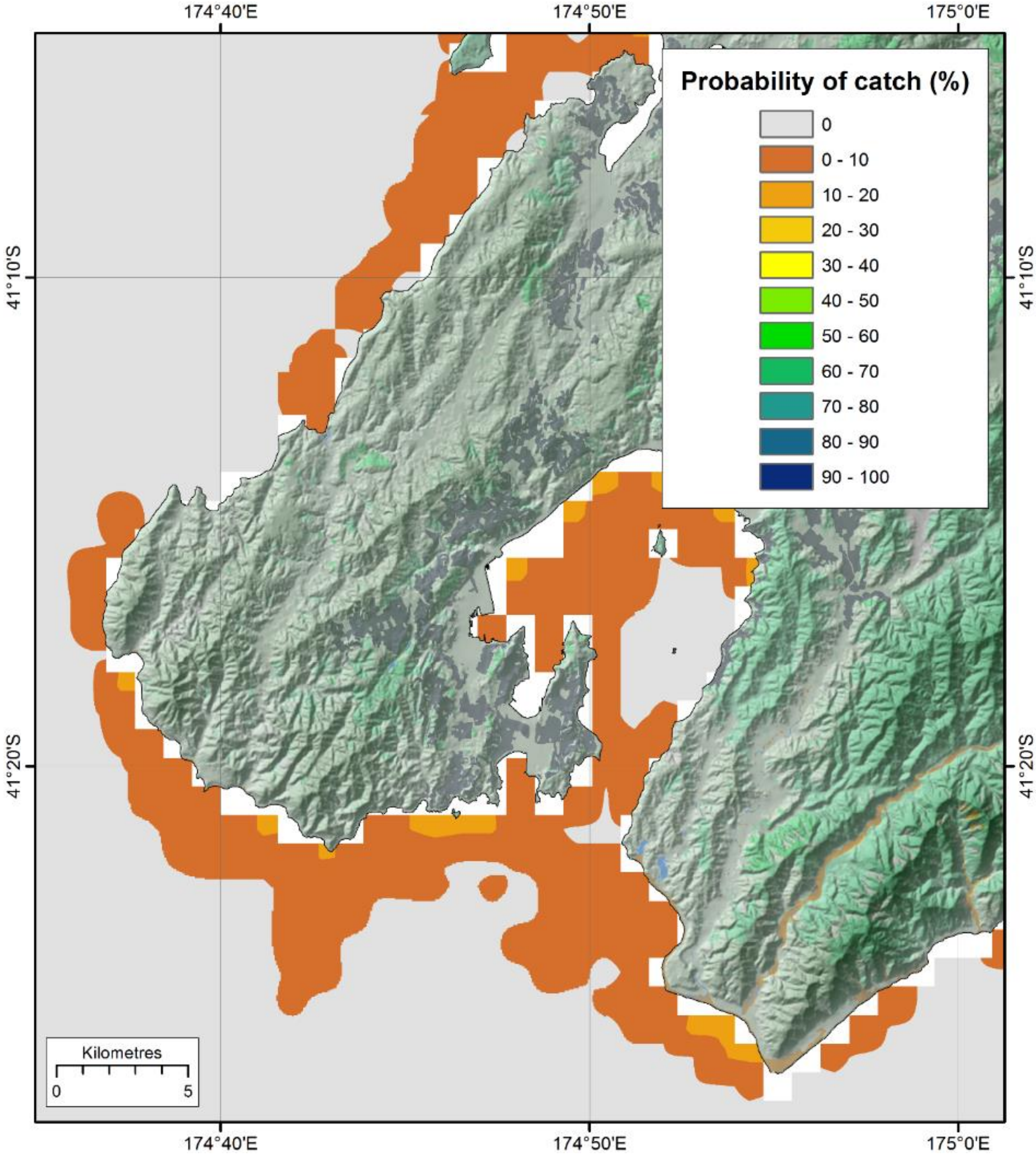


Figure 11-67: Probability of occurrence (%) of red mullet (*Upeneichthys lineatus*) in a demersal trawl in the Wellington region.

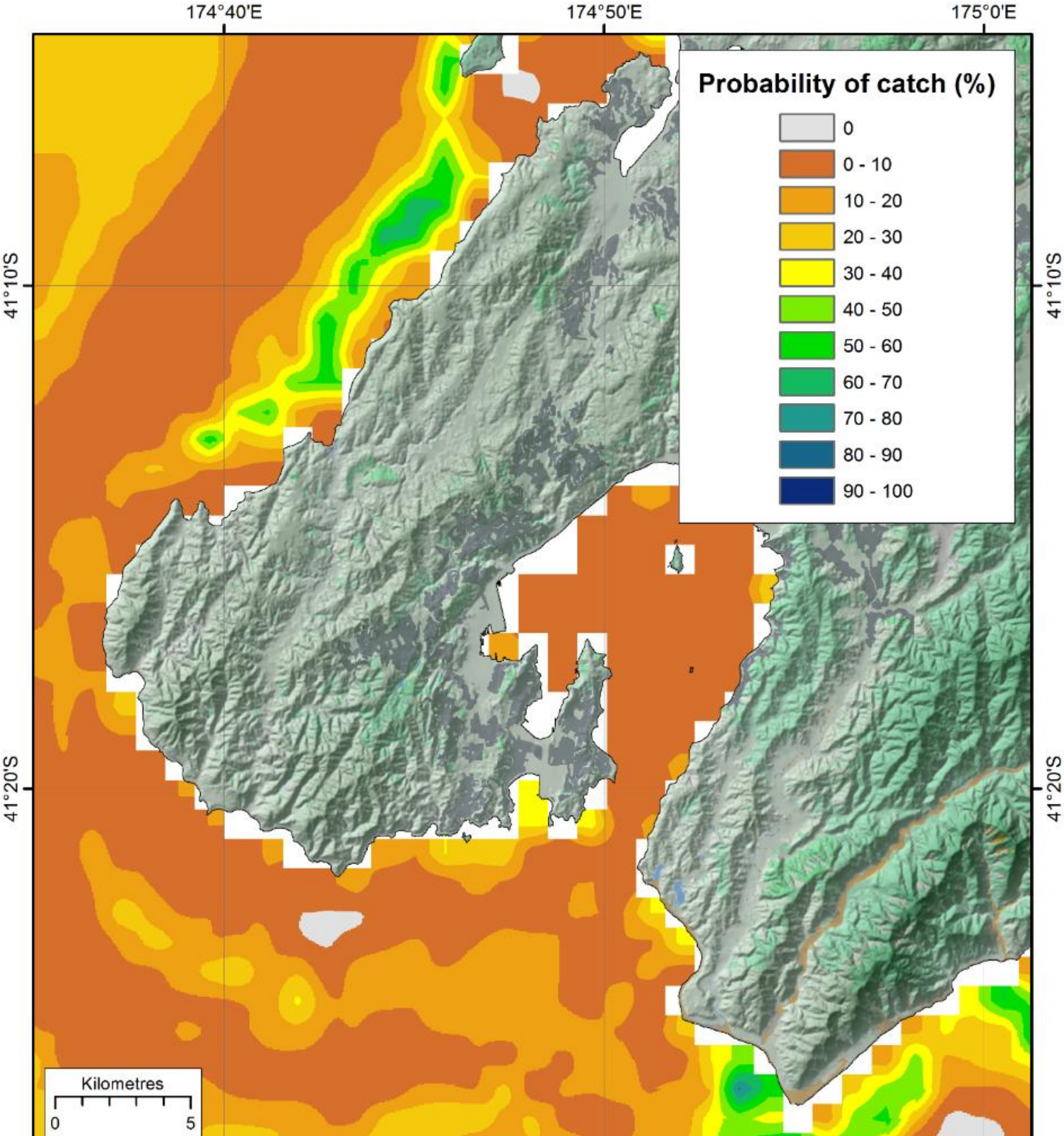


Figure 11-68: Probability of occurrence (%) of scaly gurnard (*Lepidotrigla brachyoptera*) in a demersal trawl in the Wellington region.

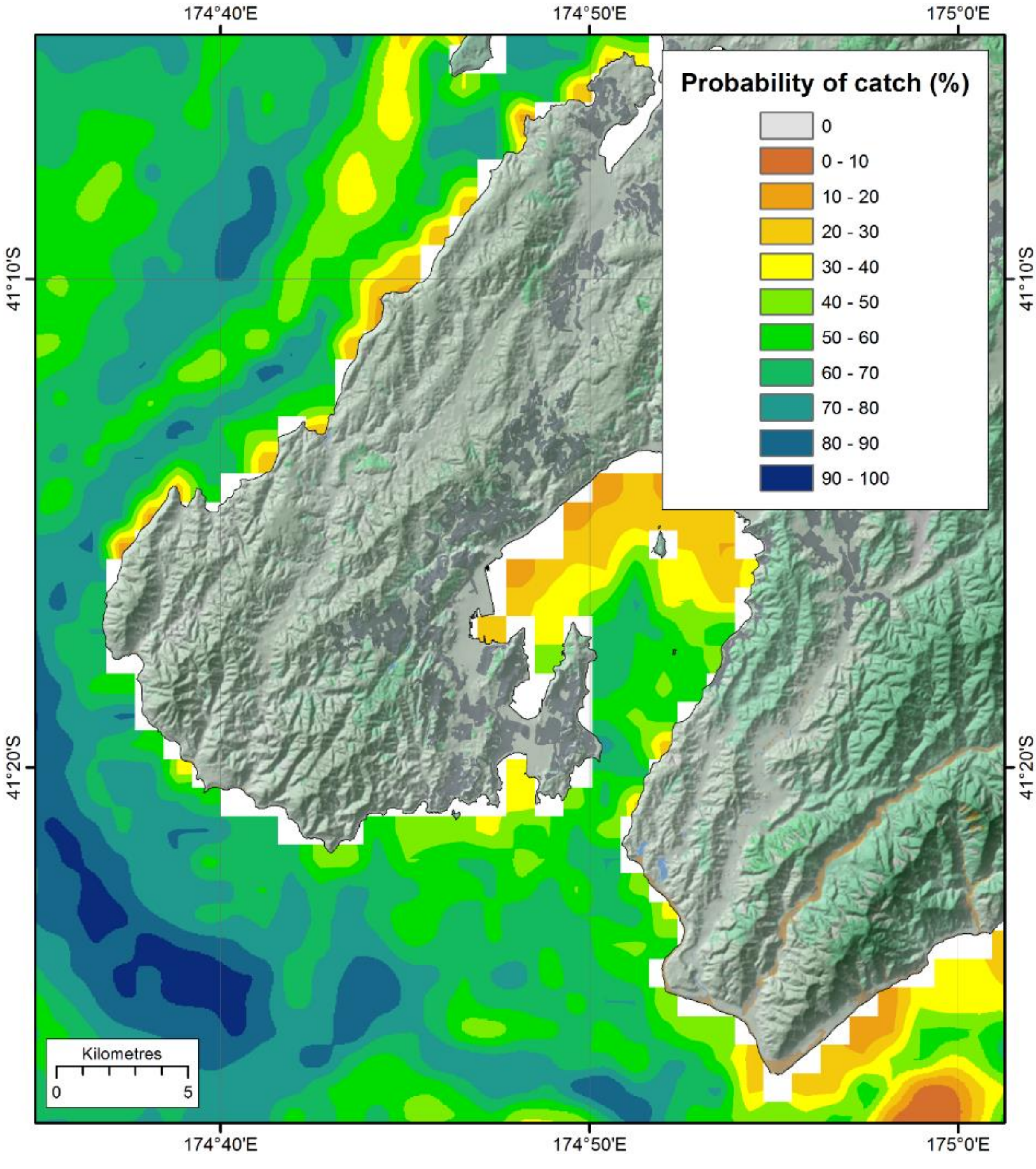


Figure 11-69: Probability of occurrence (%) of school shark (*Galeorhinus galeus*) in a demersal trawl in the Wellington region.

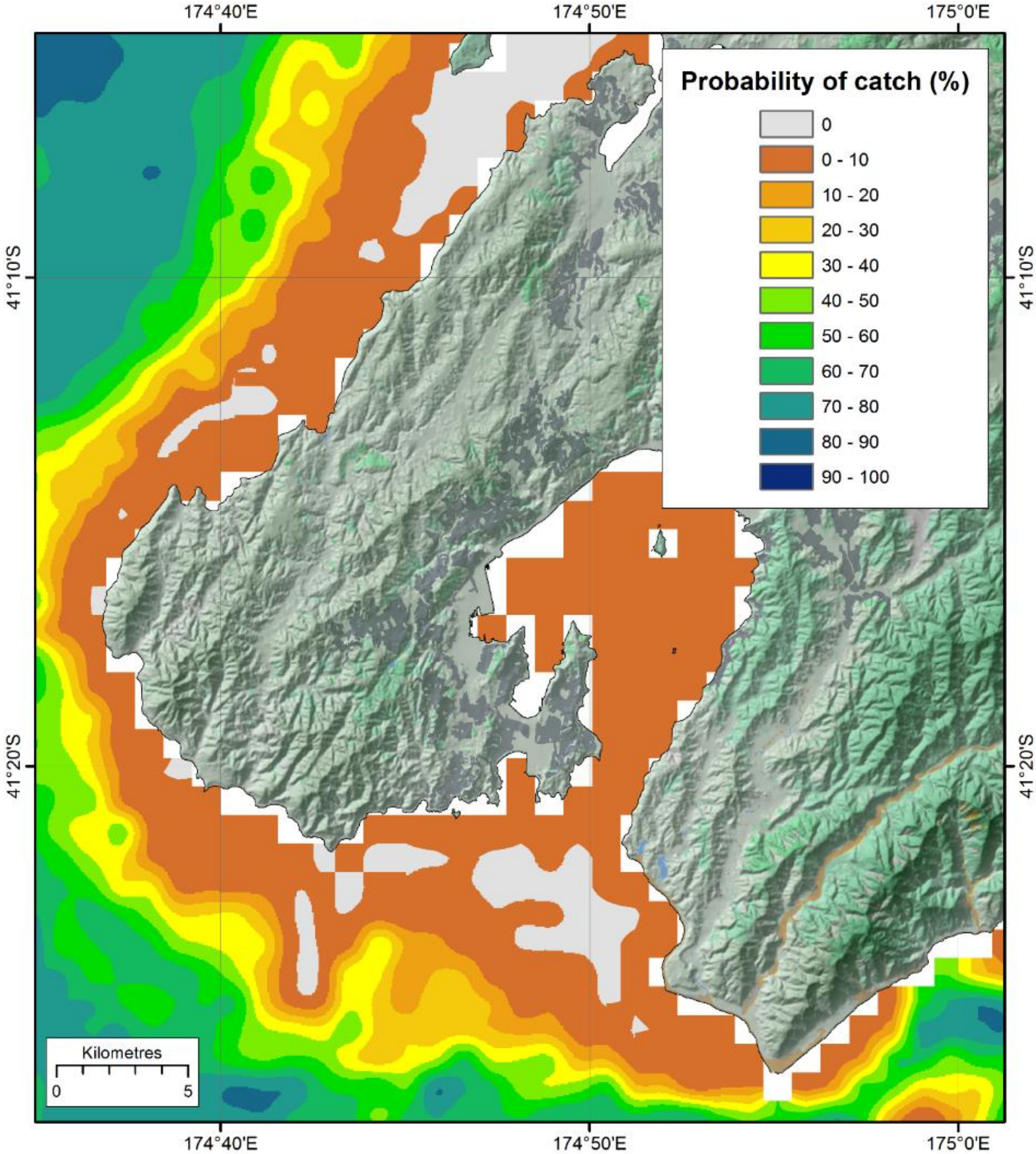


Figure 11-70: Probability of occurrence (%) of silver dory (*Cyttus novaezealandiae*) in a demersal trawl in the Wellington region.

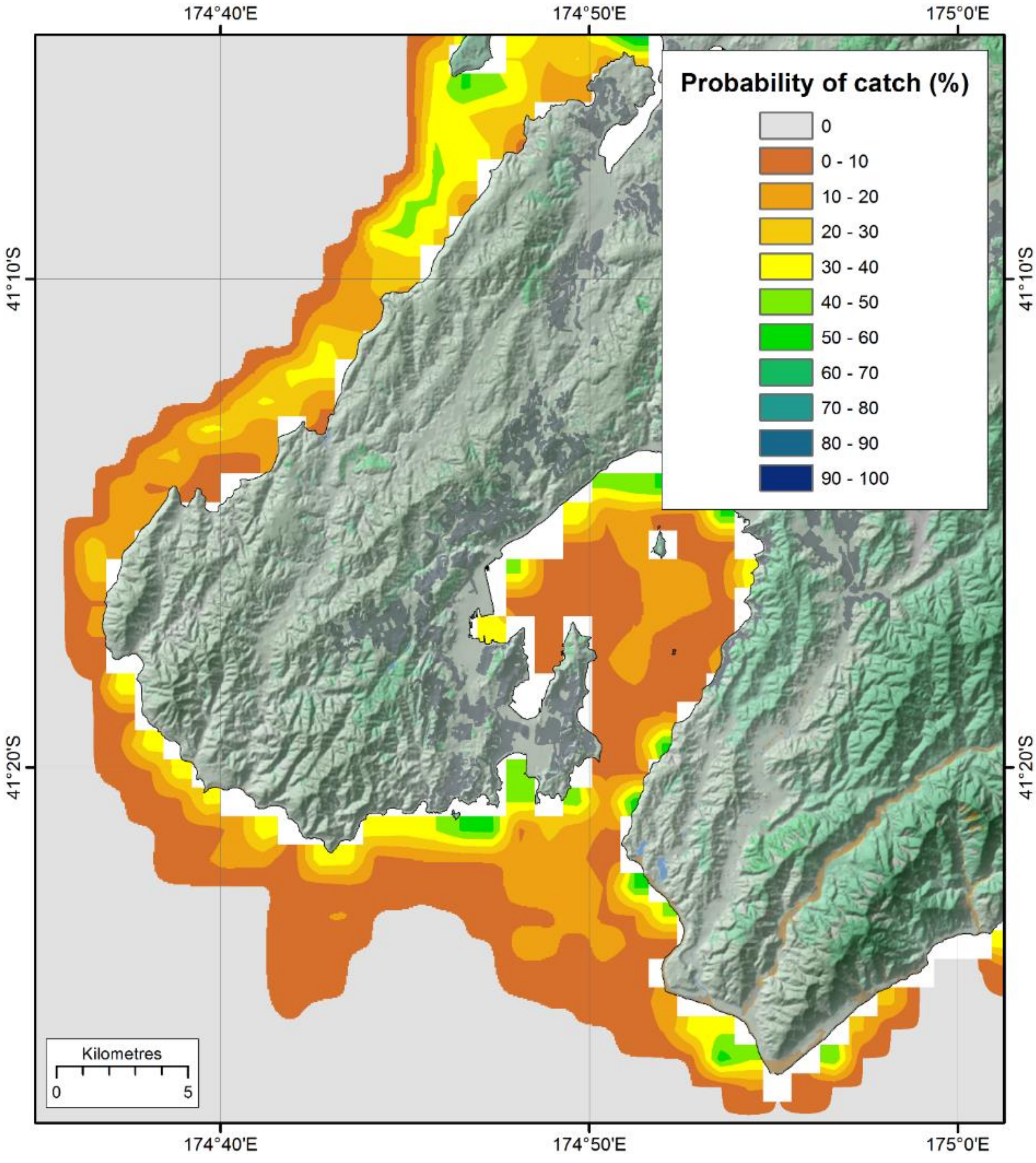


Figure 11-71: Probability of occurrence (%) of sand flounder (*Phombosolea plebeia*) in a demersal trawl in the Wellington region.

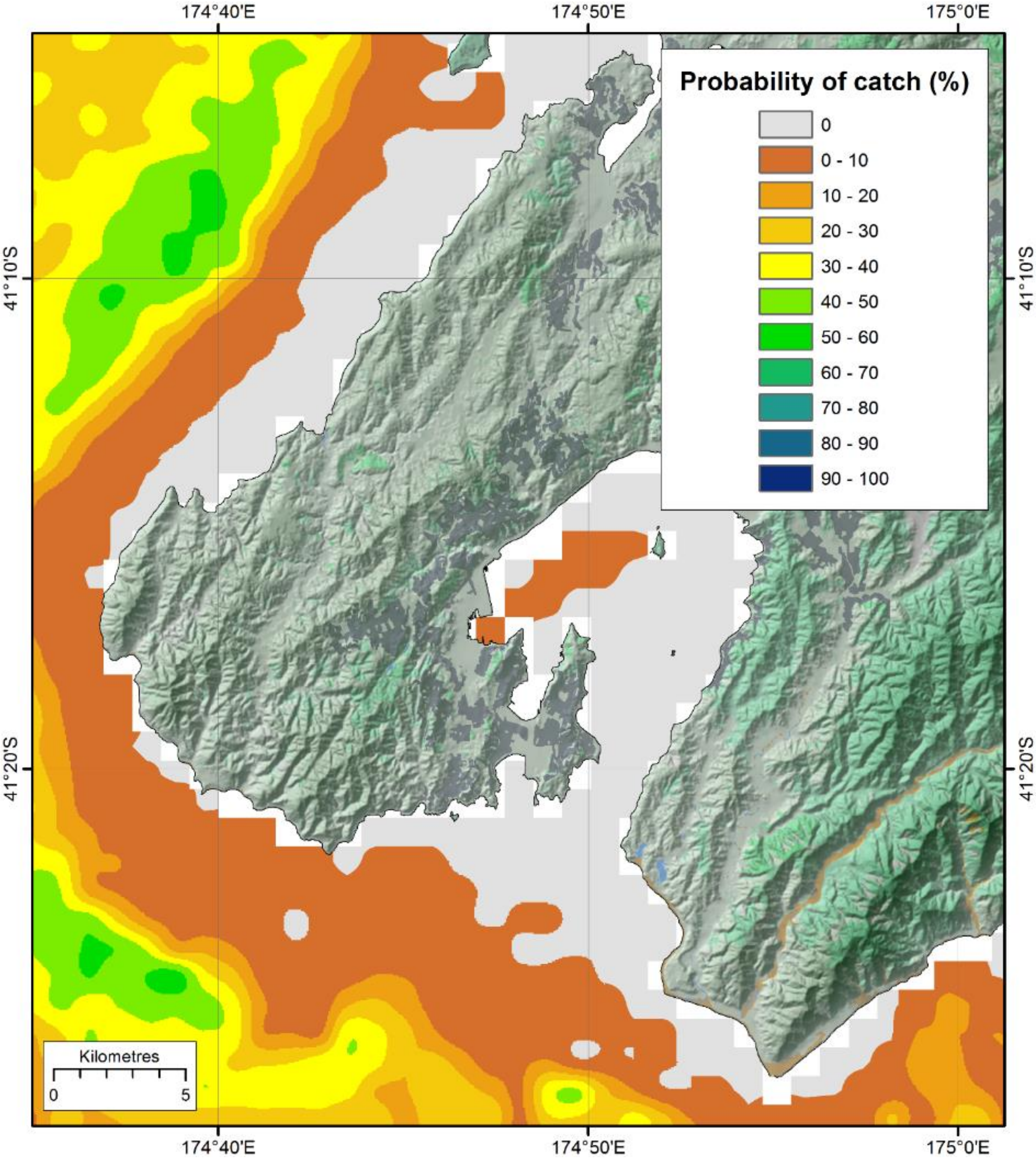


Figure 11-72: Probability of occurrence (%) of gemfish (*Rexea solandri*) in a demersal trawl in the Wellington region.

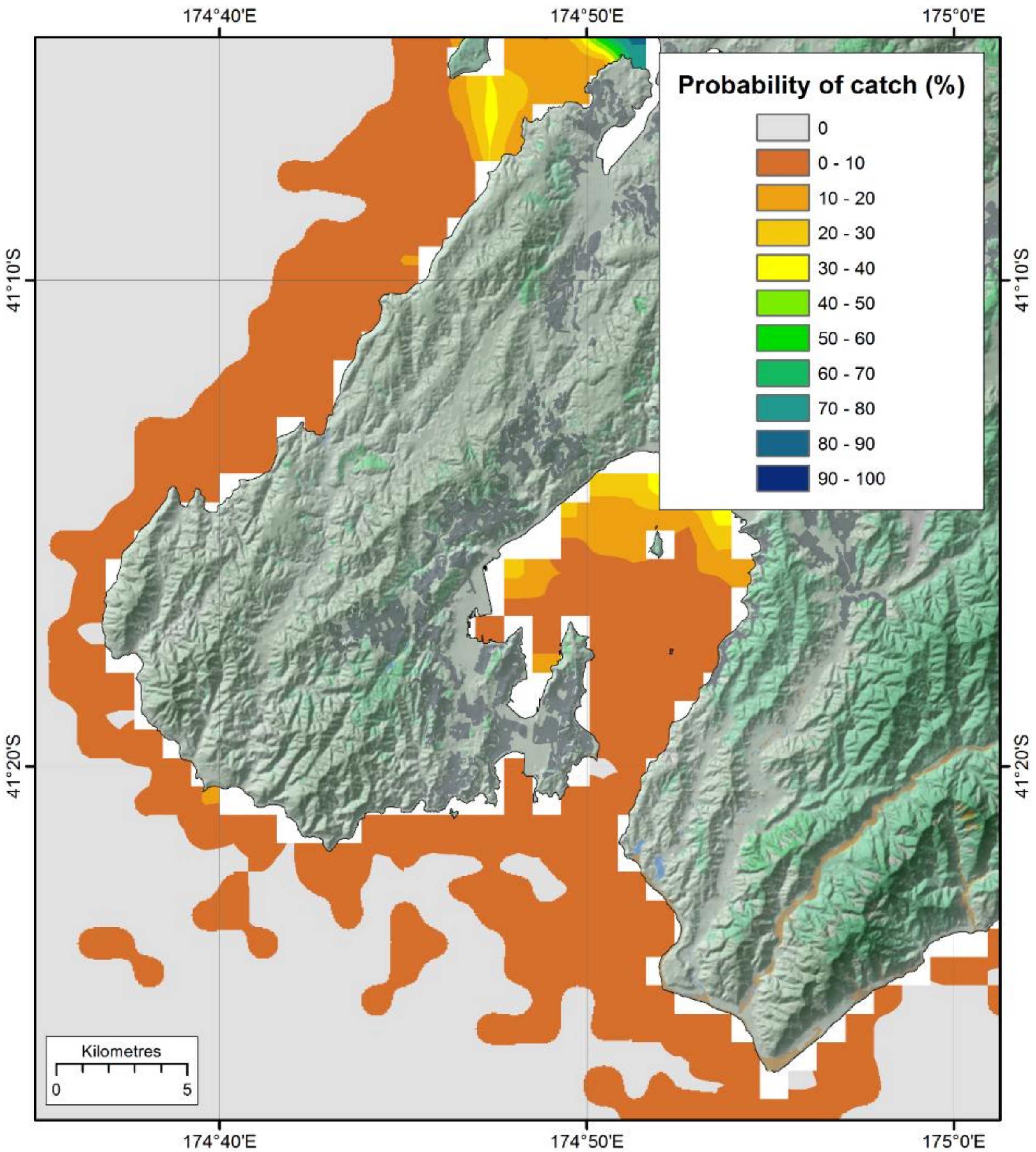


Figure 11-73: Probability of occurrence (%) of snapper (*Pagrus auratus*) in a demersal trawl in the Wellington region.

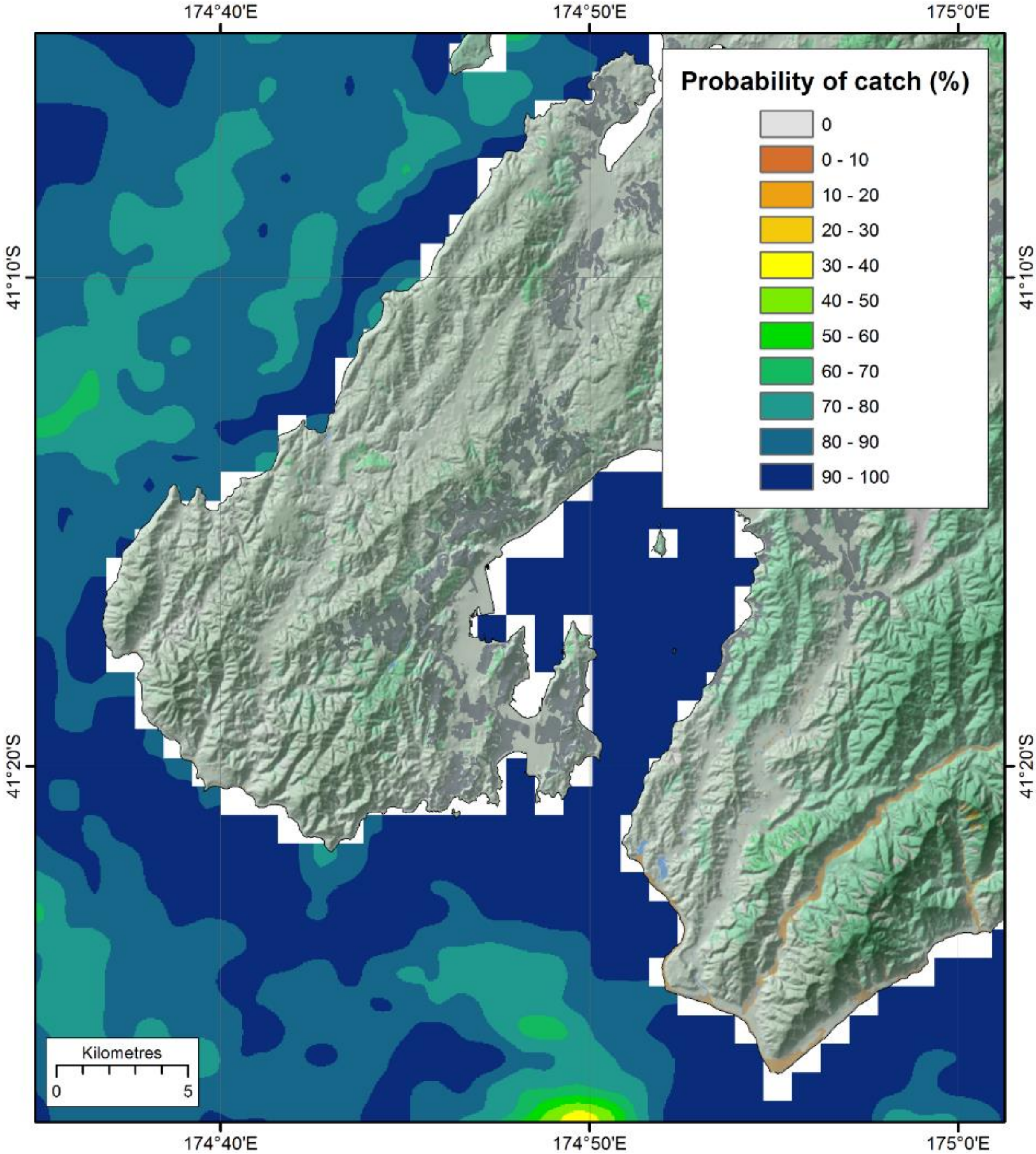


Figure 11-74: Probability of occurrence (%) of spiny dogfish (*Squalus acanthias*) in a demersal trawl in the Wellington region.

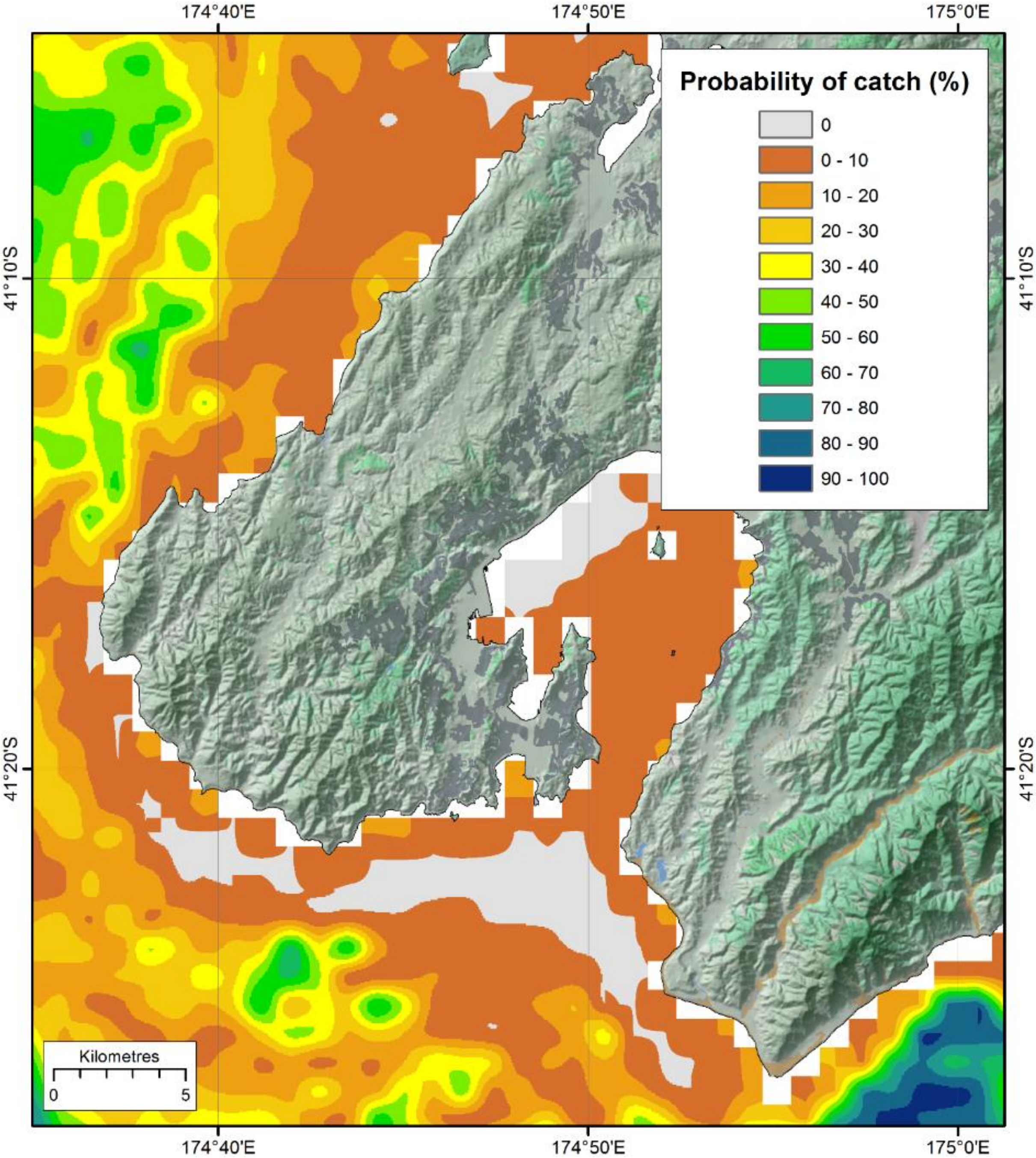


Figure 11-75: Probability of occurrence (%) of sea perch (*Helicolenus spp*.) in a demersal trawl in the Wellington region.

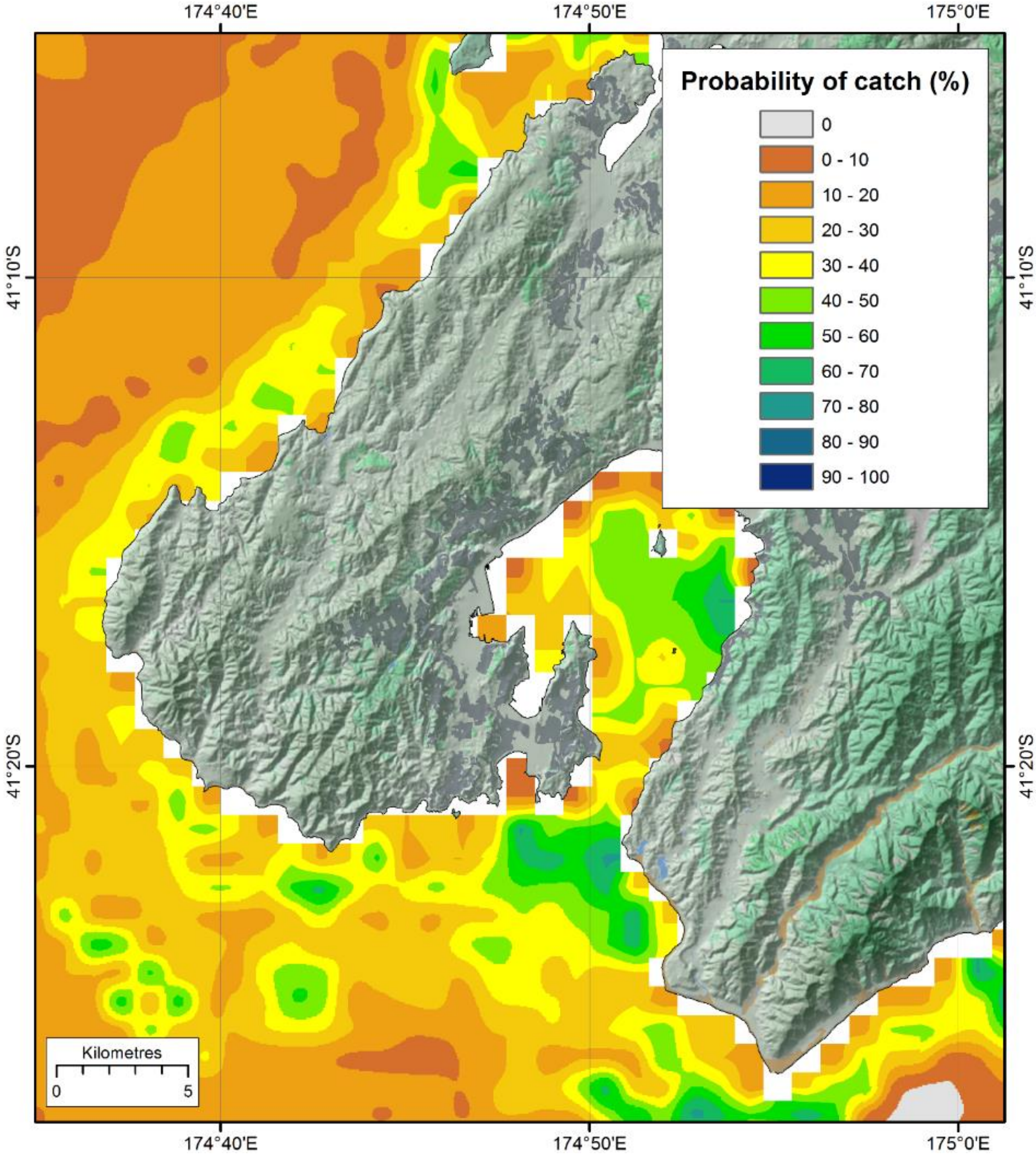


Figure 11-76: Probability of occurrence (%) of rig (*Mustelus lenticulatus*) in a demersal trawl in the Wellington region.

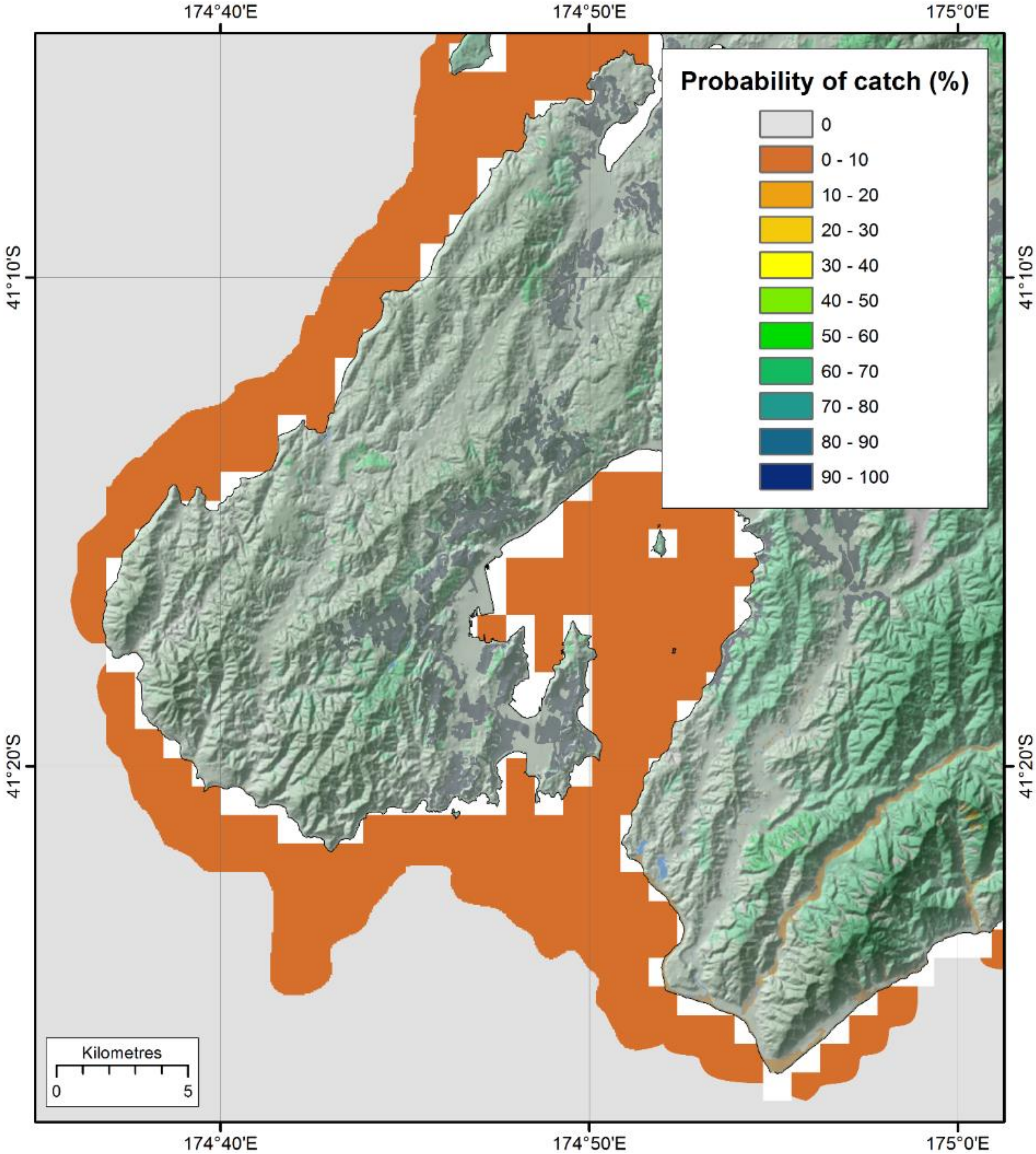


Figure 11-77: Probability of occurrence (%) of spotted stargazer (*Genyagnus monopterygius*) in a demersal trawl in the Wellington region.

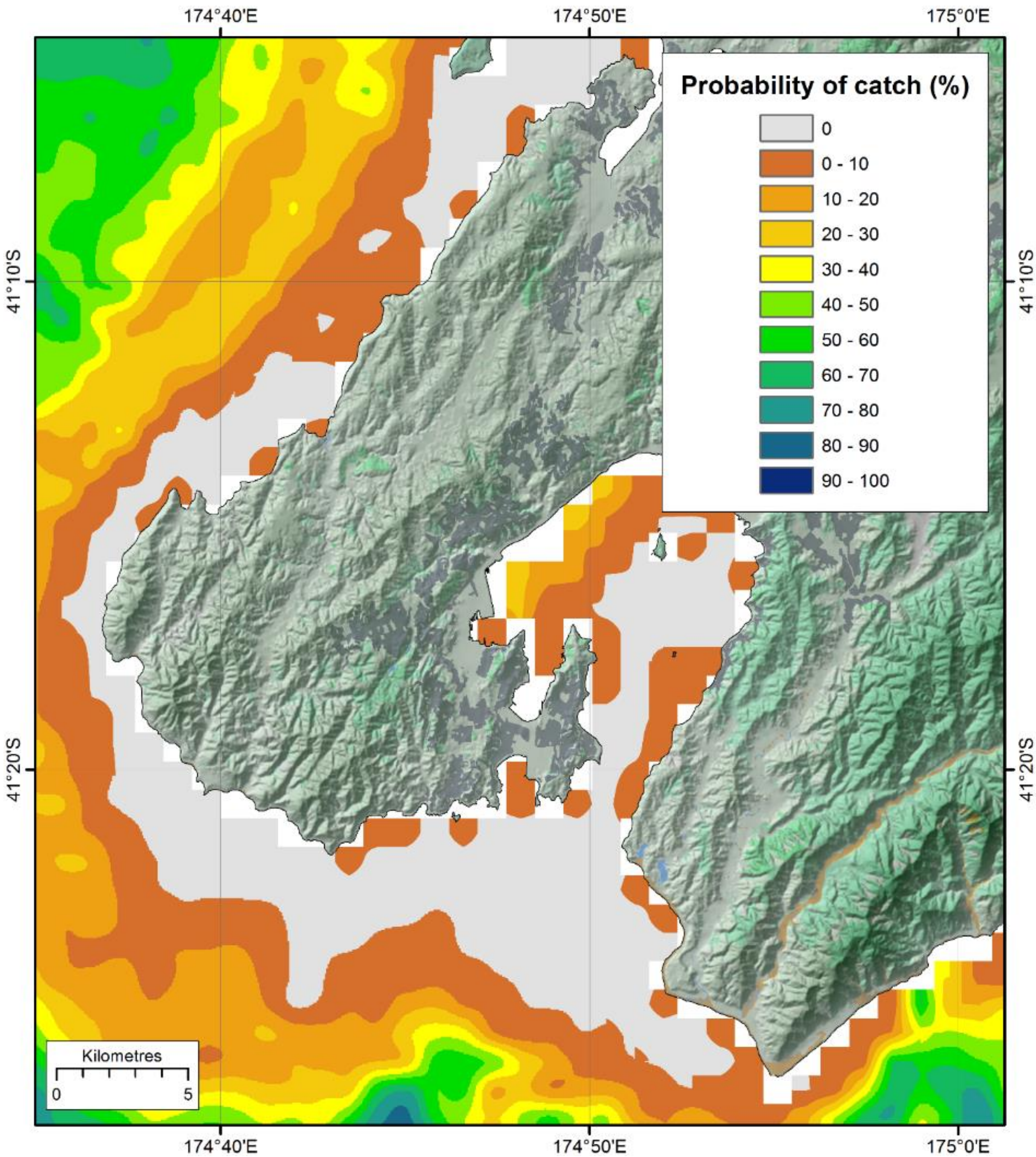


Figure 11-78: Probability of occurrence (%) of silverside (*Argentina elongata*) in a demersal trawl in the Wellington region.

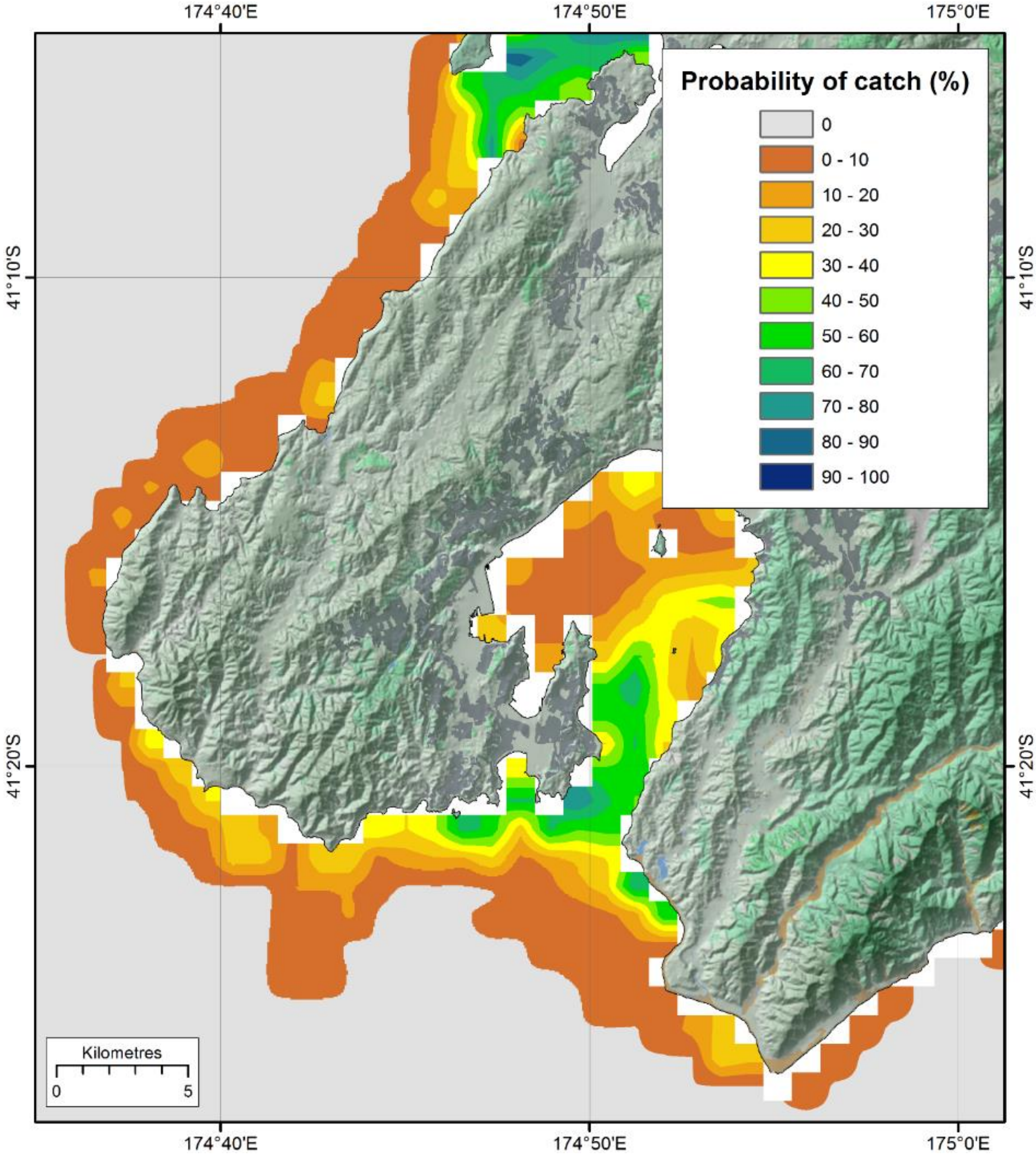


Figure 11-79: Probability of occurrence (%) of spotty (*Notolabrus celidotus*) in a demersal trawl in the Wellington region.

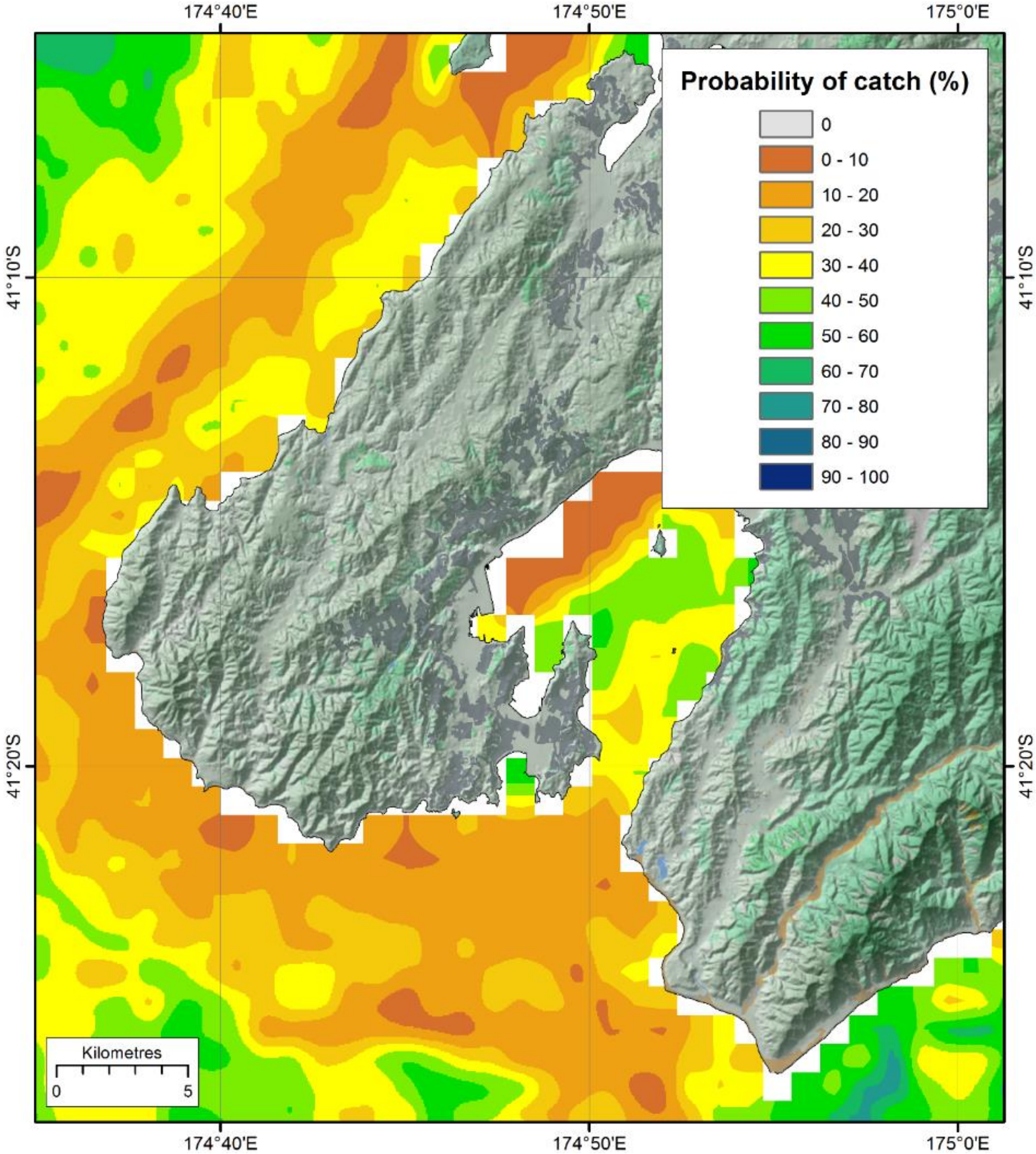


Figure 11-80: Probability of occurrence (%) of silver warehou (*Seriolella punctata*) in a demersal trawl in the Wellington region.

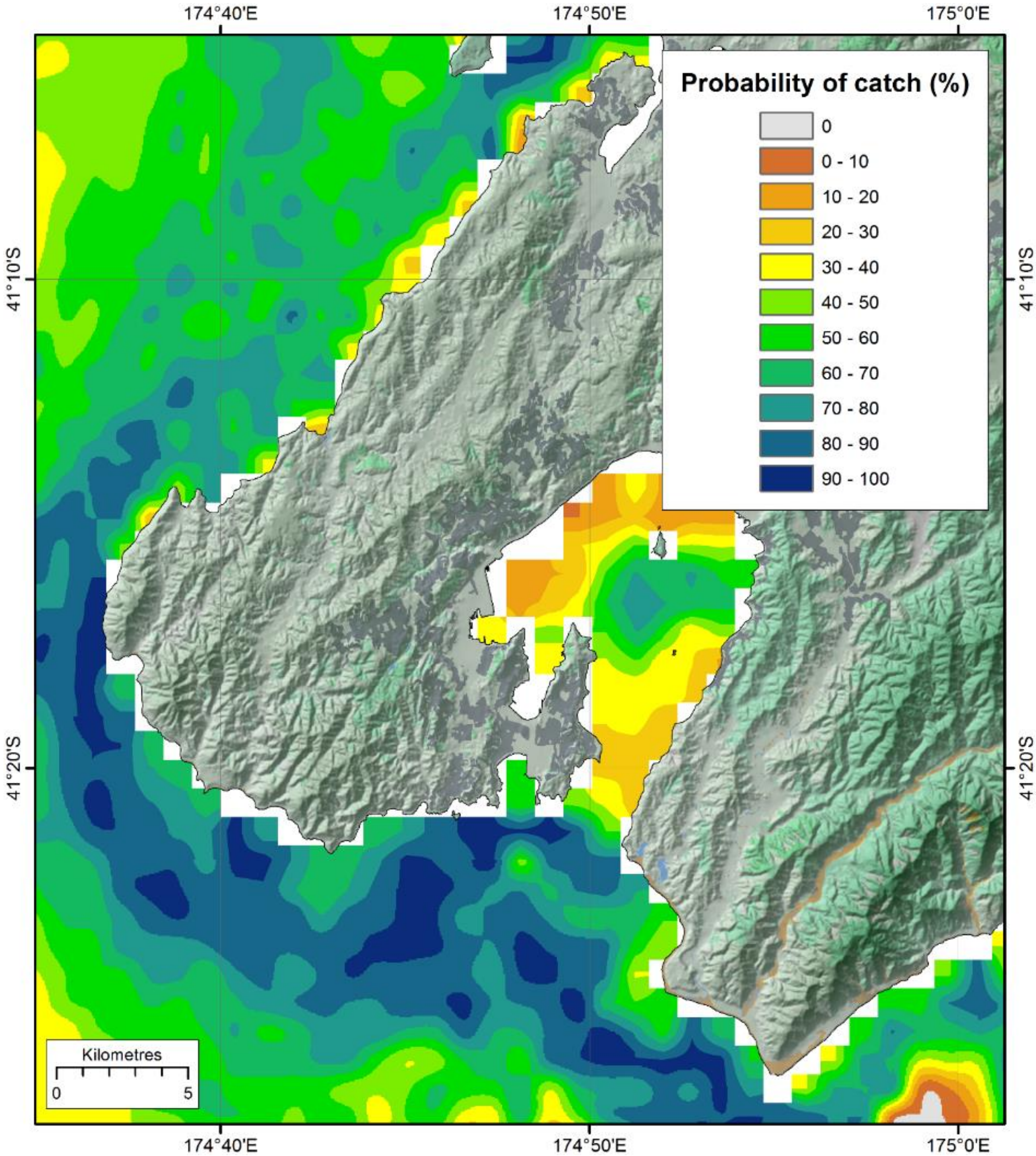


Figure 11-81: Probability of occurrence (%) of tarakihi (*Nemadactylus macropterus*) in a demersal trawl in the Wellington region.

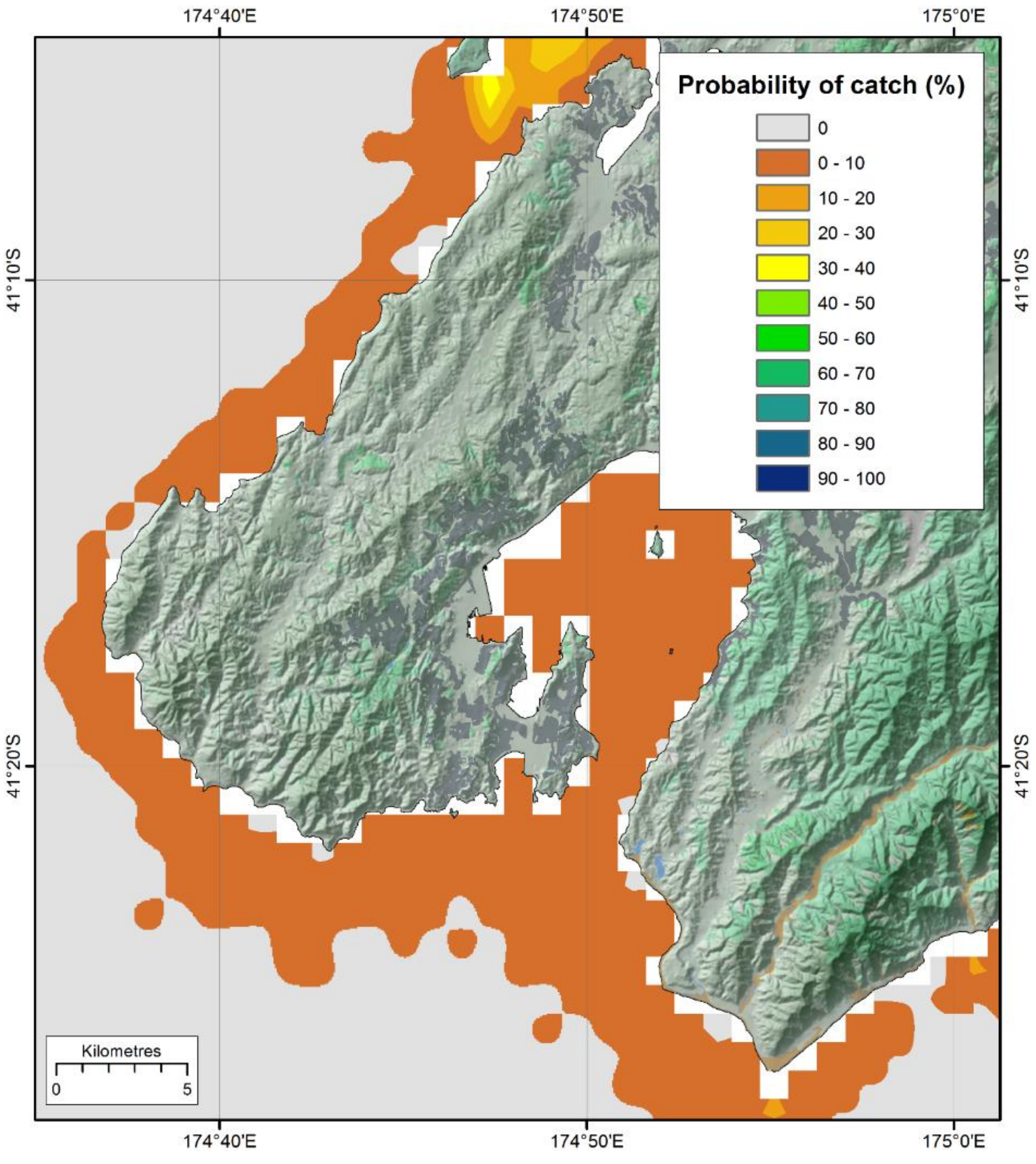


Figure 11-82: Probability of occurrence (%) of trevally (*Pseudocaranx dentex*) in a demersal trawl in the Wellington region.

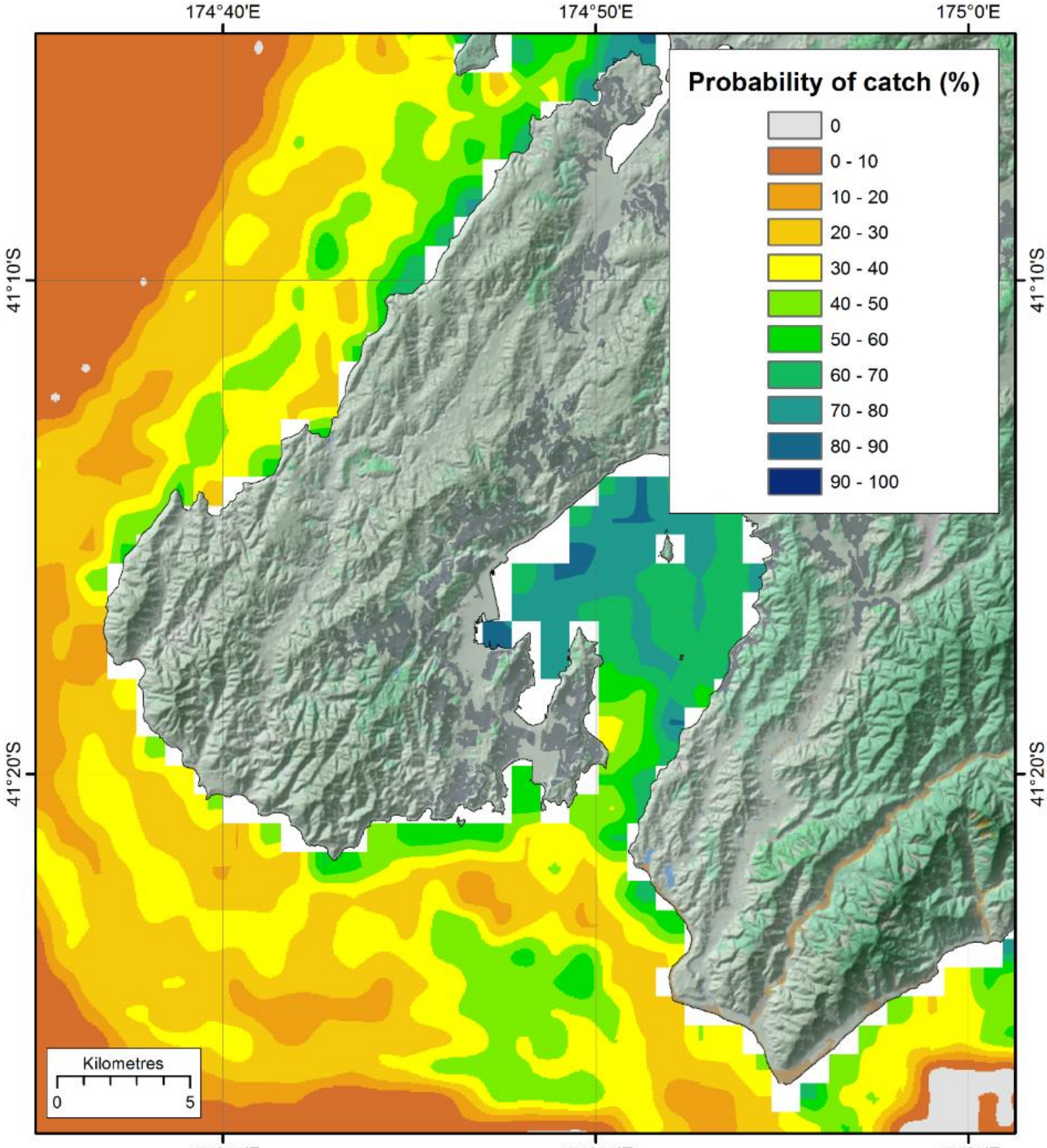


Figure 11-83: Probability of occurrence (%) of common warehou (*Seriolella brama*) in a demersal trawl in the Wellington region.

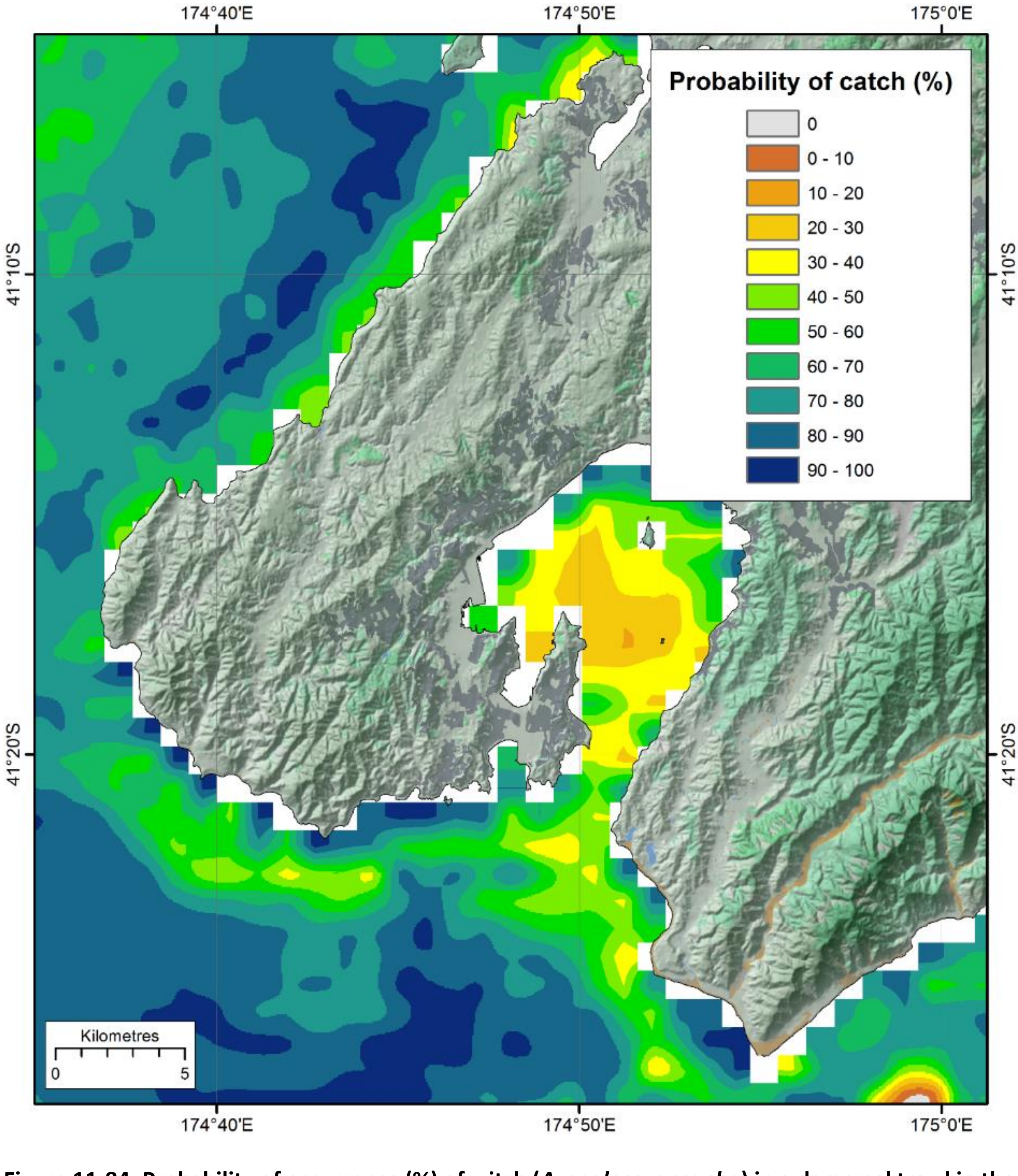


Figure 11-84: Probability of occurrence (%) of witch (*Arnoglossus scapha*) in a demersal trawl in the Wellington region.

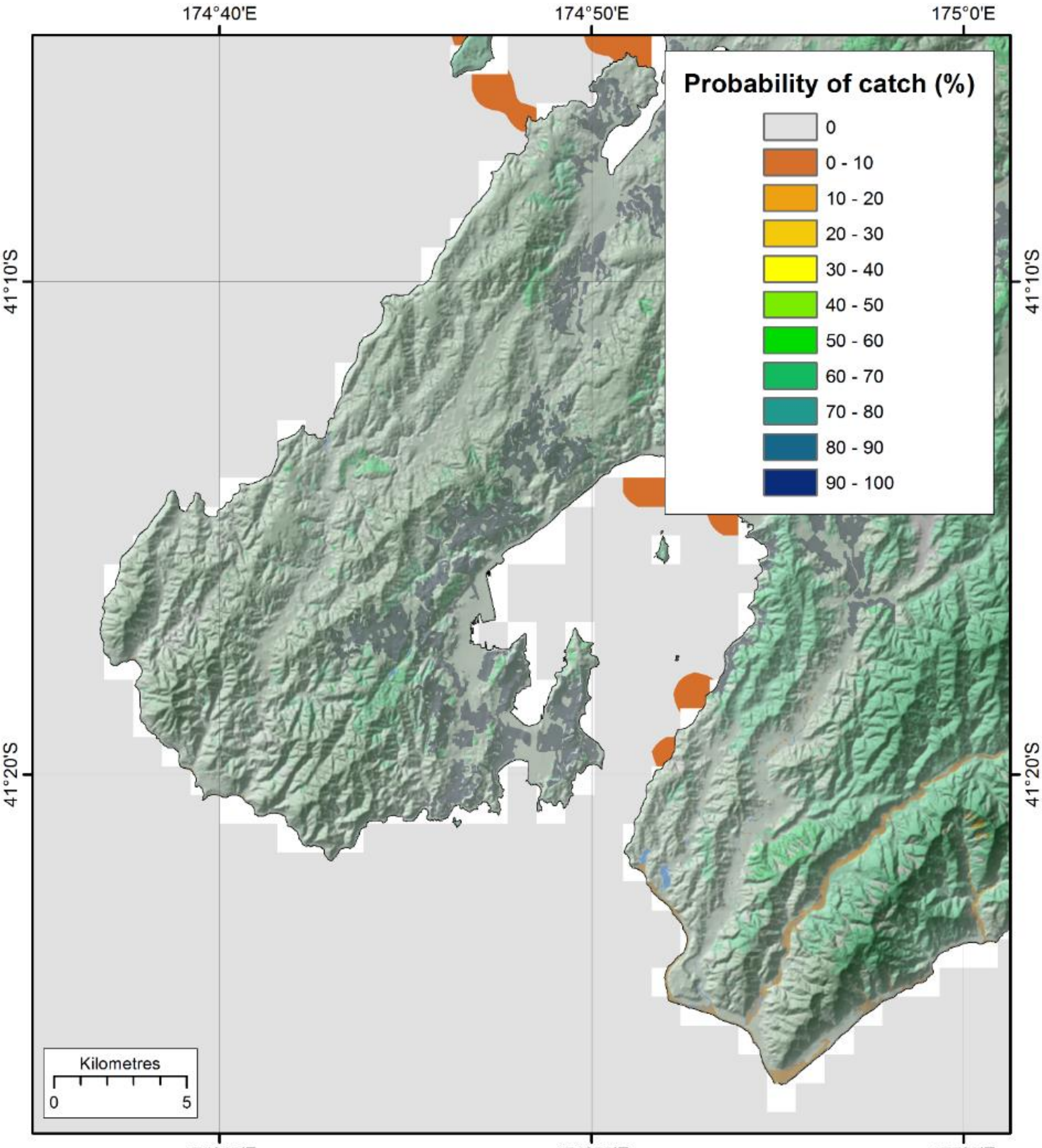


Figure 11-85: Probability of occurrence (%) of yellow-belly flounder (*Rhombosolea leporina*) in a demersal trawl in the Wellington region.

Appendix D Demersal (bottom associated) fish: modelled abundance (catch rate)

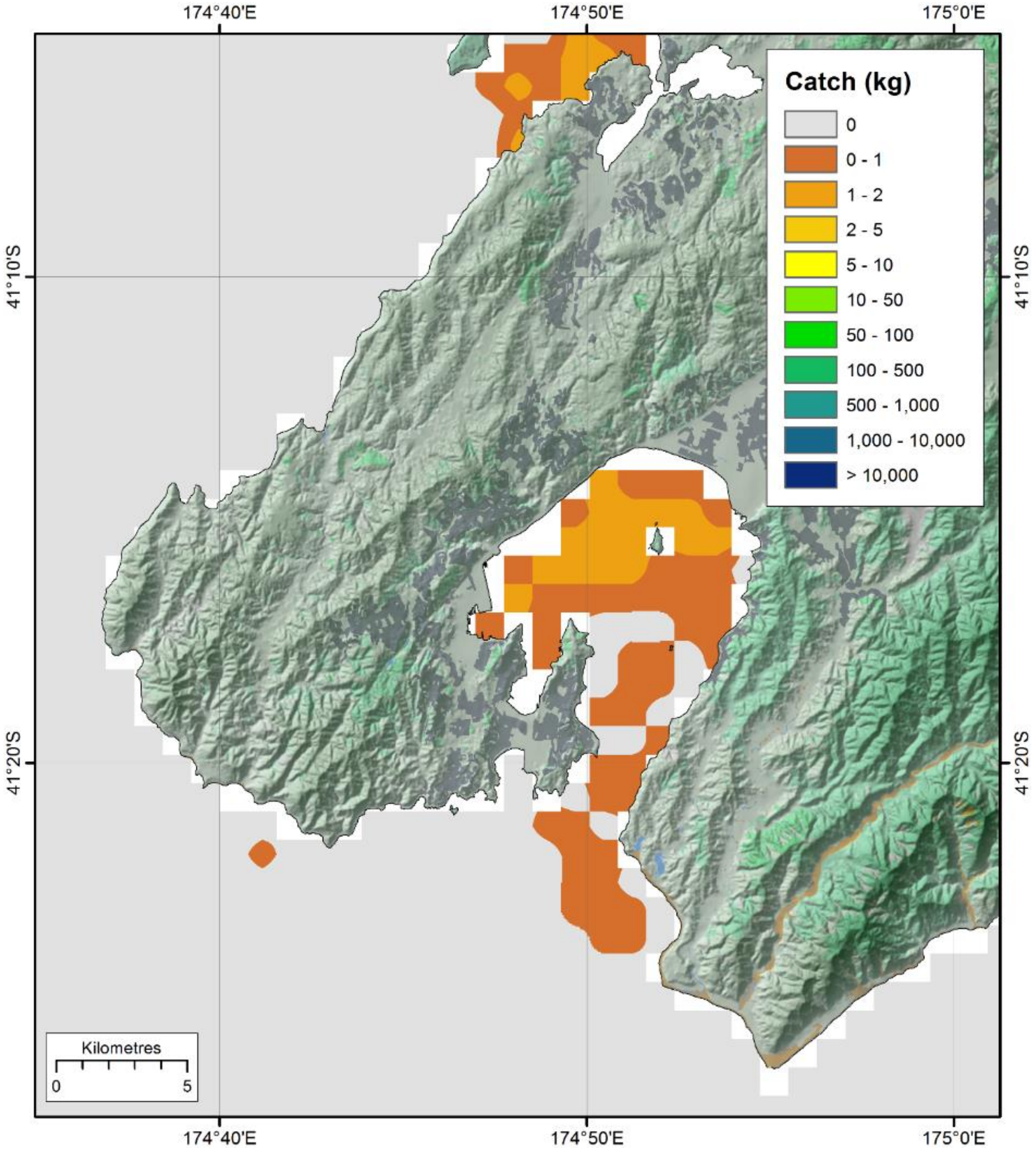


Figure 12-86: Catch (kg per hour) of anchovy (*Engraulis australis*) in a demersal trawl in the Wellington region.

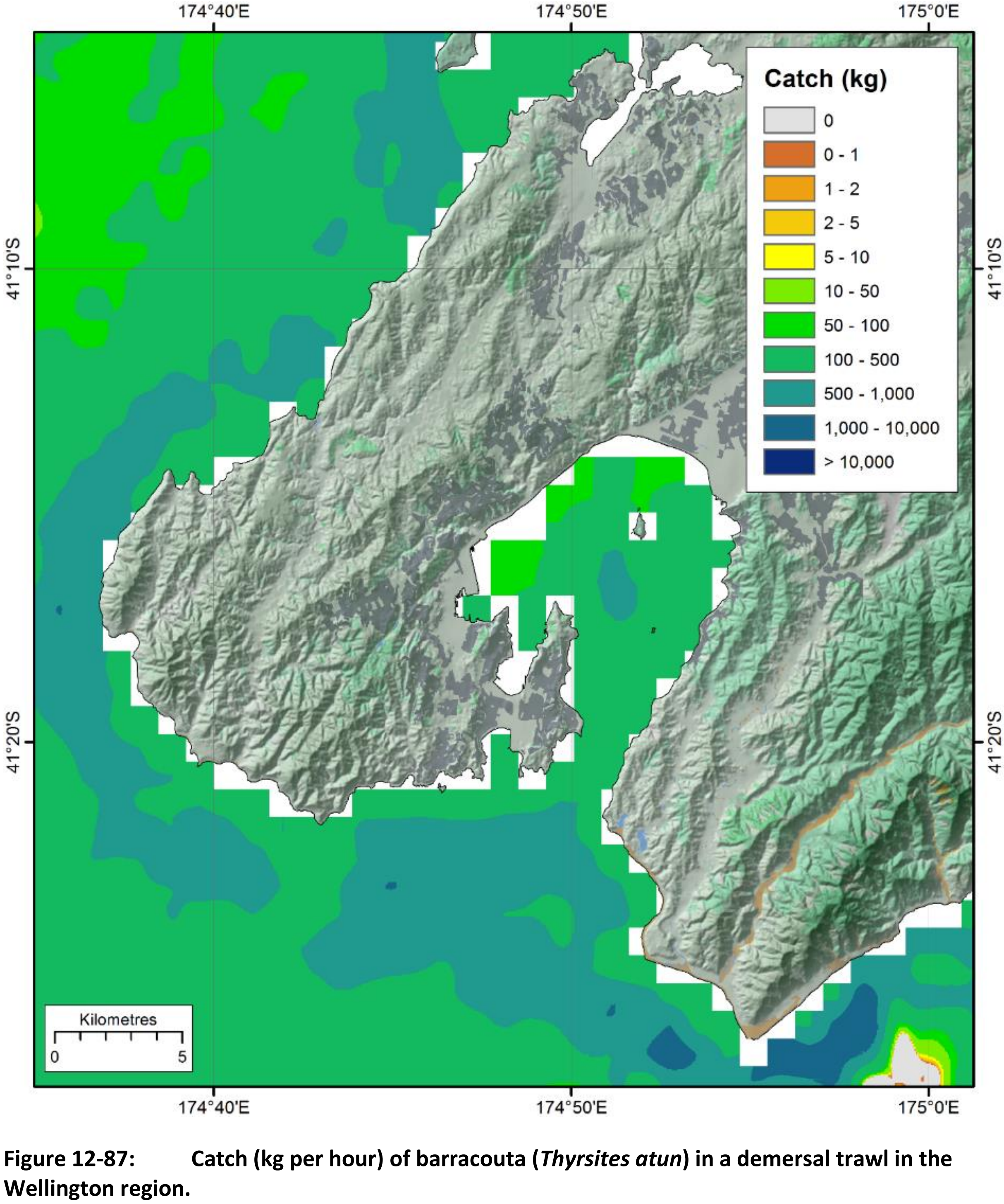


Figure 12-87: Catch (kg per hour) of barracouta (*Thyrsites atun*) in a demersal trawl in the Wellington region.

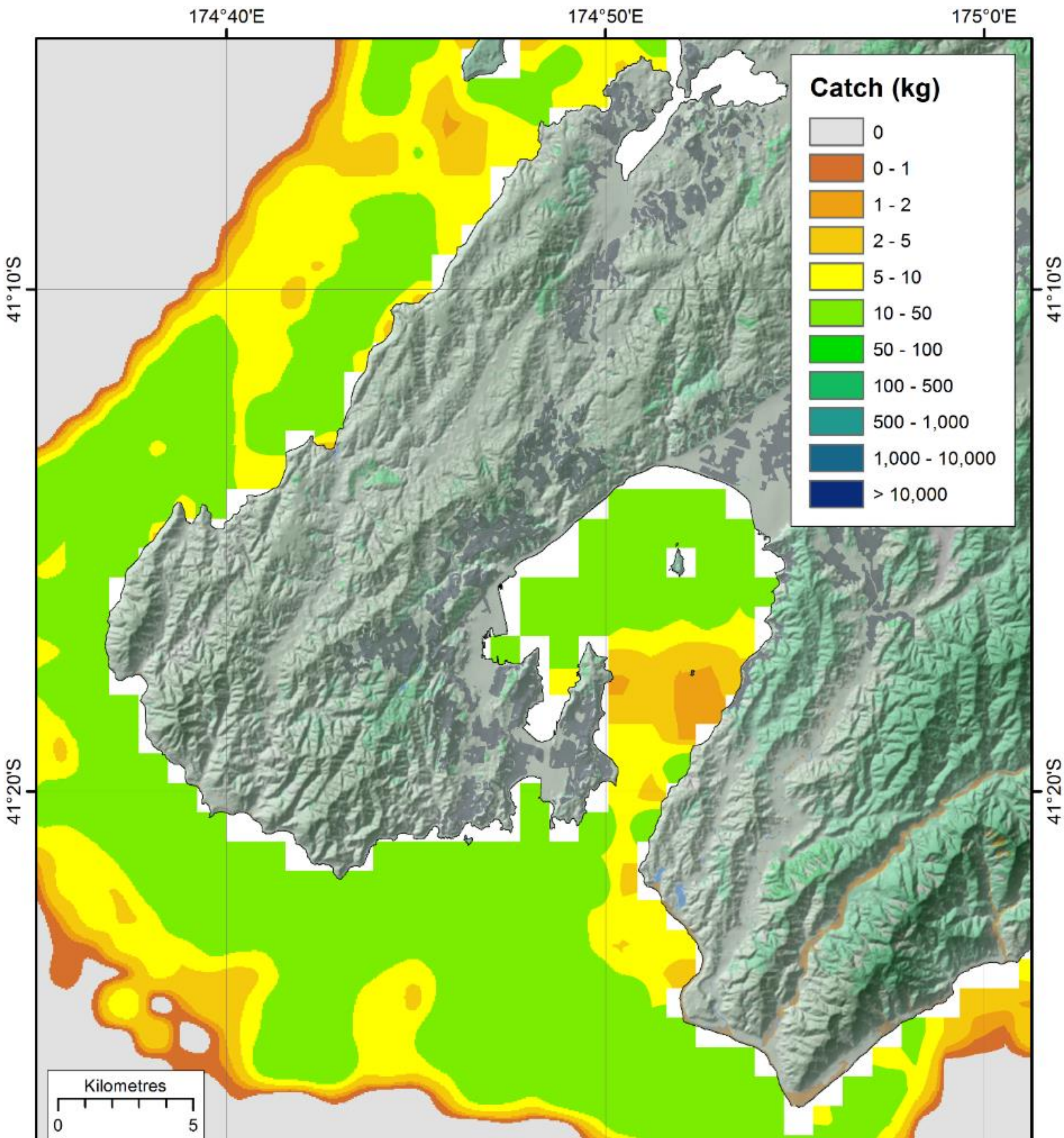


Figure 12-88: Catch (kg per hour) of blue cod (*Parapercis colias*) in a demersal trawl in the Wellington region.

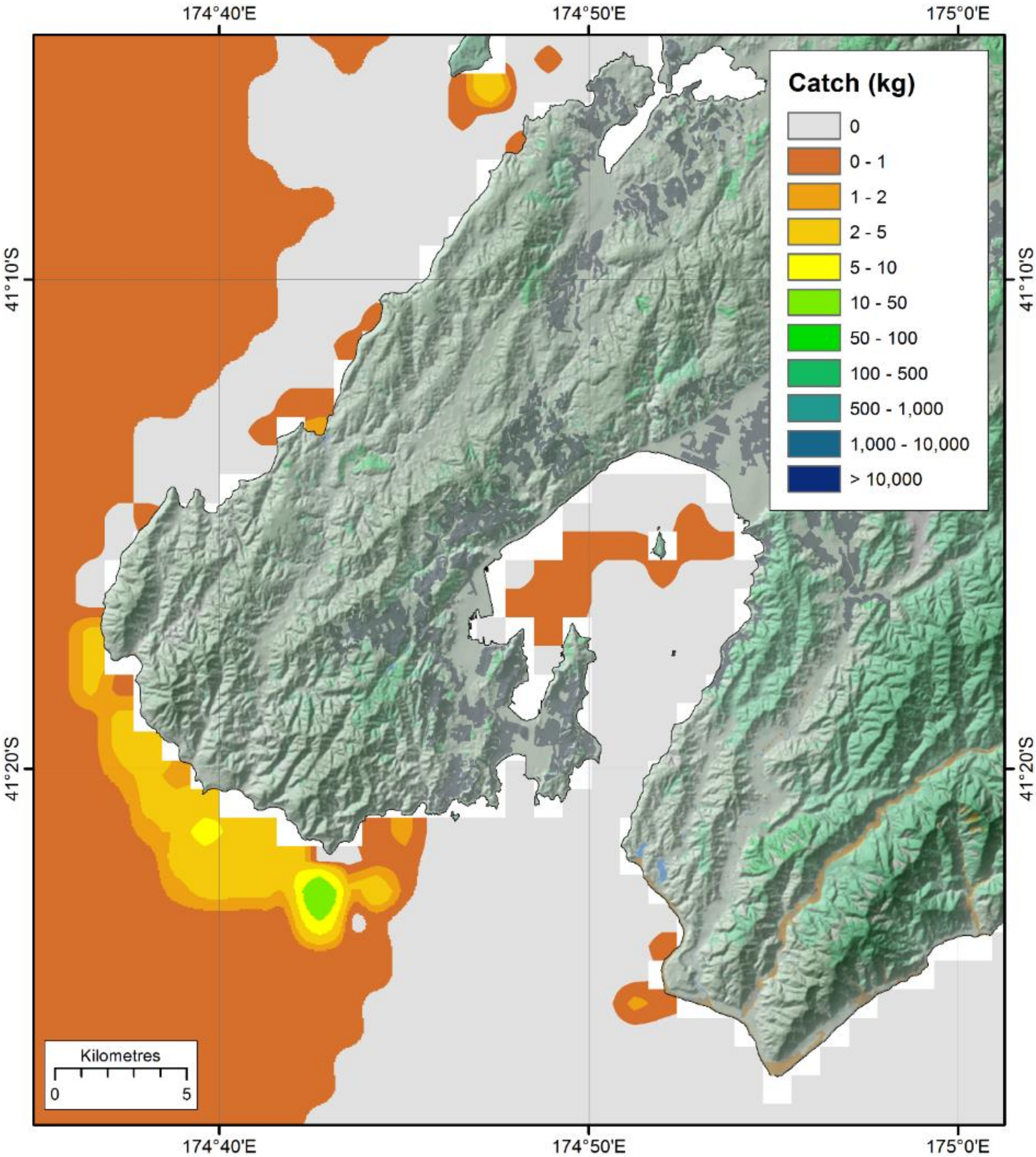


Figure 12-89: Catch (kg per hour) of short-tailed black ray (*Dasyatis brevicaudata*) in a demersal trawl in the Wellington region.

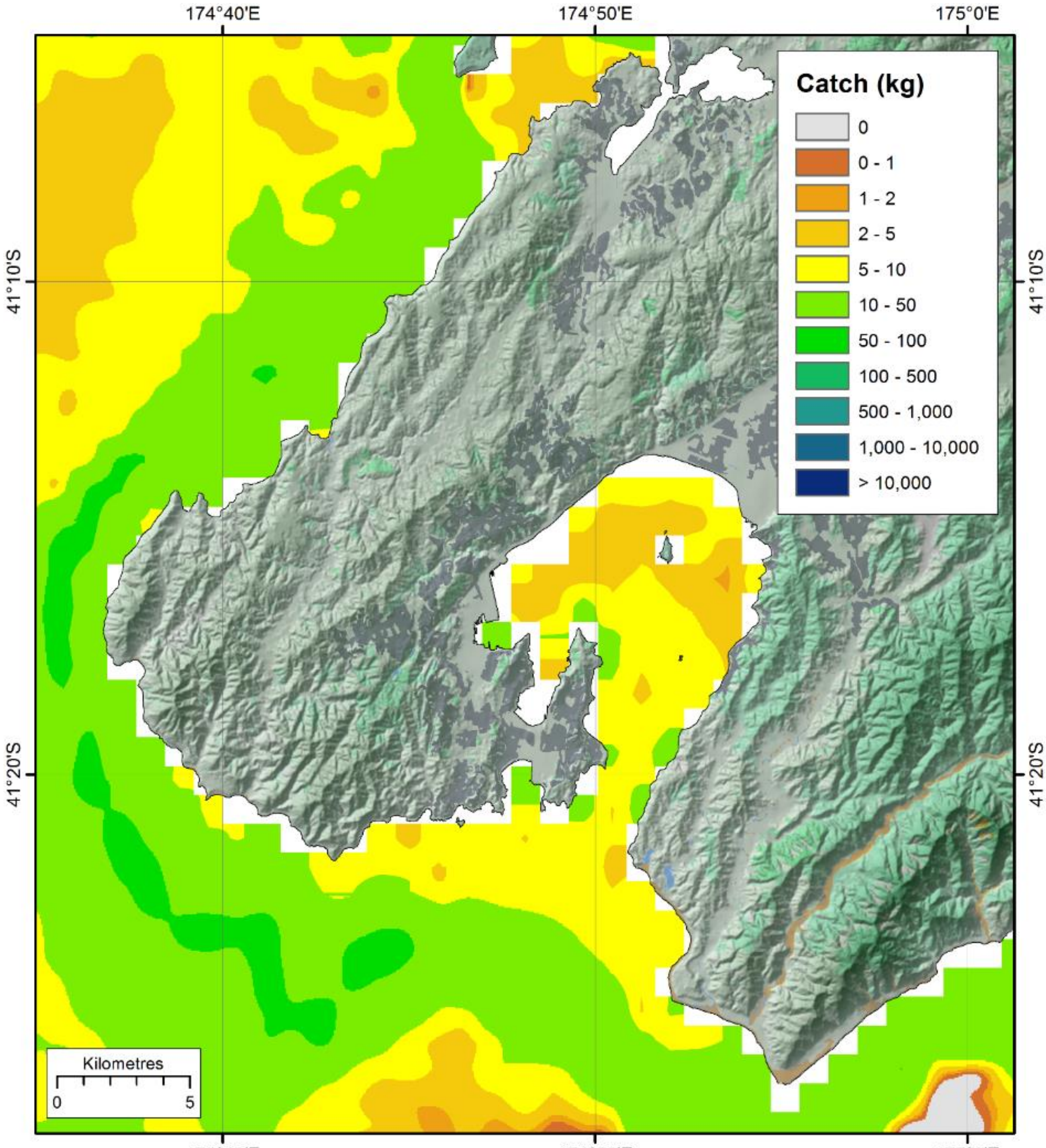


Figure 12-90: Catch (kg per hour) of carpet shark (*Cephaloscyllium isabellum*) in a demersal trawl in the Wellington region.

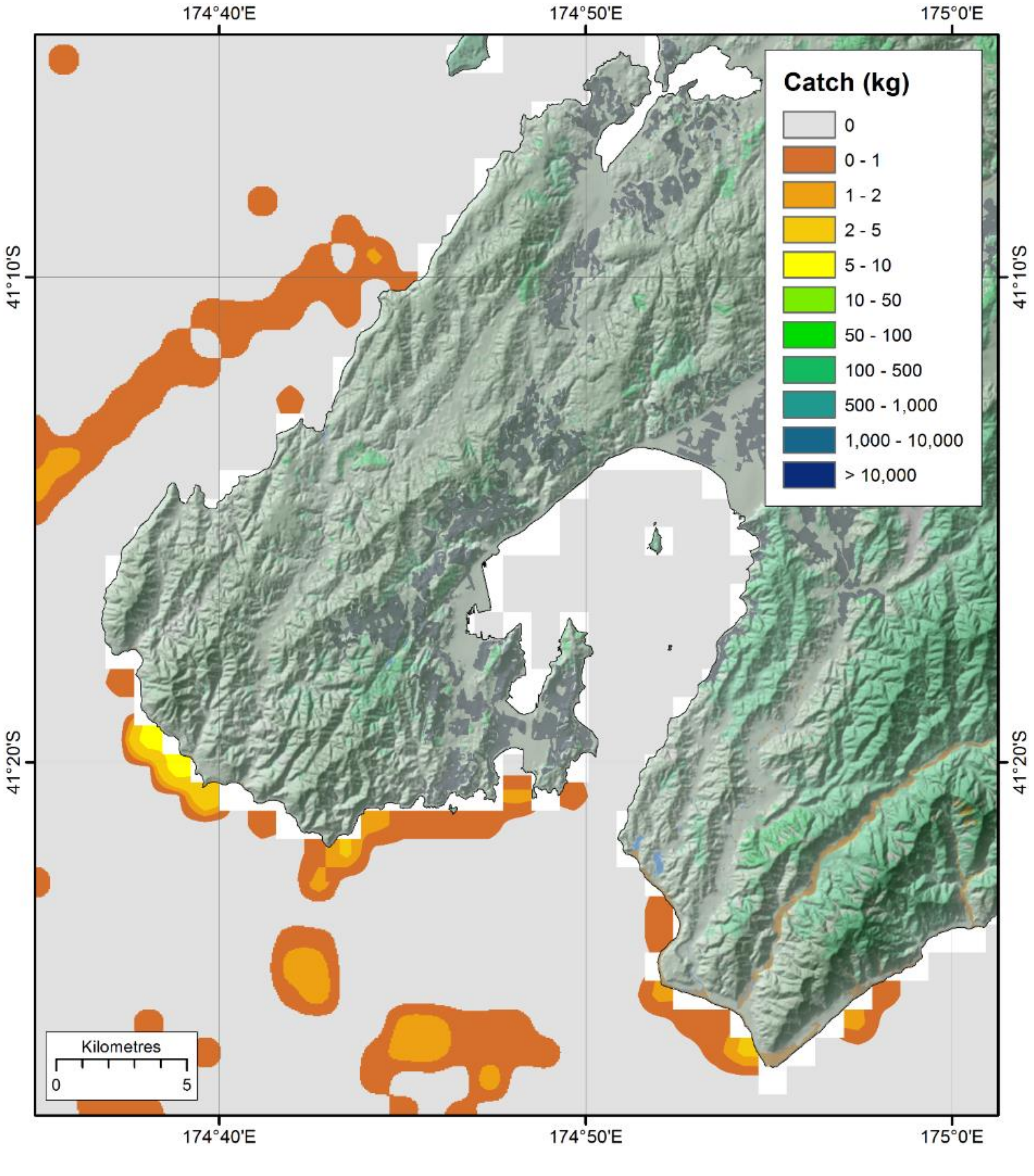


Figure 12-91: Catch (kg per hour) of crested bellowsfish (*Notopogon lillei*) in a demersal trawl in the Wellington region.

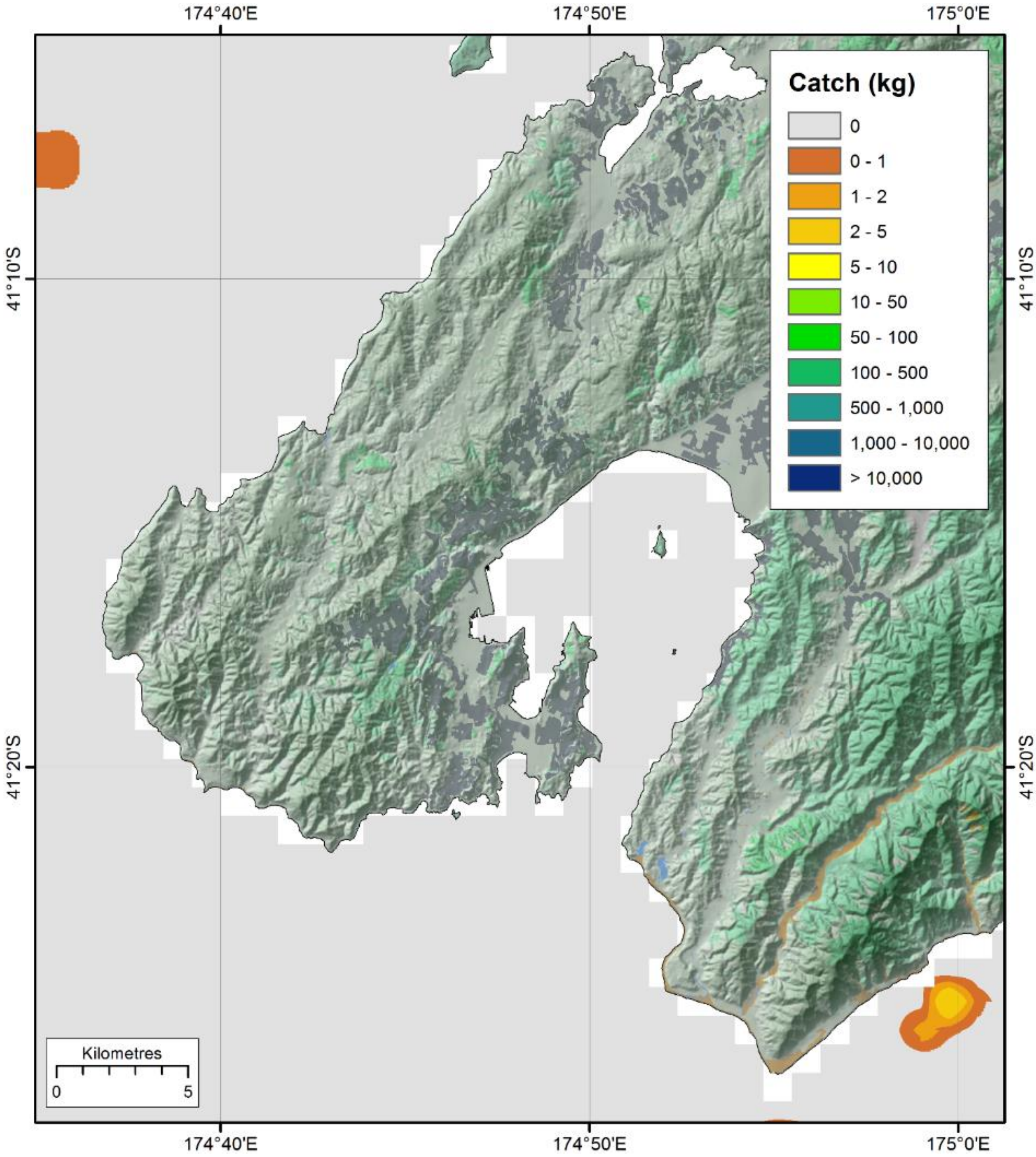


Figure 12-92: Catch (kg per hour) of cucumber fish (*Chlorophthalmus nigripinnis*) in a demersal trawl in the Wellington region.

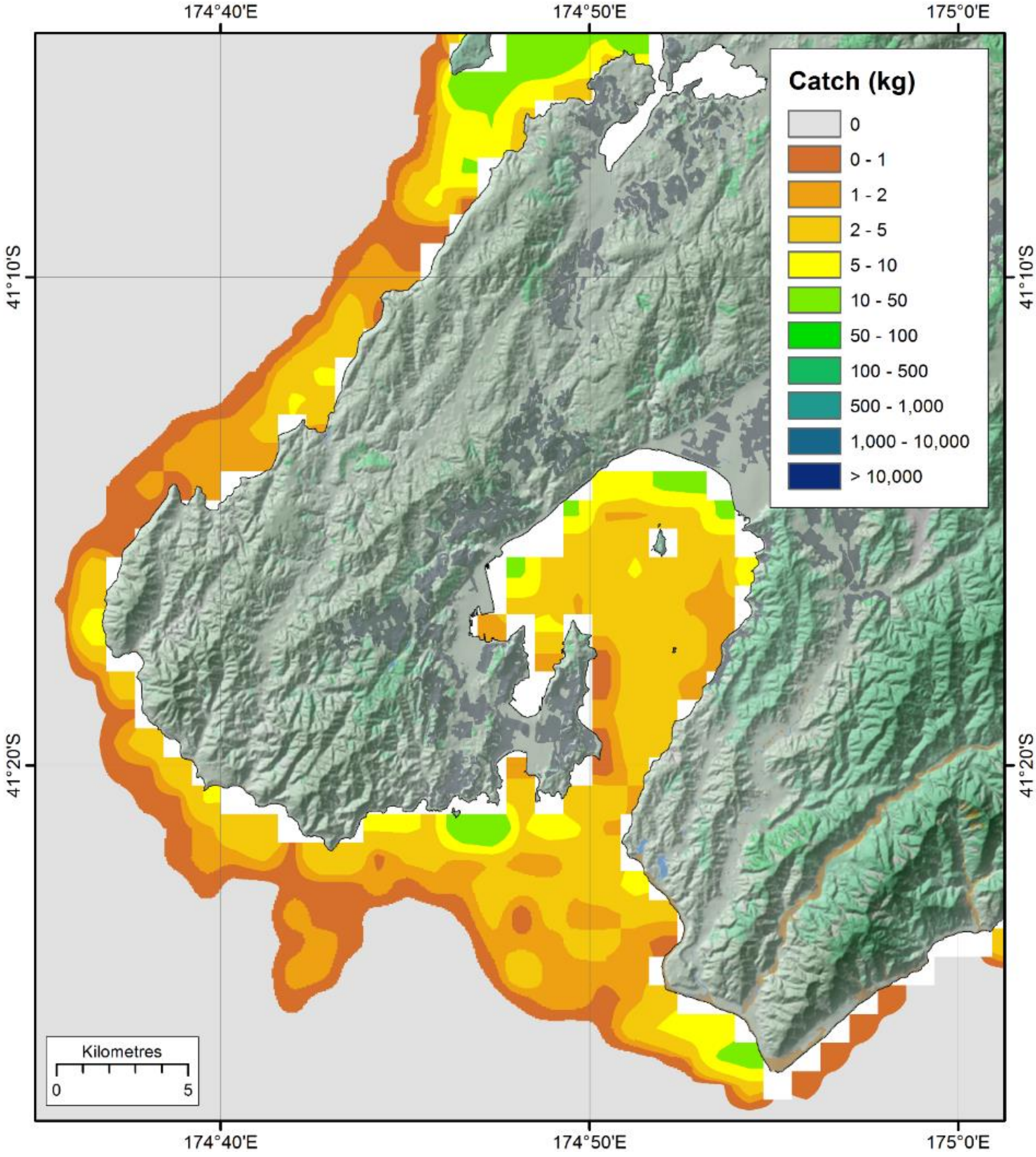


Figure 12-93: Catch (kg per hour) of eagle Ray (*Myliobatis tenuicaudatus*) in a demersal trawl in the Wellington region.

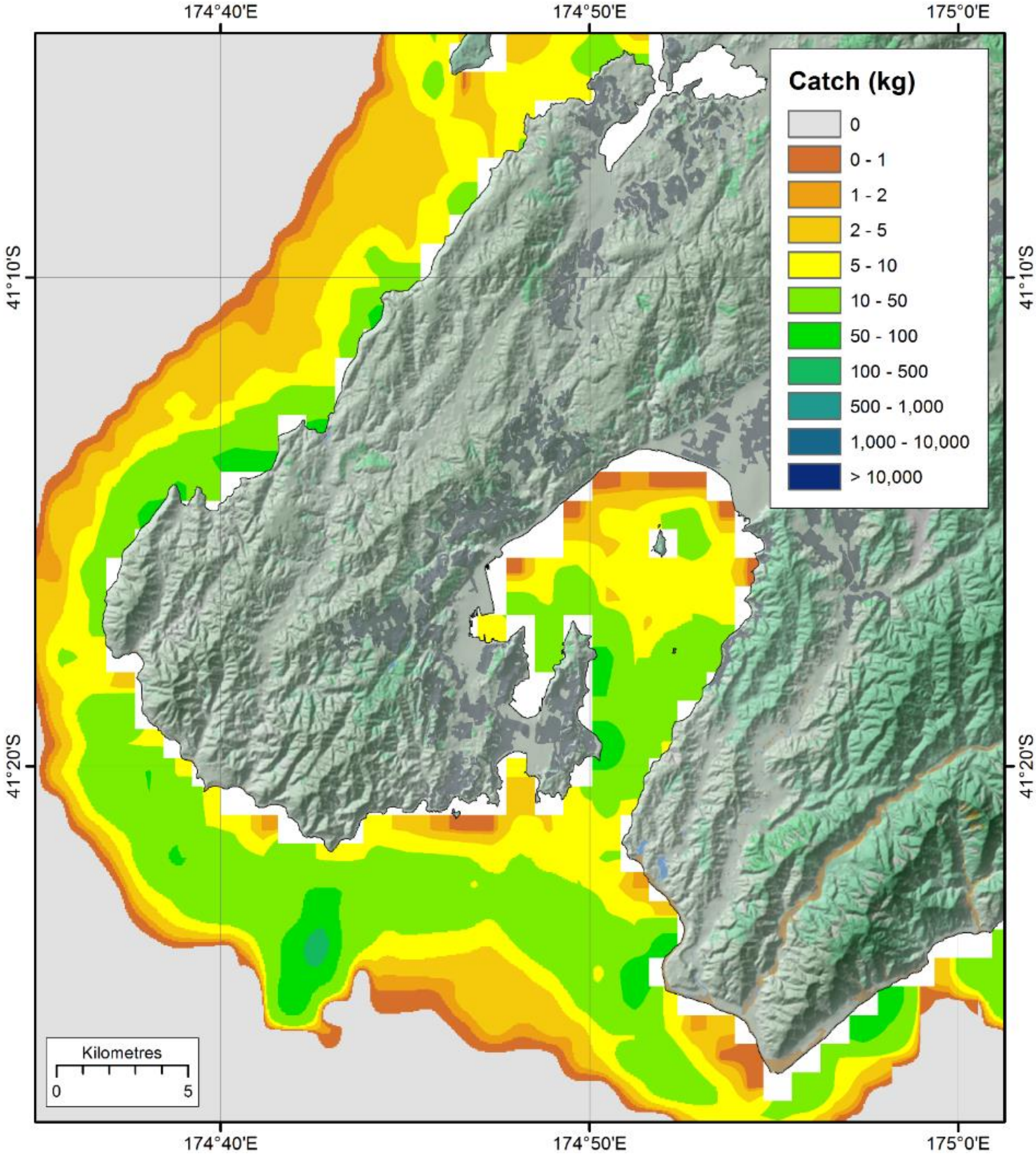


Figure 12-94: Catch (kg per hour) of elephant fish (*Callorhinchus milii*) in a demersal trawl in the Wellington region.

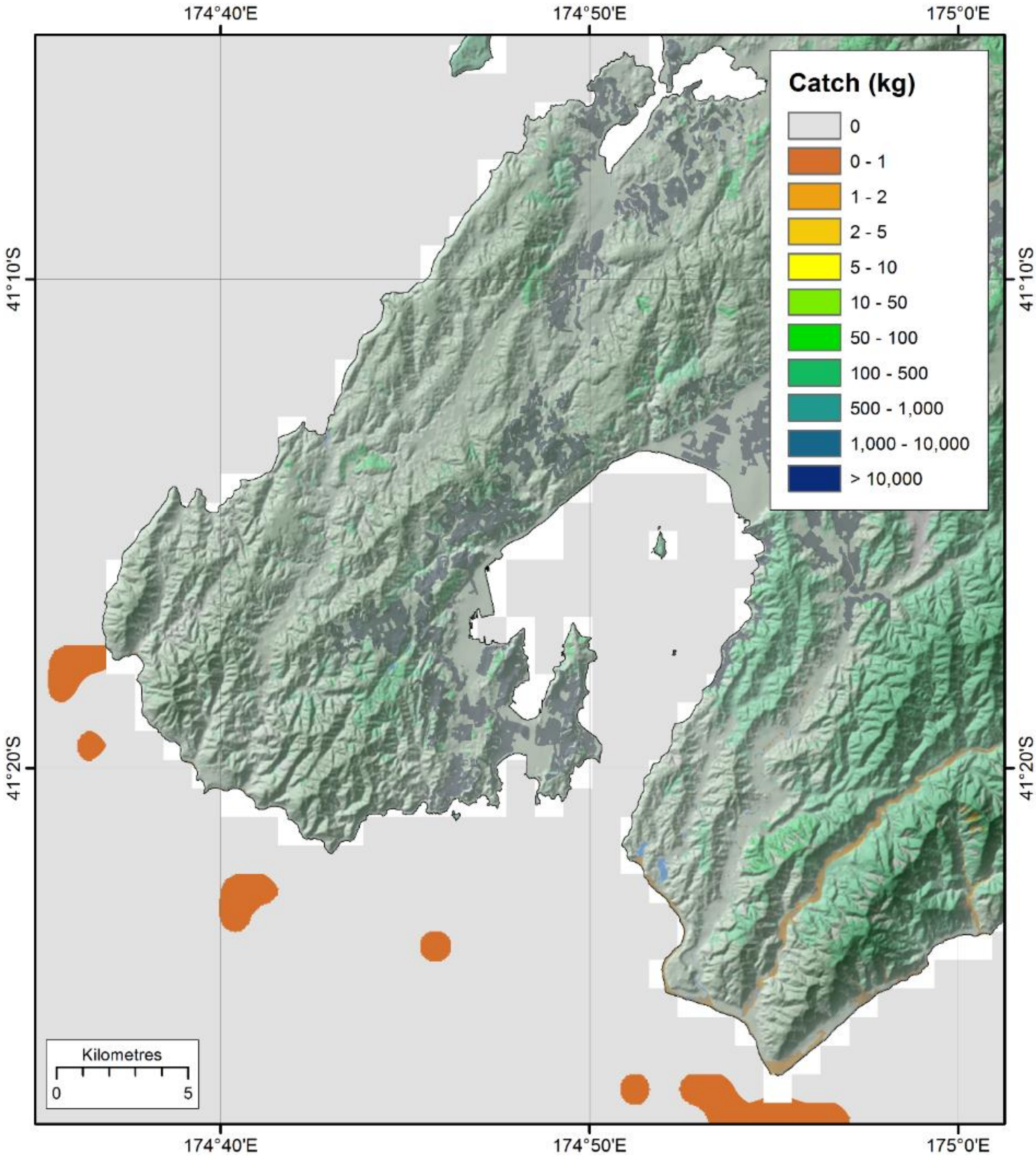


Figure 12-95: Catch (kg per hour) of blue mackerel (*Scomber australasicus*) in a demersal trawl in the Wellington region.

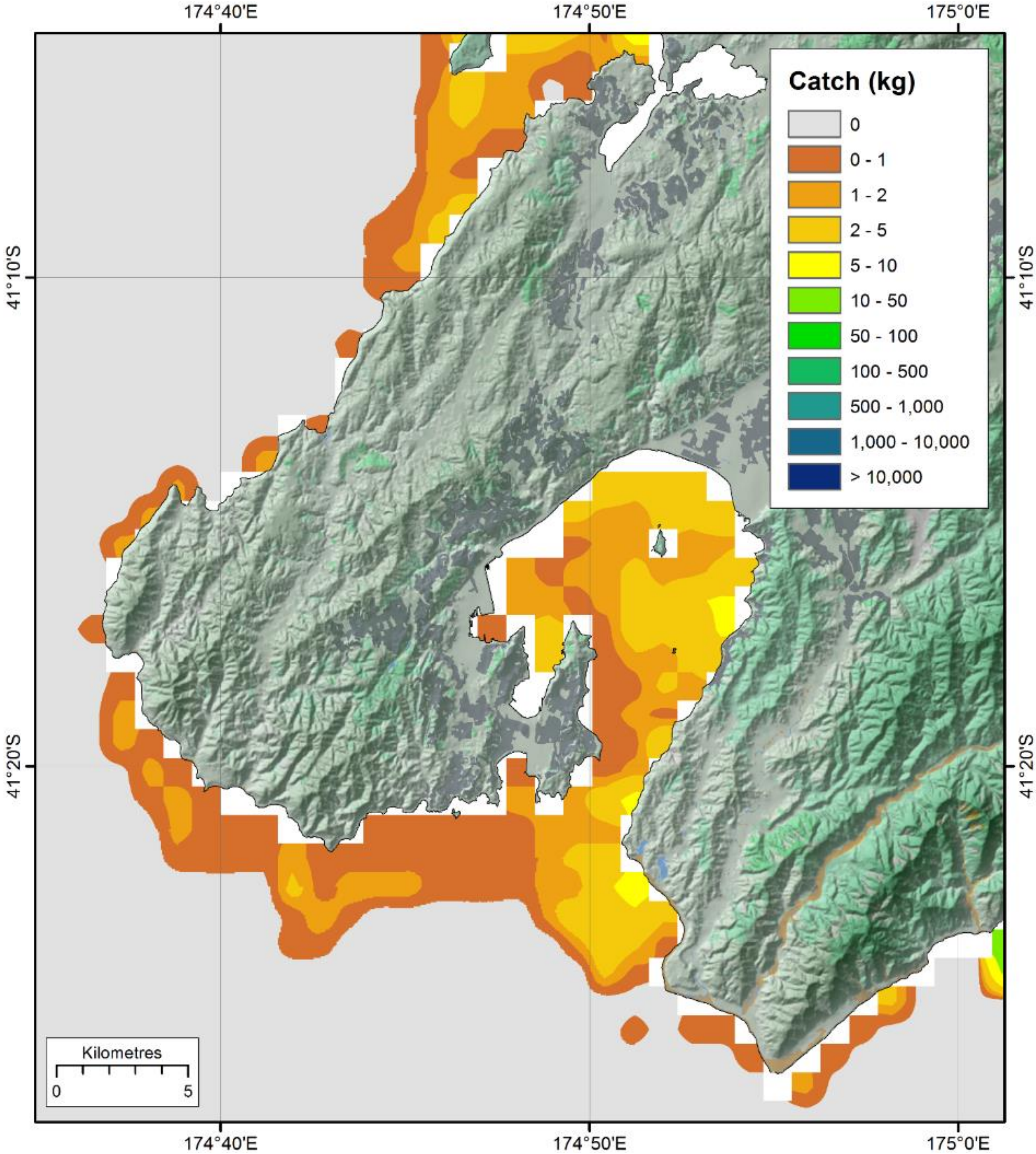


Figure 12-96: Catch (kg per hour) of N.Z. sole (*Peltorhamphus novaezeelandiae*) in a demersal trawl in the Wellington region.

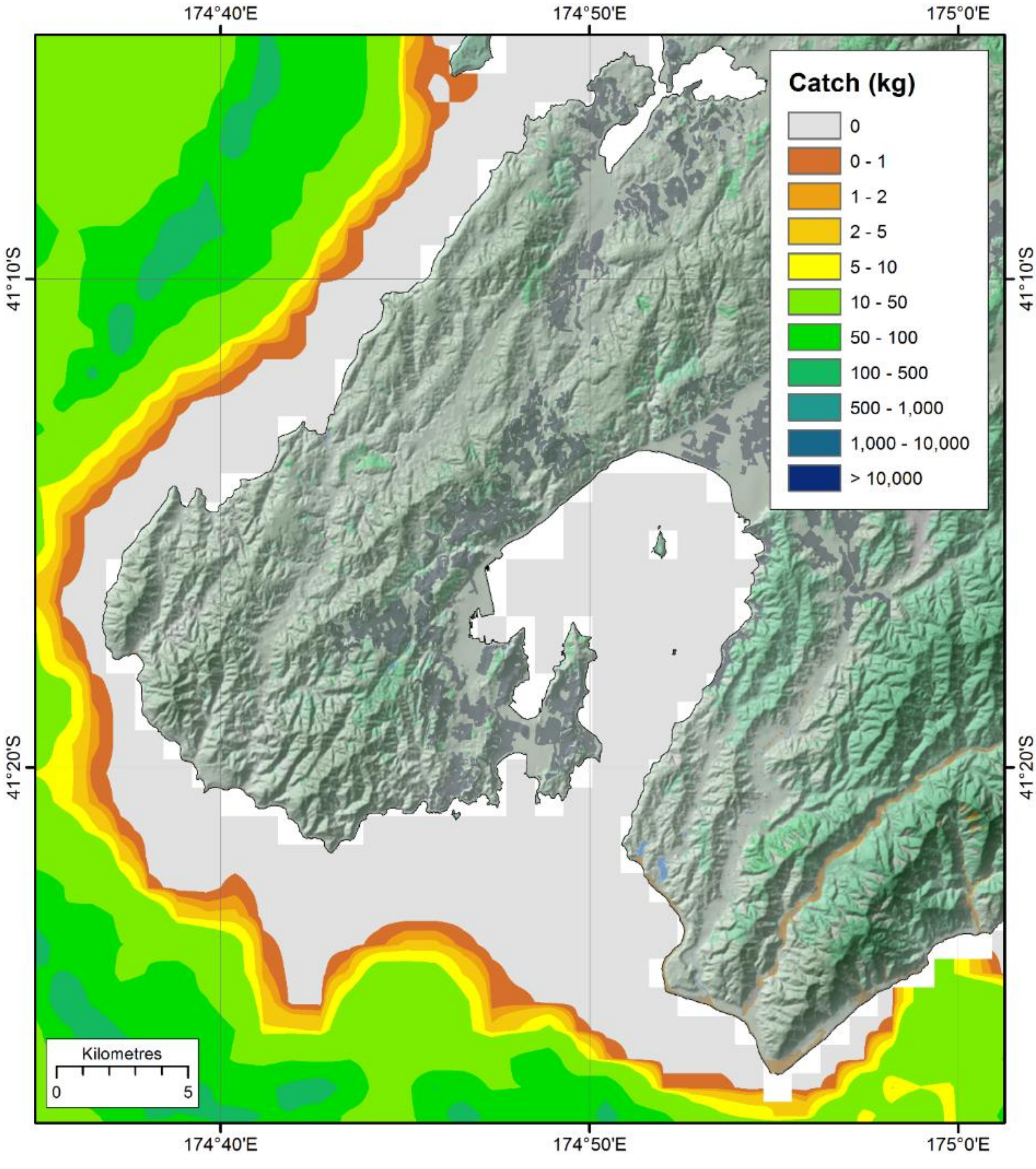


Figure 12-97: Catch (kg per hour) of frostfish (*Lepidopus caudatus*) in a demersal trawl in the Wellington region.

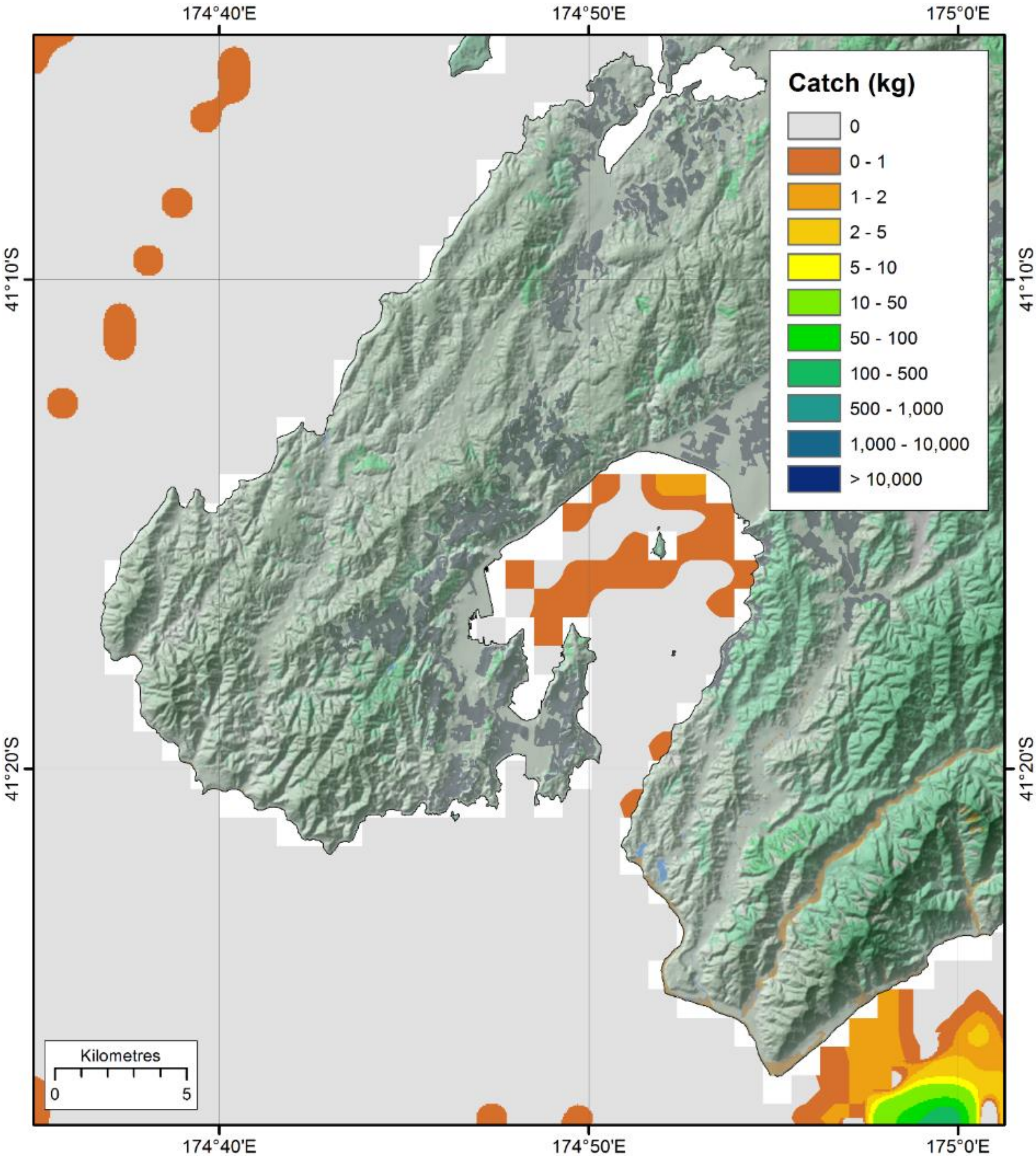


Figure 12-98: Catch (kg per hour) of pale ghost shark (*Hydrolagus bemisi*) in a demersal trawl in the Wellington region.

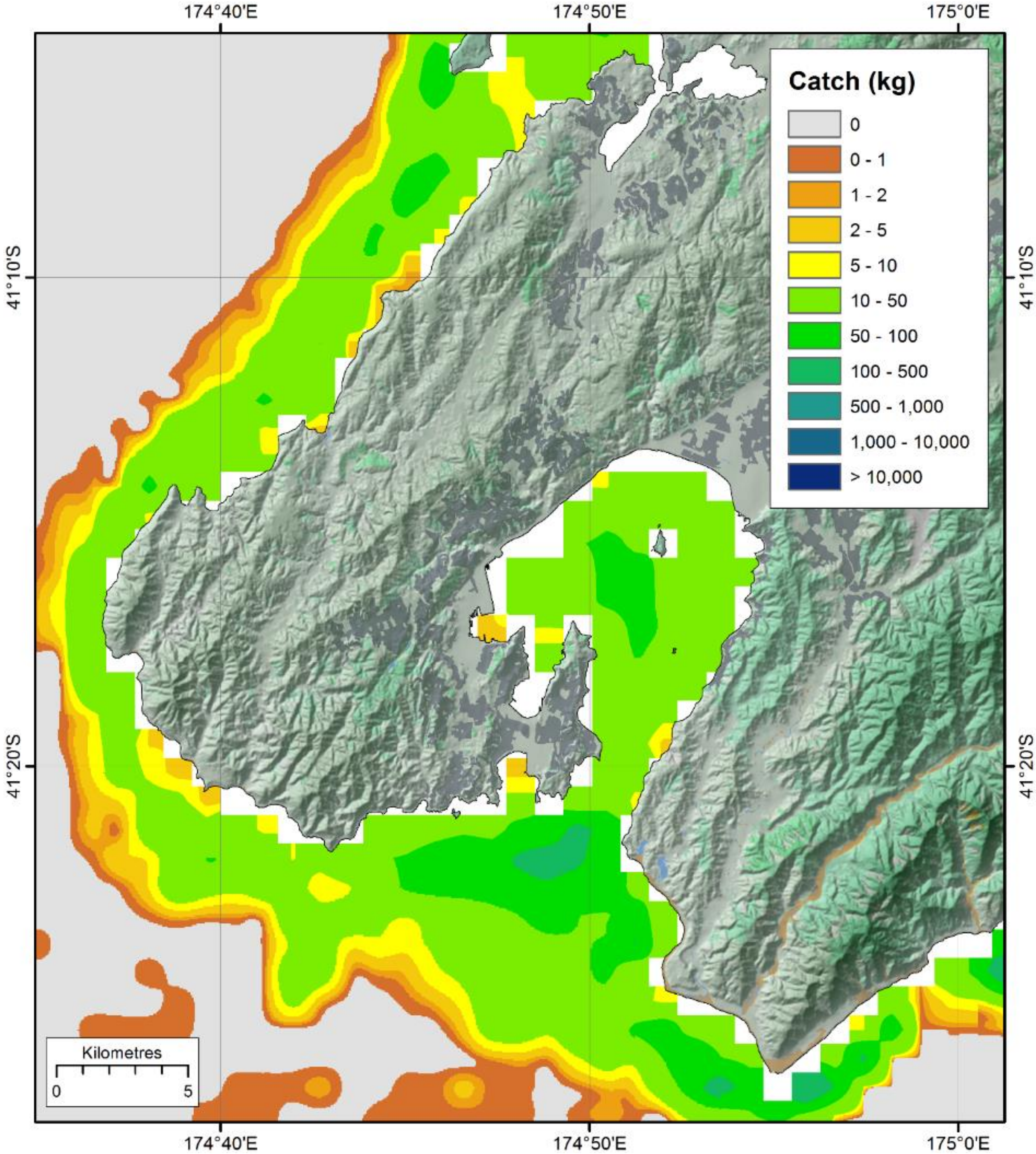


Figure 12-99: Catch (kg per hour) of gurnard (*Chelidonichthys kumu*) in a demersal trawl in the Wellington region.

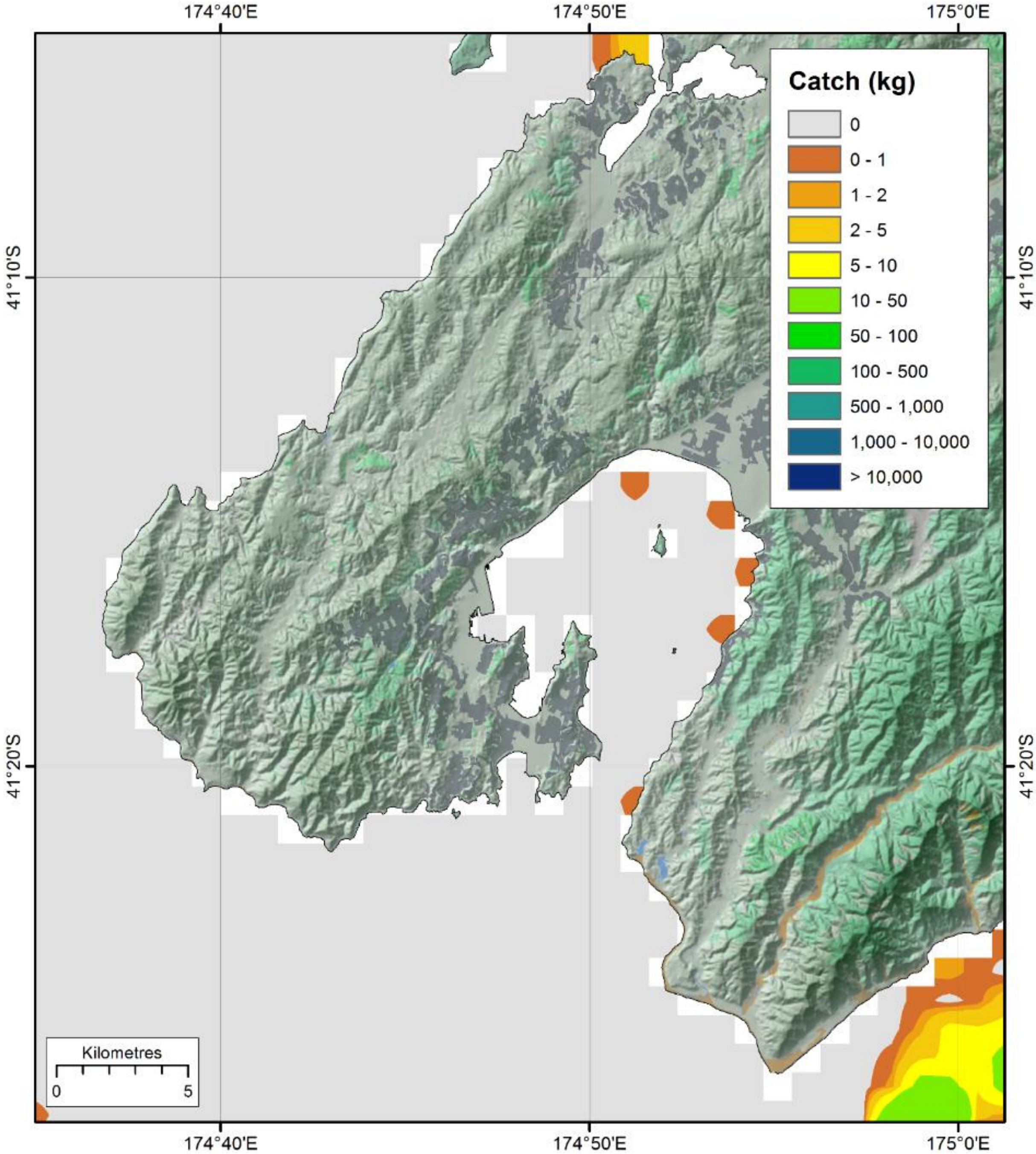


Figure 12-100: Catch (kg per hour) of Hake (*Merluccius australis*) in a demersal trawl in the Wellington region.

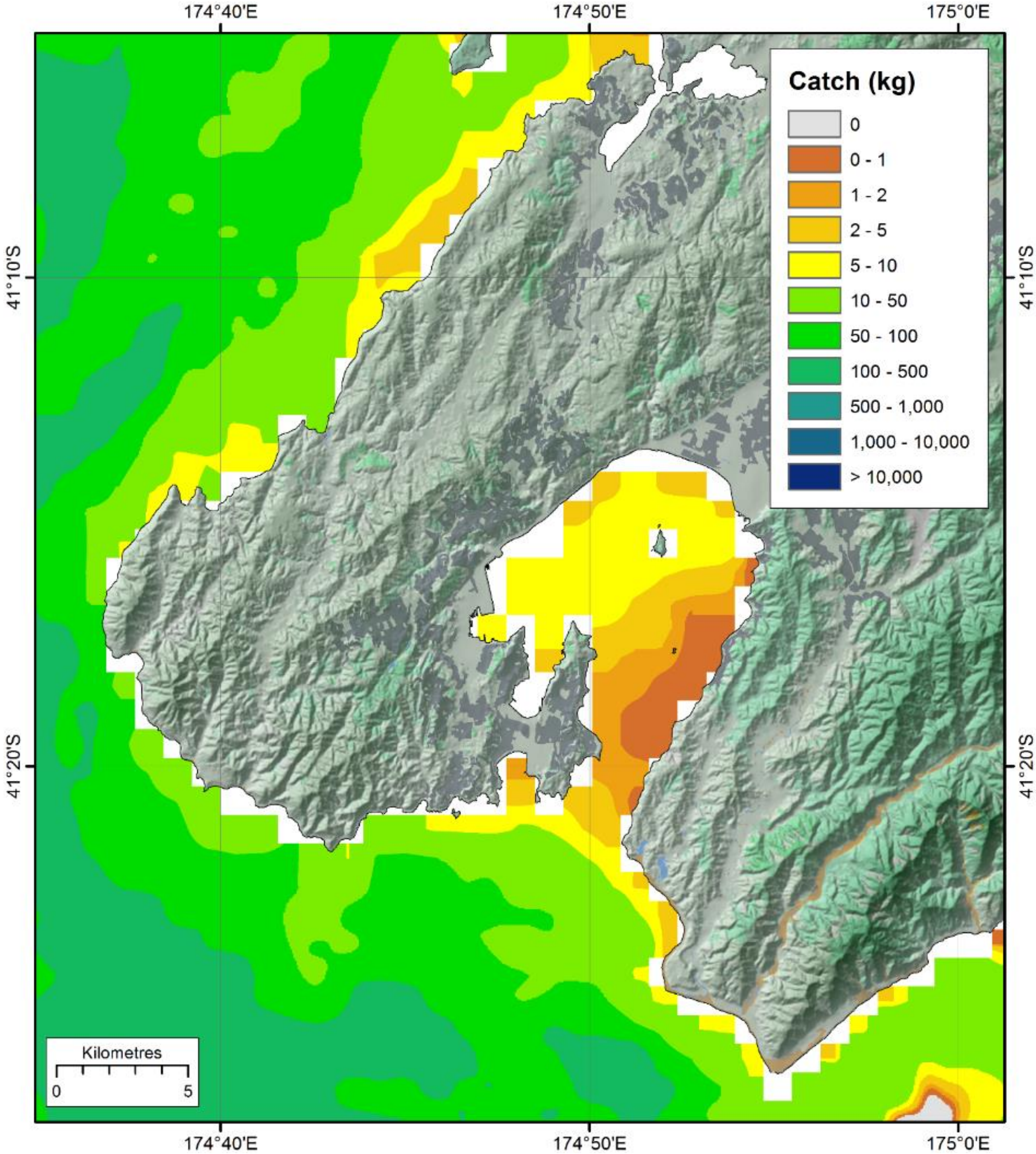


Figure 12-101: Catch (kg per hour) of hapuka (*Polyprion oxygeneios*) in a demersal trawl in the Wellington region.

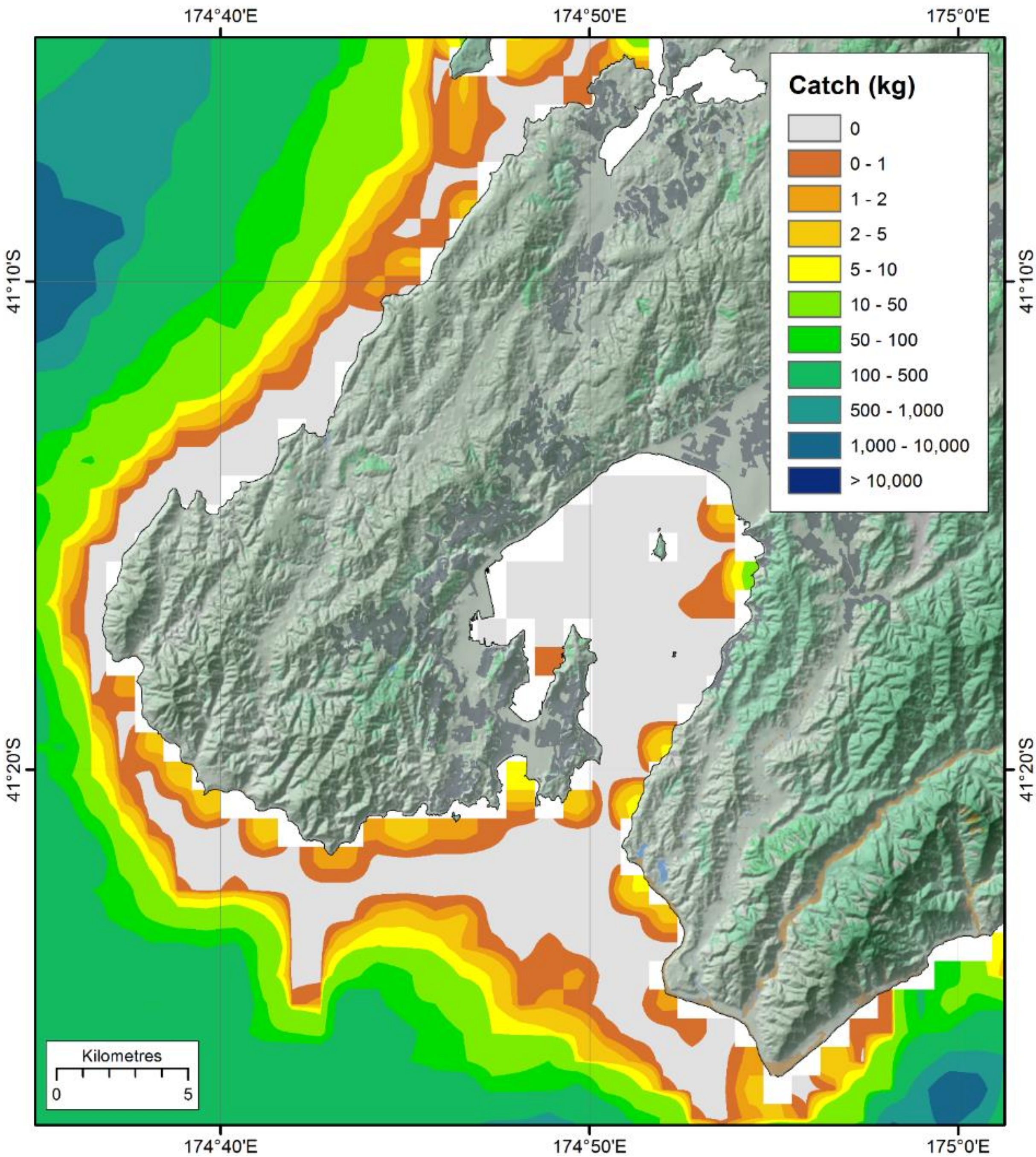


Figure 12-102: Catch (kg per hour) of hoki (*Macruronus novaezelandiae*) in a demersal trawl in the Wellington region.

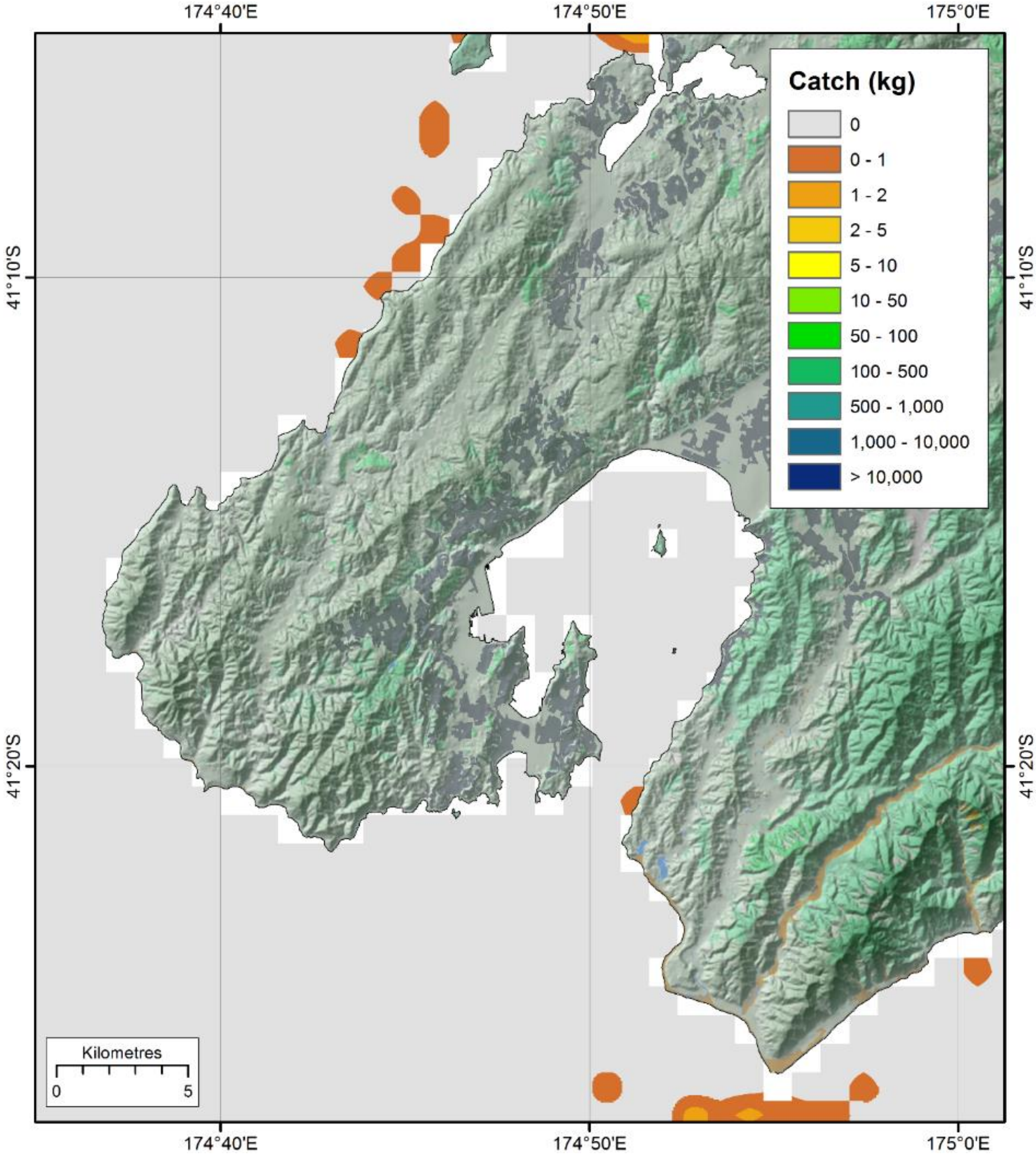


Figure 12-103: Catch (kg per hour) of John dory (*Zeus faber*) in a demersal trawl in the Wellington region.

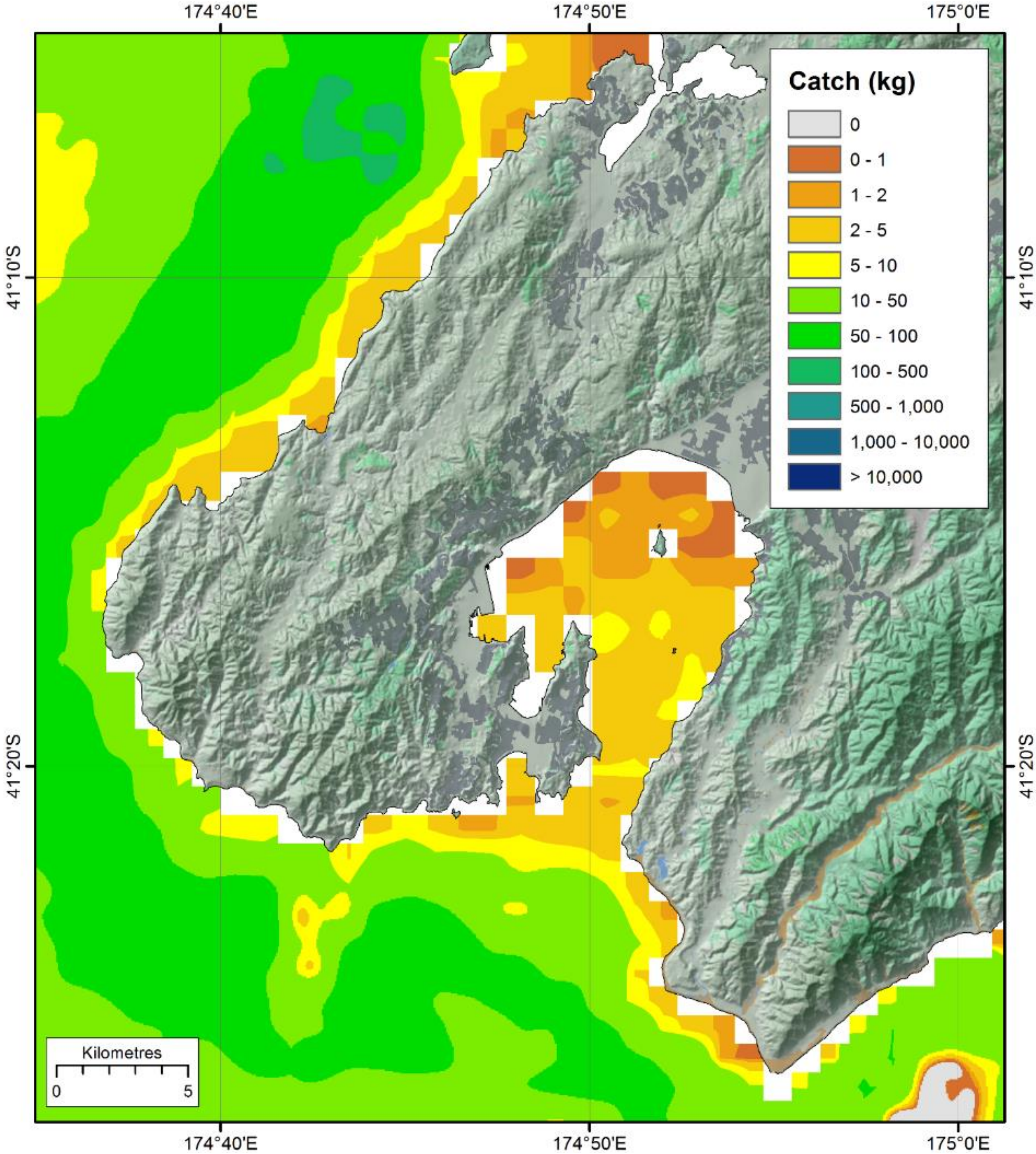


Figure 12-104: Catch (kg per hour) of horse mackerel (*Trachurus declivis*) in a demersal trawl in the Wellington region.

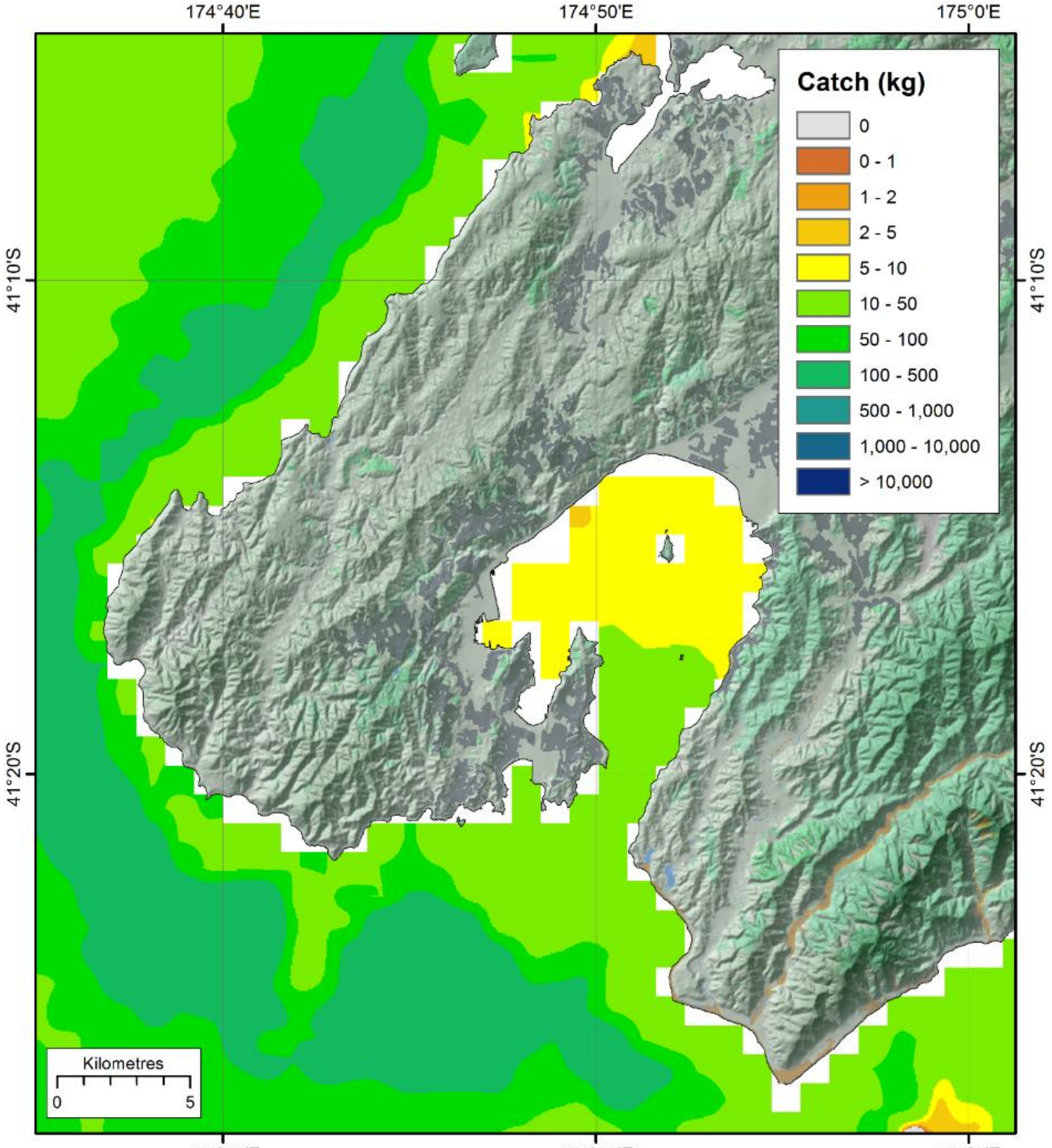


Figure 12-105: Catch (kg per hour) of Murphys mackerel (*Trachurus symmertricus murphyi*) in a demersal trawl in the Wellington region.

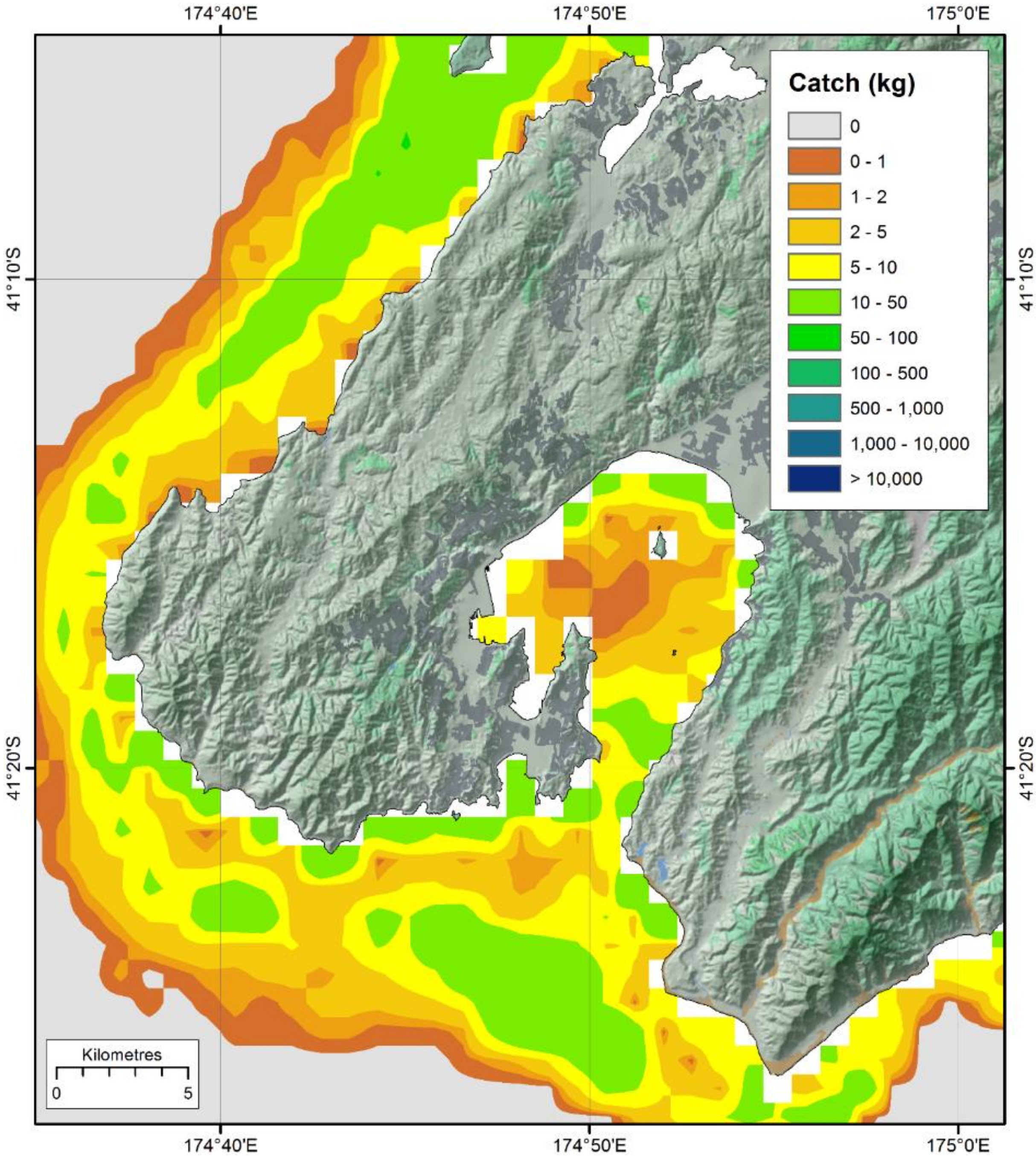


Figure 12-106: Catch (kg per hour) of golden mackerel (*Trachurus novaezelandiae*) in a demersal trawl in the Wellington region.

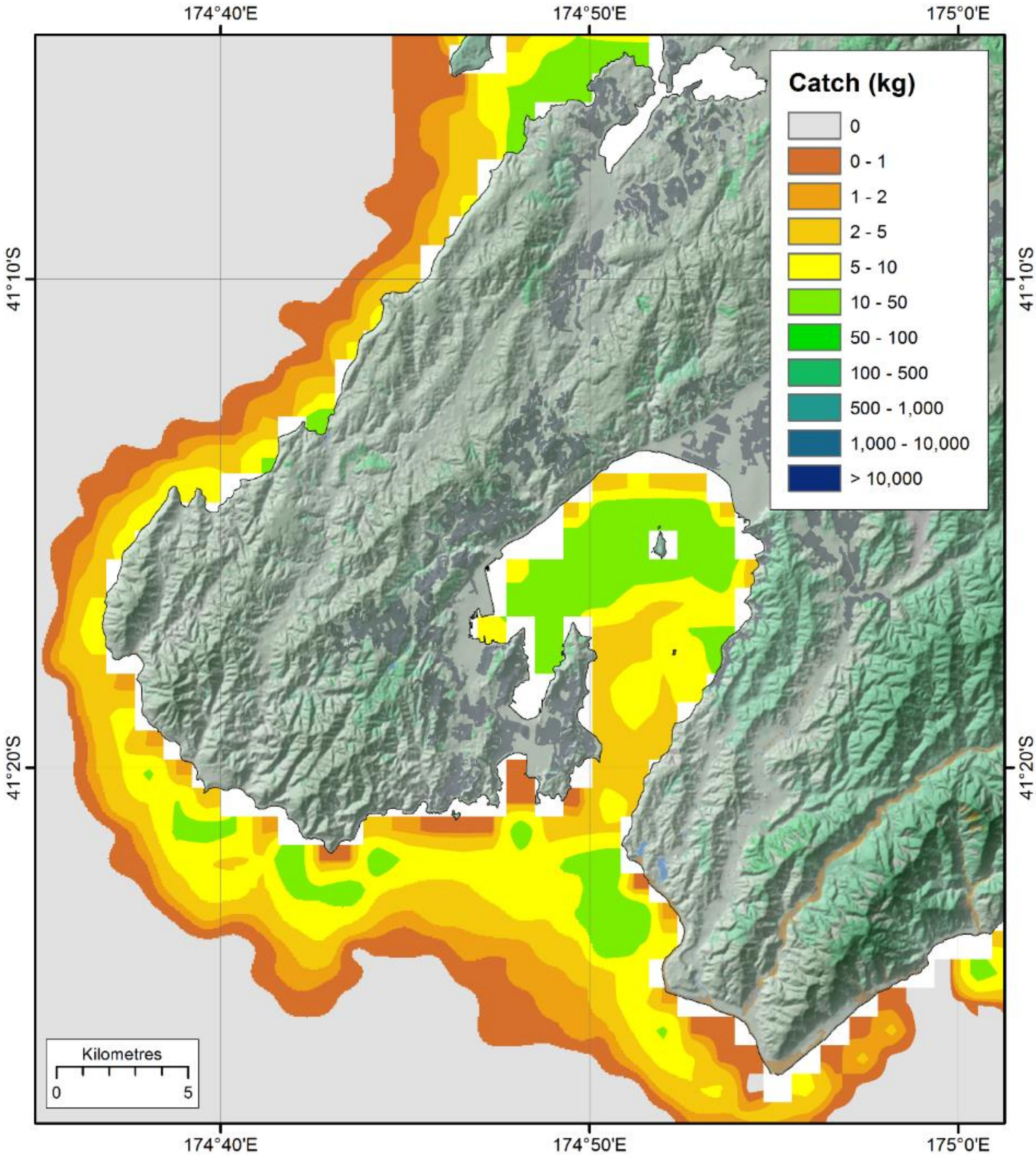


Figure 12-107: Catch (kg per hour) of kahawai (*Arripis trutta*) in a demersal trawl in the Wellington region.

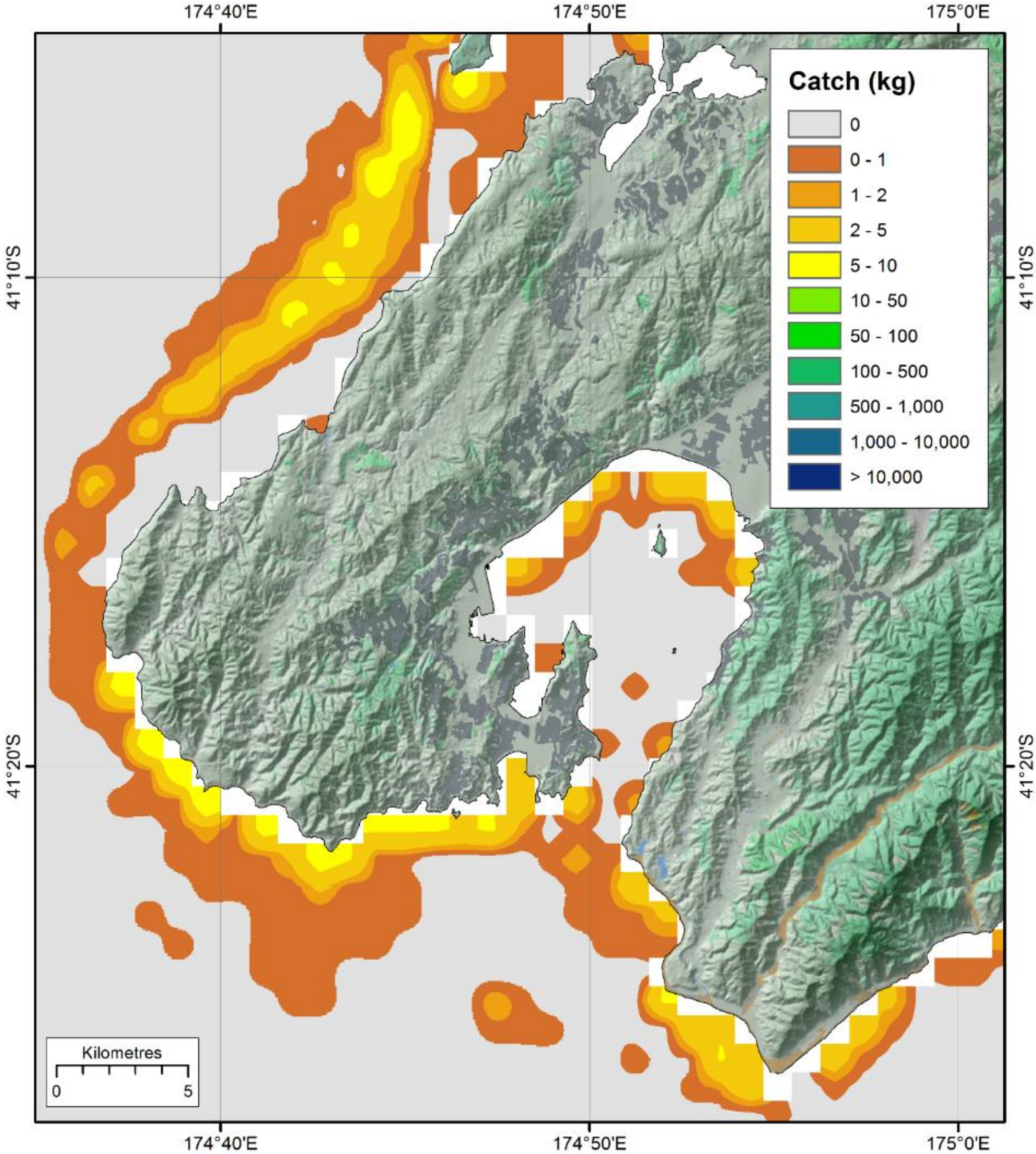


Figure 12-108: Catch (kg per hour) of kingfish (*Seriola lalandi*) in a demersal trawl in the Wellington region.

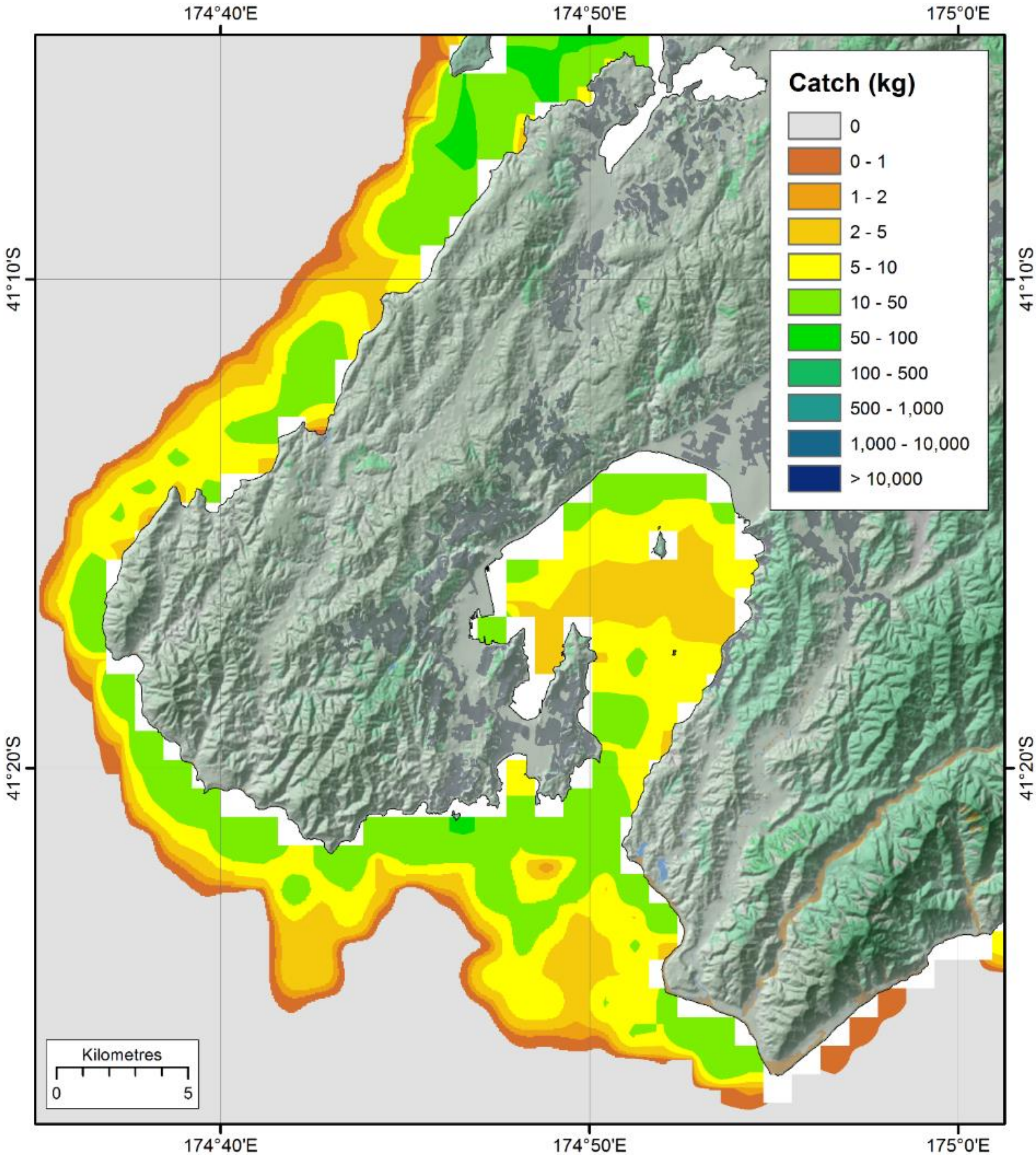


Figure 12-109: Catch (kg per hour) of leatherjacket (*Meuschenia scaber*) in a demersal trawl in the Wellington region.

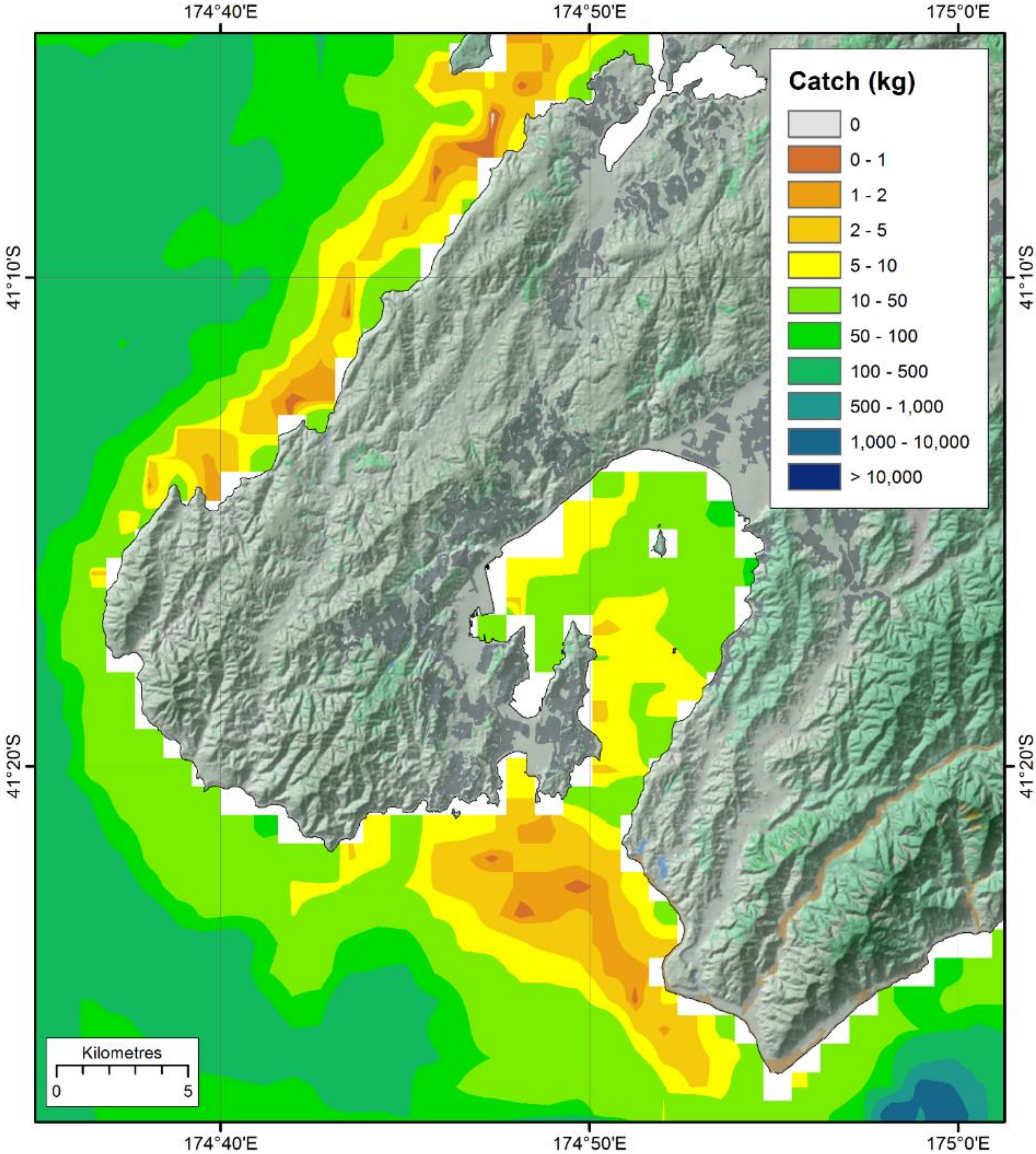


Figure 12-110: Catch (kg per hour) of ling (*Genypterus blacodes*) in a demersal trawl in the Wellington region.

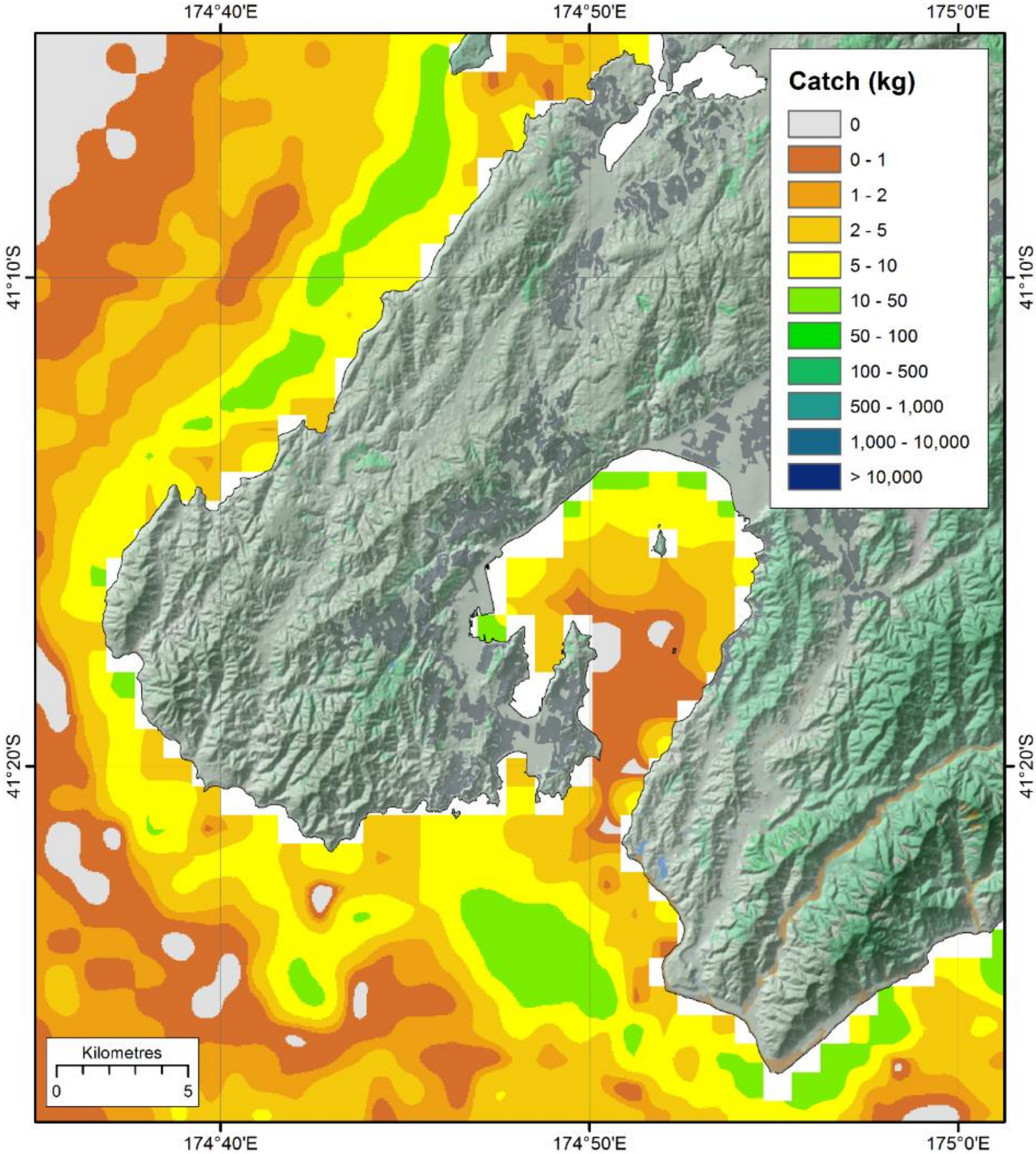


Figure 12-111: Catch (kg per hour) of lemon sole (*Pelotretis flavilatus*) in a demersal trawl in the Wellington region.

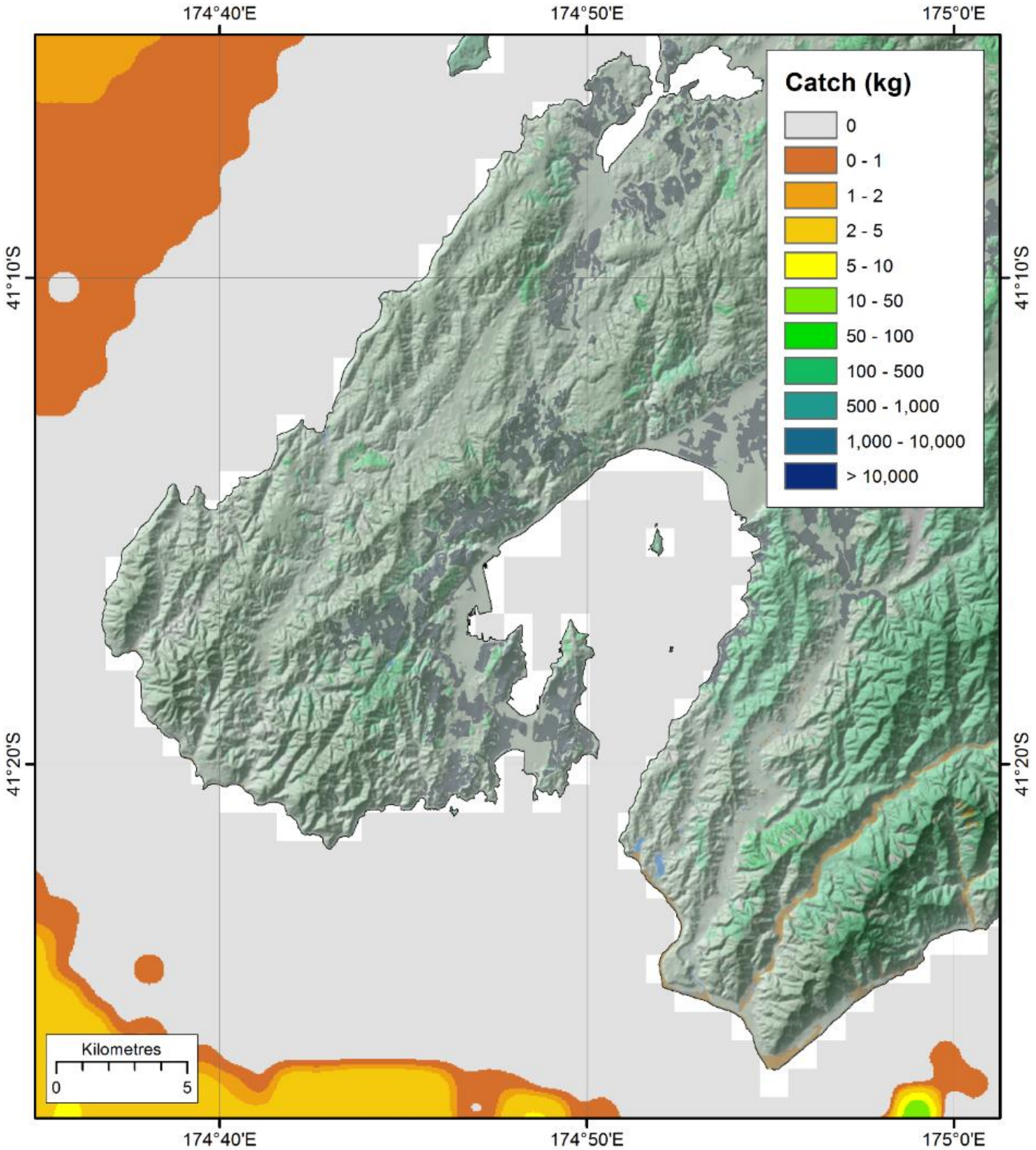


Figure 12-112: Catch (kg per hour) of northern spiny dogfish (*Squalus griffini*) in a demersal trawl in the Wellington region.

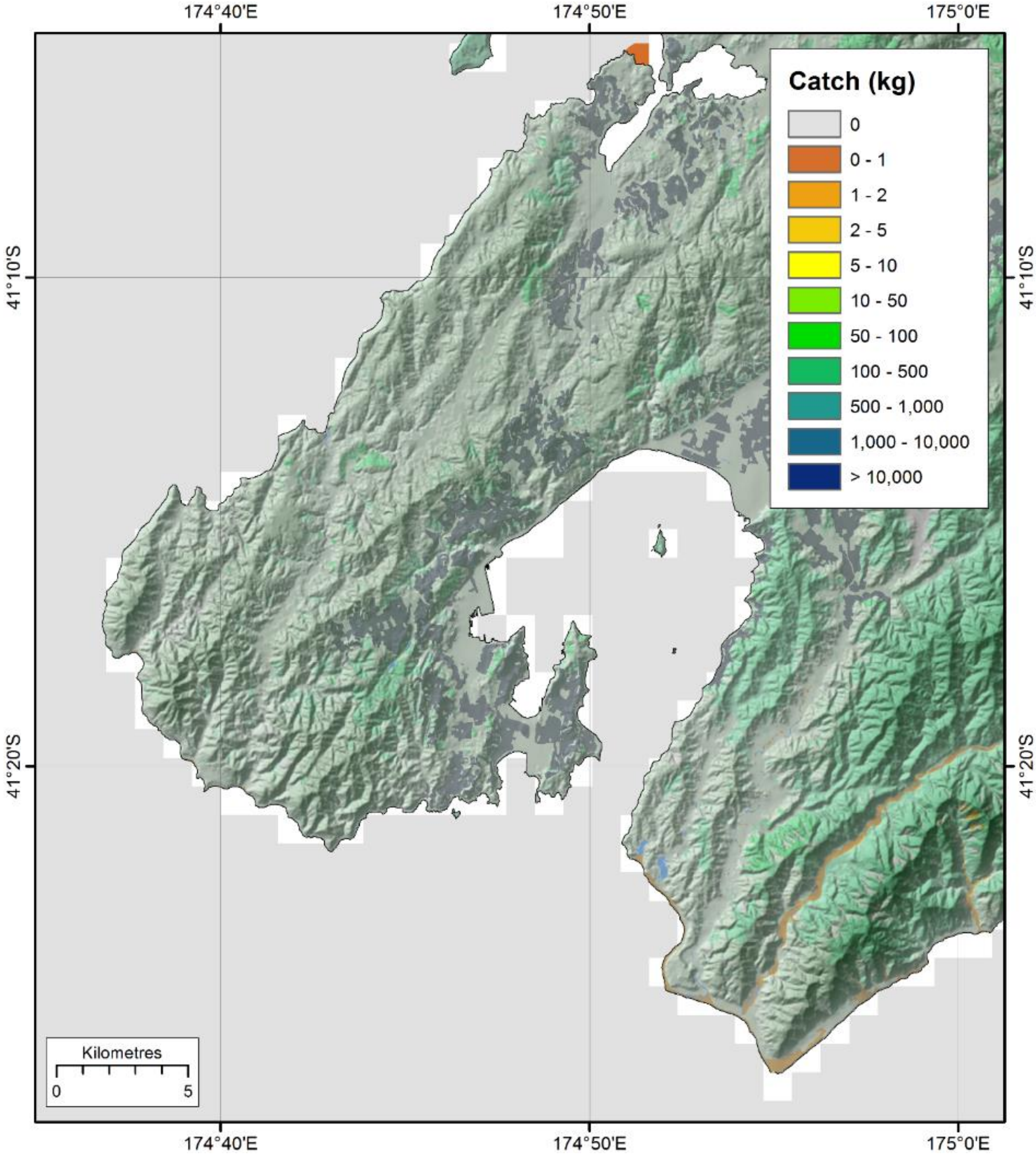


Figure 12-113: Catch (kg per hour) of ahuru (*Auchenoceros punctatus*) in a demersal trawl in the Wellington region.

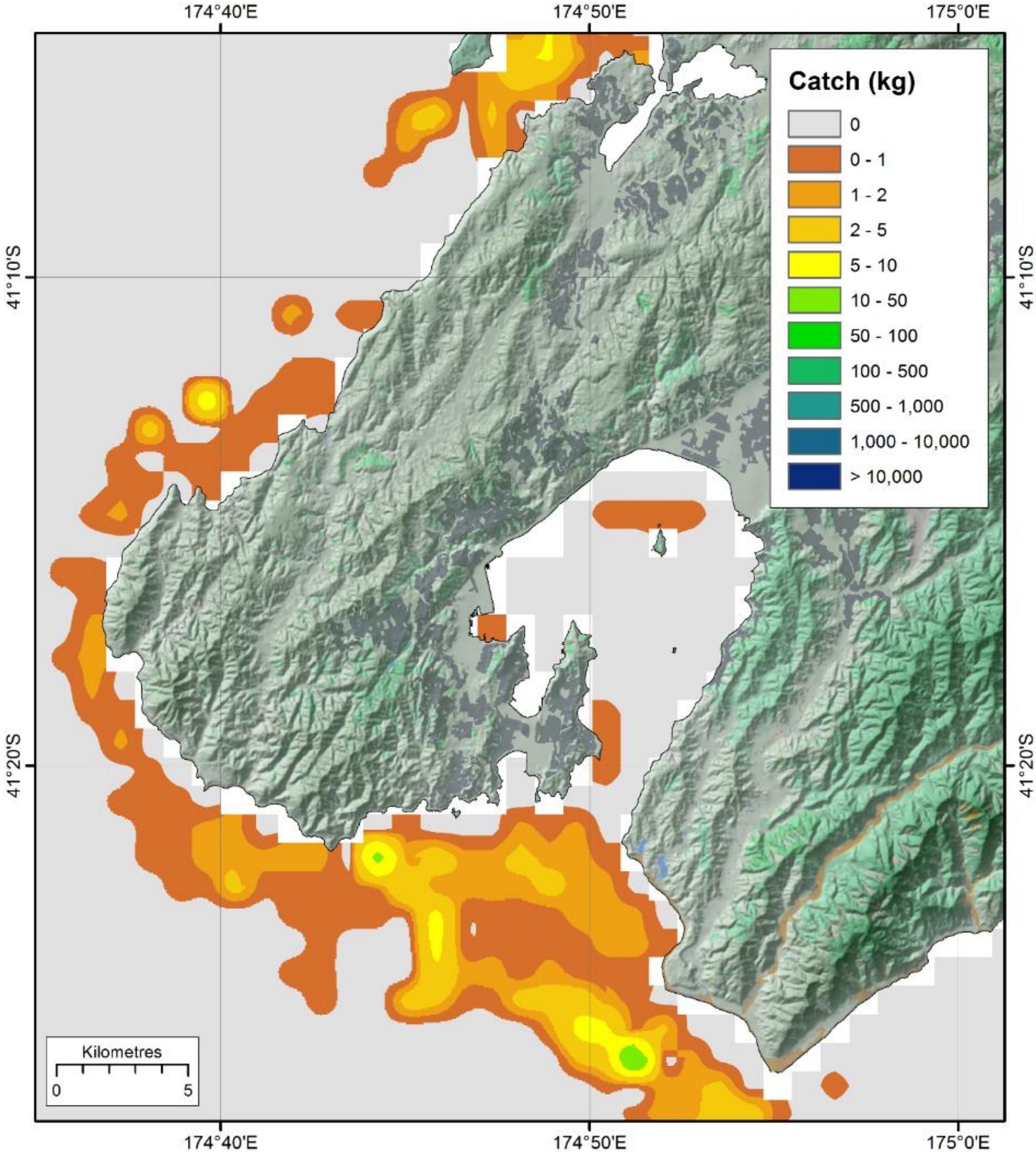


Figure 12-114: Catch (kg per hour) of porcupine fish (*Allomycterus jaculiferus*) in a demersal trawl in the Wellington region.

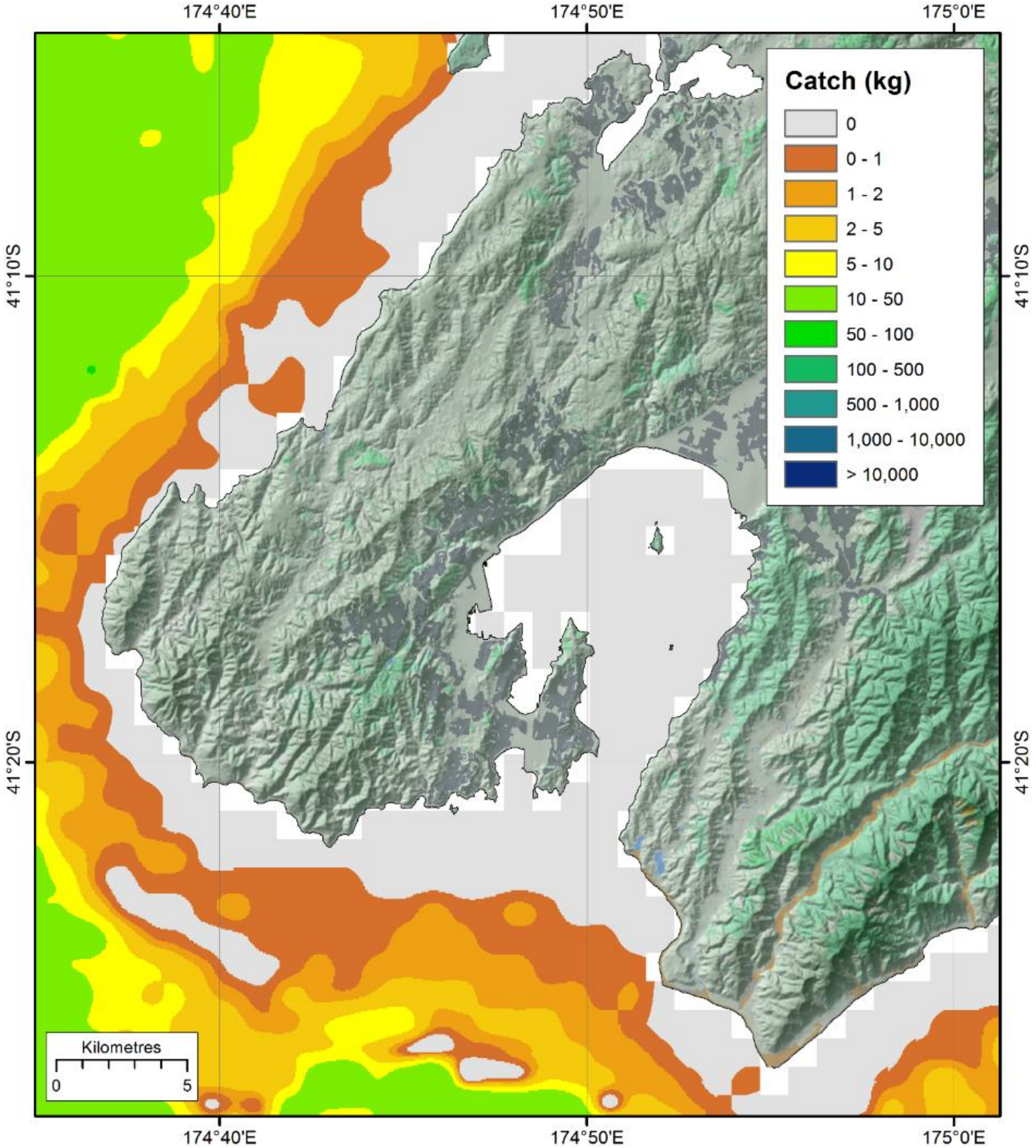


Figure 12-115: Catch (kg per hour) of Ray's bream (*Brama brama*) in a demersal trawl in the Wellington region.

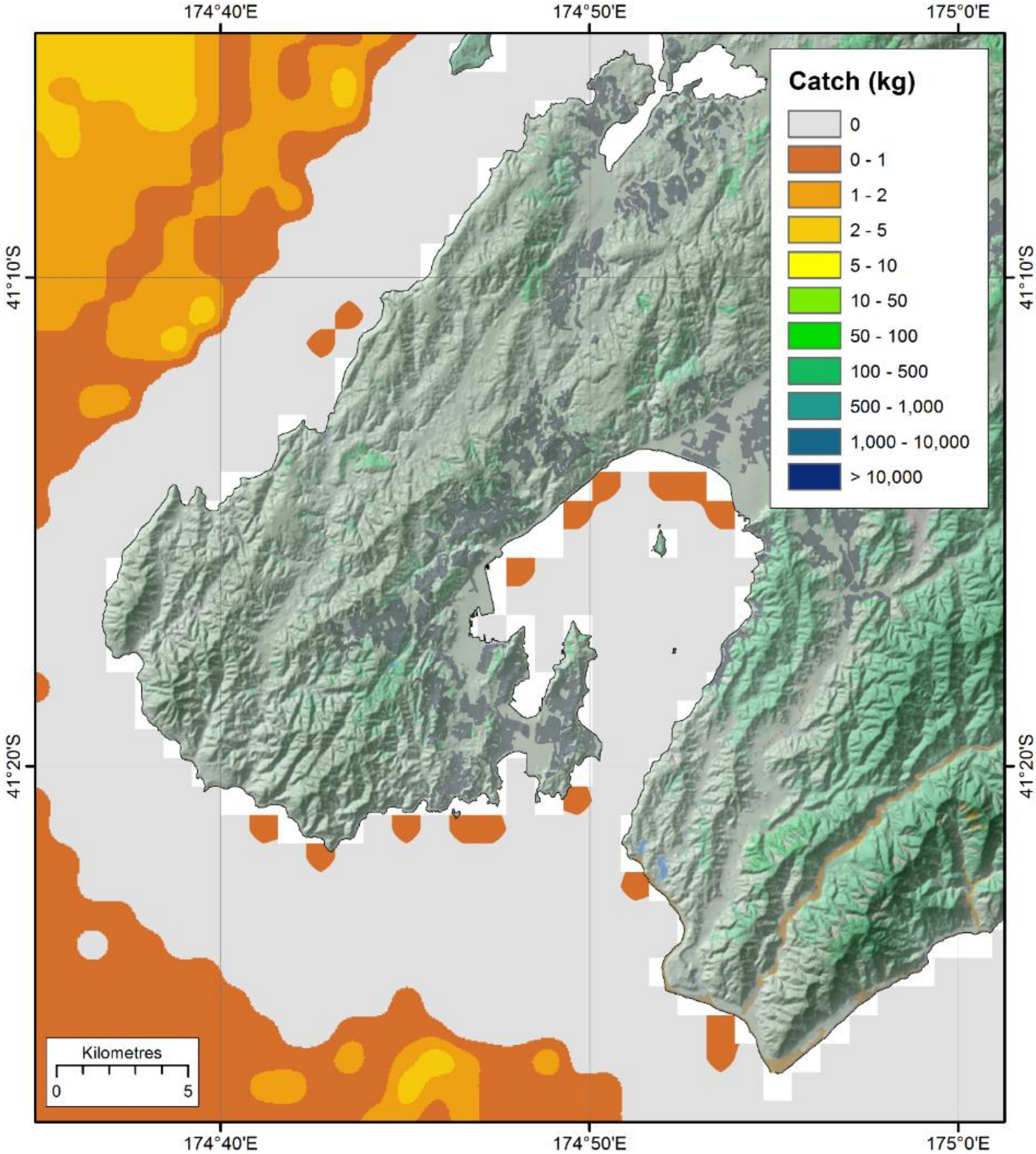


Figure 12-116: Catch (kg per hour) of redbait (*Emmelichthys nitidus*) in a demersal trawl in the Wellington region.

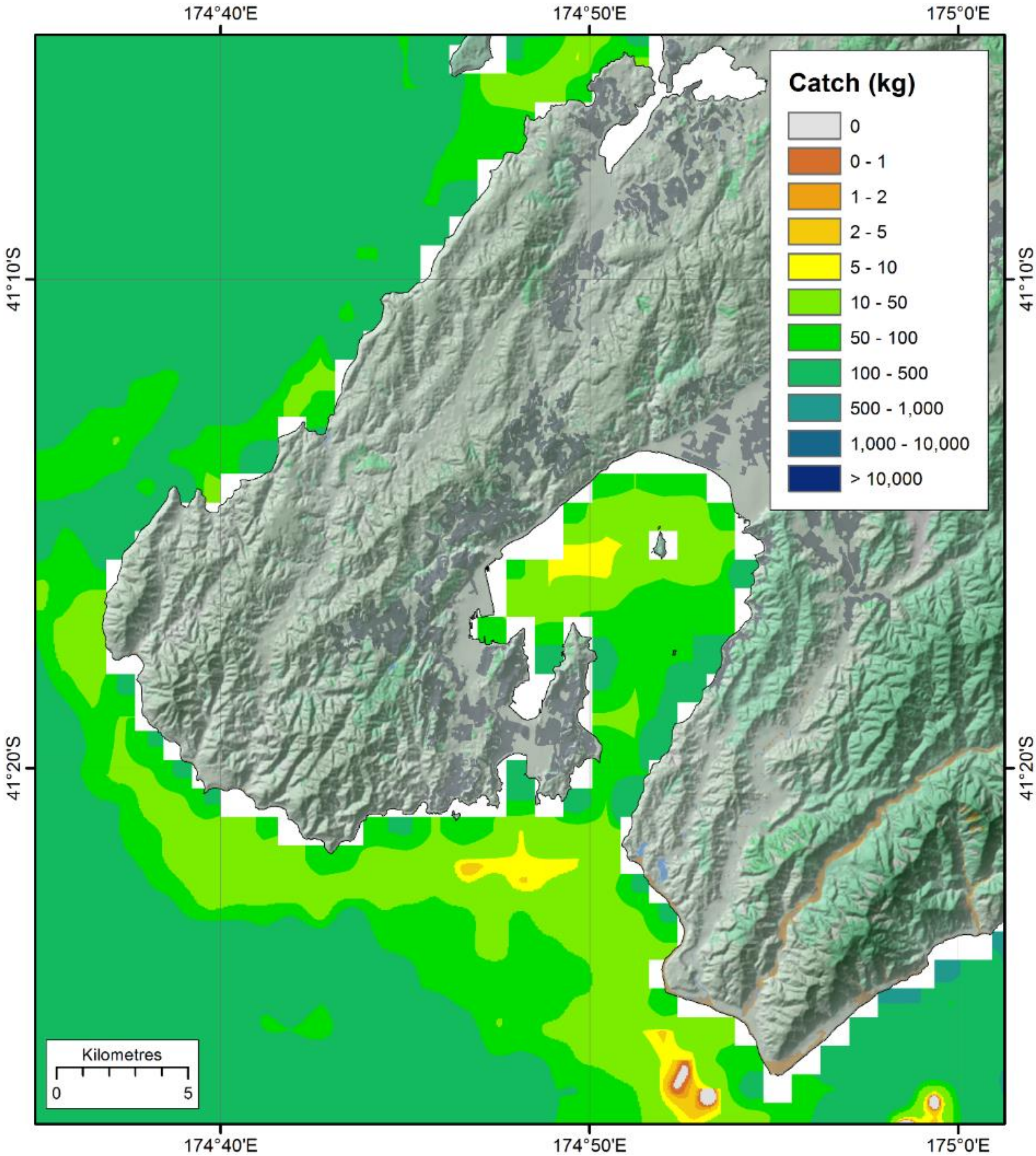


Figure 12-117: Catch (kg per hour) of red cod (*Pseudophycis bachus*) in a demersal trawl in the Wellington region.

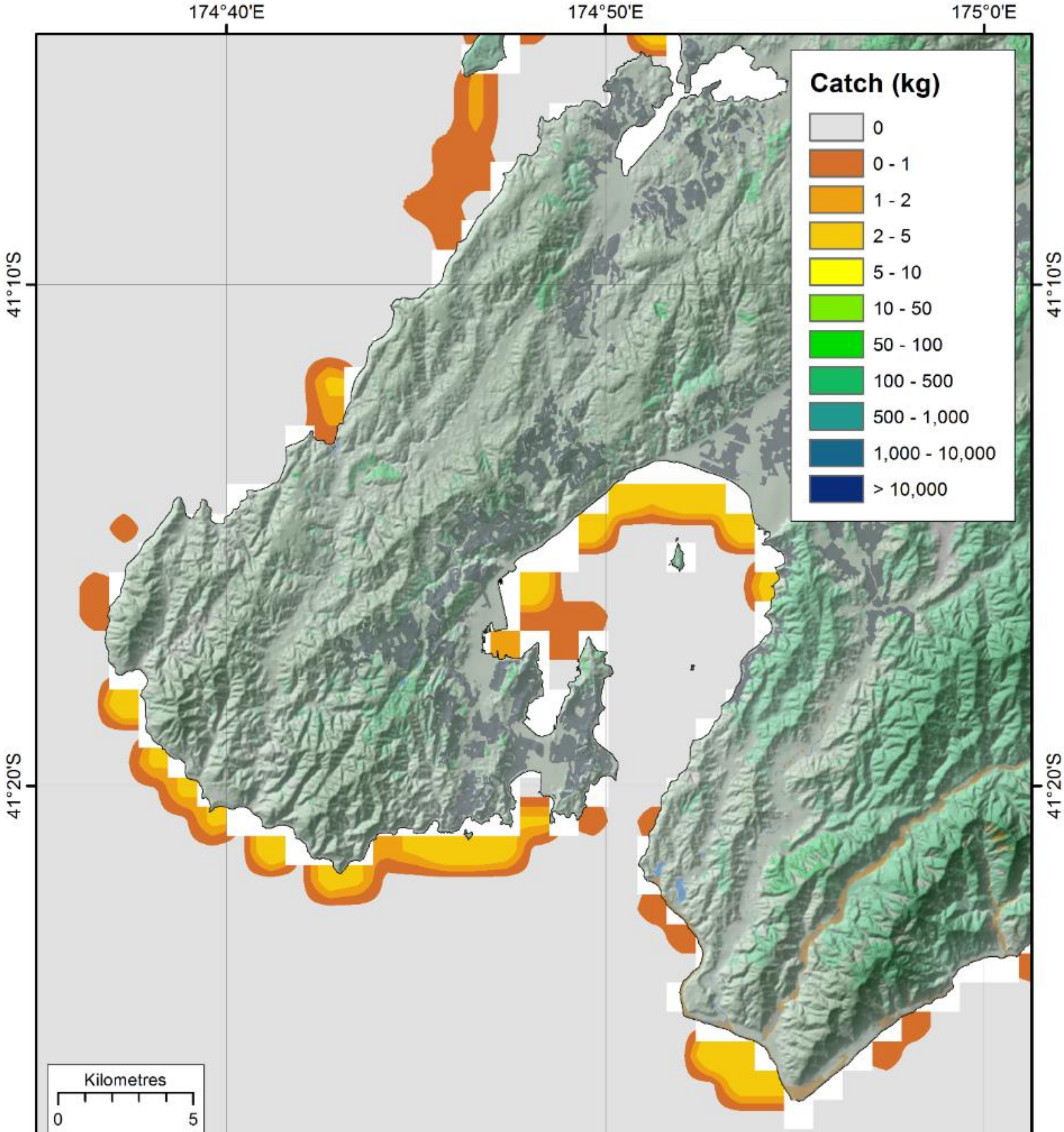


Figure 12-118: Catch (kg per hour) of red mullet (*Upeneichthys lineatus*) in a demersal trawl in the Wellington region.

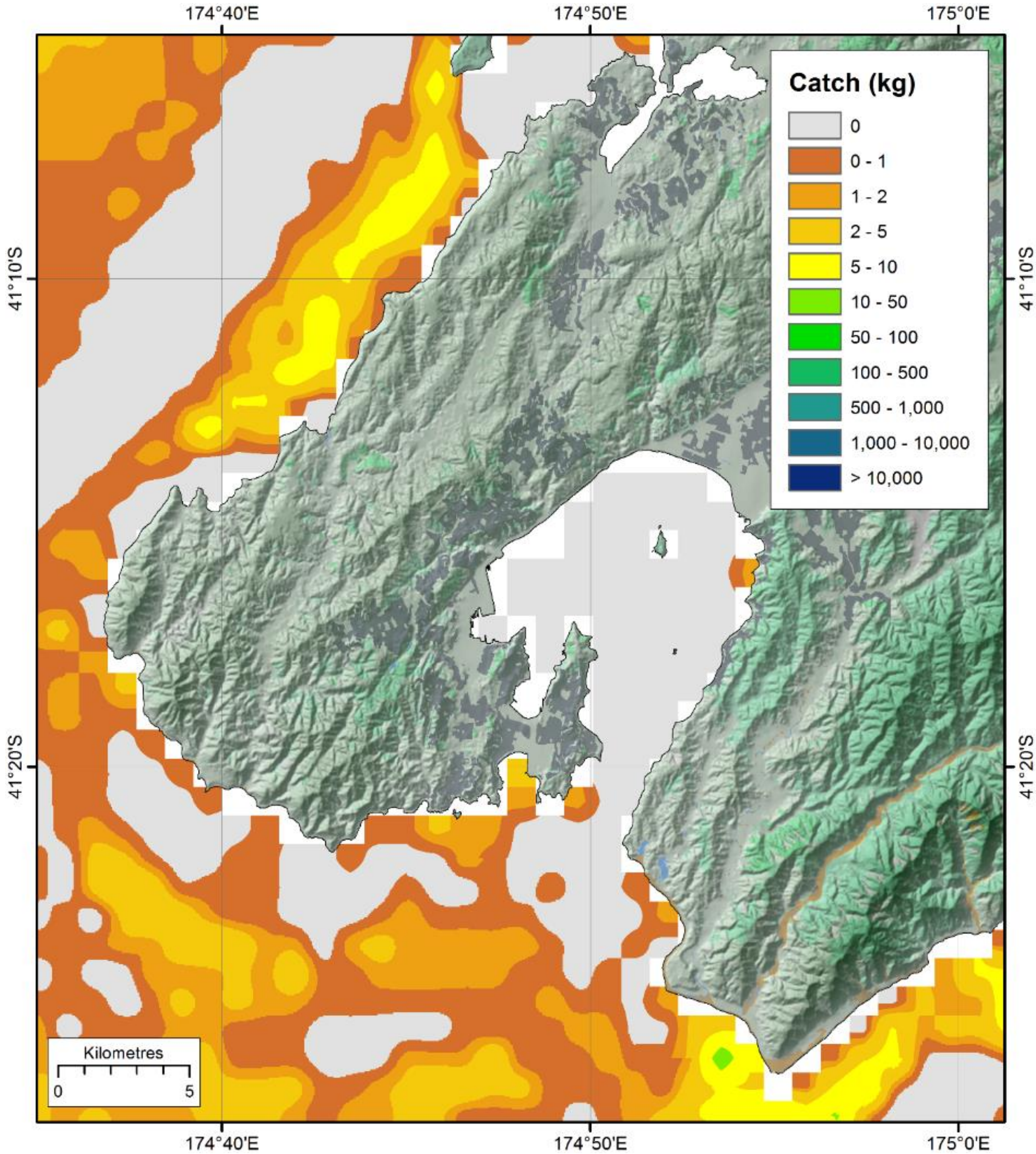


Figure 12-119: Catch (kg per hour) of scaly gurnard (*Lepidotrigla brachyoptera*) in a demersal trawl in the Wellington region.

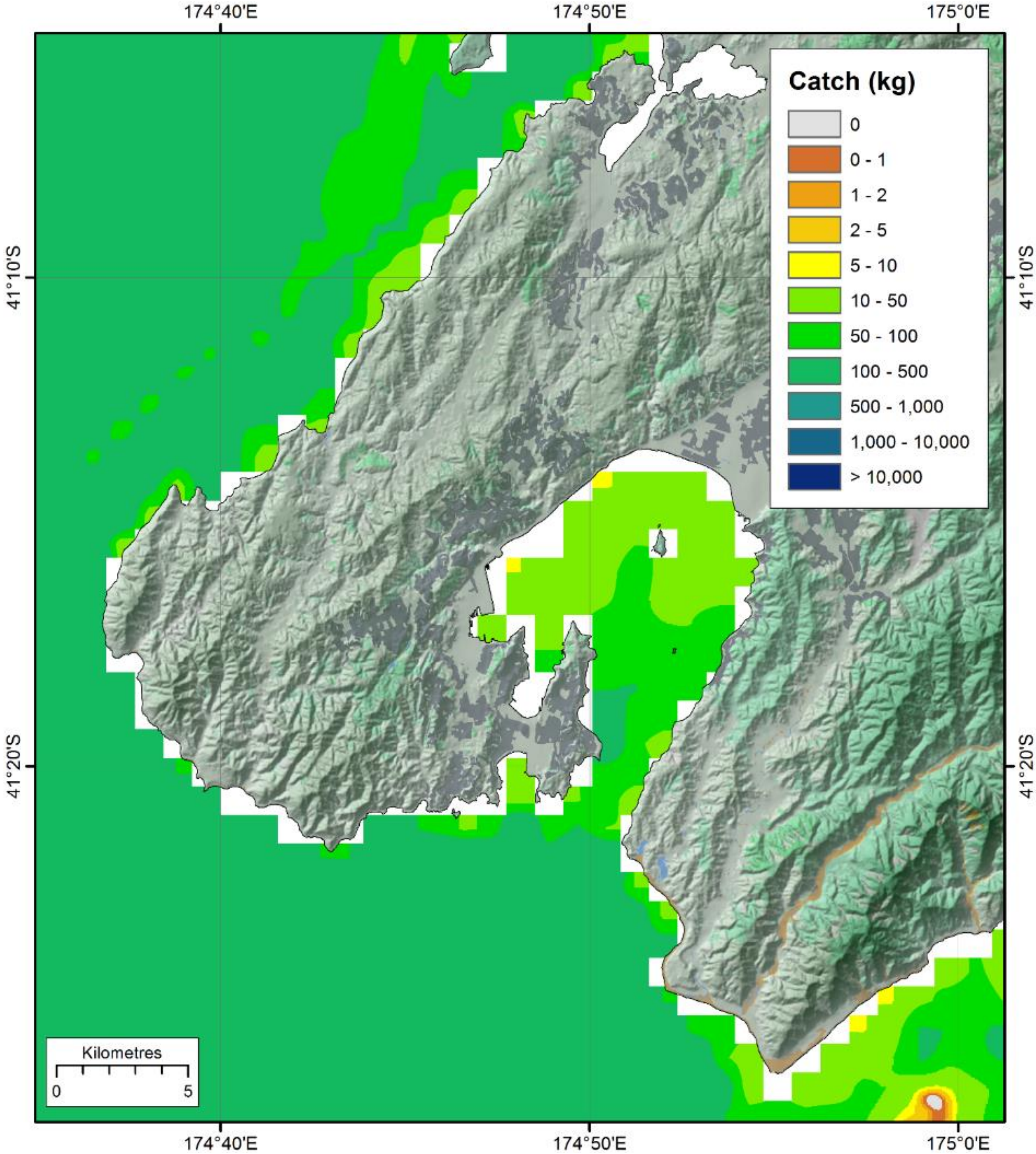


Figure 12-120: Catch (kg per hour) of school shark (*Galeorhinus galeus*) in a demersal trawl in the Wellington region.

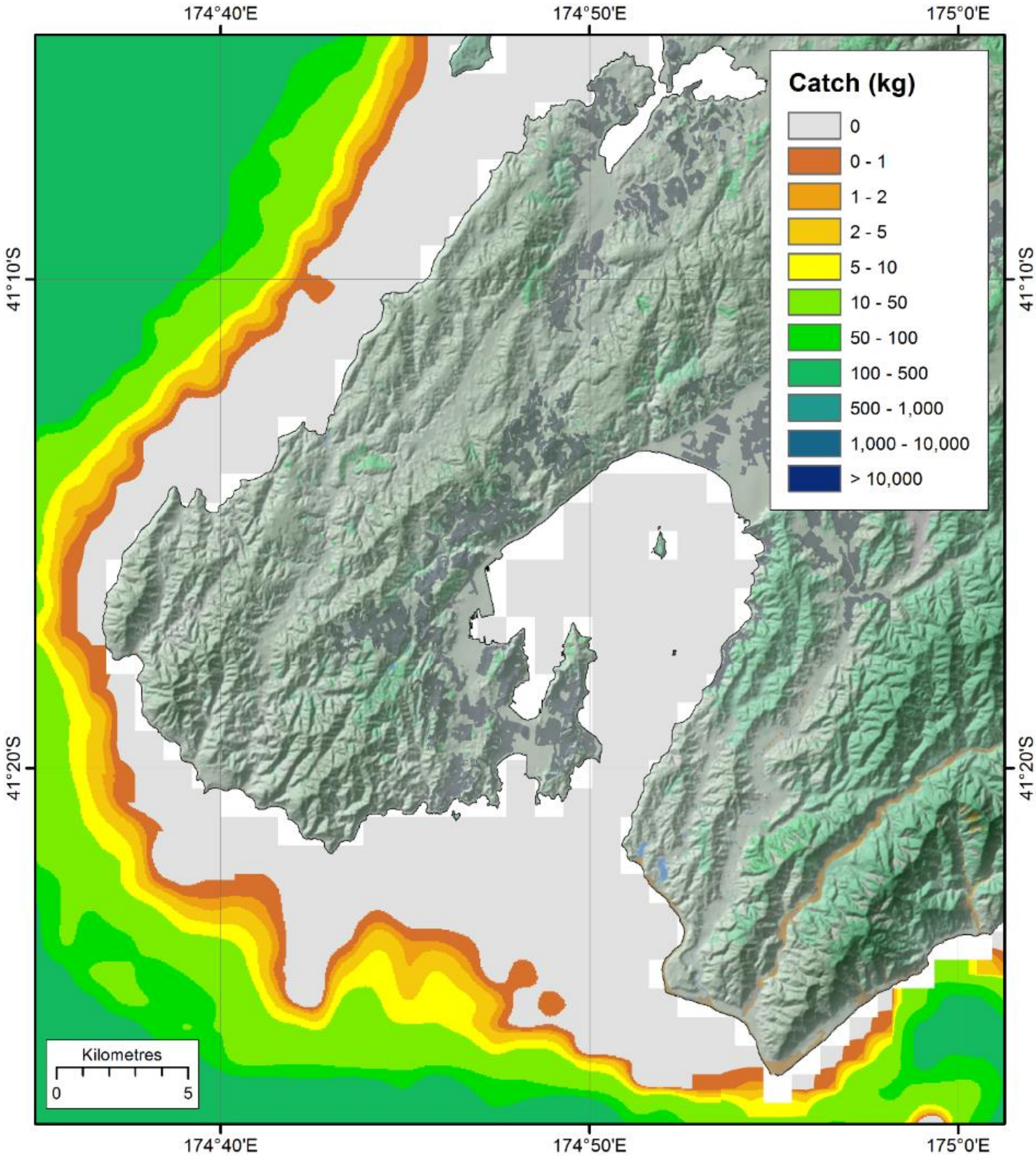


Figure 12-121: Catch (kg per hour) of silver dory (*Cyttus novaezealandiae*) in a demersal trawl in the Wellington region.

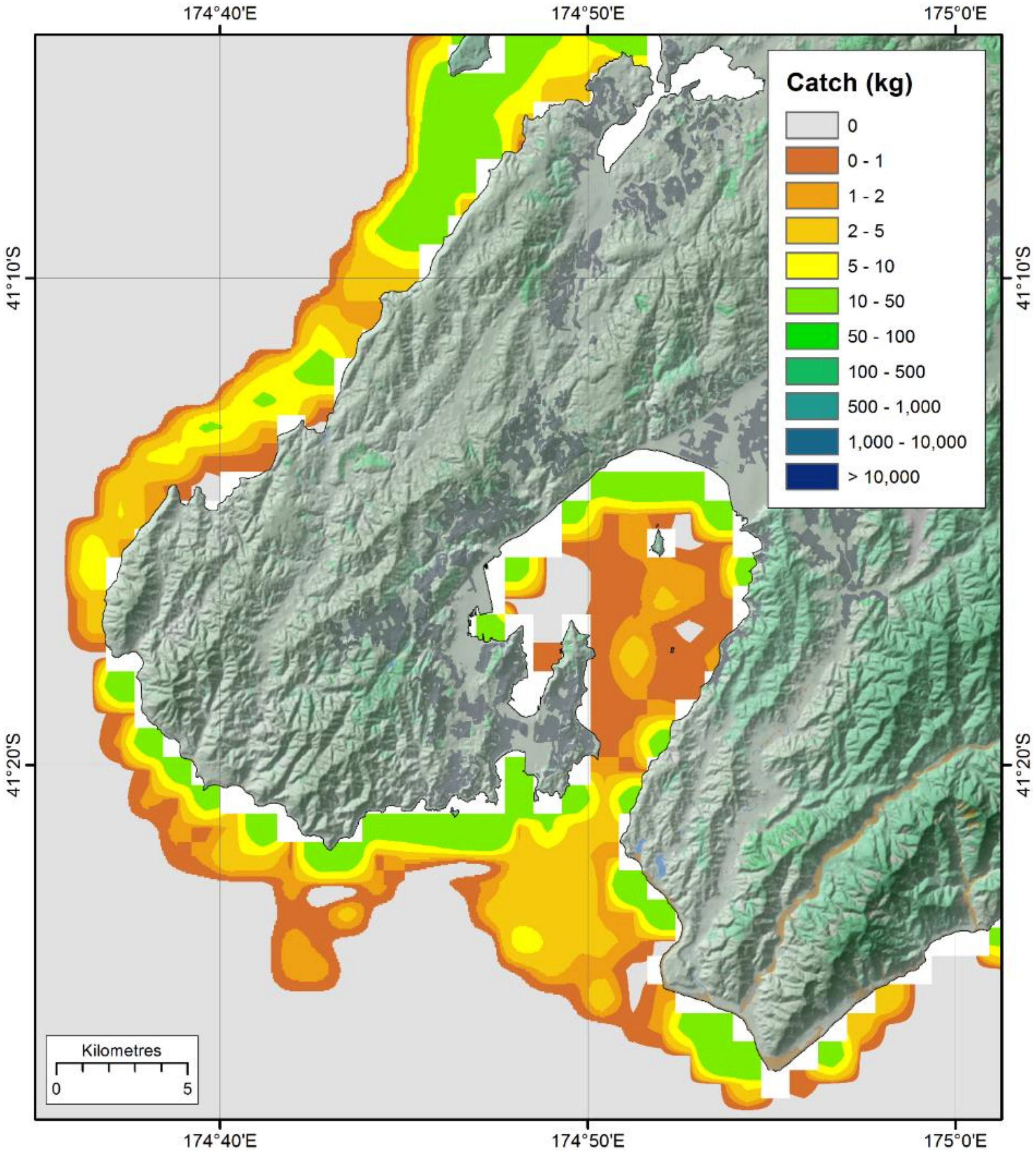


Figure 12-122: Catch (kg per hour) of sand flounder (*Phombosolea plebeia*) in a demersal trawl in the Wellington region.

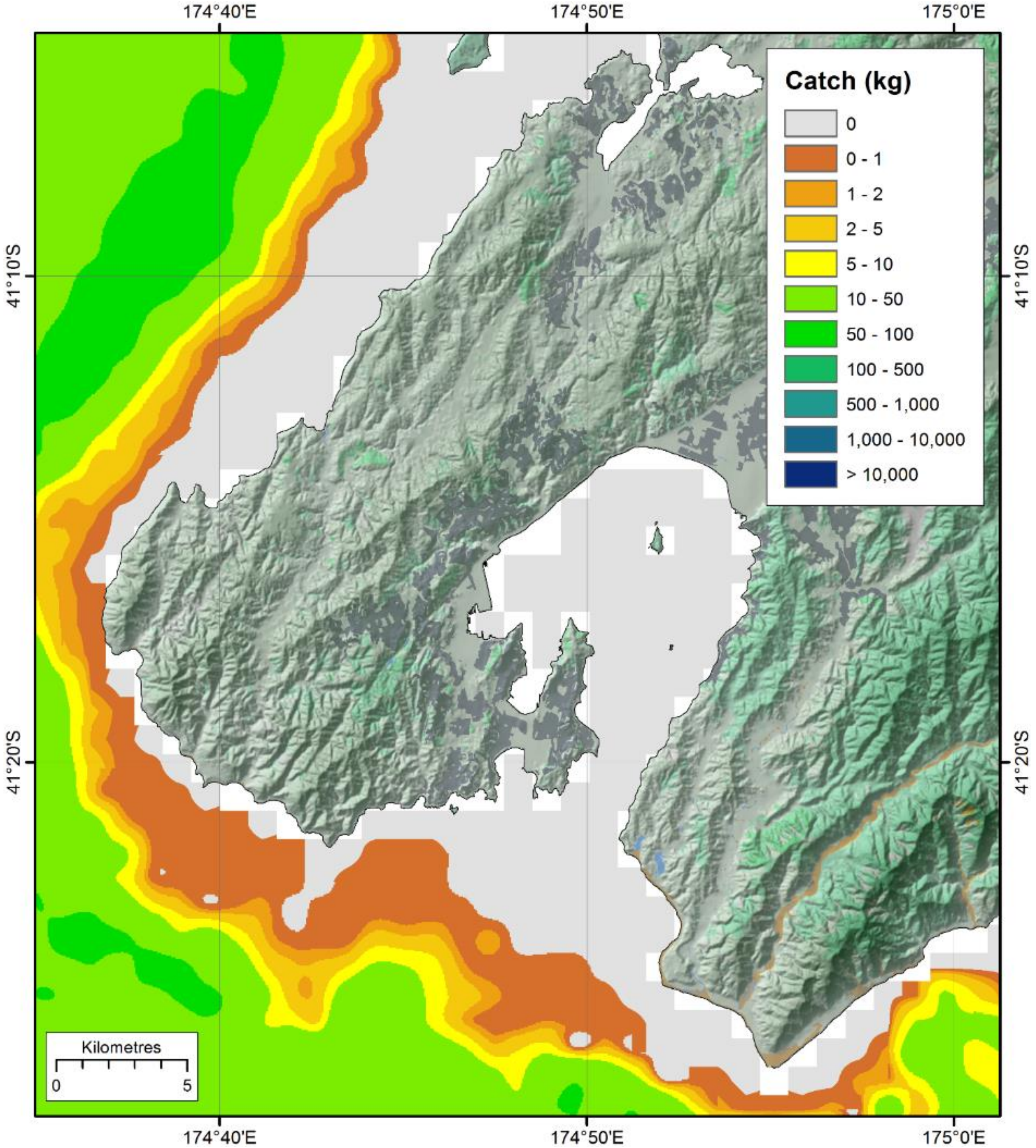


Figure 12-123: Catch (kg per hour) of gemfish (*Rexea solandri*) in a demersal trawl in the Wellington region.

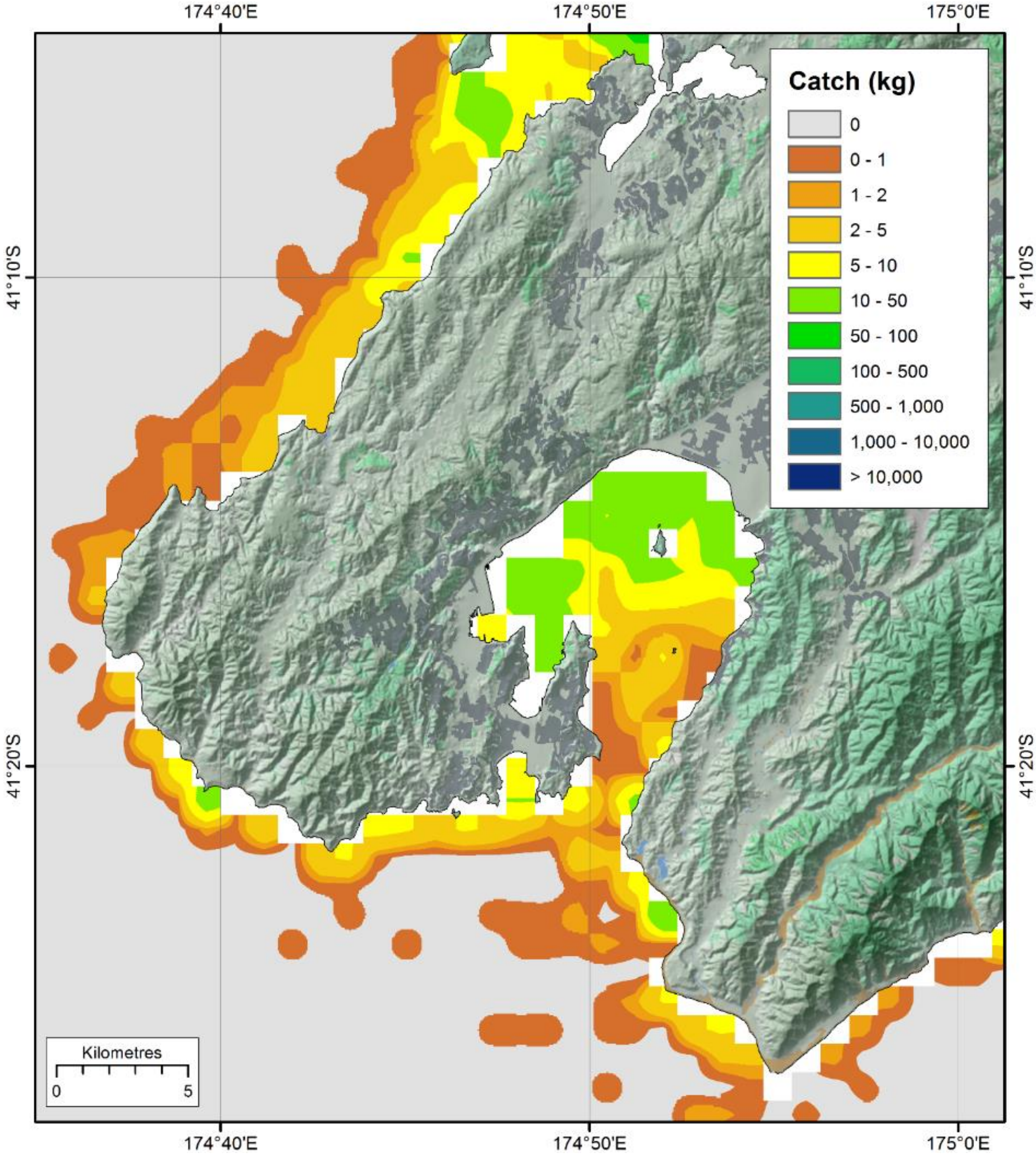


Figure 12-124: Catch (kg per hour) of snapper (*Pagrus auratus*) in a demersal trawl in the Wellington region.

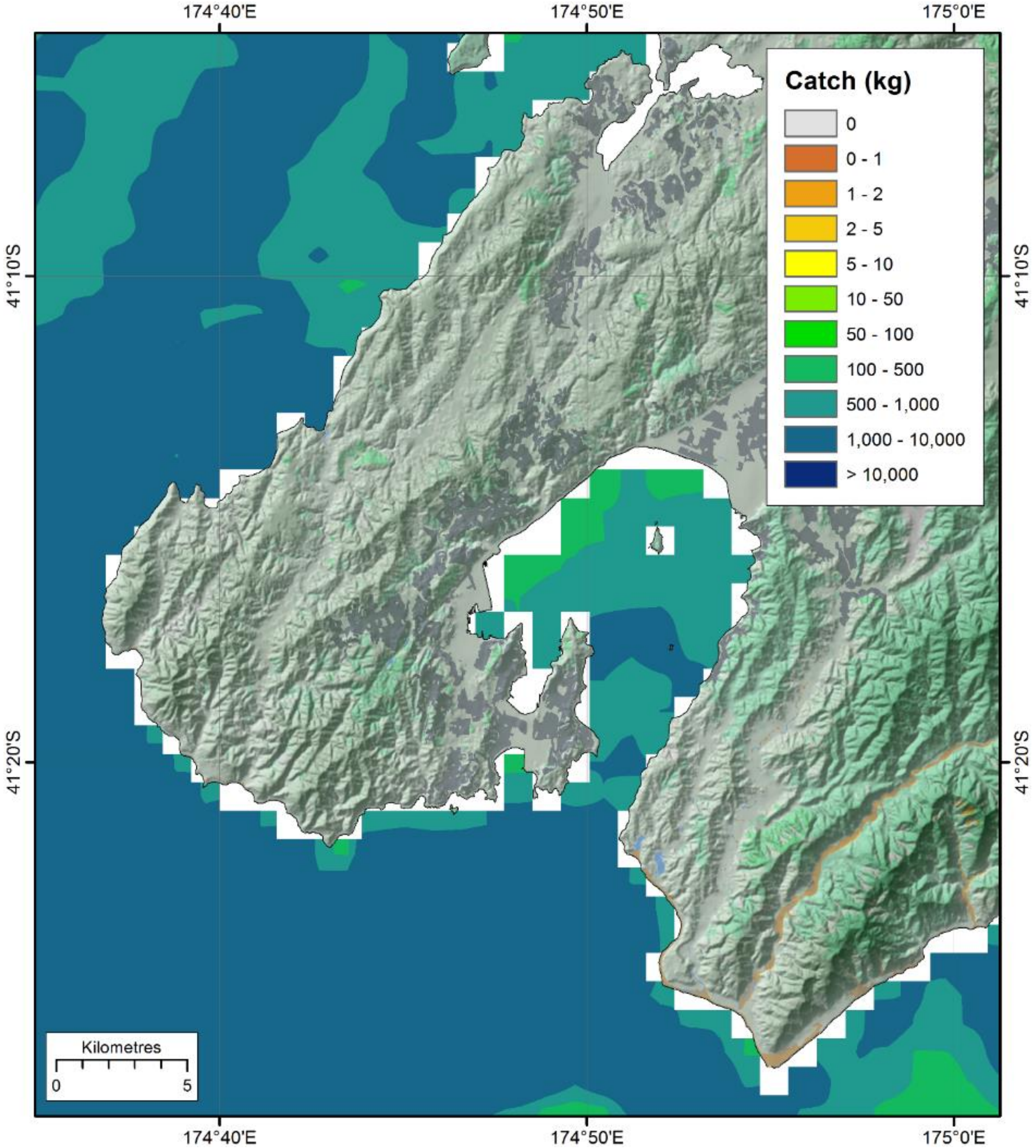


Figure 12-125: Catch (kg per hour) of spiny dogfish (*Squalus acanthias*) in a demersal trawl in the Wellington region.

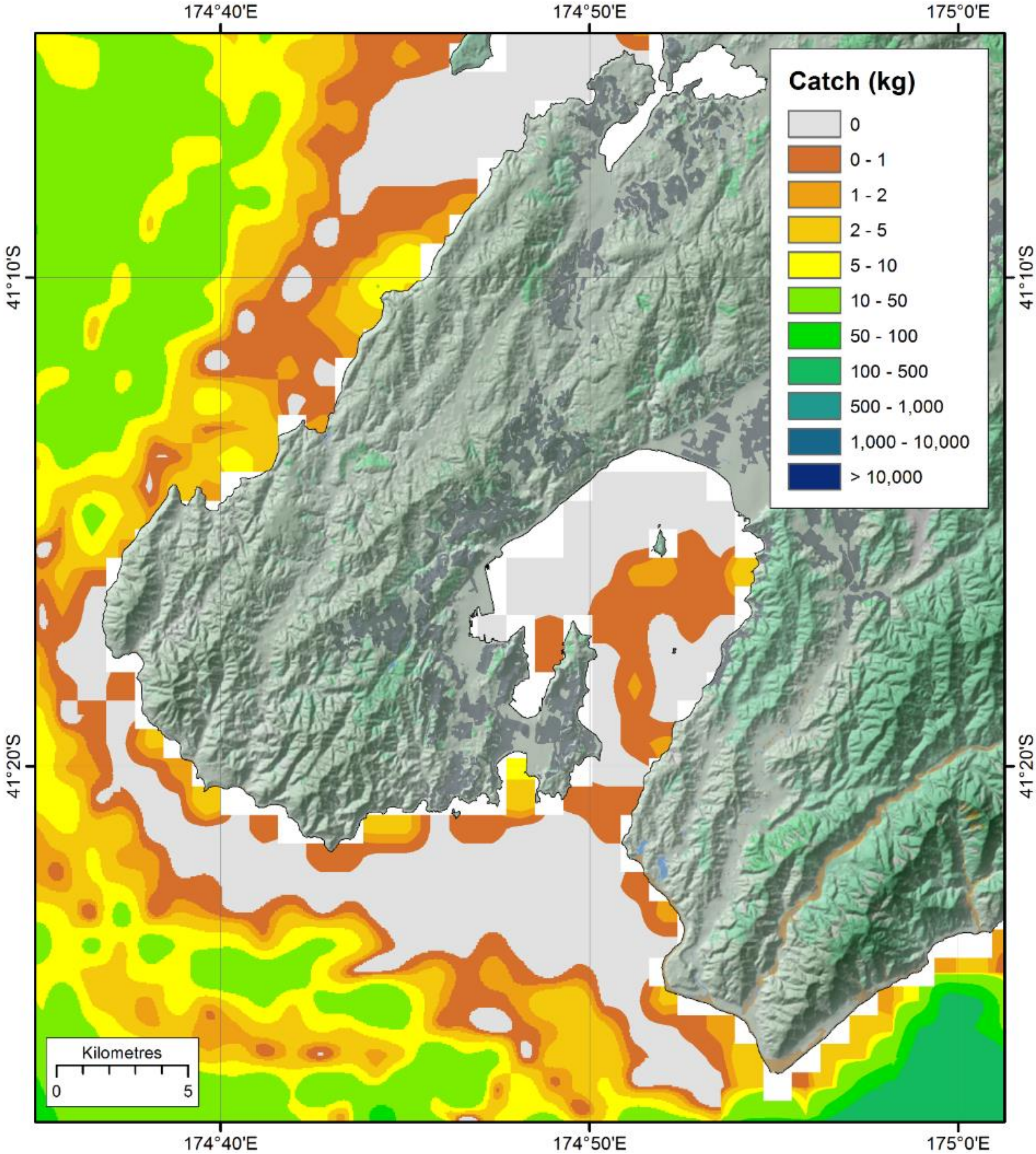


Figure 12-126: Catch (kg per hour) of sea perch (*Helicolenus* spp.) in a demersal trawl in the Wellington region.

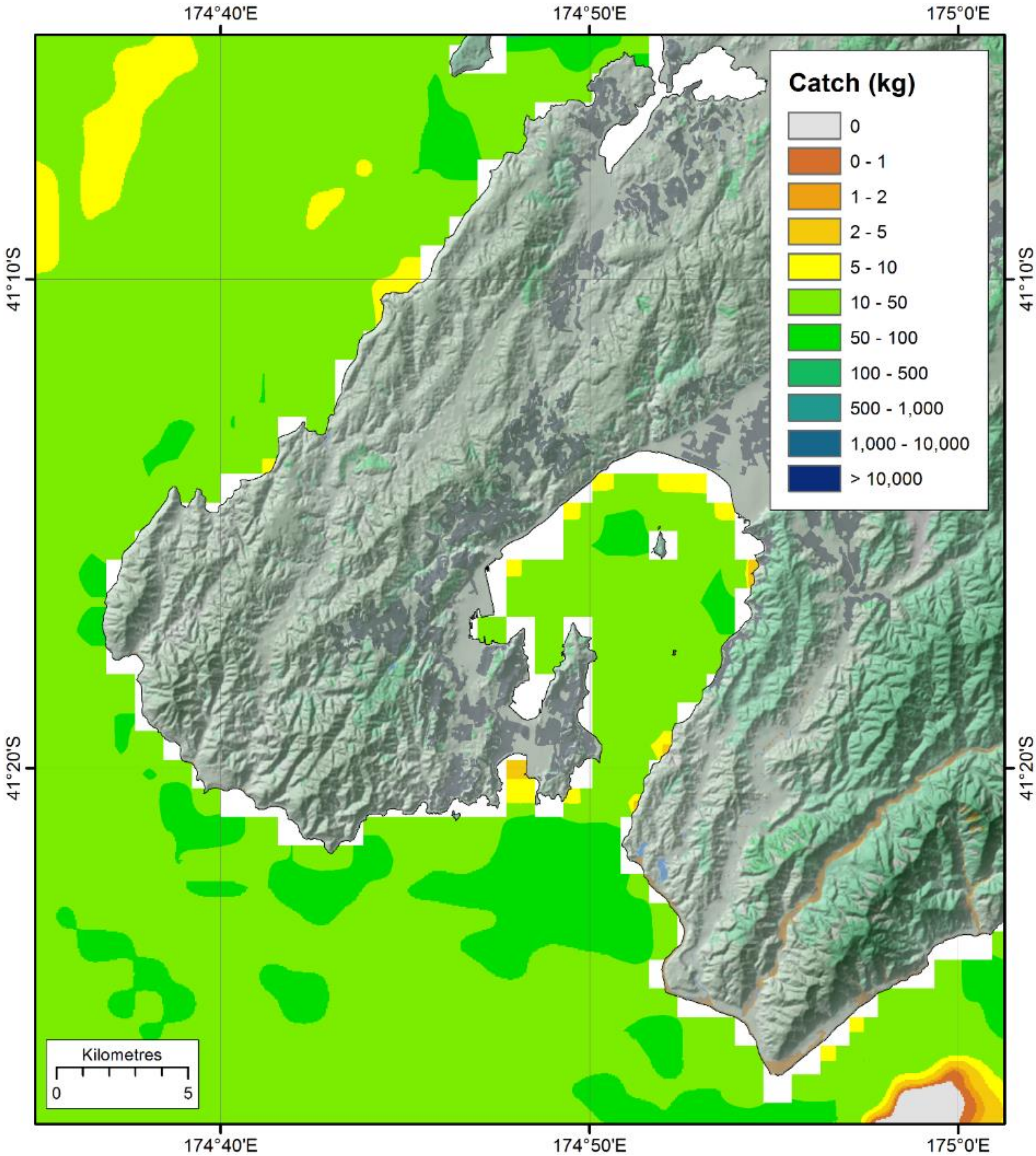


Figure 12-127: Catch (kg per hour) of rig (*Mustelus lenticulatus*) in a demersal trawl in the Wellington region.

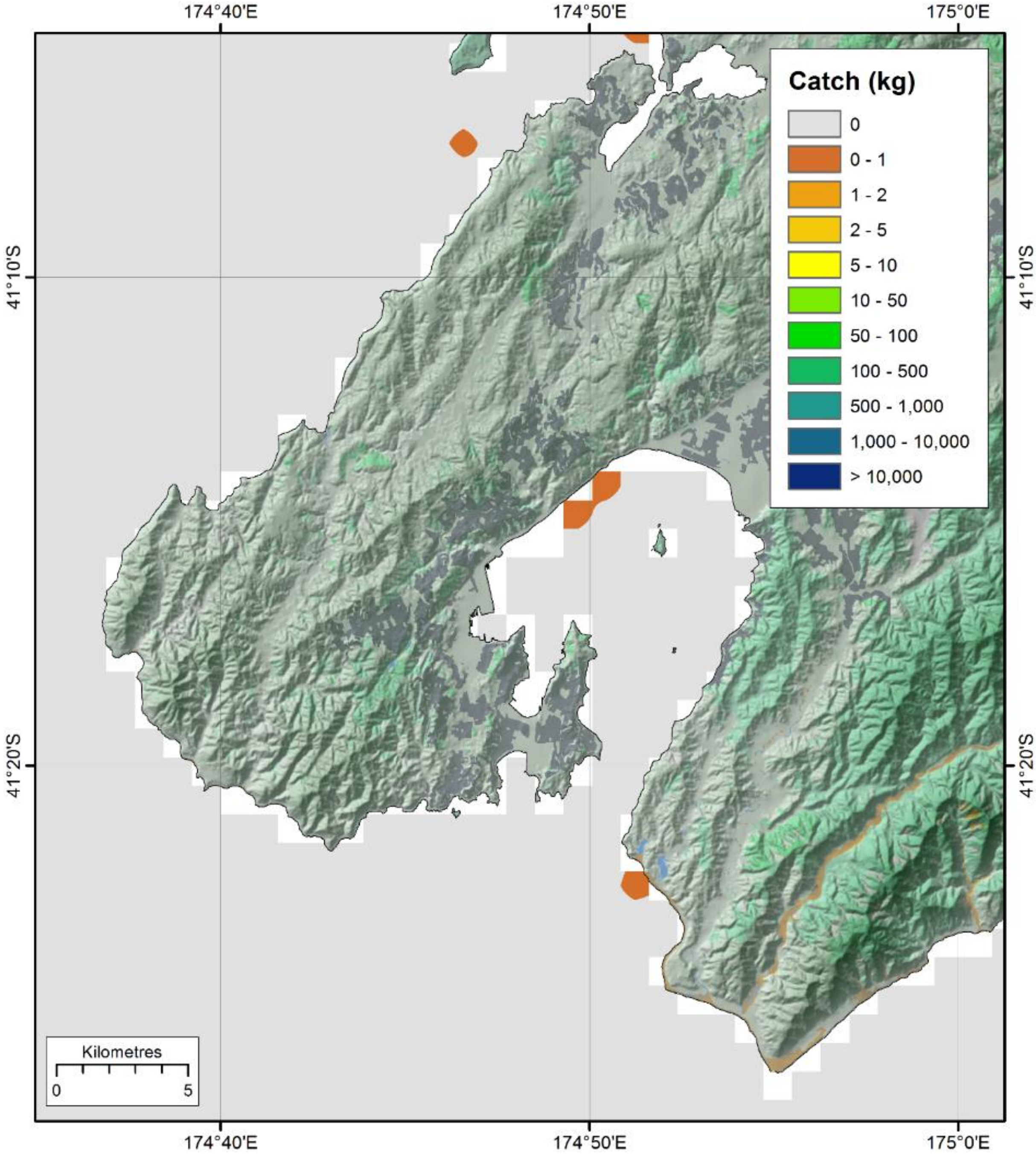


Figure 12-128: Catch (kg per hour) of spotted stargazer (*Genyagnus monopterygius*) in a demersal trawl in the Wellington region.

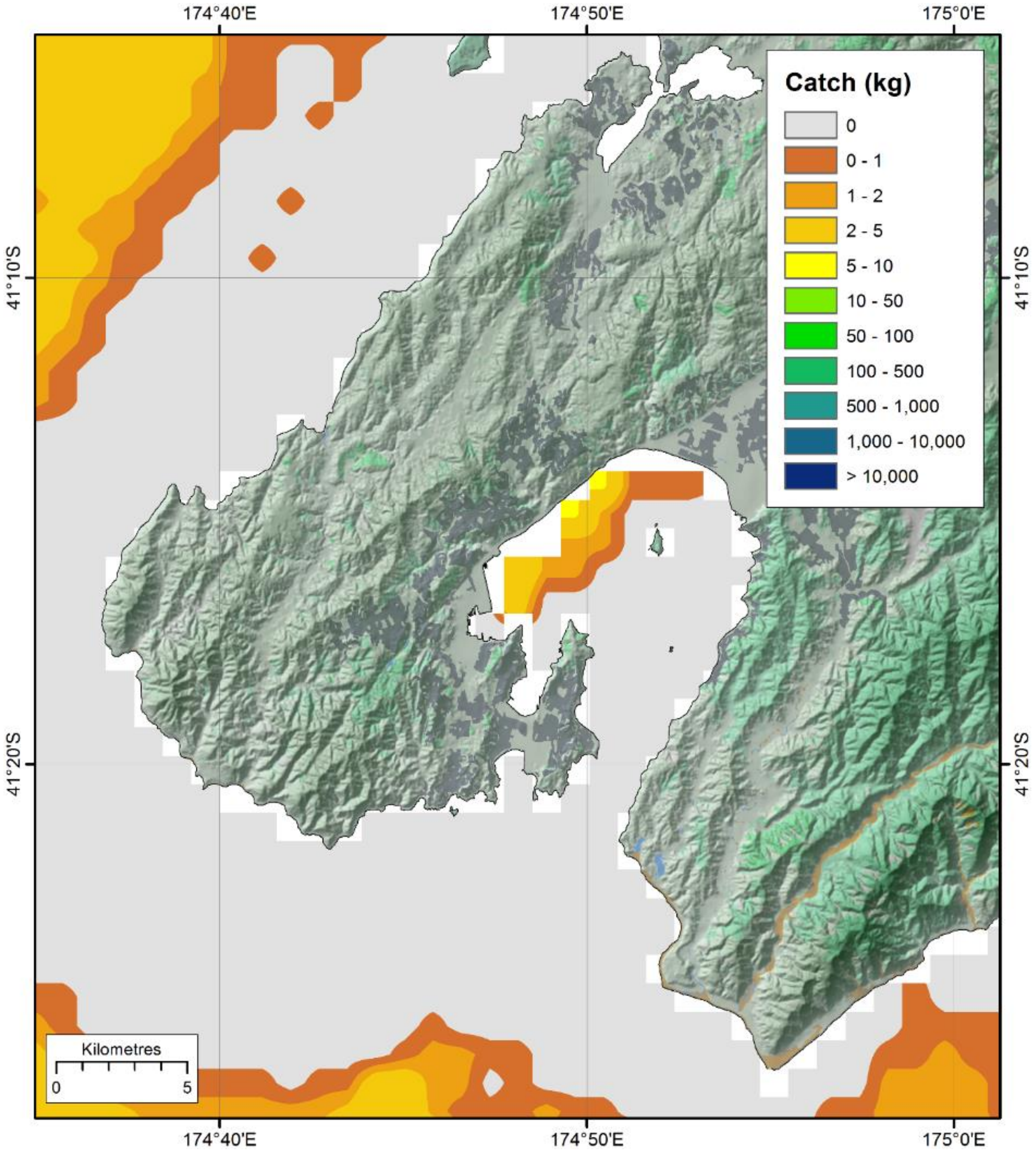


Figure 12-129: Catch (kg per hour) of silverside (*Argentina elongata*) in a demersal trawl in the Wellington region.

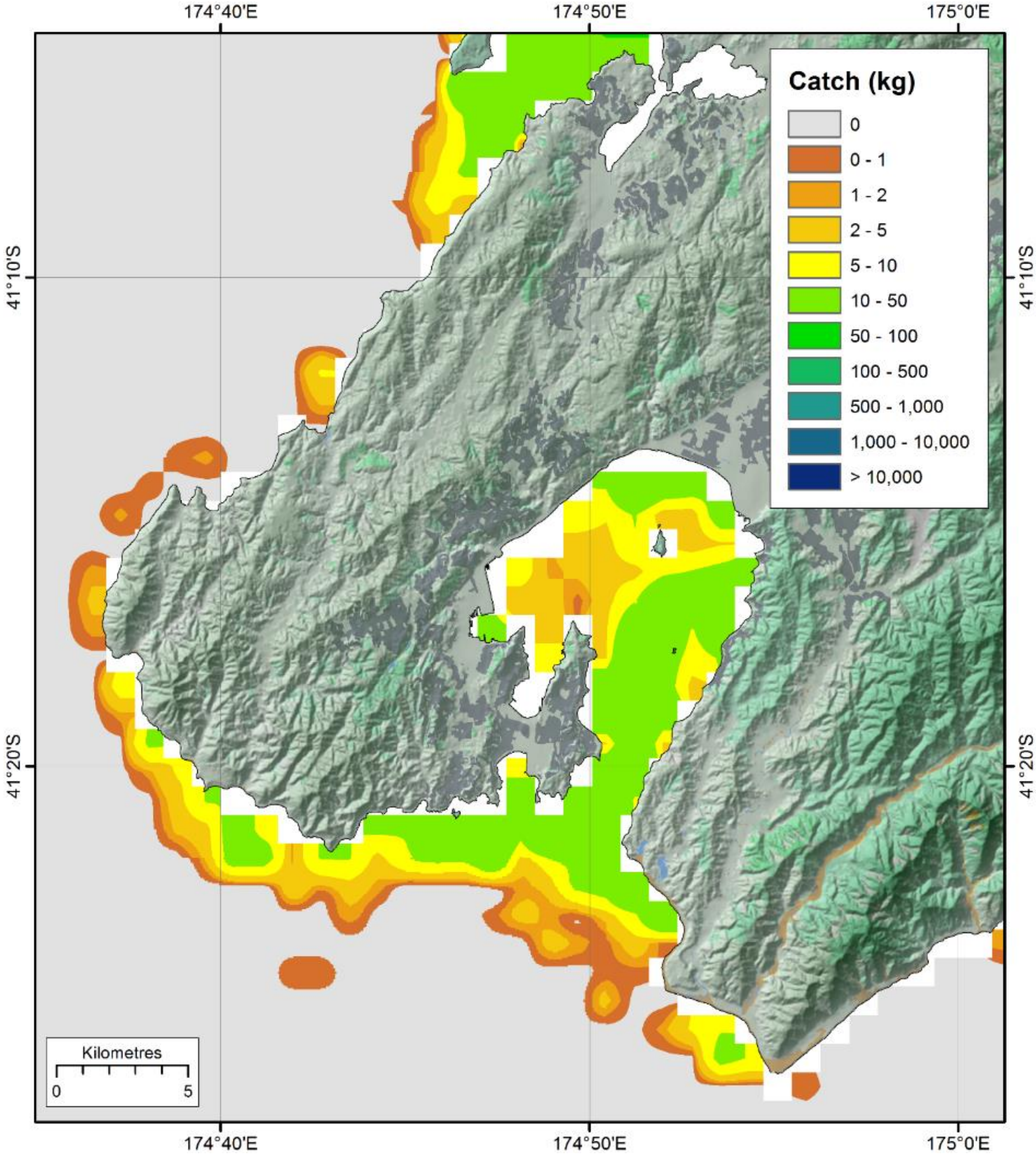


Figure 12-130: Catch (kg per hour) of spotty (*Notolabrus celidotus*) in a demersal trawl in the Wellington region.

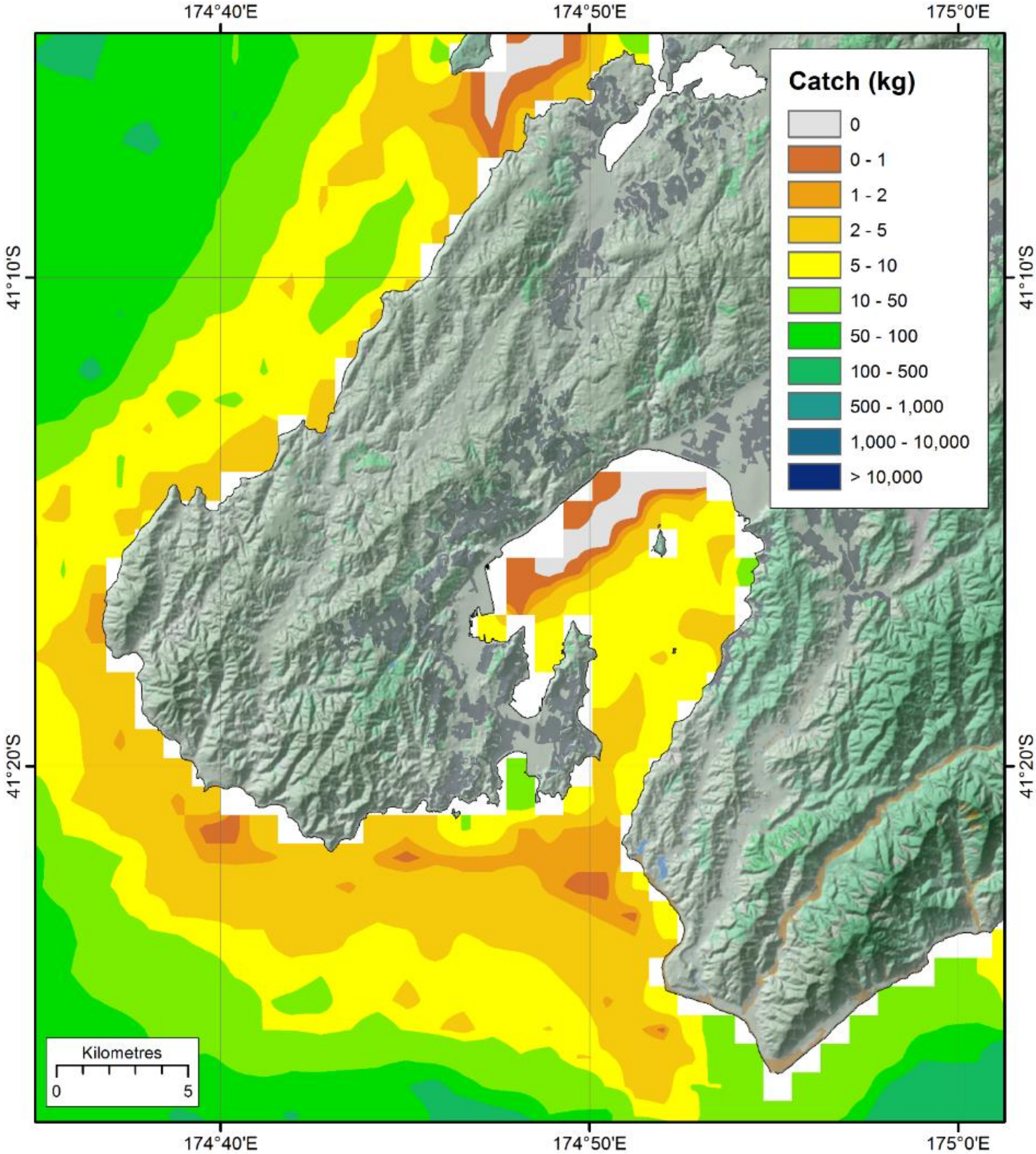


Figure 12-131: Catch (kg per hour) of silver warehou (*Seriolella punctata*) in a demersal trawl in the Wellington region.

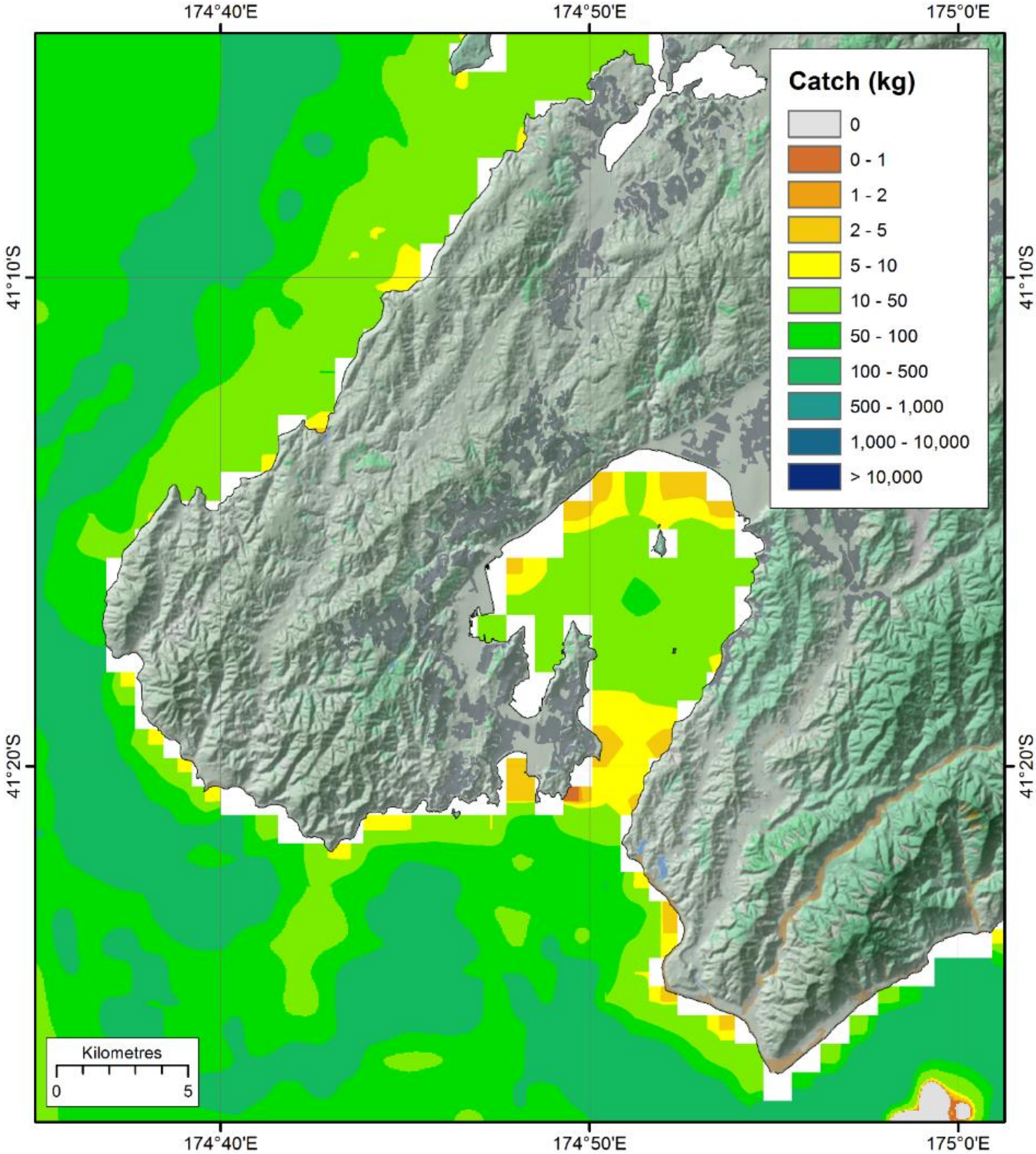


Figure 12-132: Catch (kg per hour) of tarakihi (*Nemadactylus macropterus*) in a demersal trawl in the Wellington region.

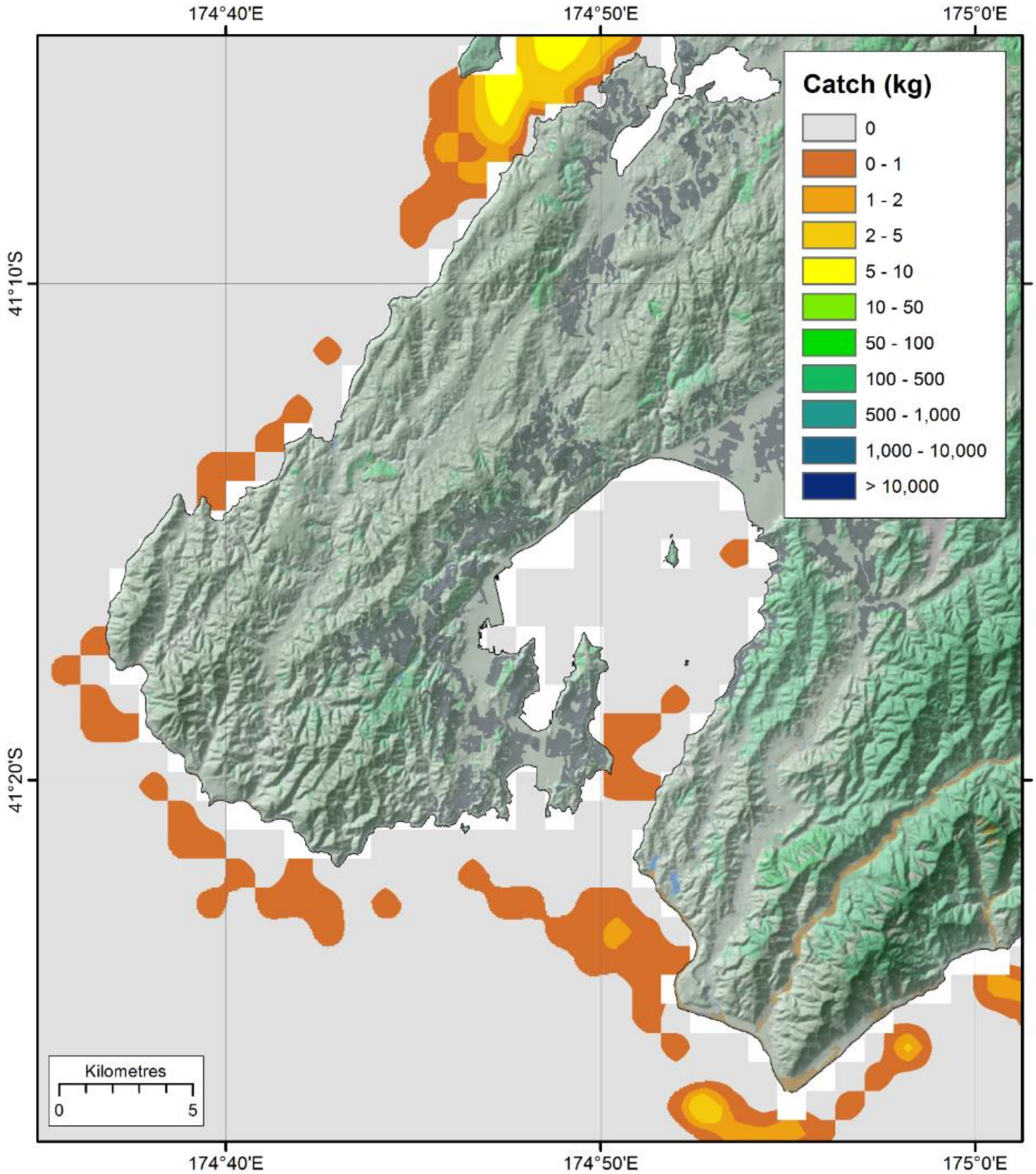


Figure 12-133: Catch (kg per hour) of trevally (*Pseudocaranx dentex*) in a demersal trawl in the Wellington region.

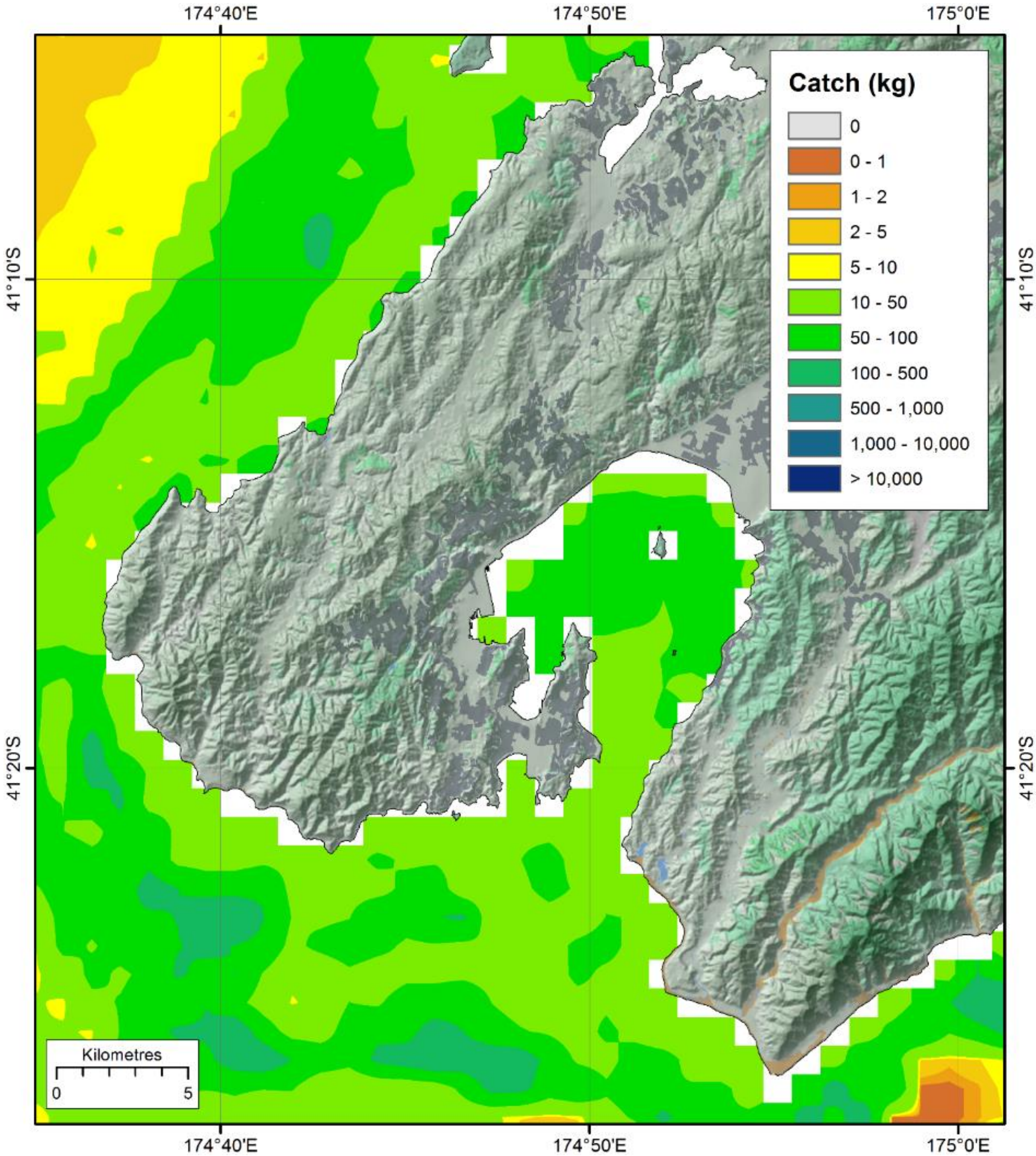


Figure 12-134: Catch (kg per hour) of common warehou (*Seriolella brama*) in a demersal trawl in the Wellington region.

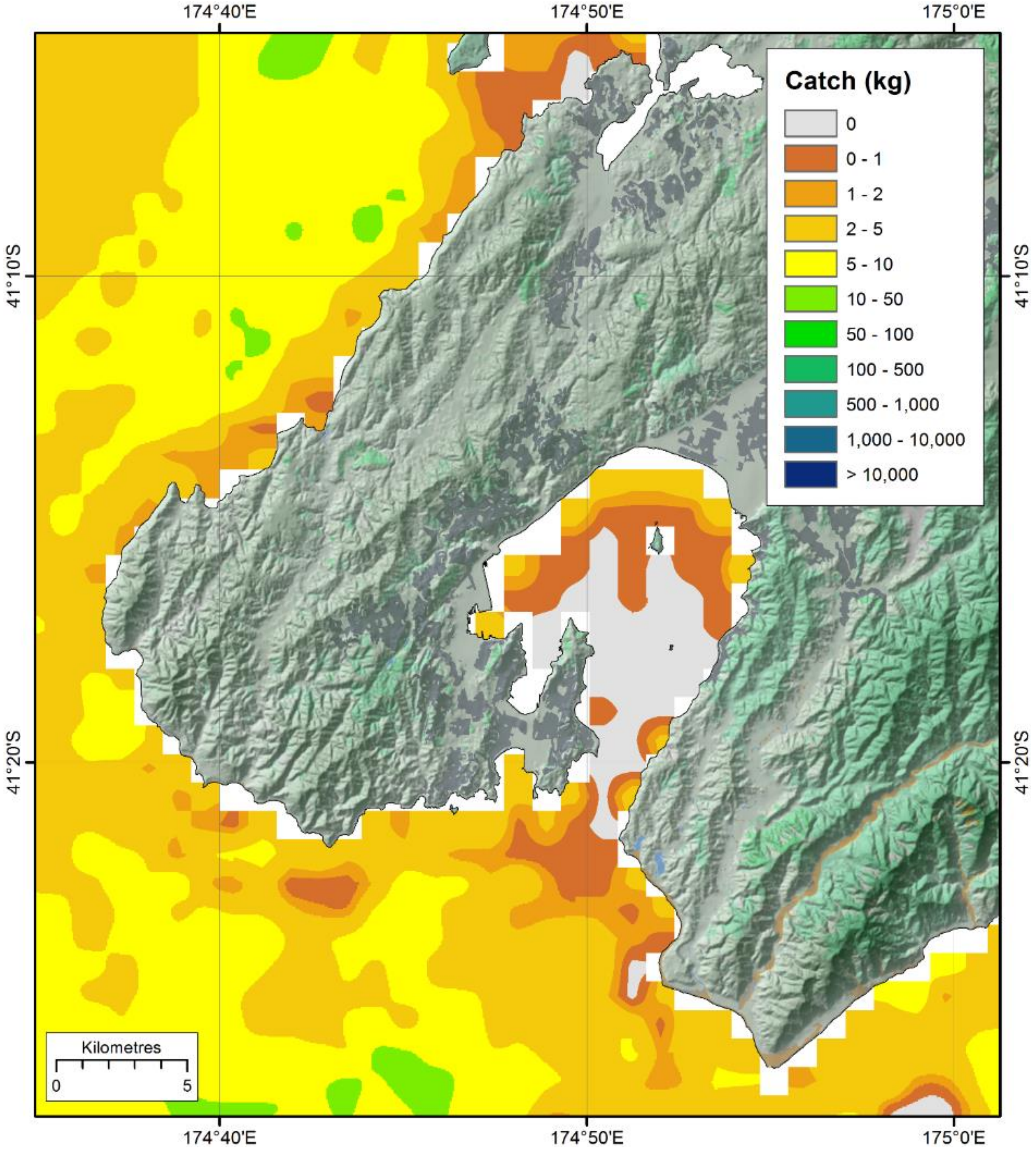


Figure 12-135: Catch (kg per hour) of witch (*Arnoglossus scapha*) in a demersal trawl in the Wellington region.

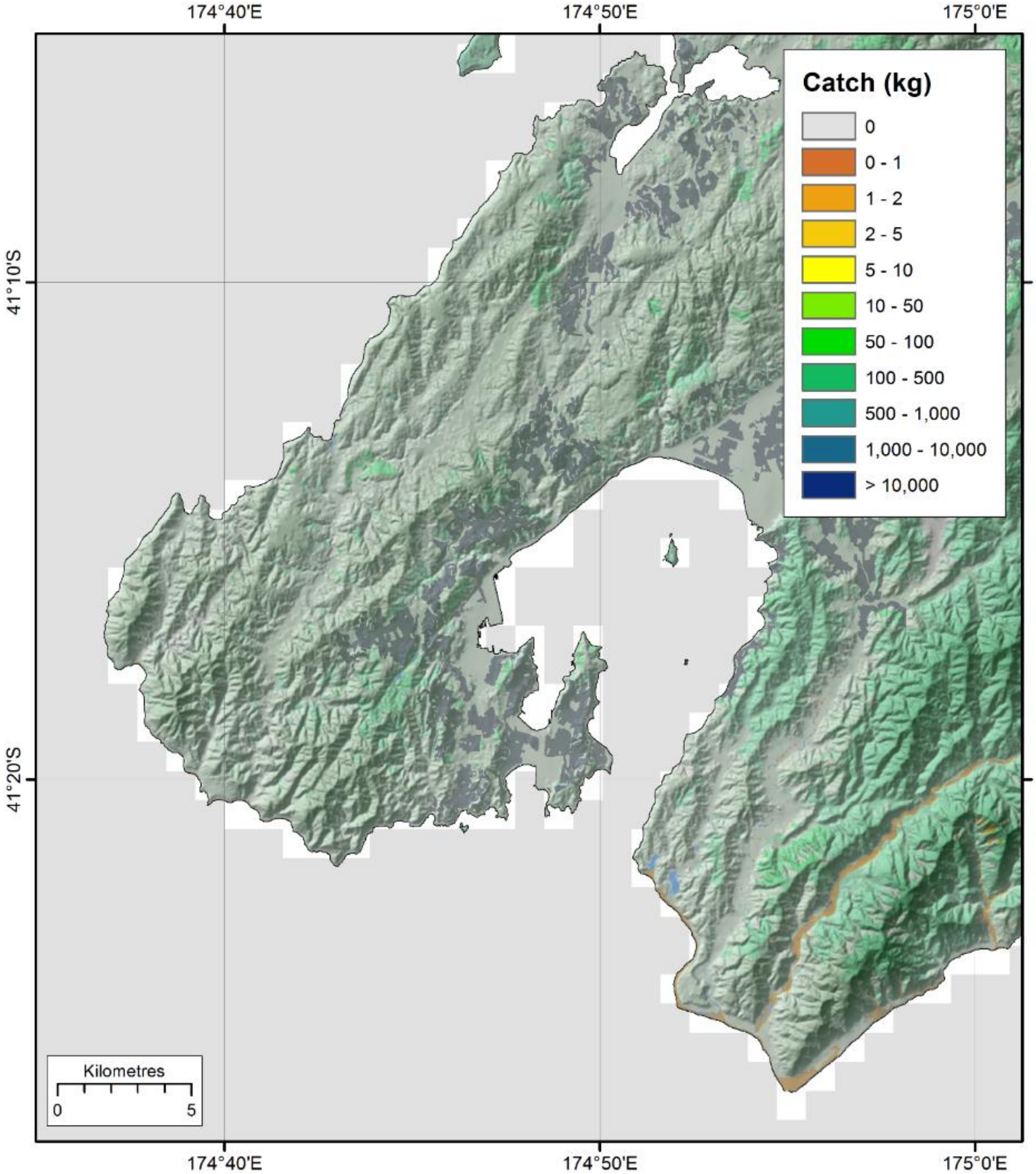


Figure 12-136: Catch (kg per hour) of yellow-belly flounder (*Rhombosolea leporina*) in a demersal trawl in the Wellington region.