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Tini a Tangaroa

Characterisation of the BCO 5 blue cod (*Parapercis colias*) commercial fishery and an update of the standardised CPUE to the 2017–18 fishing year

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EXECUTIVE SUMMARY

Large, K.; Bian, R; Beentjes, M. (2021). Characterisation of the blue cod (*Parapercis colias*) commercial fishery in BCO 5 and an update of the standardised CPUE to the 2017–18 fishing year.

New Zealand Fisheries Assessment Report 2021/10. 67 p.

This document updates and summarises the catch and effort data available for BCO 5 from 1990 to 2018 (1989–90 to 2017–18 fishing years). The three previously accepted annual CPUE series were based on data from individual Statistical Areas 025, 027, and 030. In the current analyses the standardisation was repeated for each of the three areas separately and combined. Additionally, area-weighted annual indices were developed by combining the individual annual indices for each of the three statistical areas in proportion to the blue cod habitat in each area.

In 1990 the TACC for BCO 5 was increased from 1447 t to 1491 t. Further increases followed, in 1992 to 1536 t, and in 2002 to 1548 t. In 2012, the TACC was reduced to 1239 t where it remained until it was reduced further on 1 October 2020 to 800 t. In general, reported landings in BCO 5 increased from 1990 to 2004, and in 2005 landings were slightly higher than the TACC, followed by a general decline in landings from 2006 to 2018. There was a voluntary 10% shelving of the TACC by the industry in the 2017, 2018, and 2019 fishing years. This was undertaken to account for a predicted estimated reduction of catch of around 7–8% as a result of the introduction of regulations to increase the minimum mesh size from 48 mm to 54 mm in 2016.

Almost all landings of blue cod in BCO 5 have been taken by the cod potting method, with most of the landings taken when blue cod is the target species. Since 1990, around 50–60% of the cod potting effort each fishing year has been concentrated in Statistical Area 025 (Foveaux Strait area), which has accounted for a similar proportion of the landings. Landings have remained consistent in Statistical Area 025, at around 600 t per year, with landings over 700 t per year in 2001, 2002, 2005, and 2006, and the lowest annual landing of 426 t recorded in 2018. In the last decade, effort in Statistical Areas 027 and 030 has accounted for around 40% of the potlifts in BCO 5, along with a similar proportion of the catch. There was no distinct trend in estimated catch or effort (either up or down) in these areas.

The three independent standardised CPUE series for Statistical Areas 025, 027, and 030 all display a sustained increase, reaching a peak in the early to mid-2000s, followed by a decline to new lower levels (though not as low as the early 1990s), after which CPUE has been relatively stable. The standardised CPUE series for the combined areas closely resembles the series obtained from Statistical Area 025 because this area dominates the effort in BCO 5. Similarly, the area-weighted series that combines the individual indices from the three areas, follows a similar trajectory to that of the Statistical Area 025 indices and the combined data indices, because most of the blue cod habitat is in 025.

The Southern Inshore Working Group recommended that the three individual annual indices for Statistical Areas 025, 027, and 030 be used in the current BCO 5 stock assessment.

1. INTRODUCTION

This document describes the characterisation and standardised catch per unit effort (CPUE) analyses that were conducted under Objective 1 of the contract BCO2018-01 Stock Assessment of BCO 5, awarded by Fisheries New Zealand to NIWA.

Specific objectives for the contract were:

1. To characterise the commercial fishery in BCO 5 and to update the standardised CPUE indices of relative abundance to the end of the 2017–18 fishing year.
2. To undertake a quantitative stock assessment of blue cod in BCO 5 to estimate current biomass in relation to target and limit reference points.
3. To undertake simulations predicting biomass projections under alternative TACCs

During the period from January to April 2019, the Southern Inshore Working Group (SINWG) reviewed the data and CPUE analysis conducted in Objective 1 and agreed the results be used in the stock assessment conducted in Objective 2. Analyses conducted for Objectives 2 & 3 are detailed by Doonan (2020).

Note that fishing years run from 1 October to 30 September and throughout this report are generally reported by the year-ending, e.g., 1 October 1989 to 30 September 1990 is referred to as 1990.

2. BACKGROUND

Blue cod (*Parapercis colias*) is classified by Fisheries New Zealand as a Tier One species and in BCO 5 is managed at target biomass levels using full quantitative stock assessment. The last assessment was undertaken in 2013 (Fisheries New Zealand 2019) to the end of the 2011–12 (2012) fishing year (Haist et al. 2013). That work included a comprehensive catalogue of available data (with reported landings from 1983 onwards) and a CPUE analysis of commercial catch and effort from 1989–90 (1990) to 2011–12 (2012). In this report, the data are updated to 2017–18 (2018) and the standardised CPUE is provided for the 1989–90 (1990) to 2017–18 (2018) fishing years. Results from this work were used as model inputs for a new stock assessment of blue cod in BCO 5 (Doonan 2020).

Currently, the commercial catch from the BCO 5 fishery is almost exclusively taken by the target cod pot fishery operating within Foveaux Strait and around Stewart Island (Statistical Areas 025, 027, 029, and 030) (Fisheries New Zealand 2019) (Figure 1). Most blue cod fishing is from small inshore vessels (less than 15 m), setting around six pots in a set, which are left to soak for about an hour. In a day, four to five sets might be carried out, and the last set is sometimes left in the water to fish overnight if the trip has more than 1 day. The BCO 5 fishery targets blue cod using specialised pots that have a mesh size that allows fish under about 400 g (30 cm long) to escape. In 2016 a larger mesh size of 54 mm was introduced under regulation. The catch is still sorted, and fish under the commercial minimum legal size (MLS) of 33 cm (about 570 g) are returned to the sea alive. Blue cod over 600 g are generally landed in the headed and gutted state (H&G), and those under 600 g (close to the MLS) are landed gilled and gutted with the head on (G&G).

Blue cod are always the main species caught in BCO 5 target fishery pots, with a varied bycatch of species that is area specific, but can include wrasses, leatherjackets, red cod, tarakihi, sea perch, and, increasingly, octopus in recent years. The latter species can potentially cause issues with catch rate analyses because they may discourage blue cod from entering the pot. Catch rates of blue cod are regarded by commercial fishers as ‘fickle’ in the sense that, within a short space of time, catches can increase or drop-off dramatically, presumably a consequence of feeding behaviour. Zero catches can be common in pots, and less so in pot sets, but won’t be picked up in the daily reporting unless there were no fish caught in any of

the pots set during a daily event. Further, blue cod tend to be distributed heterogeneously in association with preferred habitat, which can be rocky reef through to cobbles and shell substrates, and less commonly on mud and sand. Blue cod have limited movement and a restricted home range (Carbines & McKenzie 2001, 2004), and hence they are regarded as a species prone to serial depletion. CPUE trends could therefore vary at relatively small spatial scales.

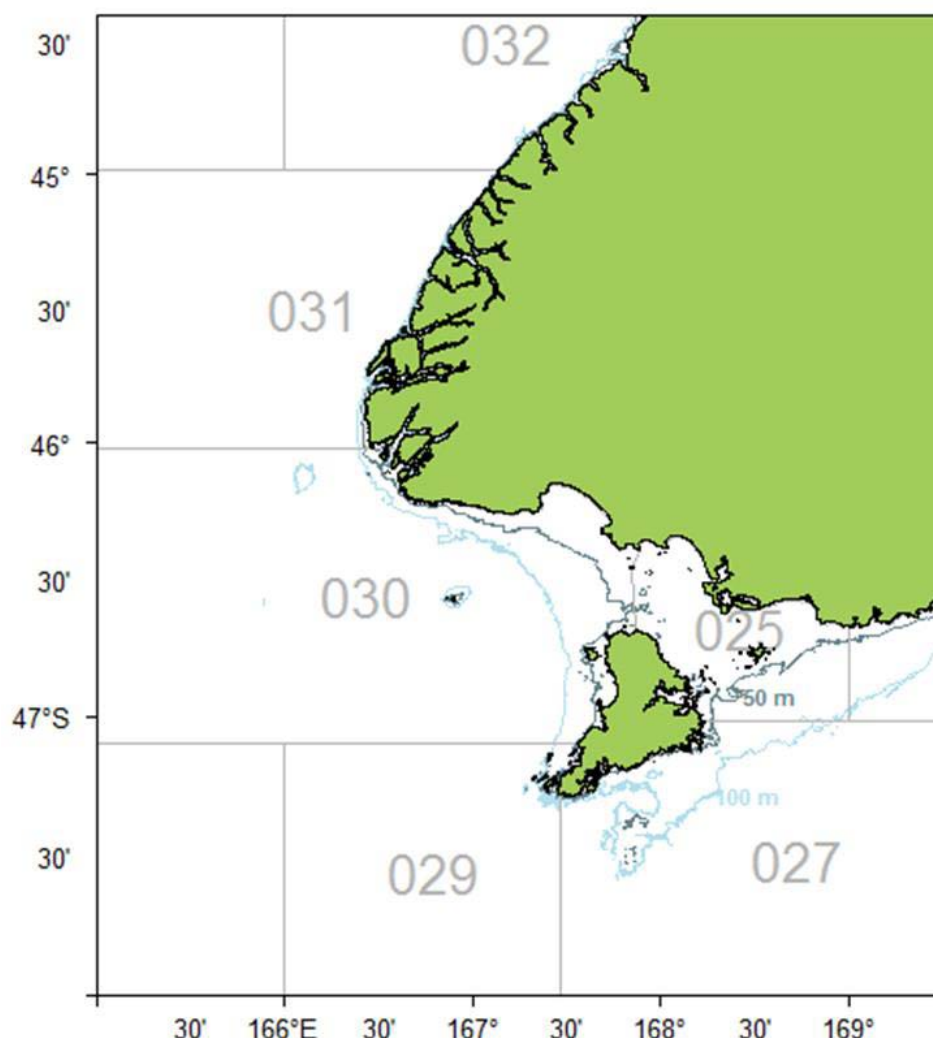


Figure 1: General Statistical Areas within BCO 5.

3. METHODS

3.1 Data

The data described in this report were based on extracts from the Fisheries New Zealand Enterprise Data Warehouse (EDW) requested in January 2019 (REPLOG_12173). The extracts consisted of all fishing and landing events associated with a set of fishing trips that reported a positive landing of blue cod in BCO 3, BCO 4, and BCO 5, or where blue cod was listed as the target species, between 1 October 1989 and 30 September 2018. Data for BCO 3 and BCO 4 were used separately for Projects BCO201803 and BCO201804, with all three projects (including this one) using the same groomed extract. Effort and estimated catch were summarised by fishing trip for every unique combination of fishing method, statistical area, and target species.

The data extracts were groomed in their entirety prior to being used separately in analyses for the fisheries in BCO 3, BCO 4, and BCO 5. The catch and effort data grooming process is listed in Appendix A. Notes, plots, and tables used to check the grooming process are reported in Appendix B. The annual landings (t) and estimated catch (t) by fishing year from 1990 to 2018 in the QMR/MHR data and the groomed data sets for BCO 5 (including the analysis data set used for this characterisation and CPUE analyses) are summarised in Table B-10 and Figure B-4. This report presents data analyses for BCO 5 only.

3.2 Standardised CPUE Analyses

The data used in the BCO 5 CPUE analysis covered the reporting period 1990 to 2018, where cod potting was the reported method. All the BCO 5 cod potting catch and effort data used in the analysis had been recorded on Fisheries New Zealand Catch Effort Landing Return (CELR) forms, the spatio-temporal resolution of these data thus being the number of potlifts per statistical area per day. The grooming methods for catch and effort data described by Haist et al. (2013) were reviewed and repeated in this analysis, and the analysis was extended to include the additional fishing years from 2013 to 2018. The basic unit of effort used in these analyses has been rolled-up to the trip-stratum level as used by Haist et al. (2013), i.e., number of potlifts per statistical area per vessel per day.

Landed catches were allocated to trip strata in proportion to estimated catches by species, or in proportion to the number of potlifts if there was no estimated catch. Methods to exclude data also followed the methods described by Haist et al. (2013); that is, to exclude implausibly large landings that were probably the result of mis-recorded species codes (most likely that of red cod); and, to exclude trips which fish in straddling statistical areas and which report more than one valid fish stock for that statistical area (i.e., BCO 5 and BCO 3). Note, as with Haist et al. (2013), data for trips that targeted more than one species or fished in more than one statistical area were not excluded. Data available for each trip included: the estimated and landed catch of blue cod, number of potlifts, number of days fished, fishing year, statistical area, month of landing, and unique vessel identifier.

The Cod Potting CELR data also supported the derivation of daily aggregated CPUE indices (Langley 2014) for BCO 5; this approach is now applied in many inshore stock assessments. The Southern Inshore Working Group (SINSWG) discussed the merits of adopting a day-based CPUE approach for BCO 5 and concluded that, due to the nature of the BCO 5 fishery, this alternative method of handling the effort data was unlikely to differ much from a trip-based effort index. Further discussions by the SINSWG (20th March 2019) confirmed that the daily aggregation method was not to be implemented because there had been no change in form, there was only one target species, and trips were mostly short and restricted to one statistical area.

In consultation with the SINSWG, five sets of standardised CPUE indices were constructed (Table 1). Four model runs fitted a generalised linear model (GLM) with the identity link to the log of the catches (i.e., a lognormal error distribution was assumed), separately for each of the main BCO 5 statistical areas 025, 027, and 030 and with the data combined for these three areas. Additionally, the results of the standardised indices for 025, 027, and 030 were combined in an area-weighted combined index (i.e., there was no further fitting of a model to data) based on the estimated blue cod habitat available in each area. The two combined CPUE indices were developed to determine their utility to a multi-area stock assessment.

Table 1: List of models constructed for standardised CPUE analysis.

Model name	Data	Model type	Post modelling process
Area025	Analysis data set with stat_area = 025	GLM with gaussian link fitted to log (catch)	NA
Area027	Analysis data set with stat_area = 027	GLM with gaussian link fitted to log (catch)	NA
Area030	Analysis data set with stat_area = 030	GLM with gaussian link fitted to log (catch)	NA
Combined data	Analysis data set with stat_area = 025 or 027 or 030	GLM with gaussian link fitted to log (catch)	NA
Area-weighted	Standardised indices from models Area025, Area027, and Area030	NA	Combine indices, weighted in proportion to habitat area (km ²) in the Statistical Area, i.e., depth < 100m

Data for standardised CPUE analysis

Each fishery is defined by the trip-stratum that used the cod potting method (CP) in Statistical Areas 025, 027, or 030 separately and targeted or landed blue cod. Data from these three areas were standardised separately, and then again with the data for these three areas combined.

Consistent with Starr & Kendrick (2011) and Haist et al. (2013), and prior to core vessel selection, data that reported the number of pots in the water at midnight as greater than the total number of pots lifted during the day were excluded from the CPUE analysis. This is a known ‘data problem’ (Starr & Kendrick 2011) with potting data entered on CELR forms when two of the effort fields are sometimes transposed: *potlifts* (total number of traps/pots lifted in the day) and *effnum* (number of pots in the water at midnight).

Vessel selection

Core vessels were selected separately for each area-specific CPUE analysis. A new set of core vessels was selected for the three-areas-combined analysis. Data were restricted to vessels participating with some consistency in each of the defined fisheries, based on two criteria: a qualifying year (based on having completed a minimum number of trips in a fishing year) and a minimum number of qualifying years during the analysis period. Qualifying criteria for inclusion in each analysis dataset are listed in Table 2.

Table 2: Vessel selection qualifying criteria for data inclusion in each CPUE model run.

Model name	Qualifying year minimum number of trips per year	Minimum number of qualifying years during the period 1990–2018
Area025	10	5
Area027	5	3
Area030	5	3
Combined data	10	5

GLM model setup

The lognormal GLM setup was used for all four models, i.e., the GLM used the default Gaussian link and was fitted to the log of the landed catch by trip (response variable). In the previous analysis, Haist et al. (2013) had assumed a log-logistic error distribution for the three separate statistical area analyses and noted that there was little difference in the residual patterns and the resulting indices between assuming a lognormal or a log-logistic error distribution. The following explanatory variables were provided to the model in a stepwise manner:

- fishing year was forced into the model as first explanatory variable;

- categorical variables: vessel identifier, fishing month, target species;
- continuous variables: log(potlifts), log(days fished), as third order polynomials.

Also, additionally for the combined area model only:

- statistical area; and,
- an interaction term: fishing year:statistical area.

Variables were accepted into the model until the improvement in the explained deviance (R^2) was less than 0.01. The following tables and plots were constructed for each model:

- Diagnostic plots of observed vs. fitted values, and residuals
- Table of variables accepted into each model, with the amount of deviance explained
- Step-influence plots for each model to demonstrate the progressive effect on the annual indices by each explanatory variable as it enters the model, and to compare the influence of each variable on observed catch in adjacent panels
- Coefficient-Distribution-Influence (CDI) plots to show the influence of an explanatory variable as a combination of its GLM coefficients and its distributional changes over time
- Plot of relative time series of the year effects of each model, along with unstandardised (annual geometric mean CPUE based on kg/potlift).

Area-weighted indices

Methods for determining the area criteria for the weighted indices were discussed at SINSWG meetings in March and April 2019, with area defined by habitat (i.e., depth and substrate) suggested as a possible avenue of investigation. However, data for identifying habitat areas were not readily available for these analyses. Fishery independent potting surveys for blue cod in Foveaux Strait (Beentjes et al. 2019) indicated that the relative abundance of blue cod across eight survey strata did not show any clear pattern in either 2014 and 2018, nor a clear association between habitat type and abundance. They further concluded that a more detailed analyses of habitat type by pot location in real time is required to determine if a relationship exists between habitat type and blue cod abundance.

Therefore, lacking specific and well-defined blue cod habitat areas, a crude habitat area definition based on depth less than 100 m was used. The SINSWG also discussed the possibility of using a depth range at 50 m, but the method was considered too crude to attempt at this finer resolution. Also, a previous industry-funded diary study revealed that most of the commercial BCO 5 catch was taken in depths shallower than 100 m, and that the mapped distribution of pots matched the 100 m depth contour reasonably well (Middleton et al. 2013). The seafloor area shallower than 100 m in each of the three Statistical Areas (Figure 2) was used to proportionally weight the annual indices from each of the separate Statistical Area models to obtain a combined area-weighted time series (Table 3).

Table 3: Proportion of blue cod habitat in each Statistical Area based on depth shallower than 100 m.

Statistical Area	Habitat area estimate (km ²)	Habitat area proportion
025	4 177	0.434
027	1 737	0.180
030	3 713	0.386

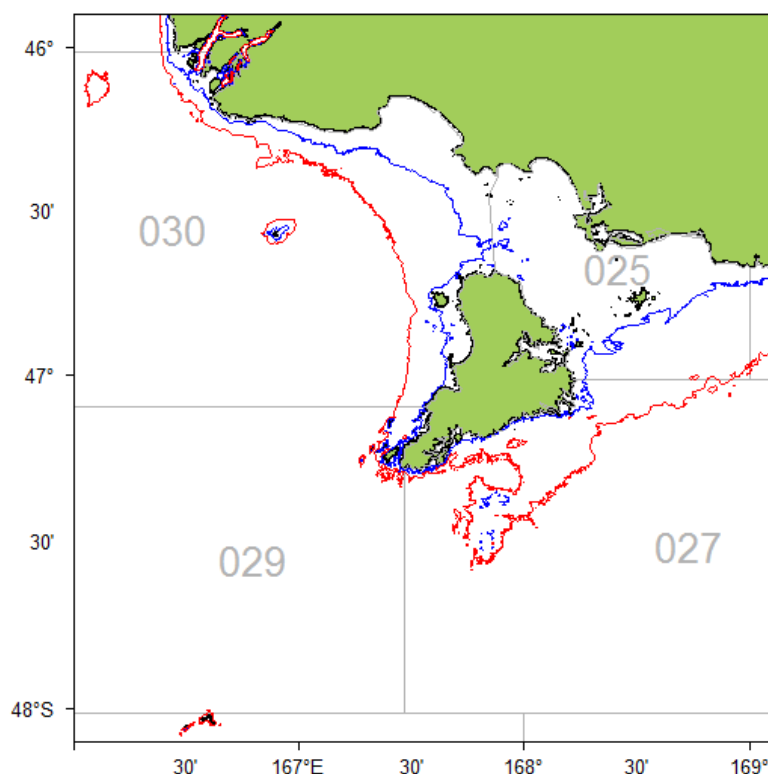


Figure 2: Depth contours at 50 m (blue) and 100 m (red) in Statistical Areas 025, 027, and 029.

4. RESULTS

4.1 Characterisation

In 1990 the TACC for BCO 5 was increased from 1447 t to 1491 t. Further increases followed, in 1992 to 1536 t, and in 2002 to 1548 t (Figure 3, Table 4). In 2012, the TACC was reduced to 1239 t where it remained until 1 October 2020, when it was further reduced to 800 t. In general, reported landings increased from 1990 to 2004. In 2005, landings were slightly higher than the TACC, followed by a general decline in landings through to 2018. Note, there was a voluntary 10% shelving of the TACC by the industry in the 2017, 2018, and 2019 fishing years. This was undertaken to account for a predicted estimated reduction of catch of around 7–8% as a result of a larger mesh size of 54 mm introduced in 2016 under regulation.

Almost all landings of blue cod in BCO 5 have been taken by the cod potting method (Figure 4), with most of the landings taken when blue cod is the target species (Figure 5). In the rock lobster potting fishery, blue cod is also landed, as a non-target species and (minimally) as a target species (Figure 5), although the latter may be due to coding errors.

Around 50–60% of the cod potting effort each fishing year has been concentrated in Statistical Area 025 (Foveaux Strait) and has accounted for a similar proportion of the landings (Figures 6 & 7, Tables C-1 to C-4 in Appendix C). In Statistical Area 025, effort has declined from over 60 000 potlifts per year in the early 1990s to around 40 000 to 50 000 potlifts since 1996. Landings have remained consistent in Statistical Area 025, at around 600 tonnes per year, with landings over 700 t per year in 2001, 2002, 2005, and 2006, and with the lowest annual landings of 426 t recorded in 2018.

In the last decade, effort (number of potlifts) in Statistical Areas 027 and 030 has accounted for around 40% of the potlifts in BCO 5, along with roughly the same proportion of the catch. There is no distinct trend in catch or effort (either up or down) in these areas (Figures 6 & 7, Tables C-1 to C-4 in Appendix C).

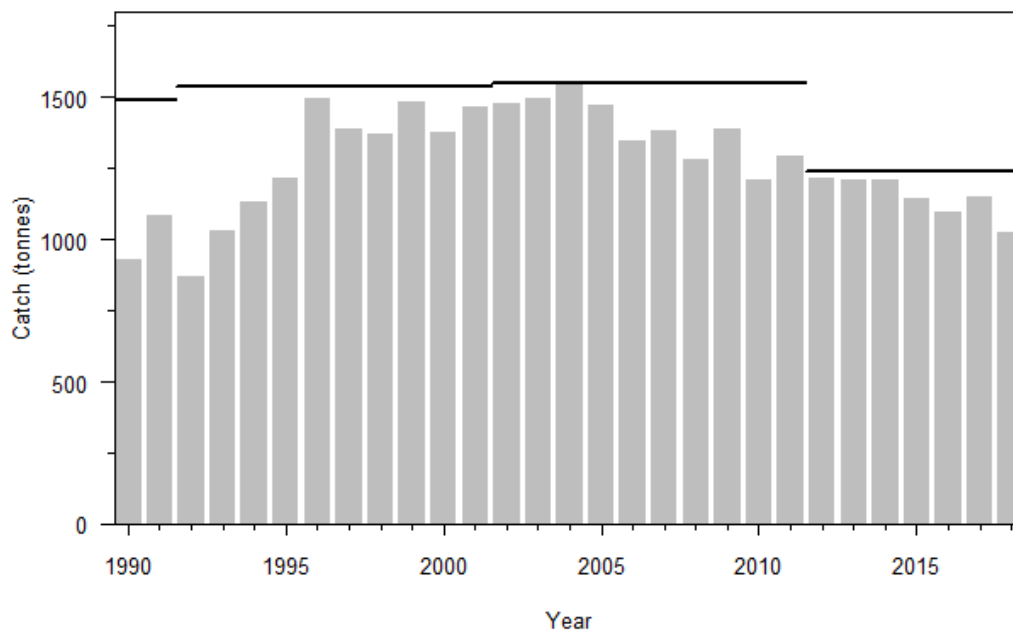


Figure 3: Reported landings (bars) and TACCs (t) of blue cod in BCO 5 for 1990 to 2018 (source: QMRs and MHRs).

Table 4: Reported landings and TACCs (t) of blue cod in BCO 5 for 1990 to 2018 (source: QMRs and MHRs).

Fishing year	Landings reported by QMR/MHR (t)	TACC (t)	Fishing year	Landings reported by QMR/MHR (t)	TACC (t)
1990	928	1 491	2005	1 473	1 548
1991	1 083	1 491	2006	1 346	1 548
1992	873	1 536	2007	1 382	1 548
1993	1 029	1 536	2008	1 280	1 548
1994	1 132	1 536	2009	1 392	1 548
1995	1 218	1 536	2010	1 209	1 548
1996	1 495	1 536	2011	1 296	1 548
1997	1 388	1 536	2012	1 217	1 239
1998	1 373	1 536	2013	1 209	1 239
1999	1 482	1 536	2014	1 208	1 239
2000	1 379	1 536	2015	1 145	1 239
2001	1 467	1 536	2016	1 099	1 239
2002	1 478	1 548	2017*	1 152	1 239
2003	1 497	1 548	2018*	1 027	1 239
2004	1 557	1 548			

* 10% of the TACC voluntarily shelved by the industry.

The BCO 5 cod potting fishery tends to operate throughout the year, particularly in Statistical Areas 025, 027, and 030 (Figures D-1 to D-6 in Appendix D), predominantly from March to September. Cod potting effort in the other areas is sporadic in comparison. For Statistical Area 025, the catches in the summer months of 2017–18 and through to May 2018 look to be lower than in previous years. It was noted at the SINSWG (31st January 2019) that fishers reported poor catch rates of blue cod in the summer of 2017–18, which was thought to result from unusually warm water and an abundance of salps on which blue cod were observed to feed.

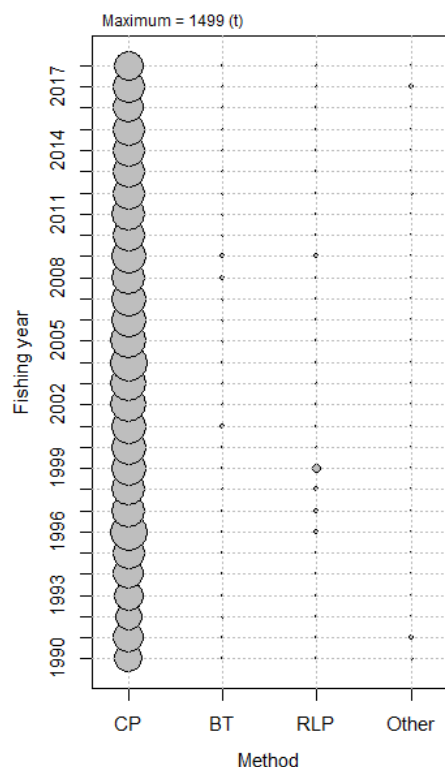


Figure 4: BCO 5 landings (t) for 1990 to 2018 by major fishing methods by fishing year. CP=cod potting, BT=bottom trawl, RLP=rock lobster potting.

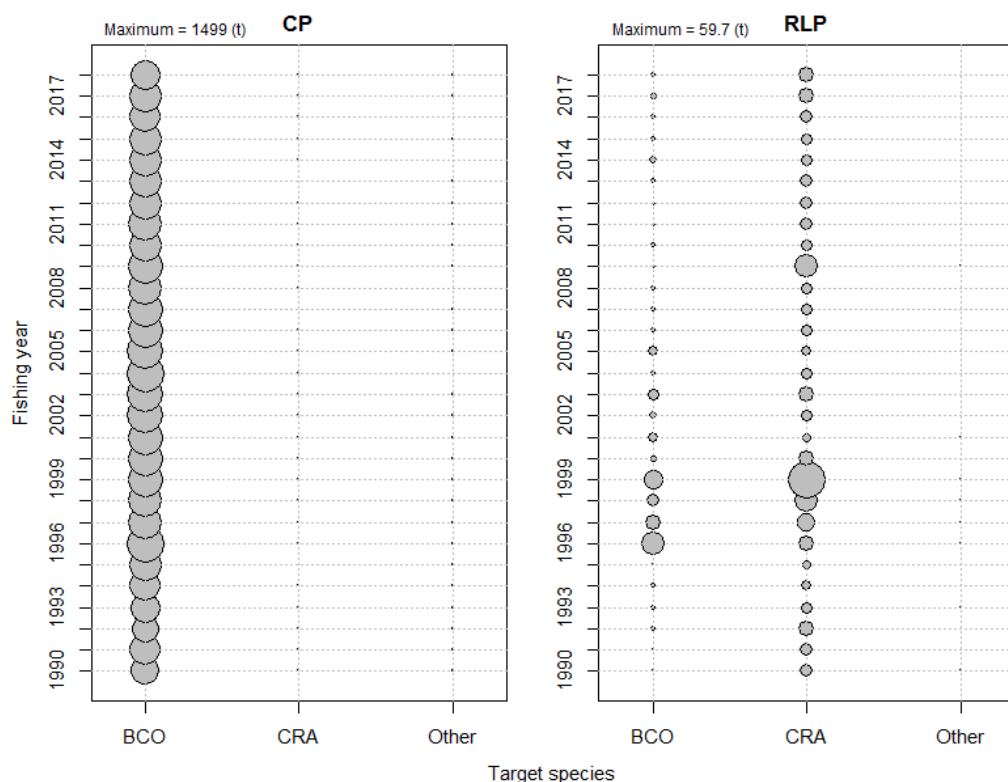


Figure 5: BCO 5 landings for 1990 to 2018 by target species (BCO=blue cod, CRA=red rock lobster) and fishing year for the cod potting (CP) method (left) and rock lobster potting (RLP) method (right). Note that the scales for the bubbles are different (maximum bubble size for CP is 1499 t, and for RLP is 57.9 t), and the blue cod catch by RLP is insignificant.

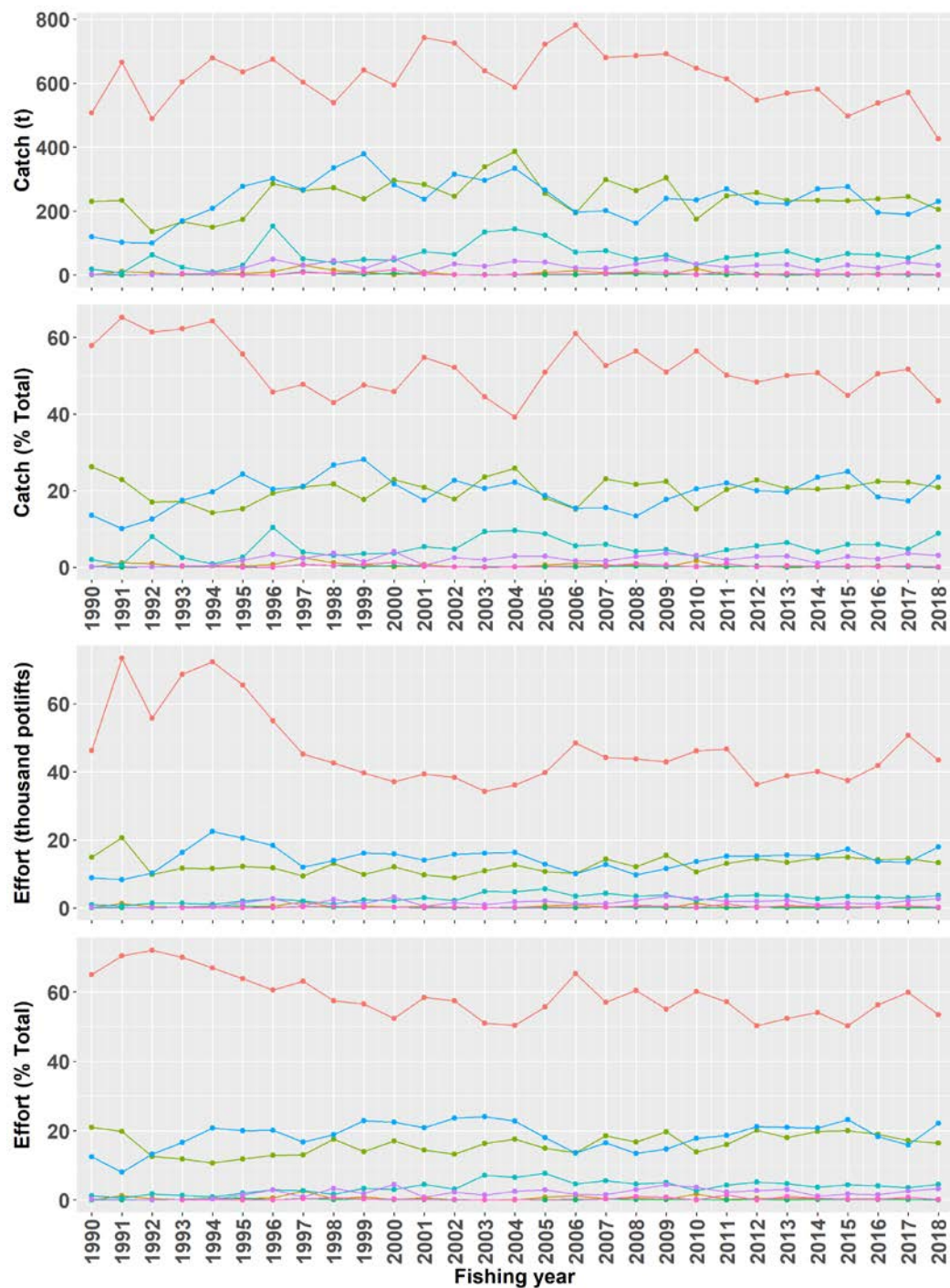


Figure 6: BCO 5 landings (catch in tonnes) and effort (number of potlifts) from the cod potting method, by statistical area and fishing year for 1990 to 2018.

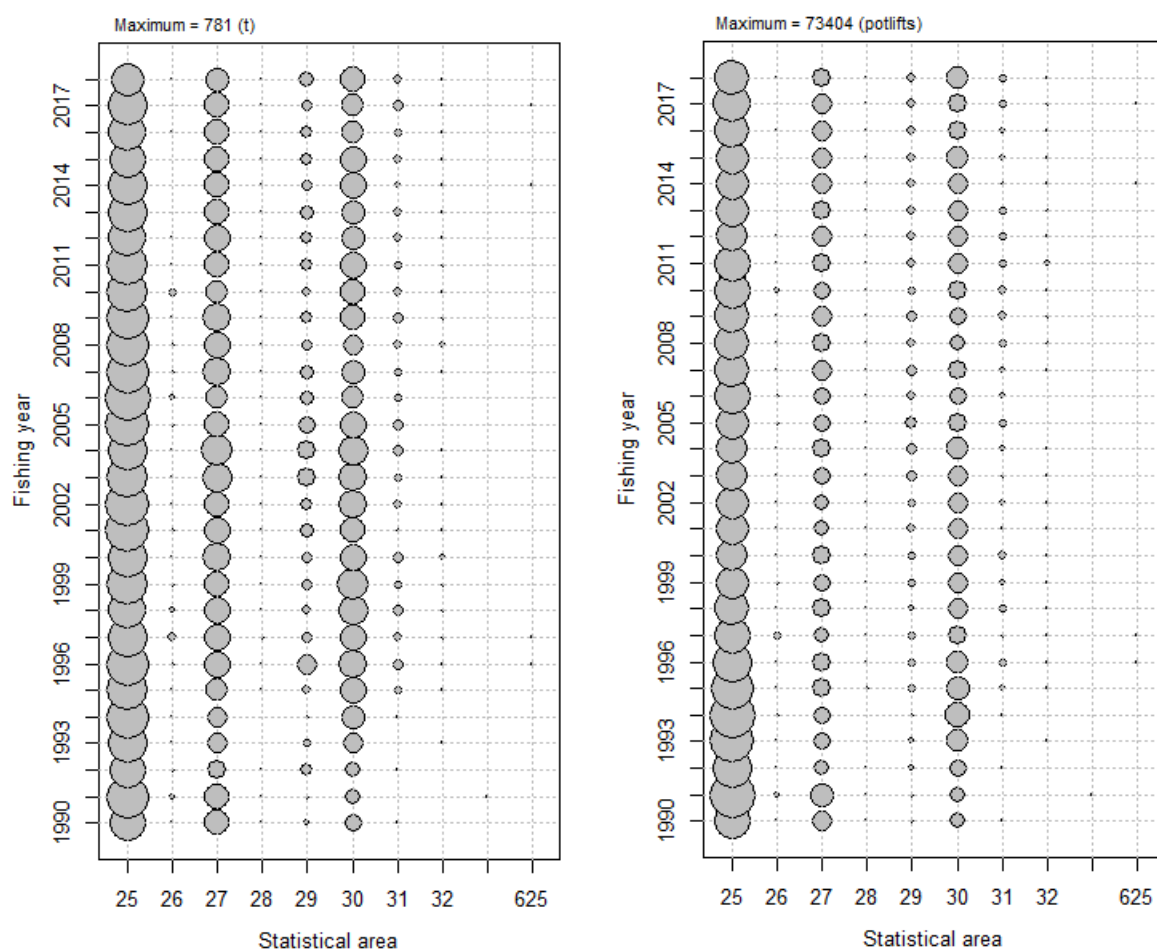


Figure 7: BCO 5 landings (left) with maximum circle size proportional to 781 t, and potlifts (right) with maximum circle size proportional to 73 404 potlifts, from the cod potting method by statistical area and fishing year for 1990 to 2018.

4.2 Standardised CPUE

Core vessel selection

The qualifying criteria used to determine core vessels operating in the cod potting fishery for each CPUE analysis (Table 5) resulted in the following data being retained: 45 vessels and 77.8% catch for the Area025 model (Figures E-2 & E-3 in Appendix E); 34 vessels and 83.5% catch for the Area027 model (Figures E-5 & E-6 in Appendix E); 39 vessels and 82.1% catch for the Area030 model (Figures E-8 & E-9 in Appendix E); and 64 vessels and 86.4% catch for the Combined Data model (Figures E-11 & E-12 in Appendix E). Final data sets for the core vessels selected for each model are summarised in Tables E-1, E-2, E-3, and E-4 (Appendix E).

Table 5: Number of vessels and percentage of catch retained in the model datasets for each standardised CPUE analysis after core vessel selection.

Model	Qualifying criteria		Analysis dataset	
	Minimum trips per year	Minimum years with minimum trips per year	Vessels (n)	catch retained (%)
Area025	10	5	45	77.8
Area030	5	3	34	83.5
Area027	5	3	39	82.1
Combined data	10	5	64	80.6

Model diagnostics

Diagnostic residual plots for each of the four models are presented in Figures F-1 to F-4 of Appendix F. Similarly, and for each model, the residuals follow the modelled distribution well except for extreme values, which is not unusual for this type of data. Haist et al. (2013) encountered similar diagnostic trends with their use of the log-logistic error distribution in the previous analysis.

Area025 Model

The final model selected for standardising cod potting catches in Statistical Area 025 is described in Table 6. Fishing year (forced into the model as the first variable) explained 12% of the variation in catch. The log of potlifts was the most important variable, explaining a further 39% of the variance, and vessel entered the model third explaining 14% of the variance. The final model explained 65% of the variance in $\log(\text{catch})$. The annual CPUE indices at each step are plotted in Figure 8.

The influence (CDI) plot for $\log(\text{potlifts})$ shows a decline in the number of potlifts in the late 1990s, followed by a consistent increase from the early 2000s (Figure 9). The model responds to these influences by lifting the annual indices in the late 1990s, and then dropping the indices from the early 2000s. The cumulative effect of these influences results in less of an increase in the annual indices over the last decade. The CDI plot for vessels behaves in a similar manner, although with the decline occurring in the early 1990s followed by a generally increasing trend from the mid 1990s that shows a stronger increase in the last decade (Figure 10). This has the effect of further modifying the annual indices, such that the trend over the last decade is generally flat, and slightly declining in recent years (Figure 11, Table 7).

Table 6: Area025 Model order of acceptance of variables into the lognormal model, with the degrees of freedom (DF), improvement in AIC, and the amount of explained deviance (R^2) as each variable is accepted.

Term	DF	AIC	R^2 (%)
fyear	28	56 546	11.94
poly(log(potlift)3)	3	43 848	50.97
vessel	44	36 516	65.17

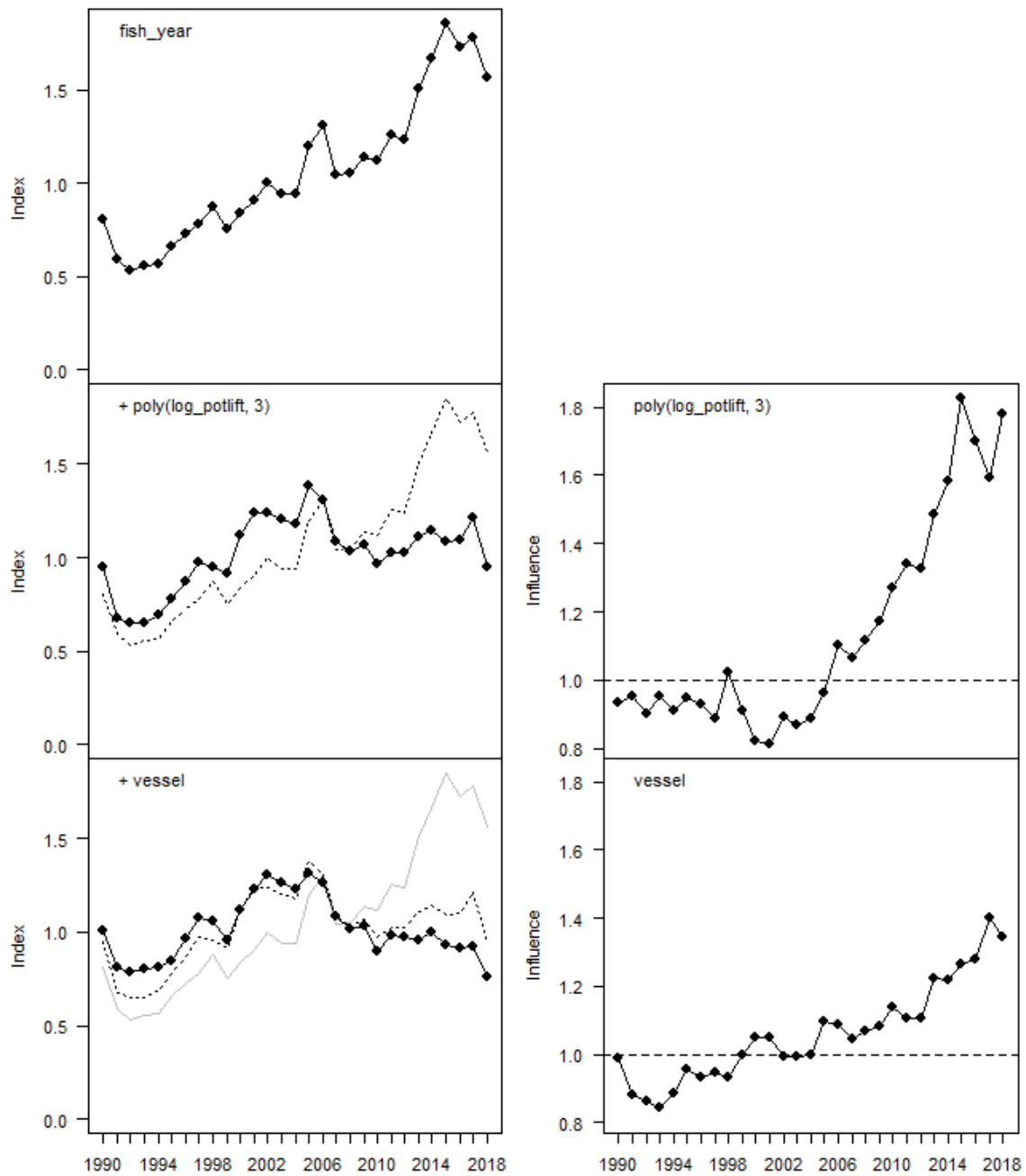


Figure 8: Area025 Model blue cod step and influence plot showing [left] annual indices at each step in the variable selection process, [right] influence of variables at each selection step.

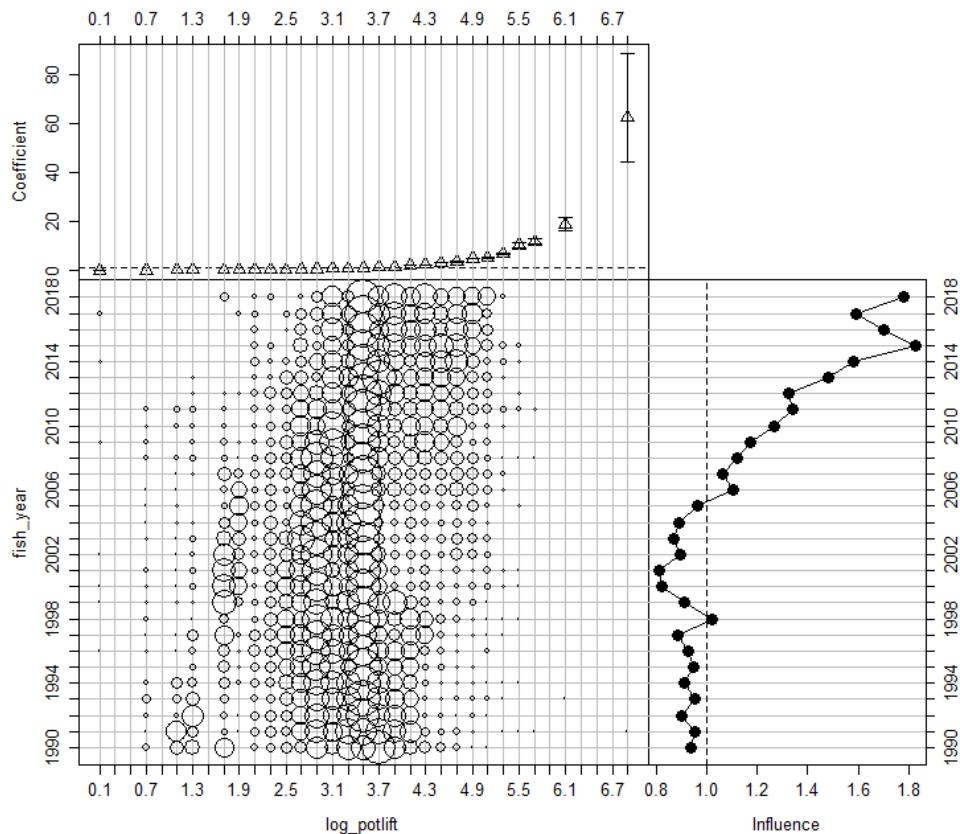


Figure 9: Area025 Model log(potlifts) influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

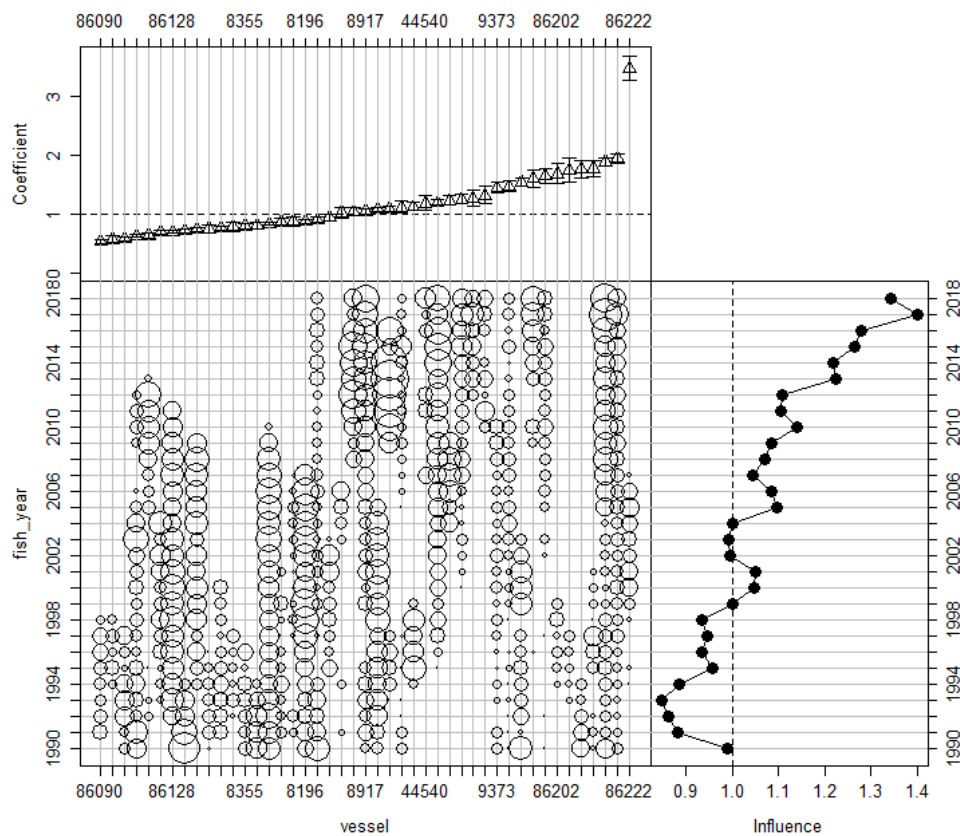


Figure 10: Area025 Model vessels influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

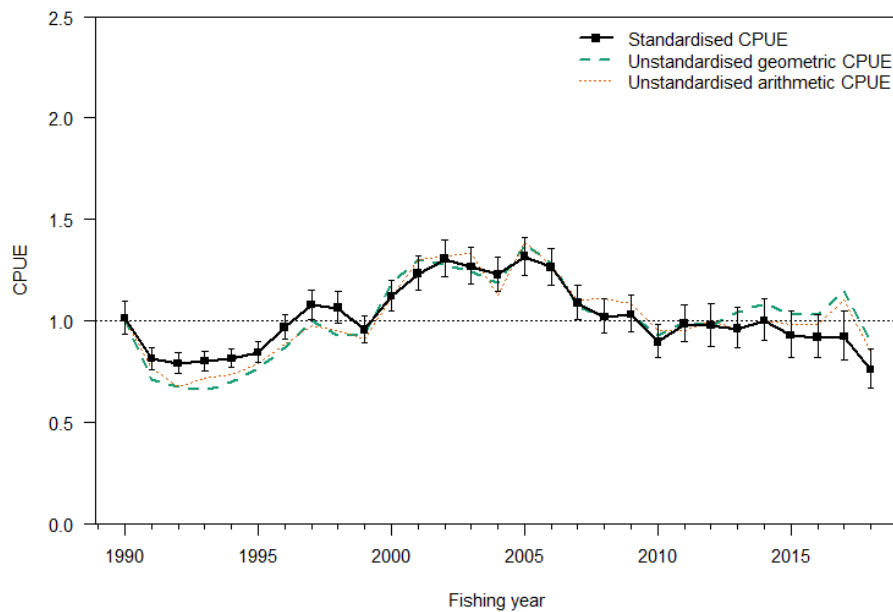


Figure 11: Area025 Model. Indices of unstandardised and standardised CPUE for blue cod core fisher data for the fishing years 1990 to 2018. The dotted line is the annual arithmetic mean of kg/potlift, the dashed line is the annual geometric mean of kg/potlift, and the solid line is the standardised canonical indices with error bars at ± 2 * std. errors.

Table 7: Annual indices for each model from 1990 to 2018.

Fishing year	Area 025	Area 027	Area 030	Areas 025, 027 & 030 Combined data	Areas 025, 027, & 030 Area-weighted
1990	1.0118	0.5911	1.0377	0.9223	0.9460
1991	0.8125	0.6181	0.9662	0.8380	0.8368
1992	0.7898	0.6618	1.0004	0.8196	0.8480
1993	0.8009	0.8453	0.8948	0.8499	0.8451
1994	0.8143	0.6141	0.6459	0.8327	0.7133
1995	0.8443	0.9120	0.6902	0.8582	0.7970
1996	0.9689	1.0748	0.7043	0.9547	0.8858
1997	1.0780	1.2420	1.1467	1.1203	1.1340
1998	1.0632	1.1349	1.2025	1.1208	1.1299
1999	0.9558	1.1144	1.3171	1.0390	1.1238
2000	1.1217	1.3168	1.1333	1.1268	1.1613
2001	1.2328	1.6494	1.1804	1.2293	1.2875
2002	1.3054	1.7476	1.3481	1.2794	1.4015
2003	1.2670	1.5086	1.3480	1.2328	1.3417
2004	1.2288	1.6275	1.2345	1.2221	1.3027
2005	1.3159	1.2450	1.2396	1.2800	1.2737
2006	1.2636	1.1799	1.2740	1.1977	1.2525
2007	1.0866	0.9612	1.1377	1.0551	1.0837
2008	1.0190	0.8775	0.9509	0.9683	0.9672
2009	1.0314	0.8833	1.0405	0.9824	1.0083
2010	0.8960	0.8204	1.0063	0.8706	0.9250
2011	0.9841	1.0093	0.8566	0.9882	0.9394
2012	0.9757	0.9850	0.8136	0.9616	0.9148
2013	0.9609	0.9164	0.9129	0.9160	0.9344
2014	1.0012	0.8398	0.9610	0.9673	0.9566
2015	0.9289	0.9174	0.9650	0.9459	0.9407
2016	0.9178	0.9705	0.8466	0.9130	0.8998
2017	0.9226	1.0129	0.8881	0.9494	0.9256
2018	0.7587	0.8965	0.8206	0.8451	0.8074

Area027 Model

The final model selected for standardising cod potting catches in Statistical Area 027 is described in Table 8. Fishing year (forced into the model as the first variable) explained 23.4% of the variation in catch. The log of potlifts was the most important variable, explaining a further 49% of the variance. Vessel entered the model third explaining 7.3% of the variance, and finally log of days explained a further 1.8% of the variance. The final model explained 81% of the variance in log(catch). The annual CPUE indices at each step are plotted in Figure 12.

The influence (CDI) plot for log(potlifts) shows an overall increase in the number of potlifts since 1990, with some sharp increases and declines in the mid 1990s to the early 2000s (Figure 13). The model responds to these influences by pivoting an increase in the annual indices followed by a flattened trend around the early 2000s. The CDI plot for vessel shows large and consistent differences in performance amongst vessels, particularly prior to 2006 (Figure 14). After 2006, many of the poorer performing vessels dropped out of the fishery, and catch rates are more consistent amongst the vessels after 2006. Vessels have a greater influence between the mid 1990s to the mid 2000s, further increasing the annual indices during this period, with less influence after this period. Although log(days) entered the model, this variable has negligible influence on the trends in the annual indices (Figure 15). Standardised CPUE annual indices increased from 1990 to a peak in 2002, followed by a declining trend in the following 5 years, after which annual indices were generally flat and stable (Figure 16, see Table 7).

Table 8: Area027 Model order of acceptance of variables into the lognormal model, with the degrees of freedom (DF), improvement in AIC, and the amount of explained deviance (R^2) as each variable is accepted.

Term	DF	AIC	R^2 (%)
fyear	28	9 259	23.41
poly(log(potlift)3)	3	6 334	72.11
vessel	33	5 516	79.43
poly(log(days)3)	3	5 257	81.22

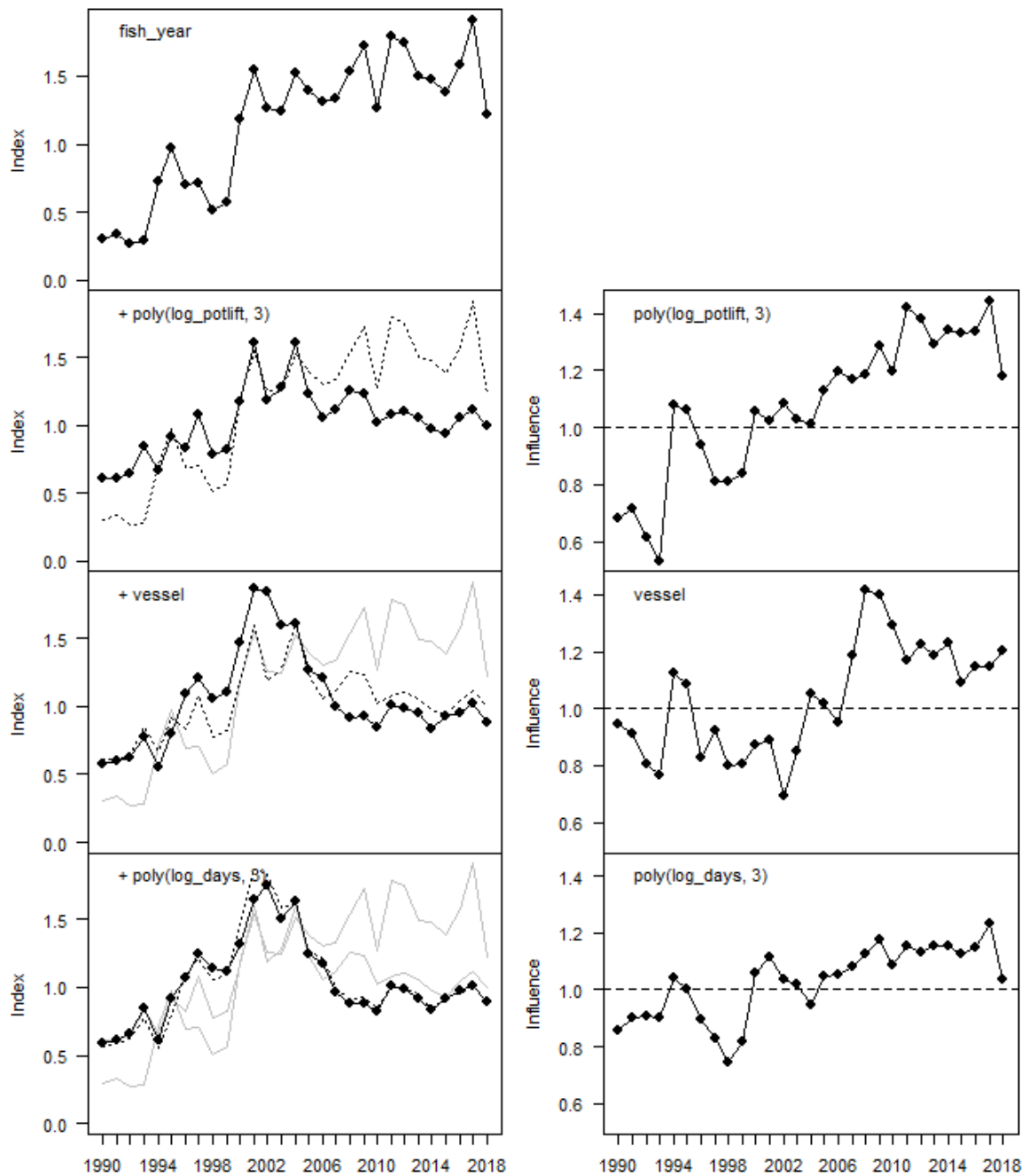


Figure 12: Area027 Model step and influence plot showing [left] annual indices at each step in the variable selection process; [right] influence of variables at each selection step.

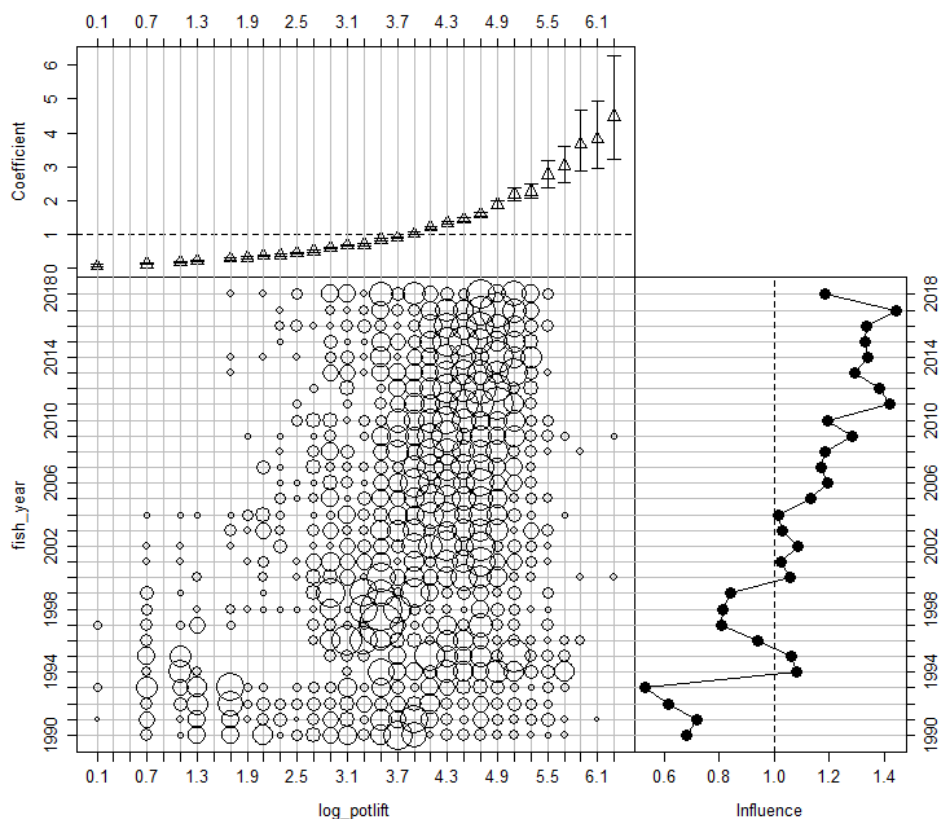


Figure 13: Area027 Model log(potlifts) influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

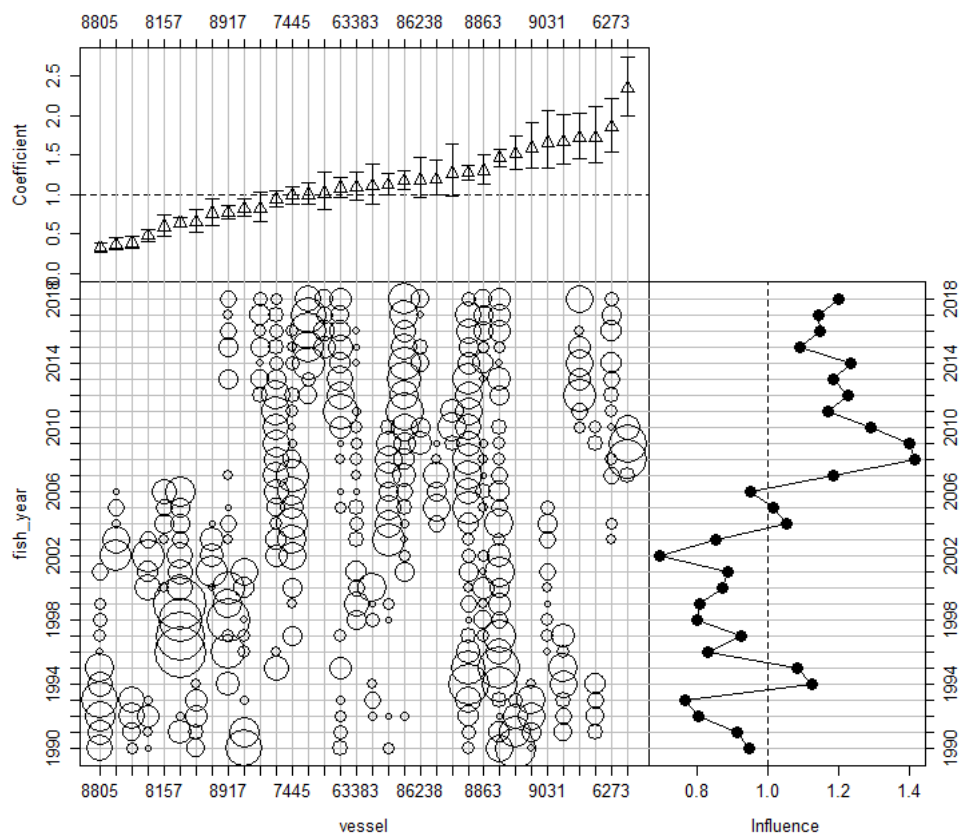


Figure 14: Area027 Model vessel influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

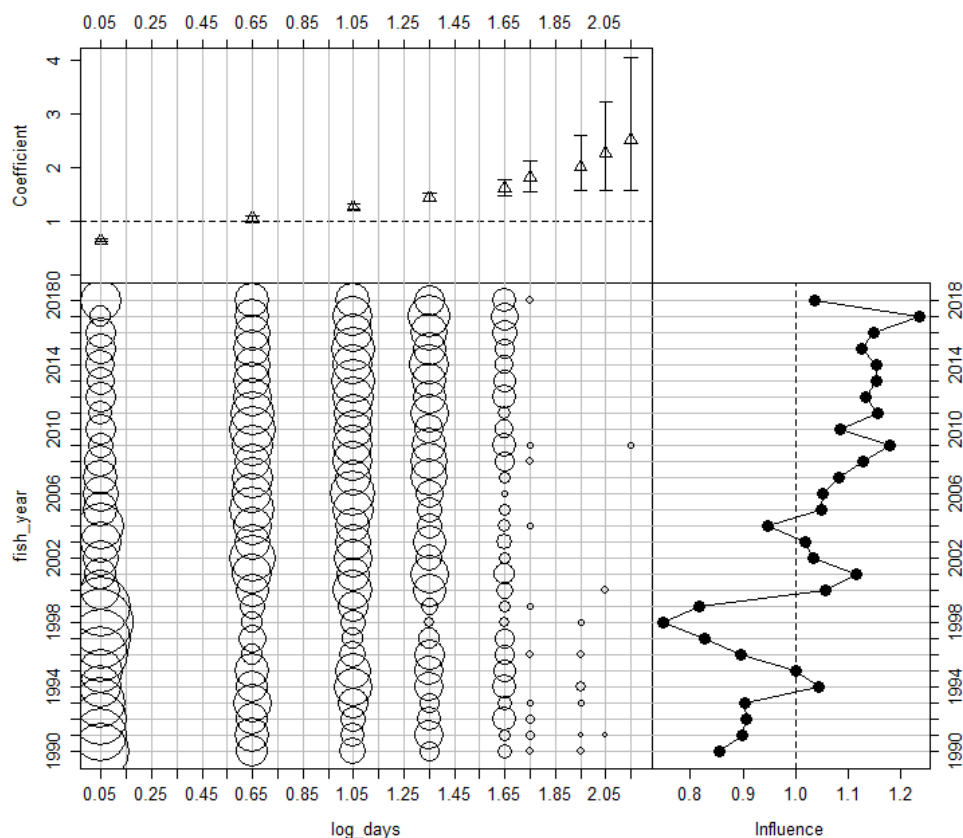


Figure 15: Area027 Model log(days) influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

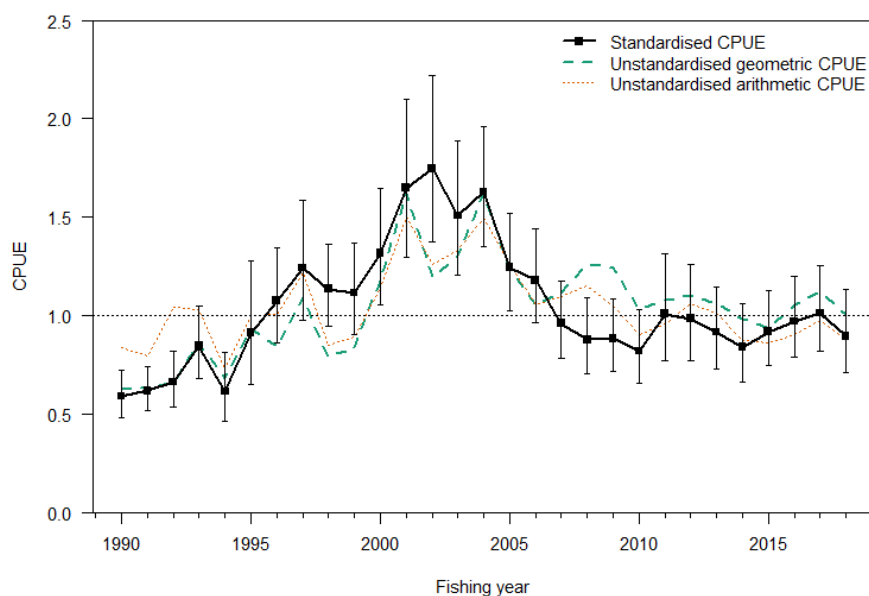


Figure 16: Area027 Model. Indices of unstandardised and standardised CPUE for blue cod core fisher data for the years 1990 to 2018. The dotted line is the annual arithmetic mean of kg/potlift, the dashed line is the annual geometric mean of kg/potlift, and the solid line is the standardised canonical indices with error bars at ± 2 * std. errors.

Area030 Model

The final model selected for standardising cod potting catches in Statistical Area 030 is described in Table 9. Fishing year (forced into the model as the first variable) explained 11.3% of the variation in catch. The log of potlifts was the most important variable, explaining a further 37.5% of the variance. Vessel entered the model third explaining 16.5% of the variance, and finally log of days explained a further 2.3% of the variance. The final model explained 67.6% of the variance in log(catch). The annual CPUE indices at each step are plotted in Figure 17.

The influence (CDI) plot for log(potlifts) shows an overall increase in the number of potlifts since 1990 but this trend varies considerably over the time series, particularly since the early 2000s when the rate of increase in the number of pots also increases (Figure 18). This variable has the greatest influence on the annual indices for the second half of the time series and the increased effort smooths the variability in the decline since 2005. Performance between vessels varied more widely in the earlier part of the series, prior to 2005 and particularly in the 1990s. Better performing vessels have operated more consistently since the early 2000s and this influence has had a positive effect on the annual indices in the early part of the series, and a negative effect latterly (Figure 19). Although the number of days per record entered the model, this variable has negligible influence on the trends in the annual indices (Figure 20).

The final resulting trend in the standardised CPUE annual indices shows a decline from 1990 to 1994, and then an increase from 1995 to 1999, with CPUE remaining at this higher level until 2006 after which it declined once more until 2010, although at a slightly higher level than in the mid 1990s. In the last decade CPUE has remained relatively flat and stable (Figure 21, see Table 7).

Table 9: Area030 Model order of acceptance of variables into the lognormal model, with the degrees of freedom (DF), improvement in AIC, and the amount of explained deviance (R^2) as each variable is accepted.

Term	DF	AIC	R^2 (%)
fyear	28	12 358	11.34
poly(log(potlift)3)	3	10 075	48.81
vessel	38	8 480	65.32
poly(log(days)3)	3	8 190	67.59

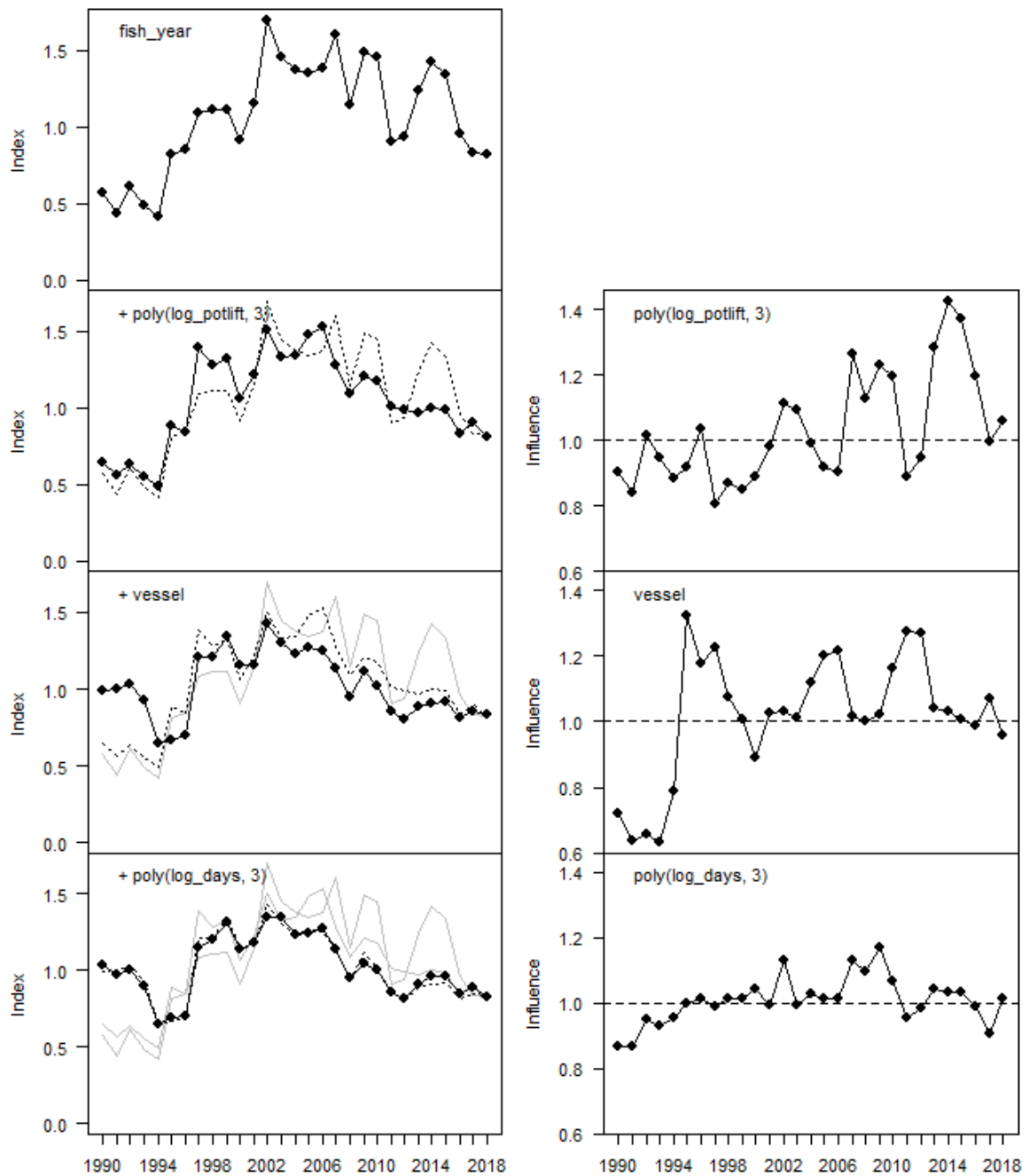


Figure 17: Area030 Model step and influence plot showing [left] annual indices at each step in the variable selection process; [right] influence of variables at each selection step.

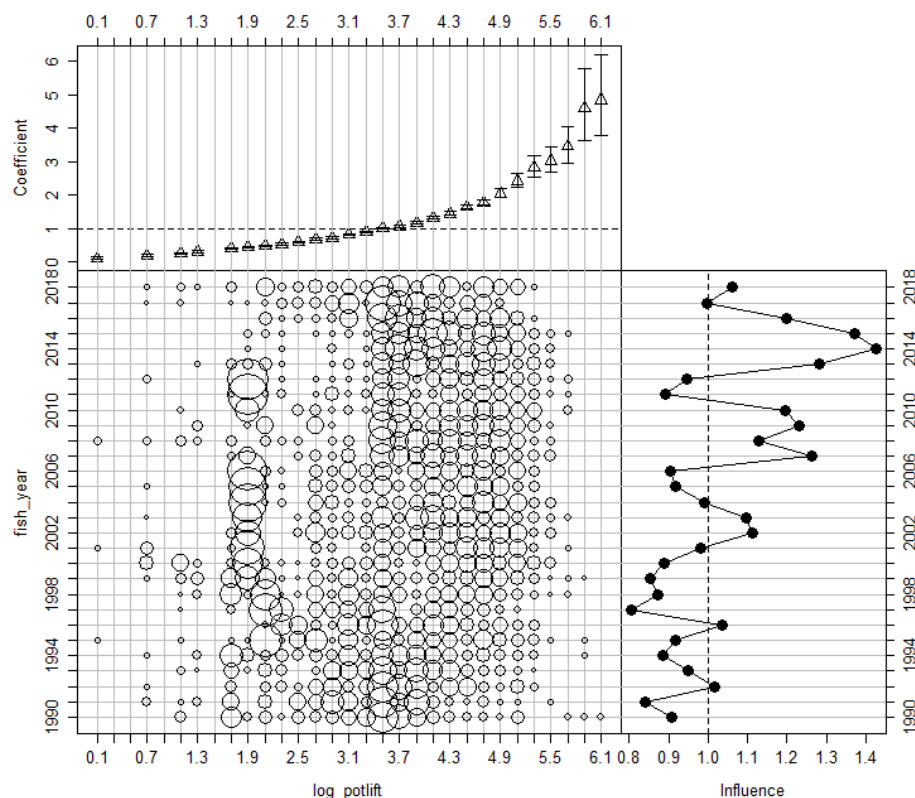


Figure 18: Area030 Model log(potlifts) influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

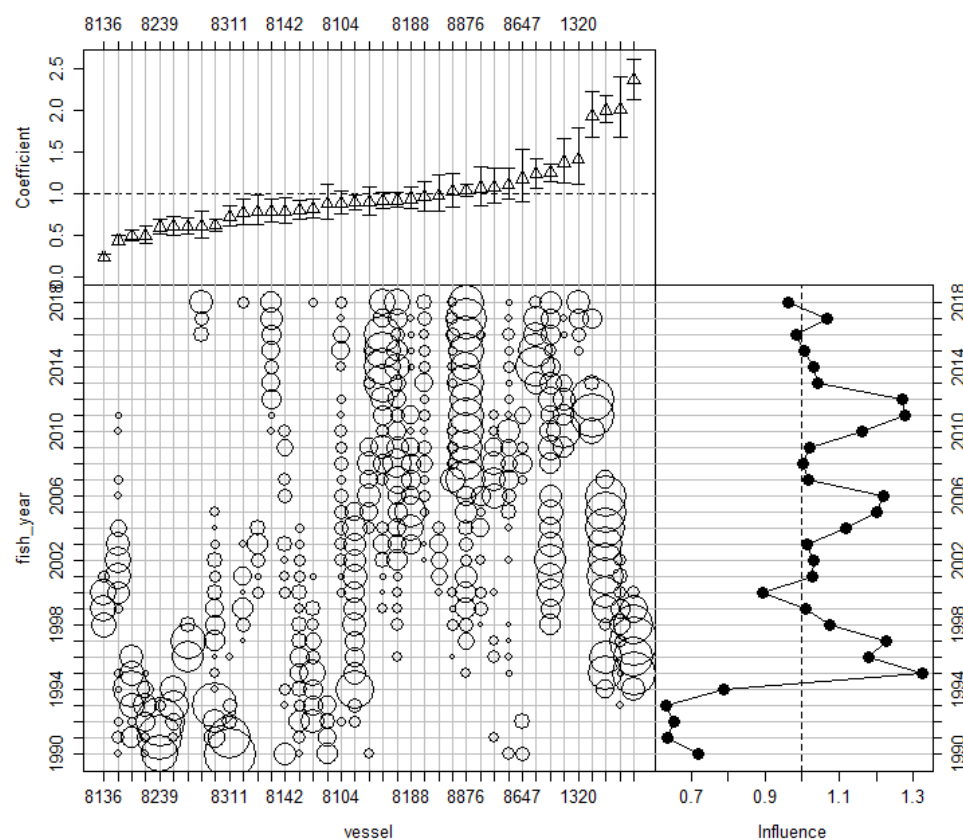


Figure 19: Area030 Model vessel influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

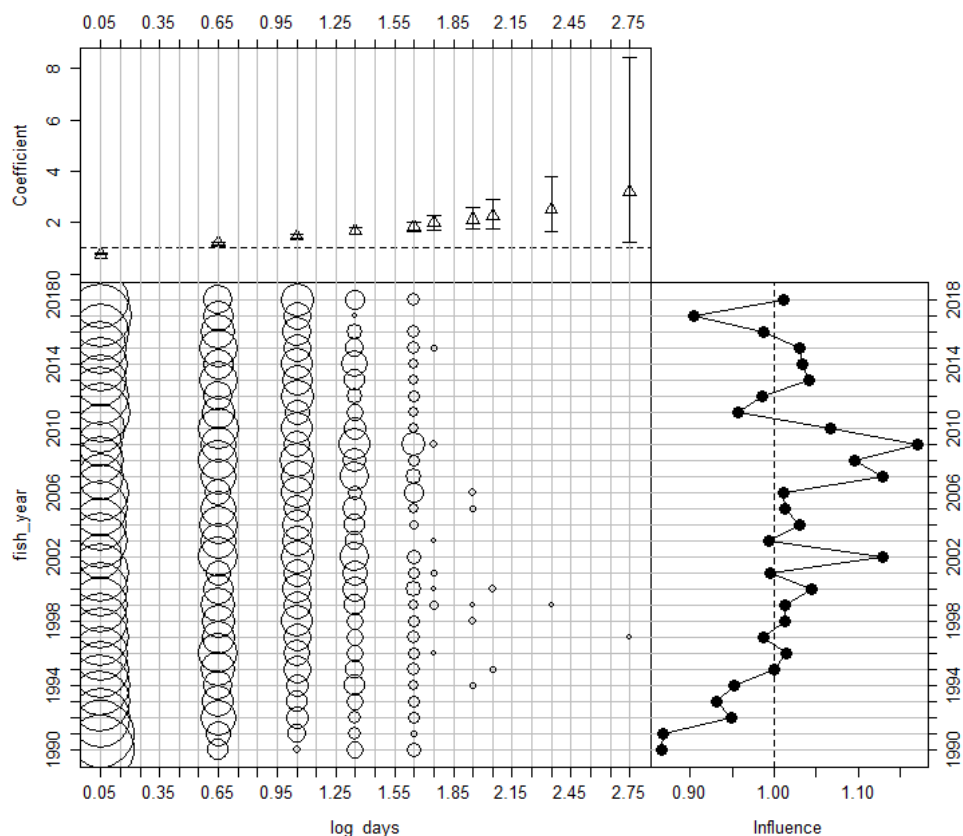


Figure 20: Area030 Model log(days) influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

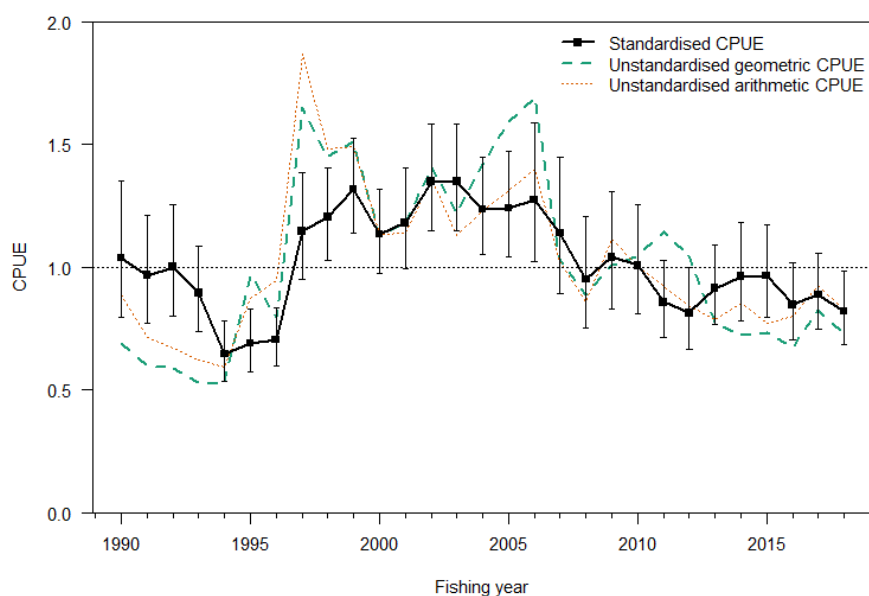


Figure 21: Area030 Model. Indices of unstandardised and standardised CPUE for blue cod core fisher data for the years 1990 to 2018. The dotted line is the annual arithmetic mean of kg/potlift, the dashed line is the annual geometric mean of kg/potlift, and the solid line is the standardised canonical indices with error bars at ± 2 * std. errors.

Combined Areas Data Model (Statistical Areas 025, 027, & 030)

The final model selected for standardising cod potting catches in the data combined for Statistical Areas 025, 027, and 030 is described in Table 10. The results from this combined model are very similar to those for the Statistical Area 025 model, including the variance explained by the potlifts and vessel variables as well as the influence these variables have on the resulting annual indices (Figure 22, Figure 25). The combined model is most similar to that of the 025 model because of the relatively high proportion of data from Statistical Area 025 in this analysis; therefore the resulting annual indices from the Combined Data model are almost indistinguishable from the Area025 model (Figure 26, see Table 7).

Table 10: Combined areas data model (025, 027, 030) order of acceptance of variables into the lognormal model, with the degrees of freedom (DF), improvement in AIC, and the amount of explained deviance (R^2) as each variable is accepted.

Term	DF	AIC	R^2 (%)
fyear	28	82 789	11.63
poly(log(potlift)3)	3	64 478	52.56
vessel	63	53 317	66.67
poly(log(days)3)	3	52 026	69.06

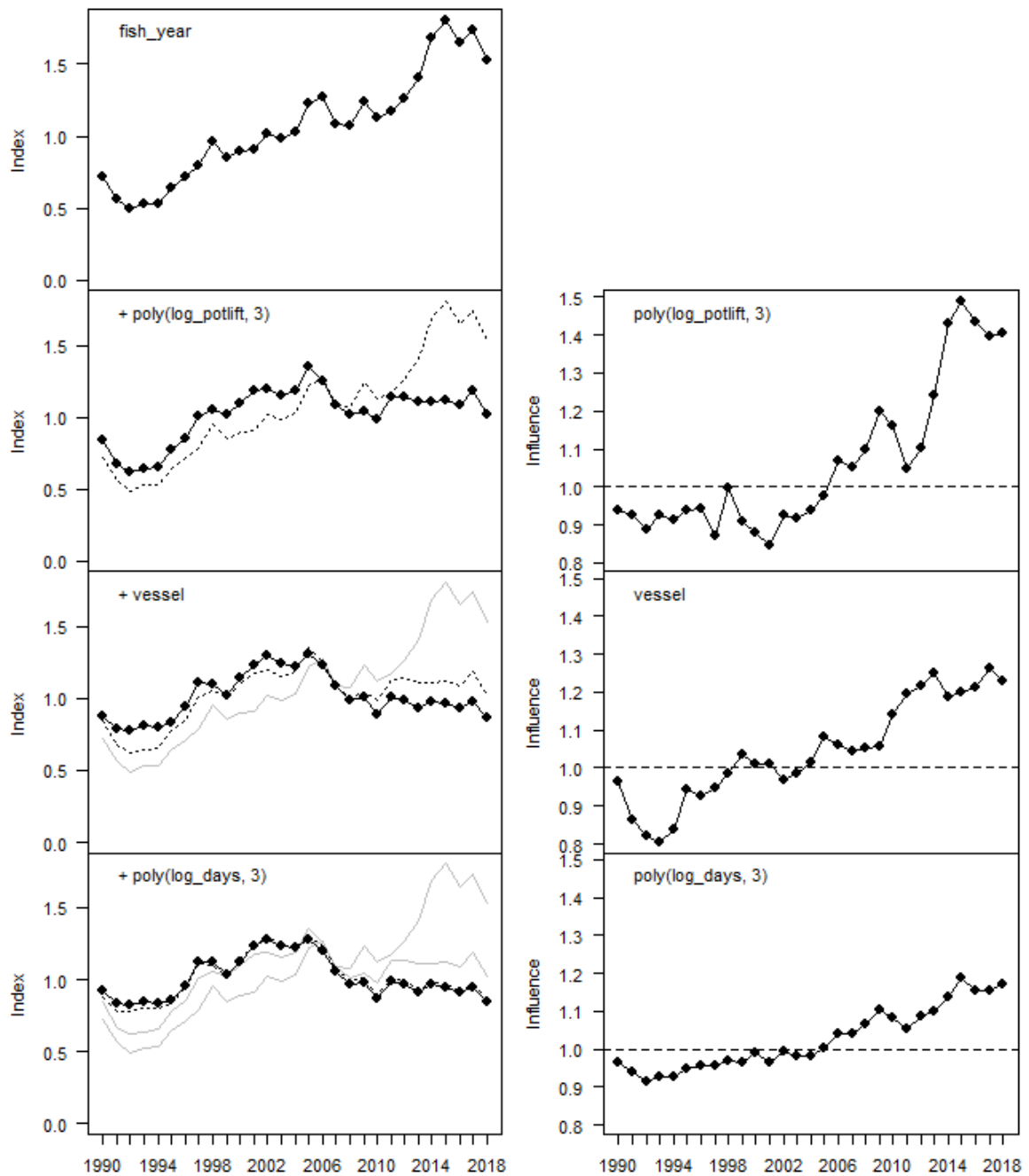


Figure 22: Combined area (025, 027, 030) data model step and influence plot showing [left] annual indices at each step in the variable selection process; [right] influence of variables at each selection step.

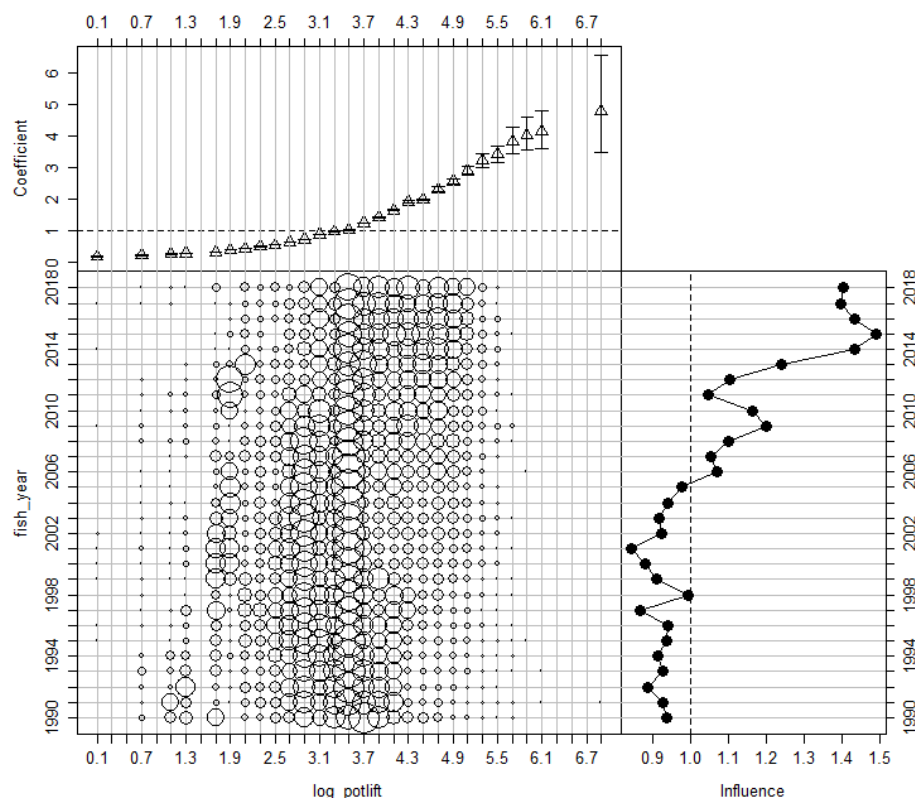


Figure 23: Combined area (025, 027, 030) data model log(potlifts) influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

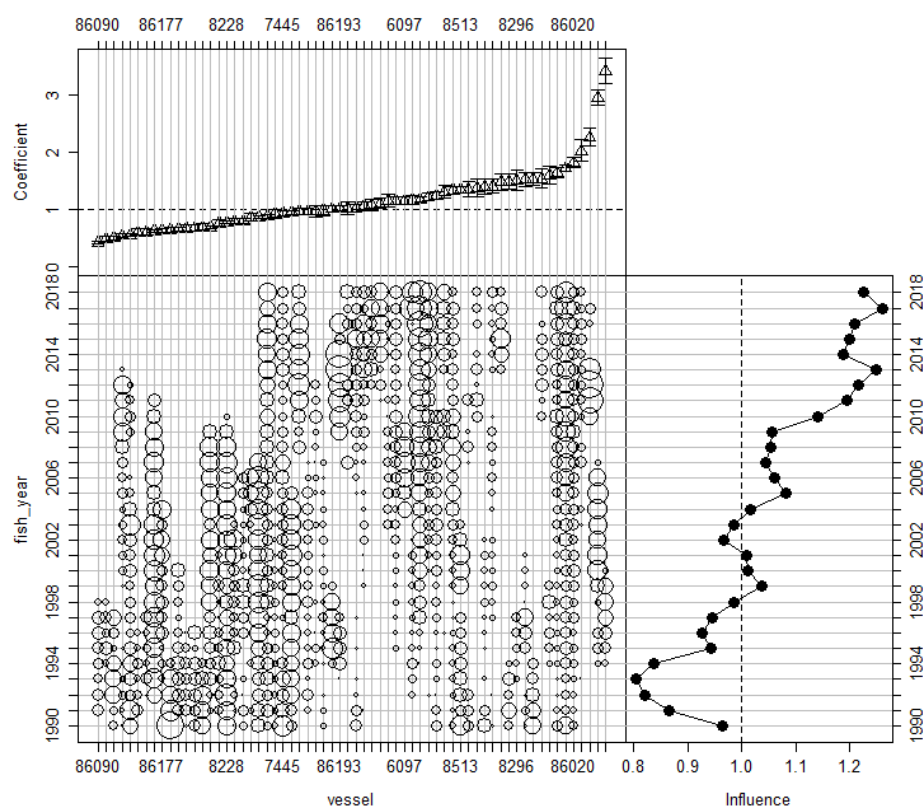


Figure 24: Combined area (025, 027, 030) data model vessel influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

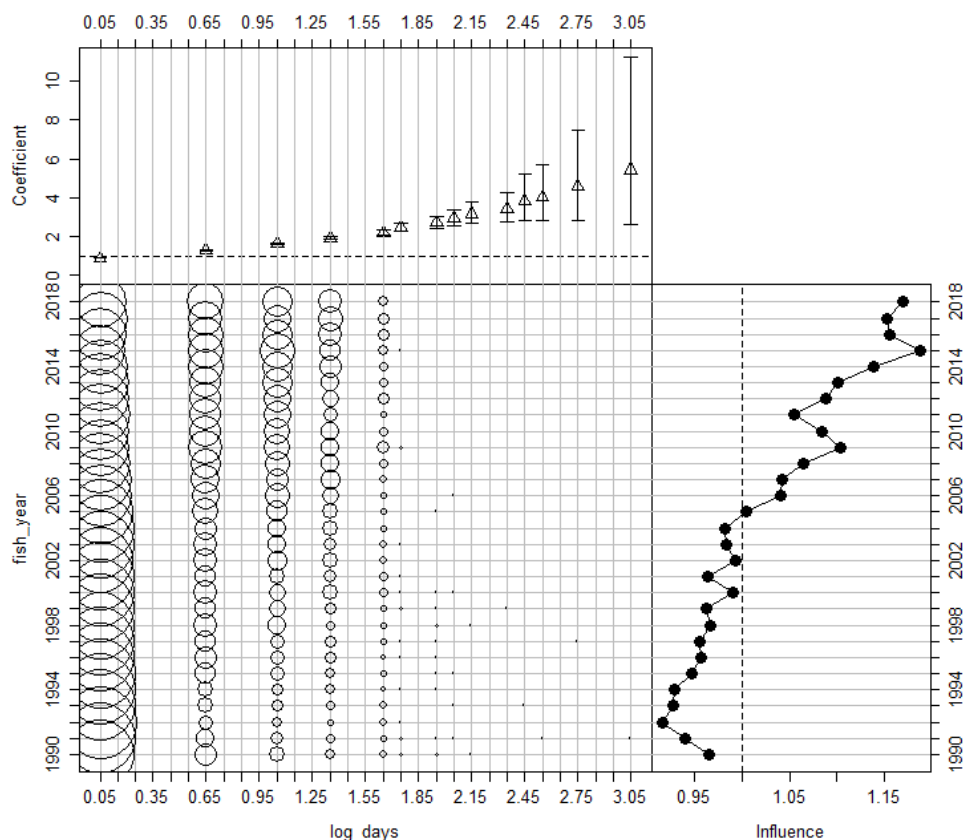


Figure 25: Combined area (025, 027, 030) data model log(days) influence plot showing [top] effect by level of variable, [bottom left] distribution of variable by fishing year, [bottom right] cumulative effect of variable by fishing year.

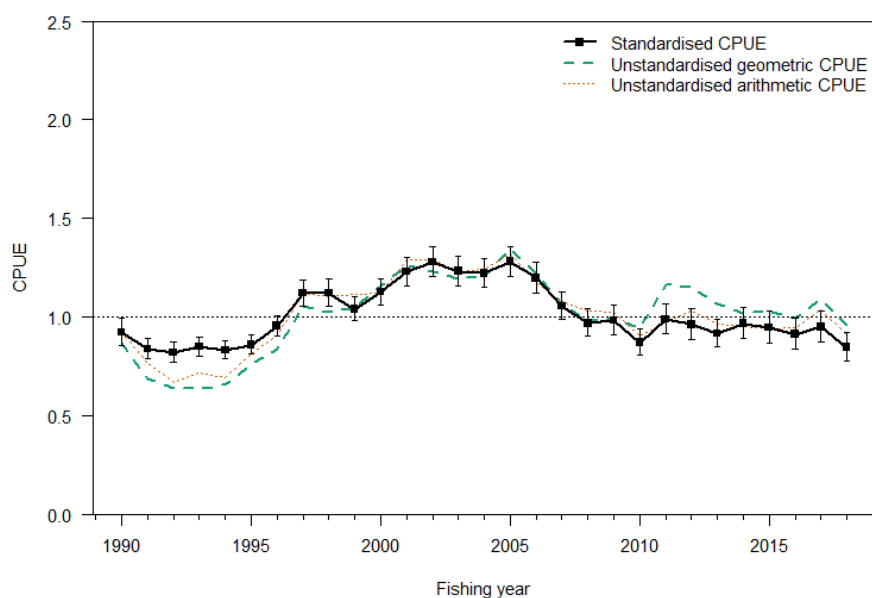


Figure 26: Combined area (025, 027, 030) data model. Indices of unstandardised and standardised CPUE for blue cod core fishers for the years 1990 to 2018. The dotted line is the annual arithmetic mean of kg/potlift, the dashed line is the annual geometric mean of kg/potlift, and the solid line is the standardised canonical indices with error bars at ± 2 * std. errors.

Area-weighted Model (Areas 025, 027, & 030)

The annual indices from the area-weighted model are included in Table 7 and plotted in Figure 27. These indices are very similar to those produced from the combined area data and the Area025 models. Most of BCO 5 data comes from Statistical Area 025, which has the largest proportional area (43%). The area-weighted indices tend to vary the most from the combined data model in the years where the Area030 model also varies the most; Statistical Area 030 has a significant proportional weight in the area-weighted model at 39%. Although the Area027 model produces indices that vary the most of all the individual models, these results are weighted at 18% and have the least influence in the area-weighted model.

5. MODEL COMPARISONS AND CONCLUSIONS

In general, all five of the time series show an increasing trend in standardised CPUE from 1994 to the mid 2000s (Figure 27, see Table 7). This is followed by a declining trend to 2018, which is steeper in the period from 2005 to 2010 and which flattens out thereafter. The annual indices for Statistical Area 027 increase to a higher level than any of the other series and decline more steeply and to a lower level in 2010 than the other series, but then flattens out at a similar level to the other series.

The trajectory of the combined data series is very similar to that of the Statistical Area 025 series, as is the area-weighted series, although the latter varies more in the period from 1990 to 2010 than does the combined data series.

The conclusions are similar to those of Haist et al. (2013) despite the additional six years of data in these analyses. That is, the three independent series for Statistical Areas 025, 027, and 030 agree on a sustained increase, reaching a peak in the early to mid 2000s, followed by a decline to new lower levels (though not as low as the early 1990s) after which each series has been relatively stable. There is, however, some indication of a slight decline over recent years for Statistical Areas 025 and 030, and all three series show a slight decline from 2017 to 2018.

Most of the data (between 50–70% each year from 1989–90 to 2017–18) for cod potting in BCO 5 comes from Area 025. As with these analyses, Haist et al. (2013) noted that any overall analysis is dominated by, and closely resembles, the series obtained from Statistical Area 025, as reported by Starr & Kendrick (2011).

The SINSWG recommended that the three individual annual indices be used in the next BCO 5 stock assessment (Doonan 2020).

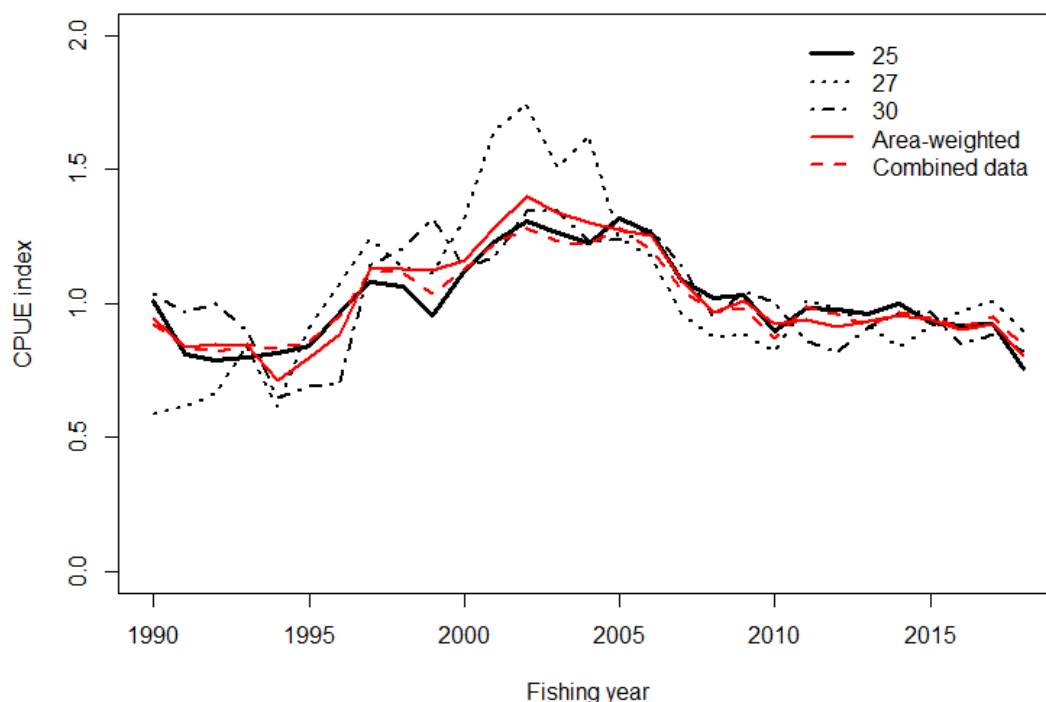


Figure 27: Relative CPUE indices for each standardised CPUE analysis: the independent series for Statistical Areas 025, 027, and 030; a series with the data from the three areas combined prior to standardisation; and a series with the independent series combined proportionally to their weighted area.

6. ACKNOWLEDGMENTS

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Appendix A: Catch and effort data grooming summary

1. Landings data were groomed:

- Best dates were determined (form dependent)
 - If landing date was missing or logically flawed (e.g., before start date) use the end date.
 - If end date missing can replace with landings date.
 - If trip length too long (>95% quantile) and not apparently a reversal of fields, then set to NA.
- Landings data were imputed for missing records as follows:
 - If the green_weight was missing, then $\text{green_weight} = \text{conv_factor} * \text{unit_num} * \text{unit_weight}$.
 - If the conv_factor was missing it was imputed with the median of all other conv_factor reported within the same year and for the same state_code, (with a switch added so the user can choose to replace it with a value of 1)
 - Green_weights were adjusted for state_codes DRE and HGU, i.e., $\text{green_weight} = \text{green_weight} * 1.95 / \text{conv_factor}$ for DRE and $\text{green_weight} = \text{green_weight} * 1.85 / \text{conv_factor}$ for HGU.
- Landings were excluded if their destination_codes were 'B', 'D', 'P', 'Q', 'R', 'T', 'J', and 'NP'.

2. Estimated catch treatment

- Estimated catch records for each event for the top 8 species were ranked in terms of estimated weight, in descending order.

3. Effort data grooming

- Exclude all trips that reported multiple primary_methods (user can choose not to exclude).
- Exclude all trips reporting on multiple form_types (user can choose not to exclude).
- Allocate start_stats_area_codes to records that have missing start_stats_area_codes given reported start_latitude and start_longitude positions and statistical area boundary polygon data. If start_latitude or start_longitude or both are missing, start_stats_area_codes will be determined by imputation using preceding event within the same trips.
- Link estimated catches of blue cod and their species rank to the effort data by event_key.

4. Linking landed green weight to effort

- Determine and exclude effort from ambiguous stocks (e.g., effort in stat-area 027 and landing in stocks BCO 3 and 5).
- Exclude effort records with no matching landings at the stock-trip level.
- Aggregate estimated blue cod catches at the stock-trip level (est_bco_total).
- Green_weight pro-ration proportions calculated for each fishing event.
 - If $\text{est_bco_total} > 0$, $\text{prorate} = \text{est_bco} / \text{est_bco_total}$.
 - If $\text{est_bco_total} = 0$, $\text{prorate} = \text{effort} / \text{effort_total}$. When primary_method = SN, $\text{effort} = \text{total_net_length}$, when primary_method = CP or RLP, $\text{effort} = \text{effort_total_num}$ and when primary_method is among BLL, BPT, BT or others, $\text{effort} = \text{effort_num}$.
- Aggregate landing green_weights to stock-trip to make sure each stock-trip has only one green_weight.
- Link landing green_weights to effort data by stock-trip.
- Calculate prorated blue cod green_weights, $\text{green_bco} = \text{pro-rate} * \text{green_weight}$.

5. Data range checking and outlier treatment

- Across all records for a fish_stock, identify the major fishing methods and conduct following range checking and outlier treatment. Fishing methods for BCO3 are BT, SN, CP, and BLL; for BCO4 are BLL, CP and BT; and for BCO5 are CP, BT and MW.

- Check and exclude catch outliers for each fishing event record: calculate $\log(\text{catch})$ and the median and standard deviation of $\log(\text{catch})$ separately for all combinations of `primary_method`, `form_type` and `vessel_id`; and deem all records with catches greater than the median + 3.5 standard deviations as outliers, which are discarded (deleted).
- Check and impute CP effort (`effort_total_num` and `effort_num`) values separately for `form_type` CEL. This is done with considered plausible effort range(s) on the basis of expert knowledge and examination of the frequency distribution of effort. Effort medians by `vessel_ids` were calculated and any effort values that are outside the specified ranges were replaced with their corresponding vessel medians. Where the imputed median was also out of range, the field was replaced with an NA (thereby excluded from CPUE analyses).

Appendix B: Data grooming algorithm notes, plots, & tables for extract REPLOG_12173

Landing data file: ../1. extract/12173/12173_5_landings.txt

- 133 trips are excluded, see file catch outlier trips.txt for details
- Fishing year and month were determined by best date
- Median conv_factors for state_code, fyear and stocks:

Table B-1: Median conversion factor for the major landing state codes by fishing year in the landings data.
 ‘-’: no landings recorded corresponding to fishing year/state code combination. DRE=Dressed, FIL=Fillets skin on, GRE=Green (or whole), GGU=Gilled and gutted tail on, HGU=headed and gutted, MEA=Fish meal, SKF=Fillets skin off, OTH=Other.

Fishing year	Landed state								
	DRE	FIL	GRE	GGU	GUT	HGU	MEA	SKF	OTH
1990	-	1.9	1	1.2	1.1	1.5	-	-	1.8
1991	1.8	1.9	1	1.2	1.1	1.4	5.6	-	0
1992	1.7	1.7	1	-	1.15	1.4	-	2.6	0
1993	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
1994	1.7	1.7	1	-	1.15	1.4	5.6	2.6	1
1995	1.7	1.7	1	-	1.15	1.4	-	2.6	1
1996	1.7	1.7	1	-	1.15	1.4	-	2.6	1
1997	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
1998	1.7	1.7	1	-	1.15	1.4	-	2.6	0
1999	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2000	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2001	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2002	1.7	1.7	1	-	1.15	1.4	-	2.6	1
2003	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2004	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2005	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2006	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2007	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2008	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2009	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2010	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2011	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2012	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2013	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2014	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2015	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2016	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2017	1.7	1.7	1	-	1.15	1.4	5.6	2.6	0
2018	1.7	1.7	1	-	1.15	1.4	-	2.6	0

- There are 4836 missing green_weights.
- Imputed conv_factors for missing green_weights and conv_factors.
- Missing conv_factor is replaced with year.state.median.
- There are still 2363 missing green_weights after calculation from conv_factor.
- Find those landings in file landings with missing green_weight.txt
- The landings with zero green_weight stay and those with NA excluded.
- The landings assigned “landed” destination type are kept for further analysis.

Table B-2: Destination codes in the unedited landing data received for BCO 3, BCO 4, and BCO 5 analysis.
The “Use in analysis” column indicates which destination codes were used to select data to be included in the characterisation and CPUE analyses

Destination code	Description	BCO3,4&5 green weight (t)	BCO3,4&5 green weight (%)	Landed or retained	Use in analysis
L	Landed in NZ to LFR	60 135.31	95.49	landed	kept
F	Landed under approval from MFish	360.90	0.57	landed	kept
U	Bait used on board	236.90	0.38	landed	kept
E	Eaten	22.35	0.04	landed	kept
W	Sold at wharf	16.24	0.03	landed	kept
A	Accidental loss	12.19	0.02	landed	kept
H	Loss from holding pot	4.88	0.01	landed	kept
C	Disposed to Crown	3.04	< 0.01	landed	kept
S	Seized by Crown	0.75	< 0.01	landed	kept
O	Conveyed outside NZ	0.45	< 0.01	landed	kept
Y	Landed at end of fishing year	0.07	< 0.01	landed	kept
Q	Holding on land	969.00	1.54	retained	dropped
R	Retained on board	814.71	1.29	retained	dropped
B	Bait stored for later use	278.38	0.44	retained	dropped
T	Transferred to another vessel	82.62	0.13	retained	dropped
NP	Not provided	25.49	0.04	retained	dropped
J	Observer advised discards	8.48	0.01	retained	dropped
P	Holding receptable in water	4.10	0.01	retained	dropped
D	Discarded (non ITQ)	1.31	< 0.01	retained	dropped
Total		62 977.18	100.00		

Table B-3: Destination codes in the unedited landing data received for BCO 3. The “Use in analysis” column indicates which destination codes were used to select data to be included in the characterisation and CPUE analyses.

Destination code	Description	BCO 3 green weight (t)	BCO 3 green weight (%)	Landed or retained	Use in analysis
L	Landed in NZ to LFR	5 094.59	89.58	landed	kept
F	Landed under approval from MFish	90.45	1.59	landed	kept
U	Bait used on board	9.62	0.17	landed	kept
E	Eaten	10.70	0.19	landed	kept
W	Sold at wharf	8.72	0.15	landed	kept
A	Accidental loss	3.72	0.07	landed	kept
H	Loss from holding pot	0.02	0.00	landed	kept
C	Disposed to Crown	3.04	0.05	landed	kept
S	Seized by Crown	0.00	0.00	landed	kept
O	Conveyed outside NZ	0.00	< 0.01	landed	kept
Y	Landed at end of fishing year	0.02	< 0.01	landed	kept
Q	Holding on land	308.93	5.43	retained	dropped
R	Retained on board	145.42	2.56	retained	dropped
B	Bait stored for later use	2.90	0.05	retained	dropped
T	Transferred to another vessel	3.43	0.06	retained	dropped
NP	Not provided	1.49	0.03	retained	dropped
J	Observer advised discards	3.31	0.06	retained	dropped
P	Holding receptable in water	0.39	0.01	retained	dropped
D	Discarded (non ITQ)	0.44	0.01	retained	dropped
Total		5 687.18	100.00		

Table B-4: Destination codes in the unedited landing data received for BCO 4. The “Use in analysis” column indicates which destination codes were used to select data to be included in the characterisation and CPUE analyses.

Destination code	Description	BCO 4 green weight (t)	BCO 4 green weight (%)	Landed or retained	Use in analysis
L	Landed in NZ to LFR	18 169.87	99.53	landed	kept
F	Landed under approval from MFish	11.04	0.06	landed	kept
U	Bait used on board	27.38	0.15	landed	kept
E	Eaten	0.31	< 0.01	landed	kept
W	Sold at wharf	0.24	< 0.01	landed	kept
A	Accidental loss	4.43	0.02	landed	kept
H	Loss from holding pot	1.00	0.01	landed	kept
C	Disposed to Crown	0.00	0.00	landed	kept
S	Seized by Crown	0.10	< 0.01	landed	kept
O	Conveyed outside NZ	0.00	0.00	landed	kept
Y	Landed at end of fishing year	0.00	0.00	landed	kept
Q	Holding on land	1.93	0.01	retained	dropped
R	Retained on board	5.79	0.03	retained	dropped
B	Bait stored for later use	4.81	0.03	retained	dropped
T	Transferred to another vessel	17.79	0.10	retained	dropped
NP	Not provided	10.46	0.06	retained	dropped
J	Observer advised discards	0.07	< 0.01	retained	dropped
P	Holding receptable in water	0.00	0.00	retained	dropped
D	Discarded (non ITQ)	0.46	< 0.01	retained	dropped
Total		18 255.67	100.00		

Table B-5: Destination codes in the unedited landing data received for BCO 5. The “Use in analysis” column indicates which destination codes were used to select data to be included in the characterisation and CPUE analyses.

Destination code	Description	BCO 5 green weight (t)	BCO 5 green weight (%)	Landed or retained	Use in analysis
L	Landed in NZ to LFR	36 870.86	94.46	landed	kept
F	Landed under approval from MFish	259.41	0.66	landed	kept
U	Bait used on board	199.90	0.51	landed	kept
E	Eaten	11.33	0.03	landed	kept
W	Sold at wharf	7.29	0.02	landed	kept
A	Accidental loss	4.04	0.01	landed	kept
H	Loss from holding pot	3.87	0.01	landed	kept
C	Disposed to Crown	0.00	0.00	landed	kept
S	Seized by Crown	0.65	< 0.01	landed	kept
O	Conveyed outside NZ	0.45	< 0.01	landed	kept
Y	Landed at end of fishing year	0.06	< 0.01	landed	kept
Q	Holding on land	658.14	1.69	retained	dropped
R	Retained on board	663.49	1.70	retained	dropped
B	Bait stored for later use	270.67	0.69	retained	dropped
T	Transferred to another vessel	61.40	0.16	retained	dropped
NP	Not provided	13.54	0.03	retained	dropped
J	Observer advised discards	5.11	0.01	retained	dropped
P	Holding receptable in water	3.71	0.01	retained	dropped
D	Discarded (non ITQ)	0.42	< 0.01	retained	dropped
Total		39 034.34	100.00		

Effort data file: ../1. extract/12173/12173_2_fising_effort.txt

- There are 428905 records in the effort data.
- 426194 remain for trips exist in landings data.
- There are 1635 trips in landings but not in effort data.
- Estimated catches are loaded from ../1. extract/12173/12173_3_est_catch.txt.
- 874 blank catch_weight in estimated catch table were replaced with 0.
- There are 2249 events in effort but not in est catch data.
- 2190 blank total_catch in effort data were replaced with 0.
- Map rock lobster statistical areas to general statistical areas.

Table B-6: Mapping algorithm used to convert rock lobster statistical areas into general statistical areas.

Rock lobster statistical area	General statistical area
917	18
918	22
919	22
920	24
921	26
922	26
923	25
924	27
925	29
926	30
927	31
928	32
929	33
930	34
931	35
940	49
941	50
942	51
943	52

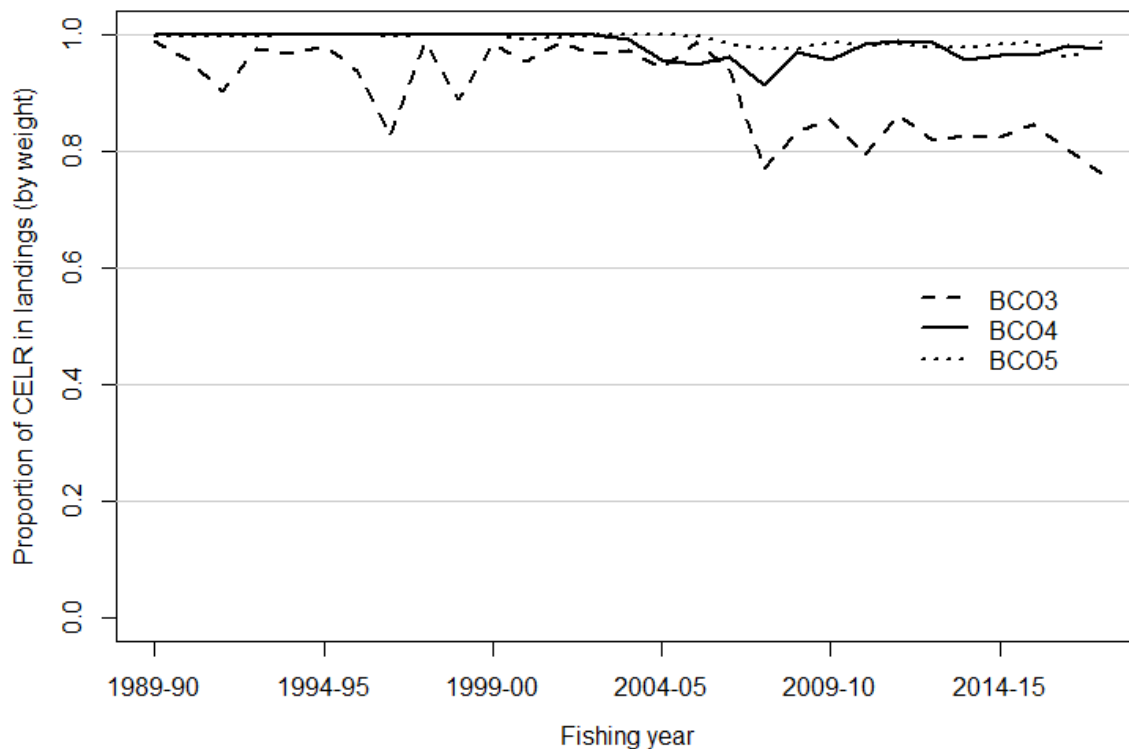


Figure B-1: Proportion of blue cod landings using Cod Pot method as reported on CELR reporting forms, by fishery and by fishing year.

- Following stat areas are replaced with NA:
Unknown 00H 0D6 0G8 0C5 0B5 0S7 0S8 0D7 00A 0G9 0S5
0F9 04B 04H 04A 0B6 04C 7EE 0B2
- There are 1454 records with blank start_stats_area_code.
- 898 records have no stats area code.
- 388470 records remain in effort data after allocating stock and fish_area.
- There are 16493 effort records unlinkable to landings by stock-trip.
- 371977 remain in effort data after linking to landing.
- There are 371977 records in the groomed data.
- The final groomed data is in file Groomed catch data for Characterisation.txt,

Table B-7: Summary of records in the effort data linked to landing data by stock-trip.

	Effort records
Linked to BCO 3 stock	153 063
Linked to BCO 4 stock	39 293
Linked to BCO 5 stock	179 621
Unlinkable	16 493
Total number of records available to be linked	388 470
Total number of records linked and available for characterisation/CPUE analysis	371 977

Table B-8: Summary of annual landings (t) and estimated catch (t) by fishing year in the QMR/MHR data and the groomed data sets for BCO 3. ** The analysis data set used for characterisation and CPUE analyses.

Fishing year	Landings (t) Reported in QMR/MHR	Estimated catch (t) linked to effort data	Green weight (t) in landing data	**Green weight (t) in landing data linked to effort data
1990	121.04	80.16	109.27	103.97
1991	143.25	102.87	146.34	137.91
1992	135.04	120.07	155.40	151.72
1993	170.68	134.00	175.88	167.43
1994	141.65	108.32	155.32	144.86
1995	154.60	120.77	320.94	312.53
1996	165.21	137.60	179.41	173.42
1997	160.08	138.35	192.14	187.13
1998	162.91	130.23	192.55	185.48
1999	153.84	134.86	209.47	198.34
2000	165.40	134.87	174.54	168.92
2001	153.79	117.19	163.27	147.98
2002	138.08	116.88	155.54	138.64
2003	168.96	150.23	175.97	171.51
2004	166.80	139.37	175.16	165.81
2005	183.17	137.03	187.09	176.22
2006	182.68	140.57	192.86	181.46
2007	176.93	130.32	197.21	186.73
2008	167.24	149.96	189.62	180.42
2009	157.73	139.65	192.58	181.45
2010	170.83	128.69	187.05	166.52
2011	182.66	131.34	198.36	167.38
2012	166.29	122.22	173.25	145.91
2013	170.13	118.69	172.48	151.07
2014	158.81	117.78	162.67	139.78
2015	175.00	133.05	173.46	159.20
2016	168.87	102.96	174.55	140.73
2017	169.77	124.04	164.73	156.31
2018	173.69	119.24	173.76	159.99

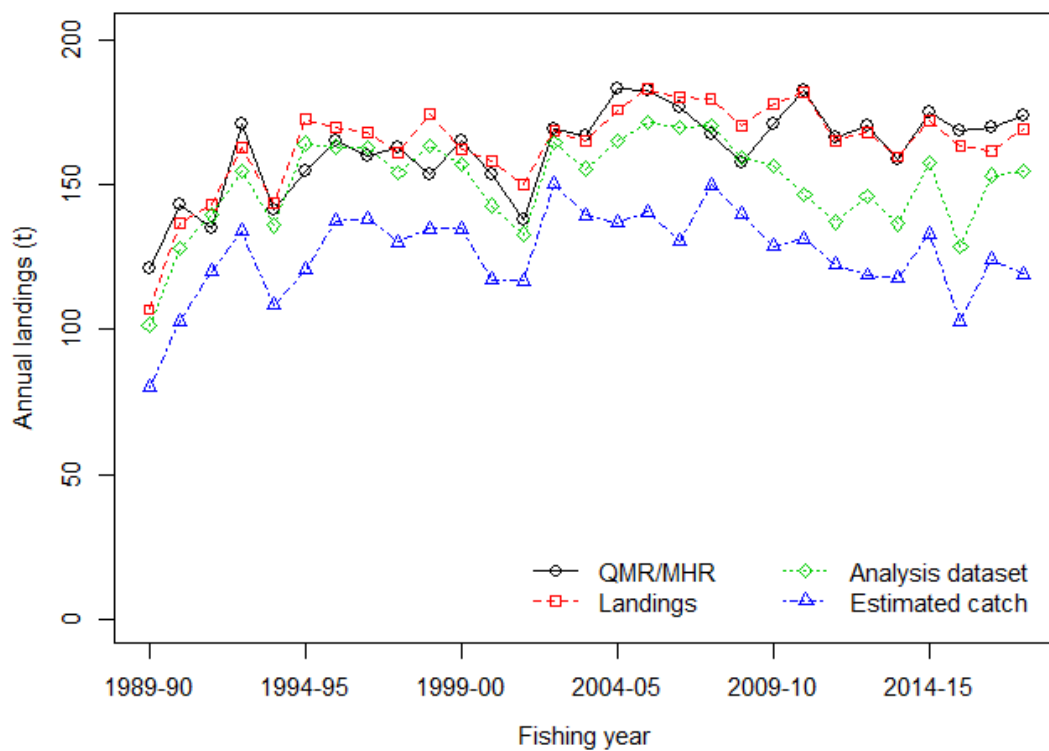


Figure B-2: BCO 3 catch (t) datasets: QMR/MHR reported landings (circles, black line), green weight in landings data (boxes, red dashed line), estimated catch linked to effort data (triangles, blue dashed line), green weight in landings data linked to effort data and prorated by estimated catch (diamonds, green dashed line).

Table B- 9: Summary of landings (t) and estimated catch (t) by fishing year in the QMR/MHR data and the groomed data sets for BCO 4. ** The analysis data set used for characterisation and CPUE analyses.

Fishing year	Landings (t) Reported in QMR/MHR	Estimated catch (t) linked to effort data	Green weight (t) in landing data	**Green weight (t) in landing data linked to effort data
1990	374.15	298.42	320.08	312.99
1991	392.25	347.70	374.25	364.78
1992	378.43	344.93	363.00	353.34
1993	441.52	434.28	444.18	444.88
1994	473.82	515.02	520.22	517.76
1995	577.91	554.86	594.18	584.15
1996	475.41	417.24	476.52	458.29
1997	462.34	416.47	451.23	436.08
1998	568.84	554.16	576.22	565.53
1999	549.62	524.38	620.26	611.43
2000	503.36	485.47	512.42	503.08
2001	626.77	617.94	645.36	639.80
2002	647.91	616.95	645.42	642.21
2003	724.37	678.69	727.18	714.60
2004	710.43	661.53	693.14	682.90
2005	731.16	713.07	763.48	755.64
2006	580.35	529.30	559.52	557.24
2007	748.70	714.15	749.55	741.13
2008	779.06	713.11	773.71	764.80
2009	786.50	757.69	789.17	784.95
2010	695.95	642.37	685.17	674.22
2011	780.81	745.95	776.83	770.65
2012	754.49	725.05	753.77	748.59
2013	739.00	710.69	737.24	730.13
2014	721.99	689.06	717.58	713.56
2015	798.95	752.11	778.52	772.03
2016	758.60	718.13	757.55	743.97
2017	741.52	707.96	723.75	722.73
2018	751.80	650.12	684.86	671.04

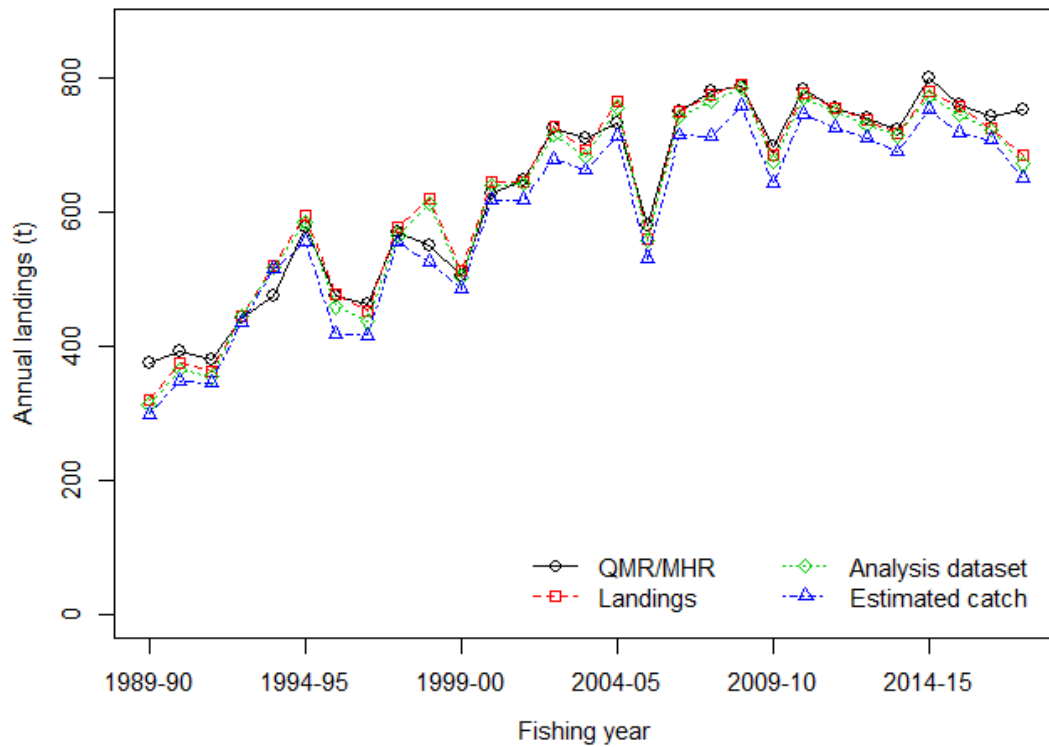


Figure B-3: BCO 4 catch (t) datasets: QMR/MHR reported landings (circles, black line), green weight in landings data (boxes, red dashed line), estimated catch linked to effort data (triangles, blue dashed line), green weight in landings data linked to effort data and prorated by estimated catch (diamonds, green dashed line).

Table B-10: Summary of annual landings (t) and estimated catch (t) by fishing year in the QMR/MHR data and the groomed data sets for BCO 5. ** The analysis data set used for characterisation and CPUE analyses.

Fishing year	Landings (t) Reported in QMR/MHR	Estimated catch (t) linked to effort data	Green weight (t) in landing data	**Green weight (t) in landing data linked to effort data
1990	927.81	748.22	939.61	911.41
1991	1 082.75	878.70	1 100.79	1 063.62
1992	872.55	689.31	894.16	834.52
1993	1 029.16	841.59	1 045.20	992.56
1994	1 131.77	931.01	1 127.79	1 079.51
1995	1 218.41	999.56	1 219.87	1 153.21
1996	1 494.59	1 162.47	1 632.21	1 526.76
1997	1 388.10	1 011.31	1 413.08	1 306.18
1998	1 372.50	1 077.90	1 428.39	1 303.07
1999	1 481.69	1 131.03	1 520.24	1 440.03
2000	1 379.03	1 090.93	1 381.94	1 321.94
2001	1 467.14	1 188.05	1 469.58	1 402.92
2002	1 477.74	1 224.61	1 486.67	1 421.22
2003	1 496.90	1 268.39	1 509.49	1 473.00
2004	1 557.44	1 347.62	1 549.95	1 518.93
2005	1 472.92	1 248.55	1 481.38	1 446.66
2006	1 346.20	1 132.72	1 353.99	1 305.30
2007	1 381.57	1 165.46	1 375.60	1 319.99
2008	1 279.75	1 093.21	1 305.58	1 254.45
2009	1 391.76	1 205.34	1 433.39	1 410.60
2010	1 209.05	1 034.25	1 218.44	1 174.22
2011	1 296.47	1 091.27	1 299.98	1 250.93
2012	1 216.94	1 010.16	1 221.64	1 166.80
2013	1 209.09	1 043.97	1 219.76	1 175.07
2014	1 208.15	1 055.50	1 218.82	1 185.81
2015	1 144.65	1 005.43	1 162.99	1 137.03
2016	1 098.80	973.72	1 111.84	1 093.31
2017	1 151.75	1 007.45	1 191.09	1 170.02
2018	1 027.04	891.25	1 042.64	1 011.57

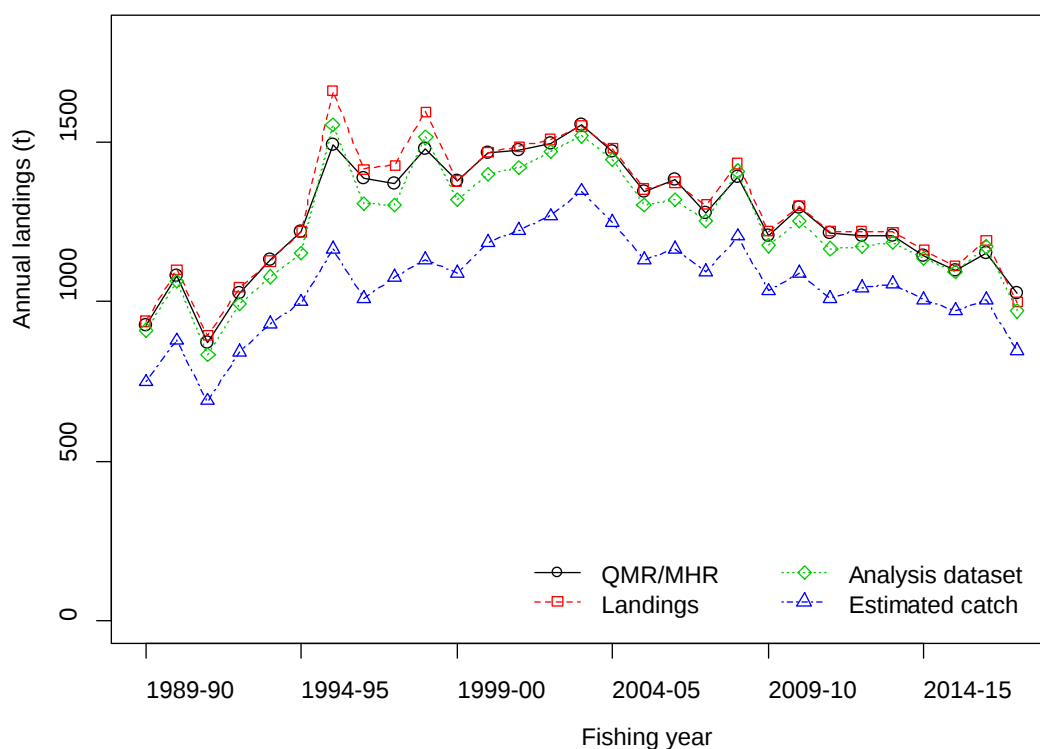


Figure B-4: BCO 5 catch (t) datasets: QMR/MHR reported landings (circles, black line), green weight in landings data (boxes, red dashed line), estimated catch linked to effort data (triangles, blue dashed line), green weight in landings data linked to effort data and prorated by estimated catch (diamonds, green dashed line).

Appendix C: Tables of BCO 5 annual effort and landings by Statistical Area

Table C-1: BCO 5 blue cod landings (tonnes) from the cod potting method, by Statistical Area and fishing year for 1990 to 2018.

Fishing year	Statistical Area								Total
	025	026	027	028	029	030	031	032	
1990	507.36	0.66	229.66	0.59	17.91	119.09	1.86	0.00	877.13
1991	665.40	11.84	233.83	0.30	6.90	102.50	0.00	0.00	1023.06
1992	488.81	7.37	135.66	0.70	63.37	99.91	1.04	0.00	796.87
1993	604.48	2.14	166.56	0.00	24.51	169.67	0.00	4.03	971.39
1994	678.50	4.11	150.11	0.00	9.49	207.96	5.23	0.00	1055.41
1995	635.44	4.06	173.99	0.64	29.58	277.52	20.71	0.44	1142.38
1996	674.35	10.27	285.39	0.27	153.22	301.00	49.75	0.51	1475.63
1997	603.37	31.49	264.81	9.84	50.17	267.02	29.49	8.10	1264.40
1998	538.09	14.63	272.86	4.20	38.95	334.63	45.22	5.91	1254.48
1999	640.43	9.16	238.30	2.40	47.81	378.82	19.86	9.66	1346.45
2000	593.37	1.64	295.96	5.19	47.40	282.16	52.84	15.87	1294.42
2001	742.12	9.57	282.86	2.48	73.18	236.93	6.93	1.95	1356.03
2002	724.72	0.88	246.30	0.82	64.83	315.28	34.59	0.74	1388.16
2003	638.62	0.51	338.66	1.58	134.46	295.42	27.13	0.37	1436.76
2004	587.18	1.43	386.94	1.52	143.36	333.12	43.27	1.92	1498.74
2005	721.42	8.18	255.73	0.96	124.44	266.12	40.77	0.00	1417.62
2006	780.78	13.58	194.16	1.11	71.39	197.19	21.42	0.00	1279.64
2007	679.58	7.14	297.88	2.96	76.28	201.15	20.67	4.93	1290.58
2008	686.37	6.59	262.96	3.85	49.77	161.99	33.96	11.99	1217.48
2009	691.97	0.93	304.35	2.57	62.60	239.56	49.25	7.61	1358.83
2010	646.81	19.84	175.47	2.24	31.70	235.31	34.95	1.35	1147.66
2011	613.31	1.22	247.84	2.52	54.63	269.28	23.64	11.14	1223.58
2012	547.07	3.16	257.90	2.77	63.14	225.74	31.04	0.56	1131.39
2013	568.68	0.00	234.03	0.34	73.23	223.50	32.78	4.10	1136.65
2014	581.57	0.00	233.64	1.11	46.48	269.02	12.25	2.82	1147.17
2015	496.54	0.00	231.93	1.50	66.18	276.48	31.18	3.15	1106.95
2016	537.39	3.44	238.15	2.12	63.67	195.29	22.00	1.02	1063.08
2017	570.91	0.00	245.24	0.81	52.44	190.36	40.03	4.13	1104.16
2018	426.16	1.17	204.63	0.28	87.01	229.98	30.11	1.10	980.45

Table C 2: BCO 5 blue cod landings by Statistical Area as a percentage of total landings from the cod potting method, by fishing year for 1990 to 2018.

Fishing year	Statistical Area							
	025	026	027	028	029	030	031	032
1990	57.84	0.07	26.18	0.07	2.04	13.58	0.21	0.00
1991	65.04	1.16	22.86	0.03	0.67	10.02	0.00	0.00
1992	61.34	0.92	17.02	0.09	7.95	12.54	0.13	0.00
1993	62.23	0.22	17.15	0.00	2.52	17.47	0.00	0.41
1994	64.29	0.39	14.22	0.00	0.90	19.70	0.50	0.00
1995	55.62	0.36	15.23	0.06	2.59	24.29	1.81	0.04
1996	45.70	0.70	19.34	0.02	10.38	20.40	3.37	0.03
1997	47.72	2.49	20.94	0.78	3.97	21.12	2.33	0.64
1998	42.89	1.17	21.75	0.33	3.10	26.67	3.60	0.47
1999	47.56	0.68	17.70	0.18	3.55	28.13	1.47	0.72
2000	45.84	0.13	22.86	0.40	3.66	21.80	4.08	1.23
2001	54.73	0.71	20.86	0.18	5.40	17.47	0.51	0.14
2002	52.21	0.06	17.74	0.06	4.67	22.71	2.49	0.05
2003	44.45	0.04	23.57	0.11	9.36	20.56	1.89	0.03
2004	39.18	0.10	25.82	0.10	9.57	22.23	2.89	0.13
2005	50.89	0.58	18.04	0.07	8.78	18.77	2.88	0.00
2006	61.02	1.06	15.17	0.09	5.58	15.41	1.67	0.00
2007	52.66	0.55	23.08	0.23	5.91	15.59	1.60	0.38
2008	56.38	0.54	21.60	0.32	4.09	13.31	2.79	0.98
2009	50.92	0.07	22.40	0.19	4.61	17.63	3.62	0.56
2010	56.36	1.73	15.29	0.20	2.76	20.50	3.05	0.12
2011	50.12	0.10	20.26	0.21	4.46	22.01	1.93	0.91
2012	48.35	0.28	22.80	0.24	5.58	19.95	2.74	0.05
2013	50.03	0.00	20.59	0.03	6.44	19.66	2.88	0.36
2014	50.70	0.00	20.37	0.10	4.05	23.45	1.07	0.25
2015	44.86	0.00	20.95	0.14	5.98	24.98	2.82	0.28
2016	50.55	0.32	22.40	0.20	5.99	18.37	2.07	0.10
2017	51.71	0.00	22.21	0.07	4.75	17.24	3.63	0.37
2018	43.47	0.12	20.87	0.03	8.87	23.46	3.07	0.11

Table C-3: BCO 5 cod potting effort (number of potlifts) by Statistical Area and fishing year for 1990 to 2018.

Fishing year	Statistical Area								Total
	025	026	027	028	029	030	031	032	
1990	46 196	58	14 897	6	894	8 864	206	-	71 121
1991	73 404	1 256	20 567	90	573	8 307	-	-	104 197
1992	55 794	309	9 755	6	1 380	10 198	42	-	77 484
1993	68 670	190	11 651	-	1 314	16 252	-	94	98 171
1994	72 347	574	11 497	-	991	22 466	301	-	108 176
1995	65 468	442	12 149	590	1 966	20 515	1 443	5	102 578
1996	55 029	525	11 720	39	-	18 314	2 619	42	90 940
1997	45 176	1 839	9 325	365	1 962	11 974	663	266	71 570
1998	42 576	250	13 012	142	1 183	13 957	2 446	500	74 066
1999	39 644	606	9 794	172	2 340	16 064	1 279	203	70 102
2000	37 049	132	12 043	142	2 153	15 901	3 181	205	70 806
2001	39 368	473	9 683	85	3 012	14 013	509	207	67 350
2002	38 308	55	8 798	6	2 099	15 738	1 548	113	66 665
2003	34 215	62	10 892	50	4 777	16 095	937	12	67 040
2004	36 086	54	12 595	84	4 672	16 308	1 780	118	71 697
2005	39 763	580	10 652	9	5 527	12 806	2 056	-	71 393
2006	48 436	882	10 102	77	3 427	9 996	1 202	-	74 122
2007	44 239	298	14 344	188	4 321	12 762	1 213	176	77 541
2008	43 756	396	12 099	122	3 359	9 697	2 223	748	72 400
2009	42 887	86	15 383	121	3 889	11 483	3 462	628	77 939
2010	46 185	1 310	10 595	95	2 111	13 623	2 790	80	76 789
2011	46 708	138	13 029	72	3 505	15 179	1 890	1 140	81 661
2012	36 257	326	14 475	143	3 693	15 252	1 935	41	72 122
2013	38 839	-	13 358	5	3 471	15 568	2 230	747	74 218
2014	40 054	-	14 625	100	2 685	15 333	790	466	74 053
2015	37 395	-	14 903	97	3 262	17 286	1 336	215	74 494
2016	41 859	264	14 119	130	3 037	13 629	1 178	192	74 408
2017	50 666	-	14 487	103	2 981	13 434	2 165	713	84 549
2018	43 397	83	13 276	25	3 657	17 935	2 664	117	81 154

Table C-4: BCO 5 cod potting effort (number of potlifts) by Statistical Area as a percentage of total effort, by fishing year for 1990 to 2018.

Fishing year	Statistical Area							
	025	026	027	028	029	030	031	032
1990	64.95	0.08	20.95	0.01	1.26	12.46	0.29	0.00
1991	70.45	1.21	19.74	0.09	0.55	7.97	0.00	0.00
1992	72.01	0.40	12.59	0.01	1.78	13.16	0.05	0.00
1993	69.95	0.19	11.87	0.00	1.34	16.55	0.00	0.10
1994	66.88	0.53	10.63	0.00	0.92	20.77	0.28	0.00
1995	63.82	0.43	11.84	0.58	1.92	20.00	1.41	0.00
1996	60.51	0.58	12.89	0.04	2.92	20.14	2.88	0.05
1997	63.12	2.57	13.03	0.51	2.74	16.73	0.93	0.37
1998	57.48	0.34	17.57	0.19	1.60	18.84	3.30	0.68
1999	56.55	0.86	13.97	0.25	3.34	22.92	1.82	0.29
2000	52.32	0.19	17.01	0.20	3.04	22.46	4.49	0.29
2001	58.45	0.70	14.38	0.13	4.47	20.81	0.76	0.31
2002	57.46	0.08	13.20	0.01	3.15	23.61	2.32	0.17
2003	51.04	0.09	16.25	0.07	7.13	24.01	1.40	0.02
2004	50.33	0.08	17.57	0.12	6.52	22.75	2.48	0.16
2005	55.70	0.81	14.92	0.01	7.74	17.94	2.88	0.00
2006	65.35	1.19	13.63	0.10	4.62	13.49	1.62	0.00
2007	57.05	0.38	18.50	0.24	5.57	16.46	1.56	0.23
2008	60.44	0.55	16.71	0.17	4.64	13.39	3.07	1.03
2009	55.03	0.11	19.74	0.16	4.99	14.73	4.44	0.81
2010	60.15	1.71	13.80	0.12	2.75	17.74	3.63	0.10
2011	57.20	0.17	15.95	0.09	4.29	18.59	2.31	1.40
2012	50.27	0.45	20.07	0.20	5.12	21.15	2.68	0.06
2013	52.33	0.00	18.00	0.01	4.68	20.98	3.00	1.01
2014	54.09	0.00	19.75	0.14	3.63	20.71	1.07	0.63
2015	50.20	0.00	20.01	0.13	4.38	23.20	1.79	0.29
2016	56.26	0.35	18.98	0.17	4.08	18.32	1.58	0.26
2017	59.93	0.00	17.13	0.12	3.53	15.89	2.56	0.84
2018	53.47	0.10	16.36	0.03	4.51	22.10	3.28	0.14

Appendix D: Plots of annual landings by method and by month for each Statistical Area

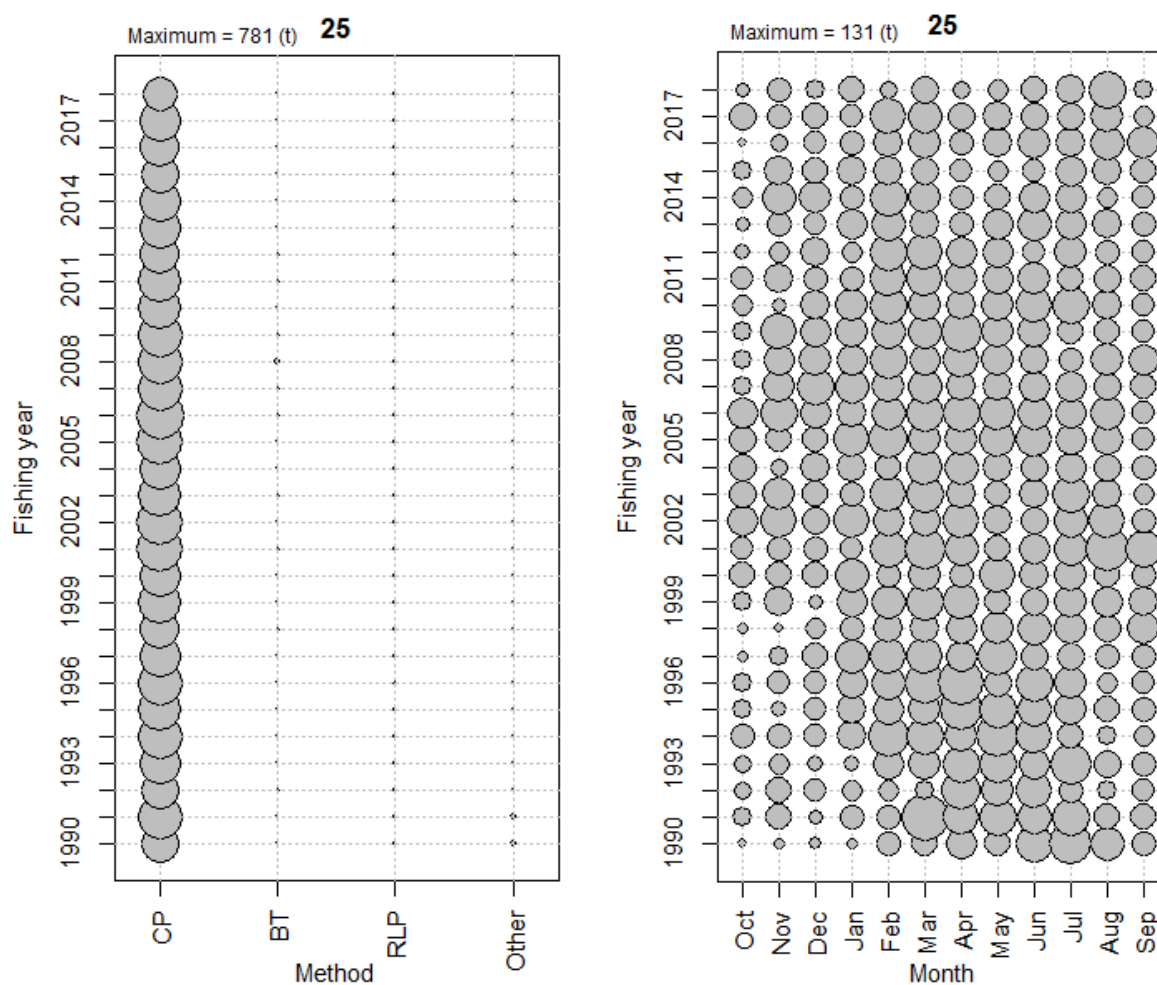


Figure D-1: BCO 5 blue cod landings (t) for 1990 to 2018 in Statistical Area 025 by fishing year and major fishing methods (left) with maximum circle size proportional to 781 t, and by month (right) with maximum circle size proportional to 131 t. CP=cod potting, BT=bottom trawl, RLP=rock lobster potting, OTH=other.

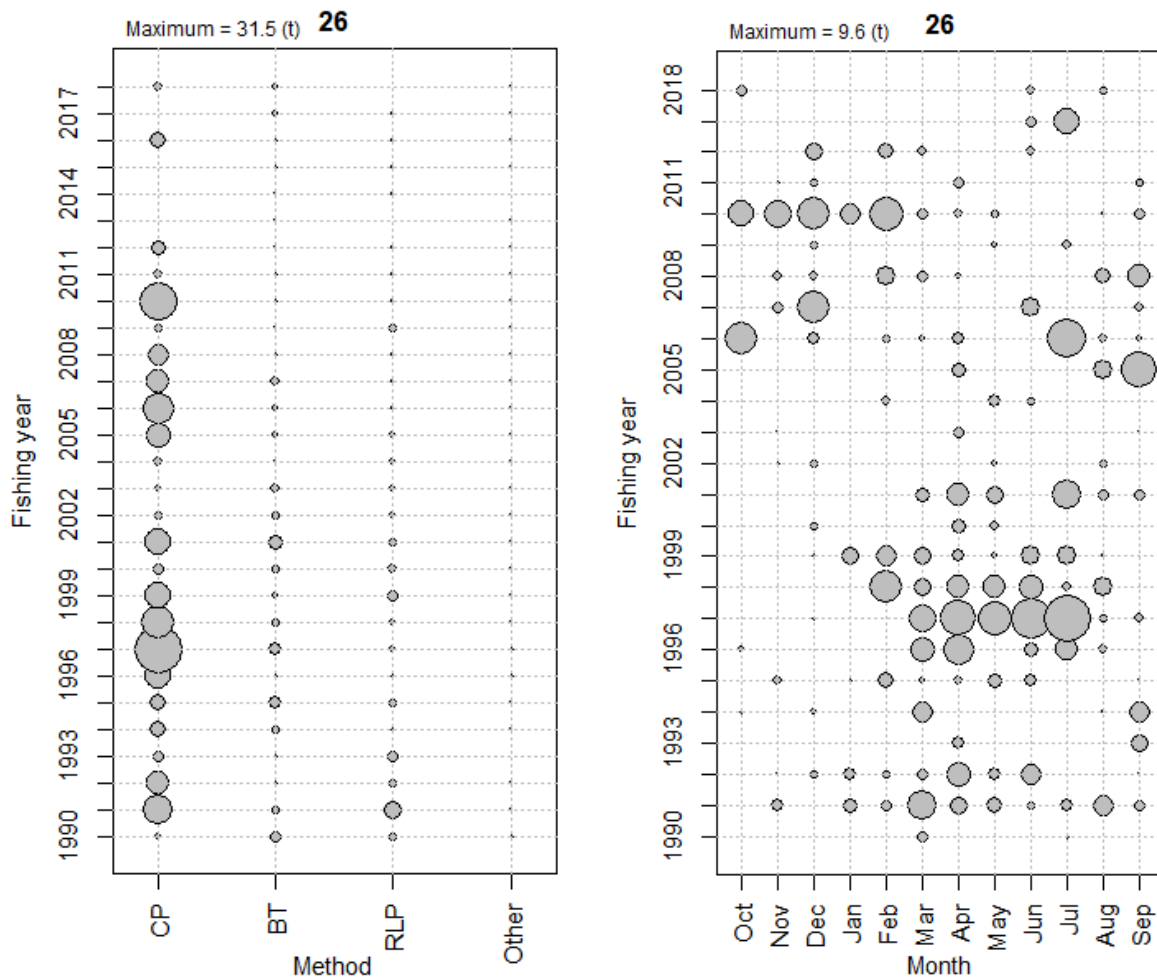


Figure D-2: BCO 5 blue cod landings (t) for 1990 to 2018 in Statistical Area 026 by fishing year and major fishing methods (left) with maximum circle size proportional to 31.5 t, and by month (right) with maximum circle size proportional to 9.6 t. CP=cod potting, BT=bottom trawl, RLP=rock lobster potting, OTH=other.

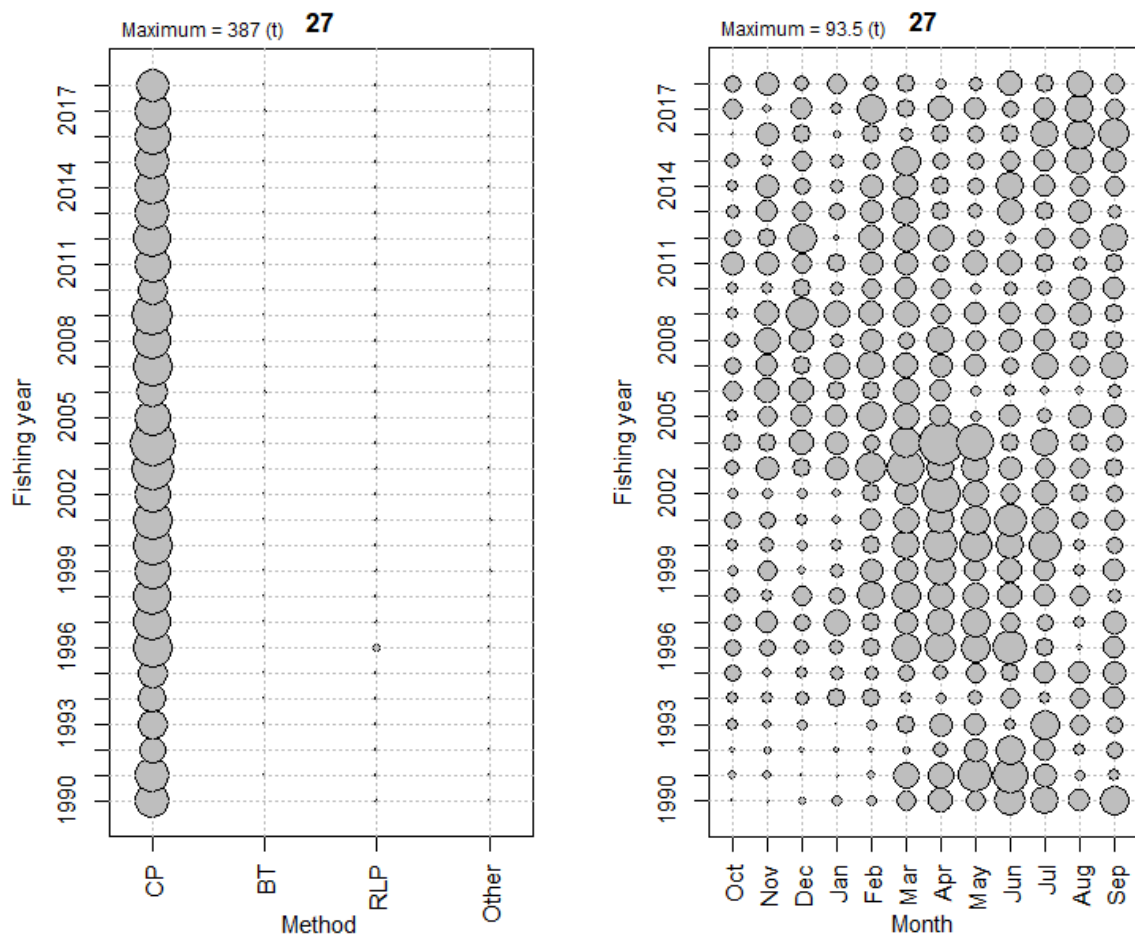


Figure D- 3: BCO 5 blue cod landings (t) for 1990 to 2018 in Statistical Area 027 by fishing year and major fishing methods (left) with maximum circle size proportional to 387 t, and by month (right) with maximum circle size proportional to 93.5 t. CP=cod potting, BT=bottom trawl, RLP=rock lobster potting, OTH=other.

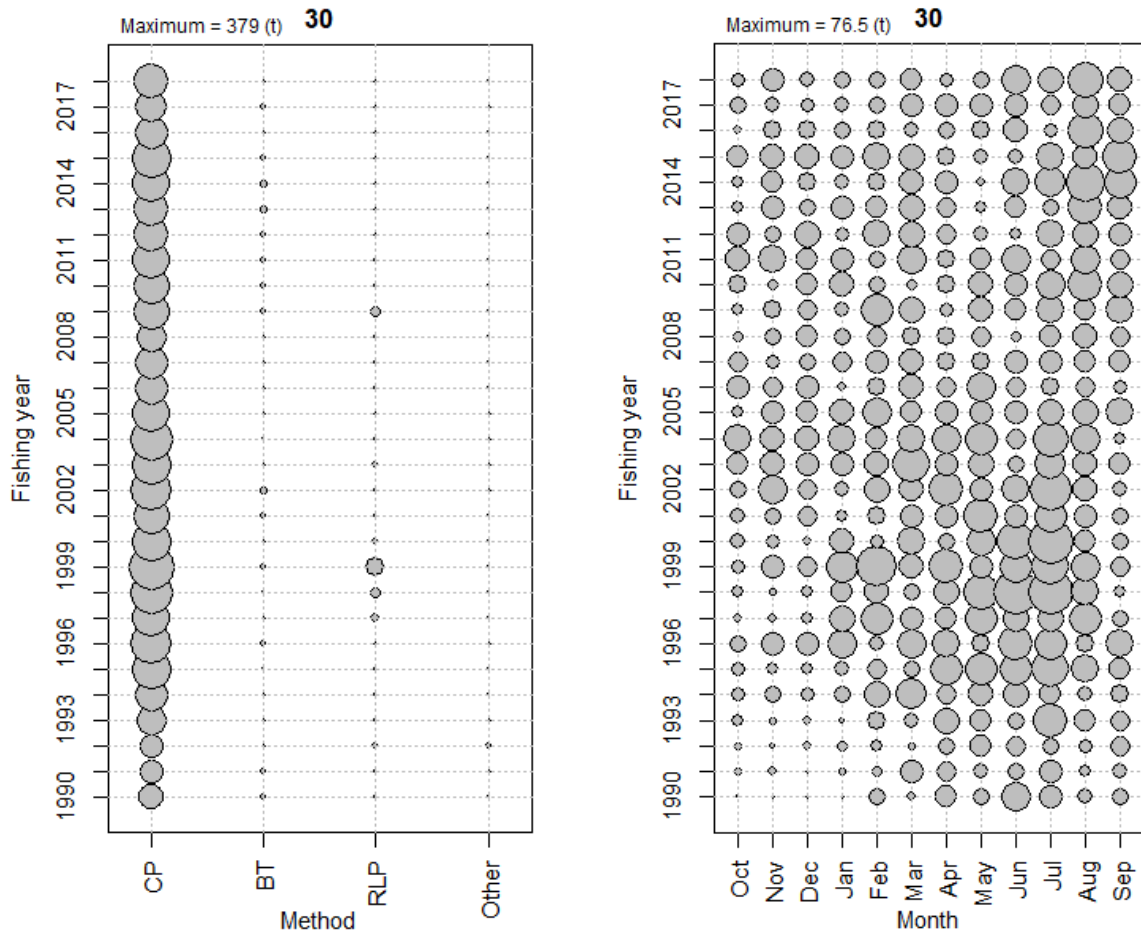


Figure D-5: BCO 5 blue cod landings (t) for 1990 to 2018 in Statistical Area 030 by fishing year and major fishing methods (left) with maximum circle size proportional to 379 t, and by month (right) with maximum circle size proportional to 76.5 t. CP=cod potting, BT=bottom trawl, RLP=rock lobster potting, OTH=other.

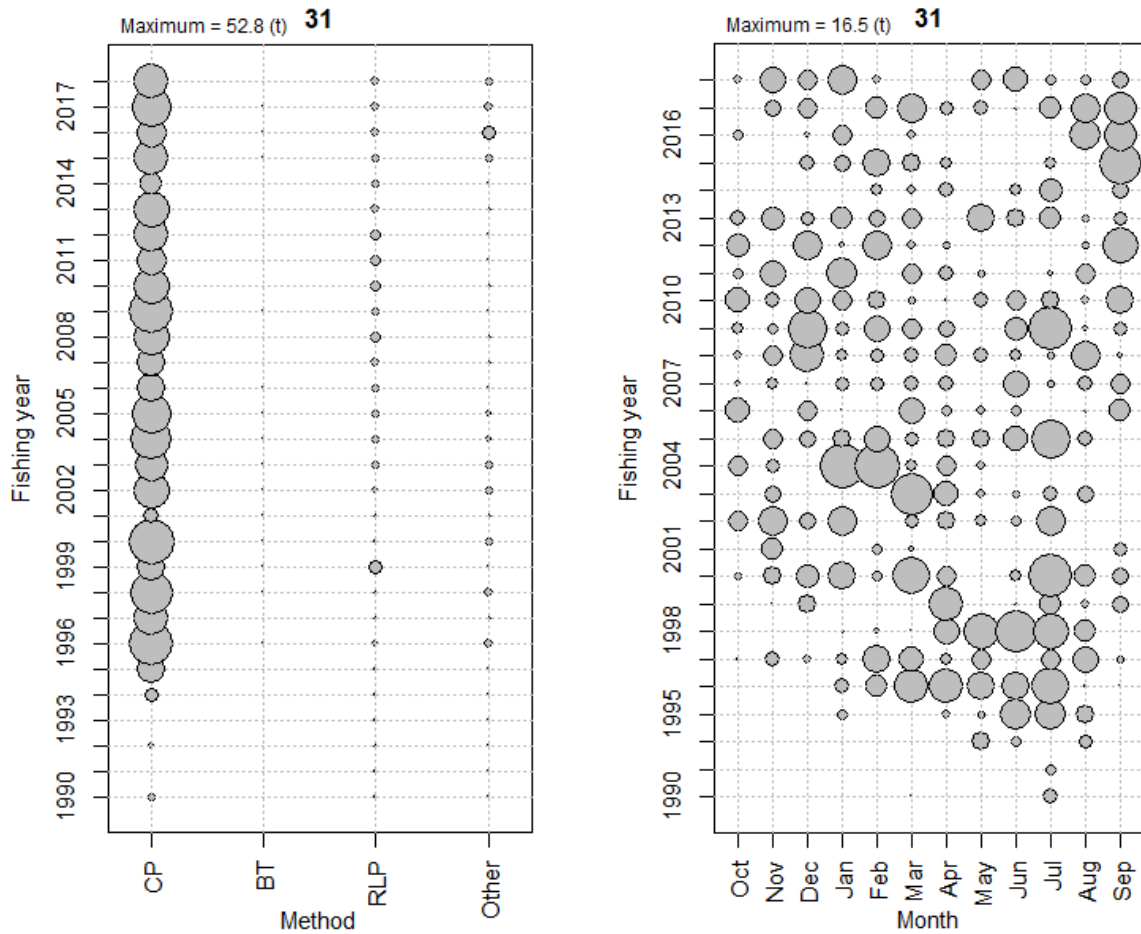


Figure D-6: BCO 5 blue cod landings (t) for 1990 to 2018 in Statistical Area 031 by fishing year and major fishing methods (left) with maximum circle size proportional to 52.8 t, and by month (right) with maximum circle size proportional to 16.5 t. CP=cod potting, BT=bottom trawl, RLP=rock lobster potting, OTH=other.

Appendix E: Vessel selection tables and plots

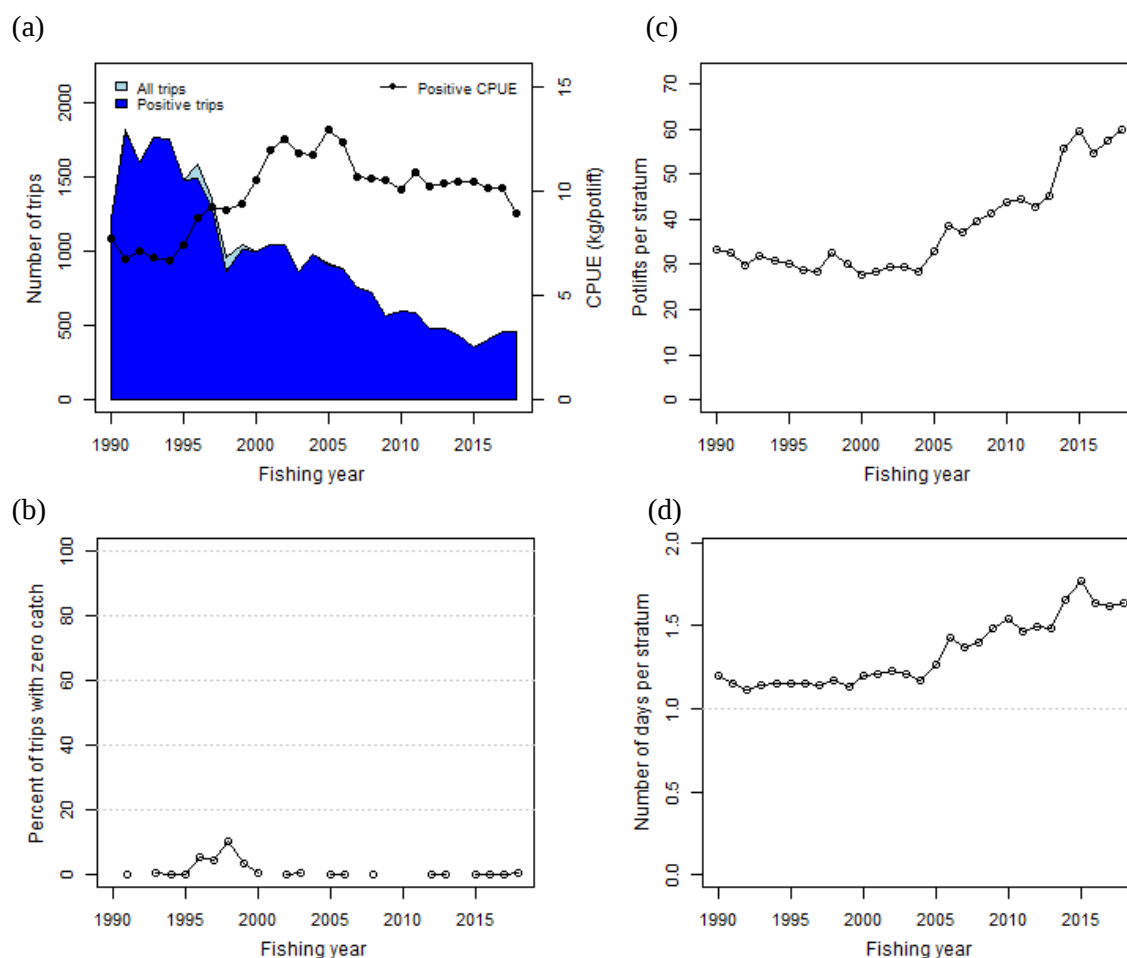


Figure E-1: Data for Area025 model: (a) number of trips targeting (light area) and landing (dark area) blue cod by cod potting method in Statistical Area 025, and the unstandardised catch rate (kg/potlift) of blue cod in successful trips, by fishing year 1990 to 2018; (b) proportion of qualifying effort-strata targeting blue cod in Statistical Area 025 and that landed zero blue cod; effect of data roll-up into trip-stratum; (c) number of potlifts per trip-stratum by fishing year; and (d) number of fishing days per trip-stratum by fishing year.

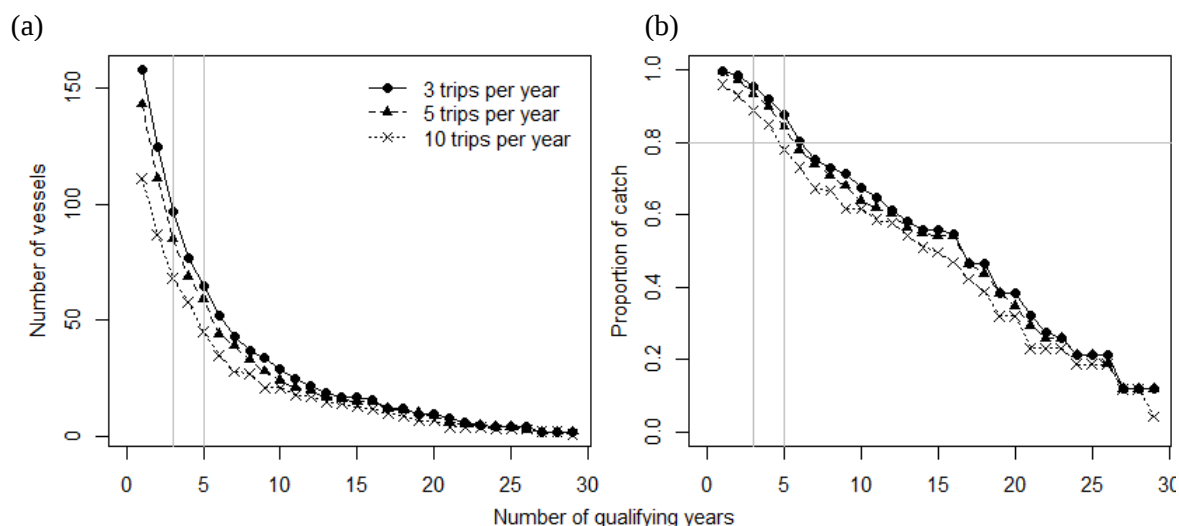


Figure E-2: Core vessel selection for Area025 model. (a) number of vessels and (b) proportion of catch retained in the dataset, depending on the minimum number of qualifying years in the fishery trips, by the number of trips per year used to define a qualifying year: 3, 5, or 10 trips per year. The qualifying criteria used for the Area025 model was a minimum of 10 trips per year and a minimum of 5 qualifying years, resulting in data being retained for 45 vessels and 77.8% of the catch.

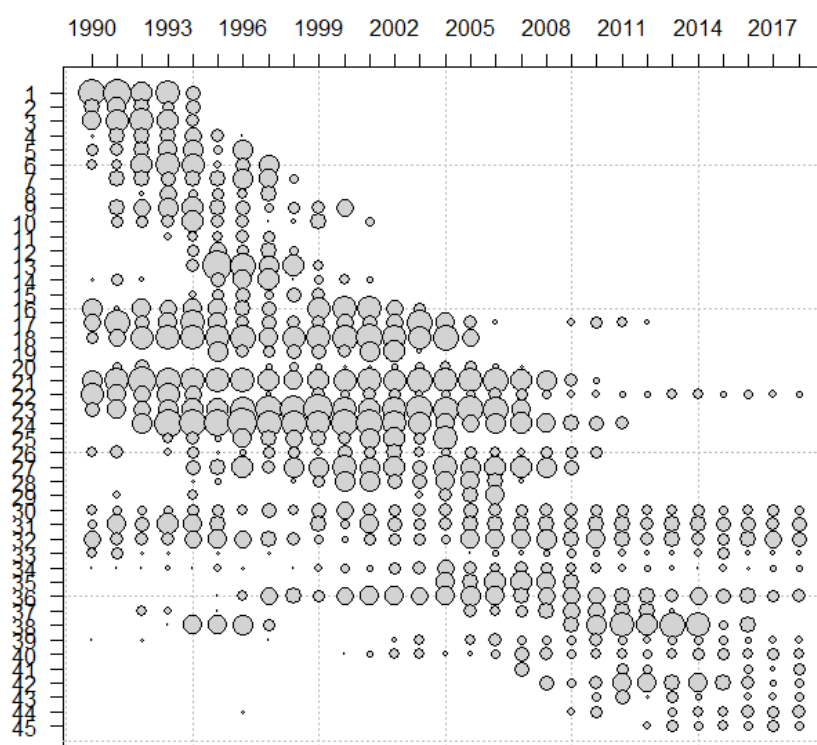


Figure E-3: Core vessel selection for Area025 model. The number of records retained in the dataset by vessel and fishing year.

Table E-1: Core vessel selection for Area025 model. Number of vessels, trips, landed blue cod (t), number of potlifts, and percentage of non-zero catch records by fishing year for the core vessels dataset.

Fishing year	Vessels	Trips	Catch (t)	Effort (potlinfts)	positive records %
1990	20	665	241.39	21 107	100.0
1991	24	997	285.43	32 858	100.0
1992	26	1 044	232.54	30 144	100.0
1993	27	1 268	317.28	39 007	99.8
1994	31	1 373	327.61	39 232	99.9
1995	31	1 191	311.61	34 770	99.8
1996	28	1 289	377.09	37 352	99.3
1997	28	1 042	331.67	30 095	99.3
1998	22	826	286.41	27 252	96.0
1999	23	942	284.40	27 936	97.6
2000	21	967	333.94	26 373	99.5
2001	21	971	383.99	25 924	99.9
2002	20	937	426.88	28 331	99.9
2003	21	818	363.13	23 884	99.9
2004	19	926	334.71	26 029	100.0
2005	21	836	424.18	26 906	99.8
2006	20	809	456.28	31 459	100.0
2007	19	666	314.01	25 010	100.0
2008	16	586	291.56	23 116	99.8
2009	19	501	248.45	20 056	100.0
2010	18	497	234.36	21 547	99.8
2011	16	470	244.23	22 535	100.0
2012	16	351	182.56	16 008	100.0
2013	15	386	213.34	19 637	99.5
2014	14	381	240.68	21 142	100.0
2015	13	263	187.92	16 769	100.0
2016	15	296	195.66	17 446	100.0
2017	14	240	167.02	13 342	99.6
2018	14	241	144.27	15 002	99.2

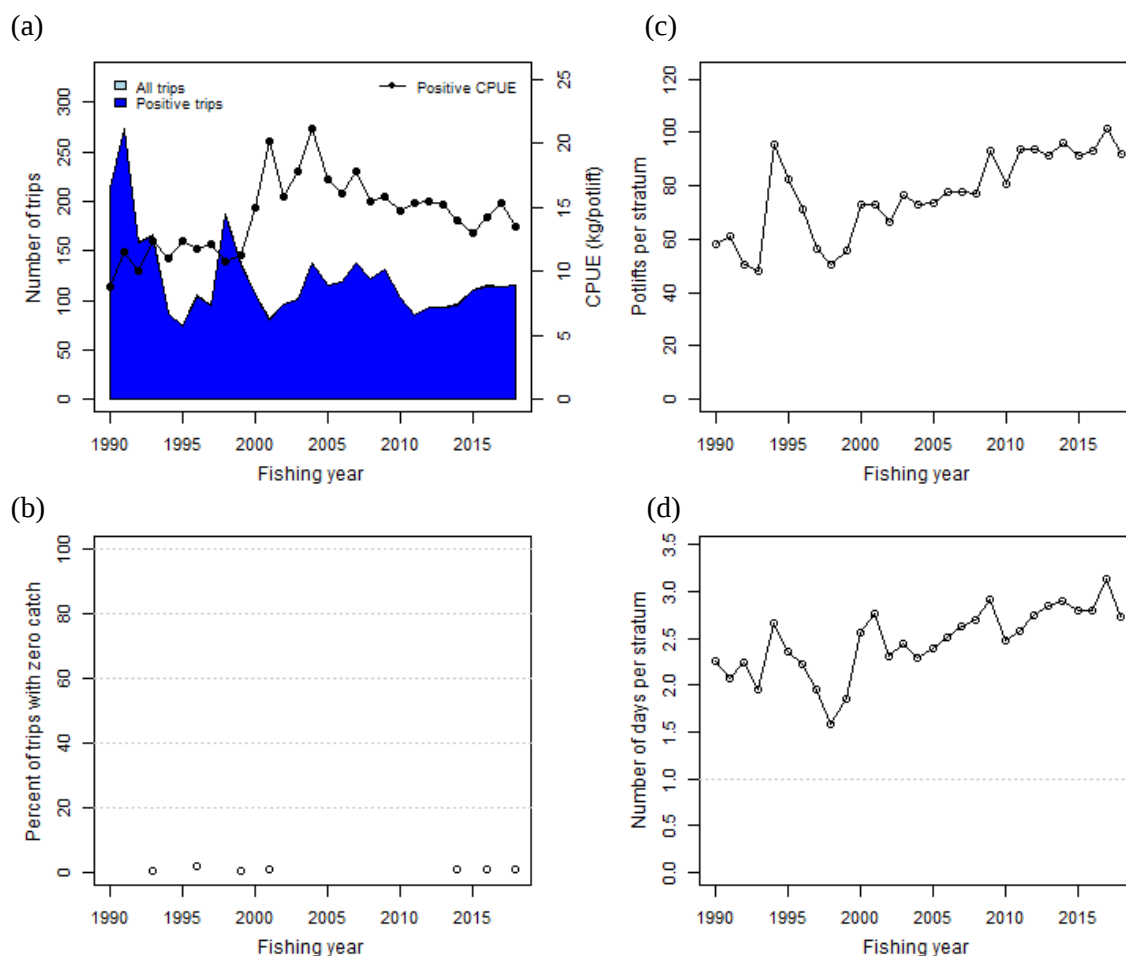


Figure E-4: Data for Area027 model: (a) number of trips targeting (light area) and landing (dark area) blue cod by cod potting method in Statistical Area 027, and the unstandardised catch rate (kg/potlift) of blue cod in successful trips, by fishing year 1990 to 2018; (b) proportion of qualifying effort-strata targeting blue cod in Statistical Area 027 and that landed zero blue cod; effect of data roll-up into trip-stratum; (c) number of potlifts per trip-stratum by fishing year; and (d) number of fishing days per trip-stratum by fishing year.

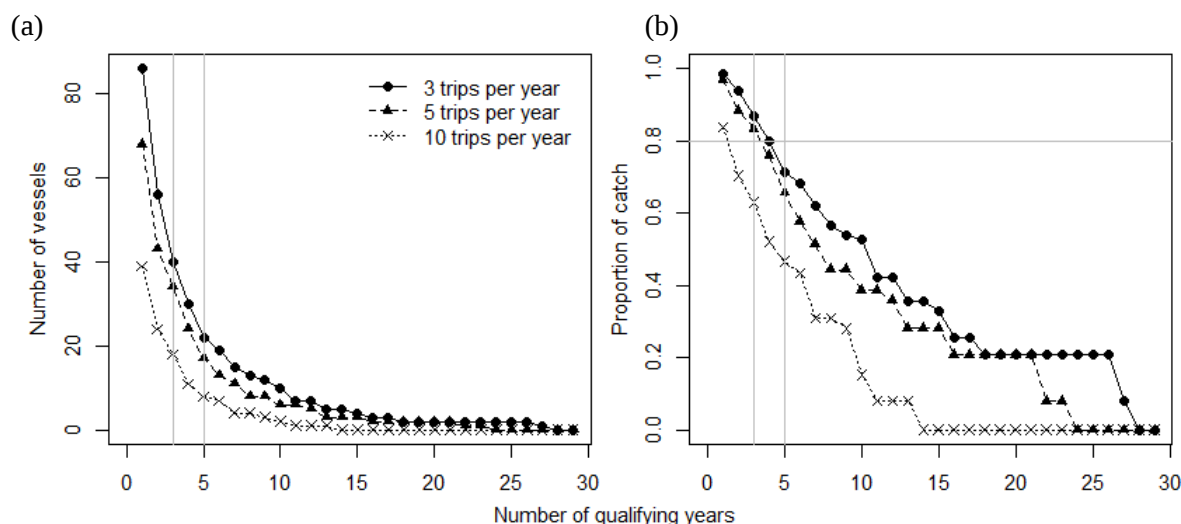


Figure E-5: Core vessel selection for Area027 model. (a) number of vessels and (b) proportion of catch retained in the dataset, depending on the minimum number of qualifying years in the fishery trips, by the number of trips per year used to define a qualifying year: 3, 5, or 10 trips per year. The qualifying criteria used for the Statistical Area 027 model was a minimum of 5 trips per year and a minimum of 3 qualifying years, resulting in data being retained for 34 vessels and 83.5% of the catch.

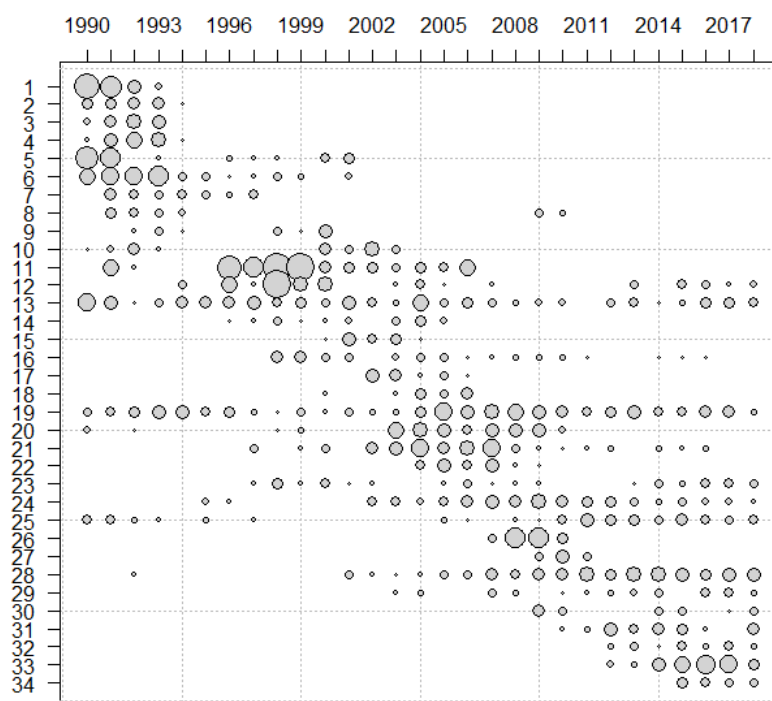


Figure E-6: Core vessel selection for Area027 model. The number of records retained in the dataset by vessel and fishing year.

Table E-2: Core vessel selection for Area027 model. Number of vessels, trips, landed blue cod (t), number of potlifts, and percentage of non-zero catch records by fishing year for the core vessels dataset.

Fishing year	Vessels	Trips	Catch (t)	Effort (potlifts)	Positive records %
1990	11	158	94.38	6 872	100.0
1991	13	190	142.23	10 946	99.5
1992	15	129	101.32	6 005	99.2
1993	13	118	91.55	5 426	99.2
1994	9	52	61.81	5 149	100.0
1995	6	35	56.32	3 423	100.0
1996	10	92	102.83	6 252	98.9
1997	11	73	81.38	4 052	97.3
1998	11	160	105.37	7 733	97.6
1999	11	110	83.96	5 891	97.3
2000	13	92	128.47	6 851	100.0
2001	11	78	137.17	5 756	97.5
2002	10	82	123.75	5 986	100.0
2003	15	92	148.84	6 810	100.0
2004	15	127	215.65	8 786	100.0
2005	15	112	171.72	8 295	100.0
2006	13	107	145.63	8 418	100.0
2007	12	109	152.76	8 489	100.0
2008	12	100	151.21	7 975	100.0
2009	14	118	190.14	11 007	100.0
2010	14	89	107.28	7 206	98.9
2011	9	59	92.64	5 885	100.0
2012	10	69	113.16	6 501	100.0
2013	11	82	124.30	7 491	100.0
2014	13	82	114.54	8 003	98.8
2015	14	109	140.17	9 919	100.0
2016	14	104	147.98	10 033	99.0
2017	12	98	164.28	10 223	100.0
2018	13	79	100.14	6 904	100.0

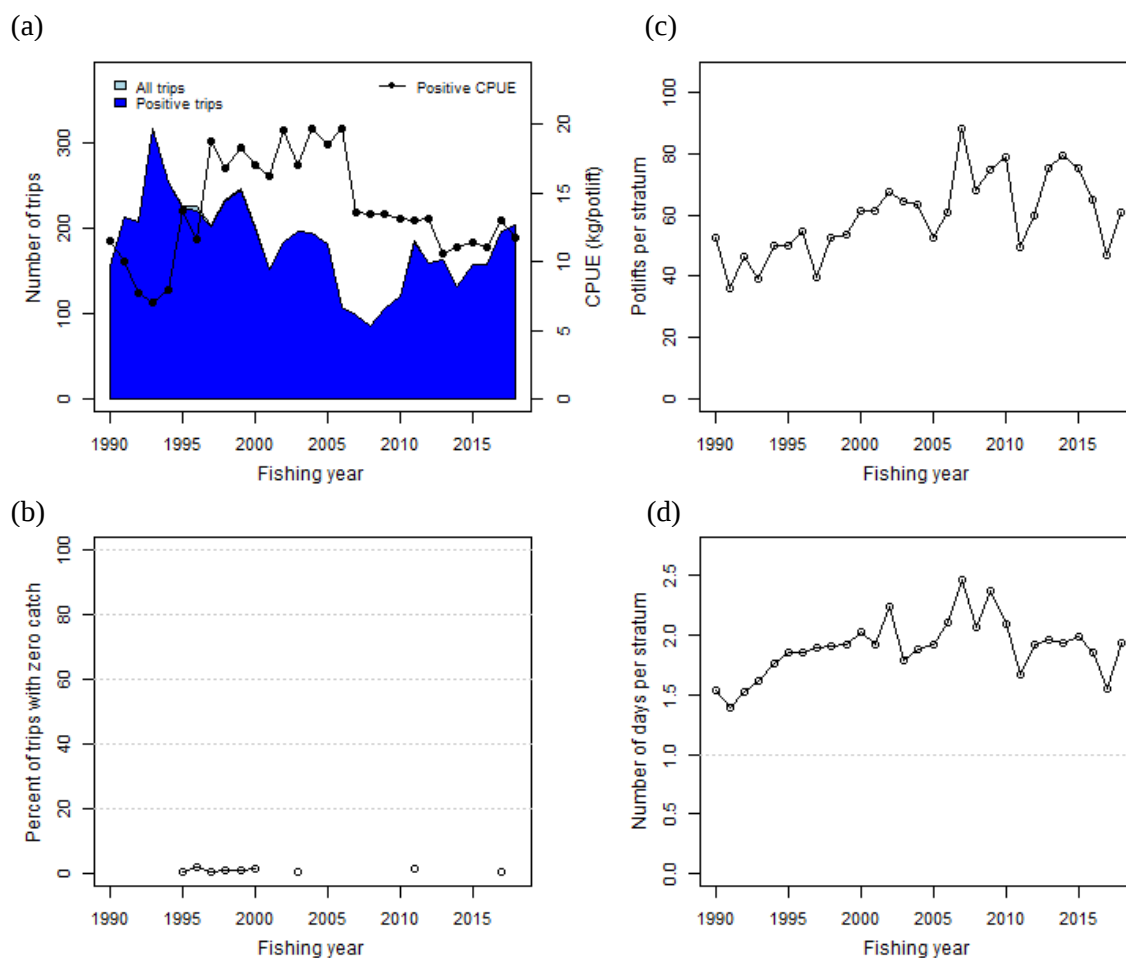


Figure E-7: Data for Area030 model: (a) number of trips targeting (light area) and landing (dark area) blue cod by cod potting method in Statistical Area 030, and the unstandardised catch rate (kg/potlift) of blue cod in successful trips, by fishing year 1990 to 2018; (b) proportion of qualifying effort-strata targeting blue cod in Statistical Area 030 and that landed zero blue cod; effect of data roll-up into trip-stratum; (c) number of potlifts per trip-stratum by fishing year; and (d) number of fishing days per trip-stratum by fishing year.

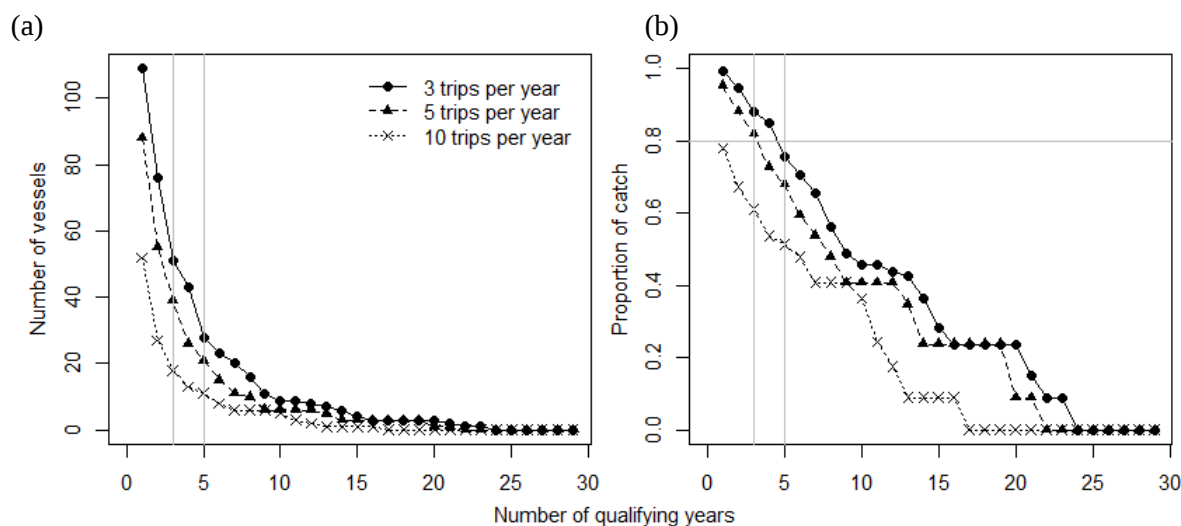


Figure E-8: Core vessel selection for Area030 model. (a) number of vessels and (b) proportion of catch retained in the dataset, depending on the minimum number of qualifying years in the fishery trips, by the number of trips per year used to define a qualifying year: 3, 5, or 10 trips per year. The qualifying criteria used for the Area030 model was a minimum of 5 trips per year and a minimum of 3 qualifying years, resulting in data being retained for 39 vessels and 81.8% of the catch.

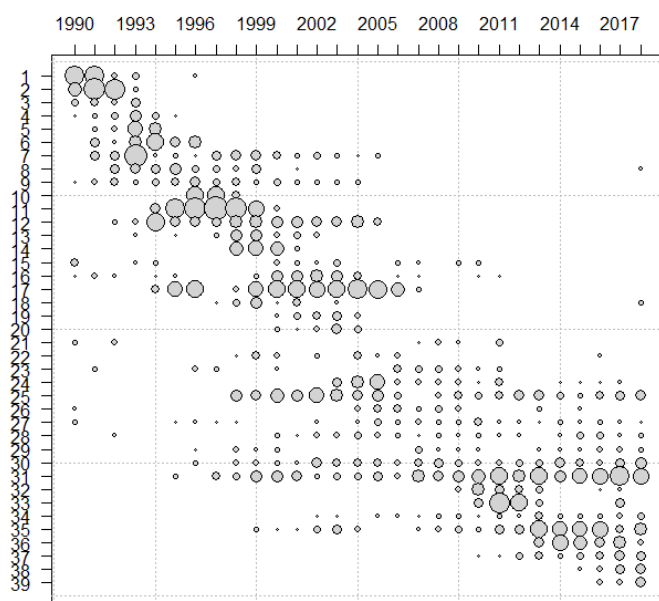


Figure E-9: Core vessel selection for Area030 model. The number of records retained in the dataset by vessel and fishing year.

Table E-3: Core vessel selection for Area030 model. Number of vessels, trips, landed blue cod (t), number of potlifts, and percentage of non-zero catch records by fishing year for the core vessels dataset.

Fishing year	Vessels	Trips	Catch (t)	Effort (potlifts)	positive records %
1990	10	99	62.59	4 777	100.0
1991	10	157	57.70	5 479	100.0
1992	13	121	58.92	5 941	100.0
1993	12	176	70.08	7 635	100.0
1994	11	157	62.68	7 159	100.0
1995	12	143	95.95	7 462	99.3
1996	13	200	141.18	10 171	99.0
1997	11	161	155.83	5 673	99.4
1998	16	209	226.07	10 581	98.6
1999	16	230	268.01	12 418	98.3
2000	20	197	200.42	12 107	98.5
2001	17	146	154.15	9 172	100.0
2002	17	167	225.43	11 211	100.0
2003	16	178	191.46	11 521	99.4
2004	16	178	202.41	11 229	98.9
2005	12	147	149.96	7 727	100.0
2006	13	87	92.05	4 478	98.9
2007	14	71	78.44	5 189	100.0
2008	12	74	63.61	5 021	100.0
2009	14	79	94.32	5 743	98.8
2010	15	94	104.53	7 069	100.0
2011	14	155	109.51	8 040	100.0
2012	10	117	87.69	7 048	100.0
2013	12	150	131.75	11 364	100.0
2014	11	111	114.18	9 073	100.0
2015	13	124	110.19	9 676	100.0
2016	15	137	99.94	8 472	100.0
2017	15	164	97.60	7 130	100.0
2018	14	153	106.16	8 716	100.0

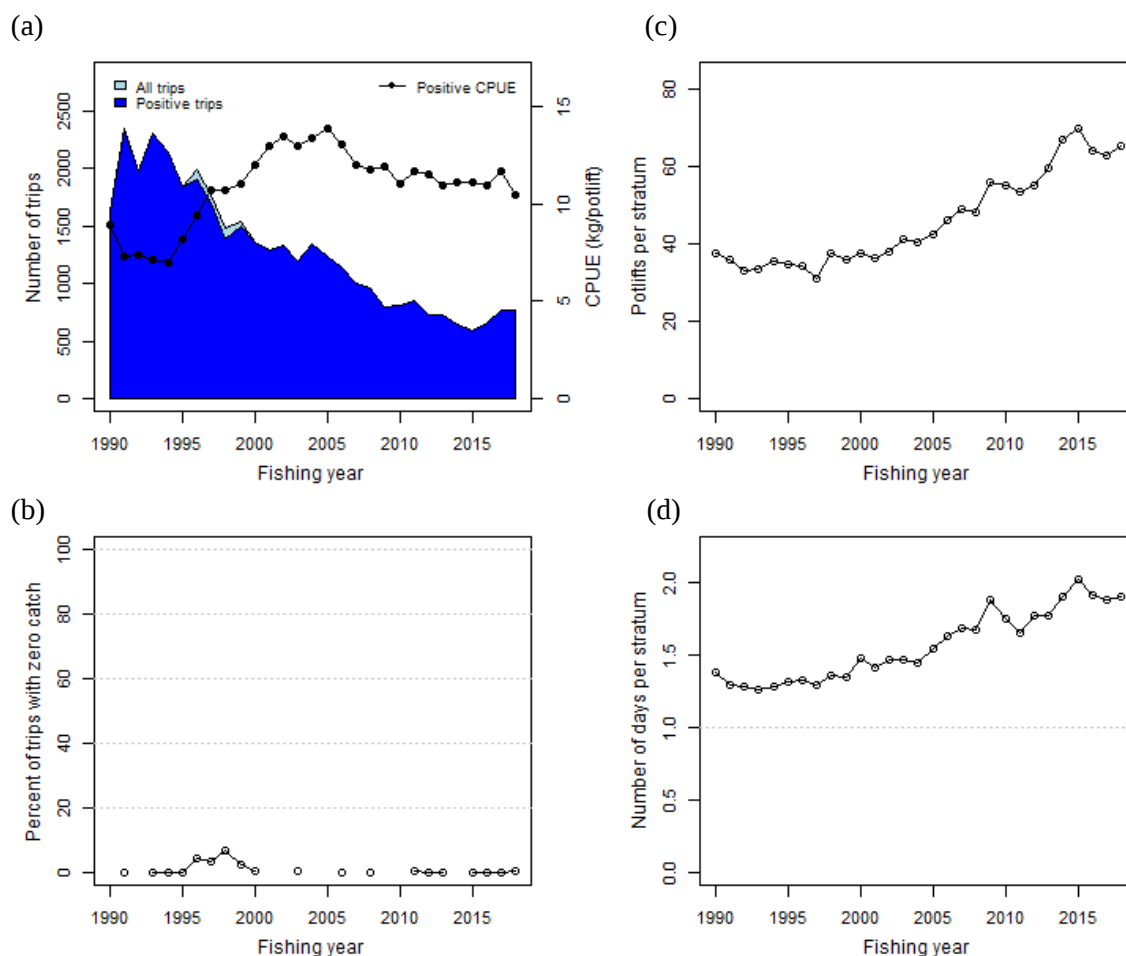


Figure E-10: Data for Combined Data (Areas 025, 027, 030) model: (a) number of trips targeting (light area) and landing (dark area) blue cod by cod potting method in Statistical Areas 025, 027, & 030, and the unstandardised catch rate (kg/potlift) of blue cod in successful trips, by fishing year 1990 to 2018; (b) proportion of qualifying effort-strata targeting blue cod in Statistical Areas 025, 027, & 030 and that landed zero blue cod; effect of data roll-up into trip-stratum; (c) number of potlifts per trip-stratum by fishing year; and (d) number of fishing days per trip-stratum by fishing year.

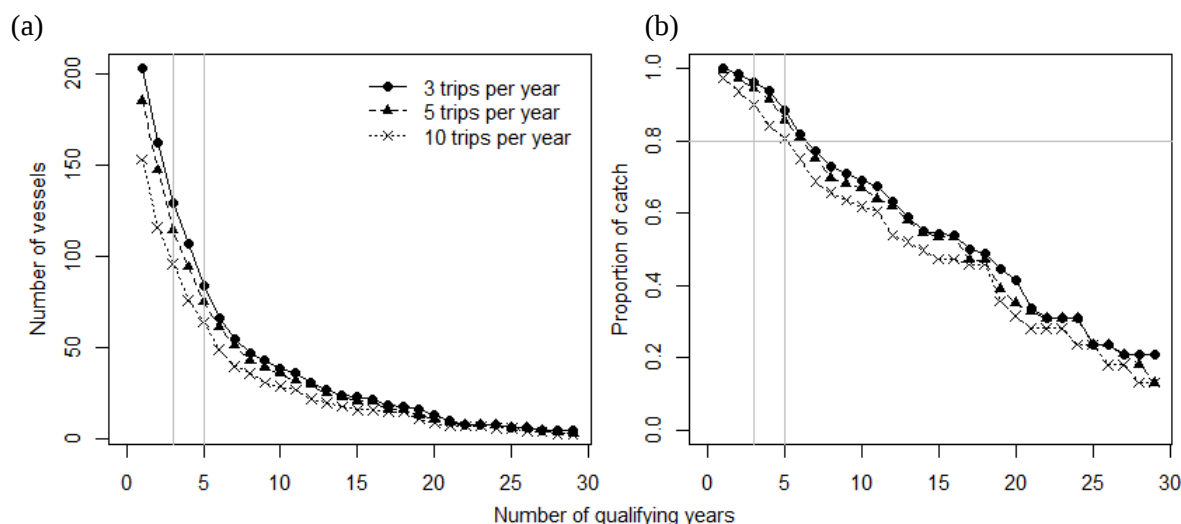


Figure E-11: Core vessel selection for Combined Data (Areas 025, 027, 030) model. (a) number of vessels and (b) proportion of catch retained in the dataset, depending on the minimum number of qualifying years in the fishery trips, by the number of trips per year used to define a qualifying year: 3, 5, or 10 trips per year. The qualifying criteria used for the Combined Data (Statistical Areas 025, 027, 030) model was a minimum of 10 trips per year and a minimum of 5 qualifying years, resulting in data being retained for 64 vessels and 80.6% of the catch.

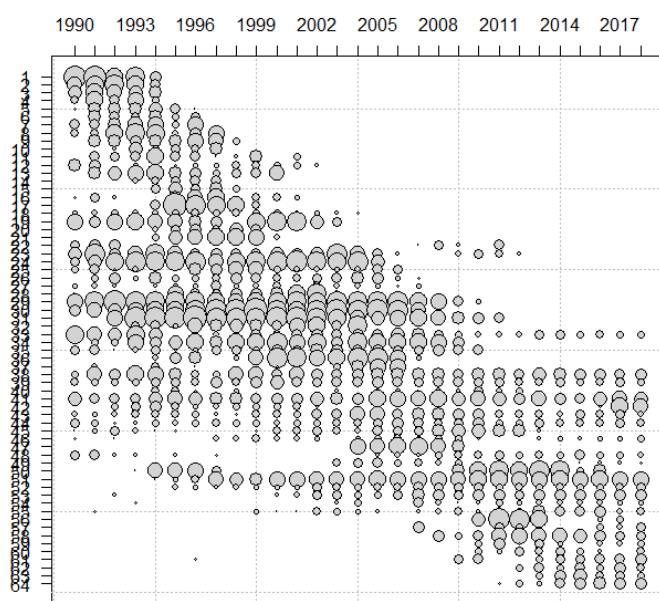


Figure E-12: Core vessel selection for Combined Data (Areas 025, 027, 030) model. The number of records retained in the dataset by vessel and fishing year.

Table E-4: Core vessel selection for Combined Data model. Number of vessels, trips, landed blue cod (t), number of potlifts, and percentage of non-zero catch records by fishing year for the core vessels dataset.

Fishing year	Vessels	Trips	Catch (t)	Effort (potlinfts)	Positive records %
1990	29	833	360.56	30 346	100.0
1991	36	1332	472.80	48 047	99.8
1992	38	1231	337.81	39 147	99.8
1993	38	1530	474.23	51 381	99.7
1994	42	1603	474.52	52 892	99.9
1995	41	1415	512.60	48 862	99.8
1996	42	1562	628.51	53 772	99.2
1997	38	1309	612.91	42 480	99.2
1998	33	1181	630.20	45 478	96.8
1999	34	1284	648.67	45 737	97.8
2000	33	1236	645.89	44 792	99.4
2001	31	1160	642.98	38 696	99.9
2002	29	1171	742.37	44 593	99.9
2003	30	1050	646.67	40 643	99.8
2004	29	1213	743.45	46 448	99.8
2005	28	1120	758.76	44 614	99.7
2006	26	1000	699.35	46 177	99.9
2007	27	870	555.03	39 816	100.0
2008	23	757	485.61	36 572	99.9
2009	26	652	479.41	36 278	99.9
2010	26	699	434.02	37 285	99.7
2011	25	765	472.02	37 449	100.0
2012	23	617	435.24	32 624	100.0
2013	23	689	499.29	40 208	99.7
2014	22	596	501.51	40 668	100.0
2015	21	508	457.14	37 694	100.0
2016	25	538	452.07	37 043	99.8
2017	23	561	490.71	36 628	99.8
2018	23	524	425.67	36 487	99.5

Appendix F: Diagnostic plots for Standardised CPUE analyses

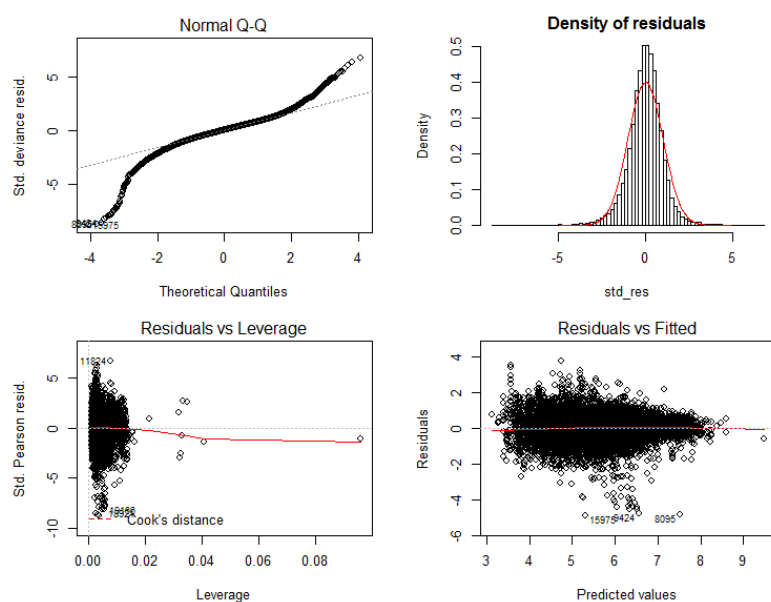


Figure F-1: Area025 Model, diagnostic plots. [top left] qq-plot of the standardised residuals; [top right] histogram of standardised residuals compared to a lognormal distribution (red line); [bottom left] Pearson residuals vs. leverage plot; and [bottom right] residuals vs fitted values plot.

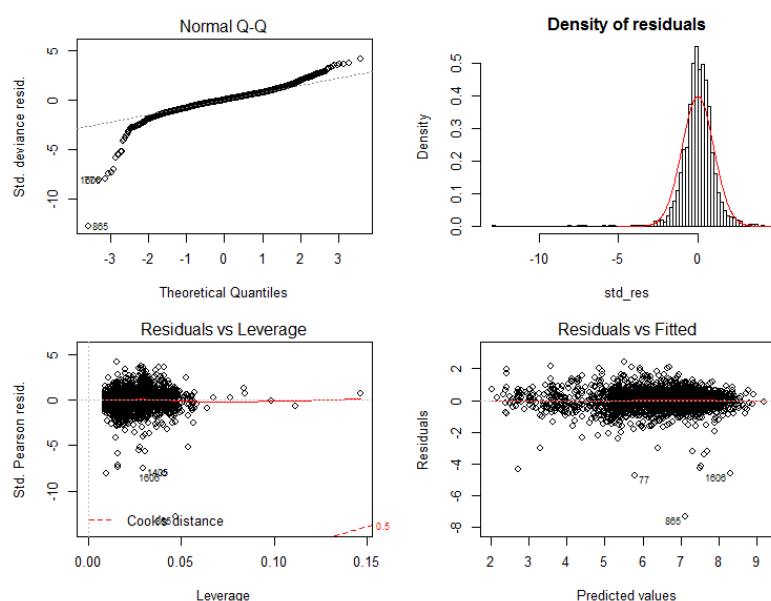


Figure F-2: Area027 Model, diagnostic plots. [top left] qq-plot of the standardised residuals; [top right] histogram of standardised residuals compared to a lognormal distribution (red line); [bottom left] Pearson residuals vs. leverage plot; and [bottom right] residuals vs fitted values plot.

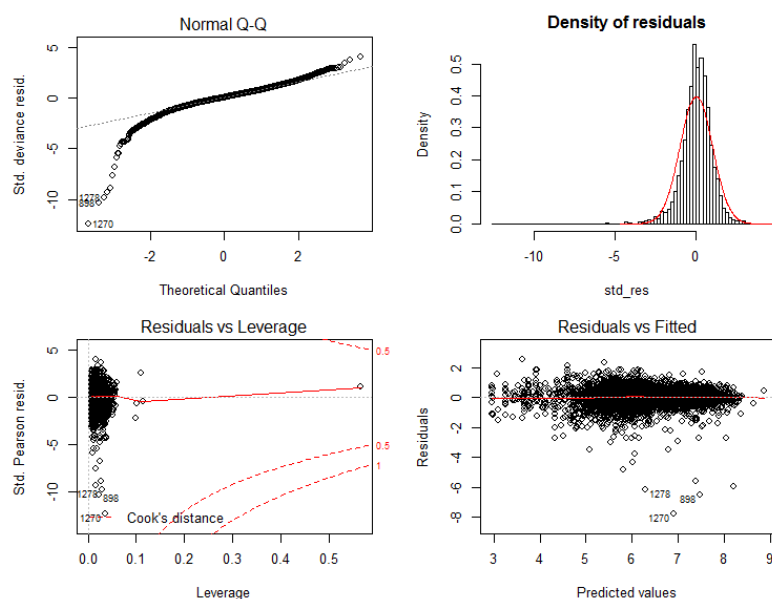


Figure F-3: Area030 Model, diagnostic plots. [top left] qq-plot of the standardised residuals; [top right] histogram of standardised residuals compared to a lognormal distribution (red line); [bottom left] Pearson residuals vs. leverage plot; and [bottom right] residuals vs fitted values plot.

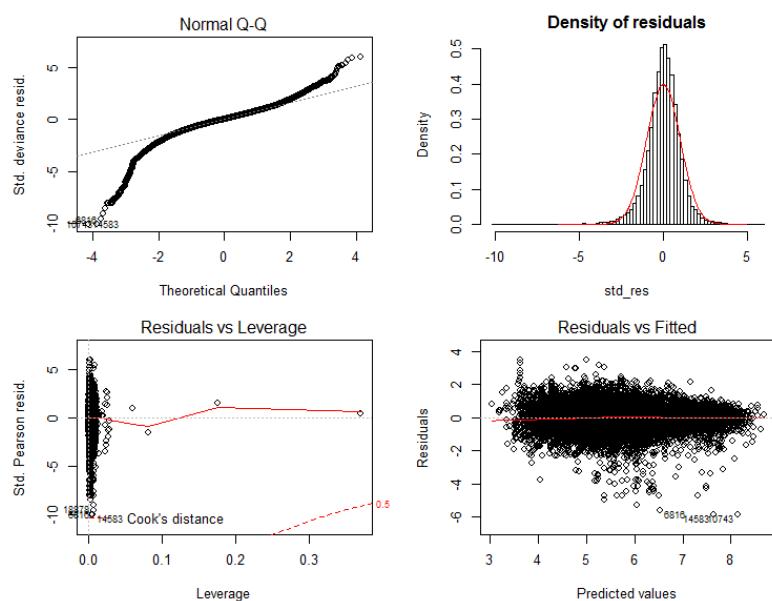


Figure F-4: Combined Data (Areas 025, 027, 030) Model, diagnostic plots. [top left] qq-plot of the standardised residuals; [top right] histogram of standardised residuals compared to a lognormal distribution (red line); [bottom left] Pearson residuals vs. leverage plot; and [bottom right] residuals vs fitted values plot.