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Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–90 to 2009–10

New Zealand Aquatic Environment and Biodiversity Report No. 110.

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This report presents the results of project DAE 2010/04A, monitoring New Zealand's trawl footprint over the time period 1989/90 to 2009/10. Trawl Catch Effort Processing Return (TCEPR) data provided by the Ministry for Primary Industries were analysed for bottom trawling for all target species. Eleven key target species (hake, hoki, jack mackerel, ling, orange roughy, oreo-dory, scampi, southern blue whiting, squid, barracouta and silver warehou) were analysed separately and all other species as an aggregate, as well as all target species combined. This represents approximately 90% of the effort for these species over the last five years (species by year averages ranged from 61 to 100% over that time).

Statistics provided include the estimate of total trawled area in the exclusive economic zone (EEZ) and territorial sea (TS), and estimates of trawled area in relation to depth zones, fishable area, habitat class (from the Benthically Optimised Marine Environment Classifications (BOMEC)) and the preferred habitat of each species (taken from the demersal fish layers in the Marine Environment Classification (MEC), where they exist).

Summary results are provided in this report, while the complete set of 2288 spreadsheet and pdf pages are provided separately in 197 documents, on a DVD (Appendix 3).

Analysis included assessment of area of sea floor contacted by bottom fishing and analysis of effort per unit area. The EEZ was divided into 5 km by 5 km cells and the number of tows and area of sea floor contacted by bottom fishing were estimated for each cell. The total swept area for all species from 1989/90 to 2009/10 is estimated to be 385 032 km^2 (about 9% of the EEZ and TS). This area is estimated to be 27% of the area available for bottom trawling, defined as that part of the TS and EEZ shallower than 1600 m and outside all Benthic Protection areas (BPAs), Seamount Closure and Marine Reserve areas. The 15 BOMEC classification areas cover the area shallower than 3000m (2 627 073 km^2), approximately 63% of the EEZ and TS. The total swept area from 1989/90 to 2009/10 for all species is estimated to be about 15% of the BOMEC zones, but ranges from 0.3 to 73% per BOMEC zone. Almost 85% of the trawled area in this period was in the depth ranges 0–400 m (46%) and 400–800 m (38%). Over the last five fishing years, effort per 5 km by 5 km cell contacted by trawls has dropped from 17.7 tows in 2005/6 to 14.7 in 2008/9, but increased slightly to 15.3 in 2009/10.

INTRODUCTION

Overview

The New Zealand Ministry for Primary Industries' (MPI) trawl catch effort and processing return (TCEPR) database contains information about trawls made by vessels greater than 28 m in length, and provides the most precise information about where bottom trawling has occurred in New Zealand's exclusive economic zone (EEZ). TCEPR reporting documents the bulk of effort for the 11 key deepwater fisheries examined here for at least the last five years (see the Methods section for more details). This report describes how these data were used to estimate the location and extent of trawling in the area within the 200 nautical mile (M) line (i.e., in the territorial sea (TS) and EEZ), to provide insight into temporal and spatial changes in fishing practice, and to help manage the effects of fishing on the environment. For the purposes of this report the two enclaves of international water that are surrounded by the EEZ, one on the Chatham Rise and the other on the Campbell Plateau, are included in the analyses.

Previous work has generated habitat predictions and distribution ranges to compare trawl footprints against. Benthically Optimised Marine Environment Classifications (BOMEC) areas were developed to classify benthic habitats on broad scales within the EEZ. The BOMEC areas are based on analysis of fish species distributions in trawl catch data, and eleven environmental variables characterising the sea floor morphology and oceanographic conditions (Leathwick et al. 2006). Preferred habitats for many species were generated in the demersal fish layers in the Marine Environment Classification (MEC). The MEC areas are based on analysis of benthic and pelagic species distributions in trawl data, estimates of mean chlorophyll concentration, and eight environmental variables characterising the sea floor morphology and oceanographic conditions (Snelder et al. 2006). Where these do not exist (i.e. for squid or scampi) the National Aquatic Biodiversity Information System (NABIS[1]) normal and full distribution ranges are used.

Previous deepwater trawl footprint analyses have been completed. Trawl effort from TCEPR from 1989/90 to 2004/05 was used to map the temporal and spatial extent of seafloor contact (Baird et al. 2011). They concluded that about 8% of the seafloor had been contacted by bottom trawls. The trawl footprint from the same 16 years of commercial trawling has been compared to the 15 BOMEC classes (Baird et al. 2009). These authors concluded that there was differential coverage of BOMEC zones (more than 50% in some zones). Both of these studies cautioned that total trawl effort was underestimated, particularly in water shallower than 200 m. The present analysis has been completed to enable direct comparisons between this study and the previous analyses of Baird & Wood (2009) and Baird et al. (2011).

Objectives

Under the overall DAE2010/04 objective that aims *to monitor the "footprint" of bottom contacting trawl fishing for deepwater and middle-depth species*, this report addresses objectives 1 and 2:

1. To estimate the 2009/10 trawl footprint and map the spatial and temporal distribution of bottom contact trawling throughout the EEZ between 1989/90 and 2009/10.

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[1] http://www.nabis.govt.nz/Pages/default.aspx

2. To produce summary statistics, for major deepwater fisheries and the aggregate of all deepwater fisheries, of the spatial extent and frequency of fishing by year, by depth zone, by fishable area, and by habitat class, and to identify any trends or changes.

METHODS

This study analyses data from the TS and EEZ, including two enclaves of international waters on the Chatham Rise and Campbell Plateau.

In this report, swept areas are determined separately for 11 key target species (i.e. the nine deepwater plan[2] Tier 1 species plus silver warehou and barracouta), (Table 1) and for the aggregate of an additional 89 species recorded as being target species on TCEPRs ("minor" target species), (Appendix 1). Finally, the aggregate swept area for all species recorded as being targeted on TCEPRs was determined. The above analyses were undertaken for the period 1989/90 to 2009/10, by year and for all years combined.

Table 1: Key target species and reporting codes. A list of the "minor" target species covered in this report is given in Appendix 1.

Common name	Reporting code
Hake	HAK
Ling	LIN
Hoki	HOK
Southern blue whiting	SBW
Oreo	OEO, BOE, SSO, SOR
Jack mackerel	JMA
Orange roughy	ORH
Squid	SQU
Scampi	SCI
Silver warehou	SWA
Barracouta	BAR

Trawl Data

Only TCEPR data were used for this analysis. TCEPR data record individual trawl positions, primarily for vessels operating in waters deeper than 200 m. Catch effort landing return (CELR) and trawl catch effort return (TCER) data were not used because it is impossible to extract precise position information about individual trawls from those records. TCER data only record tow start positions, and CELR only provide the statistical reporting area (general area) of tows, not their start and end locations.

For the fishing years 1989/90 to 2009/10, the database contains 1 235 267 records of bottom tows and of mid-water tows for which the ground rope depth is equal to the water depth. On 1 October 1988 the Ministry of Fisheries changed from the old Fisheries Statistic Unit (FSU) to the Catch and Effort system. The old FSU forms were replaced with the CELR, CLR, TCEPR, SJCER and TLCER forms. The TCEPR data from the 1989/90 fishing year are not a

[2] The National Fisheries Plan for deepwater and Middle-depth fisheries http://www.fish.govt.nz/en-nz/Consultations/Archive/2010/National+Fisheries+Plan+for+Deepwater+and+Middle-Depth+Fisheries/default.htm

full record for that year and these data may overlap with the FSU data. In 1991 the TCEPR, TLCER and SJCER forms were replaced with new versions; the CELR and CLR forms stayed the same. Therefore the footprint of bottom trawling prior to 1 October 1989 is not considered in this report.

An analysis of fishing returns for the last 6 years for the 11 major species discussed in this report (Dave Foster, MPI pers. comm. 7 March 2012; Table 2 and Appendix 2). The results show that on average more than 90% of the estimated catch of hoki, hake, orange roughy, oreos, scampi, silver warehou, squid and southern blue whiting were recorded on TCEPR forms. On average 61% of the ling catch, 78% of the jack mackerel catch, and 84% of the barracouta catch were recorded on TCEPR forms.

Table 2: Percentage of catch reported on TCEPR forms.

Fishing year	HOK	HAK	LIN	SBW	JMA	ORH	OEO	SCI	SQU	BAR	SWA
2010/11	93%	98%	55%	100%	78%	100%	100%	100%	95%	83%	96%
2009/10	93%	98%	52%	100%	78%	99%	100%	100%	96%	85%	95%
2008/09	93%	100%	58%	100%	74%	99%	96%	100%	97%	81%	96%
2007/08	92%	99%	63%	100%	75%	100%	96%	100%	96%	83%	97%
2006/07	92%	100%	69%	100%	86%	98%	96%	100%	95%	89%	99%
2005/06	95%	100%	67%	100%	77%	97%	94%	100%	90%	84%	99%
2005/06 to 2010/11	93%	99%	61%	100%	78%	98%	97%	100%	95%	84%	97%

This project is concerned with trawl effort that has had contact with the seafloor. All data in this category were provided by the Ministry for Primary Industries as extracts from the TCEPR database. The input data include all bottom trawls and mid-water trawls for which the ground rope depth is equal to the water depth. There are 1 235 267 input records for the period 1 October 1989 to 30 September 2010.

Data collected on TCEPR forms provide individual trawl information including vessel identification, date, start and end position of the vessel, duration and speed of the tow, water depth, wingspread, and target species. The start and end positions are reported to 1 minute precision.

The data are projected into an equal-area projection to allow accurate computation of areas throughout the region of interest. All maps and charts in this report are plotted using this projection. The details of the projection are:

Map Projection Name: Albers Conical Equal Area

- Standard Parallel 1: -30.000000
- Standard Parallel 2: -50.000000
- Longitude of Central Meridian: 175.000000
- Latitude of Projection Origin: -40.000000
- False Easting: 0.000000
- False Northing: 0.000000

Planar Coordinate Information
- Planar Distance Units: meters
- Coordinate Encoding Method: coordinate pair

Coordinate Representation
- Abscissa Resolution: 0.001785
- Ordinate Resolution: 0.001785

Geodetic Model
- Horizontal Datum Name: D_WGS_1984
- Ellipsoid Name: WGS 1984
- Semi-major Axis: 6378137.000000
- Denominator of Flattening Ratio: 298.257223

Trawl Data correction and editing

The original TCEPR data included records outside the EEZ (beyond the 200 M line). These were not used in the analysis (Figure 1). Unlike some previous studies (e.g. Black & Wood 2009), tows in the TS were kept in the database.

The TCEPR data are known to contain errors, and the way data are recorded adds some uncertainty to the footprint calculations. Factors inherent in the data that contribute to the uncertainty in the estimated area of trawl grounds include:

1. The locations of start and end points are typically recorded to a precision of one nautical mile.
2. There is no information about the vessel path other than the start and end positions.

Recording the start and end positions to a precision of one nautical mile means that trawls can appear to overlie each other, even though their true paths have an effect on close, but different parts of the sea floor. Because of this imprecision the analysis of the trawl grounds is likely to underestimate the total area impacted. Black & Wood (in press) analysed a subset of the data and concluded that the imprecision in coordinates may result in an underestimate of the total area by about 1.5%. To counter this effect, the end point locations were randomly varied in the calculations for this report (see discussion later in this section).

Because only the start and end positions of the tows are recorded, the actual tow paths may be longer and the analysis may underestimate the sea floor area affected by each tow. In heavily fished areas the buffered tows typically overlap and the cumulative effect of this uncertainty is small. The effect of this uncertainty on the calculations has not been estimated but it is likely to be no greater than that arising from the start/end position precision.

The most common errors in the data arise from errors in recording start and end positions. Potential errors considered for the analyses in this report were:

1. tows with identical start/end coordinates,
2. tows with NULL start/end coordinates,
3. tows outside the EEZ,
4. tows that cross land, and
5. tows longer than expected for normal NZ fishing practice.

For this project, we edited records in the EEZ and TS both before and after the records were input as lines in ArcGIS 10, a geographic information system (GIS). This helped to identify errors and to either correct them or eliminate these records from the analysis.

Pre-GIS editing of TCEPR input records

Before input into the GIS, editing involved (Table 3):

1. Flagging all records with identical start/end coordinates;
2. Flagging all records with NULL start/end coordinates.

Records with identical start/end coordinates could be legitimate short tows, but their omission is unlikely to be important for the estimation of the trawl footprint as they are relatively few in number and most lie inside the estimated trawl footprint area. Tows with identical start/end coordinates were not used in the trawl footprint analysis, but because they could be legitimate short tows they were included in the fishing effort per unit area calculations in this report.

Figure 1: Un-edited TCEPR data projected in an Albers equal area projection. The EEZ is shaded blue.

Table 3: Criteria used to identify likely errors in the input data, and the number of records that met those criteria.

Edit Steps	Number of Records Footprint analysis	Number of Records Frequency analysis
NULL start/end coordinates	350	350
Identical start/end coordinates	45 526	N/A
Tows outside EEZ	38 416	47 412
Long tows	38 557	38 557
Tows that cross coastline	8 798	8 862
TOTAL flagged	125 343*	88 877*
TOTAL analysed	1 109 924	1 146 390

*Does not equal sum of above numbers, as some records fall into multiple categories of "Tows outside EEZ", "Long tows", and "Tows that cross coastline".

GIS editing of TCEPR input records

After the data were input into the GIS, editing involved (Table 3):

1. Flagging all records that cross land;
2. Flagging all tows longer than expected for normal fishing practice;
3. Flagging all tows entirely outside the EEZ.

Some records in the TCEPR database have tow lengths that are much longer than expected for normal fishing practice in New Zealand. Many of these records have obvious errors in the start and/or end positions. The lengths of tows calculated from the start and end positions in the TCEPR records vary from 0 to more than 15 000 km.

TCEPR records with tow lengths greater than 37.8 M (70 km) for squid and scampi and 30 M (55.56 km) for all other species, calculated from the start and end positions, were flagged as "long". Representatives of the New Zealand fishing industry confirm that a maximum tow length of 37.8 M for squid and scampi, and 30 M for all other species reflects common fishing practice in New Zealand (Richard Wells, pers. comm. 2009). These limits are consistent with constraints used by Baird et al. (2011) who restricted their analysis of TECPR data to tow lengths "within [an] acceptable range". The ranges they used are not specified, but the vast majority of edited tows in their report are shorter than 60 km and few, if any, of the tows are longer than 100 km. About 95% of the distances calculated from the start and end positions and about 97% of those calculated from tow duration and vessel speed in the data are less than 30 M long (Figure 2). The distribution of squid and scampi tow lengths is somewhat different from that of other species (Figure 3), but the maximum tow length of 70 km includes about 98% of squid and scampi tows.

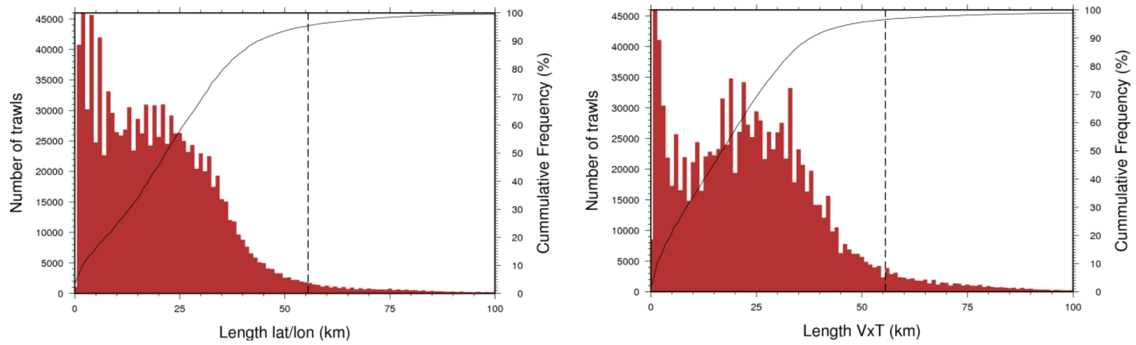


Figure 2: Distributions of tow lengths in the TCEPR database, calculated from (left) start and end latitude and longitude positions (lat/lon) and (right) speed (V) times tow duration (T). The solid line in each graph shows the cumulative percentage of tows less than the length along the X axis. The vertical dashed line highlights tows 30 M (55.56 km) long.

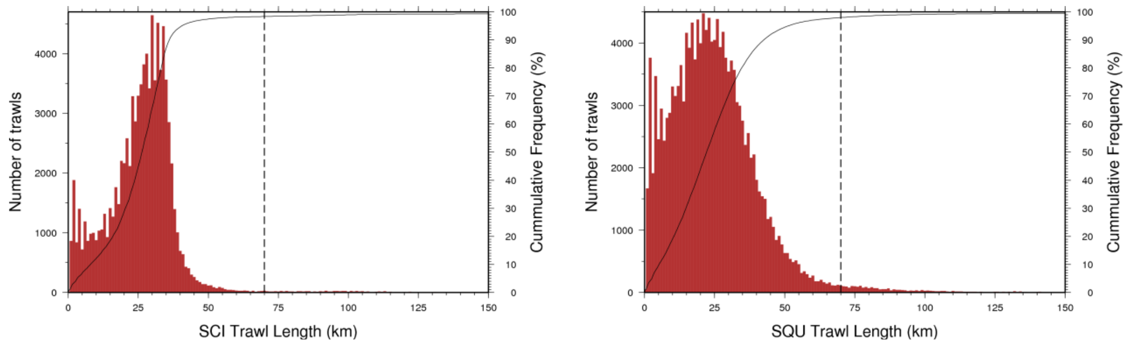


Figure 3: Distribution of tow lengths in the TCEPR database for (left) scampi, and (right) squid. The solid line in each graph shows the cumulative percentage of tows less than the length along the X axis. The vertical dashed line highlights tows 37.8 M (70 km) long.

Records crossing the boundary of the EEZ were kept in their entirety at this stage. They were considered valid if they met the other edit criteria, and were truncated at the EEZ when the total fishing area was estimated.

The records with identical start/end coordinates were flagged in a similar way to ensure they are only used appropriately (Table 3).

East-West error correction

Records were corrected for obvious east-west longitude transpositions (Figure 4). Some east-west longitude errors are a product of human error, usually when incorrectly recording the sign of the longitude of the trawl start or end, i.e., recording a longitude value as being east of Greenwich instead of west, or vice versa. New Zealand's EEZ covers areas both east and west of 180°, giving scope for trawler operators to incorrectly record tow start or end positions.

More than 1000 possible east-west longitude errors were identified and more than 400 of these were corrected before being included into the dataset (Table 4). This process was time consuming as each suspect tow had to be manually inspected, and therefore only tows for which fixing an east-west longitude error would result in its inclusion in calculations were inspected. For example, if after correcting a possible east-west error a tow would be flagged by one of the edit criteria, such as crossing land or longer than standard fishing practice, then it wasn't changed at this stage.

Three criteria were used to identify possible east-west longitude corrections for long tows:

1. Start and end positions of the tow on either side of the 180° meridian;
2. At least one end of the tow inside New Zealand's EEZ;
3. North-south difference small enough that correcting a longitude value would reduce the tow length below the relevant "long" criteria.

Once a tow with a possible east-west longitude error was identified then a decision was made about which end of the tow to move. We assumed that these tows conformed to the fishing practice in the area, so the longitude value of the position outside the total trawl foot print or beyond the area of fishable depths (Section 2.5) was changed. In total, 419 long trawls were corrected, and their "long" flags changed, increasing the number of useable records in the dataset.

Table 4: Steps taken to identify and rectify east-west longitude errors and the number of records identified and corrected by this process.

Position Status	Number of Tows
Long tows (with no other edit flags)	42 295
Possible corrections identified	1 186
Tows corrected	419

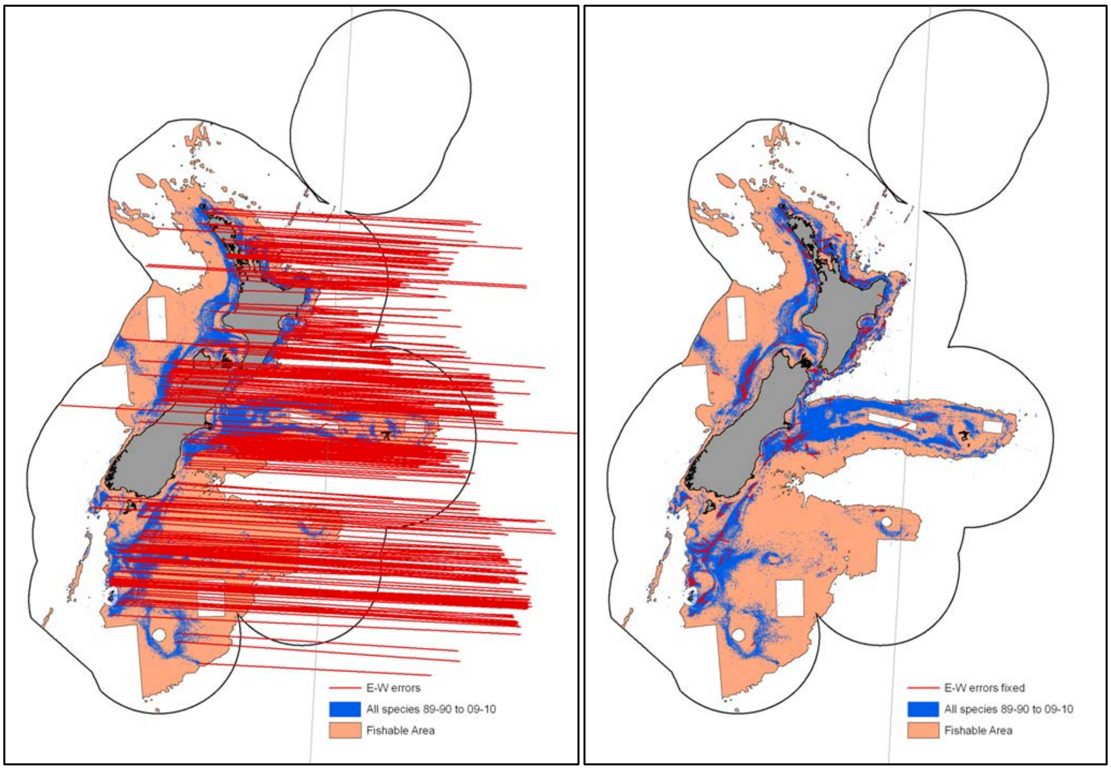


Figure 4: Maps displaying the 419 tows (red lines) corrected for an east-west longitude error. Before correction (left) and after correction (right). The majority of the corrected tows lie inside the estimated swept area, and all lie inside the Fishable Area.

Tow position offsets

Tow start and end positions are submitted to the TCEPR database rounded to the nearest arc-minute. This precision creates an unrealistic estimate of the swept area, as true tow start and end positions are distributed up to 0.5 minutes in latitude and longitude either side of the reported positions. We applied a random offset or "jitter" of between -0.5 and +0.5 minutes to the start and end co-ordinates of each tow to approximate a realistic pattern of start and end positions (Figure 5). In regions where fishing is carried out on marks (features of limited geographic extent) there could be a genuine clustering of trawl start/end locations and possibly very short tows. In these locations the application of offsets may make the estimated footprint area larger than it really is, but the effect on a national scale is unlikely to be significant.

The fishing effort per unit area calculations assume that tows with the same start and end positions may be legitimate short tows. For these calculations the same random offset was applied to records with identical start/end coordinates, so the tow continued to have zero length but its position could be moved into another cell.

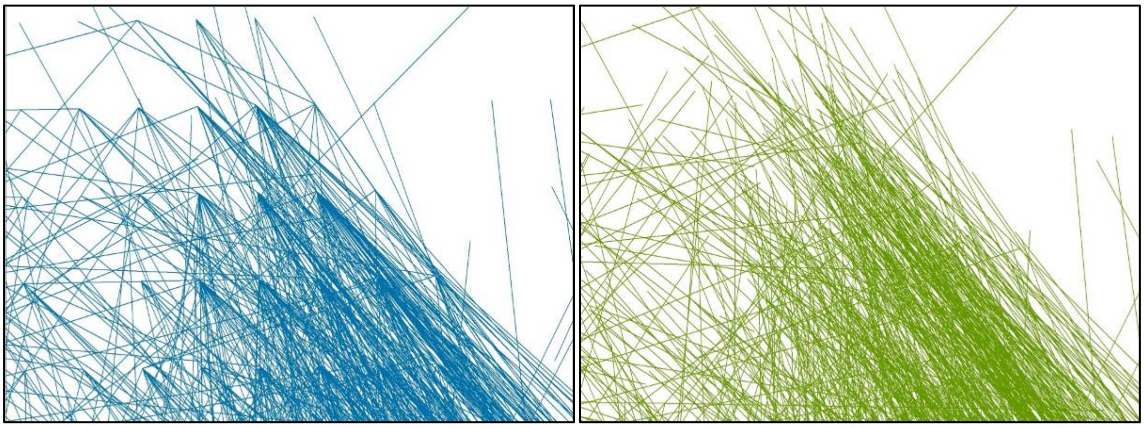


Figure 5: Example of the effect of applying a random offset to start and end tow positions. Original reported tow tracks (left) and tow tracks after the addition of -0.5 to +0.5 random offsets (right).

Calculation of total swept area

Using the projected tow lines, the next step estimated the area of sea floor contacted by each tow. Estimation of area swept by each tow required three assumptions that reasonably reflect common fishing practices in the New Zealand deep water fishery:

1. The vessel location was a reasonable proxy for the net location;
2. The vessel travelled in a straight line between start and end positions;
3. The width of sea floor contacted by the trawl gear was a function of target species and trawl gear type (single- or double-rig).

After discussion with experienced representatives of the fishing industry, characteristic door-to-door trawl widths were assigned to each target species and trawl gear type (Table 5). These widths were chosen to reflect common fishing practice in New Zealand and are a conservative (i.e., wide) estimate of the door-to-door widths of the trawl gears compared to the mean wingspread in the TCEPR database (Table 5).

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.

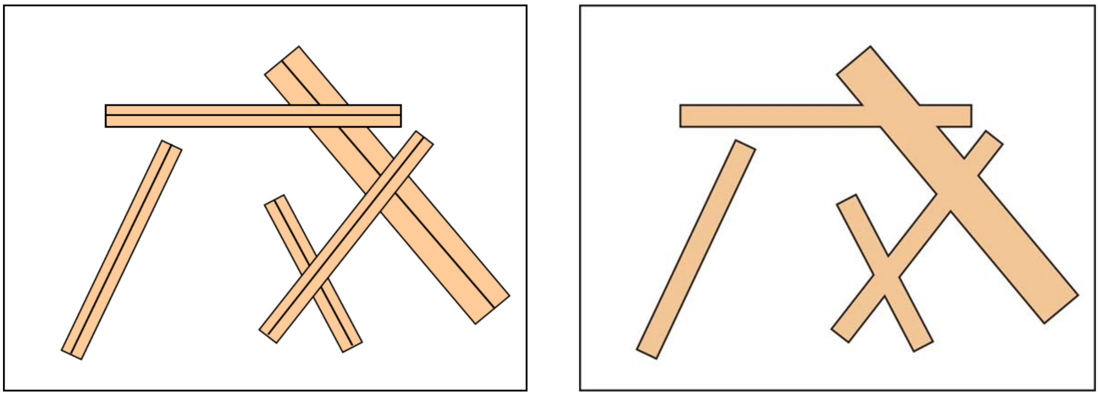


Figure 6: Example of areas (in brown) of individual tow paths (left), and areas merged for species or species aggregate (right). The assumed vessel path is shown by a straight line in the middle of the trawl (left).

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).

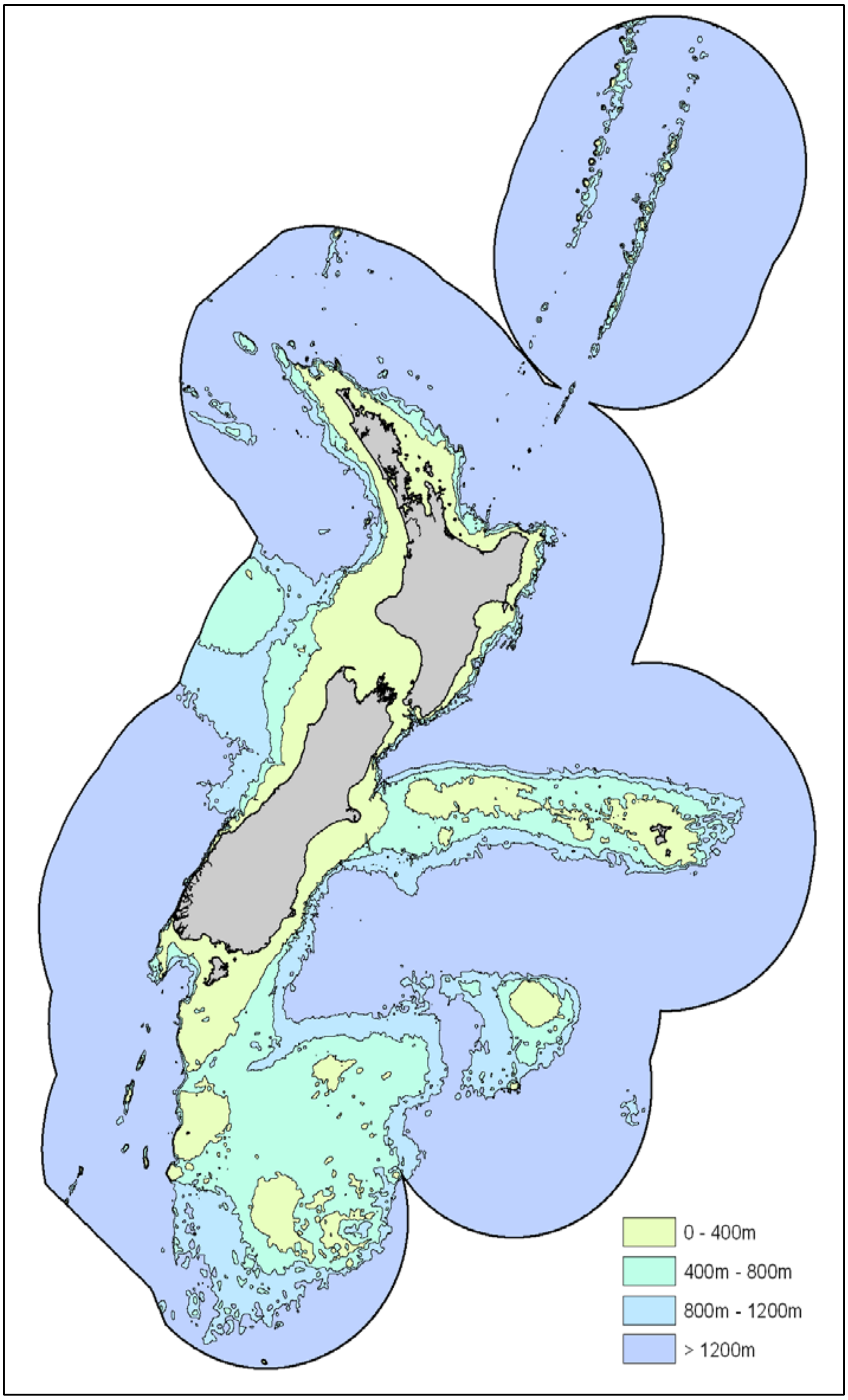


Figure 7: Depth zones within New Zealand's EEZ derived from the GEBCO 30 second bathymetry grid.

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.

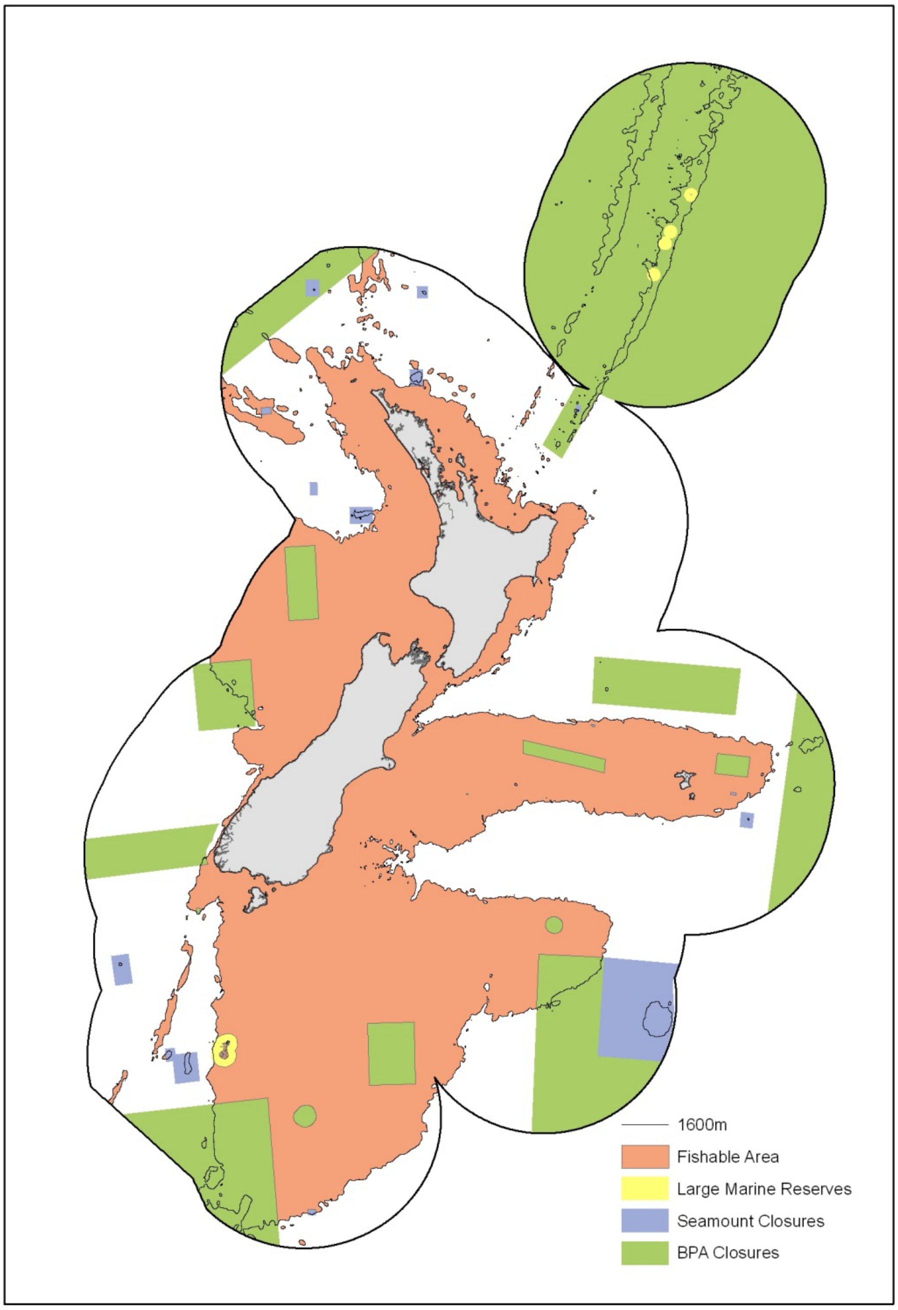


Figure 8: Fishable area within New Zealand's EEZ and TS. BPAs, seamount closures, marine reserves larger than 100km^2 and the 1,600 m depth contour are also shown.

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).

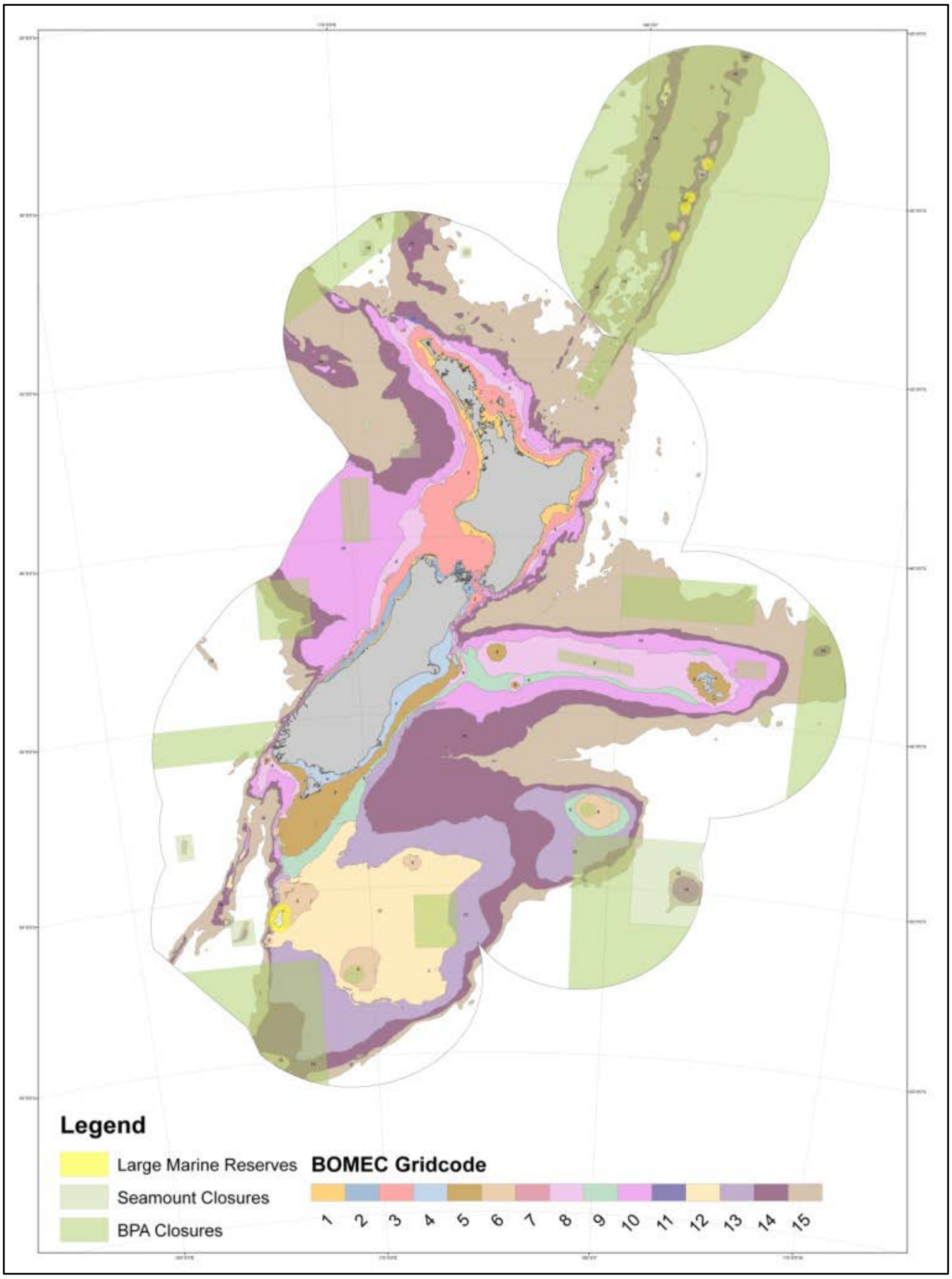


Figure 9: New Zealand's EEZ and TS showing the 15 BOMEC classification zones.

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.

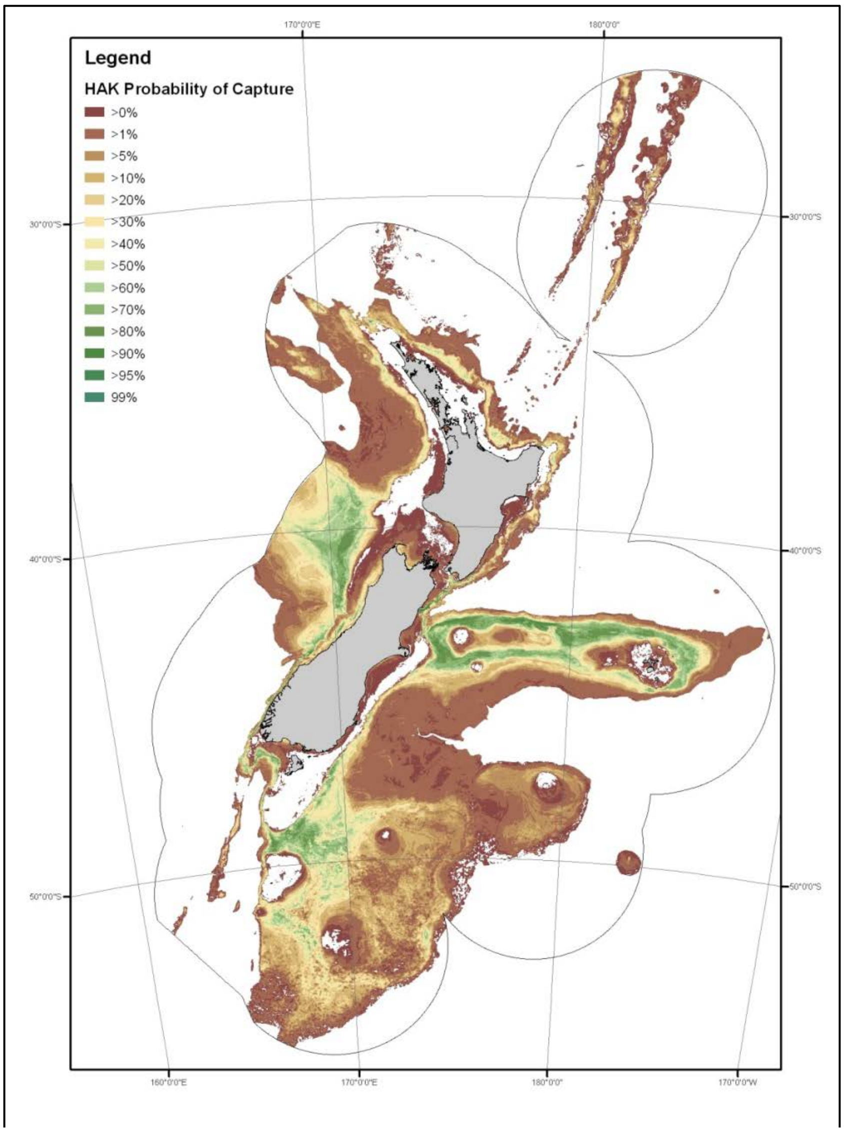


Figure 10: The predicted probability of capture of hake from the demersal fish layer of the MEC (Leathwick et al. 2006).

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.

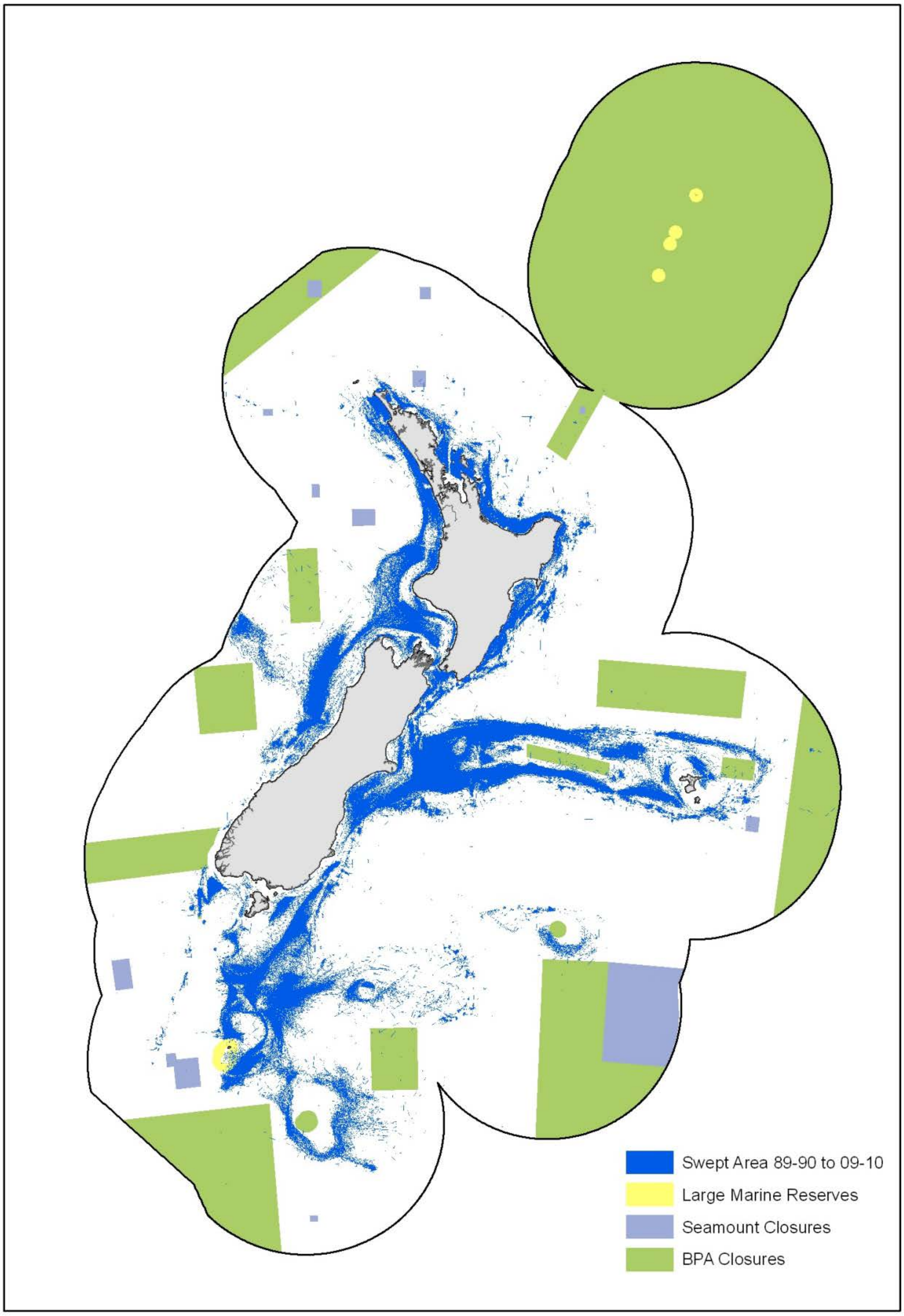


Figure 11: Estimated total area of sea floor contacted by bottom trawling, 1989/90 to 2009/10 showing large fishing restrictions.

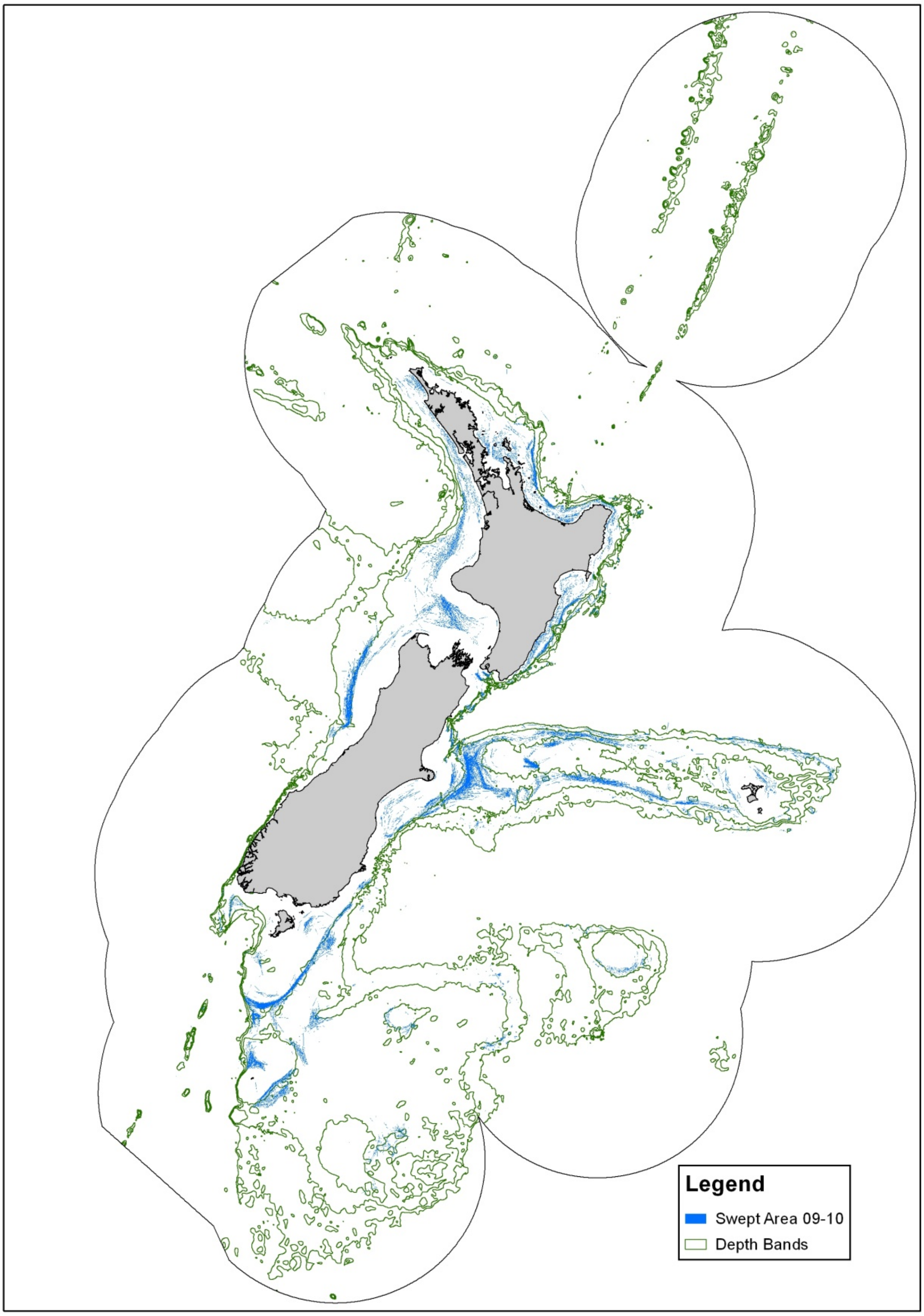


Figure 12: Estimated total area of sea floor contacted by bottom trawling, 2009/10 overlaid on 400 m, 800 m and 1200 m bathymetry contours.

Trawl footprint by target species

Tables and plots showing the estimated swept areas for each species are in Appendix 3 (tables are in files <species id>_footprint_stats.pdf and <species id>_footprint_stats.xls, e.g., barracouta data are in BAR_footprint_stats.pdf and BAR_footprint_stats.xls; plots are in files <species id>_BOMEC_fig_part<number>.pdf and <species id>_fig_part<number>.pdf, e.g. BAR_BOMEC_fig_part1.pdf and BAR_fig_part1.pdf. See file README.doc for more information). Results are provided for each species for each fishing year and for the period 1989/90 to 2009/10.

The calculated statistics for bottom trawling can be used to monitor changes in fishing activity. For some species the number of tows and the total swept area per year vary considerably with time. For example, southern blue whiting had a large peak in both number of tows and swept area in the 1991/92 fishing year (Figure 13). From the 1992/93 fishing year onwards the number of tows and the swept area are considerably lower. The most recent years have shown a continuous small rise in numbers of both.

The graph for hoki (Figure 14) shows that the number of tows and the total swept area are not necessarily directly correlated. The peak for the total swept area occurs at 2002/03, five years after the peak number of tows. These trends could reflect an increase in trawl length and/or use of twin-rig trawl nets. In 1997/98 the average trawl length was 21.8 km, and less than 1% of those tows are thought to be twin-rig because trawling with twin-rig gear was introduced in that fishing year. In 2002/03 the average tow length was 23.8 km, but 26% of these were twin-rig (the average twin-rig tow length was 25.6 km). Therefore the increase in swept area five years after the peak number of tows may reflect a small increase in average tow length (21.8 to 23.8 km) and a larger increase in the use of twin-rig gear (from less than 1% to 26%).

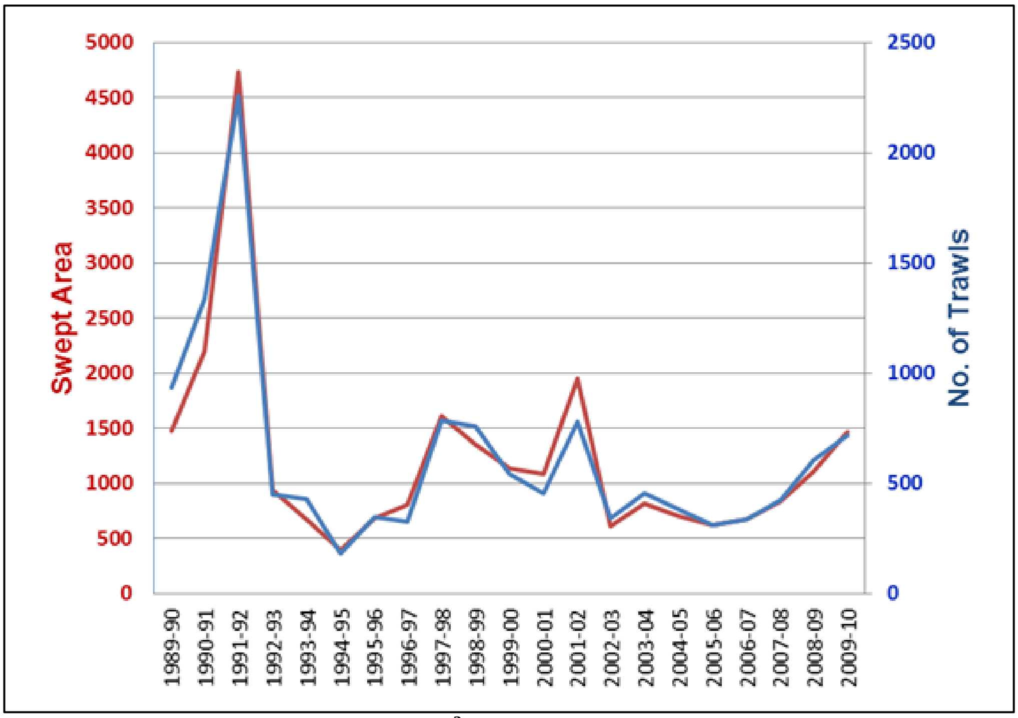


Figure 13: Number of tows and swept area (km^2) for target species southern blue whiting.

Figure 14: Number of tows and swept area (km^2) for target species hoki.

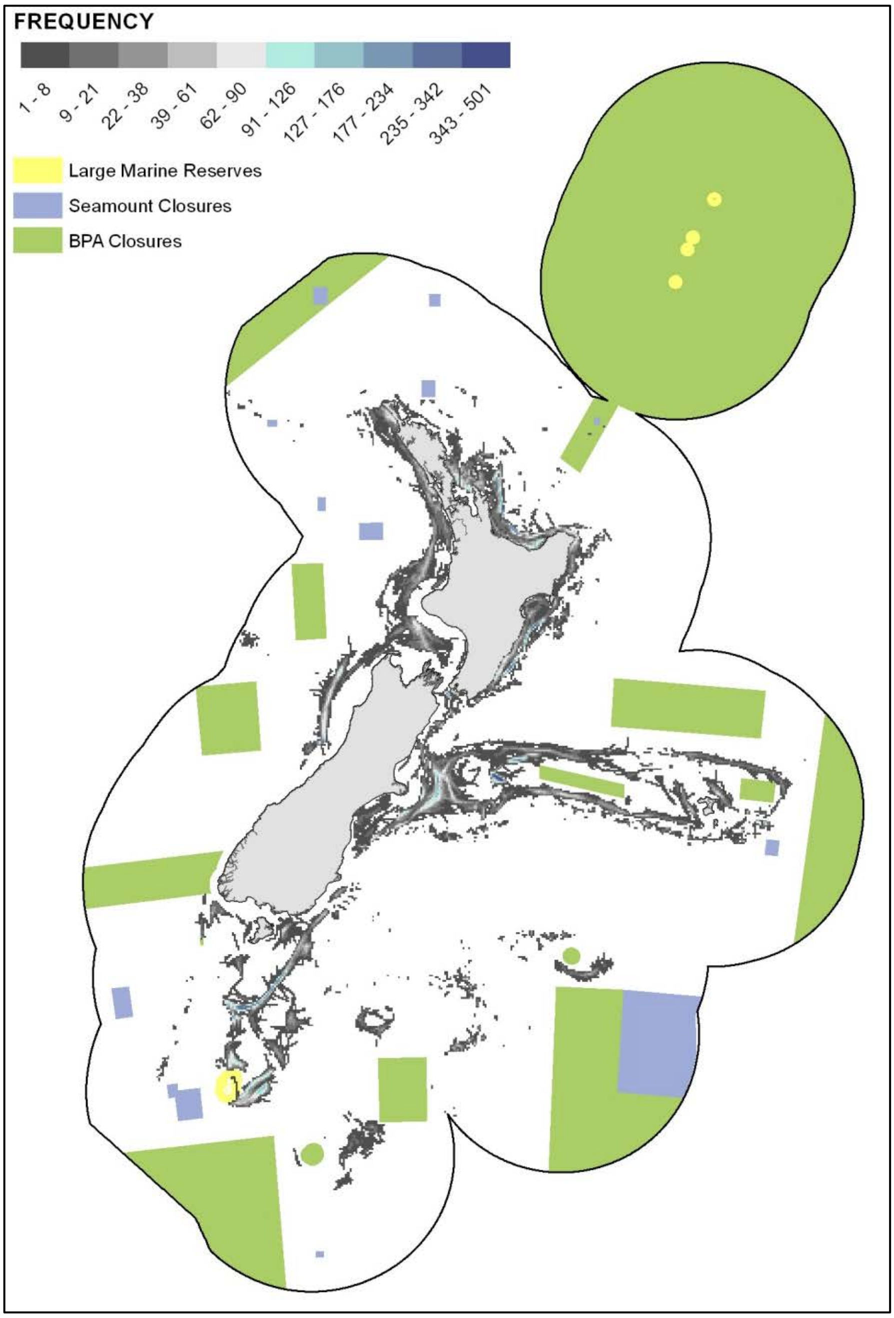
TCEPR data and frequency

Tables and plots showing the estimated trawl frequency for each species are in Appendix 3 (tables are in files <species id>_freq_stats.pdf and <species id>_freq_stats.xls, e.g., barracouta data are in BAR_freq_stats.pdf and BAR_freq_stats.xls; plots are in files <species id>_freq_fig_part<number>.pdf and <species id>_area_fig_part<number>.pdf, e.g. BAR_freq_fig_part1.pdf and BAR_area_fig_part1.pdf. See file README.doc for more information). Results are provided for each species for each fishing year and for the period 1989/90 to 2009/10.

Frequency of fishing by year was calculated by counting the number of trawls that crossed each cell in a raster grid that covered the EEZ and TS. A total of 167 477 cells, each 5 km x 5 km in size, were used for the analysis. The results can be directly compared with the analyses of Baird et al. (2011).

For the period 1989/90 to 2009/10 tows were reported in 39 731 of these cells, about 24% of the total number of cells. The highest tow frequency in a cell was 16 539. The mean frequency of tows for all fished cells was 167, and the mean frequency of tows in all cells was 40. The largest cumulative swept area in a cell was 10 010 km^2. The mean swept area for cells that tows were reported in was 80 km^2, and the mean for all cells was 19 km^2. For the fishing year 2009/10, 12 866 cells were contacted by bottom tows, about 8% of the total number of cells (Figure 15). For this most recent year in the dataset the highest number of tows in a cell was 501, and the mean frequency of tows for those cells that tows were reported in was 15.

For the period 2005/06 to 2009/10 the mean frequency of towed cells within the fishable area for all species combined declined from 17.7 to 14.7 between 2005/06 and 2008/09, but increased slightly to 15.3 in 2009/10. The increase in 2009/10 was reflected in the 0–400 m, 400–800 m and 800–1200 m depth zones, but not in the 1200–1600 m depth zone (Figure 16).



	Statistics for 2009–10
No. of filled cells reporting tows	12 866
Cells reporting tows	7.8%
Highest frequency of tows	501
Mean frequency in towed cells	15.3
Mean frequency in all cells	1.2

Figure 15: Estimated frequency of trawling in areas of sea floor contacted by bottom trawling for all species 2009/10 (top), and related statistics (bottom).

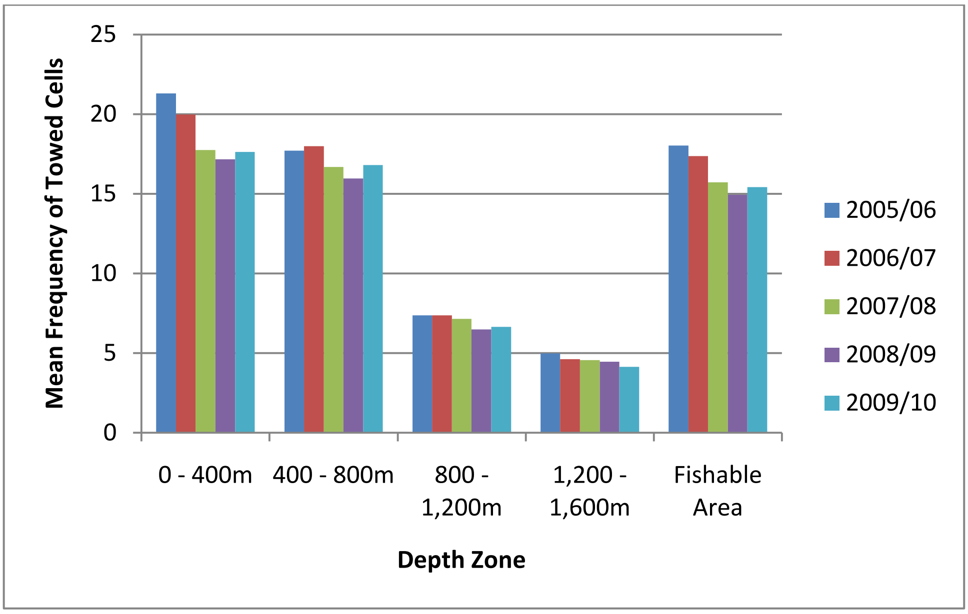


Figure 16: Mean frequency of towed cells for all species combined within the overall fishable area and by depth zone for the period 2005/06 to 2009/10.

For tows targeting hoki, the mean frequency of tows for all trawled cells between 2005/06 and 2009/10 was stable at around 14. There was a slight dip to 12.5 in 2007/08 and to 11.8 in 2008/09 when the Total Allowable Commercial Catch (TACC) was reduced by 10 000 t. When the TACC was increased by 20 000 t in 2009/10 the mean frequency increased back to 14.2. Interestingly, the swept area for hoki did not increase in response to the 20 000 t TACC increase, remaining constant at around 19 000 km^2 (Figure 14), suggesting that tows occurred in a reduced number of cells. The highest mean frequency occurred in the 400–800 m depth zone where there were between 13 and 16 tows in trawled cells. A similar trend occurred in the 0–400 m depth zone where the number of trawls ranged between 9.3 and 11.7 (Figure 17).

For oreo, there was an increase in the mean frequency of tows in trawled cells from 6.3 in 2005/06 to 7.6 in 2009/10. The highest frequency of trawls occurred in the 800–1200 m depth zone where the average number of tows per cell increased from 6.7 in 2005/06 to 8.3 in 2009/10. The trend in the deeper than 1200 m depth zone was flat. In the 400–800 m depth zone there was an increase from 2.8 to 5.6 over this period, while in the 0–400 m depth zone there was an abrupt decrease from 3.4 to 1.7 between 2007/08 and 2008/09, (Figure 17). The total area trawled declined from 1472 to 1079 km^2 between 2005/06 and 2008/09, coincident with a 3000 t TACC decrease in 2007/08, before increasing again to 1372 km^2 in 2009/10, coincident with a 250 t TACC increase.

Figure 18 shows the pattern of fishing for southern blue whiting in a small area of the fishery (Bounty Plateau) for the period 1989/90 to 2009/10. The tow path distribution shows that the fishing effort is concentrated in areas south-west and south-east of the island. The calculation of frequency of tows per cell quantifies this variation, varying from 1 tow per cell to 138 per cell in this region.

Statistics from this type of analysis for barracouta show that 9202 cells, about 5.6% of the total, had some fishing effort in the period 1989/90 to 2009/10. The largest cumulative swept area in any one cell was 909 km^2. The mean and standard deviation were 13 km^2 and 40 km^2, respectively. The maximum number of tows across any one cell was 1447. The mean and standard deviation were 28 and 78 tows, respectively. Figure 19 illustrates the distribution of area contacted and the number of tows in each cell (note that the entire ranges are not shown in the figure). More than 90% of the cells fished for barracouta have a contact area less than 40 km^2 and fewer than 70 tows.

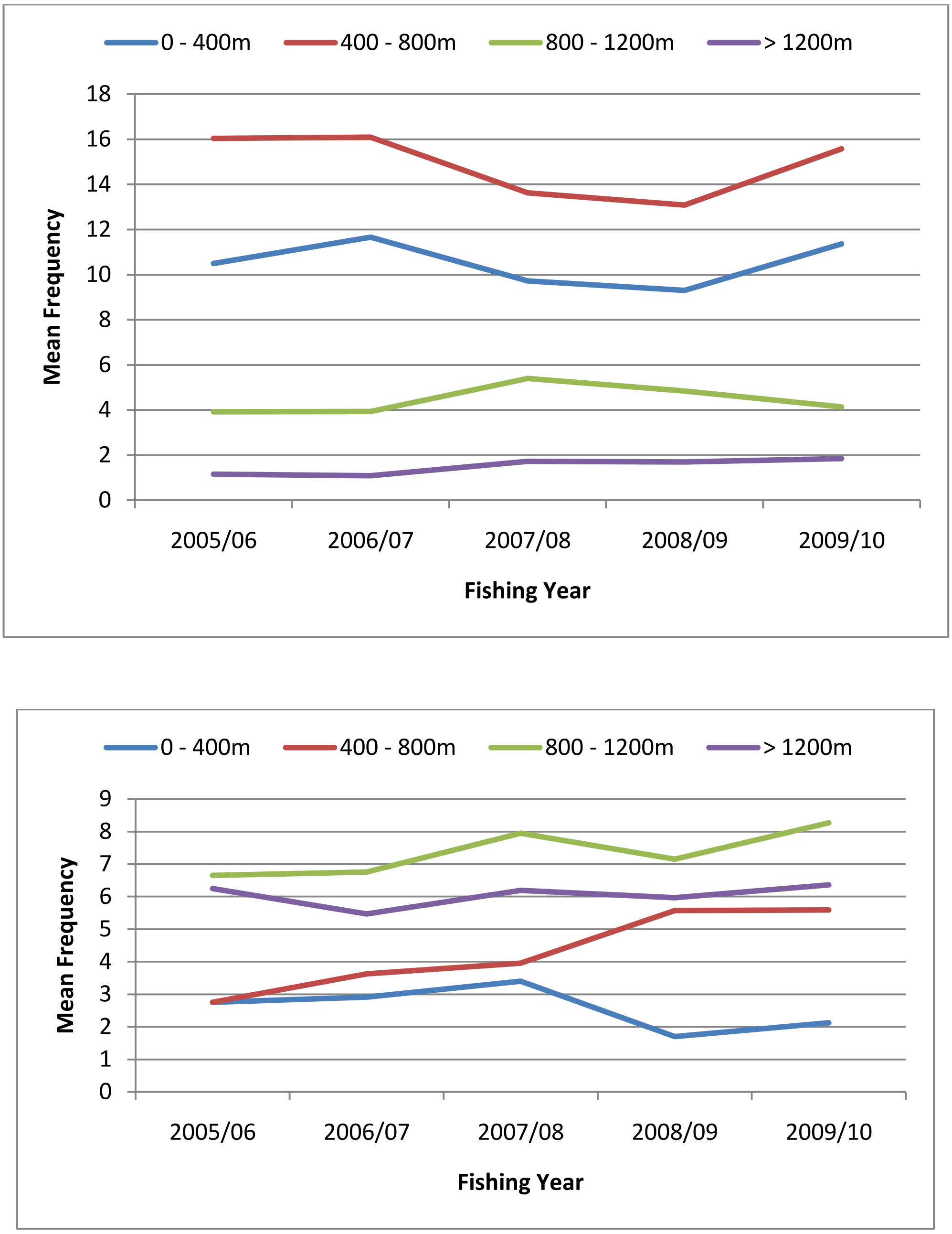


Figure 17: Mean frequency of tows in trawled cells for the period 2005/06 to 2009/10 for hoki (top) and oreo (bottom).

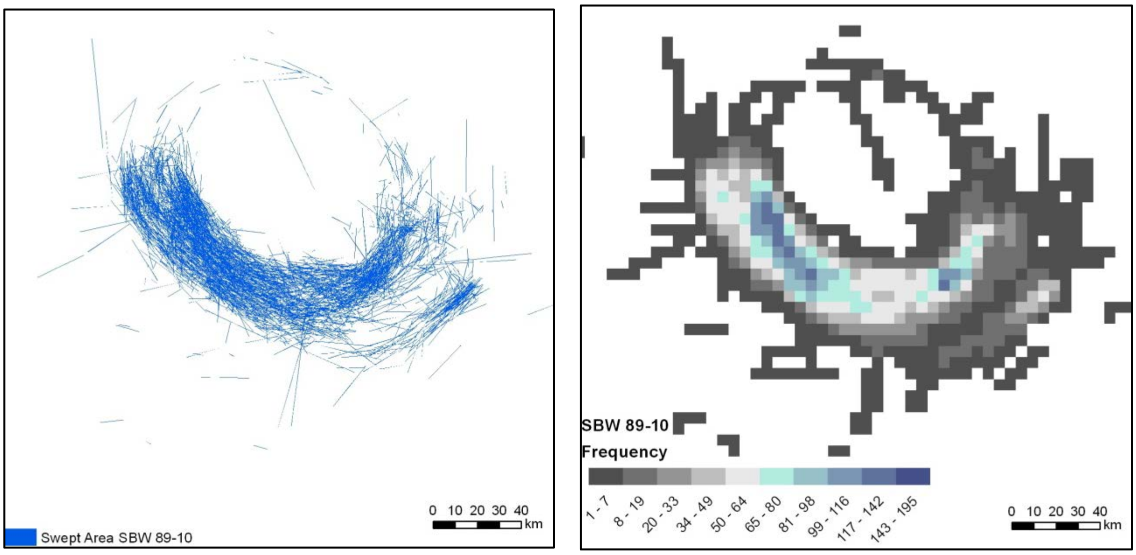


Figure 18: Frequency analysis for southern blue whiting on Bounty Plateau for the period 1989/90 to 2009/10 showing tow path distribution (left) and the frequency of tows in each cell (right).

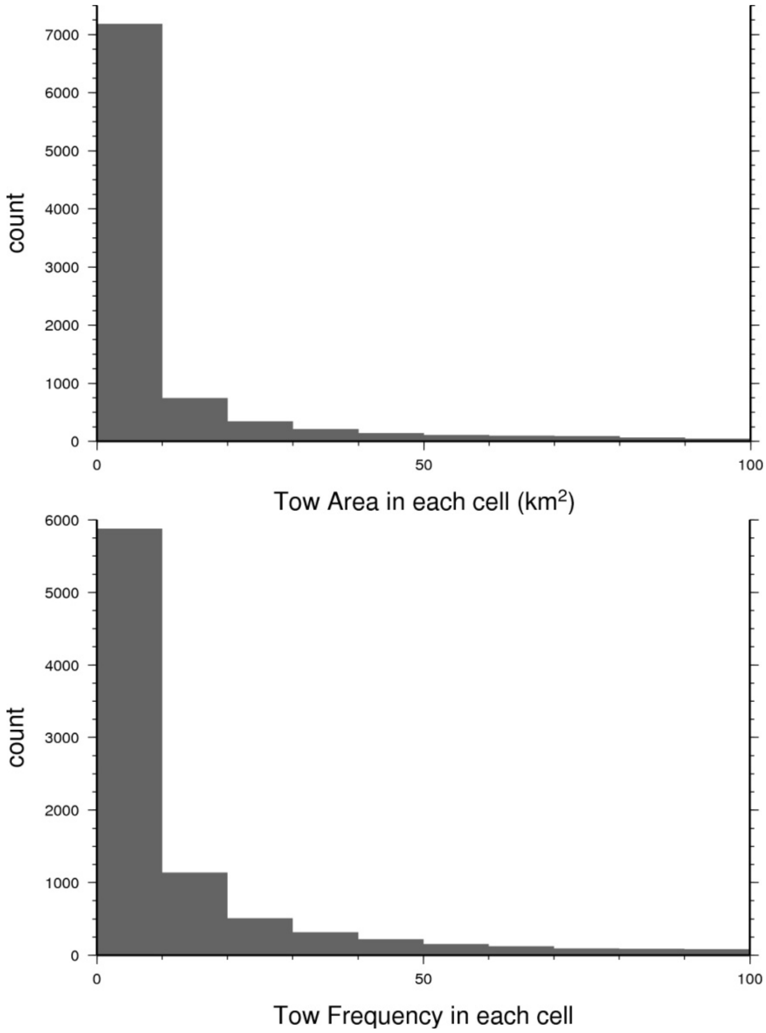


Figure 19: Frequency analysis for barracouta for the period 1989/90 to 2009/10 showing the area contacted in each cell (top) and of the number of tows contacting the seafloor in each cell (bottom). The area histogram uses a 10 km^2 bin size and the tow frequency histogram uses a 10 tow bin size.

TCEPR data and depth zone

Tables and plots showing the estimated swept areas for each species overlain on the depth bands (0–400 m; 400–800 m; 800–1200 m and deeper than 1200 m) are in Appendix 3 (tables are in files <species id>_footprint_stats.pdf and <species id>_footprint_stats.xls, e.g., barracouta data are in BAR_footprint_stats.pdf and BAR_footprint_stats.xls; plots are in files <species id>_fig_part<number>.pdf, e.g BAR_fig_part1.pdf. See file README.doc for more information). Results are provided for each species for each fishing year and for the period 1989/90 to 2009/10.

Analysis of the edited records provides statistics about the distribution of bottom trawling effort relative to the physical characteristics of the EEZ. Table 7 lists the estimated areas of sea floor contacted by bottom trawling as a function of water depth. Figure 20 shows the spatial distribution of the swept area in relation to the depth zones. The swept area for all species peaked in 2002/03 but declined again to 1989/90 levels by 2009/10. The depth zone with the largest swept area is 0–400 m, representing 178 340 km^2 or 46% of the total swept area (Table 7). This is an underestimate of the total bottom trawling effort in this depth zone because it is also fished by smaller boats that record their catches on CELR or TCER forms (see Appendix 2).

The swept area in the 0–400 m zone started at just over 25 000 km^2 in 1989/90 and rose to just over 40 000 km^2 in 1997/98. A period of relative stability followed, before a decline back to 25 000 km^2 between 2002/03 and 2009/10. In the 400–800 m zone it increased from just under 18 000 km^2 in 1989/90 to nearly 59 000 km^2 in 2002/03 and then declined to 20 000 km^2 in 2009/10. The estimated annual swept area in the 800–1200 m depth zone nearly doubled from around 5000 km^2 in 1989/90 to about 9000 km^2 in 1998/99, but had declined to about 3000 km^2 by 2009/10 (Figure 21).

The group of minor stocks contributes most of the swept area in the 0–400m zone (30%), followed by BAR (16%), JMA (15%), HOK (13%) and SQU (11%) (Figure 22). The estimated swept area in the 400–800 m depth zone is 146 922 km^2 or 31% of the total. This depth zone is dominated by trawling for HOK (64%). The remaining fisheries in this zone comprise fairly small swept areas; HAK (8%), SBW (6%), LIN (4%), SCI (4%), minor stocks (4%), SWA (3%) and SQU (3%). The 800–1200 m depth zone has a trawl footprint of 47 272 km^2 or 12% of the total swept area. This depth zone is dominated by ORH (51%), followed by OEO (22%), HOK (19%) and minor stocks (4%). The depth zone deeper than 1200 m has a total swept area of 12 473 km^2, which is around 0.4% of the total swept area. Dominant stocks in this zone are ORH (63%), OEO (15%), HOK (8%) and minor stocks (8%).

For the most recent five-year period, fishing effort as determined by the percentage of 5 × 5 km cells contacted by trawl for all species combined, showed a steady decline from 27.2% to 22.6% for the fishable area. This decline was most pronounced in the 0–400 m depth zone where the percentage of cells contacted reduced from 51% in 2005/06 to 40.6% in 2009/10. The decline in the 400–800 m depth zone was slight, from 24.2% to 20.6%, while in the 800–1200 m and 1200–1600 m depth zones the trend was flat (Figure 23).

Figures 24 and 25 provide examples, using squid and hoki, of how the database can be used to characterise fishing grounds. The data illustrate that while hoki is fished mainly in the 400 –800 m depth range, squid is trawled primarily in depths of less than 400 m.

Table 7: Estimated total area of sea floor contacted by bottom trawling for all species for the period 1989/90 to 2009/10 as a function of depth (m).

Depth Range	0–400 m	400–800 m	800–1200 m	> 1200 m
Area (km^2)	407 963	473 433	386 530	2 853 205
Swept Area (km^2)	178 340	146 922	47 272	12 473
Swept Area (%)	44	31	12	0.4

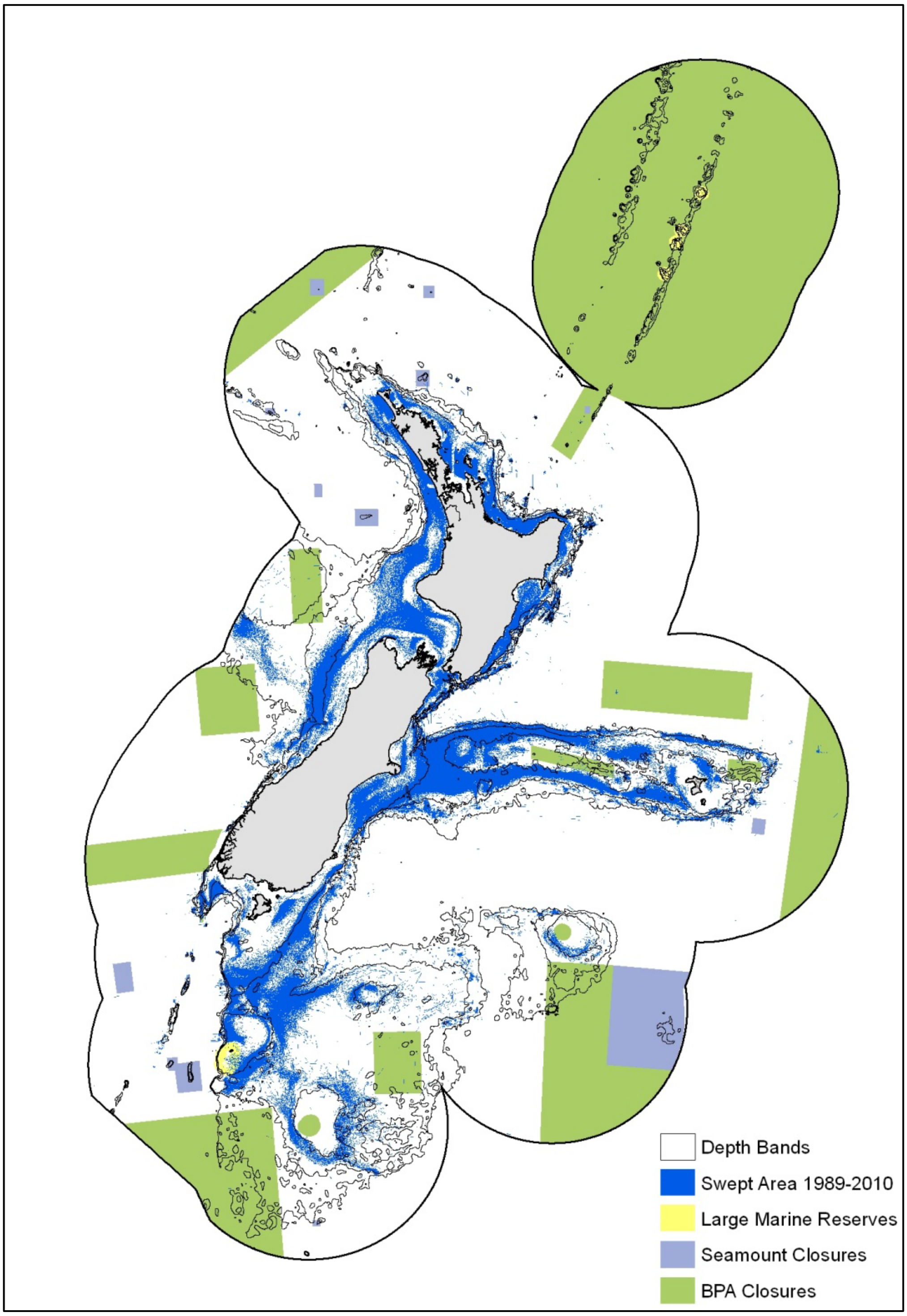


Figure 20: Total trawl footprint distributed by depth zone (200, 400, 800 and 1200 m contours are shown).

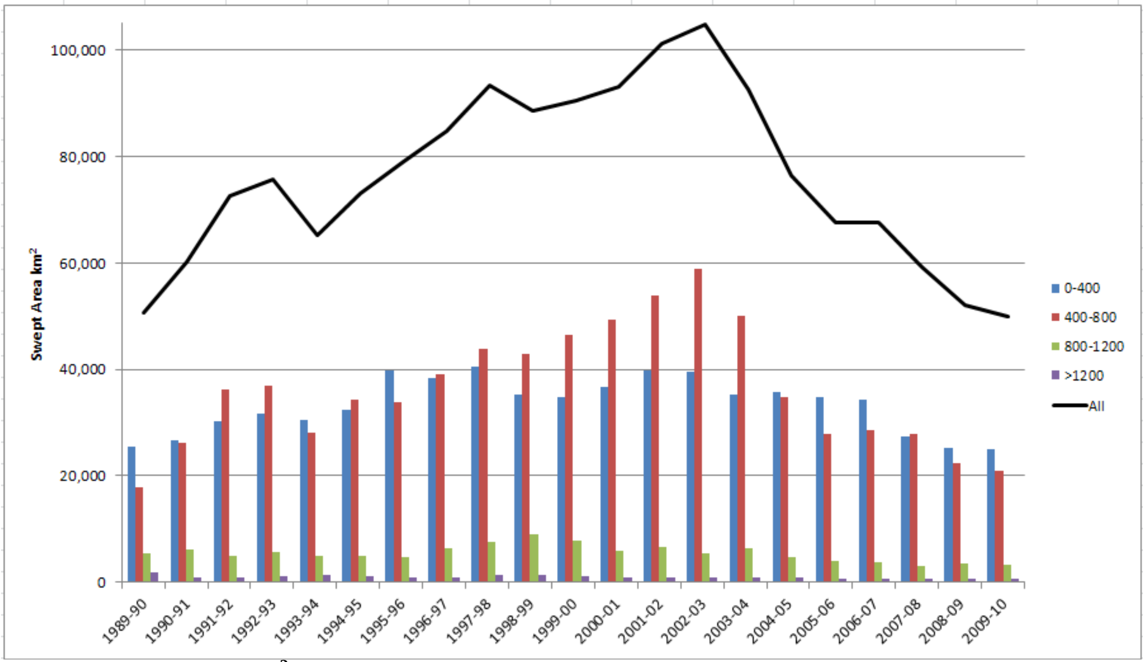


Figure 21: Swept area (km²) for all species as a function of depth zone (m) for each fishing year.

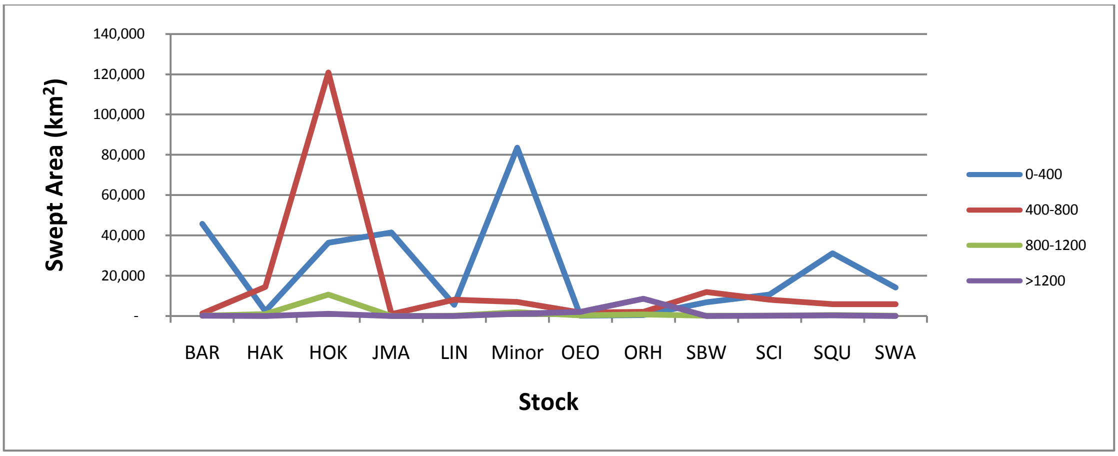


Figure 22: Swept area by species and depth zone for the period 1989/90 to 2009/10.

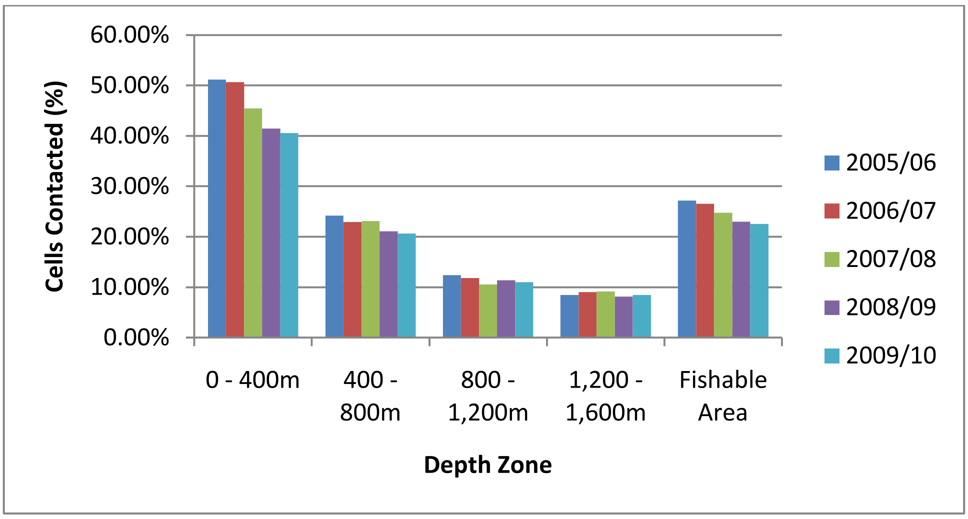


Figure 23: Percentage of cells contacted by tows during the period 2005/06 to 2009/10, for all species combined, in the fishable area and by depth zone.

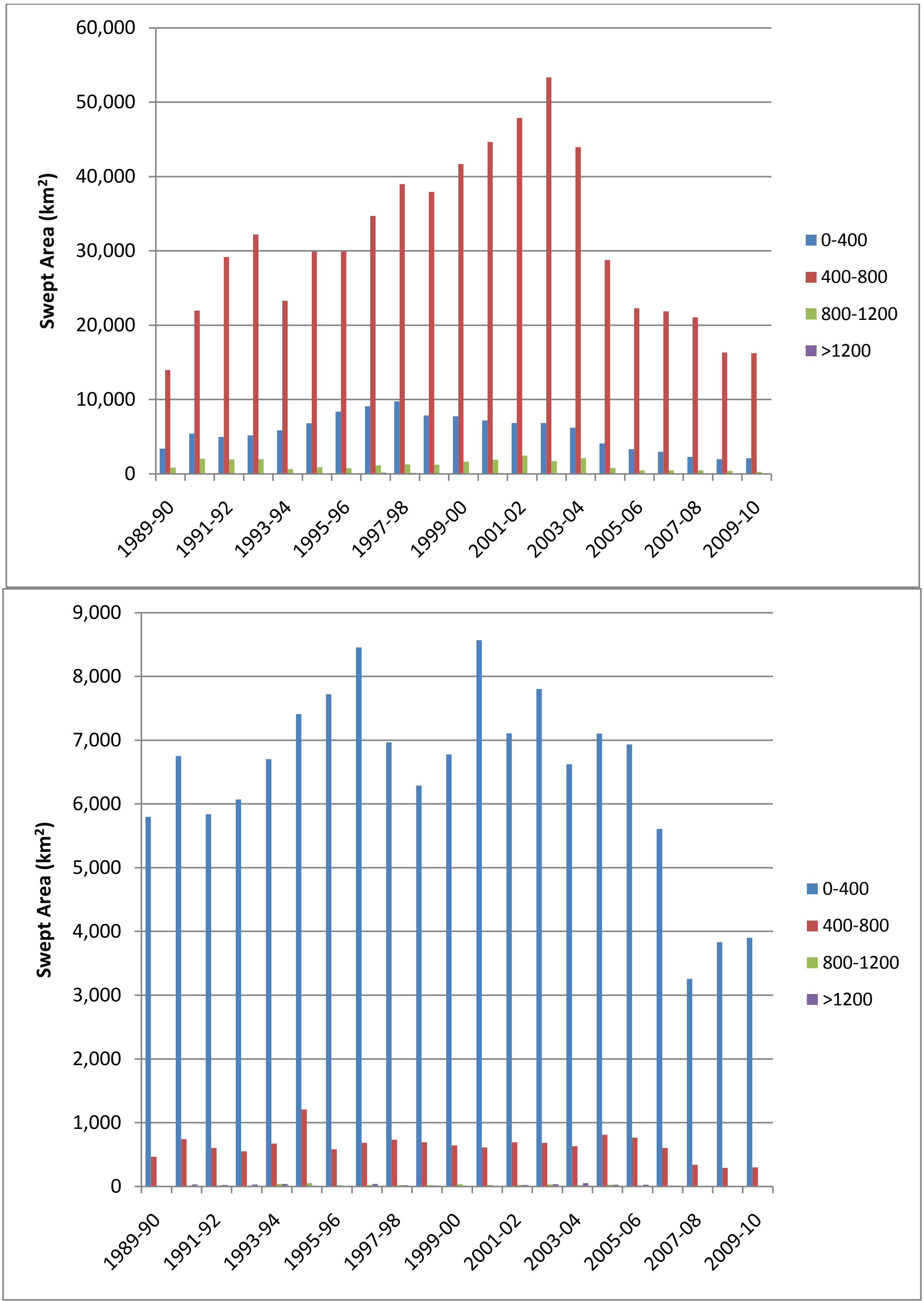


Figure 24: Swept area (km^2) for bottom trawls targeting hoki (top) and squid (bottom) as a function of depth (m) for each fishing year.

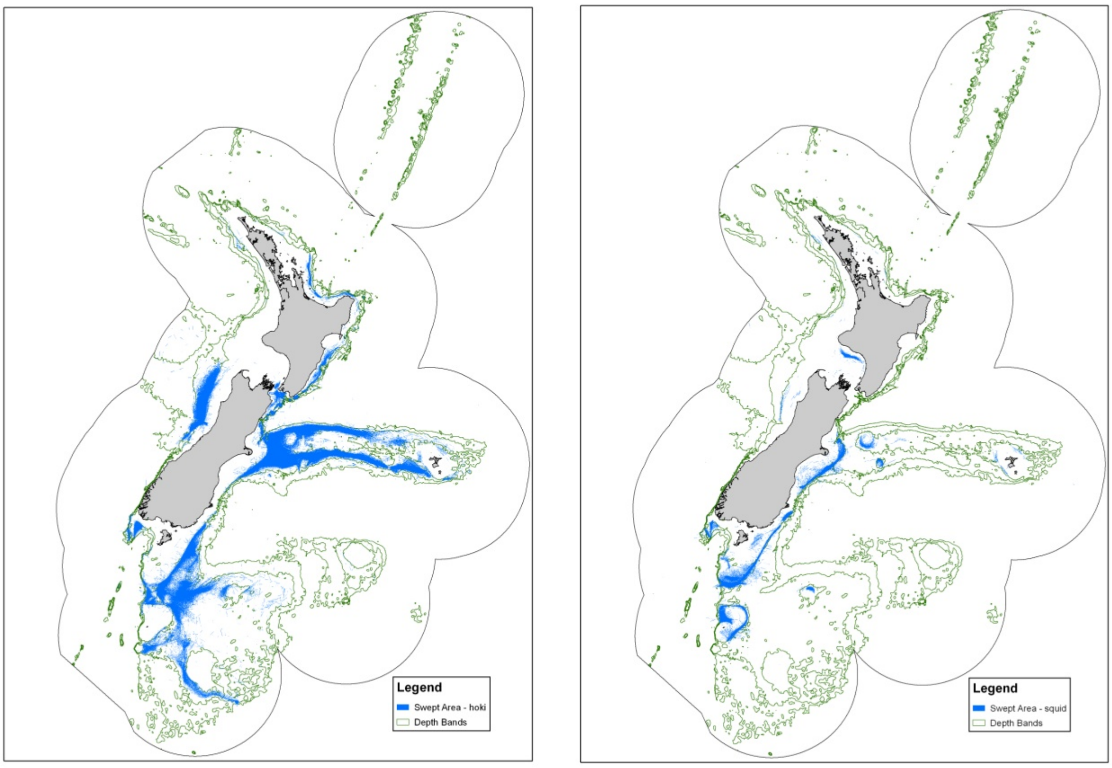


Figure 25: The swept area for bottom trawls targeting hoki (left) and squid (right), for 1989/90 to 2009/10.

TCEPR data and fishable area

Tables and plots showing the estimated swept areas for each species overlain on the fishable area are provided in Appendix 3 (tables are in files <species id>_footprint_stats.pdf and <species id>_footprint_stats.xls, e.g., barracouta data are in BAR_footprint_stats.pdf and BAR_footprint_stats.xls; plots are in files <species id>_fig_part<number>.pdf, e.g. BAR_fig_part1.pdf. See file README.doc for more information). Results are provided for each species for each fishing year and for the period 1989/90 to 2009/10.

For this analysis the fishable area is defined as that part of the TS and EEZ that is shallower than 1600 m and outside all Benthic Protection Areas (BPAs), Seamount Closure and Marine Reserve areas (Figure 26). The fishable area in the TS and EEZ is 1 408 210 km^2, which amounts to 34% of the total area of seabed in the TS and EEZ. An analysis of TCEPR data revealed that the estimated total area contacted by bottom trawling for all species is 385 032 km^2, of which 4 849 km^2 (1% of the total swept area) occurred in areas outside the fishable area (i.e. in BPAs, Seamount Closures and large MPAs or in depths deeper than 1600 m) (Table 8). There are some trawls inside closed areas (
Table 9). These trawls may have occurred before the areas were closed, Seamount Closures were implemented in 2001, and BPAs in 2007. The total area swept within the fishable area is 380 183 km^2, or about 27% of the fishable area (Table 8).

Table 8: Estimated area of total sea floor contacted by trawling for all species as a function of Fishable Area, 1989/90 to 2009/10.

	Area (km^2)	Swept Area (km^2)	Swept Area (%)
EEZ and TS	4 121 131	385 032	9.34%
Fishable Area	1 408 210	380 183	27.00%

Table 9: Estimated area of total sea floor contacted by trawling for all species outside of the Fishable Area, 1989/90 to 2009/10. There is some spatial overlap between the area deeper than 1600m, the BPAs and the Seamount Closures, and between the different types of closures.

	Area (km^2)	Swept Area (km^2)	Proportion of Swept Area (%)
Outside Fishable Area	2 712 921	4 848	1.26%
Deeper than 1600m	2 490 100	3 151	0.82%
Inside BPAs	1 138 465	935	0.24%
Inside Seamount Closures	78 466	93	0.02%
Inside large MPAs	9 433	736	0.19%

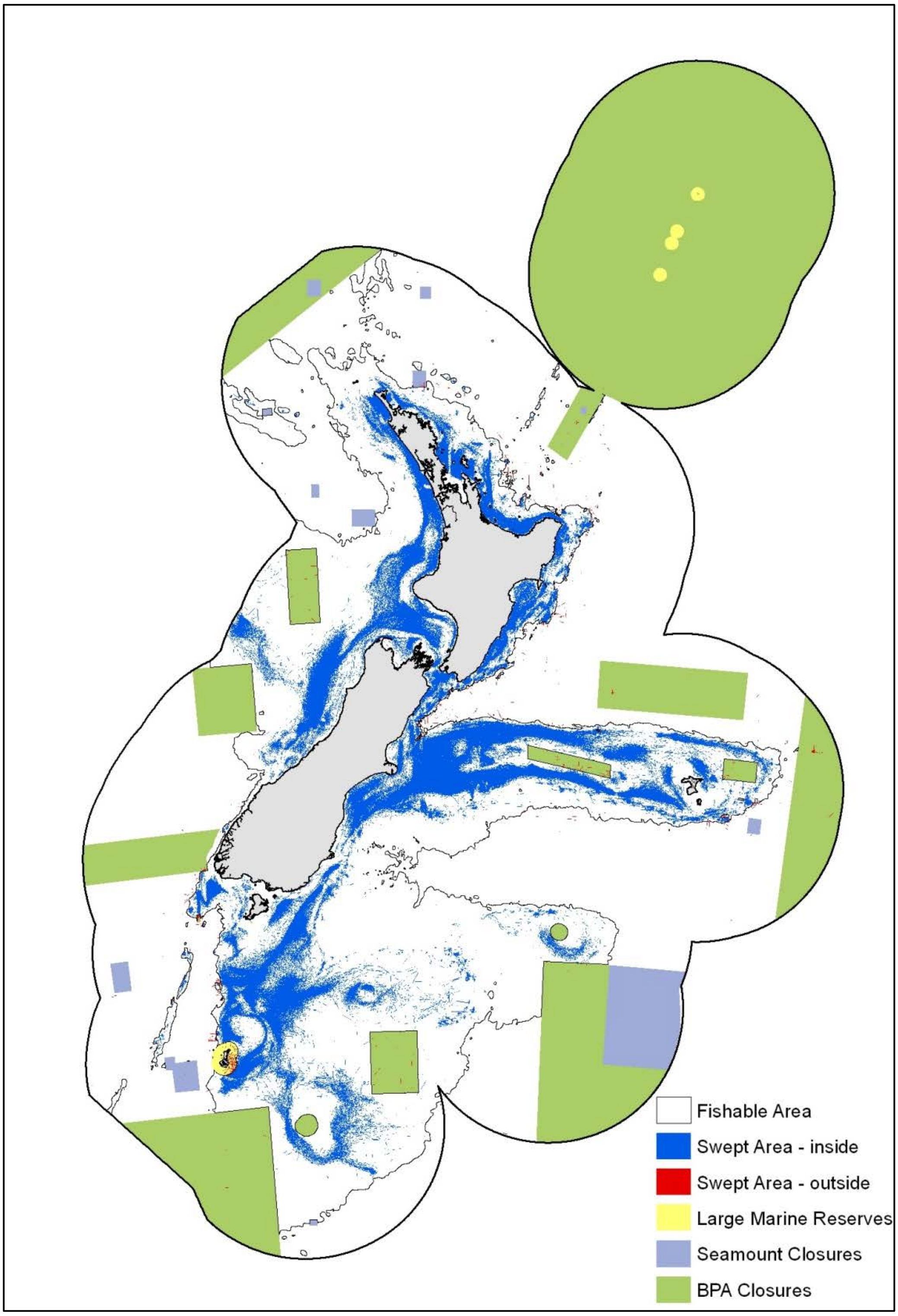


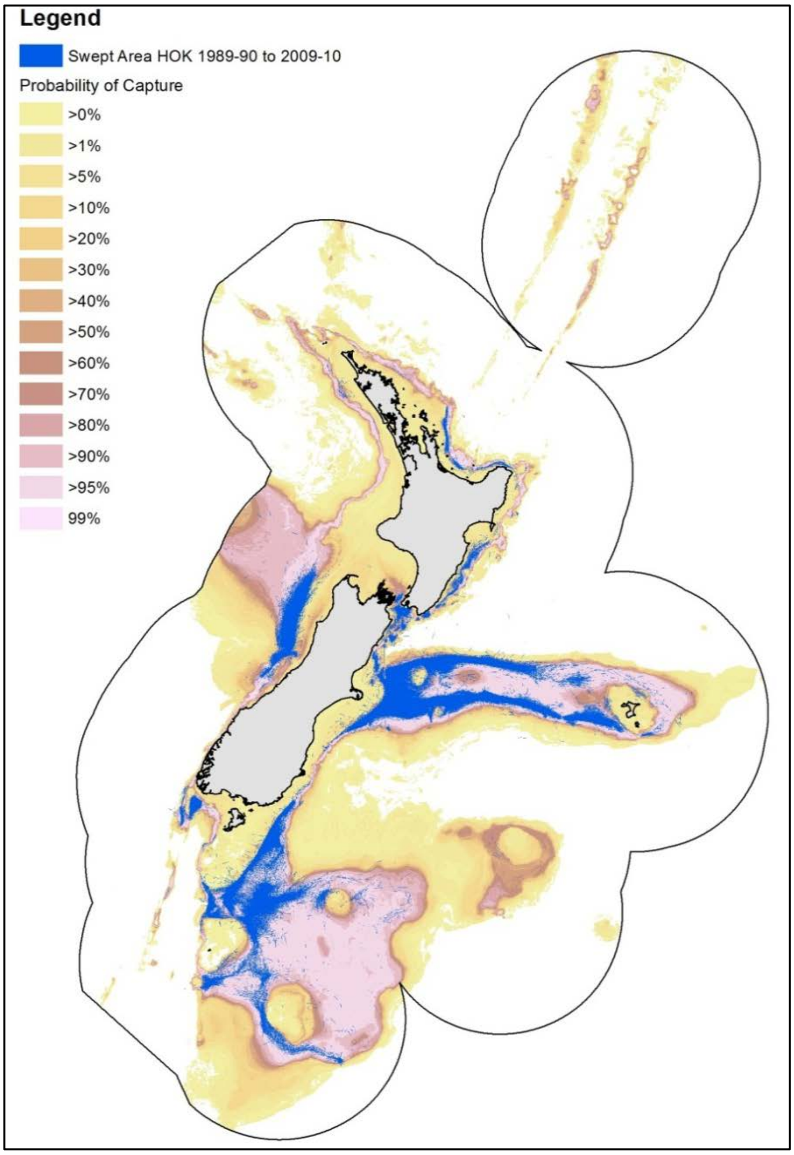
Figure 26: Trawl footprint for all species in relation to the fishable area for the period 1989/90 to 2009/10.

TCEPR data and preferred habitat

Tables and plots showing the estimated swept areas for each species overlain on the preferred habitat, represented by the probability of capture, are provided in Appendix 3 (tables are in files <species id>_footprint_stats.pdf and <species id>_footprint_stats.xls, e.g., barracouta data are in BAR_footprint_stats.pdf and BAR_footprint_stats.xls; plots are in files <species

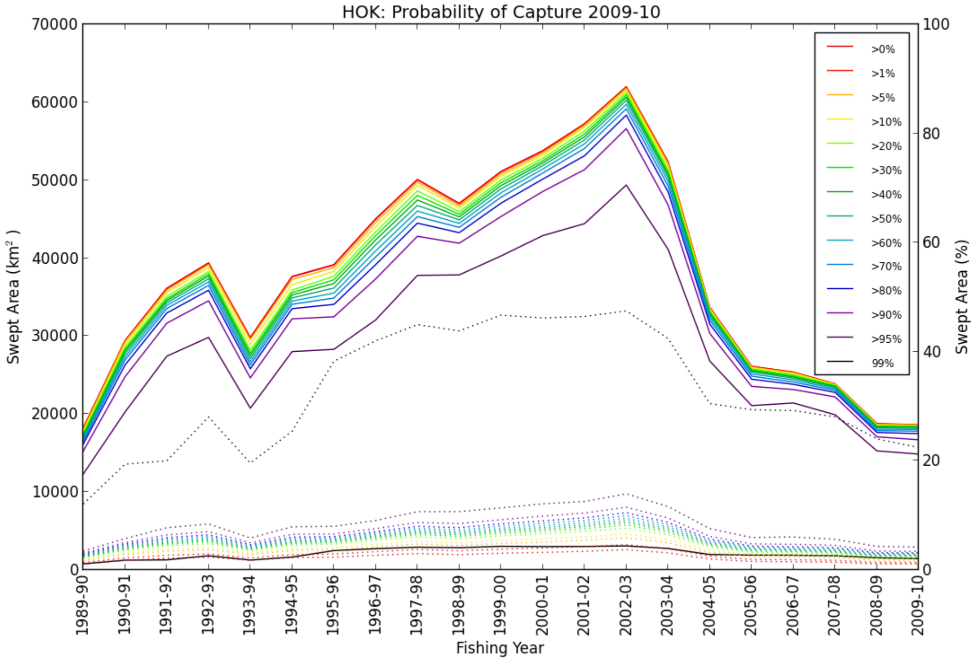
id>_fig_part<number>.pdf, e.g BAR_fig_part1.pdf. See file README.doc for more information). Results are provided for each species for each fishing year and for the period 1989/90 to 2009/10.

TCEPR data were used to map fishing effort for key target species against preferred habitat. An example is shown in Figure 27 for hoki, which illustrates that the swept area for the period 1989/90 to 2009/10 comprises a little over 10% of the total preferred habitat (i.e. in the over 0% probability of capture area). As the hoki fishing grounds occur in fairly well-established, discrete areas within the preferred habitat range there is only a gradual increase in the percentage of the habitat range swept, from 10% to 32%, between the over 0% and over 95% probability of capture areas, but then a steep escalation to 71% in the 99% probability of capture area. Figure 28 shows how the percentage swept area in the habitat range for hoki, by probability of capture areas, varies as a function of year, and how the total swept area for hoki varies by the probability of capture areas.



	Area (km^2)	Swept Area (km^2)	Swept Area (%)
EEZ and TS	4 121 131	168 975	4.10%
Probability of Capture >0%	1 667 848	168 603	10.11%
Probability of Capture >1%	1 336 861	167 988	12.57%
Probability of Capture >5%	1 045 235	165 715	15.85%
Probability of Capture >10%	933 803	162 820	17.44%
Probability of Capture >20%	798 645	158 988	19.91%
Probability of Capture >30%	739 548	156 359	21.14%
Probability of Capture >40%	697 444	153 870	22.06%
Probability of Capture >50%	663 634	151 231	22.79%
Probability of Capture >60%	630 881	148 437	23.53%
Probability of Capture >70%	595 105	145 693	24.48%
Probability of Capture >80%	556 199	141 886	25.51%
Probability of Capture >90%	492 106	135 315	27.50%
Probability of Capture >95%	353 805	114 477	32.36%
Probability of Capture 99%	6 504	4 632	71.22%

Figure 27: The trawl footprint of tows targeting hoki in 1989/90 to 2009/10 overlain on the probability of capture zones (top). Statistics for the range of probability of capture areas and swept areas within the preferred habitat for hoki (bottom).



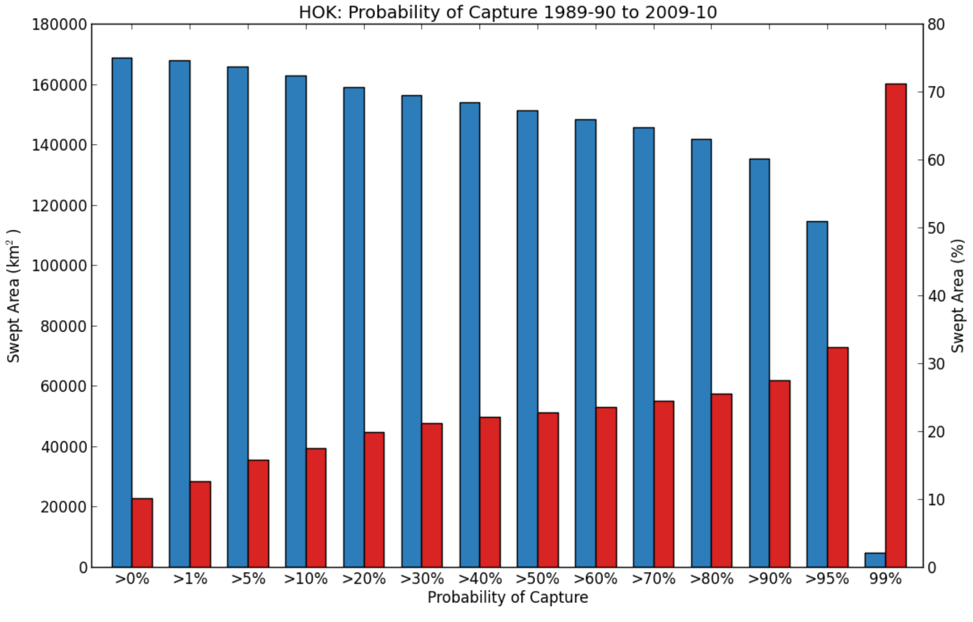


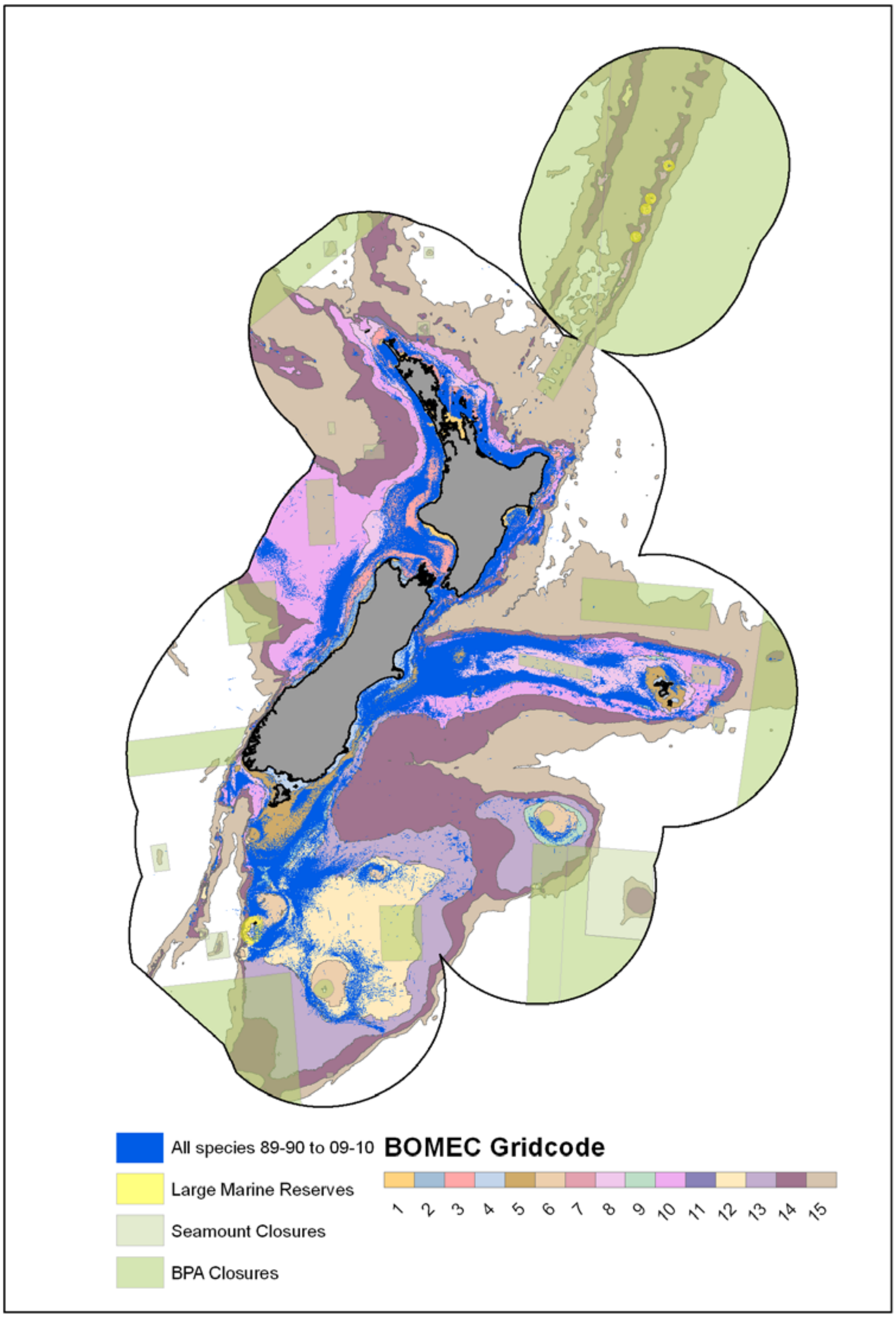
Figure 28: Swept area in square kilometres (solid) and as a percentage (dashed) for hoki for each probability of capture area per year (top); and for all years (bottom) showing the swept area in square kilometres (blue) and as a percentage (red).

TCEPR data and benthic habitats

Tables and plots showing the estimated swept areas for the each species overlain on the BOMEC areas are in Appendix 3 (tables are in files <species id>_footprint_stats.pdf and <species id>_footprint_stats.xls, e.g., barracouta data are in BAR_footprint_stats.pdf and BAR_footprint_stats.xls; plots are in files <species id>_BOMEC_fig_part<number>.pdf, e.g. BAR_BOMEC_fig_part1.pdf. See file README.doc for more information). Results are provided for each species for each fishing year and for the period 1989/90 to 2009/10.

In total, the 15 BOMEC classification areas cover 2 627 073 km², approximately 64% of the EEZ and TS. The total swept area within the BOMEC for all species for the period 1989/90 to 2009/10 is estimated to be 384 376 km², about 15% of the total BOMEC classification area (Figure 29). The swept area for all species for the 2009/10 fishing year is 49 695 km², covering about 1.9% of all BOMEC zones.

Analysis of the estimated swept area within individual BOMEC zones could be used as an indication of the scale of potential benthic effects by trawling. This analysis shows that, for the period 1989/90 to 2009/10, more than 60% of BOMEC classes 3 and 9 are estimated to have been contacted by bottom trawling; more than 40% of BOMEC classes 1, 5, 7 and 8 are estimated to have been contacted by bottom trawling; less than 10% of BOMEC classes 11, 13, 14 and 15 are estimated to have been contacted by bottom trawling.



BOMEC code	Area (km^2)	Swept Area (km^2)	Swept Area (%)
1	27 557	12 400	45%
2	12 420	3 324	27%
3	89 710	57 840	64%
4	27 268	9 592	35%
5	60 990	26 612	44%
6	38 609	6 691	17%
7	6 342	3 043	48%

8	138 551	68 389	49%
9	52 224	38 238	73%
10	311 361	71 594	23%
11	1 289	14	1.1%
12	198 577	54 337	27%
13	233 825	18 503	8%
14	493 034	11 369	2%
15	935 315	2 431	0.3%
TOTAL	2 627 073	384 376	15%

Figure 29: The BOMEC classification and trawl footprint for all species, 1989/90 to 2009/10 (top) and associated area and swept area (km^2) statistics (bottom).

BOMEC 10 has the largest swept area, followed by BOMEC 8 (Figure 30). However, in terms of the percentage of the BOMEC zone that has been swept, BOMEC 9 is the highest at over 70%, followed by BOMEC 3 at 63%. The remaining BOMEC zones have less than 50% swept area, including those with the largest swept area (BOMEC 8 and 10).

The fishing effort in the BOMEC areas has varied with time (Figure 31). For example, the swept area in BOMEC 9 (light green line in Figure 32) was maximal in 1999/2000 at 37% and has decreased in recent years and in 2009/10 it was less than 20%.

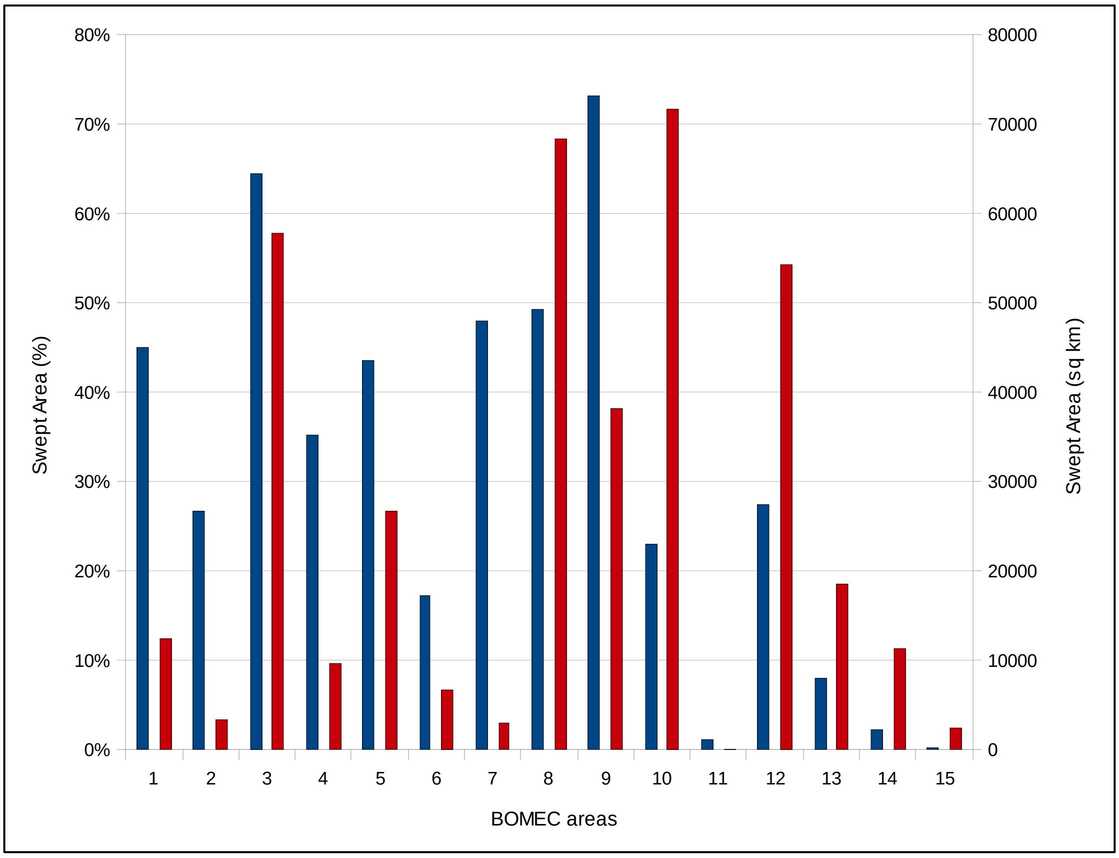


Figure 30: Swept area in each BOMEC zone as a percentage (blue), and in square kilometres (red).

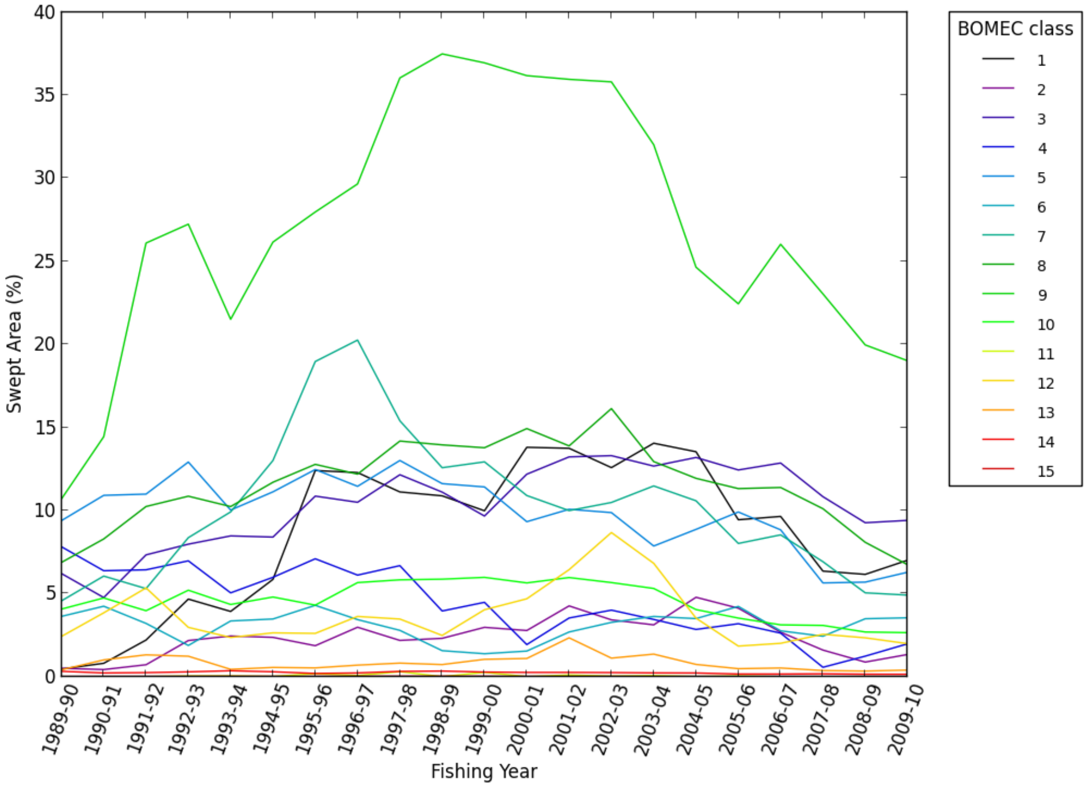


Figure 31: Swept area for all species (as a percentage of the BOMEC zone) as a function of time.

The results for individual fish species highlight the variability of their preferred habitats. Figure 32 shows that both total swept area and diversity of fishing effort varies considerably among the BOMEC areas, most likely influenced by the habitat preferences of the different target species, which is driven mainly by depth but also by latitude. The areas generally less than 250 m depth (i.e. classes 1–6) are dominated by minor species, BAR, JMA and SQU; classes 7–10 and 12–13 range from 250–1200 m depth and are dominated by HOK, and class 14, deeper than 1000 m, is dominated by ORH.

It is possible to monitor changes in fishing effort for a species across BOMEC classes. For example, the results for silver warehou show that the total swept area has fluctuated over the last five years, and the trends are not the same in all BOMEC areas (Figure 33). The results show large increases in the swept area in BOMEC class 8 in 2006/07 and 2007/08, and closer examination of the data indicates that this was likely to have been due to a very slight shift in the distribution of trawling off Banks Peninsula during these two years, rather than a response to a change in their abundance.

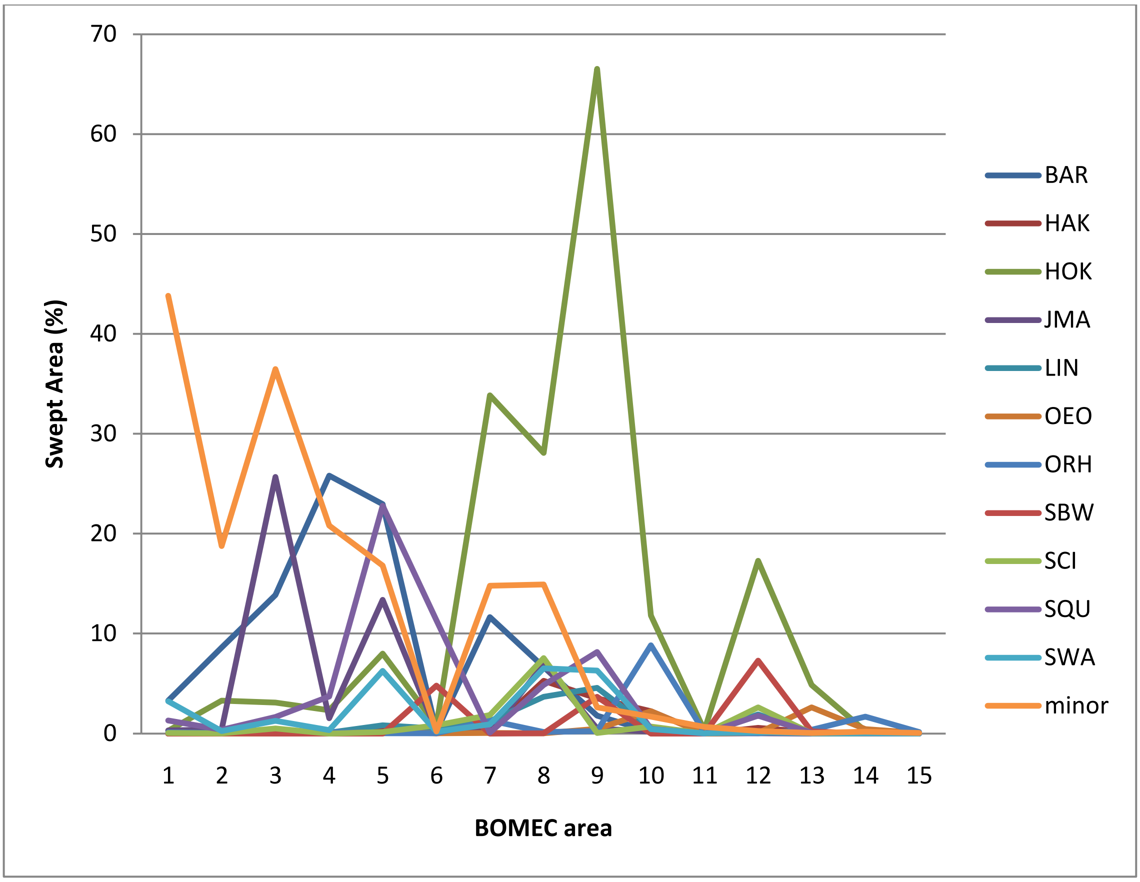


Figure 32: Percentage of BOMEC areas swept by trawls for each of the 11 major species considered by this report for fishing years 1989/90 to 2009/10.

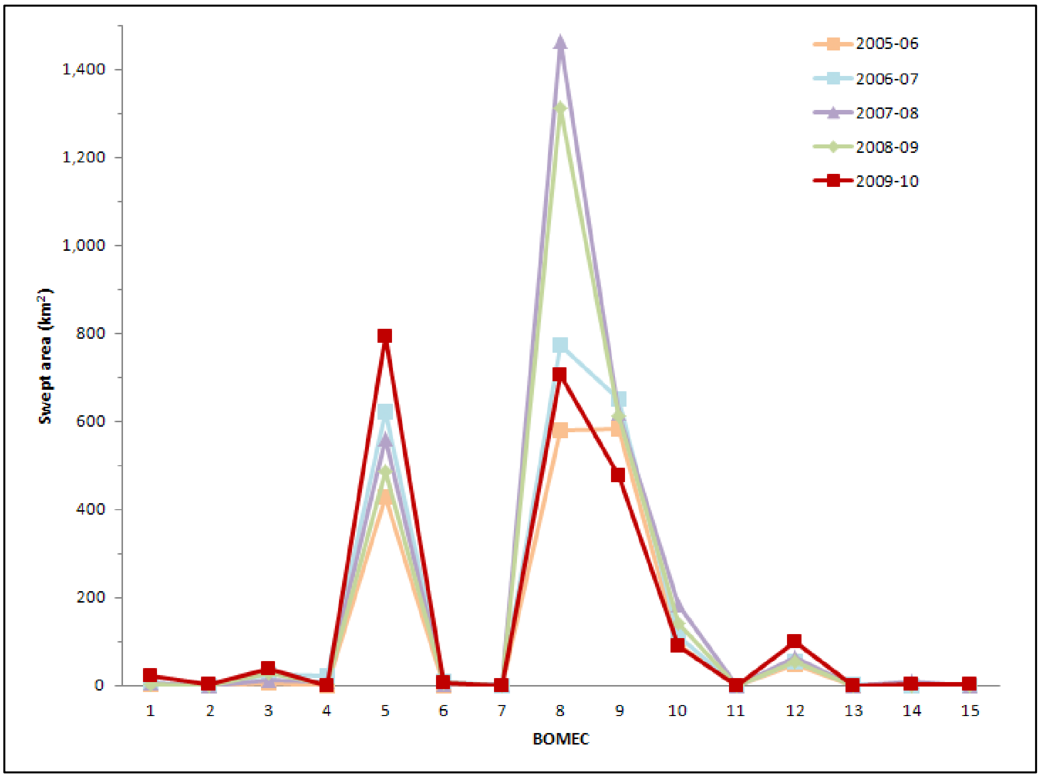


Figure 33: Swept area in the 15 BOMEC classes for silver warehou over the last five fishing years.

Trawl Footprint Analysis - Trends

The edited database can be used to estimate the area of sea floor trawled annually (Figure 34). The estimated area of sea floor trawled each year varies from about 50 000 km^2 to about 105 000 km^2, with an average of about 76 000 km^2. The area generally increased until the 2002/03 fishing year, and then declined by about 50% by 2009/10.

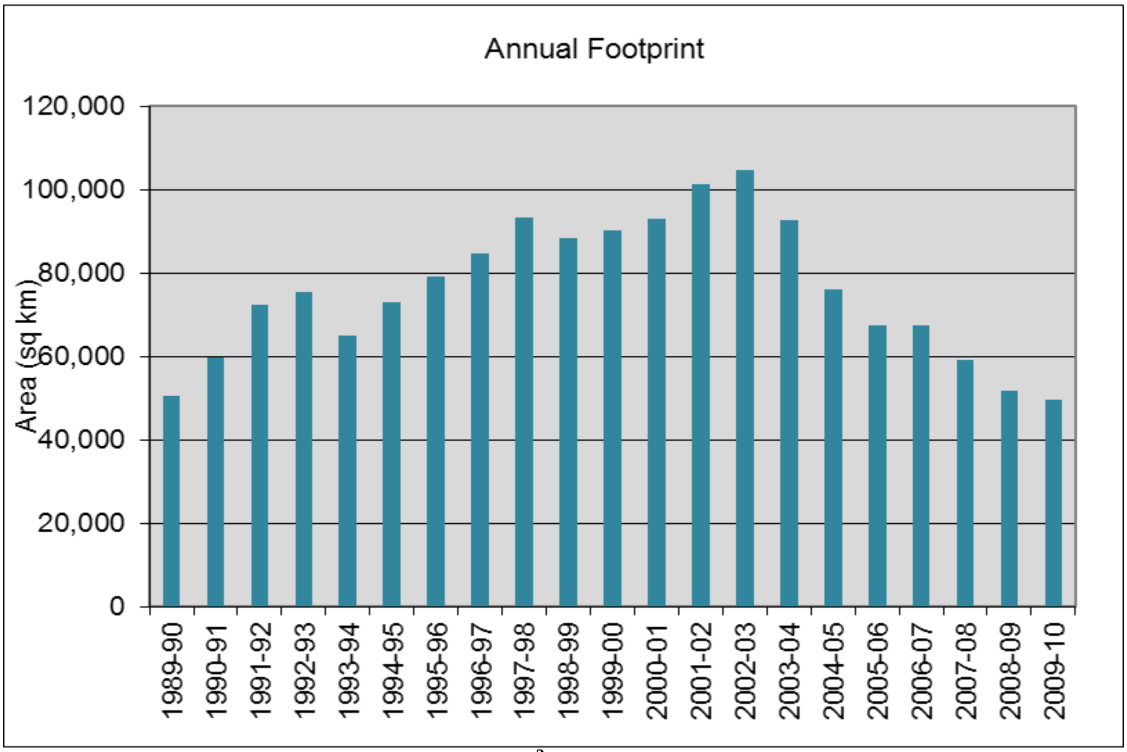


Figure 34: Estimated annual area of sea floor (km^2) contacted by trawling each year.

The database can also be used to examine what proportion of the cumulative trawl footprint had previously been trawled (Figure 35). This shows that there has been a gradual decrease in the area of seafloor trawled that had not previously been trawled. By 2009/10 only 3 208 km^2 of seafloor was trawled that had previously been untouched,

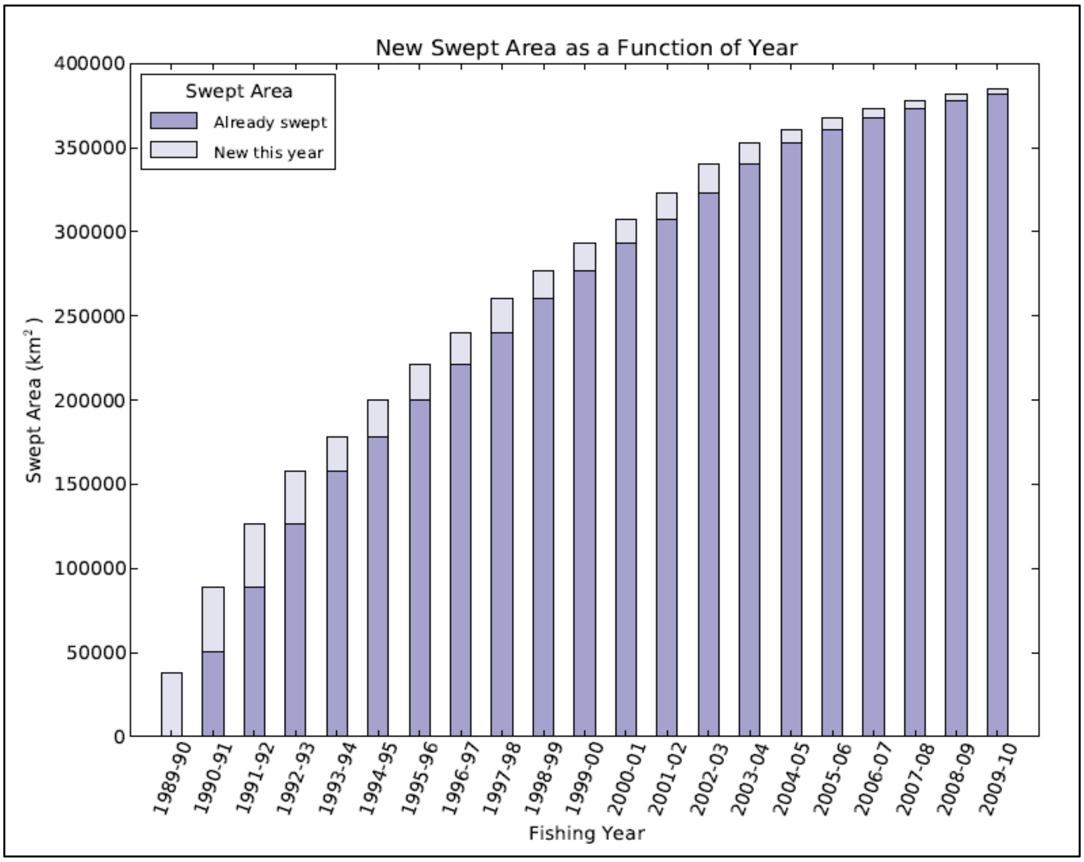


Figure 35: Cumulative trawl footprint, showing the area that had previously been trawled, and the area that had not been trawled until that year.

The results for individual fish species can be more variable. Figure 36 shows the estimated area of sea floor contacted by hoki trawling (the fishery with the most bottom-contact). Data indicates an increasing trend in annual area until the 2002/03 fishing year, followed by a decline. For 2009/10, the seafloor contacted was less than one third of that in 2002/03. Similarly for orange roughy (Figure 37), the 2009/10 footprint was approximately a third of that during the peak in 1998/99.

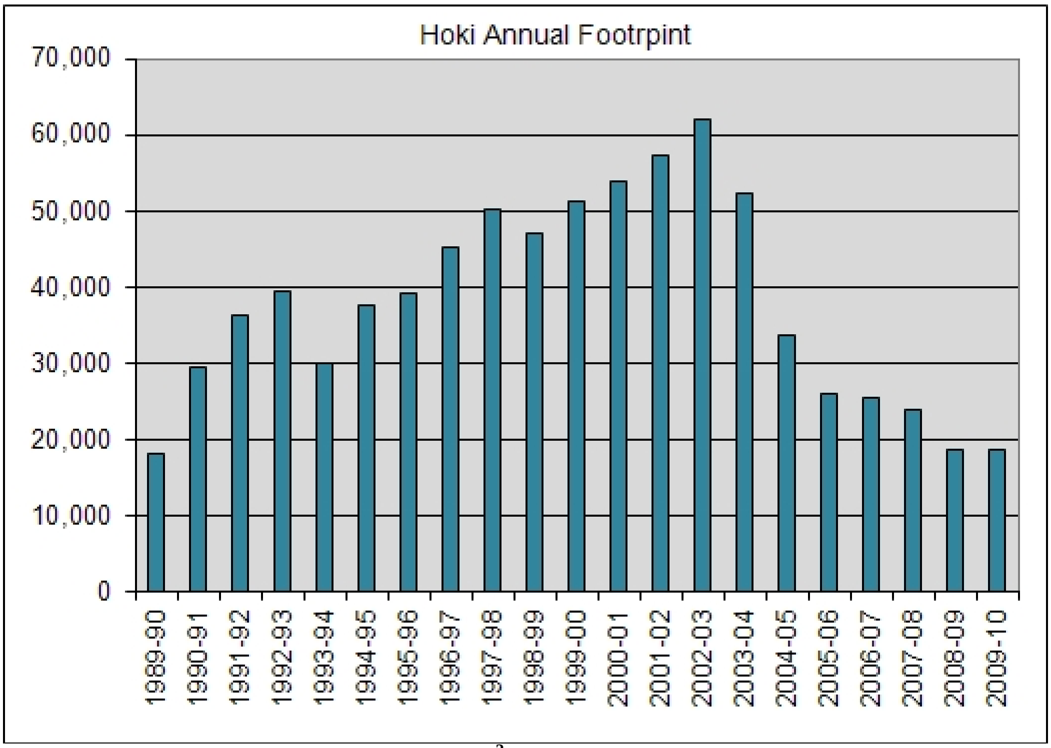


Figure 36: Estimated annual area of sea floor (km^2) contacted by trawling for hoki.

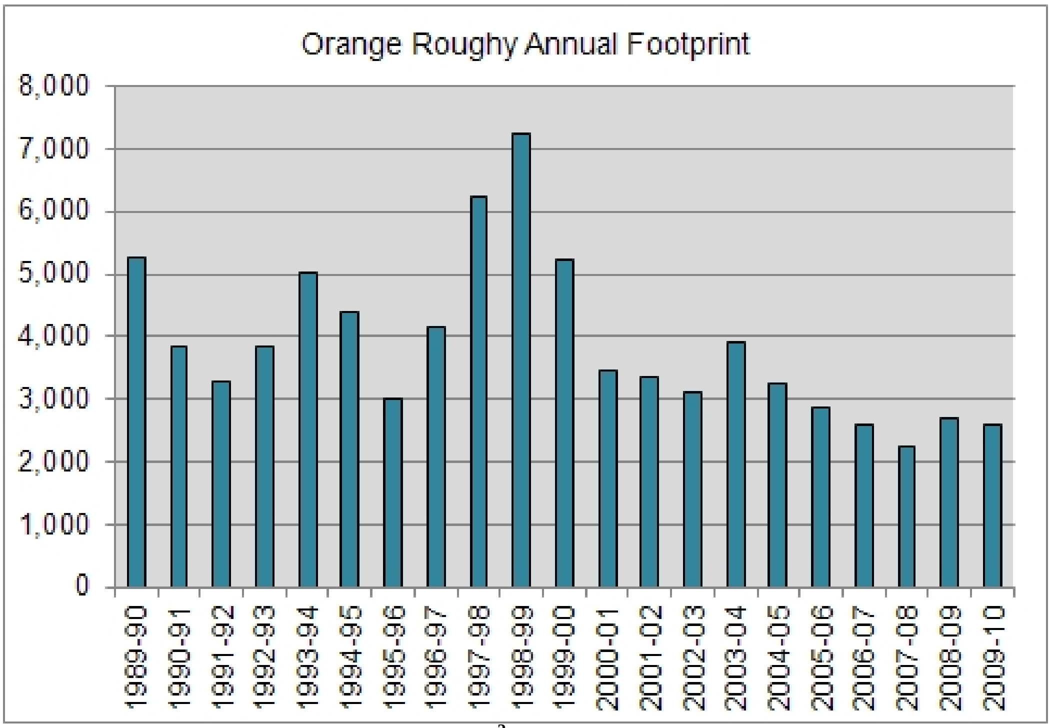


Figure 37: Estimated annual area of sea floor (km^2) contacted by trawling for orange roughy.

DISCUSSION

The aggregate swept area and extent of the trawl footprint and frequency of trawl effort by year and by depth zone, based on analysis of TCEPR data, have previously been reported by Baird et al. (2011) for the 16-year period from 1989/90 to 2004/05, as well as in relation to the BOMEC areas (Baird & Wood 2009). The Baird et al. (2011) analyses were by species group (eight groups, covering a total of 31 species) and vessel category (four size categories) and also provided descriptive effort distribution by Statistical Area for catches reported on CELRs (e.g. inshore trawl catches and scallop and oyster dredging). The present study has had a slightly different approach, with emphasis on analysing the aggregate swept area and trawl footprint for 11 key middle-depth and deepwater species/species aggregates, and for the aggregate of all other species (a total of 89 minor species), reported as target species on TCEPRs. TCEPR records for the 11 key species made up 77% of all TCEPR records in the database and were represented as follows: HOK 30%; SQU 14%; ORH 9%; SCI 8%; JMA; BAR and OEO 4%; HAK, SBW; SWA & LIN 1%.

Individual trawl footprint analyses for key inshore species would be useful as some of these are well represented in the TCEPR database, including: snapper 7% of all TCEPRs; tarakihi 4%; trevally 3%; red cod 2%; gurnard 2%; john dory and gemfish 1%.

A summary of trawl tows reported on TCEPRs, CELRs and TCERs indicates that for the 11 key species during the period between 2005/06 and 2010/11, the proportions of tows recorded on TCEPRs was: SCI and SBW 100%; HAK 99%; ORH 98%; OEO and SWA 97%; SQU 95%; HOK 93%, BAR 84%; JMA 78%; LIN 61% (Appendix 2). This high proportion of trawl tows reported using TCEPRs for these key species provides a level of comfort that the trawl footprint estimated through this study is representative of the overall trawl footprint in the EEZ, although somewhat less so in the Territorial Sea where smaller vessels have a higher incidence of reporting using CELRs and, more recently, TCERs.

Baird et al. (2011) estimated an overall trawl footprint for the 16-year period, based on 960 420 tows, to be 328 360 km^2 in a total of 36 792 fished cells. For the same time period, (i.e. 1989/90 to 2004/05), this study estimated the total trawl footprint to be slightly greater, at 360 929 km^2, based on a total of 913 883 tows (i.e. a 9% greater footprint from 5% fewer tows). These differences will have been influenced by the following:

- The current study rejected tows for which start and end co-ordinates were the same (approx. 30 000 tows), whereas Baird et al. (2011) calculated swept areas for these based on tow duration and average tow speed;
- Baird et al (2011) did not identify vessels towing twin-trawl rigs, which will have led to a slight under-estimate of the trawl footprint;
- Baird et al (2011) assigned door spread values on the basis of vessel size and target species while the current study assumes a standard door spread based on target species only, regardless of vessel size, leading to a slight over-estimate of the footprint;
- The current study includes a random offset 'jitter' of between -0.5 and +0.5 minutes to start and end co-ordinates, which effects a slight footprint increase.

The full 21-year study period, from 1989/90 to 2009/10, was based on 1 109 924 tows and provided an aggregate trawl footprint estimate of 385 032 km^2, 56 672 km^2 greater than the estimate for the 1989/90 to 2004/05 period. However, this increased swept area has not been accompanied by increases in annual trawl footprint area. In fact, the annual trawl footprint has declined by 33%, from 75 000 km^2 in 2004/05 to around 50 000 km^2 in 2009/10.

It is evident that the change in annual trawl footprint has been strongly affected by changes in the hoki TACC, as reflected by the similar trend in the total footprint for all species combined (Figure 34) and in the hoki footprint (Figure 35), both of which peaked in 2002/03 and then declined steadily through to 2008/09 before stabilising in 2009/10.

It is interesting to note that while the hoki TACC was reduced by 50 000 t (20%) from 1 October 2001, the hoki footprint continued to increase for a further two years, peaking in 2002/03. This may have been a reflection of the increased use of twin-rig trawl gear during this period when stock biomass was at an all-time low (MPI, 2012). The implication here is that swept area may be more sensitive to changes in CPUE than to changes in TACC.

Number and frequency of cells traversed:

The analysis by frequency of trawling within 5 × 5 km cells during the 21-year period 1989/90 to 2009/10 demonstrated that the total number of cells trawled was 3198 greater than for the 16-year period 1989/90 to 2004/05 (i.e. an increase from 36 792 to 39 990 cells). This indicates that new areas have continued to be explored, despite a substantial overall decline in the annual trawl footprint. Figure 38 illustrate that the extent of 'new area' subjected to trawling in each successive year has continued to decline throughout the time series and in 2009/10 amounted to 3208 km^2, which is 4% of the 2009/10 trawl footprint of 79 512 km^2 and less than 1% of the cumulative swept area for the period 1989/90 to 2009/10 of 385 032 km^2.

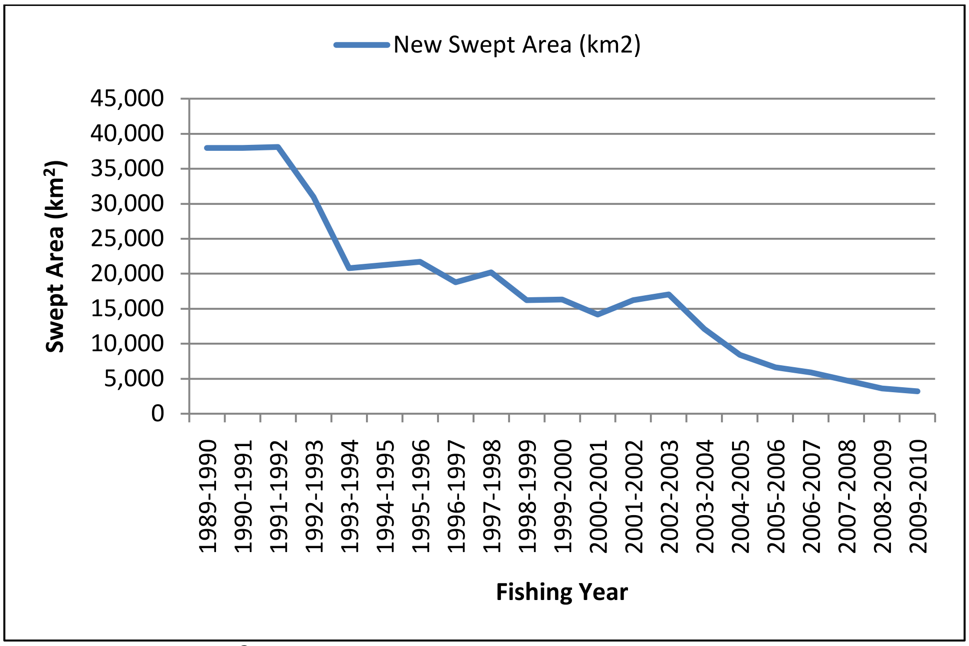


Figure 38: New swept area (km^2) in each successive year during the period 1989/90 to 2009/10.

In the most recent five-year period, the mean frequency with which 5 × 5 km fished cells have been contacted by trawling in the 0–400 m and 400–800 m depth zones has been similar and has ranged from 16 to 21 times per annum (Figure 16). The 400–800 m depth zone is heavily dominated by hoki trawling, while in the 0–400 m depth zone trawling targeted at the group of minor species dominates, followed in order by trawling for barracouta, jack mackerel, hoki and squid (Figure 22).

The most heavily fished cells in the 0–400 m depth range have been contacted between 449 and 941 times per annum during the most recent five-year period, while for the 400–800 m depth range the highest tow frequencies in cells have ranged between 302 and 564 times per annum, indicating that a small proportion of cells are fished at a much higher level than the average for all fished cells. The frequency of tows in the most heavily fished cells in the 800–1200 m and deeper than 1200 m depth zones ranged between 105–210 and 43–154 times per annum, respectively, during this period, indicative of a considerably lower rate of contact in these deeper zones (Figure 39).

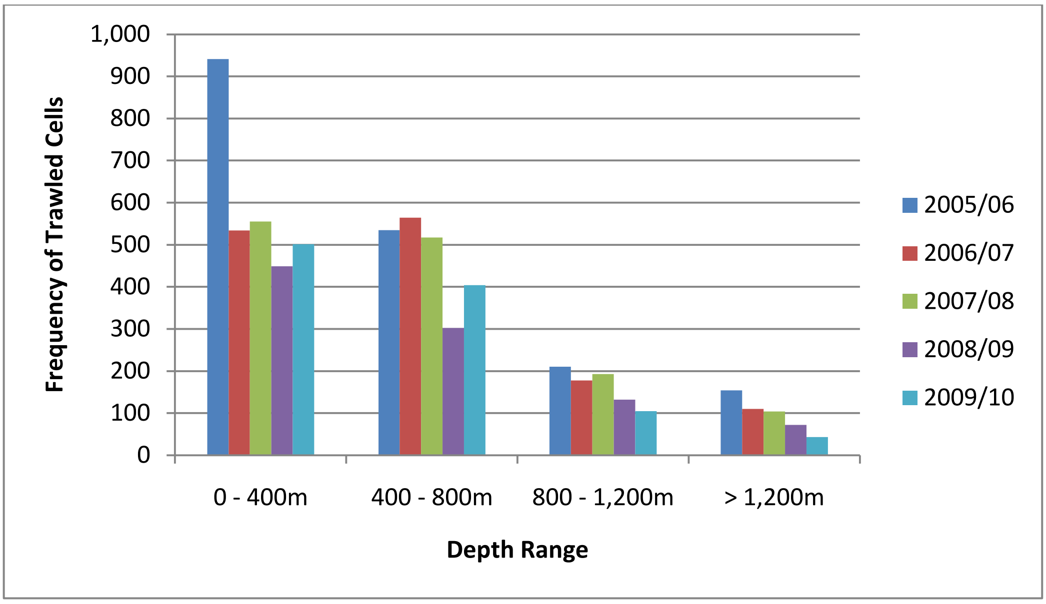


Figure 39: Maximum tow frequencies within 5 × 5 km cells by depth zone during the period 2005/06 to 2009/10.

BOMEC classes:

Class 9 has the highest proportional swept area, of 73%, for all years combined. However, from 2005/06 to 2009/10 this has been much reduced compared to previous years and has ranged between 26% and 19%. This is one of the smaller BOMEC areas, which overlaps with fishing grounds mainly on the western and southern edges of the Chatham Rise, south-east of Stewart Island along the Stewart-Snares shelf and on the Bounty Plateau. Of these three areas, the Bounty Plateau area appears least affected, while the Chatham Rise area appears to be the most affected by trawling. Further analyses could be undertaken to reveal whether the swept areas within Class 9 in recent years fall within or outside of the previous footprint.

Class 3 had the second largest proportional footprint over all years, of 64%. Over the most recent five year period it has ranged between 13% and 9%. As this class falls in water generally shallower than 250 m and includes northern areas (FMAs 1 and 9) where small vessels operate and which report using CELRs and TCERs, the footprint will be an under-estimate (Baird & Wood 2009).

The BOMEC classes with the largest swept areas are 10 and 8 (71 594 km^2 and 68 389 km^2, respectively). These are both large classes which occur in fishable depths in the productive waters of Chatham Rise and around North Island, and also off the West Coast and Challenger Plateau. By proportion, their swept areas are small, ranging between 11% and 7% for class 8 and at 3% for class 10 over the last five years.

MANAGEMENT IMPLICATIONS

The database of the trawl footprint by year, depth zone, BOMEC class and by trawl frequencies within the 5 × 5 km cell grid, provides a powerful tool for application in any future work designed to assess the scale and effects of trawling on the benthic environment. Assessment of the footprint in the shallower coastal waters is under-estimated and will not be improved unless provision is made for reporting of tow start and end co-ordinates on the reporting forms used by vessels fishing in these areas. The coastal and shelf grounds (i.e. shallower than 200 m depth) are probably the most intensely fished of all New Zealand waters and warrant greater scrutiny. This is supported by an earlier study by Leathwick et al. (2006), who demonstrated that for the period 1989/90 to 2007/08, based on TCEPR tows only, the cumulative areas trawled in Coastal and Shelf demersal fish community classes (e.g. Northern Coastal and Northern Shelf) were as high or higher than for areas typically fished by deepwater trawlers (e.g. Challenger Plateau, Campbell Plateau and Chatham Rise). Considering that the number of trawl tows reported using CELR and TCER forms (not used to estimate swept area), amounted to between 46% and 64% of the total number of tows reported, the swept area in the inshore areas, where these form types are most used, will have been under-estimated to a greater extent.

The BOMEC system was developed as a tool for use in the management of the spatial effects of fishing in the EEZ and TS (Baird & Wood 2009). However, ground-truthing the model-based BOMEC zones using direct sampling methods has indicated that they are broadly representative at spatial scales greater than about 100 km, and may therefore have application for regional-scale assessments of benthic habitat distributions, but are less representative at the smaller scales characterised by several BOMEC classes (Bowden et al. 2011).

The two BOMEC classes with historically high rates of contact by trawl gear are class 3 (64.5% swept over entire study period), (shelf zone) and class 9 (73.2% swept over entire study period), (shallow upper slope zone). For the most recent five year period between 2005/06 and 2009/10 the swept areas in class 3 and class 9 are much lower, averaging 11% and 22% respectively.

There have been no studies investigating whether current trawling frequencies, as determined for the 5 × 5 km cell grid, have had adverse effects on the structure and function of benthic communities, or on the productivity of the associated fisheries. In the orange roughy fishery on the Chatham Rise, which is prosecuted primarily in the 800–1200 m depth zone, there is evidence that fishing effort has shifted geographically over time in response to changes in catch rates on individual hills (MPI 2012). However, the extent to which this might be linked to impaired benthic ecosystem functioning has yet to be determined.

Several studies have looked at the effects of bottom trawling on soft and hard sediments in New Zealand waters (MAF 2012). While these have revealed changes in biodiversity patterns, less is known about their effects on ecological processes or on the rates of recovery following contact by trawl fishing gear (Bowden et al. 2011).

ACKNOWLEDGMENTS

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APPENDIX 1 - MINOR TARGET SPECIES INCLUDED IN THE ANALYSIS

Count	Reporting Code	Common Name	Target Tows	Percentage of Total Target Tows
1	SNA	Snapper	72 393	6.53%
2	TAR	Tarakihi	47 804	4.31%
3	TRE	Trevally	36 312	3.27%
4	RCO	Red cod	17 422	1.57%
5	GUR	Gurnard	17 416	1.57%
6	JDO	John dory	15 202	1.37%
7	SKI	Gemfish	13 120	1.18%
8	BYX	Alfonsino	12 122	1.09%
9	CDL	Black cardinal fish	10 972	0.99%
10	WAR	Blue warehou	3 512	0.32%
11	WWA	White warehou	2 796	0.25%
12	BNS	Bluenose	1 936	0.17%
13	STA	Stargazer	1 677	0.15%
14	RBY	Ruby fish	1 223	0.11%
15	SPE	Sea perch	974	0.09%
16	SPD	Spiny dogfish	909	0.08%
17	FLA	Flatfish	895	0.08%
18	FRO	Frostfish	328	0.03%
19	LEA	Leatherjacket	220	0.02%
20	ELE	Elephant fish	218	0.02%
21	SCH	School shark	194	0.02%
22	EMA	Blue mackerel	169	0.02%
23	GSH	Ghost shark, dark	143	0.01%
24	SPI	Spider crab	142	0.01%
25	MOK	Blue moki	97	0.01%
26	SSK	Smooth skate	95	0.01%
27	CAR	Carpet shark	55	<0.01%
28	BCO	Blue cod	54	<0.01%
29	RBT	Red bait	49	<0.01%
30	RSK	Rough skate	43	<0.01%
31	LDO	Lookdown dory	41	<0.01%
32	MDO	Mirror dory	39	<0.01%
33	SQX	Squid	37	<0.01%
34	PRA	Prawn	35	<0.01%
35	TRU	Trumpeter	32	<0.01%
36	SBO	Southern boarfish	31	<0.01%
37	SKA	Skate	31	<0.01%
38	PTO	Patagonian toothfish	30	<0.01%
39	SPO	Rig	22	<0.01%
40	SDO	Silver dory	20	<0.01%
41	OPE	Orange perch	19	<0.01%
42	SCO	Swollenhead conger	18	<0.01%
43	HPB	Hapuku and bass	17	<0.01%

Count	Reporting Code	Common Name	Target Tows	Percentage of Total Target Tows
44	MIX	Mixed fish	17	<0.01%
45	HOR	Horse mussel	15	<0.01%
46	RIB	Ribaldo	15	<0.01%
47	THR	Thresher shark	14	<0.01%
48	RSN	Red snapper	9	<0.01%
49	BOA	Sowfish	8	<0.01%
50	KAH	Kahawai	7	<0.01%
51	OFH	Oilfish	7	<0.01%
52	ASP	Tam 'O Shanter urchin	5	<0.01%
53	HAP	Hapuku	5	<0.01%
54	JAV	Javelin fish	5	<0.01%
55	RAT	Rattail	5	<0.01%
56	RBM	Rays bream	5	<0.01%
57	SSP	Scallop spat	5	<0.01%
58	TRA	Roughies	5	<0.01%
59	BWS	Blue shark	4	<0.01%
60	ESO	New Zealand sole	4	<0.01%
61	BAS	Bass groper	3	<0.01%
62	BAT	Large headed slickhead	3	<0.01%
63	GFL	Greenback flounder	3	<0.01%
64	LSO	Lemon sole	3	<0.01%
65	PRK	Prawn killer	3	<0.01%
66	SND	Shovelnose spiny dogfish	3	<0.01%
67	BRA	Short-tailed black ray	2	<0.01%
68	MAK	Mako shark	2	<0.01%
69	ROC	Rock cod	2	<0.01%
70	SAU	Saury	2	<0.01%
71	SKJ	Skipjack	2	<0.01%
72	SNS	Sunset	2	<0.01%
73	SSI	Silverside	2	<0.01%
74	HOL	Tubeshoulder	1	<0.01%
75	JGU	Japanese gurnard	1	<0.01%
76	MTP	Myctophum spp.	1	<0.01%
77	OSD	Smooth dog shark	1	<0.01%
78	SCA	Scallop	1	<0.01%
79	SCC	Sea cucumber	1	<0.01%
80	SCL	Scales	1	<0.01%
81	SPF	Scarlet wrasse	1	<0.01%
82	SQI	Squirrelfish	1	<0.01%
83	SWO	Swordfish	1	<0.01%
84	TRG	Triggerfish	1	<0.01%
85	YEM	Yellow-eyed mullet	1	<0.01%
		Total "minor" target trawls	259 105	23.36%
		Total all target trawls	1 109 383	100.00%

APPENDIX 2 – Catch by reporting form type as provided by Dave Foster (MPI)

PROPORTION OF ESTIMATED CATCH OF TIER 1 SPECIES (PLUS SWA AND BAR) BY RETURN TYPE

Table 1. Types of return

Return abbreviation	Description	Completed by
TCEPR	Trawl catch, effort, and processing returns	Trawlers >28m in overall length or trawlers that the chief executive has advised to complete this return
TCER	Trawl catch effort return	Trawlers 6-28m in overall length or trawlers that the chief executive has advised to complete this return
CELR	Catch, effort, and landing returns	Vessels using methods not covered by other returns
LCER	Lining catch effort return	Bottom longliners >28m in overall length or longliners that the chief executive has advised to complete this return
LTCER	Lining trip catch effort return	Bottom longliners 6-28m in overall length or longliners that the chief executive has advised to complete this return
NCER	Netting catch effort returns	Set netters >6m in overall length.

Hoki

Table 1A Estimated catch of hoki (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Others	Total
2010/11	107,443	8,351	14	14	*115,822*
2009/10	97,905	7,253	8	19	*105,185*
2008/09	81,247	6,317	16	17	*87,598*
2007/08	80,083	7,376	1	15	*87,475*
2006/07	90,452	-	7,328	10	*97,790*
2005/06	96,431	-	5,553	0	*101,984*
Total	*553,561*	*29,297*	*12,920*	*76*	*595,854*

Table 1B. Proportion of estimated catch of hoki by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Others
2010/11	93%	7%	<0.1%	<0.1%
2009/10	93%	7%	<0.1%	<0.1%
2008/09	93%	7%	<0.1%	<0.1%
2007/08	92%	8%	<0.1%	<0.1%
2006/07	92%	-	7%	<0.1%
2005/06	95%	-	5%	<0.1%

Total	*93%*	*5%*	*2%*	*<0.1%*

Hake

Table 2A. Estimated catch of hake (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	Others	Total
2010/11	4,892	46	38	*4,977*
2009/10	3,885	32	29	*3,946*
2008/09	9,134	19	21	*9,175*
2007/08	5,129	18	20	*5,166*
2006/07	9,697	-	32	*9,730*
2005/06	8,887	-	29	*8,916*
Total	*41,625*	*115*	*170*	*41,910*

Table 2B. Proportion of estimated catch of hake by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	Others
2010/11	98%	1%	1%
2009/10	98%	1%	1%
2008/09	100%	<1%	<1%
2007/08	99%	<1%	<1%
2006/07	100%	-	<1%
2005/06	100%	-	<1%
Total	*99%*	*<1%*	*<1%*

Ling

Table 3A. Estimated catch of ling (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	LCER	LTCER	CELR	TCER	NCER	Total
2010/11	6,047	1,877	2,088	75	917	82	*11,095*
2009/10	6,055	2,857	1,745	131	699	109	*11,595*
2008/09	6,728	2,593	1,462	188	563	101	*11,636*
2007/08	9,614	2,857	2,045	206	510	99	*15,331*
2006/07	10,153	2,566	-	1,818	-	133	*14,670*
2005/06	8,605	2,512	-	1,701	-	-	*12,819*
Total	*47,202*	*15,272*	*7,340*	*4,119*	*2,688*	*524*	*77,146*

Table 3B. Proportion of estimated catch of ling by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	LCER	LTCER	CELR	TCER	NCER
2010/11	55%	17%	19%	1%	8%	1%
2009/10	52%	25%	15%	1%	6%	1%
2008/09	58%	22%	13%	2%	5%	1%
2007/08	63%	19%	13%	1%	3%	1%
2006/07	69%	17%	-	12%	-	1%
2005/06	67%	20%	-	13%	-	-
Total	*61%*	*20%*	*10%*	*5%*	*3%*	*1%*

Southern blue whiting

All estimated catch information for the last six years is reported on TCEPRs.

Jack mackerel (all stocks)

Table 4A Estimated catch of jack mackerel (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	CELR	TCER	Others	Total
2010/11	29,825	8,296	159	4	*38,285*
2009/10	31,860	9,030	153	4	*41,048*
2008/09	28,921	9,781	129	6	*38,837*
2007/08	34,933	11,368	103	3	*46,407*
2006/07	32,519	5,168	-	6	*37,693*
2005/06	31,520	9,641	-	-	*41,161*
Total	*189,580*	*53,282*	*544*	*23*	*243,430*

Table 4B Proportion of estimated catch of jack mackerel by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	CELR	TCER	Others
2010/11	78%	22%	<1%	<0.1%
2009/10	78%	22%	<1%	<0.1%
2008/09	74%	25%	<1%	<0.1%
2007/08	75%	24%	<1%	<0.1%
2006/07	86%	14%	-	<0.1%
2005/06	77%	23%	-	-
Total	*78%*	*22%*	<1%	<0.1%

Orange roughy

Table 5A Estimated catch of orange roughy (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Total
2010/11	5,931	15	-	*5,946*
2009/10	8,735	66	-	*8,802*
2008/09	10,576	86	-	*10,661*
2007/08	12,077	27	-	*12,105*
2006/07	12,777	-	312	*13,089*
2005/06	14,152	-	497	*14,649*
Total	*64,249*	*195*	*808*	*65,252*

Table 5B Proportion of estimated catch of orange roughy by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR
2010/11	100%	<1%	-
2009/10	99%	1%	-
2008/09	99%	1%	-
2007/08	100%	<1%	-
2006/07	98%	-	2%
2005/06	97%	-	3%
Total	*98%*	*0*	*1%*

Oreos

Table 6A Estimated catch of oreos (all species, tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Others	Total
2010/11	13,737	2	1	<1	*13,740*
2009/10	16,418	50	<0.1	<0.1	*16,468*
2008/09	14,622	649	-	<0.1	*15,271*
2007/08	15,217	525	134	<1	*15,875*
2006/07	15,129	-	704	-	*15,833*
2005/06	15,253	-	972	<0.1	*16,225*
Total	90,376	1,225	1,810	*<1*	*93,411*

Table 6B Proportion of estimated catch of oreos (all species, tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Others
2010/11	100%	<0.1%	<0.1%	<0.1%
2009/10	100%	<0.1%	<0.1%	<0.1%
2008/09	96%	4%	-	<0.1%
2007/08	96%	3%	1%	<0.1%
2006/07	96%	-	4%	<0.1%
2005/06	94%	-	6%	<0.1%
Total	*97%*	*1%*	*2%*	<0.1%

Scampi

All estimated catch information for the last six years is reported on TCEPRs.

Squid

Table 7A Estimated catch of squid (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	SJCER[3]	TCER	CELR	Others	Total
2010/11	33,703	1,414	226	1	<0.1	*35,344*
2009/10	29,574	891	367	2	<0.1	*30,834*
2008/09	43,489	1,032	189	2	<0.1	*44,712*
2007/08	51,922	1,371	736	<1	<0.1	*54,028*
2006/07	63,261	2,278	-	1,221	-	*66,760*
2005/06	62,915	5,844	-	918	-	*69,677*
Total	284,863	12,830	1,518	*2,145*		*301,356*

Table 7B Proportion of estimated catch of squid by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	SJCER	TCER	CELR	Others
2010/11	95%	4%	1%	<0.1%	<0.1%
2009/10	96%	3%	1%	<0.1%	<0.1%
2008/09	97%	2%	<1%	<0.1%	<0.1%
2007/08	96%	3%	1%	<0.1%	<0.1%
2006/07	95%	3%	-	2%	-
2005/06	90%	8%	-	1%	-
Total	*95%*	*4%*	*1%*	*1%*	<0.1%

[3] Squid jig catch, effort return

Barracouta

Table 8A Estimated catch of barracouta (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Others	Total
2010/11	20,576	4,206	57	3	*24,841*
2009/10	22,452	3,801	100	1	*26,354*
2008/09	20,094	4,381	202	2	*24,679*
2007/08	21,512	4,234	63	6	*25,815*
2006/07	24,424	-	3,045	3	*27,472*
2005/06	21,771	-	3,998	-	*25,769*
Total	130,829	16,621	7,464	*16*	*154,929*

Table 8B Proportion of estimated catch of barracouta (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Others
2010/11	83%	17%	<1%	<0.1%
2009/10	85%	14%	<1%	<0.1%
2008/09	81%	18%	1%	<0.1%
2007/08	83%	16%	<1%	<0.1%
2006/07	89%	-	11%	-
2005/06	84%	-	16%	-
Total	*84%*	*11%*	*5%*	<0.1%

Silver warehou

Table 9A Estimated catch of silver warehou (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Others	Total
2010/11	6,828	258	1	2	*7,090*
2009/10	6,140	333	2	2	*6,478*
2008/09	7,635	303	4	2	*7,945*
2007/08	7,079	221	<1	3	*7,303*
2006/07	13,037	-	107	1	*13,144*
2005/06	9,902	-	130	-	*10,031*
Total	50,621	1,116	243	*11*	*51,991*

Table 9B Proportion of estimated catch of silver warehou (tonnes) by form type for the period 2005/06 – 2010/11

Fishing year	TCEPR	TCER	CELR	Others
2010/11	96%	4%	<0.1%	<0.1%
2009/10	95%	5%	<0.1%	<0.1%
2008/09	96%	4%	<0.1%	<0.1%
2007/08	97%	3%	<0.1%	<0.1%
2006/07	99%	-	1%	<0.1%
2005/06	99%	-	1%	-
Total	*97%*	*2%*	*<1%*	<0.1%

APPENDIX 3

COMPILATION OF SPREADSHEETS AND FIGURES –

Disk available upon request from Science Officer, Ministry for Primary Industries (Science.Officer@mpi.govt.nz).