Table 5: Door-to-door trawl gear widths used to estimate the area of sea floor contacted by individual tows in the TCEPR database. The mean wingspread in the TCEPR database is included for comparison. Refer to Table 1 and Appendix 1 for species abbreviations.

Species	Door-to-door width (m)	Mean wingspread in TCEPR database (m)
GUR, JDO, SCI, SKI, SNA, TAR, TRE, KIN, LIN	70	30
BNS, BYX, RCO	100	39
BAR, BOE, CDL, JMA, LIN, OEO, ORH, SBW, SQU, SSO, SWA, WAR, WWA	150	46
HAK, HOK	200	46
Trawl gear type DOUBLE	2 x trawl width	-

The edited database is then linked with the trawl type database compiled by the National Institute of Water and Atmospheric Research (NIWA). In the TCEPR database all tows by seven vessels known to have the capability to deploy a twin-rig are marked as twin-rig tows. For each of those tows, the NIWA database provides an estimate of the probability that the twin-rig capability was actually used. The NIWA database divides the potential twin-rig tows into five types (Table 6). This analysis assumed that all tows of type 4 or 5 were twin-rig tows, and all remaining tows were single-rig.

Table 6: Tow type from NIWA database

Twin-rig Tow Code	Explanation
1	Single-rig tow
2	Likely single-rig tow
3	Unknown
4	Likely twin-rig trawl
5	Twin-rig tow

The two databases were merged using an event key – a unique code for each tow. There are a few instances for which the event key for the same tow is different in the two databases. These tows were located and matched using the location, date and vessel ID of the tows. The NIWA database has some tows with no event key and these were also matched to the TCEPR database using the location, date and vessel ID. The NIWA trawl type database covers the period Jan 1996 to April 2007. There are thought to have been no twin-rig tows before this period. For the period between April 2007 and September 2009, twin-rig information is taken from MPI's data on the number of nets used for each tow. This potentially results in a slight over estimation of the total fishing area.

Each of the edited tow lines was made into a polygon by buffering it with the appropriate door-to-door width from Table 5, based on the target species and on the tow type in the input records and the NIWA database. Valid tows that crossed the EEZ boundary were buffered and then clipped to the EEZ.

The tows for each major species and the two species aggregates (i.e., all other trawl species and all species) were extracted into separate databases. Within these species/aggregate databases separate files were made for each year. Finally, the individual tows for each database were merged (Figure 6) to derive an estimate of the area of seafloor contacted by bottom trawling, i.e. the total swept area.

The GIS used the total swept area for each species to estimate the area and percentage of the EEZ and TS that have been swept by bottom trawling targeting that species. The swept area was then compared with a series of other data layers as discussed in the following sections.

The imprecision of start and end locations and the assumption of a straight trawl path are likely to result in an underestimate of the total trawl footprint. The assumed trawl widths are very conservative, probably leading to an overestimate of the total trawl footprint. In heavily trawled areas both over- and underestimates are irrelevant as the entire area is predicted to have been affected (Black & Wood, in press). We conclude that the uncertainty arising from the combination of over- and underestimates is likely to be small, of the order of a few percent of the total footprint area.

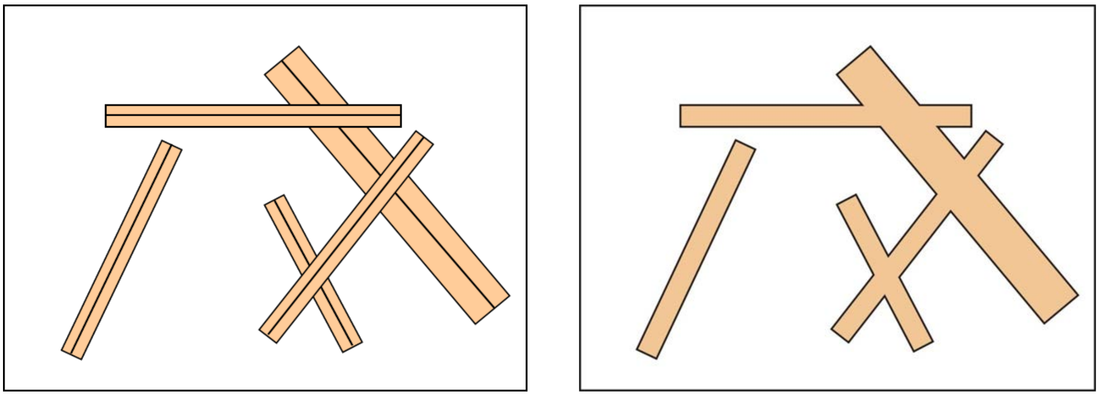

Figure 6: Example of areas (in brown) of individual tow paths (left), and areas merged for species or species aggregate (right). The assumed vessel path is shown by a straight line in the middle of the trawl (left).

Effort per unit area analysis

For the effort per unit area analysis the number of tows intersecting each 5 km × 5 km cell in a grid of 164 823 cells that covers the entire EEZ and TS was counted. For each species and year the number of cells that are crossed by tows and the maximum number of tows that cross any cell were counted and reported. The tows with zero length were added as point data to the appropriate databases of un-merged tows. The results can be directly compared with the analyses of Baird & Wood (2009) and Baird et al. (2011).

Depth Zones

In this report fishing effort in four depth zones is reported: 0 to 400 m, 400 to 800 m, 800 to 1200 m, and greater than 1200 m. Contours lines at 400, 800 and 1200 m were calculated from the Global Bathymetric Chart of the Oceans 30 arc-second bathymetry grid (GEBCO, 2010). The GIS was used to create the relevant polygons from these contour lines, the coastline, and the outer EEZ boundary (Figure 7).

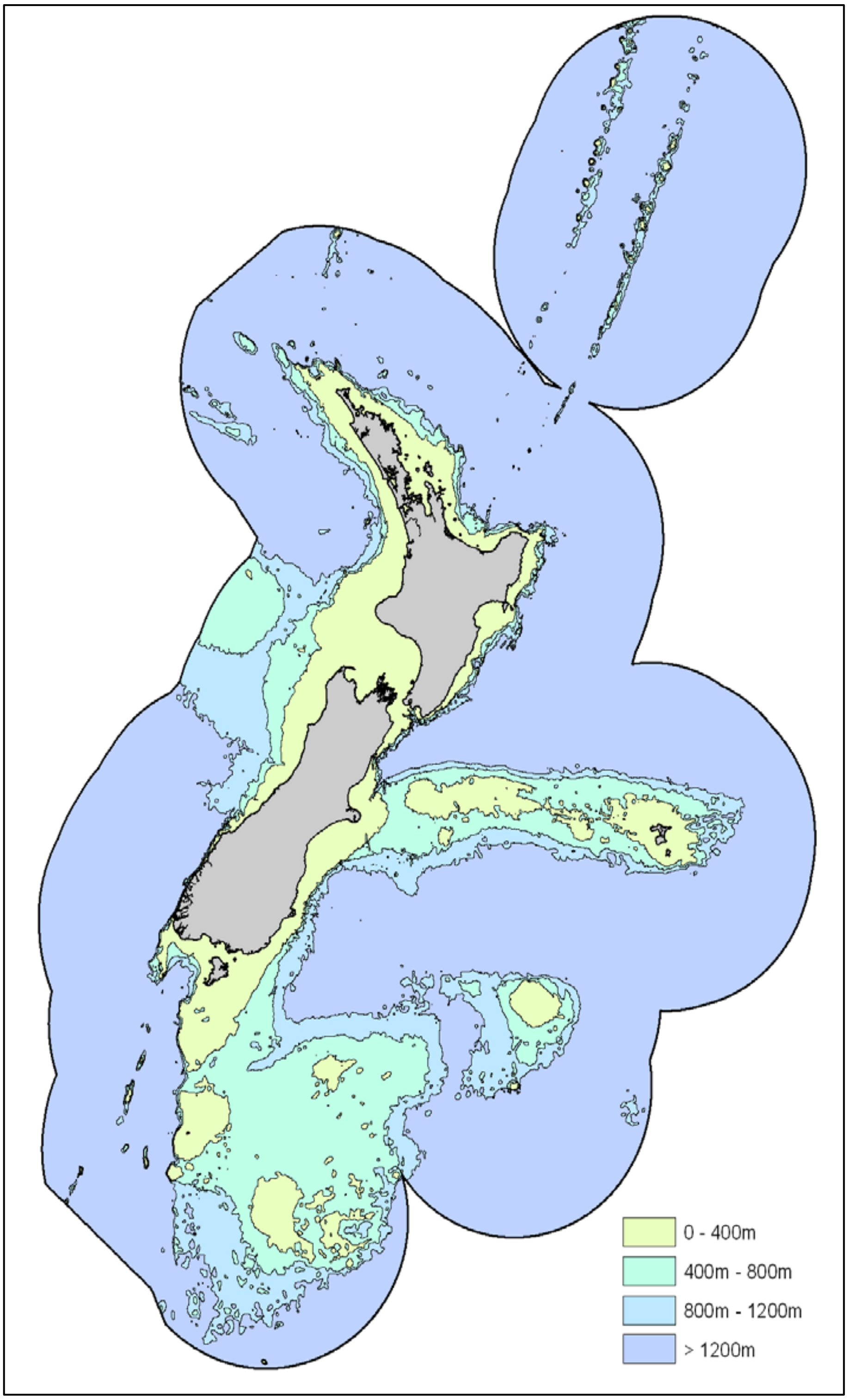

Figure 7: Depth zones within New Zealand's EEZ derived from the GEBCO 30 second bathymetry grid.

Fishable Area

The majority of New Zealand's fishing takes place on the continental shelf in depths appropriate to the target species. It is useful to compare the trawl footprint against the area within the EEZ that is currently potentially fishable.

As in previous work (e.g., Baird et al. (2009)) the maximum fishable depth is considered to be 1600 m. The "fishable area" is defined as any region within that depth range that is not closed to bottom trawling. The GIS was used to create a polygon of this region, containing those areas shallower than 1600 m that are outside Benthic Protection Areas (BPAs), seamount closures and other reserves (Figure 8). The 1600 m isobath contour was calculated from the GEBCO 30 arc-second bathymetry grid (GEBCO 2010). The resulting fishable area covers 1 408 210 km², 34% of the EEZ and TS.

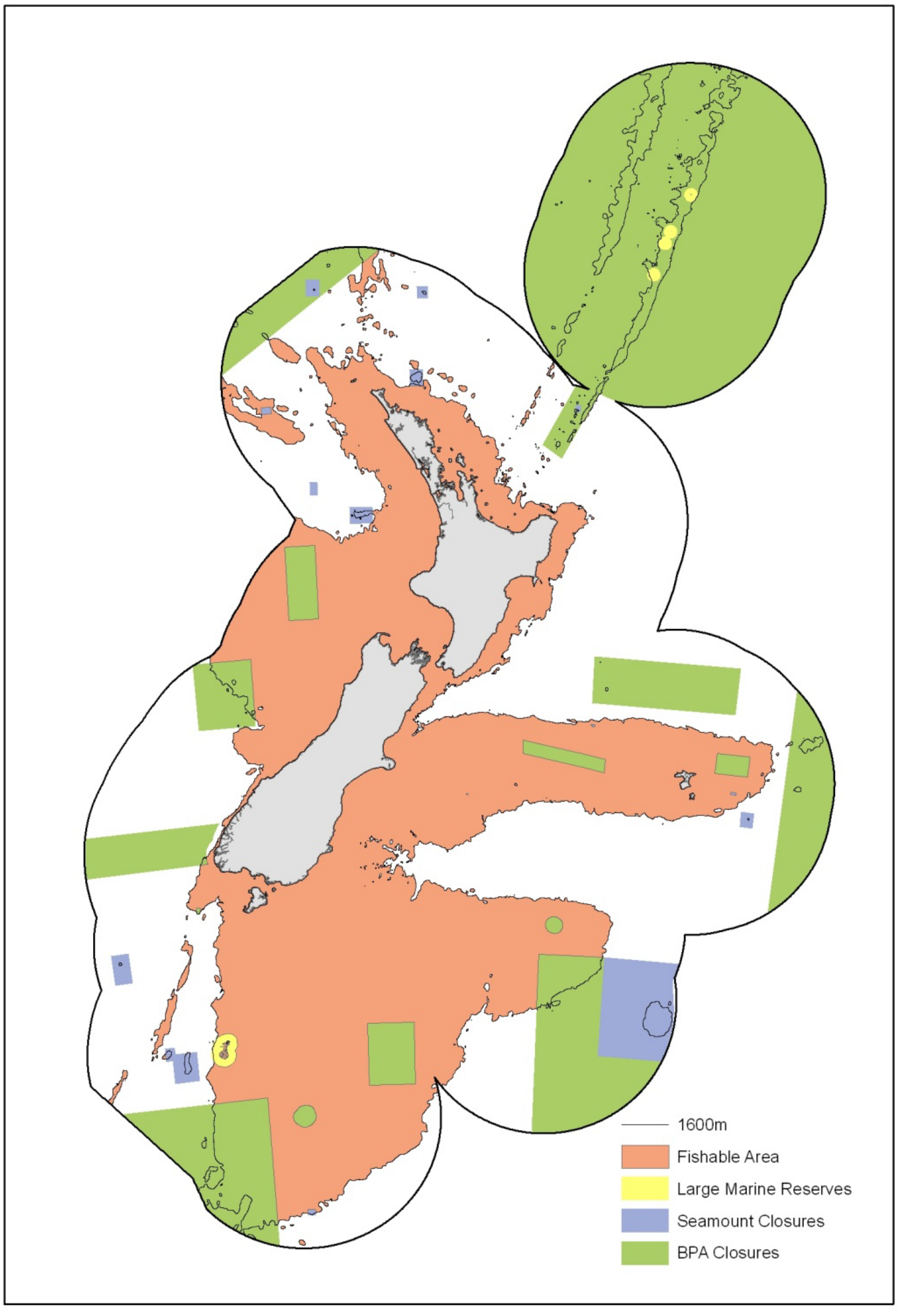

Figure 8: Fishable area within New Zealand's EEZ and TS. BPAs, seamount closures, marine reserves larger than 100km^2 and the 1,600 m depth contour are also shown.

Habitat Class

The boundaries of the Benthic-Optimised Marine Environment Classification (BOMEC) zones (Leathwick et al. 2012) were used to define 15 habitat classes (Figure 9). BOMEC was developed using generalised dissimilarity modelling to analyse a range of available environmental and biological data from the EEZ and TS that enabled broad-scale spatial patterns to be identified in the marine ecosystem. These were weighted by the distributions of benthic fish species and invertebrates to provide a tool for assessing and managing the impacts of bottom trawling on benthic organisms and habitats (Leathwick et al. 2012).

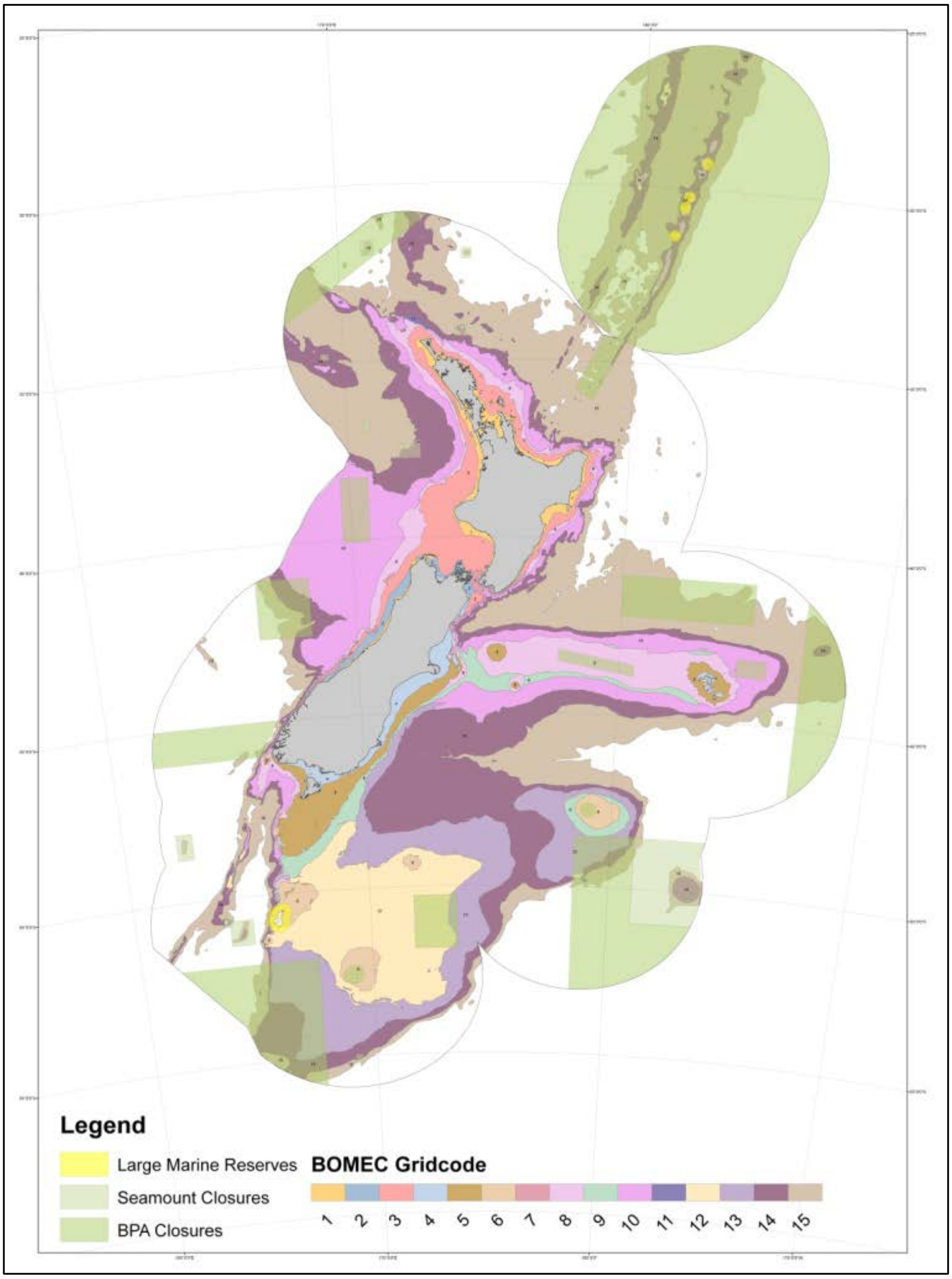

Figure 9: New Zealand's EEZ and TS showing the 15 BOMEC classification zones.

Preferred habitat

The preferred habitat for each of the major target species was used for species-specific analysis. Where possible the probability of capture layers for fish distribution from the demersal fish based Marine Environment Classification (MEC) were used (Leathwick et al. 2006). The probability of capture layers are derived from statistical analysis of 11 environmental variables and catch records from research trawls at 17 101 sites to produce distributional maps for each of 122 demersal fish species. Environment-based spatially comprehensive predictions are made to cover sites without trawl data.

A grid of predicted probability of capture was computed for each species. The GIS was used to convert the gridded values into a series of polygons, for which the probability of capture is greater than: 0%, 1%, 5%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, and for which the probability of capture is equal to 99% (e.g. Figure 10). The swept area within each, successively diminishing, polygon was determined to illustrate the extent of the fishing grounds relative to the range of probability of capture areas.

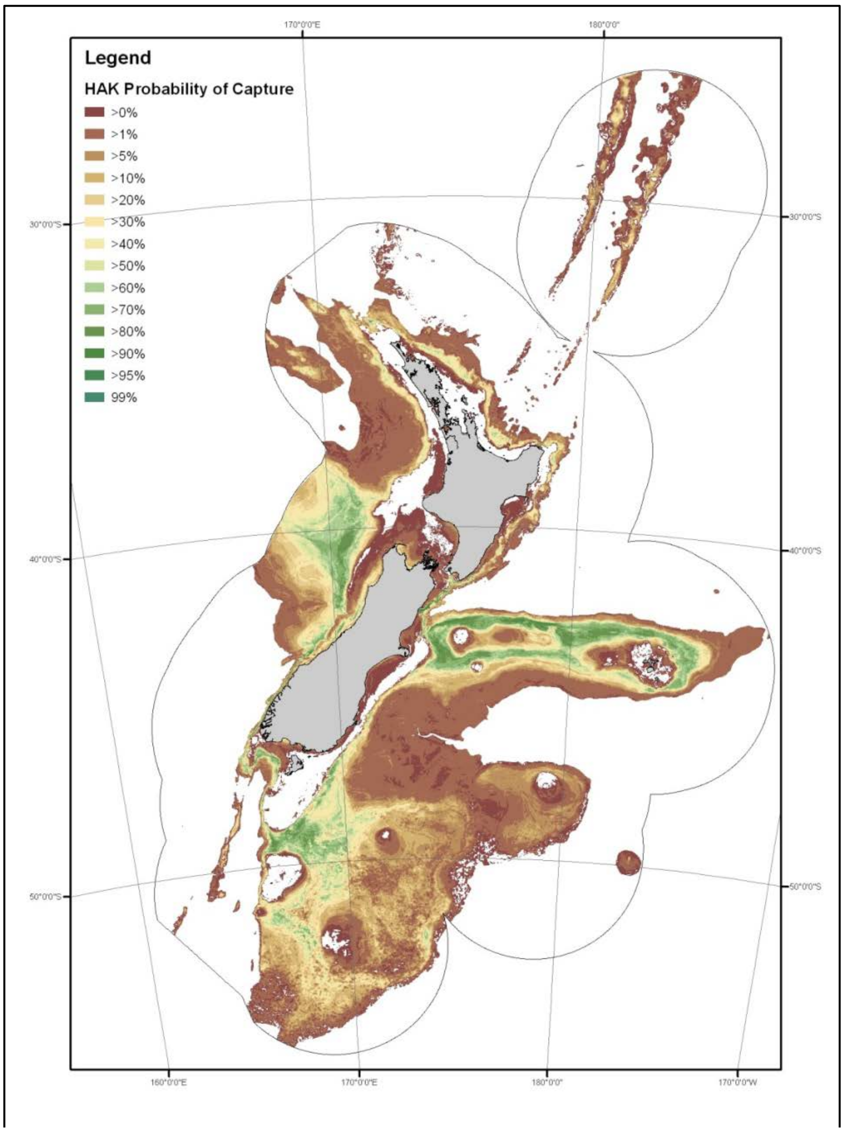

Figure 10: The predicted probability of capture of hake from the demersal fish layer of the MEC (Leathwick et al. 2006).

The preferred habitat for oreo was constructed by taking the union (spatial combination) of the predicted probability of capture layers for black oreo (BOE) and smooth oreo (SSO). Similarly, the preferred habitat for jack mackerel used the union of *Trachurus murphyi* (JMM), *Trachurus novaezelandiae* (JMN) and *Trachurus declivus* (JMD) layers.

Demersal fish layers are not available for squid or scampi. The National Aquatic Biodiversity Information System (NABIS) database of marine species distributions (Francis et al. 2003) includes normal and full distribution ranges for these species, and these were utilised for squid and scampi for this project. The full range defines the area that includes all records of that species and the normal range the area in which 90% of the population is estimated to occur.

The analysis of swept area for the aggregations of all fisheries and of minor species was not undertaken for the range of probability of capture areas, following the advice of MPI. This could be reconsidered in future years should a suitable preferred habitat be agreed for use for each species aggregate.

RESULTS

A total of 1 109 924 TCEPR records were used to estimate the area contacted by bottom trawling in New Zealand’s TS and EEZ for the fishing years 1989/90 to 2009/10. The EEZ and TS were divided into 5 × 5 km cells and the number of tows and cumulative area contacted by trawl gear in each cell were estimated. The analyses were conducted for eleven target species (hake, hoki, ling, orange roughy, scampi, southern blue whiting, squid, barracouta, silver warehou, jack mackerel and oreo), and for aggregates of all other (minor) species (Appendix 1) and for all species. Statistics are provided for each fishing year for the period 1989/90 to 2009/10 and for the entire period. Summary statistics were calculated regarding spatial extent and frequency of bottom-contact fishing by year, by depth zone, by fishable area and by habitat class.

A representative range of bottom trawl effort analysis results are presented in this section and the complete set of 2288 pages of statistics and maps are separately provided on DVD for all species and species aggregates (Appendix 3). All maps in Appendix 3 are plotted at a scale of 1:3 000 000, i.e. 1 cm on the map (viewed at 100%) represents 30 km on the ground.

Total Area of EEZ contacted by bottom trawling

The total area within New Zealand’s EEZ and TS contacted by bottom trawling between 1989/90 and 2009/10 is estimated to be 385 032 km^2 (Figure 11). This is about 9.3% of the area inside the 200 M line. The trawl footprint per year is estimated to have increased to a maximum of 107 744 km^2 in 2002/03 and then to have steadily declined to 49 708 km^2 in 2009/10 (Figure 12). These trends vary by species.

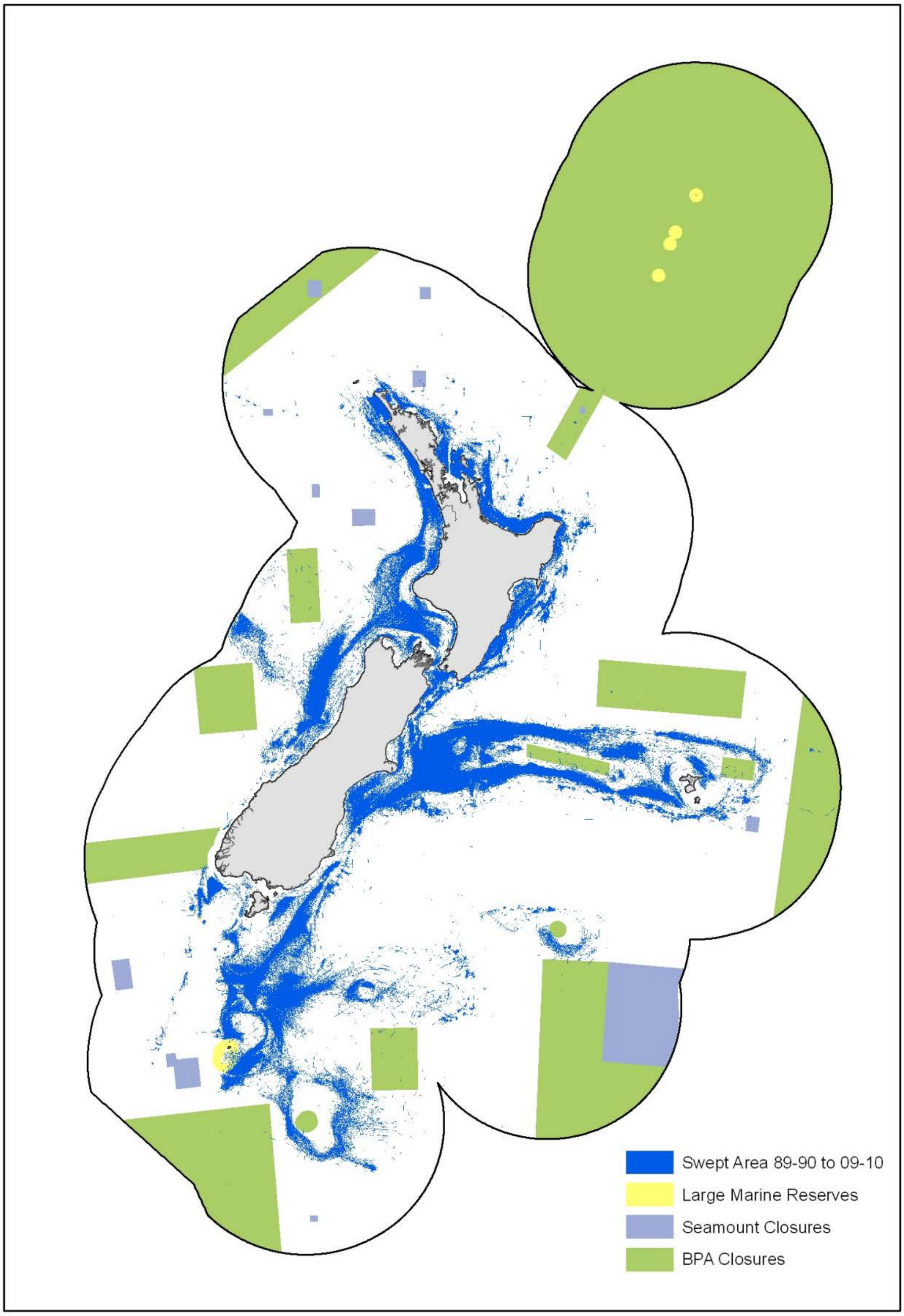

Figure 11: Estimated total area of sea floor contacted by bottom trawling, 1989/90 to 2009/10 showing large fishing restrictions.

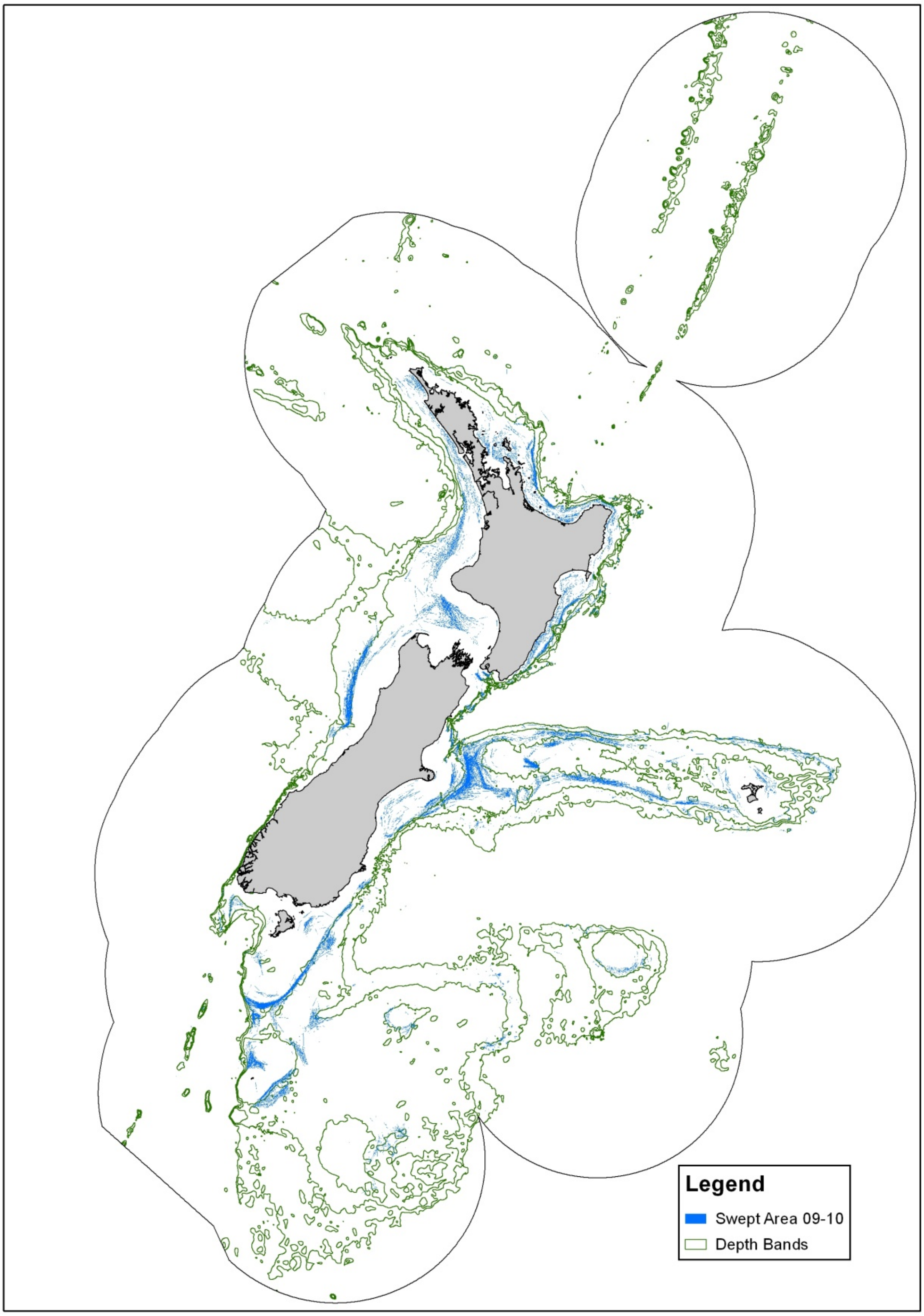

Figure 12: Estimated total area of sea floor contacted by bottom trawling, 2009/10 overlaid on 400 m, 800 m and 1200 m bathymetry contours.