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Extent of bottom contact by New Zealand commercial trawl fishing for deepwater Tier 1 and Tier 2 target species determined using CatchMapper software, fishing years 2008–17

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EXECUTIVE SUMMARY

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The footprint of commercial trawl fishing reported on Trawl Catch Effort Returns (TCERs) and Trawl Catch Effort and Processing Returns (TCEPRs) was generated for bottom-contacting effort that targeted deepwater Tier 1 and Tier 2 fishstocks in the Territorial Sea and 200 n. mile Exclusive Economic Zone (TS+EEZ). The analysis included data for the fishing years 2008–17, where the 2008 fishing year, for example, is defined as the time period between 1 October 2007 and 30 September 2008. The methodology used was based on previous work completed over the last 15 fishing years, but the analysis and spatial output was completed using the Ministry for Primary Industries in-house CatchMapper tool.

The footprint analysis included 283 100 bottom-contacting tows reported during 2008–17. The extent of the bottom-contacting trawl footprint for the 10 fishing years was 180 100 km^2, equivalent to 4.4% of the total TS+EEZ seafloor area, 13.0% of the 'fishable' seafloor area open to bottom-contacting trawling in waters shallower than 1600 m, and 11% of seafloor area in 0–1600 m depths. Tier 1 fishstocks contributed to about 87% of the overall footprint, which gave an overlap of 3.8% of the TS+EEZ, 11.4% of the 'fishable' area, and 10% of 0–1600 m depths. During 2008–17, about 1.2% of the TS+EEZ seafloor and 3.6% of the 'fishable' area seafloor was contacted annually. Effort targeting the hoki fishstock produced the greatest swept area each fishing year and this fishery was the only stock to show a steady increase over the 10 fishing years.

The 2008–17 footprint from deepwater Tier 1 and Tier 2 fishstocks showed the highest overlap in 200–400 m and 400–600 m depth zones, at 23% and 22% of the areas of the respective depth zones. Shelf and slope classes B, C, E, G–I of the Benthic-optimised Marine Environment Classification had the highest percentage coverage by the 2008–17 footprint. The total footprint extent of most of the individual Tier 1 fish species was in waters where the probability of capture of the species was at least 80%.

The 2008–17 footprint contacted 26 501 25-km^2 cells. Over the time series, 21% of cells were contacted by one tow, 54% by up to 9 tows, and 94% by up to 200 tows. The annual median number of tows per cell was 3, and 75% of annual cells had 11–15 tows, with a maximum range of 418–576 tows per cell. This contact represented an annual median percentage coverage range of 1.2–1.5 km^2, and 75% of annual cells had coverage of no more than 5.7 km^2. The areas where the intensity was highest included waters where the main scampi, hoki, and arrow squid fisheries operated.

About 25% of the cells were contacted in only one fishing year and 17% were contacted in each fishing year. The number of cells contacted each fishing year decreased from about 14 000 in 2008 to about 12 000 during 2014–17. The percentage of cells contacted in a fishing year, but not the previous two fishing years, increased over the time series from 15% in 2013 to 25% in 2017.

For the 10-y time period, the number of annual cells that were contacted in one fishing year, but not in the previous fishing years, ranged from 932 cells in 2013 (relative to 2008–12 fishing years) to a peak of 1053 cells (relative to 2008–14) before dropping to 662 cells in 2017 (relative to 2008–16). The main targets for this extension of effort were hoki, orange roughy, scampi, southern blue whiting and barracouta. About 455 km^2 of the 2017 footprint (from 15 targets) was in cells that had not been contacted in the previous nine fishing years. Other than cells at the extremity of previous effort, this 'new' contact area indicated extension of hoki effort in the main fisheries including the Southern Plateau and of orange roughy effort on the Challenger Plateau. Some of these areas were contacted by the 1990–2016 footprint, and thus were trawled prior to 2008.

A comparison between the 1990–2016 and the 2008–16 (CatchMapper version) deepwater target footprints suggested that there were more data available in the more recent series. The CatchMapper tool was readily adapted to analyse the effort data and enabled provision of a comparable footprint to those produced previously. Further development of this work could include: better characterisation of the fleets, based on vessel size, target, and gear to provide an improved basis for the estimation of swept area; improved assignment of doorspread values for scampi rigs where the data have null values; and continued use of the TCER trackline generation to provide a comparison with the tracklines developed from the finer scale position data that will be provided through the Electronic Reporting System, as that collection method is introduced.

1. INTRODUCTION

New Zealand's deepwater and middle depths trawl fisheries are ranked into three tiers: Tier 1 are high volume, Quota Management System (QMS) stocks targeted by commercial fishers; Tier 2 are QMS species that are less commercially valuable (typically taken as bycatch) or are only targeted at certain times of the year; and Tier 3 are non-QMS bycatch species (Ministry for Primary Industries 2017). Trawl fishing for the deepwater Tier 1 and Tier 2 fishstocks within the 200 n. mile New Zealand Exclusive Economic Zone (EEZ) includes the use of bottom-contacting trawl gears, that is bottom trawls and midwater trawls used within a metre of the seafloor. Masters of trawl vessels operating these gears are required to fill out Trawl Catch Effort and Processing Returns (TCEPRs) if the vessel is over 28 m in overall length or if the vessel is required by the Director-General of Fisheries to furnish a TCEPR (as required by the Fisheries (Reporting) Regulations 1990). These returns usually relate to trawl operations undertaken at depths greater than 200 m. However, masters of smaller trawl vessels (less than 28 m in length that generally fish shallow, inshore waters) may also report effort on TCEPRs (see Baird et al. 2011) and, since October 2007, on Trawl Catch Effort Returns (TCERs) – the forms that replaced the Catch Effort Landing Returns previously used to report catch and effort from small inshore trawlers.

The data collected on the TCER and TCEPR forms are used to generate annual trawl footprints that represent the area of the seafloor contacted by trawl gear. Assessment of the annual trawl footprint is a monitoring requirement for Deepwater Fisheries Management Objective 7: *Manage deepwater and middle-depth fisheries to avoid, remedy or mitigate the impacts of deepwater fisheries on the benthic habitat* (Ministry for Primary Industries 2017). Previously, trawl footprints have been determined using, where available, TCEPR and TCER data extracted from the Ministry for Primary Industries (MPI) database *warehou* (see for example, Baird et al. 2011, Black et al. 2013, Baird et al. 2015, and Baird & Wood 2018), generally for fishing years since 1989–90. Discussions on the data and methodology development and implications are given by Baird et al. (2011) and Baird & Wood (2018).

This work is the first use of the CatchMapper tool, developed by MPI, to generate the bottom-contacting trawl footprint. This tool was developed to map the commercial catch reported by commercial fishers to forecast the quantity of displaced fishing activity (Osborne 2018). Effort, catch, and landings data are aggregated into gear-species clusters based on Statistical Areas and depth to provide a spatial distribution. The data used by CatchMapper were extracted from the MPI Enterprise Data Warehouse (EDW) database. These data differ from the data previously used for trawl footprint work (extracted from MPI database *warehou*) having been subject to certain enhancements including linking of catch and effort data to generate the correct fishing year for the species or fishstocks and superior spatial querying to better map the position data to Statistical Areas. These EDW data are comprised of data from the Numeric Data Warehouse database (NDW) and have fewer null values for some variables such as 'trip', 'target species', and 'Statistical Area' (MPI Data Warehousing group, pers. comm.). In recent years, electronic data have been included in the EDW database and this allows the capture of higher resolution position data.

Whilst this work uses the CatchMapper tool, the trawl effort data were extracted as a separate dataset to include all trawl data reported on TCEPR and TCER data in EDW for the fishing years (1 October to 30 September) 2007–08 to 2016–17 (hereafter referred to as 2008–17). These data were subjected to the same grooming rules applied to earlier versions of the trawl footprint referenced above, and a subset was further groomed to provide the swept area data used to create the Tier 1 and Tier 2 footprints.

Under the overall BEN2017-01 project objective that aims to monitor the "footprint" of trawl fishing for deepwater species on or near the seabed, this report addresses the specific Objective 1:

> "*to help MPI groom data, develop summary statistics, for Tier 1 deepwater fisheries and the aggregate of all Tier 1 and Tier 2 deepwater fisheries, of the extent and frequency of fishing by year, by depth zone, by fishable area, and by predicted BOMEC habitat class, and to identify any trends or changes to meet management needs"*.

The initial requirement for Objective 1 was to transfer knowledge and methods used in previous trawl footprint projects for commercial bottom-contacting trawl effort data reported on TCEPR and TCER to

enable the MPI Spatial Intelligence team to generate the following specified outputs using the MPI CatchMapper software (Osborne 2018).

1. Annual footprints for each Tier 1 target species and for the combined Tier 1 and Tier 2 target species, for 2008–17, for waters within the combined area of the 200 n.mile New Zealand EEZ and the 12 n. mile Territorial Sea.
2. Footprints for all years combined for each Tier 1 target and the combined Tier 1 and Tier 2 targets.
3. Overlap of the above footprints on 200-m depth zones from 0 to 1600 m; the 15-class Benthic-optimised Marine Environment Classification (BOMEC) generated by Leathwick et al. (2012); 'fishable' area – waters open to trawling down to 1600 m; and 'preferred habitat' of Tier 1 target species. For the latter, Geographic Information Systems (GIS) layers that represent the predicted distribution of the probability of capture of each of the seven Tier 1 fish species (after Leathwick et al. 2006) and the annual distribution of arrow squid (*Nototodarus sloani*, *N. gouldi*) and scampi (*Metanephrops challengeri*) (www.nabis.govt.nz);
4. The intensity of contact and the years since the last bottom contact for the Tier 1 and Tier 2 targets combined.

This report provides the methods and results for Objective 1, with associated appendices to present the underlying data and the final output. The first section describes the data sources (including the trawl data and GIS layers used subsequently for footprint overlays) and the general methodology used to groom the data. The second section summarises the relevant tow-by-tow TCER and TCEPR data, the methodology used to generate the spatial output, and the underlying assumptions. The third section presents the results of these spatial analyses, including the aggregated trawl swept area (the sum of the estimated swept areas) and the footprint swept area. The fourth section provides summaries of the overlap of each data layer as required above, and the last section provides a brief discussion of data quality, methods, and management implications, with recommendations for future work.

Objective 2 under this project is:

> "*to ensure provision of specific MSC footprint and statistics for: (a) combined target HAK/HOK/LIN trawl footprint; and (b) target ORH/OEO footprint by specific ORH areas — including out of zone Westpac Bank"*.

This second objective addresses Marine Stewardship Council (MSC) certification requirements and is reported on in Appendix D of this report.

Objective 3 is "*to update the Benthic Impacts chapter of the Aquatic Environment and Biodiversity Annual Review"*, which is detailed in the 2018 version of that document.

2. METHODS

The methods below describe the data exploration and grooming and the preparation for spatial analysis. These methods build on those developed and described by Baird et al. (2011), Black et al. (2013), and Baird & Wood (2018) for TCEPR data and Baird et al. (2015) and Baird & Wood (2018) for TCER data. For the purposes of this study, the EEZ and the Territorial Sea form the full extent of the maritime area around New Zealand as the analysis area; and the two EEZ enclaves (one on the Chatham Rise and one on the Southern Plateau, see https://www.linz.govt.nz/sea/nautical-information/maritime-boundaries) are also included as waters available for fishing (total area of analysis is 4 111 569 km^2). Much of this is at depths that have not been exploited by fishing activity. Bottom-contacting trawling has been conducted mainly in continental shelf waters in depths defined by the distribution of target species, generally in waters shallower than 1600 m (Baird & Wood 2018).

2.1 Fishery data sources

The MPI Spatial Intelligence team accessed all TCEPR and TCER effort data from the EDW for 2008–17. Data required for this work included variables that describe each fishing event, such as position, depth, date and time, gear type, form type, target species, duration, tow speed, and vessel specifications.

Data collected on TCEPRs provided information about each fishing operation, with tow-by-tow records of latitude, longitude, gear depth, bottom depth, and date-time for the start and end of each tow, target species, tow duration, towing speed, and gear parameters. The TCERs provided similar tow-by-tow data but have position information for the start of the tow only which necessitates the generation of an endpoint to provide a tow trackline for spatial analysis (see Baird et al. 2015).

2.2 Fishery data grooming and treatment

A summary of the grooming of main variables and the final dataset is presented in Appendix A. Broad queries on all bottom and midwater trawl data were run by the MPI Spatial Intelligence team using R statistical package (R Core Development Team 2017) to isolate duplicates or missing data, following the same data treatment and grooming process used by Baird & Wood (2018). The EDW data for 2008–17 fishing years were generally cleaner than the data from *warehou* (which covered 1990–2016 fishing years), with fewer typographical errors and incorrect or missing values. The annual datasets appeared to have more tows than were present in the data extracted from *warehou* for comparable years (see Appendix A): this may reflect the tidier nature of the EDW data. The emphasis was on the Tier 1 and Tier 2 deepwater target species fishstocks (Fisheries New Zealand 2018), listed below in Table 1.

Table 1: Tier 1 and Tier 2 deepwater fishstocks for which there was trawl effort during fishing years 2008–17 (see Fisheries New Zealand (2018) for fishstock areas). Note that there was no reported trawl effort during this period for the following deepwater Tier 2 fishstocks: prawn killer (*Ibacus alticrenatus*), Patagonian toothfish (*Dissostichus eleginoides*), or any of the deepwater crab targets.

Code: fishstock	Common name	Scientific name
Tier 1		
HAK: all	Hake	*Merluccius australis*
HOK: all	Hoki	*Macruronus novaezelandiae*
JMA: JMA 3, JMA 7	Jack mackerels	*Trachurus declivis*, *T. murphyi*, *T. novaezealandiae*
LIN: LIN 3–LIN 7	Ling	*Genypterus blacodes*
OEO: all	Oreo species	*Allocyttus niger*, *Neocyttus rhomboidalis, Pseudocyttus maculatus*
ORH: all	Orange roughy	*Hoplostethus atlanticus*
SBW: all	Southern blue whiting	*Micromesistius australis*
SCI: all	Scampi	*Metanephrops challengeri*
SQU: all	Arrow squid	*Nototodarus sloanii*, *N. gouldi*
Tier 2		
BAR: BAR 4, BAR 5, BAR7	Barracouta	*Thyrsites atun*
BYX: all	Alfonsino	*Beryx splendens*, *B. decadactylus*
CDL: all	Black cardinal fish	*Epigonus telescopus*
EMA: EMA 3, EMA 7	Blue mackerel	*Scomber australasicus*
FRO: FRO 3–FRO 9	Frostfish	*Lepidopus caudatus*
GSH: GSH 4–GSH 6	Dark ghost shark	*Hydrolagus novaezelandiae*
LDO: all	Lookdown dory	*Cyttus traversi*
RBT: all	Redbait	*Emmelichthys nitidus*
RBY: all	Rubyfish	*Plagiogeneion rubiginosum*
RIB: RIB 3–RIB8	Ribaldo	*Mora moro*
SKI: SKI 3, SKI 7	Gemfish	*Rexea solandri*
SPD: SPD 4, SPD 5	Spiny dogfish	*Squalus acanthias*
SPE: SPE 3–SPE 7	Sea perch	*Helicolenus percoides*, *H. barathri*
SWA: all	Silver warehou	*Seriolella punctata*
WWA: all	White warehou	*Seriolella caerulea*

Data were treated separately by form type, and the primary grooming checks, numbers of changes, and final data are described in Appendix A. Particular attention in the effort checking and grooming was given to variables required to characterise the effort: location/area fished, date and time, gear type, target species, number of tows, fishing duration, towing speed, vessel characteristics (including size), effort width (wingspread), and depth.

For the final dataset of TCEPR and TCER tows targeting deepwater Tier 1 and Tier 2 fishstocks, a total of 283 203 bottom-contacting tows were retained for 2008–17. Of these, 87% were for Tier 1 fishstocks, 90.4% were from TCEPRs, and 81.6% used bottom trawl gear (see Appendix A).

2.3 GIS layers for estimating the overlap of the bottom-contacting trawl footprint

To determine the extent of coverage of the trawl footprint on 200-m depth zones, the potential 'fishable' area, and modelled environmental classification layers, as required in the project specifications, a series of Geographic Information Systems (GIS) layers were acquired from MPI or generated from NIWA data. These are described below. Note that all the spatial overlap and area calculations were made from data in the following projection: Albers Equal Area Projection (central meridian at 175° E, standard parallels at 30° S and 50° S, and the latitude of origin at 40° S). Appendix B provides maps of the spatial distributions of these layers.

2.3.1 Depth zone

This layer was created from the 2016 NIWA bathymetry data (Mitchell et al. 2012) to yield 200-m depth zones out to a depth of 1600 m, the depth that is close to the depth limit of current trawling effort (see Appendix A). The area (km^2) of each zone was then calculated using tools in ArcGIS and provided in the footprint overlap analysis in Section 5.1. The distribution of these zones is shown in Figures B1 and B2 in Appendix B.

2.3.2 'Fishable' area

This area has an outer limit at the 1600 m depth contour and reflects the waters included in the depth zone layer, but has a smaller coverage due to the exclusion of closed areas to protect underwater features including seamounts (the first of which were closed in 2001), marine reserves (for example, around the Auckland Islands group), cable lanes, and Benthic Protection Areas (BPAs) that were introduced in 2007 (see Figure B1 in Appendix B). The area covered by the 'fishable' area was calculated as 1 385 795 km^2.

2.3.3 Benthic-optimised marine environment classification (BOMEC)

This layer was created by Leathwick et al. (2012) and contains 15 classes that represent different environments generated from modelling the relationships between the distributions of relevant environmental variables to discriminate the distributions for eight taxonomic groups of benthic fish and invertebrates. The classification broadly describes three inshore classes (A, B, D), three shelf classes (C, E, F), and nine classes in deeper waters down to 3000 m (G–O) (see Figure B2 in Appendix B). Thus, it extends beyond the depths where fishing normally occurs. The area (km^2) of each class was calculated, as above, and these areas are given in the footprint overlap analysis in Section 5.2.

2.3.4 Probability of capture/annual distribution for the Tier 1 target species

For the seven fish target species in the deepwater Tier 1 group of fishstocks, Leathwick et al. (2006) predicted the distribution of the probability of capture during a standardised trawl in waters out to 1950 m within the outer EEZ boundary, based on presence/absence data and relevant modelled environmental variables (Figures B3a–B3d in Appendix B, Section 5.3). For scampi and arrow squid, the annual distributions of the populations as mapped by MPI (www.nabis.govt.nz) are used as a proxy for the species distribution (see Figure B3e). The arrow squid and scampi areas match the extent of the EEZ and

the Territorial Sea; the areas of unknown presence, hotspot, 90% and 100% annual distribution for arrow squid and scampi were calculated, as above.

3. SPATIAL ANALYSIS OF TCER AND TCEPR DATA

Both the TCEPR and TCER forms have position and operational data that allow spatial analysis and presentation. However, the two data types require different treatment to generate swept area estimates. TCEPR data include both start and end positions, whereas TCER have tow start positions only. Thus, the groomed data are treated separately before being combined to develop the swept area statistics. The methods described below follow those used and fully described by Baird et al. (2011) and Black et al. (2013) for TCEPR data and Baird et al. (2015) for TCER data.

The groomed final dataset consisted of 283 203 TCER and TCEPR bottom-contacting tows (see Table A1, Figure 1). For most tows, the data collection method meant that the resolution of tow position co-ordinates was to the nearest minute of arc (about 1.852 km – assuming no allowance for latitudinal changes). In accordance with previous work, the start and finish positions of these truncated data were randomly jittered using an offset of ± 0.5 minute, to provide a more realistic spread of effort (see Black et al. 2013). However, 15% of the latitude and longitude data were reported at a finer resolution than 1 minute and these position data were used as reported. The jittered values were stored as new fields in the dataset. Note that the reported position data represent where the vessel was at the time the net was deemed to have reached (and left) fishing depth rather than the position (location) of the net. However, the use of random jittering does limit the artificial patchiness of effort created by the spatial clumping of tows because of the data resolution.

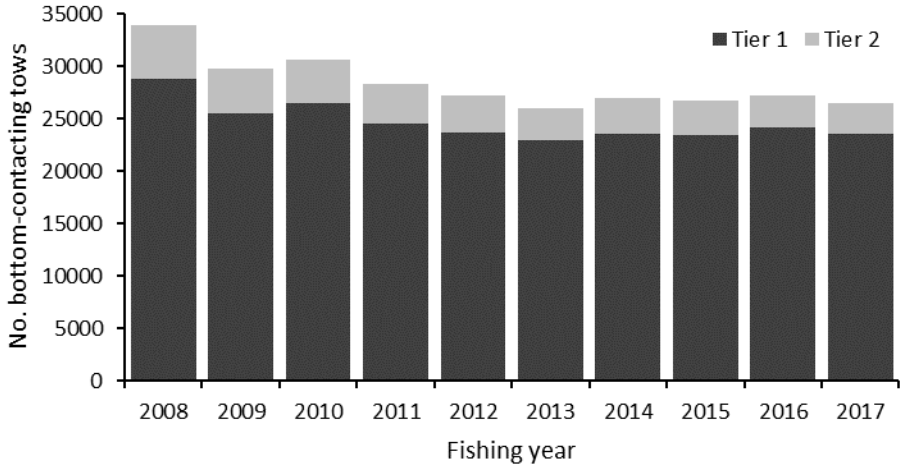

Figure 1: Annual totals of tows reported on TCERs and TCEPRs for Tier 1 and Tier 2 target fishstocks, for fishing years 2008–17. The total number of tows, for all years and targets, was 283 203.

3.1 Preparation for estimating swept area from TCER forms

The TCER data lack information that describes the finish location. Although a measure of swept area can be calculated, based on the duration of the tow and tow speed, the swept area cannot be spatially represented, other than as a circle centred on the start position. We followed the methods described by Baird et al. (2015) whereby, within a trip, a tow direction was generated from the bearing between the start position of a tow and the start of the following tow. A distance measure (in kilometres) was then estimated from the tow speed and tow duration data and used with the estimated bearing to generate finish co-ordinates.

The data summary in Appendix A indicated that the median number of tows per trip in the TCER data was 2 tows (range 1–46 tows, 75th percentile at 5 tows) (see Table A2.12). This means that a substantial number of tows had no following tow (in a given trip). Thus, the last tows and only tows of a trip are

identified, and for each of these tows, a bearing was estimated based on the median estimated bearing values from other tows by the same vessel for the same target species within 1/30th of a degree north/south or east/west, using a minimum number of 2 tows. This was used to generate finish co-ordinates (as above). Where this failed, tow end co-ordinates were generated by using the median estimated bearing values from tows of the same target species within 1/30th of a degree north/south or east/west, using a minimum number of 2 tows.

3.2 Spatial allocation of TCEPR and TCER tows

Several new variables were generated on a tow-by-tow basis to provide spatial representation of each tow.

1. **Doorspread**. The distance between the two trawl doors is considered the best measure of the width of the trawl path to estimate the potential area of the seafloor contacted by the trawl gear, that is, the swept area. This measure is not reported on commercial data forms, so previous footprint studies have applied doorspread values (with agreement from the Aquatic Environment Working Group) to each tow, based on vessel size, target species, and known gear parameters (including the number of nets used) to reflect differences in the spread of gear depending on vessel size (see for example, Baird & Wood 2018). The estimated doorspread values used in this study are given in Table A2.7, based on the "number of nets" data which were first collected in the 2008 fishing year. From 2008, the number of nets used was recorded on the TCER and TCEPR forms and this was used to identify tows that used twin trawls in hoki target fishing and twin-rig and triple-rig trawl gear in scampi fisheries.
2. **Tow distance.** A distance for each trawl track was calculated from the finalised start and fishing positions.
3. **Speed-time distance.** A second distance value was calculated for each tow; this was based on the speed and the tow duration (the difference between the reported tow start and finish times) for use with the TCER data and for some deepwater target TCEPR tows where short tows on hills resulted in the co-ordinates of the start and finish data being the same.

Using the CatchMapper tool, each tow was converted into a trackline (distance between the start and finish locations). Tows that were considered too long were identified by the rule used in the previous work by Black & Tilney (2017): "long" tows were those that were longer than 70 km for scampi and arrow squid and longer than 55.56 km for all other species considered here. Baird & Wood (2018) indicated that the 55.56 km cut-off for hake tows was too short, based on the data, and we have used 70 km as the cut-off for hake in this analysis. New end points were generated by truncating the trackline to the required upper tow length.

Each trackline was then buffered by the assigned doorspread to produce polygons to represent the trawl path. All tows were assumed to be a straight line. About 0.3% of tows touched land and < 0.1% crossed Farewell Spit. Any parts of the trawl polygons that lay on land, or in areas closed to trawling (as listed in Section 2.3.2) were removed from the analysis.

3.2.1 Assignment of TCEPR and TCER tow data to cells

To aid in the categorisation and analysis of the data, a grid of approximately 25 km^2 cells (generated in project DAE2016–05 and stored as a shapefile) was overlaid with the estimated doorspread-based polygons of swept area. A 5×5 km cell size was chosen as a reasonably fine unit for an area the size of the EEZ. This grid was generated in the Albers Conic Equal Area Projection for the New Zealand EEZ (see Section 2.3) and re-projected to latitude and longitude degrees to overlay with effort data as a basis for spatial analysis. Each cell was assigned a depth derived from the NIWA regional bathymetry dataset (Mitchell et al. 2012) that represented the depth at the cell midpoint.

Thus, the effort could be analysed by grid cell to identify and quantify the amount of effort per cell over time and to generate an indicative "footprint" of trawl effort on the seafloor. For area-based calculations, the data

were re-projected to the Albers Conic Equal Area projection to minimise distortions caused by converging lines of longitude with increasing latitude using degrees as the co-ordinate units.

3.2.2 Measures used to summarise the bottom-contacting data

The following measures were used to summarise the extent of bottom contact.

1. *Swept area* is the area (km^2) that represents each tow and is derived from the tow distance, as measured between start and finish positions, and the assigned doorspread.
2. *Trawl footprint* is the area (km^2) that represents the seafloor area estimated to have been contacted by trawl gear. This may represent, for example, the seafloor area contacted by trawl gear in a target fishery over a fishing year or all the target fisheries combined over all fishing years. Because the spatial extents of some fisheries overlap, the total footprint area (for all targets) in any year will be less than the summed areas of the separate target footprints in that year.

The following measures were used to summarise the intensity of bottom contact.

1. *Number of tows* refers to the reported number of bottom-contacting tows for TCER and TCEPR data.
2. *Aggregated swept area* is the total swept area (km^2) and may represent, for example, the sum of the *swept areas* for a target in any given fishing year or the sum of all the trawl polygon swept areas for all fishing years combined.

3.3 TCER and TCEPR data representation and underlying assumptions

The effort data used here represent subsets of the total commercial trawl effort data reported during these years. First, data are for tows that used bottom trawl gear or midwater gear within 1 m of the seafloor, and second, the data are restricted to two data sources (TCER and TCEPR) for recent fishing years, 2008–17.

Some underlying assumptions need to be stated.

1. The time series has an artificial start and end. The study treats the first fishing year of data, 2008, as the start of fishing in each area, and thus any discussion of trends is relative to 2008.
2. It is assumed that the path (trackline) of each tow follows a straight line between the reported start and end positions. In reality, tows may follow contours and may include turns, but the trackline data do not allow any determination of actual tow path. The duration-speed distance measure provides some measure of a tow path distance and, where this differs from the trackline distance, it was assumed to be closer to the 'real' length of a tow. However, the trajectory of the tows between the start and finish cannot be determined from these data.
3. It is assumed that the gear is in contact with the seafloor throughout the tow and that there are no changes in the gear parameters over time.
4. The measure of swept area will be indicative and may well be better estimated for certain target species where fishing effort is carried out by larger vessels with gear parameters that are better understood.
5. The irregular nature of the seafloor is ignored, and it is assumed that, within each cell, the seafloor is homogeneous.
6. The patchy distribution of fishing is in part due to avoidance of areas of the seafloor that are unfishable because of undersea formations or habitats such as sponge gardens that fishers may describe as "foul ground". These areas are not identified in this study.
7. The reported position data give the vessel location for each tow, and thus the vessel position is used as a proxy for the net position.

4. THE NATURE AND EXTENT OF TCER AND TCEPR TRAWLING ON OR NEAR THE SEAFLOOR

4.1 The annual number of tows and the total spatial area affected each year

Appendix C gives tables and figures that describe the spatial distribution of the swept areas: for each target fishstock, Tables C1–C4 give the number of annual tows, footprint, aggregated swept area, and number of cells contacted; Figure C1 shows the annual footprint extent of each Tier 1 fishstock; Figure C2 shows the 2008–17 footprints for the combined Tier 1 and the combined Tier 2 fishstocks; and Figure C3 shows the combined Tier 2 footprint distribution, by fishing year. For 2008–17 fishing years, 283 100 bottom-contacting tows were retained to generate the footprint statistics (Table 2), after the removal of 103 tows that were on land or located in waters too deep for trawling. The annual number of bottom-contacting tows decreased from a peak of about 34 000 tows in 2008 to about 26 000–27 000 tows during the 2012–17 fishing years (Table C1 in Appendix C).

In total, 87% of all tows included in the analysis targeted Tier 1 fishstocks. The number of Tier 1 tows in 2017 was equivalent to about 82% of those in 2008, and Tier 2 tows in 2017 were just over half that reported in 2008. Over the time series, the percentage of total bottom-contacting tows that targeted Tier 1 fishstocks increased from about 85% in 2008 and 2009 to 89% in 2016 and 2017.

The main Tier 1 targets were hoki (37% of the 246 549 Tier 1 tows), scampi (18%), arrow squid (12%), and orange roughy (9%). Over the time series, the number of bottom-contacting hoki tows increased from about 8000 in 2008 to about 10 000 tows in 2017, whereas there were minor changes in the annual scampi effort, and a decrease in bottom-contacting effort for arrow squid. Orange roughy effort decreased from about 3700 tows in 2008 to about 1600 tows per year in 2012 and 2013, then increased to about 3000 tows in 2016 and 2017. In contrast, effort for oreo decreased steadily from about 2500 tows in 2008 to 700–800 tows in 2016 and 2017. Declines in annual numbers of tows, over the time series, were evident in the hake and jack mackerel data (and the southern blue whiting data after 2011), whereas there were no trends apparent in the annual numbers for scampi and ling. Some of these fluctuations were a result of catch management in the form of Total Allowable Commercial Catch adjustments (see Fisheries New Zealand 2018).

The main Tier 2 target species were barracouta (33% of the 36 584 Tier 2 tows), silver warehou (21%), and alfonsino (17%). After a large drop in 2009, there was no appreciable trend in the reported numbers of bottom-contacting barracouta tows and other targets such as alfonsino, cardinalfish, spiny dogfish, and silver warehou showed an overall decreasing trend. Other target species fisheries indicated no real trends in tow numbers and represented small percentages of the overall number of tows in any one year.

Table 2: Bottom-contacting trawl footprint statistics for deepwater Tier 1 and Tier 2 target fishstocks, for fishing years 2008–17 and 2017, based on TCER and TCEPR data. Target species codes are defined in Table 1. The EEZ&TS is the combined seafloor area of the 200 n. mile EEZ and the Territorial Sea (equivalent to 4 111 569 km^2). The 'fishable' area is the seafloor in waters down to 1600 m that are open to trawling (1 385 795 km^2).

Analysis period	Target species	No. of tows	No. cells	Trawl footprint (km^2)	Overlap EEZ&TS (%)	Overlap 'fishable' area (%)
2008–17	Tier 1 & Tier 2	283 100	26 501	180 077.2	4.4	13.0
2008–17	Tier 1	246 549	23 515	158 093.7	3.8	11.4
2008–17	HAK	8 892	2 132	11 541.5	0.3	0.8
2008–17	HOK	90 359	10 894	74 810.0	1.8	5.4
2008–17	JMA	13 528	3 150	24 368.6	0.6	1.8
2008–17	LIN	10 923	4 187	14 323.8	0.3	1.0
2008–17	OEO	16 022	2 148	4 311.5	0.1	0.3
2008–17	ORH	25 690	3 981	11 189.0	0.3	0.8
2008–17	SBW	4 780	1 790	10 062.8	0.2	0.7
2008–17	SCI	45 256	3 292	12 693.6	0.3	0.9
2008–17	SQU	31 099	3 354	13 656.2	0.3	1.0
2017	Tier 1 & Tier 2	26 429	12 055	48 203.2	1.2	3.5
2017	Tier 1	23 578	10 203	44 152.3	1.1	3.2
2017	HAK	535	377	1 556.1	<0.1	0.1
2017	HOK	9 977	4 703	26 931.9	0.7	0.9
2017	JMA	784	1 126	3 796.5	0.1	0.3
2017	LIN	1 010	834	1 369.8	<0.1	0.1
2017	OEO	685	421	254.9	<0.1	<0.1
2017	ORH	2 983	1 741	2 703.0	0.1	0.2
2017	SBW	307	382	747.6	<0.1	0.1
2017	SCI	4 705	1 172	4 672.9	0.1	0.3
2017	SQU	2 592	1 149	3 715.1	0.1	0.3

4.1.1 Total aggregated and footprint swept areas

The total aggregated swept area for 2008–17 was estimated at 948 100 km^2, with an annual aggregated area of about 90–100 000 km^2 (Tables 3 and C3). About 92% of the 2008–17 total aggregated area was from Tier 1 fishstock tows. This represented a total footprint of almost 180 100 km^2 of seafloor contacted by trawl gear for the 10 years (Table 3 and C2). Figures 2a and 2b show the distribution of the aggregated swept area and the footprint for the combined fishing years 2008–17 and for the 2017 fishing year.

This 2008–17 footprint contacted 4.4% of the seafloor included in the TS+EEZ (about 1.2% annually) and 13% of the 'fishable' area (about 3.6% annually) (see Table 3). The estimated total footprint of the Tier 1 targets combined contacted 3.8%, or about 1.1% each year. The Tier 1 target footprint accounted for an increasing proportion of the total annual footprint, from 87% in 2008 to 92% in 2017, largely as a result of hoki and scampi effort (see Table C3). The annual hoki footprint covered 0.5–0.7% of the combined Territorial Sea and EEZ seafloor; whereas the combined annual footprints of the remaining 8 Tier 1 targets covered 0.4–0.7%.

The total footprint for the most recent fishing year (2017) contacted 48 203 km^2, about 1% of the EEZ and Territorial Sea (see Table C2 and Figure 2b). This was a similar footprint area to that in 2016 and one of the lowest in the time series. Hoki effort was the main contributor to the 2017 footprint, at 56%.

Table 3: Summary of annual deepwater Tier 1 and Tier 2 fishstock bottom-contacting trawl effort undertaken in the Territorial Sea and the EEZ, 2008–17.

Fishing year	No. tows	No. cells	Footprint			Aggregated area (km^2)
			Area (km^2)	% TS+EEZ	% 'fishable'	
2008	33 969	14 016	56 910.8	1.4	4.1	102 336.3
2009	29 795	12 993	50 638.8	1.2	3.7	91 523.1
2010	30 592	13 278	53 984.6	1.3	3.9	99 519.6
2011	28 321	12 792	52 322.1	1.3	3.8	99 576.6
2012	27 252	11 872	49 845.2	1.2	3.6	96 202.3
2013	25 935	11 126	47 747.3	1.2	3.4	89 281.4
2014	26 959	12 152	49 807.9	1.2	3.6	90 571.7
2015	26 727	12 108	50 743.9	1.2	3.7	95 003.3
2016	27 151	12 028	48 265.5	1.2	3.5	89 581.1
2017	26 429	12 055	48 203.2	1.2	3.5	94 503.6
Total	283 100	26 501	180 077.2	4.4	13.0	948 099.0

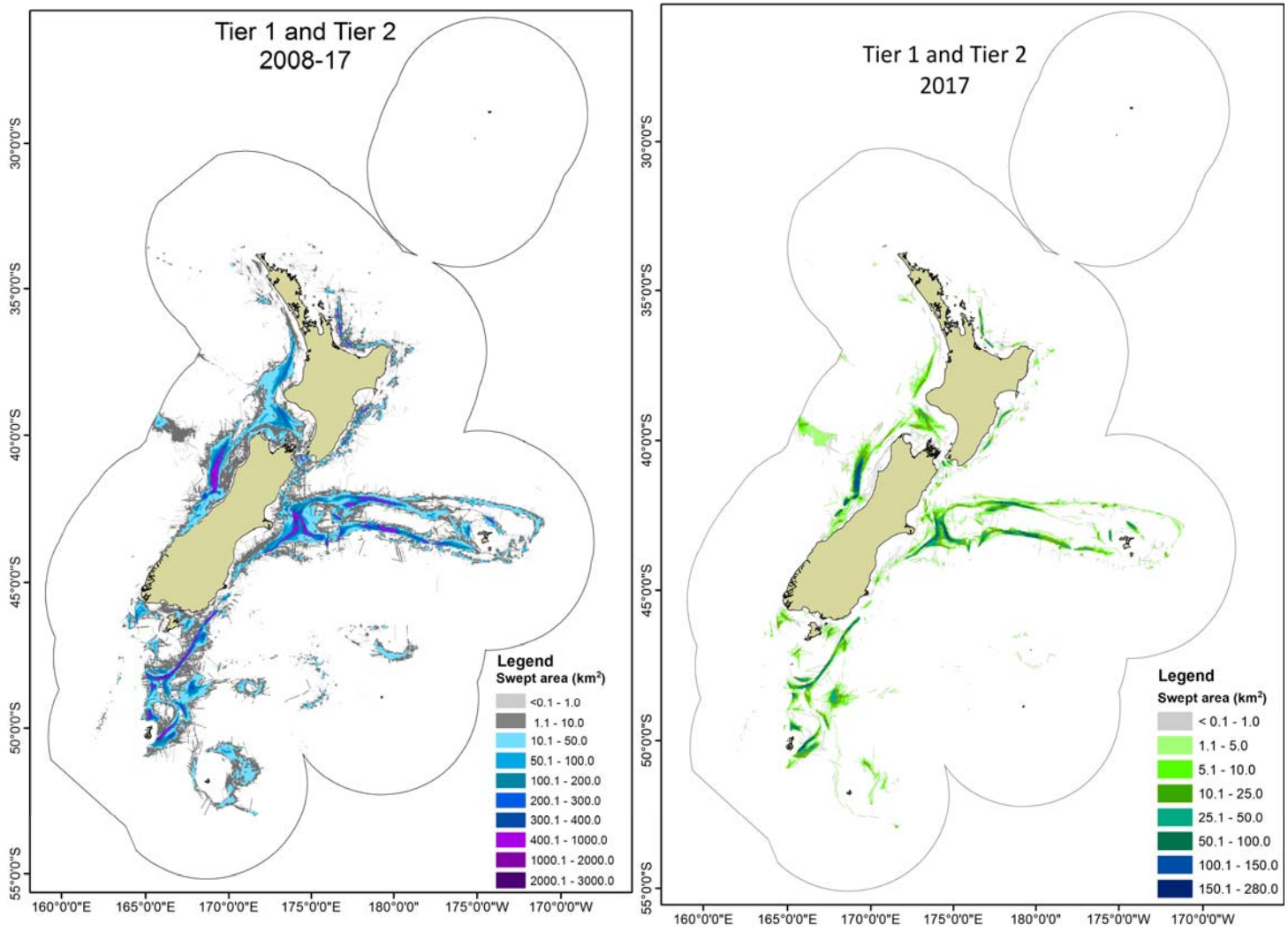

Figure 2a: Distribution of the total aggregated swept area (km^2) per 5×5 km cell for all deepwater Tier 1 and Tier 2 targets for 2008–17 (left) and for 2017 (right). Note the aggregated swept area per cell is the sum of all the individual trawl polygon swept areas in a cell and, because some of the trawl tracks overlap, this may exceed the total area of the cell (in this case 25 km²). Aggregated swept area is used here as a measure of trawl intensity in a given area.

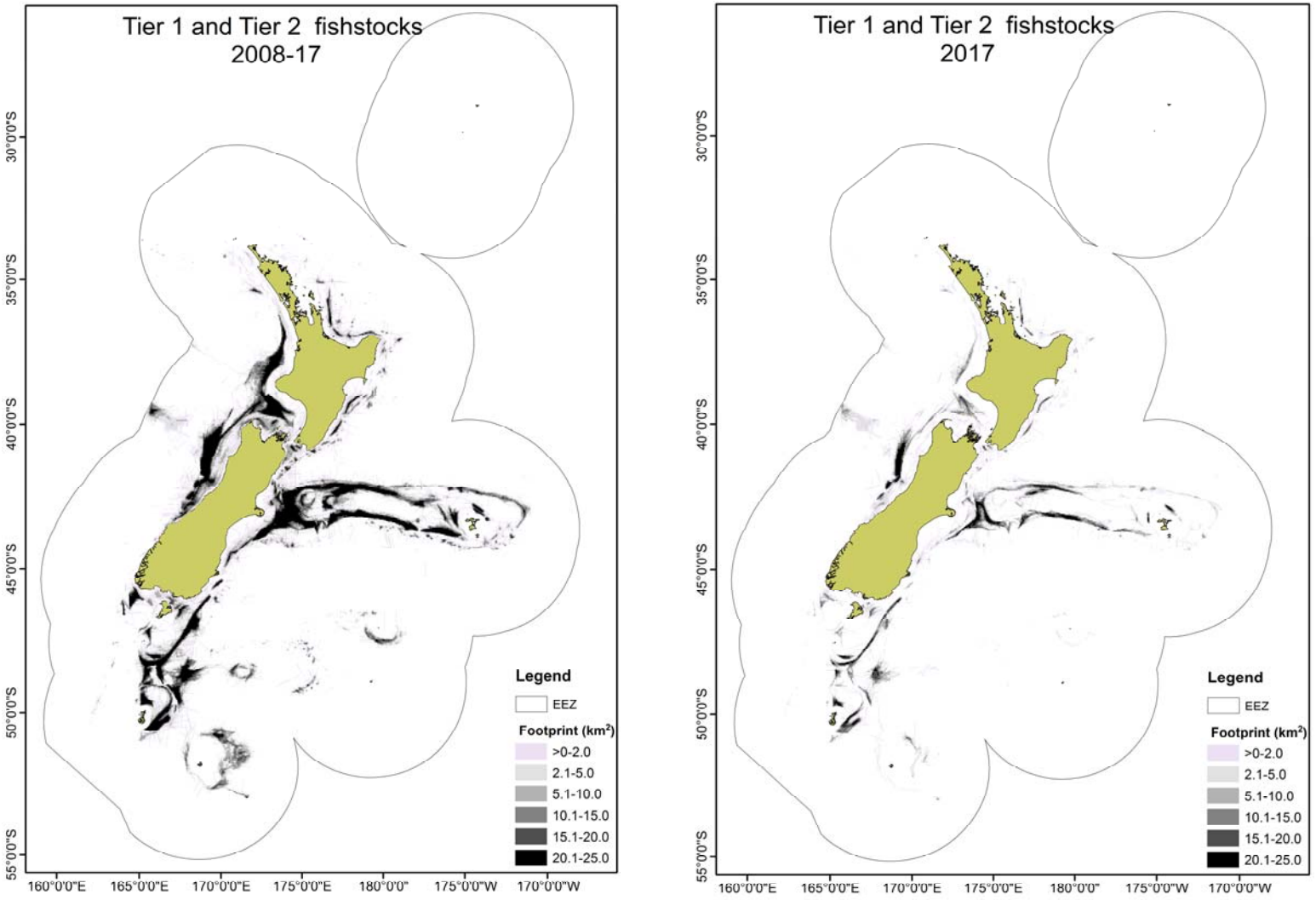

Figure 2b: Distribution of the total footprint area (km^2) for all deepwater Tier 1 and Tier 2 targets for 2008–17 (left) and for 2017 (right).

4.1.2 Tier 1 target fishstocks swept area

Over the fishing years 2008–17, there was a slight decrease in the annual totals for the aggregated swept area for Tier 1 targets (from 90 577 km^2 in 2008 to 87 678 in 2017) and for the footprint, from the peak of about 49 489 km^2 in 2008 to about 44 200 km^2 in 2016 and 2017 (Figure 3 and Tables C2 and C3).

Hoki effort contributed 50% to the total aggregated swept area and 41% to the total footprint area. Annually, hoki tows contributed between 32 611 km^2 in 2008 and 56 329 km^2 in 2017 to the aggregated swept area (Figure 3, Table C3). This represented annual footprint coverage of about 19 440 km^2 in 2008 and 26 930 km^2 in 2017 (the peak was in 2015, estimated at over 28 930 km^2) (Table C2). Reflecting the increase in the number of tows over the 10 years, hoki was the only target species to show a steady increase in aggregated and footprint swept areas. The distribution of the hoki swept area coverage defines the main fishery areas and generally the spatial extent is similar from year to year (see Figure C1).

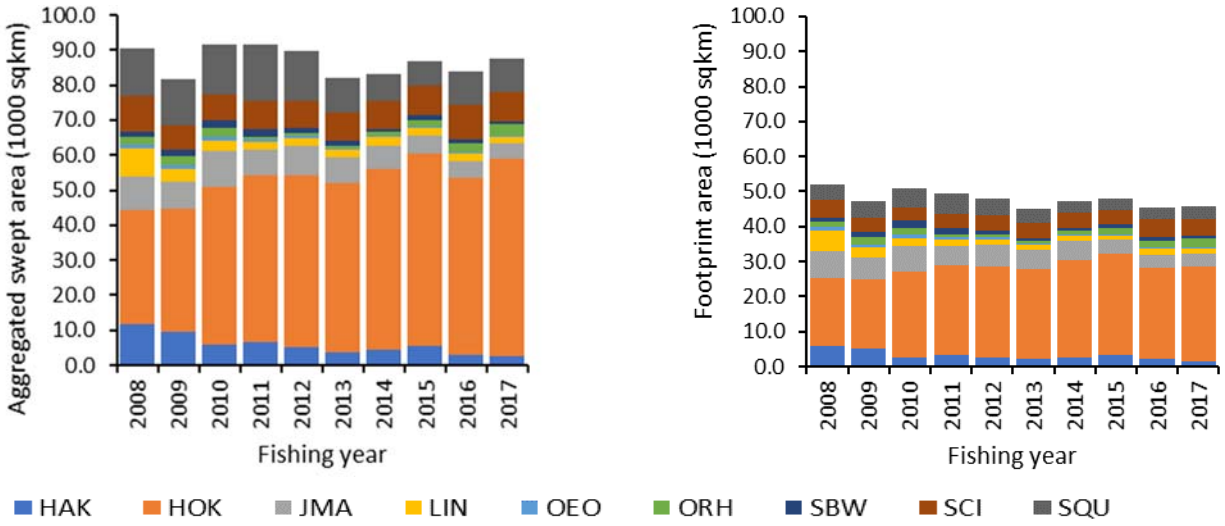

Figure 3: The annual aggregated swept area (left) and annual footprint (right) for Tier 1 deepwater fishstocks, based on TCER and TCEPR forms, for 2008–17. Target codes are defined in Table 1. Note that because of spatial overlap of the swept area measures for some targets, the totals represented here are the sums of the swept areas of each target for each fishing year. The total aggregated swept area by fishing year and footprint by fishing year are given by fishing year in Tables C3 and C2, respectively.

For other Tier 1 targets, the annual swept areas showed either no appreciable trend, or a decreasing trend, across the time series. Annual aggregated swept area estimates for scampi generally varied between 7000 and 8500 km^2 across the years, with peaks of 10 452 km^2 and 9830 km^2 in 2008 and 2016, respectively (see Figure 3, Table C3). The scampi footprint covered 4000–4700 km^2 in most years, but peaked at about 5000 km^2 in 2008 and 2016 (Table C2). The spatial distribution pattern is consistent each year, until 2012–17 when there is evidence of effort northwest of the South Island (see Figure C1).

The decline in arrow squid bottom-contacting effort is reflected in the annual aggregated swept area, with a drop from 13 300–15 800 km^2 estimated annually for 2008–12 to 7000–9800 km^2 during 2013–17 (see Figure 3, Tables C1 and C3). The annual trawl footprint covered 3800–5800 km^2 per year during 2008–12, then 3200–3800 km^2 per year for 2013–17 (Table C2). Few changes were seen in the extent of the footprint in the main fishery areas, other than in 2013–14, when the extent of the trawling off the east coast South Island decreased. In subsequent years, arrow squid was again targeted in this area using bottom-contacting gear (see Figure C1).

Annual aggregated swept areas for orange roughy were estimated at about 2100–2500 km^2 during 2008–10, then dropped to 650–835 km^2 before steadily increasing from about 1000 km^2 in 2014 to 3100 km^2 in 2017 (Figure 3, Table C3). These areas represented footprints of about 1800–2200 km^2, 570–740 km^2, and 940–

2700 km^2, respectively, over the three periods within the time series (Table C2). The extent of the spatial distribution has varied over the time series (see Figure C1), with the mid-years period of the smaller footprint showing a decreased extent across the northern Chatham Rise (due to management actions such as the lowering of the TACC (Fisheries New Zealand 2018)) and an increased extent across the Chatham Rise (in a small localised area) and to the west on the Challenger Plateau during the later years. Other areas (ORH 2A, ORH 2B, ORH 3A) were also subject to decreased TACCs during the time series.

The aggregated swept area for oreo species decreased steadily over the time series, from about 1200 km^2 in 2008–10 to 275 km^2 in 2017 (see Figure 3, Table C3). The equivalent areas for the footprint were about 900 km^2 and 250 km^2 (Table C2). The annual spatial distributions show that during 2013–15, unlike the other fishing years, there was no effort in the Bounty Platform and Pukaki Rise areas (see Figure C1). There were no changes in the management of the oreo stocks during 2008–17, other than the decrease in the OEO 4 TACC since 2016 (Fisheries New Zealand 2018).

Annual aggregated swept areas for hake, jack mackerels, ling, and southern blue whiting declined over the time series (see Tables C2, C3, and Figure 3). There were some area changes in the spatial distribution of southern blue whiting effort, with a move away from bottom-contacting trawling on the Pukaki Rise from 2013 onwards (see Figure C1); there were increases in catch limits at the Campbell Rise and variable annual catch limits at the Bounty Platform during these years (Fisheries New Zealand 2018). For the other three species, the decline in effort (as seen in the numbers of tows) was not a result of any changes in TACC over this time (Fisheries New Zealand 2018). The footprints for all these targets represent estimates of seafloor area contacted by bottom-contacting trawl gear only, as does the hoki footprint, and therefore do not represent the full spatial distribution of each target because midwater trawls used in the water column are also used to target these fishstocks. In contrast, bottom trawl gear is used almost exclusively to target orange roughy, oreo species, and scampi.

4.1.3 Tier 2 target fishstocks

Tier 2 fishstocks accounted for 8% of the total 2008–17 aggregated swept area and contacted about 22% of the total trawl footprint area (see Tables C2 and C3). Note that the percentages of Tier 1 and Tier 2 fishstock footprints add up to greater than 100% because there will be overlap between each group of targets. The primary Tier 2 fishstocks were barracouta and silver warehou (Figure 4, see Table C2) – with each contributing to 9% of the total trawl footprint. Silver warehou accounted for 4%, and barracouta accounted for 3%, of the total aggregated swept area, with annual totals at least 1000 km^2 more than other Tier 2 targets (see Table C3). Over the time series, the silver warehou footprint declined from about 4400 km^2 to 1800 km^2; whereas the barracouta footprint was in most years between about 2000 km^2 and 3000 km^2.

4.2 Coverage by 25-km^2 cell

Bottom-contacting trawling for Tier 1 target species occurred in 23 515 of the 26 501 25-km^2 cells contacted by the combined Tier 1 and Tier 2 targets (Table 3 and Table C4 in Appendix C) during 2008–17. This equated to about 10 000–11 000 cells contacted by Tier 1 targets each year. Effort for Tier 2 targets occurred in 11 076 cells. Overall, 41% of the total cells were contacted by hoki bottom-contacting tows, 17% each by barracouta and silver warehou, 16% by ling, 15% by orange roughy, and about 12% by each of squid, scampi, and jack mackerel tows.

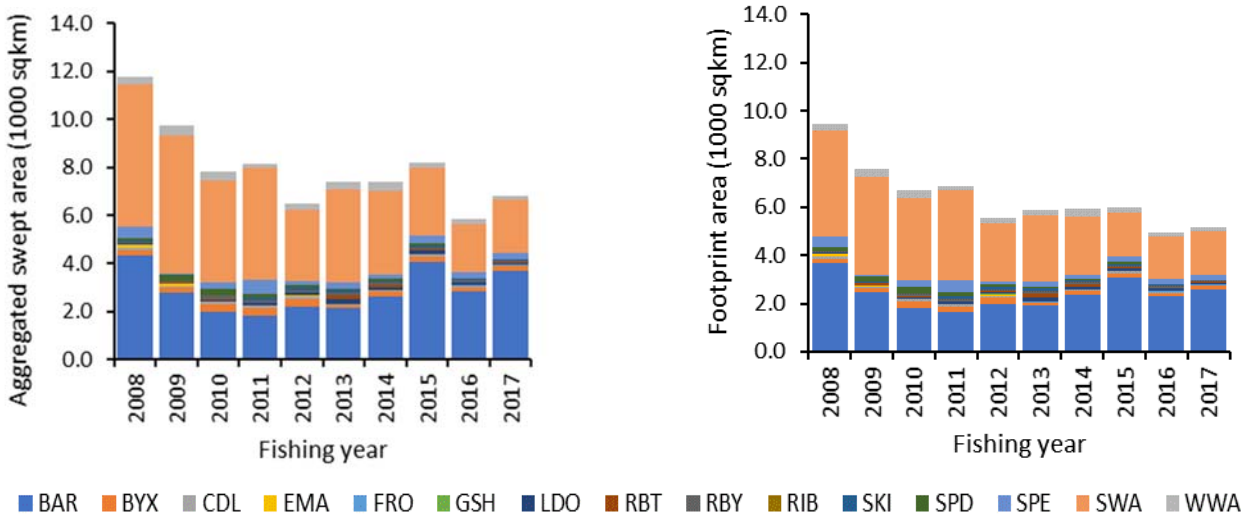

Figure 4: The aggregated swept area (left) and annual footprint (right) for Tier 2 deepwater fishstocks, based on TCER and TCEPR forms, for 2008–17. Target codes are defined in Table 1. Note that because of spatial overlap of the swept area measures for some targets, the totals represented here are the sums of the swept areas of each target for each fishing year. The total aggregated swept area by fishing year and footprint by fishing year are given by fishing year in Tables C3 and C2, respectively.

4.2.1 'New' area contacted in 2017

Two measures of the difference between the spatial extent of the 2008–16 and the 2017 trawl footprints were investigated. The spatial extent of the trawl footprint area for 2017 was compared directly with the 2008–16 total footprint in GIS; this indicated that an estimated 7430 km^2, distributed over 11 070 cells, was contacted in 2017, but not in the previous nine years. Figure 5 shows the spatial distribution of this 'new' area relative to the previous nine years footprint and the 1990–2016 footprint. Much of this 'new' area in 2017 was seafloor area close to the previous trawl footprints, often within cells that had been previously contacted, and the median value per cell was 0.36 km^2 (range < 1 m^2 to 10 km^2, with 75% less than 1 km^2). Because of the inherent uncertainty in the estimation of the swept area – from the resolution of the start and finish data, the treatment of the trawl trackline as a straight line, and the use of generic doorspread values – much of this 'new' area in 2017 may not represent expansion of the footprint extent, but rather it appears to be within, or very close to, the estimated footprint from the previous years.

However, a comparison of the cells contacted during 2008–16 with those in 2017 indicated that 662 cells were contacted in 2017, but not in 2008–16 (Table C5, Figure C4). The footprint of these cells was estimated at 455.1 km^2, from effort for orange roughy, hoki, scampi, barracouta, and 11 other targets. The location of this 'new' footprint was mainly on the extremities of the main fishery areas, usually as extensions of the fishery area and potentially misplaced trawl effort, some of which appeared to be at oblique angles to the main fishery patterns. This 'new' cell footprint represented small amounts of effort for 15 target fishstocks. Hoki tows and orange roughy tows accounted for about one-third each of this new cell footprint, with the hoki tows largely relating to extensions of the main fishery areas whereas the orange roughy tows were mainly on the Challenger Plateau off the west coast of the South Island, with further extension of the 2016 footprint representing new exploration for orange roughy (see Baird & Wood 2018).

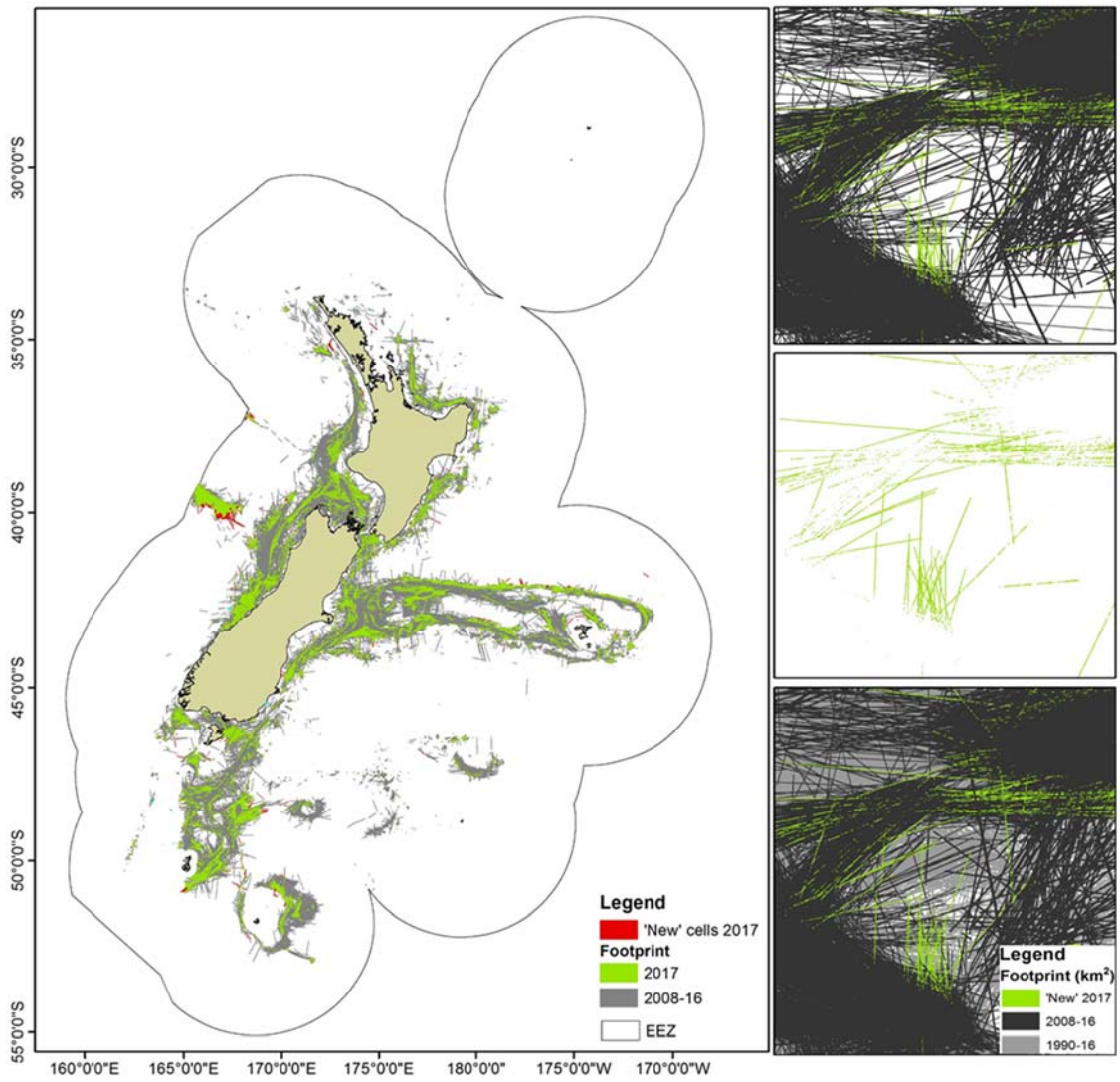

Figure 5: Extent of the bottom-contacting trawl footprint for deepwater Tier 1 and Tier 2 target fishstocks combined, within each 25-km^2 cell, for the 2017 fishing year and for the 2008–16 fishing years combined, with the cells that were contacted in 2017 (but not during 2008–16). The side panels show a subset of the overlap of the 2017 and the 2008–16 footprints (top), the area of the 2017 footprint that was not contacted during 2008–16 (centre), and overlap of the 2017, 2008–16, and the 1990–2016 footprints (the latter from Baird & Wood 2018) to indicate that much of the seafloor contacted in 2017, but not in 2008–16 (shown in green) had been contacted in earlier years.

4.2.2 Number of years a 25-km^2 cell was contacted by trawl gear, 2008–17

Of the 26 501 cells with trawl contact in 2008–17, 25% were contacted in one year only and 17% were contacted in each year (Figure 6). The number of cells contacted each year has decreased (see Table C4), although the rate of decrease has slowed toward the end of the time series. For any one year, the percentage of cells contacted in that year, but not the previous two years (that is, left fallow for two years), has increased from about 15% in 2013 to 25% in 2017 (Figure 7). Between 8 and 11% of annual cells in 2013–17 were not contacted by trawl gear in the previous five years.

The spatial distribution of the number of years contacted is shown in Figure 8, with the long-standing main fishery areas evident in the darker colours. Note that many of the cells with a few years of contact represent where 'new' effort has occurred (relative to the 2008 start of this time series) and where effort is on the fringes of the main fishery areas.

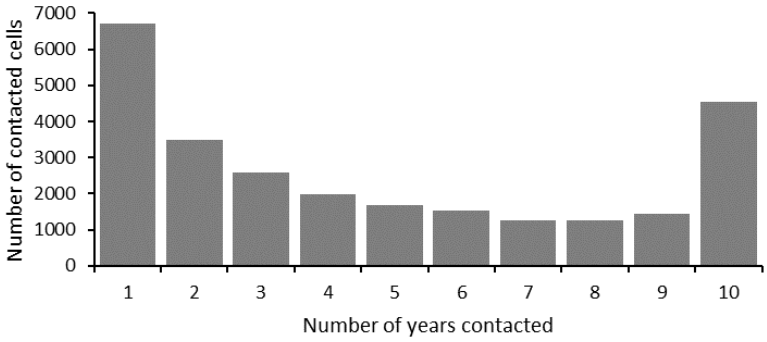

Figure 6: Number of years that 25-km^2 cells were contacted by trawl gear, from a total of 26 501 cells for 2008–17.

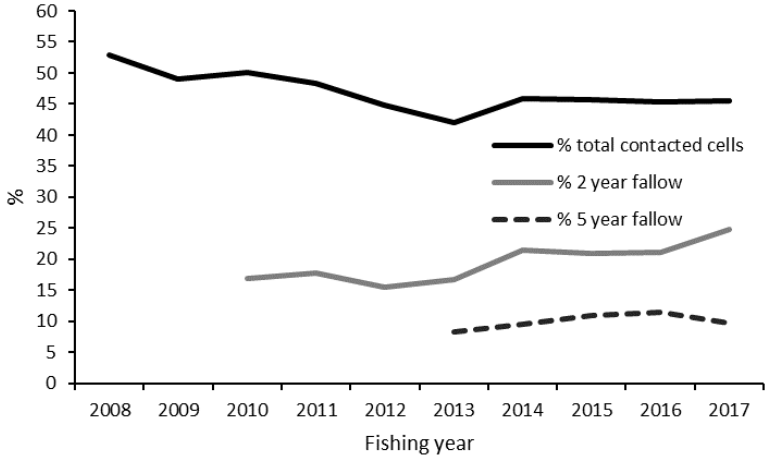

Figure 7: Percentage of the total number of contacted cells (26 501 cells during 2008–17) with at least 1 trawl in each year (black line), and the percentage of the contacted cells in each year that was fallow (not contacted) for the previous 2 years (grey line) and previous 5 years (dotted dark grey line).

4.2.3 Intensity of tows in contacted cells, 2008–17

In total, about 21% of all cells were contacted by only one tow, over 50% of cells had up to 9 tows per cell, and almost 90% had up to 100 tows (Figure 9). The spatial distribution of these data is shown in Figure 10. A total of 56 cells had 2000–3705 tows per cell: these cells are in scampi fisheries in the Bay of Plenty, east of Hawke Bay, on the Chatham Rise, and east of the Auckland Islands; in hoki fisheries off the west coast South Island, Cook Strait, and off Stewart Snares shelf; in arrow squid fisheries east of Auckland Islands and Stewart-Snares shelf (see Figure C4).

The maximum number of tows per cell for the 10-y period was 3705 tows, with a median of 7 tows, and 75% of cells had fewer than 38 tows (Table C6). There were few differences in the intensity of effort per cell between the years, with the annual median at 3 or 4 tows per cell, mean of 13–15 tows, and 75% of contacted cells each year had no more than 11–14 tows. The annual maximum tows per cell was 418–576 tows.

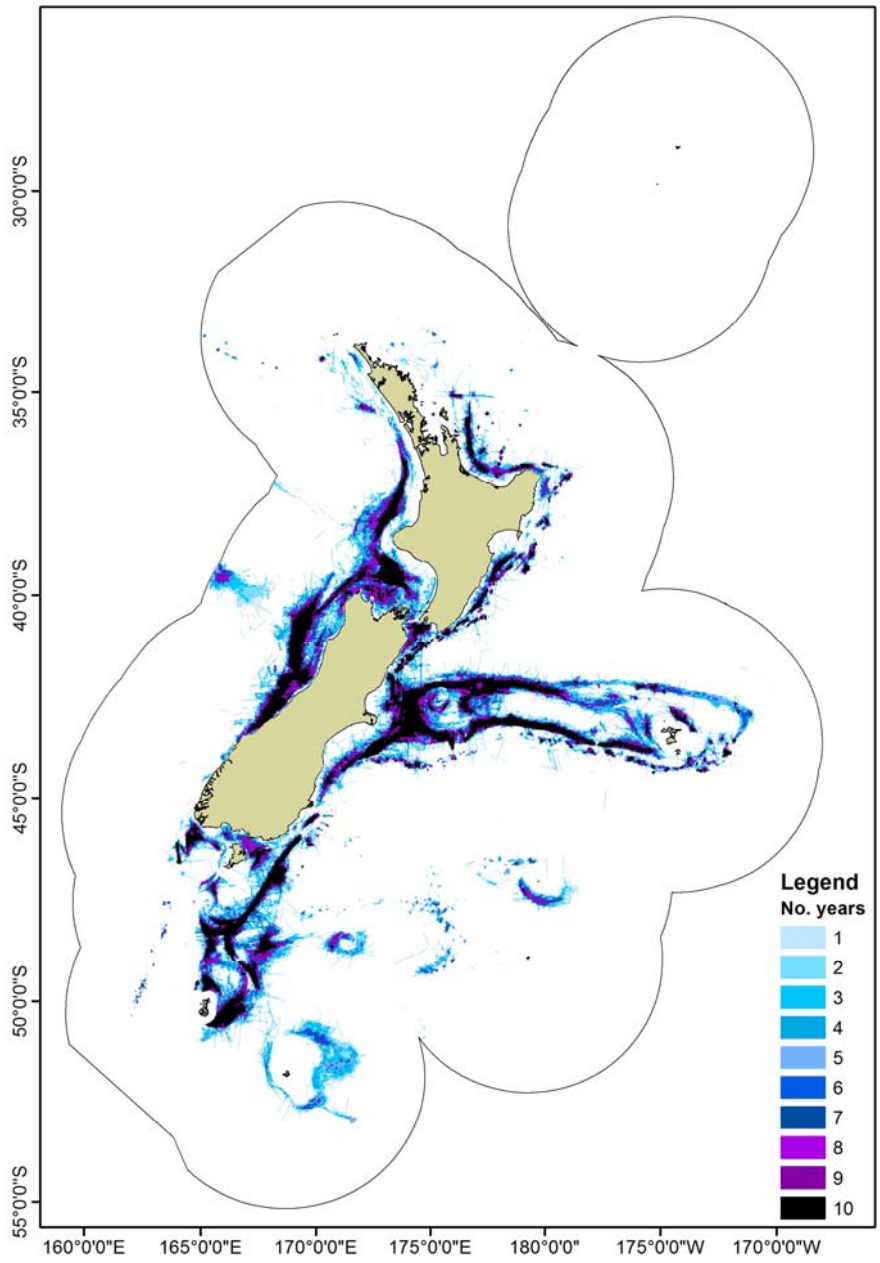

Figure 8: Number of years the seafloor of each cell was contacted by trawl gear during 2008–17.

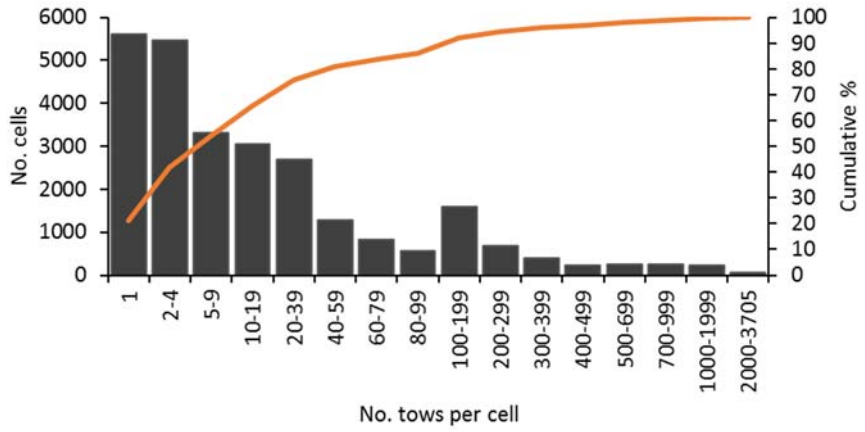

Figure 9: Number of tows per contacted cell, all fishing years combined, 2008–17.

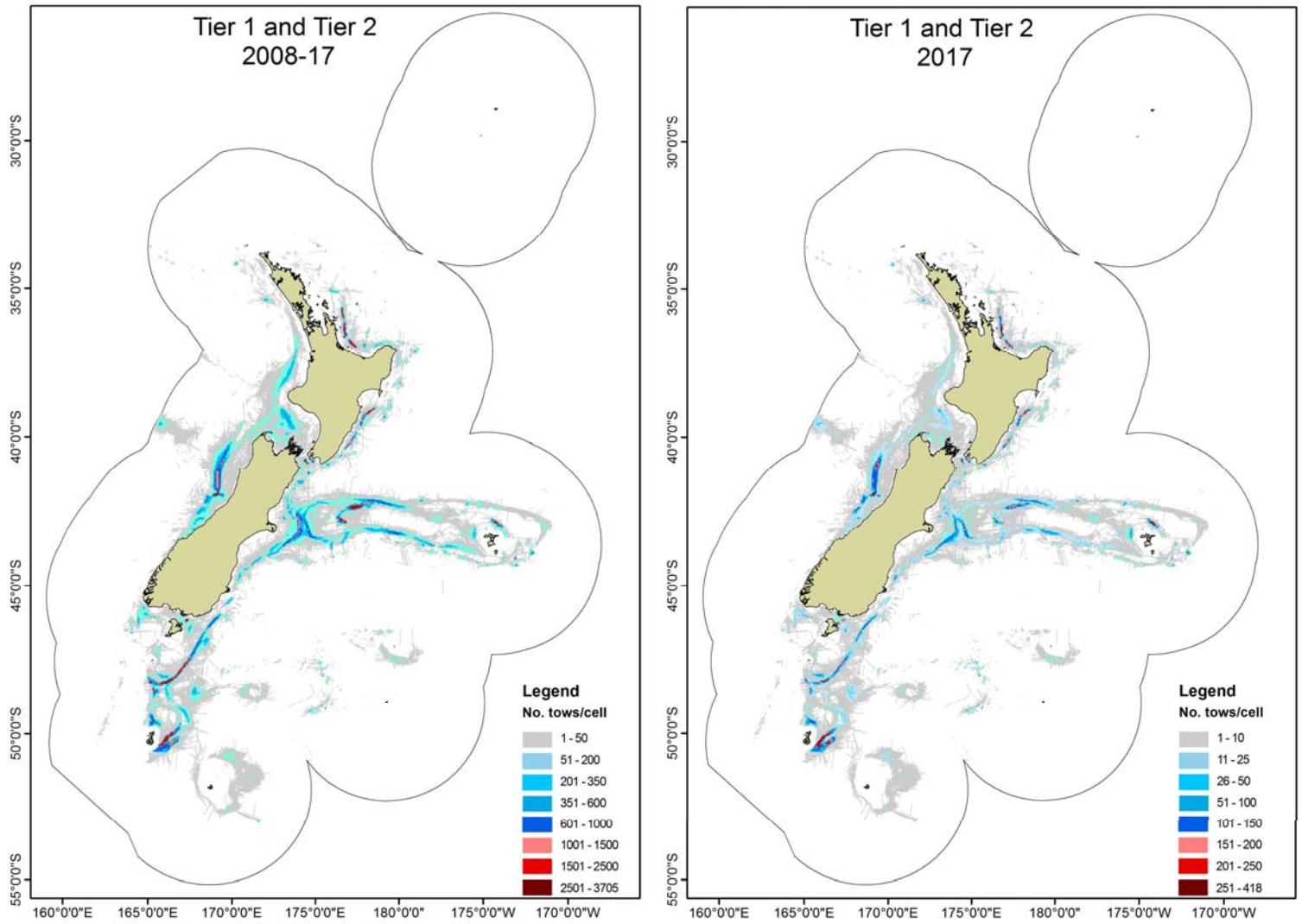

Figure 10: Number of tows per cell for deepwater Tier 1 and Tier 2 fishstock targets for 2008–17 (left) and for 2017 (right). Note the different scales used in these figures.

4.2.4 Aggregated swept area and footprint area by cell, 2008–17

The distributions of these swept areas are shown in Figure 2a. For all years combined, the median aggregated swept area per contacted cell was 2.9 km^2, with a maximum of almost 3000 km^2 (Table C7). Annual medians ranged from 1.3 to 1.6 km^2, annual means were 7.0–8.1 km^2, and annual maxima were 272–450 km^2. In most years, about 6 km^2 of each cell was contacted for 75% of the data.

Annual medians for the footprint were similar to the aggregated swept area values, at 1.2–1.6 km^2 (Table C8), equivalent to about 6% of the cell area. Annual footprint means per cell were 3.9–4.3 km^2, and 75% of contacted cells per year had footprint coverage of no more than 5.7 km^2 (< 25% of a cell area).

5. OVERLAP OF THE BOTTOM-CONTACTING TRAWL FOOTPRINT

GIS shapefiles of the footprint overlap data shown below are available from MPI Spatial Intelligence team. These files contain the underlying data and represent where the footprint overlaps the 'fishable' area and other areas of interest within the TS+EEZ area: 200-m depth zones, BOMEC, and the Tier 1 'preferred habitat'.

5.1 Overlap of the 200-m depth zones down to 1600 m

The 2008–17 footprint overlap of each depth zone, expressed as the percentage contacted in each depth zone, is shown for Tier 1 targets separately and combined in Figure 11 and in Tables 4 and 5. The extents of the footprints relative to the depth zones are shown in Figures 12a–12e and Figure 13. Most footprint coverage is in depths shallower than 1000 m, with hoki the main contributor in 400–800 m depths and the pattern of the footprint overlap has changed little from year to year. The total hoki footprint has the greatest coverage of 200–800 m waters, contacting about 6% of the 200–400 m zone, 14% of the 400–600 m zone, and 10% of the 600–800 m zone (Table 4).

In < 200 m, the targets with the greatest footprint overlap are jack mackerel species and arrow squid. Other targets with footprint overlap of at least 3% in the 200–400 m zone are ling, scampi, and arrow squid. Hake, ling, southern blue whiting, and scampi footprints cover 2–3% of the 400–600 m zone.

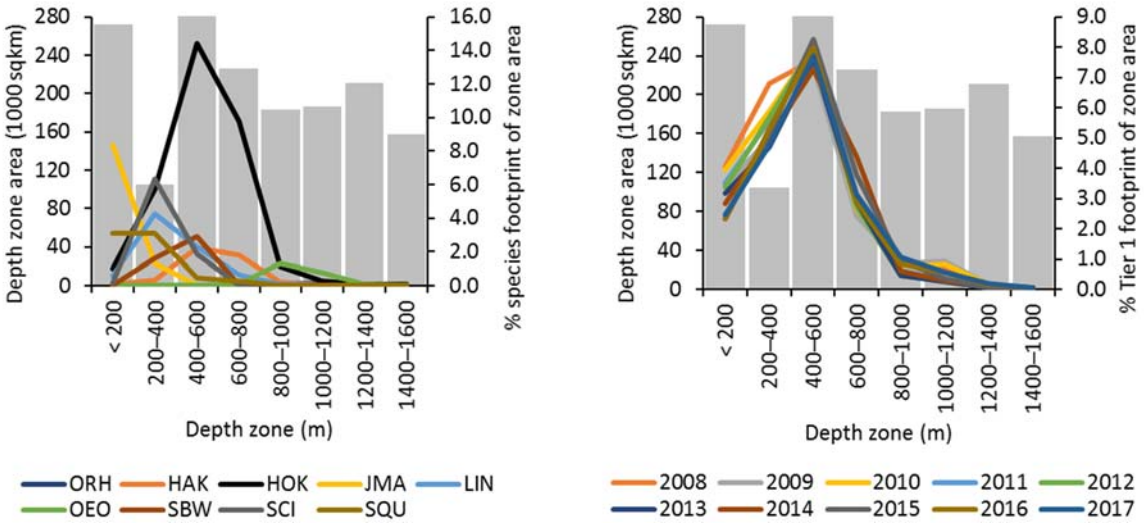

Figure 11: Total seafloor area (grey bars) of each 200-m depth zone and the percentage of each depth zone area contacted by trawl gear for 2008–17, by each Tier 1 target (left) and by combined Tier 1 targets for each fishing year (right).

In the deeper zones, orange roughy, oreo species, and hoki footprints have 1.1–2.4% overlap in 800–1000 m. The orange roughy footprint overlaps about 2.5% of the 1000–1200 m zone, and oreo species have a 0.8% overlap in this zone. Orange roughy has the largest overlap in the two deepest zones, with 0.6% in 1200–1400 m and 0.2% in 1400–1600 m. The overlap of each depth zone by the all-year, combined Tier 1 and Tier 2 target species footprint is shown in Table 6 and Figure 13.

Table 4: The total area of each depth zone, all depth zones ≤ 1600 m combined, and the percentage of each depth zone covered by the 2008–17 bottom-contact trawl footprint for each Tier 1 deepwater target species and for the Tier 1 targets combined.

Depth zone (m)	Area (km^2)	Footprint area overlap (%)									
		HAK	HOK	JMA	LIN	OEO	ORH	SBW	SCI	SQU	Tier 1
< 200	272 378	0.09	0.99	8.36	0.61	0.00	0.00	0.01	0.17	3.11	12.6
200–400	105 006	0.34	5.74	1.29	4.24	0.01	0.01	1.59	6.33	3.07	19.3
400–600	283 302	2.25	14.42	0.05	2.29	<0.01	0.01	2.91	1.87	0.44	20.9
600–800	226 302	1.83	9.75	0.02	0.63	0.09	0.10	0.05	0.06	0.26	11.3
800–1000	182 709	0.22	1.12	0.02	0.10	1.29	2.45	0.01	0.02	0.04	5.1
1000–1200	186 205	0.01	0.28	0.02	0.02	0.77	2.48	<0.01	0.01	0.02	3.5
1200–1400	210 881	<0.01	0.08	0.00	0.01	0.11	0.65	<0.01	0.01	0.01	0.9
1400–1600	157 466	<0.01	0.07	<0.01	0.01	0.03	0.20	<0.01	0.01	0.01	0.3
≤ 1600	1 624 249	0.71	4.59	1.50	0.88	0.26	0.68	0.62	0.78	0.84	9.7

Table 5: The total area of each depth zone, all depth zones ≤ 1600 m combined, and the percentage of each depth zone covered by the 2017 bottom-contact trawl footprint for the Tier 1 deepwater target species and the combined Tier 1 targets.

Depth zone (m)	Area (km^2)	Footprint area overlap (%)									
		HAK	HOK	JMA	LIN	OEO	ORH	SBW	SCI	SQU	Tier1
< 200	272 378	<0.0	0.05	0.95	0.04	–	<0.0	<0.0	0.01	0.79	2.5
200–400	105 006	0.01	1.29	0.09	0.26	–	<0.0	0.03	2.85	1.04	4.8
400–600	283 302	0.15	6.26	<0.0	0.24	–	<0.0	0.30	0.80	0.06	7.7
600–800	226 302	0.12	2.24	<0.0	0.07	<0.0	0.01	<0.0	<0.0	0.01	3.1
800–1000	182 709	0.01	0.19	<0.0	0.01	0.12	0.48	–	<0.0	<0.01	1.1
1000–1200	186 205	<0.0	0.03	<0.0	<0.0	0.07	0.47	–	<0.0	<0.01	0.6
1200–1400	210 881	<0.0	0.01	–	<0.0	0.01	0.16	–	<0.0	<0.01	0.2
1400–1600	157 466	–	0.01	–	<0.0	<0.0	0.04	–	<0.0	<0.01	0.0
≤ 1600	1 624 249	0.05	1.52	0.17	0.08	0.02	0.13	0.05	0.33	0.21	2.7

Table 6: The total area of each depth zone and the percentage of each depth zone covered by the 2008–17 and 2017 bottom-contact trawl footprints for the Tier 1 and Tier 2 deepwater target species combined.

Depth zone (m)	Area (km^2)	Footprint area overlap (%)	
		2008–17	2017
< 200	272 378	17.4	3.3
200–400	105 006	23.5	5.6
400–600	283 302	21.9	7.9
600–800	226 302	11.6	3.2
800–1000	182 709	5.3	1.1
1000–1200	186 205	3.6	0.6
1200–1400	210 881	0.9	0.2
1400–1600	157 466	0.4	< 0.1
≤ 1600	1 624 249	11.0	3.0

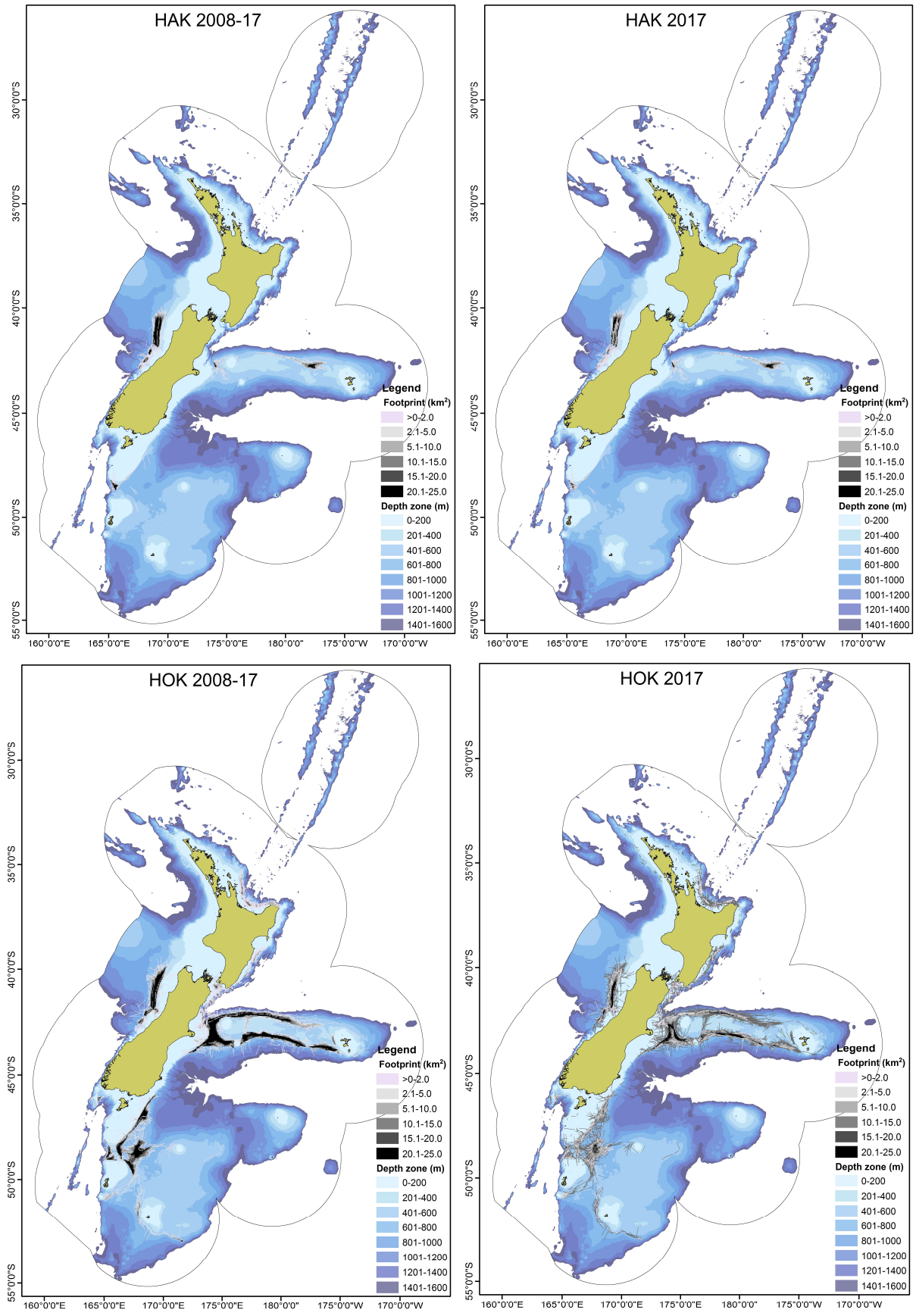

Figure 12a: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for hake (top) and hoki (bottom), relative to the 200-m depth zones.

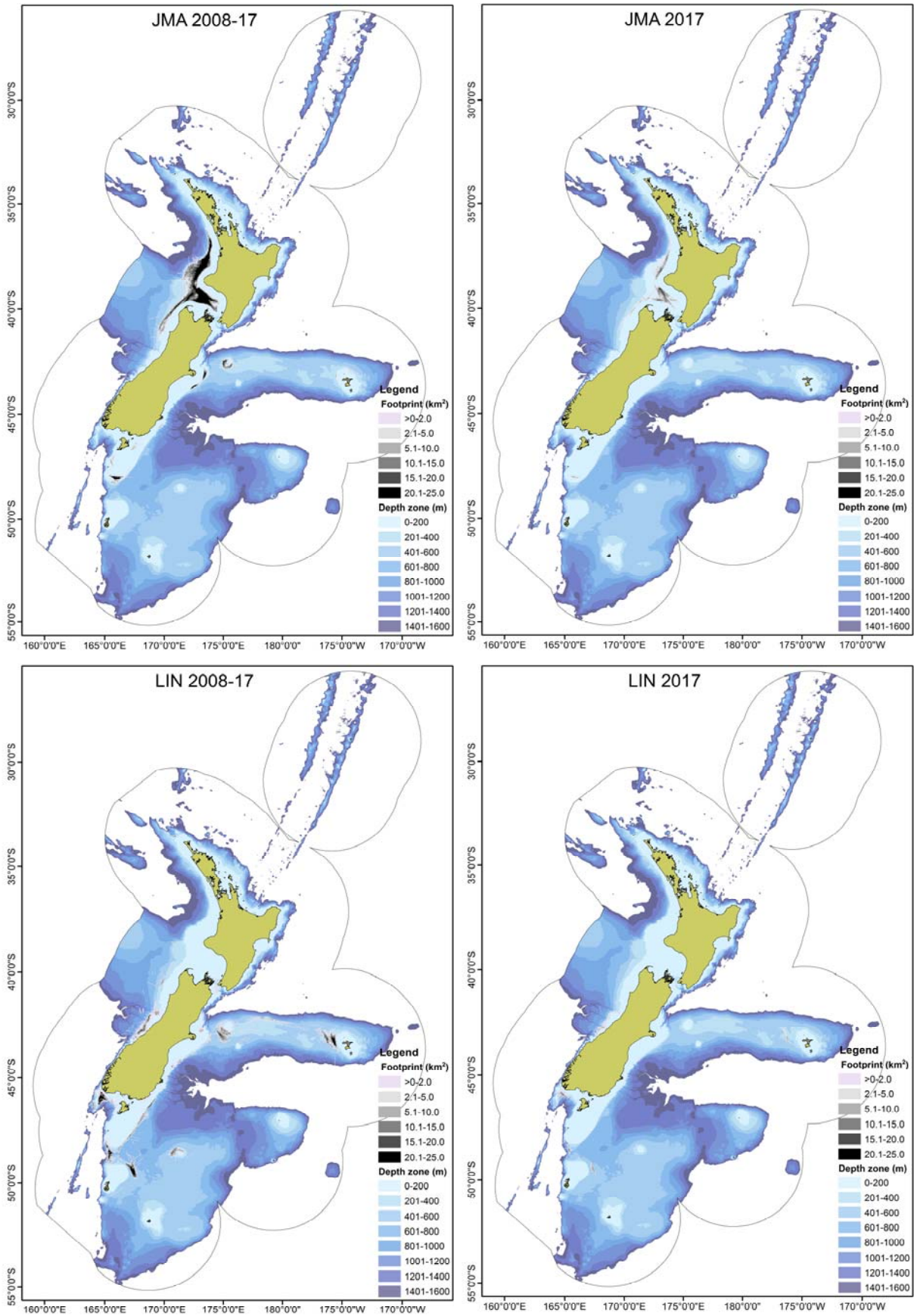

Figure 12b: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for jack mackerel species (top) and ling (bottom), relative to the 200-m depth zones.

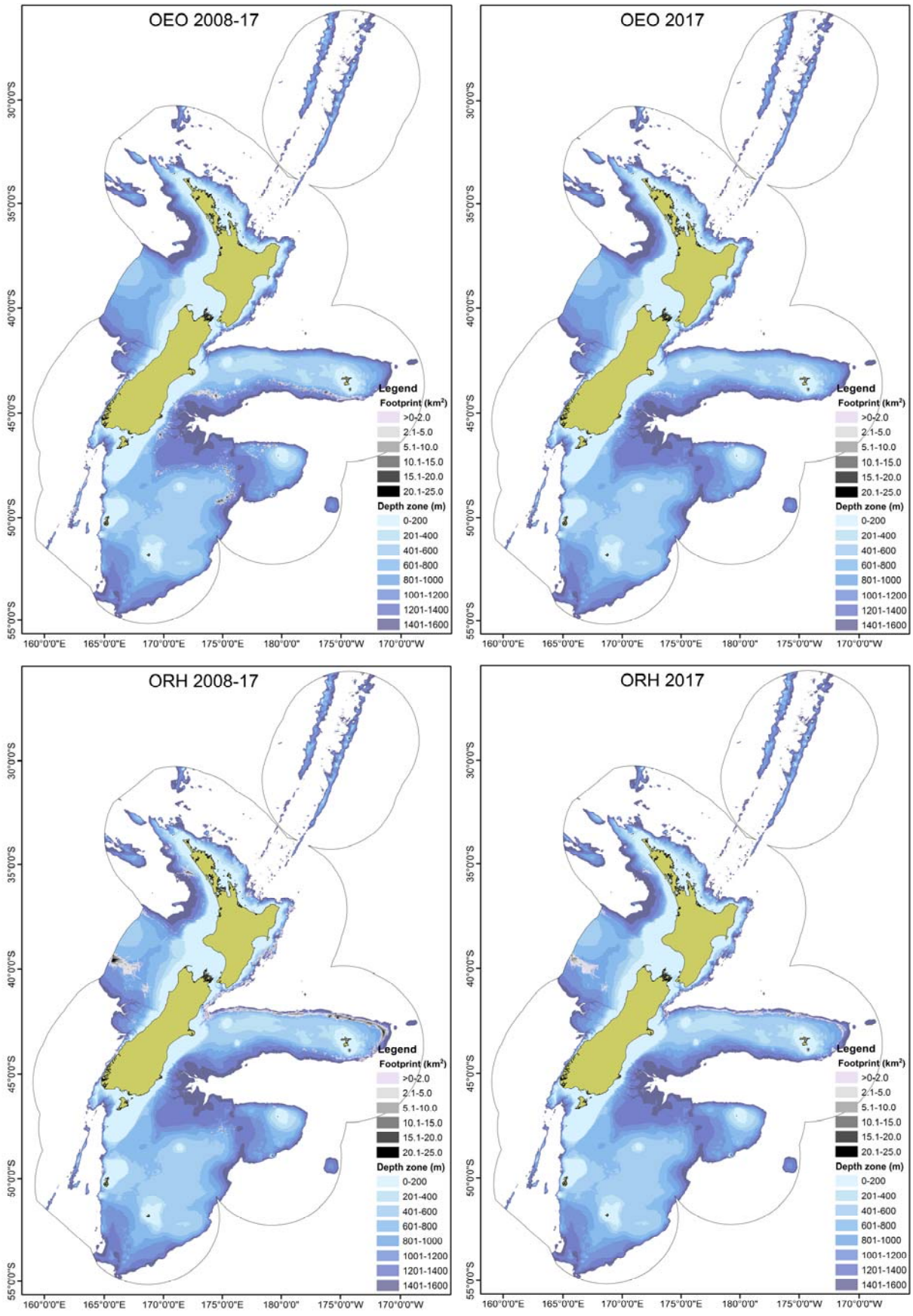

Figure 12c: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for oreo species (top) and orange roughy (bottom), relative to the 200-m depth zones.

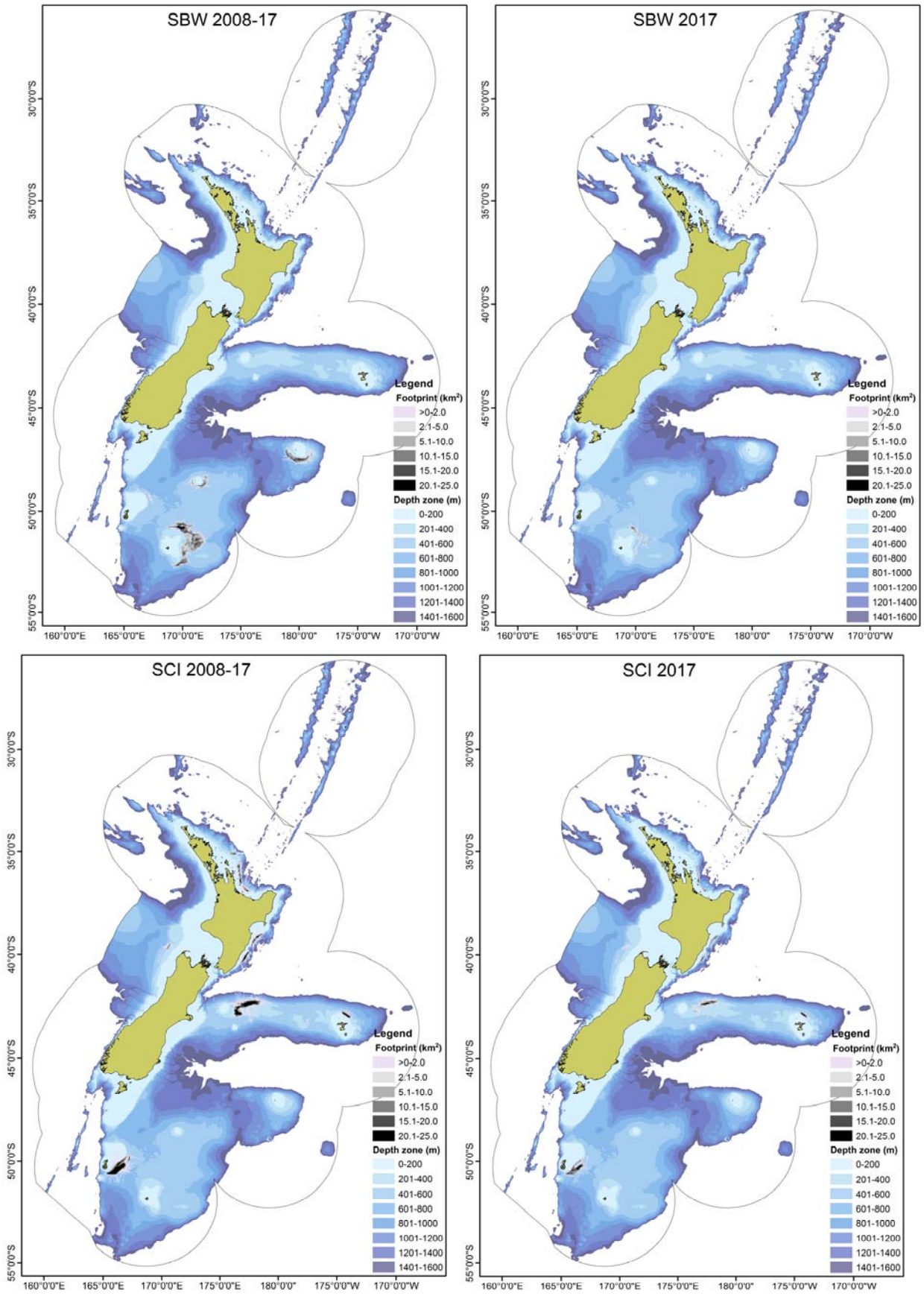

Figure 12d: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for southern blue whiting (top) and scampi (bottom), relative to the 200-m depth zones.

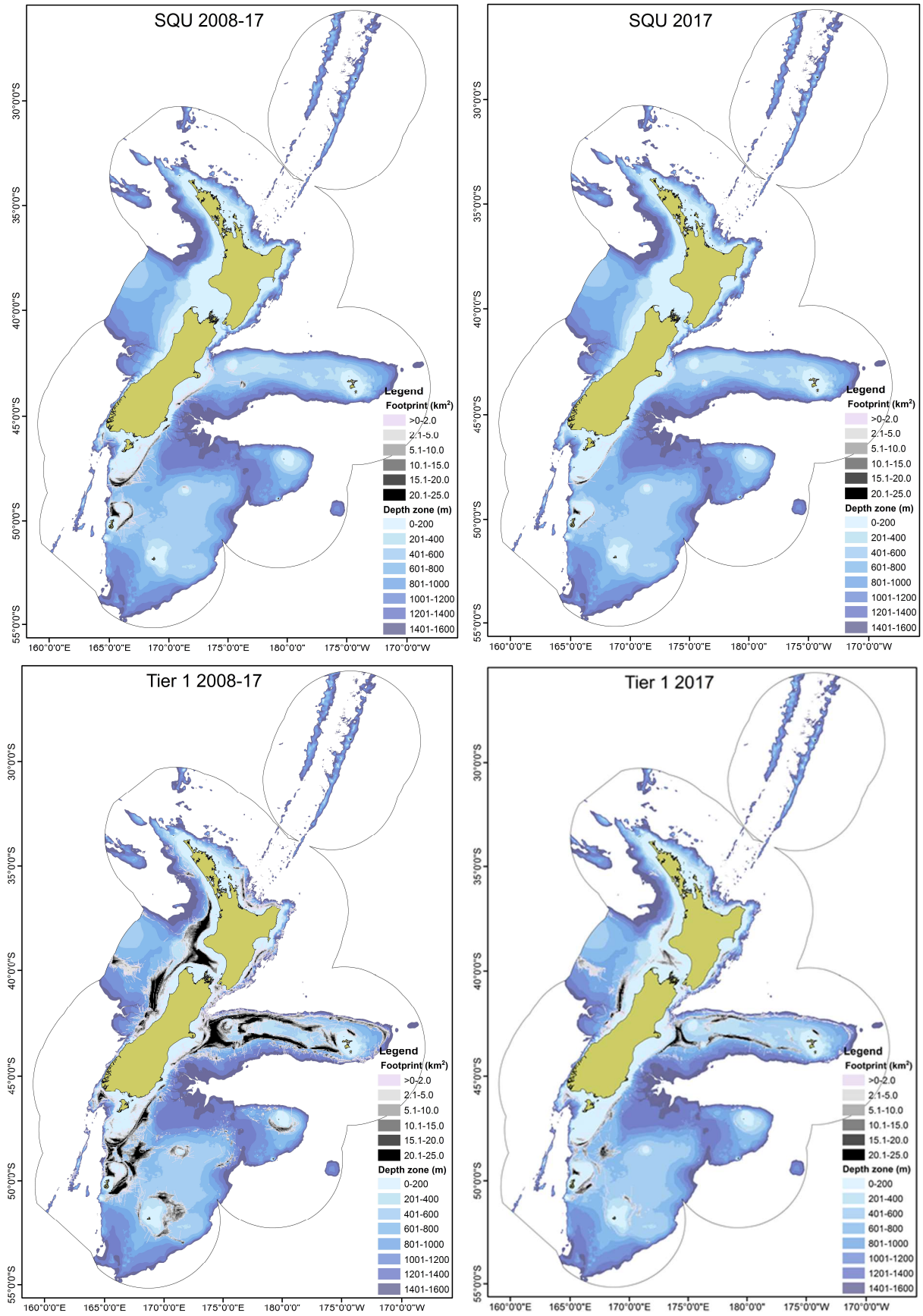

Figure 12e: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for arrow squid (top) and all Tier 1 species combined (bottom), relative to the 200-m depth zones.

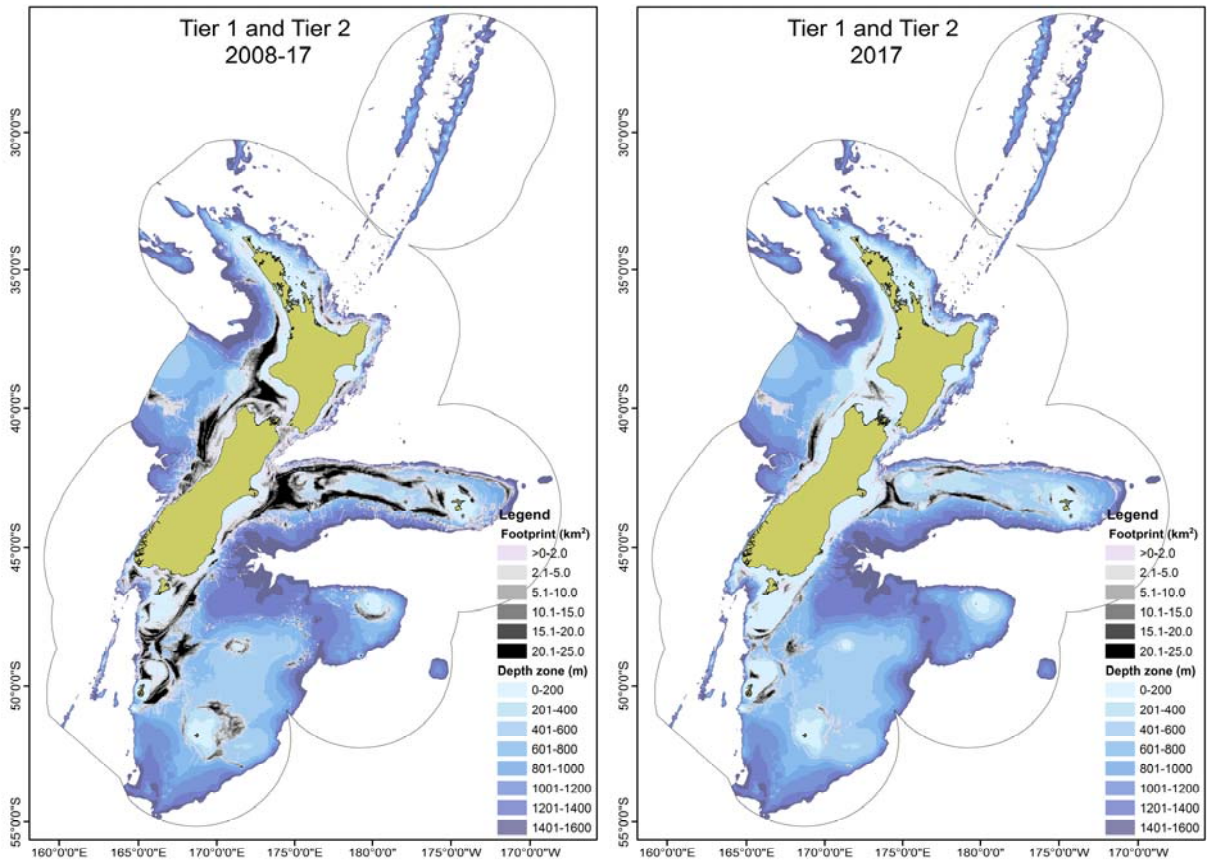

Figure 13: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for all Tier 1 and Tier 2 species combined (bottom), relative to the 200-m depth zones.

5.2 Overlap of the bottom-contacting trawl footprint and BOMEC

For the Tier 1 targets in 2008–17, the greatest percent overlaps are evident in the BOMEC classes G, H, and I (see Figure B2 in Appendix B) when hoki was targeted, class C when jack mackerel was targeted, and classes E and F from arrow squid effort (Table 7, Figures 14a–14e). The class with the highest species overlap is class I which has a very small area and the hoki footprint covers 45% of the class. Similarly, the hoki overlap is equivalent to 13% of the area of Class G, with another 10% from ling, but this class is small in area relative to others. The patterns of overlap seen for the targets and BOMEC classes in 2017 (Table 8) are similar to those in 2008–17.

Classes in predominantly deeper water, but not out to 3000 m, such as classes J, L, and M, cover the largest areas of seafloor within fishing depths and the percentage overlap is appreciably smaller; with 6% for hoki overlap and 3% for orange roughy in class J; 5% for hoki, 4% for southern blue whiting, and 2% for scampi in class L; and about 2% for all Tier 1 targets combined in class M.

Table 7: The total area of each BOMEC class and the percentage of each area covered by the 2008–17 bottom-contact trawl footprint for the Tier 1 deepwater target species. There are some large differences in the areas of some classes. – indicates no overlap.

		Footprint area overlap (%)									
Class	Area (km^2)	HAK	HOK	JMA	LIN	OEO	ORH	SBW	SCI	SQU	Tier 1
A	27 557.0	<0.01	0.10	0.08	0.01	–	–	–	0.06	–	0.25
B	12 420.0	0.24	1.51	0.17	1.54	<0.01	<0.01	–	<0.01	0.08	3.37
C	89 710.2	0.06	0.72	19.67	0.26	–	<0.01	–	0.14	0.02	20.76
D	27 267.9	<0.01	0.78	0.42	0.44	<0.01	<0.01	–	0.01	0.43	1.98
E	60 989.8	0.37	2.18	4.51	1.56	0.01	<0.01	–	0.03	9.03	14.40
F	38 608.5	0.01	0.12	0.02	0.51	<0.01	<0.01	2.70	0.38	6.24	9.74
G	6 341.9	0.49	12.93	0.13	9.75	0.01	0.05	–	0.40	0.06	22.32
H	138 551.4	1.78	12.20	2.55	4.13	<0.01	0.01	–	5.10	0.90	23.81
I	52 223.9	2.72	44.79	0.06	4.48	0.03	0.02	1.93	0.04	3.33	49.79
J	311 360.4	2.32	6.05	0.07	0.52	0.63	2.77	–	0.37	0.05	10.83
K	1 289.1	–	–	–	–	–	–	–	–	–	–
L	198 577.0	0.04	4.79	<0.01	1.10	0.01	–	3.89	2.02	1.19	11.87
M	233 825.5	<0.01	0.90	–	0.03	0.81	0.07	0.13	<0.01	0.02	1.93
N	493 034.7	<0.01	0.11	<0.01	<0.01	0.07	0.45	<0.01	0.01	0.01	0.64
O	935 315.2	<0.01	0.02	–	<0.01	<0.01	0.02	–	<0.01	<0.01	0.05
All	2 627 072.6	0.44	2.85	0.93	0.54	0.16	0.43	0.38	0.48	0.52	6.02

Table 8: The total area of each BOMEC class and the percentage of each area covered by the 2017 bottom-contacting trawl footprint for the Tier 1 deepwater target species. – indicates no overlap.

		Footprint area overlap (%)									
Class	Area (km^2)	HAK	HOK	JMA	LIN	OEO	ORH	SBW	SCI	SQU	Tier1
A	27 557.0	–	<0.01	<0.01	<0.01	–	–	–	<0.01	–	0.01
B	12 420.0	<0.01	0.44	0.01	0.24	–	<0.01	–	<0.01	0.01	0.70
C	89 710.2	<0.01	0.09	3.65	0.05	–		–	<0.01	0.01	3.80
D	27 267.9	<0.001	0.07	0.01	0.02	–	–	–	<0.01	0.05	0.15
E	60 989.8	<0.01	0.37	0.28	0.10	<0.01	–	–	<0.01	2.58	3.15
F	38 608.5	–	<0.01	–	<0.01	–	<0.01	0.25	<0.01	2.05	2.12
G	6 341.9	0.09	3.13	<0.01	2.08	–	–	–	0.01	0.01	5.34
H	138 551.4	0.02	3.95	0.24	0.34	–	<0.01	–	<0.01	0.14	6.35
I	52 223.9	0.32	19.71	–	0.33	<0.01	<0.01	0.02	<0.01	0.63	2.60
J	311 360.4	0.43	2.31	<0.01	0.07	0.04	0.69	–	<0.01	0.01	3.38
K	1 289.1	–	–	–	–	–	–	–	–	–	–
L	198 577.0	<0.001	1.33	–	0.12	<0.01	–	0.07	<0.01	0.39	2.99
M	233 825.5	<0.001	0.30	–	<0.01	0.04	<0.01	0.02	<0.01	–	0.35
N	493 034.7	<0.001	<0.01	–	<0.01	0.01	0.11	–	<0.01	<0.01	0.12
O	935 315.2	–	–	–	–	<0.01	<0.01	–	<0.01	<0.01	0.00
All	2 627 072.6	0.06	1.02	0.14	0.05	0.01	0.10	<0.01	<0.01	0.14	1.68

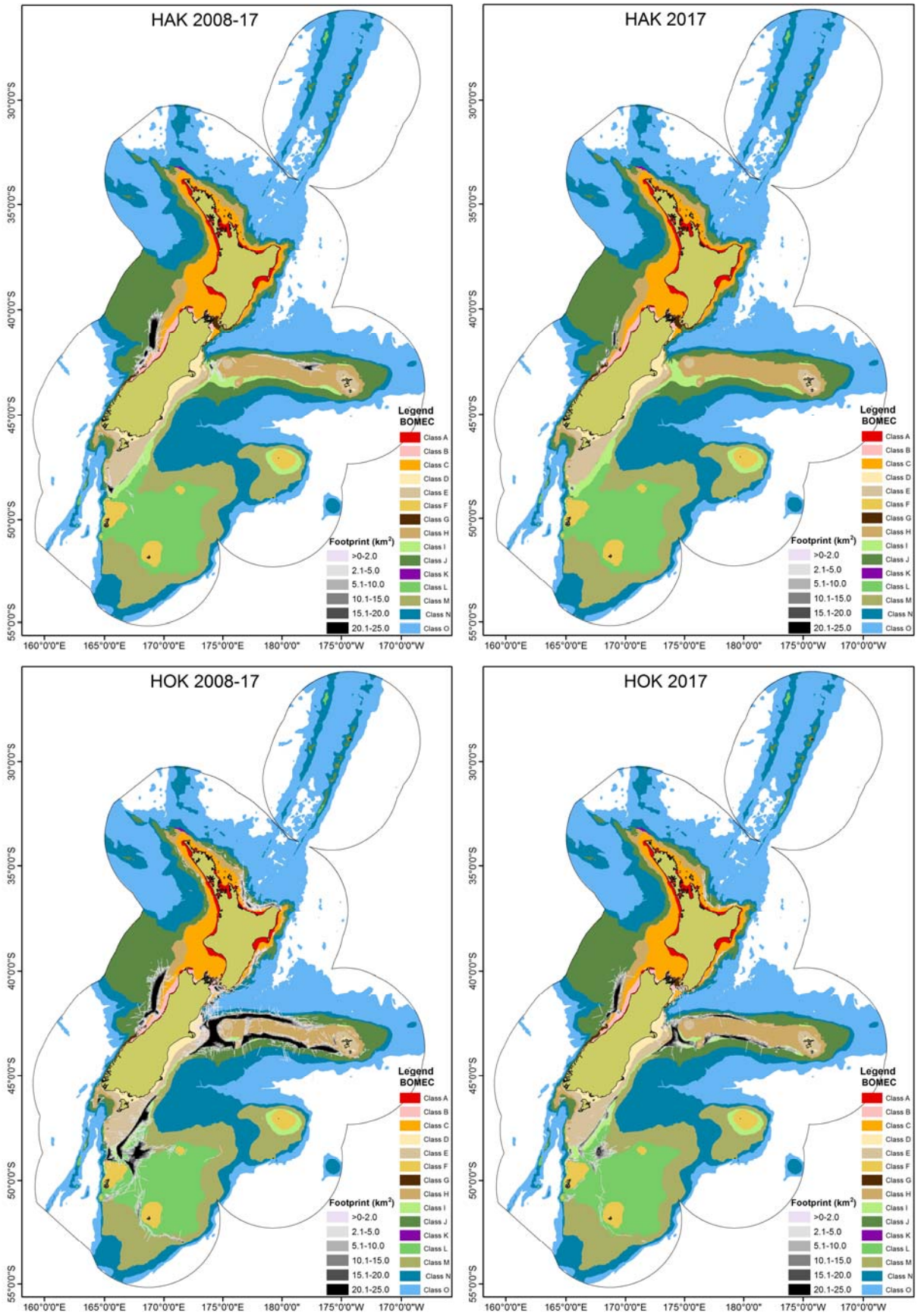

Figure 14a: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for hake (top) and hoki (bottom), relative to the 15 BOMEC classes (to depths of 3000 m) (after Leathwick et al. 2012).

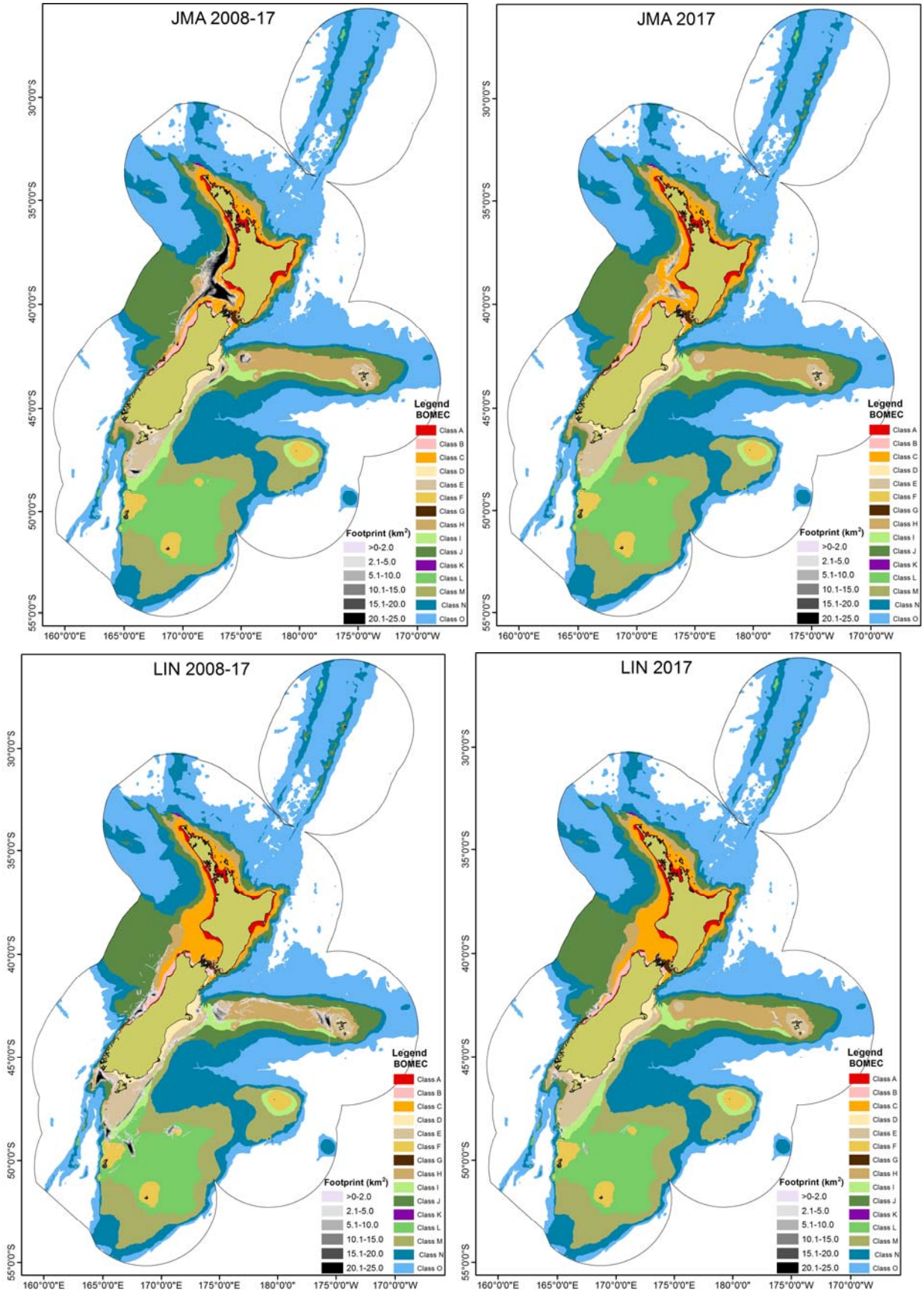

Figure 14b: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for jack mackerels (top) and ling species (bottom), relative to the 15 BOMEC classes (to depths of 3000 m) (after Leathwick et al. 2012).

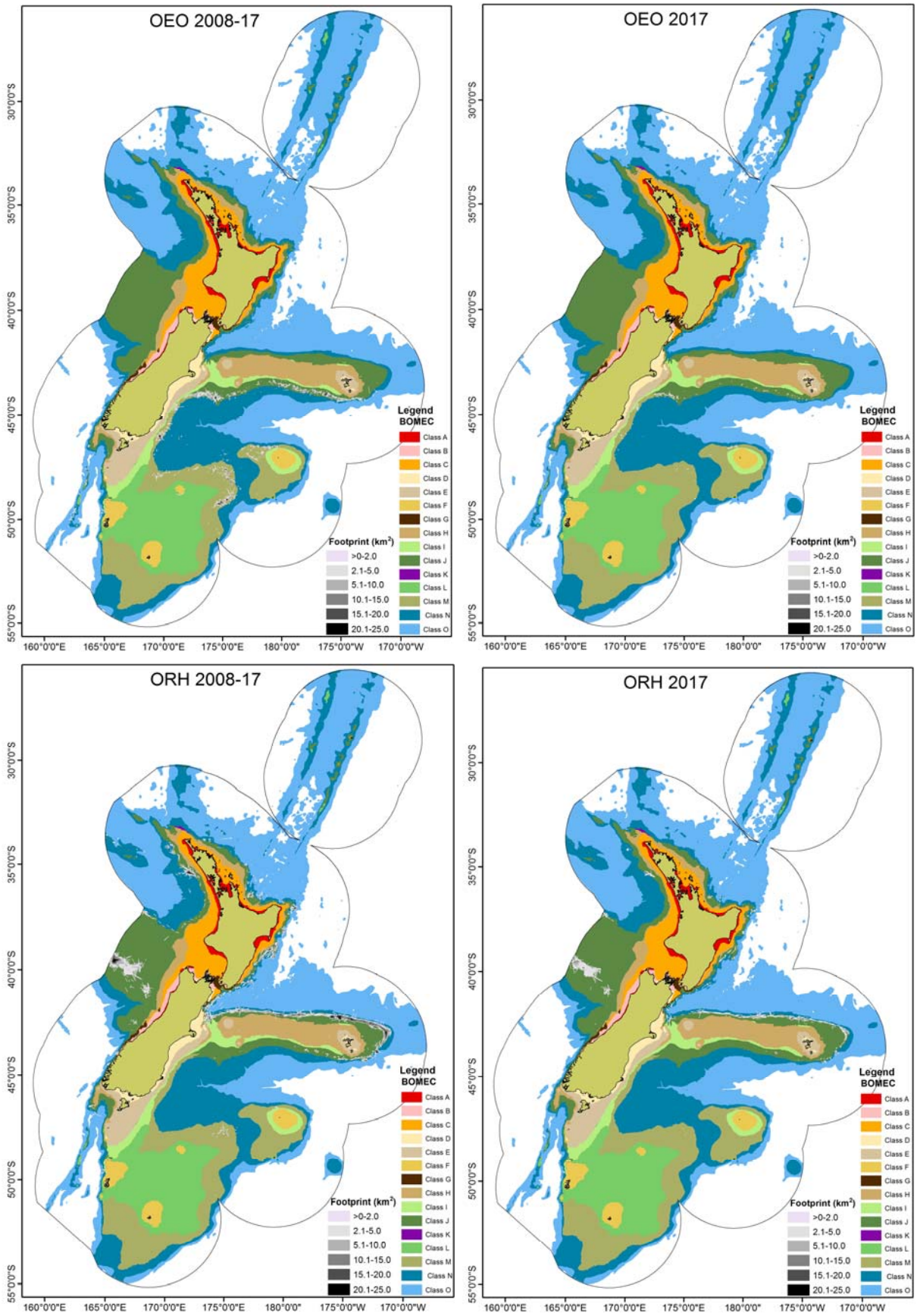

Figure 14c: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for oreo species (top) and orange roughy (bottom), relative to the 15 BOMEC classes (to depths of 3000 m) (after Leathwick et al. 2012).

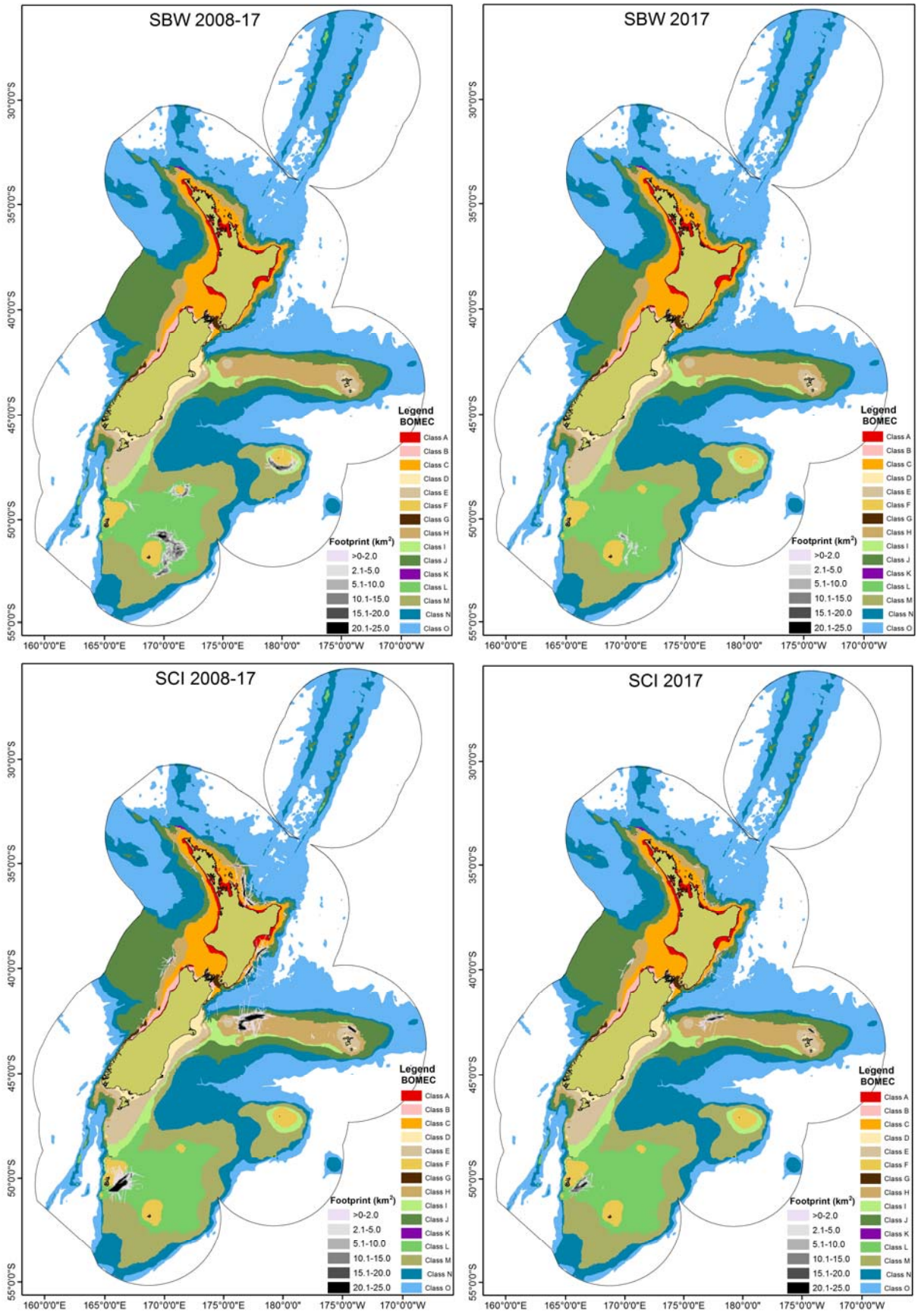

Figure 14d: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for southern blue whiting (top) and scampi (bottom), relative to the 15 BOMEC classes (to depths of 3000 m) (after Leathwick et al. 2012).

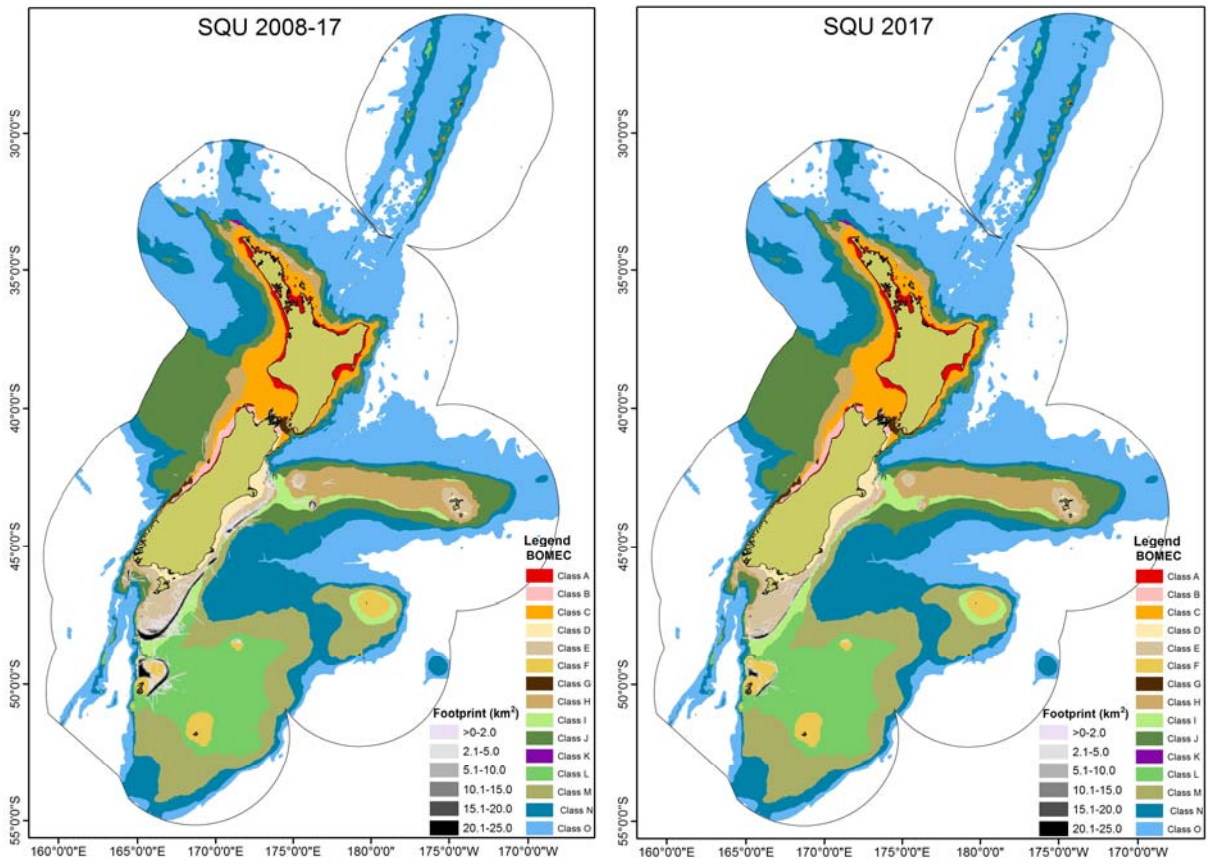

Figure 14e: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for arrow squid, relative to the 15 BOMEC classes (to depths of 3000 m) (after Leathwick et al. 2012).

The all-year, combined Tier 1 and Tier 2 species footprint was largely determined by the distribution of the Tier 1 species and had the greatest overlap in class I – at 51% from hoki effort (Table 9, Figure 15). About 33% of class G (a small area in Cook Strait region) was covered by the total footprint, 28% of class H (mainly across the Chatham Rise and off the west coast of the South Island), 25% of class C by jack mackerel species effort off the west coast of the North Island and upper South Island, and 21% of class E by mainly jack mackerel, hoki, and arrow squid effort on the shelf off the South Island east coast.

The BOMEC classes with the smallest total footprint overlap were in areas where there was little fishing for the fishstocks being considered (see Figure 15).

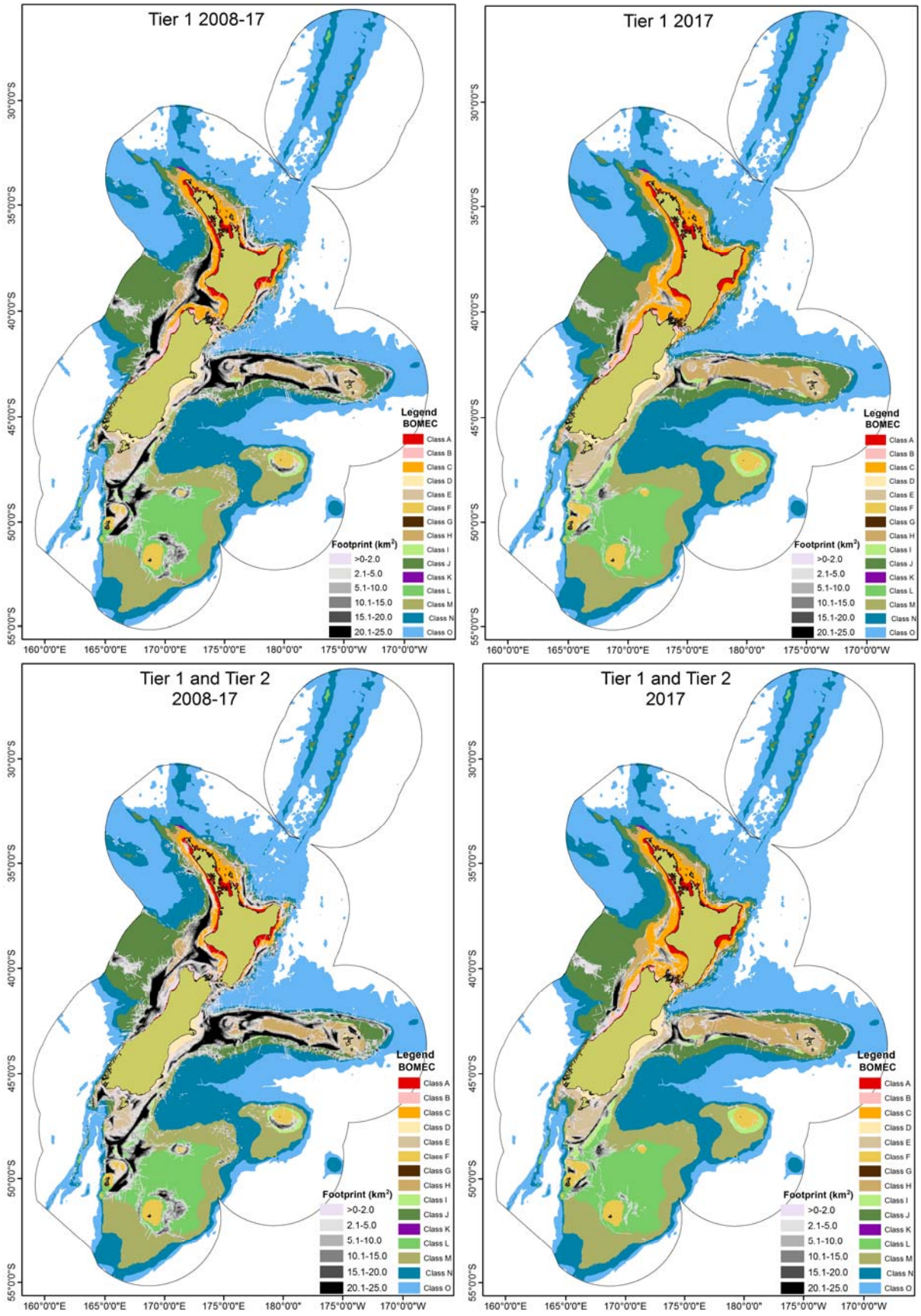

Figure 15: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for Tier 1 (top) and Tier 1 and Tier 2 combined, relative to the 15 BOMEC classes (to depths of 3000 m) (after Leathwick et al. 2012).

Table 9: The total area of each BOMEC class and the percentage of each area covered by the 2008–17 and the 2017 bottom-contacting trawl footprints for the combined Tier 1 and Tier 2 deepwater target species.

BOMEC Class	Area (km^2)	2008–17 %	2017 %
A	27 557.0	1.3	< 0.1
B	12 420.0	21.4	1.8
C	89 710.2	25.2	4.2
D	27 267.9	6.4	0.6
E	60 989.8	20.9	5.5
F	38 608.5	9.8	2.1
G	6 341.9	33.4	6.4
H	138 551.4	28.3	7.3
I	52 223.9	51.3	21.2
J	311 360.4	11.4	3.5
K	1 289.1	0.0	0.0
L	198 577.0	11.9	3.0
M	233 825.5	2	0.4
N	493 034.7	0.7	0.1
O	935 315.2	0.1	< 0.1
All	2 627 072.6	6.9	1.8

5.3 Overlap of the bottom-contacting trawl footprint and preferred fish habitat/annual distribution for Tier 1 species

Overlap of each Tier 1 species footprint on their 'preferred habitat' distribution for the seven fish species (or annual distribution for scampi and arrow squid) is shown in Figures 16a–16d and the percentage overlap is given in Table 10. This overlap is presented as the percent overlap for the probablity of capture of a fish from a standardised trawl, where 91–100% is the body of water in which a trawl is most likely to capture the species. For most targets, the greatest overlap of the footprint was where the probability of capture was highest. However, for a few targets, such as hake and jack mackerels, the footprint overlap was higher in areas where the probablity of capture was 60–90% and 50–90%, respectively. The footprint overlaps of the annual distributions for scampi and arrow squid are given in Table 10 and Figure 17.

Table 10: The total area of each 'preferred habitat' (probability of capture) and the percentage of each species 'preferred habitat' (probability of capture) area (for HAK, HOK, JMA, LIN, OEO, ORH, and SBW) or area of the annual distribution (for SCI and SQU) covered by the 2008–17 and 2017 bottom-contacting trawl footprint for the Tier 1 deepwater target species.

Preferred habitat	HAK area	HAK footprint overlap (%)		HOK area	HOK footprint overlap (%)		JMA area	JMA footprint overlap (%)	
(%)	(km^2)	2008–17	2017	(km^2)	2008–17	2017	(km^2)	2008–17	2017
0	202 097	< 0.1	0.0	204 964	< 0.1	0.0	1 418 074	< 0.1	< 0.1
0.1–1.0	244 964	< 0.1	< 0.1	330 294	0.1	< 0.1	33 410	0.1	< 0.1
1.1–5.0	577 217	< 0.1	< 0.1	291 969	0.3	< 0.1	67 480	0.3	< 0.1
5.1–10.0	204 473	0.1	< 0.1	111 676	0.7	0.1	49 148	0.2	< 0.1
10.1–0.0	170 408	0.1	< 0.1	134 901	0.7	0.1	54 084	0.8	< 0.1
20.1–30.0	103 565	0.2	< 0.1	59 165	1.3	0.2	49 732	3.7	0. 3
30.1–40.0	79 792	0.4	< 0.1	42 155	1.5	0.3	42 506	5.7	0.5
40.1–50.0	72 627	1.2	0.189	34 019	2.0	0.5	37 320	5.9	1.0
50.1–60.0	67 559	1.9	0.388	32 943	2.5	0.5	33 291	9.9	2.3
60.1–70.0	63 800	3.1	0.481	35 693	2.5	0.7	36 193	18.5	3.2
70.1–80.0	56 649	6.6	0.829	39 001	2.9	0.9	28 729	16.5	2.1
80.1–90.0	26 713	7.7	1.188	64 032	3.7	1.2	14 934	14.1	3.5
90.1–95.0	2 827	4.9	0.546	138 827	6.0	2.2	5 123	0.1	0.0
95.1–99.0	240	0.3	0.0	353 292	15.9	6.1	2 907	< 0.1	0.0
0.0–99.0	1 872 931	1.3	0.2	1 872 931	4.0	1.4	1 872 931	0.6	0.1

Table 10: — *continued*

Preferred habitat (%)	LIN area (km^2)	LIN footprint overlap (%)		OEO area (km^2)	OEO footprint overlap (%)		ORH area (km^2)	ORH footprint overlap (%)	
		2008–17	2017		2008–17	2017		2008–17	2017
0	26 441	0.01	< 0.01	706 800	< 0.01	< 0.001	994 473	0.01	< 0.001
0.1–1.0	718 182	0.01	< 0.01	171 801	< 0.01	< 0.001	141 916	0.02	< 0.001
1.1–5.0	205 226	0.04	0.01	260 248	0.01	< 0.01	156 027	0.05	< 0.01
5.1–10.0	81 338	0.10	0.01	124 020	0.02	< 0.01	67 560	0.09	0.02
10.1–0.0	114 741	0.26	0.01	114 076	0.04	0.01	73 394	0.18	0.04
20.1–30.0	77 477	1.10	0.04	70741	0.06	< 0.01	49 725	0.26	0.05
30.1–40.0	47 409	1.78	0.13	48 614	0.08	< 0.01	36 247	0.35	0.06
40.1–50.0	36 658	2.37	0.24	44 832	0.10	< 0.01	30 953	0.37	0.06
50.1–60.0	40 624	1.99	0.19	45 664	0.10	< 0.01	31 241	0.26	0.03
60.1–70.0	35 529	2.18	0.24	48 856	0.15	< 0.01	39 780	0.30	0.05
70.1–80.0	48 160	1.71	0.22	62 442	0.42	0.02	49 936	0.44	0.08
80.1–90.0	106 259	1.20	0.14	81 103	1.07	0.03	57 127	0.91	0.21
90.1–95.0	141 069	2.00	0.19	45 309	1.49	0.08	34 929	1.96	0.44
95.1–99.0	193 818	2.44	0.23	48 425	4.32	0.32	109 623	8.01	2.03
0.0–99.0	1 872 931	0.76	0.07	1 872 931	0.23	0.01	1 872 931	0.60	0.14

Table 10: — *continued.*

Preferred habitat (%)	SBW Area (km^2)	SBW Footprint overlap (%) 2008–17	SBW Footprint overlap (%) 2017	SCI Annual distribution*	SCI Area (km^2)	SCI Footprint overlap (%) 2008–17	SCI Footprint overlap (%) 2017	SQU Area (km^2)	SQU Footprint overlap (%) 2008–17	SQU Footprint overlap (%) 2017
0	1 197 845	< 0.01	0.0	None	3 654 869	< 0.01	< 0.001	3 545 982	< 0.01	< 0.001
0.1–1.0	240 707	0.01	< 0.01	Hotspot	15 122	21.68	7.43	58 591	26.47	2.71
1.1–5.0	201 706	0.09	< 0.01	90% population	78 404	7.96	2.54	251 879	12.03	1.41
5.1–10.0	28 602	0.71	< 0.01	100% population	496 344	2.49	0.94	605 231	6.33	0.61
10.1–20.0	22 369	1.08	0.01							
20.1–30.0	15 581	1.06	< 0.01							
30.1–40.0	12 632	1.26	0.03							
40.1–50.0	11 644	1.29	0.03							
50.1–60.0	10 187	1.98	0.07							
60.1–70.0	9 455	3.13	0.05							
70.1–80.0	12 704	3.81	0.25							
80.1–90.0	26 675	5.48	0.54							
90.1–95.0	23 575	9.90	1.18							
95.1–99.0	59 249	7.00	0.44							
0.0–99.0	1 872 931	0.54	0.04							

***** For SCI and SQU, the areas given here represent the areas shown for the annual distribution for scampi and arrow squid provided by MPI at www.nabis.govt.nz. The 'None' category is the area outside the 100% population area within the combined EEZ and Territorial Sea as shown in Figure 17.

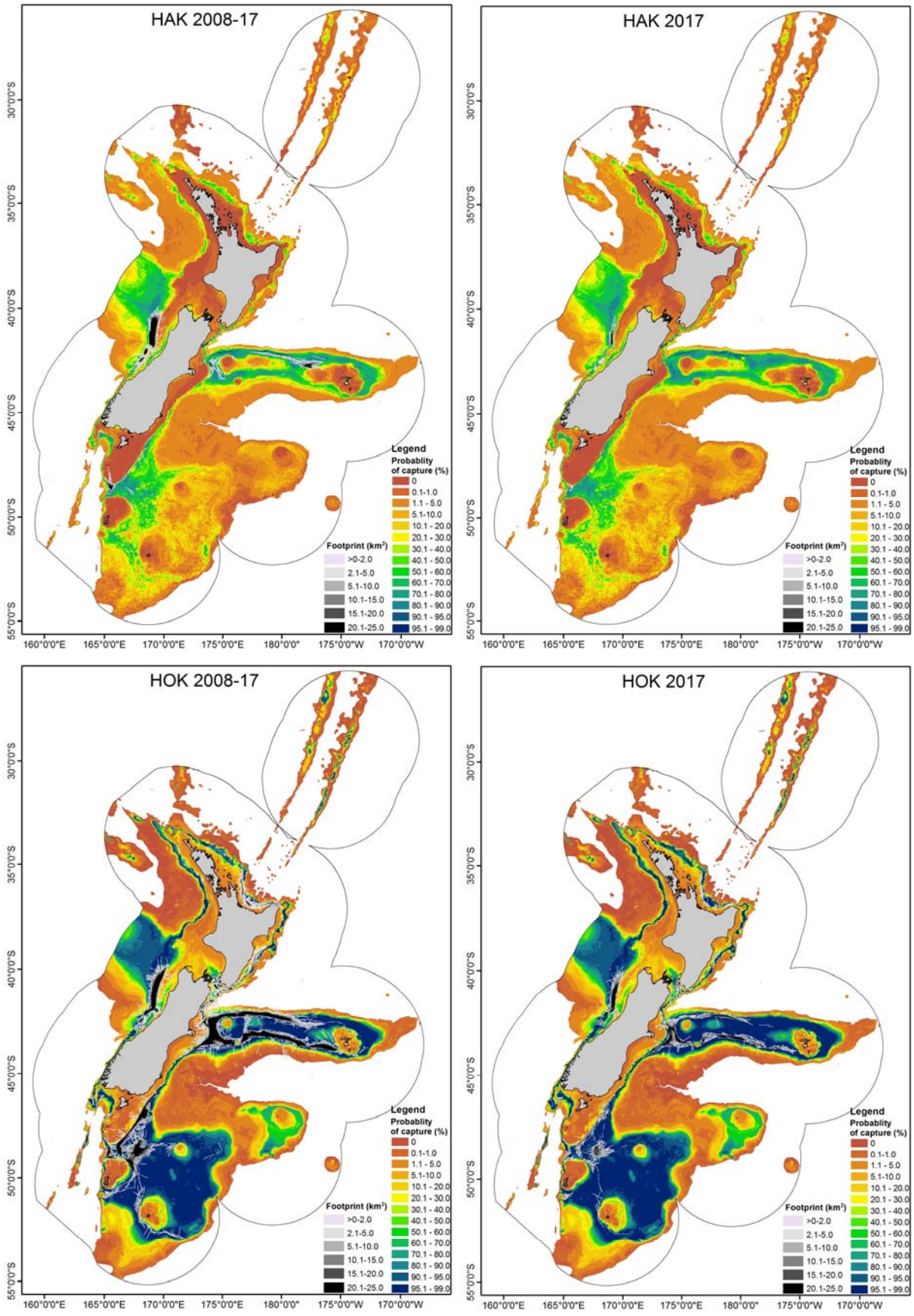

Figure 16a: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for hake (top) and hoki (bottom), relative to the probablity of capture for that species (after Leathwick et al. 2006).

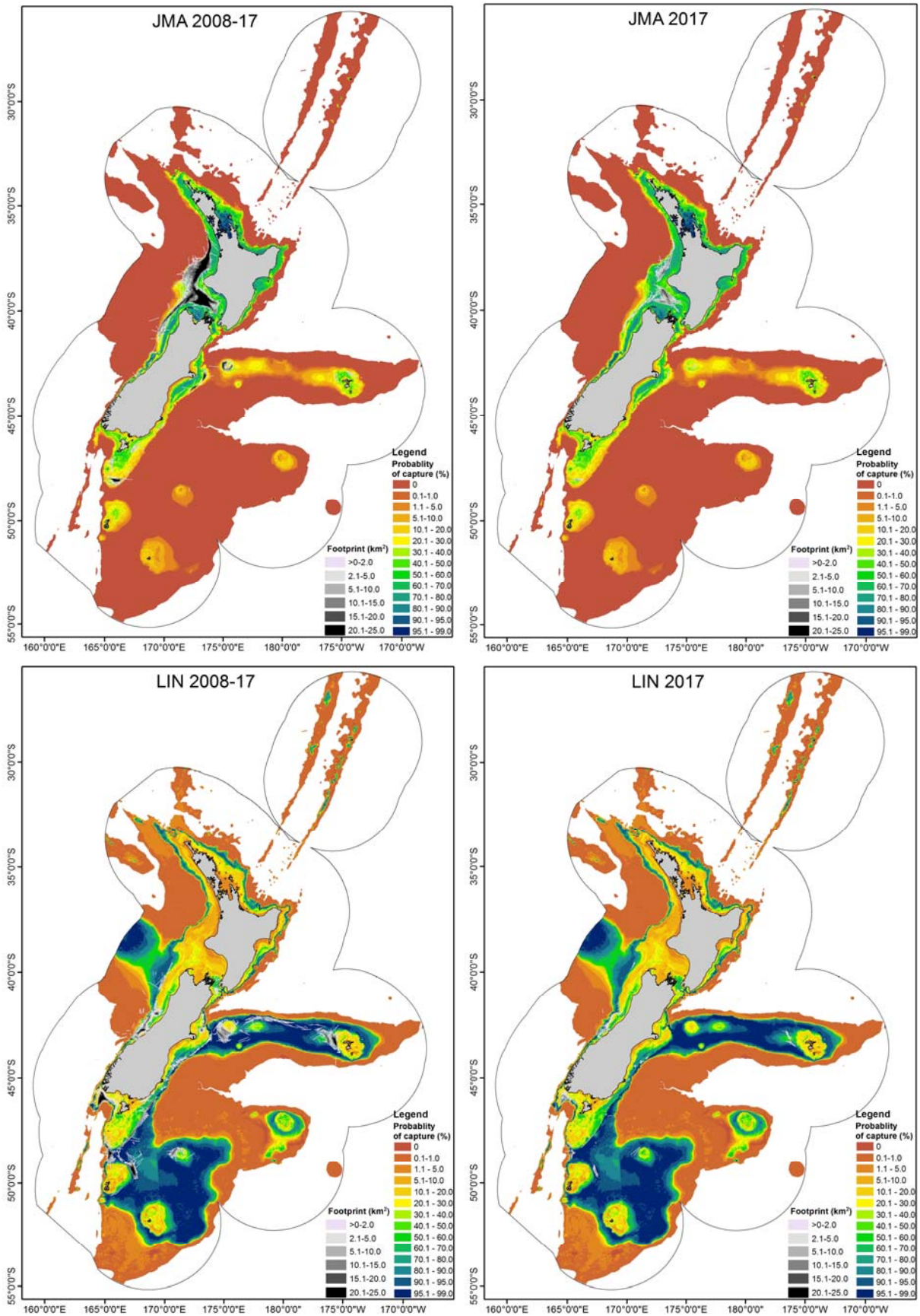

Figure 16b: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for jack mackerel species (top) and ling (bottom), relative to the probablity of capture for that species (after Leathwick et al. 2006).

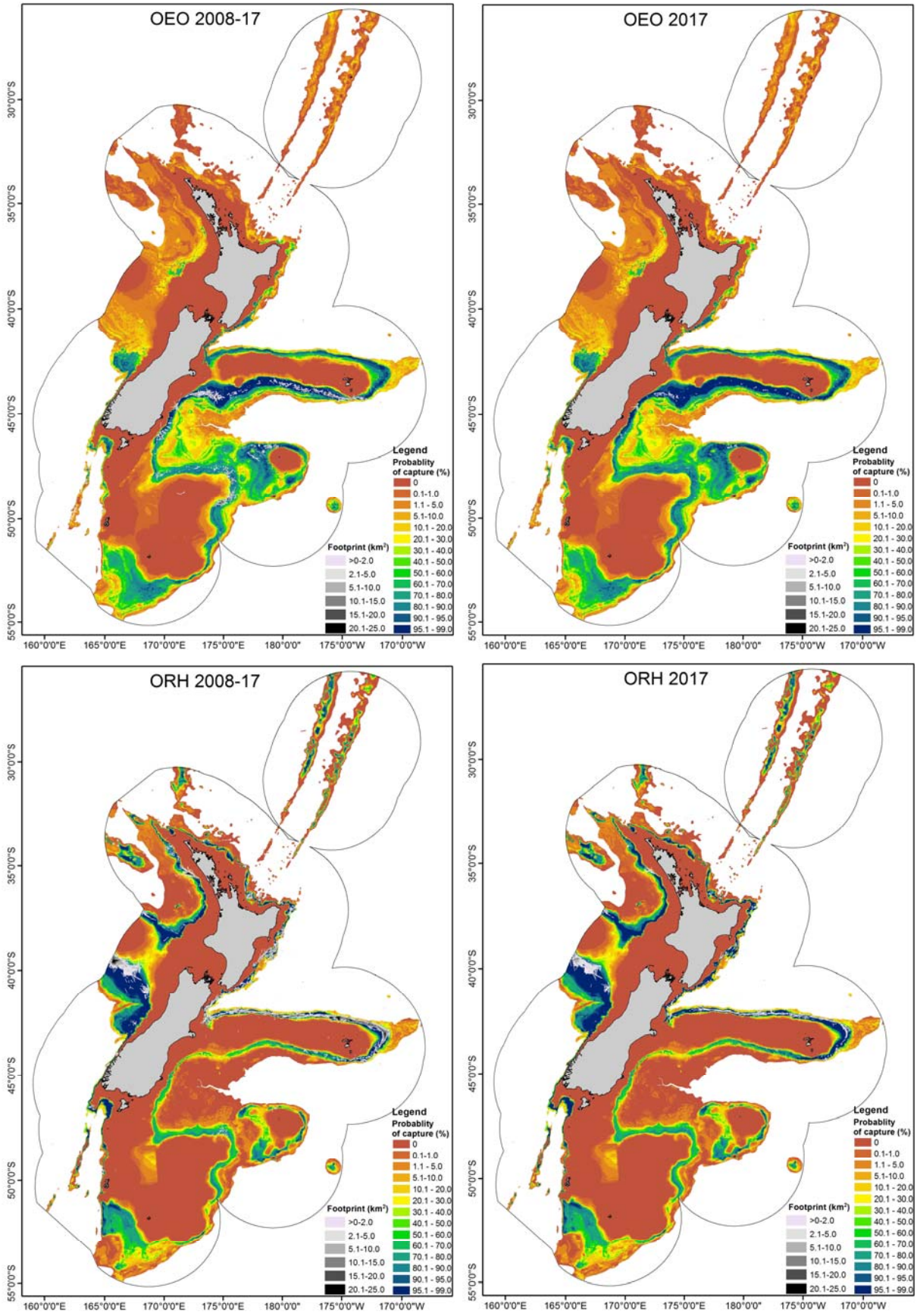

Figure 16c: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for oreo species (top) and orange roughy (bottom), relative to the probablity of capture for that species (after Leathwick et al. 2006).

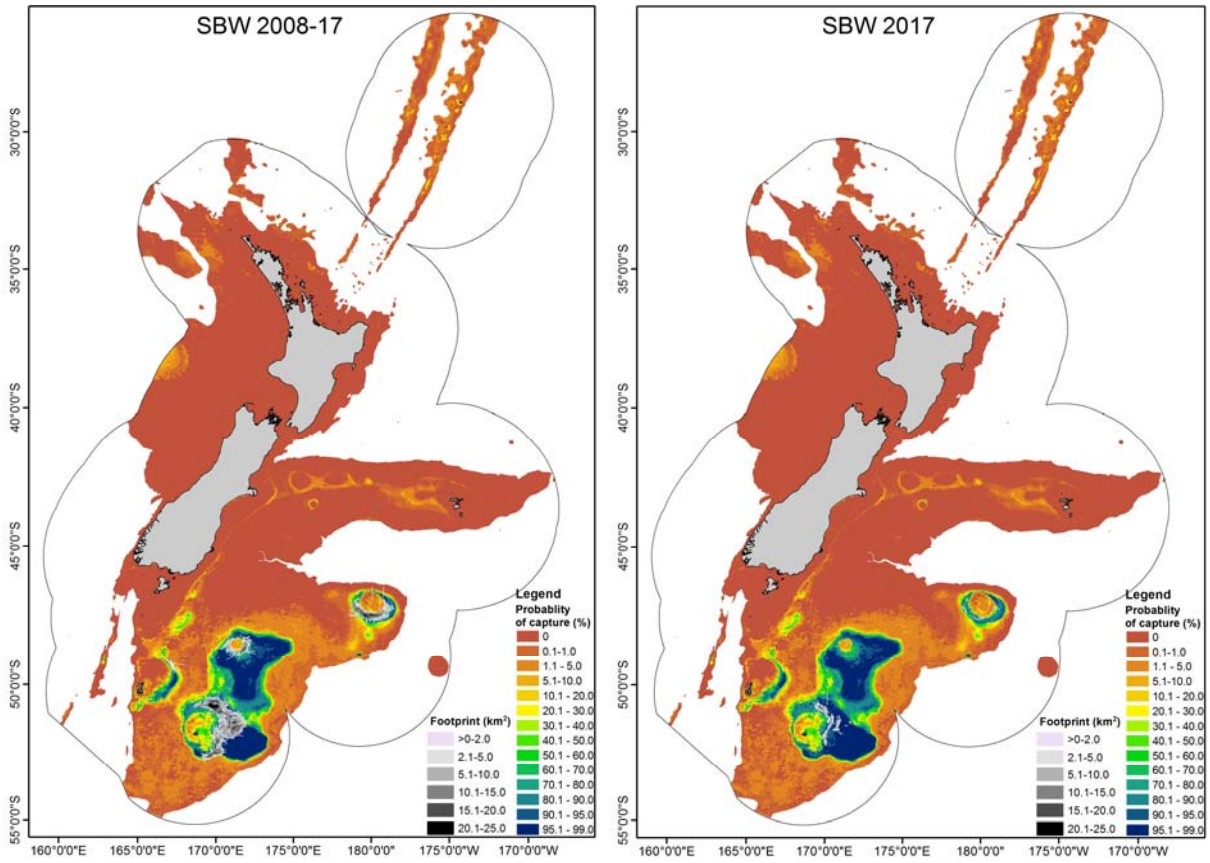

Figure 16d: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for southern blue whiting, relative to the probablity of capture for that species (after Leathwick et al. 2006).

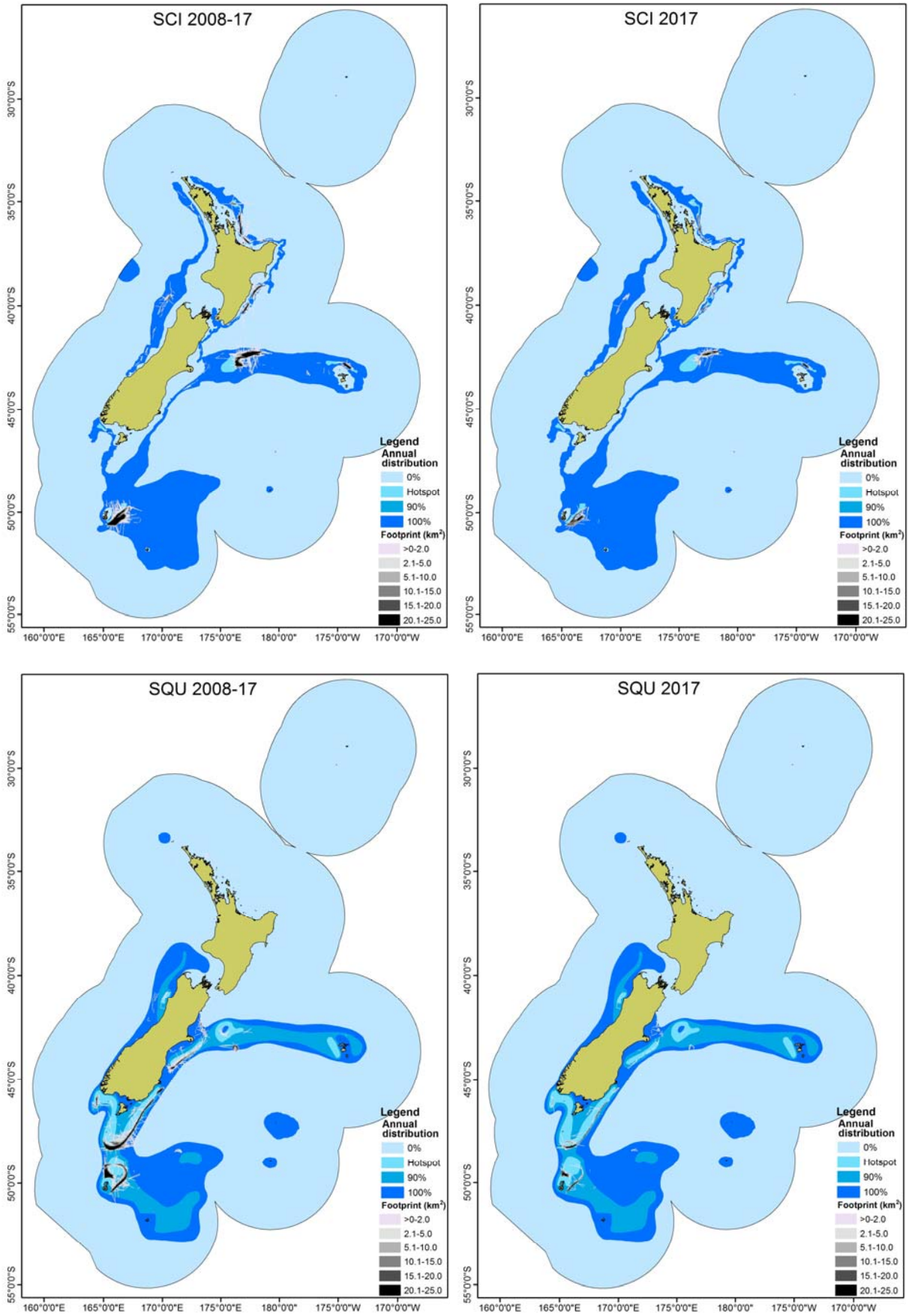

Figure 17: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for scampi (top) and arrow squid (bottom), relative to the annual distribution of the species population (see www.nabis.govt.nz).

5.4 Overlap of the trawl footprint and 'fishable' area for Tier 1 and Tier 2 species

The overlap statistics of the trawl footprint on the 'fishable' area are tabulated in Table 2 and the 2008–17 and 2016 overlaps are shown in Figure 18. About 13% of the 'fishable' area was contacted by trawl gear, 11% by Tier 1 targets, with hoki covering the greatest area, at about 5.4%. The jack mackerel 2008–17 footprint covered about 2%, and the scampi and arrow squid footprints each covered about 1% of the 'fishable' area.

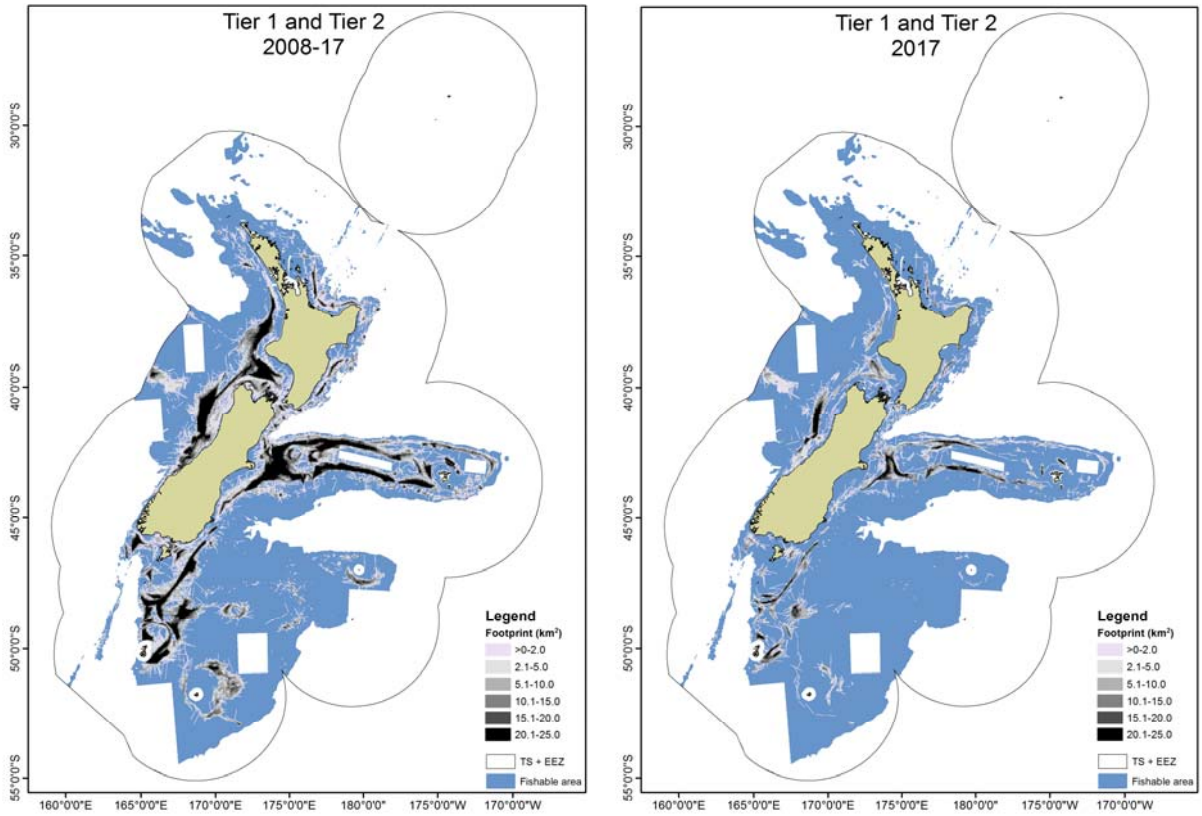

Figure 18: Distribution of the 2008–17 (left) and the 2017 trawl footprints (right) for Tier 1 and Tier 2 fishstock targets combined, relative to the 'fishable' area.

6. MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS

The use of the EDW data has provided a more complete dataset that required less grooming than the data provided from *warehou*. The CatchMapper tool aligns well with the spatial database methods used previously (e.g., Baird & Wood 2018). In concert with the grooming routines within the CatchMapper tool, the data are readily groomed and the tool is flexible to allow adaptations to provide a dataset that represents the variables that are important in the generation of the trawl swept areas. This tool also provides MPI with an in-house querying option for use within and outside Fisheries New Zealand.

The base map layers used in developing the footprint and the overlap with various environmental layers were generated in previous projects (e.g., DAE201605 for the fishing years 1990–2016 by Baird & Wood 2018). Thus, there is a good measure of compatability between the 1990–2016 and the 2008–17 footprints for deepwater Tier 1 and Tier 2 fishstocks. Where cells in the 2008–17 data indicated 'new' areas of seafloor contact, an overlay of the 2008–17 footprint on the 1990–2016 footprint (for the deepwater fishstocks) can indicate whether this 'new' contacted area was trawled in years before 2008.

The relative extents of the 1990–2016 and 2008–17 bottom-contacting trawl footprints are shown in Figure 19. The extent of the grey area indicates where the seafloor has been contacted during the 1990–2007 fishing years.

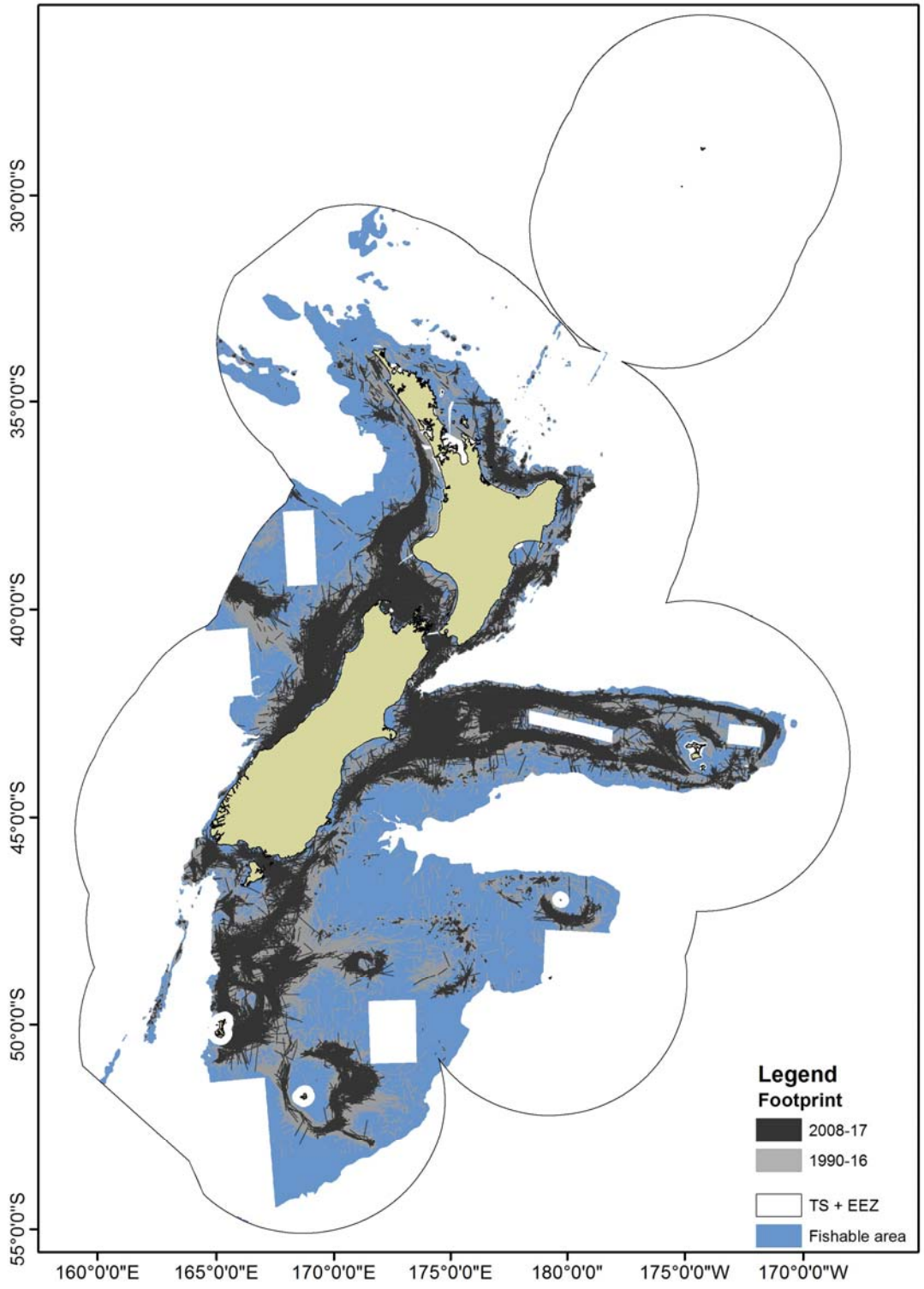

Figure 19: Comparison of the extents of the 2008–17 and the 1990–2016 (see Baird & Wood 2018) trawl footprints for Tier 1 and Tier 2 fishstock targets combined, relative to the 'fishable' area. Refer to Ministry for Primary Industries (2015) for the locations of the Benthic Protection Areas and the seamount Closures. Other closed areas are shown by Baird et al. (2011) and Baird et al. (2015).

The main change to the grooming rules in this analysis was the extension of the maximum allowed tow length for hake tows from 55.56 km to 70 km. As with the other tow length limits, this is based on the assumption that tows are straight lines between the reported start and finish positions (for TCEPR data) and that the tow speed-duration measure of a tow length used for TCER data gives a straight line measure from which to estimate an end position. This creates a mismatch between the TCEPR and TCER tow lengths, in terms of what the tracklines represent; and although it is the most suitable method at present (because of the lack of TCER end position data), it is likely that in future the full introduction of electronic reporting will generate better resolution of start and finish positions for all vessels which will not be dependent on the data collection method.

The footprint covers only those tows with bottom-contact. Consequently, for some targets, the footprint represents only a fraction of the effort targetted at that fishstock (targets such as jack mackerels, southern blue whiting, hoki, and hake are also fished in the water column with midwater gear).

6.1 Recommendations

Fleet characterisation. As noted in Section 3.3, this analysis assumes that there were no changes in the gear over time. A generic doorspread value is assumed for each target, based on vessel size. It is likely that there are fewer potential changes in the shorter time series analysed in this study than in previous analyses, but this characterisation could be improved.

> Recommendation. We recommend that vessels are characterised by vessel type and size, target, and gear to provide a stronger basis for the estimation of swept area. The Deepwater Group at Fisheries New Zealand have developed a set of vessel descriptors. These could be used or further developed with information from the observer data.

Scampi trawling. There is a significant number of scampi tows for which there is no 'number of nets used' data. Scampi trawls usually use twin or triple rigs and may use both within a single trip (Fisheries New Zealand scientific observer information not presented here). Currently, the scampi tows with a 'null' value for the number of nets are assigned a doorspread value based on vessel size category.

> Recommendation. We recommend that where the number of nets is unknown for scampi data, the main rig type reported by each vessel in that year/season/fishery area be used to assign the most appropriate doorspread.

TCER end position. With the introduction of electronic reporting, the TCER data will have a reported end position for use in generation of tracklines.

> Recommendation. We recommend the continued use of the established methodology to generate tracklines; and that where electronic data with end positions for TCER tows exist, a start-finish trackline be generated for comparison (as for TCEPR) as well as a trackline generated from the established methods.

7. ACKNOWLEDGEMENTS

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APPENDIX A: Description of data grooming and the final TCER and TCEPR dataset

Grooming routines developed from the methods used by Baird et al. (2011), Black et al. (2013), and Baird & Wood (2018) were applied to the MPI EDW database extract via the *R* Statistical package (R Development Core Team 2017). The grooming concentrated on the main variables considered necessary for the footprint spatial analysis. Previous work indicated that most amendments were necessary because of transcription, typographical, or numeric errors (see Baird et al. 2011); however, it was apparent that the prior grooming required as part of the EDW database specifications resulted in fewer null values in the 2008–17 dataset than found in the previous extracts from MPI's *warehou* database.

Data for each of the main variables were explored using the vessel/vessel size/target species categories to isolate records with invalid codes or values and any obvious transcription or recording errors and to determine the distribution of variables used to characterise the effort. Where possible these errors were amended. These variables included target species, gear type, position data, tow duration, tow speed, net depth, and bottom depth. Depth data that describe the depth of the gear and the seafloor at the start of fishing were also groomed to identify near-bottom midwater tows and summarise the main depth ranges for each target species.

In previous footprint work, some *warehou* extracts have included tow data with no trip number, which resulted in those tows being dropped from the dataset because of the use of trip number in some grooming procedures, including the estimation of the tow end positions for TCER tows (see Baird et al. 2015). However, each tow had a trip number in the 2008–17 EDW data. No data were deleted, other than duplicated records, and new fields were created to accommodate changed and new (derived) values. The grooming process was iterative, with 'corrections' made to one field at a time. Data within a defined range of values for each variable were retained as reported and those outside the range were assigned a median value determined from the data. Similarly, median values were assigned where there were zero values, missing data, or mismatched data (such as gear methods and headline heights for a given target species), based on the reported non–null data for a trip or a vessel. One exception to this was for the tow distance, where the tows over a prescribed length, for a target, were truncated to that length (see below).

All the trawl effort was retained for the first run of grooming, primarily to allow for checking of the reported target species (a dataset of 496 395 tows for all TCER and TCEPR effort during 2008–17). The next grooming run was restricted to the subset of deepwater Tier 1 and Tier 2 targets reported on these forms (n = 318 876 tows for 2008–17). The final groomed dataset retained the bottom-contacting trawls only; that is, all tows targeted at deepwater Tier 1 and Tier 2 targets that used bottom trawl gear or midwater trawl gear for which the reported net depth at the tow start was within 1 metre of the reported bottom depth at the tow start (n = 283 203 tows for 2008–17). This is summarised in Table A1. A summary of variable grooming is given below.

TCER and TCEPR grooming of main variables

Target species. Target species codes were checked for validity by comparing the area fished and the gear type used by a vessel on a trip. The full 2008–17 dataset of TCER and TCEPR effort within the EEZ (496 395 tows) was checked for inconsistencies in the recording of target species data. This was completed before the data were subsetted by the deepwater fishstocks so that 'problem' target species, caused mainly by typological or transcription errors, such as 'SNA' and 'SWA' could be amended. In total, changes to 0.02% of tows were required. These included 19 tows reported as 'SNA' that were deemed to be 'SWA' and 31 'SWA' tows that were most likely for 'SNA', based on position and tow depth data: tows south of 42° S were considered as 'SWA' and the records were amended. Effort targeted at oreo species under the codes for black oreo, smooth oreo, and spiky oreo ('BOE', 'SSO', 'SOR') were reassigned to the generic code for oreo species ('OEO'). Data for the other species group used in these analyses, comprising three jack mackerel *Trachurus* species, were already coded as the generic 'JMA' code. Similarly, data for alfonsino species were coded to 'BYX' rather than individual species. Table A2.1

gives number of annual tows by Tier 1 and Tier 2 targets in the final dataset, and Tables A2.2–A2.5 summarise the retained dataset by form type (TCEPR and TCER)

Gear type. The majority of gear codes used on the TCER and TCEPR forms were for bottom trawl gear ('BT'), with the remainder reported as midwater trawl ('MW'), and a small number as bottom pair trawl ('BPT'). Reported gear codes were checked to ensure they matched the reported headline height and wingspread values, with the defining measurements of 10 m as maximum headline height and 40 m as maximum wingspread for 'BT' tows.

All bottom pair trawl ('BPT') records were reassigned to 'BT' for this analysis; these records represented 0.04% of all TCER and TCEPR tows. All bottom-trawl tows were treated as they were fished with bottom contact. Another 35 673 midwater tows used the gear more than a metre above the seafloor and so were not included in the final dataset: of these, 61.5% targeted hoki, 18% targeted jack mackerels, 10% targeted southern blue whiting, and 5% targeted alfonsino.

During 2016 and 2017, 9 vessels reported the use of bottom and midwater gear (used within a metre of the seafloor) with the Precision Seafood Harvesting technology (see http://www.mpi.govt.nz/funding-and-programmes/primary-growth-partnership/primary-growth-partnership-programmes/precision-seafood-harvesting/) replacing the traditional cod-end. The ground gear (in contact with the seafloor) is likely to be unchanged. The effort that used this gear is identified by the 'PRB' and 'PRM' codes and is included under the 'BT' and 'MW' codes, respectively. In total, 305 'PRB' and 1088 'PRM' tows were reported during 2016–17.

Overall, of the 283 203 bottom-contacting tows retained in the dataset for the footprint analysis, 231 070 (81.5%) used bottom trawl gear and 52 133 (18.5%) used midwater gear within a metre of the seafloor (Table A.2.6). Of the 'BT' tows, 0.04% were originally 'BT', 0.04% were 'MW', and 0.1% were 'PRB'. Of the 'MW', 2.1% were originally 'PRM' and 0.002% were 'BT'.

Vessel data. The overall length (in metres) of vessels was used to group similar-sized vessels together, to aid in grooming the data, based on the assumption that similar-sized vessels target certain species, operate in certain areas, and use similar gear. Vessels were assigned to the following categories: 'A' vessels ≤ 28 m, 'B' vessels > 28 m and ≤ 46 m, 'C' vessels > 46 m and ≤ 82 m, and 'D' vessels > 82 m. Overall, 67% of the 174 vessels were in category 'A', 11.5% in category 'B; 15% in 'C', and 7% in 'D' (Tables A2.7 and A2.8).

Number of nets. The number of nets used per tow was first reported on TCERs and TCEPRs in 2008. Overall, 82.3% of tows in the final dataset had no value for this field (Table A2.9); 0.5% had a '1' in the field; 12.1% had a '2' (mostly from hoki or scampi tows); and 5.1% had a '3' (scampi tows). Where there were no records in the *EffortTotalCount* column, it was assumed that a single net was used as part of the bottom trawl rig.

Depths fished. Effort depth and bottom depth data were checked for inconsistencies. Bottom depth and net depth values reported at the start of the tow were used to describe depth ranges for each fishery and to determine which of the midwater tows were within 1 m of the seafloor, and thus be included in the final dataset for the footprint analysis. About 2% of the data had reported tow net depths deeper than bottom depths and the values for these tows were swapped. No further grooming was done on these data. For the final dataset, about 0.2% of the net depth data (measured at the tow start which is when the net is at the required fishing depth) and the bottom depth data were at depths shallower than 30 m or deeper than 1600 m or had null values. The spread of depth data by target species is shown in Figure A1 and Table A2.10.

Tow speed. Tow speed values for the final dataset were generally in the range of 2–7 kn., with an overall median of 3.8 kn. Only 3 records were amended (0.001%).

Tow duration. Less than 1% of the final dataset had amendments to the reported duration data, with most amended records for the deepwater targets such as orange roughy, oreo species, black cardinalfish, and alfonsino. Changes were made where records had zero or 'NA'. Overall, changes were made to 5% of orange roughy tows, 5% oreo tows, 10% black cardinalfish tows, and 3% alfonsino tows. Effectively this grooming

made very little difference, with the median and mean values virtually unchanged and the maxima changed from 18–24 h to 7.5 h, .4 h, 6.5 h, and 5.6 h for the targets listed above.

The full range of tow duration data after this grooming was 0.083–23.6 h; and the amended data made very little difference to the overall range, with the first quartile at 1.8 h, median of 4.2 h, mean of 4.3 h, and third quartile at 6.6 h. Almost all the tows longer than 20 h were for hake.

Duration data were particularly important in this work in the generation of the tow length and estimation of the end point of TCER tows (n = 27 092 tows, 9.6% of the final dataset). Summary statistics for TCER duration data are: range of 0.083–18.00 h; the first quartile at 2.083 h, median of 3.5 h, mean of 3.5 h, and third quartile at 4.5 h. Less than 0.1% of these tows were longer in duration than 10 h.

Tow position. The grooming of the reported start and end position data compared the position data with the Statistical Area records by trip to isolate any tows with incorrect latitude or longitude data. The final dataset included one tow that required adjustment.

Trawl length. This variable was generated for use in the algorithm used to estimate the end position for TCER tow data, with values based on the groomed duration x groomed speed and presented as kilometres trawled. Trawl lengths were subjected to the 'long tow' rule such that scampi, arrow squid, and hake tows longer than 70 km were set to 70 km and for all other Tier 1 and Tier 2 target tows, trawl lengths longer than 55.56 km were set to 55.56 km. In total, the trawl lengths of less than 0.1% of TCER tows were set to the values above. Several orange roughy fishery areas in northern waters appeared to have long tows across features that were more likely to be short because of the nature of the underwater features (see Figure A2). After consulting with fisheries experts, we chose to use the duration-speed data for oreo, orange roughy, black cardinal fish, and alfonsino to generate new tracklines based on the areas given by Anderson & Dunn (2012). The summary data for each target fishstock are given in Table A2.11.

Number of tows per trip. For the swept area analysis, it was necessary to look at the number of tows per trip, by form type: these are summarised in Table A2.12.

Doorspread. The doorspread values were assigned to TCER and TCEPR tow data based on vessel size category and the reported number of nets (see Table A2.7).

Table A1: Deepwater Tier 1 and Tier 2 species data summary for TCER and TCEPR forms, 2008–17. The TCER data summary is presented in (a) and the TCEPR data in (b). The combined summary for TCER and TCEPR data prior to the spatial analysis is given in (c), and (d) summarises the TCER and TCEPR data retained for the spatial analysis (that is, were not "long" tows or tows on the land).

(a)

TCER data 2008–17

Number of tows in the original MPI TCER dataset for all targets = 473 451 tows
Number of TCER tows for Tier 1 and Tier 2 targets = 45 261 tows
Number of TCER tows for Tier 1 and Tier 2 target fishstocks = 27 092 tows

Final TCER dataset

Total TCER tows for Tier 1 and Tier 2 target fishstocks = 27 092 tows
Number of TCER trawl vessels that targeted Tier 1 and Tier 2 target fishstocks = 99 vessels
Number of TCER trips that targeted Tier 1 and Tier 2 target fishstocks = 6904 trips

(b)

TCEPR 2008–17

Number of tows in the original MPI TCEPR dataset for all targets = 365 652 tows
Number of TCEPR tows for Tier 1 and Tier 2 targets = 294 325 tows
Number of TCEPR tows for Tier 1 and Tier 2 target fishstocks = 256 111 tows

Final TCEPR dataset

Total TCEPR tows for Tier 1 and Tier 2 target fishstocks = 256 111 tows
Number of TCEPR trawl vessels that targeted Tier 1 and Tier 2 target fishstocks = 81 vessels
Number of TCEPR trips that targeted Tier 1 and Tier 2 target fishstocks = 6828 trips

(c)

Total TCER & TCEPR Tier 1 and Tier 2 fishstock data prior to spatial analysis

Total TCER & TCEPR Tier 1 and Tier 2 fishstock data: bottom and midwater tows = 847 401 tows

Total TCER and TCEPR Tier 1 and Tier 2 fishstock data: bottom and midwater trawls within 1 m seafloor = 283 203 tows

Percent TCER and TCEPR tow-by-tow data changed

% target species changes	0.02%
% effort depth changes where effort depth zero or deeper than bottom depth	2.0%
% effort/bottom depth <20 m and >1500 m	< 0.1%
% tow speed changes (null values)	0.001%
% tow duration changes (includes null values)	0.9%

(d)

Final TCER and TCEPR spatial analysis dataset

% TCER and TCEPR tows that were 'long' tows and new end generated	7.3%

Total Tier 1 and Tier 2 fishstock tows retained for the footprint analysis (100%) = 283 203 tows
90% from TCEPRs and 78% used bottom trawl gear

Table A2.1: Number of tows by target species code for deepwater Tier 1 and Tier 2 fishstocks in the TS+EEZ, for 2008–17. Target codes are defined in Table 1.

Code	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	All
Tier 1 fishstocks											
HAK	1 533	1 700	812	798	644	680	779	933	479	535	8 893
HOK	7 897	7 117	8 555	8 367	8 997	9 397	10 372	10 180	9 504	9 978	90 364
JMA	1 959	1 576	1 895	1 249	1 514	1 379	1 329	949	894	784	13 528
LIN	2 021	1 174	998	957	837	1 002	967	984	974	1 010	10 924
OEO	2 477	2 171	2 541	1 899	1 659	1 278	1 259	1 260	795	685	16 024
ORH	3 689	3 558	2 922	1 889	1 593	1 592	2 033	2 347	3 125	2 983	25 731
SBW	429	613	740	694	495	389	311	454	348	307	4 780
SCI	4 802	3 974	4 248	4 446	4 508	4 537	4 421	4 423	5 209	4 707	45 275
SQU	3 986	3 619	3 772	4 189	3 473	2 625	2 048	1 933	2 863	2 592	31 100
Total	28 793	25 502	26 483	24 488	23 720	22 879	23 519	23 463	24 191	23 581	246 619
Tier 2 fishstocks											
BAR	2 194	1 316	1 022	917	1 159	1 115	1 180	1 160	1 028	1 111	12 202
BYX	647	776	935	878	787	257	523	516	417	456	6 192
CDL	540	417	541	389	380	228	313	193	146	117	3 264
EMA	15	24	1	4	25	6	0	0	0	0	75
FRO	0	0	0	0	0	0	3	2	11	12	28
GSH	0	0	0	0	4	11	5	1	3	0	24
LDO	28	7	39	59	47	106	46	73	64	42	511
RBT	6	18	9	3	21	39	34	17	5	13	165
RBY	98	65	201	174	114	122	112	104	252	142	1 384
RIB	0	0	0	0	0	0	0	1	0	0	1
SKI	9	10	17	71	82	74	37	47	40	19	406
SPD	167	238	243	150	113	52	72	86	0	1	1 122
SPE	124	31	157	221	46	192	144	326	298	220	1 759
SWA	1 129	1 067	755	860	615	709	735	640	595	608	7 713
WWA	223	325	205	117	153	156	244	101	103	111	1 738
Total	5 180	4 294	4 125	3 843	3 546	3 067	3 448	3 267	2 962	2 852	36 584
Tier 1 & Tier 2 fishstocks											
Total	33 973	29 796	30 608	28 331	27 266	25 946	26 967	26 730	27 153	26 433	283 203

Table A2.2: Number of TCEPR bottom-contacting tows, 2008–17. Target codes are defined in Table 1. Tier 1 target species are in bold.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	All
BAR	791	406	334	342	457	286	325	724	540	788	4 993
BYX	631	776	924	852	785	239	507	454	390	433	5 991
CDL	530	417	536	388	380	228	311	193	146	115	3 244
EMA	15	24	1	4	25	6	0	0	0	0	75
FRO	0	0	0	0	0	0	3	2	11	12	28
GSH	0	0	0	0	4	11	5	1	3	0	24
HAK	**1 516**	**1 695**	**805**	**785**	**620**	**552**	**597**	**797**	**371**	**476**	**8 214**
HOK	**7 492**	**6 718**	**7 895**	**7 841**	**8 469**	**8 808**	**9 704**	**9 689**	**9 049**	**9 555**	**85 220**
JMA	**1 958**	**1 575**	**1 889**	**1 238**	**1 513**	**1 373**	**1 328**	**944**	**892**	**779**	**13 489**
LDO	0	0	0	0	0	1	0	0	0	0	1
LIN	**1 631**	**799**	**499**	**421**	**417**	**720**	**596**	**713**	**615**	**575**	**6 986**
OEO	**2 368**	**2 043**	**2 524**	**1 899**	**1 659**	**1 278**	**1 257**	**1 260**	**795**	**685**	**15 768**
ORH	**3 661**	**3 475**	**2 836**	**1 848**	**1 551**	**1 546**	**1 817**	**2 089**	**2 976**	**2 790**	**24 589**
RBT	6	18	9	3	21	39	34	17	5	13	165
RBY	93	54	137	115	67	59	73	67	224	105	994
RIB	0	0	0	0	0	0	0	0	0	0	0
SBW	**429**	**613**	**740**	**694**	**495**	**389**	**311**	**454**	**348**	**307**	**4 780**
SCI	**4 802**	**3 974**	**4 248**	**4 446**	**4 372**	**4 126**	**4 112**	**4 028**	**4 771**	**4 441**	**43 320**
SKI	0	5	0	1	1	0	5	1	1	1	15
SPD	0	3	1	0	0	0	0	0	0	0	4
SPE	99	2	28	64	11	14	1	0	13	0	232
SQU	**3 558**	**3 576**	**3 651**	**4 108**	**3 328**	**2 600**	**2 042**	**1 831**	**2 655**	**2 525**	**29 874**
SWA	1 109	990	651	739	463	542	527	513	450	457	6 441
WWA	220	325	204	117	153	141	229	89	94	92	1 664
All	30 909	27 488	27 912	25 905	24 791	22 958	23 784	23 866	24 349	24 149	256 111

Table A2.3: Percentage of TCEPR data that used bottom-contacting trawl gear, 2008–17. Target codes are defined in Table 1. Tier 1 target species are in bold.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	All
BAR	68.9	40.9	36.2	42.7	64.6	50.0	16.9	13.1	23.5	22.3	37.4
BYX	65.1	78.7	79.7	80.3	82.5	78.7	83.4	80.8	82.3	67.2	78.1
CDL	99.1	100.0	99.4	99.7	98.9	100.0	100.0	100.0	97.3	96.5	99.4
EMA	0.0	0.0	0.0	0.0	0.0	0.0	–	–	–	–	0.0
FRO	–	–	–	–	–	–	66.7	0.0	0.0	0.0	7.1
GSH	–	–	–	–	100.0	100.0	100.0	100.0	100.0	–	100.0
HAK	**94.2**	**91.2**	**94.2**	**97.5**	**98.9**	**96.7**	**96.3**	**96.9**	**99.2**	**99.4**	**95.3**
HOK	**84.6**	**83.7**	**82.3**	**83.8**	**83.7**	**78.5**	**77.5**	**76.6**	**75.6**	**80.5**	**80.4**
JMA	**5.6**	**1.3**	**0.3**	**0.2**	**0.3**	**0.1**	**0.2**	**0.0**	**0.0**	**0.0**	**1.1**
LDO	–	–	–	–	–	100.0	–	–	–	–	100.0
LIN	**98.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**99.9**	**100.0**	**100.0**	**99.5**
OEO	**99.9**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
ORH	**100.0**	**100.0**	**99.8**	**99.8**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**99.9**	**100.0**
RBT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RBY	25.8	31.5	34.3	25.2	92.5	33.9	20.5	6.0	9.4	5.7	24.6
RIB	–	–	–	–	–	–	–	–	–	–	–
SBW	**4.9**	**17.1**	**8.1**	**10.8**	**19.4**	**1.0**	**4.8**	**0.2**	**1.1**	**1.0**	**8.0**
SCI	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
SKI	–	100.0	–	100.0	100.0	–	100.0	100.0	100.0	100.0	100.0
SPD	–	100.0	100.0	–	–	–	–	–	–	–	100.0
SPE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	–	100.0	–	100.0
SQU	**54.9**	**58.4**	**81.9**	**81.1**	**70.7**	**77.3**	**69.8**	**65.2**	**64.4**	**82.4**	**70.7**
SWA	99.6	99.8	99.8	100.0	99.6	100.0	99.6	100.0	98.2	100.0	99.7
WWA	100.0	100.0	97.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7
All	81.6	80.8	81.4	83.1	81.4	80.3	79.4	78.5	79.0	82.3	80.8

Table A2.4: Number of TCER tows, 2008–17. Note there were no TCER data for EMA, FRO, GSH, RBT, SBW. Target codes are defined in Table 1. Tier 1 target species are in bold.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	All
BAR	1 403	910	688	575	702	829	855	436	488	323	7 209
BYX	16	0	11	26	2	18	16	62	27	23	201
CDL	10	0	5	1	0	0	2	0	0	2	20
HAK	**17**	**5**	**7**	**13**	**24**	**128**	**182**	**136**	**108**	**59**	**679**
HOK	**405**	**399**	**660**	**526**	**528**	**589**	**668**	**491**	**455**	**423**	**5 144**
JMA	**1**	**1**	**6**	**11**	**1**	**6**	**1**	**5**	**2**	**5**	**39**
LDO	28	7	39	59	47	105	46	73	64	42	510
LIN	**390**	**375**	**499**	**536**	**420**	**282**	**371**	**271**	**359**	**435**	**3 938**
OEO	**109**	**128**	**17**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**256**
ORH	**28**	**83**	**86**	**41**	**42**	**46**	**216**	**258**	**149**	**193**	**1 142**
RBY	5	11	64	59	47	63	39	37	28	37	390
RIB	0	0	0	0	0	0	0	1	0	0	1
SCI	**0**	**0**	**0**	**0**	**136**	**411**	**309**	**395**	**438**	**266**	**1 955**
SKI	9	5	17	70	81	74	32	46	39	18	391
SPD	167	235	242	150	113	52	72	86	0	1	1 118
SPE	25	29	129	157	35	178	143	326	285	220	1 527
SQU	**428**	**43**	**121**	**81**	**145**	**25**	**6**	**102**	**208**	**67**	**1 226**
SWA	20	77	104	121	152	167	208	127	145	151	1 272
WWA	3	0	1	0	0	15	15	12	9	19	74
All	3 064	2 308	2 696	2 426	2 475	2 988	3 183	2 864	2 804	2 284	27 092

Table A2.5: Percentage of TCER tows that used bottom trawl gear, 2008–17. Target codes are defined in Table 1. Tier 1 target species are in bold.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	All
BAR	100.0	100.0	100.0	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BYX	12.5	–	0.0	7.7	100.0	11.1	62.5	9.7	55.6	65.2	26.9
CDL	100.0	–	80.0	100.0	–	–	100.0	–	–	100.0	95.0
HAK	**100.0**	**40.0**	**100.0**	**100.0**	**75.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**98.7**
HOK	**22.0**	**34.6**	**47.1**	**50.0**	**45.3**	**50.3**	**53.9**	**48.5**	**41.3**	**40.9**	**44.6**
JMA	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
LDO	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LIN	**100.0**	**100.0**	**100.0**	**100.0**	**99.5**	**100.0**	**100.0**	**100.0**	**99.7**	**100.0**	**99.9**
OEO	**100.0**	**100.0**	**100.0**	**–**	**–**	**–**	**100.0**	**–**	**–**	**–**	**100.0**
ORH	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
RBY	100.0	100.0	93.8	83.1	100.0	100.0	100.0	97.3	100.0	97.3	95.9
RIB	–	–	–	–	–	–	–	100.0	–	–	100.0
SCI	**–**	**–**	**–**	**–**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
SKI	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SPD	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	–	100.0	100.0
SPE	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SQU	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**
SWA	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
WWA	100.0	–	100.0	–	–	100.0	100.0	100.0	100.0	100.0	100.0
All	89.2	88.6	86.5	87.7	88.0	89.7	90.1	89.2	90.0	88.7	88.8

Table A2.6: Number of tows by target species and gear code for deepwater Tier 1 and Tier 2 fishstocks in the retained dataset, for the combined fishing years 2008–17. Target codes are defined in Table 1. 'BT' is bottom trawl gear and 'MW' is midwater trawl gear used within 1 m of the seafloor.

	Gear type		
Target code	BT	MW	Total
BAR	9 077	3 125	12 202
BYX	4 734	1 458	6 192
CDL	3 242	22	3 264
EMA	0	75	75
FRO	2	26	28
GSH	24	0	24
HAK	8 502	391	8 893
HOK	70 810	19 554	90 364
JMA	186	13 342	13 528
LDO	511	0	511
LIN	10 887	37	10 924
OEO	16 022	2	16 024
ORH	25 721	10	25 731
RBT	0	165	165
RBY	619	765	1 384
RIB	1	0	1
SBW	384	4 396	4 780
SCI	45 275	0	45 275
SKI	406	0	406
SPD	1 122	0	1 122
SPE	1 759	0	1 759
SQU	22 359	8 741	31 100
SWA	7 694	19	7 713
WWA	1 733	5	1 738
All	231 070	52 133	283 203

Table A2.7: The vessel size categories and doorspread values assigned to TCER and TCEPR tow data for the swept area analysis. Target codes are defined in Table 1.

Length	Category	No. of nets	Target	Doorspread (m)
< 28 m	A	1	All	70
28–46 m	B	1	All	90
< 46 m	A, B	2	SCI	50
		3	SCI	70
46–82 m	C	1	All except HAK, HOK, LIN, SWA	150
		1	HAK, HOK, LIN, SWA	200
		2	BT for HAK, HOK, LIN, SWA	400
> 82 m	D	1	ALL	200

Table A2.8: Numbers of vessels in each vessel size category, by fishing year.

	Vessel category				
	A	B	C	D	All
2008	64	16	23	9	112
2009	63	16	21	7	107
2010	72	15	21	7	115
2011	72	15	22	6	115
2012	65	12	21	6	104
2013	63	12	20	6	101
2014	68	13	16	8	105
2015	64	14	16	8	102
2016	67	14	15	8	104
2017	61	13	17	6	97
All	116	20	26	12	174

Table A2.9: Number of tows for number of nets used, where *EffortTotalCount* is reported variable and *NewNumNets* is assigned value, by target, 2008–17. Target codes are defined in Table 1. 'NA' tows had no value for this variable.

	EffortTotalCount				*NewNumNets*			Total
Target	1	2	3	NA	1	2	3	Sum
BAR	601	1	0	11600	12 201	1	0	12 202
BYX	0	0	0	6192	6 192	0	0	6 192
CDL	1	0	0	3263	3 264	0	0	3 264
EMA	0	0	0	75	75	0	0	75
FRO	0	0	0	28	28	0	0	28
GSH	0	0	0	24	24	0	0	24
HAK	253	28	0	8612	8 865	28	0	8 893
HOK	328	19 872	5	70159	70 487	19 877	0	90 364
JMA	0	0	0	13528	13 528	0	0	13 528
LDO	13	0	0	498	511	0	0	511
LIN	222	860	0	9842	10 074	850	0	10 924
OEO	2	0	0	16022	16 024	0	0	16 024
ORH	0	1	0	25730	25 731	0	0	25 731
RBT	0	0	0	165	165	0	0	165
RBY	4	0	0	1380	1 384	0	0	1 384
RIB	0	0	0	1	1	0	0	1
SBW	27	1	0	4752	4 779	1	0	4 780
SCI	0	13 083	14 501	17691	17 691	13 083	14 501	45 275
SKI	26	0	0	380	406	0	0	406
SPD	0	0	0	1122	1 122	0	0	1 122
SPE	0	0	1	1758	1 759	0	0	1 759
SQU	29	40	1	31030	31 059	41	0	31 100
SWA	17	236	0	7460	7 477	236	0	7 713
WWA	0	5	0	1733	1 733	5	0	1 738
All	1523	34 127	14 508	233 045	234 580	34 122	14 501	283 203

Table A2.10: Number of bottom-contacting tows (from combined TCER and TCEPR data) by target species and 200–m depth zone (based on reported depth data), for all fishing years combined, 2008–17, for deepwater Tier 1 fishstocks and Tier 2 fishstocks separately. Target codes are defined in Table 1. The total number of tows by depth zone is given in the top table in the Tiers 1+2 column. Note that the totals include 28 tows with no depth data (25 in the Tier 1 species and 3 in Tier 2). Target codes are defined in Table 1.

									Tier 1 fishstocks		Tiers 1 + 2
Depth zones (m)	HAK	HOK	JMA	LIN	OEO	ORH	SBW	SCI	SQU	Total	total
0–200	13	2 900	13 281	512	7	11	2	31	21 887	38 644	53 815
200–400	50	8 804	247	3 543	12	4	978	29 904	9 059	52 601	63 359
400–600	5 030	64 211	0	4 659	13	50	3 785	15 314	152	93 214	100 263
600–800	3 725	13 441	0	2 205	1 702	4 760	15	1	0	25 849	29 062
800–1000	74	782	0	1	10 747	13 475	0	19	0	25 098	25 478
1000–1200	1	216	0	0	3 434	6 429	0	0	1	10 081	10 091
1200–1400	0	3	0	0	104	983	0	0	0	1 090	1 090
1400–1600+	0	1	0	0	3	13	0	0	0	17	17
All	8 893	90 364	13 528	10 924	16 024	25 731	4 780	45 275	31 100	246 619	283 203

														Tier 2 fishstocks		
Depth zones (m)	BAR	BYX	CDL	EMA	FRO	GSH	LDO	RBT	RBY	RIB	SKI	SPD	SPE	SWA	WWA	Total
0–200	10 860	9	7	74	25	10	2	115	60	0	4	1 121	1 546	1 327	11	15 171
200–400	1 339	3 524	15	1	3	12	16	50	1 208	0	383	1	137	3 868	201	10 758
400–600	2	2 135	571	0	0	2	351	0	109	1	19	0	76	2 365	1 418	7 049
600–800	1	508	2 297	0	0	0	142	0	7	0	0	0	0	150	108	3 213
800–1000	0	14	364	0	0	0	0	0	0	0	0	0	0	2	0	380
1000–1200	0	1	8	0	0	0	0	0	0	0	0	0	0	1	0	10
1200–1400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1400–1600	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All	12 202	6 192	3 264	75	28	24	511	165	1 384	1	406	1 122	1 759	7 713	1 738	36 584

Table A2.11: Mean trawl lengths for final TCEPR and TCER data, 2008–17.

TCEPR target	Trawl length (km)			TCER target	Trawl length (km)		
	Mean	Minimum	Maximum		Mean	Minimum	Maximum
BAR	37.2	0.6	55.6	BAR	21.6	0.5	55.6
BYX	3.8	0.4	51.7	BYX	4.2	0.5	28.7
CDL	2.6	0.4	50.6	CDL	5.5	0.5	20.1
EMA	24.5	5.0	55.6	HAK	26.8	1.9	45.5
FRO	25.0	3.0	52.9	HOK	12.0	0.2	55.6
GSH	27.2	16.7	33.3	JMA	19.8	3.1	38.9
HAK	57.2	0.6	70.0	LDO	25.8	1.7	41.7
HOK	30.2	0.2	55.6	LIN	16.8	0.6	55.6
JMA	37.8	0.5	55.6	OEO	7.1	0.6	22.2
LDO	18.5	18.5	18.5	ORH	15.3	0.4	38.9
LIN	36.9	0.4	55.6	RBY	16.1	1.0	32.4
OEO	3.4	0.3	48.5	RIB	3.7	3.7	3.7
ORH	6.1	0.3	53.0	SCI	30.0	1.2	69.6
RBT	30.0	1.6	55.6	SKI	21.4	3.5	38.3
RBY	5.1	0.5	55.6	SPD	15.0	0.5	48.6
SBW	26.7	0.5	55.6	SPE	15.1	1.0	55.6
SCI	33.1	0.4	70.0	SQU	17.5	1.0	43.4
SKI	36.3	12.5	55.6	SWA	18.5	0.5	55.6
SPD	23.6	7.4	43.8	WWA	25.2	2.8	52.8
SPE	37.6	0.5	55.6				
SQU	41.5	0.6	70.0				
SWA	36.5	0.5	55.6				
WWA	29.6	0.5	55.6				

Table A2.12: The number of trips and the data summary for the number of tows per trip for bottom-contacting trawl effort for deepwater Tier 1 and Tier 2 species, by TCER and TCEPR forms, 2008–17.

Form	No. trips	Minimum	1st quartile	Median	Mean	3rd quartile	Maximum
TCER	6 903	1	1	2	4	5	46
TCEPR	6 828	1	7	26	38	55	339

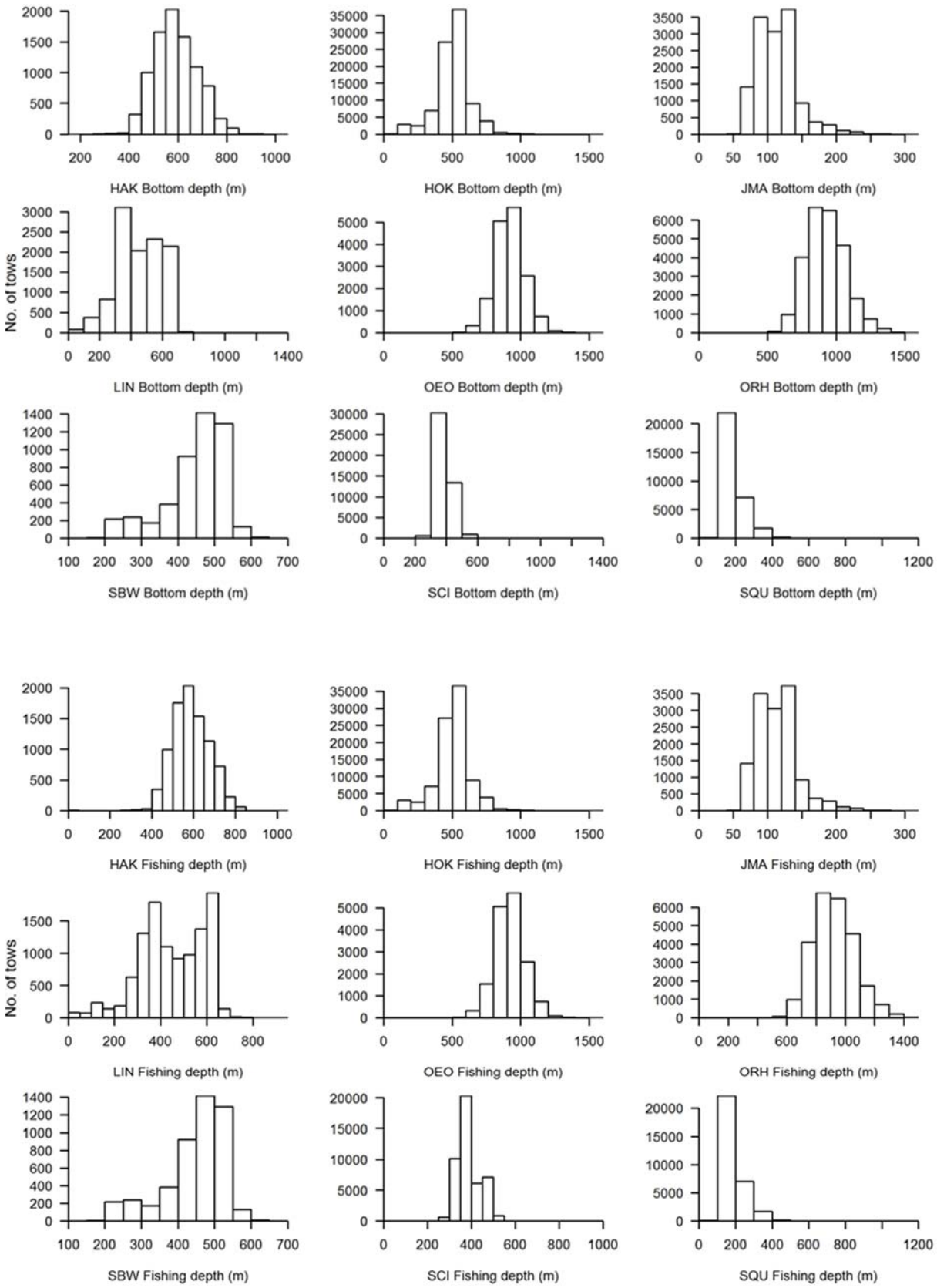


Figure A1: Distribution of bottom depth data (upper) and fishing (net) depth data (lower), for the Tier 1 fishstocks, 2008–17.

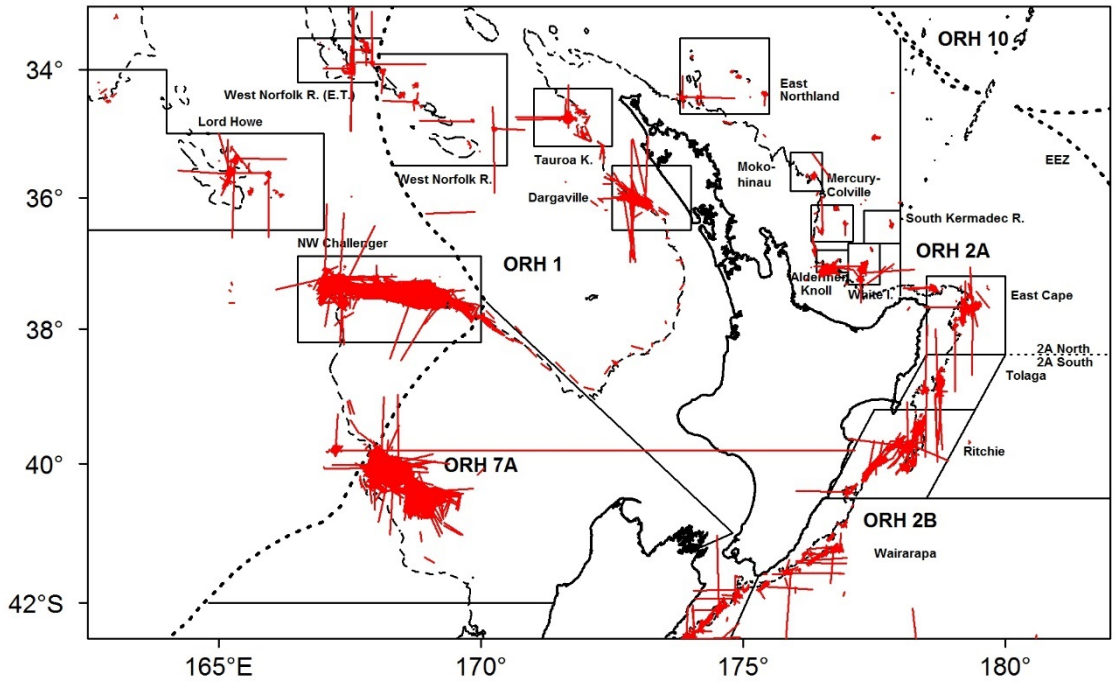


Figure A2: Tracklines plotted on underwater features where generally short tows were undertaken. Median tow duration for all areas except Dargaville, Aldermen Knoll (Bay of Plenty) for years 2000–09 (from Anderson & Dunn 2012): 0.1–0.8 h. For Dargaville, 1.7–4.3 h; for Aldermen Knoll, 0.2–2.7 h. East Coast: median duration was 0.4–0.6 h.

APPENDIX B: 'Fishable' area, depth zone, BOMEC, and probability of species capture/annual distribution maps

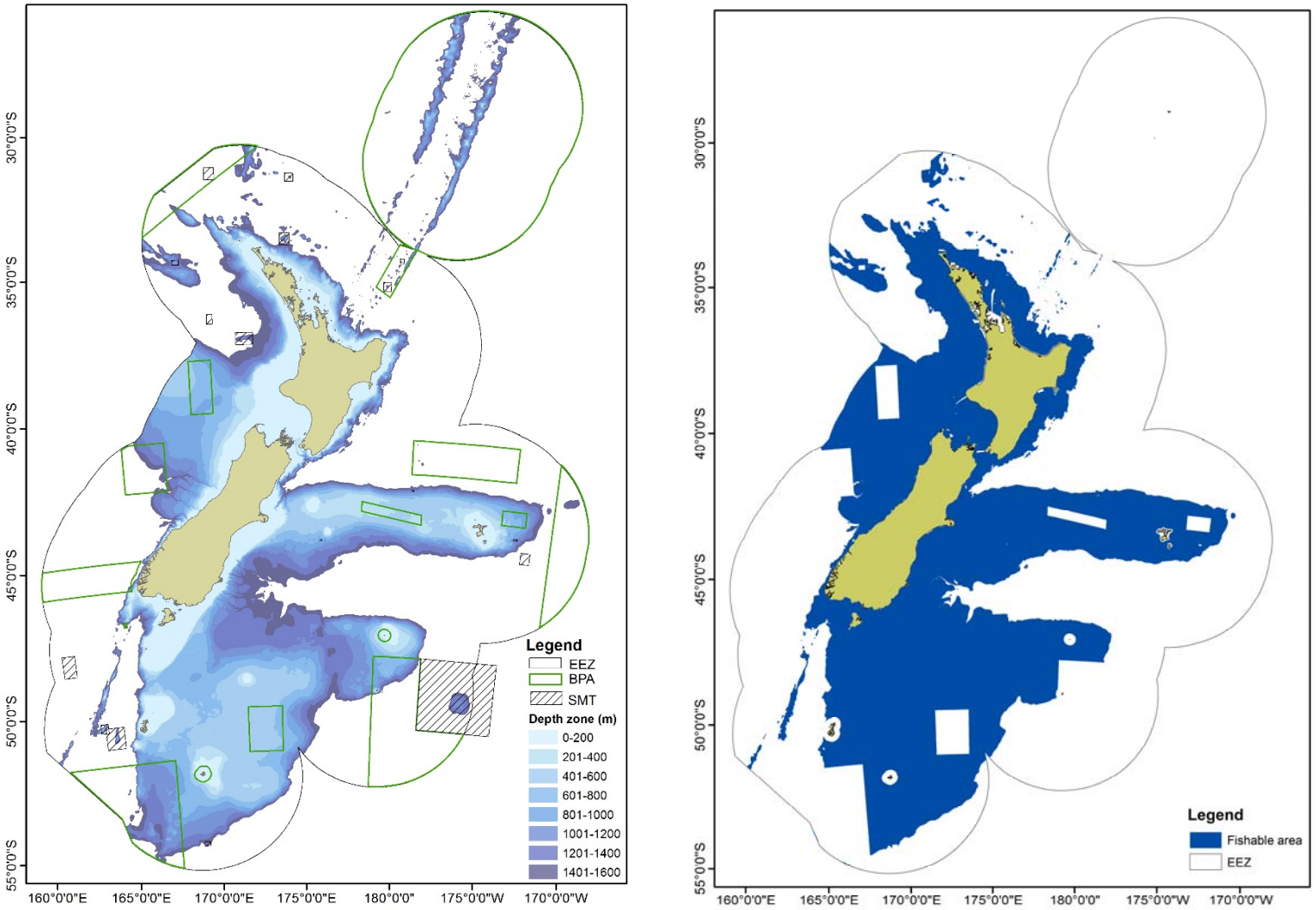


Figure B1: The extent of the waters down to 1600 m with the overlap of Benthic Protection Areas (BPA) and seamount closed areas (SMT) (left), and the 'fishable' area with areas closed to bottom trawling (including cable lanes, marine farms, and marine reserves) removed (right).

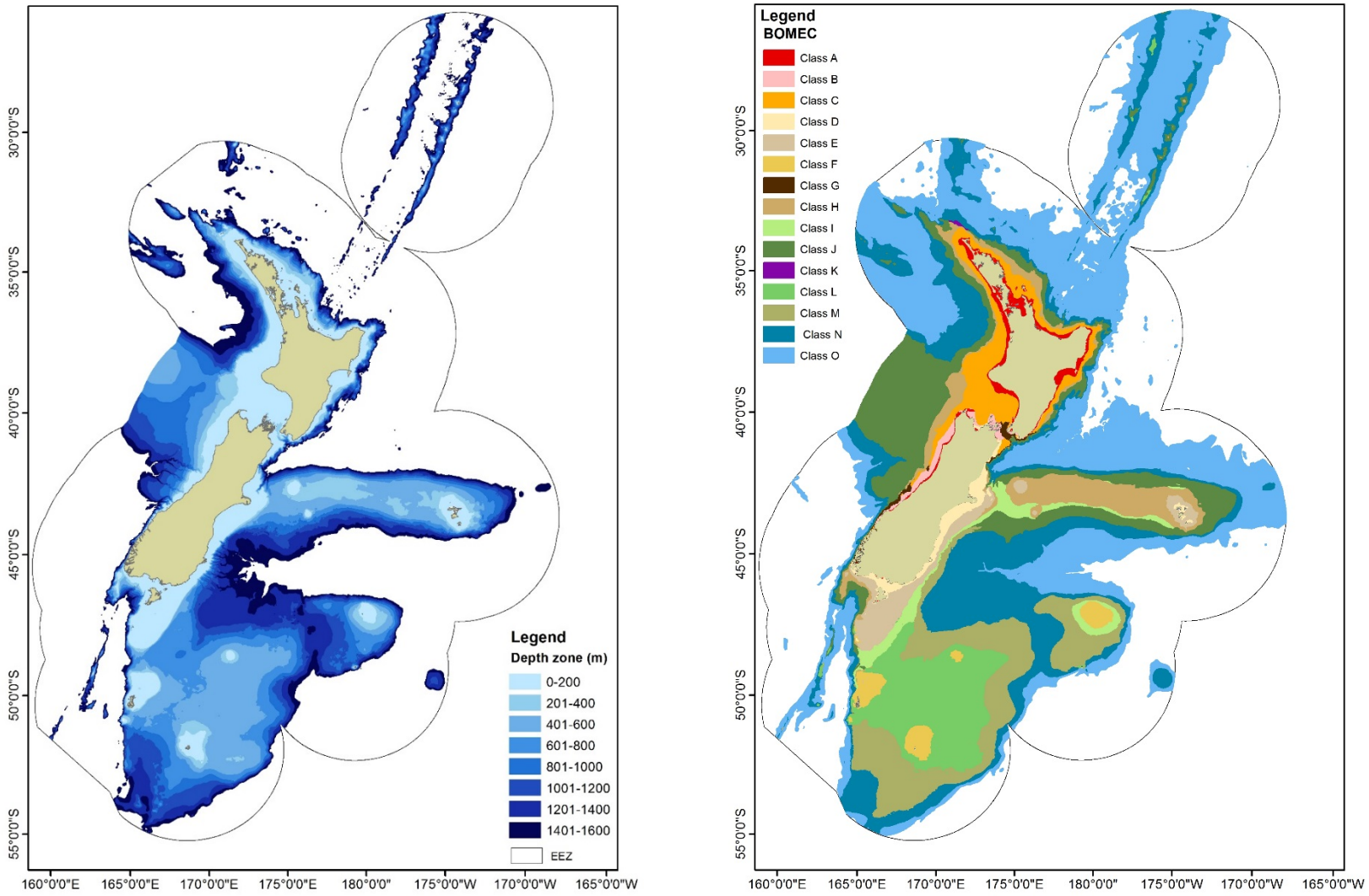


Figure B2: The extent of waters within the combined EEZ and Territorial Sea down to 1600 m depth, delineated by 200 m depth zones (left), and in waters delineated by the Benthic-optimised Marine Environment Classification (BOMEC) distribution (right), down to 3000 m (see Leathwick et al. 2012).

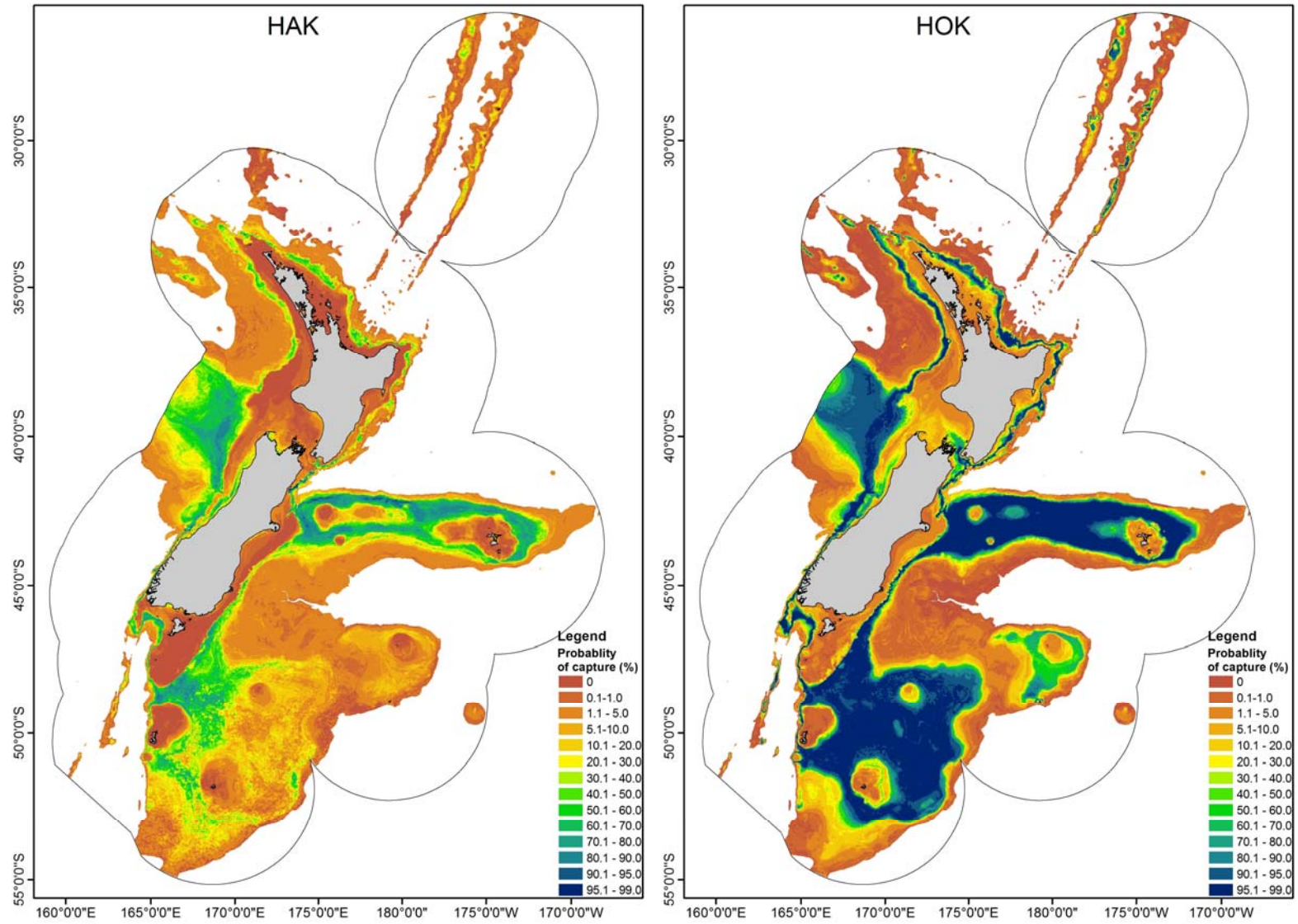


Figure B3a: The extent of waters within the combined EEZ and Territorial Sea down to 1950 m, overlappedby predicted distribution of the preferred habitat for hake (left) and hoki (right) (after Leathwick et al. 2006), where the preferred habitat represents the probability of capture of that species in a standardised trawl.

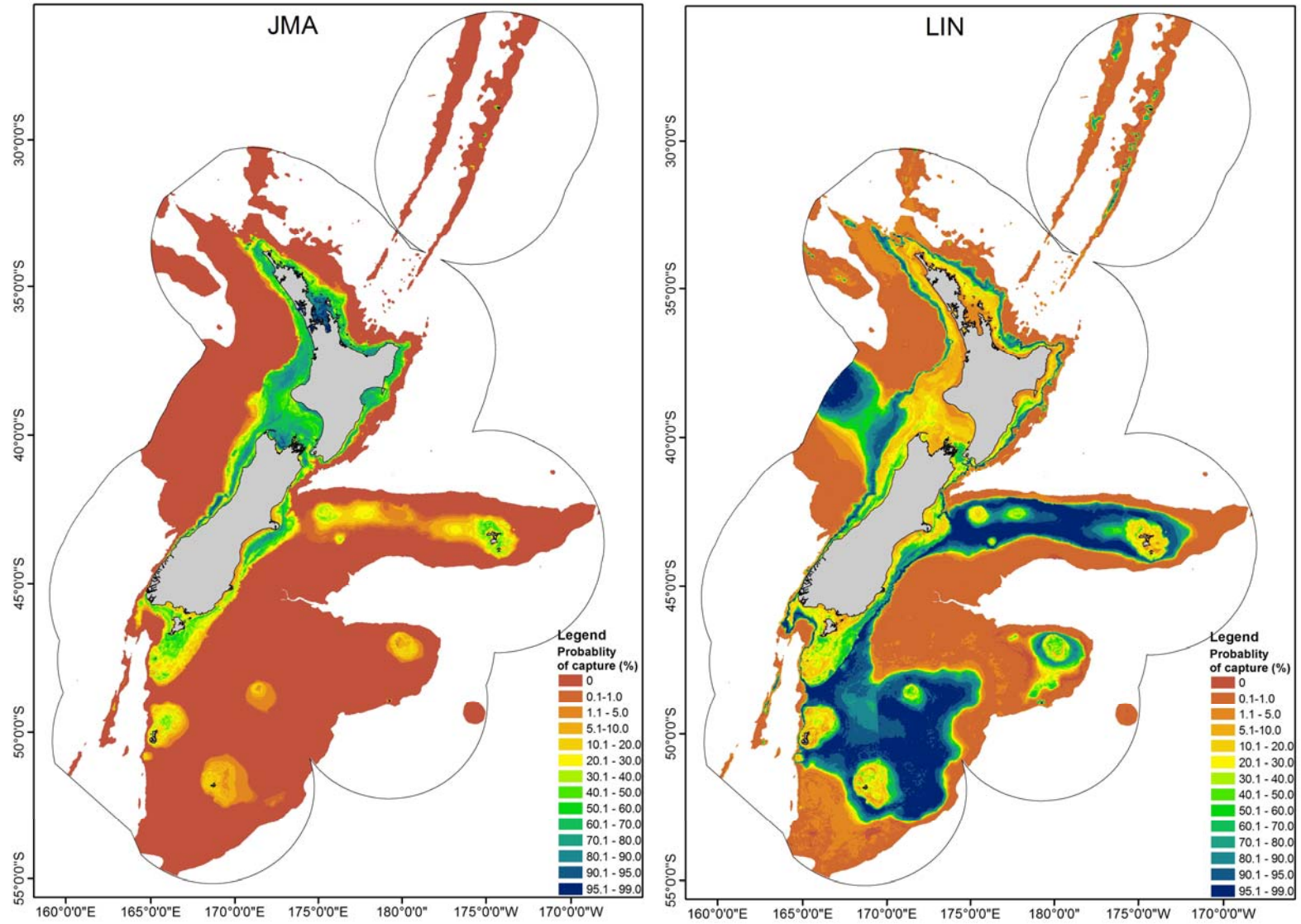


Figure B3b: The extent of waters within the combined EEZ and Territorial Sea down to 1950 m, overlapped by predicted distribution of the preferred habitat for jack mackerel species (left) and ling (right) (after Leathwick et al. 2006), where the preferred habitat represents the probability of capture of that species in a standardised trawl.

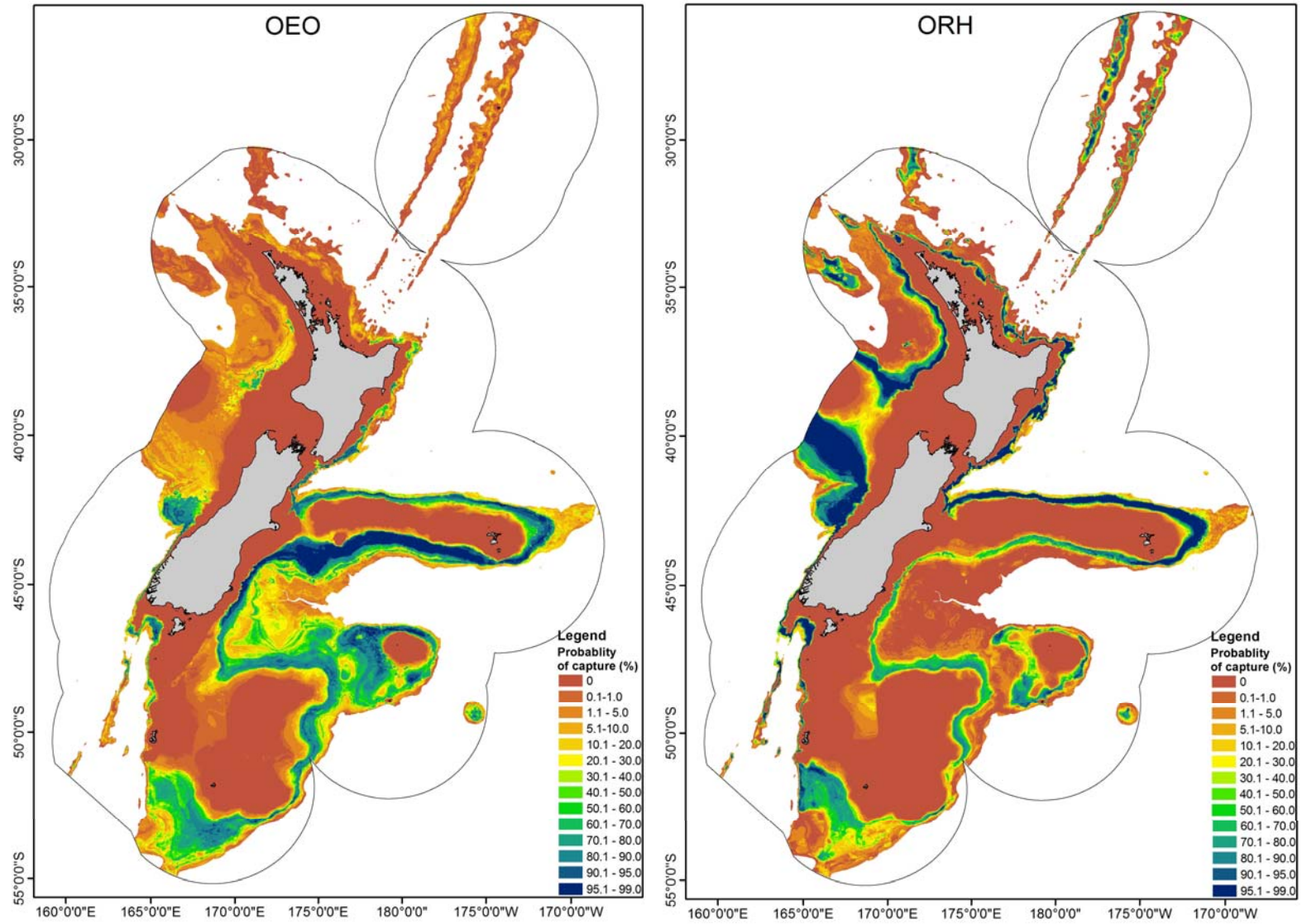


Figure B3c: The extent of waters within the combined EEZ and Territorial Sea down to 1950 m, overlapped by predicted distribution of the preferred habitat for oreo species (left) and orange roughy (right) (after Leathwick et al. 2006), where the preferred habitat represents the probability of capture of that species in a standardised trawl.

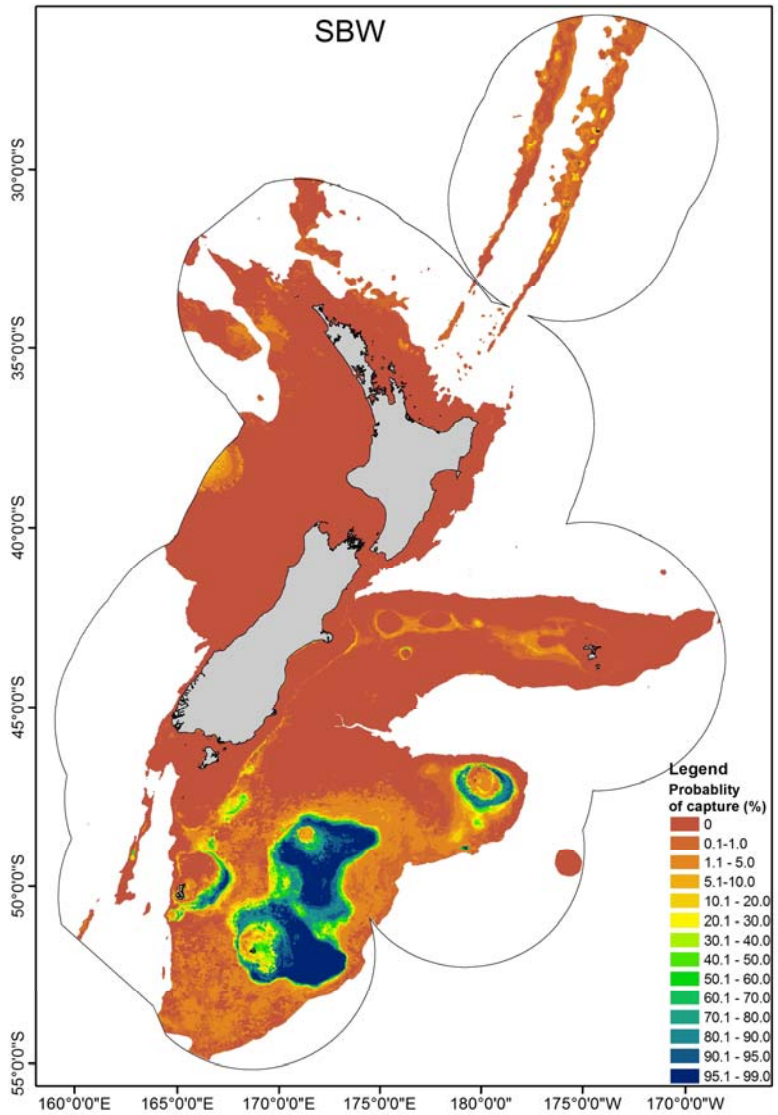


Figure B3d: The extent of waters within the combined EEZ and Territorial Sea down to 1950 m, overlapped by predicted distribution of the preferred habitat for southern blue whiting (after Leathwick et al. 2006), where the preferred habitat represents the probability of capture of that species in a standardised trawl.

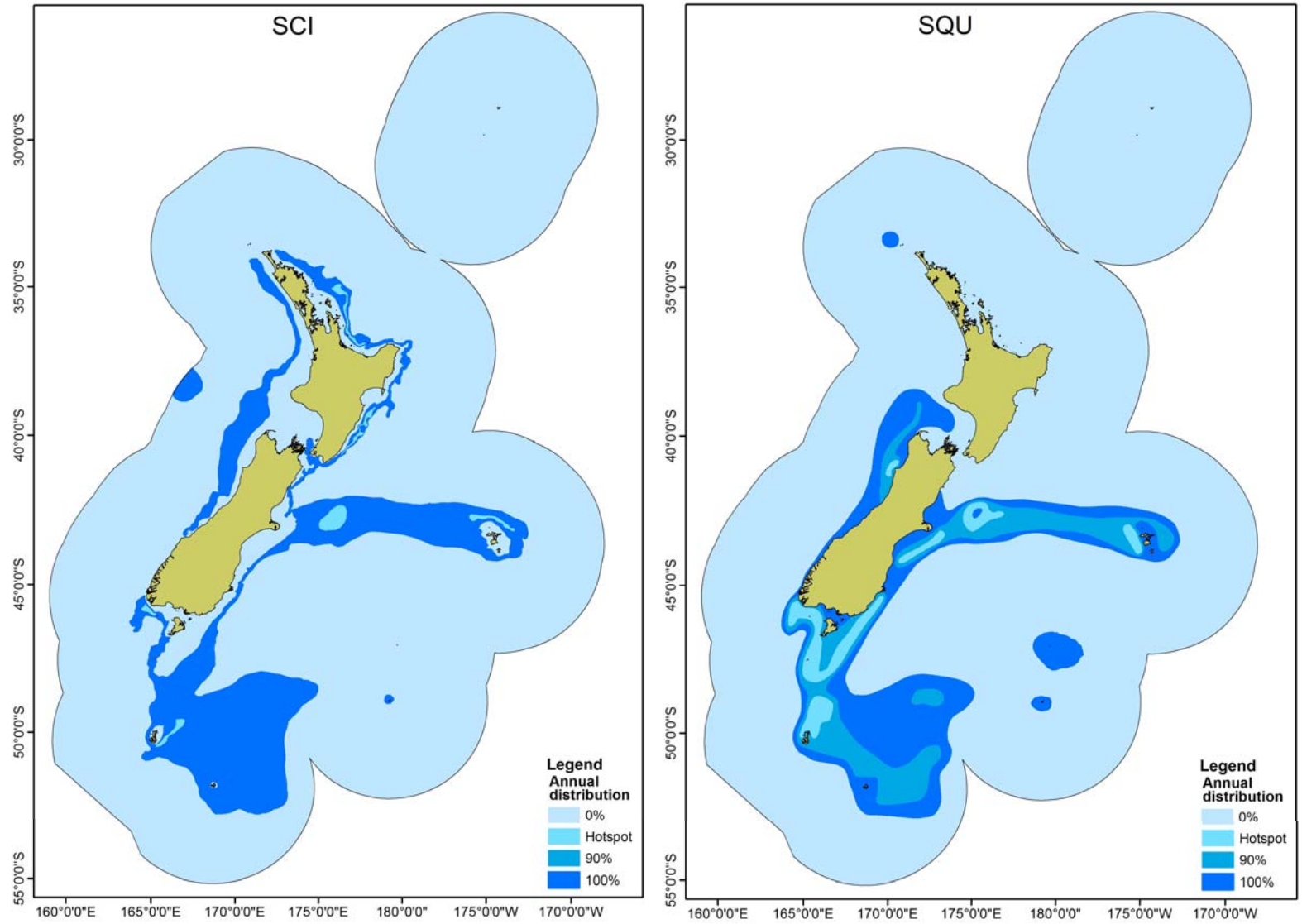


Figure B3e: The extent of waters within the combined EEZ and Territorial Sea, overlapped by the annual distribution of scampi (left) and arrow squid (right) (from www.nabis.govt.nz).

APPENDIX C: Trawl footprint and aggregated swept area summaries

Table C1: Number of bottom-contacting tows for Tier 1 and Tier 2 target species, by fishing years 2008–17. Target species codes are given in Table 1.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Tier 1 fishstocks											
HAK	1 533	1 699	812	798	644	680	779	933	479	535	8 892
HOK	7 897	7 117	8555	8 366	8 997	9 396	10 370	10 180	9 504	9 977	90 359
JMA	1 959	1 576	1895	1 249	1 514	1 379	1 329	949	894	784	13 528
LIN	2 021	1 174	997	957	837	1 002	967	984	974	1 010	10 923
OEO	2 477	2 170	2541	1 899	1 659	1 278	1 258	1 260	795	685	16 022
ORH	3 688	3 542	2922	1 885	1 583	1 590	2 029	2 344	3 124	2 983	25 690
SBW	429	613	740	694	495	389	311	454	348	307	4 780
SCI	4 802	3 965	4245	4 443	4 507	4 537	4 421	4 423	5 208	4 705	45 256
SQU	3 986	3 618	3772	4 189	3 473	2 625	2 048	1 933	2 863	2 592	31 099
Tier 1	28 792	25 474	26479	24 480	23 709	22 876	23 512	23 460	24 189	23 578	246 549
Tier 2 fishstocks											
BAR	2 192	1 316	1 021	917	1 159	1 115	1 180	1 160	1 028	1 111	12 199
BYX	647	775	933	878	784	256	523	516	417	456	6 185
CDL	540	417	534	389	380	228	313	193	146	117	3 257
EMA	15	24	1	4	25	6	0	0	0	0	75
FRO	0	0	0	0	0	0	3	2	11	12	28
GSH	0	0	0	0	4	11	5	1	3	0	24
LDO	28	7	39	59	47	106	46	73	64	42	511
RBT	6	18	9	3	21	39	34	17	5	13	165
RBY	97	65	200	173	114	116	112	104	252	141	1 374
RIB	0	0	0	0	0	0	0	1	0	0	1
SKI	9	10	17	71	82	74	37	47	40	19	406
SPD	167	236	242	149	113	52	72	86	0	1	1 118
SPE	124	31	157	221	46	191	144	326	298	220	1 758
SWA	1 129	1 067	755	860	615	709	734	640	595	608	7 712
WWA	223	325	205	117	153	156	244	101	103	111	1 738
Tier 2	5 177	4 291	4 113	3 841	3 543	3 059	3 447	3 267	2 962	2 851	36 551
Total	33 969	29 765	30 592	28 321	27 252	25 935	26 959	26 727	27 151	26 429	283 100

Table C2: Trawl footprint (km^2) for Tier 1 and Tier 2 target species, by fishing years 2008–17. Target species codes are given in Table 1.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Tier 1 fishstocks											
HAK	5 797.3	5 052.1	2 591.3	3 263.0	2 615.9	2 171.1	2 709.0	3 138.3	2 033.6	1 556.1	11 541.5
HOK	19 441.4	19 721.2	24 442.9	25 725.6	25 977.9	25 509.1	27 677.2	28 931.6	25 976.6	26 931.9	74 810.0
JMA	7 595.7	6 176.4	7 224.0	5 457.3	6 199.7	5 789.1	5 404.1	4 014.0	3 896.6	3 796.5	24 368.6
LIN	6 052.4	2 949.2	2 325.7	1 658.7	1 629.8	1 200.9	1 547.0	1 211.0	1 644.0	1 369.8	14 323.8
OEO	860.9	955.1	994.7	774.6	642.3	480.4	397.4	493.6	352.7	254.9	4 311.5
ORH	1 763.1	2 201.2	2 115.2	741.4	566.0	597.2	943.2	1 581.8	2 155.7	2 703.0	11 189.0
SBW	1 068.7	1 398.5	1 924.8	1 760.6	1 279.2	1 042.8	846.6	1186.9	1 077.5	747.6	10 062.8
SCI	5 045.3	3 948.2	3 920.5	4 333.9	4 259.5	4 305.5	4 276.2	4 201.0	4 917.0	4 672.9	12 693.6
SQU	4 408.0	4 654.4	5 202.0	5 801.4	4 613.2	3 789.0	3 259.4	3 152.7	3 484.6	3 715.1	13 656.2
Tier 1	49 489.3	44 603.0	49 016.6	47 047.6	45 605.7	43 186.2	45 400.1	46 311.0	44 204.7	44 152.3	158 093.7
Tier 2 fishstocks											
BAR	3 689.0	2 464.9	1 831.1	1 658.7	2 000.4	1 922.3	2 344.7	3 076.6	2 285.8	2 578.1	16 753.2
BYX	178.3	145.5	237.0	227.9	264.1	88.8	174.9	191.5	134.8	144.2	1 293.7
CDL	108.7	75.9	120.2	88.9	59.1	37.3	60.9	58.3	35.7	37.5	494.3
EMA	79.96	77.2	2.2	7.1	62.7	–	–	–	–	–	231.5
FRO	–	–	–	–	–	14.5	2.3	15.4	51.2	32.0	100.9
GSH	–	–	–	–	9.7	26.4	12.1	2.9	7.2	–	52.7
LDO	51.8	9.2	60.6	94.4	73.1	186.8	86.7	137.6	109.5	63.8	693.8
RBT	29.3	57.8	38.3	8.9	46.1	142.6	134.2	42.7	8.0	40.5	527.4
RBY	49.4	30.3	120.0	124.6	85.6	91.5	68.5	52.1	92.4	63.1	612.2
RIB	–	–	–	–	–	–	–	0.3	–	–	0.3
SKI	14.8	43.4	24.3	91.2	108.6	114.4	68.2	69.2	60.1	30.8	557.7
SPD	128.3	224.5	232.3	158.2	103.2	48.4	77.8	97.2	–	0.7	840.2
SPE	439.1	44.4	275.0	507.4	110.1	221.7	174.3	232.1	233.2	195.2	2 055.2
SWA	4 397.5	4 058.3	3 420.9	3 730.9	2 431.6	2 773.6	2 423.9	1 808.1	1 740.9	1 813.5	16 510.3
WWA	292.2	362.9	347.2	166.9	221.6	224.1	324.7	188.7	196.4	172.4	1 793.0
Tier 2	9 200.0	7 476.3	6 652.8	6 801.9	5 534.2	5 818.3	5 908.4	5 948.2	4 908.1	5 122.0	40 223.0
Total	56 910.8	50 638.8	53 984.6	52 322.1	49 845.2	47 747.3	49 807.9	50 743.9	48 265.5	48 203.2	180 077.2

Table C3: Aggregated swept area (km^2) for Tier 1 and Tier 2 target species, 2008–17, by fishing years 2008–17. Target species codes are given in Table 1.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
HAK	11 720.4	9 705.6	5 785.8	6 628.5	5 280.8	3 537.5	4 503.0	5 594.8	3 111.1	2 517.6	58 385.0
HOK	32 611.3	34 864.6	45 300.4	47 657.5	49 127.8	48 478.4	51 387.8	55 045.8	50 300.1	56 329.1	471 102.9
JMA	9 457.4	7 653.2	10 120.9	7196.6	8 361.9	7 456.2	6 893.7	5 105.2	4 717.4	4 663.6	71 626.2
LIN	8 168.0	3 903.0	2 790.1	2089.6	2 030.2	2 073.0	2 254.4	1 931.9	2 157.2	1 866.7	29 264.2
OEO	1 146.6	1 177.7	1 265.6	936.8	779.1	560.0	462.5	579.9	410.6	275.7	7 594.4
ORH	2 127.0	2 576.7	2 466.3	835.7	651.3	693.7	1 057.2	1 884.0	2 576.8	3 101.4	17 970.0
SBW	1 274.5	1 561.7	2 208.2	2183.7	1 429.8	1 305.2	991.6	1 403.8	1 230.0	843.4	14 432.0
SCI	10 451.9	7 048.6	7 499.4	8 117.4	7 725.2	8 000.7	7 956.5	8 218.6	9 827.2	8 582.9	83 428.4
SQU	13 600.2	13 293.1	14 277.8	15 775.9	14 346.5	9 811.1	7 649.9	7 074.8	9 394.4	9 497.3	114 721.0
Tier1	90 557.3	81 784.0	91 714.6	91 421.7	89 732.7	81 915.8	83 156.7	86 838.9	83 724.7	87 677.8	868 524.1
Tier 2 fishstocks											
BAR	4 333.7	2 794.6	2 008.6	1 858.2	2 228.2	2 155.6	2 620.6	4 091.8	2 856.5	3 722.7	28 670.5
BYX	211.8	192.3	285.0	278.2	321.3	100.5	202.1	223.6	151.7	169.9	2 136.3
CDL	130.2	88.4	138.2	100.4	67.7	41.9	67.4	62.5	39.7	45.5	781.9
EMA	80.4	81.4	2.2	7.4	66.6	14.6	–	–	–	–	252.6
FRO	–	–	–	–	–	–	2.4	15.6	54.4	33.3	105.7
GSH	–	–	–	–	9.7	27.6	12.3	2.9	7.2	–	59.8
LDO	54.3	9.2	63.2	99.9	78.2	201.9	91.1	148.3	114.8	65.2	926.0
RBT	29.4	60.1	38.7	8.9	46.6	146.9	141.8	43.3	8.0	41.1	564.6
RBY	51.8	31.3	128.1	135.7	93.4	98.8	76.7	59.8	112.7	65.0	853.3
RIB	–	–	–	–	–	–	–	0.3	–	–	0.3
SKI	14.9	43.6	24.7	97.7	114.2	118.2	69.3	73.6	62.1	31.4	649.8
SPD	135.9	242.1	262.2	173.7	112.9	52.4	82.5	102.0	–	0.7	1 164.5
SPE	466.2	44.6	282.8	556.7	111.0	244.9	191.8	304.5	268.9	262.0	2 733.5
SWA	5 926.1	5 701.1	4 182.5	4 655.6	2 950.8	3 888.5	3 450.7	2 824.1	1 967.0	2 194.6	37 741.1
WWA	344.4	450.7	388.6	182.5	268.9	273.7	406.3	212.3	213.4	194.4	2 935.1
Tier 2	11 779.0	9 739.1	7 805.0	8 154.9	6 469.7	7 365.6	7 415.0	8 164.5	5 856.4	6 825.7	79 574.9
Total	102 336.3	91 523.1	99 519.6	99 576.6	96 202.3	89 281.4	90 571.7	95 003.3	89 581.1	94 503.6	948 099.0

Table C4: Number of cells contacted by bottom-contacting tows for Tier 1 and Tier 2 target fishstocks, for fishing years 2008–17. Target species codes are given in Table 1.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
Tier 1 fishstocks											
HAK	1 101	1 185	538	669	480	521	607	646	492	377	2 132
HOK	4 641	4 112	4 377	4 741	4 558	4 612	4 854	5 102	4 567	4 703	10 894
JMA	1 818	1 645	1 600	1 442	1 421	1 468	1 573	1 246	1 228	1 126	3 150
LIN	2 229	1 436	1 590	1 192	907	790	932	761	897	834	4 187
OEO	908	926	855	759	664	497	481	483	491	421	2 148
ORH	1 330	1 478	1 443	845	777	704	1 130	1 364	1 685	1 741	3 981
SBW	389	696	811	628	636	341	332	393	474	382	1 790
SCI	1 186	1 072	1 158	1 195	1 023	1 106	1 140	1 162	1 202	1 172	3 292
SQU	1 291	1 152	1 399	1 413	1 231	969	792	880	1 132	1 149	3 354
Tier 1	11 842	11 033	11 370	10 610	9 929	9 351	10 008	10 236	10 243	10 203	23 515
Tier 2 fishstocks											
BAR	2 428	1 835	1 617	1 715	1 709	1 606	1 931	1 681	1 645	1 774	4 632
BYX	247	186	321	303	324	142	240	254	216	243	946
CDL	155	125	210	144	116	80	121	121	94	88	472
EMA	95	71	4	7	63	22	–	–	–	–	185
FRO	–	–	–	–	–	–	5	17	41	28	88
GSH	–	–	–	–	17	30	19	10	10	–	41
LDO	55	30	95	130	103	185	131	149	162	111	397
RBT	36	49	52	10	62	129	83	54	15	39	346
RBY	116	74	218	217	127	127	108	67	148	161	631
RIB	–	–	–	–	–	–	–	2	–	–	2
SKI	49	76	38	127	156	158	118	107	110	56	423
SPD	165	194	194	158	113	78	103	132	–	3	339
SPE	420	122	435	412	195	242	253	214	279	222	1 251
SWA	1 884	1 561	1 454	1 660	1 276	1 248	1 256	1 075	1 179	1 131	4 636
WWA	254	341	249	175	147	200	269	198	221	173	1 000
Tier 2	5 073	4 093	4 347	4 459	3 888	3 586	4 149	3 671	3 691	3 619	11 076
Total	14 016	12 993	13 278	12 792	11 872	11 126	12 152	12 108	12 028	12 055	26 501

Table C5: Number of 'new' cells contacted each year, compared with the previous fishing years.

	'New' cells			
Previous years	Year 'new'	No. 'new' cells	No. targets	Main targets
2008–12	2013	932	19	HOK, SCI, SBW, BAR, OEO, ORH
2008–13	2014	986	20	HOK, ORH, SCI, BAR, JMA
2008–14	2015	1053	18	ORH, HOK, SCI, BAR
2008–15	2016	847	16	ORH, HOK, SBW, SCI
2008–16	2017	662	15	ORH, HOK, SCI, BAR

Table C6: Total number of cells contacted and summary data for the annual number of bottom-contacting tows per cell, for Tier 1 and Tier 2 target species, by fishing years 2008–17.

Fishing year	No. cells	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum
2008	14 016	1	1	4	15.0	14	576
2009	12 993	1	1	3	13.4	12	472
2010	13 278	1	1	4	13.9	12	505
2011	12 792	1	1	3	14.5	12	488
2012	11 872	1	1	4	14.6	13	425
2013	11 126	1	1	4	15.0	14	465
2014	12 152	1	1	3	13.9	12	471
2015	12 108	1	1	3	14.2	13	512
2016	12 028	1	1	3	14.2	12	574
2017	12 055	1	1	3	14.3	11	418
2008–17	26 501	1	2	7	67.1	37	3 705

Table C7: Summary data for the annual aggregated swept area per cell (km^2), for Tier 1 and Tier 2 target species, by fishing years 2008–17. The minimum values ranged between 1 and 2 m^2.

Fishing year	Minimum	1st Qu	Median	Mean	3rd Qu	Maximum
2008	< 0.0001	0.5	1.6	7.3	6.3	297.3
2009	< 0.0001	0.5	1.4	7.0	5.6	345.9
2010	< 0.0001	0.4	1.4	7.5	6.0	272.2
2011	< 0.0001	0.4	1.3	7.8	6.0	323.6
2012	< 0.0001	0.4	1.4	8.1	6.4	305.4
2013	< 0.0001	0.5	1.6	8.0	6.7	342.8
2014	< 0.0001	0.4	1.5	7.5	6.1	387.0
2015	< 0.0001	0.4	1.4	7.8	6.1	433.1
2016	< 0.0001	0.4	1.3	7.4	5.9	450.9
2017	< 0.0001	0.4	1.3	7.8	5.6	279.9
2008–17	< 0.0001	0.7	2.9	35.8	15.9	2916.4

Table C8: Summary data for the annual footprint per cell (km^2), for Tier 1 and Tier 2 target species, by fishing years 2008–17. The minimum values ranged between 1 and 2 m^2.

Fishing year	Minimum	1st Qu	Median	Mean	3rd Qu	Maximum
2008	< 0.0001	0.5	1.5	4.1	5.4	25.0
2009	< 0.0001	0.5	1.4	3.9	4.8	25.0
2010	< 0.0001	0.4	1.4	4.1	5.1	25.0
2011	< 0.0001	0.4	1.3	4.1	5.1	25.0
2012	< 0.0001	0.4	1.4	4.2	5.5	25.0
2013	< 0.0001	0.4	1.6	4.3	5.7	25.0
2014	< 0.0001	0.4	1.4	4.1	5.2	25.0
2015	< 0.0001	0.4	1.3	4.2	5.2	25.0
2016	< 0.0001	0.4	1.3	4.0	5.1	25.0
2017	< 0.0001	0.4	1.2	4.0	4.8	25.0
2008–17	< 0.0001	0.7	2.7	6.8	10.8	25.0

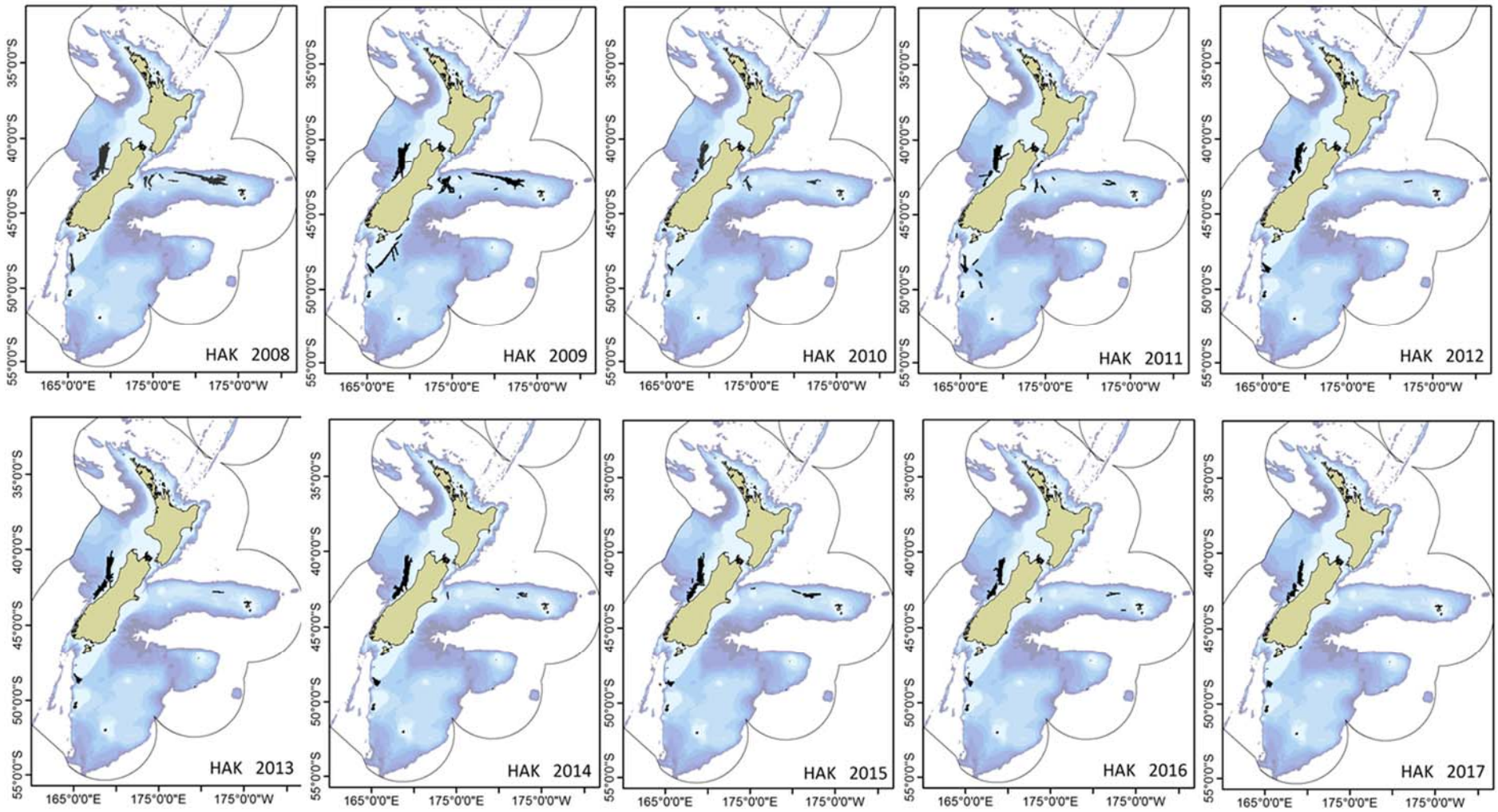


Figure C1: Annual extent of the Tier 1 data, 2008–17, where HAK is hake, HOK is hoki, JMA is jack mackerel species, LIN is ling, OEO is oreo species, ORH is orange roughy, SBW is southern blue whiting, SCI is scampi, and SQU is arrow squid.

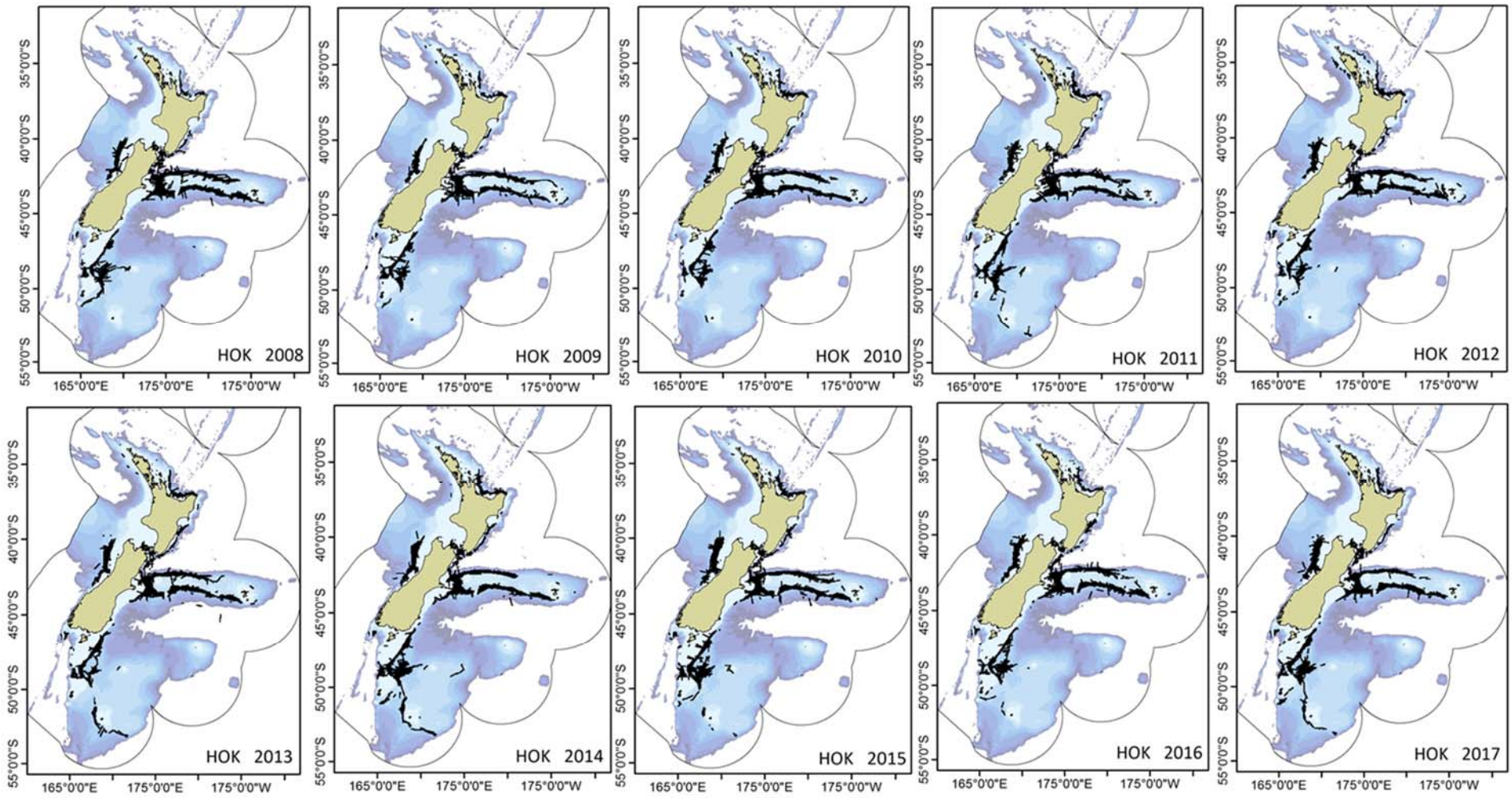


Figure C1: — *continued.*

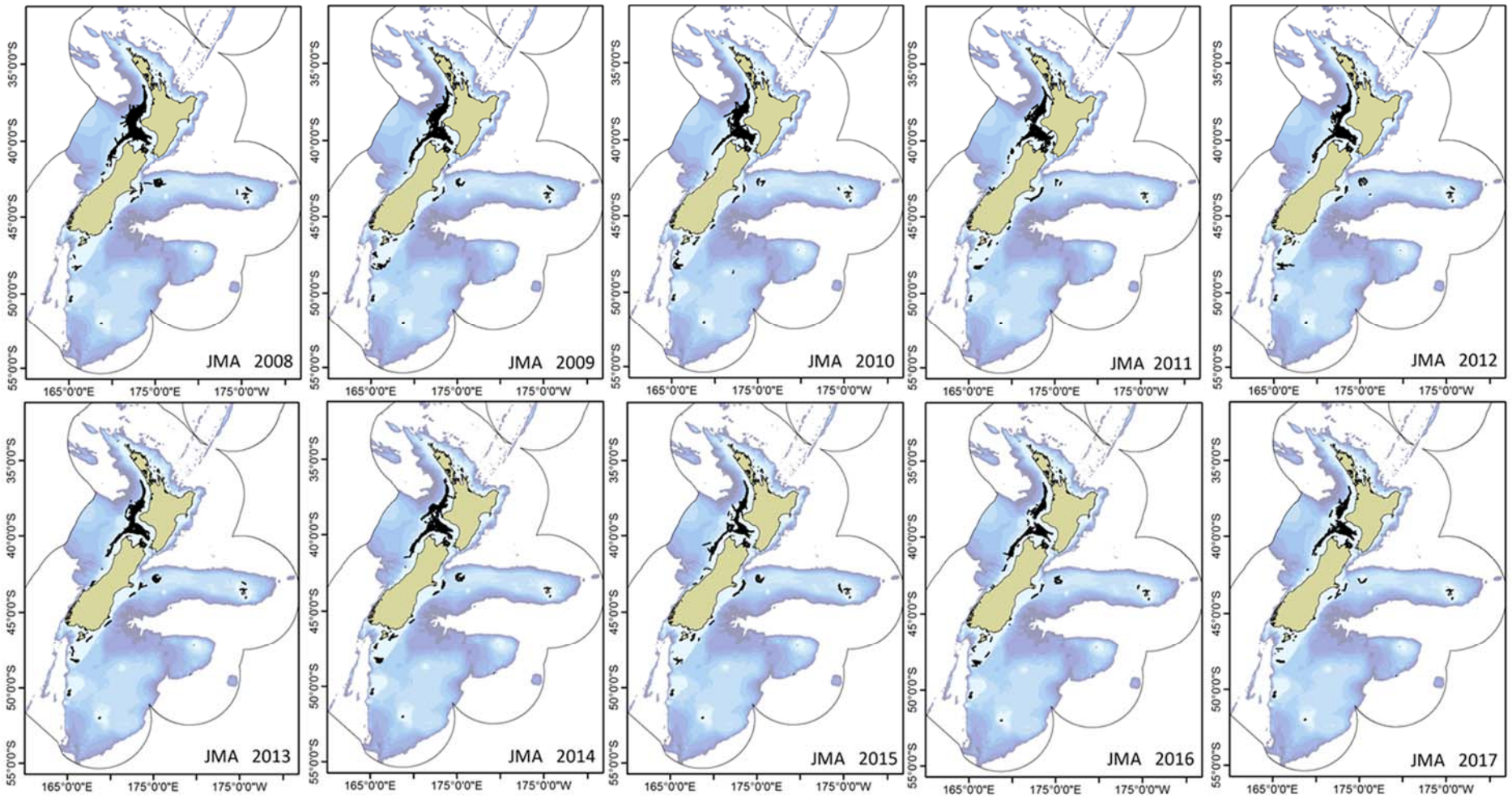


Figure C1: — ***continued.***

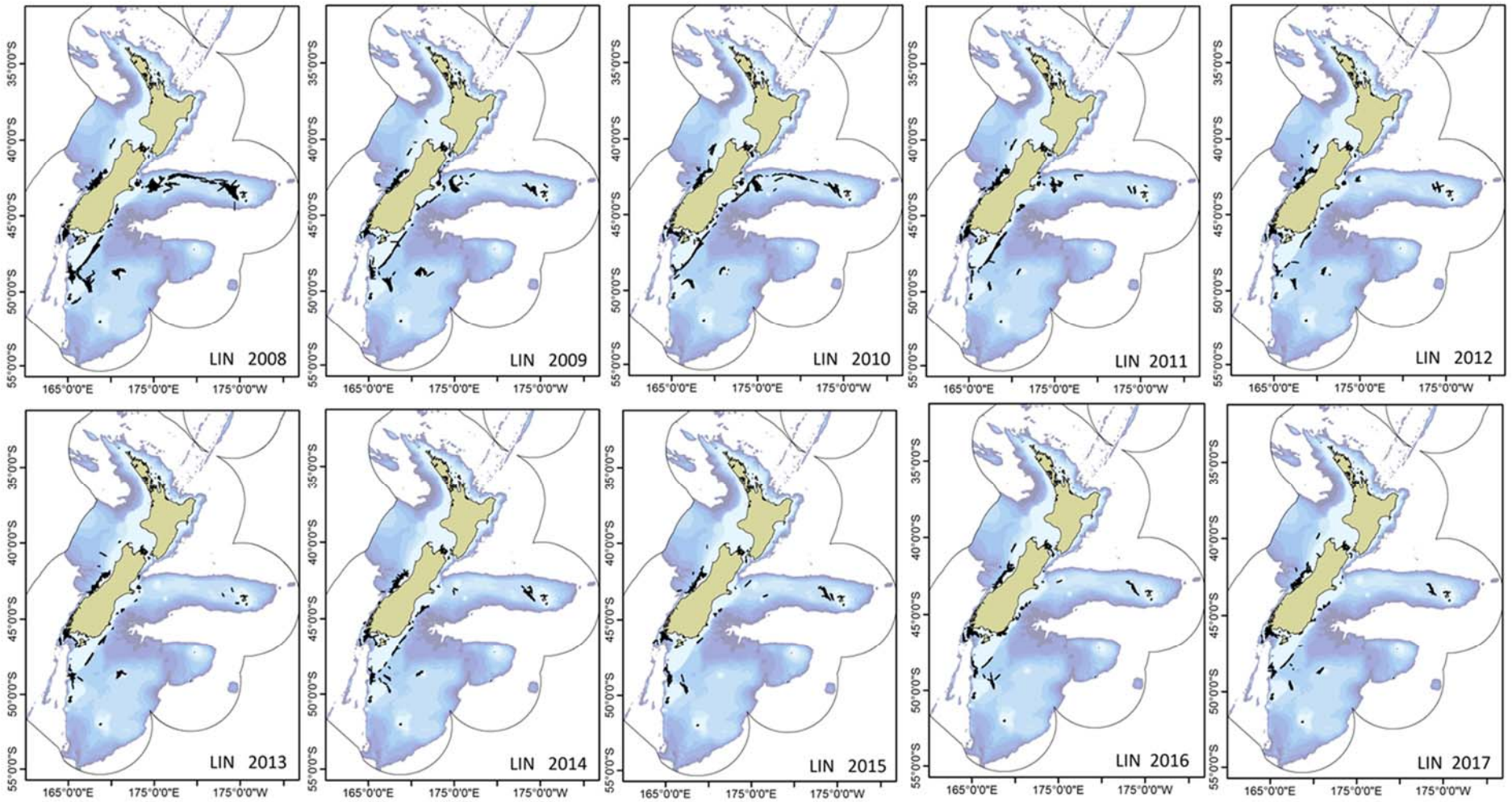


Figure C1: — ***continued.***

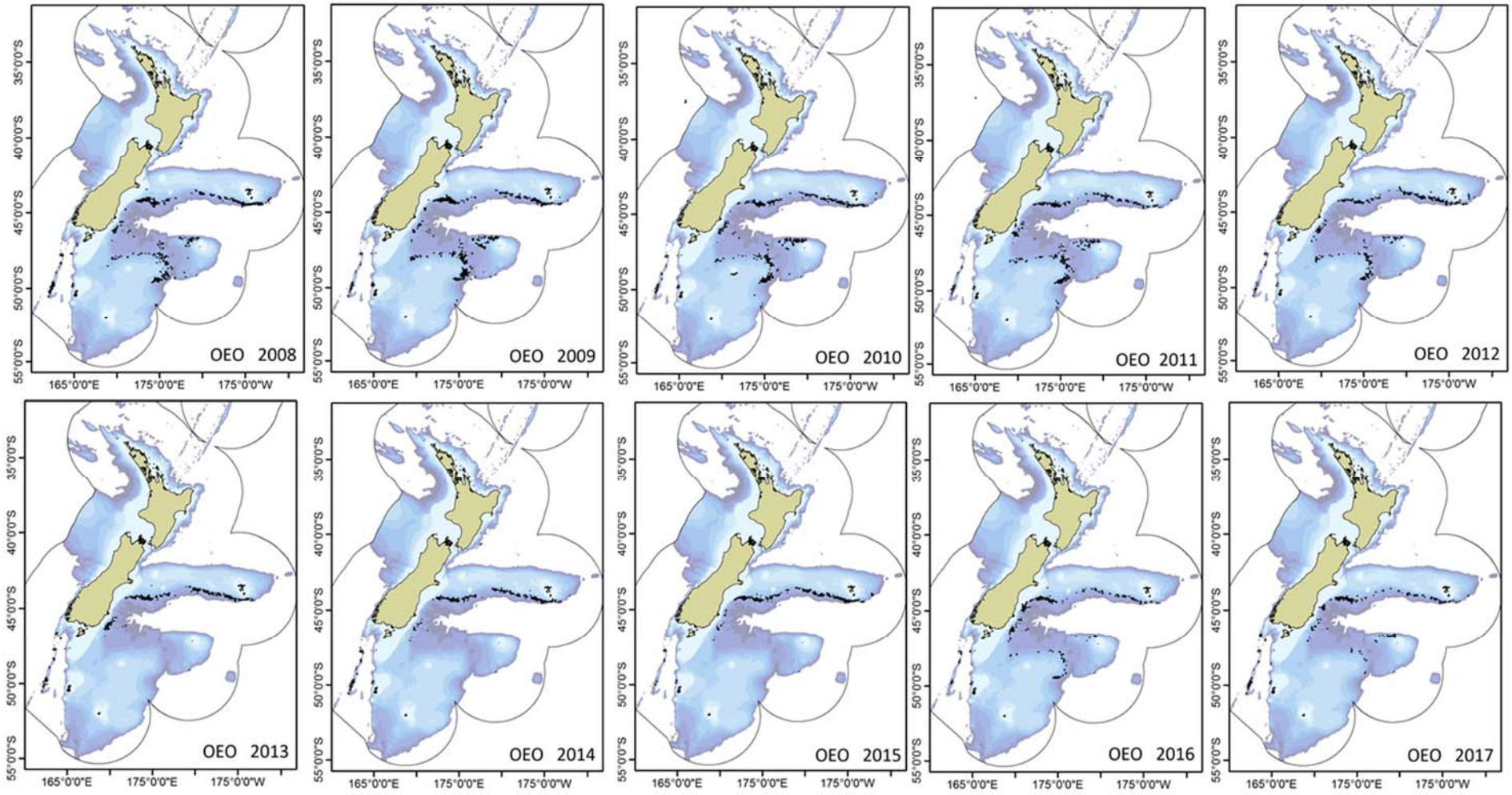


Figure C1: — *continued.*

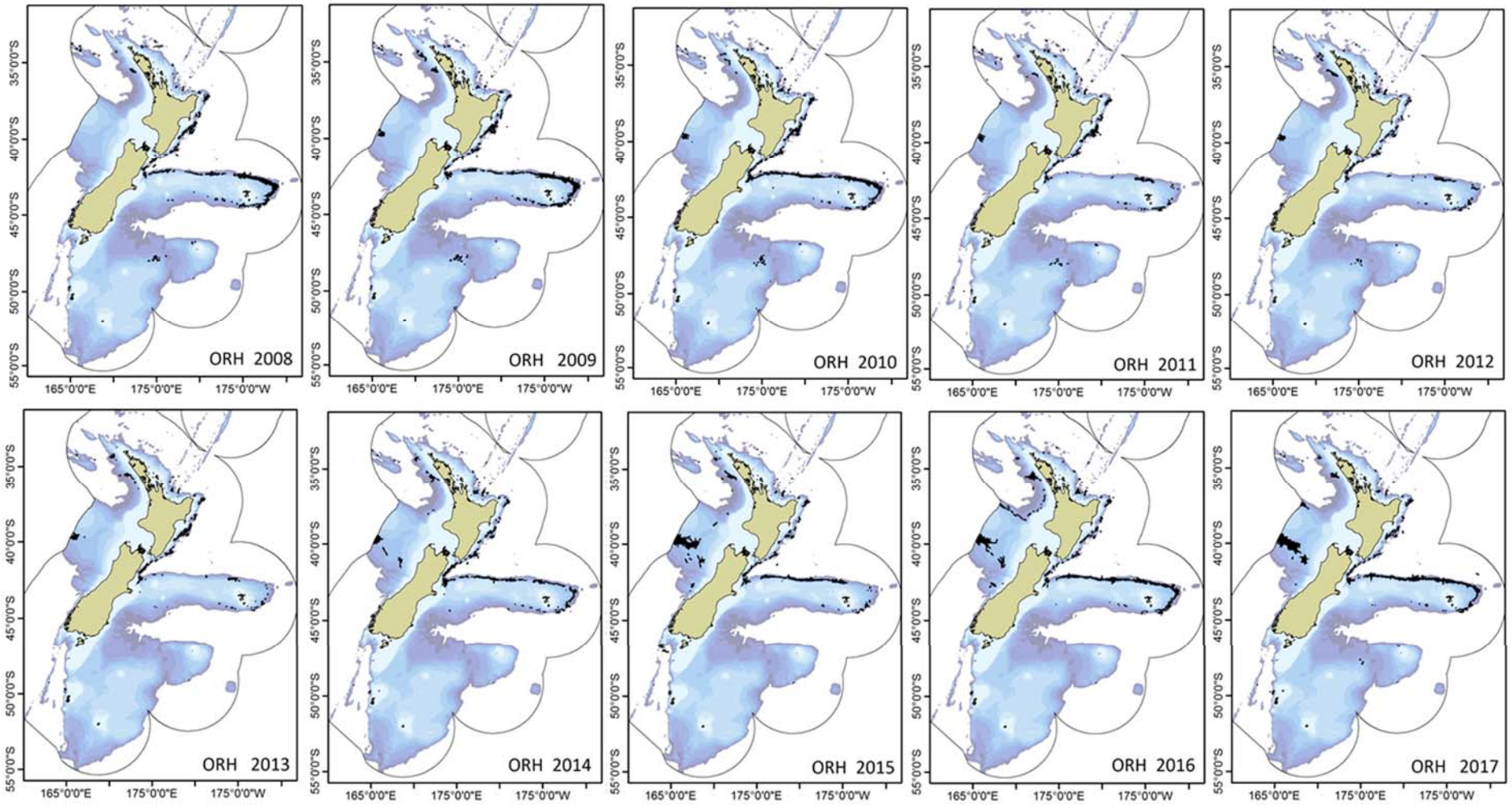


Figure C1: — *continued.*

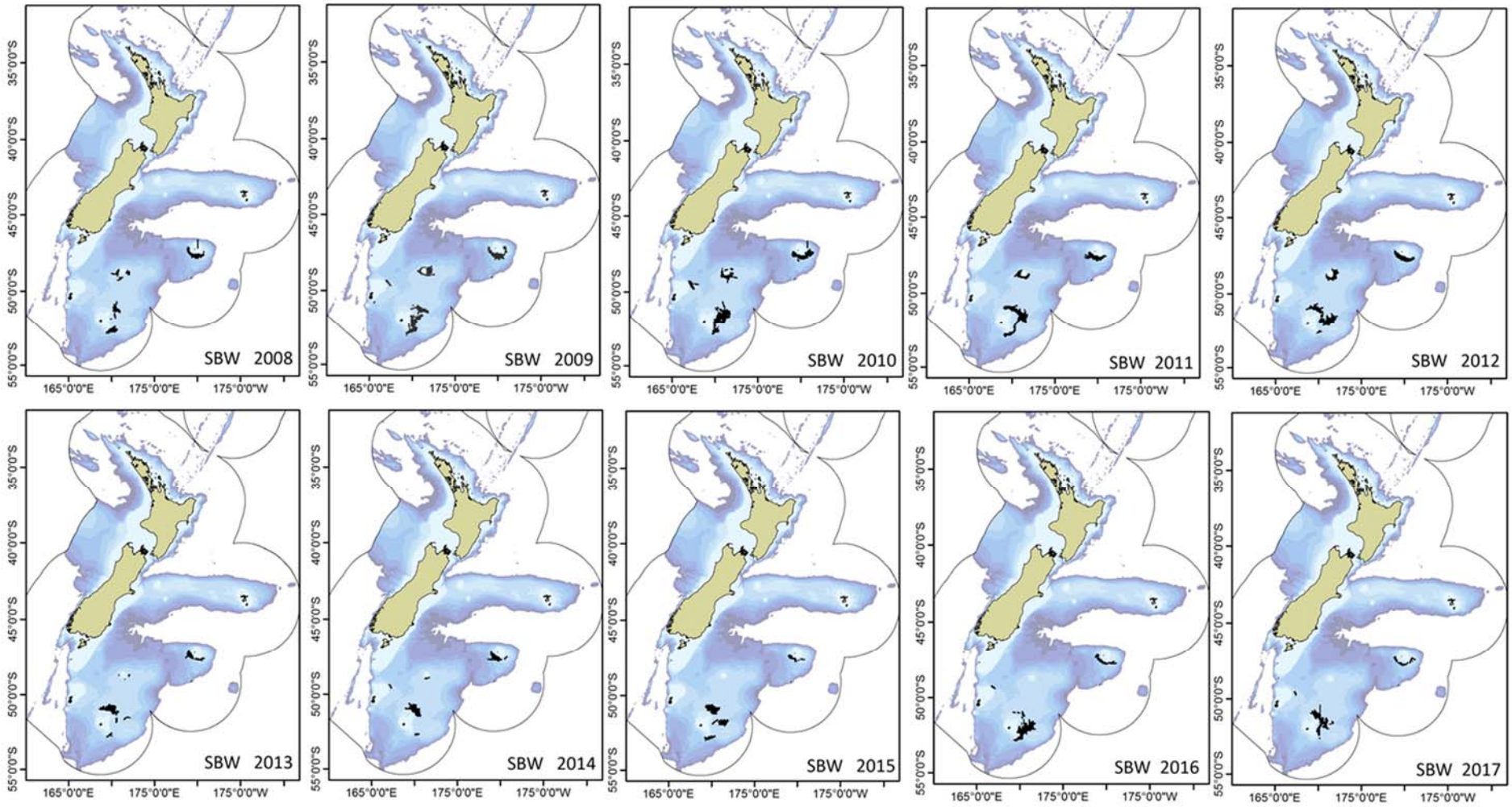


Figure C1: — *continued.*

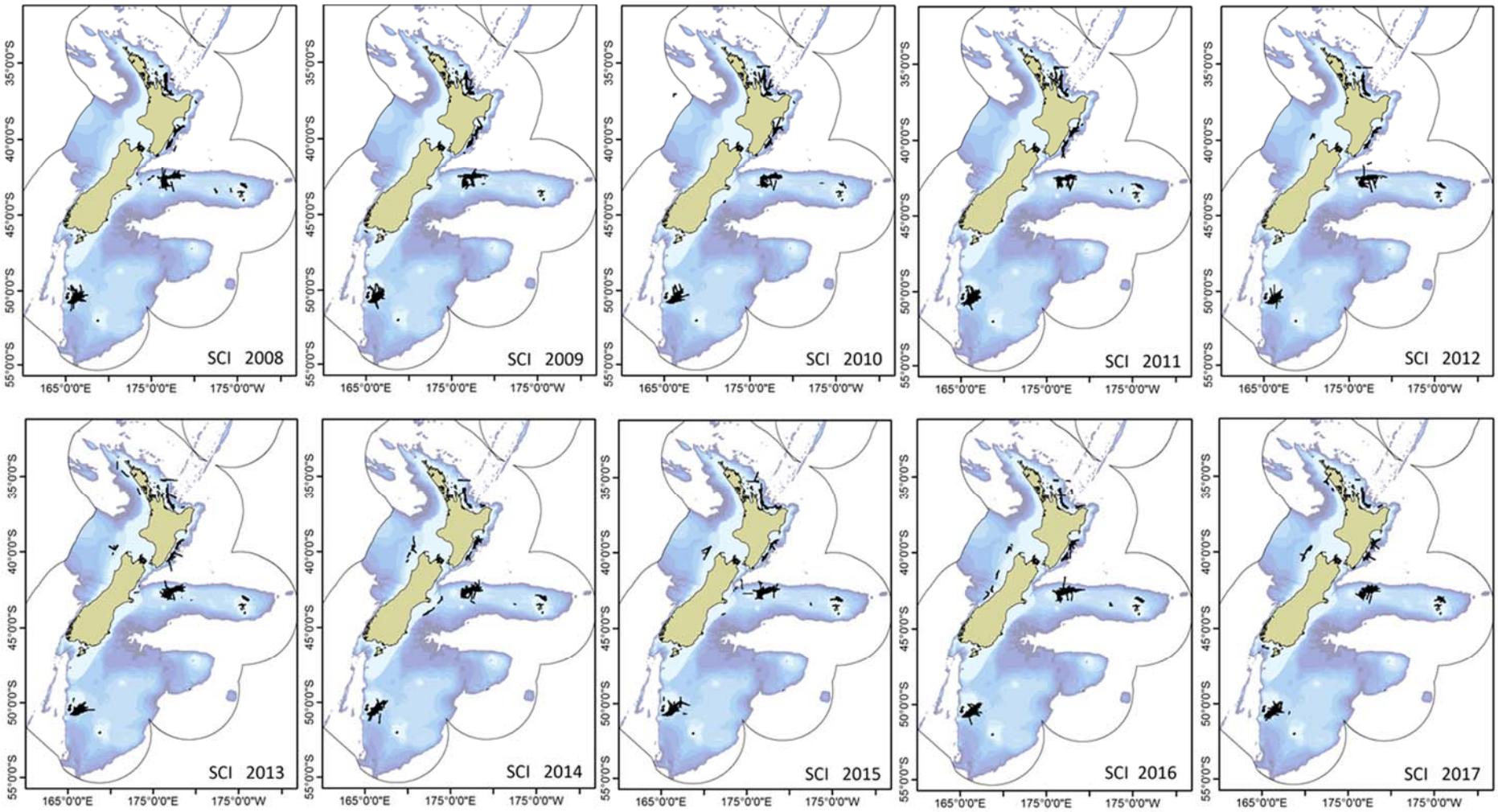


Figure C1: — ***continued.***

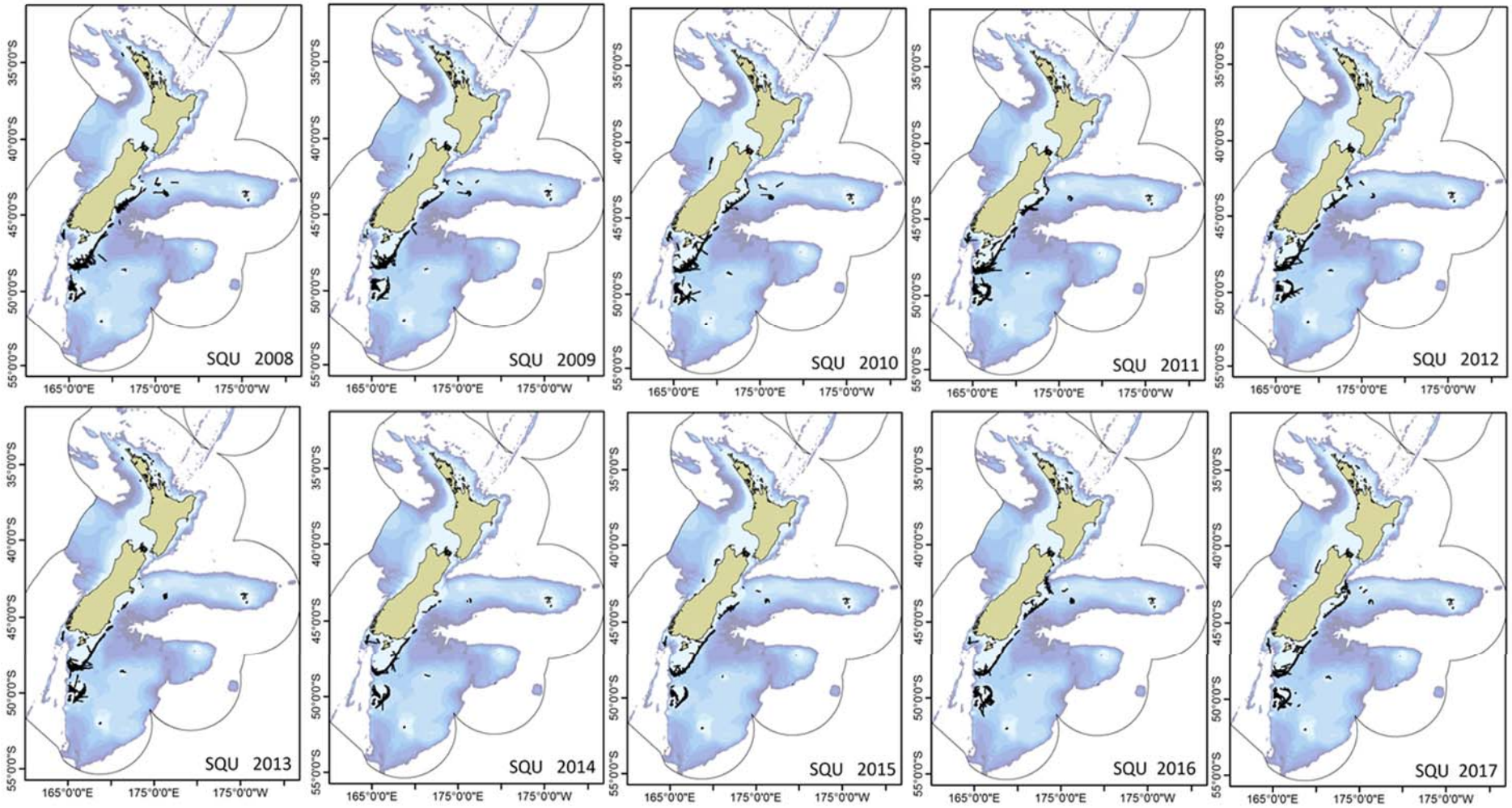


Figure C1: — ***continued.***

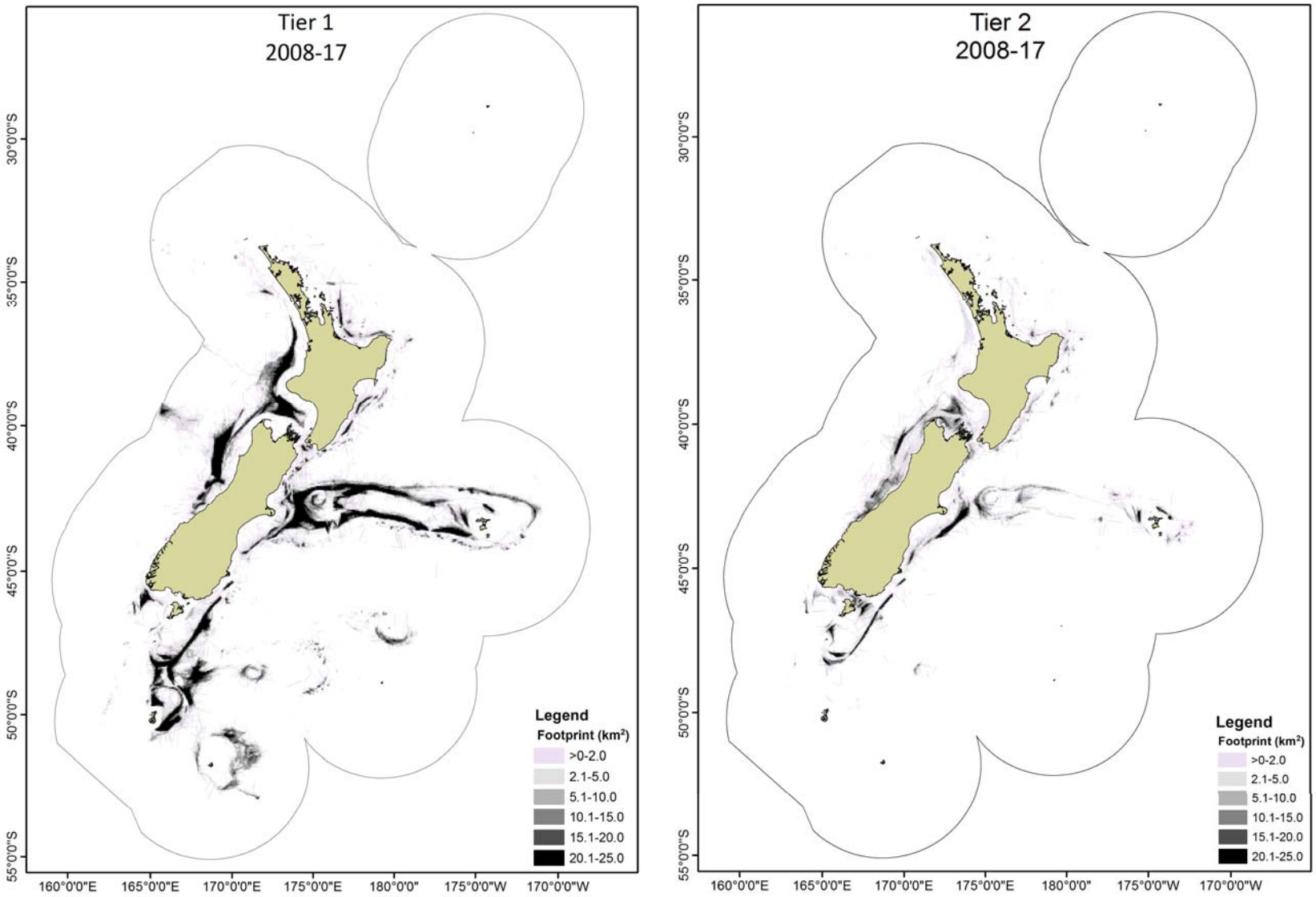


Figure C2: Tier 1 (left) and Tier 2 (right) target fishstock trawl footprints, 2008–17.

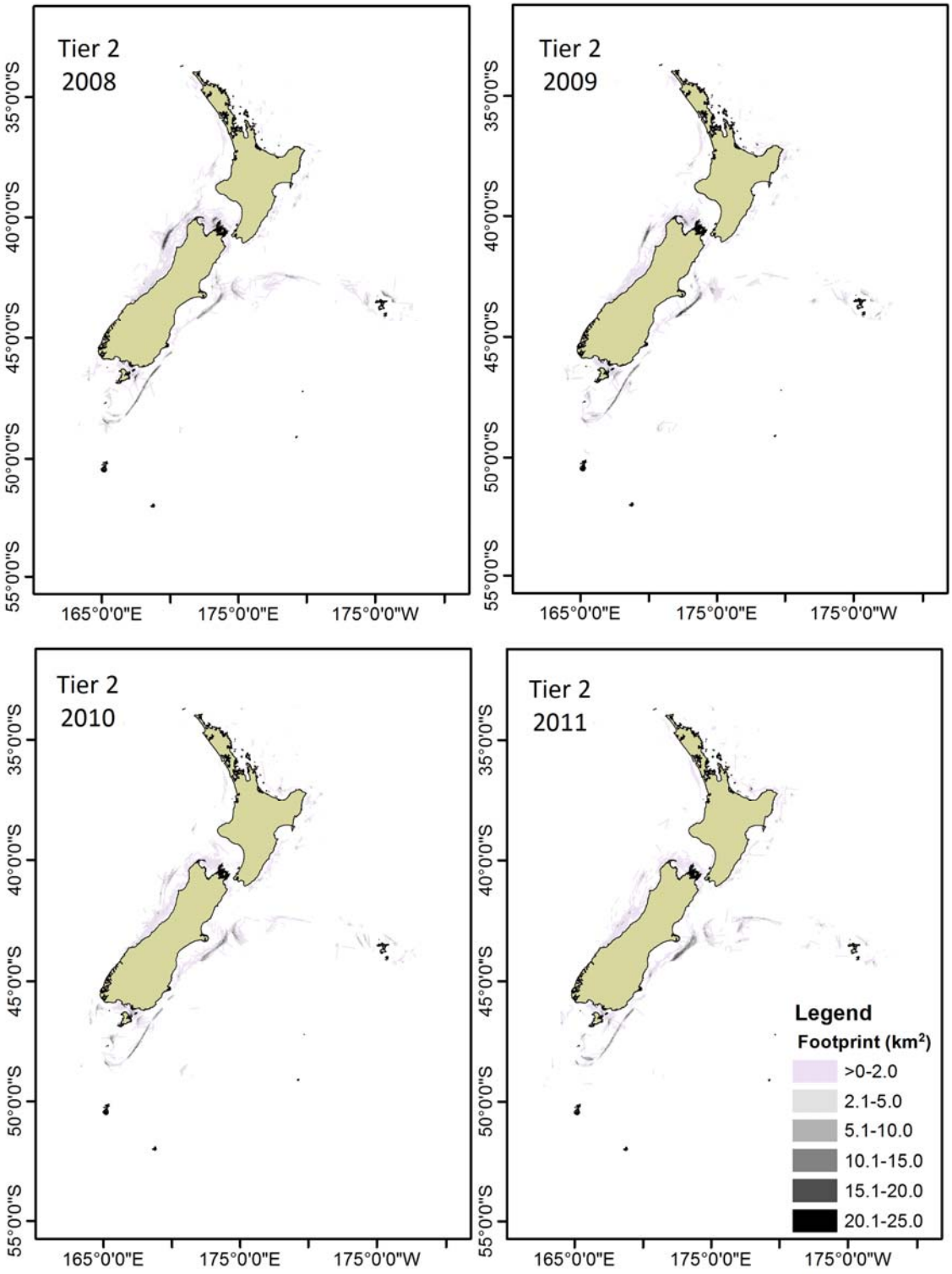


Figure C3: Tier 2 target fishstock trawl footprint, by fishing year, for 2008–17.

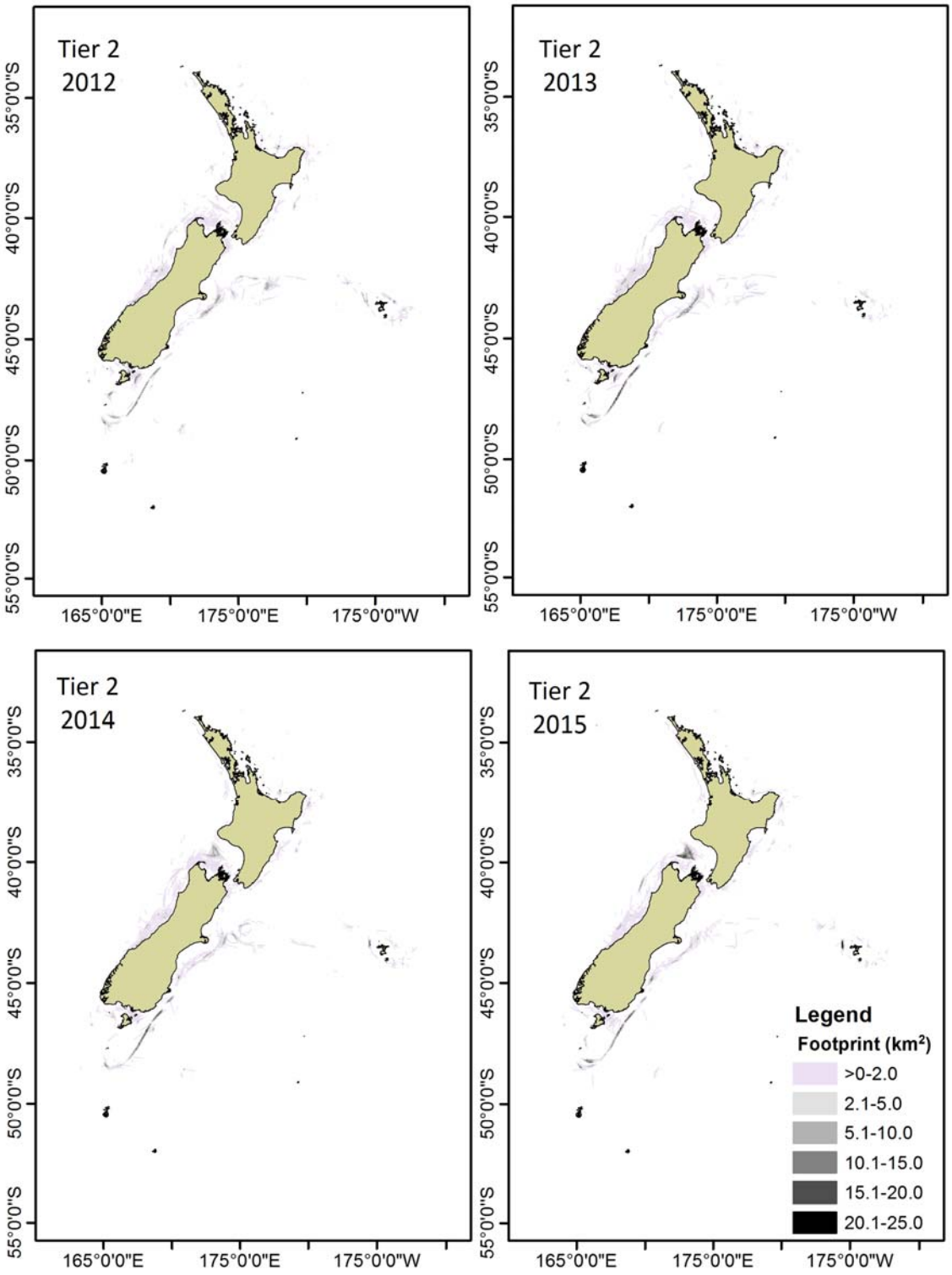


Figure C3: — ***continued.***

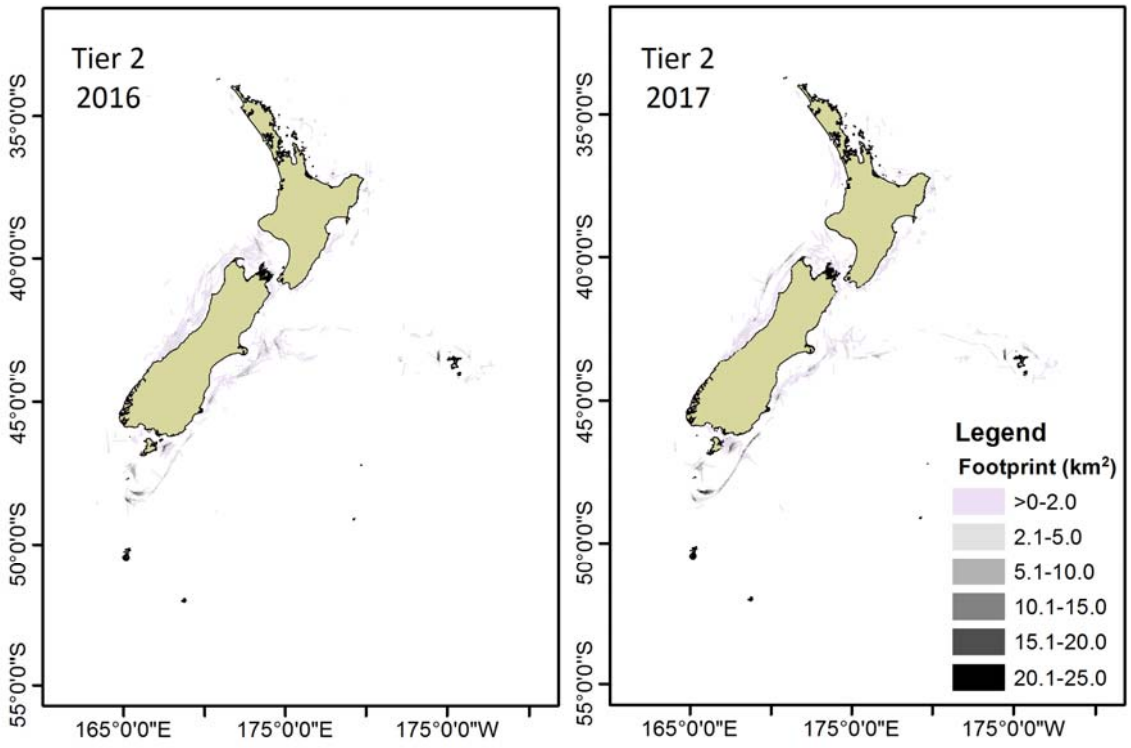


Figure C3: — ***continued.***

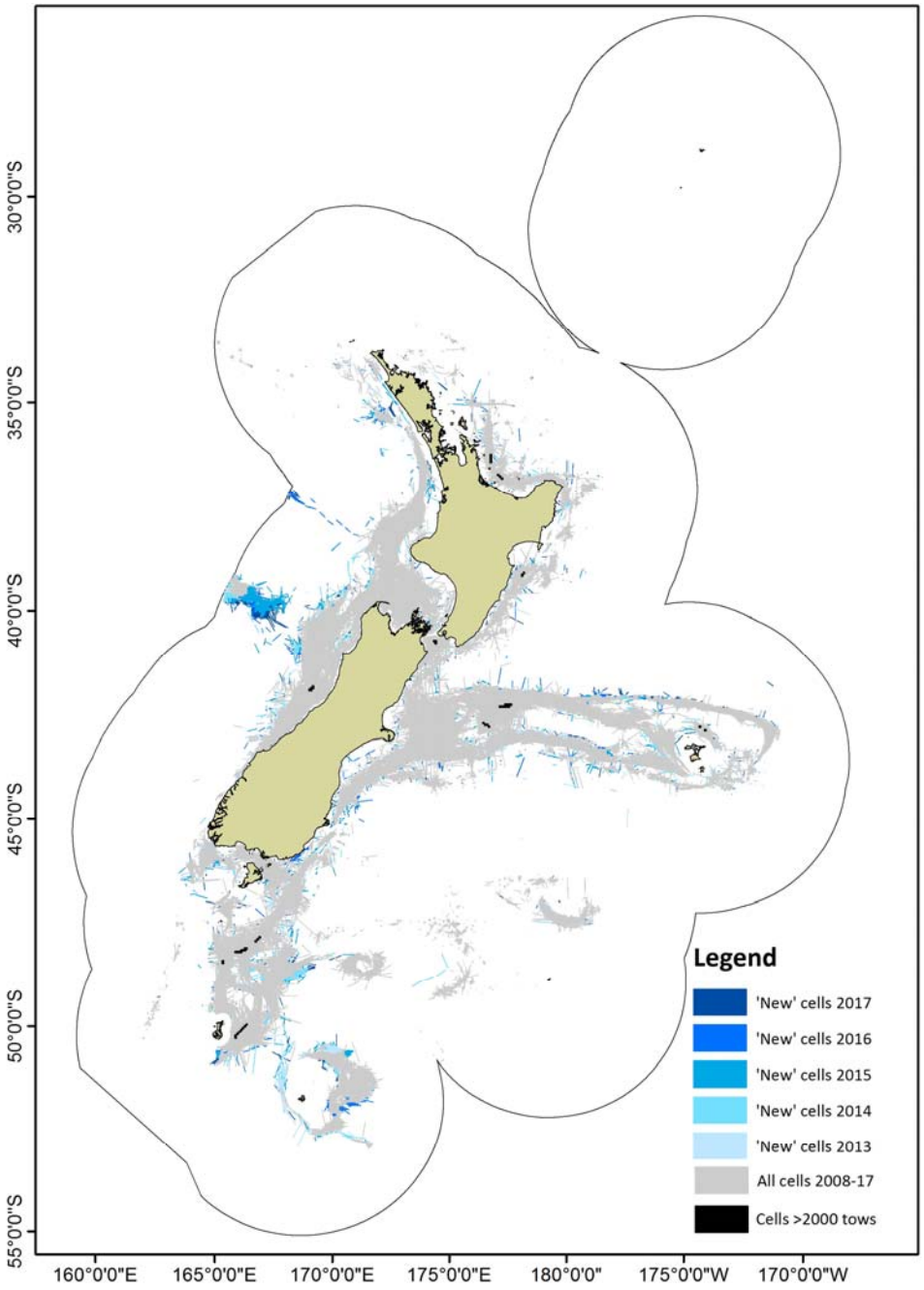


Figure C4: Location of 'new' cells in the trawl footprint, relative to previous fishing years (see Table C5) trawl footprint, 2008–17. This map also shows the locations of cells with the highest numbers of tows in the 10-y footprint (see section 4.2.3).

APPENDIX D: Specific trawl footprint statistics for Marine Stewardship Council certification requirements

Trawl footprint and statistics for combined hake (HAK)/hoki (HOK)/ling (LIN)/silver warehou (SWA)/white warehou (WWA) fisheries and for orange roughy (ORH) /oreo (OEO) fisheries, for fishing years 2008–2017

This appendix provides a summary of the bottom-contacting trawl footprint to meet the Marine Stewardship Council (MSC) requirements of BEN2017-01 Objective 2:

> "*to ensure provision of specific MSC footprint and statistics for: (a) combined target HAK/HOK/LIN trawl footprint; and (b) target ORH/OEO footprint by specific ORH areas — including out of zone Westpac Bank"*.

The work summarised here is based on two subsets of data from the analysis of the full footprint for 2008–17 generated from bottom-contacting tows that targeted deepwater Tier 1 and Tier 2 fishstocks. The analysis period covers the same fishing years, where the fishing year is denoted as the year with the most number of months (e.g., the fishing year nomenclature for 1 October 2007 to 30 September 2008 is '2007–08' and it is referred to in this appendix as '2008'). Thus, 'year' refers to the fishing year , and the footprint analyses described below are limited to bottom-contact trawling between 1 October 2007 and 30 September 2017. The methods are described in section 2 of the report body. A comparable footprint analysis for the 1990–2016 fishing years, which includes separate annual analyses for Tier 1 fishstocks, was provided by Baird & Wood (2018).

For both (a) and (b) parts of Objective 2, annual and total footprint summaries are provided with reference to relevant areas for both the HAK/HOK/LIN/WWA/SWA fishery as well as the ORH/OEO fishery. Note that for the orange roughy areas, the data are presented by the four individual areas, for waters in 800–1600 m depths. All relevant tables and figures are provided at the end of the appendix.

Combined target HAK/HOK/LIN/SWA/WWA trawl footprint, 2008–17

Between 11 100 and 13 100 bottom-contacting tows targeted either hake, hoki, ling, silver warehou, or white warehou each year (Table D.1). Most of these tows were targeted at hoki, and the peaks and troughs in the distribution of annual effort for these combined target fisheries are dominated by effort in the hoki fishery (Figure D.1, Table D.2). During the 2008–17 period, there were few changes in Total Allowable Commercial Catch (TACC) limits for these targets, other than for hoki for which the TACC increased from 90 000 t in 2008 to a peak in 2015 of 160 000 t followed by a slight drop to 150 000 t in the following two fishing years (Fisheries New Zealand 2018). Hoki target tows contributed 62–82% of annual tows, with 8400–10 400 hoki bottom-contacting tows annually during 2010–17. Ling, hake, and silver warehou accounted for most of the remaining tows.

These combined-target fishery tows contacted between 5700 and 6900 cells annually and generated annual footprints of about 31 000 km^2, with a total footprint area of 97 587 km^2 for 2008–17 (see Table D.1). This 10-year total footprint for these fishstocks contacted 2.4% of the TS+EEZ (annual footprints contacted 0.7–0.8%). When the data were restricted by depth (with a maximum depth of 1600 m), annual footprints contacted 1.8–2.1% of the seafloor and the total 10-year footprint contacted 6.0% of seafloor in these depths. Slightly higher percentages were obtained when the annual and total footprints were compared with the 'fishable' area, that is, seafloor area for waters shallower than 1600 m and open to bottom trawling (Figure D.2): annual footprint is 2.1–2.4% of the 'fishable' area and the 10-y footprint covered 7.0% (see Table D.1).

HAK/HOK/LIN/SWA/WWA footprint overlap with 200-m depth zones. About 50% of the 2008–17 footprint was in 400–600 m, with another 25% in 600–800 m, and 14% in 200–400 m (see Figure D.1, Table D.3). The spatial extent of the 2008–17 footprint relative to the 200-m depth zones is shown in Figure D.3. The total footprint contacted 17% of the seafloor area in depths of 400–600 m (about 7% per year), 11% in 600–800 m (3% per year), and 13% in 200–400 m (2.5% per year) (Table D.4, see Figure D.1).

HAK/HOK/LIN/SWA/WWA footprint overlap with BOMEC classes. The total footprint contacted 14 of the 15 BOMEC classes developed by Leathwick et al. (2012) (see section 2.3.3). There was no contact in class K, and most of the footprint coverage was in classes H (28% total footprint), I (26%), and J (23%) (Table D.5, see Figure D.1). The spatial extent of the total footprint with reference to the BOMEC classes with the greatest footprint overlap is shown in Figure D.3.

The extent of the annual footprint in class H (which includes waters shallower than 500 m on the Chatham Rise and the main spawning fishery grounds for hoki off the west coast South Island) ranged from about 9900 km^2 (in 2008) to 5700 km^2 (in 2014). In class I, a relatively narrow area which straddles the southern slope of the Chatham Rise and continental shelf edge off the east coast South Island and off Stewart-Snares shelf, the annual footprint was greater than that seen in class H (range of 9747 km^2 (in 2008) to a peak of 12 465 km^2 (in 2015)). The annual footprint extent in class J (in Chatham Rise waters slightly deeper than in class I off the Chatham Rise and waters west of the South Island) had a slightly smaller range in area (7032–8798 km^2) to that seen for class H (5658–9884 km^2, see Table D.5).

The class with the greatest percentage area covered by the total footprint was class I (at 48%), followed by class G (Cook Strait) (23%) and class H (20%) (Table D.6). In contrast, the total footprint covered about 7% of the large area in class J (which equated to about 3% per year). On an annual basis, the percent cover by the footprint in class I increased from about 19% in 2008 to almost 24% in 2015, then decreased to about 21% in the following years. For class G and class H, the percent cover decreased after 2008 from about 6% and 7% (respectively) to about 4–5% for most years. About 2% of the area of class E (off the east coast South Island and on Stewart-Snares shelf) was contacted annually.

'New' areas contacted by the HAK/HOK/LIN/SWA/WWA footprint, 2008–17. 'New' cells here are defined as 25-km^2 cells outside the main footprint area for the first year in which they were contacted, relative to previous fishing years, starting from the 2008 fishing year (see discussion in section 4.2); thus, 'new' cells in the 2013 fishing year were cells for which there was trawl contact in 2013, but not in the fishing years 2008–12. In the 2008–12 fishing years, a total of 10 999 cells were contacted by the footprint (an area of 74 081.9 km^2). Over the subsequent years in this limited period of 2008–17, between 463 cells and 175 cells each year were contacted by trawl gear for the first time (Figure D.4, Table D.7).

Much of this footprint in 'new' cells was from hoki-targeted tows and represented a small percentage of the annual footprint. For all the 'new' cells, this represented contact of a single tow (often on the outer edge of the main trawl footprint) and is likely to represent data that had some incorrect start or end of tow positions (for example, as evident on the edge of the Chatham Rise in Figure D.4). However, effort in the southern waters in recent years appears to be a true expansion of the footprint extent contacted (relative to the 2008 start). However, some of this effort is in areas that were contacted in the 1990–2016 trawl footprint (see Figure 19 in section 6 for comparison). Note that the analysis presented here was limited to the 2008–17 fishing years for this specific group of fishstocks and does not allow any comparison with the footprint before 2008. Overall, there has been a large degree of consistency in the deepwater trawl footprint distribution over time.

The ORH/OEO trawl footprint for selected ORH areas, 2008–17

A subset of the combined orange roughy and oreo species trawl footprint for 2008–17, in depths of 800–1600 m, was generated for four areas specified by the Deepwater Fishery Managers at Fisheries New Zealand, MPI (Figure D.5):

- Westpac Bank,
- ORH7A (minus the Benthic Protection Area),
- Northwest Chatham Rise (NWCR, not including the part that is on the south Chatham Rise and closed seamounts), and
- East & South Chatham Rise (ESCR, minus the Benthic Protection Area and the seamount closure).

Westpac Bank is outside the EEZ and therefore this work is restricted to the footprint summaries and their overlay with the depth zone and the 'fishable' area, because the BOMEC output used in BEN201701 was restricted to TS+EEZ waters.

ORH/OEO footprint overlap with each ORH fishery area (in 800–1600 m depths open to bottom trawling). No effort was recorded in Westpac Bank area or ORH 7A during the 2008 fishing year (Table D.8). The ORH 7A fishery was closed to trawling during the 2001–10 fishing years, with a TACC of 1 t; any effort reported here during 2009 and 2010 fishing years may represent the winter trawl and acoustic surveys (Fisheries New Zealand 2018), which is not easily distinguished from commercial effort. From the 2011 fishing year, the ORH 7A fishery TACC was increased to 500 t and from the 2015 fishing year it was further increased to 1600 t. These management changes are reflected in the ORH 7A effort during 2008–17. In ORH 7A, the annual number of tows increased over the time series to a peak in 2015 (at about 700), then decreased to 434–525 in 2016 and 2017. The eastern boundary of the Westpac Bank area (defined by the EEZ) shares a boundary with ORH 7A and thus, as an artefact of the area division, some trawls that started in ORH 7A ended in Westpac Bank. Fewer than 20 tows were reported in Westpac Bank in most years; the maximum was in 2016, with 134 tows.

Over the time period, the contacted area in ORH 7A spread eastwards from the western fishery area, with some contact in northern parts of ORH 7A in recent years. An estimated total of 2155 km^2 of the seafloor of ORH 7A was contacted during 2009–17 (about 2.6% of the area in 800–1600 m) (see Table D.8). In contrast, there has been little trawling in Westpac Bank, with most contacted area on a feature to the west and at the extreme eastern boundary where the Westpac Bank is adjacent to ORH 7A (and the trawl footprint represents the tail end of the ORH 7A trawls). The total trawl footprint (2009–17) in the Westpac Bank area was estimated at about 65 km^2, and this equated to about 0.5% of the Westpac Bank seafloor area.

Fishery management measures are also reflected in the effort in the NWCR fishery – a subset of the ORH 3B area which had steady annual reductions in the area TACC (from 10 500 t in 2008 to about 5000 t from 2015 onwards), as well as agreed non-regulated catch limits. This NWCR fishery was subject to annual catch limits of 750 t (with an additional 250 t of research catch per year) during the 2008–10 fishing years and, during the 2011–13 fishing years, quota holders agreed to avoid fishing in this area. During 2015 and subsequent fishing years, catch limit agreements enabled an annual limit for NWCR of 1043 t (Fisheries New Zealand 2018). Thus, during 2008–10 and 2014–15, fewer than 300 tows were reported each year in NWCR, with fewer than 12 per year in 2011–13 (see Table D.8). In the 2016 and 2017 fishing years, the number of tows per year in this area increased to about 400–470.

This effort was reflected in the footprint extent in the NWCR fishery which increased to 385 km^2 in 2010, was minimal during 2011–13, then steadily increased each year to a peak of 680 km^2 in 2017 (see Table D.8). For 2008–17, the NWCR fishery footprint contacted 8% of the area in 800–1600 m depths.

The main fishery area was ESCR, where effort dropped from about 2300 tows in 2008 to about 700–1000 tows during the 2011–15 fishing years, then increased to about 1200 tows in 2016 and 2017. The trawl contact decreased from over 1300 km^2 each year in 2008–10, to less than (or close to) 400 km^2

during 2011–15. There was an increase to about 630–660 km^2 in the 2016 and 2017 fishing years. For 2008–17, the ESCR fishery footprint contacted 11% of the seafloor in 800–1600 m depths.

'New' areas contacted by the ORH/OEO footprint, 2008–17. The annual distributions of bottom-contacting trawling targeting orange roughy and oreo, indicate that for all areas except ORH 7A and Westpac Bank, there was little expansion of the trawl footprint from year to year during the period 2008–17. The 'new' area contacted in each fishing year (relative to the previous years within the time period starting from 2008) presented here is an estimate of the difference in footprint (rather than 'new' cells as was estimated for the HAK/HOK/LIN/SWA/WWA) and is shown in Table D.9. Thus, the 'new' area in 2013 is the seafloor area contacted by trawl gear in 2013 but not in 2008–12, and the 'new' area in 2014 is the seafloor area with trawl contact in 2014 but not in 2008–13. It is important to note that some of these fisheries (in particular ORH 7A and Northwest Chatham Rise) were subject to management restrictions, as noted above, and were more heavily fished in years before 2008 (see Baird & Wood 2018). The trawl footprint described here represents a finite time period and does not reflect trawl effort before 1 October 2007.

The footprint in ORH 7A steadily increased over the time period, with the largest increase in contacted area in 2015 ('new' area of 702 km^2) and 2017 ('new' area of 785 km^2) (Tables D.8 and D.9) as the footprint spread to the east (particularly in 2017) and covered seafloor areas not trawled during 2008–16, although trawling occurred there prior to 2008 (see Baird & Wood 2018). There is further 'new' area in the northern part of ORH 7A, which is an extension of the 'new' area fished in 2016 (see Baird & Wood 2018).

During 2009–17, the annual coverage of 'new' area on the Westpac Bank was small, with much of the 'new' footprint area occurring in the 2016 fishing year.

Much of the 'new' area in the Chatham Rise fishery areas was around the same topographic features as in previous years (as shown by the subset of data in the ESCR area in Figure D.6); although in the NWCR there appeared to be increases in the trawled area from longer tows between features.

Table D.1: Summary data for the HAK/HOK/LIN/SWA/WWA dataset for 2008–17: number of bottom-contacting tows, number of 25-km^2 cells contacted, footprint area, percentage of TS+EEZ area contacted by the footprint, percentage of seafloor in depths of ≤ 1600 m contacted by the footprint, and percentage of 'fishable' seafloor (in ≤ 1600 m waters open to bottom trawling) contacted by the footprint.

Fishing year	No. tows	No. cells	Footprint area (km^2)	TS+EEZ* (%)	≤ 1600m* (%)	'Fishable'* (%)
2008	12 803	6 906	33 090.8	0.8	2.0	2.4
2009	11 382	5 922	29 628.2	0.7	1.8	2.1
2010	11 324	5 847	30 951.3	0.8	1.9	2.2
2011	11 098	6 124	31 993.5	0.8	2.0	2.3
2012	11 246	5 750	30 869.4	0.8	1.9	2.2
2013	11 943	5 702	30 021.2	0.7	1.8	2.2
2014	13 094	6 071	32 724.2	0.8	2.0	2.4
2015	12 838	6 198	33 646.9	0.8	2.1	2.4
2016	11 655	5 779	30 268.0	0.7	1.9	2.2
2017	12 241	5 811	30 383.7	0.7	1.9	2.2
2008–17	119 624	13 417	97 586.9	2.4	6.0	7.0

* The seafloor area of the TS+EEZ = 4 111 569 km^2; the seafloor area in ≤ 1600 m = 1 624 249 km^2; and the 'fishable' area (open to bottom trawling in ≤ 1600 m) = 1 385 795 km^2.

Table D.2: Number of bottom-contacting tows that targeted HAK/HOK/LIN/SWA/WWA*, by fishing year 2008–17.

Target	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008–17
HAK	1 533	1 699	812	798	644	680	779	933	479	535	8 892
HOK	7 897	7 117	8 555	8 366	8 997	9 396	10 370	10 180	9 504	9 977	90 359
LIN	2 021	1 174	997	957	837	1 002	967	984	974	1 010	10 923
SWA	1 129	1 067	755	860	615	709	734	640	595	608	7 712
WWA	223	325	205	117	153	156	244	101	103	111	1 738
All	12 803	11 382	11 324	11 098	11 246	11 943	13 094	12 838	11 655	12 241	119 624

* HAK is hake, HOK is hoki, LIN is ling, SWA is silver warehou, WWA is white warehou (see Table 1).

Table D.3: HAK/HOK/LIN/SWA/WWA footprint area (km^2) within each 200-m depth zone, by fishing year 2008–17.

Depth zone (m)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008–17
≤ 200	1 494.9	1 204.7	1 131.8	1 591.5	997.4	1 370.8	1 121.1	1 089.9	817.4	974.3	7 531.5
200–400	5 027.9	3 405.9	2 781.0	2 963.5	3 123.9	2 292.3	2 263.5	2 323.1	2 337.5	2 370.2	13 412.6
400–600	19 446.0	19 030.6	20 730.2	20 570.3	20 264.0	19 394.2	18 829.7	21 146.7	19 965.0	19 395.9	48 220.9
600–800	6 401.3	5 361.6	5 902.3	6 398.3	6 125.9	6 556.1	9 940.5	8 479.9	6 568.8	7 093.1	24 841.3
800–1000	615.9	460.2	298.5	373.4	304.1	340.9	501.8	474.2	422.0	480.2	2 613.6
1000–1200	61.7	128.0	69.8	43.6	30.6	47.1	41.6	91.2	108.7	53.4	624.4
1200–1400	24.6	20.4	20.7	27.7	11.0	13.9	12.3	20.9	36.4	13.0	197.5
1400–1600	18.5	16.9	17.0	25.3	12.4	5.8	13.7	21.1	12.3	3.5	145.1
≤ 1600	33 090.8	29 628.2	30 951.3	31 993.5	30 869.4	30 021.2	32 724.3	33 646.9	30 268.0	30 383.7	97 586.9

Table D.4: Total seafloor area for each 200-m depth zone and percentage contacted by the HAK/HOK/LIN/SWA/WWA footprint, by fishing year 2008–17.

Depth zone (m)	Zone area (km^2)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008–17
≤ 200	272 377.5	0.5	0.4	0.4	0.6	0.4	0.5	0.4	0.4	0.3	0.4	2.8
200–400	105 005.9	4.8	3.2	2.6	2.8	2.9	2.2	2.2	2.2	2.2	2.3	12.8
400–600	283 301.6	6.9	6.7	7.3	7.3	7.1	6.8	6.6	7.5	7.0	6.8	17.0
600–800	226 302.4	2.8	2.4	2.6	2.8	2.7	2.9	4.4	3.7	2.9	3.1	11.0
800–1000	182 709.4	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.2	0.3	1.4
1000–1200	186 205.5	< 0.1	0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1	0.1	< 0.1	0.3
1200–1400	210 881.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.1
1400–1600	157 465.7	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.00	0.1
≤ 1600	1 624 249.2	2.0	1.8	1.9	2.0	1.9	1.8	2.0	2.1	1.9	1.9	6.0

Table D.5: HAK/HOK/LIN/SWA/WWA footprint area (km^2) within each BOMEC class, by fishing years 2008–17. There was no overlap with class K, so this class is ignored in the table below.

BOMEC class	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008–17
A	2.3	1.8	9.0	5.5	6.6	4.4	2.8	3.9	0.7	3.3	39.7
B	70.2	41.1	66.5	51.6	47.7	45.8	40.1	52.4	28.0	87.1	410.4
C	155.5	131.1	218.2	208.3	149.0	150.1	154.3	130.0	125.6	145.3	1 093.7
D	73.7	63.7	58.9	91.2	75.4	71.9	49.5	23.7	76.3	49.9	518.2
E	1 166.9	1 195.2	935.3	1 316.1	887.1	1 156.6	1 028.5	986.5	655.4	832.1	4 657.1
F	83.5	75.6	30.9	15.9	8.9	45.0	22.0	17.7	10.7	3.8	290.2
G	398.0	351.8	373.1	345.1	296.1	306.6	379.4	312.8	280.6	350.6	1 463.7
H	9 883.9	7 705.1	7 061.2	7 364.3	7 666.5	6 209.5	5 658.2	6 923.2	7 226.8	6 441.5	27 624.3
I	9 746.6	10 562.8	12 390.9	11 396.2	11 722.3	12 306.6	11 595.6	12 465.2	10 823.7	10 887.8	25 237.7
J	8 762.4	7 032.0	7 448.1	7 936.4	8 049.4	7 656.2	8 798.0	8 943.8	8 340.4	7 980.3	22 859.7
L	2 465.3	2 195.8	1 916.8	2 462.3	1 547.8	1 669.3	3 989.4	3 105.9	2 163.8	2 838.5	10 667.6
M	198.8	193.4	378.6	732.0	369.0	355.4	962.0	604.9	463.8	725.1	2 198.8
N	81.9	75.7	62.3	66.1	42.3	42.7	43.7	75.9	71.8	37.5	512.0
O	1.6	2.8	0.0	0.5	0.4	0.1	0.1	0.4	0.01	0.03	6.0
Total	33 090.4	29 627.9	30 950.0	31 991.3	30 868.5	30 020.3	32 723.8	33 646.4	30 267.6	30 382.7	97 579.1

Table D.6: Total seafloor area of each BOMEC class (except class K which has no footprint overlap) and percentage of each class area that was contacted by the HAK/HOK/LIN/SWA/WWA footprint, each year and for all years, for 2008–17. The spatial distribution of the BOMEC classes is shown in Figure 4.

BOMEC class	Area (km^2)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2008–17
A	27 557.0	0.01	0.01	0.03	0.02	0.02	0.02	0.01	0.01	< 0.01	0.01	0.14
B	12 420.0	0.57	0.33	0.54	0.42	0.38	0.37	0.32	0.42	0.23	0.70	3.30
C	89 710.2	0.17	0.15	0.24	0.23	0.17	0.17	0.17	0.14	0.14	0.16	1.22
D	27 267.9	0.27	0.23	0.22	0.33	0.28	0.26	0.18	0.09	0.28	0.18	1.90
E	60 989.8	1.91	1.96	1.53	2.16	1.45	1.90	1.69	1.62	1.07	1.36	7.64
F	38 608.5	0.22	0.20	0.08	0.04	0.02	0.12	0.06	0.05	0.03	0.01	0.75
G	6 341.9	6.27	5.55	5.88	5.44	4.67	4.83	5.98	4.93	4.42	5.53	23.08
H	138 551.4	7.13	5.56	5.10	5.32	5.53	4.48	4.08	5.00	5.22	4.65	19.94
I	52 223.9	18.66	20.23	23.73	21.82	22.45	23.57	22.20	23.87	20.73	20.85	48.33
J	311 360.4	2.81	2.26	2.39	2.55	2.59	2.46	2.83	2.87	2.68	2.56	7.34
L	198 577.0	1.24	1.11	0.97	1.24	0.78	0.84	2.01	1.56	1.09	1.43	5.37
M	233 825.5	0.09	0.08	0.16	0.31	0.16	0.15	0.41	0.26	0.20	0.31	0.94
N	493 034.7	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.10
O	935 315.2	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Total	2 625 783.6	1.26	1.13	1.18	1.22	1.18	1.14	1.25	1.28	1.15	1.16	3.72

Table D.7: Number of 'new' cells relative to the footprint for the previous years, based on the combined 2008–12 fishing years, that were contacted by the HAK/HOK/LIN/SWA/WWA footprint in each subsequent fishing year, by reported target; and the footprint area in the 'new' cells by fishing year, with the percentage of the annual footprint that was covered by the annual 'new' cells footprint. The number of 'new' cells in 2013 is relative to 2008–12, and the number of 'new' cells in 2014 is relative to the 2008–13 fishing years and so on.

Fishing year	Number of 'new' cells						Footprint area	
	Total no.	HAK	HOK	LIN	SWA	WWA	'new' cells (km^2)	% annual footprint area
2013	463	14	391	35	20	3	1 068.0	3.6
2014	463	10	355	48	38	12	882.6	2.7
2015	313	10	239	34	28	2	371.0	1.1
2016	220	0	146	39	31	4	187.6	0.6
2017	175	0	147	9	19	0	168.2	0.6

Table D.8: Summary data for the ORH/OEO dataset for the four analysis areas (where the depths were restricted to 800–1600 m), for fishing years 2008–17: number of bottom-contacting tows, number of 25-km^2 cells contacted, footprint area, and the percentage of the fishery area (waters open to bottom trawling, in 800–1600 m depths) with contact from the ORH/OEO trawl footprint.

Fishing year	ORH7A (area = 83 747.6 km^2)			
	No. tows	No. cells	Footprint (km^2)	Fishery area (%)
2008	0	–	–	–
2009	65	51	13.7	< 0.1
2010	78	51	15.7	< 0.1
2011	114	59	60.2	< 0.1
2012	105	59	47.7	< 0.1
2013	154	73	66.5	< 0.1
2014	132	136	162.3	0.2
2015	707	478	819.1	1.0
2016	434	365	516.5	0.6
2017	525	560	1 030.3	1.2
2008–17	2 314	813	2 155.2	2.6

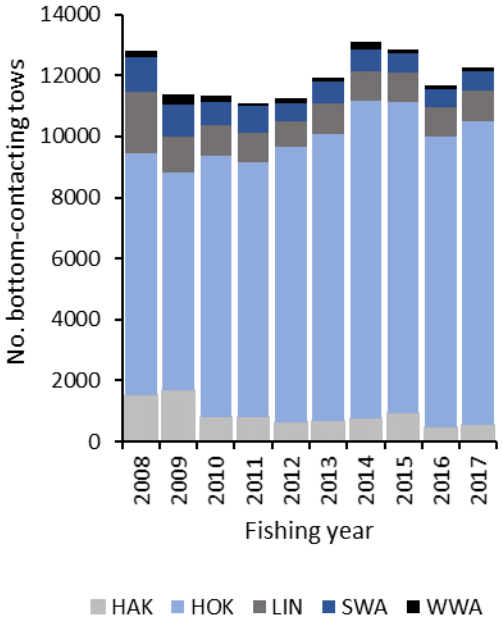
Fishing year	Northwest Chatham Rise (area = 23 439.0 km^2)			
	No. tows	No. cells	Footprint (km^2)	Fishery area (%)
2008	291	183	155.9	0.7
2009	190	215	168.7	0.7
2010	277	298	385.3	1.6
2011	10	14	3.7	< 0.1
2012	7	13	3.0	< 0.1
2013	11	17	3.8	< 0.1
2014	227	234	167.4	0.7
2015	284	270	275.8	1.2
2016	406	327	488.9	2.1
2017	466	370	680.4	2.9
2008–17	2 169	559	1 867.0	8.0

Fishing year	Westpac Bank (area = 12 988.5 km^2)			
	No. tows	No. cells	Footprint (km^2)	Fishery area (%)
2008	0	–	–	–
2009	13	15	1.9	< 0.1
2010	12	15	1.7	< 0.1
2011	3	4	0.4	< 0.1
2012	12	11	1.8	< 0.1
2013	9	9	1.6	< 0.1
2014	15	25	5.6	< 0.1
2015	20	18	4.8	< 0.1
2016	134	65	44.2	0.3
2017	29	18	6.5	< 0.1
2008–17	245	342	65.1	0.5

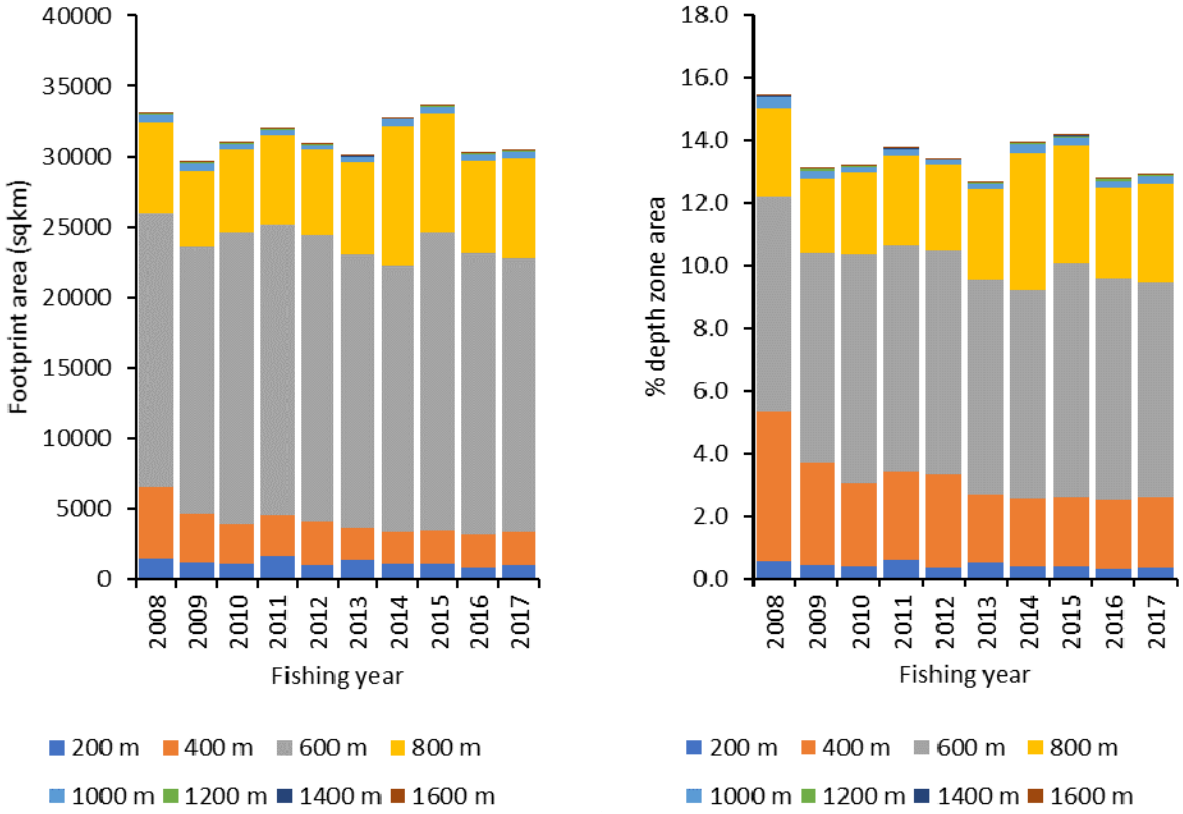
Fishing year	East & South Chatham Rise (area = 44 960.1 km^2)			
	No. tows	No. cells	Footprint (km^2)	Fishery area (%)
2008	2 288	657	1 318.8	2.9
2009	2 257	668	1 640.7	3.6
2010	1 671	562	1 391.7	3.1
2011	718	256	274.7	0.6
2012	882	311	332.9	0.7
2013	832	232	287.7	0.6
2014	946	353	356.8	0.8
2015	975	296	401.1	0.9
2016	1 284	466	635.0	1.4
2017	1 190	430	661.3	1.5
2008–17	13 043	981	4 942.3	11.0

Table D.9: Footprint area for 2008–12 and the 'new' footprint area estimated for successive fishing years, by orange roughy fishery area. Note that the 'new' area in 2013 is the seafloor area that was trawled in 2013, but not in 2008–12; the 'new' area in 2014 is the seafloor area trawled in 2014, but not in 2008–13; and so on. There was no trawl footprint in the 2008 fishing year for Westpac Bank or ORH7A.

Fishing year	Footprint area (km^2)			
period	Westpac Bank	ORH7A	ESCR	NWCR
Up to 2012	5.7	126.7	3 861.3	663.0
'new' in 2013	1.6	52.4	135.3	3.2
'new' in 2014	5.5	150.6	153.1	132.5
'new' in 2015	4.8	702.0	186.7	213.5
'new' in 2016	43.2	338.8	271.1	384.5
'new' in 2017	4.2	784.6	334.6	470.2
2008–17	65.1	2 155.2	4 942.3	18 67.0

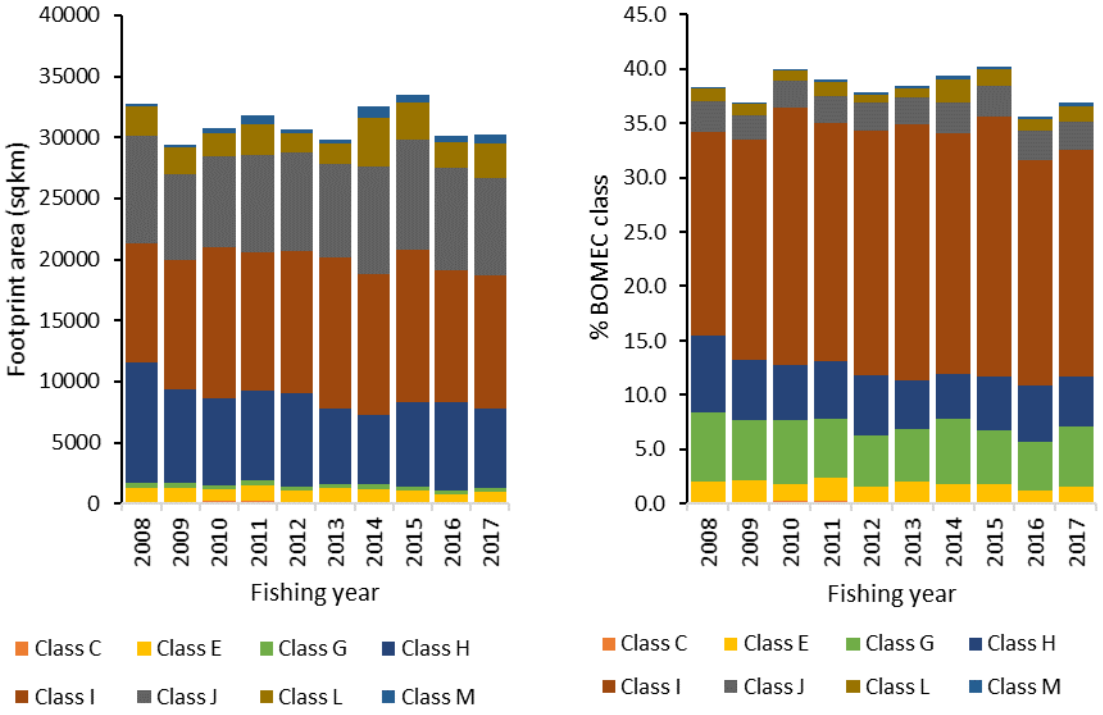


(a) Number of bottom-contacting tows, by target and fishing year.



(b) Footprint area (km^2) (left) and percentage of each 200-m depth zone area contacted by the footprint (right) (where the deepest extent is shown in the key, e.g., 200 m = 0–200 m). Data are given in Tables D.3 and D.4.

Figure D.1: Annual summaries of HAK/HOK/LIN/SWA/WWA input and output data for 2008–17.



c) Footprint area (km^2) in each BOMEC class (left), and percentage of each BOMEC class area contacted (right), for those BOMEC classes with a footprint of more than 100 km^2 per year. The full data summary is given in Table D.5. Note that the classes are stacked in alphabetical order.

Figure D.1: ***continued.***

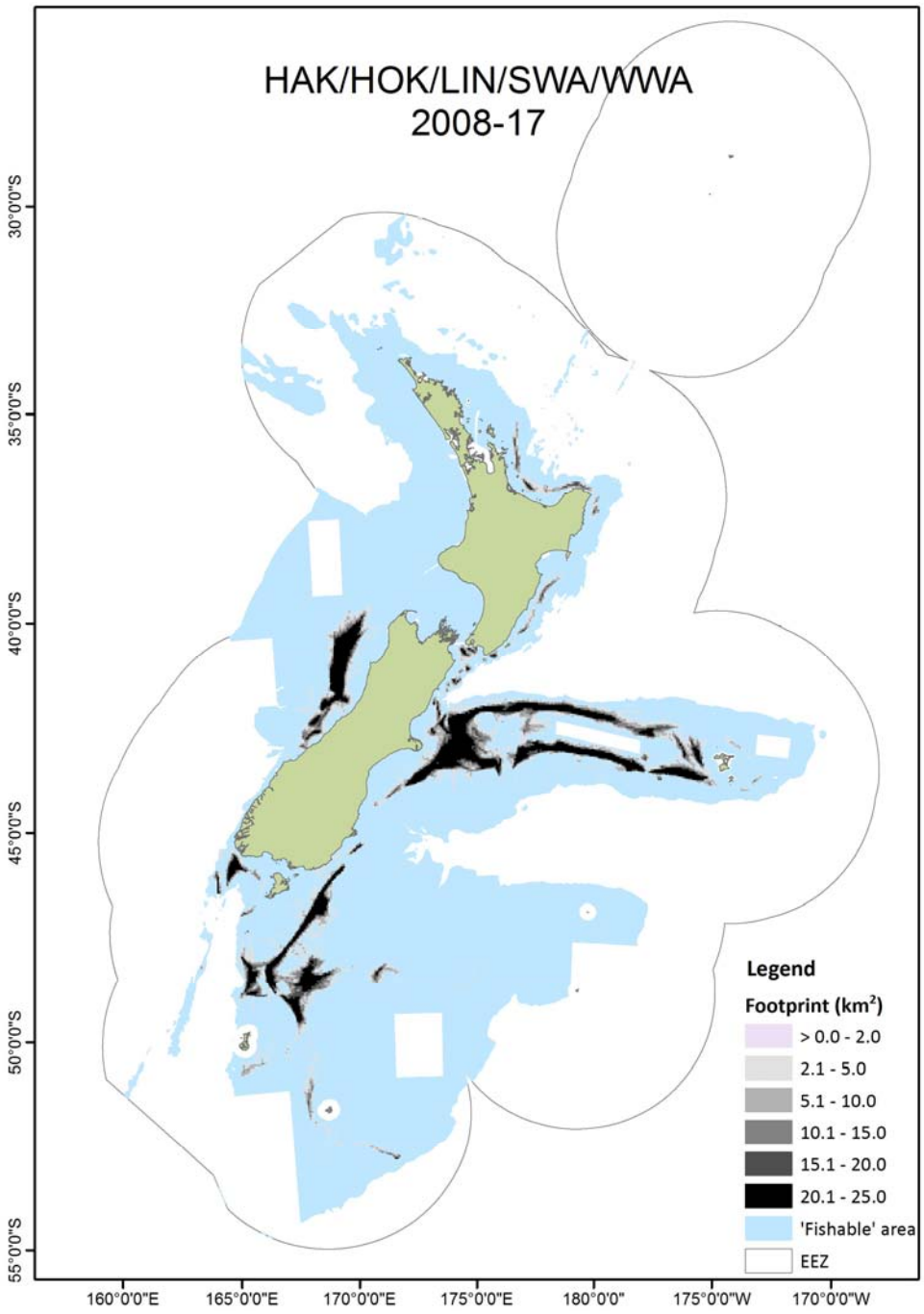


Figure D.2: Extent of the 'fishable' area (waters open to bottom trawling down to 1600 m) and the 2008–17 HAK/HOK/LIN/SWA/WWA trawl footprint. The footprint is represented by the total area of each 25-km^2 cell contacted by the 2008–17 footprint.

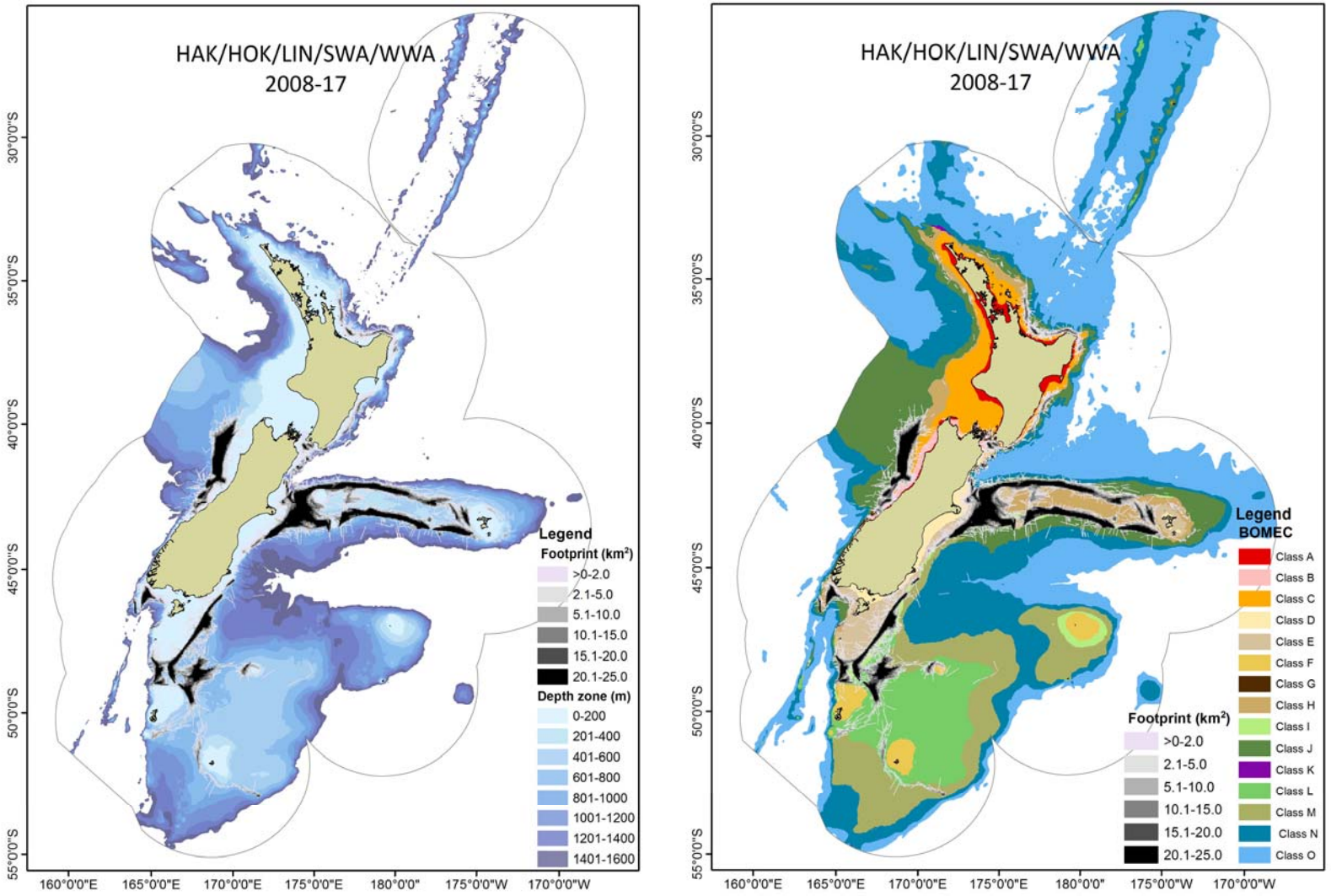


Figure D.3: Overlay of 2008–17 HAK/HOK/LIN/SWA/WWA trawl footprint on the 200-m depth zones (down to 1600 m) (left) and on the BOMEC (down to 3000 m)(right). The footprint is represented by the total area of each 25-km^2 cell contacted by the footprint. Figure B2 in Appendix B shows the distributions of the depth zones and the BOMEC classes.

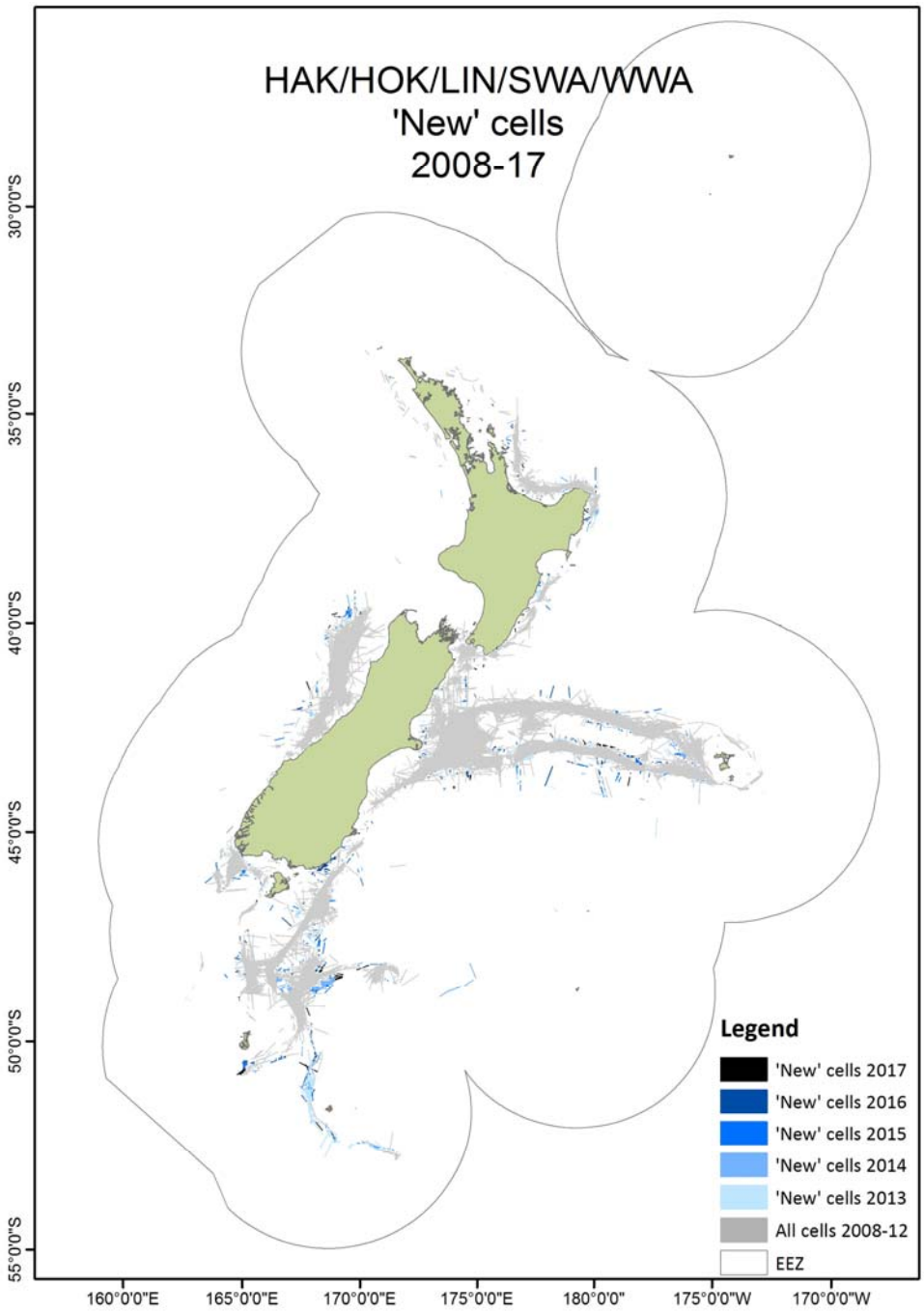


Figure D.4: The 2008–12 HAK/HOK/LIN/SWA/WWA trawl footprint and the location of 'new' cells contacted each year, relative to previous years for the 2008–17 time period. A comparison of this extent with the total deepwater Tier 1 and Tier 2 target fishstock footprints for 2008–17 and for 1990–2016, shown in Figure 19 in section 6, indicates that some of the 'new' cells shown above had trawl contact before the 2008 fishing year.

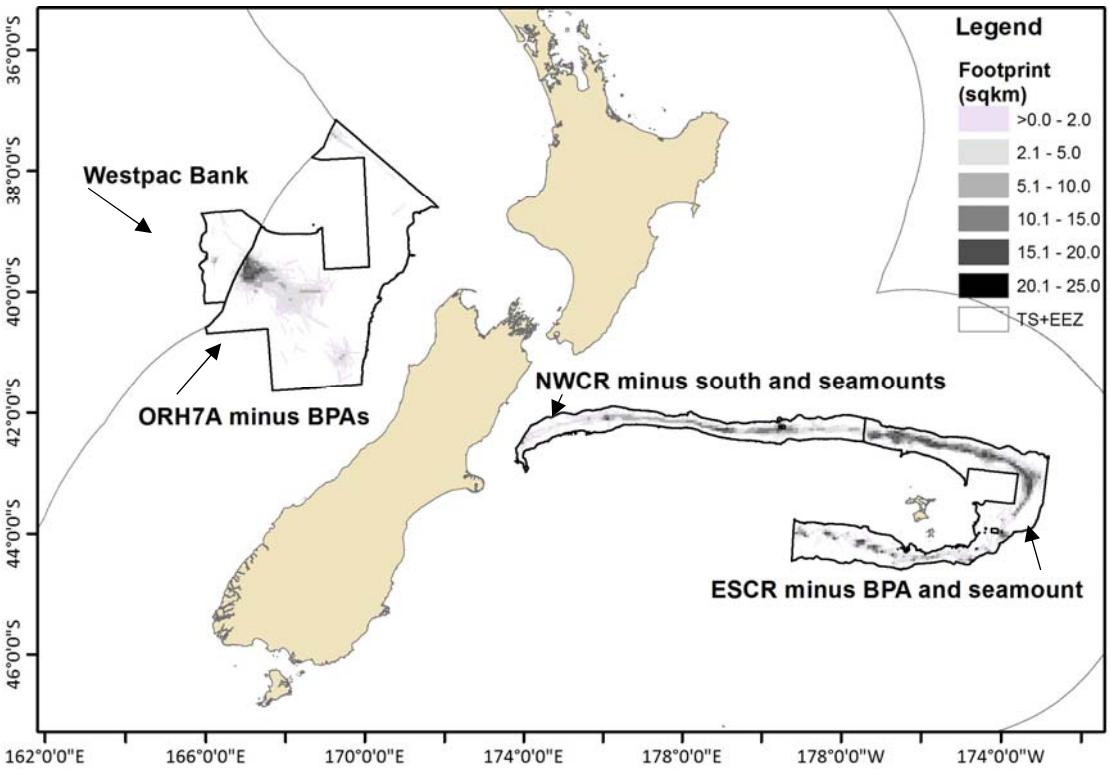


Figure D.5: The 2008–17 ORH/OEO trawl footprint in the analysis areas: Westpac Bank, ORH7A, NWCR, and ESCR, in 800–1600 m waters open to bottom trawling.

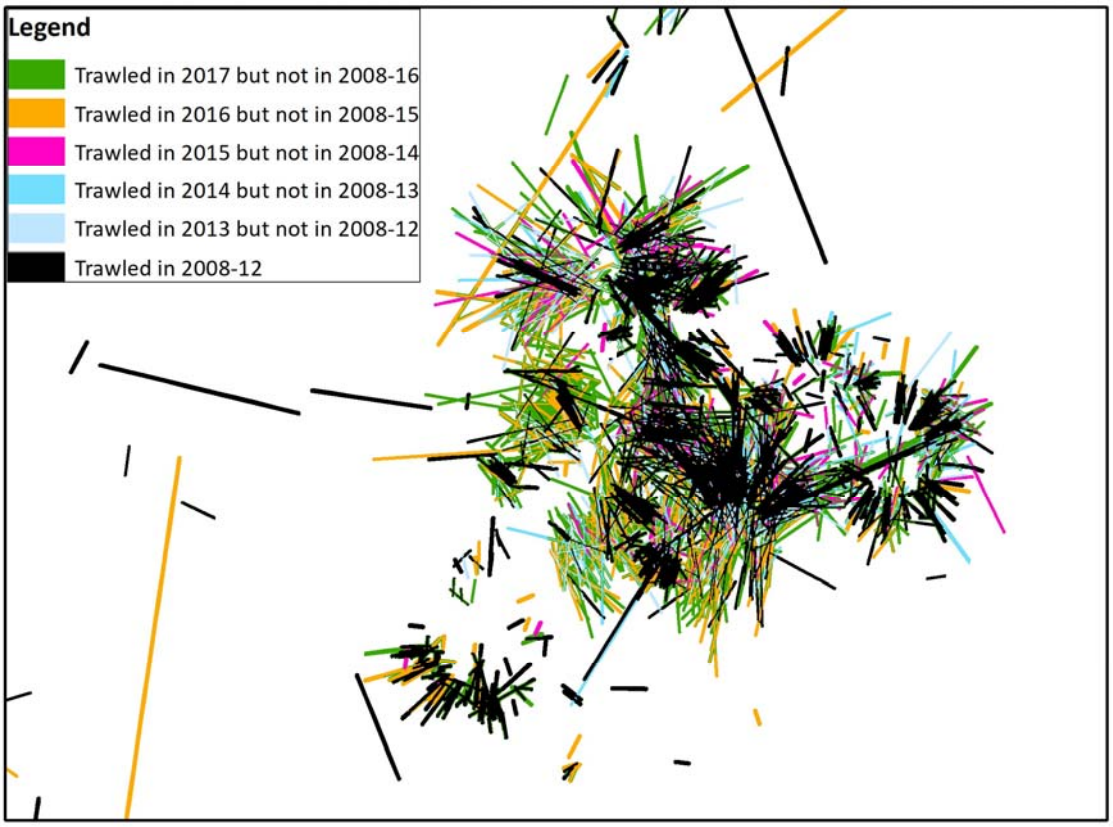


Figure D.6: Close-up of 'new' area contacted in part of ESCR, based on 2008–12 and subsequent years to fishing year 2017 (as explained in the legend). There is no overlap of the 'new' areas on the footprint of the previous years.