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Tini a Tangaroa

Forecasting quantity of displaced fishing Part 2: CatchMapper - Mapping EEZ catch and effort

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There are many situations where fisheries analysts are asked to estimate the amount of fishing that has occurred in certain places in the past. Often this is used as an indication of what is likely to occur in the future or what the effect on fishing might be of some change in other activities at that place. One such case was the impetus for the first report in this series which developed a tool for the Challenger scallop fishery using data from both commercial fisheries returns and annual biomass surveys (Osborne et al. 2017).

Most often all fisheries in an area of interest need to be investigated to inform a decision or proposal. The fisheries need to be characterised and quantified and seasonality may also be of interest. CatchMapper is a tool developed to provide quick answers to these questions. It also allows a visual representation of the country's important fishing grounds and fishing patterns to aid management.

CatchMapper is an information service that provides heat maps and spatial estimates of catch and effort anywhere in the EEZ for all types of commercial fishing except eel fishing. Estimates of fishing are usually given as annual averages but can also be provided as monthly or annual time series. CatchMapper includes all commercially fished species and all fishing methods. CatchMapper only estimates average values and does not provide statistical confidence intervals. The quality of the underlying data varies greatly for different types of fishing. Qualitative ranking of the quality of the underlying data and therefore the confidence in the estimate is provided for guidance.

Every fishing event in the EEZ since Oct 2007 has been reproduced as a polygon defining the location of the fishing event using the data recorded by fishers and other information available to MPIs fisheries analysts. Those polygons are stored in a spatial database and are a permanent record of the best information available at the time to locate the space occupied by that fishing event.

To map and visualise fishing intensity patterns, each polygon is pixelated to a 1 km^2 resolution and pixels are given values of catch per unit area, or effort per unit area, or catch per unit effort (CPUE) reported for the fishing event. The resulting images can be grouped, summed and averaged in a multitude of ways.

The reported landings of all species from every fishing trip are apportioned across the fishing events of each trip and then apportioned evenly across the area representing the fishing event to give values of fishing intensity in kg per km^2. These values can be compared to the estimated catch for each fishing event and the totals for Quota Management Areas (QMAs) can be compared to the reported quota landings. These comparisons together with the spatial resolution of reported fishing locations are used to rank the relative confidence we have in spatial estimates of fishing.

For estimating spatial catches within an area of interest (AOI), the entire set of fishing event polygons is clipped to the AOI and the amount of fishing effort for each fishing event falling within the AOI calculated. This is converted to the amount of landings of all species for each fishing event falling within the AOI and summed by species.

CatchMapper assumes that the fishing event polygon represents all the space occupied by the fishing event and that catch and effort are spread evenly across the polygon. This is a necessary simplification that provides a consistent, repeatable and transparent approach to approximating the magnitude of fishing activity and food production within any AOI. The larger the AOI the better the estimation model. CatchMapper is used by MPI to estimate spatial catches in very small areas relative to the precision of the fishing polygons such as marine farms and marine protected areas and this needs to be interpreted cautiously.

Rules around the minimum aggregation of data for both display and reporting are routinely applied to spatial catch estimates and to maps of fishing intensity to protect privacy and commercial sensitivity. These rules and their application to CatchMapper will be explained.

This report describes the amount and type of fishing represented in CatchMapper for the period October 2007 to September 2016, its comprehensiveness is verified and any omissions explained and documented. It also explains in detail the procedures for building polygons for fishing events, apportioning trip landings to each event polygon, and the range of ways the values of each polygon can be classified, pooled, and cut into spatial catch estimates and maps.

1.1 Objectives of report

1. Demonstrate how CatchMapper represents fishing events and landings and document any exclusions.
2. Explain the accuracy and uncertainty in CatchMapper spatial estimates of commercial fishing catch and effort and interpretation of quality indices.
3. Explain the mapping of fishing intensity, options for mapped values and flexibility in selection of fishing events for mapping.
4. Demonstrate the uses of CatchMapper for quantifying the potential effects of spatial allocations on commercial fishing.

2. Summary of CatchMapper Objects

CatchMapper is a term given to a collection of data tables, geodatabase files, a library of raster images, and both desktop and web-based applications that produce maps and reports in answer to queries about how much and what types of fishing (except eel fishing) occur anywhere within New Zealand's Exclusive Economic Zone and the Territorial Sea.

Geodatabase Files

The spatial data are held in ArcGIS geodatabase formats and comprise:

1. Fishing Polygons
2. Fishable Area Polygons
3. Polygons that define all fishstock boundaries

Data tables

The data are held in R-data files (R is a language and environment for statistical computing, R Core Team (2016)with MPI's Spatial Analysis team. The data files include:

1. A table of attributes for fishing polygons.
2. Annual matrices of estimated catch and landings per unit effort by fishing event and species.
3. Annual matrices of estimated catch and landings per unit effort by fishing polygon and species (some fishing polygons are individual events and some are monthly aggregated events).
4. Table of scalers that adjust predicted landings to match actual reported landings by fishstock and fishing year.
5. A look up table that links fishing polygons to fishstocks.
6. Summary tables of total fishstock landings, TACCs and total annual landings by vessel and permit holder, by fishing year.

7. An archive of intermediate data tables used to produce those above.

2.1 Raster Image Library

The raster library comprises a file system of .tif format rasters of the value of total estimated catch per hectare of all species combined (cpha) for the following groupings:

Individual fishing events

Annual images with cpha summed over gear type and target species

Annual images with cpha summed over cluster, fishing method and observer presence

Annual images of effort per ha summed for bottom contact trawl fishing events grouped by target species

Annual images of cpha summed by gear type and month

Annual averages of cpha averaged by each of the above groups

Confidentialised summaries

Annual averages of cpha by individual fisher if required

If required, the rasters can be revalued to depict effort per hectare or catch per unit effort or catch or landings of individual species per hectare (rather than total catch of all species).

Applications

A model in ArcGIS desktop is used by the MPI GIS team to clip the CatchMapper fishing polygons to any user defined area polygon and calculate the amount of fishing within the area by sending the clip result to an R-script that calls the required look up tables. A variety of reports are produced describing the amount and type of fishing occurring within the area of interest. A web-based application is also in development for deployment within MPI. This can now be accessed directly by fisheries analysts to view heat maps and will eventually allow polygons to be drawn or uploaded to get estimates of the spatial catch within.

The nature of fishing data

The standard fishing year runs from 1 October to 30 September, all reference to years in this document means October fishing years e.g. 0708 means from 1/10/07 to 30/09/08. In the examples given in this report there were 9 years of fishing records available in CatchMapper from October 2007 to September 2016.

Fishing records used here include records about the fishing trip, defined as the time from leaving port to returning to port, and records about each fishing event within a fishing trip. A fishing event is defined in different ways depending on the fishing method and the reporting form used to supply data to MPI. Table 1 gives the number of fishing events included in CatchMapper at the time of writing this report, by fishing returns form type and fishing gear type and year.

Fishing return forms from which data is used for CatchMapper include:

- Catch Effort Landing Return (CELR),
- Netting Catch Effort Landing Return (NCELR),
- Paua Catch Effort Landing Return (PCELR),
- Lining Trip Catch Effort Return (LTCER),
- Lining Catch Effort Return (LCER),

- Squid Jigging Catch Effort Return (SJCER),
- Tuna Longlining Catch Effort Return (TLCER),
- Trawl Catch Effort Return (TCER), and
- Trawl Catch Effort Processing Return (TCEPR).

Data on estimated catch and effort for each fishing event, and landings for each trip are included in a single form for the first three form types listed above. The other forms include just estimated catch and effort by fishing event and a separate trip landings form is also filed (the Catch Landing Return (CLR)).

Fishing trips are often only one day duration but they can be up to 100 days (Figure 1). The number of fishing events per fishing trip ranges from 1 to over 300 but most trawling and lining trips have fewer than 150 fishing events and most other types of fishing fewer than 25 (Figure 2).

A trip is defined by the start and end dates provided by the fisher for a particular vessel. Date errors on a form can result in some events being incorrectly grouped together as the same trip or the link between trip catch and effort and trip landings being lost.

At the lowest resolution a fishing event might be defined as all fishing undertaken within a single day and a single statistical area using a single method. This is the standard for methods including hand gathering, diving, most potting, dredging, some seining and fishing from many small vessels under 6 m in length (CELR, PCELR forms). Higher resolution definitions of fishing events, introduced into reporting forms in stages up to the 2007–08 fishing year, include a single trawl tow (TCER and TCEPR forms), a single line set (LTCER, LCER and TLCER forms), a single seine shot (CELR forms), and the total length of nets set within a radius of 2 nautical miles of the first set in the event (NCELR form).

Table 1: Number of fishing events in CatchMapper by form type, gear type and year.

Form type	Gear type	0708	0809	0910	1011	1112	1213	1314	1415	1516
CELR	DANISH	2 285	2 179	2 305	2 027	2 318	2 178	2 654	3 434	3 552
	DREDGE	2 043	2 726	1 830	1 702	2 022	2 026	2 022	1 577	1 737
	HAND	2 599	2 662	2 948	2 734	2 421	2 033	2 127	2 198	2 202
	LINE1	1 813	1 891	1 726	1 519	1 164	1 537	1 615	1 050	968
	LINE2	5 824	5 759	4 625	6 043	6 686	6 621	5 844	5 421	5 421
	NET	16 390	16 987	18 033	18 420	17 190	18 795	18 025	15 363	13 805
	POT	30 681	28 659	30 252	29 393	27 889	28 444	27 562	28 586	29 980
	SEINE	1 339	948	1 130	1 535	1 298	1 289	1 355	1 307	1 227
	TRAWL	477	622	167	60	63	63	75	38	87
LCER	LINE1	5 080	4 222	4 458	4 596	3 022	1 797	2 576	2 061	2 890
LTCER	LINE1	12 189	11 811	13 045	15 142	14 023	13 211	13 040	12 813	11 718
	LINE2	0	0	0	0	0	0	0	14	2
NCELR	LINE2	0	0	0	5	0	0	0	0	0
	NET	8 551	7 955	8 328	8 484	8 156	8 225	7 596	7 459	6 927
	POT	6	0	0	0	0	0	0	0	0
PCELR	HAND	5371	4 896	5 036	4 778	5 058	4 645	4 598	4 553	4 727
SJCER	JIG	221	247	247	246	208	225	104	147	106
TCER	LINE2	0	0	0	2	0	0	0	0	0
	TRAWL	46 146	46 863	53 366	48 663	48 351	50 367	49 143	43 891	43 646
TCEPR	SEINE	0	0	0	0	0	0	0	0	2
	TRAWL	42 166	38 974	39 106	37 287	35 860	33 226	35 699	34 742	34 081
TLCER	LINE1	1 942	2 631	2 835	2 899	2 782	2 641	2 298	2 230	2 701

Every fishing event record includes information about the location of fishing to a degree of spatial resolution dependent on how the event is defined and reported. The nature of a fishing event is critical to how that event is mapped and will be covered in more detail later.

Each fishing event record has information about the fishing effort used and one or more records of the estimated catch of the main species caught in each event. In the present CatchMapper data set spanning 9 years there are an average of 4.0 estimated catch records per fishing event.

In addition to fishing events, trip records include a landing event. Each landing event includes records of the measured weight of each species landed in the trip (more accurate than estimated weights for each event within the trip). The number of species landed per trip can range from 1 to over 50.

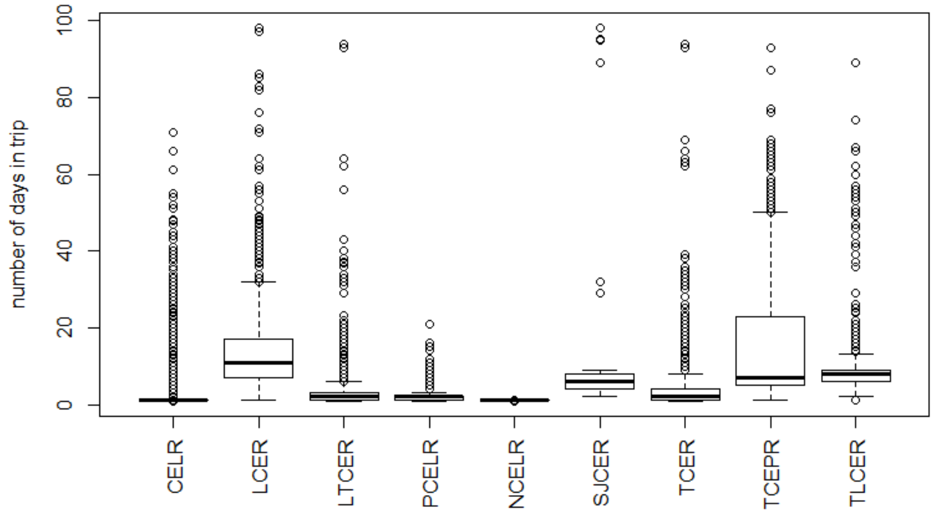


Figure1: Distribution of trip length values by form type.

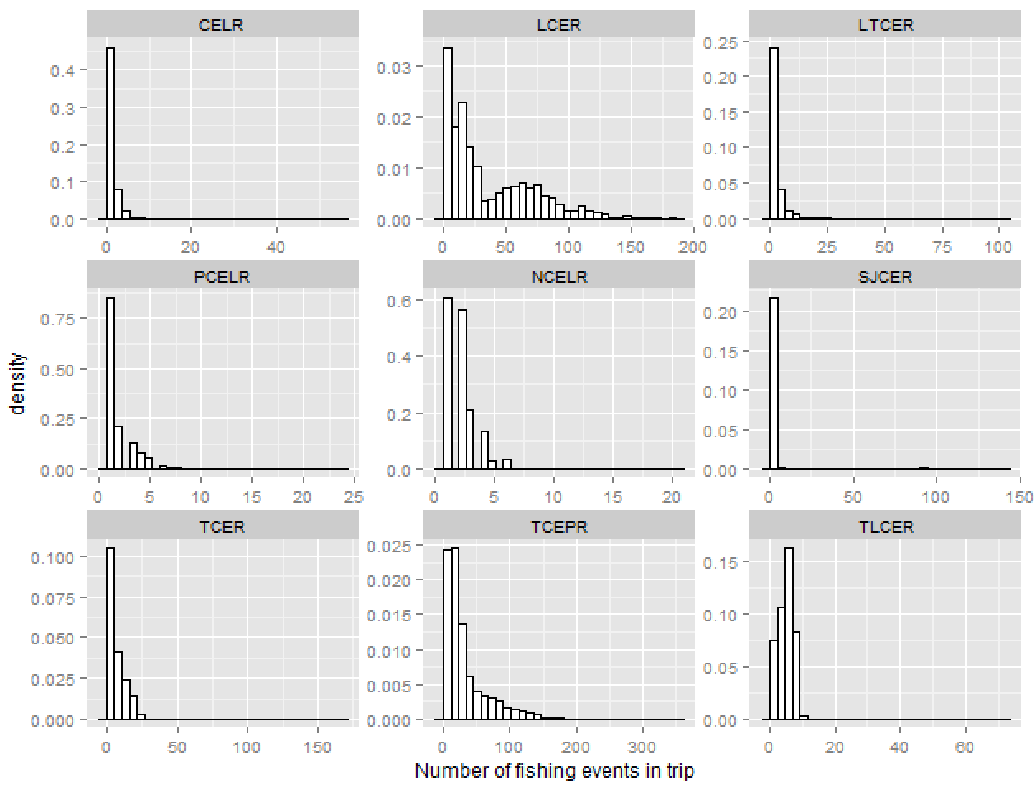


Figure 2: Frequency of values of number of fishing events per trip by form type.

So the amount of at least some species caught at the location of each fishing event can be quantified from reported catch estimates. Catch weights of other species at the location of each fishing event can be approximated by allotting an appropriate share of trip landings to each event in the trip.

The following section describes the steps for preparing and processing the stored fishing data required to map the location and quantity of fishing of all fishing events.

3. Data preparation.

Originally CatchMapper was created with 5 years of fishing records and since then has been updated at least annually. The annual updating follows mostly the same procedures as the original building of the CatchMapper database as described here with some recent improvements.

Each year, after February, all fishing events that occurred during the previous October fishing year are retrieved from the MPI Numeric Data Warehouse (NDW) or the current equivalent repository of fisheries data, including all events for the trips that straddle the start and end of the fishing year. Each annual data set is eventually trimmed to include only events wholly within the fishing year but, for the purpose of apportioning trip landings to trip events, the annual data sets start with all trip records for every trip with an event in the year. The data warehouse is used rather than the original Warehou database as many of the orphan records in Warehou (missing links to related records in the database) have been fixed on transferring the data to the warehouse. A comparison of data extracts from both sources is described in Appendix 1.

The specific variables required by CatchMapper include fishing month and year, fishing location as either coordinates or statistical area, a single summary measure of fishing effort depending on the fishing method, and the estimated total catch and catch of main species, for every fishing event. CatchMapper also requires identification of the fishing events that belong to each fishing trip and the landing weights of every species landed in the trip and how and where they were landed (landing destination codes and landing points). The list of attribute fields used for each fishing trip are given in Appendix 2 together with a summary of their values in the database and the limits chosen for defining valid ranges of each field for each type of fishing.

CatchMapper contains all EEZ fishing events that can be retrieved from the data source minus a small number that are missing some key attributes that can't be amended (see Appendix 3). Where possible, events missing key attributes or containing obvious errors, are retained in the data set and the information substituted from other sources or imputed from medians of groups of similar records.

Preparation of the data for building fishing polygons and calculating a share of trip landings for every fishing event follows the steps given next. The number and percentage of records groomed or removed from the dataset at each preparation step for each of the nine years of data included in CatchMapper so far are given in Appendix 3, Table A3.1. The paragraph reference in Table A3.1 refers to the following numbered sections.

3.1 Data Tables

We start with three main data tables. One table has a single row for each fishing event and contains all the effort data and a summary of trip and vessel data. The second table has all the species estimated catch records for every fishing event (multiple rows per fishing event). The third has all the species landing data for the trip. The fishing event effort table is the one that new data columns are added to during the data preparation phase.

3.2 Fix broken links to landings table

In the data extract we received there were 22 fishing events without valid trip keys (TripId=0). Of these 20 were from CELR forms and the links with landing records were re-established using the form number as a trip key. There were also 13 trips (21 fishing events) where the number of days between trip start date and trip end date fell outside the range 0–150 days which could mean the fishing events and landing events linked to the same trips may not have been from the same trip, or the trip start or end dates were incorrect. These trips were inspected and the landings and catch and effort records seemed reasonably matched but there were errors in the trip start and end dates in the landings table. Therefore the landings and catch effort records were kept linked and the dates in the landings table ignored.

3.3 Fishing year derived where date is missing.

Fishing year is derived from the event start date field. When start date is missing the fishing year is manually obtained by checking the other events in the trip. Missing fishing years are set to the same year as the rest of the trip or to the nearest event in the event sequence for those trips that bridge two fishing years.

3.4 Some Fishing Types not included

CatchMapper includes all EEZ and Territorial Sea fishing but not high seas or freshwater eel fishing. Fishing trips that operated entirely outside the EEZ (0.5% of the total) and those that report on the eel fishing forms (2.1% of the total) are removed from the dataset. All fishing events for trips where at least one event was reported inside the EEZ and not on an eel form were retained for this data analysis.

3.5 Species Codes standardised

Some species codes are amalgamated so that their use is consistent. For example some fishers report the 10 species of flatfish using the relevant species code and others use the generic flatfish code. Therefore all flatfish species codes are amalgamated to the generic code. Additionally, obvious typographical errors are corrected. Species codes that are automatically corrected are given in Table 2. Other cases are identified when fishing events are being classified and mapped based on their catch composition or target species. For example longlining fishing targeting SWA in the Hauraki Gulf is assumed to be fishing for SNA and these corrections are made where they cause obvious misclassifications. Baird et al. (2015) assume SNA codes in trawl fishing events in southern waters in trips that also target SWA are probably SWA. Many of these anomalies may not have been picked up yet in CatchMapper. Corrections are made as they are found and should be reported to MPIs CatchMapper administrator.

3.6 Missing estimated catch fields.

The procedure for calculating a share of trip landings for every fishing event uses all the species estimated catch records and the total estimated catch values for each event. Therefore any anomalies in these records are groomed as follows.

Sometimes estimated catch weights are missing. Where there is only one estimated catch record for the event, the missing catch is substituted with the total estimated catch.

Sometimes the total catch weight is missing and is substituted by summing all the species estimated catches for the event.

Sometimes species codes are missing but estimated catch weights are present. Where there is only one event in the trip the landings record is used to replace the missing species code with the main species landed and the landings weight for that species. If Target Species is also missing it is derived from the main species landed. Ones that can't be fixed are left in the database and the Species is coded as "missing".

Where total catch weight is reported as zero and species codes and catch weights don't exist, the event is classified as "NoCatch" and the effort is retained in the dataset. In some of these cases more than one zero estimated catch record exists per species for each event. The duplicated estimated catch records are removed from the dataset.

Paua fishers include an extra line of effort with zero estimated catch which appears to be an anomaly during transfer of data into the warehouse. These are removed as they create duplicate records in the procedures that follow.

Table 2: The automatic changes of species codes in the dataset.

Species Code used	Species Codes changed
FLA	BFL, BRI, ESO, FLO, GFL, LSO, SFL, SOL, TUR, YBF
OEO	BOE, SOR, SSO, WOE
JMA	JMD, JMM, JMN
PAU	PAA, PAI
BYX	BYS, BYD
HPB	HAP, BAS
BCO	COD where fishing method is HL, RLP or CP
RCO	COD where fishing method is BT
SCC	SSC (taken by diving and landing SCC)

3.7 Missing statistical areas

Statistical areas are provided by skippers and derived in the database from fishing coordinates. Where these disagree (0.8% of events) the value supplied by the skipper is used as these are thought less likely to contain errors. A new field is added to the database for the chosen version of statistical area. Missing statistical areas are a problem as CatchMapper is all about mapping fishing events to locations. Sometimes the missing statistical areas can be inferred from other information about recent fishing. Where fishing coordinates place the event on land the statistical area will not be generated and an obvious coordinate transcription error can sometimes be identified. In cases where the statistical area cannot be determined the event is removed from the dataset as it cannot be used in CatchMapper (0.01% of total number of records).

3.8 Missing Fishing Method Codes

These can generally be corrected by looking at the rest of the trip or the vessel history. Also those events that use the generic potting code, POT, were changed to CP for cod potting and RLP for rock lobster potting and FP for 16 others. This helps when finding similar groups of fishing (by cluster and fishing method code) for imputing missing values.

3.9 Combine units of catch

Catches are generally reported in greenweight but for some species in some fisheries, landings are reported in meatweight or fish counts. Estimated catch and landings for scallops are reported in meatweight and the southland dredge oyster is reported in oyster numbers. Also some tuna, game fish and sharks are reported as fish counts. These species specific units are converted in CatchMapper and combined into a single column. All SCA weights in CatchMapper are converted to Greenweight using a conversion factor of 8 (exceptions discussed below). Similarly, all weights for species code OYU in CatchMapper are converted to Greenweight using a conversion factor of 0.102 (1/9.8). Tuna and Gamefish catch are estimated at the time of fishing as counts of individual fish but total catch weight and landings are all recorded in greenweight so no conversions are required.

Total estimated catch weight of all species combined per fishing event is one of the main variables used in mapping fishing events so that all fisheries can be mapped with common units and maps compared and combined. We examined the reporting of SCA and OYU catches to decide when and how to convert reported catch and landings into greenweight and whether we could adjust the estimated total catch values per fishing event in these fisheries.

We firstly compared reported estimates of total catch per event with the sum of the estimated catches per species in the event. These two values may be different when not all species are estimated. In the case of these two fisheries the sum of estimated species catch weights are close to the reported total catch weight (Figure 3). This means that SCA and OYU estimated catch weights can be converted to greenweight and added to any other species estimated catches in the same event to replace to total estimated catch weight which as reported might be a mix of greenweight species and the target species measured in other units.

Secondly, we did a check to be sure that all estimated catches of SCA or OYU were likely to have been reported in the same units. We compared trip landings values, which are generally taken from the licensed fish receivers and are likely to be in the correct units, with estimated catch values summed over all events in the trip. For OYU there was a good match between these. However, for both northern and southern SCA fisheries, there was a mix of units for reported estimated catches as detected in Figure 4. Therefore estimated catches were only converted to greenweight, and total estimated catch per event values only replaced, in SCA fishing events where the ratio of total trip catches to total trip landings were less than 2.5 as shown in Figure 4.

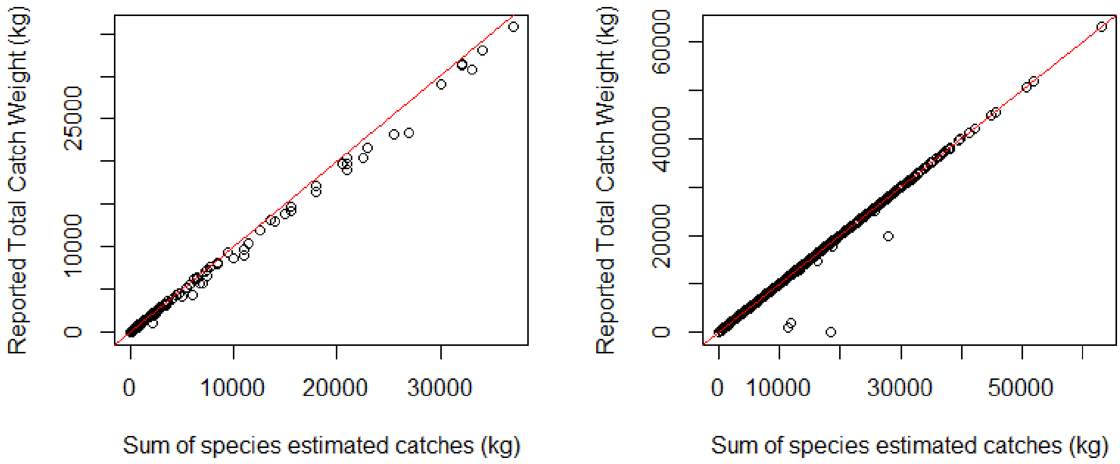


Figure 3: A comparison of total estimated catch of all species combined as reported with the sum of individual species catch estimates in each fishing event targeting scallops (SCA,left) and dredge oysters in the Foveaux Strait fishery (OYU, right). Differences can legitimately occur when not all species caught are individually estimated.

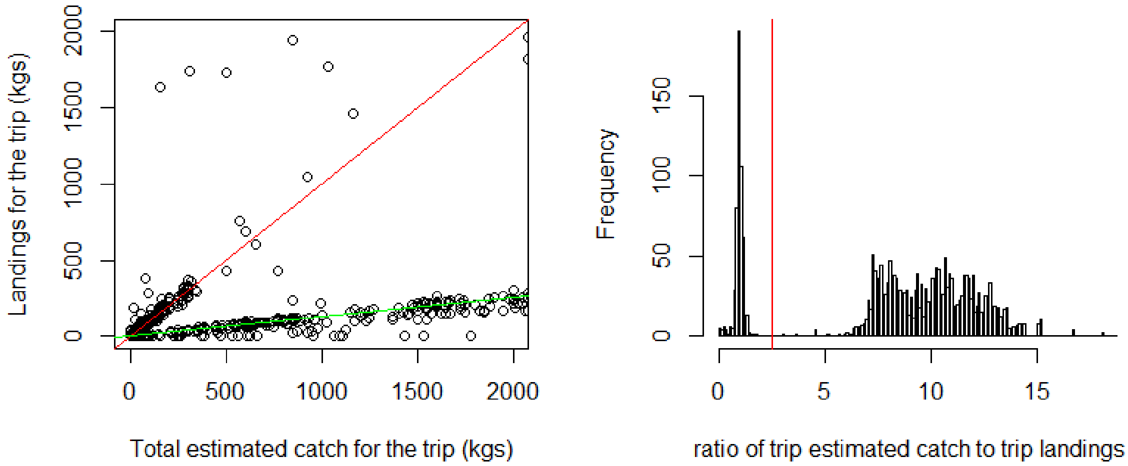


Figure 4: A comparison of total landed weight and total estimated weight for fishing trips targeting scallops. Left: Points located near the red line indicate trips where weights are reported at both times in the same units whereas points near the green line are from trips where estimated catches are about 8 times greater than landings (green line is slope 1/8 and the conversion factor of meatweight to greenweight in scallops is 8). Right: The bimodal distribution of catch to landings ratios suggest a threshold defining dissimilar reporting units at a ratio of 2.5.

3.10 Classification of fishing events

At times it is useful to summarise attributes of similar types of fishing, for example to assess the validity of records by comparison with the range and distribution of attribute values from similar fishing events, or to find suitable groups of records to use for calculating medians to substitute for missing data.

The set of all fishing events in the EEZ could be variously subdivided and summarised by fishing method or target species or location such as Fisheries Management Area (FMA) or landing region or vessel attributes, or any combination of these variables. There are 10 FMAs, 48 Port Regions, 36 fishing method codes, 201 target species codes, and 5–9 possible natural groupings of vessel size that could be used in this way. The possible permutations are many. In CatchMapper we use two other grouping variables in addition to the more familiar ones listed above, gear and cluster. Gear type is often a useful classification for mapping and estimating groups of similar types of fishing methods. Table 3 gives a grouping of 36 fishing methods into 10 gear types.

Target species code was thought to be problematic as it is ill-defined. Target species could be the species actually targeted or the species traditionally targeted or the species mostly caught or something else. A new classification was created based on a cluster analysis of catch composition in the manner described by Bentley et al. (2011) and detailed in Appendix 4. The cluster classification groups all fishing events into one of 126 clusters based on the type of gear used, the region of the EEZ where fishing occurred and the proportional make up of species in the catch. The number of clusters can be further reduced by combining clusters depending on the information of most interest. This provides great flexibility in characterising and mapping fishing events.

CatchMapper makes all of these different grouping variables available for user defined queries and maps.

Table 3: Grouping of 36 fishing methods into gear types.

Fishing Method Code	Description	Gear Classification	Effort measure
DPS	Pair Danish seine	DANISH	Number of shots
DS	Danish seine	DANISH	"
D	Dredge	DREDGE	Number of shots
DI	Dive	HAND	Number of hours
H	Hand gathering	HAND	"
MH	Mechcanical harvester	HAND[1]	"
SJ	Squid Jigging	JIG	Number of Days
BLL	Bottom longline	LINE1 (passive lining)	Number of hooks
DL	Dahn line	LINE1 (passive lining)	"
SLL	Surface longline	LINE1 (passive lining)	"
TL	Trot line	LINE1 (passive lining)	"
HL	Hand line	LINE2	Number of hours
PL	Pole line	LINE2	"
T	Troll	LINE2	"
DN	Inshore drift net	NET	Net length
RN	Ring net	NET	"
SN	Set net	NET	"
CP	Cod pot	POT	Number of pot lifts
CRP	Crab pot	POT	"
EP	eel pot	POT	"
FN	Fyke net	POT	"
FP	Fish pot	POT	"
OCP	Octopus pot	POT	"
POT	pot	POT	"
RLP	Rock lobster pot	POT	"
SCP	Scampi pot	POT	"
BS	Beach seine	SEINE	Number of shots
DPN	Dip net	SEINE	"
L	Lampara net	SEINE	"
PS	Purse seine	SEINE	"
SCN	Scoop net	SEINE	"
BPT	Bottom pair trawl	TRAWL	Number of tows x tow length x tow width
BT	Bottom trawl	TRAWL	"
MW	Midwater trawl	TRAWL	"
PRB	Precision bottom trawl	TRAWL	"
PRM	Precision midwater trawl	TRAWL	"

[1] Combined with Hand methods rather than dredge as measure of effort is the same

3.11 Defining and grooming effort

A new field called "effort" is created in the dataset to contain the best measure of effort available for each type of fishing method (see Table 3).

Reported measures of effort for fishing events are used by CatchMapper in two important ways. Firstly, to define the polygon of space which represents the location of that fishing and secondly, to calculate estimated catch or landings per unit effort for all fishing events with complete data which are summarised and used to impute missing values of effort or landings in other fishing events.

The quality of these reported effort measures were checked and limits set to define valid value ranges (detailed in Appendix 2). All values that did not fall within valid value ranges were removed. All missing data (and those removed for ineligibility) were imputed with median values from appropriate grouping of similar records. The numbers of records where values were changed is given in Table A2.2 in Appendix 2.

In fishing events where the effort value is missing (or trawl length or line length is missing) these values are replaced with the median value for the same fishing method and cluster. If there is no median at that level of grouping then the median for the fishing method is used.

Landings Data

Species codes are aggregated in the same way as explained in Section 3.5 (Table 2) and SCA meatweight and OYU unit quantity values merged with the greenweight values in a single field in the same way described in Section 9 above. Only 1 out of 13515 SCA landings records reported landings by Greenweight (in SCA 9), the rest used meatweight. This exception was ignored.

3.12 Grooming Landings Points

Fishers report the name of the place where they land their catch. There is no quality check on this field in database entry so any values can be entered with any random spelling. However, this information is useful for mapping some fishing events. It is used in CatchMapper to determine a likely direction for the last tow of the day for trawls that are reported on TCER forms where only start position is recorded. It is also used for determining the likely area of set netting by small vessels in the Hauraki Gulf area. To use this information it needs grooming to correct all the various spelling versions. This has been done for all trawl ports and for Hauraki Gulf beach landing points where it is possible to reasonably interpret the intended location name. The data in this field is checked against a list of possible versions.

The location of landing is recorded on either the Catch Effort section of the CELR and NCELR forms or on the CLR form depending on which effort form is used. The latter is added to the Catch Effort table as a new field.

For trawl landing names only 64.4% were spelt correctly. Corrections were made to 25 822 records which increased correct spelling to 99.3%.

3.13 Add New Variables

3.13.1 Bottom contact flag

In order to be able to quickly extract the fishing events that involve gear being in contact with the seabed (to create footprints for effects on seabed fauna), a flag is added to those events in the dataset and the list of variables available for selecting and grouping fishing events. Method codes flagged as involving bottom contact include BT, BPT, D, DS, MH, BS, and DPS. Additionally, all MW trawls where reported trawl depth is within 1 m of the reported bottom depth are flagged as having bottom contact in accordance with Baird et al. (2015). The number of trawl events flagged for bottom contact are given in Table 4. These are the trawl events that would be included in a trawl footprint.

Table 4: The number of trawl fishing events within the EEZ in contact with the seabed, by trawl method type, form type and fishing year.

	0708	0809	0910	1011	1112	1213	1314	1415	1516
BT	78 837	76 887	82 770	76 156	75 391	74 780	74 891	67 879	67 063
BPT	1 260	1 073	1 219	1 312	258		8	330	
PRB									991
MW	6 435	6 015	6 106	5 156	5 191	5 146	5 631	5 841	5 146
% of MW	74.0%	70.8%	70.6%	60.4%	60.2%	58.0%	56.2%	55.8%	57.1%
PRM									543
% of PRM									72.1%
CEL	477	622	167	60	63	63	75	38	87
TCE	45 899	46 656	53 043	48 162	47 987	49 998	48 770	43 366	43 022
TCP	40 156	36 697	36 885	34 402	32 790	29 865	31 685	30 646	30 634
Total	86 532	83 975	90 095	82 624	80 840	79 926	80 530	74 050	73 743

Note these numbers of records are not directly comparable with those used by Black et al. (2013) and Baird et al. (2015). The estimates above differ to these as Black et al. (2013) included trawl events outside EEZ in the numbers given and Baird et al. (2015) ncluded only those within 250 m depth.

3.13.2 Number of Days per trip –

The number of days between trip start and end are calculated and added to the effort table. If someone wanted to compare the amount of fishing activity across all fisheries days fished is the only consistent measure of fishing effort that could be applied to all fisheries.

Unique anonymous key for Vessel and Permit holder

The original dataset contained the names of vessels and permit holders. These are stripped from the CatchMapper datasets and replaced with a unique key for each combination of vessel and permit holder. Most CatchMapper functions can be performed without the need to identify the vessel or permit holder. The original key file is held by the CatchMapper administrator within the MPI Spatial Analysis team. Note: duplicate names can enter this file with different use of upper and lower case in the original database. If wanting to retrieve all the fishing for a particular vessel or permit holder use case insensitive search of the key file to retrieve all possible keys.

3.13.3 Observer presence

A data extract from the database of Observer trips is obtained from MPIs Research Data Management (RDM) team each year. This dataset includes the vessel name and Id number, and trip start and end dates. All trips by a vessel that fall within observer trip dates for that vessel are flagged as having an observer on-board. Figure 5 shows the distribution of observer trip length. Most trips are less than 60 days but a few exceed 100 days. This data has been checked and groomed by RDM personnel and is taken as given. The number of fishing events by fishing method tagged as having an observer on-board within CatchMapper are given in Table 5.

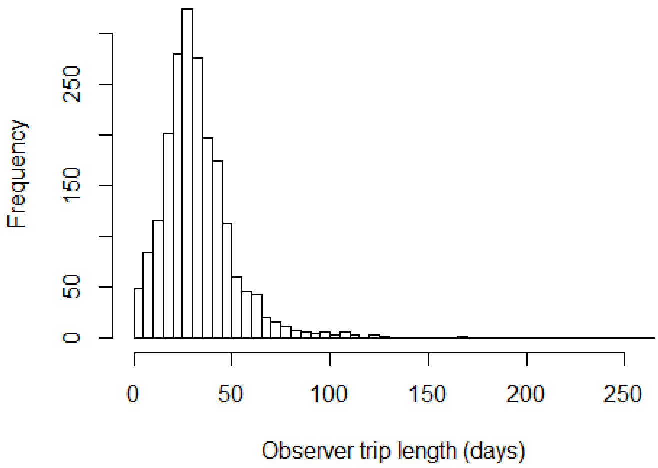


Figure 5: Distribution of values for the length of observer trips.

Table 5: The number of fishing events in CatchMapper with observer coverage by fishing method and fishing year.*

	0708	**0809**	**0910**	**1011**	**1112**	**1213**	**1314**	**1415**	**1516**
BLL	517	894	1 361	326	301	181	1 043	424	1 063
BS	0	0	0	0	0	0	0	0	2
BT	5 726	7 552	7 378	5 814	4 846	6 928	7 962	8 081	7 821
CP	1	33	14	0	0	0	0	14	0
CRP	0	2	0	0	0	0	1	0	0
DI	0	27	81	0	0	0	0	0	26
DL	7	4	8	8	0	1	9	2	0
DS	0	0	0	0	0	0	11	246	38
FP	0	14	12	0	0	0	0	0	0
H	0	0	0	0	0	1	0	0	0
HL	2	11	40	14	20	3	58	10	12
MW	2 681	2 853	2 855	2 240	4 078	5 524	5 957	6 184	5 014
PL	0	0	1	0	8	25	3	0	0
PRB	0	0	0	0	0	0	0	0	660
PRM	0	0	0	0	0	0	0	0	21
PS	167	162	123	183	83	107	129	106	68
RLP	20	30	40	20	5	7	20	0	67
SJ	0	14	6	0	0	0	0	0	0
SLL	261	427	362	332	347	248	351	303	383
SN	322	552	563	238	85	422	284	352	269
T	19	71	78	44	29	67	27	22	5
TL	0	1	0	3	0	0	0	2	1

*Note these numbers may not be directly comparable with those published elsewhere e.g. the Dragonfly protected species data website, due to the exclusion of high seas fishing events in CatchMapper and possible differences in definition of fishing events.

New Variables Required for Building Fishing event Polygons

Modify start and end coordinates

Start and end positions of fishing events are reported to the nearest 1 minute of latitude and longitude. On mapping this has the effect of aggregating fishing events to common start or end positions causing marked patterns which probably aren't real. In practice it is likely that start and end positions are dispersed within the square nautical mile encapsulating the precision of the coordinates. To avoid patterns caused by truncated precision, all start and end positions are instead modified to be dispersed randomly within the square nautical mile represented by each set of coordinates through a process known as jittering (a random quantity from -0.5 to 0.5 minutes latitude and longitude is added to each coordinate).

3.13.4 Predict trawl bearing and end coordinates.

The start coordinates for the next tow in the same trawl fishing trip are added to the fishing event dataset for every trawl where available. Where there is no next tow in the trip (i.e. the record is the last tow of the trip) the coordinates of the subsequent landing point are added to the dataset. The bearings from start coordinate to the coordinate of the start position of the next tow (or the landing point) are calculated and added to the dataset. In the case of TCP trawls with reported end coordinates, the bearing from start to end is calculated and also added to the dataset. For trawls without reported end positions the expected end position is derived from the bearing to the next tow and the length of the tow.

3.13.5 Line width

SLL lines are given an arbitrary width of 100 m. Trawl lines are given the width of generic door spread values as detailed in Appendix 2.

Polygon Quality Index.

A quality index is assigned to all mapped fishing events. Those events mapped to event-specific polygons created from reported coordinates are rated as quality A, meaning we have relatively high confidence in the location of the fishing. Those events where little is known about the spatial pattern of fishing within large statistical areas are rated as quality C, meaning we don't know precisely where the fishing occurred and have low confidence in estimates of spatial catch from this source in areas much smaller than the statistical area. In between these two extremes are the B-rated polygons where the location of the fishing grounds within the broader statistical areas are known from biomass surveys or information from fishers. This is discussed further in the next section on building fishing polygons.

4. Building Fishing Event Polygons

There are two broad types of data available to pinpoint the location of fishing events in the coastal waters and EEZ of New Zealand. At low spatial resolution, all reported fishing events can be located to a set of statistical areas and the events are mapped to polygons representing all or part of the statistical area as discussed further below and in Appendix 5. These fishing event polygons are given quality class B or C depending on the quality of the information used to identify where within the statistical areas the fishing is likely to have occurred.

Progressively over time, most types of fishing have moved to reporting at a higher spatial resolution based on start position coordinates. The polygons created for these fishing events are rated as A class polygons. So the method of building polygons for fishing events and the quality class assigned to each polygon depends on the resolution of reported fishing location.

High Spatial Resolution Fishing Polygons

In the nine years since October 2007, 64% of all fishing events have been reported with location defined by the coordinates of the position where fishing started. Start coordinates are reported to a precision of one nautical mile (one minute of latitude and longitude). Each fishing event is mapped with a polygon built using start coordinates and other data depending on the type of fishing as detailed below. As explained in the data preparation section start points are jittered to be randomly located within the range of precision. The resulting fishing event polygons are called class A polygons.

After building all the polygons they are clipped by overlaying the coastline and any prohibited fishing areas. It is assumed that any part of fishing polygons that fall on land or within prohibited areas are in error as a consequence of the lack of precision in the location data. The fishing is assumed to have occurred in the remaining area of the polygon after clipping. On rare occasions a whole polygon will be lost with nothing remaining after clipping. The effort lost in this way is still represented within CatchMapper by scaling up the effort in the group of mapped events for the same cluster, fishing method, year and statistical area as the lost events.

The area of a fishing polygon is used to calculate the fishing intensity of each fishing event as effort per hectare (EpHa), catch per hectare (CpHa) or landings per hectare (LpHa). Fishing intensity can be mapped as a continuous variable and the maps can be summed or averaged.

4.1 Clipping closed areas out of fishing polygons

A question not yet resolved in CatchMapper is whether areas closed to fishing year round should be clipped from all fishing events (of the type affected by the regulated closure) before and after the start of the regulation or only after the start. There are practical considerations.

Most fishing maps are displayed as annual averages so areas closed to fishing may show low quantities of fishing within them if the closure has not been in place for the whole period of the fishing averaged in the maps. This can be confusing. It is generally more desirable to show areas closed to fishing as clear of all fishing. Note areas not closed year round are not clipped from any fishing events.

It would have been more work to separate out closed areas by years where they had effect and years where they didn't. When CatchMapper was first built and in subsequent rebuilds the list of closed areas was updated and the entire collection clipped from all fishing polygons.

CatchMapper's original purpose was as a tool for assessing the effects on fishing of closing areas by way of fisheries spatial regulations or granting aquaculture consents. Activities in areas that are already closed to fishing are generally assumed to have no impact on fishing even if there was fishing there before the area was closed (although this might not be the case if the closure was only temporary).

Any closed area that overlaps a fishing event polygon because of imprecision in defining the location of that fishing i.e. because the closure was in place before the fishing and we assume the fishing did not actually occur there, is clipped from that polygon and the fishing catch or effort is redistributed in the remaining event polygon. This probably mimics the effect of implementing a closure after some fishing events occurred in the closed area i.e. in future the fishing had to relocate possibly nearby. Any subsequent further closure in the vicinity might be expected to affect not only the fishing indicated by the history at that site but also the fishing that may have been redistributed there as a result of the earlier closure i.e. a cumulative effect.

Therefore, clipping all current closed areas from all past fishing events in CatchMapper has a desirable outcome for assessments of the effects on fishing of future closures. However, it also means that CatchMapper is not useful for assessing the effects on fishing of past closures.

The following paragraphs give more detail on how individual fishing event polygons are created for different fishing types

4.2 Trawl and SSL lines

Surface longlining events with valid start and end coordinates and trawl events with valid start coordinates and reported or predicted end coordinates (as discussed in the data preparation section) are represented within CatchMapper as rectangles covering the area swept by the trawl gear. Firstly, lines are created in GIS software between start and end coordinates (jittered by ± 0.5º). Then the lines are buffered by line width values of the fishing events to create individual rectangular polygons for each event. The process is illustrated in Figure 6 and the final result in CatchMapper is shown in Figures 7 (trawl) and 9 (SSL).

Trawl and SSL events without valid start and end points are not mapped (Table 6). A total of 16 and 1265 SSL and Trawl polygons respectively, were lost after clipping areas of land, closed areas, and areas outside the EEZ, out of the original polygons. The unmapped and lost fishing effort is replaced in CatchMapper by scaling other mapped effort as discussed earlier.

Table 6: Number of trawl and SSL events mapped to classes of polygons and the number mapped and lost to clipping or not mapped, by form type.

Methods	Form	A	B	C	Not Mapped	Clipped out
SLL	CELR	0	0	0	6	0
	LTCER	48	0	0	0	0
	TLCER	22 943	0	0	0	16
TRAWL	CELR	0	0	0	1 652	0
	TCER	427 309	0	0	2 119	1 008
	TCEPR	330 884	0	0	0	257

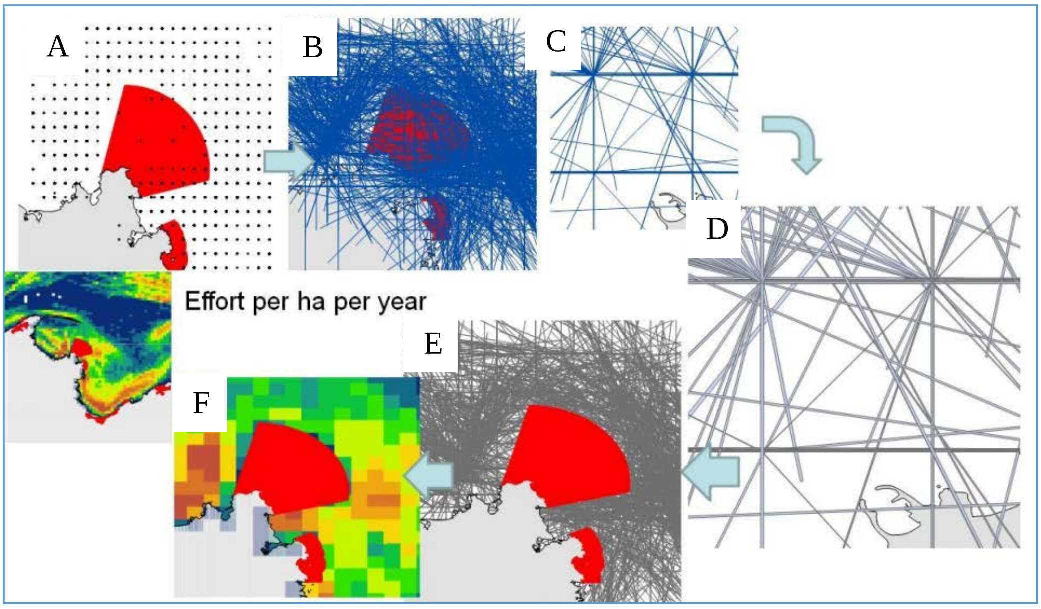


Figure 6: The process of building fishing polygons for trawl and surface longline fishing events. A. Start and end coordinates are located to the nearest nautical mile. B. Lines are created from start to end coordinates. C start and end coordinates are jittered to avoid concentration of lines at coordinate grid centres. D. The lines are given width and turned into rectangular polygons. E. Land and closed areas (shown in red) are clipped out. F. The polygons are converted into raster images and displayed as heat maps.

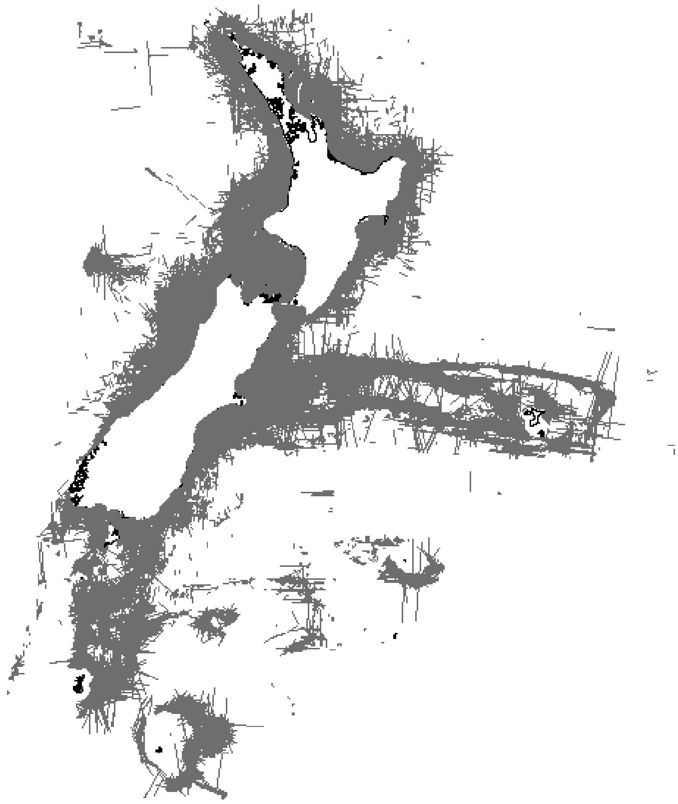


Figure 7: CatchMapper trawl polygons spanning nine fishing years.

4.3 Set Lining:

Most (97.6%) BLL and TL events in CatchMapper are reported with start coordinates (Table 7). The individual polygons for these lining events with valid start coordinates are represented in CatchMapper as circles with centres at the start coordinates and radii equal to line lengths. The direction of the line set is not known but all the fishing occurred within the area of the circle (Figure 8). All set lining polygons in CatchMapper to date are shown in Figure 9.

The 2.4% of set lining that reports location by statistical area on CELR forms is mapped to low spatial resolution polygons (class C polygons) as discussed in the next section. These are the fishing events undertaken by vessels less than 6m in length that are not required to report fishing by start coordinates. They are assumed to occur in a zone close to the coastline where small vessels may operate (Figure 8). The events not mapped due to invalid coordinates or lost in clipping are represented in CatchMapper by scaling other mapped effort as discussed earlier.

Table7: The number of BLL and TL events mapped to classes of polygons and the number mapped and lost to clipping or not mapped, by form type.

Methods	Form	A	B	C	Not Mapped	Clipped out
BLL & TL	CELR	101	0	3 693	0	0
	LCER	30 688	0	0	0	14
	LTCER	116 775	0	0	12	157

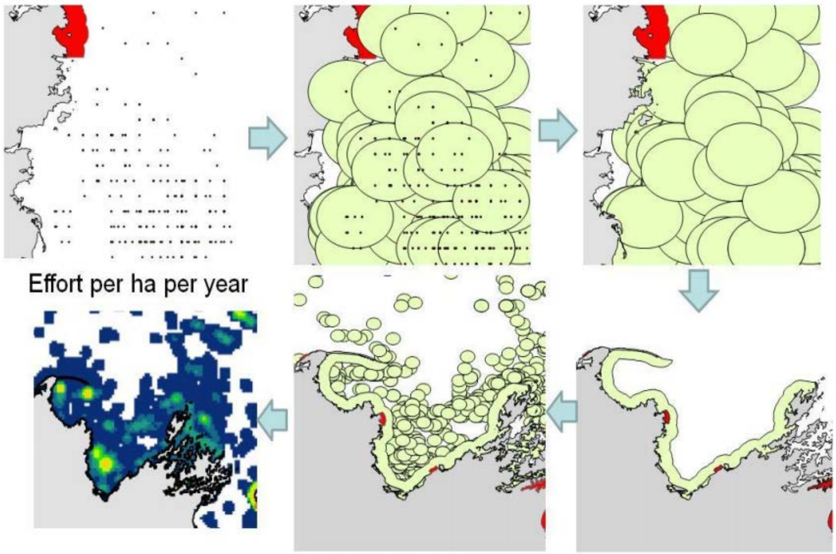


Figure 8: The process of building fishing polygons for net, line and seine fishing events where only a start coordinate is available. Start coordinates are located to the nearest nautical mile. A. The points are jittered to avoid excessive overlapping of polygons due to regular arrangement of start points. B. The points are buffered to give circle polygons the radius depending on the type of fishing as discussed in the text. Here buffering of set net events is shown where the radius is 2 nautical miles. C. Land and closed areas (shown in red) are clipped out. D. Fishing events by vessels under 6 m in length that report by statistical area are mapped to a zone of the statistical area that is up to 3 nm from the shore (C-class polygons see Appendix 5). E-F. The polygons are combined and converted into raster images and displayed as heat maps.

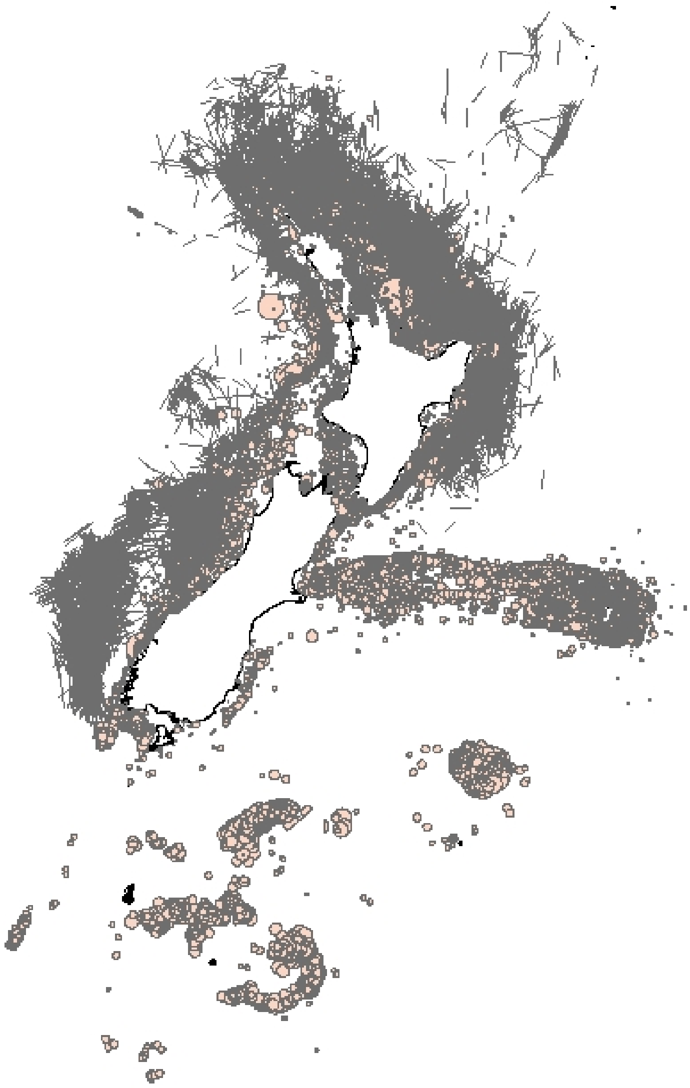


Figure 9: CatchMapper longlining polygons spanning nine fishing years. The rectangular lines are SSL events and the circles are BLL or TL events.

4.4 Set Netting:

Only some netting events are reported with start coordinates (33.1%). The individual polygons for these events are circles centred on the start coordinates with a radius of 2 nm in accordance with the definition of netting events (Figure 8). Most set netting reported with start coordinates is reported on NCELR forms but 3.7% is reported on CELR forms (Table 8). Most set net fishing reported on CELR forms is located to statistical areas. In cases where start coordinates are given it is assumed that the events follow the same definition as those on NCELR forms i.e. all fishing within an event occurs within 2 nm of the start position. However, set netting events reported on CELR forms may include all the days fishing within one statistical area covering an area wider than 2 nm in which case the area fished is underrepresented in CatchMapper. The 66.9% of set netting that reports location by statistical area on CELR forms is mapped to low spatial resolution polygons discussed in the next section. The individual event polygons are shown in Figure 10.

Table 8: The number of SN events mapped to classes of polygons and the number mapped and lost to clipping or not mapped, by form type.

Methods	Form	A	B	C	Not Mapped	Clipped out
NET	CELR	2 707	34 162	94 084		169
	NCELR	70 798	40		838	2

Figure 10: CatchMapper set netting polygons spanning nine fishing years. Only individual fishing event polygons are shown here. Most set netting still reports by statistical area and is mapped in a different way shown in Appendix 5.

4.5 Purse and Danish seining

All Purse and Danish seining is reported on CELR forms (Table 9). If a start position is reported and the number of shots is only one then the event is individually mapped with a 3 nm radius circle centred on the start position. The radius used to represent the area fished in a typical event is arbitrary and could be corrected if better information becomes available. A single Danish seine fisher spoken to thought 3 nm was appropriate.

Only 69.2 % of purse seine events (Figure 11) and 39.1% of Danish seine events (Figure 12) can be individually mapped, the rest either report by statistical area or the number of shots in the event is more than one and the range of area over which the fishing took place is unknown. The events not mapped individually are mapped to low spatial resolution polygons as discussed in the next section.

In this case, any fishing events where the individually mapped polygons are lost in clipping to land and closed areas are mapped to low spatial resolution polygons as discussed in the next section.

Table 9: The number of DS and PS events mapped to classes of polygons and the number mapped and lost to clipping or not mapped, by form type.

Methods	Form	A	B	C	Not Mapped	Clipped out
PS	CEL	5 983	0	2 660	0	-
DS & DPS	CEL	8 923	0	14 009	0	-

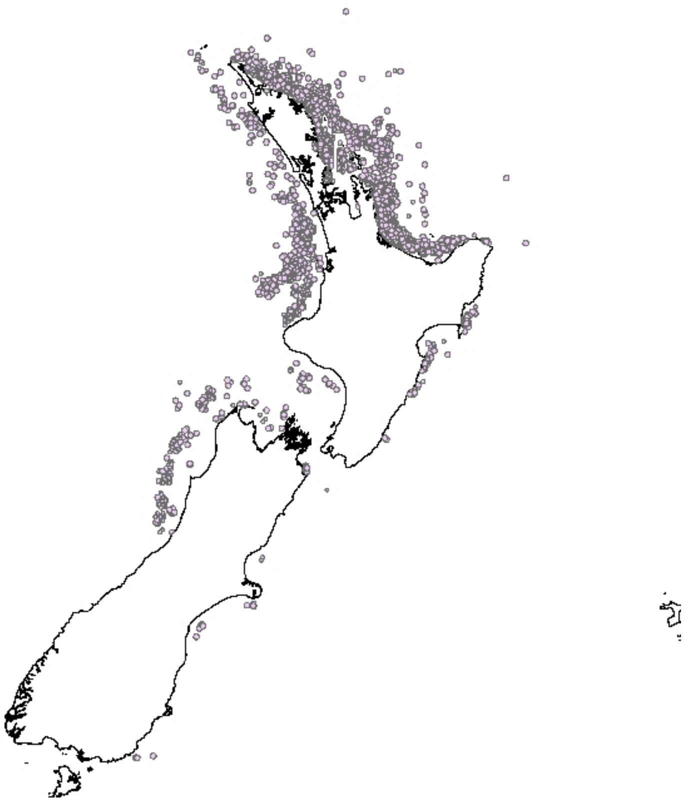


Figure 11: CatchMapper purse seine polygons spanning nine fishing years. Only individual fishing event polygons are shown here. Some purse seining is not reported by individual shot location and is mapped in a different way shown in Appendix 5.

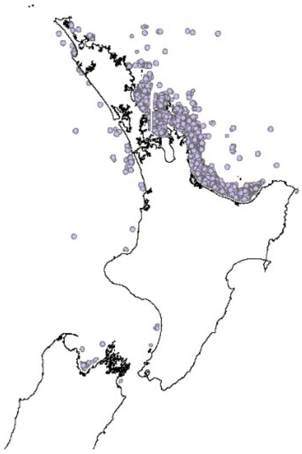


Figure 12: CatchMapper Danish seine polygons spanning nine fishing years. Only individual fishing event polygons are shown here. Some Danish seining and in particular that occurring in the South Island, is not reported by individual shot location and is mapped in a different way shown in Appendix 5.

4.6 Squid jigging

Squid Jigging is undertaken at night time and the requirement for position reporting is a single location coordinate at midnight. Information on how far afield vessels travel in a night's fishing has not yet been incorporated into CatchMapper. Arbitrarily, squid jigging coordinates are buffered by a radius of 5 nm to encompass the area fished in a night (Figure 13). This is an area of CatchMapper requiring verification and future improvement.

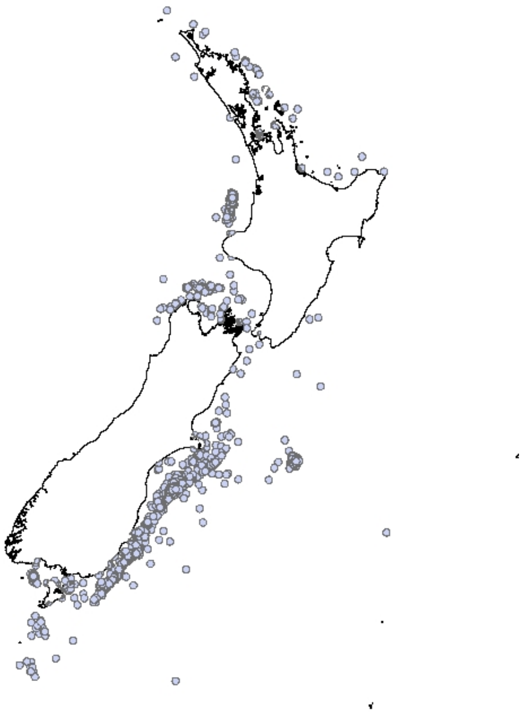


Figure 13: CatchMapper squid jigging polygons spanning nine fishing years.

4.7 Low Spatial Resolution Fishing Polygons

All the fishing events that do not report location by coordinates of start position instead report by pre-defined statistical areas. The statistical areas are the first information used to pinpoint the location of each fishing event. Depending on the type of fishing event only a small part of a statistical area might be used. So the location of many of these fishing events are mapped to parts of statistical areas where that type of fishing is feasible. CatchMapper contains a set of polygons called fishable areas for every type of fishing based on the fishery cluster classification. The fishable areas have been constructed using some or all of the following types of information:

- Depth range of the target species
- Depth range of the fishing gear e.g. dive
- Habitat distribution e.g., shelf, reef
- Closed areas for that type of fishing
- In-house knowledge of fishing locations
- Range of locations of similar fishing that report by coordinates
- Information provided by fishers

The fishery areas defined by this set of polygons encapsulate readily accessible information available to the author. The fishable areas have been developed over time and are kept in a database. They represent the knowledge gained over time from a variety of sources about where certain types of fishing occur or be limited to within the broader statistical areas. Changes made and the source of information for each change are recorded. In this way the database encapsulates the knowledge of successive Fisheries Analysts. A summary of fishable areas is given in Appendix 5.

They are not perfect and could be refined when better information becomes available. The fishable areas are further subdivided into the pieces of the whole that fall within each of MPIs statistical areas.

Every fishing event is assigned a polygon that matches the type of fishery and the reported statistical area for that event. Many of these polygons include complex shapes of coastline and the computer storage and processing of them can be resource intensive. Rather than storing the individual polygons for every fishing event in CatchMapper, events are aggregated into monthly groups to minimise computational load. Fishing events are aggregated into groups defined by the CatchMapper classification variables:

- Gear
- Fishing Method
- Key for combination of Vessel and Permit Holder
- Cluster
- Target Species
- Statistical Area
- Year
- Month
- Map Quality rank
- Bottom contact flag
- Vessel size category (proposed)

Therefore, these fishing events cannot be selected and analysed or displayed as individual events or by a selection of specific days. The finest time grouping is by month. In this way an average of 64 435 fishing events per year are aggregated and stored as 14 258 polygons.

In CatchMapper, fishable areas have been created only for combinations of fishing method and statistical areas where each method is thought to occur. During this process anomalies were found in the reporting and/or transcription of statistical areas. There are some fishing events that report positions to statistical areas that are thought unlikely locations or depths for the use of the particular method. These cases are mapped to the whole reported statistical area and can be distinguished in maps as they are shaped like the unmodified statistical areas. These cases are relatively rare so the mapped fishing intensity is always low.

A few cases are left out of CatchMapper as the method definitely cannot occur in the reported statistical area. A total of 31 events were not mapped in CatchMapper as the statistical area was not correct for that type of fishing. These are described in Table 10.

Table 10: Thirty one fishing events could not be mapped in CatchMapper due to the statistical area being implausible for that type of fishing.

Type of fishing	Statistical areas
Mechanical harvesting of mussel spat	004, 048, 036 – all offshore with no beach
Beach Seining	023, 048, 106, 412,004 – all offshore with no beach
Danish Seining	044 ,009H – method has always been prohibited in harbours
Paddle crab potting	019 offshore with no beach
Purse seining	044 method prohibited in harbour
Diving	001, 023, 605, 107, 019, 303, 405 offshore and beyond diving depth

5. Building Catch and Landings Look Up Tables

Information about catch of fish species for each mapped fishing event is collated into look-up tables indexed by fishing event key. A spatial query in CatchMapper will select a list of fishing events and clip them if necessary to the area of the query. The amount of effort for each fishing event calculated to be in the query area is transformed into landings of all species by that amount of effort with a landings by event lookup table. If only part of any fishing event polygon is included within the spatial query the fishing effort in that event is reduced to the proportion of the event polygon within the query area.

In the past when evaluating the amount of fishing that might occur within a specific area such as a statistical area, MPI fisheries analysts would use the estimated catches and add 10% by value to account for bycatch. CatchMapper instead uses estimated catch and trip landings information to account for all landings of all species within the EEZ.

New look up tables are created for each October fishing year. One table has values of catch per unit effort by fishing event and species derived from the estimated catch data recorded at the time of fishing of each fishing event. Another table has estimated landings per unit of effort by fishing event and species. The latter data is derived by apportioning trip landings to trip events. A set of formulae have been developed to do this and are explained in this section.

The spatial query reports provide summaries of both estimated catch and apportioned ladings in the query area so that fisheries analysts can gauge which data they have most confidence in under different circumstances.

5.1 Are apportioned landings necessary?

The number of species for which catch is estimated in each fishing event is variable. Only the main species are estimated and that could be up to 5 or 8 species depending on the form type used but it might also only be one. Many bycatch species are not estimated. Figure 14 shows the numbers of estimated catch events per fishing event, by gear type. The gear types that are likely to get a larger number of bycatch species are trawl, net, seine and set line. Hand, pot, dredge and some active lining fishing methods are more likely to land only the target species with little if any bycatch taken.

The differences between species estimated catches and landings within trips are shown in Figure 15. Estimated catch may generally be a pretty good estimator of landings for target species in a trip but will generally have low accuracy for bycatch species. Estimated catches don’t factor in the amount of fish that is not landed for commercial sale but is either returned to sea or taken as recreational catch.

5.2 How are trip landings apportioned to trip events?

As already discussed, one of the problems with apportioning trip landings to trip events is that only some species catches in the events are estimated. Another problem is that trip landings are not always a correct match for the amount of effort in the trip. This is because catches are sometimes “landed” to transitional destinations and then landed to port at a later time. For example fish might be transhipped at sea so another vessel lands them and records the landings but doesn’t record the fishing effort. Another example is live fish being held in storage on land or at sea and then eventually landed to the Licensed Fish Receiver at which time the landings record will not match the trip effort records.

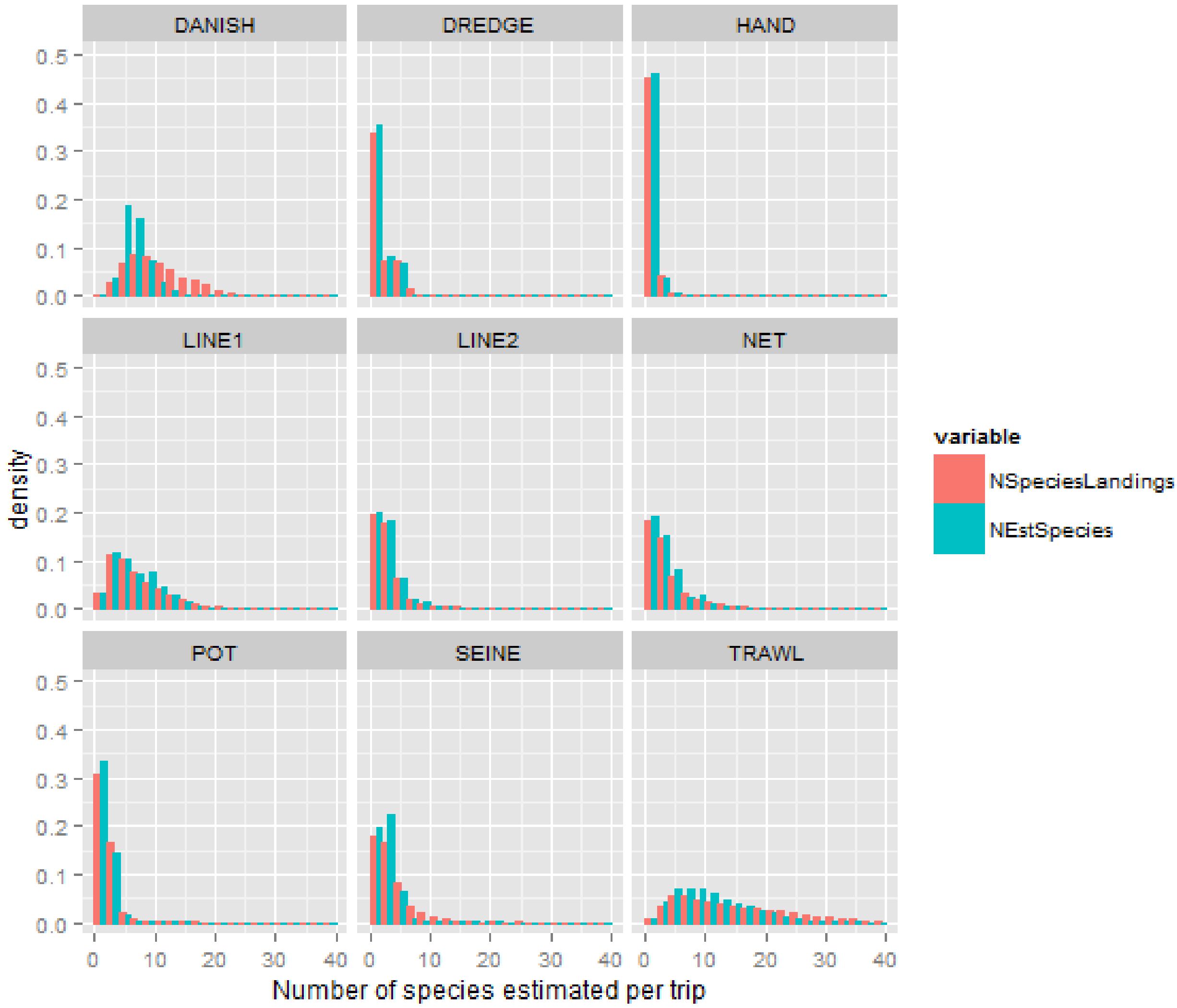


Figure14: Distribution of numbers of species landed per trip (NSpeciesLandings) and number of species where catch is estimated per trip (nEstSpecies). Danish and purse seine (seine in the graphic above) and trawl land many more species than are recorded as estimated catches.

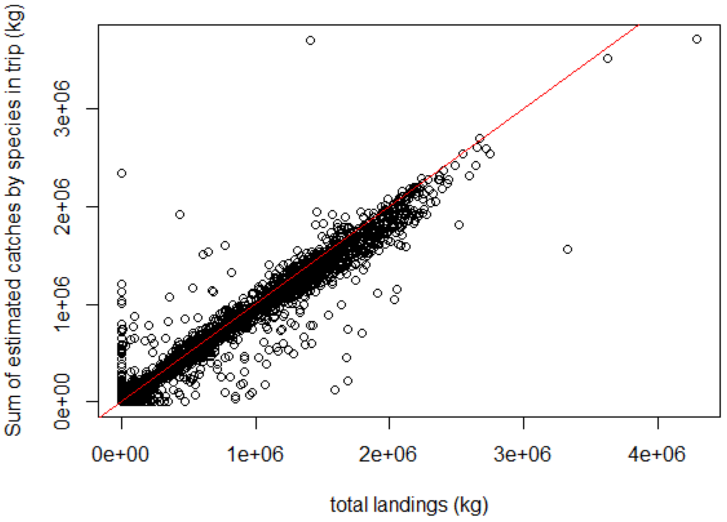


Figure 15: Comparison of trip landings (all species combined) with the sum of the individual species catch estimates in the trip. Red line is x=y.

Fish can also be taken as recreational catch during commercial fishing trips and this catch may be recorded as estimated catch but then landed to a separate landing destination code indicating that it was not taken for sale. Returns from many commercial fishing trips include catch and effort by hand lining which is likely to be recreational fishing.

So some trip landings will be less than the amount actually caught with the reported trip effort and some will be more. At this stage we examined the landings records and separated the landings destination codes into commercial landings, non-commercial landings and interim landings. The landing codes in each of the three groups are given in Table 11 and the frequency of use of the main commercial landing code versus other codes is shown in Figure 16

Table 11: Groups of landings destination codes.

Code	Commercial	Code	Non-commercial	Code	Transitional
C	Disposed to Crown	D	Discarded (Non-ITQ)	B	Stored as bait
L	Landed to LFR in NZ	F	Recreational Catch		
W	Sold at wharf	M	QMS returned to Sea (Part 6A)	NP	Not provided
S	Seized by Crown	X	QMS returned to sea (except 6A)	O	Conveyed outside NZ
U	Used for bait	E	Eaten	P	Holding in water
		A	Accidental loss	Q	Holding on land
		H	Loss from holding pot	R	Retained on board
		Z	Dead or near dead pelagic shark returns	T	Transfer at sea
		J	Observer authorised discard of ITQ species		

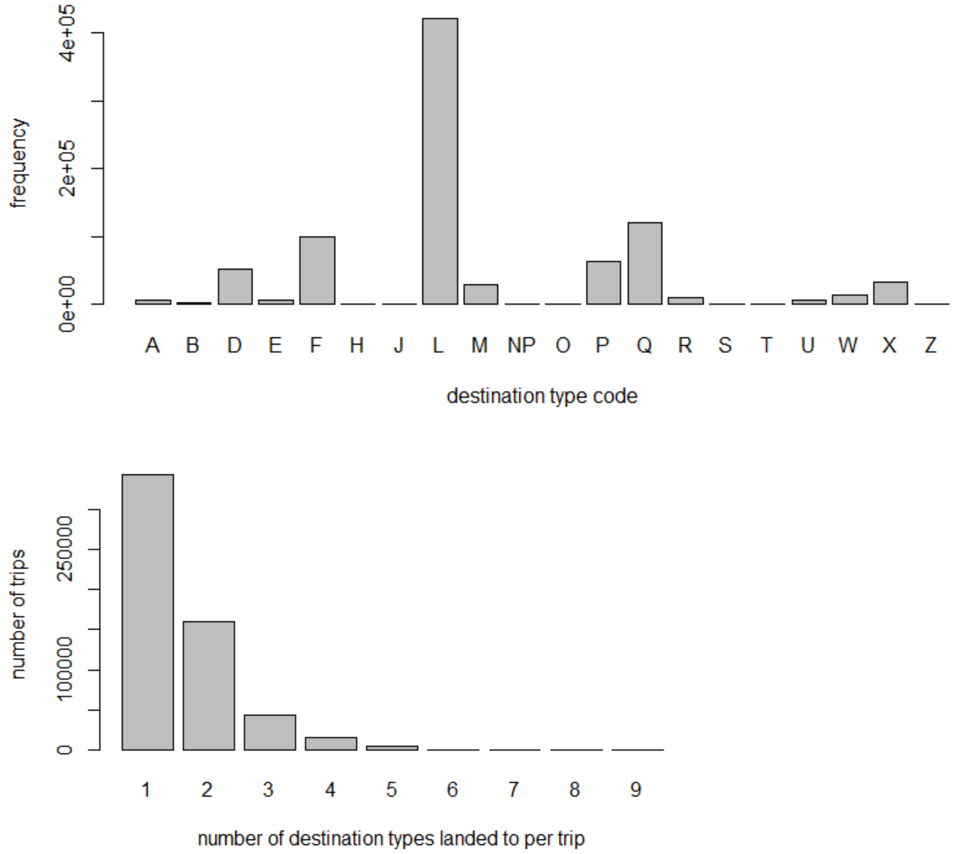


Figure 16: Top: the frequency of landings destination codes in trip species landings data set. Codes explained in Table 11. Bottom: the number of trips recording one or more destination types per trip.

Additionally there are some missing landings where the database link between catch effort and landings records has been lost or no landings were recorded for some reason (0.9% of all trips). There are some other mysterious anomalies between reported landings and reported catch. In a paper-based record keeping system with a lot of information recorded for many events these are unsurprising.

Therefore, apportioning landings to fishing events is done in a way that uses the best possible information with a set of methods that are generalised to groups of fishing events and individual anomalies are ignored. The end result is quality tested to see if it is fit for purpose.

5.3 Ten Trip Landings Scenarios

We developed a summary dataset of number of records, fishing effort, estimated catches and landings at species-level, event-level and trip-level. With these data we identified 10 mutually exclusive cases in the data and developed an algorithm that estimated the amount of trip landings expected to have come from each fishing event by a method specific to each case.

The ten cases are described in Table 12 and the numbers of species landings events falling in each of the ten cases is shown in Figure 17. The decision tree defining membership of the cases is shown in Figure 18.

Table 12: Every combination of landed species and fishing event for a trip is allocated to one of 10 cases described here: Close matches are defined by a ratio of estimated catch to landings between 0.75 and 1.1.

Case	Description
1.	Species is estimated in every trip event and close match between species estimated catches and landings by trip
2.	Species estimated in event but not all events in trip, close match between species estimated catches and landings.
3.	Species estimated in event and catch and landings not close but combined catch and landings totals closely match.
4.	Species estimated in event but neither species nor total trip catches and landings match
5.	Species not estimated in event but other events in trip are case 2
6.	Species not estimated in event but other events in trip are case 3
7.	Species not estimated in event but other events in trip are case 4
8.	Species not estimated in the trip but total trip catch and landings closely match
9.	Species not estimated in the trip and total catch and landings not closely match
10.	Species estimated but not landed

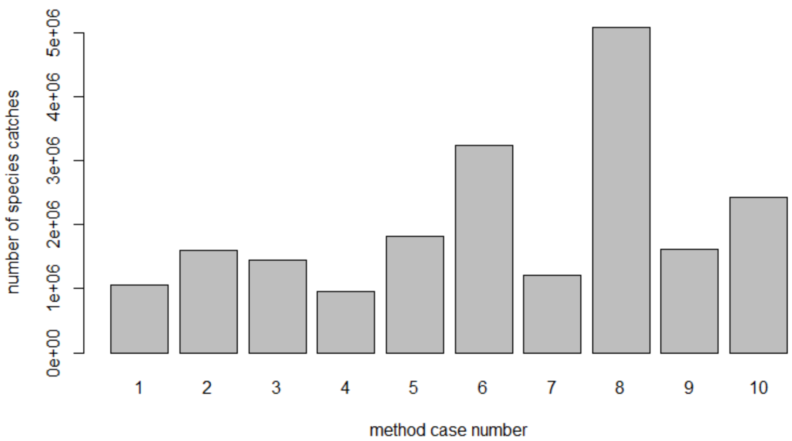


Figure 17: The number of species catch/landing events that fall into each of the ten cases described in Table 12. .

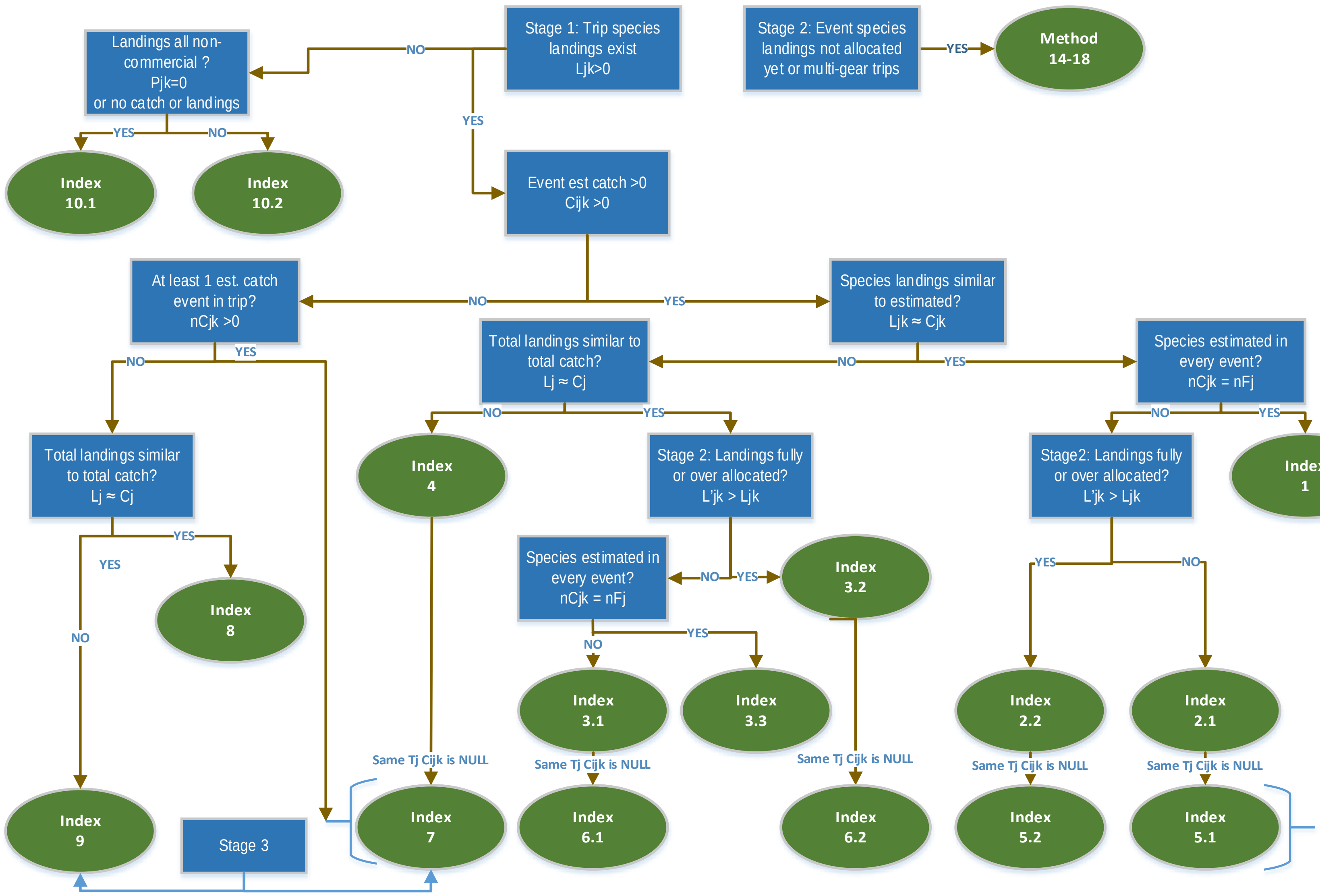


Figure 18: Decision tree defining membership of ten cases in fishing event catch and landings data and subdivision of them at Stage 2

The data and equations used at each of three stages to calculate expected landings per fishing event in the ten cases are given in Tables 13 and 14. Stage 2 and 3 decisions give subsets of the cases and the numbers in each of the subcases are shown in Figure 19.

Table13: Species by event data and summary statistics and event-level and trip-level used in calculations to apportion trip landings to trip events.

Field	Equation
Trip ID for every trip *j*	T_j $j = 1,2,\dots ntrips$
Fishing event key for every event *i* in trip *j*	F_{ij} $i = 1,2,\dots nF_j$
Number of events in trip *j*	nF_j
Species code for every species *k* in trip *j*	S_{kj} $k = 1,2,\dots nspecies$
Number of estimated catch events of species *k* in trip *j*	nC_{jk}
Est catch of species *k* in event *i*, trip *j*	C_{ijk}
Total est catch of species *k* in all trip *i* events	$C_{jk}=\sum C_{ijk}$ for all $i \in T_j$
Total est catch of all species for event *i* as reported	C_{ij}
Total est catch of all species in trip *j*	$C_j = \sum C_{ij}$ for all $i \in T_j$
Commercial landings of each species *k* in trip *j*	L_{jk}
Non-commercial landings of each species *k* in trip *j*	R_{jk}
Proportion landed commercially	$P_{jk}=L_{jk} / (L_{jk}+R_{jk})$
Total trip landings of all species in trip *j*	$L_j = \sum L_{jk}$ for all $k \in T_j$
Event effort	E_{ij}
Total effort in trip *j*	$E_j= \sum E_{ij}$ for all $i \in T_j$
Apportioned landings of species *k* in event *i*	L'_{ijk}
Total apportioned trip event Landings	$L'_{jk} = \sum L'_{ijk}$ for all $i \in T_j$
Group Classification of events	G_x , G_y $x = 1,2,\dots nlpecgroups$, $y = 1,2,\dots nlpuegroups$
Landings per unit of estimated catch in group x	$lpec_{Gx} = L'_{ijkx} / C_{ijkx}$
Bycatch landings per unit effort in group *y*	$lpue_{Gy} =$

Table14: Decision rules for membership of 10 cases and subdivisions of them and equations explaining the methods for apportioning trip landings of each species to trip events.

Case	C_{ijk} exists?	Stage 1	calculate difference	Stage 2	Stage 3
1	Y	$L'_{ijk} = C_{ijk} / C_{jk} * L_{jk}$		-	-
2.1	Y	$L'_{ijk} = Ipec_G * C_{ijk}$	$L_{jk} - L'_{jk} > 0$	-	-
2.2	Y	$L'_{ijk} = Ipec_G * C_{ijk}$	$L_{jk} - L'_{jk} < 0$	$L'_{ijk} = L'_{ijk} * L_{jk} / L'_{jk}$	-
3.1	Y	$L'_{ijk} = Ipec_G * C_{ijk}$	$L_{jk} - L'_{jk} > 0$	-	-
3.2	Y	$L'_{ijk} = Ipec_G * C_{ijk}$	$L_{jk} - L'_{jk} < 0$	$L'_{ijk} = L'_{ijk} * L_{jk} / L'_{jk}$	-
3.3	Y	$L'_{ijk} = Ipec_G * C_{ijk}$	$L_{jk} - L'_{jk} > 0$	$L'_{ijk} = L'_{ijk} * L_{jk} / L'_{jk}$	-
4	Y	$L'_{ijk} = Ipec_G * C_{ijk}$	-	-	-
5.1	N (same trips as 2.1)	-	$L_{jk} - L'_{jk} > 0$	$L'_{ijk} = (L_{jk} - L'_{jk})/(nF_j-nC_{jk})$	-
5.2	N (same trips as 2.2)	-	$L_{jk} - L'_{jk} < 0$	$L_{ijk} = 0$	-
6.1	N (same trips as 3.1)	-	$L_{jk} - L'_{jk} > 0$	$L'_{ijk} = (L_{jk} - L'_{jk})/(nF_j-nC_{jk})$	-
6.2	N (same trips as 3.2)	-	$L_{jk} - L'_{jk} < 0$	$L'_{ijk} = 0$	-
7	N (same trips as 4)	-	-	-	$L'_{ijk} = Ipue_G * E_{ij}$
8	N	$L'_{ijk} = L_{jk} * E_{ij}/E_j$	-	-	-
9	N	-	-	-	$L'_{ijk} = Ipue_G * E_{ij}$
10.1	Y	all non-commercial or event total catch = 0		0	-
10.2	Y	$L'_{ijk} = Ipec_G * C_{ijk}$	-	-	-

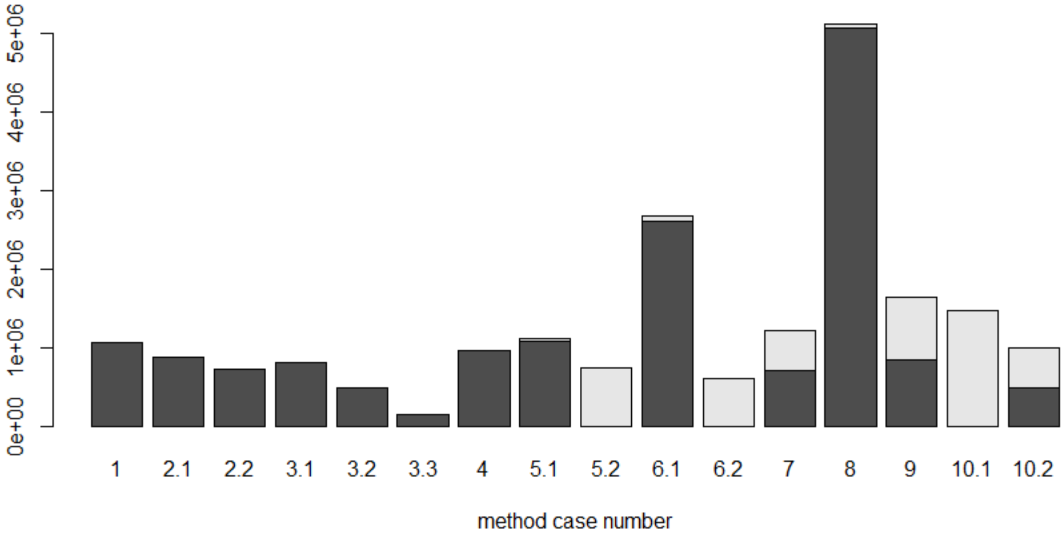


Figure 19: The number of species catch/landing events that fall into the 10 cases and subdivisions of them. Light bars are cases where event species landing were assumed to be zero.

The ratios of species estimated catch to species landings per trip that are considered to be close matches range from 0.75 to 1.1 (Figure 20). Thresholds of 0.7, 0.8 and 1.2 were explored as well. Fishers generally underestimate catch weights so the range below 1 is wider than above 1.

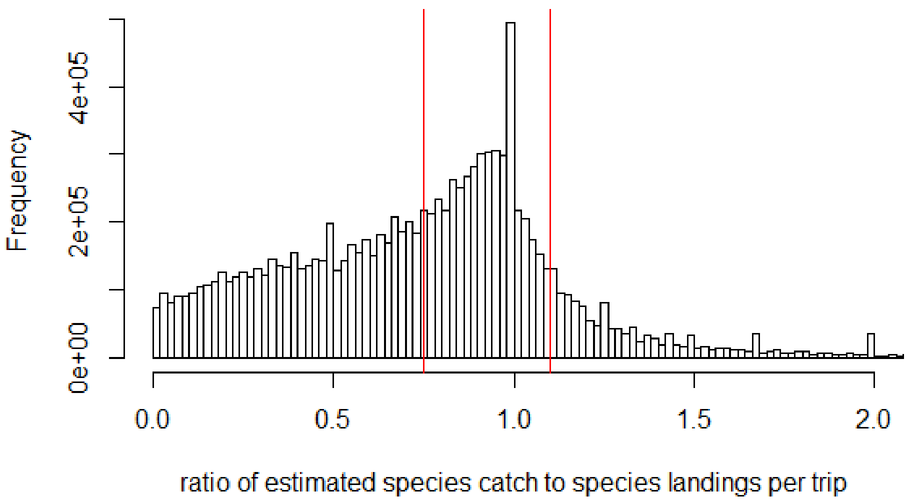


Figure 20: The ratios of species estimated catch to species landings per trip that are considered to be close matches fall within the range 0.75 to 1.1 as shown by the red lines on the distribution of trip ratios.

5.4 Stages in Calculating Expected Landings

In stage 1, the expected ratio between actual landings and estimated catches for any species (lpec in Table 13) is calculated as the mean of the ratios in case 1 events after expected landings are calculated in case 1. The best available mean ratio to use as expected ratio for other events is the one from the most similar group of case 1 events. For each event in cases 2, 3, 4 and 10 a hierarchy of groupings of similar events is searched until a match is found. The groupings searched in order of searching are:

- cluster, fishing method, statistical area, permit holder and vessel
- permit holder and vessel,
- cluster, fishing method and statistical area
- cluster and fishing method.

The best available ratios are then used to scale the estimated catches in the other events.

Also in stage 1, for the case 8 events where the species is never estimated in the events of a particular trip, and the total estimated catches and landings match well, the expected landings are allocated to each event in proportion to the event effort.

In stage 2, for the cases where estimated catch for the trip and trip landings reasonably match (ratio of the former to the latter being within the range 0.75 - 1.1), the difference in trip landings and the sum of the expected event landings allocated so far are used to adjust the expected event landings.

If after stage 1 the amount of landings allocated is greater than the actual reported landings the expected event landings are scaled down (cases 2.2, 3.2, 3.3). For any other events in those trips where the species is not estimated it is assumed that the species was not caught so expected landings equal zero (cases 5.2, 6.2).

On the other hand, if there are still more landings to be allocated after stage 1 then the expected landings for those events remain the same (cases 2.1, 3.1) and the balance of the landings are allocated to the other trip events where the species wasn't estimated. This assumes that the species was still caught as bycatch (cases 5.1, 6.1) in every other event in the trip. If there weren't any other events to allocate to then the expected event landings are scaled up (case 3.3)

In cases where the trip landings were not a reasonable match to the estimated catches (ratio of the latter to the former being outside the range 0.75–1.1), they are not used to calculate expected event landings. Instead, where species catch is estimated in an event the expected landings equals the estimated catch scaled by the best available lpec ratio for the species and the characteristics of that fishery (case 4 and 10) after first checking that the reason for the mismatch between catch and landings was not because the landings were non-commercial. If the species was not estimated then mean catch rate (lpue, Table 13) for the species and the characteristics of that fishery is used multiplied by the event effort (case 7 and 9).

Expected bycatch catch rates are calculated as the mean of event landings per unit effort for all other species catches except cases 4 and 10. At first, only the events in cases 5, 6 and 8 were used as these are all the events where the species is a bycatch species and not one of the main species caught. This resulted in underestimating bycatch catches when compared to annual reported landings by fishstock.

The best available mean catch rates to use as expected lpue for other events is the one from the most similar group other events. For each event in cases 7 and 9 a hierarchy of groupings of similar events is searched until a match is found. The groupings searched in order of searching are:

- cluster, fishing method, statistical area, permit holder/vessel, month
- cluster, fishing method, statistical area, month

- cluster, fishing method, statistical area
- fishing method, statistical area
- gear type, statistical area

The best available lpec values are then multiplied by event effort to give expected event landings.

There are also events where the species trip landings are zero because they are all classed as non-commercial landings i.e. either dumped or lost or eaten or taken as recreational catch. In this case the event landings are set to zero as well.

Note that mean lpues were calculated only for events that did not have imputed effort values.

5.5 Multi-gear trips

The algorithm assumes that all species landed in a trip could have been caught in any of the trip events. This does not hold if more than one gear type is used in a trip. Apportioning trip landings to all trip events in multi-gear trips would give rise to anomalies where species are caught by unlikely methods. Instead for all multi-gear trips where a species is estimated in an event the landings are estimated as though they were in case 3.2 or 3.3 and 6.2. All species that weren't estimated in any trips were allocated landings as in case 9. Trip landings of a species were not allocated to events unless that species was estimated in the event or that species was estimated in similar events using the same method (i.e. a mean lpue exists for that species and that gear type).

5.6 Quality of Event Landings estimates

It is not very informative to compare estimated event landings with estimated event catch by species as the former is calculated based on the latter. But we can compare the sum of apportioned landings for each event with the reported total estimated catch for each event as the latter is not used in calculating the former. It has also been mentioned already that estimated catches will differ from landings in our calculations in cases where the catches were landed to interim or non-commercial destinations. Figure 21 shows pretty good agreement between total landings apportioned to fishing events compared to the total estimated catches for those events. Some of the cases where there is not agreement have been confirmed to be where significant quantities of interim or non-commercial landings were involved.

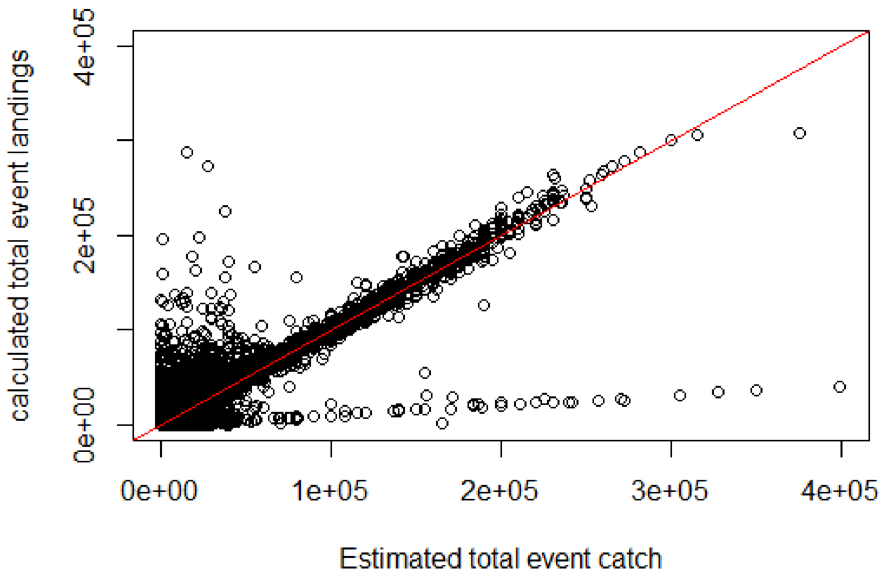


Figure 21: Comparison of the sum of apportioned species landings for events with the total estimated catch for the event estimated at the time of fishing. Red line is x=y.

A similar comparison is shown aggregated by gear type (Figure 22) and apportioning method case (Figure 23). Apportioned landings are on the whole slightly overestimated. Except notably in the LINE2 gear class which includes trolling for albacore. This fishery is not well predicted by CatchMapper at the moment (shown later in Figure 27). Figure 24 illustrates that by weight the landings of species not estimated at the time of fishing are very minor.

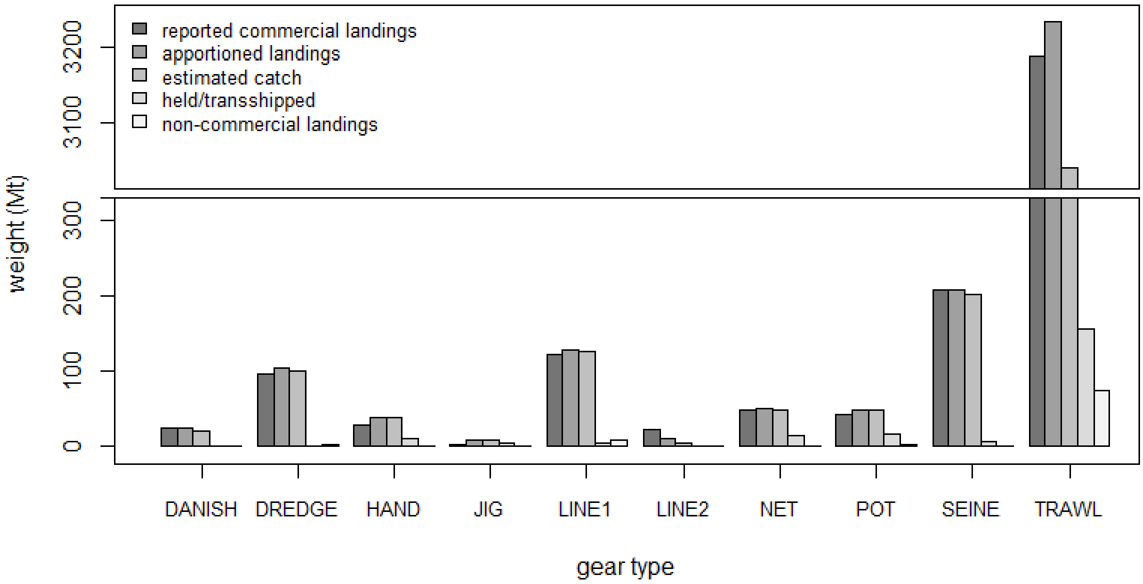


Figure 22: Comparison of reported and apportioned landings and estimated catch summed over all trips in CatchMapper by gear type (only for trips that use a single gear type). The amount of non-commercial and interim landings are also shown. Note: the y-axis is broken to display trawl with the other gear types.

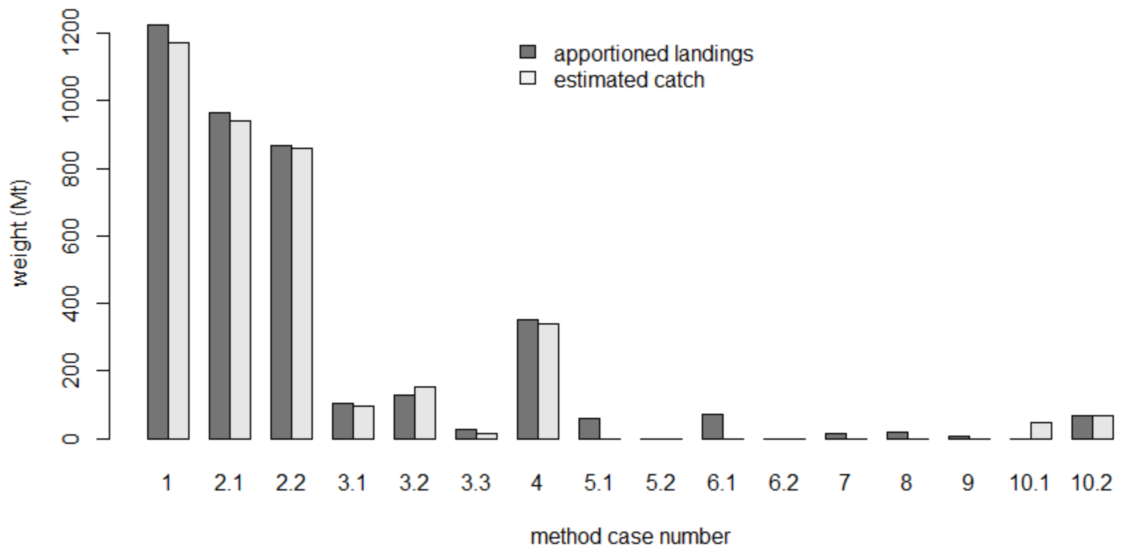


Figure 23: Comparison of apportioned landings and estimated catch summed over all events in CatchMapper by method case (see Figure 18 and Table 14). Cases 1–4 and 10 are those where the species catch is individually estimated at the time of fishing.

Another source of information to test the accuracy of our algorithm is to compare CatchMapper predicted fishstock landings at the QMA scale with the actual QMA annual landings for the fishstock. We calculate and store an annual adjustment scaler for each fishstock which scales predicted to actual values. These scalers are applied to CatchMapper estimates by fishstock at the time of estimating spatial landings. The annual average mean scaler for each fishstock is also included in the tables giving spatial catch estimates so that analysts can gauge how well CatchMapper estimates landings for that fishstock (see next section). Figure 24 shows the distribution of annual scalers for all fishstocks. There are many scalers that are far from one but they are mostly for the species that are only caught in small quantities. On closer examination of the landings less than 5000 tonne per year, the trip landings apportioning scheme does better at predicting fishstock landings than the catch estimated at the time of fishing (Figure 25).

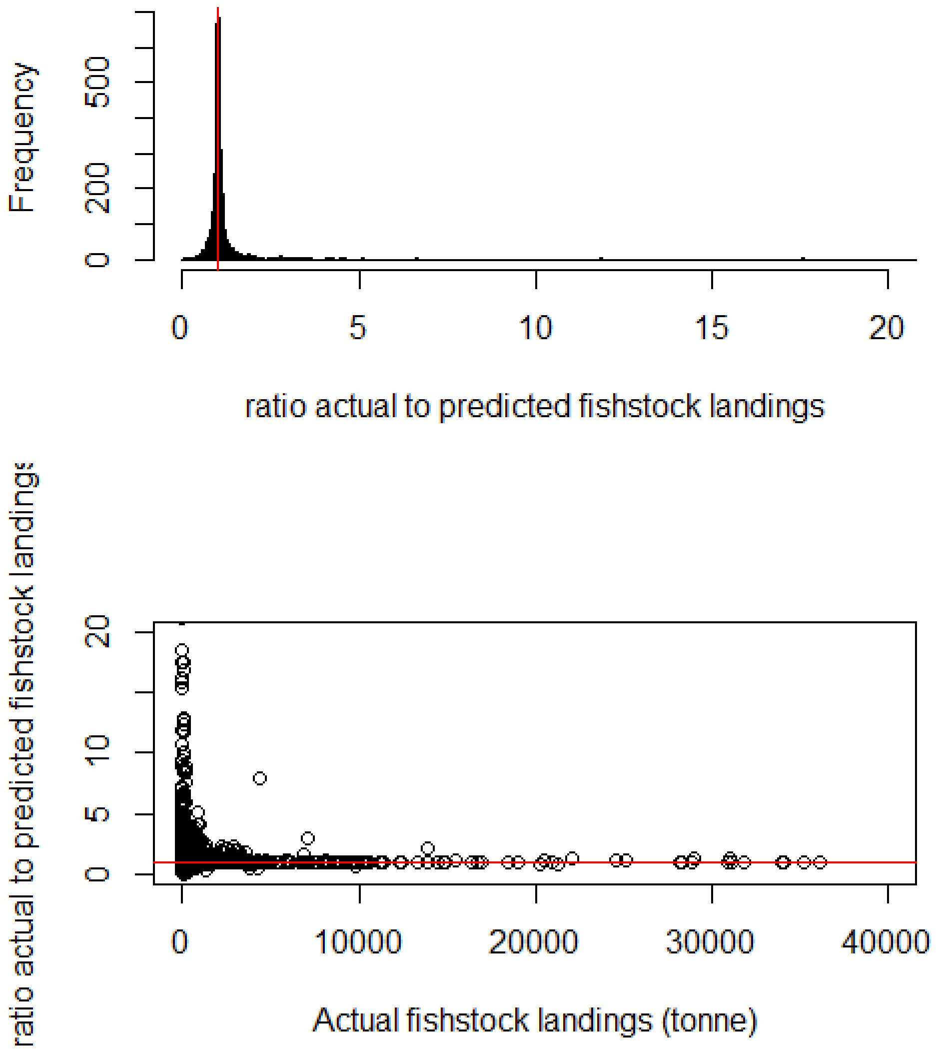
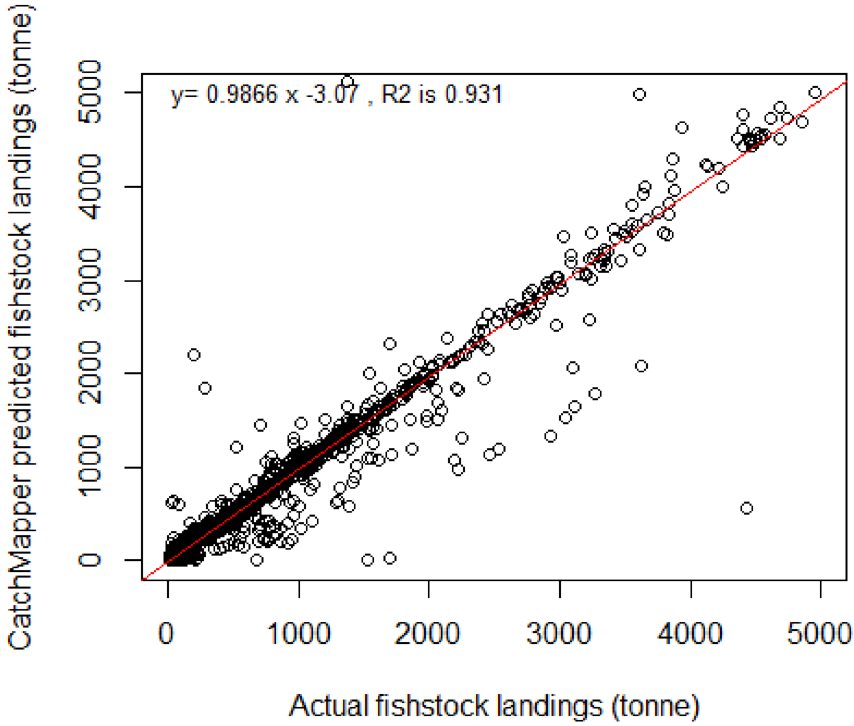


Figure 24: Distribution of fishstock scalers (ratio of actual to predicted annual landings) for all annual landings over 10 tonne. The closer to one (red lines) the better the prediction. Four percent of annual fishstock records are in the very long tails here truncated to a ratio of 20:1 on the x-axis (top) and y-axis (bottom). Hoki landings exceeding 40000 tonne are excluded from the bottom figure to show more detail for the smaller fisheries (ratios for hoki range from 0.92–1.0).



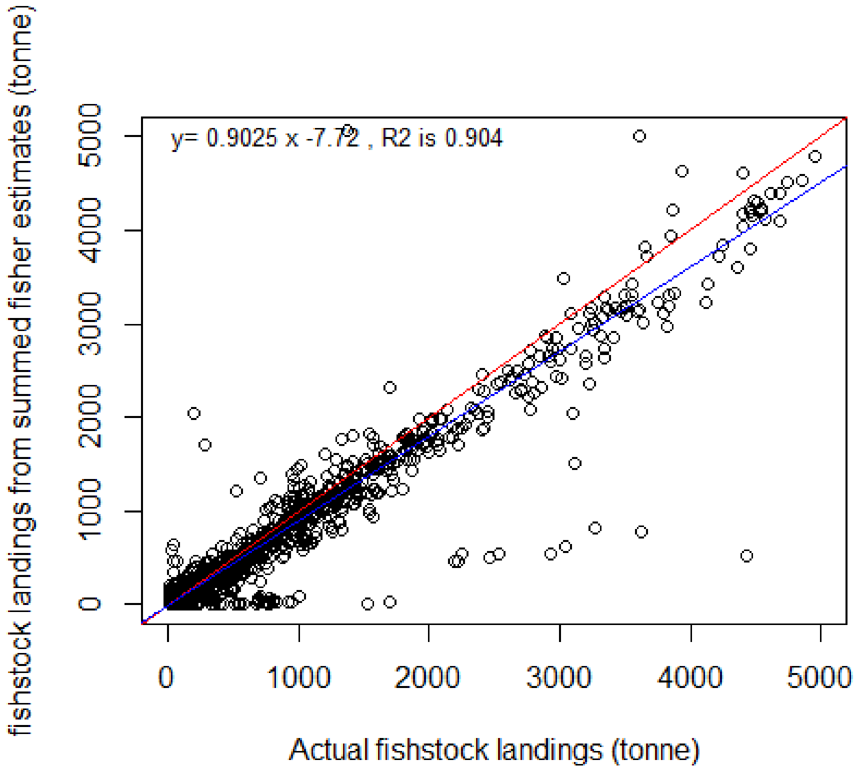


Figure 25: Comparison of predictors of annual fishstock landings for smaller fisheries (between 10 and 5000 tonnes). The CatchMapper trip landings apportioning algorithm (top) performs better than catch weight estimated at time of fishing (bottom) Red lines are x=y, blue lines are least squares and equation given (blue line underneath red line in top figure).

The performance target for the CatchMapper algorithm was to achieve fishstock scalers within a range of 0.9–1.1 for fishstocks of the largest fisheries. Figure 26 shows the distributions of annual fishstock scalers grouped by species for the 36 species with mean annual landings over 300 tonne. The CatchMapper algorithm outperforms estimated catches for nearly all of these stocks.

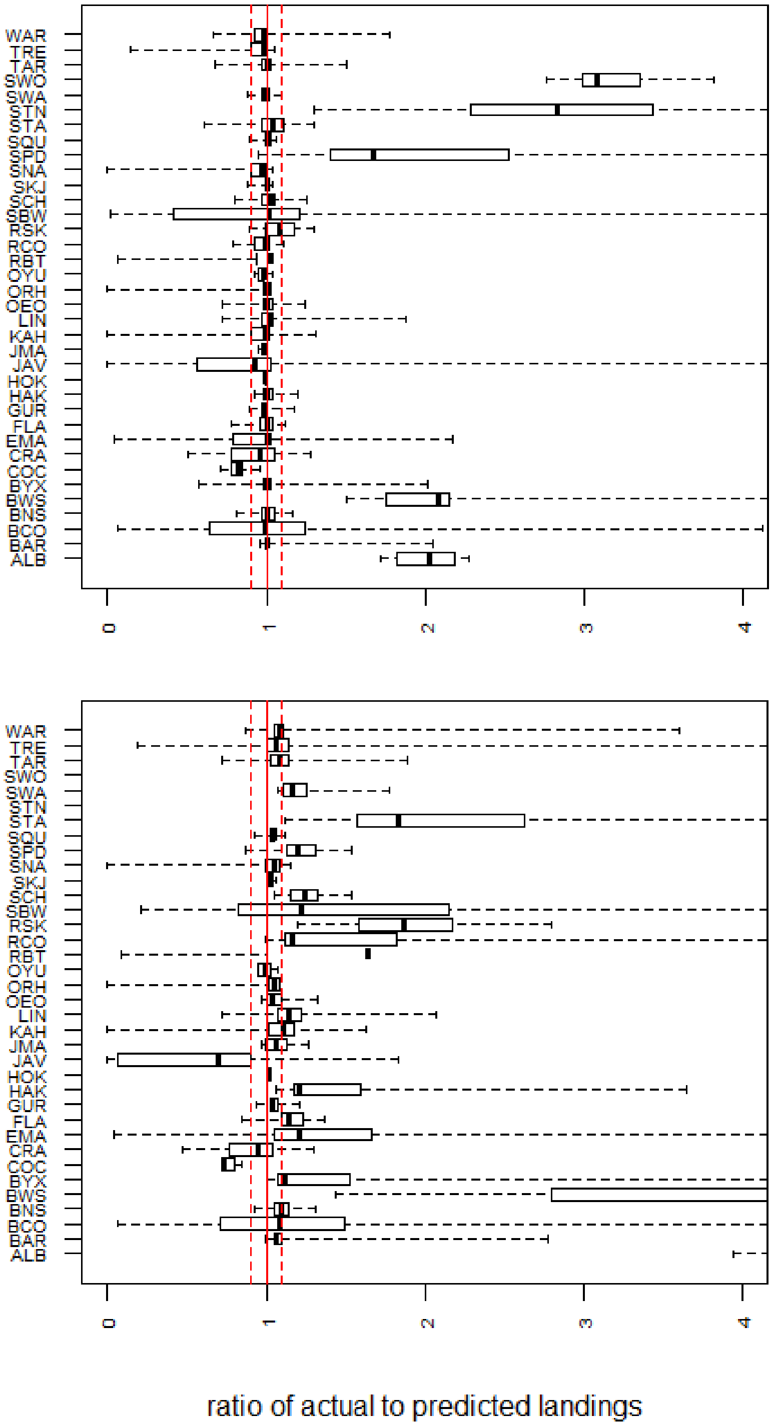


Figure 26: Comparison of predictors of annual fishstock landings for the largest fisheries. The boxplots show the distribution by species of values for actual fishstock landings / predicted fishstock landings. The CatchMapper trip landings apportioning algorithm (top) performs better than catch weight estimated at time of fishing (bottom) Solid red lines indicate ratio=1, dotted lines are the range 0.9 – 1.1.

Much of the variance in the scalers within species is due to misallocation of fishstock to the location of fishing. The comparison of actual and predicted catch by species rather than fishstock, i.e. annual scalers for adjusting predicted to actual total catch of species each year is shown in Figure 27. Here the data spread portrayed in the boxplots is annual variation in how well the algorithm performs for each species. CatchMapper's spatial catch estimator provides estimates by fishstock so that comparison can be made with annual fishstock landings and TACC. Wherever a fishstock is clearly misallocated i.e. where the query area is known to be wholly within a single fishstock, the catches for all fishstocks for the species should be summed by the analyst and reallocated to the appropriate fishstock. In this way the quality of the estimates for each species is more suitably depicted by Figure 27 than Figure 26.

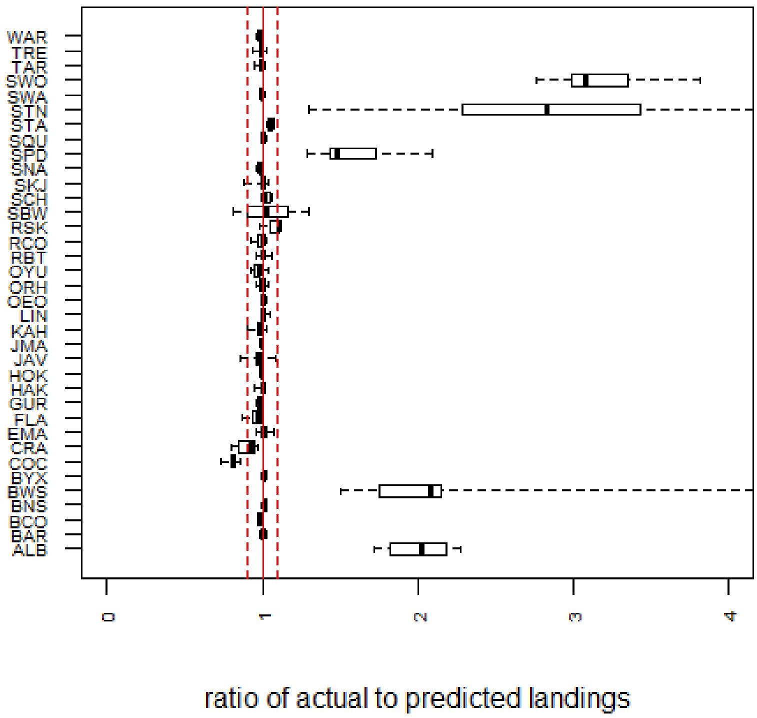


Figure 27: Quality of CatchMapper predictions for annual species landings for the largest fisheries. The boxplots show the distribution of values for actual species landings / predicted species landings. Solid red lines indicate ratio=1, dotted lines are the range 0.9 – 1.1.

CatchMapper underestimates the fishery for Spiny dogfish (SPD), predominantly a bycatch species, and the big game species and tunas (BWS, STN, SWO, ALB). Graphs and Tables in Appendix 7 give this information by year and for more fishstocks. Investigation into these stocks shows that the algorithm developed here may not perform very well where a high proportion of the landings for a species or fishstock come from case 4 and 10.2 fishing events, or a very low proportion come from case 1 events. This is the case for the six species that fall outside the 0.9–1.1 range for the ratio of actual to predicted landings shown in Figures 26 and 27; those underestimated (ABL, SWO, SPD, STN, BWS) and one species overestimated (COC) (Figure 28). Case 4 is where only some of the catches were landed directly for sale and the rest were otherwise disposed or transferred somewhere before landing; and case 10.2 is where either the landings were missing or orphaned in the database or none of the catches were landed directly for sale but were all transhipped or retained or stored somewhere before landing. Figure 28 shows the relative numbers of events in each case of the six poorly represented species and four others where the algorithm performs well.

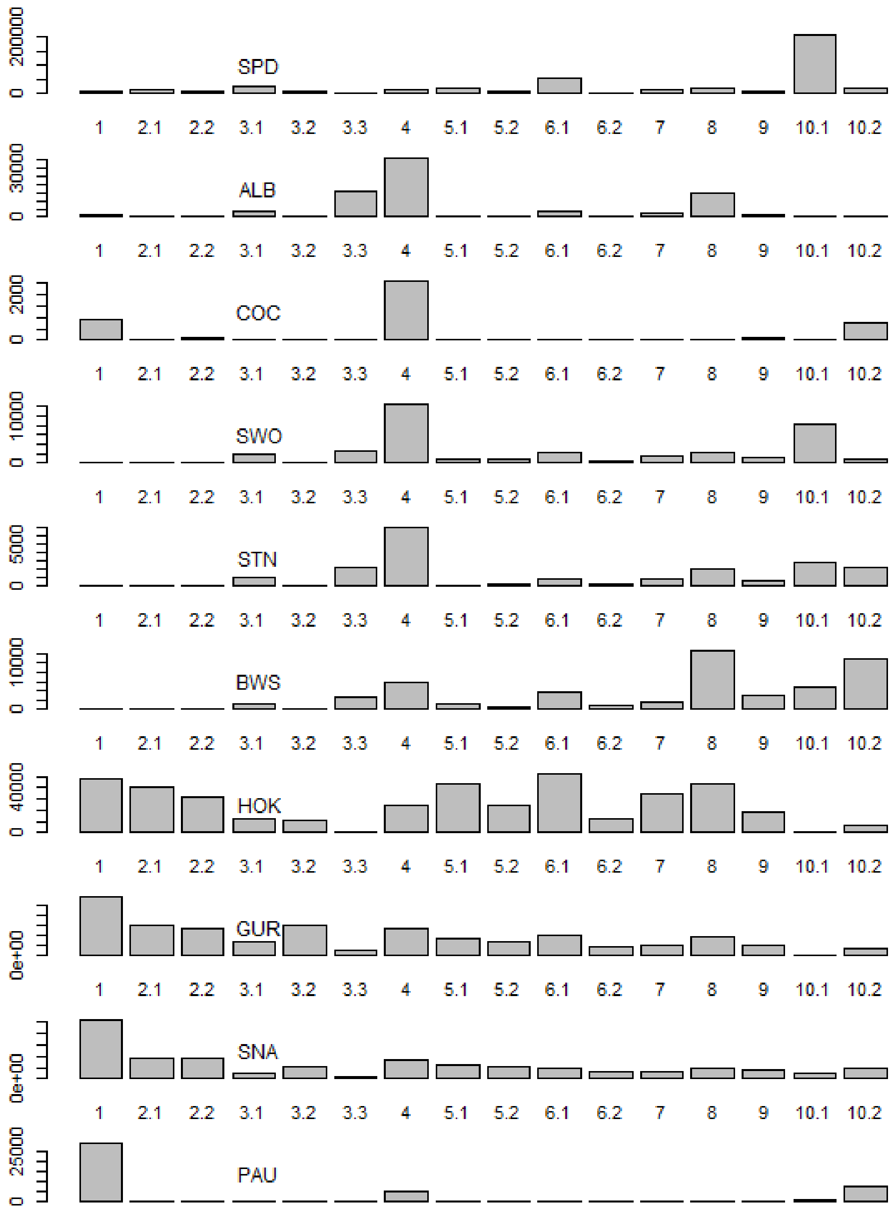


Figure 28: The number of species catch events that fall into the different algorithm cases for a range of species including the ones where the algorithm performs poorly (top six) and some where it performs well. The numbers for all species combined are given in Figure 19 for comparison.

SPD and COC are species where a portion of the catch is often returned to sea. The mismatch between catch and landings for the tuna and game species has not been further investigated but may be exacerbated by the requirement to use different units of amount of catch and landings. Catches are estimated by numbers of fish but landings should still be recorded in greenweight tonnes. As for scallops there may be a mix of units used by different fishers through misunderstanding of the requirements, or the CatchMapper algorithm may need to be adjusted to account for the different units used for estimated catch and landings.

The annual scalers for all fisheries over 10 tonne annual average landings are given in Appendix 7. Applying adjustment scalers to all species landings estimates helps to improve the spatial catch estimates made using CatchMapper especially for those with poor matches between catch and landings in the database.

5.7 Other reference tables

5.7.1 GIS LPUE Look up tables

The lpue and cpue tables are replicated and condensed to match the fishing event polygons. The low resolution fishing events that are aggregated into monthly fishing polygons have their catch rates also aggregated to give a 1:1 relationship between the spatial database and lpue and cpue look up tables.

5.7.2 NIQs and Fishstocks

So far these look up tables are based on species rather than fishstock. Many fishing trips range widely and cross stock boundaries. For this reason the landings apportioning is done at the species level and then species landings by fishing events are changed to fishstock landings based on the location of the fishing event. The EEZ is subdivided into sections that locate a single fishstock for each species (Figure 29) by performing a GIS union of all QMAs for all species.

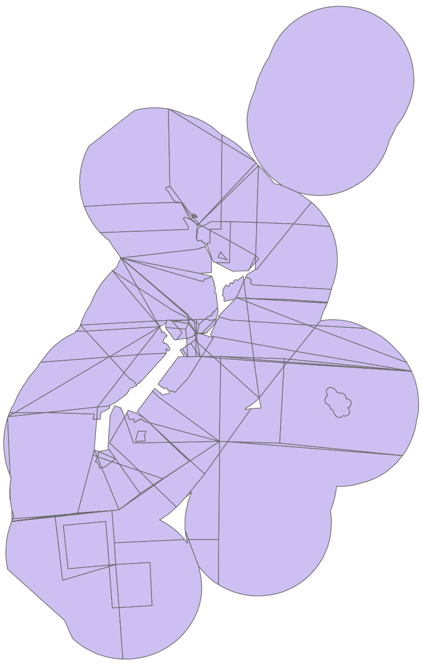


Figure 29: The geoprocessing union of all QMAs gives a set of non-intersecting polygons that in various combinations define the boundaries of all QMAs. Minor slithers less than 1 ha are removed.

Every fishing event polygon is located into one of these non-intersecting QMA sections (NIQs) and a look up table identifies which species fishstock each polygon lies within. Associating each fishing event with the NIQ where the majority of the fishing event lies should allocate event species landings to the correct fishstocks. In CatchMapper the NIQ where the fishing polygon centre lies is automatically assigned to that event. Some of the NIQs are quite small and fishing polygons might overlap several of them leading to some errors in fishstock assignment to fishing events. Any anomalies identified by users where landings appear to be assigned to the wrong fishstock can be corrected by the CatchMapper administrator changing the NIQ associated with the relevant fishing events.

5.7.3 Average Annual Landings

An annually updated look up table of average annual landings by fishstock is used by CatchMapper to calculate and report the percentage of fishstock landings that occur in the area of a spatial query (Figure

30A). This table is also used as the source of actual landings for calculating the fishstock scalers discussed above.

5.7.4 Total Vessel – Permit holder landings

An annually updated look up table of total annual landings by Client-Vessel key is used by CatchMapper to calculate and report the percentage of fisher's landings that occur in the area of a spatial query (Figure 30C).

6. Estimating Spatial catches

CatchMapper was designed primarily as a tool for fisheries analysts to assess the amount of fishing that might be affected by spatial allocation proposals for purposes such as marine farms and marine reserves. CatchMapper maps, covered in the next section, allow the relative importance of fishing grounds to be visualised. CatchMapper spatial queries provide data and summary reports on the amount and type of fishing, number of fishers and proportion of fishers' activity occurring within the area of interest.

CatchMapper spatial queries involve selecting and clipping all the fishing polygons that intersect an area of interest. A list of individual fishing polygon ID numbers and corresponding area of the clipped polygons (quantity of spatial overlap between fishing polygons and area of interest) is obtained from the spatial query of the CatchMapper GIS database containing all the fishing polygons.

The resulting data is loaded into the R statistical program and linked to data on the amount of effort in each fishing event, the original area of the polygon, and catch and landings look up tables for each fishing polygon. The proportion of effort in each fishing event occurring within the area of interest is calculated as the ratio of the area of clipped fishing polygons to the area of the original polygons.

The amount of effort by fishing event is transformed into catch or landings by fishing event and then summarised by type of fishing event (Figure 30A).

6.1 Quality indices

CatchMapper provides point estimates of the annual mean landings of fishstocks by area and selection of fishing years. It is not able to quantify the uncertainty around the means. However, some qualitative indices have been developed and included in the standard report (landings by gear type) to guide fisheries analysts in how much weight they can give the reported information (Figure 30A).

6.1.1 Percentage of estimate from polygon type.

As discussed earlier, CatchMapper polygons are ranked A, B or C depending on the resolution of the location data for fishing events. The percentage of any particular fishstock landings estimate that comes from either A (high resolution) or C (low resolution) polygons is provided. The higher the percentage of the estimate that comes from 'A' polygons the higher the confidence in the accuracy of the estimate.

A

Fishstock	All	TRAWL	SEINE	DREDGE	NET	LINE1	DANISH	LINE2	HAND	POT	JIG	PercentHighRes	PercentLowRes	EstCatch	CLRatio	AvQMAScaler	AnAvLandings	percentOfQMALandings	confidence
AnAvEffort	0	7083421057	36.36	678.24	814773.46	206991.77	716.25	3966.74	1595.95	113312.51	5								
AnAvLandings	4277632	1925894	1002252	363103	258409	181574	149067	146547	136404	113546	836	51	49						
SKJ1	831468	4	830408	0	0	0	0	1056	0	0	0	0	100	366544	0.44	1.93	10199754	8.2	LOW
BAR7	349824	346604	543	0	6	11	456	2201	0	0	4	99.2	0.8	318299	0.91	1.01	8003773	4.4	HIGH
FLA7	344732	245523	0	40	22140	0	76387	643	0	0	0	76.5	23.5	280487	0.81	1.05	782672	44.1	HIGH
COC7A	310344	0	0	310344	0	0	0	0	0	0	0	0	100	358093	1.15	0.89	279438	111.1	MEDIUM
RCO7	268121	239423	0	1	208	102	27769	607	0	11	0	89.4	10.6	227180	0.85	1.03	1788386	15.0	HIGH
GUR7	239677	220993	0	5	741	166	17700	71	0	0	0	92.7	7.3	219932	0.92	1.02	680414	35.2	HIGH
SCH7	182981	45135	0	2	45005	90251	2534	54	0	0	0	54.2	45.8	150568	0.82	1.06	634102	28.9	MEDIUM
SNA7	156214	148399	0	1	3242	2198	2343	25	0	5	0	98.3	1.7	157057	1.01	0.95	204763	76.3	HIGH
ALB1	138127	153	73	0	8	8	0	137885	0	0	0	0.1	99.9	55425	0.40	1.69	2787550	5.0	LOW
SPO7	132213	34334	0	3	91609	49	6215	0	0	1	0	90.8	9.2	117096	0.89	0.99	230048	57.5	HIGH
WAR7	125366	115884	30	0	9451	1	0	0	0	0	0	99.9	0.1	115693	0.92	1.02	633695	19.8	HIGH
SUR7A	119212	0	0	4365	0	0	0	0	114847	0	0	0	100	113989	0.96	1.02	124577	95.7	LOW

B

gearType	nfishers	nfishersOver100kgpa
DANISH	12	12
DREDGE	15	15
HAND	47	46
JIG	3	3
LINE1	40	40
LINE2	179	178
NET	76	74
POT	53	52
SEINE	9	9
TRAWL	75	75
Total	315	310

C

Fisher	LandingsInArea	TotalAnnualLandings	percent
31	1261.6	1261.6	100
32	7860.2	7868.5	99.9
33	12.9	12.9	99.8
58	114421.4	134547.4	85
59	43083.6	51131.2	84.3
60	3081.3	3713.6	83
61	1480.4	1832	80.8
62	13680.2	17055.5	80.2
63	742.3	927.4	80
88	543.9	976.1	55.7
89	26217.4	47358.4	55.4
90	10.6	19.2	55

D

	Total	BT_FLA_BT_A_	BT_GUR_BPT_A_	PS_MIX_PS_A_	PS_MIX_PS_C_	SN_FLA_SN_A_	SN_FLA_SN_C_
Qual	NA	A	A	A	C	A	C
method	NA	BT	BPT	PS	PS	SN	SN
cluster	NA	BT_FLA	BT_GUR	PS_MIX	PS_MIX	SN_FLA	SN_FLA
gear	NA	TRAWL	TRAWL	SEINE	SEINE	NET	NET
AnAvEffort	NA	1633566648	97230	1.625	15.125	103898.2605	127890.0471
AnAvLandings	4277632	171141	8	27398	973553	13546	11175
SKJ1	831468	0	0	288	830120	0	0
BAR7	349824	2253	0	474	69	1	0
FLA7	344732	95628	0	0	0	12853	6051

Figure 30: Samples of reports available from CatchMapper where a selection of fishing events is made by area and a list of fishing years to include is specified by the user. A: Annual average landings in area by gear type with the quality metrics explained in Section 6.1 of the text. B: Number of fishers fishing in area. C: Extract from report on % of fishers annual landings coming from area (each row refers to an anonymous permit holder and vessel). D: Extract from report the same as A but by cluster and method (without quality metrics). Another report available has full details on every fishing event in the area that fisheries analysts can do their own analysis on.

6.1.2 Catch vs Landings.

CatchMapper provides estimates of catch based on both the weights estimated by fishers for each fishing event at the time of fishing, and weights measured at the end of the trip, when the catch is landed, back calculated to each fishing event. The landings-by-gear-type report includes total landings and total catches estimated by fishers for comparison. The ratio between the two is also calculated.

6.1.3 Mean annual scaling factor

The mean annual scaling factor for each fishstock corrects predicted annual landings to match actual annual landings against fishstock quota. This factor indicates how well CatchMapper predicts landings at the spatial scale of fishstock management areas. This factor was already applied to the landings estimates in the report.

6.1.4 Percent of Quota Management Area Landings.

If the estimated annual average landings are more than 100% of the annual average QMA landings then clearly they are overestimated.

6.1.5 Confidence Ranking

An overall confidence ranking of high, medium or low. If at least 70% of an estimate comes from ‘A’ polygons the confidence ranking is given as high. Conversely, if at least 70% of an estimate comes from C’ polygons the confidence ranking is given as low. If no more than 50% of the estimate comes from ‘A’ polygons but at least 70% of the balance comes from ‘B’ polygons then the confidence ranking is given as medium. Subsequently, if the fishstock scaler is greater than 1.5 or less than 0.5 the confidence ranking is set as low. Finally, if the confidence ranking is high but the fishstock scaler is greater than 1.2 or less than 0.8 then the confidence ranking is downgraded to medium.

A future enhancement to the query report would be to provide the range and CV of the annual landings estimates to indicate the interannual variation. Additionally, a comparison of the size of the spatial query in relation to the size of the low resolution fishing polygons should be used to modify the assessment of confidence of estimates based on these ‘C’; polygons. If the area of interest is large the relative confidence improves.

6.2 Metadata/caveats

CatchMapper reports and maps are often utilised by third parties subject to suitable aggregation to protect privacy and commercial sensitivity. An example of the sort of explanation and caveats that accompany CatchMapper maps and spatial fishing estimates is provided in Appendix 6.

6.3 Assessment of Effects on Fishing

The reports illustrated in Figure 30 provide Fisheries Analysts within MPI with quantities and characterisation of all commercial fishing that occurs in a specified area and that may be affected if the use or status of the area were to change. This information is the basis of assessing the effects of other activities on fishing. The measure quantified can be either fishing effort or catch, in absolute units or as a percentage of the annual average fishstock landings. A selection of years back to 0708 can be chosen to give an annual average metric. The number of fishers that will be affected based on their past patterns of fishing and the proportions of their fishing income affected can be estimated. Running these analyses is a rapid and easy routine within MPI.

6.4 SeaSketch reports

Making this type of analysis available to a wider audience for specific marine planning purposes has been achieved with the help of the Department of Conservation and their online tool SeaSketch. A SeaSketch project involves a specific planning area. The example shown in Figure 31 is the South-East Marine Protection Forum (SEMPF) area. Rastered and confidentialised heat maps (see Section 8 below) are provided from CatchMapper into SeaSketch to give a visual display of fishing. These maps can be separated into different types of fisheries. Gear type is a useful classifier for this purpose. Figure 31 shows the choice of 7 maps for display in the SeaSketch SEMPF project.

Additionally, two types of information are provided about commercial fishing within any area sketched on a map in a SeaSketch project: (1) The amount of fishing that would be displaced from the area if fishing was prohibited (as a percentage of the total for each fishery within the planning project region), and (2) the relative quality or specialness of the fishing grounds within the sketch area. The fishing grounds are ranked as High, Medium or Low based on the intensity of fishing that occurs there. In general we applied a classification scheme defining the top 20% of space in terms of annual average catch per unit area as high intensity or quality, the bottom 50% as low intensity and the middle 30% as moderate intensity. These two metrics indicate the regional impact and the very local impact, respectively. In the SEMPF case these two metrics are calculated at the cluster level of classification to ensure that any small but locally important fisheries are accentuated. Whereas the gear type fisheries are displayed as confidentialised maps the cluster fisheries maps are kept confidential by being hidden from view and the data is only available as summary reports (Figure 32).

Metadata for the maps supplied to the SEMPF SeaSketch project is given in Appendix 6 as an example of the type of instructions and caveats included with the release of CatchMapper products outside of MPA.

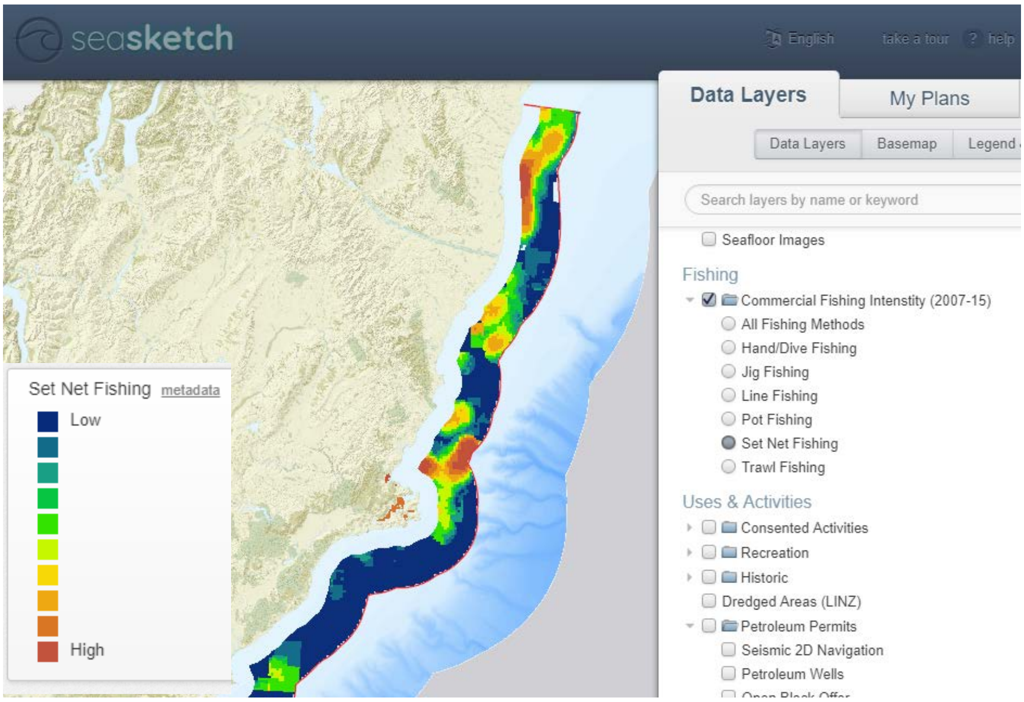
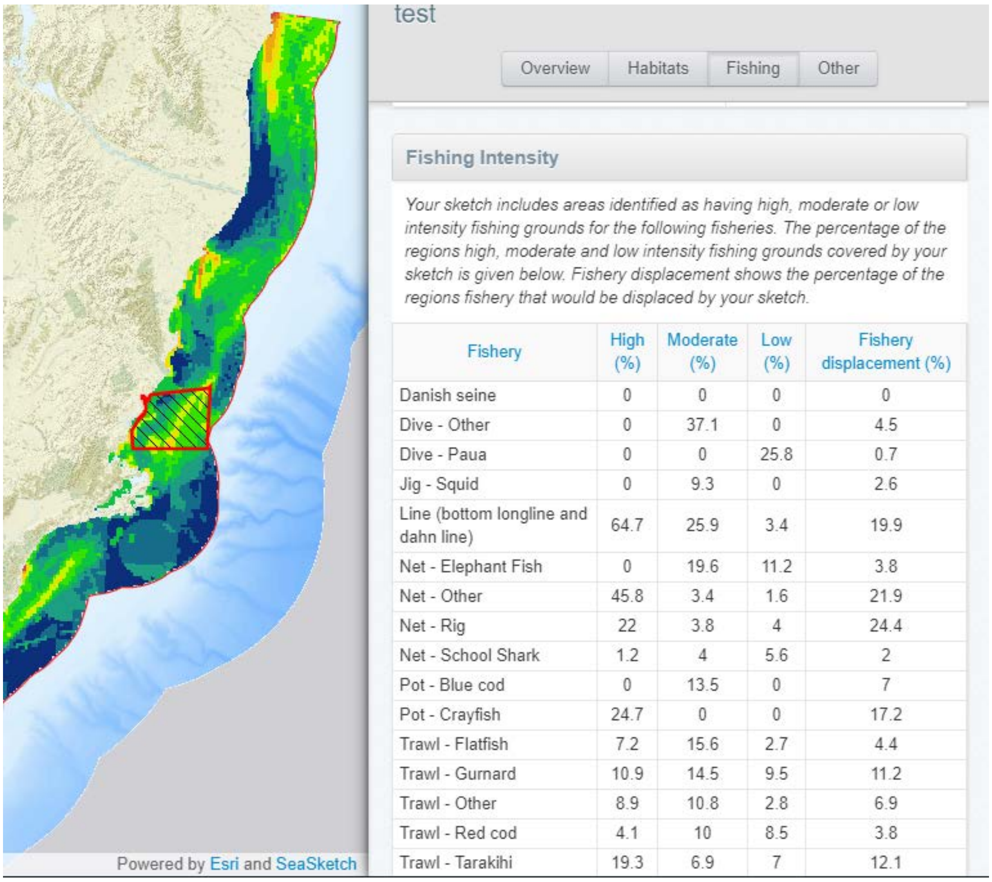


Figure 31: A CatchMapper map shown online in SeaSketch. Each of seven maps can be selected and viewed. The maps are summarised fishing events grouped by gear type.



Fishery	High (%)	Moderate (%)	Low (%)	Fishery displacement (%)
Danish seine	0	0	0	0
Dive - Other	0	37.1	0	4.5
Dive - Paua	0	0	25.8	0.7
Jig - Squid	0	9.3	0	2.6
Line (bottom longline and dahn line)	64.7	25.9	3.4	19.9
Net - Elephant Fish	0	19.6	11.2	3.8
Net - Other	45.8	3.4	1.6	21.9
Net - Rig	22	3.8	4	24.4
Net - School Shark	1.2	4	5.6	2
Pot - Blue cod	0	13.5	0	7
Pot - Crayfish	24.7	0	0	17.2
Trawl - Flatfish	7.2	15.6	2.7	4.4
Trawl - Gurnard	10.9	14.5	9.5	11.2
Trawl - Other	8.9	10.8	2.8	6.9
Trawl - Red cod	4.1	10	8.5	3.8
Trawl - Tarakihi	19.3	6.9	7	12.1

Figure 32: An example fisheries report available in SeaSketch by online drawing a sketch on a planning map. The example sketch is the hatched area with red boundary and the report on fishing intensity indicates the importance of fishing within the sketch relative to the whole planning area (boundary of the heat map). The report gives values at the level of fishing clusters so the set net fishery displayed in Figure 31 is split into four net fishing clusters in this report.

7. Mapping fishing events

The collection of fishing polygons are used for providing spatial estimates of the amount and type of fishing but they are not very useful for visualising fishing intensity patterns. Neither are maps showing points of start positions as they overlap and don't show density once an area is covered with points. An improved version of mapping start points is to map the count of start points in grid cells and counts can be classified into ranges shown with different colours to display intensity. However start positions can be misleading in the case of fishing methods that cover a lot of space such as trawling and surface longlining. Examples of start points, grid cell counts and CatchMapper heat maps are shown in Figure 33.

Heat mapping is a term used to refer to intensity maps that use the intuitive rainbow colour scheme of blue = cold = low through to red = hot =high. Colour schemes other than rainbow colours can be used and defined in a legend and would be more informative for those with red-green colour blindness. The advantage of the rainbow colours is that the scale is immediately recognisable even without a legend. At the moment CatchMapper maps continue to be produced in rainbow colours but a better colour scheme could be developed.

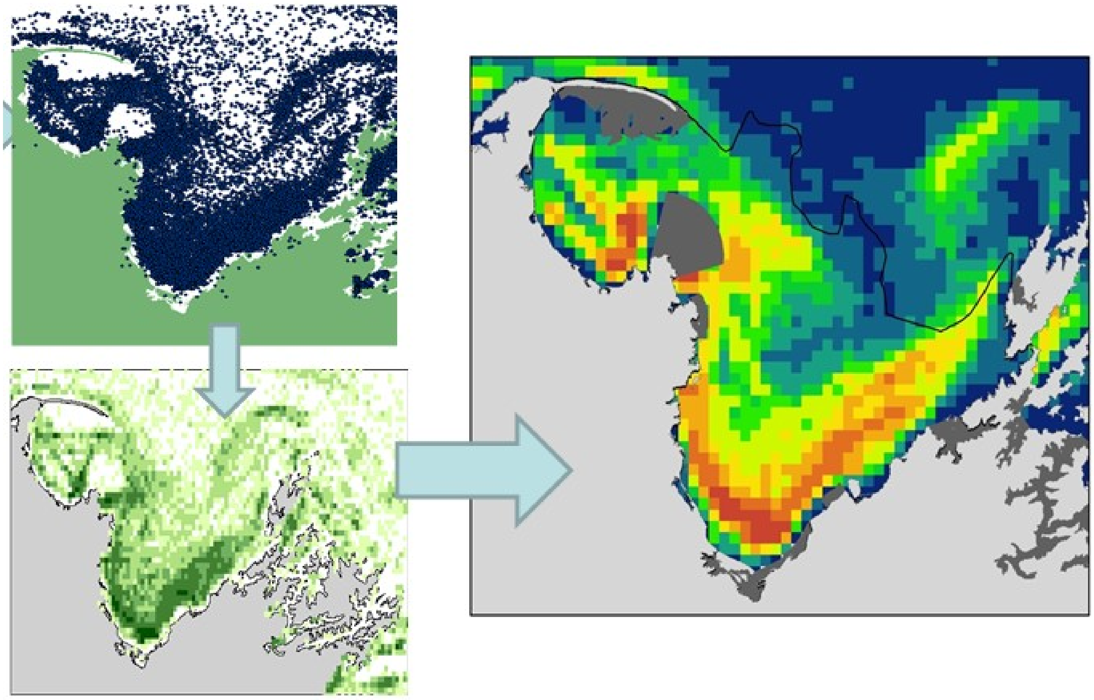


Figure 33: Option 1 just plotting fishing event start points (upper left). Option 2 counts of start points shown with colour intensity. Option 3 CatchMapper heat maps.

At the beginning of CatchMapper development, fishing intensity was mapped as the amount of fishing effort per unit area. Now the most common maps are total catch weight per unit area (based on estimated total catch weight at the time of fishing). The former were more easily interpreted and focused on fishing as an activity but could only be aggregated to the level of different gear types as the units of effort differ between gears. The latter grouped catch weight of all species and could be misleading in terms of the relative value or importance of the catches. However the latter maps can be aggregated across gear types and provide useful summaries of all fishing.

CatchMapper was designed to quickly and easily produce maps of comparative fishing intensity for almost any grouping of fishing events. CatchMapper can provide a user-defined grouping by fishing event keys or trip keys or date but the need for this level of specificity in grouping is likely to be rare, especially given that the former two variables are generated by MPI's database. The following variables are more likely to be useful for selecting groups of fishing events and CatchMapper is set up to readily provide these variables for user-defined queries.

CatchMapper classification variables:

- Gear
- Fishing Method
- Key for combination of Vessel and Permit Holder
- Cluster
- Target Species
- Statistical Area
- Year
- Month
- Map Quality rank
- Bottom contact flag

- Vessel size category (proposed)

To achieve this flexibility every mapped fishing event (or monthly aggregate of low resolution fishing event) is converted into a pixelated image called a raster.

There are two ways to produce gridded or pixelated images, either

1. by overlaying a grid of cells, each cell defined by corner coordinates, and calculating the amount of the underlying fishing polygon value in each cell, or,
2. rastering, whereby a set of pixels are defined by rows and columns within a rectangular extent and the value in each pixel is taken as the underlying value at the pixel centre.

The former is more precise assuming the underlying polygons are accurate but the latter is faster and stores the information in a more efficient manner and is more flexible. Raster images can be quickly and easily combined using raster algebra within GIS software. If needed, rastering can obtain very similar results to the grid cell calculations by starting with very small pixels and aggregating them into larger pixels with averaged values. For example 400 × 50m square pixels can be aggregated into a 1000 m square pixel, the value of which is the mean of the 400 small pixel values. This is a very close approximation to an area weighted sum of underlying polygon values.

CatchMapper's raster library contains a fishing intensity image (total catch of all species per unit area) of every fishing polygon in the spatial database at 1 km ×1 km pixel size. The high resolution fishing polygons for each individual fishing event are rastered directly to 1 km^2 pixels as shown in Figure 34B. This process increases the area that represents the spatial coverage of each fishing event but given the uncertainty in the area covered by each event, pixelating the polygon representation of an event is considered to be acceptable. The alternative is to raster each fishing polygon at 50 m resolution and aggregate to 1 km^2 as in Figure 34D.

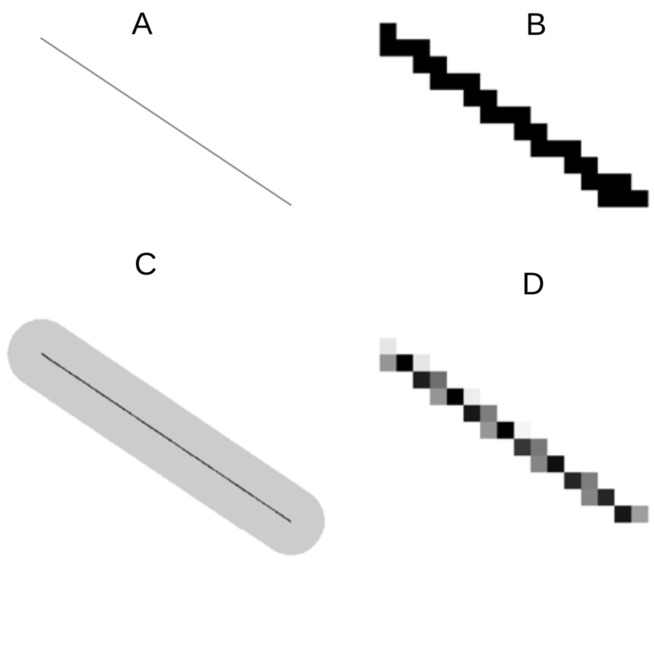


Figure 34: Edge effects in rasters depending on how they are created. Trawl polygon A can be rastered to 1 km2 resolution by assigning all intersecting pixels the same catch per unit area value (after calculating the area of all the intersecting pixels and taking that as the area swept) or it can be rastered with a pixel resolution of 50 m (C) with a background value of zero (light grey) and then pixels aggregated to 1 km2 (D). D is an accurate area weighted mean of the amount of the trawl polygon that falls within each pixel.

The low resolution fishing event polygons are based on the library of fishable area polygons which generally do not change from year to year. Each year a new set of values for the amount of fishing occurring in the previous year are assigned to the fishable area polygons and their rasters. The polygons are used in spatial queries as discussed in the previous section and the rasters are used for building heatmap images. In this case the library rasters are created by aggregating 50 m rasters up to 1 km resolution. This only has to be done once and then annual values are assigned to create the low resolution fishing event images each year. If the fishable areas were rastered directly to 1 km resolution and then combined, the fishing intensity at the boundaries between fishable areas (often based on statistical areas) would be overestimated (see Figure 35). This may seem a minor issue but can give users of maps low confidence in their values.

In CatchMapper, 1 km^2 pixel size rasters of the low resolution fishing polygons are created from 50 m pixel rasters so the fishing intensity value is an average of 400 sample points within the 1 km^2 area of each pixel. The 50 m rasters are created using the FME software package by Safe Software Inc which has a very efficient way of rastering polygons within tiles without having to clip the polygons to the tiles. The area surrounding each polygon is buffered with a value of zero (rather than no data) so that the mean of 50 m rasters accurately represent an area weighted mean at the 1 km^2 resolution. Aggregating 50 m rasters by a factor of 20 on each dimension is performed with the R raster package as is summing groups of rasters into summary images by groups of fish events.

Figure 35: When low resolution fishing polygons, such as these 3 cod potting statistical areas, are rastered directly to 1 km2 pixel size the boundaries between them get added together and overestimated causing annoying change in intensity colour at the boundaries. More accurate edge values are obtained by using the approach described in Figure 34 C and D.

The rasters for any groups of fishing events can be combined to create a fishing intensity image. The groups can be selected with a polygon using GIS software. Creating an image by combining a large number of fishing events is time consuming so the most common groupings have already been combined and stored in an image library.

Map units of fishing intensity can be changed to any value that is known for all fishing events such as the default catch per hectare (all species estimated catch), effort per hectare required for trawl footprints), landings per hectare (all species apportioned event landings), catch per unit effort, or catch or landings of a particular species or group of species (e.g. maps of snapper catch produced for Hauraki Gulf for the planning exercise Sea Change, see Figure 36). Maps in the default units and by one of the common groupings can be produced in short time frame and added to a web service for users to access directly. Custom maps in different groupings or different units take a bit longer to produce.

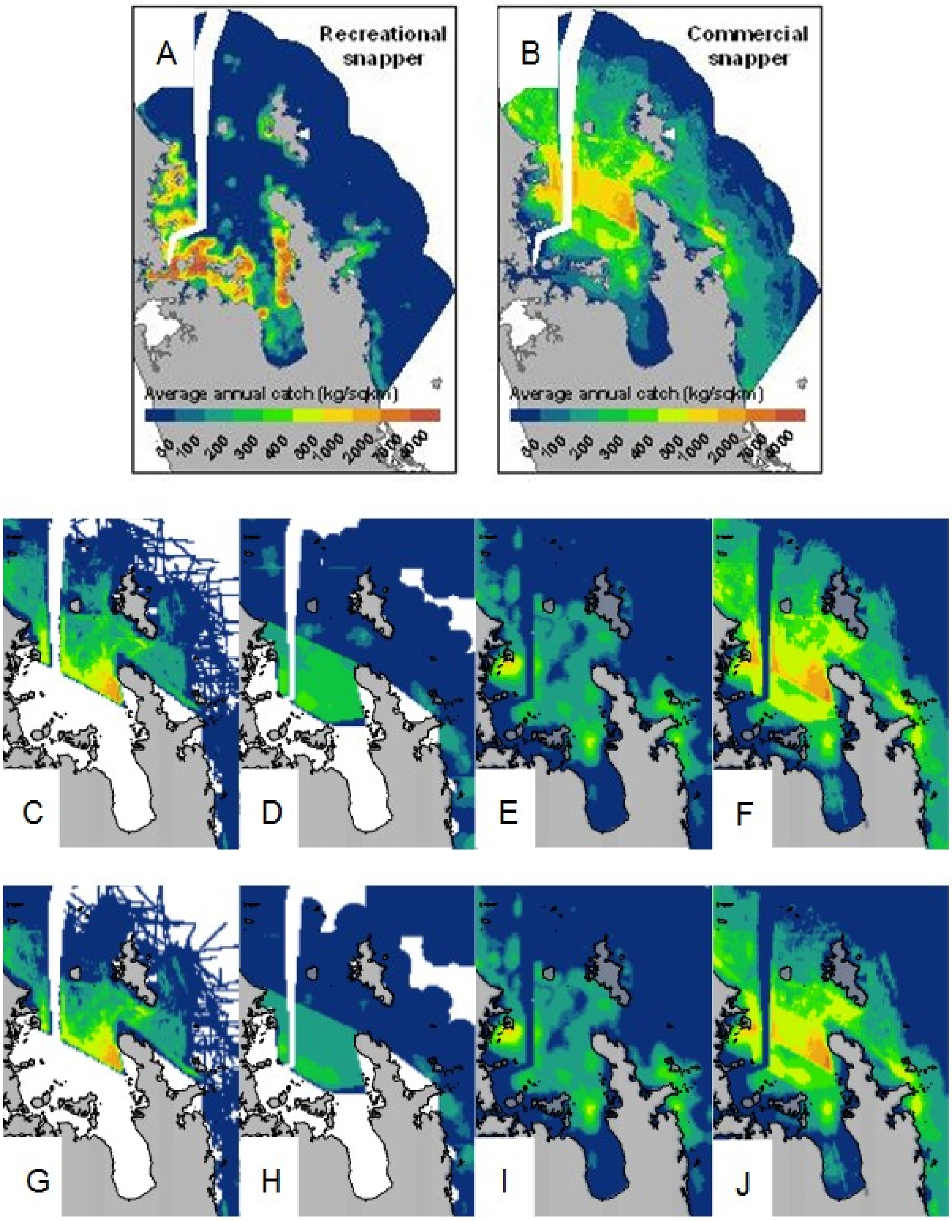


Figure 36: CatchMapper heat maps can summarise fishing from a variety of classifications. These images all show snapper fishing in the Hauraki Gulf but with subtle differences. A: catch of snapper by recreational line fishing, B: catch of snapper by commercial fishing, C-F: Total catch of all species in fishing events that predominantly catch snapper (snapper clusters) by trawl, Danish seine, longline and all methods combined. G-J Total catch of all species in fishing events that report targeting snapper by trawl, Danish seine, longline and all methods combined. All maps use the same units as shown in panels A and B.

7.1 Confidentialising

MPI's policy on protecting privacy and commercial sensitivity values of fisheries data for public release (data which is supplied by commercial fishers) requires that summary values must aggregate data from a minimum of 3 permit holders or vessels. Most maps produced for public release from CatchMapper are highly aggregated to the level of annual averages by gear type. Furthermore, the value scale may be left without any detail on the absolute magnitude of catch intensity only indicating the relative scale of colours from high to low intensity.

However, even at the highest aggregation of catch from all methods and all years combined, there are some 1 km^2 pixels that summarise data from fewer than 3 vessels or permit holders. To ensure maps for public release comply with policy settings a process of confidentialising maps has been developed. This process involves adaptively aggregating individual pixels until the minimum level of summarising is achieved. Starting with 1 km^2 pixels, all those pixels that don't meet the criteria for minimum number of vessels and permit holders are aggregated through a series of 2, 5, 10, and 50 km^2 and up to the level of statistical areas as required until the criteria are met for each pixel. Figure 37 shows the differences which are barely detectable at a small map scale and the different pixel sizes illustrated for an anonymous example at a large map scale.

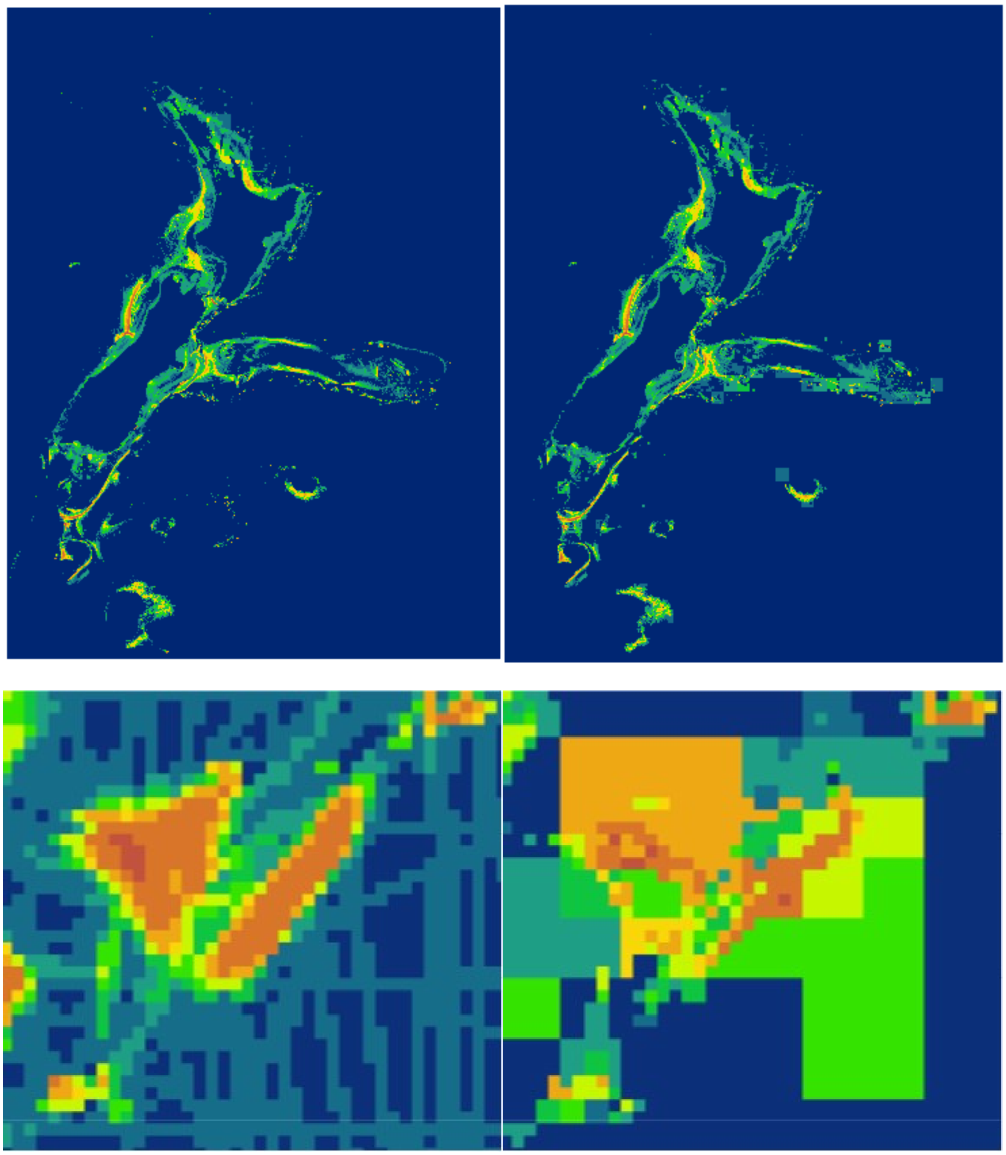


Figure 37: Maps at two different scales showing the average annual catch intensity of all species and all fishing methods combined displayed with 1 km2 pixels (left) and adaptive pixel size that meets aggregation criteria (right).

7.2 Displaying Images

Raster images of coastal fishing will appear to overlap land and areas closed to fishing due to the pixelated effect. Maps to be used for planning purposes at scales relevant to coastal marine planning are usually converted from rasters into vector shapes and then clipped to the coastline and closed areas to avoid confusion.

7.3 Trawl Footprints

MPI requires trawl footprint polygons to be produced and analysed annually to maintain a time series of metrics on the amount of seabed contacted by trawling. To date the annual building of CatchMapper trawl polygons duplicates the trawl footprint work. One of the products from trawl footprint analysis is also a set of raster images of trawl fishing intensity which are also produced in CatchMapper. To date, the annual data extracts, data grooming and building of trawl event polygons for CatchMapper and the trawl footprint analysis happen independently. This can lead to slight differences between the fishing intensity maps between the two and confusion over which is the more authoritative version.

Apart from the fishing intensity maps, the other products produced by the trawl footprint analysis are not directly available from CatchMapper. These are the total coverage per cell and the number of tows per cell. Therefore, these processes have to be run in addition to CatchMapper processes. However, both sets of analysis could start with the same data extract, grooming procedures and use the same polygons that would only be built once and serve both purposes. This would also minimise any potential for differences in intensity mapping.

Differences in data grooming or the method of building of trawl polygons are not necessary for the two purposes of trawl foot printing and CatchMapper spatial catch estimating. The differences that exist could be easily standardised. Differences in the method of intensity mapping are likely to be inconsequential in the final display of images that summarise large numbers of trawl events at a resolution of 25 km^2 pixels which is the case for the intensity maps produced from the trawl foot printing analysis.

CatchMapper intensity maps offer a lot more flexibility to map a variety of different groupings of trawl events. They are also produced at a finer resolution which can be important for coastal planning purposes. CatchMapper maps can be re-pixelated at a lower resolution where this is required. To avoid confusion it is recommended that all MPI fishing intensity maps come from CatchMapper.

8. Conclusions and Recommendations

1. CatchMapper has pre-processed all New Zealand's commercial salt water fishing events since October 2007 into a form that can be easily and visually queried, summarised and characterised. The main innovation is the creation of a geospatial polygon for each fishing event that represents the best readily available information on the space over which the fishing event is thought to have occurred. Most processes have been applied with automated algorithms developed with the author's knowledge of fisheries. In many cases improvements to the data of individual or small groups of fishing events could be made with new or more specific knowledge. These improvements are encouraged via the CatchMapper administrator at MPI and in future some additional knowledge may be incorporated into the algorithms.
2. CatchMapper development excluded eel fishing and high seas fishing events only to limit the scope of the initial project. There is no reason why these events could not be incorporated.
3. It is recommended that the Fisheries Data Working Group be the mechanism for overseeing future changes to CatchMapper and integration with other routine fisheries data uses. This could start with the amalgamation of grooming scripts between NIWA, Trident, Dragonfly and CatchMapper. It is suggested that a single annual extract of all fishing events is groomed and stored for dissemination to each of the routine data summarising projects such as CatchMapper, trawl footprints and the Dragonfly and Trident web-based data summaries. This will ensure some consistency in the number of records used by each project.
4. The Fisheries Data Working Group or CatchMapper administrator should liaise with MPI fisheries data warehouse developers about solutions to any data anomalies in the warehouse and other issues arising such as the stability and reliability of fishing event keys with which grooming changes are recorded against. They should also request documentation for the Data Warehouse.
5. Assigning species landings to fishstocks could be improved for the majority of fishing trips where all landings of a species are for only one fishstock. For example, a table could be created of the number of fishstocks by species and trip in the landings data and that table could be used to adjust fishstock names in the landings by event table calculated in the estimator script.

6. Complete the work to put the CatchMapper estimator online for fisheries analysts. An application was developed in 2016 for the CatchMapper estimator on the MPI GIS portal and this project should be completed.
7. CatchMapper estimates are not precise for very small query areas relative to the size of the underlying fishing event polygons. An additional quality index could be put into the estimator reports to help analysts gauge this. For example a weighted mean (weighted by contribution to landings estimate) of ratio of query area to event polygons that overlap the query area could be a useful quality metric. However, in the case of marine farming, although each farm is very small the aggregate of them is much larger and therefore the estimate of cumulative effect is more defendable than the accuracy of an estimate for an individual farm.

9. Acknowledgements

CatchMapper was funded under MPI project SEA2016-26ORC and produced for and with the assistance of MPI's fisheries spatial allocations team. In particular the advice from Alex Thompson, Christine Bowden and Demelza Turnbull were instrumental in setting the requirements for CatchMapper's outputs.

For the last two years CatchMapper has been administered by Riki Mules of MPI's Spatial Analysis team who has continued to implement on-going improvements.

The fisheries clustering analysis was modified from that previously designed by Nokome Bentley of Trophia.

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11. Appendix 1: Compare data sources

NDW (Numeric Data Warehouse) vs WAREHOU (MPI's catch effort database)

Traditionally, fisheries data analyses were performed on data extracted from the Ministry's Warehou database which is familiar to fisheries scientists and well documented in a Ministry report (Warehou Database Documentation V9, unpubl). The CatchMapper data instead comes from the Ministry's Numeric Data Warehouse (NDW). The Numeric Data Warehouse receives data from Warehou daily and the process of transfer also re-establishes the relationships between catch, effort and landing records, grouping all vessel records within trip start and end dates. Warehou database is known to have some cases where the trip key that links effort and landings records for a trip has been lost. Therefore the NDW data should have very similar numbers of records to data taken from Warehou and may have improved identification of catch, effort and landings records within trips.

To be sure the data extract from NDW delivers the expected data and is as fit for purpose as Warehou data a comparison was performed on extracts taken at the same time from the two datasets for a subset of three years (Table A1). NDW delivers identical number of fishing events to Warehou for most form types but more events than Warehou for the CELR and PCELR form types. Also more of the events are linked by trip key in NDW than in Warehou.

Table A1: A comparison of the number of fishing trips and fishing events obtained from the NDW data source with that from Warehou, by year and by form type. The number of trips in the NDW dataset and the number and percentage of those where effort and landing records are linked by the trip key are given. The number of extra trips recoverable from NDW compared to Warehou is given as the difference in trip numbers and the difference in matched trip numbers is the extra trips in NDW that have linked landings records compared to Warehou. Likewise numbers of events and difference in the number of events between the two datasets is also given. Note PCE entries in Warehou don't have trip keys.

No. of Trips From NDW	TCE	TCP	CEL	NCE	LTC	LCE	TUN	PCE	SJC
0708	6976	1209	45687	4500	4445	210	415	2662	97
0809	7155	1202	44441	4249	4456	160	540	2424	112
0910	8031	1170	44610	4395	4686	158	573	2535	103
Matched with landings									
0708	6687	1194	45592	4495	4313	207	408	2652	2
0809	6942	1182	44351	4243	4359	147	521	2413	8
0910	7759	1134	44526	4393	4558	145	546	2523	8
% of NDW trips matched									
0708	96%	99%	100%	100%	97%	99%	98%	100%	2%
0809	97%	98%	100%	100%	98%	92%	96%	100%	7%
0910	97%	97%	100%	100%	97%	92%	95%	100%	8%
Difference in trip nos									
0708	288	14	415	1	131	2	6	2662	94
0809	212	19	484	0	96	12	18	2424	103
0910	271	35	570	0	127	12	26	2535	94
Difference in matched trip numbers									
0708	0	0	321	-2	0	0	0	2652	0
0809	14	8	423	3	5	4	0	2413	0
0910	5	7	516	6	6	3	2	2523	0
No. of Events from NDW	TCE	TCP	CEL	NCE	LTC	LCE	TUN	PCE	SJC
0708	46143	42165	63451	8543	12189	5080	1942	5372	210
0809	46862	38973	62434	7955	11811	4222	2631	4897	225
0910	53369	39106	63027	8337	13045	4458	2835	5036	237
Difference in event nos									
0708	0	0	528	0	0	0	0	232	0
0809	0	0	772	0	0	0	0	210	0
0910	0	0	1101	0	0	0	0	250	0

12. Appendix 2: Data ranges and Grooming Criteria

In this section we tabulate what changes have been made to data values in the dataset and explain grooming criteria for groups of fishing methods. The catch, effort and landings data fields used in building CatchMapper are summarised in Table A2.1 before and after grooming.

The data extracted from the MPI fisheries catch effort database have some errors likely caused by fishers writing the wrong information down as well as data entry errors. The larger the number to be written or transcribed the more susceptible to error (e.g. coordinates are likely more susceptible to errors than fishing duration). There are also some errors in the assigning of records to trips probably as a result of errors in recorded dates (see range of trip length (TripDays) in Table A2.1).

The data fields that are used to build fishing event polygons such as event length (distance) and location are groomed to remove outliers that are considered highly likely to be errors and would result in improbable fishing polygons. The missing data are then replaced with medians from other similar events. Similarly, missing landings data are imputed with mean landings per unit effort data from similar events so all required effort variables are groomed.

Light Grooming only

The box plots that follow here show that for many of the variables a large number of data points fall outside 1.5 times the interquartile range of values and could be considered to be outliers. We don't assume to know the different practices tried by fishers over the years that may have caused some unusually large or small values for fishing effort measures. CatchMapper attempts to include as much past fishing as can be retrieved from the MPI database and only a very few are groomed out of the dataset (see Appendix 3). The policy for CatchMapper data grooming has been to only remove values that are extreme outliers and to identify these at the level of fishing clusters within fishing methods (Fishing clusters further classify types of fishing by fishing method and are explained in Section 4.10). The number of records where effort variables are out of range and are replaced with medians of groups of similar fishing events are given in Table A2.2 by fishing year.

Table A2.1: Summary of fishing catch effort and landing variables used in CatchMapper.

		Raw Data						Groomed Data					
name in NDW	name in Warehou	unique number	Min.	Median	Mean	Max.	NA's	unique number	Min	Median	Mean	Max	NA's
Effort Table													
FishingEventKey	event_key	1,648,807						1,605,817					
TripId	trip	566,699						561,684					
TripNEvents *(events per trip)*	new								1.0	11.0	24.1	339.0	0
StartDatetime	start_datetime		15/11/2002			2/05/2017	209		1/10/2007			30/09/2016	136
Month	new							13					0
StatisticalAreaCode	NA	117					0						
StartStatsAreaCode	start_stats_area_code	1,118					25,699						
TrueStatArea	new							572					0
FishingMethodCode	primary_method	37					1,311	35					0
gear	new							10					0
cluster	new							128					0
nECevents *(per event)*	new								1.0	5.0	5.6	19.0	0
StartLatitude	start_latitude		-90.0	-41.5	-41.5	15.2	609,043		-90.0	-41.5	-41.5	15.2	573,634
StartLongitude	start_longitude		0.2	173.8	173.8	238.1	609,207		0.2	173.9	173.8	191.8	573,793
EndLatitude	end_latitude		-60.0	-42.6	-42.4	-7.4	1,288,437		-53.9	-42.2	-42.1	-17.1	822,667
EndLongitude	end_longitude		18.4	174.4	174.0	205.9	1,288,437		17.1	173.5	173.5	191.6	822,667
FormType	form_type	14					0		9.0				0
TargetSpeciesCode	target_species	219					10,980		201.0				0
FishingDepth	effort_depth		0.0	98.0	217.8	7,451.0	879,423		0.0	96.0	212.7	7,451.0	842,433
BottomDepth	bottom_depth		0.0	108.0	226.4	11,210.0	730,028		0.0	105.0	221.8	11,210.0	694,442
TotalCatchWeight	TotalCatchWeight		0.0	300.0	2,301.0	1,001,000.0	4,843		0.0	305.0	2,345.0	1,001,000.0	0
calcTotalCatchWeight	new								0.0	440.0	2,121.0	1,001,000.0	0
FishingDuration	fishing_duration		0.0	4.0	5.6	99.8	442,010		0.0	4.0	5.6	99.8	405,203
EffortCount	effort_num		0.0	1.0	17.8	10,100.0	259,228		0.0	1.0	17.9	10,100.0	223,934
EffortWidth	effort_width		0.0	25.0	46.1	9,120.0	535,070		0.0	25.0	46.3	9,120.0	498,862
TotalHookCount	total_hook_num		0.0	1,000.0	1,617.0	36,000.0	1,412,946		0.0	1,000.0	1,621.0	36,000.0	1,370,958
LineLength	effort_length or total_net_length		0.0	3,000.0	3,762.0	138,000.0	1,478,576		0.0	3,000.0	3,780.0	138,000.0	1,436,476
length	new								6.0	16,670.0	19,510.0	165,400.0	672,229
length2	new								6.7	17,890.0	20,990.0	301,300.0	1,250,876
EffortTotalCount	effort_total_num		0.0	50.0	62.0	3,535.0	1,289,931		0.0	1.0	21.7	3,535.0	581,029
TotalNetLength	total_net_length		0.0	700.0	882.1	80,000.0	1,394,518		0.0	700.0	882.7	80,000.0	1,351,561
TrawlSpeed	effort_speed		0.0	3.0	3.1	1,200.0	880,926		0.0	3.0	3.1	1,200.0	843,941
Door.Spread	new								40.0	70.0	104.0	200.0	
halfwidth	new								20.0			100.0	841,728
effort	new								0.0	3,000.0	1,230,000.0	29,970,000.0	0

Table A2.1 cont.

		Raw Data						Groomed Data					
name in NDW	name in Warehou	unique number	Min	Median	Mean	Max	NA's	unique number	Min	Median	Mean	Max	NA's
VesselNameWithVesselId	vessel_name + vessel_id	1,722					10,980	1,721					10,043
PermitHolderNameWithClientNo	client_name + client_no	1,651					10,980	1,547					10,072
CV_ID	new								1.0	402.0	772.4	3,229.0	10,072
OverallLengthMetres	overall_length_metres		0.0	14.9	21.5	104.5	10,980		0.0	15.1	21.9	104.5	10,072
LandingName	NA	24/04/1923					0		7,281.0				0
BottomContact	new							2					0
ObsPres	new							2	0.0			1.0	0
mapquality	new							5					0
FA_Poly	new							81					0
Estimated Catch Table													
SpeciesCode	species_code	537					10,980	492					0
GreenweightKgQuantity	catch_weight		0.0	40.0	567.3	1,001,000.0	136,763		0.0	40.0	584.2	1,001,000.0	0
MeatweightKgQuantity	catch_weight		0.0	300.0	539.0	7,300.0	6,507,290						
UnitQuantity	catch_weight		0.0	5.0	486.0	63,000.0	6,313,449						
Landings Table													
TripId	trip	556,922						556,712					
LandingDate	landing_datetime		8/04/2004			24/04/2017	7		8/04/2004			24/04/2017	7
FormType	form_type	5					0	5					0
FormNumber	form_number		22,120			50,040,000			22,120			50,040,000	
tripStartDatetime	trip_start_datetime		13/01/1995			22/04/2017	1		13/01/1995			22/04/2017	20
tripEndDatetime	trip_end_datetime		8/04/2004			24/04/2017	20		8/04/2004			24/04/2017	20
TripDays*	new		-5843	1.0	2.1	6,580.0	1		-3,652.0	1.0	2.1	6,580.0	20
SpeciesCode	species_code	598					0	568					0
FishstockCode	fishstock_code	2,805					0	2,740					0
DestinationTypeCode	destination_type	20					0	20					0
No_Destinations *(per trip)*	new								1.0	2.0	2.2	9.0	11,714
GreenweightKgQuantity	green_weight		0.0	32.5	1,247.0	2,744,000.0	36,335		0.0	33.0	1,261.0	2,744,000.0	8,364
MeatweightKgQuantity	green_weight		0.0	75.0	94.0	2,200.0	3,302,401		0.0	75.0	94.0	2,200.0	3,298,566
UnitQuantity	green_weight		0.0	720.0	6,595.0	52,460.0	3,301,413		0.0	720.0	6,595.0	52,460.0	3,297,578
VesselNameWithVesselId	NA	1,716					0	1,716					0
LandingName	landing_name	8,508					0	7,702					0

*The number of trip days is wrong where there are errors in dates given or entered (13 trips) – other than the dates the landings and catch effort records seemed to be good matches.

Table A2.2: The number of fishing event effort values either missing or deemed outside of valid range and replaced with imputed values.

	% of total	0708	0809	0910	1011	1112	1213	1314	1415	1516	0716
Events with no reported effort		1120	1301	838	721	924	705	762	617	581	7569
% of events with no effort reported		0.61%	0.72%	0.44%	0.39%	0.52%	0.40%	0.43%	0.37%	0.35%	0.47%
Effort grooming											
Trawl											
end coordinates removed where length (start to end) > 150 km		3	5	2	3		1		1		
length and effort removed where length (time x speed) > 150 km		14	39	4	4	9	1	4	2	2	
BLL											
Line length too long (>= 25,000 m)		29	25	18	16	12	7	18	29	26	
Number of hooks out of valid range (outside range 3-17400)		5	22	5	16	4	3	17	3	3	
DL effort outside range 1 – 1400 hooks			9						1		
SLL effort outside range 50 – 4900 hooks or line < 200 km		3	1	1		4			1	3	
SN line length outside range 20-4000 m		17	12	18	11	12	21	27	22	35	
RN line length outside range 20-1500 m		13	15	12	5	24	11	2	5	7	
DN line length outside range 20-1000 m					2		13	9	1	2	
Seine and Dredge effort out of valid range (see Table A2.7)				1				2		1	
HL effort outside range 0.01-24 hours			1	2		1		3	6		
Pots effort out of valid range (see Table A2.6)		3	1	27	26	3				1	
Effort replaced with medians	0.5%	1172	1400	907	785	977	754	826	657	632	8110
% of events with effort imputed		0.6%	0.8%	0.5%	0.4%	0.5%	0.4%	0.5%	0.4%	0.4%	0.5%
Line length replaced with medians out of 183936 line events	0.2%	55	120	47	18	17	9	48	36	71	421
Trawl length replaced with medians out of 763229 trawl events	0.1%	112	338	125	77	58	41	50	29	70	900

In the following sections the distribution of values for various fishing effort variables are described often grouped by either fishing method type (see Table 3 in Section 4) or fishing cluster. The clusters are explained further in Appendix 4. Cluster naming convention uses the predominant method code and species code caught in the cluster. Other abbreviations in the names include “ot” = other and for trawling: “Dot”= Deepwater other, “Iot”= inshore other, “MW_oth”= midwater other, “Mot”= Mid-depth other”, “TR”= mixed MW and BT.

Trawl Effort

The measure for trawl effort used in CatchMapper is area swept by a single tow or in a minority of cases where the tows are not reported as separate events the effort is total area swept by all tows in the event. Four reported measures are be used to calculate area swept in a trawl event. Distributions of these measures by trawl method are shown in Figure A2.1.

Most tows are reported individually but a small number are reported as the number of tows in a day or statistical area on CELR forms. Trawl speed is not reported on these forms so the effort variable for these fishing events is imputed from the median area swept per tow of similar events multiplied by the number of tows.

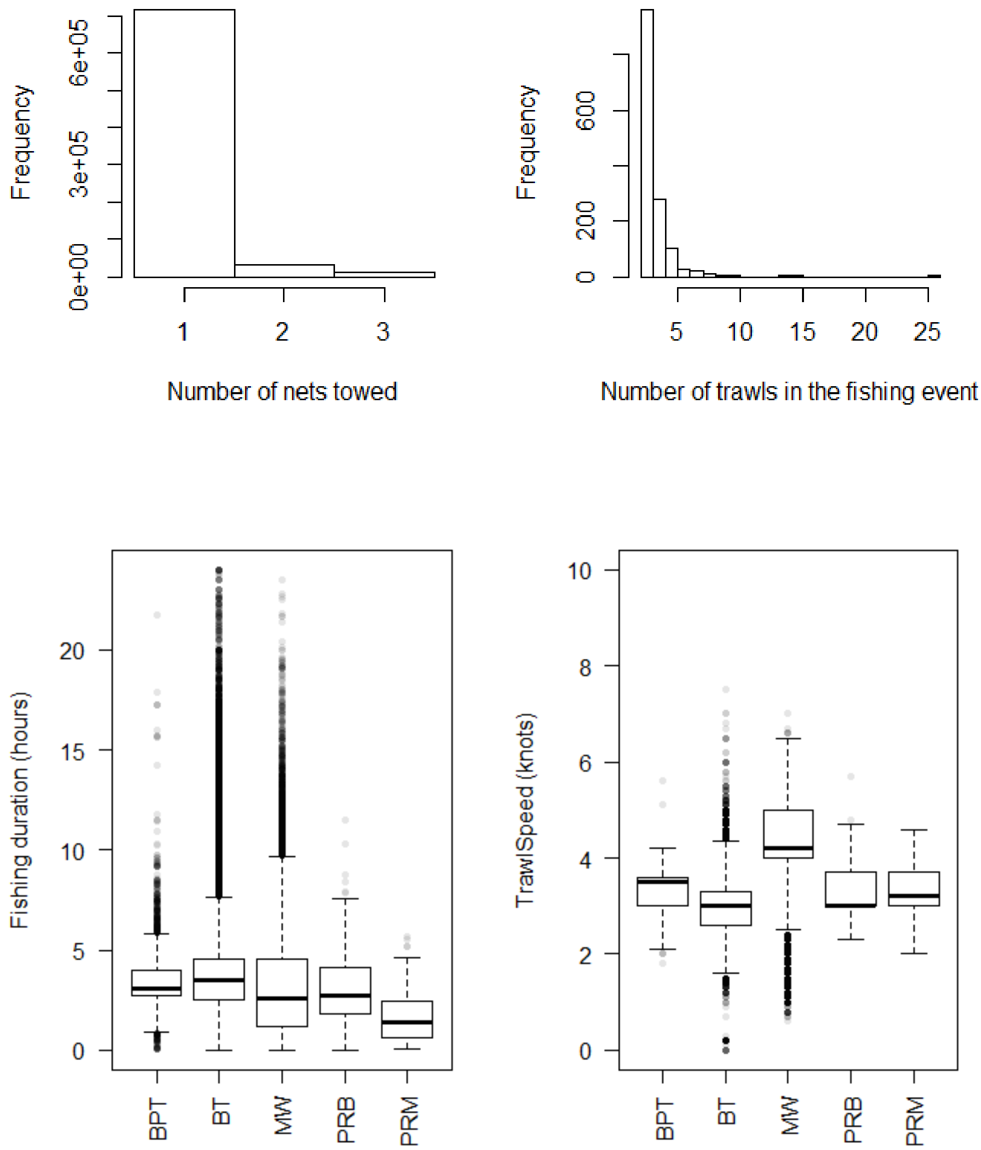


Figure A2.1: Reported trawl effort variables include the number of nets towed (top left) which for 94% of trawl events is a single net but bottom trawling may be done by some vessels with 2 or 3 nets (6 records with incorrect data in this field were assumed to be single net events). Top Right: The number of tows greater than one in the trawl fishing events reported on CELR forms. The distribution of fishing duration and trawl speed values are shown by trawl method (bottom). Box and whisker plots show median, interquartile range (box) and whiskers extend to nearest data point less than 1.5 times interquartile range; outliers are shown as points.

The majority of trawls tow one net but a few tow 2 or 3 nets. This variable could be factored into the width of the trawl polygon but at present in CatchMapper is ignored. The door spread values recommended by Black et al. (2013) are used but applied by cluster as shown in Table A2.3.

Most tows are less than 10 hours duration. There is a long tail on the distribution of fishing duration data out to 24 hours but it is hard to identify outliers so all the fishing duration data was left as retrieved from the MPI database. Of the trawl speed data, only 85 records out of over 750 000 had trawl speed values outside the range 1–7 knots. Two records had speeds over 20 knots and the range otherwise was 0.2 to 7.5. No grooming was applied to trawl speed values. Instead, where trawl speed is used to calculate tow length, the final area swept values are groomed to defined limits.

The length of the tow (distance towed) can be calculated as either the distance between start and end points where they are both available (TCEPR forms but not TCER forms) or the duration of the tow and the reported speed (Figure A2.2). The former assumes that the tow path is a straight line and can suffer from errors in reporting coordinates that are known to occur. The latter uses fishing duration which itself is indicative of effort magnitude but both duration and speed may not be reported with high precision. To be consistent among trawls events, all trawl effort values (area swept) in CatchMapper are calculated using duration and speed. However, the trawl polygons are built using reported coordinates for end points where they exist.

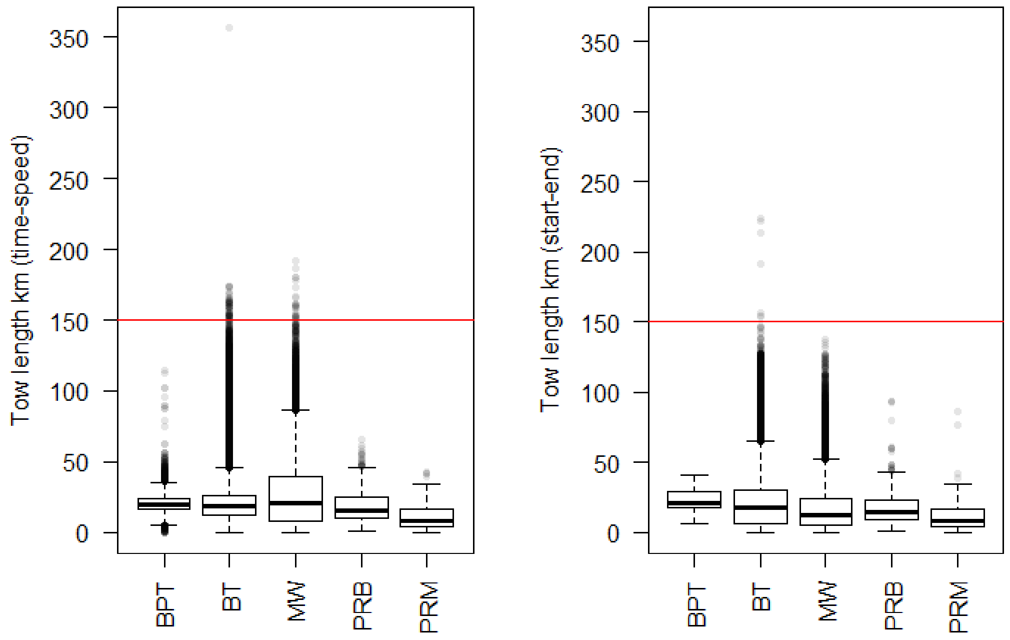
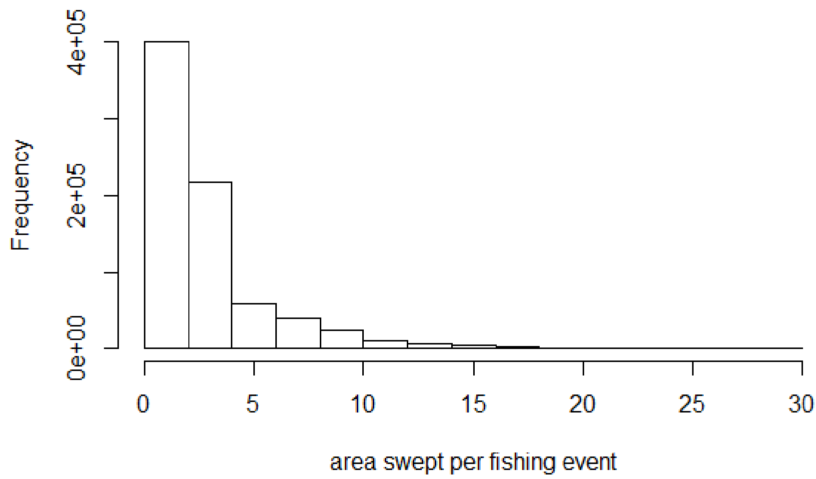


Figure A2.2: Comparison of distributions of tow length estimates. Red line indicates defined criteria for valid data. Eight records had start-end lengths-, and one had time-speed length greater than 350 km and these are not shown here.

Table A2.3: Door spread values assigned to clusters of trawl events after Black et al. (2013). For explanation of clusters see Appendix 4.

Cluster	Door spread (m)
BT_QSC	40
BT_ELE, BT_GSH, BT_GUR, BT_IMIX, BT_IMO, BT_IMT, BT_JDO, BT_MOK, BT_RSK, BT_SCI, BT_SNA, BT_SPD, BT_STA, BT_TAR, BT_TRE	70
BT_FLA, BT_RCO, TR_BYX,	100
BT_CDL, DT_DMIX, BT_LIN, BT_OEO, BT_ORH, BT_SWA, TR_BAR, TR_SQU, TR_WAR, MW_JMA, MW_MIX, MW_RBY, MW_SBW, TR_NoCatch	150
TR_HAK, TR_HOK, TR_MMIX,	200

The resulting distribution of groomed values for trawl area swept are shown in Figure A2.3



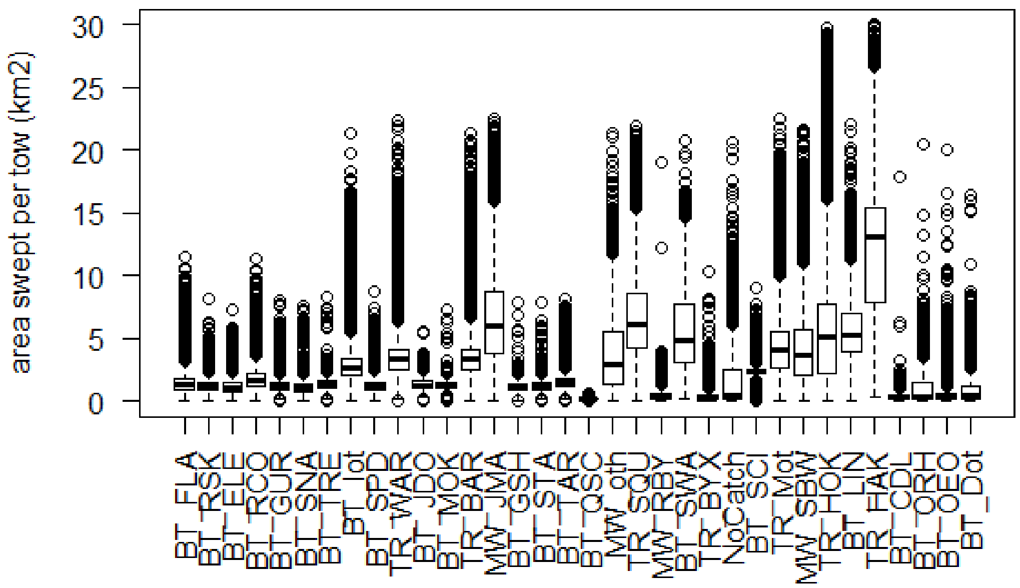


Figure A2.3: Overall distribution of groomed area swept (km2) values for nine years of trawl events in CatchMapper (top) and by cluster in order of bottom depth at fishing location, left to right from shallow to deep (bottom).

Lines

Lining effort is measured by the number of hooks set. Most line fishing event polygons are built using line length values. Where lining records include both a start and end position in coordinates (SLL fishing reporting on the tuna TLCER forms), the event polygon is built with the start and end coordinates and a nominal fishing width of 50 m. Where only a start position is given in coordinates, line polygons are built as circles with radius equal to line length.

Line length for bottom longlining and trot lining is a field in the MPI database derived by multiplying the reported number of hooks by hook spacing. For surface longlining, line length is reported in nautical miles and in CatchMapper is converted to metres. The range of values in the raw dataset for nine fishing years and the criteria used to define valid data ranges are given in Table A2.4. The distribution of values in the raw dataset by lining methods are shown in Figures A2.4 and A2.5.

Table A2.4: Ranges of Line fishing effort variables in raw data set and criteria defining valid data ranges.

Range in Database	Hook spacing (m)	Number of hooks	Line length (m)
BLL	0.1–50	1–36000	6–138 000
SLL	0.9–50	50–4900	9–10 989 768
TL	0.2–3	1–1400	18–1960
DL		1–3500	
Defined valid range			
BLL		3–17 400	< 25 000
SLL		50 – 4900	< 200 000
TL			
DL		1 – 1400	

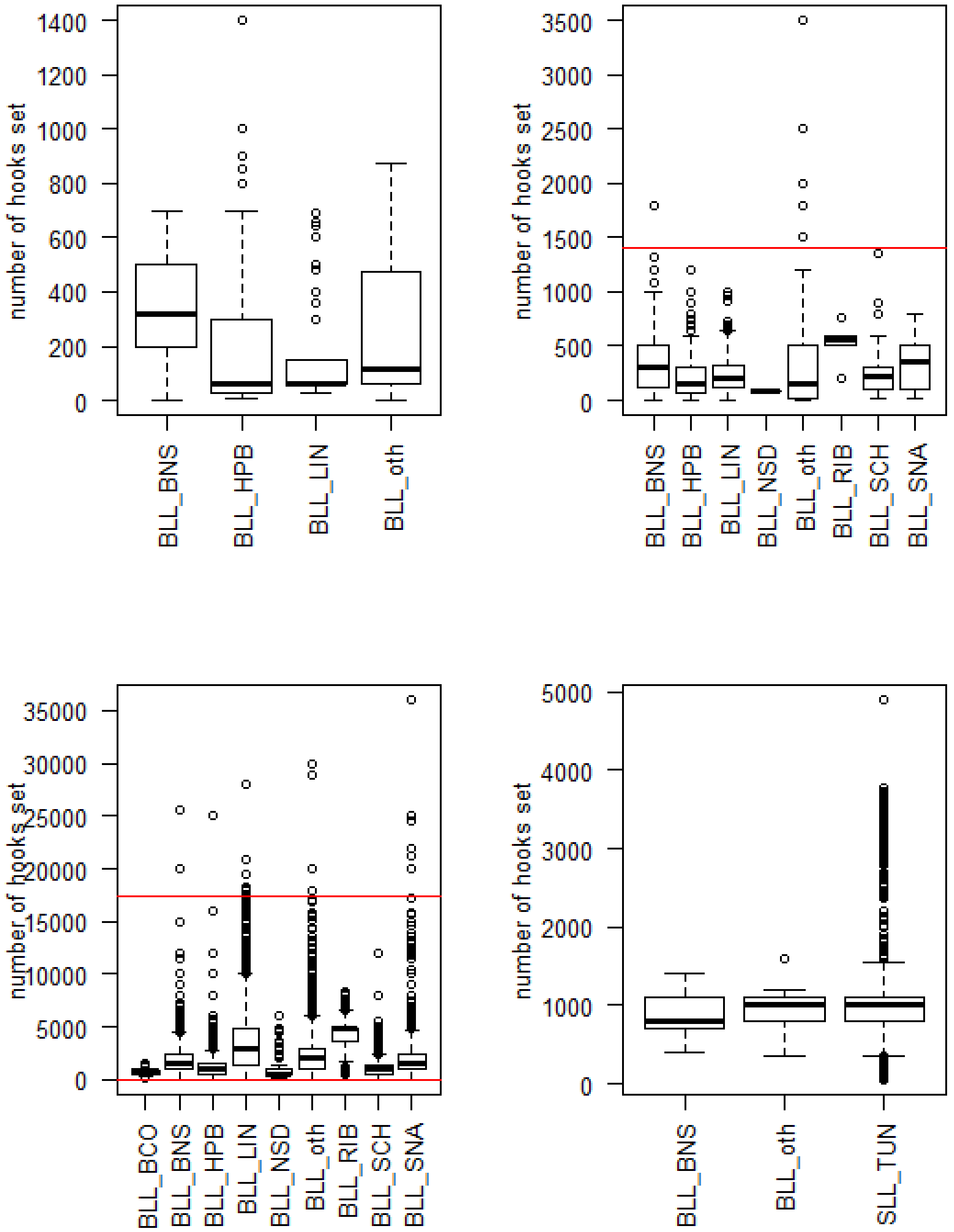


Figure A2.4: Distribution of effort values (number of hooks set) in the raw data set for trot lining (top left), dahn lining (top right), bottom longlining (bottom left) and surface longlining (bottom right). Red line indicates defined criteria for valid data (no criteria for trot lining or surface longlining).

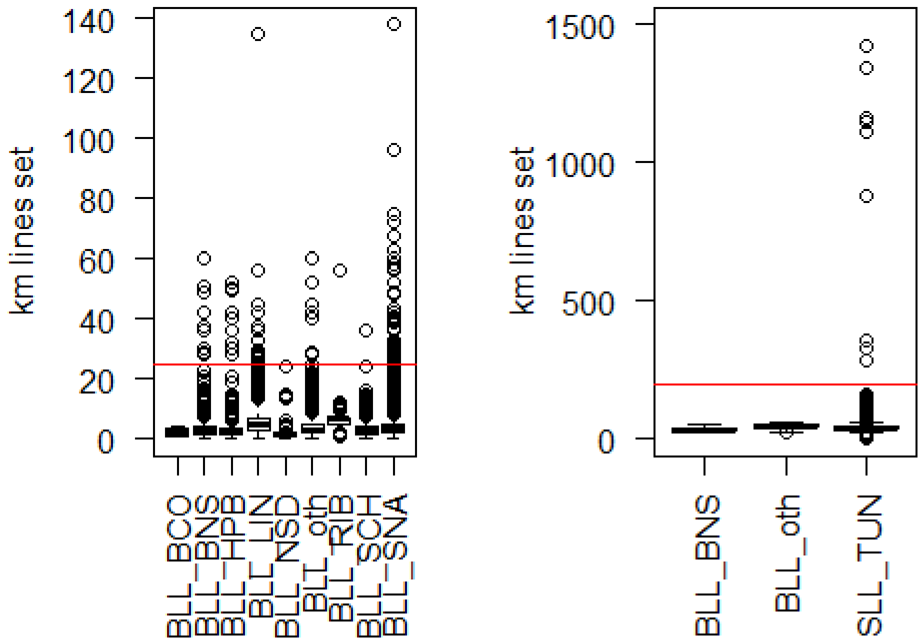


Figure A2.5: Distribution of line length values in the raw data set for bottom longlining (left) and surface longlining (right). Red line indicates defined criteria for valid data. Two outlier data points are left out of the SLL plot

Nets

Net fishing effort is measured as the length of nets set per fishing event. Net length is also used to build the net fishing polygons. The range of values in the raw dataset and grooming criteria are given in Table A2.5 and the distribution of values shown in Figure A2.6.

Where a start position is given in coordinates on NCELR forms net polygons are built as circles with radius equal to 2 nautical miles as that is the distance beyond which is defined as the start of a new event. A new net set that starts within 2 nautical miles of the previous set will be included in the same event as the previous set and the whole net is assumed in CatchMapper to lie within a 2 nautical mile radius of the previous sets start position. In practice, most of the net could lie outside the 2 nautical mile radius and still be included in the same event as the previous one so CatchMapper may underestimate the radius of space occupied by the fishing event by an amount similar to the average length of net set in events that include more than one set net.

Table A2.5: The range of net lengths in raw data set and criteria defining valid data ranges used in CatchMapper.

Method code	Net Length reported (m)	Valid range (m)
SN	0.3 – 10000	20 – 4000
RN	0.5 – 7000	20 – 1500
DN	1 – 3000	20 – 1000

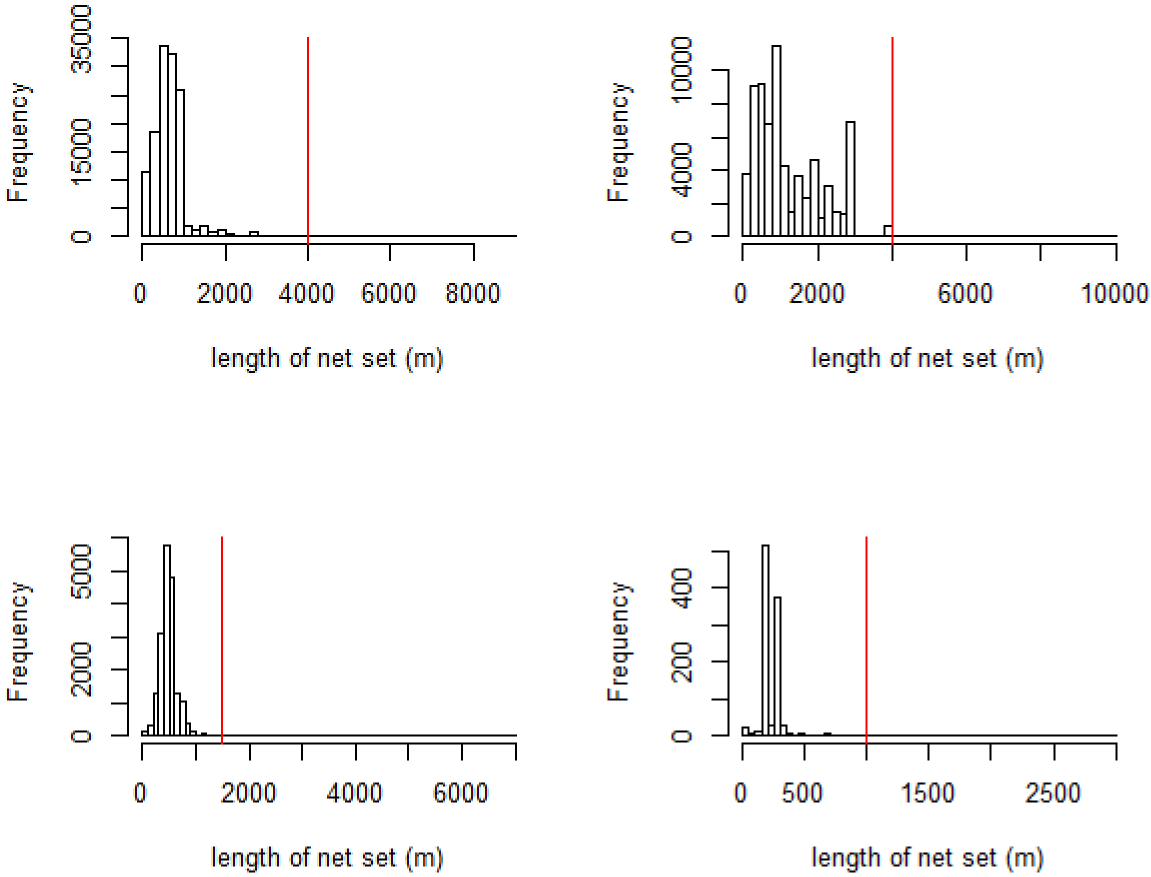


Figure A2.6: Distribution of Net fishing effort values SN (top) reported on CELR forms (left) and on NCELR forms (right), RN (bottom left) and DN (bottom right). Red line indicates defined criteria for valid data.

Pots

The effort measure used in CatchMapper for pot fishing is the number of pot lifts per fishing event. Table A2.6 gives the range of values in the raw dataset and the defined criteria for valid ranges by potting type.

Table A2.6: The range of number of pot lifts per day in raw data set and criteria defining valid data ranges used in CatchMapper. Not much is known about Hagfish potting at this stage and all data are accepted as valid.

Method code	Pot lifts reported	Valid range
CP	1 – 180	1 – 500
CRP	1 – 720	1 – 500
FP (not HAG)	1 – 1800	1 – 500
FP (HAG)	1 – 1000	1 – 1000
OCP	3 – 850	1 – 500
RLP	1 – 3535	1 – 500

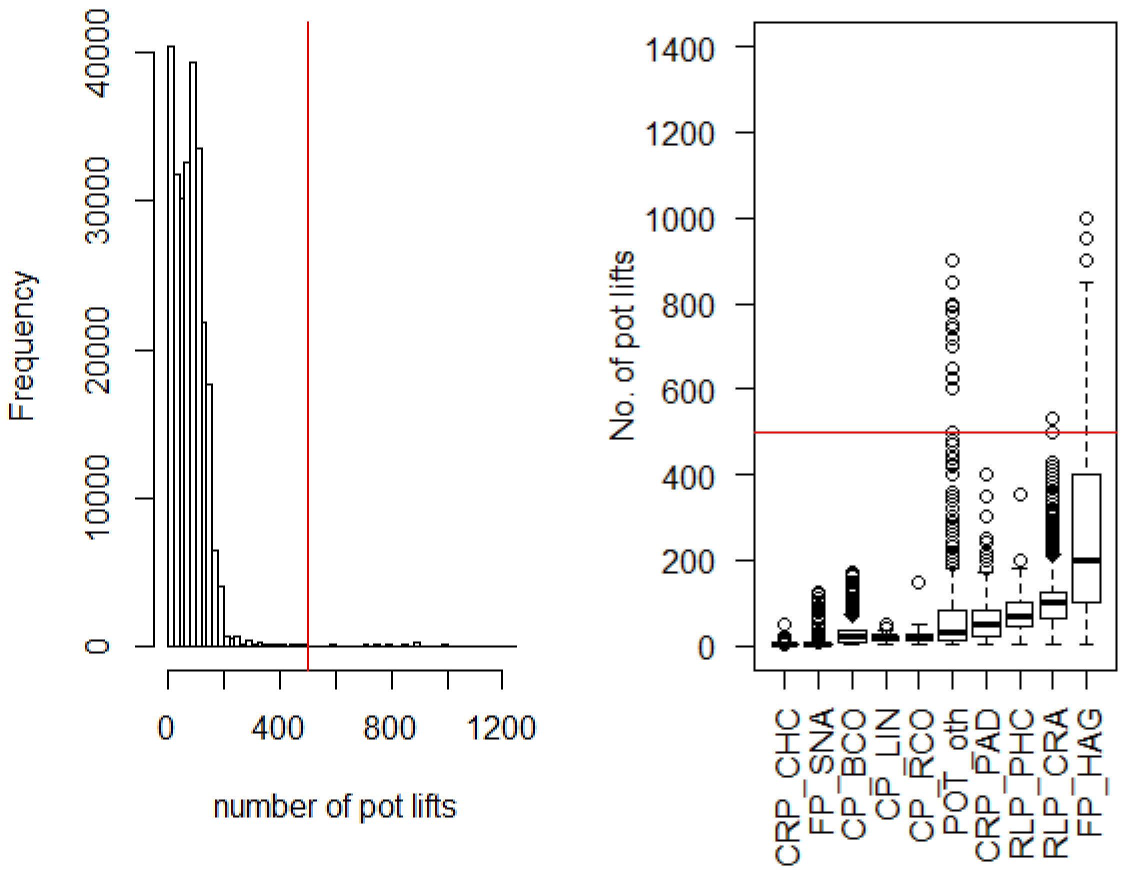


Figure A2.7: Distribution of all pot fishing effort values (left) and by fishing cluster (right). Red line indicates defined criteria for valid data (not applied to Hagfish potting).

Seine and Dredge

The effort measure used in CatchMapper for all the seining methods and dredging is the number of shots per fishing event. A fishing event may be a single shot for some purse and Danish seining in which case effort=1 or the total time spent fishing on a day within a single statistical area. Table A2.7 gives the range of values in the raw dataset and the defined criteria for valid ranges by method type.

Table A2.7: The range of number of seine or dredge shots per day in raw data set and criteria defining valid data ranges used in CatchMapper.

Method code	No. shots reported	Valid range
BS	1 – 500	1 – 100
D	1 – 300	1 – 100
DPN	1 – 1500	1 – 1500
DPS	1 – 3	1 – 3
DS	1 – 4500	1 – 100
L	1 – 100	1 – 100
PS	1 – 14	1 – 14
SCN	1 – 40	1 – 40

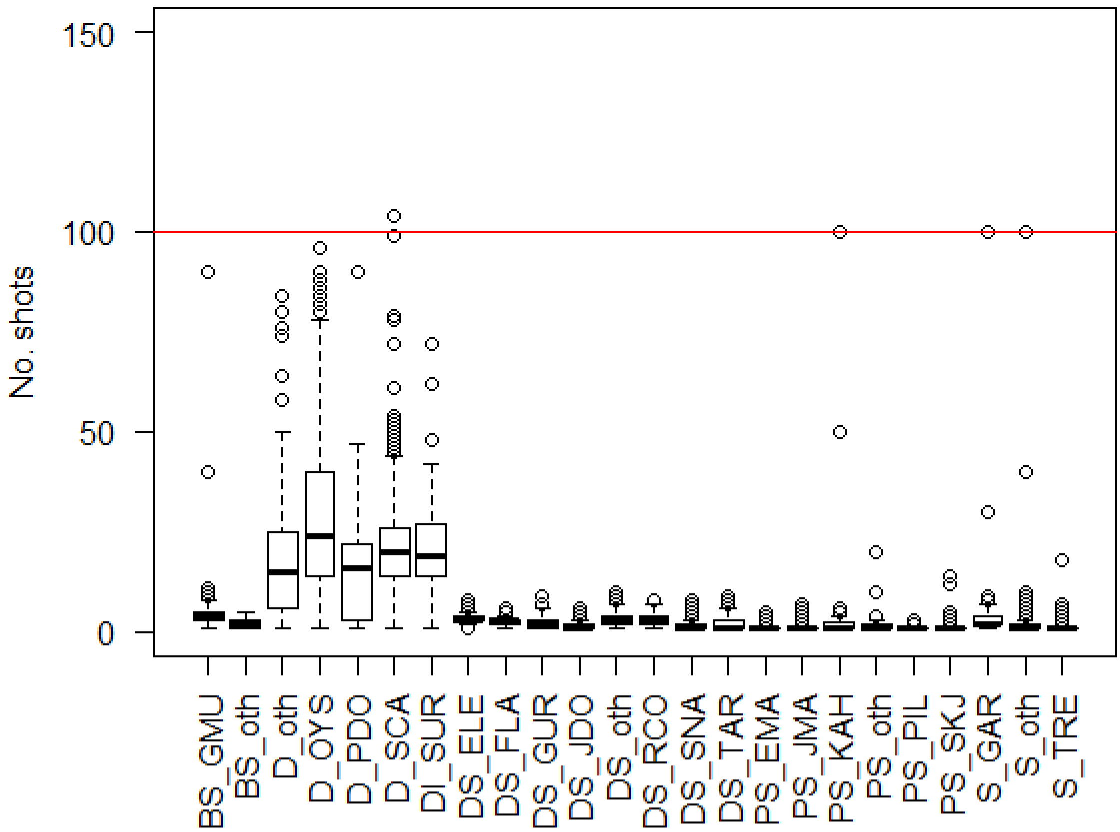


Figure A2.8: Distribution of seine and dredge fishing effort values by fishing cluster. Red line indicates defined criteria for valid data (for BS, D, DS, L methods see Table A2.7 for others).

Others

The remaining group of fishing methods are quantified by the number of hours spent fishing per fishing event. This group includes the active lining methods of hand lining, pole lining and trolling, and hand gathering including by diving, and mechanical harvesting. The latter three methods report person hours and the former reports vessel hours.

Table A2.8: The range of number of person hours (DI, H, MH) or vessel hours fished per day in raw data set and criteria defining valid data ranges used in CatchMapper.

Method code	No. hours reported	Valid range
DI	0.17 – 48	0.01 – 50
H	0.17 – 50	0.01 – 50
MH	0.2 – 15	0.01 – 50
HL	0.17 – 92	0.01 – 24
PL	0.17 – 15	0.01 – 24
T	0.05 – 72	0.01 – 24

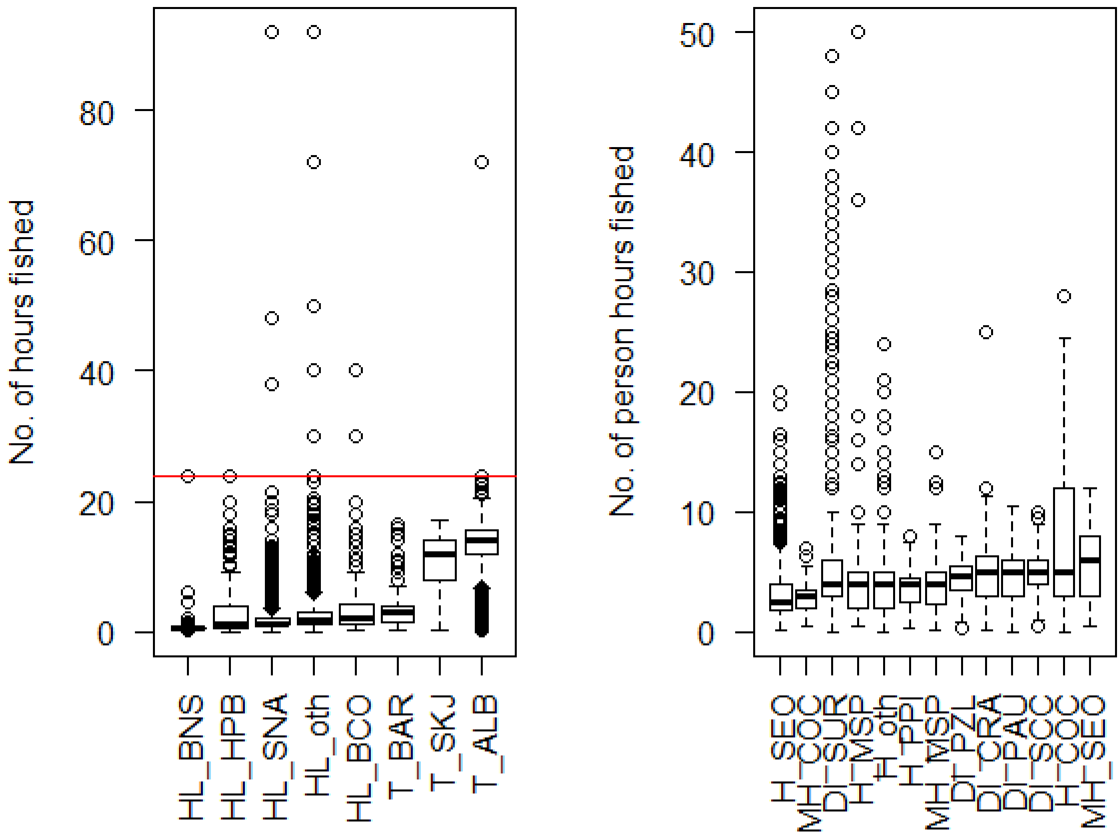


Figure A2.9: Distribution of fishing effort values by fishing cluster for the active lining methods (left). Red line indicates defined criteria for valid data (24 hours). Right: methods recording effort by person-hours. All data shown are treated as valid.

13. Appendix 3: Record Grooming Changes

Table A3.1: Numbers of records of fishing events and fishing trips involved in grooming steps described in Section 4 of this report (paragraphs 4.1 to 4.11) by fishing year and total for all nine years and percentage of records affected. Fishing records kept in CatchMapper must have data on location and fishing year. Where possible fishing methods, target species and caught species data are also checked and errors corrected. Estimates for species catch and total catch are checked and events with no apparent catch are identified. The reference to paragraph in the text (first column) refers to the paragraph in Section 4 of the text where the change is explained.

Grooming Step	% of total	0708	0809	0910	1011	1112	1213	1314	1415	1516	0716
Start number of fishing trips		65647	64068	65680	64099	62633	63883	62483	59098	59508	567099
fix 20 of the zero tripIds		65647	64068	65680	64099	62633	63883	62483	59117	59508	567118
Start number of events		190345	184121	194291	190349	184037	182944	181618	171198	169904	1648807
Fixed Unknown Fishing Year	0.01%	39	30	17	25	18	9	3	14	14	169
Remaining number of fishing events		190384	184151	194308	190374	184055	182953	181621	171212	169918	1648976
remove eel fishing	2.1%	4657	3277	3697	3726	4505	4490	4381	3580	2921	35234
High Seas events removed	0.5%	590	833	1149	1058	1035	1134	880	726	1174	8579
Remaining number of fishing events		185137	180041	189462	185590	178515	177329	176360	166906	165823	1605163
Speciescode COD and "HL","RLP","CP" = BCO											19
Speciescode COD and "BT" = BCO											19
TargetSpeciescode COD and "HL" = BCO											2
TargetSpeciescode SSC and "DI" = SCC											1
species code corrections to SEO											4
Total estimated catch >0 but sum of species estimated catch = 0		3	8	11	7	11	0	7	32	25	104
Total estimated catch=0 but sum of species estimated catch> 0		421	376	378	439	576	528	372	315	240	3645
One or more Species Code missing but Total estimated catch for event >0		1	3	5	3	7	0	5	25	16	65
number fixed		1	1	0	2	1	0	2	17	5	29
number changed to "missing" species code		0	2	5	1	6	0	3	8	11	36
"NoCatch" events no species code		1784	1343	1509	1580	1094	826	769	622	612	10139
removed half PAU gwt=0,TotalCatchWeight=0, changed half to NoCatch		2	19	11	19	15	7	10	24	22	129
SpeciesCodes->NoCatch, remove duplicates where TotalCathcWeight=0, GWT=0		186	282	303	416	319	389	435	427	399	3156
removed zero catch events where TotalCatchWeight>0 and nECevents>1		1433	997	988	1234	926	798	4637	6630	6311	23954
removed all PAU gwt=0,TotalCatchWeight>0		5359	4862	5017	4750	5032	4620	4583	4489	4642	43354
Total zero catch events	0.8%	1972	1644	1823	2015	1428	1222	1214	1073	1033	13424
remaining number of fishing events		185134	180040	189461	185584	178514	177324	176358	166906	165823	1605144
Unknown Statistical Area - fixed	0.02%	88	41	50	77	32	23	0	16	26	353
not fixed and deleted from dataset	0.01%	11	8	24	49	3	1	25	22	44	187
Unknown Fishing Method - fixed	0.07%	57	118	145	137	182	80	31	174	260	1184
remaining number of fishing events		185123	180032	189437	185535	178511	177323	176333	166884	165779	1604957
fixed trawl EffortTotalCount				2	4						
Events with effort=NA		1027	1225	760	655	867	656	700	560	521	6971
Events with effort=0		93	76	78	66	57	49	62	57	60	598
Events with no reported effort		1120	1301	838	721	924	705	762	617	581	7569
% of events with no effort reported		0.61%	0.72%	0.44%	0.39%	0.52%	0.40%	0.43%	0.37%	0.35%	0.47%

14. Appendix 4: Clustering

A new classification was created based on a cluster analysis of catch composition in the manner described by Bentley et al.(2011). The classification groups all fishing events into one of 126 clusters based on the type of gear used, the region of the EEZ where fishing occurred and the proportional make up of species in the catch. Species proportions in the total estimated catch for each event were analysed for clustering. Fishers only report the main species caught in each fishing event and while some might report up to eight species others might only report two. Total catch weight is estimated independent of species catch weights. Therefore calculated proportions of species weight in the total catch weight are not affected by how many individual species weights are reported.

A cluster analysis of five years of catch composition data in 2013 formed the basis of the classification implemented for the nine years of data in CatchMapper. The cluster analysis is not redone each year. In 2017 the cluster analysis was repeated to see if any significant shifts had occurred and the results are discussed in the following sections.

There are many types of clustering approaches. A more intensive examination of this dataset may come up with variations on our results. There is no single right answer and it is important to examine the characteristics of clusters to see if they are informative in a real-world sense.

Here we want to identify natural clusters of catch bag composition that occur from different fishing strategies (combination of season and fishing method and location of fishing).

Of all the methods possible to use, Bentley et al. (2001) chose to use medoid partitioning to find many groups of similar catch compositions followed by hierarchical aggregation of similar medoid clusters to choose the best number of clusters with the help of a dendrogram. Once a set of interesting clusters are identified, classification rules are devised that define the membership of each cluster as close as possible. In this way future fishing events can be easily classified without further cluster analysis or the need to refer to the original cluster centres. The classification rules also describe the main features of the clusters. We use the same procedure here.

Methods

Clustering was run separately by gear types. The entire data set of estimated catches of species by fishing event was split into sets by gear type. The species codes that feature in the cluster analysis and are used throughout this text are explained in Table A4.1.

For each gear dataset an array was created with fishing events as rows and species as columns, giving the proportion of species in estimated total catch for each event. The rows were analysed for natural clusterings around catch composition medoids using the CLARA clustering method in R. The whole dataset is too large for the cluster algorithm on a desktop computer with 16 GB of RAM so the CLARA program uses a subsampling routine. Sample size and number of samples were initially varied to examine the stability of the resulting clusterings. Ten repeated samples of 2% of the records (minimum sample 5000) was adequate to give stable clustering.

For each gear type any shift in clustering over time was also examined by comparing clusterings for the 2007–08, 2011–12, 2015–16 fishing years with that for the whole dataset of 9 years.

The best number of clusters across the whole data set was determined using silhouette distance, as an indicator of the quality of the clustering on a national scale. K-medoid clustering tends to find clusters of similar size. Typically, larger single species target fisheries would be identified as clusters as well as some mixed species variants. For example a cluster might be defined by a medoid that has 90% snapper and another that has 80% gurnard and a third cluster that has 30% snapper, 20% gurnard and 40% trevally. The two single species clusters would be retained and the third might be kept if the proportion of trevally was distinctive. Or the third cluster in this example might be added to a default class for all other types of catch composition.

Table A4.1: Scientific and common names of species used in cluster analysis and the three letter code used throughout the text.

species_code	species_scientific_name	species_preferred_common_name
ALB	Thunnus alalunga	Albacore tuna
BAR	Thyrsites atun	Barracouta
BCO	Parapercis colias	Blue cod
BIG	Thunnus obesus	Bigeye tuna
BNS	Hyperoglyphe antarctica	Bluenose
BUT	Odax pullus	Butterfish
BYX	Beryx splendens, B. decadactylus	Alfonsino & Long-finned beryx
CDL	Epigonus telescopus	Cardinal fish
CHC	Chaceon bicolor	Red crab
COC	Austrovenus stutchburyi	Cockle
CRA	Jasus edwardsii	Spiny red rock lobster
DAN	Dosinia anus	Ringed dosinia
ELE	Callorhinchus milii	Elephant fish
EMA	Scomber australasicus	Blue mackerel
FLA	N/A	Flatfish
GAR	Hyporhamphus ihi	Garfish
GMU	Mugil cephalus	Grey mullet
GSH	Hydrolagus novaezealandiae	Ghost shark
GUR	Chelidonichthys kumu	Gurnard
HAG	Eptatretus cirrhatus	Hagfish
HAK	Merluccius australis	Hake
HOK	Macruronus novaezelandiae	Hoki
HPB	Polyprion oxygeneios, P. americanus	Hapuku & Bass
JAV	Lepidorhynchus denticulatus	Javelinfish
JDO	Zeus faber	John dory
JMA	Trachurus declivis, T. murphyi, T. novaezelandiae	Jack mackerel
KAH	Arripis trutta, A. xylabion	Kahawai
KBB	Macrocystis pyrifera	Bladder kelp
KIC	Lithodes murrayi, Neolithodes brodiei	King crab
KIN	Seriola lalandi	Kingfish
KWH	Austrofusus glans	Knobbed whelk
LEA	Parika scaber	Leatherjacket
LIN	Genypterus blacodes	Ling
MMI	Mactra murchisoni	Large trough shell
MOK	Latridopsis ciliaris	Blue moki
MSP	Perna canaliculus	Green-lipped mussel (spat)
NSD	Squalus griffini	Northern spiny dogfish
OCT	Pinnoctopus cordiformis	Octopus
OEO	Oreosomatidae (Family)	Oreo
ORH	Hoplostethus atlanticus	Orange roughy
OYS	Ostrea chilensis	Oysters, dredge (except Foveaux Strait)
OYU	Ostrea chilensis	Oysters, dredge (Foveaux Strait)
PAD	Ovalipes catharus	Paddle crab
PAR	Girella tricuspidata	Parore
PAU	Haliotis iris, H. australis	Black Paua & Yellowfoot Paua
PDO	Paphies donacina	Deepwater tuatua
PHC	Jasus verreauxi	Packhorse rock lobster
PIL	Sardinops sagax	Pilchard
PPI	Paphies australis	Pipi
PTO	Dissostichus eleginoides	Patagonian toothfish
PZL	Panopea zelandica	Deepwater clam
QSC	Zygochlamys delicatula	Queen scallop
RBM	Brama brama	Ray's bream
RBT	Emmelichthys nitidus	Redbait
RBY	Plagiogeneion rubiginosum	Rubyfish
RCO	Pseudophycis bachus	Red cod
RIB	Mora moro	Ribaldo
RSK	Dipturus nasutus	Rough skate
SAE	Spisula aequilatera	Triangle shell
SBW	Micromesistius australis	Southern blue whiting
SCA	Pecten novaezelandiae	Scallop
SCC	Stichopus mollis	Sea cucumber
SCH	Galeorhinus galeus	School shark
SCI	Metanephrops challengeri	Scampi
SEO	N/A	Seaweed
SKI	Rexea spp.	Gemfish, southern kingfish
SKJ	Katsuwonus pelamis	Skipjack tuna
SNA	Pagrus auratus	Snapper
SPD	Squalus acanthias	Spiny dogfish
SPO	Mustelus lenticulatus	Rig
SQU	Nototodarus sloanii, N. gouldi	Arrow squid
STA	Kathetostoma spp.	Giant stargazer
STN	Thunnus maccoyii	Southern bluefin tuna
SUR	Evechinus chloroticus	Sea urchin, kina, sea egg
SWA	Seriolella punctata	Silver warehou
SWO	Xiphias gladius	Swordfish
TAR	Nemadactylus macropterus; Nemadactylus sp. ("King Tarakihi")	Tarakihi
TRE	Pseudocaranx dentex	Trevally
TUA	Paphies subtriangulata	Tuatua
ULV	Ulva spp.	Sea lettuce
WAR	Seriolella brama	Common warehou
WWA	Seriolella caerulea	White warehou
YEM	Aldrichetta forsteri	Yellow-eyed mullet

After clustering on a national scale, additional, regionally distinctive clusters were identified by splitting the datasets into regional groups. Seven regions were distinguished that gave similar clusterings within and include Fisheries Management Areas 1 and 2, east coast South Island, west coast South Island, west coast North Island, top of the south, and offshore (Figure A4.1).

Next the process is further described for the case of clustering the trawl fishing events. Graphs and tables characterise the resulting clusters and compare regions, years and an alternative classification based on reported target species. The process was repeated for all other gear types and the same figures and tables reported here for each gear type.

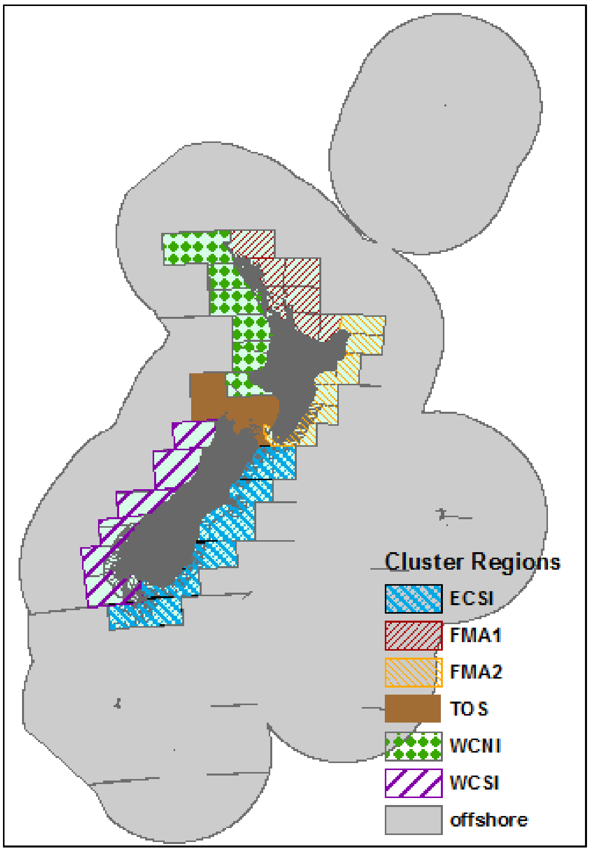


Figure A4.1: Regions used in cluster analysis were defined by groups of statistical areas that showed similar clusterings.

Trawl

The initial cluster analysis for trawl events was performed on 59 out of the 386 species caught by trawl. These 59 species had either catch of over 2000 tonne or occurred in at least 0.02% of the catches. Queen scallops was also included. In the whole trawling data set the best number of clusters was 16 (Figure A4.2).

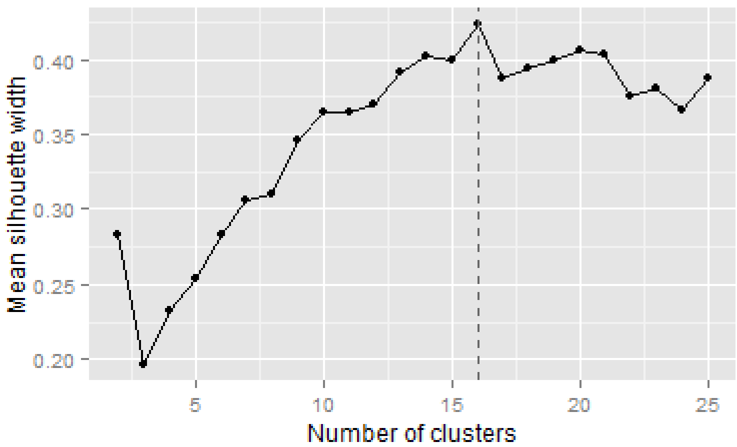


Figure A4.2: The cluster quality criteria mean silhouette width improves with a larger number of clusters up to a maximum of 16 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation).

We used the best clustering from 10 random samples of 5000 records. Stability of the clustering result was illustrated by repeating the cluster analysis seven times. Five of the seven analysis runs produced the same 16 clusters (SBW, ORH, OEO, JMA, SQU, HOK, BAR, SCI, Mixed, TAR, GUR, FLA, RCO, SNA, TRE, and STA). The other two runs produced 15 of the same clusters and a second FLA cluster instead of the STA cluster. The stability of the results was also tested for different years 2007–08, 2011–12, 2015–16. There was little difference in the clusters between the years.

Figure A4.3 shows the main species proportions that define the initial set of clusters identified for trawl events. Cluster 3 contained all the events that didn't fit elsewhere.

The 16 clusters detected are those fisheries that are large enough to be detectable in the sampling fractions of the whole dataset. To identify distinctive smaller and perhaps regionally important fisheries that might not show up on the national scale (e.g. QSC), the procedure was repeated for regional subsets of fishing records. The dendrogram for an arbitrarily large number of clusters (n=26) was examined to find any smaller distinctive fisheries and to determine which similar clusters can be aggregated by choosing a cut-off level on the dendrogram. About 100 events per year was used as an arbitrary minimum threshold for cluster size.

In addition to the initial 16 clusters, smaller clusters were distinguished for ELE, GSH, JDO, LIN, MOK, QSC, RSK, SPD, SWA, RBY, BYX, HAK, and WAR (Table A4.2). The remaining events that didn't fit into any of these were separated into depth classes to give inshore, mid-depth and deep-water "other" classes. The other midwater trawl events were grouped into their own class. This gave a total of 33 clusters. Clusters could also have been separated for LEA, SCH, WWA, and SKI. The clusters can be aggregated at any time when a more coarse classification is required.

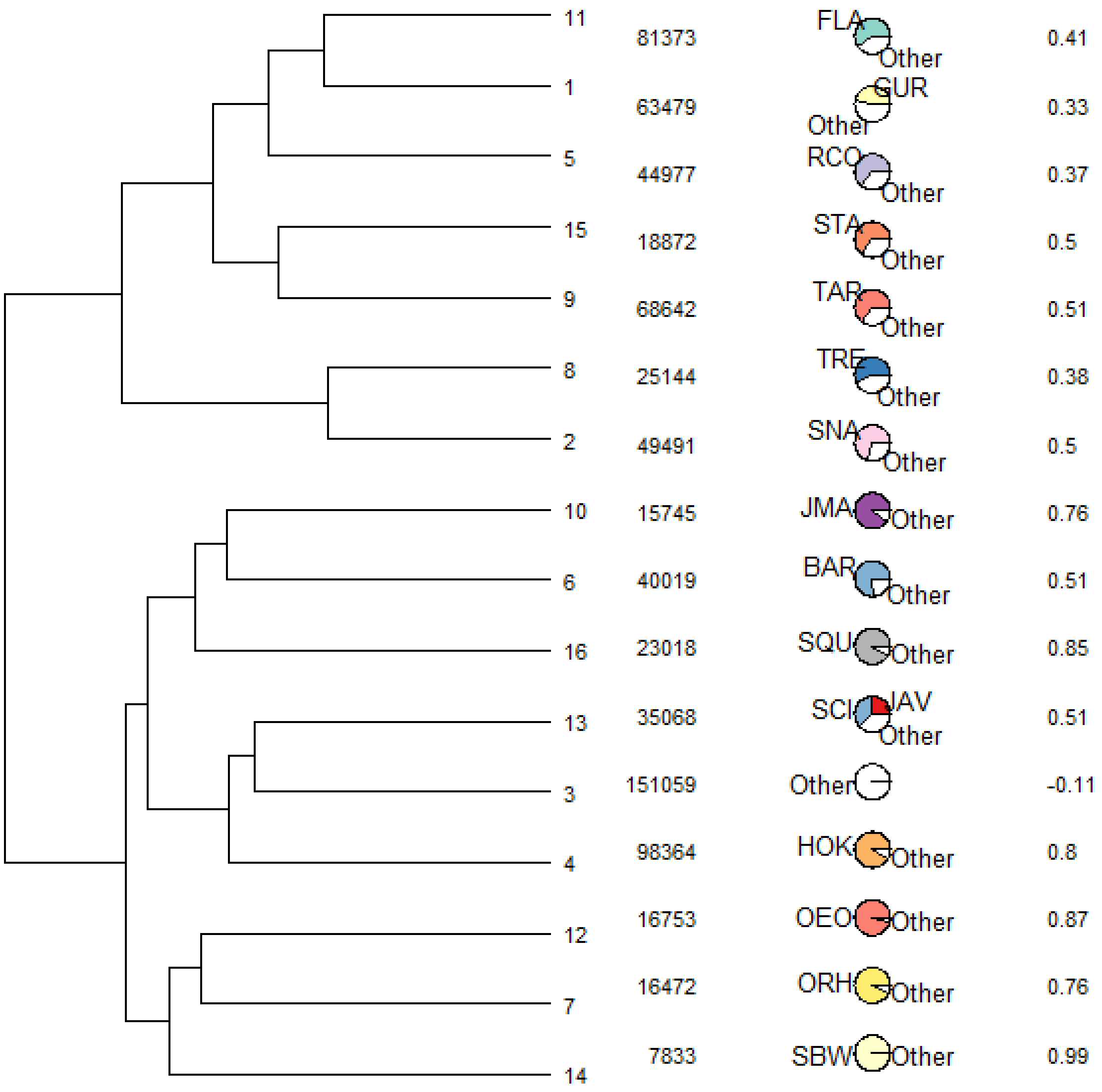


Figure A4.3: A dendrogram of the similarity between 16 clusters found in the 9-year trawl dataset. Also shown from left to right is the cluster label that matches the labels in Table A4.3, count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters. Cluster 3 has a negative silhouette distance indicating that the points within this cluster (19%) are more similar to other clusters than to other points within this cluster, but not similar enough to be included in other clusters i.e. the points in this cluster are the remaining ones that don't fit elsewhere.

Table A4.2: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets after cluster analysis with high k to search for small distinct clusters (initial clustering k=16) and in three individual years (initial clustering k=26). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into a default cluster called "other".

k=26	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	0708	1112	1516
BT_FLA		9138		13579	53607	12952		8584	11717	8076
TR_HOK	2271	12280		5912	21454	28259	33581	9492	11445	12597
BT_TAR	15173	36070	4437	5341	7390	4330	1427	8717	9543	7513
BT_SNA	34732	5948	3845	5410				7391	6547	3710
BT_RCO		2920		5811	9921	10770		3967	3732	2581
BT_GUR		20108	5302	7726	10446	3627		3841	5244	3003
BT_SCI	8109	7035					26616	4704	4303	4690
TR_BAR	1468	3871	2673	6386	7469	4191	3544	4482	3495	3924
TR_SQU					15312		21518	3715	2817	2489
BT_OEO					1742		15156	2781	1736	1051
BT_ORH	1170	2364	1458		1297		10820	2679	1184	2263
BT_TRE	6480	3146	6611					2802	2474	1910
MW_JMA			8863	4876		752	1384	2104	1692	1362
BT_LIN					2179	3072	6341	1894	1034	962
BT_STA					10929	3169		1590	1792	1819
BT_ELE					8302	729		1306	1036	1072
BT_SPD		901		2017	3582	703	580		1516	
MW_SBW							7837	800	944	444
BT_SWA		741			2974		1503			600
TR_BYX		1946					4211	728	755	565
TR_HAK						4874	1569	1213		
BT_RSK					10288			2005	1450	
TR_WAR		846		1265	1876	1967			683	634
BT_GSH				3021						
BT_JDO	2611									
other	7587	967	14558	23071	26707	14127	6324	12680	8445	16154
BT_MOK		1936								
BT_QSC					850					
MW_RBY	617	644								
BT_CDL	295	515								
Total	80513	111376	47747	84415	196325	93522	142411	87475	83584	77419

No new clusters were identified arising from the four years additional data since the initial clustering was performed and no clusters were disestablished although the amount of fishing characterised by some of the clusters had declined. Across the individual years examined there was a reduction in the number of trawling events especially those that catch predominantly SNA, RCO, SQU, OEO,TRE, JMA,LIN, and SBW, and an increase in trawling events catching predominantly HOK, STA and other species or mixed bags of species (Table A4.2).

A set of rules were developed heuristically that reproduce the regional clusterings as close as possible. These are given in Table A4.3. The cross tabulation of the number of fishing events among the 16 clusters in Figure A4.3 and the classification scheme in Table A4.3 is given in Table A4.4. The classification scheme isn't perfect and could probably be improved using classification training algorithms but the rules are simple and self-explanatory. Catch composition of the final set of clusters are shown in Figure A4.4.

Table A4.3: Classification into cluster membership for trawl fisheries uses rules based on region, order of precedence, species composition, fishing method, and fishing depth,. Cluster naming convention uses the predominant method code and species code in the cluster. Other abbreviations in the names include "Dot"= Deepwater other, "Iot"= inshore other, "MW_oth"= midwater other, "Mot"= Mid-depth other", "TR"= mixed MW and BT. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules for example in ECSI, an event that had more than 50% ORH would initially be classed as BT_ORH but then if it also had more than 30% SWA its classification would change to BT_SWA as the latter rule is applied after the former rule and supersedes it.

cluster	Region rule	order rule	species rule	method rule	depth rule	cluster	Region rule	order rule	species rule	method rule	depth rule
BT_Iot	ECSI	1	default			BT_SCI	offshore	5	SCI > 0.1 OR JAV>0.2		
TR_Mot	ECSI	2	default		depth >250	TR_BYX	offshore	6	BYX>0.3		
BT_Dot	ECSI	3	default		depth >800	MW_JMA	offshore	7	JMA>0.4		
MW_oth	ECSI	4	default	MW		MW_SBW	offshore	8	SBW>0.6		
BT_OEO	ECSI	5	OEO>0.5			BT_TAR	offshore	9	TAR>0.2		
TR_HOK	ECSI	6	HOK>0.4			BT_OEO	offshore	10	OEO>0.4		
BT_SWA	ECSI	7	SWA>0.3			BT_ORH	offshore	11	ORH>0.4		
TR_SQU	ECSI	8	SQU>0.5			TR_HOK	offshore	12	HOK>0.5		
BT_TAR	ECSI	9	TAR>0.3			TR_HAK	offshore	13	HAK>0.3		
BT_RCO	ECSI	10	RCO>0.3			BT_LIN	offshore	14	LIN>0.35		
TR_BAR	ECSI	11	BAR>0.4			TR_SQU	offshore	15	SQU>0.4		
BT_SPD	ECSI	12	SPD>0.35			TR_BAR	offshore	16	BAR>0.3		
BT_STA	ECSI	13	STA>0.4			BT_Iot	TOS	1	default		
BT_FLA	ECSI	14	FLA>0.4			TR_Mot	TOS	2	default		depth >80
BT_GUR	ECSI	15	GUR>0.35			TR_HOK	TOS	3	default		depth >200
BT_RSK	ECSI	16	RSK>0.35			MW_JMA	TOS	4	default	MW	
BT_ELE	ECSI	17	ELE>0.35			TR_BAR	TOS	5	BAR>0.35		
TR_WAR	ECSI	18	WAR>0.35			BT_SPD	TOS	6	SPD>0.3		
BT_QSC	ECSI	19	QSC>0.4			MW_JMA	TOS	7	JMA>0.4		
BT_Iot	FMA1	1	default			BT_SNA	TOS	8	SNA>0.35		
TR_Mot	FMA1	2	default		depth >300	BT_TAR	TOS	9	TAR>0.4		
BT_Dot	FMA1	3	default		depth >600	BT_GSH	TOS	10	GSH>0.4		
MW_oth	FMA1	4	default	MW		TR_HOK	TOS	11	HOK>0.5		
BT_SNA	FMA1	5	SNA>0.5			TR_WAR	TOS	12	WAR>0.4		
BT_TAR	FMA1	6	TAR>0.4			BT_GUR	TOS	13	GUR>0.35		
BT_SCI	FMA1	7	SCI > 0.2 OR JAV>0.2			BT_FLA	TOS	14	FLA>0.4		
BT_ORH	FMA1	8	ORH>0.4			BT_RCO	TOS	15	RCO>0.4		
BT_TRE	FMA1	9	TRE>0.3			BT_Iot	WCNI	1	default		
BT_JDO	FMA1	10	JDO>0.4			TR_Mot	WCNI	2	default		depth >300
TR_BAR	FMA1	11	BAR>0.3			BT_Dot	WCNI	3	default		depth >750
BT_Iot	FMA2	1	default			MW_oth	WCNI	4	default	MW	
TR_Mot	FMA2	2	default		depth >300	MW_JMA	WCNI	5	JMA>0.45		
BT_Dot	FMA2	3	default		depth >700	BT_TAR	WCNI	6	TAR>0.25		
BT_SNA	FMA2	4	SNA>0.3			TR_BAR	WCNI	7	BAR>0.3		
BT_TRE	FMA2	5	TRE>0.3			BT_TRE	WCNI	8	TRE>0.5		
BT_RCO	FMA2	6	RCO>0.3			BT_SNA	WCNI	9	SNA>0.4		
BT_GUR	FMA2	7	GUR>0.4			BT_GUR	WCNI	10	GUR>0.4		
BT_FLA	FMA2	8	FLA>0.5			BT_Iot	WCSI	1	default		
TR_BAR	FMA2	9	BAR>0.3			TR_Mot	WCSI	2	default		depth >300
BT_MOK	FMA2	10	MOK>0.3			BT_Dot	WCSI	3	default		depth >800
BT_TAR	FMA2	11	TAR>0.4			MW_oth	WCSI	4	default	MW	
MW_RBY	FMA2	12	RBY>0.4			BT_FLA	WCSI	5	FLA>0.1		
BT_CDL	FMA2	13	CDL>0.4			BT_RCO	WCSI	6	RCO>0.4		
TR_BYX	FMA2	14	BYX>0.4			TR_BAR	WCSI	7	BAR>0.4		
BT_SCI	FMA2	15	SCI>0.1			BT_STA	WCSI	8	STA>0.4		
TR_HOK	FMA2	16	HOK>0.4			TR_WAR	WCSI	9	WAR>0.4		
BT_Iot	offshore	1	default			BT_TAR	WCSI	10	TAR>0.4		
TR_Mot	offshore	2	default		depth >300	TR_HAK	WCSI	11	HAK>0.2		
BT_Dot	offshore	3	default		depth >700	TR_HOK	WCSI	12	HOK>0.6		
MW_oth	offshore	4	default	MW							

Table A4.4: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns) and those produced by the classification rules (rows).

clusters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
BT_CDL	0	0	522	0	0	0	8	0	0	0	0	1	0	0	0	0	531
BT_Dot	0	3	3185	75	0	0	5014	0	0	0	0	131	55	0	0	1	8464
BT_ELE	572	0	7803	0	93	134	0	0	9	0	700	0	0	0	90	1	9402
BT_FLA	3834	27	856	0	3053	22	0	2	24	0	68131	0	0	0	38	0	75987
BT_GSH	2	0	3144	3	95	21	0	1	54	0	1	0	0	0	1	0	3322
BT_GUR	37937	84	12	0	174	85	0	211	25	0	639	0	0	0	47	0	39214
BT_Iot	14251	6249	72237	197	3248	2119	3	7209	1554	364	10912	0	188	1	866	143	119541
BT_JDO	38	496	1416	0	0	0	0	54	1	0	0	0	0	0	0	0	2005
BT_LIN	0	0	4822	427	3	0	0	0	0	0	0	0	111	1	0	0	5364
BT_MOK	218	31	1810	0	3	53	0	38	4	0	3	0	0	0	0	0	2160
BT_OEO	0	0	171	34	0	0	0	0	0	0	0	16499	2	0	0	0	16706
BT_ORH	0	0	322	13	1	0	11366	0	0	0	0	97	1	0	0	0	11800
BT_QSC	0	0	852	0	0	0	0	0	0	0	0	0	0	0	0	0	852
BT_RCO	233	3	415	3	33529	36	0	10	131	0	543	0	0	0	3	60	34966
BT_RSK	1313	0	5481	2	592	96	0	0	16	0	5867	0	0	0	25	0	13392
BT_SCI	0	0	1445	179	23	0	0	0	0	0	0	0	36371	0	13	0	38031
BT_SNA	697	42418	686	0	4	12	0	1324	117	1	84	0	0	0	0	0	45343
BT_SPD	130	0	5697	34	88	221	0	8	19	1	192	0	0	0	25	9	6424
BT_STA	19	0	0	0	28	33	0	0	12	0	55	0	0	0	14985	0	15132
BT_SWA	0	0	2999	240	0	29	0	0	0	0	0	0	0	0	1	44	3313
BT_TAR	68	96	3319	1	48	194	0	39	59343	5	78	0	2	0	160	2	63355
BT_TRE	18	382	54	0	0	0	0	15122	16	0	5	0	0	0	0	0	15597
MW_JMA	2	0	321	9	1	243	0	8	1	14098	1	0	0	0	0	0	14684
MW_oth	0	5	3054	392	14	51	1	0	0	925	0	0	18	2	0	6	4468
MW_RBY	0	0	672	0	0	0	0	0	1	0	0	0	0	0	0	0	673
MW_SBW	0	0	0	0	0	0	0	0	0	0	0	0	0	7808	0	0	7808
TR_BAR	334	370	1055	2	293	37945	0	201	160	313	14	0	0	0	1	585	41273
TR_BYX	0	0	6455	6	0	0	2	0	0	0	0	3	2	0	1	0	6469
TR_HAK	0	0	6044	1000	5	1	3	0	0	0	0	0	9	0	1	0	7063
TR_HOK	2	0	909	94588	5	5	3	0	82	0	0	2	101	1	10	1	95709
TR_Mot	6	1	16335	2554	36	14	131	2	0	19	2	60	654	32	48	73	19967
TR_SQU	0	0	124	1	59	0	0	0	0	0	0	0	2	0	0	22441	22627
TR_WAR	29	4	3955	0	59	587	0	5	10	2	4	0	0	0	10	2	4667
Total	59703	50169	156172	99760	41454	41901	16531	24234	61579	15728	87231	16793	37516	7845	16325	23368	756309

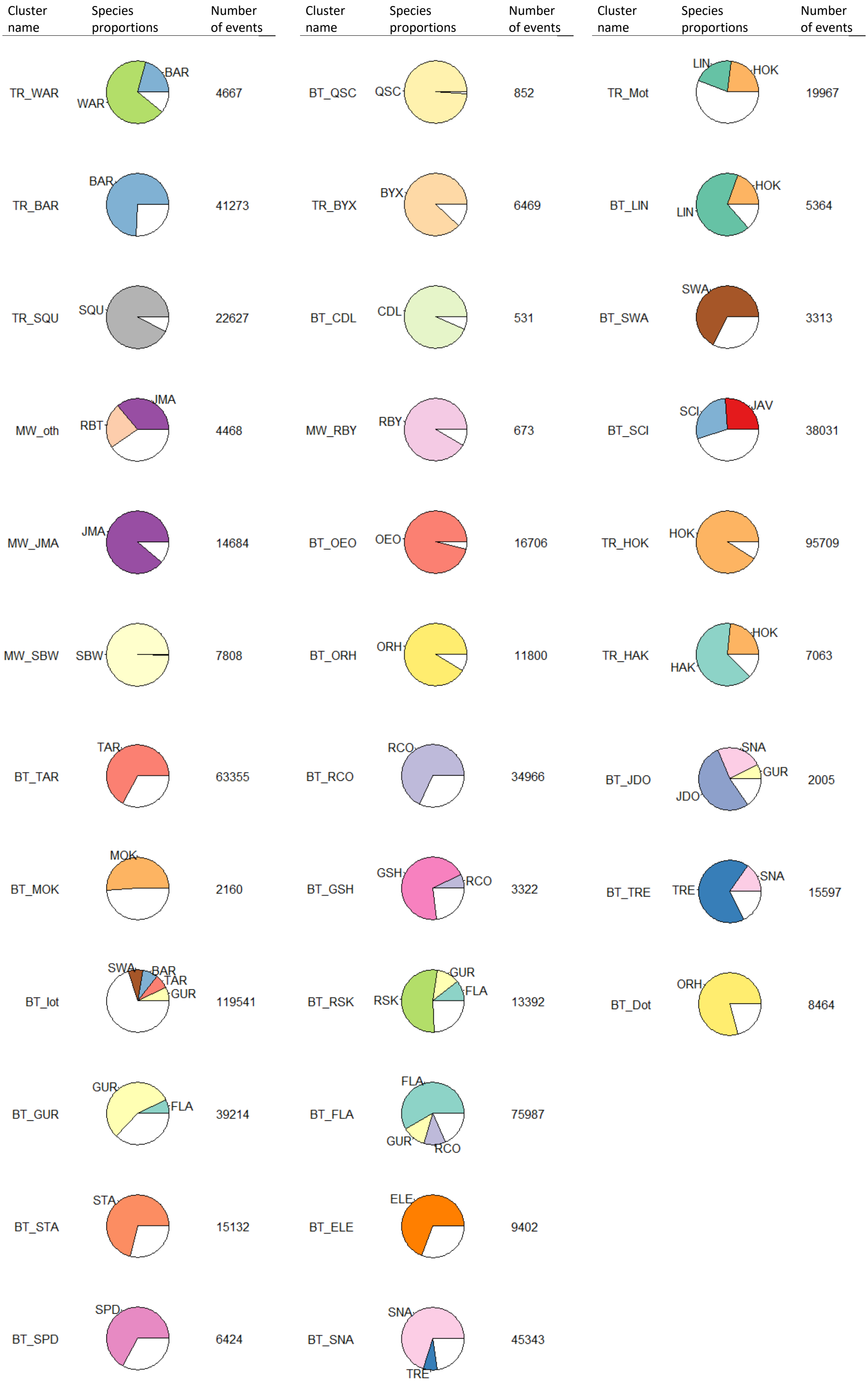


Figure A4.4: The final set of clusters adopted in CatchMapper for trawl fishing events.

Table A4.5: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named “other” and “% other” give the sum and percentage of events for each cluster reported as other target species. The table is continued on the next page and includes column for the total number of events for each reported target species.

Target + gear	BT_CDL	BT_Dot	BT_ELE	BT_FLA	BT_GSH	BT_GUR	BT_Iot	BT_JDO	BT_LIN	BT_MOK	BT_OEO	BT_ORH	BT_QSC	BT_RCO	BT_RSK	BT_SCI	BT_SNA
CDL TRAWL	460	547	0	0	0	0	3	0	0	0	21	275	0	0	0	0	0
ELE TRAWL	0	0	3806	109	0	382	1113	0	0	0	0	0	0	102	379	0	1
FLA TRAWL	0	0	3279	72536	47	11391	26791	0	0	23	0	0	0	18398	9517	0	1470
GSH TRAWL	0	0	1	1	2148	26	951	0	0	1	0	0	0	361	9	0	0
GUR TRAWL	0	0	456	1409	30	22985	17130	8	0	544	0	0	0	1971	627	0	4763
JDO TRAWL	0	1	0	6	35	305	7590	1819	0	11	0	0	0	47	0	0	5274
LEA TRAWL	0	0	6	3	1	28	1061	0	0	0	0	0	0	4	4	0	108
LIN TRAWL	0	2	4	2	16	0	1059	0	3492	1	0	0	0	121	14	12	1
MOK TRAWL	0	0	0	0	8	4	392	0	0	264	0	0	0	6	0	0	26
OEO TRAWL	0	256	0	0	0	0	0	0	0	0	14172	138	0	0	0	15	0
ORH TRAWL	24	7454	0	0	0	0	6	0	0	0	2242	11351	0	0	0	35	0
QSC TRAWL	0	0	0	0	0	0	7	0	0	0	0	0	851	1	0	0	0
RCO TRAWL	0	0	493	553	267	587	4287	0	1	1	0	0	0	10182	1453	0	7
RSK TRAWL	0	0	39	4	0	122	124	0	0	0	0	0	0	16	471	0	0
SCI TRAWL	0	1	0	0	5	0	16	0	195	0	0	0	0	0	0	37474	0
SNA TRAWL	0	0	0	152	1	380	6044	101	0	25	0	0	0	19	0	0	24676
SPD TRAWL	0	0	84	9	0	13	355	0	0	0	0	0	0	27	1	0	0
SKI TRAWL	0	0	0	0	0	0	734	0	0	0	0	0	0	2	0	5	0
SPE TRAWL	0	0	30	1	0	5	1090	0	15	0	0	0	0	50	9	2	0
STA TRAWL	0	2	262	40	4	181	2722	0	1	0	0	0	0	233	60	0	0
SWA TRAWL	0	2	0	0	0	0	1139	0	93	0	0	0	0	64	11	21	2
TAR TRAWL	0	1	226	441	603	1378	27038	30	2	1118	0	0	0	1958	468	0	3358
TRE TRAWL	0	1	0	0	1	857	8217	45	0	13	0	0	0	6	0	0	5317
JMA TRAWL	0	0	0	1	0	2	51	1	0	0	0	0	0	2	0	0	11
RBY TRAWL	3	4	0	0	0	0	146	1	0	0	0	0	0	0	0	0	0
SBW TRAWL	0	0	0	0	0	0	3	0	12	0	0	0	0	0	0	5	0
BAR TRAWL	0	0	308	52	92	385	3835	0	1	9	0	0	0	592	158	0	180
BYX TRAWL	33	29	0	0	0	0	52	0	9	0	24	6	0	0	0	12	0
HAK TRAWL	0	5	0	0	0	0	5	0	205	0	0	0	0	0	0	1	0
HOK TRAWL	11	152	0	0	13	0	314	0	1030	0	242	27	0	27	2	430	0
SQU TRAWL	0	0	1	0	0	0	1411	0	50	0	0	0	0	301	5	8	0
WAR TRAWL	0	0	46	20	39	78	3880	0	0	148	0	0	0	288	49	0	103
WWA TRAWL	0	1	0	0	0	0	17	0	253	0	1	0	0	2	0	0	0
other	0	6	361	648	12	105	1958	0	5	2	4	3	1	186	155	11	46
Total	531	8464	9402	75987	3322	39214	119541	2005	5364	2160	16706	11800	852	34966	13392	38031	45343
% other	0.0%	0.1%	3.8%	0.9%	0.4%	0.3%	1.6%	0.0%	0.1%	0.1%	0.0%	0.0%	0.1%	0.5%	1.2%	0.0%	0.1%

Table A4.5. cont.

Target + gear	BT_SPD	BT_STA	BT_SWA	BT_TAR	BT_TRE	MW_JMA	MW_oth	MW_RBY	MW_SBW	TR_BAR	TR_BYX	TR_HAK	TR_HOK	TR_Mot	TR_SQU	TR_WAR	Total
CDL TRAWL	0	0	1	0	0	0	7	3	0	0	331	0	296	370	0	0	2314
ELE TRAWL	115	27	0	20	1	0	0	0	0	319	0	0	0	0	1	7	6382
FLA TRAWL	1638	1622	0	1263	49	8	0	0	0	1473	0	3	4	8	0	47	149567
GSH TRAWL	211	25	1	113	0	0	0	0	0	123	0	0	51	11	1	6	4040
GUR TRAWL	373	154	0	1268	2529	16	0	0	0	2743	0	0	6	3	0	97	57112
JDO TRAWL	97	7	0	327	373	18	0	0	0	624	0	0	0	1	0	3	16538
LEA TRAWL	37	0	0	7	3	1	0	0	0	39	0	0	0	0	0	4	1306
LIN TRAWL	45	127	49	35	0	5	6	1	16	55	10	102	1132	5010	18	12	11347
MOK TRAWL	8	0	1	46	4	1	0	0	0	47	0	0	8	1	0	4	820
OEO TRAWL	0	0	0	0	0	0	0	0	4	0	0	1	13	9	0	0	14608
ORH TRAWL	0	0	0	0	0	0	2	0	0	0	32	17	158	166	0	0	21487
QSC TRAWL	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	861
RCO TRAWL	428	134	171	276	2	4	0	0	0	3687	0	7	19	66	64	170	22859
RSK TRAWL	13	0	0	4	0	0	0	0	0	49	0	0	0	0	0	0	842
SCI TRAWL	3	1	0	4	0	0	0	0	0	0	3	10	227	2427	3	0	40369
SNA TRAWL	67	0	1	508	2079	6	0	0	0	791	0	0	5	5	1	3	34864
SPD TRAWL	1080	28	21	30	0	0	0	0	0	65	1	0	4	3	0	11	1732
SKI TRAWL	0	21	0	80	0	0	1	13	0	28	5	1	61	688	0	1	1640
SPE TRAWL	16	0	4	67	0	0	0	0	0	74	1	0	61	99	0	11	1535
STA TRAWL	184	10256	12	331	0	0	0	0	0	407	0	1	7	129	0	68	14900
SWA TRAWL	230	2	1632	72	1	7	3	0	1	234	13	20	1758	1648	151	2	7106
TAR TRAWL	812	2366	151	57739	749	19	0	9	0	7288	0	1	570	209	14	376	106924
TRE TRAWL	18	0	0	303	9772	10	0	0	0	793	0	0	0	1	0	4	25358
JMA TRAWL	20	1	16	2	1	14021	1970	0	0	2565	0	0	6	7	7	9	18693
RBY TRAWL	0	0	0	19	0	0	378	620	0	4	30	0	9	418	0	0	1632
SBW TRAWL	0	0	0	0	0	0	13	0	7766	0	0	0	9	31	3	0	7842
BAR TRAWL	552	191	173	392	12	433	283	0	0	14147	0	1	21	24	50	510	22401
BYX TRAWL	0	0	0	1	0	0	119	12	0	6	5793	1	257	559	0	0	6913
HAK TRAWL	0	5	4	0	0	0	99	0	0	3	1	6022	1225	931	1	0	8507
HOK TRAWL	150	5	449	64	0	39	791	2	13	78	159	805	89365	4948	19	0	99135
SQU TRAWL	142	5	596	12	0	22	234	0	4	3069	0	4	172	515	22285	59	28895
WAR TRAWL	115	138	12	233	13	24	13	0	0	2422	0	1	8	6	2	3251	10889
WWA TRAWL	4	3	19	0	0	0	2	0	4	0	3	44	203	1043	7	0	1606
other	66	13	0	139	9	50	547	13	0	138	87	22	54	630	0	12	5283
Total	6424	15132	3313	63355	15597	14684	4468	673	7808	41273	6469	7063	95709	19967	22627	4667	756309
% other	1.0%	0.1%	0.0%	0.2%	0.1%	0.3%	12.2%	1.9%	0.0%	0.3%	1.3%	0.3%	0.1%	3.2%	0.0%	0.3%	0.7%

This new classification of fishing events has combined 86 reported trawl target species into 29 distinct catch composition clusters and four additional clusters containing all other events that are either mixed species catches or small single species dominated fisheries. The similarity between catch composition (as defined in Table A4.2) and reported target species for the fishing events is indicated by the distribution of fishing events in the array given in Table A4.5.

The fishing cluster classification described here is not a replacement for the use of target species to group fishing events but is an informative alternative that might be more useful in some circumstances. In CatchMapper it is particulalry useful for finding similar types of fishing to use for imputing missing data from median values of a group of other records.

The fishing depths involved with each trawl cluster are shown in Figure A4.5

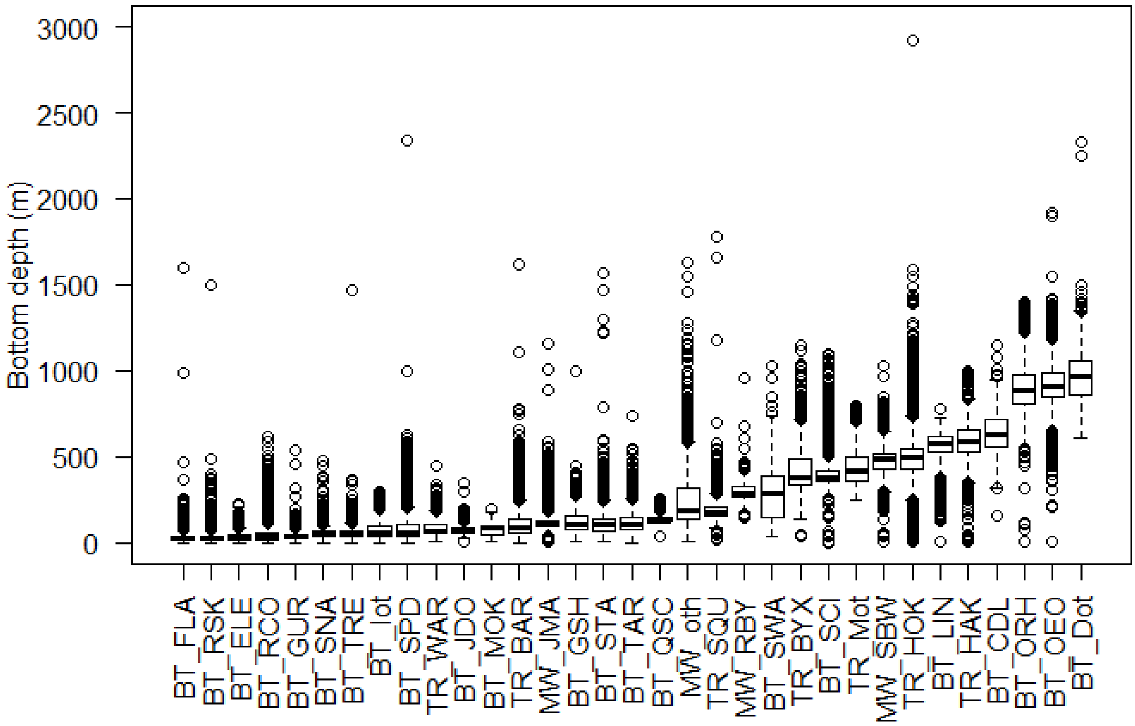


Figure A4.5: The range of depths fished within each trawl cluster arranged in order of median depth.

NETS

The clustering developed for net fishing is shown in Figure A4.6. This clustering was developed as follows:

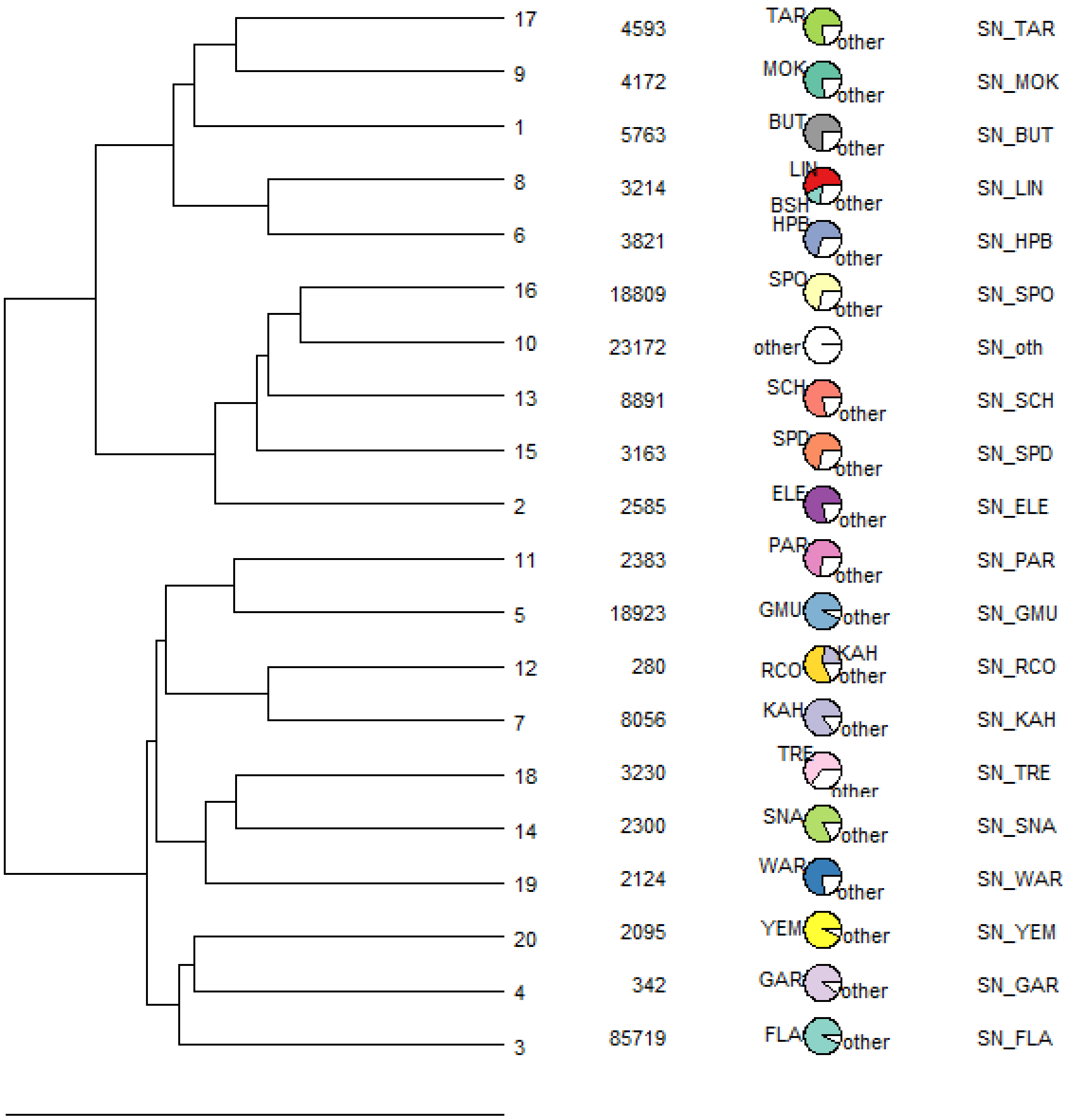


Figure A4.6: The final set of clusters adopted in CatchMapper for set net fishing events. Shown in order from left to right are the dendrogram of similarity, the cluster number, the number of fishing events in each cluster, the average species composition and the cluster label.

The initial cluster analysis was performed on 47 out of the 200 species caught by nets. These 47 species had either catch >20 tonne or occurred in at least 10% of the catches. In the whole netting data set the best number of clusters was 18 (Figure A4.7). Of these, 17 were accepted and two variants of flatfish clusters were combined (Figure A4.8). After examining regional clusterings additional clusters for GAR, RCO, and LIN were accepted giving a total of 20 net fishing clusters (Table A4.6).

Over the three years examined there was a reduction in the number of set netting events especially those that catch predominantly LIN, SPD, WAR, FLA, and SNA, and an increase in netting events catching predominantly SCH, TRE, KAH and HPB (Table A4.6). No new clusters were found for recent years when the clustering was repeated in 2017.

The classification rules used to closely reproduce the 20 clusters are given in Table A4.7. A cross tabulation of the clusters from cluster analysis with those created from the classification rules is given in Table A4.8 A cross tabulation between clusters and reported target species is given in Table A4.9.

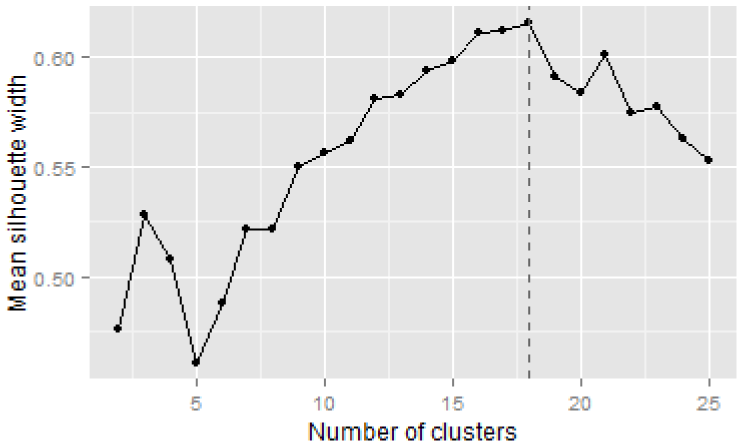


Figure A4.7: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 18 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation).

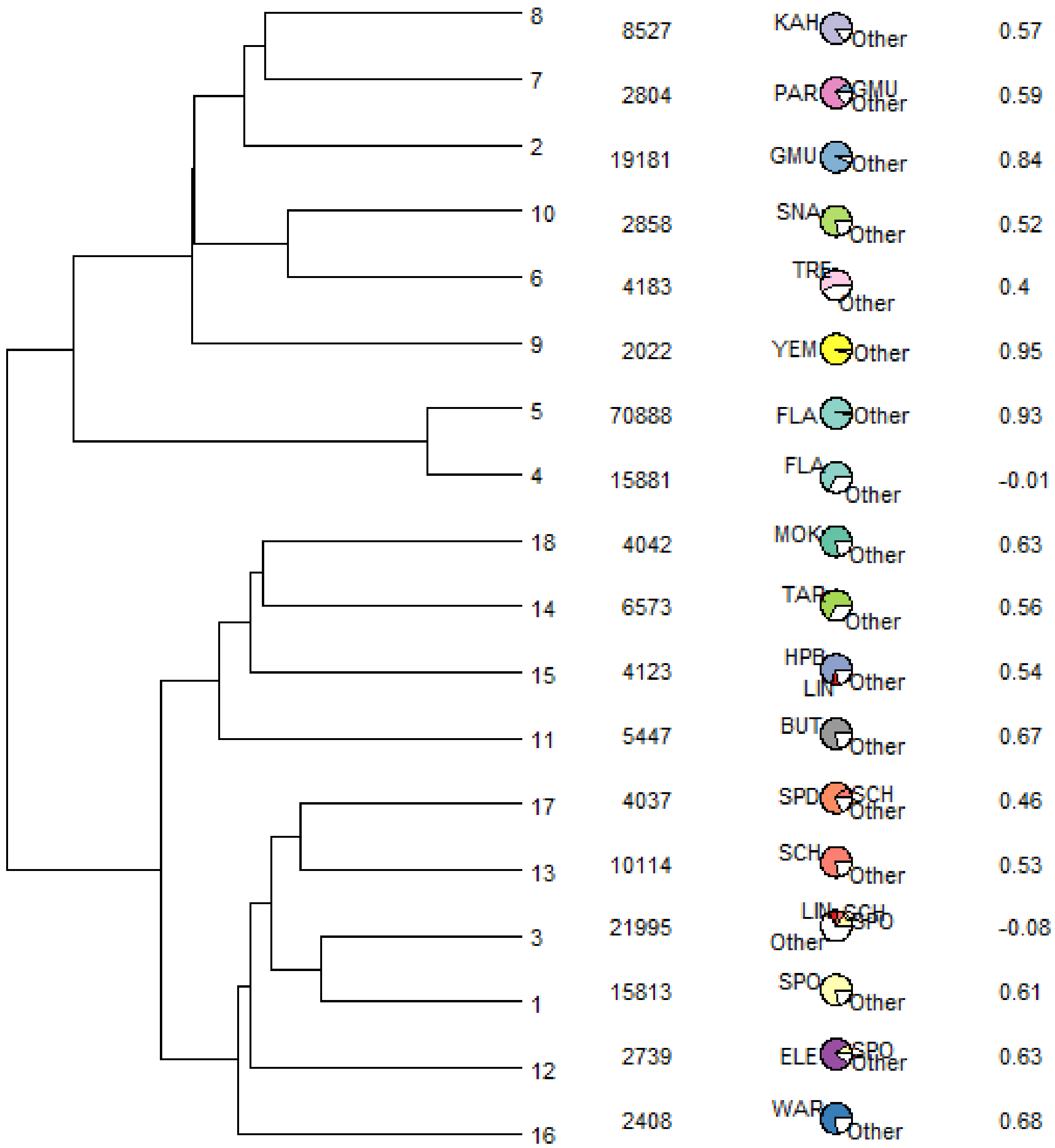


Figure A4.8: A dendrogram of the similarity between 18 clusters initially found in the 9-year set netting dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.8, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters. Cluster 3 and 4 have a negative silhouette distance indicating that the points within these clusters are more similar to other clusters than to other points within their cluster, but not similar enough to be included in other clusters i.e. the points in these clusters are the remaining ones that don't fit elsewhere.

Table A4.6: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=20). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries were combined into a default cluster called "SN_oth".

	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	0708	1112	1516
k=20										
SN_BUT		2910		1917	981	35	16	658	584	518
SN_ELE					2891	11	2	309	314	237
SN_FLA	33042	2788	41835	3281	5200	156	439	10039	9440	7091
SN_GAR	343									
SN_GMU	7613		12101			8		2112	2383	1945
SN_HPB					4738		4	398	485	562
SN_KAH	4833	304	4150	841		28		753	817	1011
SN_LIN					2939	122	4	581		
SN_oth	6519	1050	3390	895	6914	43	367	1597	1570	1380
SN_MOK		1536		227	1998		7	386	415	476
SN_PAR	1731		615			11		232	325	292
SN_RCO		262								
SN_SCH	501	261	1723	1349	5085	301	33	964	1219	1654
SN_SNA	2094							323	273	224
SN_SPD				189	2326	30	2	669	301	
SN_SPO	3194	491	8153	2555	3803	75	6	2479	2561	2221
SN_TAR					4755			755	951	582
SN_TRE	1774		1435					245	490	387
SN_WAR		1014	1318	88				230	294	
SN_YEM	578		539	385	463	18		184	205	207
Total	62222	10616	75259	11727	42093	838	880	22914	22627	18787

Table A4.7: Classification into cluster membership for set net fisheries uses rules based on region, order of precedence, species composition, and fishing method. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule	method rule	cluster	Region rule	order rule	species rule	method rule
SN_oth	ECSI	1	default		SN_oth	offshore	1	default	
SN_TAR	ECSI	2	TAR>0.5		SN_TAR	offshore	2	TAR>0.5	
SN_HPB	ECSI	3	HPB>0.3		SN_HPB	offshore	3	HPB>0.3	
SN_FLA	ECSI	4	FLA>0.5		SN_FLA	offshore	4	FLA>0.5	
SN_SPD	ECSI	5	SPD>0.35		SN_SPD	offshore	5	SPD>0.35	
SN_SCH	ECSI	6	SCH>0.4		SN_SCH	offshore	6	SCH>0.4	
SN_SPO	ECSI	7	SPO>0.3		SN_SPO	offshore	7	SPO>0.3	
SN_MOK	ECSI	8	MOK>0.35	Not DN	SN_MOK	offshore	8	MOK>0.35	Not DN
SN_BUT	ECSI	9	BUT>0.3		SN_BUT	offshore	9	BUT>0.3	
SN_ELE	ECSI	10	ELE>0.4		SN_ELE	offshore	10	ELE>0.4	
SN_LIN	ECSI	11	LIN>0.3 or BSH>0.4		SN_LIN	offshore	11	LIN>0.3	
SN_YEM	ECSI	12	YEM>0.4		SN_YEM	offshore	12	YEM>0.4	
SN_oth	FMA1	1	default		SN_oth	TOS	1	default	
SN_SPO	FMA1	2	SPO>0.4		SN_FLA	TOS	2	FLA>0.6	
SN_FLA	FMA1	3	FLA>0.4		SN_KAH	TOS	3	KAH>0.4	
SN_KAH	FMA1	4	KAH>0.5		SN_BUT	TOS	4	BUT>0.3	
SN_SNA	FMA1	5	SNA>0.5		SN_SCH	TOS	5	SCH>0.5	
SN_GMU	FMA1	6	GMU>0.5		SN_SPO	TOS	6	SPO>0.5	
SN_PAR	FMA1	7	PAR>0.4	Not DN	SN_YEM	TOS	7	YEM>0.3	
SN_TRE	FMA1	8	TRE>0.4		SN_oth	WCNI	1	default	
SN_GAR	FMA1	9	GAR>0.4		SN_SPO	WCNI	2	SPO>0.45	
SN_YEM	FMA1	10	YEM>0.4		SN_KAH	WCNI	3	KAH>0.5	
SN_oth	FMA2	1	default		SN_WAR	WCNI	4	WAR>0.3	
SN_MOK	FMA2	2	MOK>0.5	Not DN	SN_YEM	WCNI	5	YEM>0.45	
SN_FLA	FMA2	3	FLA>0.2		SN_SCH	WCNI	6	SCH>0.35	
SN_WAR	FMA2	4	WAR>0.5		SN_TRE	WCNI	7	TRE>0.4	
SN_SPO	FMA2	5	SPO>0.3		SN_FLA	WCNI	8	FLA>0.45	
SN_SCH	FMA2	6	SCH>0.4		SN_GMU	WCNI	9	GMU>0.5	
SN_BUT	FMA2	7	BUT or GTR >0.2		SN_oth	WCSI	1	default	
SN_KAH	FMA2	8	KAH>0.4		SN_LIN	WCSI	2	LIN>0.3	
SN_RCO	FMA2	9	RCO>0.35		SN_SCH	WCSI	3	SCH>0.3	

Table A4.8: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and shown in Figure A4.8) and those produced by the classification rules (rows and shown in Figure A4.6).

Clusters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
SN_BUT	1	0	349	2	0	0	0	1	0	0	5353	0	15	2	0	2	3	35	5763
SN_ELE	9	0	0	0	0	0	0	0	0	0	0	2555	12	0	0	0	5	4	2585
SN_FLA	13	1	177	14746	70754	4	5	10	0	1	0	3	1	0	0	0	0	4	85719
SN_GAR	0	0	341	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	342
SN_GMU	0	18852	18	10	0	7	3	33	0	0	0	0	0	0	0	0	0	0	18923
SN_HPB	0	0	248	0	0	0	0	0	0	0	0	0	7	63	3485	1	17	0	3821
SN_KAH	0	0	71	176	0	4	0	7783	0	0	19	0	0	0	0	0	0	3	8056
SN_LIN	3	0	2692	0	0	0	0	0	0	0	0	1	3	4	495	1	11	4	3214
SN_MIX	72	293	14900	764	134	920	563	595	60	497	72	145	986	1517	85	442	705	422	23172
SN_MOK	20	0	295	0	0	0	0	0	0	0	0	1	9	224	44	2	44	3533	4172
SN_PAR	1	22	29	63	0	2	2224	22	0	18	1	0	1	0	0	0	0	0	2383
SN_RCO	1	0	202	31	0	0	0	38	0	0	2	3	0	1	0	2	0	0	280
SN_SCH	48	0	108	0	0	0	0	0	0	1	0	0	8552	6	0	9	159	8	8891
SN_SNA	0	0	0	7	0	0	0	0	0	2293	0	0	0	0	0	0	0	0	2300
SN_SPD	0	0	7	0	0	0	0	0	0	0	0	0	0	159	9	3	2985	0	3163
SN_SPO	15631	0	2371	43	0	27	0	0	0	42	0	31	528	4	5	3	96	28	18809
SN_TAR	0	0	0	0	0	0	0	0	0	0	0	0	0	4593	0	0	0	0	4593
SN_TRE	13	0	0	0	0	3204	8	1	0	3	0	0	0	0	0	0	0	1	3230
SN_WAR	1	0	149	0	0	15	0	1	0	3	0	0	0	0	0	1943	12	0	2124
SN_YEM	0	13	38	39	0	0	1	42	1962	0	0	0	0	0	0	0	0	0	2095
Total	15813	19181	21995	15881	70888	4183	2804	8527	2022	2858	5447	2739	10114	6573	4123	2408	4037	4042	203635

Table A4.9: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species.

Target + Gear	SN_BUT	SN_ELE	SN_FLA	SN_GAR	SN_GMU	SN_HPB	SN_KAH	SN_LIN	SN_oth	SN_MOK	SN_PAR	SN_RCO	SN_SCH	SN_SNA	SN_SPD	SN_SPO	SN_TAR	SN_TRE	SN_WAR	SN_YEM	Total
BUT NET	5746	0	1	0	0	0	154	0	267	18	1	3	9	0	1	8	0	0	2	0	6210
ELE NET	0	1373	3	0	0	4	0	0	128	22	0	1	35	0	29	68	0	0	0	0	1663
FLA NET	4	0	85557	0	227	0	1299	0	3338	2	279	48	8	262	0	720	0	94	0	114	91952
GAR NET	0	0	0	342	0	0	4	0	16	0	4	0	0	0	0	0	0	0	0	22	388
GMU NET	0	0	23	0	18589	0	1483	0	2044	0	1135	0	8	44	0	89	0	259	0	46	23720
HPB NET	0	7	0	0	0	2889	0	509	444	189	0	0	38	0	99	6	1	1	0	0	4183
KAH NET	0	0	23	0	69	0	4362	0	595	0	238	21	0	41	0	62	0	76	3	2	5492
LIN NET	0	1	1	0	0	391	0	2504	457	19	0	0	7	0	51	1	1	0	0	0	3433
MOK NET	5	17	0	0	0	15	4	6	474	2044	0	0	60	0	87	140	2	2	11	0	2867
PAR NET	0	0	0	0	1	0	8	0	96	0	614	0	0	2	0	2	0	6	0	1	730
RCO NET	0	0	1	0	0	0	35	0	52	0	0	203	0	0	0	31	0	0	6	0	328
SCH NET	0	141	1	0	0	192	3	51	2276	179	0	0	6988	1	1160	753	4	14	22	0	11785
SNA NET	0	0	8	0	5	0	127	0	615	0	23	0	7	1526	0	58	0	42	0	1	2412
SPD NET	0	11	0	0	0	2	0	0	72	13	0	0	14	1	279	27	0	0	0	0	419
SPO NET	0	1023	81	0	7	54	293	26	4383	626	24	2	1446	292	323	16653	1	538	44	1	25817
TAR NET	2	11	0	0	0	177	1	18	2496	876	0	0	31	2	1117	16	4583	7	0	0	9337
TRE NET	0	0	7	0	7	0	172	0	1639	0	59	0	21	98	0	103	0	2108	3	0	4217
WAR NET	0	1	0	0	0	1	13	1	922	147	0	0	154	0	3	16	0	28	2031	0	3317
YEM NET	0	0	3	0	15	0	38	0	106	0	2	0	0	0	0	0	0	0	0	1893	2057
POR NET	0	0	0	0	0	0	5	0	903	0	2	0	24	16	0	6	0	39	0	0	995
other	6	0	10	0	3	96	55	99	1849	37	2	2	41	15	14	50	1	16	2	15	2313
Total	5763	2585	85719	342	18923	3821	8056	3214	23172	4172	2383	280	8891	2300	3163	18809	4593	3230	2124	2095	203635
% other	0.1%	0.0%	0.0%	0.0%	0.0%	2.5%	0.7%	3.1%	8.0%	0.9%	0.1%	0.7%	0.5%	0.7%	0.4%	0.3%	0.0%	0.5%	0.1%	0.7%	1.1%

Set Lines

The clustering developed for set line fishing is shown in Figure A4.9. This clustering was developed as follows:

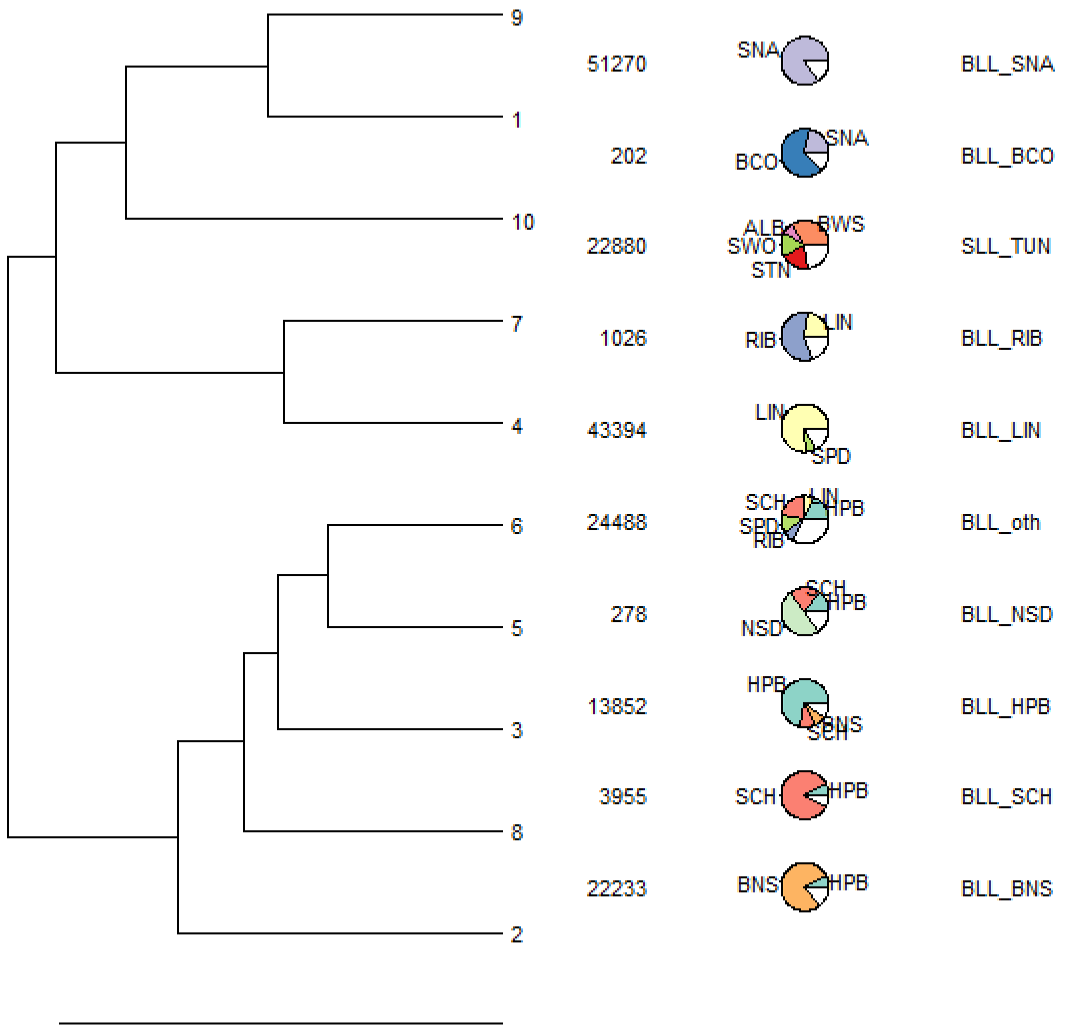


Figure A4.9: The final set of clusters adopted in CatchMapper for set line fishing events. Shown from left to right are the dendrogram of similarity, a cluster number label, the number of fishing events in each cluster, the average species composition and the cluster label.

The initial clustering for set line events was performed on 39 out of the 268 species caught by set lines. These 39 had either catch of over 200 tonne or occurred in at least 10% of the catches. In the whole data set the best number of clusters was 6 (Figure A4.10) and the dendrogram is shown in Figure A4.11. After examining regional clusterings and re-clustering the "other" cluster additional clusters for BCO, NSD, and RIB and surface longlining for tuna species were accepted giving a total of 10 set line fishing clusters (Table A4.10).

Over the three years examined separately there was a reduction in the number of set lining events especially those that catch predominantly BNS and HAP, and an increase in surface longlining events catching predominantly tunas and other game fish (Table A4.10). No new clusters were found for recent years when the clustering was repeated in 2017.

The classification rules used to closely reproduce the 10 clusters are given in Table A4.11. A cross tabulation of the clusters from cluster analysis shown in Figure A4.12 with those created from the classification rules is given in Table A4.12 A cross tabulation between clusters and reported target species is given in Table A4.13.

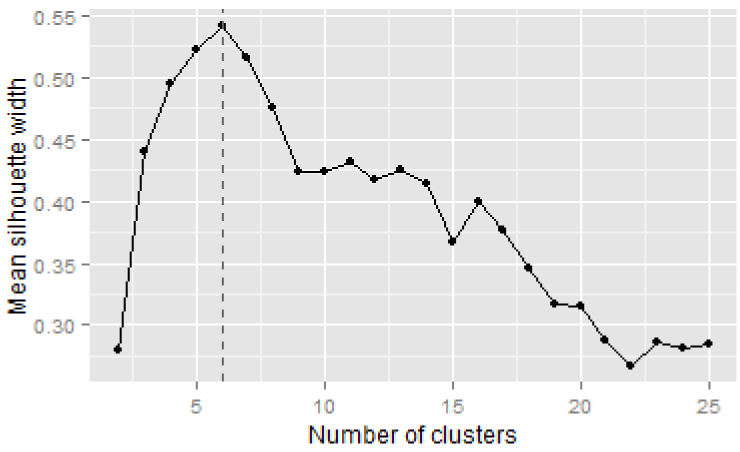


Figure A4.10: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 6 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation).

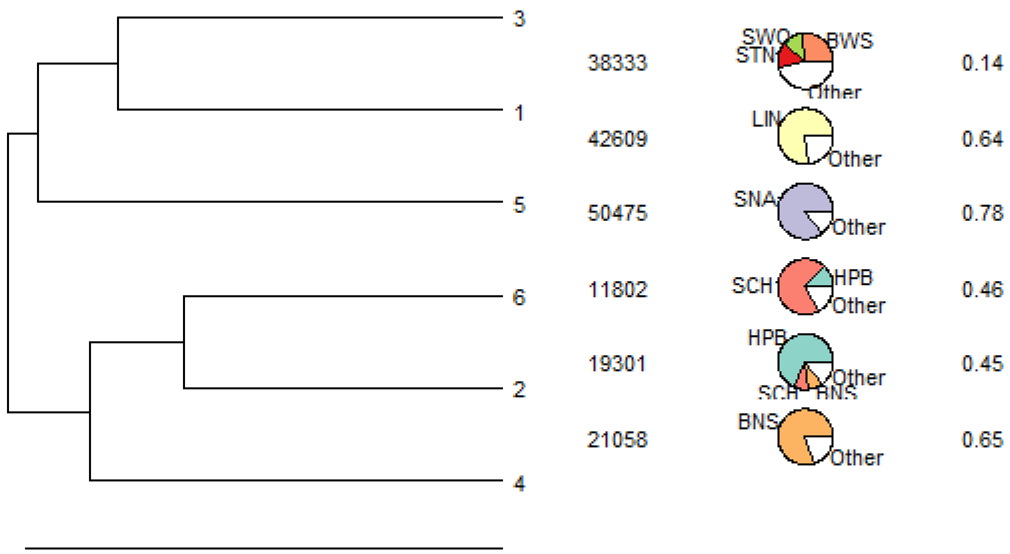


Figure A4.11: A dendrogram of the similarity between six initial clusters found in the 9-year set lining dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.12, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters.

Table A4.10: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=13). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into a default cluster called "BLL_oth".

k=13	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	0708	1112	1516
BLL_BCO			222		100					
BLL_BNS	6593	6828	1691	644	784	703	7524	3986	2048	1323
BLL_HPB	1916	3680	2377	1665	2435	324	6437	2209	2878	883
BLL_LIN	2029	8323	1673	233	6073	6808	14285	5342	3573	4958
BLL_oth	3854		1093	260	1207		2739	1670	1604	1492
BLL_NSD				281						
BLL_RIB		1866			1110		3171		1148	1045
BLL_SCH		946	1043	3153	515	934	2642	661	1217	865
BLL_SNA	51080		1129	163				5491	5712	4993
SLL_TUN	4881	4698	754	115		2821	9776	1603	2779	2699
Total	70353	26341	9982	6514	12224	11590	46574	20962	20959	18258

Table A4.11: Classification into cluster membership for set line fisheries uses rules based on region, order of precedence, species composition, and fishing method. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule	method rule	cluster	Region rule	order rule	species rule	method rule
BLL_oth	ECSI	1	default		BLL_oth	TOS	1	default	
BLL_HPB	ECSI	2	HPB>0.6		BLL_HPB	TOS	2	HPB>0.3	
BLL_BNS	ECSI	3	BNS>0.4		BLL_NSD	TOS	3	NSD>0.3	
BLL_LIN	ECSI	4	LIN>0.4		BLL_LIN	TOS	4	LIN>0.4	
BLL_RIB	ECSI	5	RIB>0.3		BLL_BNS	TOS	5	BNS>0.4	
BLL_oth	FMA1	1	default		BLL_SCH	TOS	6	SCH>0.5	
SLL_TUN	FMA1	2		SLL	BLL_oth	WCNI	1	default	
BLL_SNA	FMA1	3	SNA>0.3		SLL_TUN	WCNI	2		SLL
BLL_BNS	FMA1	4	BNS>0.3		BLL_LIN	WCNI	3	LIN>0.1	
BLL_LIN	FMA1	5	LIN>0.3		BLL_SCH	WCNI	4	SCH>0.3	
BLL_HPB	FMA1	6	HPB>0.3		BLL_BNS	WCNI	5	BNS>0.4	
BLL_oth	FMA2	1	default		BLL_HPB	WCNI	6	HPB>0.4	
BLL_HPB	FMA2	2	HPB>0.2		BLL_SNA	WCNI	7	SNA>0.5	
BLL_LIN	FMA2	3	LIN>0.3		BLL_BCO	WCNI	8	BCO>0.4	
BLL_BNS	FMA2	4	BNS>0.4		BLL_oth	WCSI	1	default	
SLL_TUN	FMA2	5		SLL	SLL_TUN	WCSI	2		SLL
BLL_oth	offshore	1	default		BLL_BNS	WCSI	3	BNS>0.3	
BLL_LIN	offshore	2	LIN>0.3		BLL_LIN	WCSI	4	LIN>0.4	
BLL_BNS	offshore	3	BNS>0.3						
SLL_TUN	offshore	4		SLL					

Table A4.12: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and shown in Figure A4.11) and those produced by the classification rules (rows and shown in Figure A4.9).

clusters	1	2	3	4	5	6	Total
BLL_BCO	0	0	178	0	24	0	202
BLL_BNS	207	990	339	20570	0	127	22233
BLL_HPB	23	12249	167	291	14	1108	13852
BLL_LIN	41841	395	931	102	1	124	43394
BLL_oth	260	5615	11811	75	448	6279	24488
BLL_NSD	1	49	165	2	0	61	278
BLL_RIB	274	2	748	2	0	0	1026
BLL_SCH	3	1	0	0	6	3945	3955
BLL_SNA	0	0	1130	0	49982	158	51270
SLL_TUN	0	0	22864	16	0	0	22880
Total	42609	19301	38333	21058	50475	11802	183578

Table A4.13: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species.

Target + gear	BLL_BCO	BLL_BNS	BLL_HPB	BLL_LIN	BLL_oth	BLL_NSD	BLL_RIB	BLL_SCH	BLL_SNA	SLL_TUN	Total
BCO LINE1	201	1	3	0	408	0	0	10	45	0	668
BNS LINE1	0	20316	1369	914	2204	48	3	99	1	0	24954
HPB LINE1	1	1346	11623	979	9388	167	1	765	27	0	24297
LIN LINE1	0	486	211	41215	3662	18	811	16	0	0	46419
GUR LINE1	0	0	0	3	828	0	0	28	551	0	1410
RSN LINE1	0	1	9	0	304	0	0	2	86	0	402
PTO LINE1	0	0	0	0	273	0	0	0	0	0	273
SPO LINE1	0	0	0	0	210	0	0	0	2	0	212
TAR LINE1	0	2	31	3	887	0	0	24	233	0	1180
TRU LINE1	0	3	2	2	280	0	0	1	0	0	288
RIB LINE1	0	3	1	194	599	0	211	0	0	0	1008
SCH LINE1	0	34	549	79	3516	44	0	2936	18	0	7176
SNA LINE1	0	1	51	2	1329	0	0	73	50169	0	51625
BIG LINE1	0	1	0	0	7	0	0	0	0	10174	10182
STN LINE1	0	10	0	0	12	0	0	0	0	10217	10239
SWO LINE1	0	0	0	0	92	0	0	0	0	2184	2276
other	0	29	3	3	489	1	0	1	138	305	969
Total	202	22233	13852	43394	24488	278	1026	3955	51270	22880	183578
% other	0.0%	0.1%	0.0%	0.0%	2.0%	0.4%	0.0%	0.0%	0.3%	1.3%	4.1%

Other lines

The clustering developed for active line fishing (labelled LINE2 in CatchMapper and includes PL, T, HL) is shown in Figure A4.12. This clustering was developed as follows:

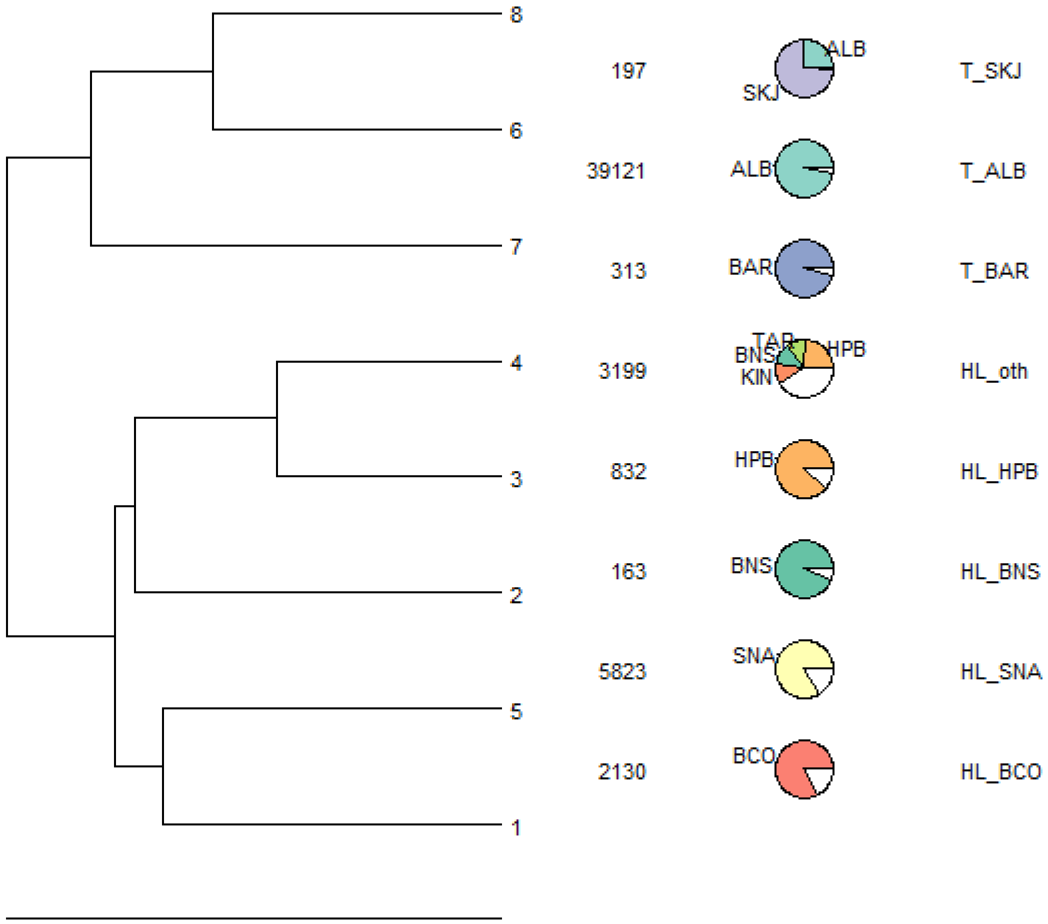


Figure A4.12: The final set of clusters adopted in CatchMapper for active line fishing events. Shown are the dendrogram of similarity, the number of fishing events in each cluster, the average species composition and the cluster label.

The initial cluster analysis was performed on 15 out of the 118 species caught by active lining. These 15 species had either catch over 5 tonne or occurred in at least 10% of the catches. In the whole data set for this gear type the best number of clusters was 5 (Figure A4.13). Of these, two variants of ALB clusters were combined (Figure A4.14). After examining regional clusterings additional clusters for BAR, BNS and HPB and other or mixed species events were added giving a total of 8 LINE2 fishing clusters (Table A4.14).

Over the three years examined there was no consistent trend in numbers of events for these fisheries (Table A4.14).

The classification rules used to closely reproduce the 8 clusters are given in Table A4.15. A cross tabulation of the clusters from cluster analysis with those created from the classification rules is given in Table A4.16 A cross tabulation between clusters and reported target species is given in Table A4.17.

Except for trolling for albacore, it is possible that most of this fishing is non-commercial fishing by the crews on the vessels or perhaps fishing for bait. .

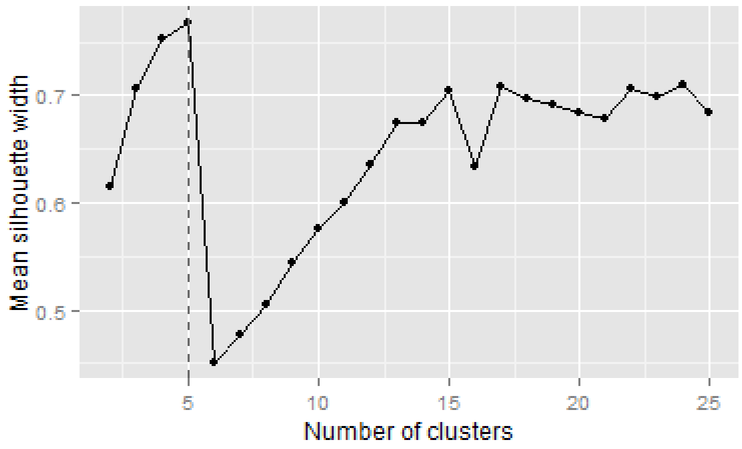


Figure A4.13: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 5 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation).

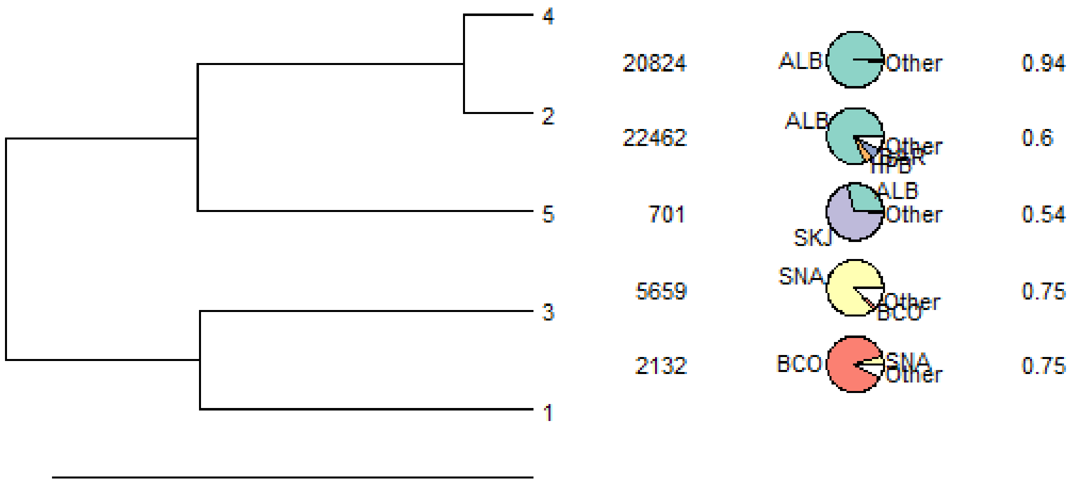


Figure A4.14: A dendrogram of the similarity between 5 initial clusters found in the 9-year active lining (LINE2) dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.16, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters.

Table A4.14: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=15). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into a default cluster called "HL_oth".

k=15	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	0708	1112	1516
T_ALB	962	1566	7097	2156	30	26776	249	4426	4855	4037
T_BAR				100	284		8	33	68	26
T_SKJ	175	117	195	27		62	20	42	35	61
HL_BCO		198	378	756	368	147	136	257	190	230
HL_BNS	208	80	58		189	23	27	18	74	51
HL_HPB	115	170	321	55	306		203	115	132	114
HL_oth	814	453	139	328	271	20	25	343	388	307
HL_SNA	4912	40	1085	31			98	567	898	532
Total	7186	2624	9273	3453	1448	27028	766	5801	6640	5358

Table A4.15: Classification into cluster membership for active lining fisheries uses rules based on region, order of precedence, species composition, and fishing method. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule	method rule
HL_oth	ECSI	1	default	
T_BAR	ECSI	2		T
HL_BNS	ECSI	3	BNS>0.4	
HL_HPB	ECSI	4	HPB>0.4	
HL_BCO	ECSI	5	BCO>0.3	
HL_oth	FMA1	1	default	
HL_SNA	FMA1	2	SNA>0.3	
T_ALB	FMA1	3		T
HL_oth	FMA2	1	default	
HL_BCO	FMA2	2	BCO>0.2	
T_ALB	FMA2	3		T
HL_oth	offshore	1	default	
HL_SNA	offshore	2	SNA>0.3	
T_ALB	offshore	3		T
HL_HPB	offshore	4	HPB>0.4	
HL_BCO	offshore	5	BCO>0.2	
HL_oth	TOS	1	default	
T_ALB	TOS	2		T
HL_BCO	TOS	3	BCO>0.2	
HL_oth	WCNI	1	default	
T_ALB	WCNI	2		T
T_SKJ	WCNI	3	SKJ>0.4	
HL_HPB	WCNI	4	HPB>0.4	
HL_BCO	WCNI	5	BCO>0.4	
HL_SNA	WCNI	6	SNA>0.5	
HL_oth	WCSI	1	default	
T_ALB	WCSI	2		T

Table A4.16: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and Figure A4.14) and those produced by the classification rules (rows and Figure A4.12).

clusters	1	2	3	4	5	Total
HL_BCO	1953	153	24	0	0	2130
HL_BNS	0	163	0	0	0	163
HL_HPB	0	831	1	0	0	832
HL_oth	166	2888	113	22	10	3199
HL_SNA	12	289	5521	0	1	5823
T_ALB	1	17855	0	20772	493	39121
T_BAR	0	283	0	30	0	313
T_SKJ	0	0	0	0	197	197
Total	2132	22462	5659	20824	701	51778

Table A4.17: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species.

target + gear	HL_BCO	HL_BNS	HL_HPB	HL_oth	HL_SNA	SJ_SQU	T_ALB	T_BAR	T_SKJ	Total
BCO LINE2	1931	0	13	372	31	0	0	0	0	2347
BNS LINE2	6	160	19	365	3	0	0	0	0	553
HPB LINE2	62	2	793	504	13	0	1	0	0	1375
SNA LINE2	99	0	5	488	5664	0	0	0	0	6256
SQU JIG	0	0	0	0	0	1584	0	0	0	1584
ALB LINE2	0	0	0	25	0	0	38652	53	187	38917
BAR LINE2	1	0	0	42	0	0	23	251	0	317
SKJ LINE2	0	0	0	8	0	0	125	0	10	143
other	31	1	2	1395	112	0	320	9	0	1870
Total	2130	163	832	3199	5823	1584	39121	313	197	53362
% other	1.5%	0.6%	0.2%	43.6%	1.9%	0.0%	0.8%	2.9%	0.0%	3.5%

POTS

The clustering developed for pot fishing is shown in Figure A4.15. This clustering was developed as follows:

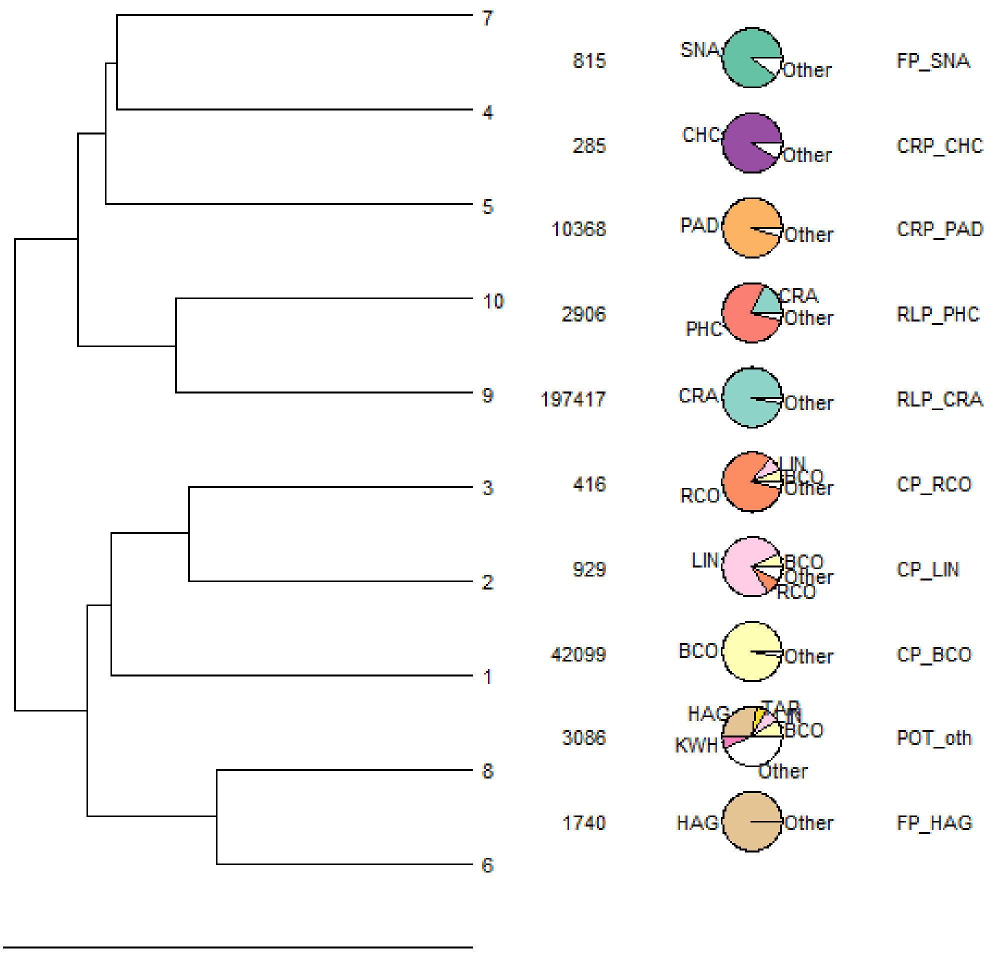
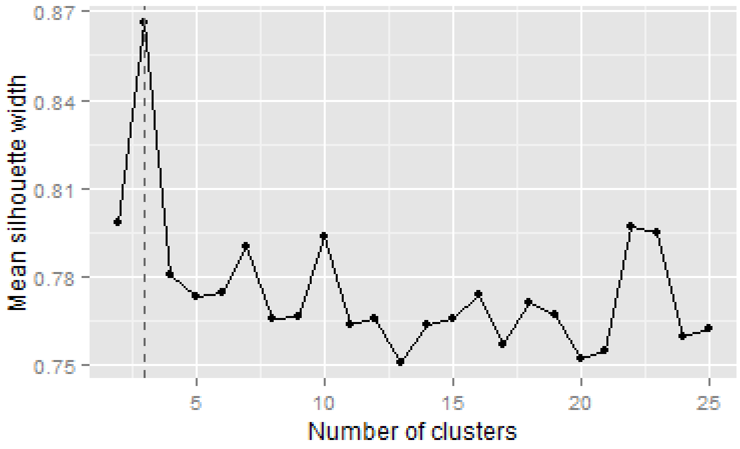


Figure A4.15: The final set of clusters adopted in CatchMapper for pot fishing events. Shown are the dendrogram of similarity, the number of fishing events in each cluster, the average species composition and the cluster label.

The initial cluster analysis was performed on 25 out of the 146 species caught by potting. These 25 species had either catch over 10 tonne or occurred in at least 10% of the catches. In the whole potting data set the best number of clusters was 3 (Figure A4.16). After examining regional clusterings smaller target fisheries can be found for hagfish, ling, and, snapper. And even smaller fisheries for red cod and king crabs give a total of 10 pot fishing clusters (Table A4.18).

Over the three years examined the numbers of potting events was reasonably constant but there was a reduction in potting for paddle crabs in particular (Table A4.18). No new clusters were found for recent years when the clustering was repeated in 2017.

The classification rules used to closely reproduce the 10 clusters are given in Table A4.19. A cross tabulation of the clusters from cluster analysis with those created from the classification rules is given in Table A4.20 A cross tabulation between clusters and reported target species is given in Table A4.21.



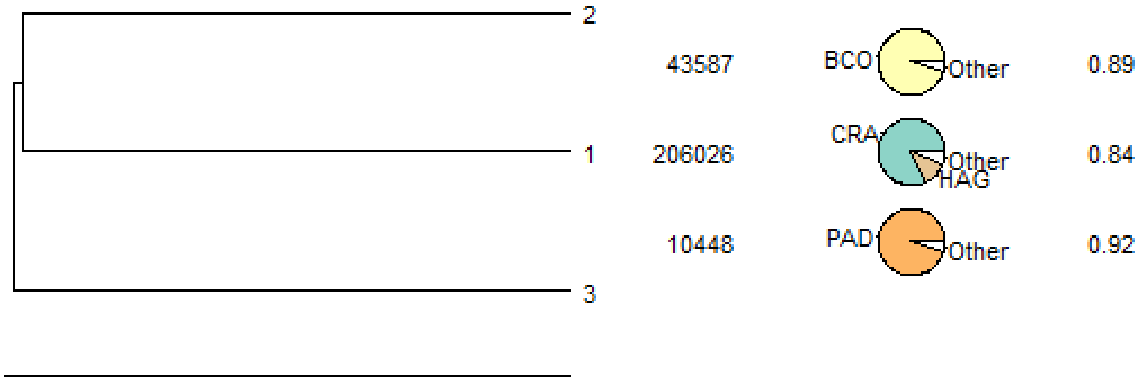


Figure A4.16 Top: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 3 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation). Bottom: A dendrogram of the similarity between the 3 initial clusters found in the 9-year pot fishing dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.20, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters.

Table A4.18: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=11). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into a default cluster called "POT_oth".

k=11	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	708	1112	1516
CP_BCO		517	243	1708	32208	956	5809	4890	4749	3929
CP_LIN				22	686					306
CP_RCO					625					
CRP_CHC		153								
CRP_PAD	3278	1487		3905	1525		35	1622	1206	929
FP_HAG	772	237	171	41		380	167	156	137	123
FP_SNA	814								80	181
POT_oth	1510	343	438	363	1979		89	474	721	728
RLP_CRA	44231	53307	9317		44857	25104	19355	23225	20620	23483
RLP_PHC	2377		1052					210	187	172
Total	52982	56044	11221	6039	81880	26440	25455	30577	27700	29851

Table A4.19: Classification into cluster membership for potting fisheries uses rules based on region, order of precedence, and species composition. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule
POT_oth	ECSI	1	default
CP_LIN	ECSI	2	LIN>0.4
CP_RCO	ECSI	3	RCO>0.5
CRP_PAD	ECSI	4	PAD>0.1
CP_BCO	ECSI	5	BCO>0.3
RLP_CRA	ECSI	6	CRA>0.1
POT_oth	FMA1	1	default
CRP_CHC	FMA1	2	CHC>0.1 OR KIC>0.1
CRP_PAD	FMA1	3	PAD>0.2
FP_HAG	FMA1	4	HAG>0.4
RLP_CRA	FMA1	5	CRA>0.2
RLP_PHC	FMA1	6	PHC>0.4
FP_SNA	FMA1	7	SNA>0.5
POT_oth	FMA2	1	default
RLP_CRA	FMA2	2	CRA>0.1
CP_BCO	FMA2	3	BCO>0.3
FP_HAG	FMA2	4	HAG>0.1
CRP_PAD	FMA2	5	PAD>0.1
POT_oth	offshore	1	default
CRP_CHC	offshore	2	CHC>0.1 OR KIC>0.1
FP_HAG	offshore	3	HAG>0.4
CP_BCO	offshore	4	BCO>0.3
RLP_CRA	offshore	5	CRA>0.2
POT_oth	TOS	1	default
CP_BCO	TOS	2	BCO>0.1
CRP_PAD	TOS	3	PAD>0.1
POT_oth	WCNI	1	default
CP_BCO	WCNI	2	BCO>0.1
FP_HAG	WCNI	3	HAG>0.3
RLP_CRA	WCNI	4	CRA>0.2
RLP_PHC	WCNI	5	PHC>0.4
POT_oth	WCSI	1	default
RLP_CRA	WCSI	2	CRA>0.05
CP_BCO	WCSI	3	BCO>0.3
FP_HAG	WCSI	4	HAG>0.05

Table A4.20: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and Figure A4.16) and those produced by the classification rules (rows and Figure A4.15).

clusters	1	2	3	Total
CP_BCO	96	42003	0	42099
CP_LIN	434	492	3	929
CP_RCO	212	195	9	416
CRP_CHC	285	0	0	285
CRP_PAD	0	0	10368	10368
FP_HAG	1739	1	0	1740
FP_SNA	802	13	0	815
POT_oth	2366	655	65	3086
RLP_CRA	197253	163	1	197417
RLP_PHC	2839	65	2	2906
Total	206026	43587	10448	260061

Table A4.21: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species

Target + gear	CP_BCO	CP_LIN	CP_RCO	CRP_CHC	CRP_PAD	FP_HAG	FP_SNA	RLP_CRA	RLP_PHC	POT_oth	Total
NSD LINE1	0	0	0	0	0	0	0	0	0	1	1
BCO POT	41437	26	18	0	0	0	2	80	0	288	41851
LIN POT	144	891	17	0	1	0	0	1	0	194	1248
RCO POT	77	8	375	0	2	0	0	0	0	44	506
CHC POT	0	0	0	283	0	2	0	0	0	39	324
PAD POT	0	0	0	0	10364	0	0	3	0	98	10465
HAG POT	0	0	0	0	0	1714	0	0	0	78	1792
SNA POT	2	0	0	0	0	0	586	0	0	48	636
COC DREDGE	0	0	0	0	0	0	0	0	0	5	5
CRA POT	366	0	5	0	0	7	133	197182	1694	799	200186
PHC POT	1	0	0	0	0	0	0	142	1209	98	1450
KIC POT	0	0	0	2	0	3	0	0	0	167	172
WSE POT	33	0	0	0	0	0	0	0	0	253	286
other	39	4	1	0	1	14	94	9	3	974	1139
Total	42099	929	416	285	10368	1740	815	197417	2906	3086	260061
% other	0.1%	0.4%	0.2%	0.0%	0.0%	0.8%	11.5%	0.0%	0.1%	31.6%	0.4%

Hand fishing

The clustering developed for hand fishing (shore fishing and diving) is shown in Figure A4.17. This clustering was developed as follows:

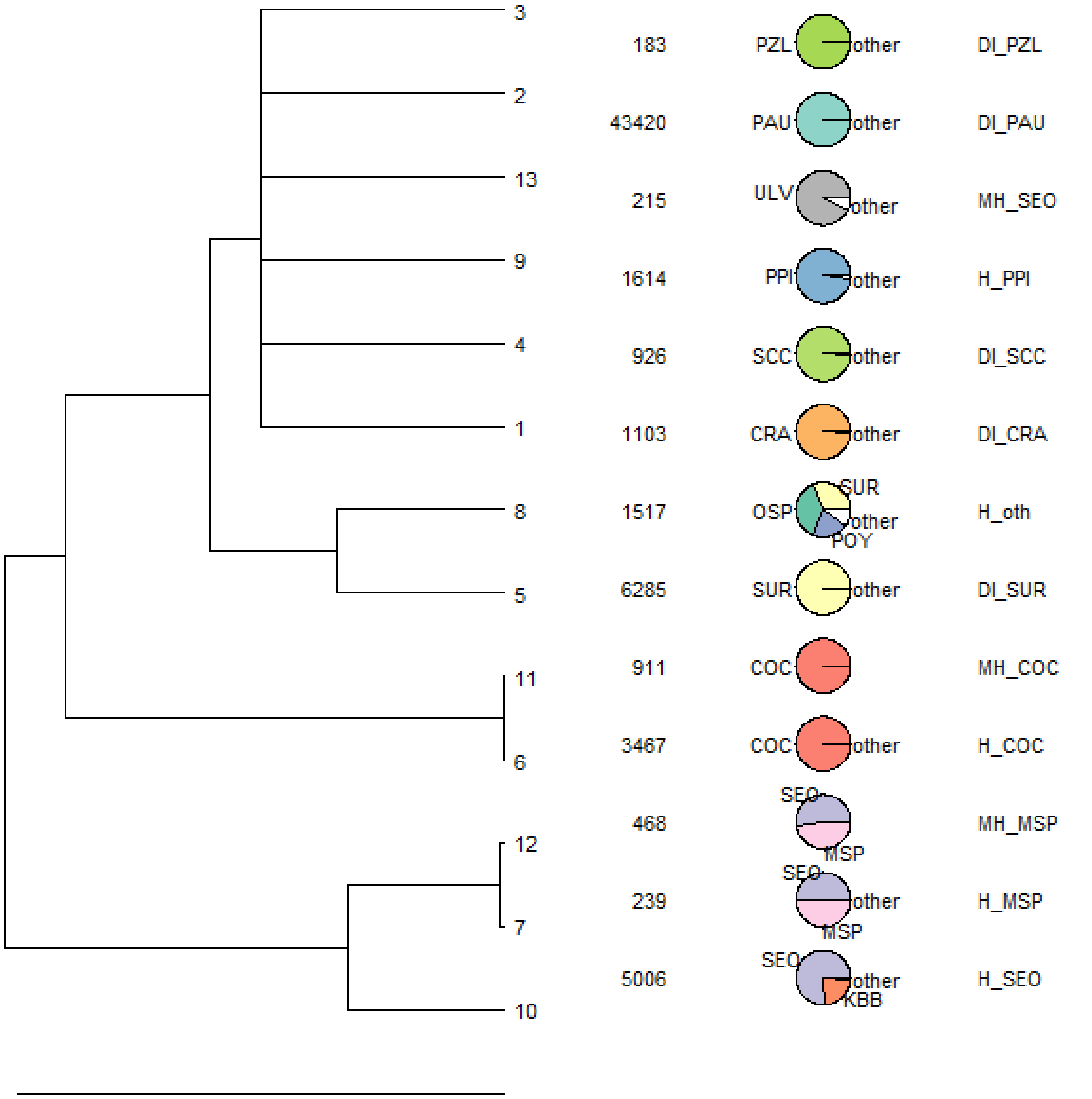


Figure A4.17: The final set of clusters adopted in CatchMapper for hand gathering fishing events. Shown are the dendrogram of similarity, the number of fishing events in each cluster, the average species composition and the cluster label.

The initial cluster analysis was performed on 21 out of the 67 species caught by hand. These 21 species had either catch over 2 tonnes or occurred in at least 10% of the catches. In the whole hand fishing data set the best number of clusters was 22 but most gains in cluster performance were achieved with fewer than 14 clusters (Figure A4.18). Several of the smallest clusters (see Figure A4.19) were aggregated into the "other" class and the seaweeds were combined to give a total of 10 clusters. Over recent years the number of seaweed harvesting events has increased and ULV and PRP were added to the seaweed cluster. Sea cucumber fishing events have also risen while cockle and kina (sea urchin) fishing events have declined (Table A4.21).

The classification rules used to closely reproduce the 10 clusters are given in Table A4.22. A cross tabulation of the clusters from cluster analysis with those created from the classification rules is given in Table A4.23. A cross tabulation between clusters and reported target species is given in Table A4.24.

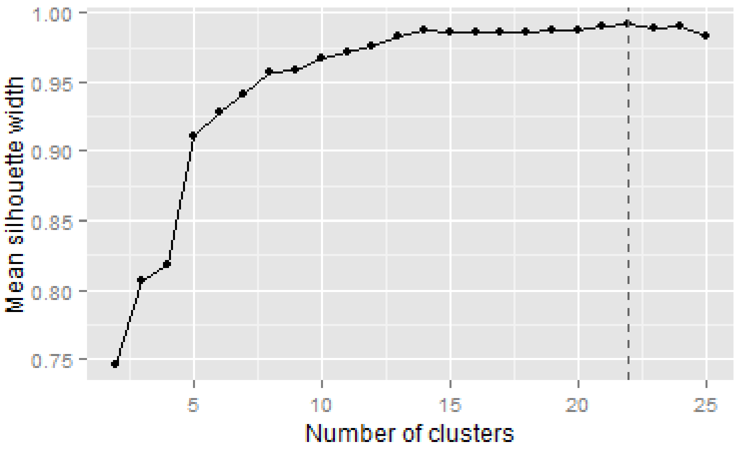


Figure A4.18: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 22 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation).

Table A4.22: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=16). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into a default cluster called "H_oth".

k=16	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	708	1112	1516
DI_CRA	11	11	8	5	198	37	905	127	113	152
H_oth	720	107	46	118	69	2	20	48	110	100
DI_PAU		5360	135	13256	16091	2542	6179	5376	5044	4707
DI_PZL				183	8			3	33	15
DI_SCC	306	82	9	610	56	17	6	54	128	158
DI_SUR	1673	124	92	1786	1375	81	1270	811	725	625
H/MH_COC	1328	1		914	2124		3	784	516	332
H_PPI	1630			1				402	208	
H/MH_SEO	2012	2226	81	26	822	1	19	266	523	721
MH_MSP			520				149	91	55	88
Total	7680	7911	891	16899	20743	2680	8551	7962	7455	6898

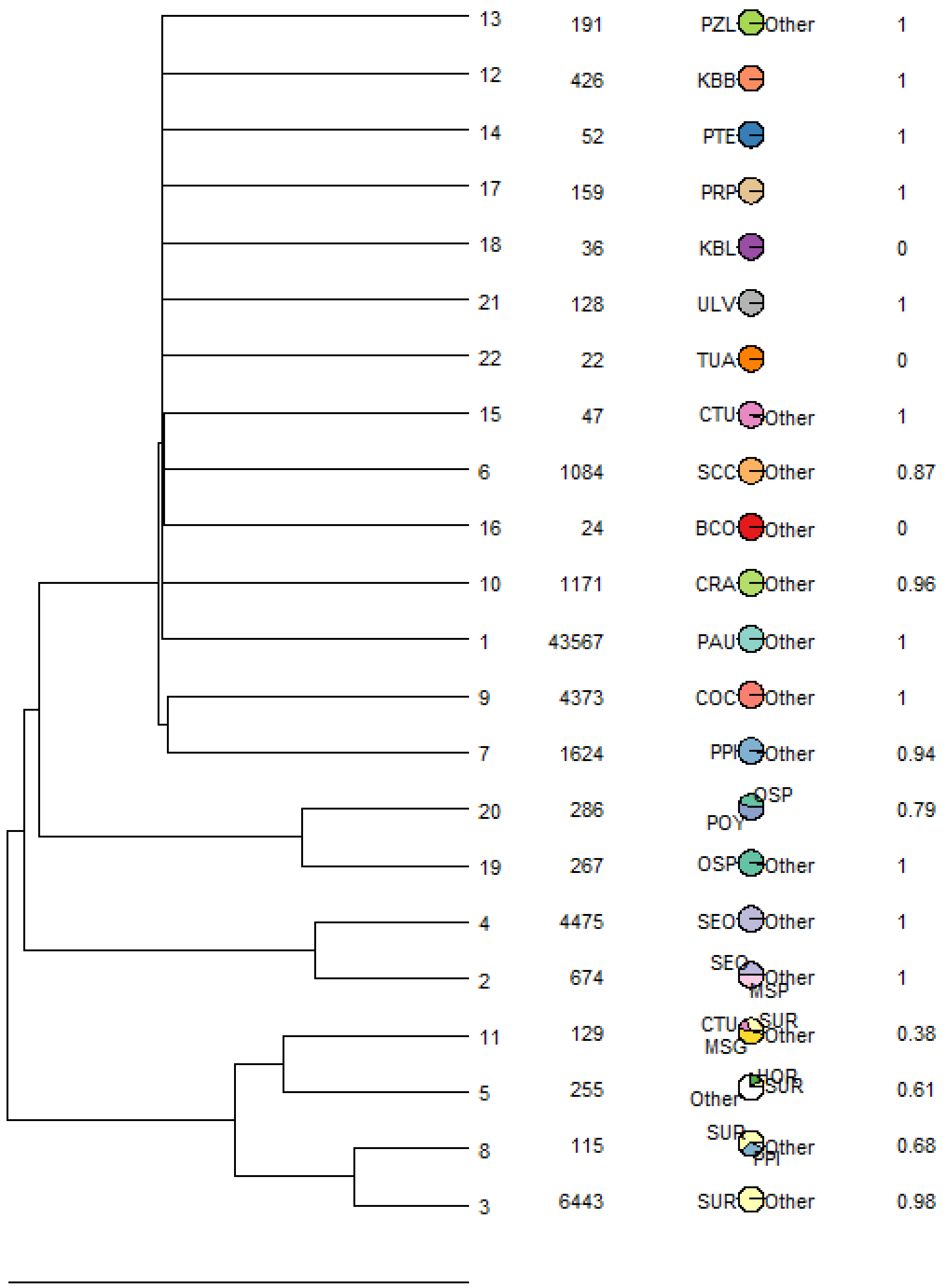


Figure A4.19: A dendrogram of the similarity between the 22 initial clusters found in the 9-year hand fishing dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.23, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters.

Table A4.23: Classification into cluster membership for hand gathering fisheries uses rules based on region, order of precedence, species composition, fishing method, and declared target species. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule	method rule	Target rule
H_oth	ECSI	1	default		
H_SEO	ECSI	2	SEO, KBB, KBL, LES, PRP, ULV or PTE >0.1	Not MH	
H_COC	ECSI	3	COC>0.4	Not MH	
DI_SUR	ECSI	4	SUR>0.2		
DI_CRA	ECSI	5	CRA>0.4		
H_oth	FMA1	1	default		
H_PPI	FMA1	2	PPI>0.2		
H_COC	FMA1	3	COC>0.4		
DI_SUR	FMA1	4	SUR>0.2		
HM_SEO	FMA1	5	SEO, KBB, KBL, LES, PRP, ULV or PTE >0.1	Not MH	
DI_SCC	FMA1	6	SCC>0.4		
H_oth	FMA2	1	default		
H_SEO	FMA2	2	SEO, KBB, KBL, LES, PRP, ULV or PTE >0.1	Not MH	
DI_SUR	FMA2	3	SUR>0.2		
H_oth	offshore	1	default		
H_COC	offshore	2	COC>0.4		
DI_SUR	offshore	3	SUR>0.2		
HM_SEO	offshore	4	SEO, KBB, KBL, LES, PRP, ULV or PTE >0.1	Not MH	
DI_CRA	offshore	5	CRA>0.4		
DI_PAU	offshore	6	PAU>0.2		
DI_SCC	offshore	7	SCC>0.4		
DI_PAU	Paua stat areas	1			
H_oth	TOS	1	default		
DI_SUR	TOS	2	SUR>0.2		
DI_SCC	TOS	3	SCC>0.4		
DI_PZL	TOS	4	PZL>0.1		
MH_COC	TOS	5		MH	COC
H_oth	WCNI	2	default		
H_SEO	WCNI	3	SEO, KBB, KBL, LES, PRP, ULV or PTE >0.1		
H_oth	WCSI	1	default		
MH_SEO		1	SEO, KBB, KBL, LES, PRP, ULV or PTE >0.1	MH	
MH_SEO		2		MH	ULV or SEO
H_MSP		3			MSP
MH_MSP		4		MH	MSP

Table A4.24: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and shown in Figure A4.19) and those produced by the classification rules (rows and shown in Figure A4.17).

clusters	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total
DI_CRA	0	0	0	0	0	0	0	2	0	1101	0	0	0	0	0	0	0	0	0	0	0	0	1103
DI_PAU	43417	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	43420
DI_PZL	0	0	0	0	0	0	0	0	0	0	0	0	183	0	0	0	0	0	0	0	0	0	183
DI_SCC	0	0	0	0	1	920	0	4	0	0	1	0	0	0	0	0	0	0	0	0	0	0	926
DI_SUR	0	0	6273	0	5	0	3	107	0	2	87	0	0	0	2	0	0	0	0	0	0	0	6479
H_COC	0	0	0	0	1	0	8	0	3458	0	0	0	0	0	0	0	0	0	0	0	0	0	3467
H_MSP	0	226	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	239
H_oth	150	0	170	27	229	164	1	2	4	67	41	10	8	0	45	24	0	0	267	286	0	22	1517
H_PPI	0	0	0	0	2	0	1612	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1614
H_SEO	0	2	0	4329	12	0	0	0	0	0	0	416	0	52	0	0	159	36	0	0	0	0	5006
MH_COC	0	0	0	0	0	0	0	0	911	0	0	0	0	0	0	0	0	0	0	0	0	0	911
MH_MSP	0	446	0	19	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	468
MH_SEO	0	0	0	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	128	0	215
Total	43567	674	6443	4475	255	1084	1624	115	4373	1171	129	426	191	52	47	24	159	36	267	286	128	22	65548

Table A4.25: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species.

Target + gear	DI_CRA	DI_PAU	DI_PZL	DI_SCC	DI_SUR	H_COC	H_MSP	H_oth	H_PPI	H_SEO	MH_COC	MH_MSP	MH_SEO	Total
CRA HAND	1102	1	0	0	3	0	0	80	0	0	0	0	0	1186
PAU HAND	0	43416	0	0	0	0	0	144	0	0	0	0	0	43560
PZL HAND	0	0	183	0	0	0	0	9	0	0	0	0	0	192
SCC HAND	0	0	0	920	25	0	0	172	0	0	0	0	0	1117
SUR HAND	0	0	0	1	6432	0	0	187	1	0	0	0	0	6621
COC HAND	0	0	0	0	0	3454	0	6	0	0	911	0	0	4371
OSP HAND	0	0	0	0	0	0	0	452	0	0	0	0	0	452
PPI HAND	0	0	0	0	4	11	0	2	1611	0	0	0	0	1628
SEO HAND	0	0	0	0	0	0	0	27	0	4327	0	0	87	4441
MSP HAND	0	0	0	0	0	0	238	1	0	0	0	467	0	706
KBB HAND	0	0	0	0	0	0	0	10	0	416	0	0	0	426
ULV HAND	0	0	0	0	0	0	0	0	0	0	0	0	128	128
other	1	3	0	5	15	2	0	428	2	25	0	1	0	482
Total	1103	43420	183	926	6479	3467	238	1518	1614	5244	911	468	215	65548
% other	0.1%	0.0%	0.0%	0.5%	0.2%	0.1%	0.0%	28.2%	0.1%	0.5%	0.0%	0.2%	0.0%	0.7%

Dredge

The clustering developed for dredge fishing is shown in Figure A4.20. Clustering of dredge fishing events was very straight forward. There are four main fisheries and the landings are dominated by the target species (little bycatch). Oyster dredging is split into two species codes because the fishery in the south reports catch and landings by numbers of oysters rather than by greenweight. The surfclam fishery contains 4–5 species but most reporting uses a generic surfclam code (SAE).

The initial cluster analysis was performed on 11 out of the 62 species caught by dredging. These 11 species had either catch over 10 tonne or occurred in at least 10% of the catches. In the whole dredge data set the best number of clusters was 5 (Figure A4.21). Of these, the two oyster clusters were combined and the two surf clam clusters were combined (Figure A4.22).

Over the three years examined there was a reduction in the number of dredging events for SCA and an increase for surfclams (PDO, MMI, SAE) (Table A4.25). No new clusters were found for recent years when the clustering was repeated in 2017.

The classification rules used to closely reproduce the 20 clusters are given in Table A4.26. A cross tabulation of the clusters from cluster analysis with those created from the classification rules is given in Table A4.27 A cross tabulation between clusters and reported target species is given in Table A4.28.

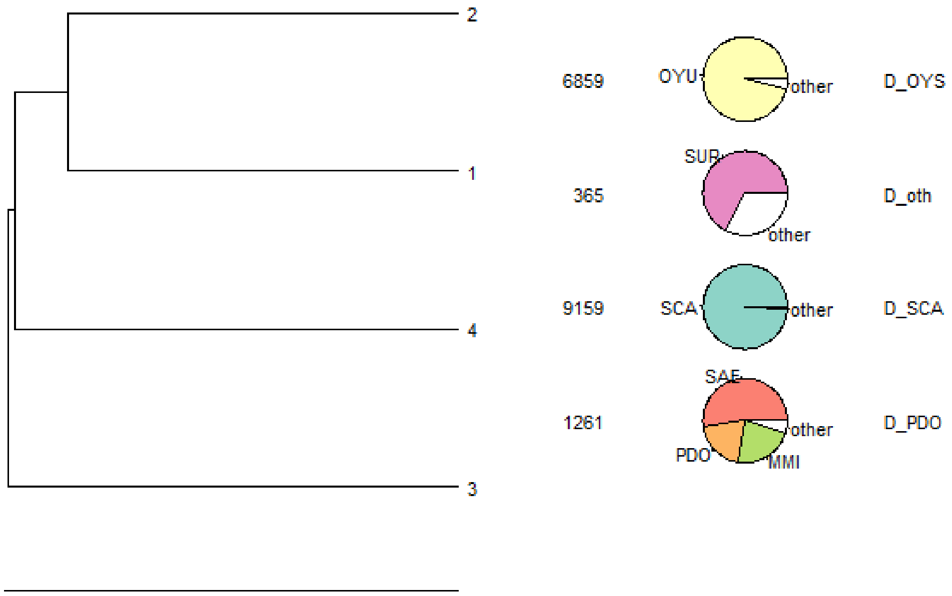


Figure A4.20: The final set of clusters adopted in CatchMapper for dredge fishing events. Shown are the dendrogram of similarity, the number of fishing events in each cluster, the average species composition and the cluster label.

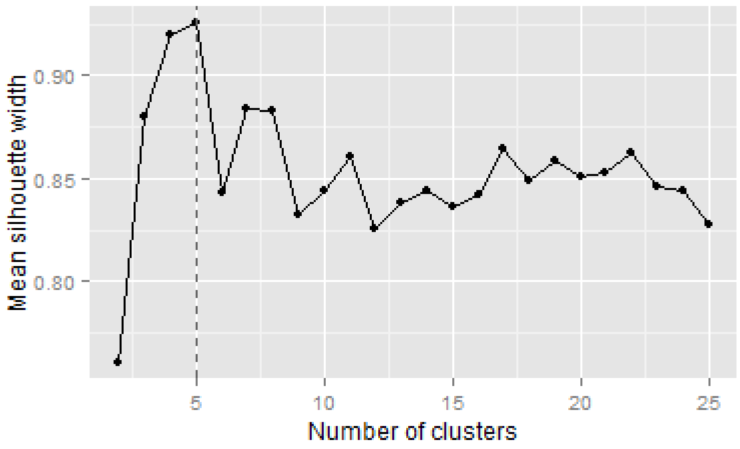


Figure A4.21: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 5 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation).

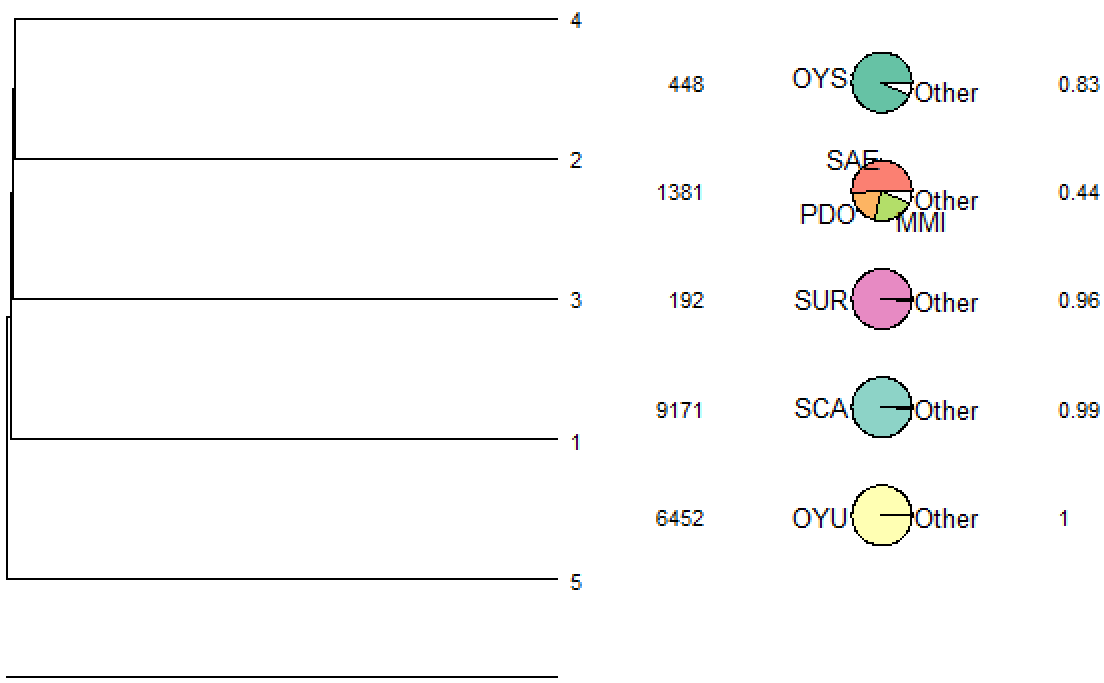


Figure A4.22: A dendrogram of the similarity between the 5 initial clusters found in the 9-year dredge fishing dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.27, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters.

Table A4.26: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=6). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into a default cluster called "D_oth".

k=6	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	0708	1112	1516
D_oth										
D_OYS				463	6468			698	931	735
D_PDO	2	2		859	399			58	96	326
D_SCA	6024	1	171	3060		1		1261	952	636
Total	6026	3	171	4382	6867	1	0	2017	1979	1697

Table A4.27: Classification into cluster membership for dredge fisheries uses rules based on region, order of precedence, and species composition. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule
D_oth	ECSI	1	default
D_OYS	ECSI	2	OYU>0.2
D_PDO	ECSI	3	PDO or SAE or MMI >0.2
D_oth	FMA1	1	default
D_SCA	FMA1	2	SCA>0.2
D_oth	FMA2	1	default
D_oth	TOS	1	default
D_SCA	TOS	2	SCA>0.2
D_OYS	TOS	3	OYS>0.2
D_PDO	TOS	4	PDO or SAE or MMI >0.2
D_SCA	WCNI	1	default
D_oth	WCSI	1	default

Table A4.28: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and shown in Figure A4.22) and those produced by the classification rules (rows and shown in Figure A4.20).

clusters	1	2	3	4	5	Total
D_oth	16	104	192	8	45	365
D_OYS	5	7	0	440	6407	6859
D_PDO	0	1261	0	0	0	1261
D_SCA	9150	9	0	0	0	9159
Total	9171	1381	192	448	6452	17644

Table A4.29: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species.

Target + gear	D_oth	D_OYS	D_PDO	D_SCA	Total
OYS DREDGE	16	439	0	0	455
OYU DREDGE	46	6408	0	0	6454
MMI DREDGE	3	0	368	0	371
PDO DREDGE	1	0	268	0	269
SAE DREDGE	1	0	617	0	618
SCA DREDGE	50	6	0	9152	9208
SUR DREDGE	193	0	0	0	0
other	55	0	8	7	75
Total	365	6859	1261	9159	17450
% other	15.1%	0.0%	0.6%	0.1%	0.4%

Ringnet

Ring netting is a specific type of fishing method primarily used mainly in northern New Zealand for catching grey mullet. The clustering developed for ringnet fishing is shown in Figure A4.23. This clustering was developed as follows:

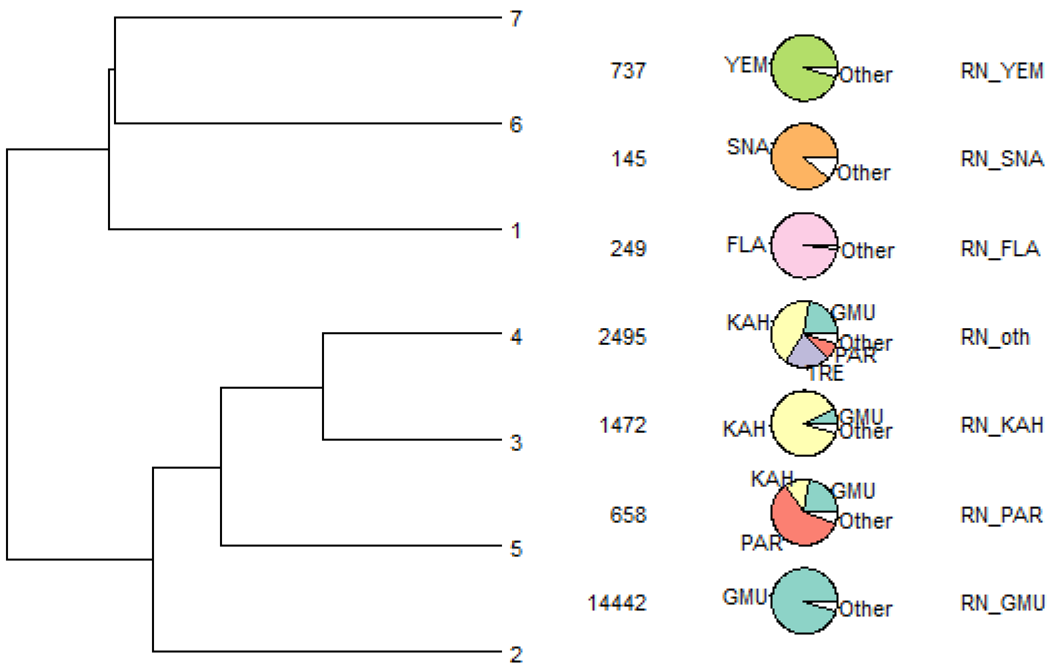
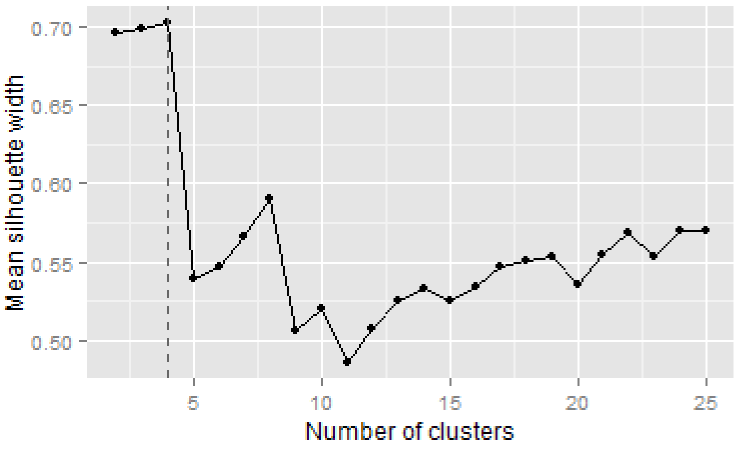


Figure A4.23: The final set of clusters adopted in CatchMapper for ring net fishing events. Shown are the dendrogram of similarity, the number of fishing events in each cluster, the average species composition and the cluster label.

The initial cluster analysis was performed on 9 out of the 58 species caught by ring nets. These 9 species had either catch over 5 tonne or occurred in at least 10% of the catches. In the whole ring netting data set the best number of clusters was 4 (Figure A4.24). After examining regional clusterings and a closer look at the "other" class an additional 3 clusters were added for PAR, FLA, and SNA giving a total of 7 ringnet fishing clusters (Table A4.29).

The classification rules used to closely reproduce the 20 clusters are given in Table A4.30. A cross tabulation of the clusters from cluster analysis with those created from the classification rules is given in Table A4.31 A cross tabulation between clusters and reported target species is given in Table A4.32.



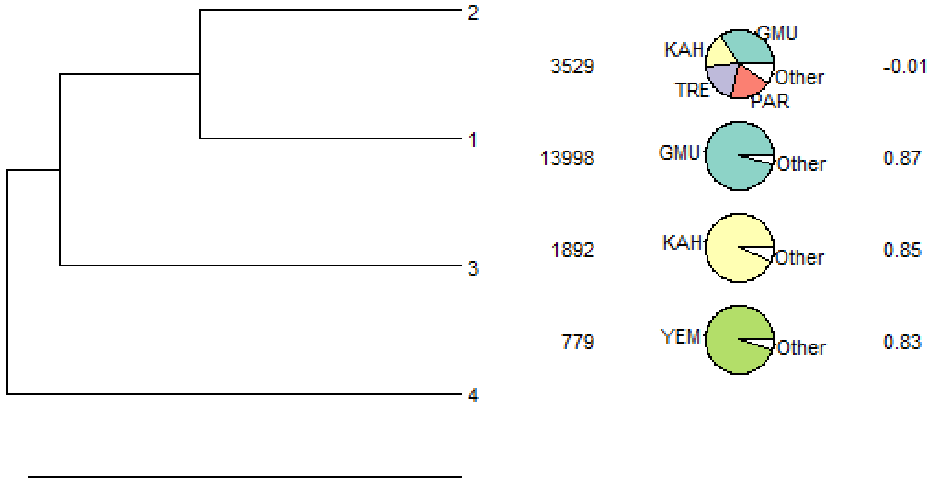


Figure A4.24 Top: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 4 clusters and then deteriorates. The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation). Bottom: A dendrogram of the similarity between the 4 initial clusters found in the 9-year ringnet fishing dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.31, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters.

TableA4.30: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=8). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into a default cluster called "RN_oth".

k=8	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	0708	1112	1516
RN_FLA			249					52	21	
RN_GMU	2931	3	12236		5		16	1479	1929	1545
RN_KAH	1485	1	1293		2			120	265	208
RN_oth	110		643	3	4	1	3	120	126	51
RN_PAR	334							51	111	35
RN_SNA	134							28		
RN_YEM			745					53	156	56
Total	4994	4	15166	3	11	1	19	1903	2608	1895

Table A4.31: Classification into cluster membership for ring net fisheries uses rules based on region, order of precedence, and species composition. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule
RN_oth	FMA1	1	default
RN_GMU	FMA1	2	GMU>0.4
RN_SNA	FMA1	3	SNA>0.3
RN_KAH	FMA1	4	KAH>0.2
RN_PAR	FMA1	5	PAR>0.3
RN_oth	ECSI	1	default
RN_oth	FMA2	1	default
RN_oth	WCSI	1	default
RN_oth	TOS	1	default
RN_oth	WCNI	1	default
RN_GMU	WCNI	2	GMU>0.6
RN_FLA	WCNI	3	FLA>0.5
RN_YEM	WCNI	4	YEM>0.5
RN_oth	offshore	1	default
RN_GMU	offshore	2	GMU>0.6

Table A4.32: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and shown in Figure A4.24) and those produced by the classification rules (rows and shown in Figure A4.23).

clusters	1	2	3	4	Total
RN_FLA	0	249	0	0	249
RN_GMU	13954	488	0	0	14442
RN_KAH	29	271	1170	2	1472
RN_oth	15	1739	701	40	2495
RN_PAR	0	637	21	0	658
RN_SNA	0	145	0	0	145
RN_YEM	0	0	0	737	737
Total	13998	3529	1892	779	20198

Table A4.33: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species.

Target + gear	RN_FLA	RN_GMU	RN_KAH	RN_oth	RN_PAR	RN_SNA	RN_YEM	Total
FLA RINGNET	249	0	0	11	0	0	0	260
GMU RINGNET	0	14431	459	1702	504	37	1	17134
KAH RINGNET	0	7	989	465	88	5	2	1556
PAR RINGNET	0	0	2	19	60	2	0	83
SNA RINGNET	0	0	7	5	2	97	0	111
YEM RINGNET	0	0	3	86	0	1	734	824
TRE RINGNET	0	1	12	161	2	3	0	179
other	0	3	0	46	2	0	0	51
Total	249	14442	1472	2495	658	145	737	20198
% other	0.0%	0.0%	0.0%	1.8%	0.3%	0.0%	0.0%	0.3%

Danish Seine

The clustering developed for Danish seine fishing is shown in Figure A4.26. This clustering was developed as follows:

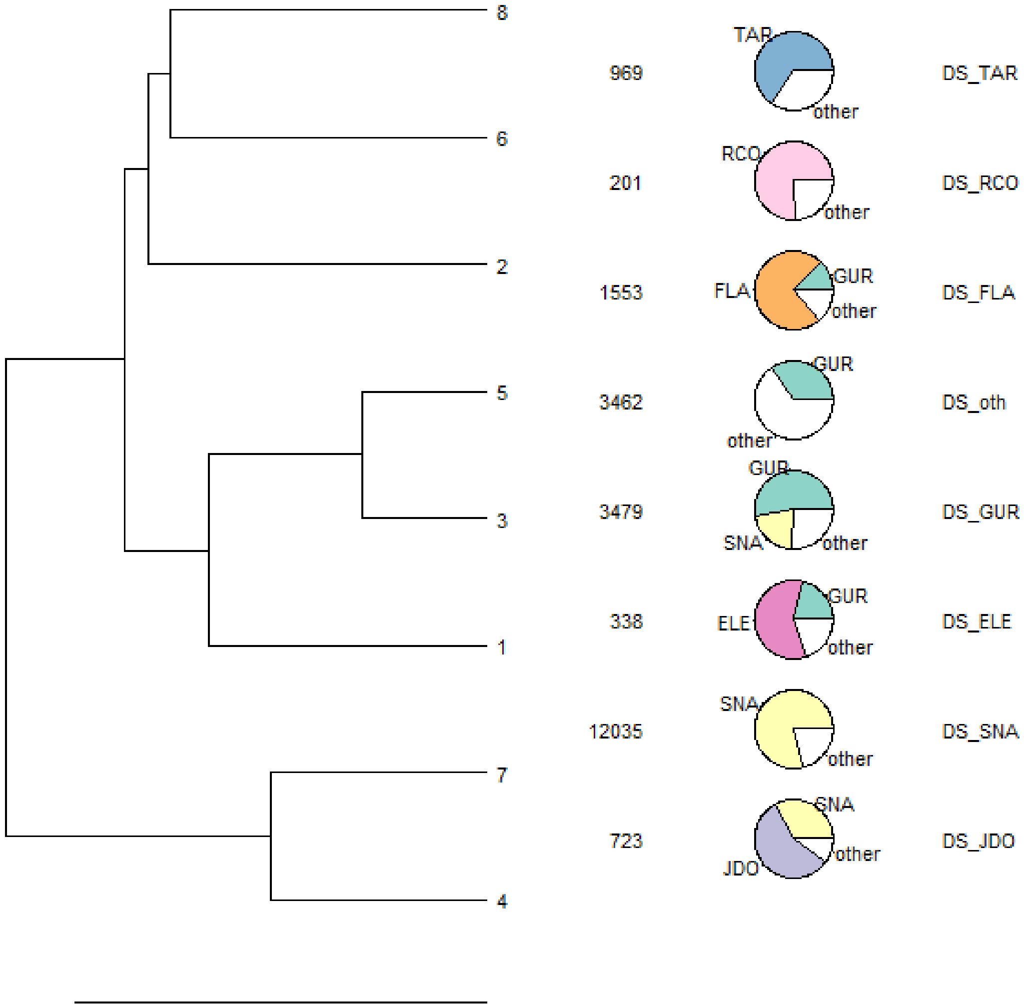
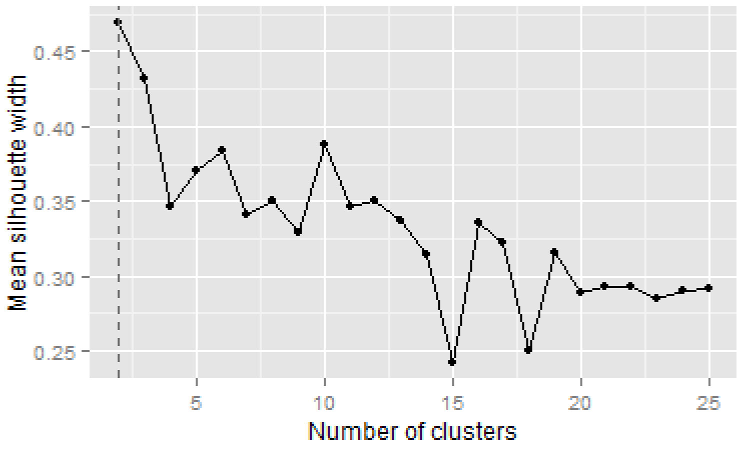


Figure A4.26: The final set of clusters adopted in CatchMapper for Danish seine fishing events. Shown are the dendrogram of similarity, the number of fishing events in each cluster, the average species composition and the cluster label.

The initial cluster analysis was performed on 18 out of the 90 species caught in Danish seine shots. These 18 species had either catch over 100 tonne or occurred in at least 10% of the catches. In the whole Danish seine data set the best number of clusters was 2 (Figure A4.27). After examining regional clusterings, additional clusters for ELE, FLA, GUR, JDO, RCO, and TAR were added giving a total of 8 Danish seine fishing clusters (Table A4.33).

Over the three years examined there was an increase in the number of DS events especially those that catch predominantly SNA, and a decrease in DS events catching predominantly RCO (Table A4.33). No new clusters were found for recent years when the clustering was repeated in 2017.

The classification rules used to closely reproduce the 8 clusters are given in Table A4.34. A cross tabulation of the clusters from cluster analysis with those created from the classification rules is given in Table A4.35. A cross tabulation between clusters and reported target species is given in Table A4.36.



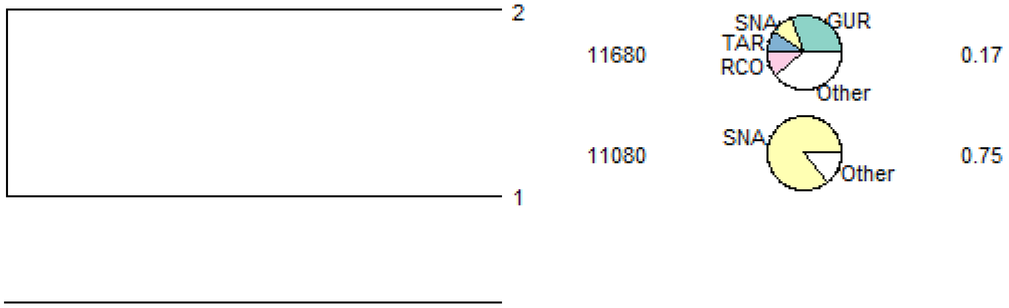


Figure A4.27 Top: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 2 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation). Bottom: A dendrogram of the similarity between 2 initial clusters found in the 9-year Danish seine fishing dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.35, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters.

Table A4.34: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=9). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into a default cluster called "DS_oth".

k=9	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	0708	1112	1516
DS_ELE					317	4				
DS_FLA				1701	155	15		212	340	171
DS_GUR	1034	201	948	186	603	6	2	405	189	245
DS_JDO	816					1	1	112	96	143
DS_oth	568	37	5	444	998	1	3	254	236	533
DS_RCO				146	304	9	1	209	37	
DS_SNA	12977	79	170	93			16	988	1342	2317
DS_TAR	539	22	26		332			62	70	97
Total	15934	339	1149	2570	2709	36	23	2242	2310	3506

Table A4.35: Classification into cluster membership for Danish seine fisheries uses rules based on region, order of precedence, and species composition. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule 1
DS_SNA	FMA1	1	default
DS_TAR	FMA1	2	TAR>0.3
DS_JDO	FMA1	3	JDO>0.35
DS_GUR	FMA1	4	GUR>0.3
DS_oth	WCNI	1	default
DS_oth	WCSI	1	default
DS_oth	TOS	1	default
DS_FLA	TOS	2	FLA>0.5
DS_GUR	FMA2	1	default
DS_oth	ECSI	1	default
DS_TAR	ECSI	2	TAR>0.3
DS_RCO	ECSI	3	RCO>0.5
DS_GUR	ECSI	4	GUR>0.4
DS_ELE	ECSI	5	ELE>0.3
DS_oth	offshore	1	default
DS_SNA	offshore FMA1	2	default
DS_GUR	offshore FMA1	3	GUR>0.3
DS_GUR	offshore ECSI	4	GUR>0.4

Table A4.36: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and shown in Figure A4.27) and those produced by the classification rules (rows and shown in Figure A4.26).

clusters	1	2	Total
DS_ELE	0	338	338
DS_FLA	0	1553	1553
DS_GUR	166	3313	3479
DS_JDO	91	632	723
DS_oth	179	3283	3462
DS_RCO	0	201	201
DS_SNA	10581	1454	12035
DS_TAR	63	906	969
Total	11080	11680	22760

Table A4.37: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species.

Target + gear	DS_ELE	DS_FLA	DS_GUR	DS_JDO	DS_oth	DS_RCO	DS_SNA	DS_TAR	Total
ELE DANISH	124	0	76	0	32	1	0	0	233
FLA DANISH	55	1553	175	0	1107	17	11	1	2919
GUR DANISH	3	0	1563	27	1226	0	1479	17	4315
JDO DANISH	0	0	120	246	3	0	959	4	1332
RCO DANISH	72	0	158	0	412	163	0	8	813
SNA DANISH	0	0	1118	437	77	0	8780	143	10555
TAR DANISH	27	0	110	8	300	19	552	794	1810
other	57	0	159	5	305	1	254	2	783
Total	338	1553	3479	723	3462	201	12035	969	22760
% other	16.9%	0.0%	4.6%	0.7%	8.8%	0.5%	2.1%	0.2%	3.4%

SEINE

The clustering developed for net fishing is shown in Figure A4.28. This clustering was developed as follows:

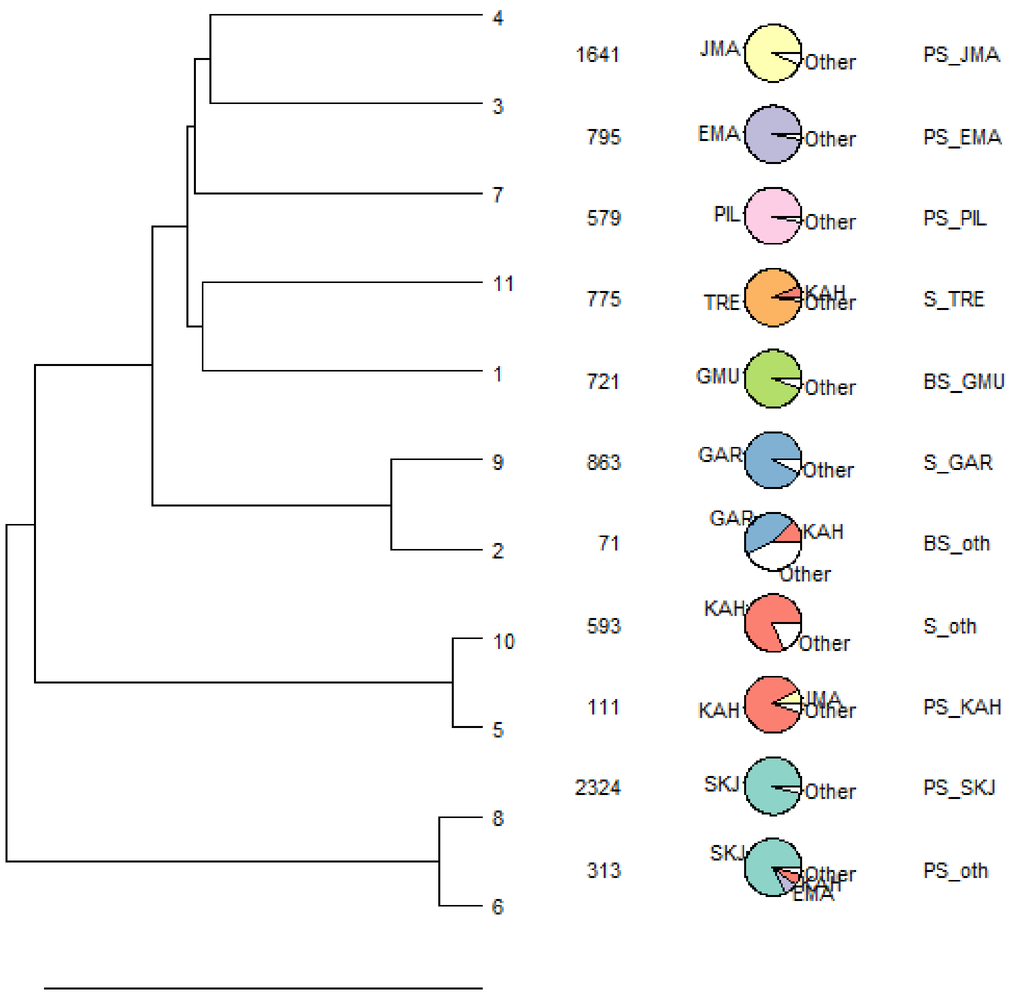


Figure A4.28: The final set of clusters adopted in CatchMapper for seine fishing events. Shown are the dendrogram of similarity, the number of fishing events in each cluster, the average species composition and the cluster label.

The initial cluster analysis was performed on 15 out of the 102 species caught by seine nets. These 15 species had either catch over 20 tonne or occurred in at least 10% of the catches. In the whole seine fishing data set the best number of clusters was 11 (Figure A4.29). Of these, two JMA variants were combined and SUN was combined with “other” (Figure A4.30). Three “other” clusters were created separating out into the main method types for BS, PS and other minor methods in a cluster called S_oth giving a total of 11 seine fishing clusters. BS and PS methods are used in very different environments and for both mapping and imputation purposes they needed to be separated.

The differences between years and regions is given in Table A4.37. No new clusters were found for recent years when the clustering was repeated in 2017.

The classification rules used to closely reproduce the 11 clusters are given in Table A4.38. A cross tabulation of the clusters from cluster analysis with those created from the classification rules is given in Table A4.39 A cross tabulation between clusters and reported target species is given in Table A4.40.

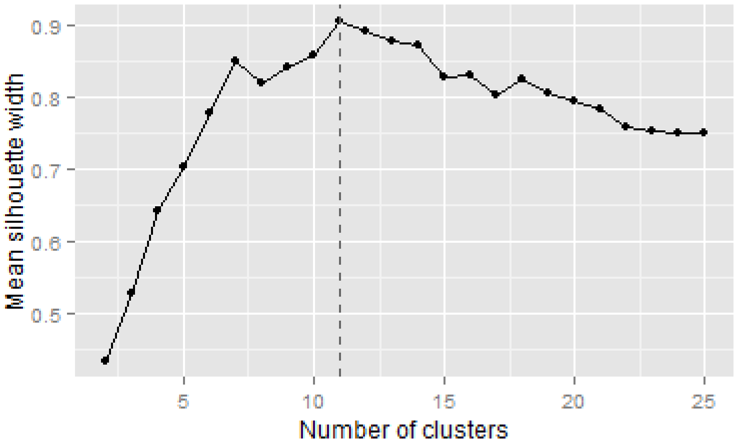


Figure A4.29: The cluster quality criteria mean silhouette width improves with adding more clusters up to a maximum of 11 clusters and then deteriorates The silhouette value is a measure of how similar an object is to its own cluster (cohesion) compared to other clusters (separation).

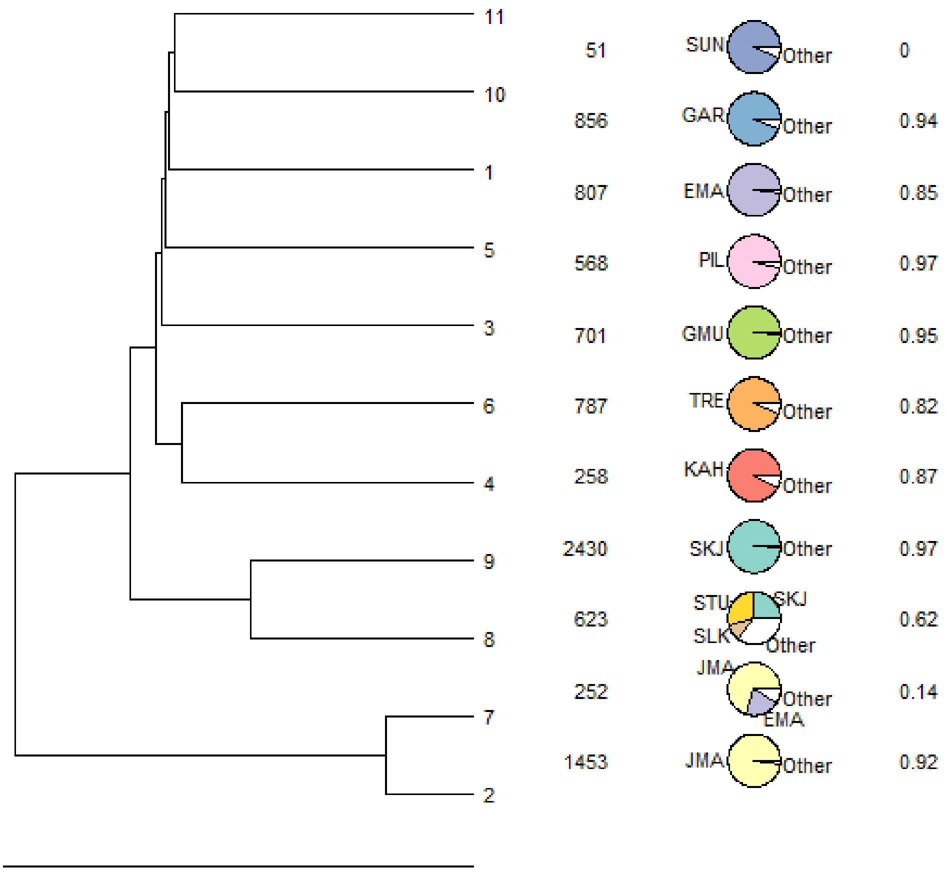


Figure A4.30: A dendrogram of the similarity between 11 clusters found in the 9-year seine fishing dataset. Also shown from left to right is a cluster label that matches the labels in Table A4.39, the count of fishing events per cluster, pie chart of average species proportion in the cluster and silhouette distance indicating the level of dissimilarity from the other clusters. The higher the average silhouette distance the more distinctive the cluster is from other clusters.

Table A4.38: Comparison of regional clusterings (regions shown in Figure A4.1) and changes over time (0708 = 2007–08, 1112 = 2011–12 and 1516 = 2015–16 fishing years). Number of fishing events assigned to each cluster in each of the regional datasets and in three individual years after cluster analysis with high k to search for small distinct clusters (initial clustering k=13). Variants of species clusters were combined into the classes where the dominant species was the same. Other clusters of mixed species compositions or small target fisheries are combined into default clusters for each of the main methods called "BS_oth", "PS_oth", or "S_oth".

k=13	FMA1	FMA2	WCNI	TOS	ECSI	WCSI	Offshore	0708	1112	1516
BS_GMU			685				11	57	133	36
BS_oth										
PS_EMA	786		8	17			2	108	106	101
PS_JMA	1632	3	28	5			1	227	210	158
PS_KAH	134	92		33	3			31	32	102
PS_oth	336		65	3	97	29	2	5		11
PS_PIL	590			2				108	24	34
PS_SKJ	1458	13	753	69	1	151	2	341	325	204
S_GAR	825			28			2	51	98	205
S_oth	98	4		44				21		15
S_TRE	736		34	4				127	79	101
Total	6595	112	1573	205	101	180	20	1076	1007	967

Table A4.39: Classification into cluster membership for other seine fisheries uses rules based on region, order of precedence, species composition and fishing method. Cluster naming convention uses the predominant method code and species code in the cluster. Clusters of the same name may have different classification rules for each region. The order rule allows rules applied later to supersede earlier rules (see Table A4.3 for example).

cluster	Region rule	order rule	species rule 1	method rule
S_oth	All			DPN
S_oth	FMA1	1	default	
PS_SKJ	FMA1	2	SKJ>0.4	
PS_EMA	FMA1	3	EMA>0.4	
PS_JMA	FMA1	4	JMA>0.4	
PS_PIL	FMA1	5	PLI>0.4	
S_GAR	FMA1	6	GAR>0.4	OR L
S_TRE	FMA1	7	TRE>0.4	
PS_KAH	FMA2	1	default	
S_oth	FMA2	2		BS
PS_MIX	WCSI	1	default	
PS_MIX	TOS	1	default	
BS_MIX	TOS	2		BS OR L
S_oth	WCNI	1	default	
BS_GMU	WCNI	2		BS
PS_SKJ	WCNI	3		PS
S_oth	ECSI	1	default	
S_oth	offshore	1	default	
BS_GMU	offshore	2		BS
PS_EMA	offshore	3		PS

Table A4.40: Comparison of numbers of fishing events in clusters produced by cluster analysis (columns and shown in Figure A4.30) and those produced by the classification rules (rows and shown in Figure A4.28).

clusters	1	2	3	4	5	6	7	8	9	10	11	Total
BS_GMU	0	0	696	0	0	15	0	7	0	3	0	721
BS_oth	0	0	0	8	0	0	1	34	0	28	0	71
PS_EMA	782	1	0	2	0	0	6	1	3	0	0	795
PS_JMA	0	1419	0	3	0	0	218	0	1	0	0	1641
PS_KAH	0	3	0	88	0	0	4	3	13	0	0	111
PS_oth	16	2	0	23	1	4	2	41	219	0	5	313
PS_PIL	0	0	0	0	566	0	12	1	0	0	0	579
PS_SKJ	8	28	0	0	0	19	3	51	2193	0	22	2324
S_GAR	0	0	1	3	0	0	2	32	0	825	0	863
S_oth	0	0	3	129	1	0	3	432	1	0	24	593
S_TRE	1	0	1	2	0	749	1	21	0	0	0	775
Total	807	1453	701	258	568	787	252	623	2430	856	51	8786

Table A.4.41: The cross tabulation of numbers of fishing events by cluster membership (columns) and declared target species (rows). Greyed cells are where the species most caught (given in the name of the cluster) agrees with the reported target species. Only the main target species are included in the rows. The rows named "other" and "% other" give the sum and percentage of events for each cluster reported as other target species.

Target + gear	BS_GMU	BS_oth	PS_EMA	PS_JMA	PS_KAH	PS_oth	PS_PIL	PS_SKJ	S_GAR	S_oth	S_TRE	Total
GMU SEINE	699	0	0	0	0	0	0	0	0	3	2	704
EMA SEINE	0	1	769	12	0	16	0	10	0	9	0	817
JMA SEINE	0	0	10	1572	3	3	3	33	0	13	1	1638
KAH SEINE	0	4	5	6	92	25	0	0	0	104	2	238
PIL SEINE	0	3	4	41	0	1	576	0	0	8	0	633
SKJ SEINE	0	0	7	8	13	252	0	2256	0	49	0	2585
GAR SEINE	3	53	0	1	0	0	0	0	855	72	2	986
TRE SEINE	15	0	0	1	0	4	0	19	0	117	768	924
other	4	10	0	0	3	12	0	6	8	218	0	261
Total	721	71	795	1641	111	313	579	2324	863	593	775	8786
% other	0.6%	14.1%	0.0%	0.0%	2.7%	3.8%	0.0%	0.3%	0.9%	36.8%	0.0%	3.0%

Appendix 5: Fishing Event Polygons and Fishable Areas.

The number of low resolution fishing events mapped using fishable areas are given here for each gear type. The coverage of the fishable areas for each gear type and cluster are displayed in the following sections. In the original dataset, a few fishing events are reported to statistical areas that are thought unlikely locations or depths for the use of the particular method. These may be data recording errors. In CatchMapper, fishable areas have been created for only the reported statistical areas where each method are thought to occur. In the case of events reported in other statistical areas where we have no knowledge of how that type of fishing might occur there or where it might occur within the statistical area, we map the events to the whole statistical area rather than leaving the events out of CatchMapper even if that statistical area is considered unlikely to be correct. These can be distinguished in the figures below as they are shaped like the unmodified statistical areas. In some cases where it seems to be impossible for a method to occur in a reported area the event is left out of CatchMapper (see Table 10).

Many improvements could be made to these fishable areas but soon they will be of historical interest only as more accurate location reporting is being introduced for all fishing events. The following sections document progress with developing fishable areas and no further work is currently planned.

Zones closed to fishing by regulations for all, or certain types of methods, are clipped out of the relevant fishable areas. If any effort was historically located within those closed areas before they were closed it is represented within CatchMapper as being evenly spread across the remaining part of the fishable area that falls within the relevant statistical area.

Most of the fishable areas were created in 2013 and included all statistical areas where fishing had been reported at that time. Since then additions and alterations have been made when better information became available. Occasionally, fishing events are reported in a new statistical area which may not be present in the fishable area for that gear type or cluster. In this case the fishable area has to be modified to include the new part so that the event can be mapped. This has not always happened and at the time of writing, 3 line fishing events are missing from CatchMapper due to the fishable area not covering the reported statistical areas.

SEINE – Purse Seine

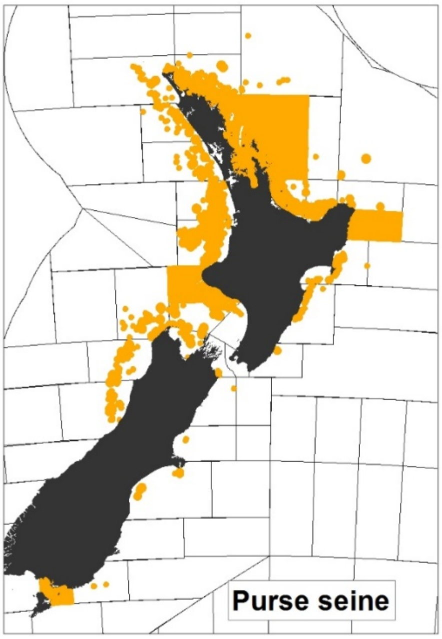
	0708	0809	0910	1011	1112	1213	1314	1415	1516
No. of PS vessels	11	10	10	14	13	10	11	10	10

Number of events each year reporting by start position coordinates (high res) or statistical areas (low res).

Purse Seine	0708	0809	0910	1011	1112	1213	1314	1415	1516
High res	759	441	608	768	612	598	714	786	697
Low res	279	277	317	424	345	358	304	219	137
% high	73%	61%	66%	64%	64%	63%	70%	78%	84%

On average 69% of Purse seine fishing in CatchMapper is represented by high resolution polygons. In these cases the start position coordinates are plotted and buffered by a circle of 3 nautical mile radius to represent the possible range of space used in the fishing event. The buffer radius is arbitrary but matches the radius used for Danish seine events based on discussion with fishers.

All high resolution polygons are merged to represent the general fishable area for purse seining on the assumption that those vessels reporting at low resolution fish in similar locations to the others. Other statistical areas where purse seining is reported are added to the fishable area as needed. All areas closed to Purse seine are removed from the fishable area. The first fishable area in use up to the present was built using fishing data from Oct 2007 to Sep 2012. It has now been updated with data to Sep 2016 as shown below.



SEINE – Danish Seine

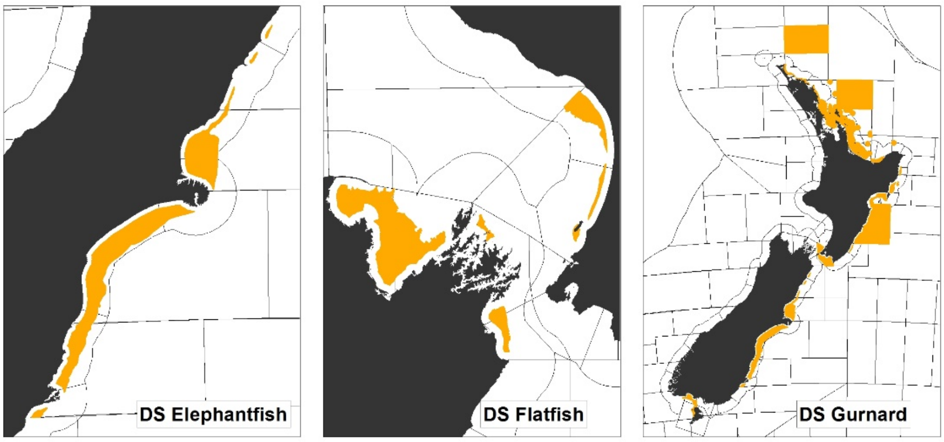
Danish Seine	0708	0809	0910	1011	1112	1213	1314	1415	1516
No. of DS vessels	24	23	28	25	25	23	19	19	18

Number of events each year reporting by start position coordinates (high res) or statistical areas.

Danish Seine	0708	0809	0910	1011	1112	1213	1314	1415	1516
High res	296	341	281	229	266	252	1453	2839	2984
Low res	1926	1838	2024	1796	2052	1926	1198	595	568
% high	13%	16%	12%	11%	11%	12%	55%	83%	84%

On average 33% of Danish seine fishing events were reported at a high resolution and this has improved markedly since the 2012–13 fishing year. For high resolution events the start position coordinates are plotted and buffered by a circle of 3 nautical mile radius to represent the possible range of space used in the fishing event. The buffer radius was set based on discussion with fishers in the Hauraki Gulf.

High resolution polygons for each type of Danish seine fishery (clusters) are merged to represent the general fishable area for that fishery cluster on the assumption that those vessels reporting at low resolution fish in similar locations to the others within the same cluster. Where a fishing event is reported in a statistical area not represented by other events in that cluster the merged events of other Danish seine clusters are used to represent where the fishing is feasible. Otherwise the whole statistical area is used. It is likely that the statistical areas far from shore included in these fishable areas and actually are reporting/transcribing errors. When fishing intensity (catch per ha) is mapped these areas will show very low intensity fishing due to the size of the area and the low number of fishing events reporting there. In this way, possible reporting errors give minimal distortion and are left in the dataset unless they are very obviously wrong. All areas closed to Danish seine are removed from the fishable areas. The first fishable area in use up to the present was built using fishing data from Oct 2007 to Sep 2012. It has now been updated with data to Sep 2016 as shown below.




DS John dory
DS Mixed species
DS Red cod
DS Snapper
DS Tarakihi

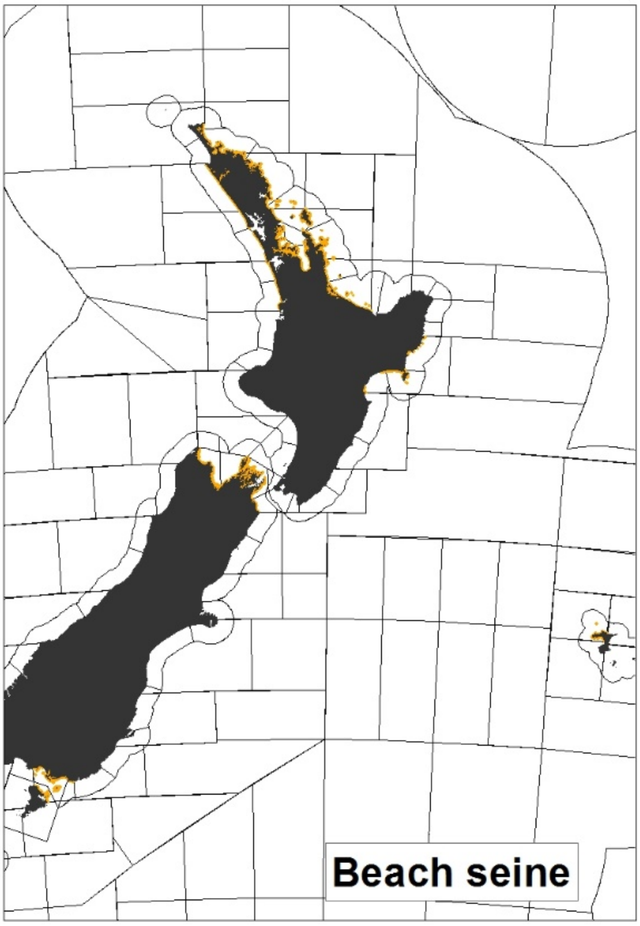
SEINE – Beach Seine

Beach Seine	0708	0809	0910	1011	1112	1213	1314	1415	1516
No. of BS vessels	13	12	15	13	16	16	14	17	18

Number of events each year reporting by start position coordinates (high res) or statistical areas.

Beach Seine	0708	0809	0910	1011	1112	1213	1314	1415	1516
High res	0	0	0	0	0	0	0	0	2
Low res	273	185	161	324	328	318	307	289	351
% high	0%	0%	0%	0%	0%	0%	0%	0%	1%

Only one beach seine event was reported at high resolution. The Fishable area has been mapped as a strip of about 500 m from shore in areas where beach seining (or drag netting) is not prohibited.



DREDGE.

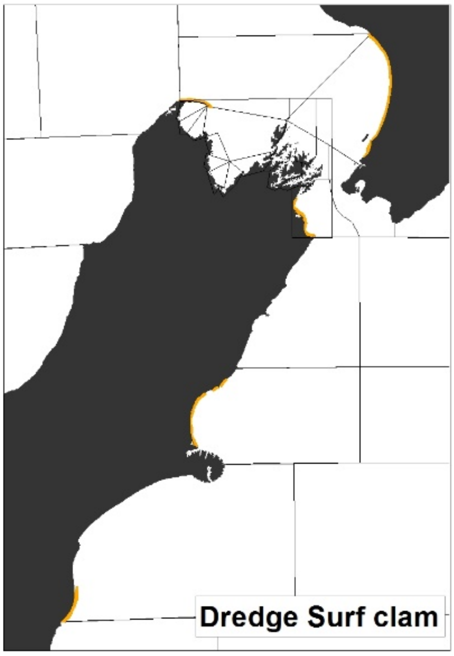
Dredge	0708	0809	0910	1011	1112	1213	1314	1415	1516
No. of D vessels	67	68	63	55	52	45	50	45	49

Number of events each year reporting by start position coordinates (high res) or statistical areas.

Dredge	0708	0809	0910	1011	1112	1213	1314	1415	1516
Other	37	76	26	37	75	78	64	25	54
Oyster	667	623	688	825	893	842	858	721	735
Surf clam	57	41	32	53	95	185	211	259	314
Scallop	1282	1986	1084	787	959	921	889	571	634
Low res total	2043	2726	1830	1702	2022	2026	2022	1576	1737

No dredge effort is reported using high resolution. Scallop and oyster dredging is reported using smaller statistical areas than the fin fisheries. The whole statistical areas with any regulated closures removed are used as the Fishable Areas. In the case of the Challenger scallop fishery (SCA 7) at the top of the South Island a specific analysis protocol is used to map fishing at a higher resolution that provided by the statistical areas (Osborne et al. 2014) and these maps are added to CatchMapper for mapping catch but not effort.

Surf clam dredging occurs on a few beaches out to a depth of about 10 m. The polygons were drawn manually using knowledge of the location of fishing and a digital bathymetry map.


Dredge Surf clam


Dredge Other

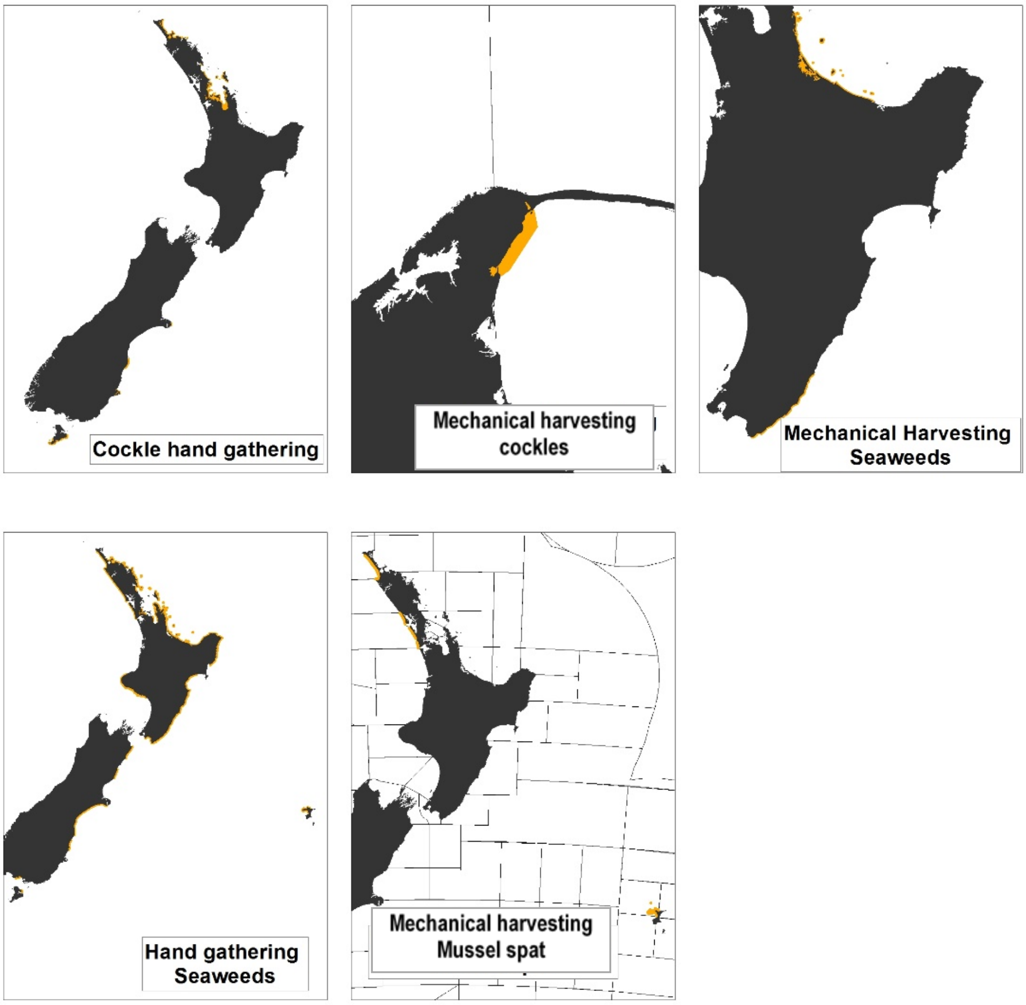
HAND

Hand Gather/ Dive	0708	0809	0910	1011	1112	1213	1314	1415	1516
No. of permit holders	171	164	162	167	163	147	149	149	143

Hand Gathering	0708	0809	0910	1011	1112	1213	1314	1415	1516
Dive	6365	6077	6144	5871	6076	5529	5478	5559	5723
Hand gathering	1466	1344	1641	1484	1272	983	1080	961	935

All hand gathering is reported at a low resolution and represented in CatchMapper with low resolution polygons. The diving fisheries are all mapped to a maximum of 10 m depth (freehold diving) except the geoduck fishery which uses compressed air. The kina, paua and rock lobster fisheries are sited on a map of hard substrates obtained originally from the Department of Conservation and of unknown provenance. As better information comes to hand in areas that are mapped for marine planning purposes (e.g. Hauraki Gulf) the MPI GIS team update their hard substrate map used for this purpose (contact CatchMapper administrator). The location of the main fisheries for pipi, cockles and geoduck are obtained from MPI stock assessment reports. Mechanical harvesting of seaweed is assumed to be intertidal. All regulated closed areas for the relevant fisheries are erased. Some areas included may be from reporting/transcribing errors.


Diving rock lobster
Diving Paua
Diving Sea cucumber
Diving Kina
Diving Geoduc
Pipi hand gathering

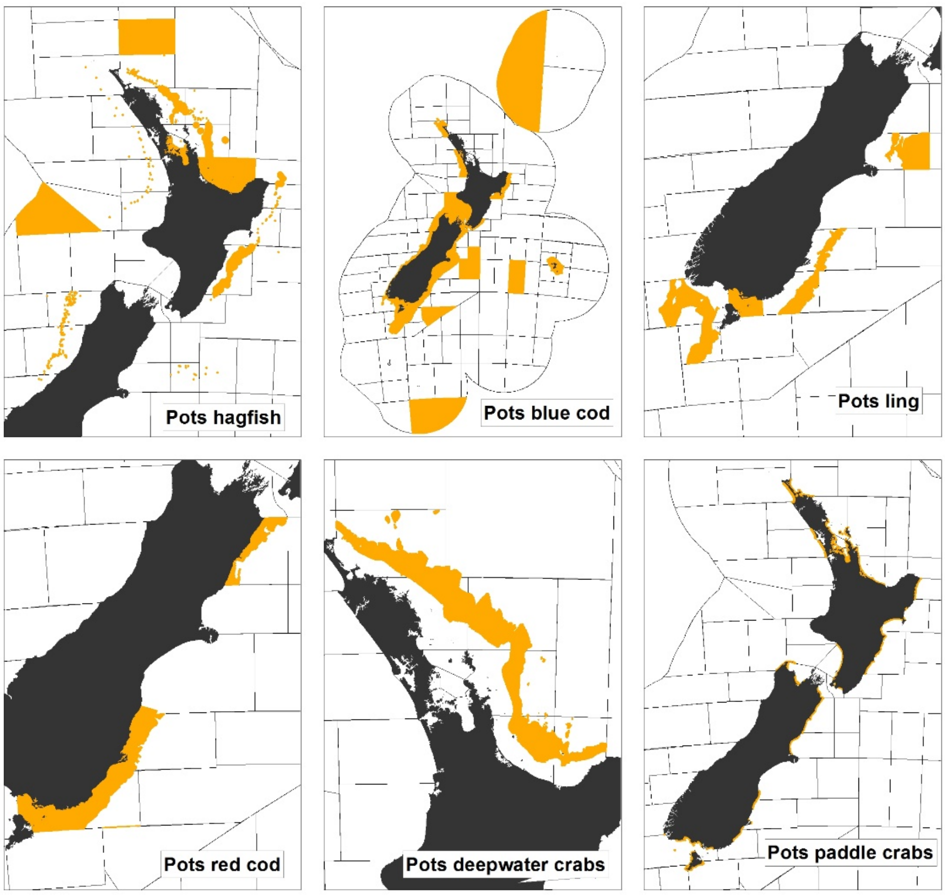

Cockle hand gathering
Mechanical harvesting cockles
Mechanical Harvesting Seaweeds
Hand gathering Seaweeds
Mechanical harvesting Mussel spat

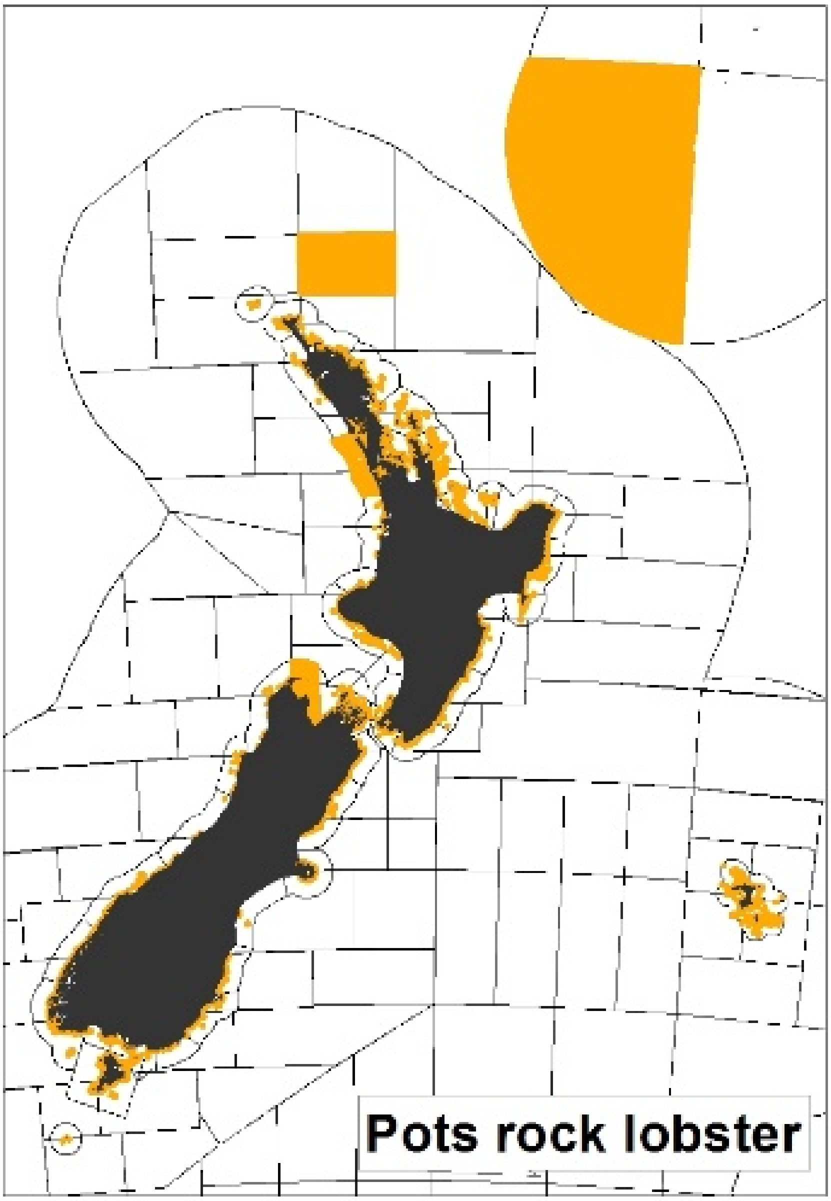
POT

Hand Gather/ Dive	0708	0809	0910	1011	1112	1213	1314	1415	1516
No. of vessels	182	168	171	162	165	147	161	151	150

Pots	0708	0809	0910	1011	1112	1213	1314	1415	1516
No. of events	30687	28659	30252	29393	27889	28444	27562	28586	29980

All potting is reported at a low resolution and represented in CatchMapper with low resolution polygons. Most of the hagfish potting reports position coordinates for the days fishing but it is not known how far the vessels range in a day. The fishable area for hagfish is constructed with all the reported fishing coordinates buffered to 1 nautical mile radius and merged into a single polygon. Other statistical areas are added whole to the fishable area where the reported positions don't cover all of the reported statistical areas. The rock lobster potting fishable area is based on a map of hard substrates around the coast originally obtained from the Department of Conservation and of unknown provenance. As better information comes to hand in areas that are mapped for marine planning purposes (e.g. Hauraki Gulf) the MPI GIS team update their hard substrate map used for this purpose (contact CatchMapper administrator). The paddle crab fishable area includes sandy substrates out to 10 m depth. The deepwater crab fishable area is based on the 500–1000 in depth zone of the statistical areas where it is reported. The blue cod and red cod fishable area are based on a maximum depth of 150 m. The ling fishable area is thought to occur in the 200–1000 m depth range.




Pots rock lobster

Net

Netting	0708	0809	0910	1011	1112	1213	1314	1415	1516
Number of SN vessels	319	306	303	315	326	322	299	280	262
Number of RN vessels	40	39	43	45	39	45	47	44	36

Netting	0708	0809	0910	1011	1112	1213	1314	1415	1516
High res	8100	7860	8284	8403	8118	8568	8397	8245	7530
Med res	3402	3897	5225	5154	4359	5003	4206	3520	3067
Low res	13156	13057	12709	13218	12702	13249	12824	10880	9920
% high	32.8%	31.7%	31.6%	31.4%	32.2%	31.9%	33.0%	36.4%	36.7%

On average 33% of net fishing in CatchMapper is represented by high resolution polygons. In these cases the start position coordinates are plotted and buffered by a circle of 2 nautical mile radius to represent the possible range of space used in the fishing event. The buffer radius comes from the definition of a set netting event whereby a new event starts if a net is set more than 2 nm from the position of the first net in the event.

Vessels under 6 m in length do not have to report fishing position by start coordinates and instead continue to use statistical areas (low resolution). According to Maritime Safety rules these vessels should only be operating within 2 nautical miles from the coast. In CatchMapper the fishable area for set netting is somewhat arbitrarily taken as a strip of water 3 nautical miles from the coast. All areas closed to set netting are removed from the fishable area. Other statistical areas are added whole to the fishable area where the reported statistical area is offshore more than 3 nautical miles.

There is a large amount of set and ring netting by small vessels in the Hauraki Gulf. They use many small boat ramps around the Gulf as landing points and report the landing point name in their fishing returns. A group of fishers helped to identify a set of polygons that represent the areas fished for each declared target species from each landing point. These polygons are rated as 'B' class or medium resolution polygons and are used to represent the location of all the fishing events for each combination of target species and landings point. First, the spelling of the names of the landing points are standardised.

The C-class (low resolution) fishable area polygons for fishing events by vessels under 6 m or which do not for some other reason report fishing position by coordinates, and the B-class (medium resolution) polygons in the Haruaki Gulf are shown below.


Net vessels under 6m

Line

Lining	0708	0809	0910	1011	1112	1213	1314	1415	1516
No. of TL, DL and BLL vessels	215	213	204	216	208	207	203	179	171
No. of PL and T vessels	171	173	139	167	178	171	162	143	145

Lining	0708	0809	0910	1011	1112	1213	1314	1415	1516
High res	17229	16055	17491	19702	17029	14991	15599	14855	14613

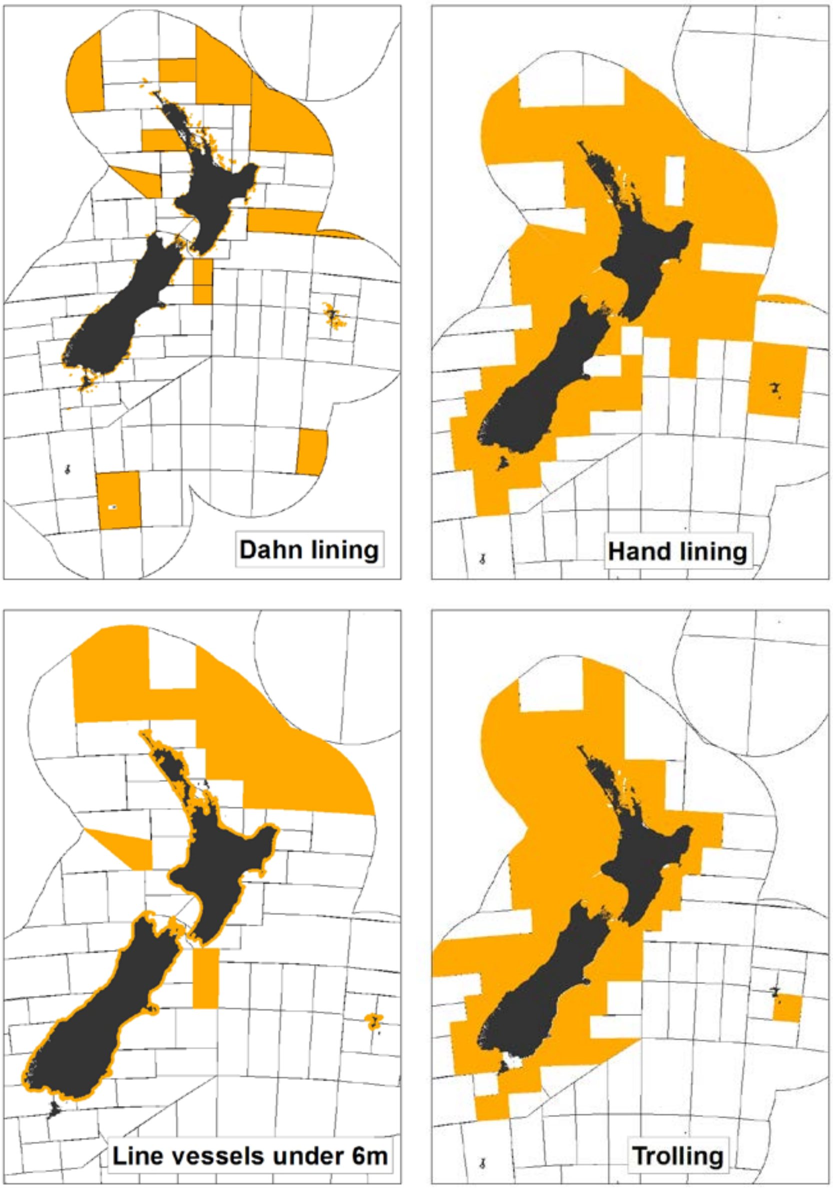
Haurki Huraki Hauaki

Low res	7664	7628	6359	7598	7866	8171	7455	6502	6383
% high	69%	68%	73%	72%	68%	65%	68%	70%	70%

On average 69% of line fishing in CatchMapper is represented by high resolution polygons, and this appears stable over time. In these cases the start position coordinates for each set line are plotted and buffered by a circle of radius equal to line reported line length to represent the possible range of space used in the fishing event. Vessels under 6 m in length do not have to report fishing position by start coordinates and instead continue to use statistical areas. According to Maritime Safety rules these vessels should only be operating within 2 nautical miles from the coast. In CatchMapper the fishable area for lining by methods BLL and TL that report only by statistical area is somewhat arbitrarily taken as a strip of 3 nautical miles from the coast. All areas closed to lining are removed from the fishable area. Other statistical areas are added whole to the fishable area where the reported statistical area is offshore more than 3 nautical miles.

In the case of dahn lining (DL) and the active lining methods HL, PL and T, fishers do not have to report by start positions and only report by statistical area. Fishable areas for dahn lining have been limited to areas of reef similar to those used for rock lobster potting. Trolling is assumed to be able to occur anywhere within the statistical areas in which it is reported except for the areas closed to trolling. Similarly the hand lining fishable area includes complete statistical areas except for areas closed to all commercial fishing. Little was known about pole lining so the hand lining fishable areas are used for this method.

The C-class fishable area polygons for BLL and TL fishing events by vessels under 6 m or which do not for some other reason report fishing position by coordinates, and the C-class polygons for other lining methods that all report by statistical area are shown below.


Dahn lining
Hand lining
Line vessels under 6m
Trolling

Appendix 6: Metadata and Caveats

An example of the sort of explanation and caveats that accompany CatchMapper information products when they are released externally is given below. This example covers the display maps and underlying maps that provided report metrics for use in SeaSketch for the Southeast Marine Protection Planning Forum.

Explanation of MPI SeaSketch Map Layers.

Series 5 SEMPF Maps for Display - Unclassified

This series includes seven maps of the estimated distribution of annual commercial catch within the Southeast Marine Protection Planning Area, one for each of the six main types of fishing gear, trawl, set line, set net, jig, pot and hand-gathering (incl. diving), and one showing the catch of all fishing methods combined.

The distribution of total commercial catch is estimated for all fishing events reported in statutory catch and effort returns for the period 1 October 2007 to 30 September 2013.

The location of fishing events is reported by either start (or start and end) coordinates (precise to 1 nautical mile) or by large statistical areas. The total catch of all species from each and every fishing event is spread uniformly over a polygon of space estimated to be occupied by that fishing. Trawl fishing polygons are derived from the length and width of the door-spread for the duration of the tow. The path of each tow is taken as a straight line between start and end coordinates where these are reported, or between start and estimated end coordinates. Where not required to report end coordinates, (the case for most inshore trawling) tow end points are derived using the direction of the next tow start position or the direction of the landing point for the last tow of the day. This has proven to be a reasonably good predictor of trawl direction.

Line fishing is attributed to a circle with centre at the reported start position and radius of the reported length of line set. Set net fishing is attributed to a circle with centre at the reported start position and radius of 2 nm in accordance with the definition of a single set netting event prescribed in reporting regulations. Jig fishing reports a single nightly position and is assumed to occur within 5 nm of that position. Hand and Pot fishing reports by statistical area, and where available, information on habitat and depth or information supplied by fishers is used to define the parts of each statistical area where each type of fishing is likely to have occurred. In the case of lobster potting and paua diving an informal map of reef area supplied by the Department of Conservation is used to estimate where this fishing may have occurred.

Catch intensity (kg/ha) is mapped to a square kilometre grid for all fishing events and summed over gear types. The data is aggregated into grid squares of between 1 and 2,500 km ^{2} as required to give 6-year annual averages of data from at least three permit holders. Catch per unit area values are classified into ten intensity classes and displayed in intuitive heatmap colours.

MPI has high confidence in the data on catch quantities used here but the spatial distributions of those catches are only approximate and should be used with caution especially at large map scales (maps of small spatial extent). Nevertheless, the aggregation of a large number of fishing events tends to provide consistent patterns that have passed scrutiny when tested with groups of fishers. Fishers in the Southeast marine area have not been given the opportunity to "ground-truth" this series of maps at this time.

This series of maps is comprised of 47,289 fishing events over 6 years. Trawl 37,511, Pot 4,057, Net 3,723, hand/dive 806, set lines 562, Jig 134, and Danish seine 369 fishing events. MPI do not hold information on the location of Danish seine fishing in this region other than that it occurs in statistical area 022 north of Oamaru. Occasionally, beach seine, purse seine, trolling or hand lining has also been reported from this region.

Series 6 SEMPF Map Data for Report Metrics – In Confidence

This series includes seventeen map layers each containing a set of features with two attributes: The percentage of the fishery within the SEMP area that is taken per km^2 within that feature and an indication of the quality of the fishing ground within that feature.

Commercial fishing within the SEMP area falls into natural clusters of fishing activities that use similar fishing methods and target and catch similar composition of fishing species. Often these different types of fisheries will occur in specific seasons or locations and a fleet will depend upon them to maintain year-round income and market supply, and to balance their catch against quota holdings for different species. These clusters have been derived from statistical analysis of catch composition and vessel gear configuration.

The distribution of total commercial catch for each fishery has been estimated for all fishing events reported in statutory catch and effort returns for the period 1 October 2007 to 30 September 2013. The method of estimating spatial distribution of reported catch is explained in the preceding section on Map Series 5.

The metrics contained within these map layers can be used to provide an indicative magnitude of two types of effects on fishing from spatial proposals (sketches) that would displace fishing:

1. What is quality and specialness of the fishing grounds beneath the sketch, if any?
2. What is the proportion of that fishery affected within the SEMP area?

The first is achieved by classifying fishing grounds as high (impact_cat = 3), moderate, or low (impact_cat = 1) intensity fishing on average over 6 years and separating the fishing out into 17 distinct fishery types. The area of each fishery in each class is provided in the section below with details of the classification. It is intended that the % of each class of fishing ground for each fishery falling with a sketch is reported from this attribute so, percent impact on highest quality fishing grounds (I_3) is calculated for each sketch that intersects *n* number of cells c_i as:

$$I_3 = \sum_{c=3,i=1}^{n} (intersection\ km^2) / (total\ SEMP\ km^2_{c=3})$$

The second measure is derived from estimates of average catch (kgs) in 1 km^2 grid cells (or larger areas depending on the spatial resolution of the original map data). Catch per cell *i* is converted to percentage of the total catch for the fishery in the SEMP area and divided by the area of the cell to give the % of the fishery occurring per unit area within each cell. The % of a fishery (%F) intersected by a sketch that intersects *n* number of cells c_i is given by:

$$\%F = \sum_{i=1}^{n} cell\ value * km^2\ of\ intersection\ with\ cell$$

MPI has high confidence in the data on catch quantities used here but the spatial distributions of those catches are only approximate and should be used with caution especially at large map scales (maps of small spatial extent). Nevertheless, the aggregation of a large number of fishing events tends to provide consistent patterns that have passed scrutiny when tested with groups of fishers. Fishers in the Southeast marine area have not been given the opportunity to "ground-truth" this series of maps at this time.

This series of maps is comprised of 47,289 fishing events over 6 years. Trawl 37,511, Pot 4,057, Net 3,723, hand/dive 806, set lines 562, Jig 134, and Danish seine 369 fishing events. MPI do not hold information on the location of Danish seine fishing in this region other than that it occurs in statistical area 022 north of Oamaru. Occasionally, beach seine, purse seine, trolling or hand lining has also been reported from this region.

Classification of Fishing Grounds

The three classes of fishing grounds indicate the relative quality of different space for fishing in any particular types of fisheries. In general we applied a classification scheme defining the top 20% of space in terms of annual average catch per unit area as high intensity or quality, the bottom 50% as low intensity and the middle 30% as moderate intensity.

Example of Metadata for SeaSketch maps

Group	Sub-group		Description
Overview	Item Description	Title	MPI Annual Fishing Intensity Map Series 5 v1.0 - Southeast Marine Protection Area Display Maps of Catch By Gear Types.
		Summary	This series includes seven maps of the estimated distribution of annual commercial catch within the Southeast Marine Protection Planning Area, one for each of the six main types of fishing gear, trawl, set line, set net, jig, pot and hand-gathering (incl. diving), and one showing the catch of all fishing methods combined.
		Description (Abstract)	The distribution of total commercial catch is estimated for all fishing events reported in statutory catch and effort returns for the period 1 October 2007 to 30 September 2013. The location of fishing events is reported by either start (or start and end) coordinates (precise to 1 nautical mile) or by large statistical areas. The total catch of all species from each and every fishing event is spread uniformly over a polygon of space estimated to be occupied by that fishing. Trawl fishing polygons are derived from the length and width of the door-spread for the duration of the tow. The path of each tow is taken as a straight line between start and end coordinates where these are reported, or between start and estimated end coordinates. Where not required to report end coordinates, (the case for most inshore trawling) tow end points are derived using the direction of the next tow start position or the direction of the landing point for the last tow of the day. This has proven to be a reasonably good predictor of trawl direction. Line fishing is attributed to a circle with centre at the reported start position and radius of the reported length of line set. Set net fishing is attributed to a circle with centre at the reported start position and radius of 2 nm in accordance with the definition of a single set netting event prescribed in reporting regulations. Jig fishing reports a single nightly position and is assumed to occur within 5 nm of that position. Hand and Pot fishing reports by statistical area, and where available, information on habitat and depth or information supplied by fishers is used to define the parts of each statistical area where each type of fishing is likely to have occurred. In the case of lobster potting and paua diving an informal map of reef area supplied by the Department of Conservation is used to estimate where this fishing may have occurred. Catch intensity (kg/ha) is mapped to a square kilometre grid for all fishing events and summed over gear types. The data is aggregated into grid squares of between 1 and 2500 km ^{2} as required to give 6-

			year annual averages of data from at least three permit holders. Catch per unit area values are classified into ten intensity classes and displayed in intuitive heatmap colours. MPI has high confidence in the data on catch quantities used here but the spatial distributions of those catches are only approximate and should be used with caution especially at large map scales (maps of small spatial extent). Nevertheless, the aggregation of a large number of fishing events tends to provide consistent patterns that have passed scrutiny when tested with groups of fishers. Fishers in the Southeast marine area have not been given the opportunity to "ground-truth" this series of maps at this time. This series of maps is comprised of 47289 fishing events over 6 years. Trawl 37511, Pot 4057, Net 3723, hand/dive 806, set lines 562, Jig 134, and Danish seine 369 fishing events. MPI do not hold information on the location of Danish seine fishing in this region other than that it occurs in statistical area 022 north of Oamaru. Occasionally, beach seine, purse seine, trolling or hand lining has also been reported from this region. For further information contact the Fisheries Data Manager, Fisheries Management, Ministry for Primary Industries.
		Credits (if applicable)	Ministry for Primary Industries (MPI) Nov 2015.
		Use Limitations	See Legal Constraints for any licences attached to this dataset. Disclaimers This map and all information accompanying it (the "Map") is intended to be used as a guide only, in conjunction with other data sources and methods, and should only be used for reference purposes. The information shown in this Map is based on a summary of data obtained from various sources. While all reasonable measures have been taken to ensure the accuracy of the Map, MPI: (a) gives no warranty or representation in relation to the accuracy, completeness, reliability or fitness for purpose of the Map; and (b) accepts no liability whatsoever in relation to any loss, damage or other costs relating to any person's use of the Map, including but not limited to any compilations, derivative works or modifications of the Map. © Crown copyright. This map is subject to Crown copyright administered by Ministry for Primary Industries (MPI)."

	Topics & Keywords	Topic Categories (Select)	Biota – Economy– Oceans
		Theme Keywords	fisheries, food production
			Managing natural resources
	Resource Citation	Dates (dataset)	Creation: Ministry for Primary Industries (MPI) Published: November 2015 Revised: annually

Metadata	Details	File Id (UUID)	
		Date Stamp (metadata)	
		Character Set	Character set: Uf16
		Hierarchy Level	Dataset
	Contacts	Contact	Name: Tracey Osborne Organisation: Ministry for Primary Industries Position: Senior Analyst, Spatial Analysis Services Role: Point of Contact

Resource	Details	Credit (if applicable)	
		Language	Language: English Character set: uf16
		Spatial (enter one)	Scale Resolution: Distance Resolution: Map resolution 1 kilometre, data resolution 1 nautical mile.

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Name:

Organisation: Ministry for Primary Industries

Position:

Role: Owner

Custodian (Business Custodian)

Name: Tracey Osborne

Organisation: Ministry for Primary Industries

Position: Senior Analyst, Spatial Analysis Services

Role: Custodian

Custodian (Technical Custodian)

Name: Tracey Osborne

Organisation: Ministry for Primary Industries

Position: Senior Analyst, Spatial Analysis Services

Role: Custodian

Publisher

Organisation: Ministry for Primary Industries

Role: Publisher</td></tr>
<tr><td>Maintenance</td><td>Update</td><td>Update Frequency: annually

Next Update: Nov 2016</td></tr>
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<tr><td>Defined Validity Period:</td></tr>
<tr><td>Legal</td><td>Use Limitation:

Access Constraints:

Use Constraints:</td></tr>
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			Any hard copies produced should display the following text "Disclaimer: This map and all information accompanying it (the "Map") is intended to be used as a guide only, in conjunction with other data sources and methods, and should only be used for reference purposes. The information shown in this Map is based on a summary of data obtained from various sources. While all reasonable measures have been taken to ensure the accuracy of the Map, MPI: (a) gives no warranty or representation in relation to the accuracy, completeness, reliability or fitness for purpose of the Map; and (b) accepts no liability whatsoever in relation to any loss, damage or other costs relating to any person's use of the Map, including but not limited to any compilations, derivative works or modifications of the Map. © Crown copyright. This map is subject to Crown copyright administered by Ministry for Primary Industries (MP I)."
		Security	Classification: Open
	Quality	Data quality	Level Scope: Dataset
	Lineage	Statement	
	Distribution	Distribution Format	Format Name: File geodatabase Format Version: ArcGIS 10.2
		Digital Transfer Options	Transfer size:

Appendix 7: Annual Fishstock Scalers

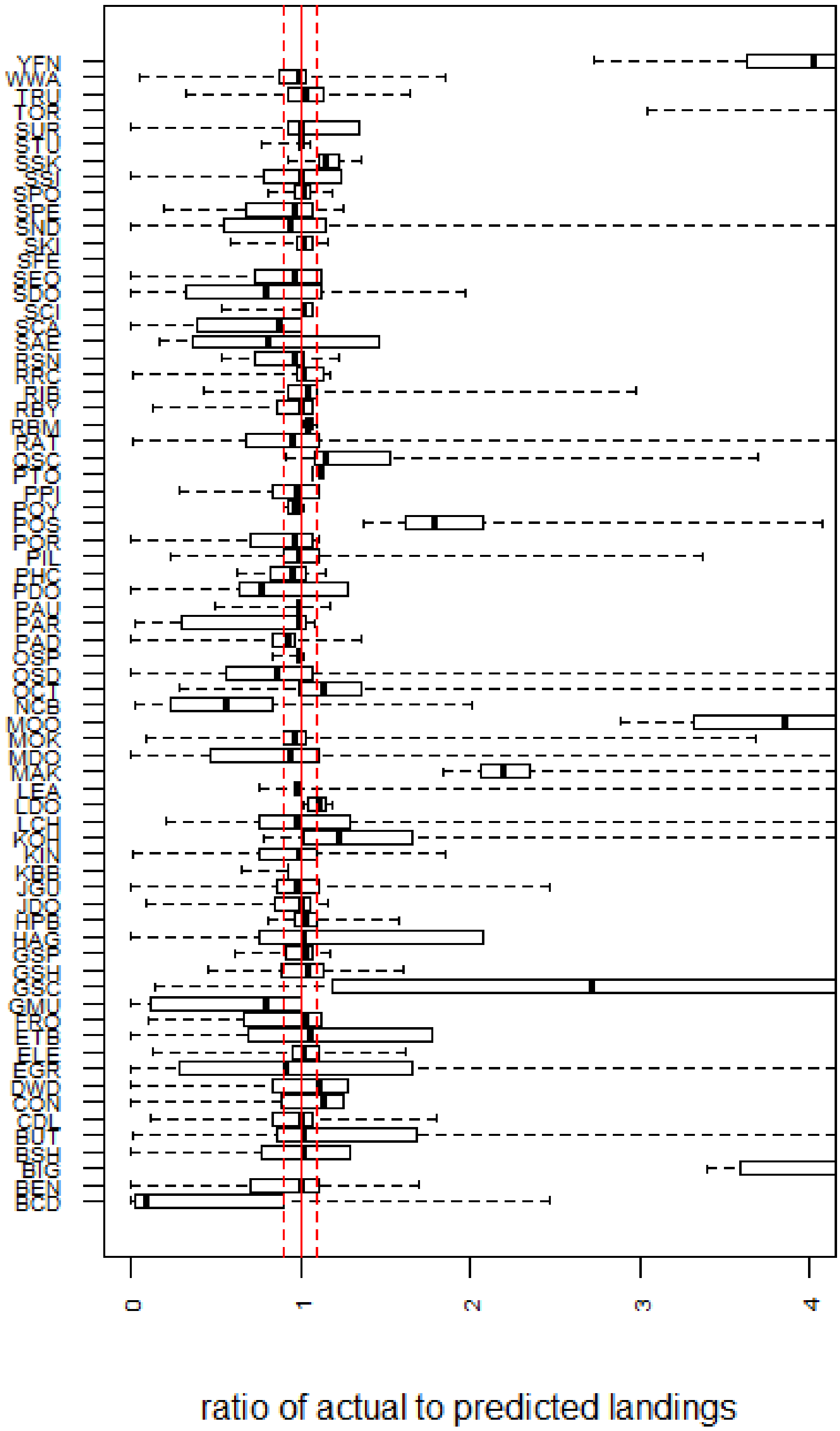

Figure A7.1 Quality of CatchMapper predictions for annual fishstock landings for the next tier of species after those shown in Figure 26 (mean landings over 10 tonne). The boxplots show the distribution of values for actual fishstock landings / predicted fishstock landings per year. Solid red lines indicate ratio=1, dotted lines are the range 0.9 – 1.1.

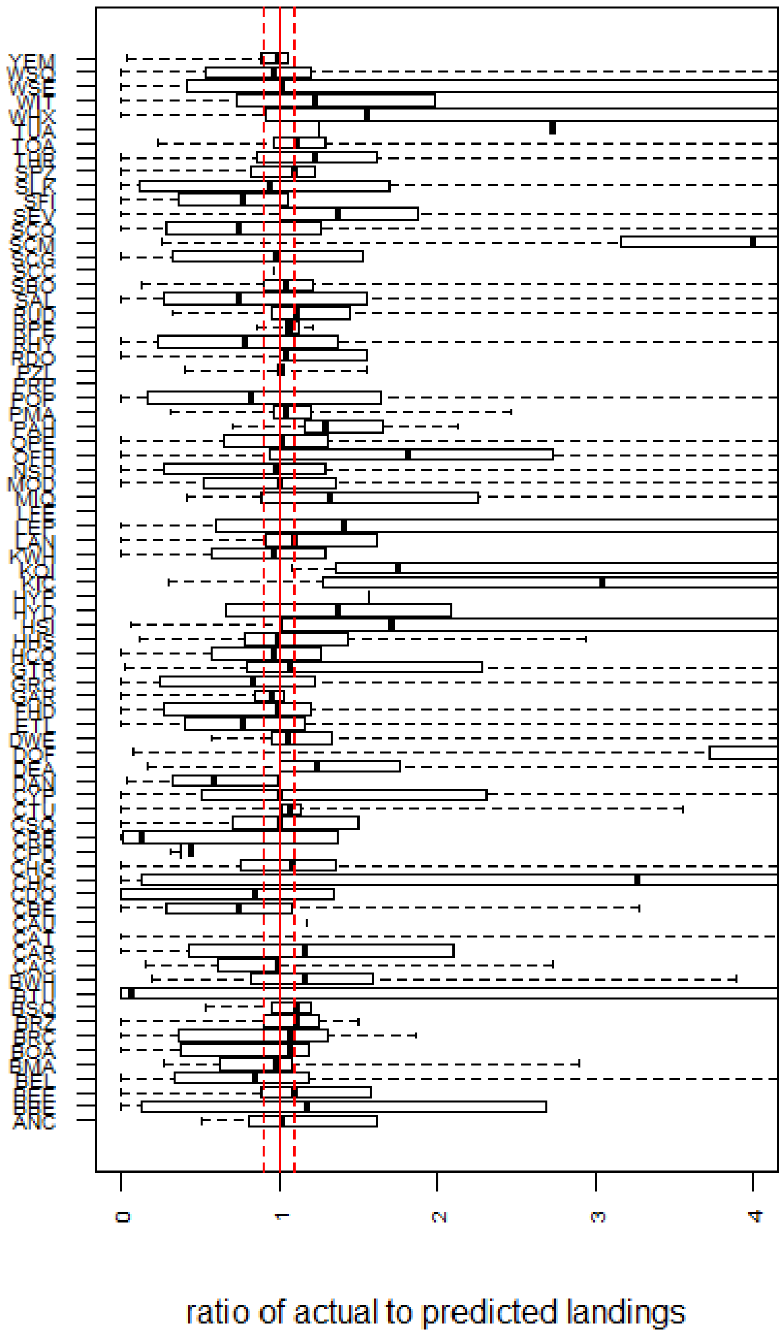

Figure A7.2. Quality of CatchMapper predictions for annual fishstock landings for the next tier of species after those shown in Figure A7.1 (mean landings over 1 tonne). The boxplots show the distribution of values for actual fishstock landings / predicted fishstock landings per year. Solid red lines indicate ratio=1, dotted lines are the range 0.9 – 1.1.

Table A7.1: Annual fishstock scalers and mean of the 9 years (AvScaler) for all fishstocks with annual average landings over 10 tonne.

fishstock	0708	0809	0910	1011	1112	1213	1314	1415	1516	AvScaler	AnAvLandings (t)
ALB1	1.738	1.715	2.024	1.826	1.994	2.21	2.188	2.114	2.278	2.01	2724.4
BAR1	1.011	1.007	1.029	1.008	1.014	1.005	1.002	1.018	1.001	1.011	8858.8
BAR4	0.978	0.994	1.007	1.001	0.974	2.05	0.995	1.01	0.992	1.111	1836.1
BAR5	1.003	0.977	0.962	1.014	0.99	1.015	1.01	1.023	1.027	1.002	7510.6
BAR7	0.996	0.958	0.99	0.973	1.009	1.01	1.006	0.987	1.005	0.993	7724.8
BCD6	0.893	0.832	0.243	1.005	1.144	2.466	1.002	0.531	0.889	1.001	22.6
BCO3	0.944	1.03	1.344	1.32	1.292	1.185	1.229	1.261	1.458	1.229	168.6
BCO4	0.974	0.989	1.012	0.95	0.957	0.963	0.922	0.966	0.963	0.966	756.7
BCO5	0.997	1.01	1.002	1.01	0.999	0.998	0.991	0.963	0.956	0.992	1226.9
BCO7	0.982	0.999	1.169	1.266	1.966	1.516	1.575	1.847	2.246	1.507	59.9
BCO8	4.125	1.842	1.698	1.757	1.082	1.233	1.217	1.403	0.654	1.668	13.1
BEL4	0.891	1.238	1.461	1.276	1.078	1.287	0.974	1.17	1.339	1.19	13.7
BEN7	1.543	1.005	1.063	1.111	1.048	1.042	1.033	0.999	1.017	1.096	29
BIG1	4.25	3.614	3.4	3.59	3.547	4.484	6.724	11.741	8.365	5.524	151.8
BNS1	1.045	0.98	1.052	1.032	1.016	1.016	1	1.001	1.004	1.016	490.7
BNS2	0.97	0.992	0.987	1.019	1.061	1.004	0.987	0.972	0.989	0.998	607.9
BNS3	1.063	1.053	1.07	1.067	1.031	1.091	1.027	1.134	1.16	1.077	336.7
BNS7	0.901	0.814	0.85	0.905	0.977	0.963	0.905	0.873	0.977	0.907	79.3
BNS8	1.094	1	0.972	1.103	0.955	1.017	0.955	1.103	1.106	1.034	27.7
BRZ1	1.503	1.311	1.293	1.382	1.292	1.385	1.348	1.21	1.313	1.337	14.8
BSH1	2.877	1.486	6.346	9.66	739.445	7.166	16.892	4.606	8.606	88.565	30.2
BSH2	0.981	1.194	1.064	0.815	0.871	0.904	0.968	1.304	0.547	0.961	10.9
BSH3	1.094	1.035	0.876	0.977	1.04	1.069	0.831	0.954	1.08	0.995	69.8
BSH4	1.015	0.706	0.826	0.698	1.036	0.586	0.644	0.666	0.679	0.762	36.5
BSH5	1.111	0.551	0.715	0.911	1.055	1.285	1.113	0.671	1.467	0.987	18.1
BSH6	1.203	1.556	0.897	0.761	0.249	1.248	0.997	0.889	0.975	0.975	18.3
BSH7	1.748	1.85	1.14	1.256	1.387	1.063	0.897	0.97	0.96	1.252	36.1
BTU1	18.113	11.872	17.57	11.985	40.293	10.52	18.538	88.468	85.696	33.673	11.6
BUT2	0.771	0.817	0.823	0.816	0.943	1.006	1.013	0.852	0.921	0.885	45.3
BUT5	1.008	1.018	1.102	1.012	1.224	1.041	1.004	0.917	0.976	1.034	37.7
BUT7	1.849	1.822	2.209	1.65	1.607	1.19	1.3	1.415	1.228	1.586	21.6
BWS1	1.576	2.078	2.155	2.122	1.755	1.809	1.509	2.79	8.987	2.753	566.9
BYX1	1.312	1.015	2.01	1.019	1.035	1.053	0.972	0.955	0.996	1.152	78.4
BYX2	1.016	1.031	0.992	1.004	1.029	1	1.01	1.017	1.007	1.012	1605.3
BYX3	0.993	0.986	1	1.001	1.002	1.066	0.994	1.002	0.988	1.004	1009.6
BYX7	0.864	0.87	0.822	0.88	0.632	1.596	1.162	0.838	1.033	0.966	27.9
CAR3	1.888	2.092	2.78	2.457	3.653	3.446	0.985	1.159	0.69	2.128	13
CAR7	1.846	1.4	1.233	0.982	1.169	1.399	0.996	3.09	0.823	1.438	37.2
CAR8	0.917	1.375	0.898	0.787	1.06	1.287	1.269	7.211	0.528	1.704	15
CDL1	1.082	1.069	1.195	0.141	0.944	1.158	0.973	1.04	0.996	0.955	103.6
CDL2	1.007	1.034	1.045	0.991	1.015	0.963	0.998	1.043	1.038	1.015	623.7
CDL3	0.786	0.937	1.038	1.361	1.102	1.286	1.111	1.025	0.9	1.061	72.5
CDL4	1.079	1.005	0.993	0.852	0.939	0.849	0.808	0.859	0.929	0.924	25.2
CDL5	1.015	1.04	1.196	1.144	1.032	1.025	1.04	1.07	1.336	1.1	20.3
CDO7	11.889	0.83	1.063	0.98	0.487	0.567	2.634	1.348	1.065	2.318	15
COC1A	0.823	0.962	0.959	0.922	0.827	NA	NA	NA	NA	0.899	48.8
COC3	0.837	0.824	0.796	0.81	0.713	0.765	0.822	0.851	0.874	0.81	812.6
COC7A	0.89	0.754	0.818	0.849	0.822	0.747	0.754	0.767	0.805	0.801	277.7
CON1	1.23	1.179	1.138	1.433	1.415	1.329	1.131	1.27	1.417	1.282	10.6
CON2	0.865	0.948	0.901	0.889	0.691	0.859	0.919	0.88	0.891	0.871	19.7
CON3	1.169	1.301	1.408	1.287	1.355	1.233	1.251	1.29	1.278	1.286	31
CON5	1.063	1.075	0.975	0.936	0.993	1.039	1.209	1.059	0.993	1.038	25.9
CON7	1.152	1.091	1.251	1.213	1.241	1.253	1.204	1.106	1.078	1.177	46.7
CRA1	0.662	0.583	0.686	0.668	0.659	0.589	0.552	0.564	0.703	0.63	130.4
CRA2	0.987	0.989	1.086	1.013	0.956	1.056	1.047	1.02	1.05	1.023	221.6
CRA3	1.002	1.149	0.932	1.028	1.279	0.998	1.174	1.081	1.173	1.091	199.3
CRA4	0.987	0.797	0.753	0.86	1.033	0.883	1.125	1.229	1.071	0.971	397.5
CRA5	0.919	0.928	0.985	0.987	0.974	0.945	1.013	0.92	0.895	0.952	349.9
CRA6	0.96	1.053	0.905	1.051	1.036	0.933	0.994	0.965	0.926	0.98	351.2
CRA7	0.779	0.846	1.023	0.959	0.886	0.726	0.503	0.584	0.59	0.766	84.3

fishstock	0708	0809	0910	1011	1112	1213	1314	1415	1516	AvScaler	AnAvLandings (t)
CRA8	0.71	1.075	0.695	1.034	0.864	0.77	0.924	0.877	0.733	0.854	951.7
CRA9	1.098	1.077	0.687	1.156	1.091	0.839	0.634	1.119	1.177	0.986	50
CRB6	1.324	1.7	1.228	0.486	1.28	1.521	2.306	4.106	1.678	1.737	46.7
CSQ5	1.53	1.473	1.631	2.448	8.712	1.561	1.143	0.975	1.159	2.292	14.3
CSQ6	NA	0	NA	NA	NA	1.418	1.106	2.274	1.003	1.16	10.2
CSQ7	1.473	1.009	1.177	0.885	0.967	0.803	1.123	0.909	0.491	0.982	10.6
DWD3	2.547	2.98	0.888	1.156	1.212	1.302	1.209	0.87	0.829	1.444	12.5
DWD4	1.175	1.072	1.271	1.327	1.041	1.112	1.57	1.197	1.108	1.208	66.9
EGR1	1.94	1.674	1.422	1.709	1.656	1.583	1.404	1.256	1.407	1.561	39.5
EGR8	6.634	46.096	16.142	21.206	2.606	2.529	1.857	3.392	3.552	11.557	15.2
ELE2	1.282	1.274	1.104	1.067	0.721	0.959	1.031	1.105	1.063	1.067	15.3
ELE3	0.925	0.869	0.979	0.968	0.983	1.008	0.976	0.99	0.94	0.96	1099.7
ELE5	1.065	1.014	0.969	1.024	0.999	1.001	1.024	1.068	1.03	1.022	171.5
ELE7	1.149	1.043	1.16	1.139	1.174	1.159	1.113	1.157	1.105	1.133	104.6
EMA1	1.113	1.022	1.008	1.033	0.997	1.033	1.003	1.044	0.996	1.028	6861.7
EMA3	0.988	0.876	0.257	0.141	0.634	0.78	0.492	0.759	0.538	0.607	55.9
EMA7	1.005	0.993	1.013	1.028	1.003	1.033	0.799	1.022	1.072	0.996	2183.2
ETB3	35.311	0.931	1.129	1.062	0.83	1.05	0.827	0.749	1.093	4.776	22.1
ETB4	0.365	1.962	0.629	1.026	1.789	1.011	1.164	1.244	1.105	1.144	35
ETB6	0.232	0.955	0.984	1.168	3.519	1.09	1.375	1.743	1.224	1.366	25.4
FLA1	1.027	1.023	1.025	1.01	1.037	1.036	1.01	1.065	1.048	1.031	513.7
FLA2	0.983	1.001	1.01	1.011	0.971	0.964	0.961	1.012	1.122	1.004	235.8
FLA3	0.833	0.773	0.914	0.967	0.963	0.966	0.908	0.972	0.878	0.908	1413.3
FLA7	0.962	0.938	1.032	1.049	1.035	1.096	1.067	1.05	1.011	1.027	768.6
FRO1	1.11	1.154	1.153	1.117	1.096	1.096	1.094	1.079	1.129	1.114	43
FRO2	0.925	0.986	1.224	1.087	0.664	1.031	1.023	1.019	0.951	0.99	30.4
FRO3	0.918	0.641	0.487	0.095	0.494	0.976	0.745	0.317	0.473	0.572	20.1
FRO4	1.061	1.001	1.249	1.079	1.26	1.036	0.557	0.747	0.995	0.998	15.2
FRO7	1.06	1.094	1.173	1.083	1.335	1.04	1.243	1.168	1.083	1.142	683.7
FRO8	1.119	1.14	1.11	1.549	1.093	1.221	1.011	0.855	1.111	1.134	729.9
FRO9	0.562	0.477	0.697	0.42	0.586	0.588	0.904	1.203	0.726	0.685	230.1
GAR1	0.944	1.074	1	0.835	0.943	1.048	0.979	0.915	0.861	0.955	12.6
GMU1	0.986	1.011	0.999	0.988	1.005	1.008	0.999	1.002	0.997	0.999	851.8
GSC5	3.162	0.726	49.788	1.875	0.92	12.845	1.529	2.86	2.665	8.486	38.1
GSC6A	1.96	0.412	12.696	0.832	2.767	12.376	1.324	2.169	0.45	3.887	53
GSH1	1.401	1.308	1.605	1.222	1.509	1.265	1.316	1.207	1.255	1.343	15.3
GSH2	0.661	0.451	0.579	0.656	0.641	0.7	1.155	1.104	0.8	0.75	66.9
GSH3	1.053	1.036	1.062	1.198	1.067	1.084	1.252	1.208	1.147	1.123	518.8
GSH4	1.041	1.104	1.116	1.077	1.126	1.024	1.091	1.078	1.161	1.091	298.4
GSH5	0.918	0.867	0.995	0.801	0.85	0.922	0.812	0.607	0.863	0.848	71.5
GSH6	1.048	1.018	0.901	0.981	0.817	1.163	1.169	1.442	1.061	1.067	50.7
GSH7	1.163	1.008	1.13	1.114	1.121	1.138	1.127	1.041	1.053	1.099	790.6
GSH8	0.842	0.649	0.863	0.949	0.946	0.921	0.888	0.905	0.92	0.876	27.8
GSP1	1.048	1.167	1.094	1.143	1.057	1.046	1.07	1.107	1.089	1.091	469.1
GSP5	0.951	1.027	0.961	0.928	1.013	1.027	1.065	1.035	1.067	1.008	233
GSP7	0.828	0.609	0.66	0.707	0.7	0.891	1.013	0.856	1.046	0.812	20.8
GUR1	0.967	0.97	1.016	0.911	0.997	0.984	0.998	0.998	0.977	0.98	1038.9
GUR2	0.975	1.002	1.003	1.013	1.004	0.996	0.985	0.991	1.02	0.999	637.9
GUR3	0.915	0.939	0.969	0.976	0.973	1	0.954	0.991	0.972	0.965	1059
GUR7	0.944	0.895	0.983	0.991	1.006	1.056	1.029	1.004	1.011	0.991	699.4
GUR8	1.073	1.173	0.968	1.027	1.035	0.972	0.983	0.962	0.972	1.018	199.1
HAG1	1.229	0.931	0.943	1.063	0.929	2.726	0.718	3.616	0	1.351	116.6
HAG2	1.206	1.396	1.069	0.007	0.892	0.125	0.167	0.009	0.017	0.543	64.8
HAG3	0.997	12.913	1.468	0.248	3003.159	0.241	1.697	1.309	0.795	335.87	31.1
HAG7	1.017	0.949	1.05	1.089	0.926	1.115	0.085	0.936	1.142	0.923	200.1
HAG9	0.786	0.901	0.921	NA	NA	NA	0	0.347	NA	0.591	10.5
HAK1	0.925	0.963	1.013	0.977	0.995	0.97	0.998	0.981	0.981	0.978	2126.6
HAK4	1.04	1.039	1.067	1.175	1.067	1.158	0.989	1.097	1.2	1.092	354.8
HAK7	1.001	1.003	1.005	1.01	0.997	1.026	0.93	1.02	1.015	1.001	4144.3
HOK1	1.003	0.996	0.997	1.001	0.997	1.001	0.989	1.003	0.997	0.998	123378.9

fishstock	0708	0809	0910	1011	1112	1213	1314	1415	1516	AvScaler	AnAvLandings (t)
HPB1	0.978	0.899	0.981	0.963	0.956	0.983	0.955	0.945	0.968	0.959	348.4
HPB2	0.892	0.903	0.896	0.925	0.925	0.907	0.98	0.944	0.802	0.908	214.2
HPB3	1.052	0.912	0.989	1.046	1.047	1.049	1.01	1.023	1.031	1.018	331.3
HPB4	1.104	1.027	1.01	1.043	1.063	1.021	0.945	1.032	1.037	1.031	190.4
HPB5	1.144	1.142	1.088	0.889	1.016	1.123	1.051	1.169	1.195	1.091	142.4
HPB7	1.066	0.958	1.06	0.997	1.086	1.112	1.025	0.965	1.053	1.036	184.2
HPB8	1.566	1.176	1.421	1.575	1.429	1.36	1.237	1.282	1.463	1.39	66.8
JAV2	0.125	0.506	0.452	1.081	0.539	1.187	0.975	1.582	1.291	0.86	10.5
JAV3	0.927	0.923	1.036	0.95	0.94	1.181	0.868	0.994	0.922	0.971	1186.9
JAV4	0.95	0.871	0.962	0.929	1.008	1.023	1.05	0.992	1.046	0.981	1047.6
JAV5	0.857	0.51	0.806	0.889	0.881	0.865	0.668	0.604	0.815	0.766	159.3
JAV6	1.097	1.005	0.986	0.945	1.018	1.101	1.309	1.368	0.983	1.09	359.9
JAV7	1.22	0.598	0.52	0.511	0.758	1.071	0.961	0.927	0.971	0.837	81.1
JDO1	1.003	1.011	1.008	0.958	1.011	1.002	1	1.019	0.999	1.001	377.9
JDO2	1.106	0.984	1.076	1.09	1.126	1.161	1.069	1.063	1.094	1.085	138.5
JDO7	0.936	0.85	1.003	0.999	1.037	1.023	1.027	1.098	1.003	0.997	128
JGU1	1.224	1.103	1.109	1.111	1.248	1.438	1.092	1.057	1.054	1.16	64.7
JGU9	0.613	0.853	0.867	0.735	0.741	0.69	0.786	0.716	0.635	0.737	36.9
JMA1	0.972	0.98	0.971	0.975	0.987	0.997	0.984	1.006	0.949	0.98	9219.8
JMA3	0.961	0.991	1.011	1.003	0.966	1.003	0.968	0.972	0.982	0.984	3263.2
JMA7	0.995	1.001	1	0.999	1.005	1.003	1.004	1.01	0.998	1.002	31364.2
KAH1	1.036	0.956	0.889	0.906	0.93	1.036	1.039	0.977	1.019	0.976	1019.7
KAH2	1.02	0.994	1.31	1.004	0.931	0.974	1.005	0.993	1.004	1.026	550.5
KAH3	0.963	0.903	0.569	1.053	1.007	0.873	0.884	0.921	0.749	0.88	152.5
KAH8	0.966	0.999	1.019	0.775	1.016	1.042	1.147	1.05	0.999	1.001	489.2
KBB3	Inf	Inf	Inf	NA	NA	NA	NA	NA	NA	Inf	10.9
KBB3G	NA	NA	NA	0.655	0.982	1.019	0.917	0.829	0.658	0.843	34.3
KIN1	1.088	1.017	1.077	1.111	1.054	1.011	1	0.979	0.943	1.031	79.4
KIN2	0.987	0.988	0.963	0.999	0.957	1.053	0.968	0.966	0.989	0.986	57.6
KIN7	0.687	1.2	1.609	1.275	1.86	1.466	1.439	1.743	1.307	1.398	13
KIN8	0.779	0.869	0.966	0.715	0.869	0.987	1.117	1.119	1.104	0.947	58.1
KOH1	5.007	1.523	1.325	1.663	1.147	1.975	1.068	1.012	3.001	1.969	20.9
LCH3	1.093	1.037	0.898	0.782	0.924	0.952	0.781	0.758	0.851	0.897	22.7
LCH4	1.01	1.097	1.1	1.064	1.095	1.166	1.278	1.238	1.428	1.164	55.7
LDO1	1.061	1.11	1.114	1.045	1.03	1.046	1.061	1.143	1.154	1.085	173.3
LDO3	1.162	1.189	1.16	1.144	1.132	1.02	1.041	1.086	1.141	1.119	283.5
LEA1	0.977	1	0.973	0.993	0.975	0.966	0.974	0.985	0.972	0.979	162.5
LEA2	0.947	0.749	0.888	0.97	0.958	0.993	0.979	0.961	0.987	0.937	219.1
LEA3	0.953	0.957	0.959	1.07	0.958	0.944	0.912	0.968	0.99	0.968	119.3
LEP1	5.49	4.63	3.771	5.115	5.979	4.653	8.793	11.706	4.395	6.059	16.2
LIN1	0.957	1.042	0.967	1.038	1.005	0.989	0.969	0.955	0.991	0.99	385.5
LIN2	1.006	1	1.039	1.005	1.038	0.989	1.046	1.078	0.978	1.02	645.9
LIN3	0.988	1.006	1.032	1.021	0.988	1.015	0.968	0.962	0.957	0.993	1543
LIN4	0.966	1.035	1.032	1.052	1.007	1.023	1.014	1.02	1.048	1.022	2193.9
LIN5	0.921	1	0.877	0.938	0.912	0.723	0.848	0.72	0.902	0.871	3723.4
LIN6	1.062	1.182	1.243	1.096	1.118	1.504	1.248	1.884	1.214	1.283	2742.3
LIN7	1.036	1.023	1.079	1.061	1.066	1.043	1.039	1.005	1.039	1.043	2824
MAK1	1.979	2.25	2.06	2.194	2.356	2.157	1.84	2.459	5.778	2.564	73.2
MDO1	1.539	1.147	1.101	1.114	1.095	1.013	1.033	1.038	1.037	1.124	98.7
MDO2	1.108	0.932	1.129	0.729	0.927	1.068	0.843	0.696	1.011	0.938	18.2
MMI3	0.938	0.853	0.783	Inf	NA	0.448	0.651	0.754	0.805	Inf	35.7
MMI7	1.957	18.339	0.379	0.548	0.493	2.086	0.589	0.54	0.79	2.858	17.9
MOD4	0.981	1.016	1.023	1.349	1.011	1.699	1.375	0.842	1.061	1.151	44.3
MOK1	0.993	0.897	1.01	0.992	0.932	0.989	0.93	1.033	1.024	0.978	399.9
MOK3	0.911	0.903	0.938	0.963	0.972	0.964	0.887	0.962	0.925	0.936	140.1
MOO1	3.315	3.142	2.891	4.086	4.59	3.48	4.179	3.862	6.443	3.999	73
NCB6	0.775	0.403	2.015	1.077	0.836	0.232	0.637	1.2	0.352	0.836	33.5
NSD7	1.418	1.162	1.412	1.148	1.015	1.405	1.295	0.977	0.974	1.201	26.1
NSD8	0.336	0.532	1.002	1.009	1.066	0.996	0.922	0.688	0.978	0.837	22.2
OCT1	0.957	0.889	1.015	0.986	0.955	0.906	0.984	0.97	0.99	0.961	18.1
OCT2	1.289	1.348	1.141	1.252	1.323	1.377	1.582	1.353	1.197	1.318	14.5

fishstock	0708	0809	0910	1011	1112	1213	1314	1415	1516	AvScaler	AnAvLandings (t)
OCT3	1.075	1.118	1.096	0.988	1.088	1.076	1.008	1.133	1.076	1.073	28.9
OCT5	0.906	1.028	1.088	1.019	1.141	0.983	1.177	1.077	0.925	1.038	24.2
OCT7	1.276	1.084	1.14	1.219	1.182	1.184	1.155	1.044	1.29	1.175	14
OEO1	1.044	0.996	1.245	0.908	0.98	1.056	0.931	0.942	0.973	1.008	532.6
OEO3A	0.947	1.03	1.009	1.021	1.029	1.081	1.081	1.067	1.014	1.031	3287.7
OEO4	1.011	0.99	0.98	0.972	0.984	1.013	1.012	0.974	0.976	0.99	6561.2
OEO6	1.048	0.992	1.027	1.083	1.009	0.717	1.018	1.063	0.994	0.995	2791.4
OPE4	1.107	1.114	1.004	1.195	1.375	1.392	1.156	149.847	1.033	17.691	21
ORH1	1.041	1.07	1.116	1.107	0.944	1.063	0.997	0.98	0.982	1.033	1014.8
ORH2A	0.997	1.001	1.01	0.947	1.058	0.987	0.999	1.014	0.986	1	855.9
ORH2B	0.99	0.994	1.011	1.011	0.967	1.015	0.979	0.987	0.889	0.983	135.2
ORH3A	1.017	1.007	1.008	0.981	1.038	1.087	0.973	0.954	0.997	1.007	338.2
ORH3B	1.011	1.019	1.006	1.002	0.968	0.981	1.004	1.003	1	0.999	5360.5
ORH7A	NA	Inf	0	1.113	1.029	0.674	1.021	1.033	1.245	Inf	573.2
OSD3	0.857	0.948	1.164	1.036	0.962	1.02	0.956	1.065	0.885	0.988	81.4
OSD4	0.93	0.969	0.918	1.127	1.015	1.136	0.672	0.671	1.167	0.956	88.2
OSD5	0.973	0.731	0.839	0.731	0.637	0.772	0.442	0.238	1.446	0.757	26.1
OSD6	1.148	1.141	0.935	0.757	1.04	1.073	0.697	0.63	0.816	0.915	51
OSD7	1.032	0.779	0.857	0.916	1	0.437	0.743	0.633	0.49	0.765	13.5
OSP1	NA	NA	NA	NA	1.01	0.981	0.992	0.99	0.838	0.962	29
OYS7C	0.973	0.974	1.867	Inf	Inf	Inf	NA	NA	212.88	Inf	29.6
OYU5	0.928	1.04	0.983	0.963	0.996	0.979	0.954	0.977	0.953	0.975	10442.6
PAD1	0.821	0.785	0.758	0.959	0.979	0.189	1.01	0.905	0.927	0.815	38.6
PAD2	0.916	0.851	0.832	0.941	0.944	0.997	0.941	0.959	1.085	0.941	16.8
PAD3	0.775	0.903	0.914	0.942	0.862	0.959	0.804	1.014	0.375	0.839	43.6
PAD7	1.062	1.001	0.953	0.952	0.859	1	0.922	0.68	0	0.825	15
PAD8	1.025	0.912	0.961	0.932	0.983	0.901	0.94	0.923	0.9	0.942	10.6
PAR1	1.02	1.011	1.04	1.041	1.012	1.038	1.085	1.034	1.058	1.038	58.6
PAR9	0.956	1.045	0.999	0.983	1.024	0.966	0.835	0.974	0.976	0.973	17.9
PAU2	0.994	0.937	0.97	0.943	0.989	1	0.972	0.995	0.982	0.976	120.6
PAU3	1.019	1.015	1.047	0.994	0.999	1.008	0.983	1.01	1.002	1.009	91.1
PAU4	0.978	0.988	0.995	0.992	0.968	0.994	0.979	1.007	1.003	0.989	293.5
PAU5A	0.996	0.987	0.969	1.05	1.045	1.036	0.984	1.064	0.961	1.01	105.3
PAU5B	0.999	1.001	0.997	1.01	1.015	1.016	0.997	1.054	1.009	1.011	89.7
PAU5D	0.979	1.057	0.963	0.973	0.978	0.982	0.998	0.984	0.921	0.982	84
PAU7	0.952	0.967	0.982	0.959	0.982	0.977	0.958	0.978	0.964	0.969	167
PDO3	1.365	0.302	1.864	Inf	NA	0.684	0.733	0.695	1.195	Inf	17.7
PDO7	1.712	2.095	0.394	0.842	0.772	0.629	0.895	0.809	0.631	0.975	33.6
PHC1	1.137	0.629	1.149	0.975	1.034	0.824	0.956	0.716	0.891	0.923	35.1
PIL1	0.891	0.93	0.898	0.947	0.9	0.98	0.891	0.953	0.988	0.931	382
PIL8	0.93	1.054	1.055	0.71	1	1.042	1.042	1.102	1.128	1.007	46.5
POR1	1.109	1.1	1.074	1.074	1.078	0.911	1.064	0.99	1.066	1.052	54.5
POS1	1.549	1.76	2.071	1.783	1.86	1.364	1.614	2.928	4.074	2.111	64.1
POY1	NA	NA	NA	NA	0.944	0.923	0.978	0.99	0.903	0.948	15.7
PPI1A	0.982	0.975	1.091	1.062	1.111	NA	NA	NA	NA	1.044	61.1
PTO1	NA	NA	NA	1.066	1.065	1.065	NA	1.125	1.745	1.213	14.1
QSC3	0.906	1.193	0.991	2.679	1.098	1.146	3.702	1.087	1.528	1.592	19.9
RAT1	5.922	2.789	0.227	2.379	22.206	21.991	3.968	5.633	8.694	8.201	17.1
RAT2	0.674	0.749	0.539	0.419	0.543	0.225	0.249	0.507	0.565	0.497	14.6
RAT3	0.888	0.955	0.963	0.947	0.983	1.135	0.945	1.062	1.016	0.988	1228.3
RAT4	0.995	0.877	0.91	0.94	0.994	0.948	1.001	0.885	0.887	0.937	718.2
RAT5	0.843	0.422	0.915	0.743	0.737	0.946	1.042	0.844	0.988	0.831	110.8
RAT6	1.137	0.959	1.121	0.942	0.987	0.781	0.976	1.043	0.895	0.982	142.4
RAT7	1.377	0.648	0.968	0.735	0.68	0.976	1.345	1.051	1.083	0.985	166.6
RAT8	8.447	2.96	1.365	0.4	2.749	0.783	4.296	1.724	1.997	2.747	14.8
RBM1	1.058	1.09	1.029	1.061	1.095	1.011	1.023	1.058	1.044	1.052	282.7
RBT3	0.583	0.151	0.962	1.024	1.005	1.034	1.014	1.02	1.049	0.871	1189.3
RBT5	Inf	Inf	NA	NA	NA	NA	NA	NA	NA	Inf	192.6
RBT7	0.73	0.935	1.326	1.004	0.845	1.221	0.707	0.854	0.947	0.952	597.9
RBT8	Inf	Inf	NA	NA	NA	NA	NA	NA	NA	Inf	84.7

fishstock	0708	0809	0910	1011	1112	1213	1314	1415	1516	AvScaler	AnAvLandings (t)
RBY1	0.974	0.939	1.067	0.973	1.002	1.144	0.999	1.054	0.922	1.008	203.7
RBY2	1.108	1.126	1.07	1.003	1.132	1.002	0.969	1.036	0.93	1.042	327.4
RBY4	1.162	1.001	0.977	1.073	0.998	1.175	0.243	1.025	1.039	0.966	14.4
RBY7	1.047	1.002	0.773	0.855	0.956	1.389	1.044	1.261	0.404	0.97	11.2
RCO1	0.902	0.853	0.904	1.052	1.105	0.794	0.999	1.019	0.79	0.935	10.9
RCO2	0.809	0.867	1.03	0.999	0.971	0.948	1.012	0.917	1.049	0.956	320.4
RCO3	0.925	0.963	1.005	1.006	1.004	0.999	0.954	1.012	1.035	0.989	3826.8
RCO7	0.983	0.898	0.997	1.012	1.011	1.019	1.008	1.01	1.012	0.994	1747.2
RHY4	5.974	1.918	0.122	1.383	0.025	1.217	1.028	1.051	1.084	1.534	12.2
RHY7	10.013	1.424	1.366	0.547	0.322	0.325	1.095	0.241	0.72	1.784	12.5
RIB1	1.036	1.051	1.09	1.054	1.253	1.078	1.091	1.035	1.024	1.079	36.1
RIB2	1.049	0.932	1.006	0.983	1.089	1.07	1.125	1.087	1.135	1.053	88.8
RIB3	1.008	1.215	1.029	0.962	0.841	0.943	0.971	1.003	1.013	0.998	184
RIB4	1.082	1.084	1.114	1.367	1.186	1.107	1.014	1.058	1.074	1.121	265.4
RIB5	0.724	0.702	0.78	0.777	0.818	0.664	0.666	0.547	0.859	0.726	36.6
RIB6	1.224	1.089	0.892	1.06	0.883	1.39	1.345	1.835	1.356	1.23	82.3
RIB7	1.108	1.033	0.972	1.025	1.05	1.035	1.025	1.042	1.044	1.037	283.6
RIB9	0.84	1.042	0.925	0.848	0.81	1.005	0.931	0.926	1.042	0.93	16.8
RRC1	1.128	1.171	1.132	1.167	1.044	0.997	0.976	0.972	1.012	1.067	22
RSK1	1.199	1	1.161	1.083	1.044	0.989	1.051	1.295	1.204	1.114	87.2
RSK3	0.992	0.986	1.09	1.115	1.096	1.106	1.038	1.097	1.07	1.066	1459.9
RSK7	1.084	1	1.188	1.208	1.23	1.231	1.221	1.188	1.168	1.169	190.6
RSK8	1.072	0.9	1.083	0.927	1.011	1.008	0.994	0.887	0.912	0.977	43.7
RSN1	1.094	1.225	0.957	0.991	0.965	1.032	0.972	0.956	1.04	1.026	34
RSN2	0.73	0.586	0.813	0.671	0.536	0.624	1.019	0.925	0.868	0.752	13.9
RUD3	1.02	1.224	1.626	1.143	1.075	1.189	0.928	1.021	0.912	1.126	12
SAE7	1.673	3.297	0.169	0.224	0.359	0.778	0.943	0.782	1.457	1.076	113.5
SBO1	1.539	1.139	1.72	1.19	1.131	1.143	1.133	1.237	1.137	1.263	22.7
SBW1	0.015	0.178	0.299	0.033	0.068	0.018	0.034	0.152	0.143	0.104	15.1
SBW6A	1.191	0.666	1.616	1.213	1.531	1.213	0.693	1.152	2.208	1.276	142.6
SBW6B	0.389	0.652	1.108	2.141	0.97	1.606	0.5	2.987	0.95	1.256	7807.2
SBW6I	1.031	1.086	0.973	0.71	1.338	0.757	1.21	1.13	1.206	1.049	23193.7
SBW6R	0.42	0.269	1.035	7.994	0.483	76.911	1.292	1.016	2.477	10.211	1521.8
SCA7	1	1	1	1	1	1	1	1	1	1	71.2
SCACS	0.777	1.844	1.139	0.932	0.615	0.865	0.678	1.143	1.063	1.006	48.3
SCH1	1.105	1.032	1.045	0.871	1.032	1.034	1.035	1.044	0.955	1.017	647.5
SCH2	0.858	0.8	0.859	0.893	0.854	0.916	0.941	0.848	0.818	0.865	193.8
SCH3	1.103	0.946	1.066	1.031	1.038	1.039	1.043	1.048	1.005	1.035	369.9
SCH4	1.152	1.117	1.07	1.041	1.009	0.987	0.891	0.996	1.032	1.033	169
SCH5	1.009	1.007	1.007	1.003	1.038	1.018	0.992	1.019	1.019	1.012	719.8
SCH7	1.034	0.969	1.133	1.024	1.052	1.027	0.964	0.983	0.962	1.016	625
SCH8	1.2	1.044	1.094	1.17	1.259	1.192	1.165	1.081	1.229	1.159	510.9
SCI1	1.05	1.019	1.007	0.971	0.996	1	0.999	1.004	1.06	1.012	110.7
SCI2	0.996	1.005	1.008	1.005	1.024	0.999	1.017	0.996	0.98	1.003	107
SCI3	1.041	1.011	1.014	1.01	1.006	1.006	0.972	1.01	1.007	1.009	281.3
SCI4A	1.122	Inf	0.532	1.011	1.061	1.013	1.014	1.02	1.073	Inf	55.5
SCI6A	1.008	1.016	1.015	1.023	1.003	1.023	1.001	1.03	1.006	1.014	186.2
SDO5	1.97	1.104	1.011	1.361	1.117	1.106	1.31	1.306	1.519	1.312	26
SDO7	1.578	1.005	1.022	1.263	1.133	0.939	1.172	1.196	1.027	1.148	46
SDO8	1.031	1.163	1.095	1.153	0.839	1.183	0.572	0.211	0.798	0.894	46.3
SDO9	0.692	0.672	0.786	0.326	1.171	0.566	0.861	0.689	1.117	0.764	12.8
SEO1	0.394	0.76	0.91	1.403	1.042	1.6	1.682	1.862	1.513	1.241	116.7
SEO2	0.413	0.915	0.869	0.686	0.909	1.057	0.411	0.166	0.068	0.61	43.7
SEO9	0.773	0.742	0.727	1.003	1.065	0.959	1.117	1.299	1.415	1.011	137
SKI1	1.07	1.1	0.948	1.017	0.97	1.014	0.936	1.086	0.977	1.013	193.7
SKI2	1.024	1.024	1.164	1.128	1.143	1.09	1.024	0.985	1.017	1.067	207.8
SKI3	0.996	0.816	1.058	0.966	0.584	1.098	0.982	0.798	1.134	0.937	27.5
SKI7	1.01	1.008	1.009	0.974	0.926	1.074	1.04	1.071	1.067	1.02	224
SKJ1	1.033	1.037	1.02	0.876	0.992	1.022	1.005	0.988	0.991	0.996	9617.4
SLK4	1.056	1.027	1.027	1.398	1.001	3.177	0.9	1.01	1.107	1.3	32.2

fishstock	0708	0809	0910	1011	1112	1213	1314	1415	1516	AvScaler	AnAvLandings (t)
SNA1	0.997	1.005	0.992	0.987	0.976	0.99	0.997	1.009	0.996	0.994	4499.3
SNA2	0.995	0.974	0.95	1.041	1.013	0.931	0.939	0.958	0.979	0.976	313.8
SNA7	0.745	0.724	0.916	0.952	0.997	0.989	0.968	1.036	0.974	0.922	203.1
SNA8	0.936	0.97	1.001	0.908	1.007	1.004	0.993	0.996	0.995	0.979	1312
SND1	1.414	1.121	2.82	2.713	40.15	5.84	6.112	2.623	2.772	7.285	24.1
SND3	0.987	1.465	0.743	0.531	0.936	0.837	0.853	0.76	1.042	0.906	38.2
SND4	0.945	1.116	0.948	1.407	0.538	0.828	0.936	1.141	0.997	0.984	72.7
SND5	1.733	0.562	0.466	1.359	0.89	0.88	1.242	0.776	1.154	1.007	13.9
SND7	1.046	1.45	1.115	0.943	0.993	0.989	1.077	0.999	0.929	1.06	25.1
SPD1	3.387	2.768	2.707	2.052	2.795	2.856	7.548	29.067	5.88	6.562	189.1
SPD3	1.302	1.272	1.222	1.317	1.494	2.018	1.685	1.557	2.089	1.551	1709.3
SPD4	1.583	2.483	1.468	2.216	1.748	2.647	2.539	2.404	1.965	2.117	936.1
SPD5	1.383	1.372	1.199	1.131	1.163	1.41	1.221	1.177	1.43	1.276	1673.2
SPD7	1.521	1.52	1.352	1.418	1.492	1.665	2.252	2.969	4.167	2.04	1139.3
SPD8	2.523	1.546	1.72	0.944	1.403	1.597	2.062	2.263	2.756	1.868	168.4
SPE1	1.151	1.229	1.172	1.103	1.022	1.054	1.075	1.149	1.126	1.12	41.3
SPE2	0.989	0.739	0.89	0.938	0.968	0.919	0.995	0.971	1.14	0.95	58.6
SPE3	0.97	0.965	0.976	0.987	0.947	0.972	0.97	0.99	0.982	0.973	518.6
SPE4	1.094	1.159	1.139	1.112	1.122	1.132	1.025	1.123	1.125	1.115	457
SPE5	0.648	0.421	0.618	0.583	0.55	0.72	0.82	0.455	0.817	0.626	19.2
SPE7	1.122	0.694	0.962	1.022	0.916	0.76	0.979	1.071	1.25	0.975	102
SPO1	1.031	1.053	1.083	1.027	1.078	1.072	1.078	1.06	1.085	1.063	321.6
SPO2	1.022	1.043	1.029	1.021	0.969	1.021	1.023	0.987	0.991	1.012	111.2
SPO3	0.908	0.904	0.917	0.969	0.965	0.964	0.979	0.974	0.923	0.945	450.6
SPO7	0.806	0.865	0.963	0.958	1.018	0.966	1.013	0.984	1.001	0.953	232
SPO8	1.059	1.186	1.05	1.075	1.068	1.033	1.003	0.992	1.021	1.054	197.7
SPZ7	0.993	0.733	1.243	1.496	1.162	1.153	1.356	1.16	1.207	1.167	15.3
SQU1J	0.931	1.01	1.023	1.062	0.889	1.033	1.021	1.057	1	1.003	986.5
SQU1T	0.997	0.953	0.98	0.989	0.994	1.013	0.991	0.986	0.973	0.986	16820.3
SQU6T	1.024	1.027	1.022	1.014	1.024	1.017	1.03	1.027	1.061	1.027	16239.8
SSI3	0.801	1.236	1.362	0.952	0.739	0.846	1.64	1.008	1.047	1.07	10.7
SSI6	1.005	1.299	1.025	1.205	1.097	0.918	1.376	1.434	1.209	1.174	48.7
SSK1	1.235	1.261	1.255	1.198	1.35	1.239	1.122	1.164	1.348	1.241	35.2
SSK3	1.182	1.24	1.197	1.184	1.165	1.133	1.239	1.203	1.253	1.2	336.4
SSK7	1.142	1.131	1.175	1.098	1.141	1.124	1.158	1.117	1.135	1.136	207
SSK8	0.975	1.051	1.076	0.921	1.024	1.083	1.064	1.141	1.083	1.046	29.5
STA1	1.093	1.014	0.963	0.856	1.148	1.045	1.046	1.13	0.989	1.032	22
STA2	1.103	0.802	0.861	0.984	0.854	0.687	0.816	0.994	0.797	0.878	17.5
STA3	0.991	0.995	1.003	1.107	1.041	1.034	1.064	1.087	1.064	1.043	512.6
STA4	1.077	1.296	1.211	1.08	1.217	1.213	1.154	1.151	1.134	1.17	184.9
STA5	1.007	1.034	1.034	1.039	1.021	1.015	0.988	1.055	1.02	1.024	1221.2
STA7	1.108	1.034	1.125	1.074	1.11	1.102	1.076	1.075	1.104	1.09	1065.3
STN1	1.302	2.828	2.49	2.285	1.852	3.429	2.867	5.139	4.067	2.918	668.1
STU1	1.052	0.977	0.999	1.006	1.007	0.987	0.769	1.008	0.995	0.978	181.6
SUR1A	0.645	0.6	0.8	0.661	0.571	0.599	0.76	0.596	0.548	0.642	37.3
SUR1B	1.062	1.078	1.091	1.045	1.113	1.086	0.983	1	1.072	1.059	135.7
SUR2A	2.645	3.167	0.213	12.777	68.952	61.773	Inf	188.41	2.503	Inf	11.7
SUR4	0.956	0.986	0.975	1.002	0.996	0.974	1.025	1.003	1.041	0.995	112.2
SUR5	0.921	0.966	0.973	0.973	0.988	1.005	0.977	0.759	0.945	0.945	386.3
SUR7A	0.962	0.907	0.89	0.93	0.942	0.914	0.936	0.996	0.942	0.935	125.6
SWA1	0.988	0.97	0.96	1	0.968	0.94	0.899	0.885	1.028	0.96	1053.1
SWA3	0.995	1.002	1.004	0.985	1.055	1.078	1.05	1.096	1.031	1.033	3282.1
SWA4	1.01	1.003	0.994	1.015	0.962	0.978	0.981	0.966	0.933	0.982	3707.3
SWO1	2.768	2.988	3.082	2.9	3.32	3.054	3.816	3.351	3.743	3.225	618
TAR1	0.988	0.988	0.989	1.011	1.012	1.011	1.002	1.032	0.97	1	1311.1
TAR2	0.991	0.995	0.988	0.994	1.03	0.999	1.015	1.021	0.99	1.003	1813.6
TAR3	0.927	0.879	0.952	0.997	0.983	0.959	0.967	0.994	0.956	0.957	1012.7
TAR4	1.032	1.225	1.024	1.021	1.278	1.097	1.013	1.045	1.085	1.091	135.4
TAR5	1.076	1.054	1.502	1.074	1.013	1.083	1.041	0.917	0.981	1.082	114
TAR7	1.008	0.925	0.975	0.961	1.022	0.992	0.968	0.971	1.014	0.982	1057.9
TAR8	1.035	0.675	0.813	1.033	1.027	1.034	0.92	0.85	1.067	0.939	215.5

fishstock	0708	0809	0910	1011	1112	1213	1314	1415	1516	AvScaler	AnAvLandings (t)
THR7	0.954	1.03	1.211	1.238	1.317	1.453	1.548	1.408	1.296	1.273	12.1
TOR1	4.993	3.05	4.499	4.845	7.273	3.477	4.45	6.078	10.675	5.482	17.2
TRE1	1.02	1.013	1.051	0.973	1.041	1.038	0.994	0.99	1.007	1.014	1195.5
TRE2	0.994	1.004	0.988	1.007	0.983	0.971	0.977	0.981	0.979	0.987	247.8
TRE7	0.967	0.979	0.981	0.907	1	0.984	0.978	1.011	1.043	0.983	1869.8
TRU3	0.797	0.894	0.872	1.047	1.04	1.028	1	1.025	1.111	0.979	18
TRU4	1.206	0.872	1.01	1.06	0.986	1.014	0.977	0.979	0.978	1.009	51.8
WAR1	1.776	0.799	0.75	1.157	0.937	0.932	0.911	1.079	0.662	1	11.2
WAR2	0.868	1.006	0.914	0.922	0.966	0.892	0.946	0.965	0.868	0.927	162.3
WAR3	0.994	0.974	0.98	0.995	0.987	0.98	0.997	0.999	0.985	0.988	2002
WAR7	1.023	0.925	0.99	1	0.996	1.024	0.969	0.975	0.998	0.989	648.2
WAR8	0.995	0.915	1.007	0.99	1.022	0.988	0.926	0.953	1.439	1.026	111.3
WSQ3	0.854	1.295	1.29	0.937	1.05	0.958	0.945	0.921	1.03	1.031	15
WSQ4	0.987	1.05	1.078	1.047	0.867	1.019	1.202	0.958	1.205	1.046	18.4
WSQ6	1.662	1.312	2.029	1.037	1.16	1.198	1.385	1.696	1.515	1.444	19.8
WWA2	1.01	0.926	1.202	1.097	0.753	0.689	0.868	0.77	0.968	0.92	12.5
WWA3	1.06	0.996	1.071	0.995	1.066	1.103	1.088	1.196	1.083	1.073	285.2
WWA4	0.988	0.816	0.902	0.988	0.848	0.992	0.96	0.748	0.79	0.892	112.4
WWA5B	1.008	1.021	1.014	0.984	1.012	1.019	1	1.008	1.02	1.01	1055.8
WWA7	0.972	1.036	0.984	0.855	0.953	1.003	0.998	0.981	0.813	0.955	83.2
YEM1	1.015	1.047	1.056	0.891	0.97	0.958	1.055	0.923	0.871	0.976	11.8
YEM9	0.936	1.057	0.916	1.016	1.015	0.863	0.979	0.988	1.121	0.988	10.5
YFN1	4.031	3.638	4.302	4.426	3.646	2.73	3.632	9.45	6.604	4.718	12.5