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Monitoring New Zealand's trawl footprint for deepwater fisheries: 1989–90 to 2011–2012 and 2012–13

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This report presents the results of projects DAE 2010/04C and DAE 2010/04D, monitoring New Zealand's trawl footprint[1] over the time period 1989/90 to 2011/12 and 1989/90 to 2012/13. Trawl Catch Effort Processing Return (TCEPR) data provided by the Ministry for Primary Industries were analysed separately for bottom trawl tows targeting the nine tier 1 species (hake, hoki, jack mackerel, ling, orange roughy, oreo-dory, scampi, southern blue whiting, squid) plus two tier 2 species (barracouta and silver warehou) and all tier 1 and tier 2 species (alfonsino, barracouta, black cardinal fish, blue mackerel, deepwater crabs, frostfish, gemfish, ghost shark dark, ghost shark pale, lookdown dory, prawn killer, red bait, ribaldo, ruby fish, sea perch, silver warehou and spiny dogfish) as an aggregate (t1t2).

Statistics provided include the estimate of swept 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 Benthic-optimised Marine Environment Classification (BOMEC)) and the preferred habitat of each species (using the demersal fish layers in the Marine Environment Classification (MEC), where these exist).

Summary results are provided in this report, while the complete set of 600 spreadsheet and pdf pages are provided separately in 207 documents, on a DVD (Appendix 2). For the eleven key target species, analyses are provided for the 2011/12 and 2012/13 fishing years as well as the 1989/90 to 2011/12 and 1989/90 to 2012/13 periods. The statistics for previous years are provided in Black et al. (2013) and Black & Tilney (2015). Analyses for the t1t2 aggregate are provided for each year between 1989/90 and 2012/13 inclusive, and for the entire 1989/90 – 2012/13 period.

The swept area for trawls targeting tier 1 and tier 2 species between 1989/90 and 2012/13 is estimated to be 347 290 km^2 (about 8% of the EEZ and TS), an increase of 1720 km^2 on 1989/90 to 2011/12, which in turn was an increase of 2169 km^2 on 1989/90 to 2010/11. This area is estimated to be 24% 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 Closures and Marine Reserve areas.

The 15 BOMEC zones cover areas shallower than 3000 m (2 627 073 km^2), approximately 63% of the EEZ and TS. The swept area from 1989/90 to 2012/13 for the t1t2 species aggregate is estimated to comprise about 13% of the BOMEC zones, but ranges from 0.3% to 73% for individual BOMEC zones.

[1] 'Trawl footprint' is a generic term used to reflect the area of seabed contacted by trawl nets. In this study two terms are used. The first, 'swept area', is the area of seabed contacted one or more times by a trawl net. The second, 'cumulative swept area', is used as an indicator of trawl fishing effort, and is the additive area of all trawls regardless of overlap.

Almost 83% of the swept area in this period was in the depth ranges 0–400 m and 400–800 m. This comprised 138 574 km^2 in the 0–400 m depth range (34% of the area in the depth band) and 148 429 km^2 in the 400–800 m depth range (31% of the area in the depth band), note, these numbers are for the entire depth band, including areas that are currently closed to trawl fishing.

Analysis included assessment of trawling effort per unit area in which the EEZ and TS was divided into 5 km by 5 km cells and the number of tows and cumulative area of sea floor contacted by bottom fishing were estimated for each cell. Approximately 23% of the cells in the EEZ and TS were contacted by trawls at least once between 1989/90 and 2012/13. Fewer than 6% of the cells in the EEZ and TS were contacted in each of the 2011/12 and 2012/13 fishing years. The cumulative swept area in 2011/12 was 82 871 km^2, 2993 km^2 less than in 2010/11. There was a further decrease of 4941 km^2 in 2012/13 (which saw a cumulative swept area of 77 930km^2, the lowest recorded since 2009/10).

1. INTRODUCTION

1.1 Overview

The New Zealand Ministry for Primary Industries' (MPI) Trawl Catch Effort and Processing Return (TCEPR) database contains information about trawls 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 (see the Methods section for more details). This report describes how these data were used to estimate the location and frequency 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, potentially as a guide for managing the effects of fishing on the benthic 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.

This work updates the deepwater trawl footprint analyses reported by Black et al. (2013) and Black & Tilney (2015), which were based on TCEPR data from 1989/90 to 2009/10 and 1989/90 to 2010/11 respectively. This report is a continuation of that work, using similar methodology, and including data from the 2011/12 and 2012/13 fishing years. The main difference in this report lies in the analysis of a new species aggregate, containing all tier 1 and tier 2 species "t1t2 species", to replace the previously used "all species" aggregate. The previously used "all species" aggregate included a number of inshore and non deepwater tier 1 and 2 target species (see Appendix 1 for a list), previously described as "minor species", due to the exclusion of these species from this analysis the "minor species" aggregate is no longer reported on. An earlier study to Black et al. (2013) and Black & Tilney (2015) was conducted by Baird et al. (2011) in which trawl effort from TCEPRs from 1989/90 to 2004/05 was used to map the temporal and spatial extent of seafloor contact.

Trawl swept area estimates and trawl frequency are provided for a range of parameters including: depth zones, fishable area, habitat class and preferred habitat area. Habitat class analysis uses the Benthic-Optimised Marine Environment Classification (BOMEC) which was developed to classify benthic habitat groups on broad scales within the EEZ (Leathwick et al. 2012). The BOMEC zones are based on analyses of distributional data from eight taxonomic groups

(including 38 benthic fish species from research trawls) and eleven environmental variables characterising the sea floor morphology and oceanographic conditions. The demersal fish probability of capture layers from the Marine Environment Classification (MEC), (Leathwick et al. 2006) are used as indicators of preferred habitat for the key species/species groups. Where these do not exist (i.e. for squid or scampi) the National Aquatic Biodiversity Information System (NABIS[2]) normal and full distribution ranges[3] are used (Francis et al. 2003).

1.2 Objectives

This report presents the results of the third and fourth years of DAE2010/04, *to monitor the "footprint" of bottom contacting trawl fishing for deepwater and middle-depth species*, and addresses the following objectives:

1. To estimate the 2011/12 and 2012/13 trawl footprints and map the spatial and temporal distribution of bottom contact trawling throughout the EEZ between 1989/90 and 2012/13.
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.

2. METHODS

This study analyses data from the TS and EEZ, including two enclaves of international waters on the Chatham Rise and Campbell Plateau (Figure 1).

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

[3] The full range contains all known records of that species and the normal range the area in which 90% of the population is estimated to occur

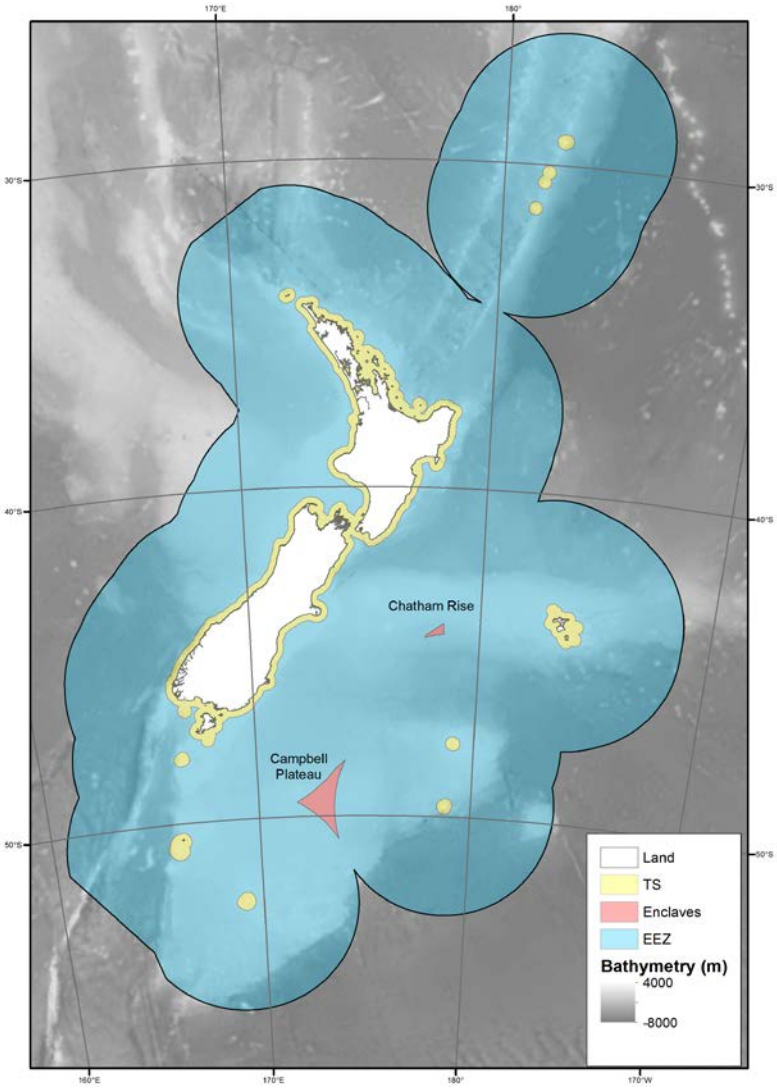

Figure 1: Map of New Zealand. The regions for which data is analysed in this report are coloured: TS (yellow), enclaves of international waters (pink) and the EEZ (blue), the land area is white and the offshore area beyond the scope of this report in shades of grey.

The methodology is similar to that described in Black et al. (2013) and Black & Tilney (2015). This report extends the data set to include the 2011/12 and 2012/13 fishing years.

Swept areas are determined separately for 11 key target species (i.e. the nine deepwater Fisheries Plan[4] tier 1 species plus silver warehou and barracouta), Table 1. The above analyses were undertaken for the 2011/12 and 2012/13 fishing years, for all years in the period 1989/90 to 2011/12 combined, and for all years in the period 1989/90 to 2012/13 combined.

[4] 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

Table 1: Key target species, reporting codes and number of analysed tows (1989/90 to 2012/13).

Common name	Reporting code	Tier	Number o
Hoki	HOK	1	351 849
Squid	SQU	1	159 802
Orange roughy	ORH	1	105 465
Scampi	SCI	1	103 044
Oreo	OEO, SSO, BOE	1	48 798
Jack mackerel	JMA	1	46 722
Barracouta	BAR	2	43 638
Hake	HAK	1	14 943
Southern blue whiting	SBW	1	14 714
Silver warehou	SWA	2	14 168
Ling	LIN	1	13 940

This analysis was repeated for the aggregate of the tier 1 and tier 2 target species ("t1t2 species"), (Table 1 and Table 2). Target species other than tier 1 and tier 2 species that were reported on TCEPRs but not used in this analysis are listed in Appendix 1. Analyses of the t1t2 species were undertaken for each of the fishing years between 1989/90 and 2012/13 years (inclusive) and for the periods 1989/90 to 2010/11, 1989/90 to 2011/12 and 1989/90 to 2012/13.

Table 2: Tier 2 species reporting codes and number of analysed tows (1989/90 to 2012/13). Note that BAR and SWA are both key target species and tier 2 species, and so are also listed in Table 1.

Common name	Reporting code	Number o
Barracouta	BAR	43 638
Silver warehou	SWA	14 168
Alfonsino	BYX	13 798
Gemfish	SKI	13 379
Black cardinal fish	CDL	11 566
Ruby fish	RBY	1 385
Sea perch	SPE	1 057
Spiny dogfish	SPD	911
Frostfish	FRO	329
Blue mackerel	EMA	204
Ghost shark, dark	GSH	167
Red bait	RBT	110
Lookdown dory	LDO	42
Ribaldo	RIB	15
Prawn killer	PRK	3
Pale ghost shark	GSP	0
Deepwater crabs	CHC, GSC, KIC	0

2.1 Trawl Data

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 (MPI) 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.

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. TCERs only record tow start positions and CELRs only provide the statistical reporting area (general area) of tows, not their start and end locations.

For the fishing year 2011/12, the TCEPR database contains 33 650 records of bottom tows and of mid-water tows for which the ground rope depth is equal to the water depth. The same database contains 30 584 records from the 2012/13 fishing year. These two new databases are added to the existing data from 1989/90 to 2010/11. The entire data base from 1989/90 to 2012/13 contains 1 334 795 records. 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 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.

It should be noted that the original (1989/90 to 2010/11) database was not re-requested from MPI. On occasion the TCEPR database is amended by MPI staff to correct errors. These corrections will not be present in the datasets analysed here. It is likely that this error is negligible in the scale of the analysis.

The proportion of catch reported using TCEPR, as opposed to other forms, varies by species. Black & Tilney (2015), using data from MPI (Dave Foster, pers. comm. 7 March 2012) showed that for the 11 key target species between 2005/06 and 2010/11 the majority of catch is recorded on TCEPR and that it is lowest for ling (61%), jack mackerel (78%) and barracouta (84%).

Data reported 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, net wingspread, and target species. The start and end positions are reported to a precision of one minute (i.e. 1 M).

The data are projected into an equal-area projection to allow accurate computation of areas throughout the region of interest (Black et al. 2013). All maps and charts in this report are plotted using this projection.

2.2 Trawl Data correction and editing

Some errors in data entry are expected with the large number of records analysed. The data correction here focuses on the main sources of error that can be corrected without intensive, time consuming effort, and without potentially creating further errors. Where it is not possible to correct the error, the trawl is flagged and not used.

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. 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.

We apply the same edit criteria as described in Black et al. (2013) to the 2011/12 and 2012/13 data, and combine this with the 1989/90 to 2010/11 data (Table 3).

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	Percentage of Analysed Footprint Records	Number of Records Frequency analysis	Percentage of Analysed Frequency Records
NULL start/end coordinates	352	0.03%	352	0.03%
Identical start/end coordinates	49 159	4.10%	N/A	N/A
Tows outside EEZ	40 217	3.35%	50 053	4.04%
Long tows	41 739	3.48%	41 739	3.37%
Tows that cross coastline	8 996	0.75%	9 066	0.73%
No or invalid species	1 958	0.16%	1 958	0.16%
TOTAL flagged	134 620*	11.22%	95 376*	7.70%
TOTAL all species	1 200 175		1 239 386	
TOTAL t1t2 species	**960 291**	**80.01%**	**993 358**	**80.15%**

*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".

Over the last 10 fishing years, the number of records flagged and edited out has progressively decreased. Only "cross coast tows" and "outside EEZ tows" have more flagged records in 2011/12 than in 2010/11, an increase of only five tows (Figure 2). There were no increases in any category between the 2011/12 and 2012/13 fishing years. The number of "long tows" has remained stable (showing a small decrease). This suggests that our edit criteria are still suitable. If fishing practice was changing such that tows were increasing in length, we would expect to observe a progressively increasing number of tows flagged as "long tows".

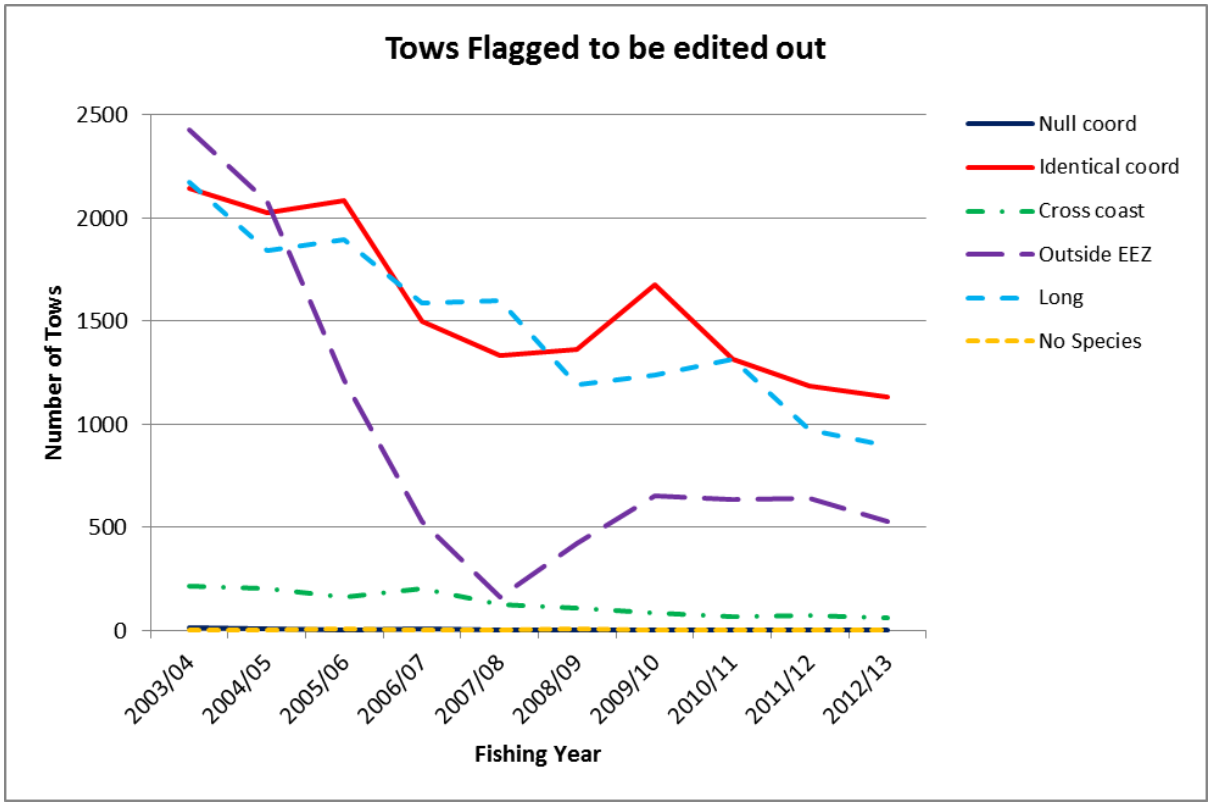

Figure 2: Number of tows flagged to be edited out under each criteria in each of the last ten fishing years (2003/4 to 2012/13) in the EEZ and TS.

When the tows flagged to be edited out are plotted as a percentage of annual effort (Figure 3) slightly different trends are observed. Recent years show fairly flat trends for most edit criteria, suggesting that the situation remains constant. This provides further reassurance that the cut off for tows flagged as "long tows" (greater than 37.8 M (70 km) for squid and scampi and 30 M (55.56 km) for all other species) is still valid.

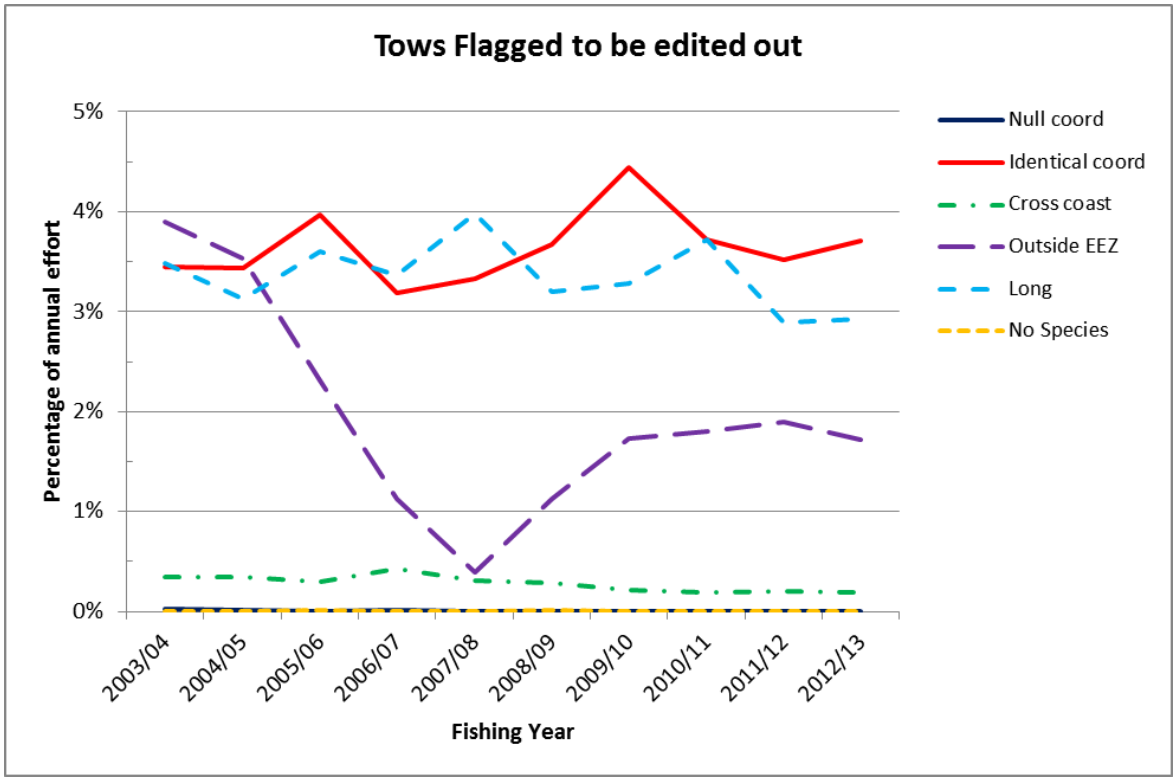

Figure 3: Tows flagged to be edited out for each of the criteria in each of the last ten fishing years (2003/4 to 2012/13) in the EEZ and TS, as a percentage of total effort in that year.

2.2.1 Zero Length trawls

Trawls with identical start and end positions are only included in the frequency based analysis. It is not possible to include them in the footprint based analysis as they have no length, and therefore no area to contribute to the footprint. The omission of these trawls will lead to a potential underestimation of the footprint, in particular for species with a proportionally high number of such trawls. Approximately 3% of trawls targeting the t1t2 species between 1989/90 and 2012/13 have zero length, and therefore do not contribute to the footprint analysis (Table 4). The effect on the size of the footprint will be considerably less than 3%, as the majority of these trawls (88%) lie inside the trawl footprint.

Table 4: Number of zero length trawls targeting the key target species and all tier 1 and 2 species between 1989/90 and 2012/13. The total number of trawls (including zero length trawls), and the percentage of zero length trawls are given.

Species	Zero length	All trawls (inc zero length)	
	No.	No.	%
BAR	378	43 638	1%
HAK	212	14 943	1%
HOK	3 525	351 849	1%
JMA	170	46 722	0%
LIN	235	13 940	2%
OEO	6 706	48 798	12%
ORH	15 132	105 465	13%
SBW	88	14 714	1%
SCI	1 118	103 044	1%
SQU	1 174	159 802	1%
SWA	80	14 168	1%
t1t2	**33 076**	**960 291**	**3%**

For certain target species there are, proportionately, more zero length trawls than others. Approximately 13% of trawls targeting orange roughy and 12% of those targeting oreo are not included in the footprint analysis. For orange roughy 87% of these trawls lie inside the footprint for that species, and for oreo 71%.

If the most recent two fishing years are considered in isolation, similar percentages are seen (Table 5). Approximately 4% of trawls targeting the tier 1 and 2 species in each of 2011/12 and 2012/13 were of zero length and therefore not included in the footprint analysis. Orange roughy target tows show the largest percentage of zero length tows per species at 16% in 2011/12 and 28% in 2012/13. Oreo target tows are the second highest at 12% in 2011/12 and 13% in 2012/13.

Table 5: Number of zero length trawls targeting the key target species and all tier 1 and 2 species in 2011/12 and in 2012/13. The total number of trawls (including zero length trawls), and the percentage of zero length trawls are given.

	Zero length trawls		All trawls (including zero length trawls)			
Species	No. 2011/12	No. 2012/13	No. 2011/12	No. 2012/13	% 2011/12	% 2012/13
BAR	25	11	957	823	3%	1%
HAK	2	7	310	382	1%	2%
HOK	48	72	8 161	8 421	1%	1%
JMA	11	4	1 400	1 264	1%	0%
LIN	11	28	420	694	3%	4%
OEO	182	148	1 470	1 120	12%	13%
ORH	217	335	1 318	1 205	16%	28%
SBW	4	2	491	385	1%	1%
SCI	46	38	4 307	4 070	1%	1%
SQU	29	38	3 171	2 479	1%	2%
SWA	2	4	416	417	0%	1%
t1t2	862	844	23 487	21 762	4%	4%

2.2.2 Species Correction

There are thought to be several errors in the recording of the target species on the TCEPR. Where possible these have been corrected, following the advice of MPI and summarised in Table 6. There may be further errors still present, but it is likely that these represent a negligible proportion of the total tows. Tows that were not recorded as targeting the tier 1 or tier 2 species, but that met the other criteria described above are listed in Appendix 1.

Table 6: Corrections made to species codes.

Reported species	Corrected to	Number of tows	Fishing year (s)
SPI	SCI	142	1989/90, 1990/91
CAR	CDL	56	1990/1991, 1993/94, 2004/05, 2008/09, 2009/10, 2010/11
SQX	SQU	37	1996/97, 2005/06
OFH	ORH	7	2001/02, 2003/04

2.2.3 East-West error correction

Records were corrected for obvious east-west longitude transpositions as described in Black et al. (2013). In the 2011/12 and 2012/13 datasets only five and three tows respectively were identified for possible east-west longitude corrections. A decision about which end of the tow to move was based on the assumption that these tows conformed to the fishing practice in the area and so the longitude value of the position outside the total trawl footprint, or beyond the area of fishable depths (Section 2.5), was changed. For six of the tows identified it was impossible to decide which end was in need of correction as either both or neither of the ends

fitted with recorded fishing practice. For the tows where neither end conformed to current fishing practice, it is likely that the error was not an East-West error, but a different kind of transcription error. For the tow where correcting either end would fit with current fishing practice, there is insufficient information to make a correction. In total, only two of these long trawls were corrected.

2.2.4 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. To counter this 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, as described in Black et al (2013). 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. Trawling in the orange roughy and oreo fisheries is particularly concentrated on features; therefore the impact of applying tow position offsets will be greatest here. Trawls targeting oreo and orange roughy occur particularly in the 800–1200 m depth band. This depth band has few tows for other target species, so there is likely to be a small over estimation of the trawl footprint in this depth band.

The fishing effort per unit area calculations assume that tows with the same start and end positions are 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.

2.3 Calculation of 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 7). These widths were chosen after industry consultation for Black & Wood (2011) 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. Baird et al (2011) also assign widths of between 70 m and 200 m to trawls, though slightly different species categories are used.

Table 7: Door-to-door trawl gear widths used to estimate the area of sea floor contacted by individual tows targeting tier 1 and tier 2 species. The mean wingspread in the 1989/90 to 2012/13 TCEPR database for these species is included for comparison. Refer to Table 1 and Table 2 for species abbreviations.

Species	Door-to-door width (m)	Mean wingspread in TCEPR database (m)
EMA, FRO, GSH, LDO, LIN, PKR, RBT, RBY, SCI, SKI, SPD	70	49
BYX, RIB	100	30
BAR, BOE, CDL, JMA, OEO, ORH, SBW, SQU, SSO, SWA, SPE	150	49
HAK, HOK	200	47
Trawl gear type DOUBLE	2 × door-to-door width	-

For the 2011/12 and 2012/13 tows, twin-rig information is taken from MPI's data on the number of nets used for each tow. This information is based on whether a vessel is known to have twin-rig capability rather than whether it was used on that particular tow, which 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 7, based on the target species and on the tow type in the input record. Valid tows that crossed the EEZ boundary were buffered and then clipped to the EEZ.

We have previously created databases containing the trawl data for the period 1989/90 to 2010/11 for all target species recorded on TCEPR. From this a new database has been extracted for the t1t2 species aggregate. There were no tows reported between 1989/90 and 2012/13 on TCEPR targeting deepwater crabs (CHC, GSC, or KIC) or pale ghost shark (GSP). There are also separate databases for each of the 11 key species. The tows for 2011/12 and 2012/13 were extracted and placed into new files in the relevant databases. Finally, the individual tows for each database were merged (Figure 4) to derive an estimate of the area of seafloor contacted by bottom trawling, i.e. the swept area. The t1t2 species aggregate has been created for each year between 1989/90 onwards, to replace the previous "all species" aggregate.

Each file for 2011/12 and 2012/13 is combined with the appropriate file in the 1989/90 to 2009/10 database (Black et al. 2013) so that the database used in these analyses covers the full time period (i.e. 1989/90 to 2012/13).

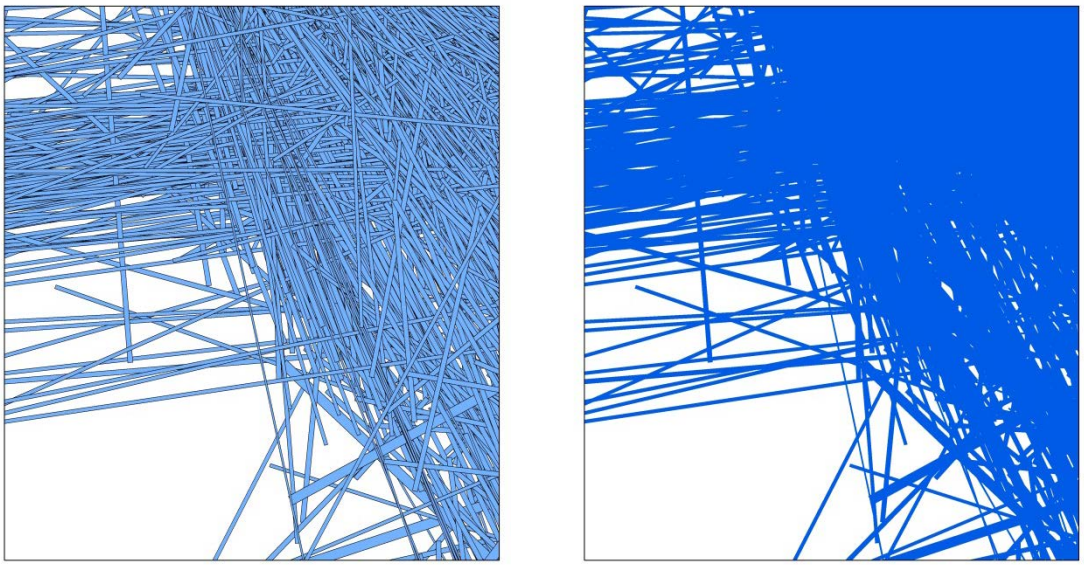

Figure 4: An example of individual tow paths (left), merged for species or species aggregate (right). The merged tow paths constrain the area of seafloor contacted by bottom trawling, i.e. the swept area.

The GIS used the swept area for each species to estimate the area and percentage of the EEZ and TS that has been swept by bottom trawling targeting that species. The swept area is then compared with a series of other parameters 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, 2014). We conclude that the uncertainty arising from the combination of over- and under-estimates is likely to be small, of the order of a few percent of the total footprint area.

2.4 Effort per unit area analysis

The EEZ was divided into a grid of 164 823 cells, 5 km × 5 km in dimension. To calculate the effort per unit area the trawl polygons described above were used along with the trawls of zero length, which were added as points. The number of trawls to intersect each cell was calculated and added as an attribute. The cumulative swept area of trawls in each cell was also calculated and added as another attribute (Figure 5). Each trawl contributes to the total area value regardless of overlap with other trawls, thus the cumulative swept area in each cell will always be equal to or greater than the swept area. A file is made for each target species and for the t1t2 species aggregate for the 2011/12 and 2012/13 fishing years and added to our database. A second set of files is made combining this data with the 1989/90 to 2010/11 data to provide information on the entire time period (i.e. 1989/90 to 2012/13).

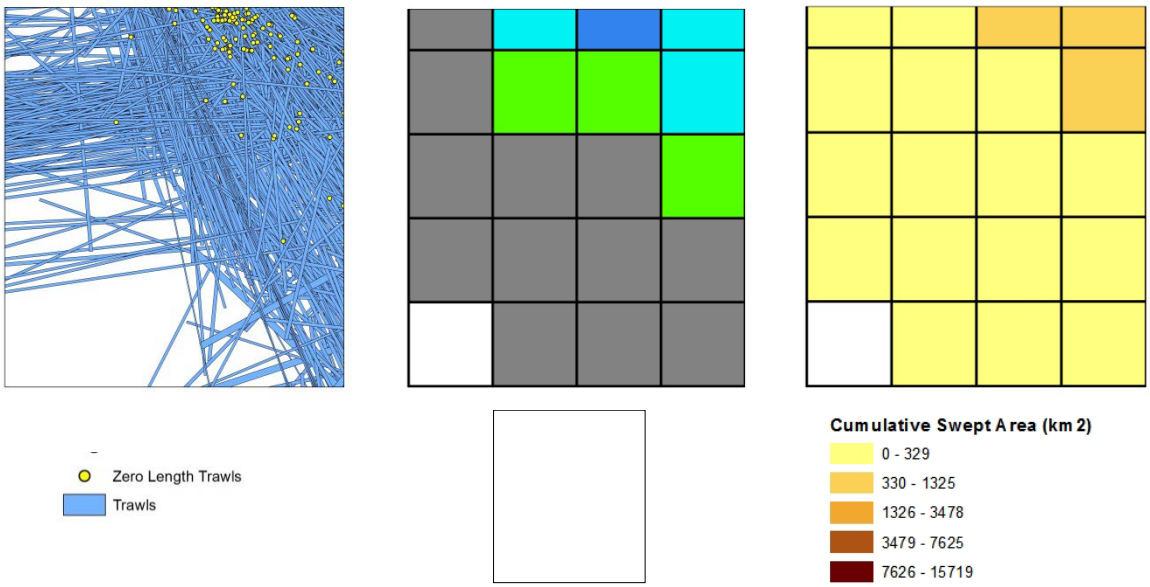

Figure 5: An example of individual tows used for the frequency based analysis (left), number of tows per cell (centre) and cumulative swept area per cell (right). For the frequency based analysis zero length trawls (as points) are used as well as the same tow paths used for the swept area analysis.

Using the two attributes (number of trawls, and cumulative swept area of trawls) recorded for each cell, a series of statistics are calculated for the file. These include: number of cells contacted by trawls (Cells Contacted), largest number of trawls in a cell (Highest Trawl Frequency), mean number of trawls across cells that contain trawls (Mean Frequency of Trawled Cells), mean number of trawls across all cells (Mean Frequency of All Cells) and total area of all trawls (Cumulative Swept Area of Trawls).

The results can be directly compared not only with Black & Tilney (2015) and Black et al. (2013) but also with the analyses of Baird & Wood (2009) and Baird et al. (2011).
For the effort per unit area calculations, the analysis is based on the parameter at the centre of the cell (Figure 6).

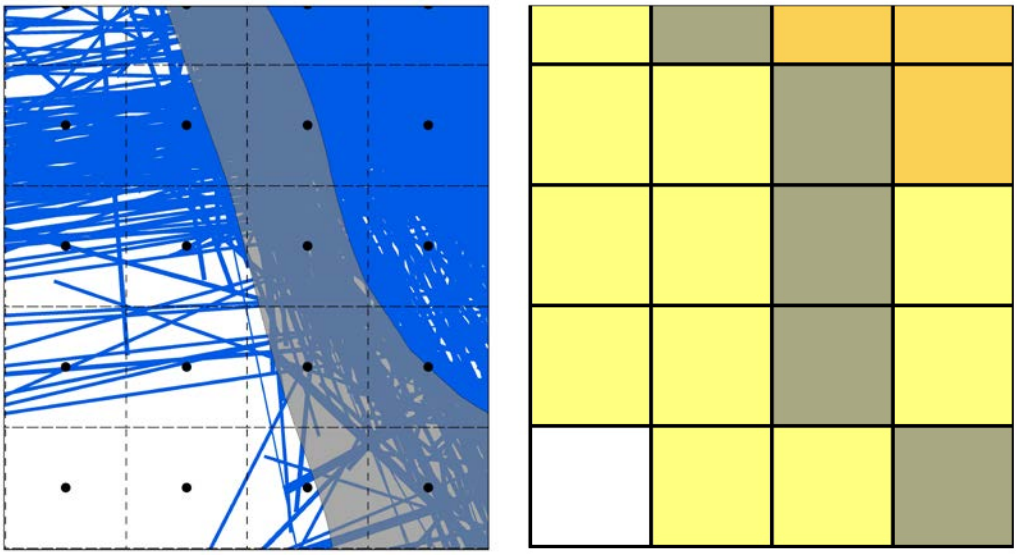

Figure 6: Swept area in blue overlain by the exact boundary of the 400–800 m depth band in grey (left). Cell boundaries are marked by dashed lines and cell centres by black dots.
Cumulative swept area, with cells in the 400–800 m depth band shaded grey (as allocated by the location of the cell centre) (right), for remaining key see Figure 5 (right).

2.5 Parameters

In this report, the trawl footprint and the fishing effort per unit area are each compared against a series of parameters. These are:

- **Depth zones**: 0 to 400 m, 400 to 800 m, 800 to 1200 m, and deeper than 1200 m (GEBCO 2010)
- **Fishable area**: the region shallower than 1600 m that is not closed to bottom trawling
- **Habitat class**: Benthic-Optimised Marine Environment Classification (BOMEC) (Leathwick et al. 2012)
- **Species specific preferred habitat**: Where possible the probability of capture layers for fish distribution from the demersal fish based Marine Environment Classification (MEC) were used as a proxy for preferred habitat (Leathwick et al. 2006). A series of polygons was created 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%. 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 analysis of swept area for the aggregation of all tier 1 and 2 species was not undertaken against any proxy for preferred habitat.

For more information regarding these parameters, see Black et al. (2013).

2.5.1 Fishable area

The maximum cut off for the "fishable area" has been set at 1600 m, following the advice of MPI (Black et al., 2013). It is possible that fishing practice changes over time, and the region that is considered fishable may extend. In order to asses this, the recorded water depth of trawls has been analysed (Figure 7). This shows that in each of the recent fishing years only a handful of trawls have recorded a water depth of more than 1600 m. This provides confidence that 1600 m water depth is still a conservative outer boundary for the fishable area.

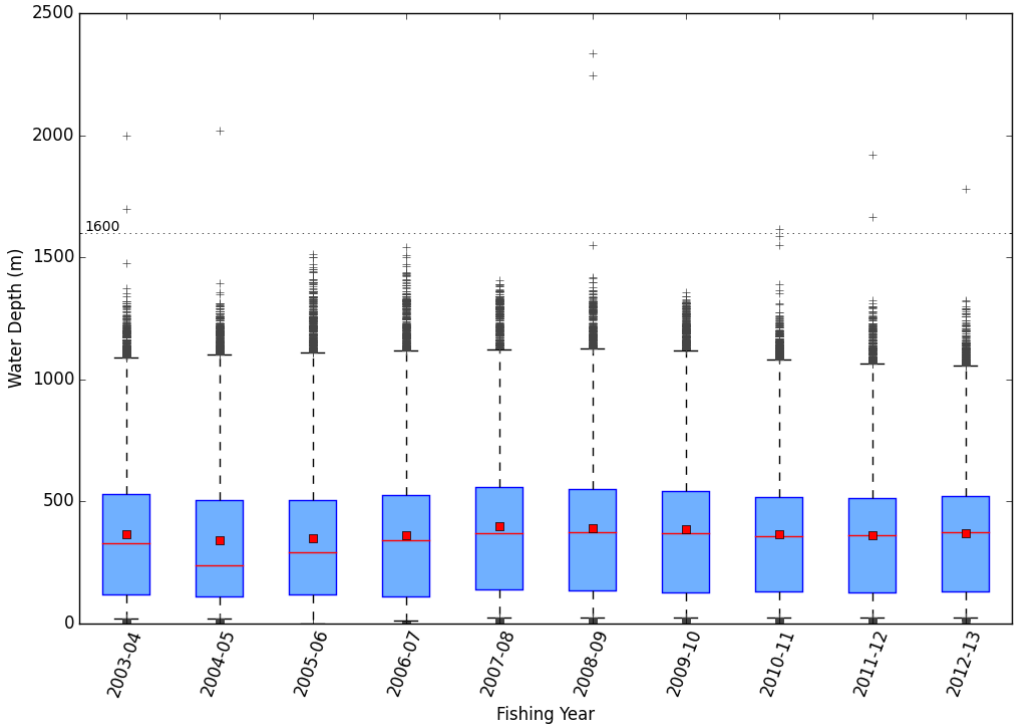

Figure 7: Box and whisker plot for the most recent ten fishing years (2003/04 to 2012/13) showing the distribution of recorded water depth. The blue box extends from the lower to upper quartiles; the red line shows the median value and the red square the mean. The whiskers extend to include 24% of data points to either side, outliers with a water depth of less than 4000m are plotted (black pluses).

3. RESULTS

The results of two types of analysis that were conducted for eleven target species, and for the aggregates of all tier 1 and tier 2 species are presented here.

A total of 960 291 TCEPR records for tows targeting tier 1 and tier 2 species were used to estimate the swept area (footprint area contacted by bottom trawling) in New Zealand's TS and

EEZ for the fishing years 1989/90 to 2012/13. A total of 993 367 tows were used to analyse the effort per unit area (i.e. 5 × 5 km cells).

For both analyses, statistics are provided for the 2011/12 and 2012/13 fishing years and for the entire periods 1989/90 to 2011/12, and 1989/90 to 2012/13 for each of the key target species. In the case of the t1t2 species aggregate, which is reported on for the first time in this report, statistics are provided for the 1989/90 to 2012/13 fishing years inclusive and for the entire periods 1989/90 to 2009/10, 1989/90 to 2010/11, 1989/90 to 2011/12 and 1989/90 to 2012/13. Summary statistics were calculated regarding spatial extent and frequency of bottom-contact fishing by year, depth zone, fishable area, preferred habitat and habitat class. A representative range of bottom trawl effort analysis results are presented in this section and the complete set of 600 pages of statistics and maps are separately provided on DVD for all species and species aggregates (Appendix 2). All maps in Appendix 2 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.

3.1 TCEPR Swept Area

The area within New Zealand's EEZ and TS contacted by bottom trawling for trawls targeting tier 1 and tier 2 species between 1989/90 and 2011/12 is estimated to be 345 570 km^2. In the period 1989/90 to 2012/13 the area is estimated at 347 290 km^2 (Figure 8). These areas are each about 8.4% of the area inside the 200 M line. The increase in swept area (i.e. the approximate area of seafloor that was trawled for the first time) is 2169 km^2 in 2011/12 (Figure 9), and is 1720 km^2 in 2012/13. The swept area has increased in size each year since 1989/90, but the increase has been getting steadily smaller since 2002/03 (Figure 9).

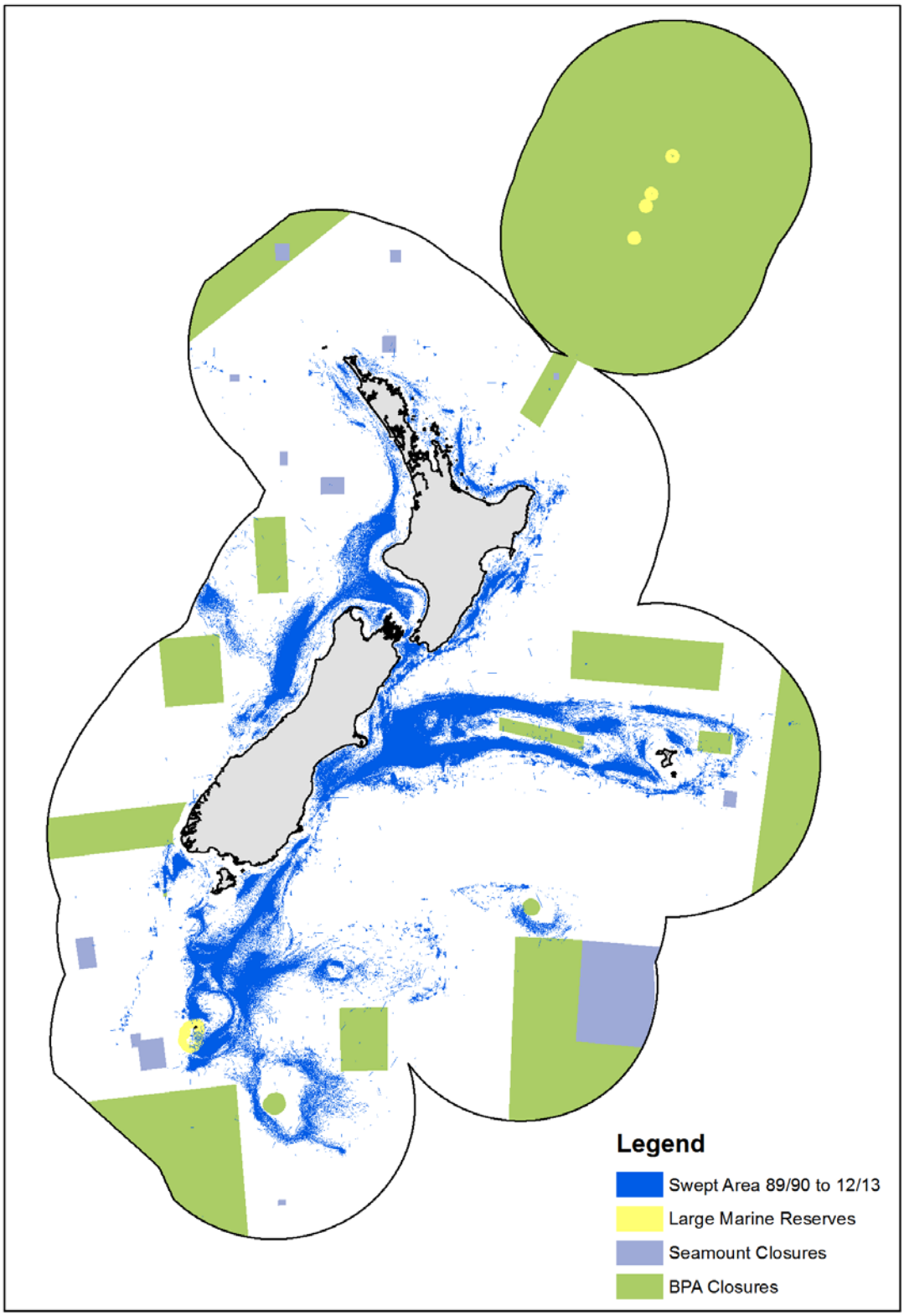

Figure 8: **Estimated swept area (blue) for trawls targeting the tier 1 and tier 2 species in the period 1989/90 to 2012/13 across the EEZ and TS. Areas closed to trawl fishing are marked: BPA closures (green), Seamount closures (mauve), large marine reserves (yellow).**

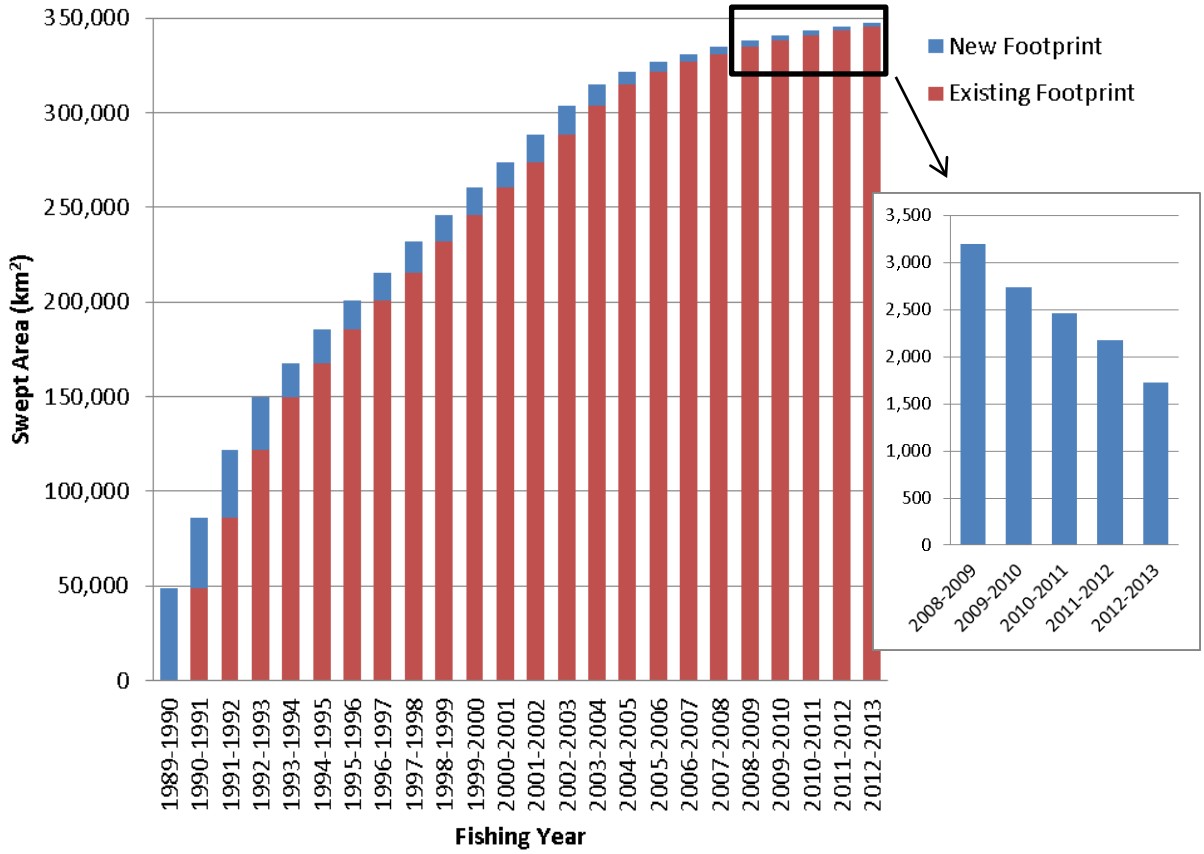

Figure 9: **The change in swept area between 1989/90 and 2012/13 in the EEZ and TS. Red shows the component of the swept area that had been trawled before each fishing year, blue is the area trawled for the first time that year. The inset graph shows the area trawled for the first time in each of the last five fishing years.**

Note that trawls that occurred before 1989/90 were not reported using TCEPR forms and are therefore not represented. The zero on the y-axis should therefore not be taken literally.

The swept area in 2012/13 was 41 511 km^2. This is approximately 1.0% of the area of the EEZ and TS combined and 12% of the total swept area for all years combined. The swept area in 2011/12 was 43 914 km^2. This is approximately 1.1% of the EEZ and TS combined. Both of these are lower than that recorded in the 2010/11 fishing year, the 2012/13 footprint is the lowest annual footprint recorded.

Tables and plots showing the estimated swept areas for each species are in Appendix 2:

- Tables are in files <species id><year>_footprint_stats.pdf and <species id><year>_footprint_stats.xls, e.g., barracouta data for the 2012/13 fishing year are in BAR2013_footprint_stats.pdf and BAR2013_footprint_stats.xls
- Plots are in files <species id><year>_BOMEC_fig.pdf and <species id><year>_fig.pdf, e.g. BAR2013_BOMEC_fig.pdf and BAR2013_fig.pdf.
- See file README.doc in Appendix 2 for more information.

Results are provided for each of the key target species and for the 2011/12 and 2012/13 fishing years and for the entire periods (1989/90 to 2011/12 and 1989/90 to 2012/13), and for the t1t2 species aggregates for each year between 1989/90 and 2012/13 and for each of the time periods.

The calculated statistics for bottom trawling can be used to monitor changes in fishing activity. The swept area for orange roughy was considerably lower in 2010/11 than in any other fishing year during the period of analysis, at less than half that of the previous fishing year (Black & Tilney 2015). This trend has continued with similarly low values for the swept area in 2011/12 and 2012/13 (Figure 10). The number of tows and the cumulative swept area for orange roughy show a similar pattern, suggesting that the current trend of low swept area is due to a reduction in fishing effort rather than a concentration of trawl location.

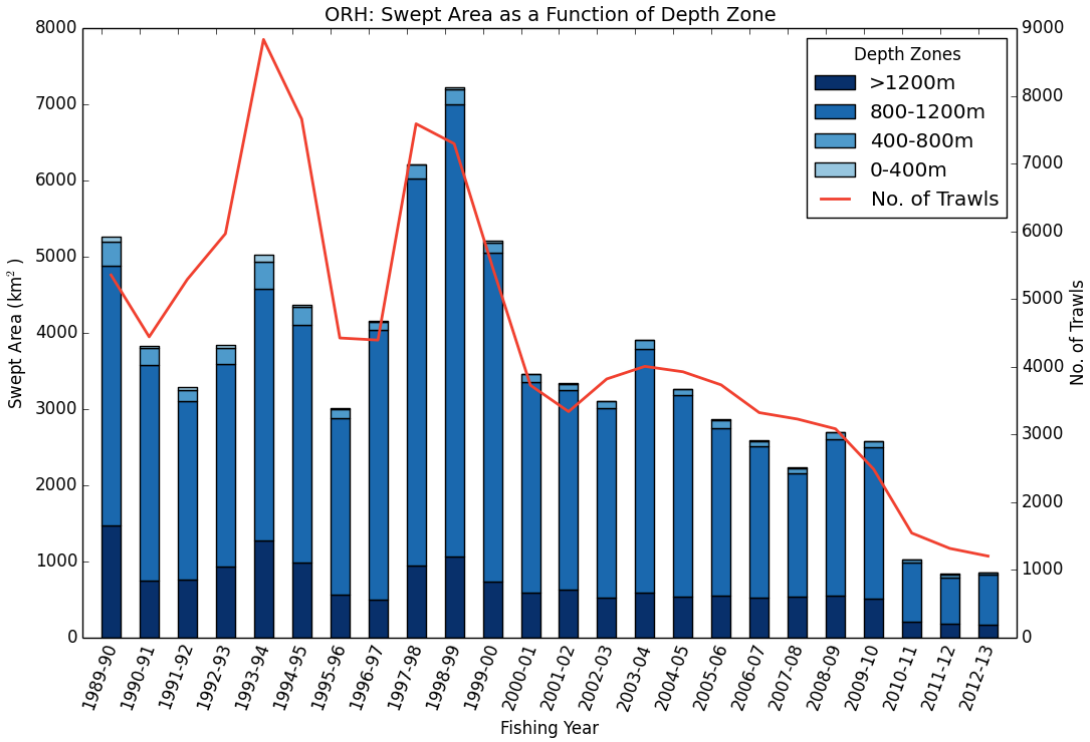

Figure 10: Swept area (km^2) for trawls targeting orange roughy in the EEZ and TS as a function of depth (m) for each fishing year (shades of blue), also plotted is the number of trawls targeting orange roughy in year fishing year (red). The swept area is considerably lower for 2010/11 onwards than in previous fishing years. The number of tows shows a similar pattern.

The swept area for tows targeting squid saw a year-on-year increase between 2007/08 and 2010/11 (Figure 11). This trend has since reversed, and 2012/13 saw the lowest recorded annual swept area (3322 km^2).

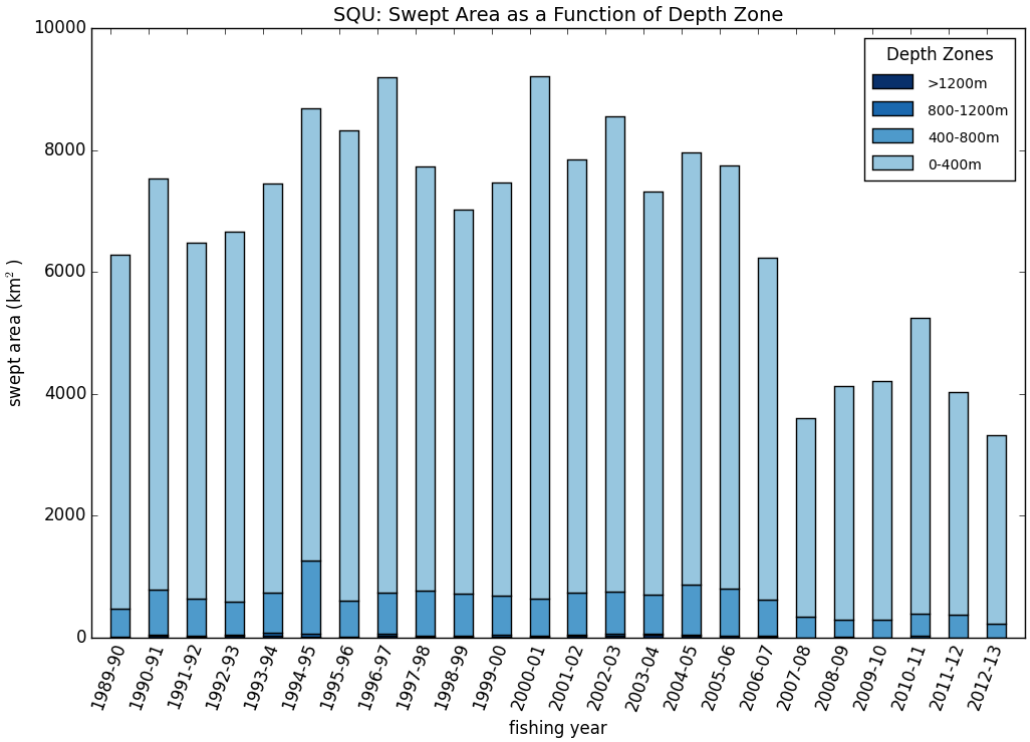

Figure 11: Swept area (km^2) by year for trawls targeting squid in the EEZ and TS, as a function of depth (m). The 2012/13 fishing year saw the lowest recorded annual swept area.

3.2 TCEPR Trawl Frequency

Tables and plots showing the estimated trawl frequency for each species are in Appendix 2:

- Tables are in files <species id><year>_freq_stats.pdf and <species id><year>_freq_stats.xls, e.g., barracouta data for the 2012/13 fishing year are in BAR2013_freq_stats.pdf and BAR2013_freq_stats.xls.
- Plots are in files <species id><year>_freq_fig.pdf and <species id><year>_area_fig.pdf, e.g. BAR2013_freq_fig.pdf and BAR2013_area_fig.pdf.
- See file README.doc in Appendix 2 for more information.

Results are provided for each of the key target species for the 2011/12 and 2012/13 fishing years and for the entire periods (1989/90 to 2011/12 and 1989/90 to 2012/13), and for the t1t2 species aggregates for each year between 1989/90 and 2012/13 and for each of the time periods.

The cumulative swept area is the total area of trawls (i.e. each individual trawl contributes to the total area, even if it overlaps with other trawls). Between 1989/90 and 2012/13 the cumulative swept area is 3 175 204 km^2. The cumulative swept area in 2012/13 (77 930 km^2) is 6% lower than it was in 2011/12 (82 871 km^2, and 3% lower than in 2010/11).

Between the 2011/12 and 2012/13 fishing years, the number of 5 × 5 km cells contacted has decreased from 9739 (5.9% of the total number of cells) to 8981 (5.5%), a decrease of 758 cells. There has been a continuous decrease in the annual number of cells contacted since the 2001/02 fishing year. The cumulative swept area is also lower now than it was in 2001/02, but the year-on-year trend has been less marked, with values in 2010/11, 2011/12 and 2012/13 all exceeding those in 2009/10 (Figure 12).

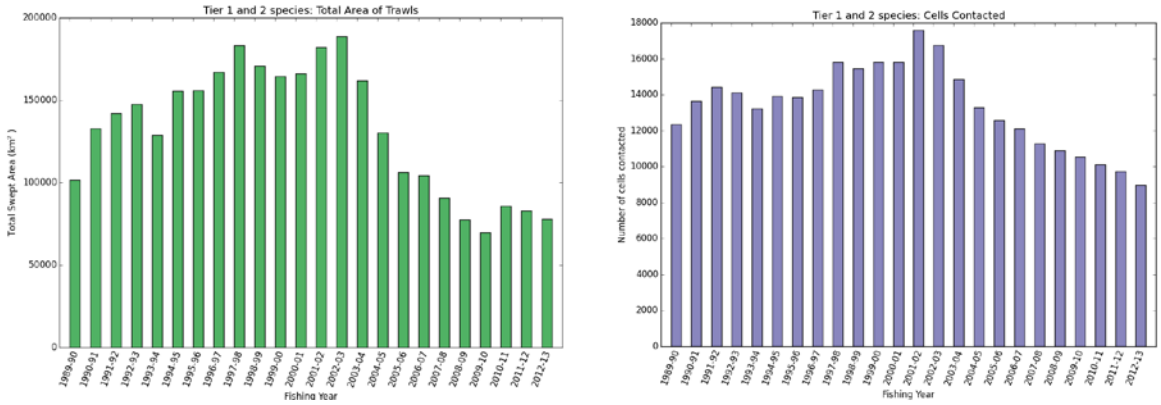

Figure 12: Cumulative swept area (left, green) and number of contacted cells (right, purple) by year for all tier 1 and tier 2 species in the EEZ and TS.

For the period 1989/90 to 2012/13 tows were reported in 38 516 cells, about 23% of the 164 823 5 × 5 km cells that cover the EEZ and TS (Figure 13). Of these 38 516 cells, 93 were trawled for the first time in 2012/13. There were also 93 cells contacted for the first time in the 2011/12 fishing year. For the full time period (1989/90 to 2012/13) the highest tow frequency in a cell was 17 530 (an average of 730 tows per fishing year). The mean frequency of tows for all fished cells was 153 (an average of 6 per fishing year), and the mean frequency of tows for all cells was 36 (an average of 1.5 per fishing year).

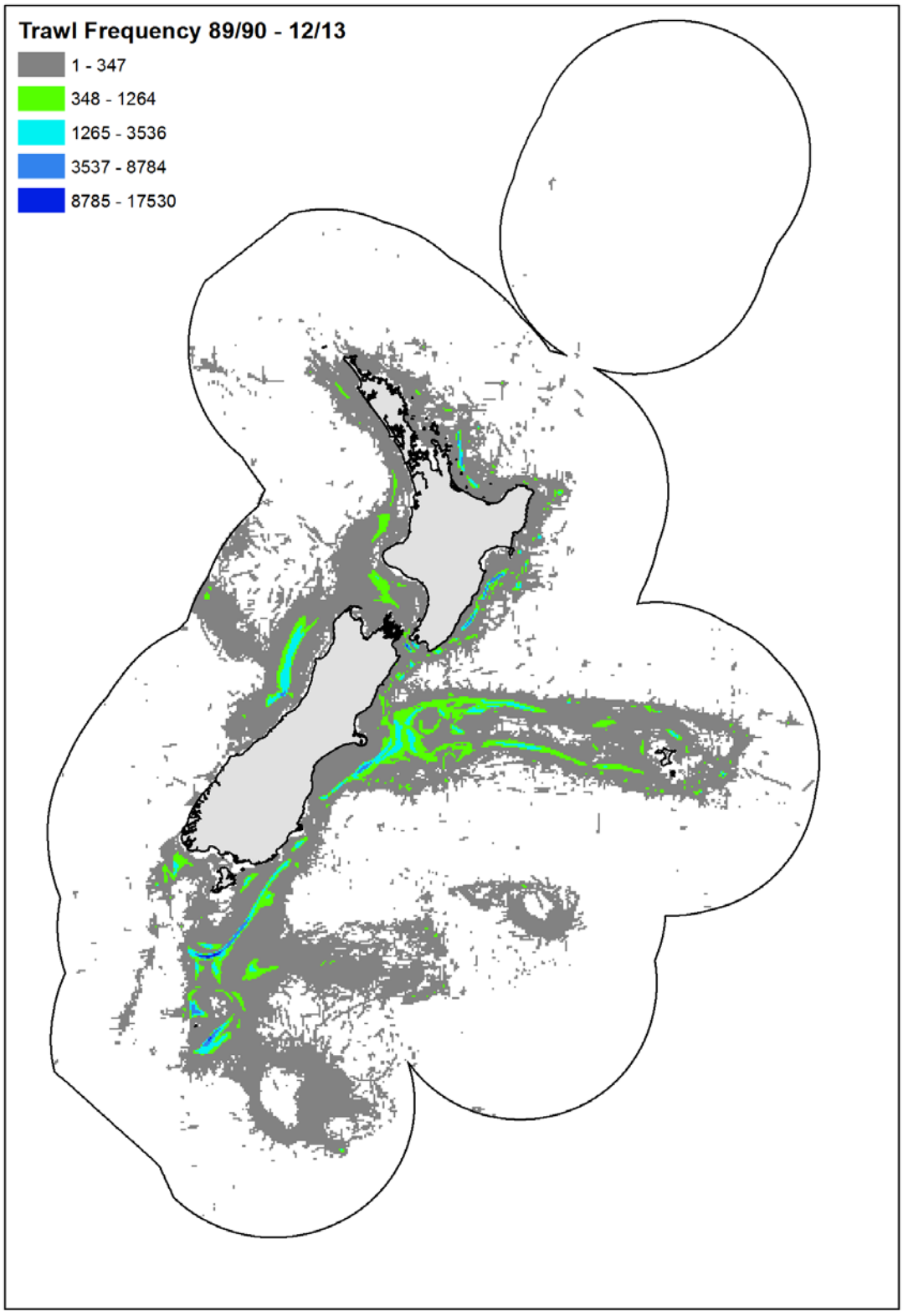

Figure 13: Trawl frequency (i.e. number of tows per 5 × 5 km cell) for trawls targeting the tier 1 and tier 2 species in the period 1989/90 to 2012/13 in the EEZ and TS.

The mean frequency for 2011/12 was 15.2 for trawled cells and 0.9 for all cells, and in 2012/13 it was 15.3 for trawled cells, and 0.8 for all cells. The mean frequency for trawled cells in the last two fishing years is slightly lower than the 15.5 recorded in 2010/11, but higher than the values recorded in 2007/08 to 2009/10 inclusive (Figure 14).

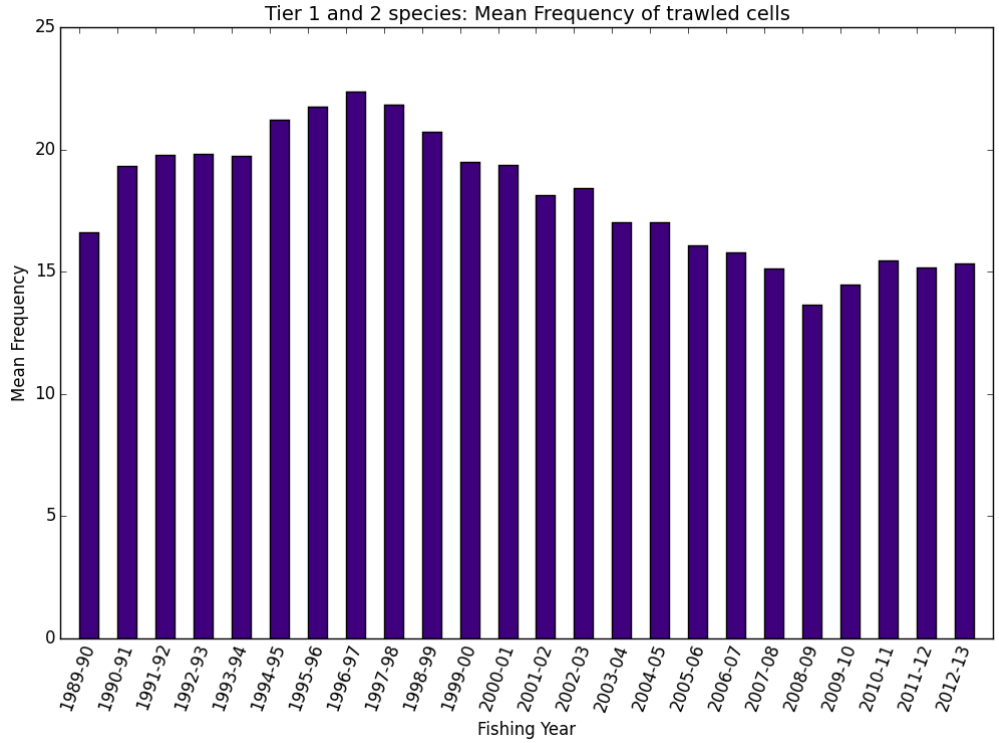

Figure 14: Mean trawl frequency of trawled cells for all tier 1 and tier 2 species in the EEZ and TS.

The maximum trawl frequency for the tier 1 and tier 2 species is slightly lower in the most recent two fishing years than in the preceding years (452 and 413 in 2013/12 and 2011/12 respectively, 468 and 501 in 2010/11 and 2009/10). The maximum trawl frequency has stayed fairly constant over the last five fishing years. Before 2005/06 it was higher, while the maximum of 2293 trawls occurred in 1990/91 (Figure 15).

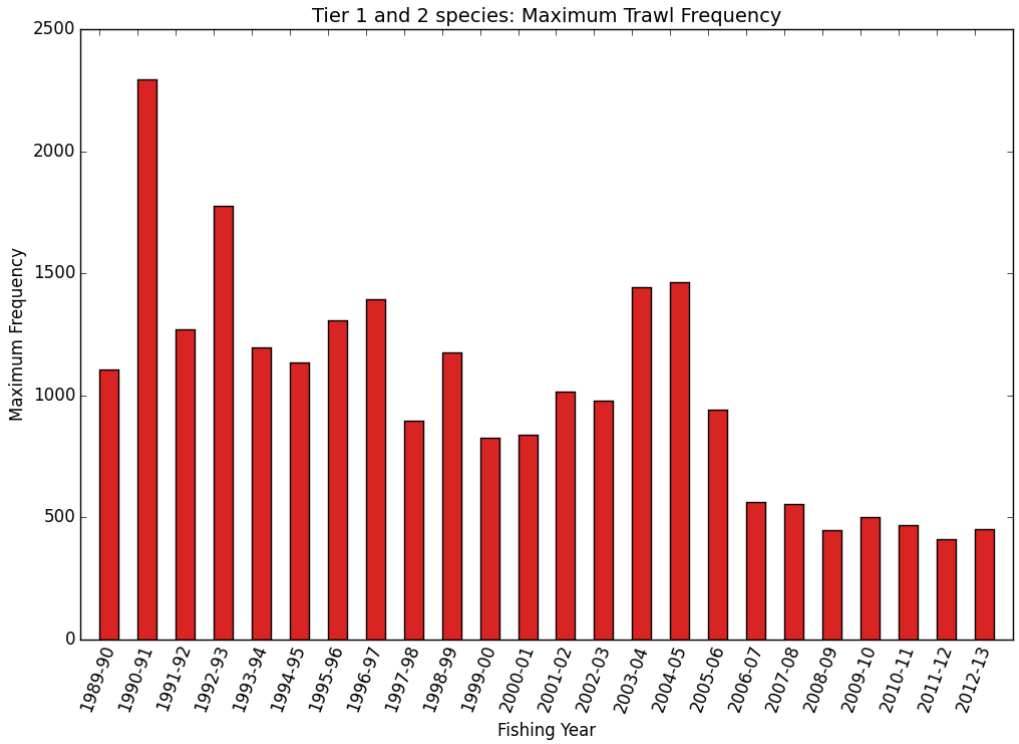

Figure 15: Maximum trawl frequency per 5 × 5 km cell for the tier 1 and tier 2 species in the EEZ and TS.

For the 1989/90 to 2010/11 period, a total of 67 cells have a cumulative swept area of more than 100 times the area of the cell (i.e. greater than 2500 km^2, an average of 104 km^2 per fishing year). A further 322 cells have a cumulative swept area between 50 and 100 times the area of the cell (i.e. between 1250 and 2500 km^2, between 52 km^2 and 104 km^2 per fishing year on average). These cells are all on or close to the 400 m depth contour (Figure 16), the cells with more than 2500 km^2 are primarily located around the east of the South Island and to the south of Stewart Island. Trawls targeting hoki and squid have been the main contributors to the swept area in these cells.

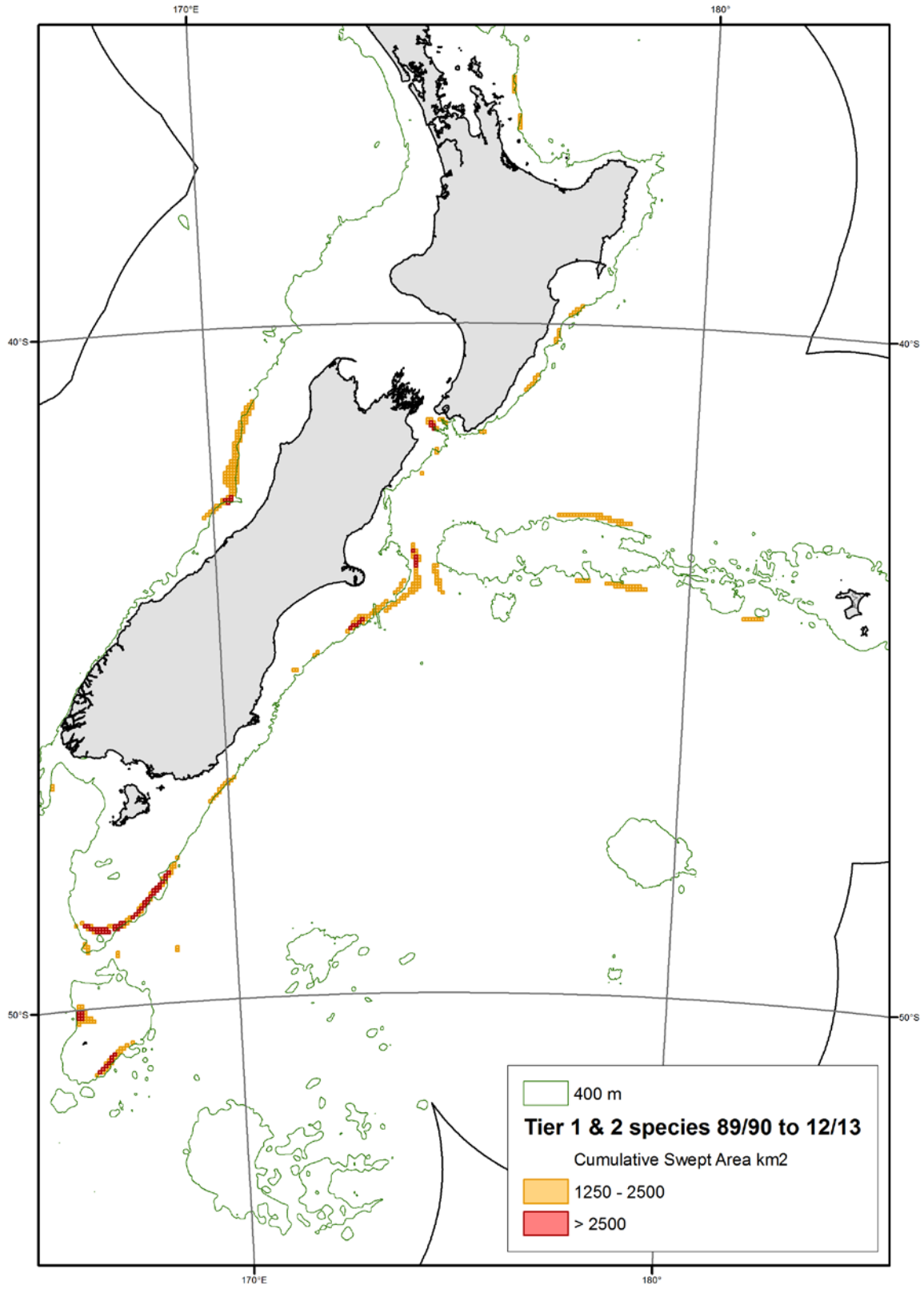

Figure 16: Cells with a cumulative swept area between 50 and 100 times the area of the cell (between 1250 and 2500 km^2) in orange, and cells with a cumulative swept area more than 100 times the area of the cell (more than 2500 km^2) in red. These cells are all on or close to the 400 m depth contour (green).

In the 2012/13 year, two cells have a cumulative swept area of more than ten times the area of the cell (i.e. greater than 250 km^2). A further 22 cells have a cumulative swept area of between five and ten times the area of the cell (i.e. between 125 and 250 km^2). In total, 839 cells have a cumulative swept area greater than the area of the cell (25 km^2), Figure 17. For the 2011/12 year one cell has a swept area of ten times the cell area and 39 cells have a swept area between five and ten times the area of a cell. A total of 935 cells have a cumulative swept area greater than the area of the cell, Figure 18.

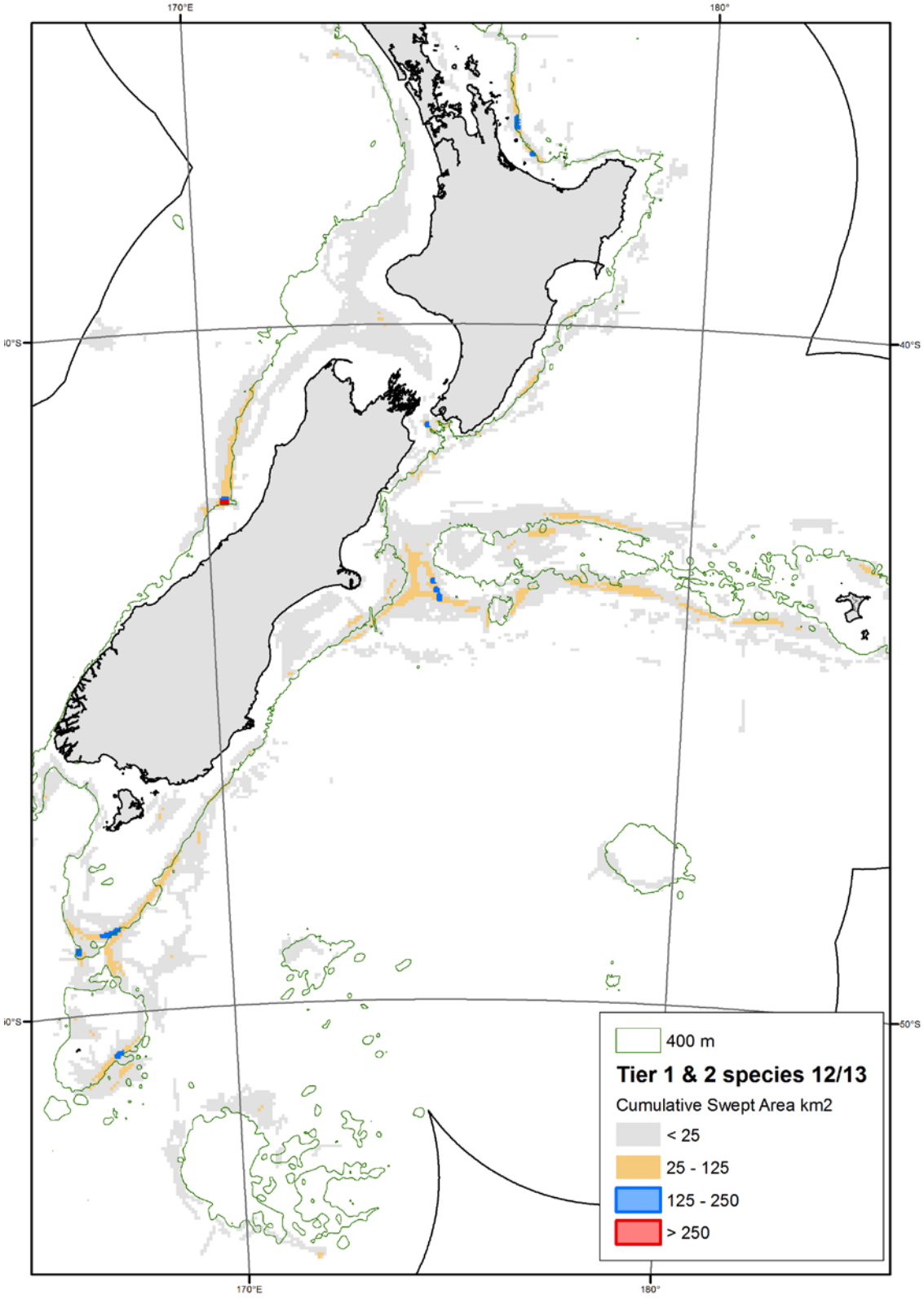

Figure 17: 2012/13: Cells with a cumulative swept area more than ten times the area of a cell (more than 250 km^2) in red, between five and ten times (125 km^2 to 250 km^2) in blue, and between one and five times the area of a cell (25 km^2 to 125 km^2) in orange. Remaining trawled cells are grey. Many of these cells are on or close to the 400 m depth contour (green).

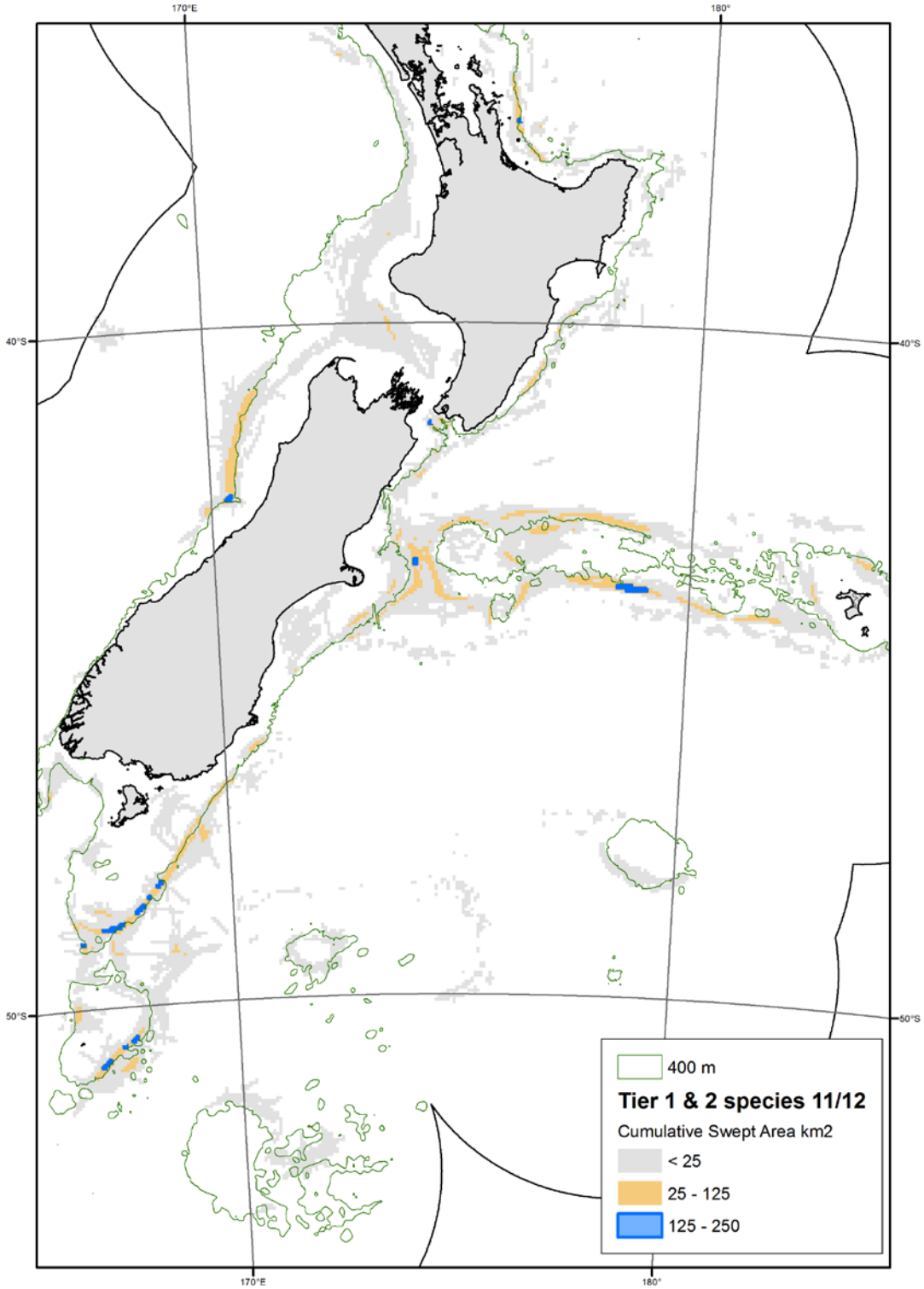

Figure 18: 2011/12: Cells with a cumulative swept area between five and ten times the area of the cell (125 km^2 to 250 km^2) in blue, and between one and five times the area of a cell (25 km^2 to 125 km^2) in orange. Remaining trawled cells are grey. There are no cells with a swept area more than ten times the area of a cell (more than 250 km^2). Many of these cells are on or close to the 400 m depth contour (green).

The largest cumulative swept area in a cell for the period 1989/90 – 2012/13 was 10 531 km^2. This cell lies south of Stewart Island (Figure 19) and is the same cell that had the largest swept area for the period 1989/90 – 2011/12 (10 341 km^2). In this cell the majority (96%) of trawls

targeted squid. In 2011/12 the cell with the largest cumulative swept area occurs in the same region south of Stewart Island. This cell had 246 km^2 in the fishing year – about ten times the area of the cell. This was also the cell with the largest cumulative swept area in 2008/09, and close to the cell with the maximum in 2010/11. The vast majority of trawls contributing to these maximum areas were targeting squid. The cell with the maximum cumulative swept area in 2012/13 is off the West Coast. This cell had 314 km^2 in the fishing year – over 12 times the area of the cell. This was also the cell with the largest cumulative swept area in 2009/10. The vast majority of trawls crossing this cell in 2009/10 and 2012/13 were targeting hoki.

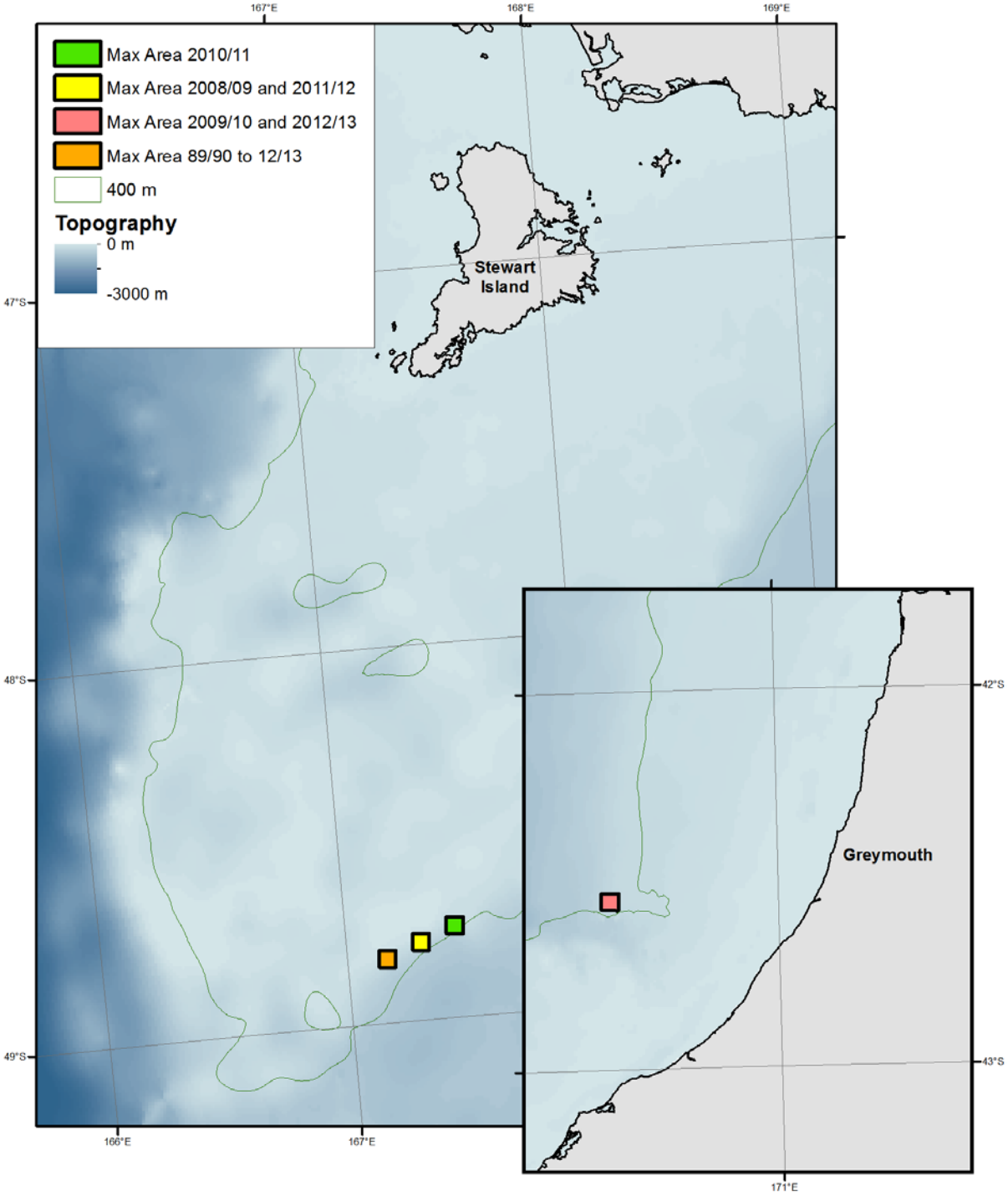

Figure 19: The location of the cells with the largest cumulative swept area for the period 1989/90 to 2012/13 (orange), and each of the last five fishing years (green, yellow and pink). The 400 m contour is plotted (dark green), along with the bathymetry (shades of blue, GEBCO 2010).

During 2012/13, 8981 cells were contacted by bottom tows, about 5.5% of the total number of cells in the EEZ and TS, and 758 fewer than in 2011/12. For 2012/13 the cell with the highest number of tows in a cell is the same cell that has the largest cumulative swept area (the pink square in Figure 19). This was not the case in 2011/12; the cell with the maximum cumulative area (the yellow square in Figure 19) was the cell with the third largest number of tows. The cell with the highest number of tows in 2011/12 was the same as the cell with the maximum cumulative area in the 1989/90 to 2012/13 period (the orange square in Figure 19).

The calculated statistics for bottom trawling can be used to monitor changes in fishing activity. For trawls targeting ling, the last four years show a fairly constant cumulative trawled area. The mean frequency of trawled cells and the maximum trawl frequency have increased, especially in the 2012/13 fishing year. This suggests a focussing of effort for trawls targeting ling. This demonstrates that the different statistics need to be considered together to give a full picture of what is happening (Figure 20).

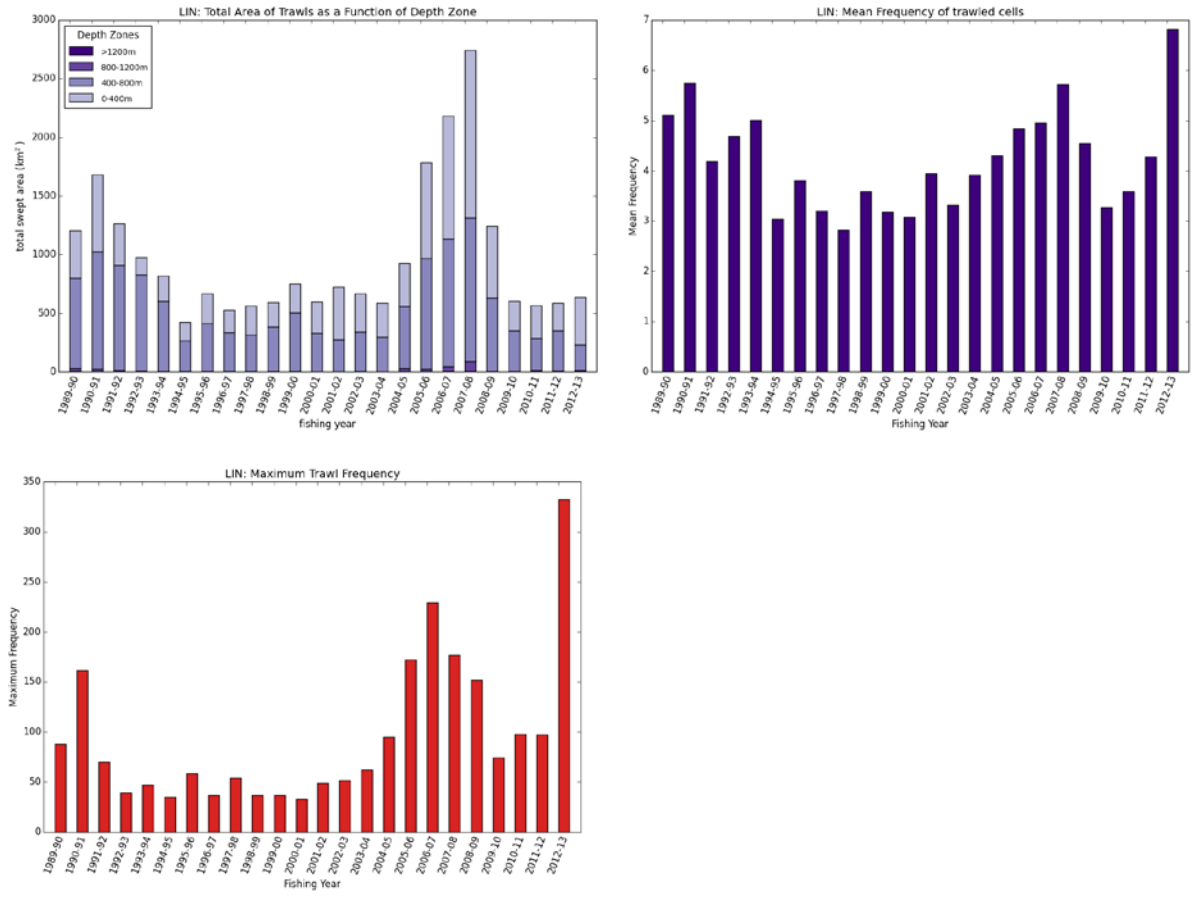

Figure 20: Cumulative swept area by depth zone (top left), mean frequency of trawled cells (top right), and maximum frequency (bottom left), by year for trawls targeting ling in the EEZ and TS.

3.3 TCEPR Data and Depth Zone

The swept area (for all t1t2 species) in each depth band is shown in Figure 21 and Figure 22. The 2011/12 and 2012/13 data show a similar pattern as seen in the previous few fishing years, with the largest swept area occurring in the 400–800 m depth band (2012/13: 24 668 km^2, 2011/12: 25 318 km^2, both comprising almost 60% of the swept area in the EEZ and TS). The swept area in the 0–400 m, 800–1200 m and deeper than 1200 m depth bands are 14 964 km^2, 1577 km^2 and 302 km^2 respectively in 2012/13, and 16 692 km^2, 1630 km^2 and 272 km^2 in 2011/12. The decrease in swept area in 2011/12 and 2012/13 compared with 2010/11 is due to decreases in swept area in each of the depth bands. The largest decreases have been in the 0–400 m depth band which has dropped from 17 615 km^2 in 2010/11 to 16 692 km^2 in 2011/12 and then to 14 964 km^2 in 2012/13.

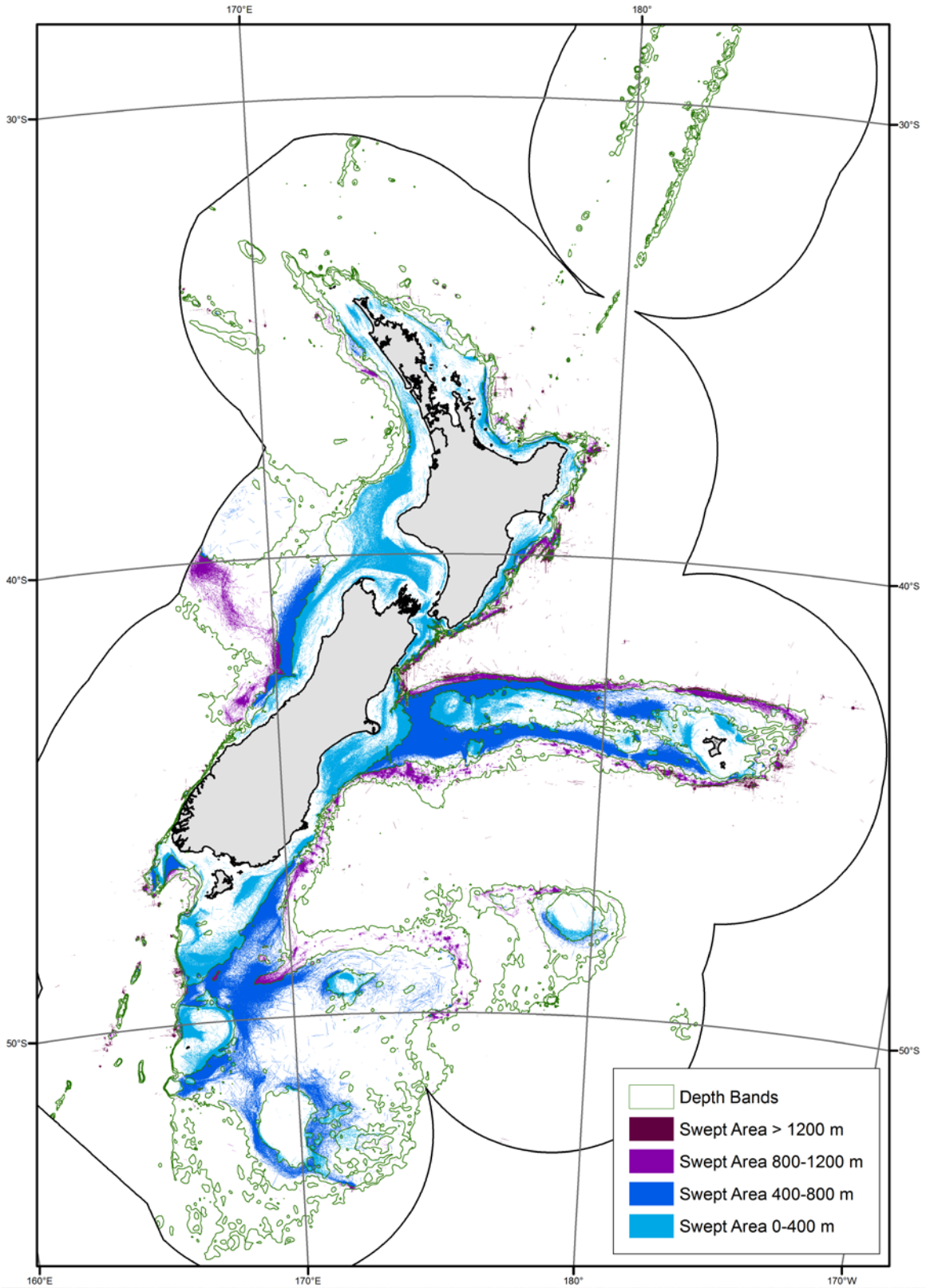

Figure 21: 1989/90 to 2012/13: Swept area in the EEZ and TS coloured by depth zone (400, 800 and 1200 m contours are also shown, in green).

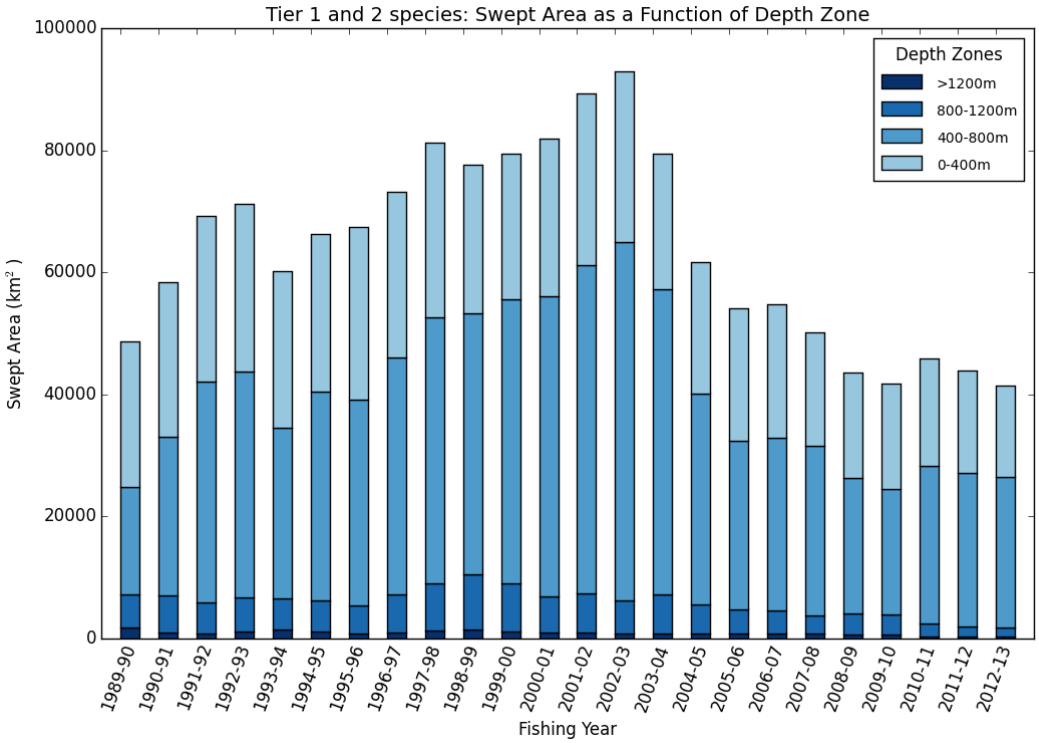

Figure 22: Swept area for each fishing year of the series for trawls targeting the tier 1 and tier 2 species in the EEZ and TS, coloured by depth zone.

If we consider the cumulative swept area, the trends are similar. In 2011/12 and 2012/13 the cumulative swept area has decreased particularly in the 0–400 m depth band (Figure 23). The decrease in 0–400 m is from 34 759 km^2 in 2010/11 to 32 569 km^2 to 27 805 km^2 in 2012/13, a total drop of 20%, this is primarily due to decreases in the swept area of trawls targeting squid and to a lesser extent, scampi.

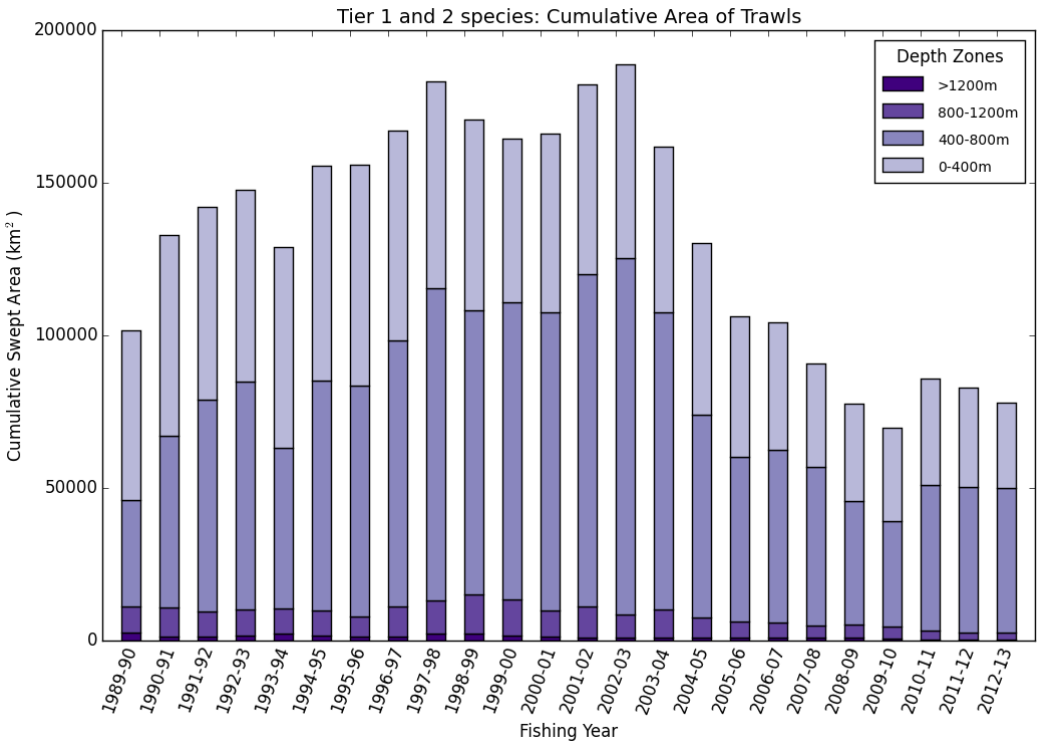

Figure 23: Cumulative swept area per year for trawls targeting the tier 1 and tier 2 species in the EEZ and TS, coloured by depth band.

These trends vary for different target species. For example, the swept area from trawls targeting hoki increased 29% between 2009/10 and 2010/11, which was reflected in each depth band (Black & Tilney, 2015). There was another increase in the 2011/12 fishing year, but it was considerably smaller (just under 3%). In 2012/13 there was a decrease (just over 3%) to slightly below 2010/11 levels (Figure 24, Table 8).

Table 8: Swept area in each depth band for trawls targeting hoki and orange roughy in 2009/10 and 2010/11.

Depth band	Hoki Swept Area (km^2)		Orange Roughy Swept Area (km^2)	
	2011/12	2012/13	2011/12	2012/13
0–400 m	2 951	2 460	6	1
400–800 m	21 334	20 979	37	33
800–1200 m	380	427	610	656
Deeper than 1200 m	18	50	186	173

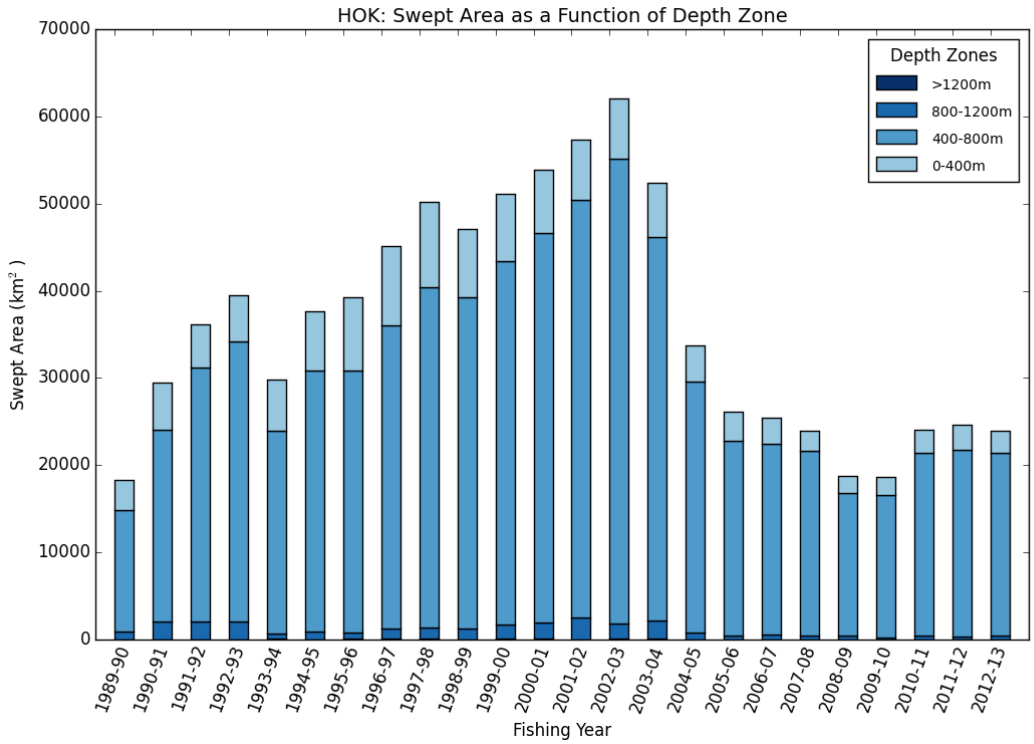

Figure 24: Swept area (km^2) for hoki targeted trawls in the EEZ and TS as a function of depth (m) by fishing year (1989/90 to 2012/13).

A marked decrease in the swept area for trawls targeting orange roughy was noted in the 2010/11 fishing year (Black & Tilney, 2015). This trend was observed in each depth band, but most noticeably in the 800–1200 m band, where the decrease was over 60%. The decreasing trend has continued, but at a slower rate. The 2011/12 and 2012/13 years both show a smaller swept area per year than in 2010/11, with the lowest in 2011/12 (Figure 10, Table 8).

The cumulative swept area for trawls targeting squid show an increase, in particular in the 0-400 m depth zone between the 2007/08 and 2010/11 fishing years. The 2011/12 and 2012/13 fishing years show a reverse of this trend (Figure 11). The swept area in the 2012/13 fishing year is the lowest recorded for squid. When the total area of trawls is considered, there is also a progressive decrease in 2011/12 and 2012/13 to reach the lowest recorded level (Figure 25). This decrease in the 0–400 m depth zone in the most recent two fishing years was evident in the cumulative swept area for the t1t2 species as noted above (Figure 23)

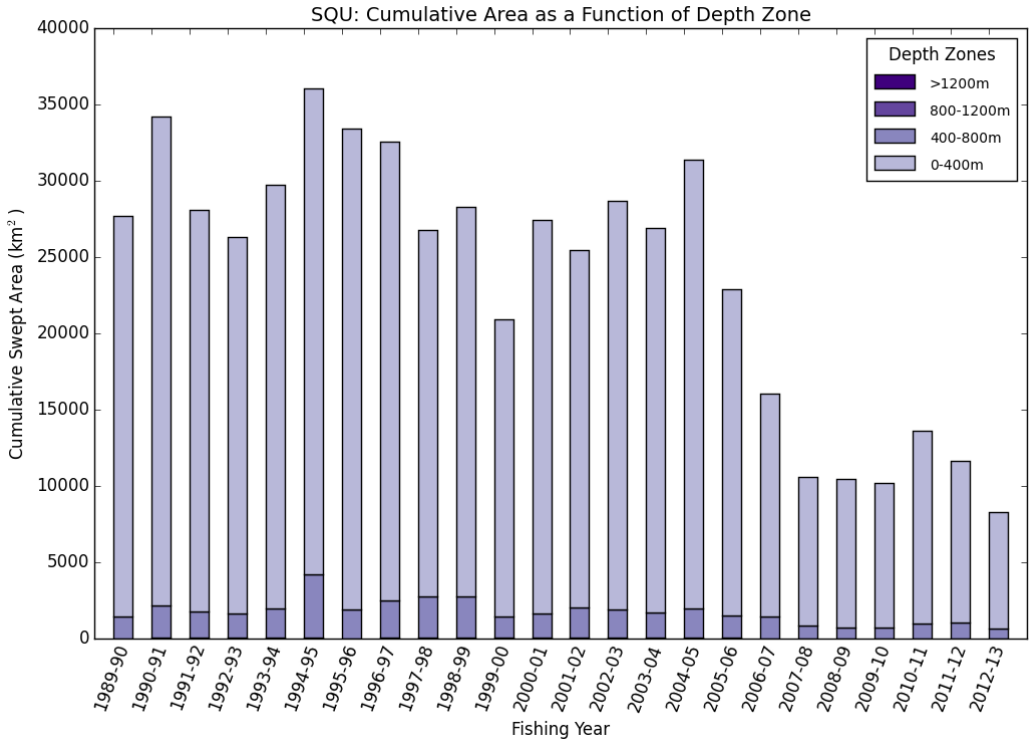

Figure 25 Cumulative swept area (km^2) for trawls targeting squid for each fishing year (1989/90 to 2012/13), coloured by depth zone.

Hake is another species that has a year-on-year decrease in the swept area in the last two fishing years. The swept area in 2012/13 is the lowest since the 1990/91 fishing year (Figure 26). The same trend is apparent in the cumulative swept area, but less marked, and not when individual depth zones are considered (Figure 27). This suggests that for trawls targeting hake in 2012/13 trawls have been more concentrated in location than in 2011/12.

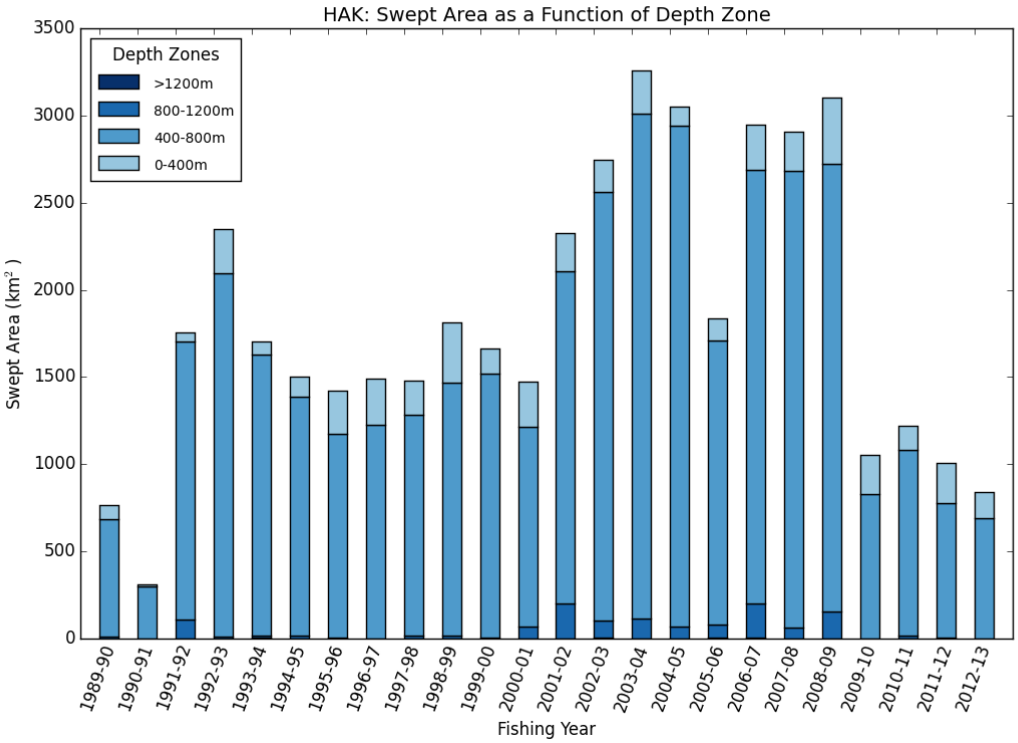

Figure 26 Swept area (km^2) by year (1989/90 to 2012/13) for trawls targeting hake in the EEZ and TS, as a function of depth (m).

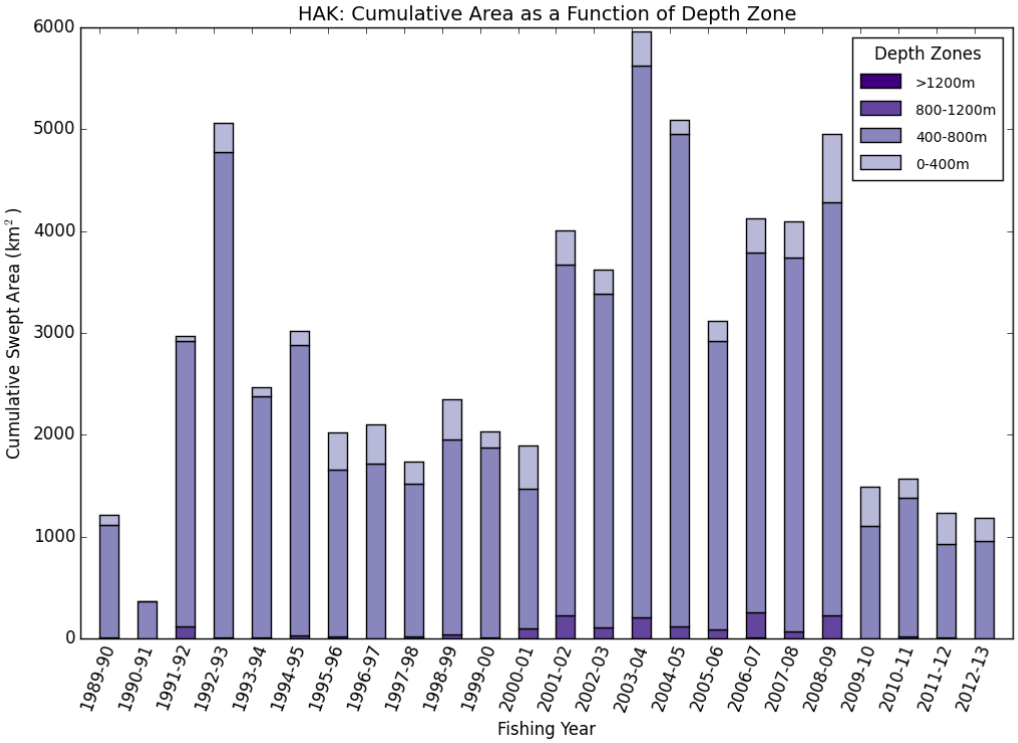

Figure 27: Cumulative swept area (km^2) by year (1989/90 to 2012/13) for trawls targeting hake in the EEZ and TS, as a function of depth (m).

3.4 TCEPR Data and Fishable Area

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 28). The fishable area in the TS and EEZ is 1 408 210 km², which amounts to 34% of the total area of seabed in the TS and EEZ. The swept area within the fishable area is 382 500 km², or about 24% of the fishable area. Of this, 1647 km^2 was trawled for the first time in 2012/13, and 2137 km^2 for the first time in 2011/12. This equates to 0.1% and 0.2% of the fishable area, or 4.0% and 5.1% of the respective swept area in each of the fishing years. In 2012/13, the swept area is 2.9% of the fishable area and 1.0% of the EEZ and TS combined (Figure 29), both of these percentages are slightly lower than 2011/12 where the swept area was 3.1% of the fishable area and 1.1% of the EEZ and TS.

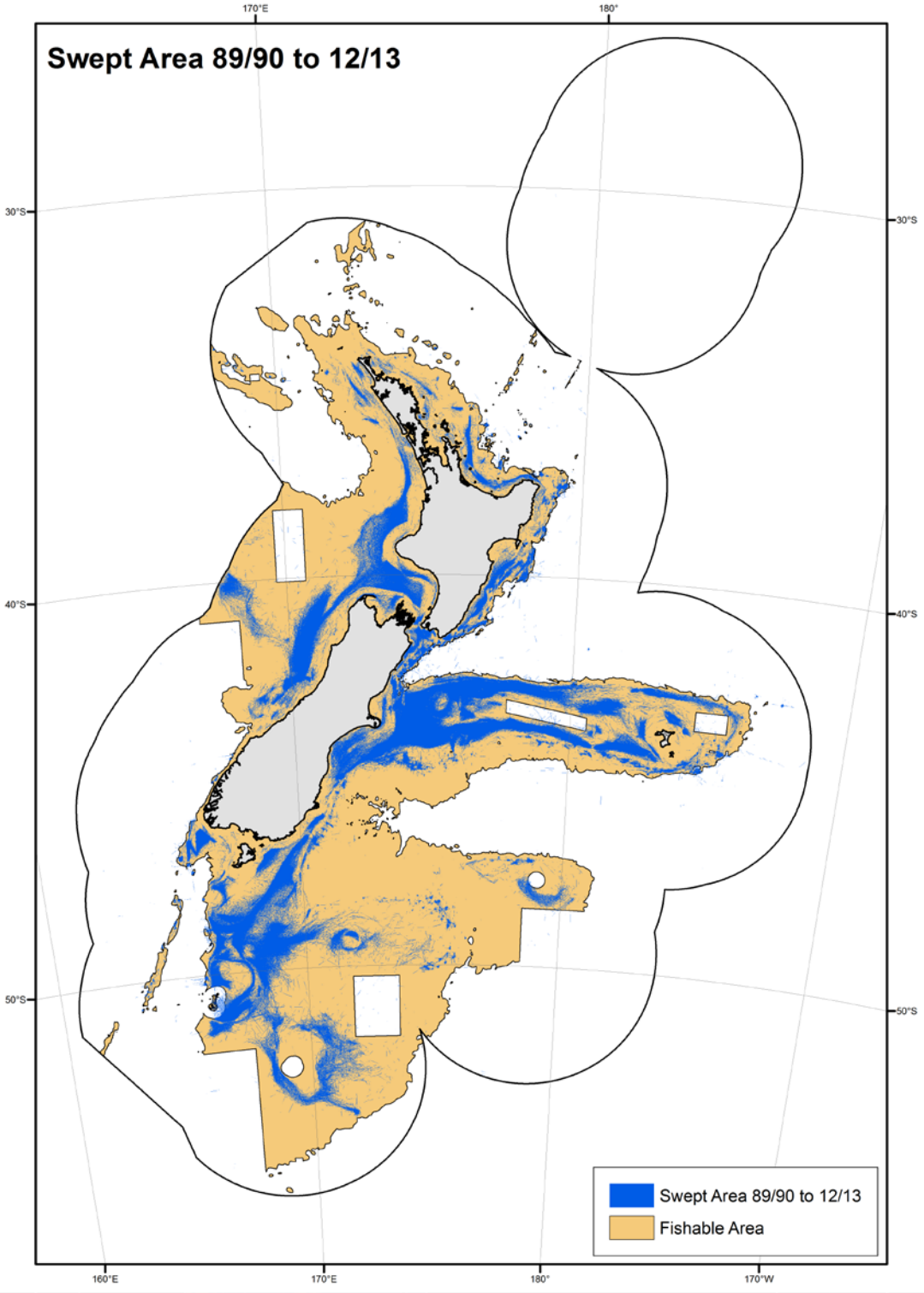

Figure 28: Trawl footprint for trawls targeting all tier 1 and tier 2 species (blue) in relation to the fishable area (pale orange) for the period 1989/90 to 2012/13.

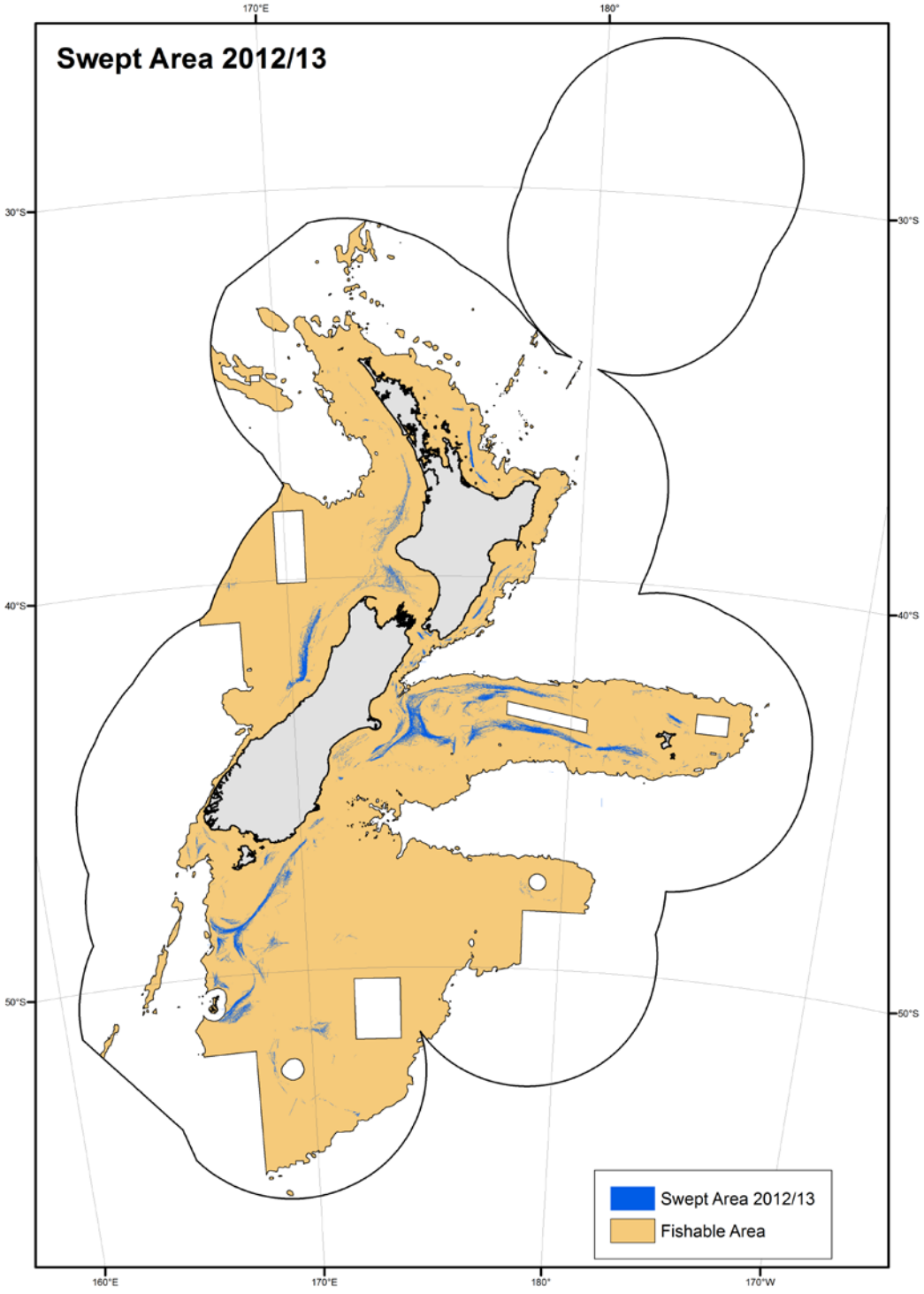

Figure 29: Estimated swept area in 2012/13 for trawls targeting all tier 1 and tier 2 species (blue) overlain on the fishable area (pale orange). The swept area comprises 2.9% of the fishable area (i.e. shallower than 1600 m) and 1.0% of the EEZ and TS combined.

The frequency-based analysis shows that 62% (34 864) of cells in the fishable area have been swept at some point between 1989/90 and 2012/13. Only 51 of these cells were swept for the first time in 2012/13, and 69 for the first time in 2011/12. In total, 16% (8825) of cells in the fishable area were swept in 2012/13, compared with 17% (9605) of cells in 2011/12 and 18% (9985) in 2010/11.

3.5 TCEPR Data and Preferred Habitat

TCEPR data were used to map fishing effort for key target species against preferred habitat. An example is shown in Figure 30 for hoki, which illustrates that the swept area for the period 1989/90 to 2012/13 comprises a little over 10% of the total preferred habitat (i.e. in the over 0% probability of capture area). As was the case with the 1989/90 to 2010/11 data, 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 33%, 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 31 shows how the swept area and percentage swept area in the preferred habitat range for hoki varies by probability of capture area.

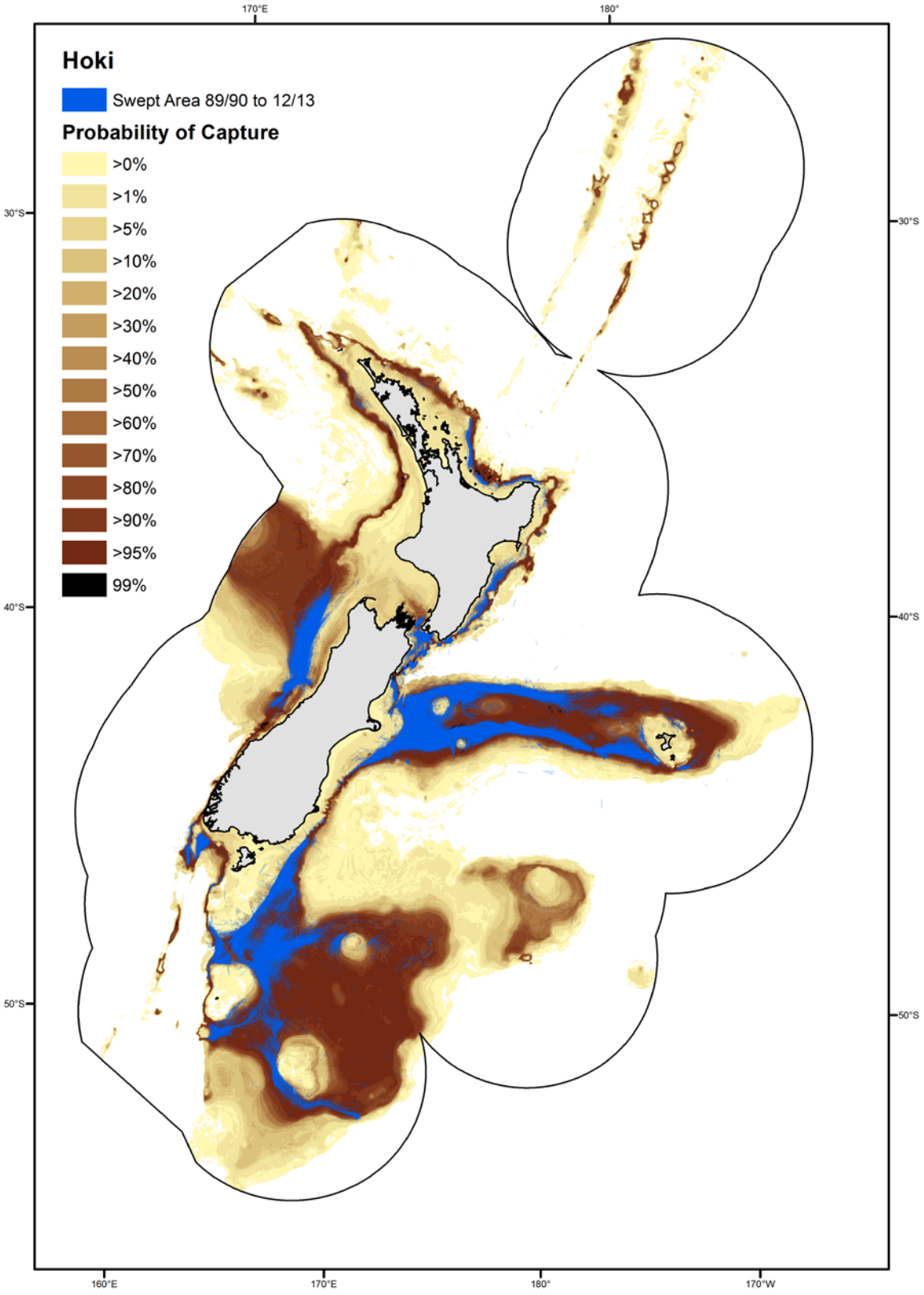

Figure 30: Preferred habitat (probability of capture) for hoki, overlain by the 1989/90 to 2012/13 swept area for trawls targeting hoki in the EEZ and TS.

Orange roughy has a similar (but less pronounced) pattern (Figure 31, Figure 32). The swept area makes up 4% of the 0% probability of capture area for orange roughy. There is a gradual

increase from 4% up to 25% in the more than 95% probability of capture areas, followed by a sharp increase to 46% in the 99% probability of capture area.

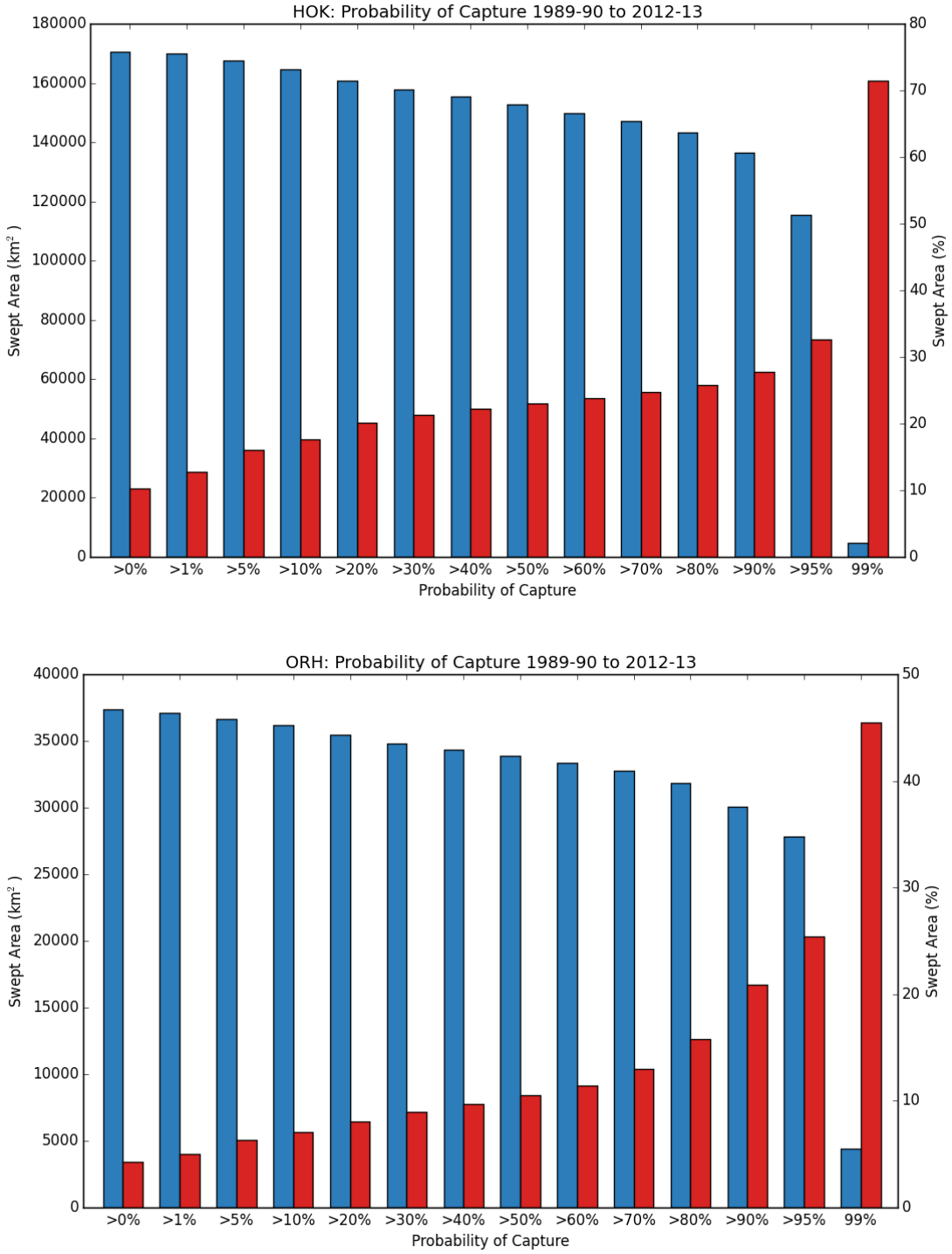

Figure 31: Swept area in square kilometres (blue) and as a percentage of each probability of capture area (red) for trawls targeting hoki (top) and orange roughy (bottom). Note that the two graphs have different ranges on their y-axis scales.

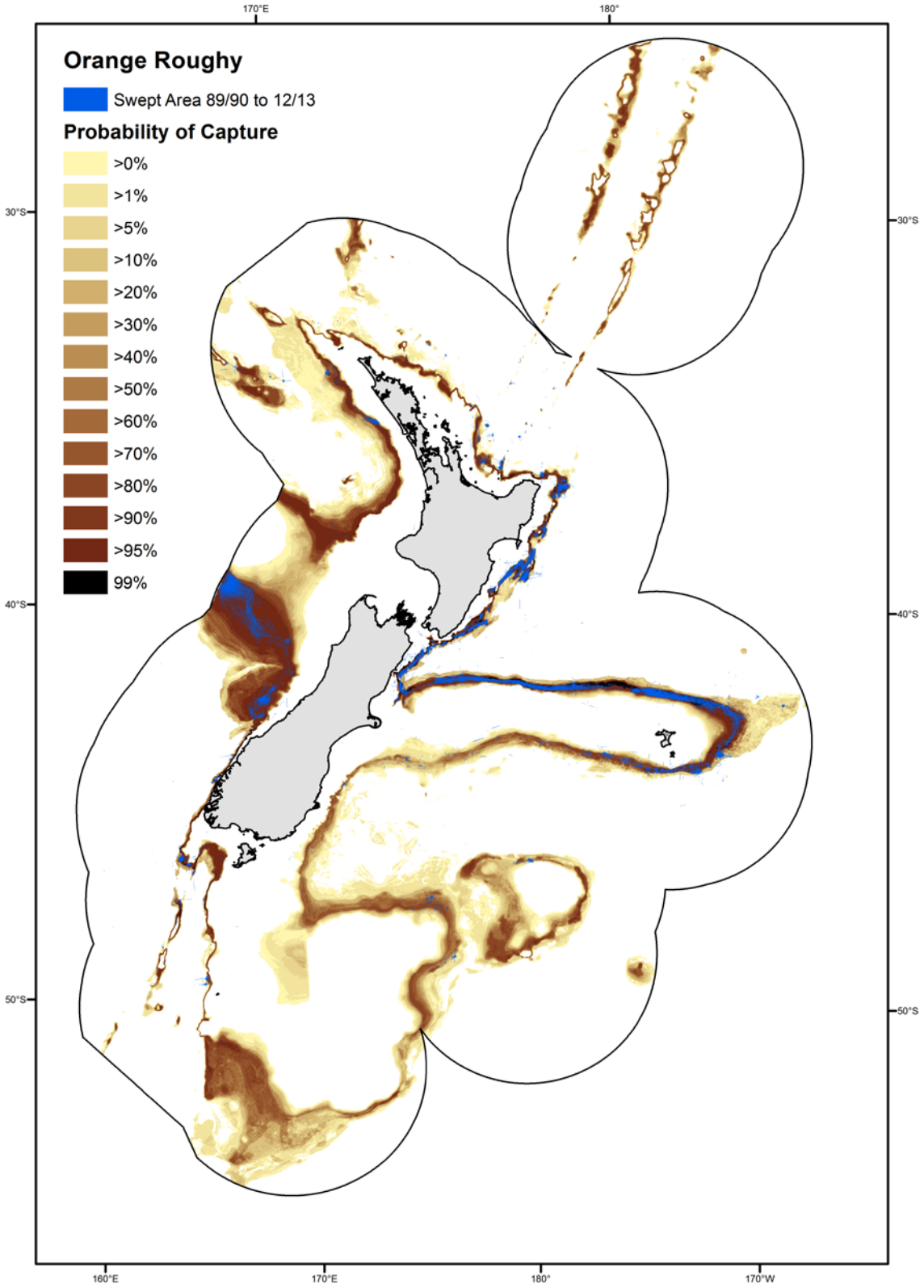

Figure 32: Preferred habitat (probability of capture) for orange roughy, overlain by the 1989/90 to 2012/13 swept area for trawls targeting orange roughy in the EEZ and TS.

3.6 TCEPR Data and Benthic Habitats

In total, the 15 BOMEC classification areas cover 2 627 073 km², approximately 64% of the EEZ and TS. The swept area within the BOMEC for all tier 1 and tier 2 species for the period

1989/90 to 2012/13 is estimated to be 346 811 km², about 13% of the total BOMEC classification area (Figure 33; Figure 34). Of this, 1704 km^2 was swept for the first time in 2012/13, and 2165 km^2 or the first time in 2011/12. The swept area for all tier 1 and tier 2 species for the 2012/13 fishing year is 41 495 km², covering about 1.6% of all BOMEC zones. This is lower than in the 2011/12 fishing year when the swept area was 43 908 km^2, or 1.7% of all BOMEC zones. This in turn was lower than the 2010/11 fishing year when the swept area was 45 894 km^2, or 1.8% of all BOMEC zones.

The frequency based analysis shows that approximately 36% of cells in the BOMEC have been swept since 1989/90. The cumulative swept area in the BOMEC region is 3 174 671 km^2 between 1989/90 and 2012/13.

Analysis of the estimated swept area within individual BOMEC zones could be used as an indication of the potential benthic effects by trawling. This analysis shows that, for the period 1989/90 to 2012/13, BOMEC 9 has the highest percentage swept area at 74% (Figure 9). Forty percent or more of BOMEC classes 3, 5, 7 and 8 are estimated to have been contacted by bottom trawling; less than 10% of BOMEC classes 1, 11, 13, 14 and 15 are estimated to have been contacted by bottom trawling.

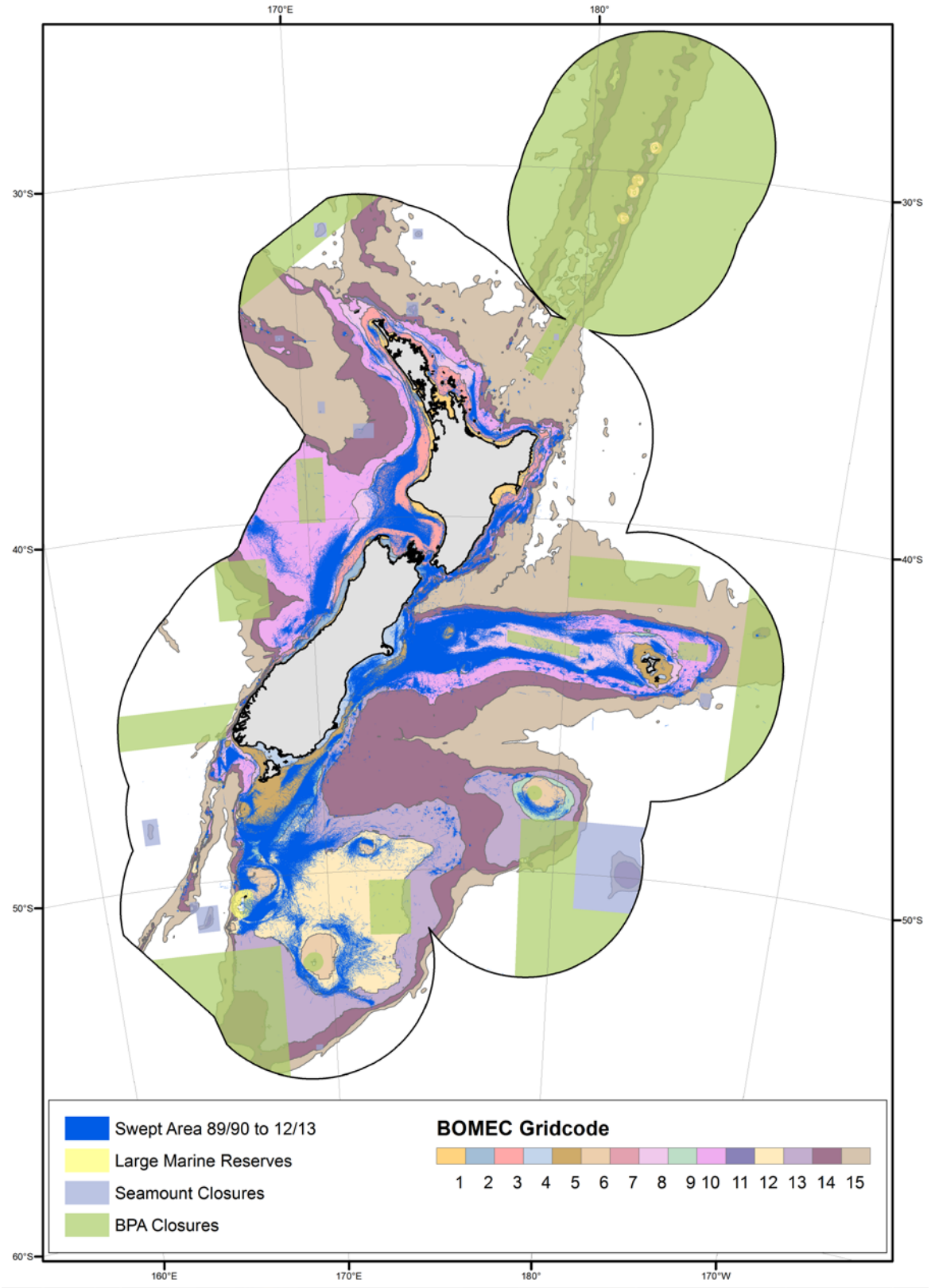

Figure 33: The BOMEC classification and trawl footprint for trawls targeting all tier 1 and tier 2 species in the EEZ and TS, 1989/90 to 2012/13.

Table 9: The area of each BOMEC zone and the corresponding swept area for trawls targeting all tier 1 and tier 2 species, 1989/90 to 2012/13.

BOMEC code	Area (km^2)	Swept Area (km^2)	Swept Area (%)
1	27 557	2 165	8%
2	12 420	1 507	12%
3	89 710	37 744	42%
4	27 268	8 001	29%
5	60 990	24 429	40%
6	38 609	6 889	18%
7	6 342	2 783	44%
8	138 551	64 385	46%
9	52 224	38 448	74%
10	311 361	71 890	23%
11	1 289	6	0%
12	198 577	55 958	28%
13	233 825	18 767	8%
14	493 034	11 437	2%
15	935 315	2 400	0%
TOTAL	**2 627 073**	**346 811**	**13%**

The frequency based analysis shows a similar pattern, the percentage of cells contacted is similar to the swept area, but the percentages are larger (Table 10). In the 1989/90 to 2012/13 period more than 90% of the cells in BOMEC classes 3 and 9 have been contacted by trawling; between 50% and 90% of cells in BOMEC classes 1, 2, 4, 5, 6, 7, 8, 10 and 12 have been contacted by trawling, and fewer than 50% of cells in BOMEC 11, 13, 14 and 15 have been contacted by trawling (Table 11). The cell with the largest number of trawls between 1989/90 and 2012/13 is in BOMEC 5 which has seen 17 530 trawls. The BOMEC class with the largest trawl frequency is BOMEC 9 with a mean frequency of 509 trawls per cell.

Table 10: Trawl statistics for trawls targeting t1t2 species in 2011/12 and 2012/13 in the fifteen BOMEC zones.

BOMEC code	Swept Area (%)		Cells Contacted (%)		Mean Frequency of Trawled Cells	
	2011/12	2012/13	2011/12	2012/13	2011/12	2012/13
1	<1%	<1%	2%	1%	1	1
2	<1%	<1%	1%	3%	1	1
3	4%	4%	31%	29%	8	8
4	1%	2%	19%	22%	4	5
5	6%	5%	29%	27%	24	20
6	2%	2%	15%	15%	10	10
7	4%	4%	27%	29%	20	26
8	7%	6%	37%	34%	19	19
9	22%	23%	62%	61%	22	24
10	3%	2%	16%	15%	12	12
11	0%	0%	0%	0%	0	0
12	2%	2%	15%	12%	18	19
13	<1%	<1%	4%	2%	5	5
14	<1%	<1%	2%	2%	5	5
15	<1%	<1%	<1%	<1%	2	2
TOTAL	**2%**	**2%**	**9%**	**9%**	**15**	**15**

Table 11: Trawl statistics for trawls targeting all t1t2 species in 1989/90 to 2012/13 in the fifteen BOMEC zones.

BOMEC code	Number of Cells	Cells Contacted (number)	Cells Contacted (%)
1	1 086	673	62%
2	502	392	78%
3	3 572	3 330	93%
4	1 091	768	70%
5	2 450	2 071	85%
6	1 542	883	57%
7	255	219	86%
8	5 559	4 998	90%
9	2 087	2 018	97%
10	12 431	8 218	66%
11	54	16	30%
12	7 926	5 677	72%
13	9 356	3 717	40%
14	19 758	2 927	15%
15	37 386	2 025	5%
TOTAL	**105 055**	**37 932**	**36%**

The fishing effort in the BOMEC areas has varied with time (Figure 34). For many of the areas (1, 4, 5, 6, 10, 12, 13, 14 and 15 between 2010/11 and 2011/12, and 1, 3, 5, 6, 8, 10, 12, 13 and 14 between 2011/12 to 2012/13) the swept area has decreased. However, the swept area in

BOMEC areas 2, 7 and 9 has increased in each of these fishing years. Although these three BOMEC zones all have an increased swept area, all of them have seen a larger swept area in previous years. For example, while the swept area in BOMEC 9 (dashed orange line in Figure 34) has increased from 21.5% in 2010/11 to 23.5% in 2012/13 it was maximal in 1998/99 at 37.4%. These changes in BOMEC 9 are primarily due to fluctuations in the number and location of trawls targeting hoki (Figure 35). It should be noted that this increase in BOMEC 9 is not matched by an overall increase in the swept area for trawls targeting hoki which has stayed very similar for the last three fishing years (Figure 36).

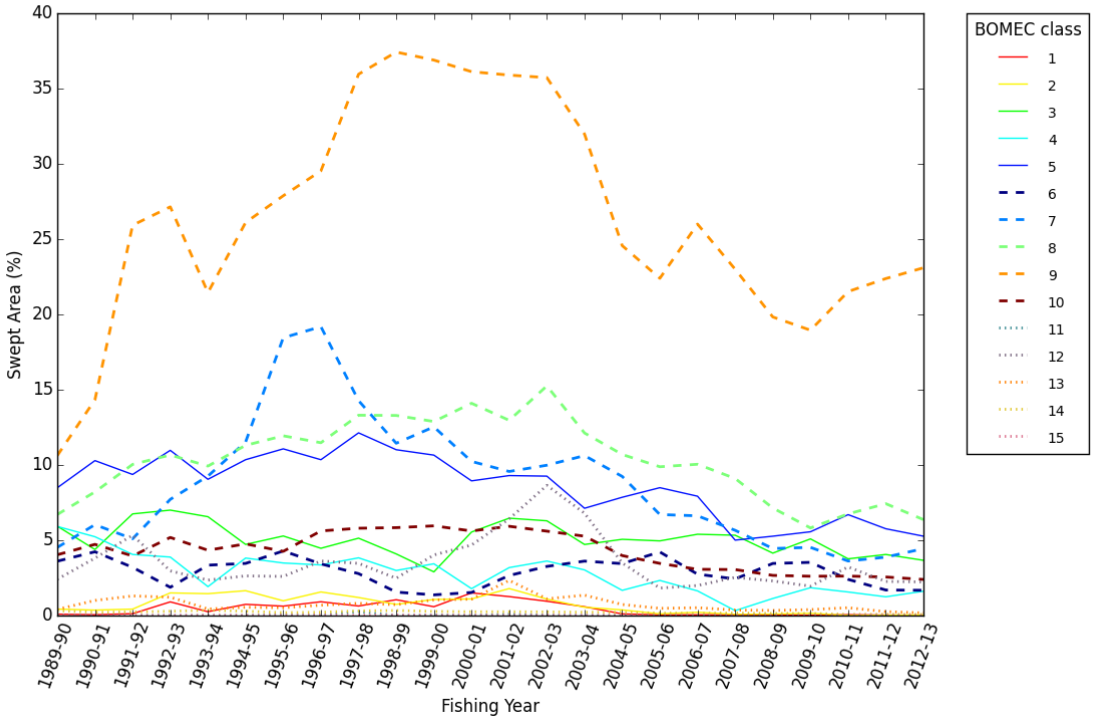

Figure 34: Swept area for trawls targeting all tier 1 and tier 2 species in the EEZ and TS (as a percentage of the BOMEC zone) as a function of time (1989/90 to 2012/13).

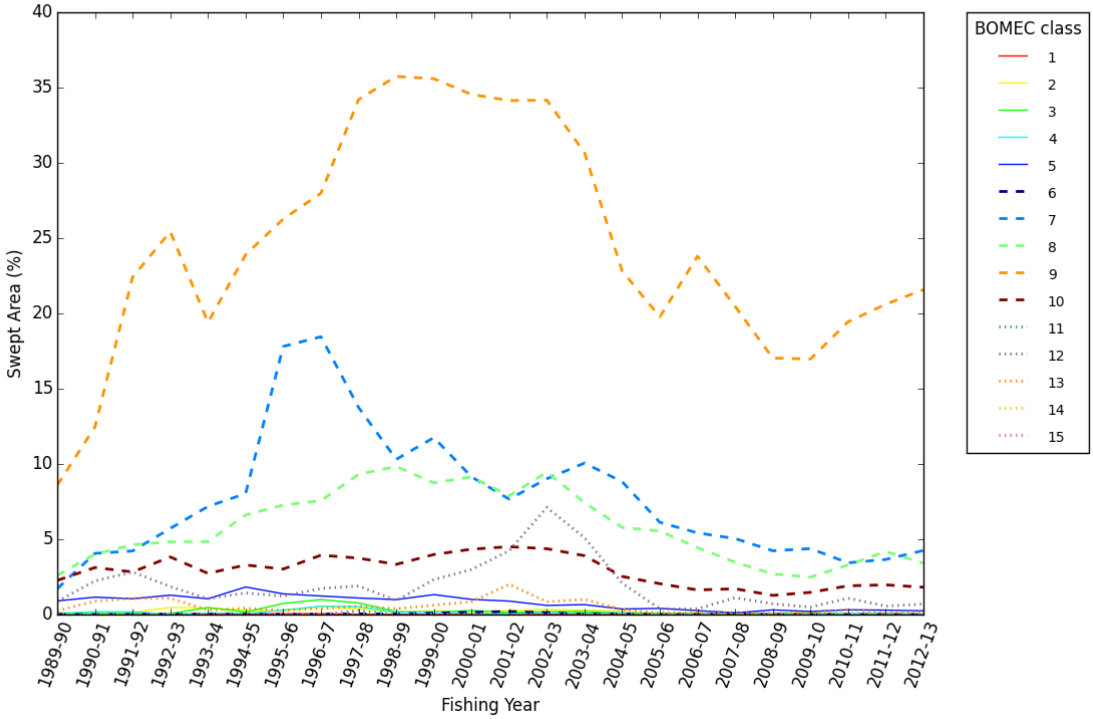

Figure 35: Swept area for trawls targeting hoki in the EEZ and TS (as a percentage of the BOMEC zone) as a function of time (1989/90 to 2012/13).

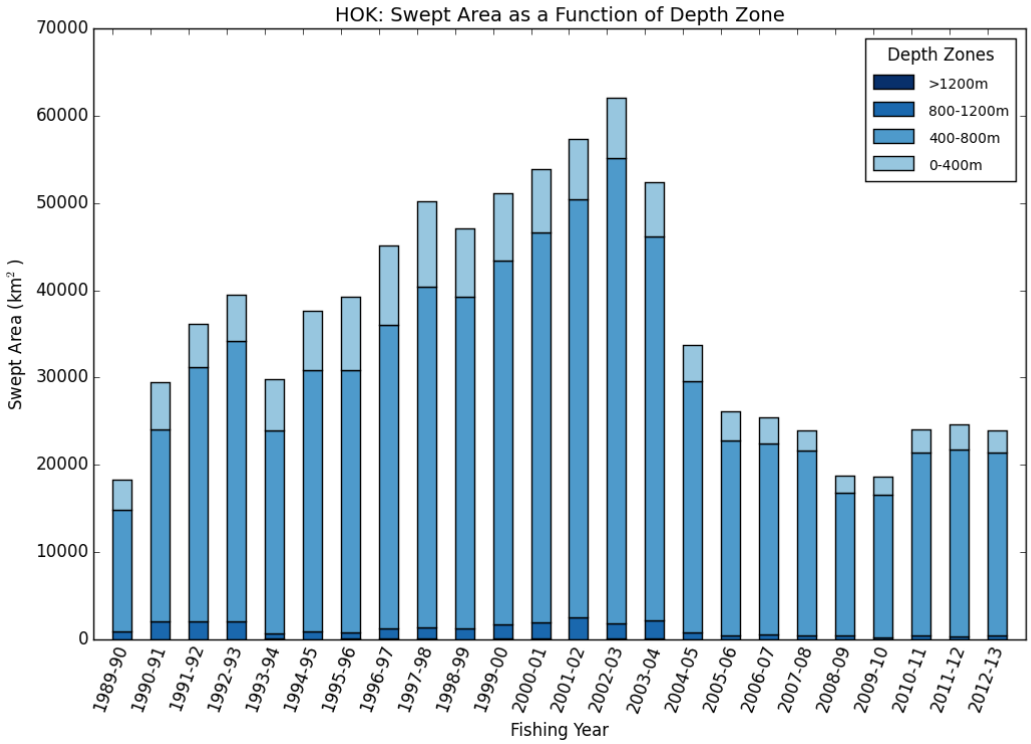

Figure 36: Swept area for trawls targeting hoki in the EEZ and TS (coloured by depth zone) as a function of time (1989/90 to 2012/13).

3.7 Trawl Footprint Analysis - Trends

The edited database has been used to estimate the area of sea floor trawled annually and to estimate what proportion of the most recent year's trawl footprint had previously been trawled (Figure 9). This shows that there has been a gradual decrease in the area of seafloor trawled that had not previously been trawled. In 2011/12 and 2012/13 only 2169 km^2 and 1720 km^2 respectively of seafloor was trawled that had previously been untouched.

Much of the sea floor that was swept for the first time in 2011/12 and 2012/13 comprises many small patches of sea floor across much of the existing trawl footprint (for example, Figure 37). Many of these are infilling areas surrounded by grounds that have already seen much trawl effort, and the newly swept area is 'filling in the gaps' and may represent very little actual new area due to the inaccuracies in knowing the exact position of the trawl gear (see Methods section).

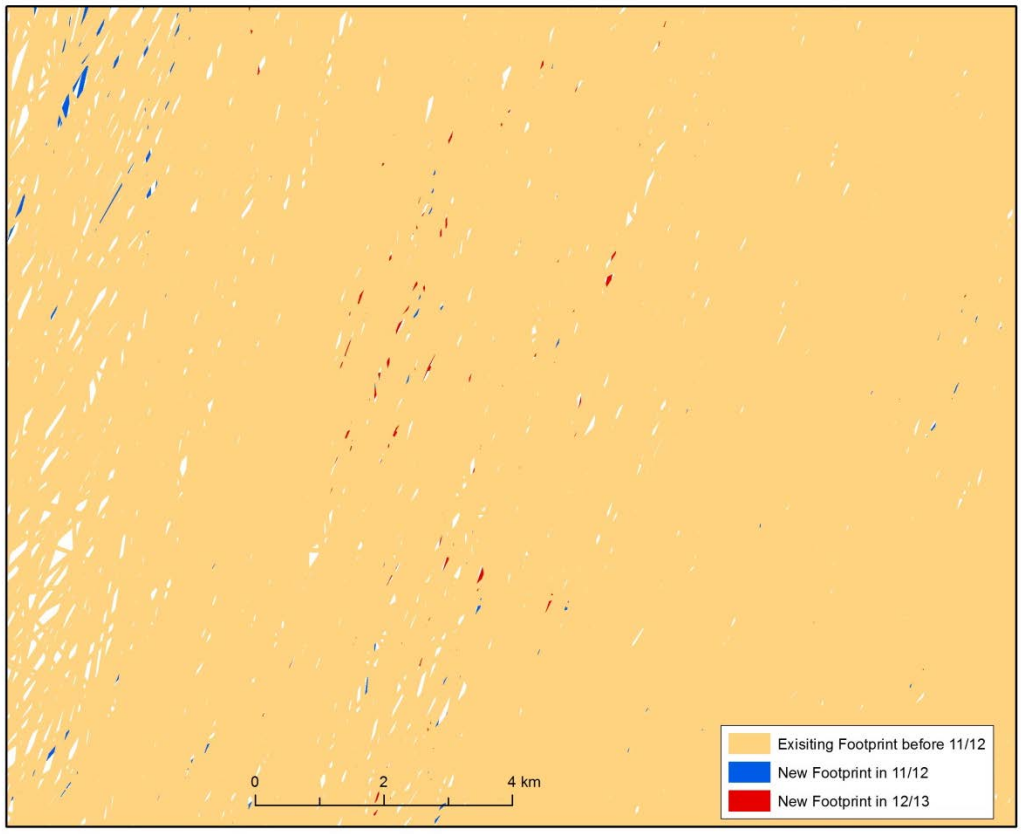

Figure 37: An area off Taranaki showing the common spatial distribution of seafloor trawled for the first time in 2011/12 (blue) and 2012/13 (red). Seafloor that was first trawled before 2011/12 is also shown (pale orange).

There are a few regions where newly swept area represents an extension of the fishing grounds and more than just the filling in of small spaces between trawls. An example is the Campbell Plateau region (Figure 38), where in both 2011/12 and 2012/13 there were trawls targeted at southern blue whiting, in an area that previously had been only sparsely trawled.

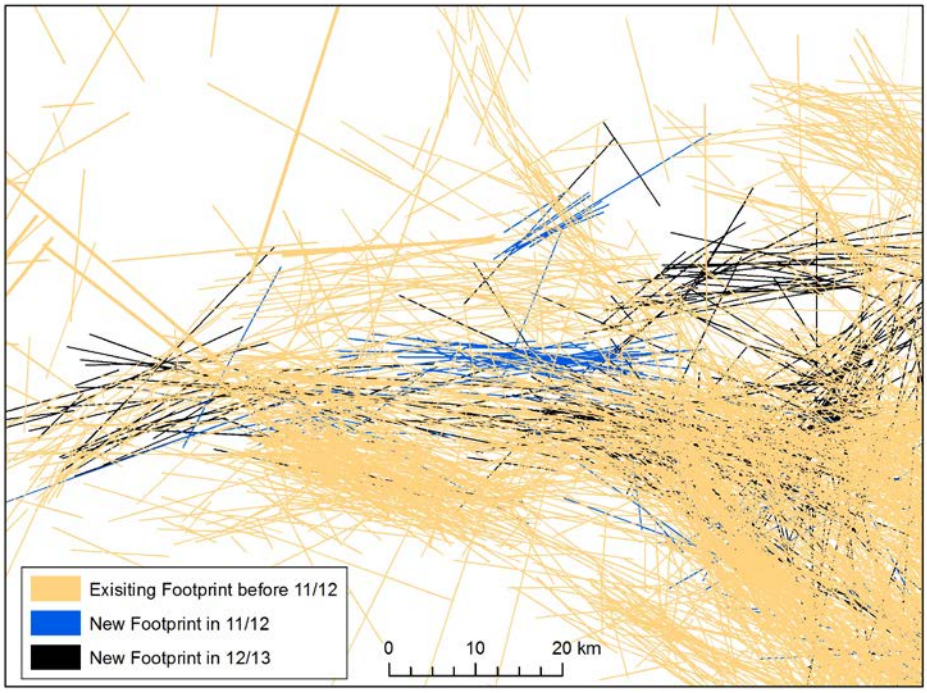

Figure 38: A region on the Campbell Plateau showing a shift in trawl effort during 2011/12 (blue) and 2012/13 (black) into an area that was previously only sparsely trawled.

Black & Tilney (2015) reported on a region on the southern flank of the Chatham Rise with a small cluster of trawls targeting oreo in 2010/11 in a previously untrawled area. Further trawls have occurred in this region in 2011/12 and 2012/13, but these generate only small additions to the trawl footprint here (Figure 39).

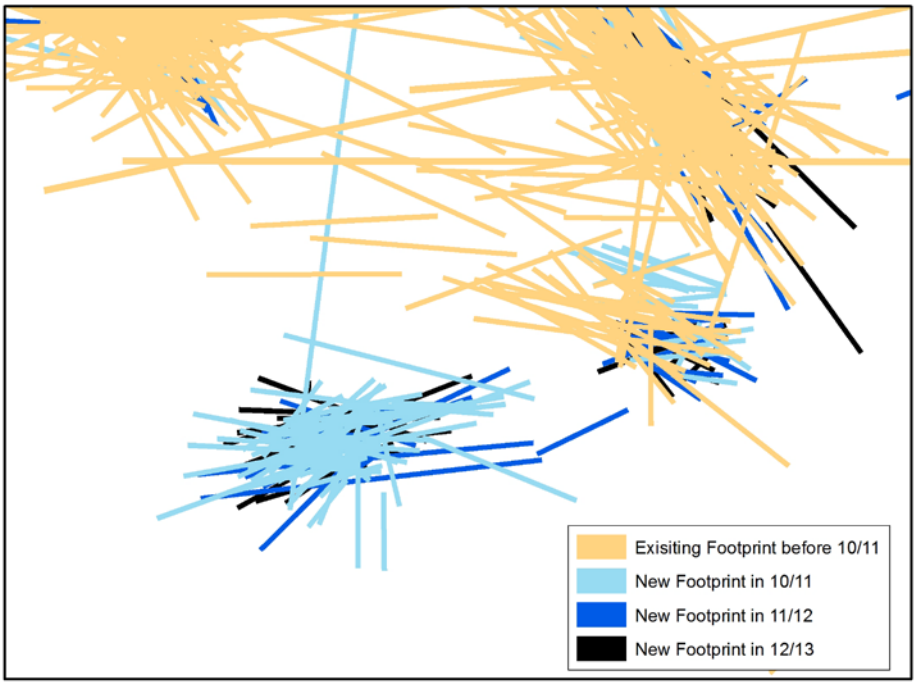

Figure 39: A region on the southern flank of the Chatham Rise showing recent trawls on features that were unswept during the period 1989/90 to 2009/10.

Seafloor trawled for the first time in 2011/12 and 2012/13 can be further analysed to examine the breakdown by target species (Table 12, Table 13). These statistics need to be interpreted with caution as some of the area will be filling in of small spaces (as seen for example in, Figure 37) and may not actually represent newly trawled seafloor. The target species that have contributed most to the newly swept area are southern blue whiting and hoki. Trawls targeting hoki represent 18% of the newly swept area in 2011/12 and 27% in 2012/13; trawls targeting southern blue whiting represent 25% and 18% of the newly swept area in 2011/12 and 2012/13 respectively.

Table 12: The breakdown of area that has been trawled for the first time in 2011/12 for key target species.

Target species	Newly swept area 2011/12 (km^2)	Newly swept area 2011/12 as a % of total newly swept area	Swept area (km^2)	Newly swept area 2011/12 as a % of swept area
BAR	169	8%	1 947	9%
HAK	46	2%	1 008	5%
HOK	388	18%	24 682	2%
JMA	194	9%	4 330	4%
LIN	46	2%	517	9%
OEO	114	5%	678	17%
ORH	152	7%	839	18%
SBW	536	25%	1 033	52%
SCI	161	7%	4 816	3%
SQU	94	4%	4 037	2%
SWA	188	9%	1 539	12%

Table 13: The breakdown of area that has been trawled for the first time in 2012/13 for key target species.

Target species	Newly swept area 2012/13 (km^2)	Newly swept area 2012/13 as a % of total newly swept area	Swept area (km^2)	Newly swept area 2012/13 as a % of swept area
BAR	96	6%	1 721	6%
HAK	18	1%	841	2%
HOK	460	27%	23 916	2%
JMA	202	12%	4 025	5%
LIN	38	2%	411	9%
OEO	83	5%	541	15%
ORH	97	6%	863	11%
SBW	306	18%	840	36%
SCI	204	12%	4 609	4%
SQU	78	5%	3 322	2%
SWA	51	3%	1 582	3%

The newly trawled area can also be compared against the swept area (new or otherwise) for each target species in this year. This analysis shows that over 50% of the swept area in 2011/12 for trawls targeting southern blue whiting was in areas of sea floor that had not previously seen trawling for any species, this dropped to 36% in 2012/13. In 2012/13, 15%, and in 2011/12 17%, of the swept area for trawls targeting oreo was in new areas of sea floor. For trawls

targeting orange roughy, 11% in 2012/13 and 18% in 2011/12 of the swept area was in new areas (Table 12 and Table 13).

The total number of 25 km^2 cells in the fishable region is 164 823 and the number of fished cells is 38 516. The frequency-based analysis can be used to determine how many years it has been since each cell was last trawled. When all tier 1 and tier 2 species are considered, it is evident that 12 035 of the trawled cells (31%) were trawled within the last two fishing years (Figure 40, Figure 41). However, there are some regions where no recorded trawls have occurred in the last 10 years (e.g. on the Campbell and Challenger Plateaus). Some regions to the east of Pukaki Rise have not been trawled for considerably longer.

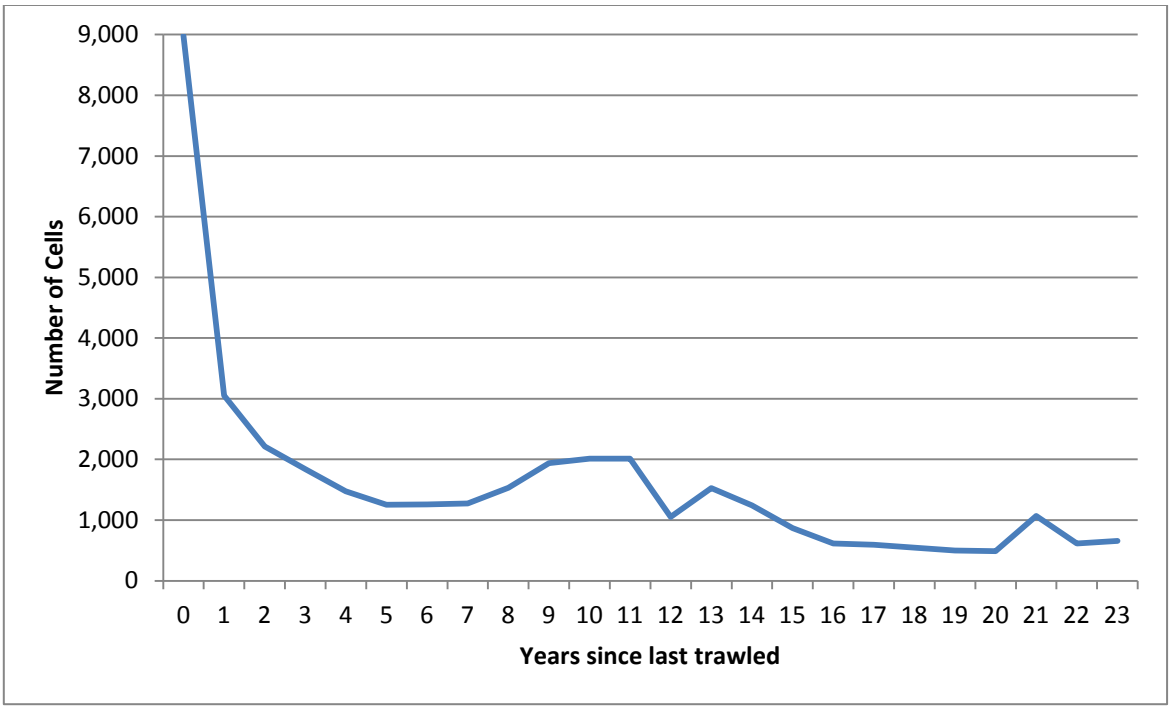

Figure 40: Number of years since 2012/13 that each cell was last trawled, for all tier 1 and tier 2 species for the period 1989/90 to 2012/13 in the EEZ and TS.

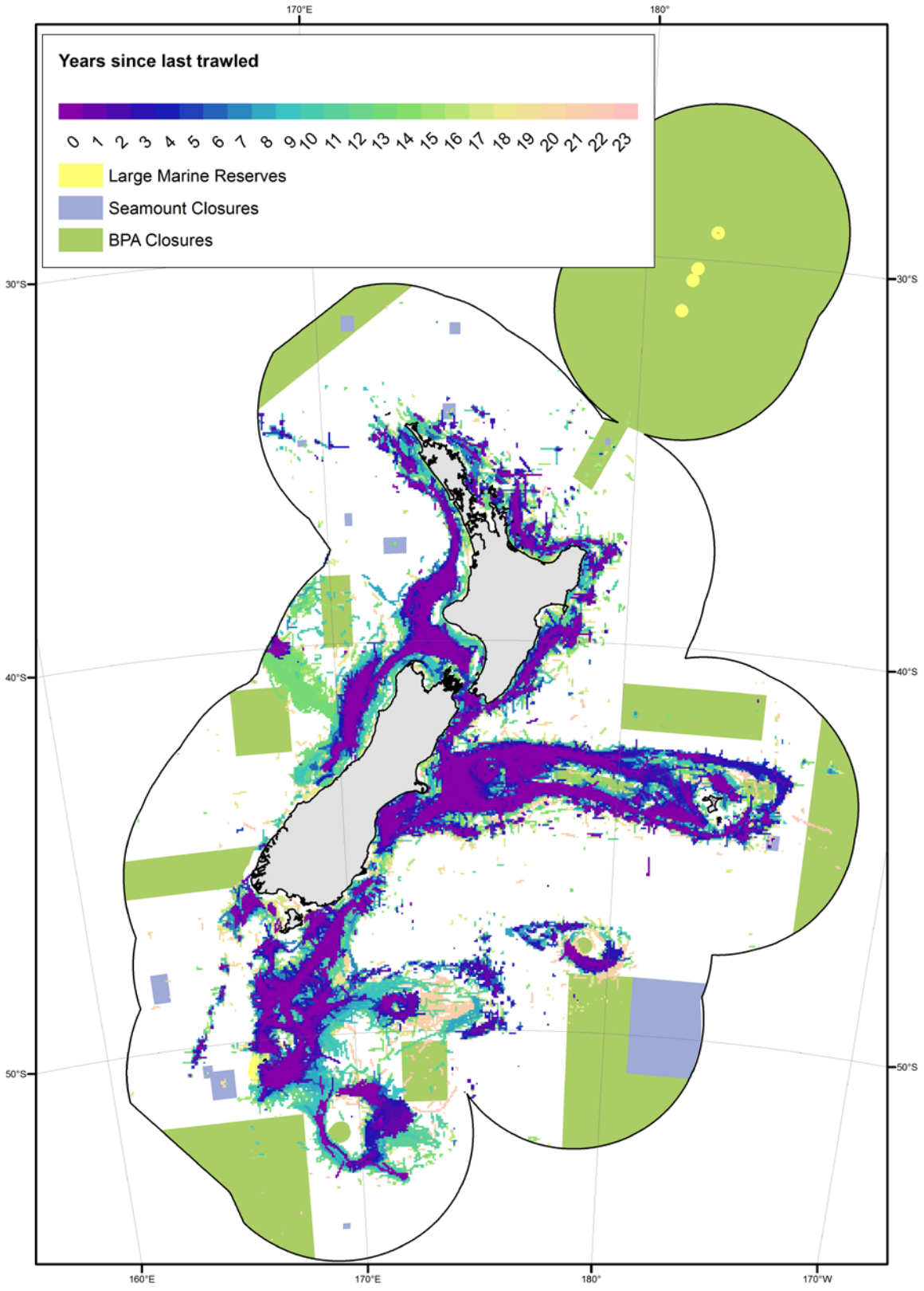

Figure 41: The number of years since 2012/13 that each cell was last trawled (for all tier 1 and 2 species). Areas closed to trawling are also shown.

This analysis has also been carried out on individual key target species to investigate how many years since each cell was last trawled for that species. For example, for trawls targeting hoki, the trawl footprint appears to have become more focused over the years. There are significant areas on the Campbell Plateau that appear not to have been fished in the last decade (Figure 42). There are similar areas on the north-eastern and central Chatham Rise.

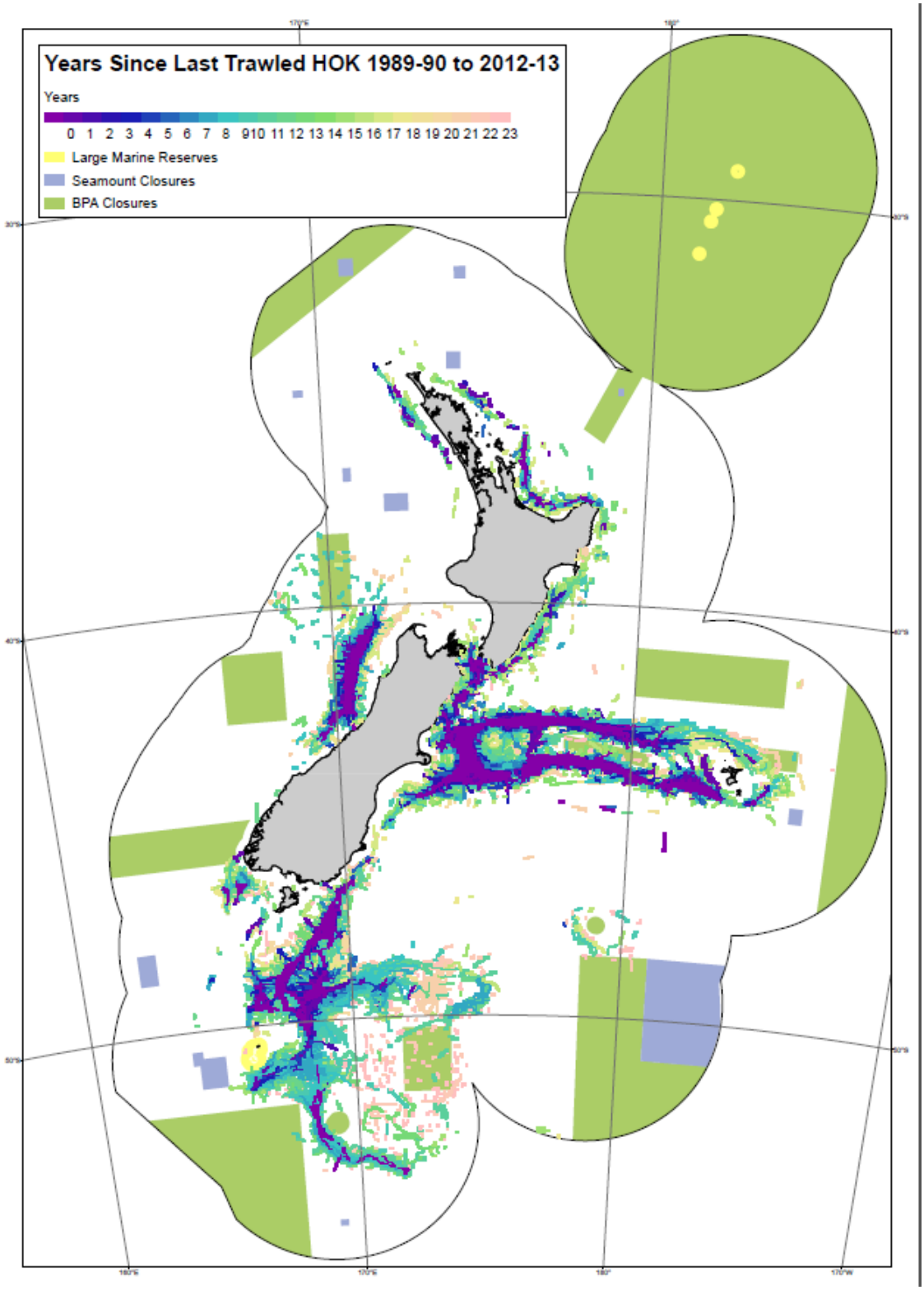

Figure 42: The number of years since 2012/13 that each cell has last been trawled by trawls targeting hoki. Areas closed to trawling are also shown.

Plots showing the number of years since cells were last trawled by trawls targeting each key species are in Appendix 2:

- Plots are in files <species id><year>_yearssince_fig.pdf, e.g. barracouta data for the 1989/90 to 2012/13 fishing years are in BAR2013_yearssince_fig.pdf.
- See file README.doc in Appendix 2 for more information.

Results are provided for the entire periods (1989/90 to 2011/12 and 1989/90 to 2012/13).

4. DISCUSSION

This work is a continuation of projects DAE 2010-04A and DAE 2010-04B (Black et al. 2013, Black & Tilney 2015), which involved analyses of all TCEPR data from 1989/90 to 2009/10 and from 1989/90 to 2010/11 respectively. The current analyses are not all directly comparable with those from the above reports because some different species groupings are involved. DAE 2010-04A and DAE 2010-04B analysed: the 11 key target species; the aggregate of 89 "minor" target species, and the aggregate of all species combined. This report includes TCEPR data for deepwater species only, with the following: the 11 key target species (i.e. as before); the aggregate of the 11 key target species and 17 tier 2 species (t1t2 species). A total of 72 "minor" target species are now excluded from the analysis.

In order to ensure comparability of outputs over all years, the trawl footprint analyses (i.e. swept area and trawl frequency by depth zone, BOMEC zone and preferred habitat area), have been revised for each year from 1989/90 through to 2012/13 for the new t1t2 species grouping.

Of the "minor" species now excluded from the study, the majority (97%) of tows were targeted at snapper, tarakihi, trevally, gurnard, red cod and john dory, which are regarded as inshore species. A trawl footprint analysis undertaken for inshore species by Baird et al. (2014), for the years 2007/08 to 2011/12, includes these species.

While the analyses were conducted for 11 key deepwater species/species groups (BAR, HAK, HOK, JMA, LIN, OEO, ORH, SBW, SCI, SQU and SWA) and for the aggregate of the tier 1 and tier 2 deepwater species (resulting in 600 pages of spreadsheets and figures, provided separately on DVD), only a few examples of these are provided in the report, to illustrate the nature of the information generated and provide insights into some of the observed trends.

The overall swept area estimate for the period 1989/90 to 2011/12 of 345 570 km^2 was exceeded during the period 1989/90 to 2012/13 by 1720 km^2, an increase of less than 1%.

For the grouping of 11 key target species: swept areas, numbers of 5×5 km^2 cells trawled, and numbers of trawls, have shown declines of between 6% and 8% over the most recent three years of analyses (2010/11 to 2012/13), Figure 43.

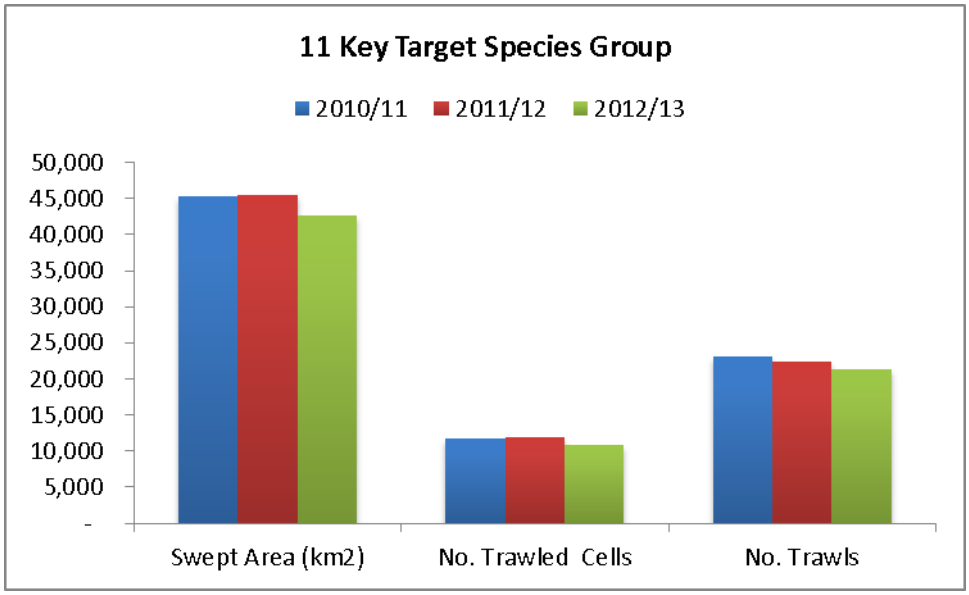

Figure 43: Variation in catch, swept area, number of trawled cells and number of trawls for the 11 key target species over the most recent three-year period 2010/11 to 2012/13.

For individual key target species the hoki fishery has the greatest swept area, number of trawled cells and number of trawls, while the scampi and squid fisheries are characterised by very high trawl frequencies, indicative of concentrated effort (Figure 44).

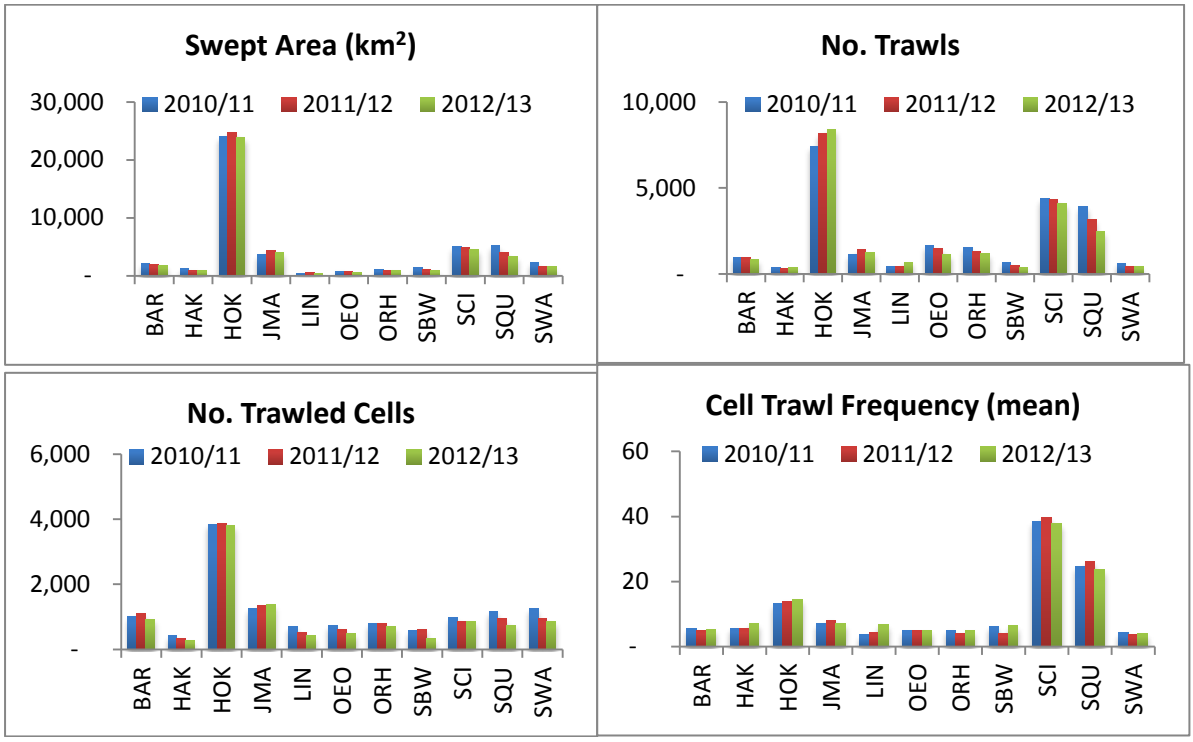

Figure 44: Variation in catch, swept area, number of trawled cells and number of trawls for each of the 11 key target species over the most recent three-year period 2010/11 to 2012/13.

For all deepwater species combined (t1t2) the swept area declined by 1% over the most recent four-year period, 2009/10 to 2012/13, the number of trawls declined by 16% and the number of 5 × 5 km^2 cells trawled declined by 15% (Figure 45).

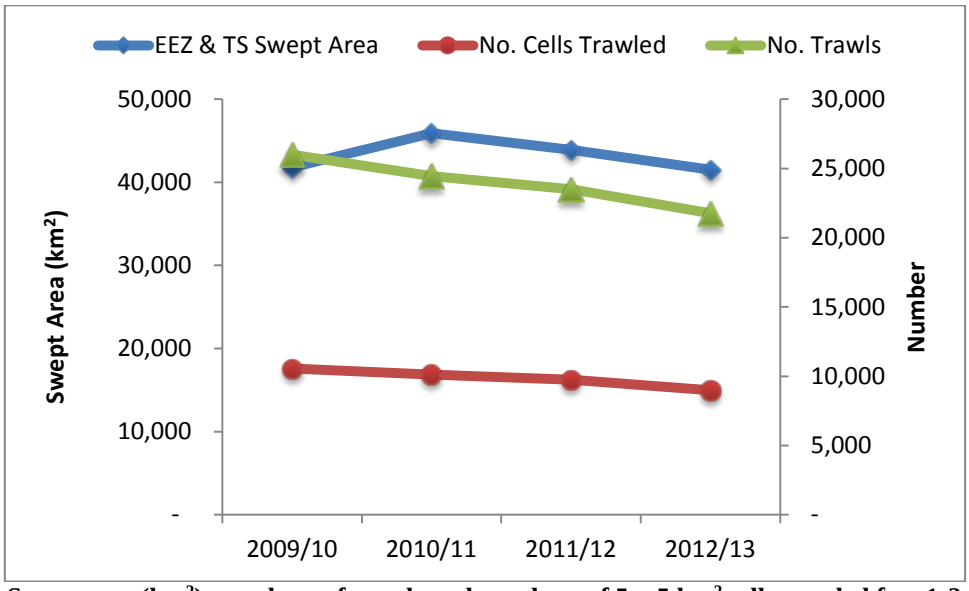

Figure 45: Swept area (km^2), numbers of trawls and numbers of 5 × 5 km^2 cells trawled for t1t2 species for the most recent period, 2009/10 to 2012/13.

For all species combined (t1t2) for the period 2009/10 to 2012/1313 there was little change in the percentage swept area in the deeper than 1200 m depth zone. In each of the 0–400 m and 800–1200 m depth zones there were decreases of 0.6 and 0.4 percentage points respectively. In the 400–800 m depth zone there was a 1 percentage point increase. The number of trawls in the EEZ and TS has decreased in each year since 2009/10.

The mean frequency of tows per fished 5 × 5 km cell remained steady at 15 tows in 2010/11, 2011/12 and 2012/13. The areas with the highest trawl frequencies per cell occur south-east of Stewart Island, on the western Chatham Rise, and in a small area off the west coast of the South Island in the Hokitika Canyon.

Analysis of swept area by BOMEC class for the recent period 2009/10 to 2012/13 revealed slight decreases in proportional swept area for BOMEC classes 3 and 6. BOMEC class 9 was the only class showing a noticeable increase, of 4 percentage points. The remaining BOMEC classes showed changes of less than 1 percentage point. BOMEC 9 is closely associated with the hoki-targeted fisheries, for which there was an 11 000 t catch increase from 2010/11 to 2011/12 for the western hoki stock, for which BOMEC 9 in the Southland area is an important fishing ground. The mean frequency of trawls within trawled cells during this period decreased by more than 1 in BOMEC 3, 6 and 13 and increased by more than 1 in each of BOMEC 7, 10 and 12. The numbers of cells contacted by trawls during this period decreased by between 1 and 6 percentage points in BOMEC classes 1, 2, 3, 5, 6, 8, 10, 12, 13 and 14, and increased in BOMEC 7 and 9 by 3.5 and 0.5 percentage points respectively. Both of the increases are likely to have been driven by the hoki fishery, in Cook Strait (BOMEC 7) and on the western Chatham Rise (BOMEC 9).

5. MANAGEMENT IMPLICATIONS

The 24-year database now available for interrogation by scientists and fisheries managers provides a powerful tool for monitoring trawl fishing trends in terms of both the scale of the trawl footprint (swept area), and the intensity of trawling (cumulative swept area) by depth zone, BOMEC zone, preferred habitat area and by 5 × 5 km^2 cell.

The database also provides a useful tool for predicting the consequences of fishery management decisions on benthic habitats (e.g. relating to TACC/catch limit adjustments, vessel and gear parameters, area closures etc.).

Monitoring areal changes in the trawl footprint for individual species over time can also be used, by proxy, to reveal trends in the distribution behaviour of fish stocks, and offers the potential to establish links between distribution shifts and environmental phenomena such as El Niño/La Niña cycles and climate change.

The database provides an important source of information for directing studies aimed at investigating and evaluating the effects of varying levels of trawling intensity on benthic ecosystem structure and function (for example: Baird et al. 2014, Bowden et al. 2014, Tuck et al. 2014). The cumulative swept area and frequency of trawling information, at a scale of 5 × 5 km, provides opportunities for studies aimed at ground-truthing the effects of trawling on deepwater benthic communities, while the 'new areas' trawled information provides insights into the scale of fishery expansion into previously untrawled areas. This kind of information is becoming important as fisheries management moves increasingly towards ecosystem approaches, and for the certification of fisheries as being environmentally sustainable (e.g. Marine Stewardship Council certification).

These analyses of trawl footprint for New Zealand's deepwater fisheries have demonstrated declining swept area and trawling frequency trends for most fisheries and areas over the recent four-year period (2009/10 to 2012/13). Where there have been increases they have been shown to be slight.

6. ACKNOWLEDGEMENTS

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APPENDIX 1 - SPECIES NOT INCLUDED IN THE ANALYSIS

There are some species that are reported on the TCEPR, but that are not tier 1 or tier 2 species and therefore have not been included in the analysis. The following table lists all species that were not included in the analysis, but that passed the other tests.

Count	Reporting Code	Common Name	Target Tows	Percentage of Total Target Tows
1	SNA	Snapper	77 620	6.47%
2	TAR	Tarakihi	53 926	4.49%
3	TRE	Trevally	41 741	3.48%
4	GUR	Gurnard	18 450	1.54%
5	RCO	Red cod	17 635	1.47%
6	JDO	John dory	16 960	1.41%
7	WAR	Blue warehou	3 916	0.33%
8	WWA	White warehou	3 194	0.27%
9	BNS	Bluenose	1 969	0.16%
10	STA	Stargazer	1 819	0.15%
11	FLA	Flatfish	895	0.07%
12	ELE	Elephant fish	382	0.03%
13	LEA	Leatherjacket	279	0.02%
14	SCH	School shark	266	0.02%
15	MOK	Blue moki	104	0.01%
16	SSK	Smooth skate	95	0.01%
17	BCO	Blue cod	55	<0.01%
18	RSK	Rough skate	43	<0.01%
19	MDO	Mirror dory	41	<0.01%
20	PRA	Prawn	35	<0.01%
21	SBO	Southern boarfish	33	<0.01%
22	SOR	Spiky Oreo	33	<0.01%
23	TRU	Trumpeter	32	<0.01%
24	SKA	Skate	31	<0.01%
25	PTO	Patagonian toothfish	30	<0.01%
26	SFL	Sand flounder	29	<0.01%
27	SPO	Rig	23	<0.01%
28	SDO	Silver dory	22	<0.01%
29	SCO	Swollenhead conger	21	<0.01%
30	OPE	Orange perch	19	<0.01%
31	HPB	Hapuku and bass	18	<0.01%
32	MIX	Mixed fish	17	<0.01%
33	HOR	Horse mussel	15	<0.01%
34	THR	Thresher shark	14	<0.01%
35	KAH	Kahawai	13	<0.01%
36	BOA	Sowfish	9	<0.01%
37	RSN	Red snapper	9	<0.01%
38	JAV	Javelin fish	6	<0.01%
39	ASP	Tam 'O Shanter urchin	5	<0.01%
40	HAP	Hapuku	5	<0.01%
41	RAT	Rattail	5	<0.01%
42	RBM	Rays bream	5	<0.01%
43	SSP	Scallop spat	5	<0.01%
44	TRA	Roughies	5	<0.01%

Count	Reporting Code	Common Name	Target Tows	Percentage of Total Target Tows
45	BWS	Blue shark	4	<0.01%
46	ESO	New Zealand sole	4	<0.01%
47	LSO	Lemon sole	4	<0.01%
48	BAS	Bass groper	3	<0.01%
49	BAT	Large headed slickhead	3	<0.01%
50	FIS	Unknown	3	<0.01%
51	GFL	Greenback flounder	3	<0.01%
52	SND	Shovelnose spiny dogfish	3	<0.01%
53	BRA	Short-tailed black ray	2	<0.01%
54	MAK	Mako shark	2	<0.01%
55	ROC	Rock cod	2	<0.01%
56	SAU	Saury	2	<0.01%
57	SCA	Scallop	2	<0.01%
58	SKJ	Skipjack	2	<0.01%
59	SNS	Sunset	2	<0.01%
60	SSI	Silverside	2	<0.01%
61	BFL	Black flounder	1	<0.01%
62	HOL	Tubeshoulder	1	<0.01%
63	JGU	Japanese gurnard	1	<0.01%
64	MTP	Myctophum spp.	1	<0.01%
65	OSD	Smooth dog shark	1	<0.01%
66	SCC	Sea cucumber	1	<0.01%
67	SCL	Scales	1	<0.01%
68	SPF	Scarlet wrasse	1	<0.01%
69	SQI	Squirrelfish	1	<0.01%
70	SWO	Swordfish	1	<0.01%
71	TRG	Triggerfish	1	<0.01%
72	YEM	Yellow-eyed mullet	1	<0.01%
	Total of not included tows		**239 884**	**19.99%**
	Total all (included and not included) tows		**1 200 175**	**100.00%**

APPENDIX 2 COMPILATION OF SPREADSHEETS AND FIGURES

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