Orange Roughy and Oreo-dory Trawl Footprint Analysis of Slope Habitat and Summary Analysis of UTF Habitat (Part 1)

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EXECUTIVE SUMMARY

Trawl footprint analysis within the EEZ & Westpac Bank, the Bioregion, and three Unit of Assessment (UoA) areas for orange roughy (ORH) and oreo (OEO/BOE/SSO) fisheries has been carried out for application in an assessment against Marine Stewardship Council's (MSC) certification standards.

Trawl catch effort processing return (TCEPR) data have been analysed for the periods between 1989-90 to 2007-08 and 2008-09 to 2012-13, in order to examine the extent of both historical and current trawling that targeted orange roughy and oreo over slope habitat. In the EEZ (including the Westpac Bank) for the historical time period, the swept area is 6.2% of the orange roughy habitat area in the EEZ. For the current fishery (i.e. the most recent five years for which data are available - 2008-09 to 2012-13) it is 1.2%. Newly swept ORH habitat area in the EEZ over the 2008-09 to 2012-13 period amounts to 0.3% of the ORH habitat area, this is 5.1% of the swept area over all years.

Trawl information provided by fishing skippers operating the key orange roughy trawlers in the UoA areas have been mapped and assessed on each of the 72 fished Underwater Topographic Features (UTFs). For the three UoA areas the total UTF area trawled is estimated to be 184.8 km^2 which is 16.1% of the available UTF habitat area (i.e. 1,146 km^2). On average, for each UTF that has been fished, 51.4% of the area has been trawled. Using statistics derived from the three UoA areas it is estimated that 2.8% of the known UTF habitat in the EEZ has been trawled and 8.2% of the known UTF habitat within the Bioregion has been trawled.

1.0 INTRODUCTION

The Deepwater Group Ltd (DWG) asked GNS Science to undertake spatial analyses of bottom trawl tows for orange roughy (ORH) and oreo (OEO/BOE/SSO) fisheries for application in an assessment against Marine Stewardship Council's (MSC) certification standards. These analyses have been undertaken in two parts in response to MRAG Amercias request for information on the impacts on benthic habitats to be assessed against each of two habitat types: the relatvely flat 'slope' habitat and the relatively steep Underwater Topographical Features (UTF) habitat.

The first part of these analyses establishes the spatial location and extent of target trawling for orange roughy and oreo over slope habitat, based on analyses of trawl catch effort processing return (TCEPR) data obtained from the Ministry for Primary Industries' (MPI).

The second part of these analyses estimates, maps and analyses trawl tow locations on UTF habitat for the five-year period 2008-09 to 2012-13, using information on trawl towlines obtained from skippers and provided by DWG. It provides an assessment of the spatial extent of bottom trawling on all UTFs within the UoA areas, within New Zealand's Exclusive Economic Zone (EEZ) and within the relevant Bioregion. Specific UTF location data (i.e. bathymetry maps) and metrics are commercial in confidence and as such are provided separately in a confidential report (O'Brien, Black & Tilney 2015) for consideration by the MRAG MSC assessment team.

The three UoA areas are: ORH7A including Westpac Bank (ORH7A/WB), ORH3B Northwest Chatham Rise (ORH3B NWCR), and ORH3B East and South Chatham Rise (ORH3B ESCR). The ORH3B ESCR UoA area has been defined as east of 179° 30'W. Estimation of UTF trawl footprints have also been carried out on the UTFs within the EEZ and in the Bioregion separately, incorporating UTF data from Roux *et al*. (2015).

For the purposes of these analyses:

- The New Zealand EEZ includes the designated extension of ORH7A, known as the Westpac Bank and the two enclaves of international water within the EEZ boundaries: one on the Chatham Rise and the other on the Campbell Plateau.
- The Bioregion is defined as the lower bathyal New Zealand-Kermadec province (UNESCO, 2009).
- The bottom trawls that targeted orange roughy or oreo were analysed against the orange roughy habitat area, defined to be the area between the 800 and 1600 m depth contours.

1.1 SLOPE HABITAT

The TCEPR analyses were carried out for the current fishery, over the most recent five-year period for which data are available (i.e. fishing years 2008-09 to 2012-13) and for the historical fishery, over the twenty four-year period for which TCEPR data are available (i.e. fishing years 1989-90 to 2012-13). Maps were constructed for the five-year period data to show the spatial relationships between the orange roughy and oreo trawl footprints and the bioregion, the orange roughy habitat area and the areas closed to trawling. The areas closed to trawling include large marine reserves, Benthic Protection Areas (BPAs) and Seamount Closures.

1.2 UTF HABITAT

The UTF trawl footprint analysis was carried out on UTFs fished in the most recent five-year period (fishing years 2008-09 to 2012-13). For the purposes of ascertaining the impact of orange roughy and oreo targeted trawls within each UoA area, DWG requested the following UTFs be considered UTF habitat:

- *Hill: elevation between 100 – 499 m*
- *Knoll: elevation between 500 – 999 m*
- *Seamount: elevation of 1000 m or greater*

UTF scale spatial information on actual trawl towlines was collated by DWG into trawl "corridors" for each of 72 UTFs. The spatial extent of each trawl corridor was analysed in relation to the spatial extent of the estimated surface area for each UTF. UTF boundary areas were determined for UTFs fished within the five-year period, and boundary areas for the remaining UTFs were supplied by DWG, incorporating UTF data from Roux *et al.* (2015).

2.0 METHOD

2.1 TRAWL FOOTPRINT ANALYSIS ON SLOPE HABITAT

Bottom trawls (and mid-water trawls for which the ground rope depth equalled the water depth) which targeted either orange roughy or oreos were used for this analysis. Trawls in which these species were caught as bycatch were not considered due to limitations of the TCEPR database. This assumption is commonly made when undertaking this type of analysis (e.g. Black & Wood, 2014).

The TCEPR data sourced from MPI were edited and corrected using the methods reviewed by the Aquatic Environment Working Group (AEWG) in March 2012 (Black and Wood, 2012), and described in Black *et al.* (2013).

Four datasets were created, one for each time period for each target species. Trawl footprint statistics were calculated for each dataset and a corresponding map constructed. The statistics included: *Swept Area* (the footprint area of trawls targeting orange roughy or oreo-dory) and the *New Swept Area* (the area that was trawled for the first time in the recent five-year period 2008-09 to 2012-13, but not swept by trawls targeting oreos or orange roughy between 1989-90 and 2007-08).

The 800 m and 3500 m bathymetric contours, calculated from the Global Bathymetric Chart of the Oceans 30 arc-second grid (GEBCO, 2010), were used to construct a polygon of the Bioregion. The same process was used with 800 and 1600 m contours to construct the orange roughy habitat area.

The Bioregion extends outside of the EEZ. However, it should be noted that as trawl information is currently available only for the area inside the EEZ, the estimate of the area of slope habitat trawled in the Bioregion has the potential to be underestimated. Consequently, the percentage trawled in the EEZ portion of the Bioregion has been separately calculated. Furthermore, closed areas within the EEZ only, are considered in this report. It should be noted that other types of closures exist in the Bioregion outside of the EEZ.

Maps were constructed for each region showing the swept area over the last five years. The swept area for trawls targeting orange roughy is shown in blue and for trawls targeting oreo-dory in red. It should be noted that the dataset contains no trawls targeting oreos in the most recent five-year period in either ORH7A/WB or ORH3B NWCR.

2.2 TRAWL CORRIDOR ANALYSIS ON UTF HABITAT

2.2.1 Processing of single beam data

Single beam bathymetric data (raw and ungridded xyz points) collected within the three fishery regions were provided by DWG. These single beam bathymetric data were collected by fishing vessels as they transit and fish between and within each fishery area. Bathymetric data for each UTF lie along vessel track lines rather than providing complete coverage, therefore the spatial data coverage for each UTF varies depending on the number of passes made and the proportions of each UTF in which both trawlable ground and fish co-exist. The appropriate regions to encompass each UTF were defined and the single beam data within each defined UTF region extracted. Bathymetric data were groomed and filtered to remove

spurious data points. These data were then interpolated and gridded and an n-dimensional uniform filter applied to clean the data to the specified degree.

2.2.2 Defining a UTF boundary

The basal boundary of each UTF was defined for the purpose of ascertaining the areal extent and the area of contact on UTF habitat by trawl gear through targeting orange roughy or oreos. Determining the basal extent of each UTF is complex. For example, if the deepest continuous contour that encompasses a UTF is selected it will not necessarily be representative of the UTF area; potentially due to local or regional bathymetric trends and where two or more UTFs are part of a larger multiple UTF complex.

The following hierarchy was employed:

1. The UTF will start from the apex/shallowest point,
2. Extending outward from the apex, the deepest contour that characterises the basal shape of the UTF (e.g. encompassing at least 30 – 50% of the base) will be used to define the base, where this contour is present,
3. The line defining the base of the feature may also follow the characteristic shape of the UTF where it is shallower than the deepest contour (e.g. the UTF is on a regional bathymetric slope),
4. Where two or more UTF's are part of a larger bathymetric complex the boundary between the two UTF's will be defined by a line connecting the lowest points of the saddle separating the two features.
5. Smaller features (e.g. peaks and pinnacles) that are superimposed on the surface of the UTF and are congruent with the overall characteristic shape are incorporated into the UTF area,
6. Smaller features (e.g. peaks and pinnacles) surrounding the basal extent of a UTF that are not congruent to the characteristic shape of the UTF are excluded,
7. Finally, the polygon defining the UTF boundary is smoothed by fitting Bezier curves between the vertices.

2.2.3 Lateral conical surface area

UTFs are complex 3-dimensional features that geometrically may be inadequately described by their basal areal extent, which only takes into account their 2-dimensional (2-D) plan view area. A reliable measurement of the UTF surface area in 3-dimensional (3-D) space is for many of the UTFs beyond the capabilities of the single-beam data (where data coverage is poor and the requested level of cleaning leaves a large degree of surface irregularity). However, in 3-D the geometry of each UTF may be approximated to the shape of a right-circular cone (Figure 1). The radius (r) of an appropriate bounding circle generates an area equalling that of the convex hull (for each UTF) and the vertical height (h) between the UTF base and the summit (UTF elevation). The formula for calculating the lateral conical surface area (LCA) of a right-circular cone is:

$$LCA = \pi r s$$

Where the hypotenuse/slant length (*s*) is derived using:

$$s = \sqrt{r^2 + h^2}$$

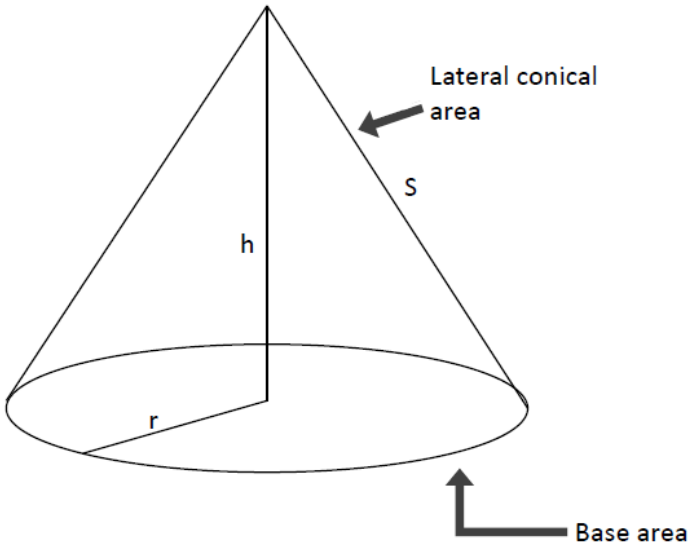

Figure 1 Diagram depicting the geometry of a right-circular cone relevant to calculating the lateral surface area.

For the purposes of this report the lateral conical surface area as estimated above is referred to as the surface area of the UTF.

2.2.4 Construction of trawl corridors

MPI's TCEPR database contains trawl start and end positions to the nearest one minute of latitude and longitude (i.e. a resolution of one nautical mile (NM)). These data relate to the vessel's position, not the net's position, and when bottom trawling at depths of 1,000 m the vessel's position will be offset from the actual location of the trawl net by approximately 0.7 NM. As most trawls on UTFs are shorter than one nautical mile in length and as many fished UTFs are smaller than one nautical mile in diameter, the TCEPR data start and end coordinates are often the same, or are not spatially well located on the UTF and these data cannot therefore be used to precisely map the trawl tows on each UTF. The TCEPR data can however be used to determine which UTFs have been fished during the periods of interest and these have been identified (Roux *et al*., 2015).

In order to gain information on the actual areas bottom trawled on individual UTFs, DWG conducted a series of interviews with fishing skippers and mates of the key trawlers operating in the three UoA areas. During the period 2008-09 to 2012-13, between 99% and 100% of the ORH catch in ORH3B was taken by the three major companies (Sanford Limited, Sealord Group Limited and Talley's Group Limited), involving four vessels, FVs *Amaltal Explorer* (Talley's), *Otakou*, and *Thomas Harrison* (Sealord) and *San Waitaki* (Sanford). In ORH7A & Westpac Bank, 75% of the catch was taken by Sealord using FV *Thomas Harrison*. Skippers/mates from these four vessels were interviewed; an initial meeting with eight skippers and vessel managers took place on 20 June 2014, followed by one-on-one meetings with individual skippers on 30 June – 1 July 2014 (Sanford & Sealord), 8 December 2014 (Talley's) and 10 December 2014 (Sanford & Sealord).

The skippers were each provided with 3-D images of each of the fished UTFs and asked to provide precise spatial details from their logs on the exact tow lines they each have used, along with tow start/stop depths, locations, any observations relating to coral presence and any areas that cannot be bottom trawled. Marked-up UTF images were returned by six of the key orange roughy skippers who have actively fished over the last five years. Note that their information is not specific to the most recent five-year period; rather, it is a reflection of their traditional trawling practices on these UTFs. The skippers were asked to use their plotter information where possible to ensure their tow lines were as spatially precise as is possible. The information from all skippers was then collated to determine the probable overall trawl corridors and to calculate the trawled area for each UTF.

The trawl data provided by skippers comprised trawl start depth (depth gear down), trawl stop depth (depth gear up) and trawl azimuth or azimuthal range.

For the purposes of this analysis, the width of a single trawl track/corridor was specified to be 150 m. This is the approximate door-to-door width of the trawl gear used when operating on flat or gently sloping ground, and is the width typically used in GIS analyses of trawl footprint based on TCEPR data (Black & Tilney, 2015). For much of the time when trawling down UTFs, however, the trawl doors are off the bottom and only the groundrope is in contact with the seabed, (i.e. a trawl track in the order of 20 – 30 m wide). When the doors do contact the seabed their spread is often highly variable (i.e. typically 90 – 150 m), due to the steepness and roughness of the terrain and the much slower speed over the ground as wire is paid out to keep the groundrope on the bottom. The 150 m width was applied in this study to compensate, in some measure, for the fact that the trawl net may not always follow strictly behind the vessel (e.g. due to the effects of current) and likely provides an over-estimate of the actual areas contacted by bottom trawling on each UTF.

Polygons, 150 m wide, were drawn from the centre of each UTF out to beyond the edge of the UTF in the specified azimuths or azimuthal range (e.g. 350° – 10°, 160°, 300°). Polygons were then clipped to the specified trawl start and stop depths and merged to create larger polygons where overlap existed. Due to the rough nature of the UTF bathymetry (and/or data) and trawl line geometry, the upper and lower (trawl start and stop) extent(s) of the polygons were smoothed to better replicate known trawl geometries. Trawl corridors were then manually assessed with respect to trawl capability (i.e. trawling occurs down slope only) and modified where necessary. Finally, trawl corridors were clipped to the UTF boundary area. An example is shown in Figure 2.

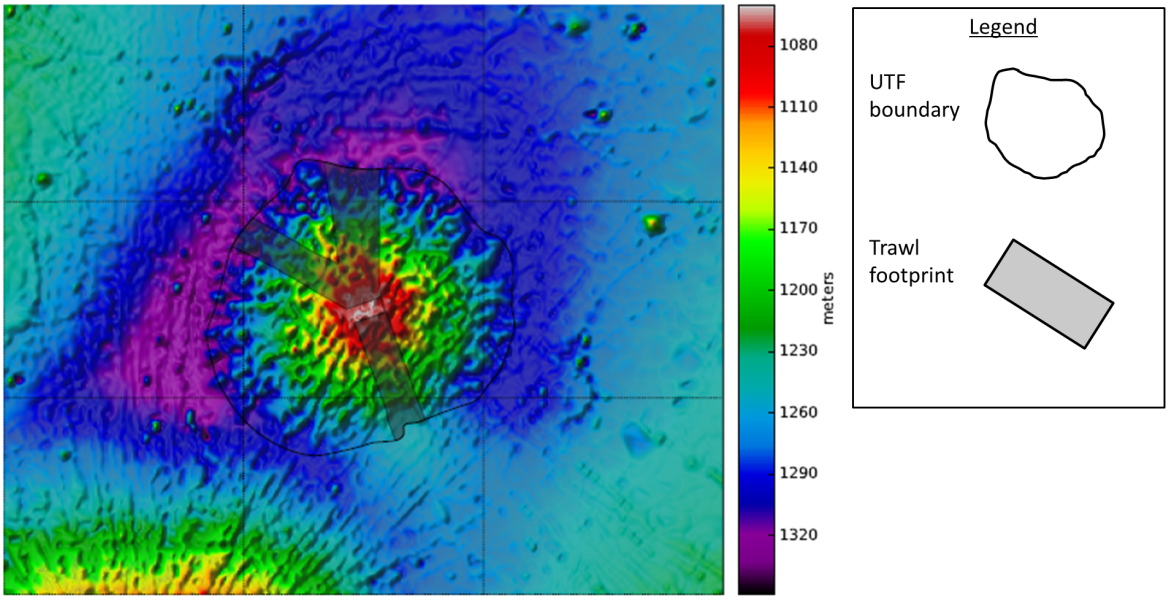

Figure 2 A typical UTF (Reg No. 1594 named "Briscoes", ORH3B ESCR) showing the UTF boundary and the trawl footprint.

For six UTFs in the ORH3B ESCR UoA area and two UTFs in the ORH3B NWCR UoA area no skipper information on tow corridors was available. For these eight UTFs, estimated trawled area was assumed to be equivalent to the trawled proportions determined for ESCR UoA (i.e. 53.0%) and NWCR UoA (i.e. 41.5%) areas respectively. Between one and six tows were undertaken on each of these UTFs during the five-year period (Roux *et al.*, 2015). The average number of tows per UTF in these two UoA areas was 37 and 16 respectively.

For each UTF the clipped plan-view trawled area (i.e. the surface area inside the boundary/conical area) was translated onto the conical surface and recalculated.

2.2.5 Relating UoA area UTF statistics to UTFs in the EEZ and Bioregion

The numbers of fished UTFs in the non-UoA EEZ and Bioregion were determined by Roux *et al*. (2015) and trawl footprints have been estimated for these using the statistics calculated for fished UTFs in the three UoA areas. However, the degree of trawling on a UTF within the three UoA areas does not appear to be systematic regarding the size or category of a UTF, and no correlation (of statistical significance) was observed between trawl footprint size and percentage trawled. Therefore, applying the spatial statistics determined from the analysed UoA areas to other fishery areas carries a larger degree of uncertainty. Several statistical methods were investigated to estimate an amount of trawling on fished UTFs within the EEZ and Bioregion. The method used in this report was to employ the mean percentage trawled (i.e. 51.4%) for all fished UTFs within the three UoA areas to estimate the total UTF trawled area in the non-UoA component of the EEZ and Bioregion.

3.0 RESULTS, CONCLUSIONS

3.1 ANALYSIS OF TRAWL FOOTPRINT ON SLOPE HABITAT

The swept area (i.e. trawl footprint) for trawls targeting orange roughy and oreos was calculated for each of the five regions and for the two time periods of interest (i.e. 1989-90 to 2012-13 and 2008-09 to 2012-13).

3.1.1 UoA areas

The proportion of the ORH habitat area that falls within closed areas (i.e. BPAs, seamount closures and large marine reserves) ranges between 0.3% (NWCR) and 15.1% (ORH7A/WB).

In the most recent five-year period the proportion of ORH habitat area swept ranges between 0.3% (ORH7A/WB) and 7.6% (ORH3B ESCR). Over the full time period this swept area ranges between 9.1% (ORH7A/WB) and 35.1% (ORH3B NWCR).

ORH7A/WB has the lowest percentage of newly swept seafloor during the most recent five-year period (2008-09 to 2012-13), at 0%, followed by ORH3B NWCR (0.9%) and ORH3B ESCR (2.1%), (Table 1.).

The spatial extent of the ORH and OEO/BOE/SSO targeted trawl footprint in the three UoA areas, in relation to the ORH slope habitat and closed areas, is illustrated in Figure 3, Figure 4 & Figure 5 below.

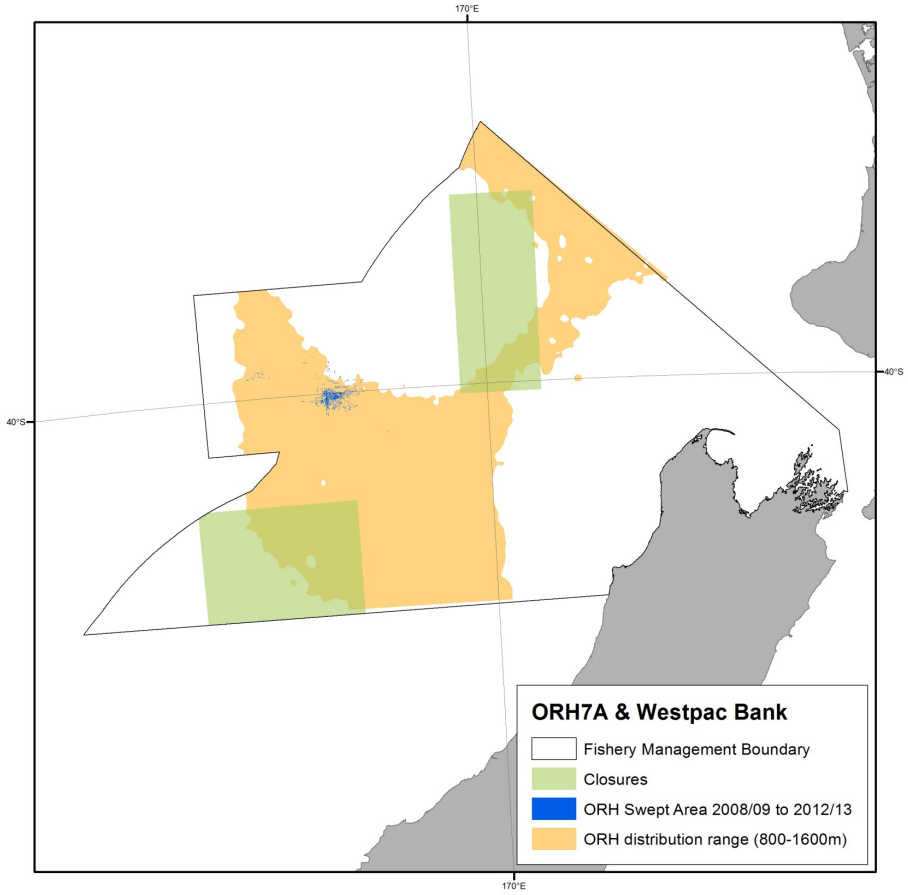

Figure 3 The extent of the ORH trawl footprint in relation to ORH slope habitat area and closed areas during the period 2008-09 to 2012-13 in the ORH7A/WB UoA area. (Note: no OEO/BOE/SSO trawling in this UoA area.)

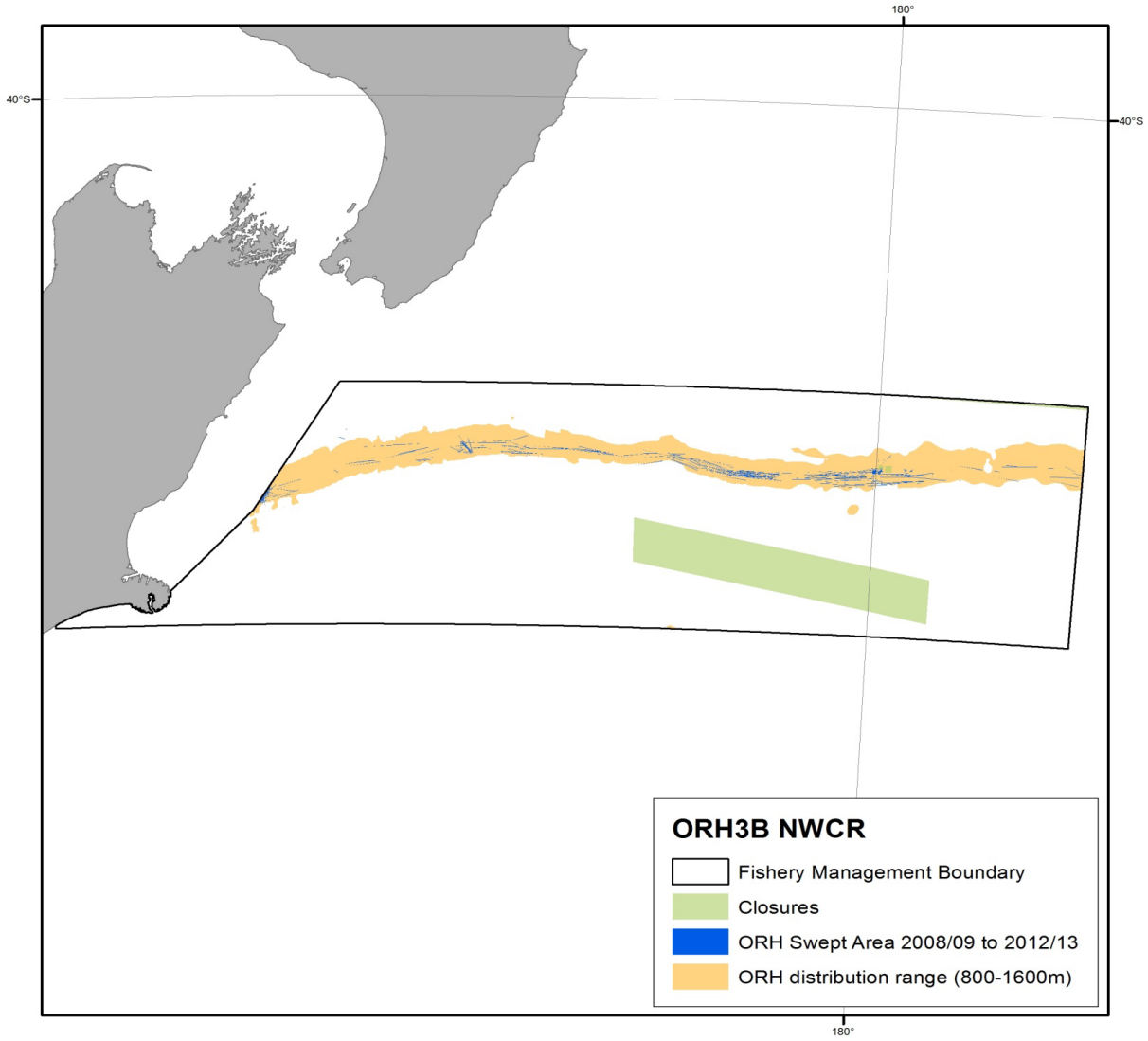

Figure 4 The extent of the ORH trawl footprint in relation to ORH slope habitat area and closed areas during the period 2008-09 to 2012-13 in the ORH3B NWCR UoA area. (Note: no OEO/BOE/SSO trawling in this UoA area.)

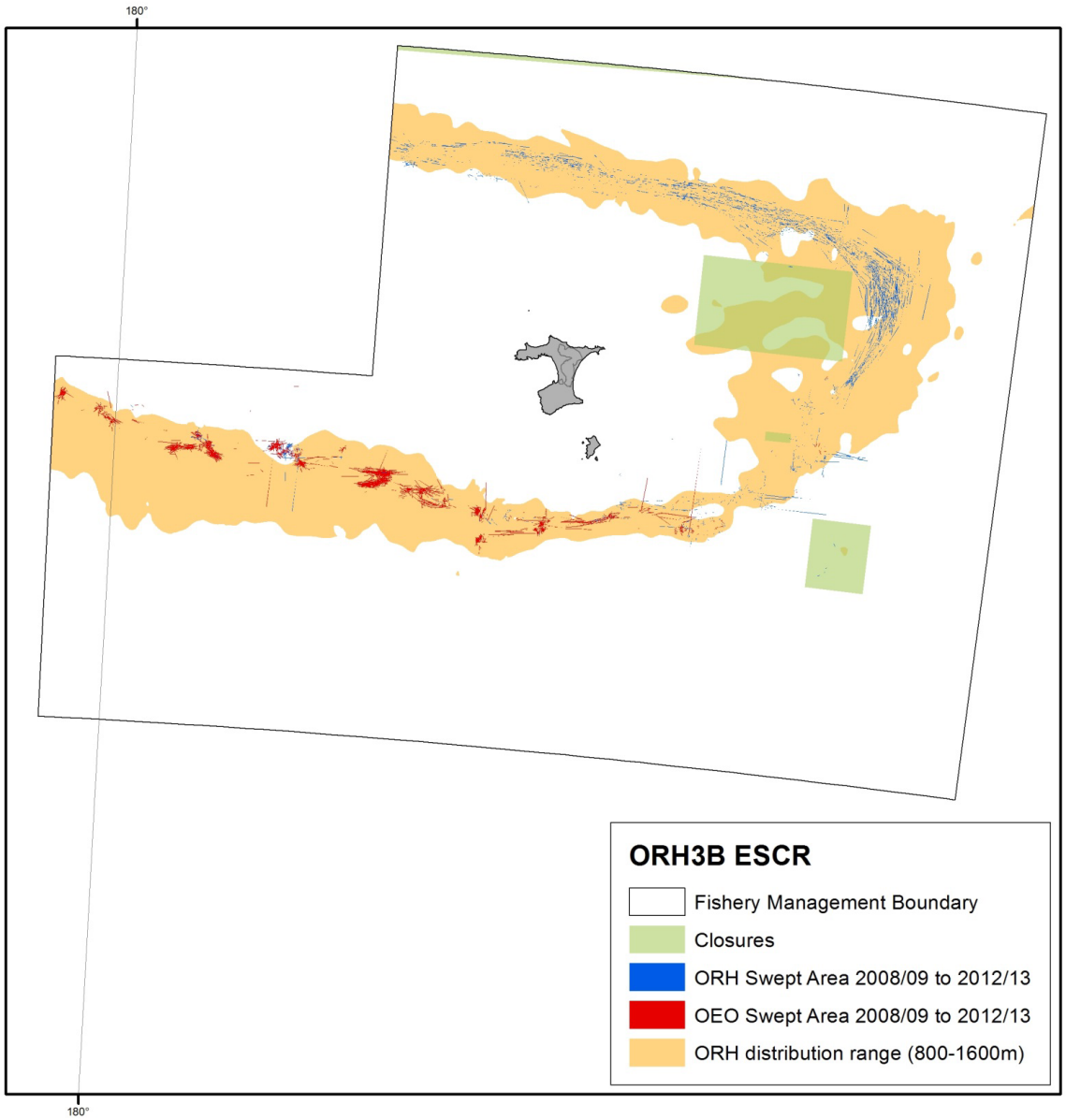

Figure 5 The extent of the ORH and OEO/BOE/SSO trawl footprint in relation to ORH slope habitat area and closed areas during the period 2008-09 to 2012-13 in the ORH3B ESCR UoA area.

3.1.2 New Zealand EEZ (including Westpac Bank)

The proportion of ORH habitat area that falls within closed areas is 19.1%.

The proportion of ORH habitat area swept by bottom trawls for orange roughy and oreos in the most recent five-year period is 1.2% and over the full time period is 6.2%.

Newly swept area over the most recent five-year period amounts to 0.3% of the ORH habitat area, this is 5.1% of the swept area over all years (Table 1.).

The extent of the ORH and OEO/BOE/SSO targeted trawl footprint in the EEZ & Westpac Bank, in relation to the ORH slope habitat, is illustrated in Figure 6 below.

3.1.3 Bioregion

The proportion of ORH habitat area that falls within closed areas is 6.6%.

The proportion of ORH habitat area swept in the EEZ component of the Bioregion over the most recent five-year period is 1.3%, and over the full time period is 7.1%. The proportion of ORH habitat area swept in the overall Bioregion is unknown as trawl data outside the EEZ area are currently unavailable to DWG.

Newly swept ORH habitat area in the EEZ component of the Bioregion over the most recent five-year period amounts to 0.4% of the ORH habitat area, this is 5.1% of the swept area over all years (Table 1).

The Bioregion and associated ORH habitat area are illustrated in Figure 7. Note that at this large scale the trawl footprint (i.e. as determined for the EEZ component of the Bioregion) is too small to be clearly evident.

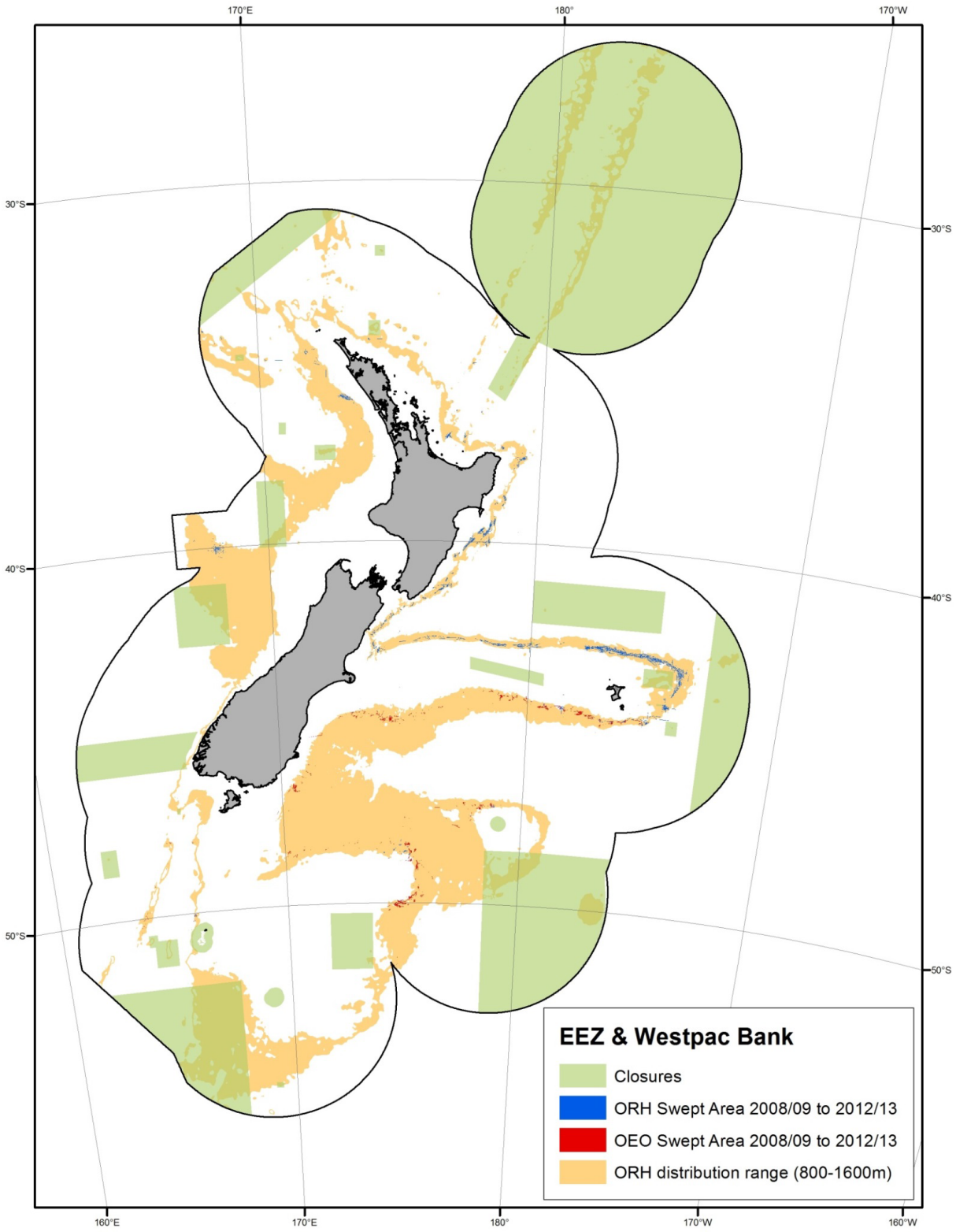

Figure 6 The extent of the ORH and OEO/BOE/SSO targeted trawl footprint during the period 2008-09 to 2012-13 in relation to the ORH habitat area and area closures.

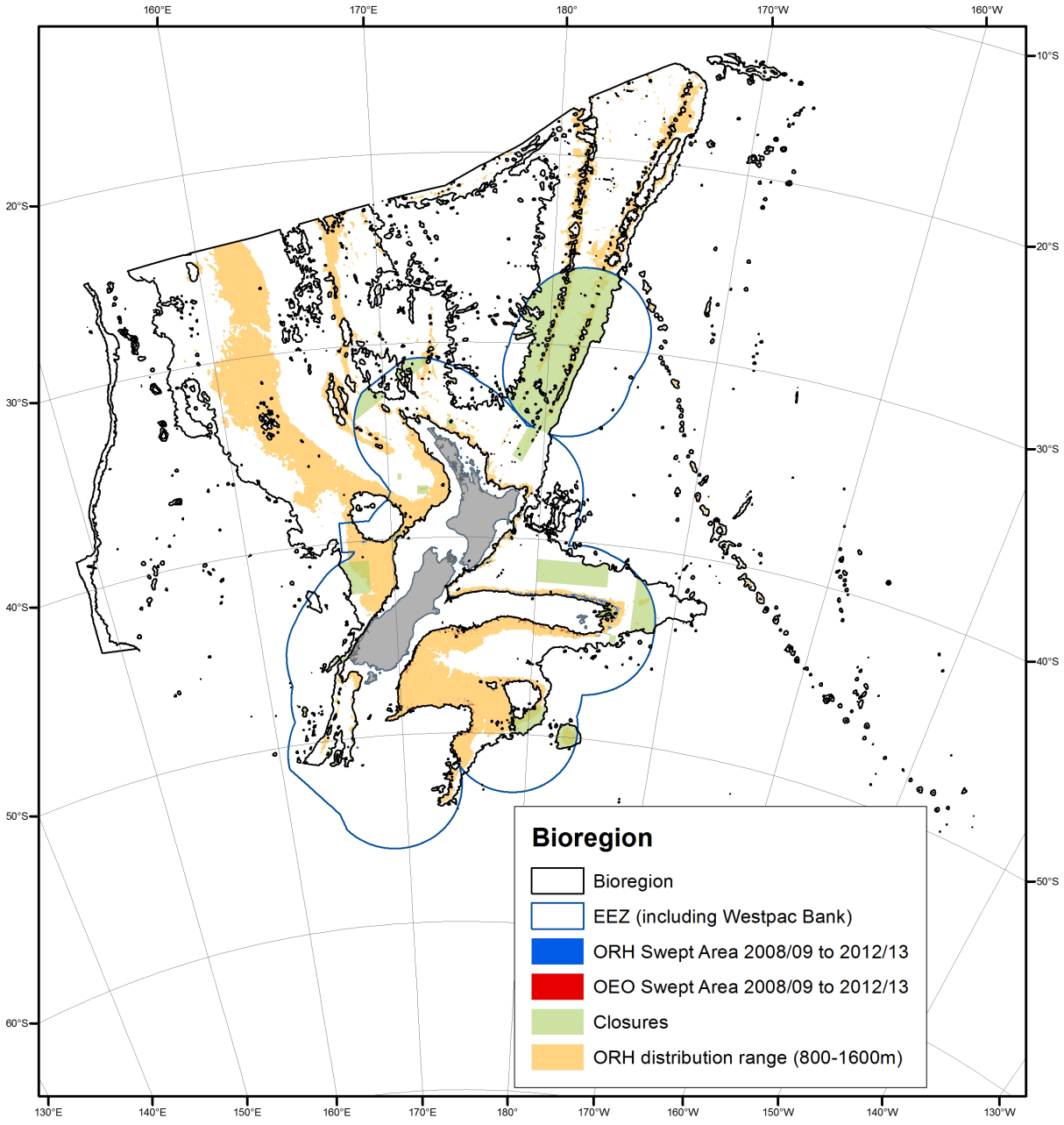

Figure 7 The extent of the ORH habitat area within the Bioregion (lower bathyal New Zealand-Kermadec province (UNESCO, 2009). No swept area data are currently available for the Bioregion outside the New Zealand EEZ.

3.1.4 Uncertainties

The uncertainties present in the TCEPR-based analysis of trawl footprint on slope habitat are discussed in Black & Wood (2014).

Table 1 ORH and OEO/BOE/SSO targeted trawl footprint analysis for slope habitat in the three UoA areas, the EEZ and the Bioregion for the most recent five-year period (2008-09 to 2012-13) and for all years for which TCEPR data are available (1989-90 to 2012-13). * In the EEZ component of the Bioregion only

	UoA ORH3B NWCR		UoA ORH3B ESCR		UoA ORH7A & WB		EEZ and Westpac Bank		Kermadec Bioregion	
	All Years	5 Years	All Years	5 Years	All Years	5 Years	All Years	5 Years	All Years	5 Years
Area (km^2)	135,222	135,222	213,381	213,381	212,825	212,825	4,141,488	4,141,488	4,750,049	4,750,049
Closed area (km^2)	9,046	9,046	7,402	7,402	36,819	36,819	1,219,558	1,219,558	525,886	525,886
Closed area (%)	6.7%	6.7%	3.5%	3.5%	17.3%	17.3%	29.4%	29.4%	11.1%	11.1%
Orange roughy habitat area (km^2)	16,929	16,929	45,391	45,391	80,640	80,640	759,477	759,477	1,378,594	1,378,594
Closed area within ORH habitat area (km^2)	45	45	3,051	3,051	12,146	12,146	145,041	145,041	90,689*	90,689*
Closed area (% of ORH habitat area)	0.3%	0.3%	6.7%	6.7%	15.1%	15.1%	19.1%	19.1%	6.6%	6.6%
Swept area (km^2 of ORH habitat area)	5,936	721	10,103	3,468	7,302	267	47,254	8,804	47,088*	8,783*
Swept area (% of ORH habitat area)	35.1%	4.3%	22.3%	7.6%	9.1%	0.3%	6.2%	1.2%	3.4%	0.6%
Swept area change (km^2 in habitat area)		-5,215		-6,635		-7,035		-38,450		-38,305
Swept area change (% of all years)		-87.9%		-65.7%		-96.3%		-81.4%		-81.3%
New swept area (km^2 of ORH habitat area)		148		950		22		2,414		2,404
New swept area (% of all years)		2.5%		9.4%		0.3%		5.1%		5.1%
New swept area (% of ORH habitat area)		0.9%		2.1%		0.0%		0.3%		0.2%
Orange roughy habitat area in EEZ Bioregion (km^2)									660,591	660,591
Swept area (% of ORH habitat area in EEZ Bioregion)									7.1%	1.3%
New swept area (% of ORH habitat area in EEZ Bioregion)										0.4%

3.2 TRAWL CORRIDOR ANALYSIS ON UTF HABITAT

3.2.1 UoA areas

Fifty-eight trawl footprints from ORH3B ESCR, 10 from ORH3B NWCR and 4 from ORH7A & Westpac Bank (totalling 72 trawl footprints) were processed, analysed and had their spatial extent calculated with regard to the UTF extent (O'Brien, Black & Tilney, 2015). A summary of the results presented below utilises the calculated surface area for each UTF and the translated (i.e. onto the conical area) trawl footprint.

For the ORH3B ESCR UoA area the estimated trawl coverage on UTFs ranged from 4.6% to 95.0%, with the mean estimated trawl coverage of 53.2%. The surface area of fished UTFs ranged from 0.6 km^2 to 26.6 km^2 with a mean of 5.5 km^2. Combining the surface areas of all the UTFs in the ORH3B ESCR UoA area (1,090 km^2), it is calculated that the trawl footprint has covered 15.6% of this area (170.5 km^2).

For the ORH3B NWCR UoA area the estimated trawl coverage on UTFs ranged from 16.0% to 72.1%, with the mean UTF trawl coverage of 41.5%. The surface area of fished UTFs ranged from 0.45 km^2 to 8 km^2 with a mean of 1.9 km^2. Combining the surface areas of all the UTFs in the ORH3B NWCR UoA area (43.7 km^2), it is calculated that the trawl footprint has covered 21.0% of this area (9.2 km^2).

For the ORH7A & Westpac Bank UoA area the estimated trawl coverage on UTFs ranged from 35.0% to 85.8%, with the mean coverage of 52.0%. The surface area of fished UTFs ranged from 2 km^2 to 4.3 km^2 with a mean of 2.7 km^2. Combining the surface areas of all the UTFs in the ORH7A & Westpac Bank UoA area (12.3 km^2) it is calculated that the trawl footprint covers 41.7% of this area (5.1 km^2).

Combining the three UoA areas (ORH3B ESCR, ORH3B NWCR and ORH7A & Westpac Bank) the total surface area of all fished UTFs sums to 350.4 km^2 and the total surface area of all known UTFs sums to 1,145.9 km^2. The total area trawled on UTFs is estimated to be 184.8 km^2 which equates to 16.1% of the total surface area of all known UTFs. For the three UoA areas combined, the mean surface area for all known UTFs is 10.0 km^2 and the mean trawled area is 1.6 km^2. Smaller UTFs generally have a greater percentage trawled than larger UTFs, thus skewing the average UTF percentage trawled to be larger than the mean trawled area divided by the mean surface area. Therefore, the average UTF percentage trawled within the three UoA areas is 32.2%.

New Zealand EEZ

For the entire New Zealand EEZ area, the estimated total surface area of fished UTFs is 5,335 km^2 and the estimated total surface area of known UTFs is 97,214 km^2 (derived from data in Roux et al. 2015). Applying the mean fished UTF trawled area proportion determined for fished UTFs in the three UoAs, (i.e. 51.4%), to all UTFs in the EEZ provides an estimated trawl footprint of 2,741.7 km^2, which equates to 2.8% of the known UTF habitat.

Bioregion

For the overall Bioregion (i.e. both within and beyond the EEZ), the total surface area of fished UTFs comprises 43,735.8 km^2 and the total UTF surface area for all known UTFs comprises 272,741.4 km^2. Applying the methodology used for the EEZ, the total UTF trawl footprint in the Bioregion is estimated to be 22,476.1 km^2, which equates to 8.2% of the known UTF habitat.

Summary statistics for the UTF analyses are presented in Table 2. The complete UTF trawl corridor analysis is presented in O'Brien & Black (2015).

Table 2 Estimated UTF surface area (estimated from the 'conical' area), UTF fished area and the proportion of UTF habitat fished in the three UoA areas, the EEZ and the Bioregion for the five-year period 2008-09 to 2012-13. UTF surface areas for non-UoA designated areas and identities of fished UTFs were derived from Roux *et al*. (2015). UTF area fished in the UoA areas was estimated using skippers' tow corridor information. UTF area fished in non-UoA areas was estimated using the mean area fished for fished UTFs in the three UoA areas.

Designated Area	No. UTFs	Total Conical Area (km^2)	Total Trawled Area (km^2)	Total Trawled Area (%)	Total Untrawled Area (%)
Fished UTFs					
UoA ORH3B ESCR	58	320.5	170.5	53.2%	46.8%
UoA ORH3B NWCR	10	19.3	9.2	47.6%	52.4%
UoA ORH7A & Westpac Bank	4	10.6	5.1	48.3%	51.7%
UoAs - Total	72	350.4	184.8	52.7%	47.3%
UoAs - Mean		4.9	2.6	51.4%	48.6%
EEZ	144	5,335.0	2,741.68	51.4%	48.6%
Bioregion	151	43,736.0	22,476.08	51.4%	48.6%
All UTFs					
UoA ORH3B ESCR	85	1,090.0	170.5	15.6%	84.4%
UoA ORH3B NWCR	26	43.7	9.2	21.0%	79.0%
UoA ORH7A & Westpac Bank	5	12.3	5.1	41.7%	58.3%
UoAs - Total	116	1,145.9	184.8	16.1%	83.9%
UoAs - Mean		10.0	1.6	32.2%	67.8%
EEZ	451	97,214.2	2,741.68	2.8%	97.2%
Bioregion	573	272,741.4	22,476.08	8.2%	91.8%

3.2.2 Uncertainties

The method used to calculate the UTF basal extent may influence the calculated percentage trawled. Every effort was made to maintain consistency when defining the basal area. However, where there are areas of limited single beam coverage (particularly over the deeper portions of a UTF) there will be greater uncertainty. In order to minimise the uncertainty several interpolation methods were employed and compared in the gridding of single beam bathymetric data. The overall estimate in the uncertainty of the boundary area is ± 5 – 10%. Using a right-circular cone to approximate the UTF geometry (lateral conical surface area) potentially underestimates the actual surface area (as any local roughness in slope is approximated to a smooth shape and further because a bounding circle is taken as the base of the cone). If the data quality and coverage were to increase, future studies may be able to accurately calculate this.

The supplied trawl start and trawl stop depths (depth gear down and depth gear up) were often a range (e.g. depth gear down: 670 m – 680 m and depth gear up: 870 m – 880 m). The greatest range was always used (e.g. 670 m – 880 m in the above example). With respect to the accuracy

of the supplied trawl data (including trawl width of 150 m), the calculated extent trawled should be considered as a maximum.

UTF boundaries that have been incorporated in the EEZ and Bioregion statistics of Table 1 (i.e. UTFs within EEZ and Bioregion but outside the three UoA areas), have been determined using a slightly different methodology; for specific details regarding these UTF data refer to Roux *et al*. (2015).

4.0 REFERENCES

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