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

New Zealand Aquatic Environment and Biodiversity Report No. 110.

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

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

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

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

INTRODUCTION

Overview

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

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

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

Objectives

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

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

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

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

METHODS

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

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

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

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

Trawl Data

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

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

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

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

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

Table 2: Percentage of catch reported on TCEPR forms.

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

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

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

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

Map Projection Name: Albers Conical Equal Area
- Standard Parallel 1: -30.000000
- Standard Parallel 2: -50.000000
- Longitude of Central Meridian: 175.000000
- Latitude of Projection Origin: -40.000000
- False Easting: 0.000000
- False Northing: 0.000000

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

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

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

Trawl Data correction and editing

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

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

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

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

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

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

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

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

Pre-GIS editing of TCEPR input records

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

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

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

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

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

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

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

GIS editing of TCEPR input records

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

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

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

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

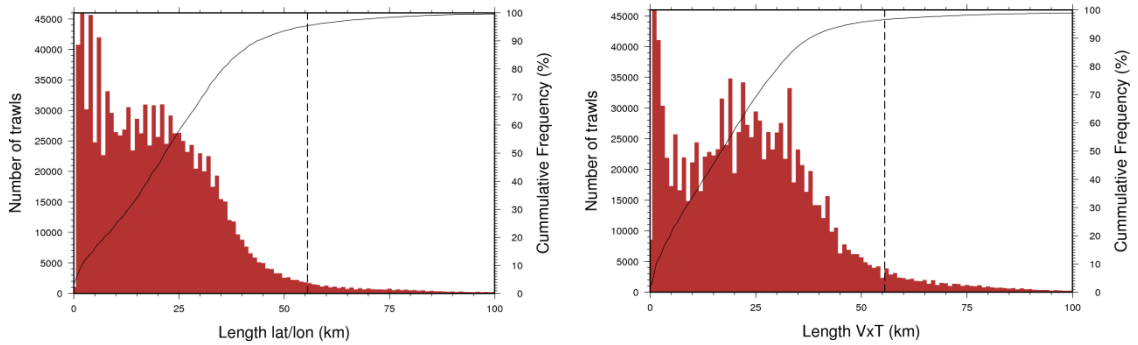

Figure 2: Distributions of tow lengths in the TCEPR database, calculated from (left) start and end latitude and longitude positions (lat/lon) and (right) speed (V) times tow duration (T). The solid line in each graph shows the cumulative percentage of tows less than the length along the X axis. The vertical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

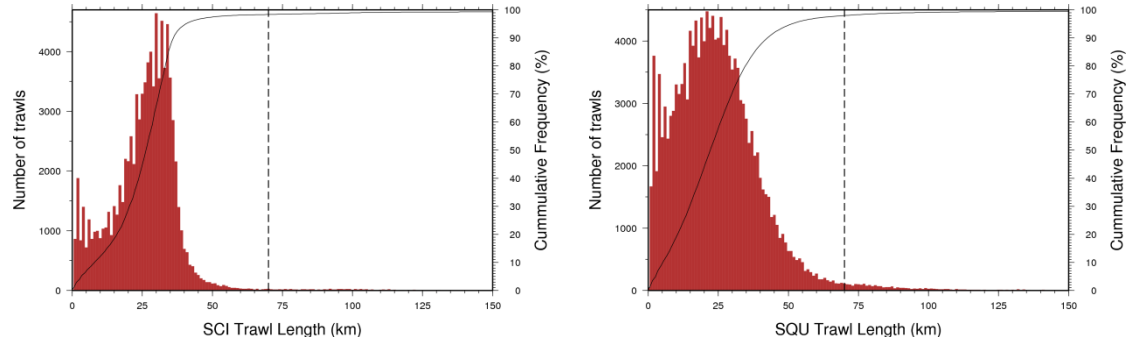

Figure 3: Distribution of tow lengths in the TCEPR database for (left) scampi, and (right) squid. The solid line in each graph shows the cumulative percentage of tows less than the length along the X axis. The vertical dashed line highlights tows 37.8 M (70 km) long.

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

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

East-West error correction

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

More than 1000 possible east-west longitude errors were identified and more than 400 of these were corrected before being included into the dataset (Table 4). This process was time consuming as each suspect tow had to be manually inspected, and therefore only tows for which fixing an east-west longitude error would result in its inclusion in calculations were inspected. For example, if after correcting a possible east-west error a tow would be flagged

by one of the edit criteria, such as crossing land or longer than standard fishing practice, then it wasn't changed at this stage.

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

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

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

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

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

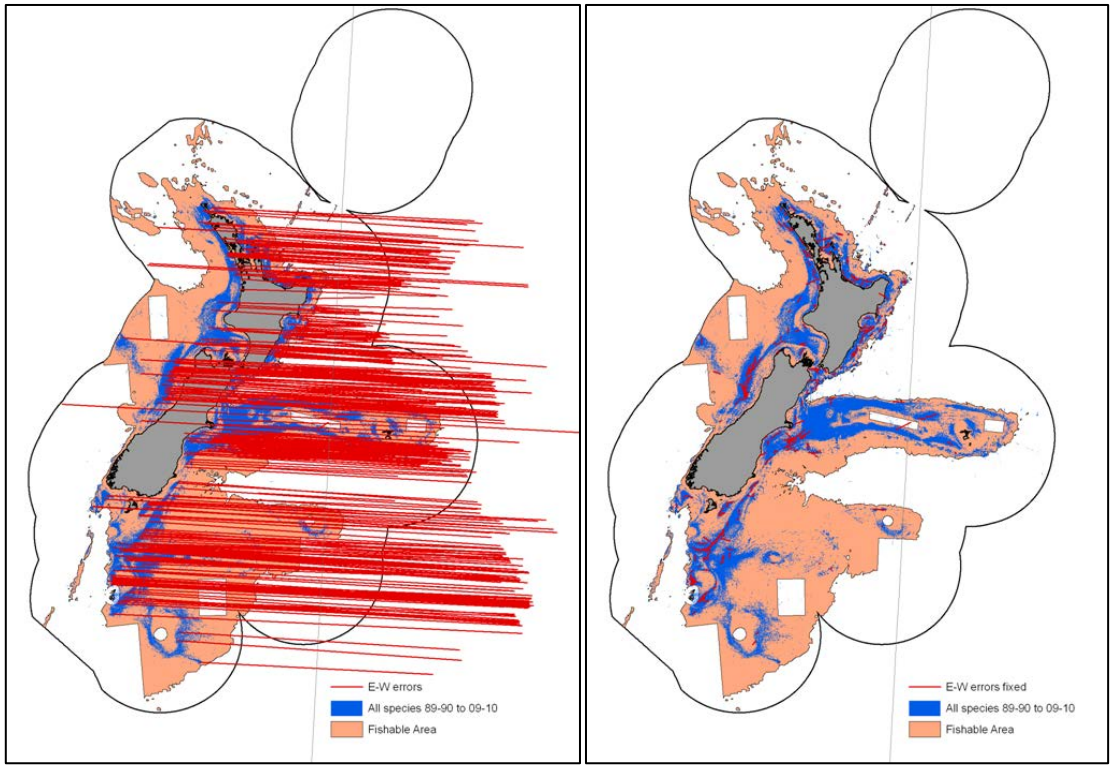

Figure 4: Maps displaying the 419 tows (red lines) corrected for an east-west longitude error. Before correction (left) and after correction (right). The majority of the corrected tows lie inside the estimated swept area, and all lie inside the Fishable Area.

Tow position offsets

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

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

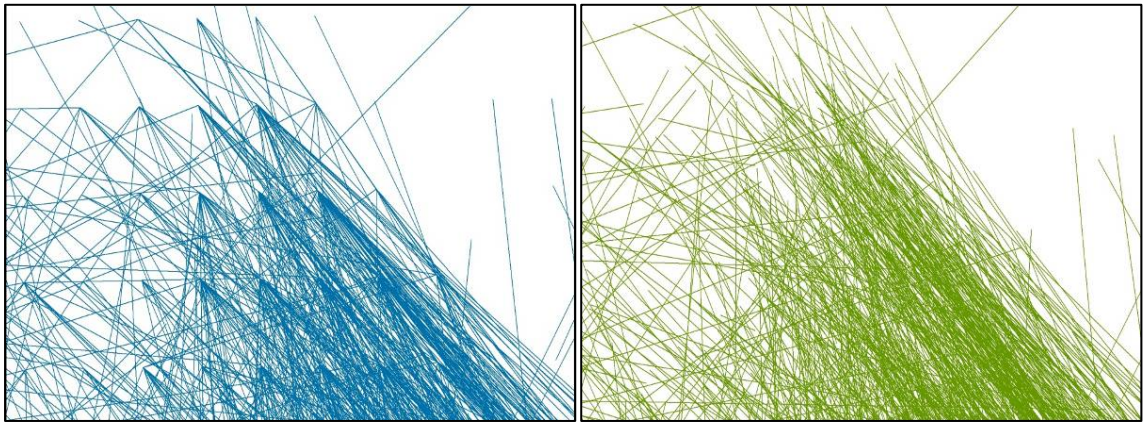

Figure 5: Example of the effect of applying a random offset to start and end tow positions. Original reported tow tracks (left) and tow tracks after the addition of -0.5 to +0.5 random offsets (right).

Calculation of total swept area

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

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

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