Ministry for Primary Industries
Manatū Ahu Matua

Stock assessment of blue cod (*Parapercis colias*) in BCO 5

New Zealand Fisheries Assessment Report 2013/49

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ISSN 1179-5352 (online)
ISBN 978-0-478-42023-4 (online)

September 2013

New Zealand Government

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EXECUTIVE SUMMARY

Haist, V.; Kendrick, T.; Starr, P.J. (2013). Stock assessment of blue cod (*Parapercis colias*) in BCO 5.
***New Zealand Fisheries Assessment Report* 2013/49. 118 p.**

This document describes a stock assessment of blue cod (*Parapercis colias*) in BCO 5. The work was conducted by Trophia Limited, under Ministry of Primary Industries contract BCO2012-01.

The stock assessment was conducted using a Bayesian length- and sex-based model, which explicitly modelled the sex change process. The Southern Inshore Working Group (SINS-WG) reviewed this work periodically, and all technical decisions were agreed by that group.

The general categories of data used in the stock assessment models include: catch and landings; fishery and survey length frequencies; abundance indices; and biological information on growth, maturation, and sex change. Separate data sets were compiled and analyzed for Statistical Areas 025, 027, and 030. The data available for each of these areas differs, and little data are available for the remainder of the BCO 5 Statistical Areas. Combined, Statistical Areas 025, 027 and 030 represent 92% of the recent commercial fishery landings.

Historical time series of landings (1900–2012) were compiled for three gear categories: commercial line fishing, commercial pot fishing and recreational fishing. Additionally, non-reported blue cod bait usage for the rock lobster fishery was estimated and included with commercial landings. Fisheries were modelled assuming length-based selectivity for catch and discards, and discard rates estimated.

Stock abundance data fitted in the model included: relative abundance indices from commercial potting fishery Catch per Unit Effort (CPUE) standardisations and survey-based estimates of total mortality (Areas 025 and 030 only). An Area 025 drift underwater video estimate of absolute blue cod abundance was also fitted in the model for that area. Length frequency data were fitted in the model as point estimates, as consistent time series were not available. The length frequency data came from commercial fishery logbook and shed sampling projects, recreational fishery catch and landings sampling, potting survey samples, and a mesh-size selectivity study.

A base case structure for the assessment model was developed in consultation with the SINS. Numerous runs were conducted to develop the base case, and three sensitivity runs agreed for the final assessment. The sensitivity runs explored alternative assumptions about the sex-change process and an alternative recreational catch scenario.

Reasonable fits were obtained to all data, with no indications of model misspecification. Results indicate that blue cod in Statistical Areas 025, 027 and 030 are all close to the target biomass target of 40% B_0, with slightly lower abundance in Area 025 than in the other Areas. There is a high probability that fishing mortality rates are below the F_{msy} limit.

Five- and 10-year stock projections were conducted under two assumptions of future recruitment. The projections indicate that the current Total Allowable Commercial Catch (TACC) is sustainable in the near future.

1. INTRODUCTION

This document describes a stock assessment of blue cod in BCO 5, conducted under Objective 1 of contract BCO2012-01, awarded by the Ministry for Primary Industries (MPI) to Trophia Limited. The overall objective of the project was to:

1. Determine the status of blue cod stock biomass in BCO 5 relative to MSY based reference points.

Specific objectives for the work were to:

1. Undertake a quantitative stock assessment of blue cod in BCO 5.
2. Determine the status of blue cod stock biomass in BCO 5 relative to MSY.
3. Estimate the level of catch that will achieve B_{MSY} BCO 5.

The stock assessment used a model developed for Management Strategy Evaluation for the BCO 5 commercial fishery. That work was conducted as part of the South East Finfish Management Ltd. and Seafood Innovations Ltd. *Ecosystem Spatial Management for Blue Cod* (ESM) research programme, which comprised a number of field studies in addition to the MSE. In developing the BCO 5 MSE, all relevant data were compiled and reviewed by the Southern Inshore Working Group (SINS). The same data is used for the BCO 5 stock assessment, with catch estimates and Catch per Unit Effort (CPUE) analyses updated through to the 2011/12 fishing year.

Over the period February 2013 to April 2013, the SINS reviewed and agreed the data to be used in the stock assessment, the form of a base case and assessment sensitivity runs, and the assumptions for stock projections.

2. DATA

Data were compiled from a number of sources, including MPI (formerly Ministry of Fisheries) databases and research programmes, and the field studies conducted through the ESM programme.

The general categories of data used in the stock assessment models include: catch and landings; fishery and survey length frequencies; abundance indices; and biological information on growth, maturation, and sex change. For the stock assessments, separate data sets were compiled for Statistical Areas 025, 027, and 030. The data available for each of these areas differs, and few data are available for the remainder of the BCO 5 Statistical Areas (Figure 1). Combined, Statistical Areas 025, 027 and 030 represent 92% of the recent commercial fishery landings.

2.1 CATCH AND LANDINGS

Historical time series of BCO 5 landings were constructed for three gear types: commercial line fishing, commercial pot fishing, and recreational fishing. Additionally, non-reported blue cod catch used as bait in the CRA 8 rock lobster fishery was estimated and included with the commercial landings, and customary catch estimates were included with the recreational harvest.

Historically, catch data were reported by calendar year until 1989/90 when they were reported by fishing year. For these analyses all data are represented by the second year of the fishing year (i.e. 1989/90 is represented as 1990).

2.1.1 Commercial landings

Commercial landings data for BCO 5 are available graphically beginning in 1931 (figure 5 in Warren et al. 1997). Landings by Statistical Area were reported by McGregor (1988) for 1983 to 1986 and by Starr & Kendrick (2011) for the 1989/90 to 2009/10 fishing years. These were updated through to 2011/12 using data provided by MPI (see Appendix G). The 1989/90 to 2009/10 average proportion of the total BCO 5 catch in each Statistical Area was used to prorate the earlier landings estimates (derived from figure 5 in Warren et al. 1997) to Statistical Area. As suggested by the SINS, the proportion of the total catch taken from Statistical Area 027 was linearly decreased from the 1989/90 to 2009/10 average (0.20) to 0.10 in 1901, based on a belief that this Area was less significant to the fishery in earlier years. The decrease was reallocated to the remaining BCO 5 Statistical Areas. The stock assessment model begin from an unexploited equilibrium state in 1900, so the 1931 reported catch was decreased linearly back to 1900 (Figure 2).

Historically, the BCO 5 commercial fishery predominantly used hand-lines but during the 1980s a potting fishery developed and became the prevalent fishing method. McGregor (1988) reports that by 1986, 87% of the Southland blue cod catch was taken in pots. We assume a linear increase in blue cod potting beginning from 0% in 1979 and increasing to 87% in 1986 and 100% in 1988 and later (Table 1).

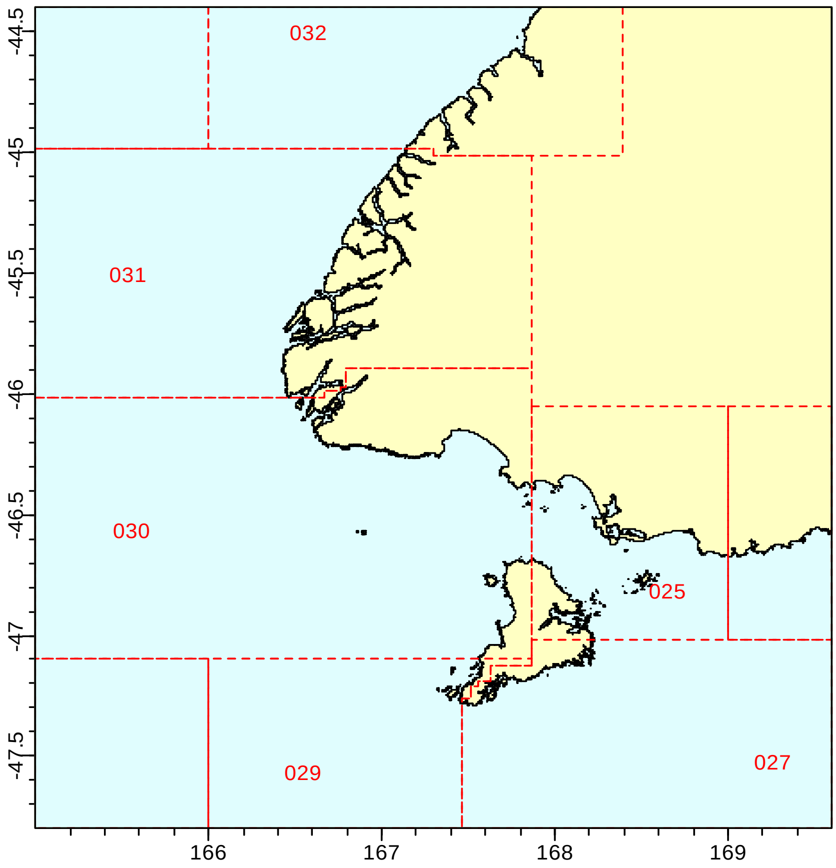


Figure 1: General Statistical Areas within BCO 5.

Table 1: Assumed proportion of BCO 5 commercial catch harvested by pot gear. Estimates are linearly extrapolated based on the pot fishery beginning in 1980 and harvesting 87% of the commercial catch by 1987.

Year	Proportion	Year	Proportion	Year	Proportion
1979	0.000	1983	0.497	1987	0.994
1980	0.124	1984	0.621	1988	1.000
1981	0.249	1985	0.746	1989	1.000
1982	0.373	1986	0.870	1990	1.000

2.1.2 Utilization for bait in the rock lobster fishery

Historically, significant quantities of blue cod taken by potting, were used as bait in the commercial rock lobster fishery. A diary study of rock lobster fishers in Southland estimated that 161 t of blue cod was used in the 1985 CRA 8 fishery, although fishers felt that this substantially underestimated the actual usage (Warren et al. 1997). Since 1996, reporting of blue cod used for bait is mandatory and included as part of the commercial catch reporting. Unreported blue cod catch is not thought to be significant since then (Starr & Kendrick 2011).

To develop a time series for BCO 5 bait utilization, a time series of rock lobster landings by BCO 5 Statistical Area was generated. From 1945 to 1978 CRA 8 rock lobster landings were reported annually, and since the 1979/80 fishing year they have been reported by Rock Lobster Statistical Area (Starr 2012). Rock Lobster Statistical Areas differ from the General Statistical Areas used for reporting BCO, so a basis for converting between them was developed using figure A.2 of Starr & Kendrick (2011) to estimate the proportion of each Rock Lobster Statistical Area within each General Statistical Area (Table 2). Using this cross-reference, the rock lobster catch by BCO 5 Statistical Area was estimated for the period 1979/80 to 2009/10. Over this time, the average proportion of the CRA 8 rock lobster catch taken from the main BCO 5 Statistical Areas was 52%, with 15%, 13%, and 24% taken from Statistical Areas 025, 027, and 030, respectively (Table 2). These average proportions were used to pro-rate the 1945 to 1978 CRA 8 rock lobster catch to BCO 5 Statistical Area.

Based on 1985 rock lobster landings in CRA 8, the estimated 161 t of blue cod used for bait implies that 0.0854 tonnes of blue cod were used for each tonne of rock lobster landed. Assuming that blue cod bait usage is proportional to the rock lobster catch in each Statistical Area, and that this has been constant over the history of the CRA 8 fishery, produces a time series of blue cod used for bait in the rock lobster fishery (Figure 2). This may, however, underestimate the amount of bait used: rock lobster fishers believed the 161 t estimate was biased low, and more blue cod bait may be used in areas of higher blue cod abundance. If we assume that the actual 1985 tonnage of blue cod used for bait was double the estimated value (322 t) and that 75% of that bait was used in the “prime” BCO 5 Statistical Areas (025, 027, and 030), then 0.246 tonnes of bait was used for each tonne of rock lobster landed in these key Statistical Areas. The bait use series based on the 161 t estimate is used in the *base* catch scenario, while the series based on a 322 t usage in 1985 is used in a *high catch* scenario.

Table 2: Assumed proportion of each CRA 8 Statistical Area in each BCO 5 Statistical Area and the average proportion of the CRA 8 rock lobster catch taken in each BCO 5 Statistical Area.

BCO 5 Statistical Area	CRA 8 Statistical Area 922	923	924	925	926	927	928	Average proportion of CRA 8 catch
025	0.25	0.75	0.25					0.149
027			0.50					0.126
030		0.25	0.25		0.50			0.244
029, 031 and 032	0.75	0	0	1.00	0.50	1.00	1.00	0.481

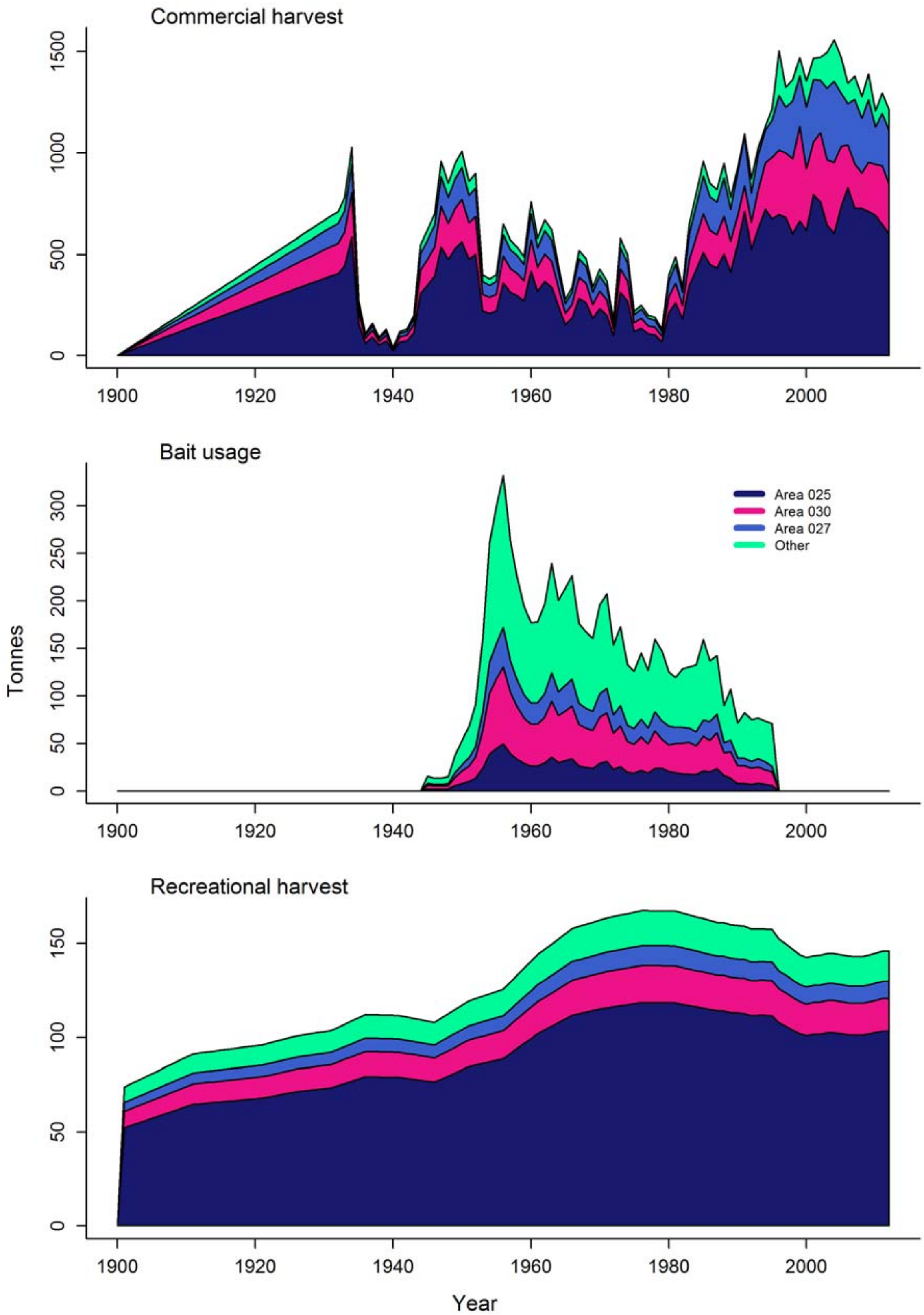


Figure 2: Estimated tonnage of BCO 5 commercial landings, bait usage (in addition to that included in commercial landings), and recreational harvest by Statistical Area and year. Estimates are for the *base* catch scenario.

2.1.3 Recreational harvest

Recreational blue cod harvest estimates are available from a series of diary surveys conducted throughout New Zealand. Although there are potential issues with the survey methods, this is currently the only available information on recreational blue cod harvest (Ministry for Primary Industries, 2012). Survey estimates ranged from 171 000 to 326 000 fish over the 1991/92 to 1999/2000 studies (Table 3). The SINS agreed that the 1999/2000 estimates were less reliable and these are not used here.

To generate a time series of recreational blue cod harvest we assume that the average catch per person residing in the Southland area has remained constant, and base recreational harvest on population trends. Southland District population census data were obtained from the Statistics New Zealand web sites (Appendix Table A1), and estimates linearly extrapolated between census years.

Although the SINS suggested that recreational estimates be based on numbers of fish harvested because of concerns with the average weights used to generate the biomass estimates, weight-based values are needed for the population model. The average weights assumed in the recreational fishery surveys were checked against the model predicted mean weights for the recreational fishery to ensure that there was no major discrepancy in these values.

For the 1991/92 and 1996 recreational harvest surveys the average amount of blue cod harvested per person residing in Southland was calculated (Table 3), and the average of these two values used to calculate the *base* recreational catch time series. The estimate of 1.55 kg/resident was increased and decreased by 50% to generate *high* and *low* recreational harvest scenarios.

Warren et al. (1997) present a figure showing the BCO 5 recreational catch by location, reportedly from data collected during the 1991/92 Marine Recreational Diary Survey. These data were used to obtain an estimate of the proportion of BCO 5 recreational harvest by Statistical Area (Table 4), and these proportions were assumed to remain constant over the history of the fishery. The estimated recreational catch by Statistical Area, using the *base* catch assumptions, is shown in Figure 2.

2.1.4 Customary harvest

Customary harvest data were obtained from the MPI Research Data Manager, and consisted of the Te Rūnanga o Ngāi Tahu reported quantities approved and quantities harvested by quarter for 1999 to 2011. The measurement units included numbers and weights, and in some cases this field was blank. To estimate total annual harvest an average weight of 1 kg/fish was assumed. Estimates of total harvest generally increased over the time series, possibly the result of increased reporting (Table 5). For use in the stock assessment, an annual customary harvest of 2 t was assumed for the entire time series. Without any information on the location of the harvest, it is all attributed to Statistical Area 025, and we assume that the size structure of the customary catch is the same as that of the recreational fishery and include it with that harvest.

Table 3: Estimates of recreational BCO 5 harvest from the Marine Recreational Diary Survey (Ministry for Primary Industries 2012). Note that the Charter vessel survey data is not used in the analyses.

	Marine Recreational Survey		Southland	Catch
Year	Number of fish	Tonnes	Population	(kg)/resident
1991/1992	188 000	150–200	102 500	1.71
1996	171 000	120–155	99 000	1.39
1999/2000	326 000	165–293		
Charter vessel survey				
1997/1998	62 885	51		

Table 4: Recreational Catch Estimates from diarists (derived from figure 11 of Warren et al. 1997).

	Categories for number of fish caught						
Min	1	26	51	100	501		
Max	25	50	100	500	900		
Avg. of min and max	13	38	75.5	300	700.5		
	Number of observations per category						
Area 025	10	5	1	3	0		
Area 027	6	1	0	0	0		
Area 030	5	2	1	0	0		
Area 031	3	0	2	0	0		
Unknown 025,027,030	0	0	1	0	1		
Area 029	1	0	0	0	0		
	Number of fish per category					Total fish	Proportion
Area 025	130	190	75.5	900	0	1295.5	0.708
Area 027	78	38	0	0	0	116	0.063
Area 030	65	76	75.5	0	0	216.5	0.118
Area 031	39	0	151	0	0	190	
Unknown 025,027,030	0	0	75.5	0	700.5	776	
Area 029	13	0	0	0	0	13	
Total with known Area						1831	

Table 5: Estimates of the customary harvest (kg) of BCO 5.

Year	Harvest
1999	100
2000	260
2001	200
2002	20
2003	450
2004	190
2005	270
2006	310
2007	550
2008	480
2009	1856
2010	1820
2011	2890

2.1.5 Catch scenarios

Three catch scenarios were generated for Statistical Areas 025, 027 and 030. The first, the *base* scenario, used the lower estimates for bait usage and the *base* recreational harvest. The second, the *high catch* scenario, used the higher bait and recreational harvest estimates. The third, the *low catch* scenario used the low recreational catch estimates. The estimates for these scenarios are given in Appendix Tables A2, A3, and A4.

2.2 LENGTH FREQUENCY DATA

Length frequency (LF) data were compiled from a variety of sources including samples from commercial and recreational catches and landings, potting and Drift Underwater Video (DUV) surveys, and a mesh size selectivity study. These data were used to inform the selectivity and retention ogives used in the stock assessment model.

2.2.1 Commercial pot fishery LFs

Length frequency data were collected through a commercial fishers' logbook project and a shed sampling project as part of the ESM programme.

From February 2009 to July 2011, 10 fishers measured 6668 blue cod through the logbook project. Sampling effort was highest in the first year, and subsequently declined (Table 6). Mean fish lengths tended to be higher in Areas 027 and 030 than in Area 025.

Shed sampling of landed blue cod provides a potentially valuable source of information on the sex structure of the landings, as well as their size composition. From November 2009 to August 2011, 52 samples were processed for a total of 6047 blue cod measurements. As with the logbook LFs, average lengths were higher in Statistical Area 027 than in Statistical Area 025 (Table 7). No shed samples were collected from Statistical Area 030.

Unexpectedly, the average lengths of blue cod from the shed sampling programme tended to be smaller than those from the logbook programme (Figure 3). Instructions for the logbook programme were to sample and measure all fish caught. For the shed sampling programme the instructions were similar: to collect and land a sample of the catch from a tagged pot. Unfortunately, no arrangements could be put in place to allow landing under-sized blue cod, so it is not clear whether the shed samples represent catch or landings. The expectation would be that the size distribution of logbook sampled blue cod would be similar to or smaller than the size distribution of the shed sampled fish, assuming that both programmes represent random sampling of the catch or that shed samples represent landings.

The SINS thought, *a priori*, that the shed samples were more likely to represent random samples from the fishery than the logbook samples. A more detailed analysis of the data collected from the two sampling programmes was pursued to investigate whether there was any evidence that one programme or the other generated biased samples.

Table 6: Number of blue cod measured and average length of blue cod sampled through the fishers' logbook programme, by Statistical Area and year.

	Number Sampled					Mean Length (cm)			
Year	025	027	030	Other/ Unknown	Total	25	27	30	Other/ Unknown
2009	2 216	926	1 075	55	4 272	37.3	38.5	38.2	38.8
2010	1 132	737	141	17	2 027	38.1	39.6	38.1	37.4
2011	113	205	51		369	37.3	40.1	40.4	
Total	3 461	1 868	1 267	72	6 668				

Table 7: Number of blue cod measured and average length of blue cod sampled through the shed sampling programme, by sex, Statistical Area and year.

		Number Sampled				Mean Length (cm)		
Year	Sex	025	027	Unknown	Total	025	027	Unknown
2009	Female		36		36		35.1	
	Male		64		64		42.7	
2010	Female	489	29	133	651	34.8	36.4	34.8
	Male	994	76	217	1 287	36.5	37.0	35.8
	Unknown	3			3	34.0		
2011	Female	1 118	215		1 333	35.4	37.2	
	Male	2 159	193		2 352	36.4	39.2	
	Unknown	236	85		321	36.2	37.1	
	Total	4 999	698	350	6 047	36.0	38.1	35.4

Mean lengths of fish sampled, by vessel, are shown in Figure 4. There is considerable overlap in the shed and logbook mean lengths by vessel, with shed samples having some of the highest mean lengths even though the overall mean is lower. For the three vessels that contributed both shed and logbook samples from Statistical Area 025, the mean lengths of their shed samples were consistently lower than their logbook samples. One of these vessels (vessel #9, Figure 4) contributed a reasonable number of samples to both programmes and those were explored further.

The spatial distribution of the mean lengths of fish sampled, by 5 n.mile grid cells, indicates that shed and logbook samples from the central Foveaux Strait area tend to be smaller than those from other areas (top panels, Figure 5). The spatial distribution of the shed samples is much more restricted than the logbook samples, with the majority of shed samples collected in the central Foveaux Strait area.

Comparing only those 5 n.mile cells where both shed and logbook samples were collected, does not indicate any major difference in mean lengths between the shed and logbook samples (middle panel, Figure 5). Finally, comparing the mean lengths by 5 n.mile cell, for samples collected from a single vessel (vessel #9, Figure 4) indicates that the higher overall mean length of the vessels' logbook samples is the result of samples collected outside of the central Foveaux Strait area (bottom panel, Figure 5). The mean lengths of shed and logbook samples from this vessel are similar for samples from the central Foveaux area.

These analyses suggest that the main reason for the smaller average size observed in shed samples is the result of a more restricted geographical range of samples collected by this programme. The shed samples tend to be taken during the last day of a trip because they need to be kept whole, and hence tend to be taken closer to home ports. Which programme better represents the spatial structure of the fishery is unknown, however these results suggest there is no obvious reason to reject samples from the logbook programme on the basis of geographical coverage.

The temporal distribution of samples collected through the shed and logbook sampling projects was compared with that of the commercial fishery. Over the period October 2008 through to September 2010 the commercial catch was distributed fairly evenly throughout the year (Figure 6). The majority of shed samples were collected early in the year from January through to April, while logbook samples were more evenly distributed through the year. Hence there is no reason to reject the logbook samples based on their temporal distribution relative to that of the commercial fishery.

2.2.2 Recreational fishery LFs

Recreational fishery Length Frequency distributions (LFs) were obtained from a 2009/10 study of the Southland recreational blue cod fishery (Davey & Hartill 2011). This study included a boat ramp survey (Bluff, Riverton/Colac, and Halfmoon Bay) and a logbook survey of charter and recreational vessels.

Between October 2009 and September 2010, 1471 blue cod were measured during the boat ramp survey. Over the same period, logbook participants measured 586 fish caught by recreational vessels and 1878 fish caught by charter vessels.

Fish measured through the boat ramp survey can be assumed to represent landings and fish measured through the logbook programme can be assumed to represent catch. The proportion of BCO 5 recreational catch taken by charter vessels was estimated by dividing the 1997/98 Marine Recreational Charter Vessel catch estimate by the average of the three Marine Recreational Fishery survey estimates (Table 3). This proportion (27.5%) was used to weight the charter vessel and recreational vessel LFs to obtain an overall LF to represent the recreational fishery catch.

The same recreational fishery LF dataset is fitted in stock reconstructions for Areas 025, 027 and 030.

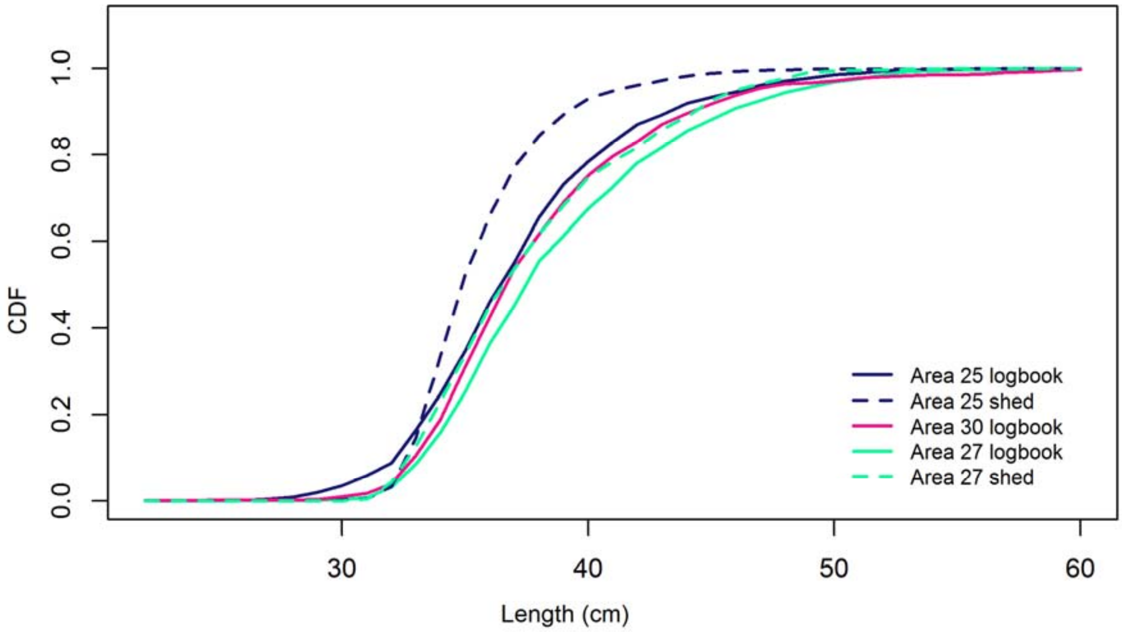


Figure 3: Cumulative density function (CDF) for blue cod measured through the logbook and shed sampling projects by Statistical Area.

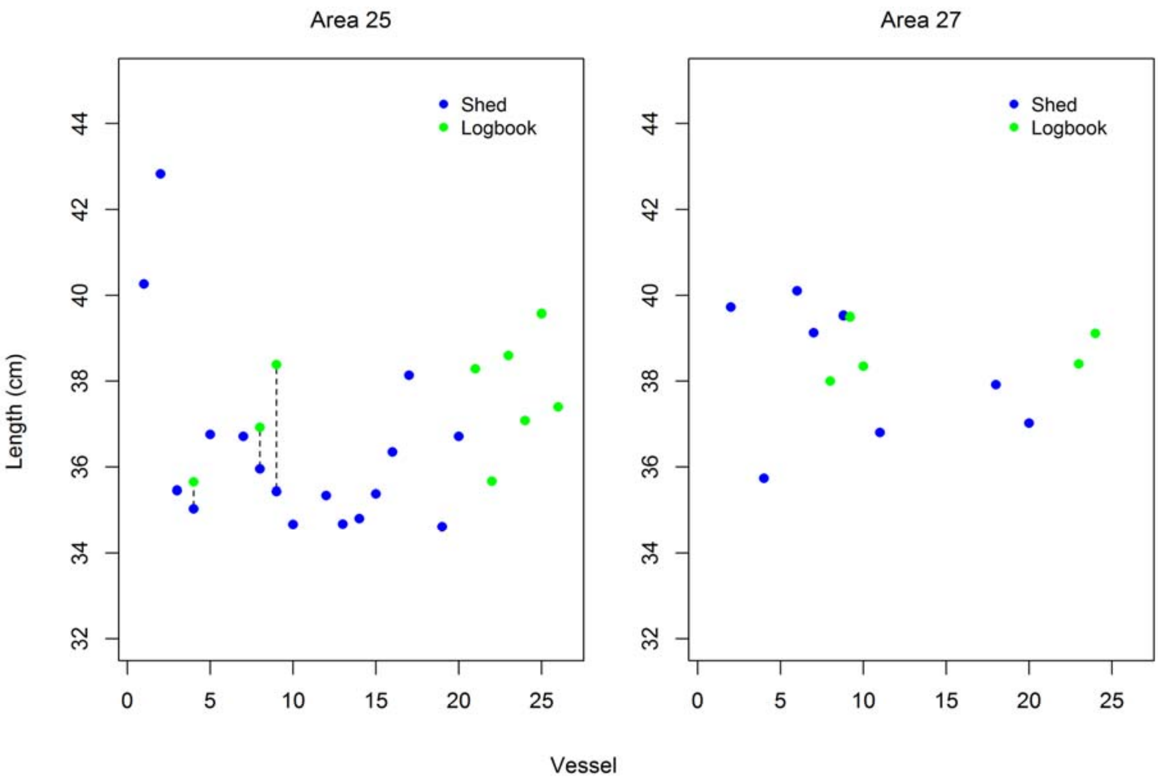


Figure 4: Mean length of blue cod sampled by the shed sampling and logbook programmes by Statistical Area and individual vessel. Vessels that participated in both programmes are indicated by the dashed vertical lines.

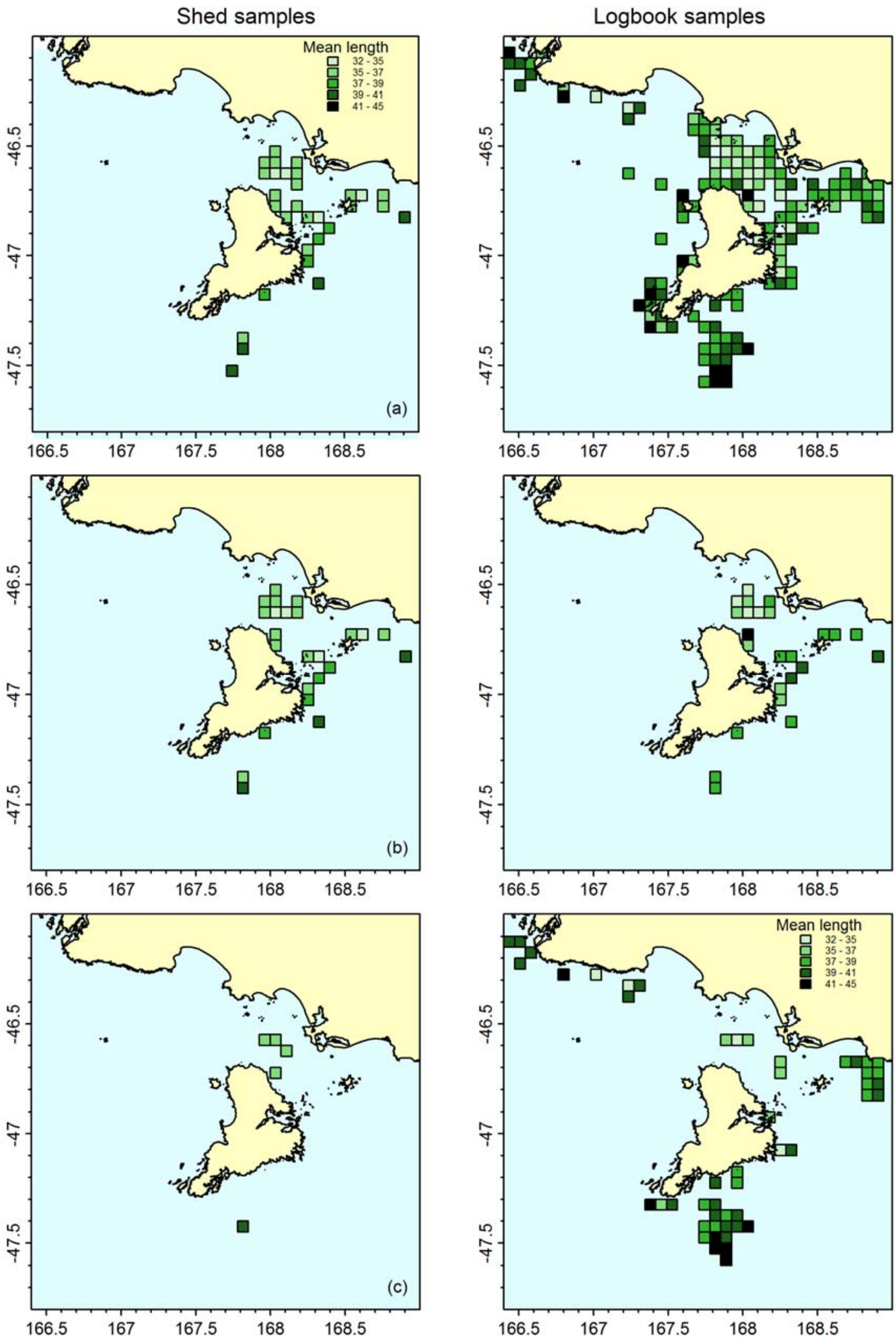


Figure 5: Mean length (cm) of fish sampled through the shed sampling (left panels) and logbook (right panels) programmes by 5 n.mile square cells. The upper panels (a) plot all the sample data; the middle panels (b) plot only cells represented in both sampling programmes; and the lower panels (c) plot samples from a single vessel that participated in both the shed sampling and logbook programmes.

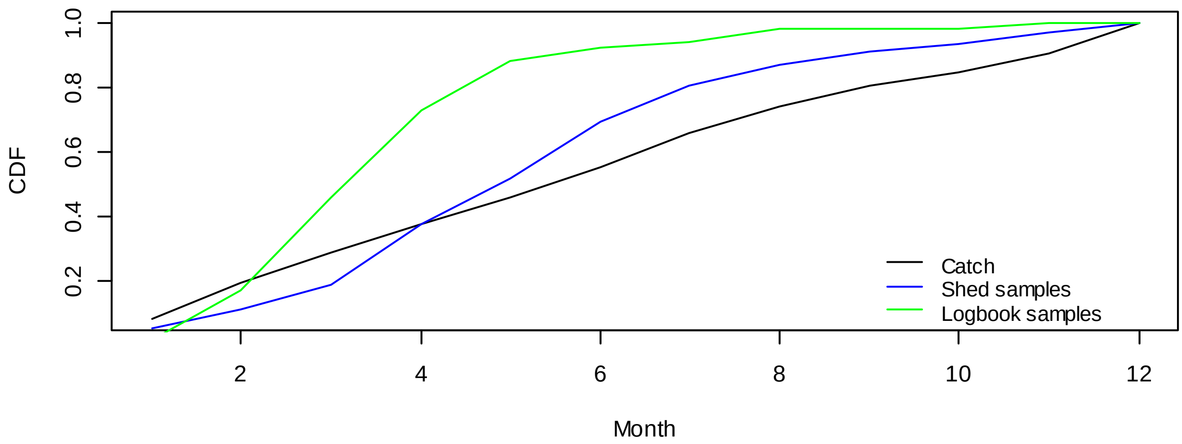


Figure 6: Cumulative density function (CDF) of the BCO 5 commercial catch (Oct. 2008 – Sept. 2010) and samples collected through the shed and logbook projects by month.

2.2.3 Mesh-size selectivity study

A blue cod mesh size selectivity study was conducted in 1986 to determine the optimum mesh size for the BCO 5 fishery (unpublished Bauckham letter, Appendix B). The study was conducted at Bluff and Stewart Island using pots with the then-standard 38 mm mesh as well as pots with 50 mm mesh and pots with escape gaps.

The length frequency of the catch from the 38 mm mesh pots was derived from Figure 7, and this is used to represent the size composition of the BCO 5 commercial pot fishery catch prior to the 1992 and 1994 pot regulation changes. In the stock assessment model, this data is fitted to the predicted average size distribution of the 1985 to 1992 potting fishery.

The mesh size selectivity study LF data are fitted in stock assessments for Areas 025, 027 and 030.

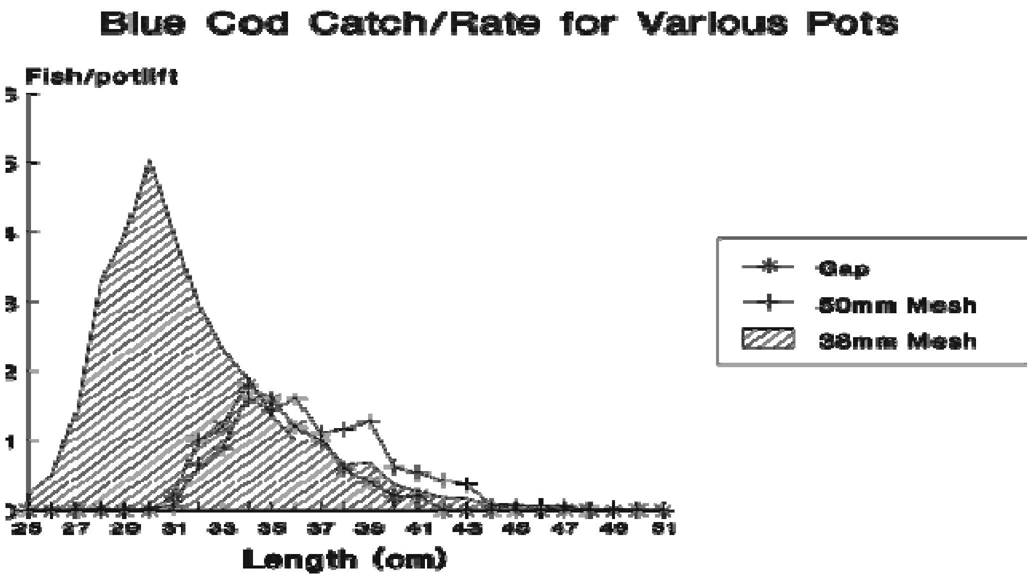


Figure 7: Size structure of blue cod caught during a 1986 mesh selectivity study. The figure is taken from a letter dated 18 November 1991 from G.R.L. Brown (Regional Manager, MAF Fisheries South) to A.P. Bauckham (Manager Fisheries Administration, Greta Point).

2.2.4 Potting survey LFs

Random stratified potting surveys, using 30 mm mesh pots, were conducted in Areas 025 and 030 in 2010. These surveys provide not only length frequency data, but also are one of the few information sources about the population sex structure.

The Area 025 survey, conducted between 1 February and 16 June, caught and measured 4340 fish at 56 potting sites. The Area 030 survey, conducted between 6 March and 25 June, caught and measured 823 fish at 18 potting sites. For fish less than 30 cm, the samples are predominantly female with slightly more than 60% females by length bin (Figure 8). Beyond 30 cm, the proportion of males at length increases and by 44 cm virtually all blue cod are male. For Area 030, the sex ratio at length is somewhat shifted to the right, with lower proportions of males in the 30–44 cm size bins.

The survey sex-ratio at length provides a basis for selecting the sex ratio of recruiting fish for the stock assessment model. This is fixed at 35:65 in favour of females recruiting at age 0.

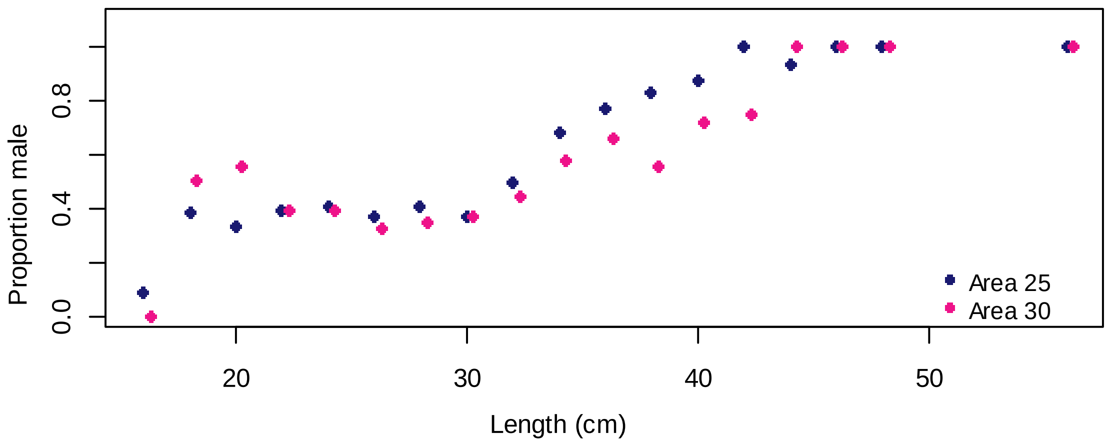


Figure 8: Sex ratio by length for blue cod caught in the Area 025 and Area 030 random stratified potting survey.

2.2.5 Drift Underwater Video Length Frequency distribution

Drift underwater video (DUV) samples of length frequency are potentially useful for representing the size structure of the population as these samples should be less impacted by gear selectivity associated with line or potting gear. DUV length frequencies, collected in conjunction with potting surveys, are available for the 2009 fixed site potting survey (Carbines & Usmar (2012) and for the 2010 random-stratified potting survey (Carbines & Beentjes 2012). The number of blue cod recorded in the 2010 concurrent random site DUV survey was relatively small and is not reported here, but substantial numbers of fish were measured from the 2009 fixed site survey and these are presented here (Carbines & Usmar 2012).

LFs from the 2009 DUV survey are compared with those from the 2009 and 2010 fine-mesh potting surveys, and with those from the Area 025 2009–2011 commercial fishery which has a 48 mm minimum pot mesh regulation (Figure 9). Length frequencies from the two potting surveys are similar, with a slight suggestion that the 2010 random site survey caught larger fish. The DUV clearly samples smaller fish than the potting surveys and the commercial fishery samples are skewed to larger fish.

If the sampling gears have asymptotic selectivity, the modes of the LF distributions may be indicative of the length at which maximum selectivity is attained, and the right hand limb of the LF distribution may be representative of the population length distribution. Distribution modes are clear for the DUV and commercial data with modes of 22 cm and 35 cm, respectively. The potting survey LFs are relatively flat over the 26 cm to 33 cm size range, but the LFs generally support the hypothesis that maximum selectivity is attained by 31 to 33 cm.

Comparing the portions of the length frequency distributions beyond their modes may indicate the relative selectivity of different gears over the selected size range. Assuming that the maximum selectivity for the potting survey gear is attained at lengths of 31 cm or 33 cm suggests that the potting survey does not sample all the larger fish observed in the DUV survey (see two panels on left in Figure 10), although the differences in selectivity appear to be small. Assuming that the maximum selectivity for the commercial fishery is attained at a length of 35 cm suggests that neither the potting survey or DUV surveys fully sample the larger fish caught in the potting fishery (see panel on right in Figure 10).

Note that the DUV LF data is not fitted in the assessment model, but is presented here to provide information about the survey selectivity.

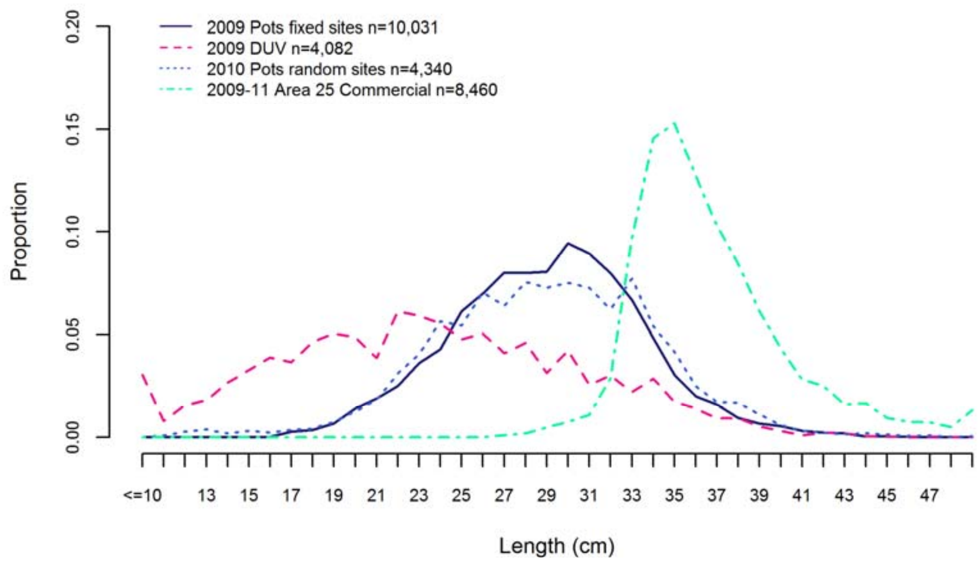


Figure 9: Comparison of LF distributions for: 2009 fixed sites potting survey; 2009 DUV survey; 2010 random sites potting survey; and 2009–2011 Area 025 commercial catch (shed and logbook samples).

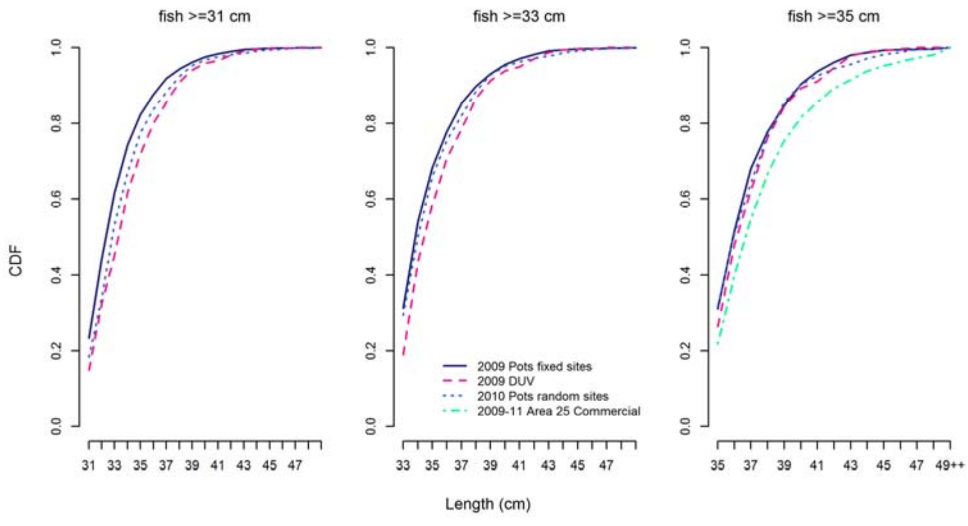


Figure 10: Comparison of cumulative density function (CDF) for all fish greater than or equal to 31 cm, 33 cm, and 35 cm, for three survey LFs (2009 fixed site potting survey; 2009 DUV fixed sites; 2010 random site potting survey) and the 2009–2011 Area 025 commercial LFs (shed plus logbook).

2.3 ABUNDANCE INDICES

Three sets of data are available that can inform stock abundance estimates: fishery-based CPUE which provides relative abundance indices, survey-based estimates of total mortality (*Z*), and a drift underwater video survey (DUV) estimate of absolute stock abundance.

2.3.1 CPUE

A methodology for selecting BCO 5 commercial fishery data for CPUE standardization was developed and reviewed by the SINS Working Group in 2011 (Starr & Kendrick, 2011). The same methodology was used to select data for a CPUE standardization updated through to the 2011/12 fishing season, and again reviewed by SINS. Details of the analysis are provided in Appendix C. Separate CPUE indices, representing catch rates of legal-sized blue cod, were calculated for Statistical Areas 025, 027, and 030.

2.3.2 Survey *Z* estimates

Total mortality (*Z*) estimates were derived from the Area 025 and Area 030 random-stratified potting survey data using standard methods described in Beentjes & Francis (2011). The fully-recruited age, reflecting the age where most blue cod are above the minimum legal size (MLS), was selected as 8. Uncertainty in the *Z* estimates was estimated using a simulation/bootstrap approach (Beentjes & Francis, 2011).

The distributions of *Z* estimates are approximately lognormal (Figure 11), and are fitted with lognormal priors in the stock assessment model. The mean *Z* estimate for Area 030 (0.377) is lower than that for Area 025 (0.465).

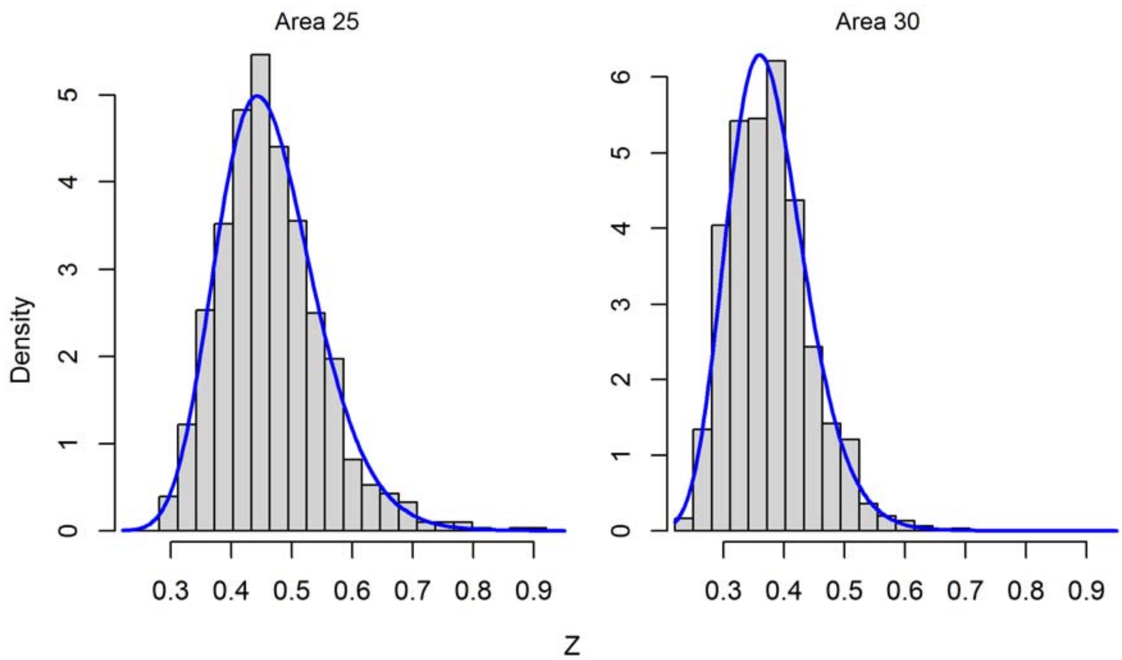


Figure 11: Distribution of blue cod *Z* estimates from bootstrap simulations of random stratified potting survey data for Statistical Areas 025 and 030 (histograms), and the lognormal curves having the same mean and standard deviation (blue line).

2.3.3 DUV-based abundance estimate

A DUV survey was conducted in Area 025 in 2010, surveying a number of sites sampled during the random-stratified potting survey. Sixty-one DUV transects were completed over twelve sites. The DUV sites were not randomly selected from the set of potting sites, and as such cannot be considered a random survey of Area 025.

Review of the DUV video footage provided an estimate of the mean density of blue cod for the surveyed area and a size distribution of the blue cod observed (Carbines & Beentjes 2012). The mean blue cod density can be extrapolated to the survey area, and when adjusted for the higher average blue cod potting counts at the DUV sites relative to the average counts for the overall potting survey, extrapolated to an abundance estimate for Area 025 (Table 8). The number of legal-sized blue cod is calculated using the proportion of blue cod greater than or equal to 33 cm measured in the DUV video footage.

Table 8: Data used to calculate the number of legal-sized blue cod in Statistical Area 025 from the DUV survey data.

DUV area surveyed (m^2)	137 220
DUV blue cod count	435
DUV blue cod density (#/100 m^2)	0.317
Ratio of mean blue cod potting survey counts:	
DUV sites to potting survey sites	1.29
DUV blue cod density adjusted for station bias (#/m^2)	0.246
Area 025 area (km^2)	4 284
Total blue cod (thousands)	10 527.7
Percentage greater than or equal to 33 cm	0.366
Area 025 legal-sized blue cod (thousands)	3 848.0

2.4 BIOLOGICAL DATA

2.4.1 Growth

Sex-specific von Bertalanffy (vB) growth models have been fitted to several sources of BCO 5 age, sex, and length data. These include: Carbines PhD thesis data (Carbines, 2004); the 2010 Foveaux Strait random-stratified survey data (Carbines & Beentjes 2012); and the 2010 Area 030 random-stratified survey (Haist & Middleton 2011). Growth model parameters and growth trajectories are substantially different for the Carbines (2004) data which was collected over a much more constrained area and available size range (Table 9).

For the stock assessment, the vB growth parameters from the 2010 random-stratified potting surveys are used for their respective areas.

Table 9: Estimated growth model parameters.

	Carbines (2004)		2010 Area 025		2010 Area 030	
	Male	Female	Male	Female	Male	Female
L_{inf}	41.55	34.5	58.928	45.506	58.830	41.830
k	0.29	0.35	0.0875	0.1192	0.0810	0.1501
t_0	1.22	1.22	-1.540	-1.2706	-1.640	-0.4475

2.4.2 Sex change

Carbines (2004) studied the sex change of Foveaux Strait blue cod, categorizing fish by state: male, female, or transitional (Table 10).

The proportions of fish at length that are transitional (ratio of transitional to transitional plus females) are fitted with a parametric relationship to describe the sex change process. The left hand portion of the observations, to 410 mm where 50% of females are transitional, is fitted with a logistic function (Figure 12). For lengths greater than 410 mm, sex change is modelled with a linear decrease in the proportion changing sex to 0 at 450 mm (Figure 12).

Table 10: Number of gonads staged as male, female and transitional (Carbines, 2004). The proportion transitional is the number of transitional fish divided by the number of transitional plus number of females.

Length Bins (mm)	Transitional	Male	Female	Total	Proportion transitional
180–199	0	1	0	1	-
200–219	0	1	4	5	0.00
220–239	0	2	7	9	0.00
240–259	0	1	4	5	0.00
260–279	0	3	14	17	0.00
280–299	2	6	20	28	0.09
300–319	2	11	41	54	0.05
320–339	5	19	36	60	0.12
340–359	5	19	14	38	0.26
360–379	2	16	15	33	0.12
380–399	5	7	6	18	0.45
400–419	3	11	3	17	0.50
420–439	1	8	2	11	0.33
440–459	0	3	4	7	0.00
460–479	0	2	0	2	-
480–499	0	1	0	1	-
Total	25	111	170	306	0.13

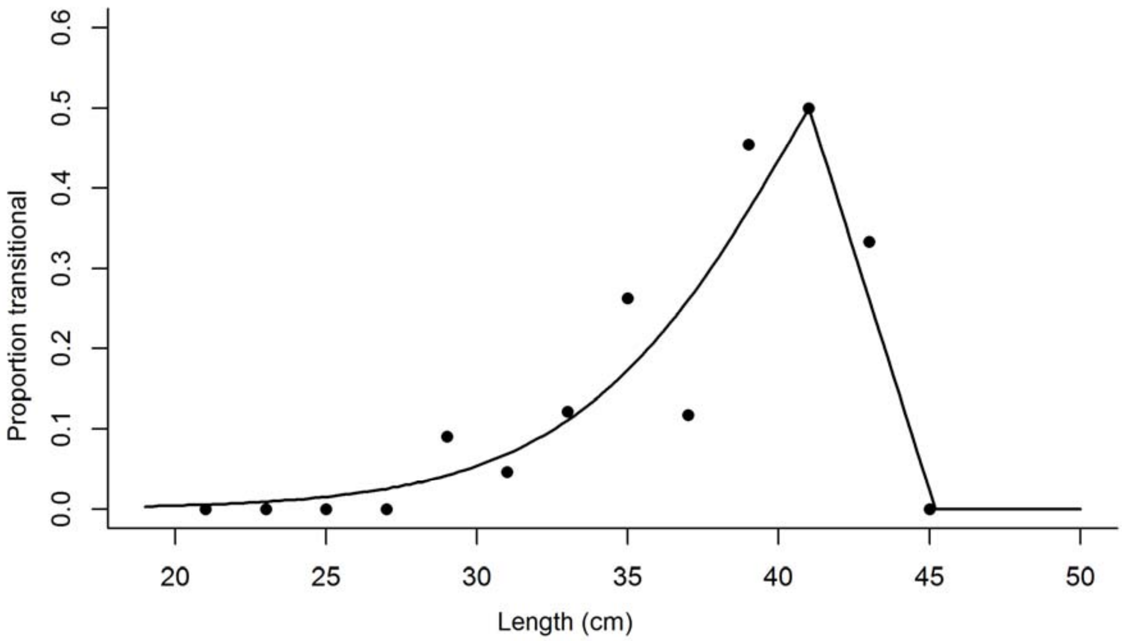


Figure 12: Relationship (solid line) fitted to the observed proportion of females in transitional state (points).

2.4.3 Maturity

Sexual maturation of Foveaux Strait blue cod was studied by Carbines (2004), for his PhD dissertation. Although females below 26 cm were not sampled, complete gonad development was observed in all females above 28 cm, and none of the females less than 28 cm (29 fish) were considered reproductively mature. Few small males were sampled, however advanced stages of spermatogenesis was only observed in males 28 cm or larger. For the stock assessment models, sexual maturation is assumed to be knife-edge with males and females maturing at 28 cm.

3. STOCK ASSESSMENT MODEL

3.1 MODEL STRUCTURE

The stock assessment model is length-based, using growth transition matrices calculated from the von Bertalanffy growth models to transition fish through size bins. This approach is similar to that used for New Zealand rock lobster (Haist et al. 2009) and other strictly length-based models (Chen et al. 2005, Punt & Kennedy 1997). A length-based approach is adopted because of data limitations: age-length keys are available for survey data but not for fishery catch and landings.

The model is conditioned on the landings for the three modelled fisheries (commercial line, commercial pot, and recreational line), using a Newton-Raphson algorithm to calculate fishing mortality rates for each sex, size bin and fishery. Each fishery is modelled with a selectivity ogive and a retention ogive (Table 11). Catch and catch LFs are a function of the selectivity ogives, and landings and landings LFs are a function of the product of selectivity and retention ogives. Separate pre-1993 and post-1996 commercial and recreational fishery retention functions account for the change in MLS in 1993.

Two commercial pot fishery selectivity functions are estimated to account for changes to the commercial pot mesh size regulations that occurred in 1992 and 1994. It appears that actual changes in mesh size were gradual, occurring over a number of years, and the process is modelled as a gradual change from 1992 to 1997. Length-specific selectivity is modelled as a linear change between values estimated for 1992 and 1997.

Discard mortality is assumed for fish that are caught but not landed. Carbines (1999) studied catch and release mortality of blue cod caught with two types of hooks. He estimated no mortality for fish caught with large hooks and 25% mortality for fish caught with small hooks. We assume a discard mortality rate of 13% for the recreational fishery. Anecdotal evidence indicates significant predation mortality of blue cod released from commercial fishing gear, but direct estimates of the mortality rate are not available. The SINS suggested an assumption of 50% discard mortality for the commercial fishery would be appropriate. Sensitivity runs, where the recreational and commercial discard mortality rates were doubled, were investigated but had little effect on key model parameters and are not presented here.

A Beverton-Holt stock recruitment relationship is assumed. The standard deviation of recruitment residuals (log-scale) is fixed at 0.6 and the steepness prior is beta distributed (mean= 0.75, std. dev.=0.10). Recruitment residuals are estimated for 1980 to 2010. Spawning stock biomass (SSB) is measured as the total mature biomass. Fish recruit to the model at age 0 with 65% of fish recruiting as females, based on sex ratios for lengths associated with age 2 (see Section 2.2.4)

Initial model runs, which assumed time invariant sex-change, estimated that the sex ratio of mature fish in the unexploited population strongly favoured males, with greater than 5 males for each female. Biologically, this seems implausible. The only information on blue cod sex change comes from work conducted in Area 025 in 1995 (Carbines 2004), and this data is used to model sex change in the stock assessment model. It is likely that the relationship between sex change and length is not constant, rather some function of demographic features of the population.

Sex-change is modelled as a dynamic process. Assuming that sex-change is a function of the relative abundance of mature males was found to result in the best model convergence performance. The length at 50% sex change (*dmax*) is modelled as a function of the ratio of mature male biomass in year $y\left(B_y^M\right)$ relative to mature male biomass in the virgin state $\left(B_0^M\right)$:

$$dmax = \lambda \left(B_y^M \big/ B_0^M \right)^{\delta},$$

where the parameters λ and δ are estimated through the minimisation. In practice, only λ was estimated and δ was fixed at 0.4 in the *base case* run. When dynamic sex-change is modelled, the form of the sex-change relationship remains the same, but is shifted along the x-axis. That is, the length at which 50% of females change sex varies and the sex-change function moves along the length axis (Figure 13). With the dynamic sex-change parameterisation it is not possible to fix the 1995 length at 50% sex change (to 41 cm, as observed in the sex transition data set collected in 1995), so a penalty function is used to encourage that value.

The populations are initialised at unexploited equilibrium conditions in 1900.

Natural mortality is modelled assuming a normal distribution with a mean of 0.14 and a standard deviation of 0.015. The majority of the prior density is in the range of 0.11 to 0.17, which is the range of uncertainty considered in blue cod potting survey analyses (Beentjes & Francis, 2011).

LF data are fitted in the model assuming multinomial distributions with sample sizes specified as 100. The model parameter prior distributions and assumed distributions for data fitted in the model are shown in Table 12.

MSY statistics are calculated assuming deterministic recruitment and the final years' selectivity and retention ogives. Only commercial fishing mortality rates are varied, with recreational and customary catches fixed at the 2012 level. B_{msy} is measured as total mature biomass and MSY is presented as the commercial catch at B_{msy}.

Table 11: Model selectivity and retention ogives by fishery, their form and parameter values if fixed or data fitted in the model to inform their estimation. DHN = double half normal.

Ogives	Form	Parameters if fixed or data that informs
Selectivity		
Commercial line fishery	Logistic	50% selected at 280; 95% selected at 305
Commercial pot fishery <=1992	DHN	Mesh size trial LF
Commercial pot fishery >=1993	Logistic	Logbook LF
Recreational fishery	Logistic	Recreational catch LF
Survey	DHN	Survey LF
Retention		
Commercial line fishery	Knife-edge	MLS
Commercial pot fishery <=1992	Knife-edge	MLS
Commercial pot fishery >=1993	Knife-edge	MLS
Recreational fishery <=1992	Logistic	Recreational landings LF
Recreational fishery >=1993	Logistic	Shifted +3 cm from <=1992 retention curve

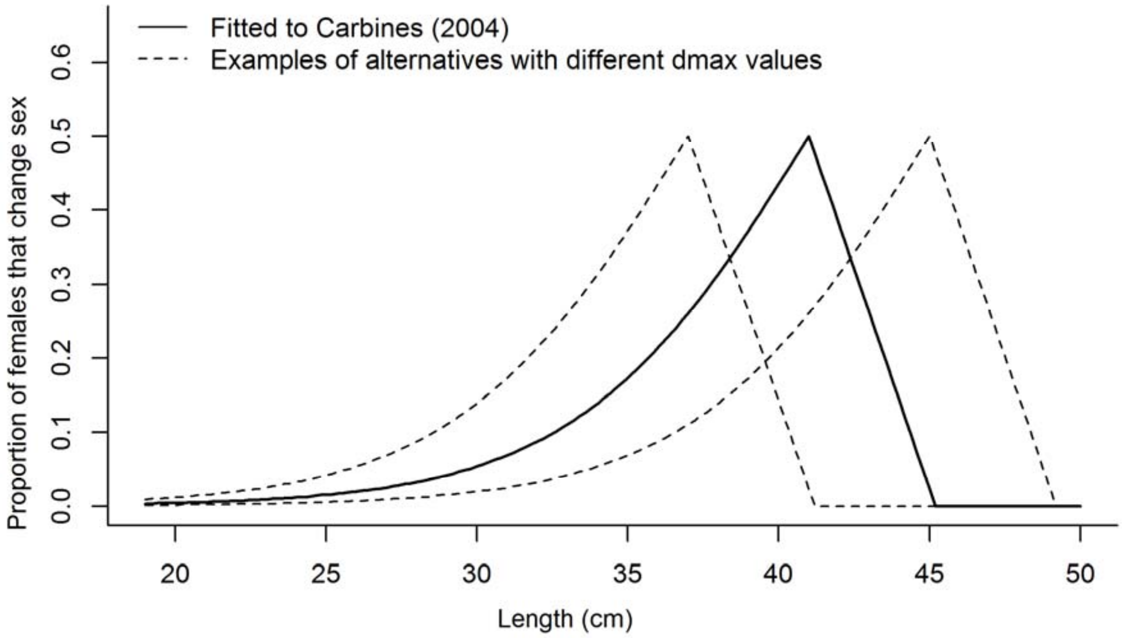


Figure 13: The form of the relationship for proportion of females changing sex at length. The solid line shows the function fitted to the 1995 data (see Section 2.6.2), and the dashed lines show two variants where the relationship is shifted along the length axis (as a result of different *dmax* values).

Table 12: Model parameter priors and assumed distributions for fitting to model data

	Distribution	Distribution parameters
<u>Model parameters:</u>		
M	Normal	Mean: 0.14 Std. dev: 0.015
S-R steepness	Beta (defined on 0.2 – 1.0)	Mean: 0.75 Std. dev: 0.10
Recruitment variation	Normal-log	Std. dev: 0.60
1995 sex-change dmax	Normal-log	Mean: ln(410) Std. dev: 0.05
<u>Data:</u>		
Logbook LF	Multinomial	N: 100
Shed samples LF	Multinomial	N: 100
Mesh size trials LF	Multinomial	N: 100
Recreational catch LF	Multinomial	N: 100
Recreational landings LF	Multinomial	N: 100
Survey LF	Multinomial	N: 100
CPUE	Normal-log	Std. dev: 0.20
Survey Z –Area 025	Normal-log	Mean: -0.782 Std. dev: 0.178
Survey Z –Area 030	Normal-log	Mean: -0.991 Std. dev: 0.173
DUV LegalN	Normal-log	Mean: 15.163 Std. dev: 0.300

3.2 DEVELOPING A *BASE CASE*

Numerous model runs were conducted to develop a base case for a MSE operating model. An *initial base case* was developed and presented to the SINS, along with model sensitivities. The SINS requested additional investigations, which led to model refinements and agreement on the appropriate model structure for the *base case* operating model (as described in the previous section) and for sensitivities to that structure.

The key issues explored though the initial model runs were: the dynamics of sex-change; what assumptions to make about LF data from the logbook and shed sampling programmes; and the apparent asymptotic survey selectivity.

Investigation of the samples collected through the logbook and shed sampling programmes suggested that the logbook programme was likely to be as good as, or better than, the shed sampling programme at obtaining representative samples of the fishery (see Section 2.2.1), so the SINS decided that both shed and logbook data should be fitted in the model as representative of the catch.

Fishery independent potting survey LF data were included in the model for Areas 025 and 030. Model fits to the survey LF data strongly support dome-shaped selectivity for the surveys. When asymptotic selectivity is modelled, fits to the LF data are much degraded. Previous blue cod survey analyses have assumed that the potting surveys are non-selective for fish above the MLS (e.g. the *Z* analyses assume knife-edge selectivity above the assumed age of recruitment to the fishery), which is supported by the comparison of potting survey and DUV LFs (see Section 2.2.5). However, because of the degradation in model fits when asymptotic survey selectivity is assumed, the assumption of domed survey selectivity was retained.

The final base case model structure is described in Section 3.1. Sensitivity to assumptions of this model structure (MPD fits only) included:

- Alternative weighting for the LF and CPUE data.
- Alternative recreational catch and bait usage assumptions (Appendix Tables A.2 to A.4).
- Removing the shed sampling data from the model fits.
- Modelling the recreational fishery selectivity ogive as a non-asymptotic function.
- Removing the DUV abundance estimate (Area 025) from the model fit.
- Fish recruiting to the model at age 2.
- Assuming a standard deviation of YCS of 0.4.
- Doubling discard mortality estimates.

There was little sensitivity in key model outputs to the alternative assumptions tested in the sensitivity runs. The sensitivity runs, selected by the SINS to be carried through to MCMCs and stock projections, are: sex-change power parameter (δ) fixed at values of 0.2 and 0.6 and a low recreational catch scenario.

3.3 MPD RESULTS

The *base case* model was fitted for Areas 025, 027, and 030, using the data available for each area (Table 13). Only a subset of model diagnostics are presented for the modes of the posterior distributions (MPDs), with additional diagnostics presented for the posterior distributions.

Overall, the Area 025 *base case* fits to the LF data are quite good (Figure 14), noting that both shed and logbook LF data are assumed to represent the commercial catch. Fits to the frequency of fish in the 34–35 cm range are variable: the model underestimates these frequencies for fits to male and female shed LFs and male potting survey LFs, and overestimates the frequencies for fits to the logbook LF data. Fits to the declining right hand side of the LFs is generally good, with some lack-of-fit indicated for male shed sample LFs.

Modelling results suggest highly domed selectivity for the pre-1993 commercial pot fishery and for the survey (Figure 15). The post-1993 commercial pot selectivity is quite steep around the MLS but suggests that less than half of fish at the MLS (33 cm) are selected. The recreational fishery has a very broad range of partial selectivity, indicating targeting of the largest fish in the population.

The lack-of-fit to fish in the 34–35 cm range is less evident in the fits to the Area 027 LF data, where there is no survey LF data (Figure 16). Overall there is no pattern to the residuals. The Area 027 selectivity and retention ogives (only fitted for the recreational fishery) are similar to those from Area 025 (Figure 17).

The Area 030 *base case* fits to the LF data are generally good, though males in the 32–36 cm range are underestimated for the survey as are fish in the 33–39 cm range for the recreational catch (Figure 18). The estimated selectivity and retention ogives for Area 030 are similar to those for Area 025.

The estimated amount of mortality associated with fishery discards is low relative to the amount of catch landed (Table 14). For the commercial line fishery, it amounts to about 4% of the landings for the *base case* discard mortality assumption. Discard mortality estimates are highest for the pre-1993 commercial pot fishery, ranging from 11% to 14% of landings. The post-1993 commercial pot fishery discard estimates are lower because the change in selectivity more than compensates for the increased MLS. For the recreational fishery, the increase in MLS from 30 to 33 cm results in an increase in discard mortalities from less than 1% to about 3% of the landings.

The model predicted mean weight of blue cod harvested in the recreational fishery is higher in Area 025 than in Areas 027 and 030, and variable over the 1990–2000 period as a result of recruitment fluctuations (Table 15). These model predicted values are close to or within the range of mean weights assumed for the BCO 5 Marine Recreational Fisheries Survey conversions of numbers landed to biomass landed (Table 15).

Table 13: Data series fitted in the stock assessments for Areas 025, 027, and 030.

Data type	Series	Area 025	Area 027	Area 030
LF data:	Shed	✓	✓	-
	Logbook	✓	✓	✓
	Survey	✓	-	✓
	Mesh sel. trials	Data common to all areas		
	Rec. landings	Data common to all areas		
	Rec. catch	Data common to all areas		
Abundance Index:	CPUE	✓	✓	✓
	Survey *Z*	✓	-	✓
	DUV abundance	✓	-	-
Biological:	Sex-change	Data common to all areas		
	Growth	From survey data	From Area 025	From survey data

Table 14: Discard mortality relative to catch mortality estimates (average biomass of discard mortalities/average biomass of landings) for the Area 025, Area 027 and Area 030 *base case* runs.

Fishery	Area 025	Area 027	Area 030
Commercial line	0.038	0.037	0.045
Commercial pot <=1992	0.137	0.123	0.113
Commercial pot >=1993	0.056	0.032	0.052
Recreational <=1992	0.004	0.007	0.008
Recreational >=1993	0.024	0.030	0.034

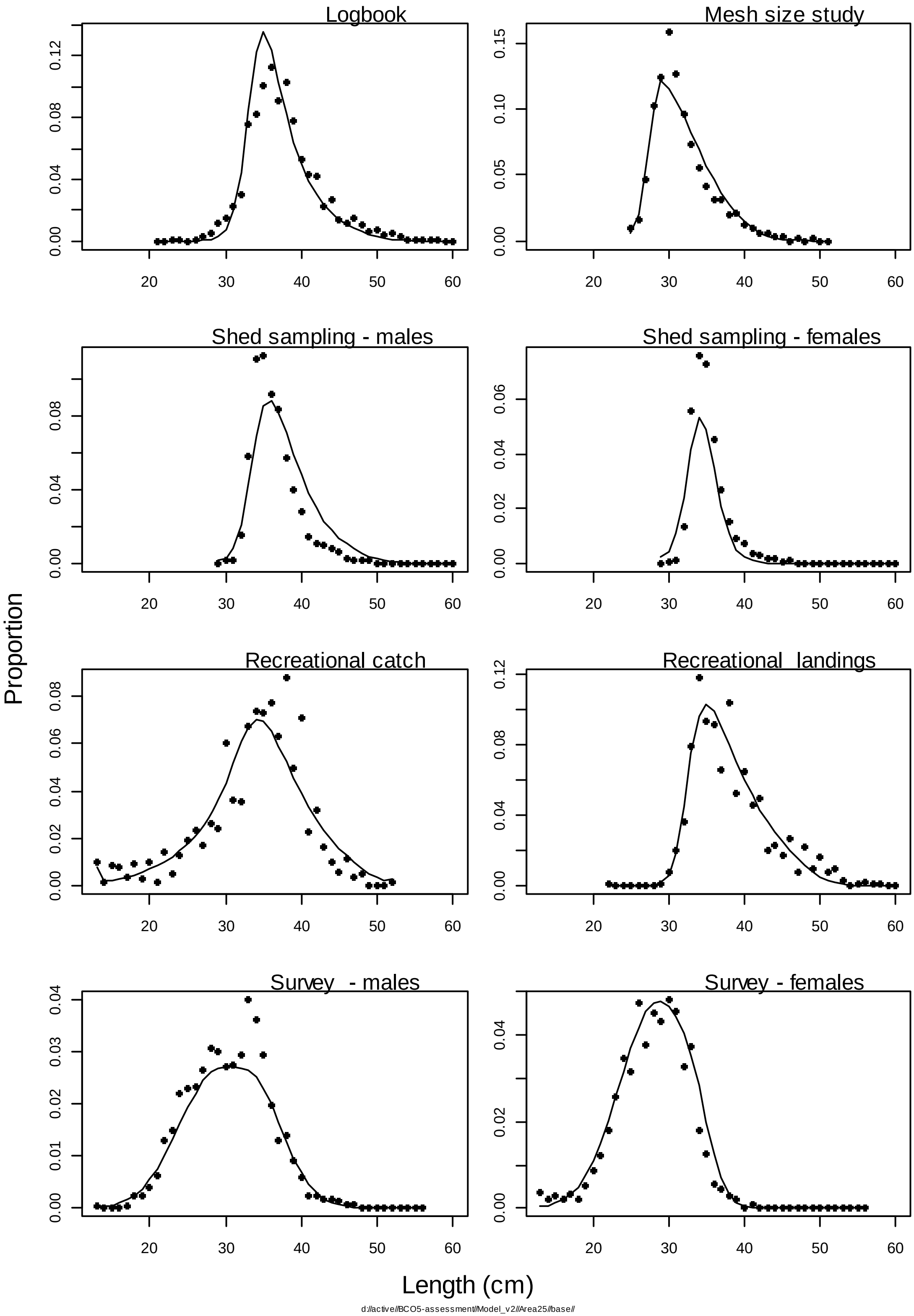


Figure 14: Area 025 *base case* model fits to the length-frequency data sets.

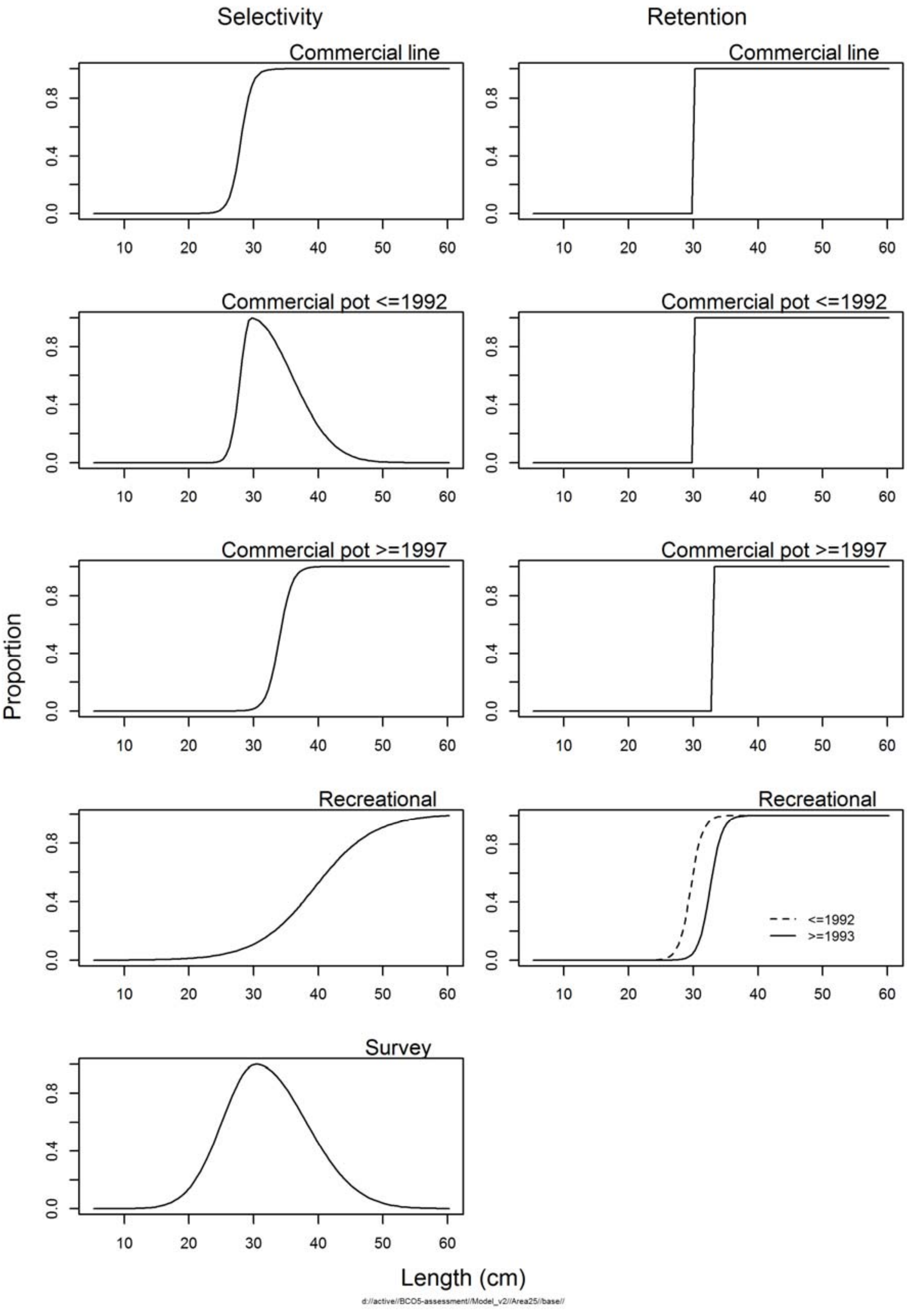


Figure 15: Estimated selectivity and retention ogives for the fisheries and potting survey from the *base case* fit to the Area 025 data. Note that the commercial line selectivity ogive and the commercial line and commercial pot retention ogives are fixed rather than estimated in the analysis.

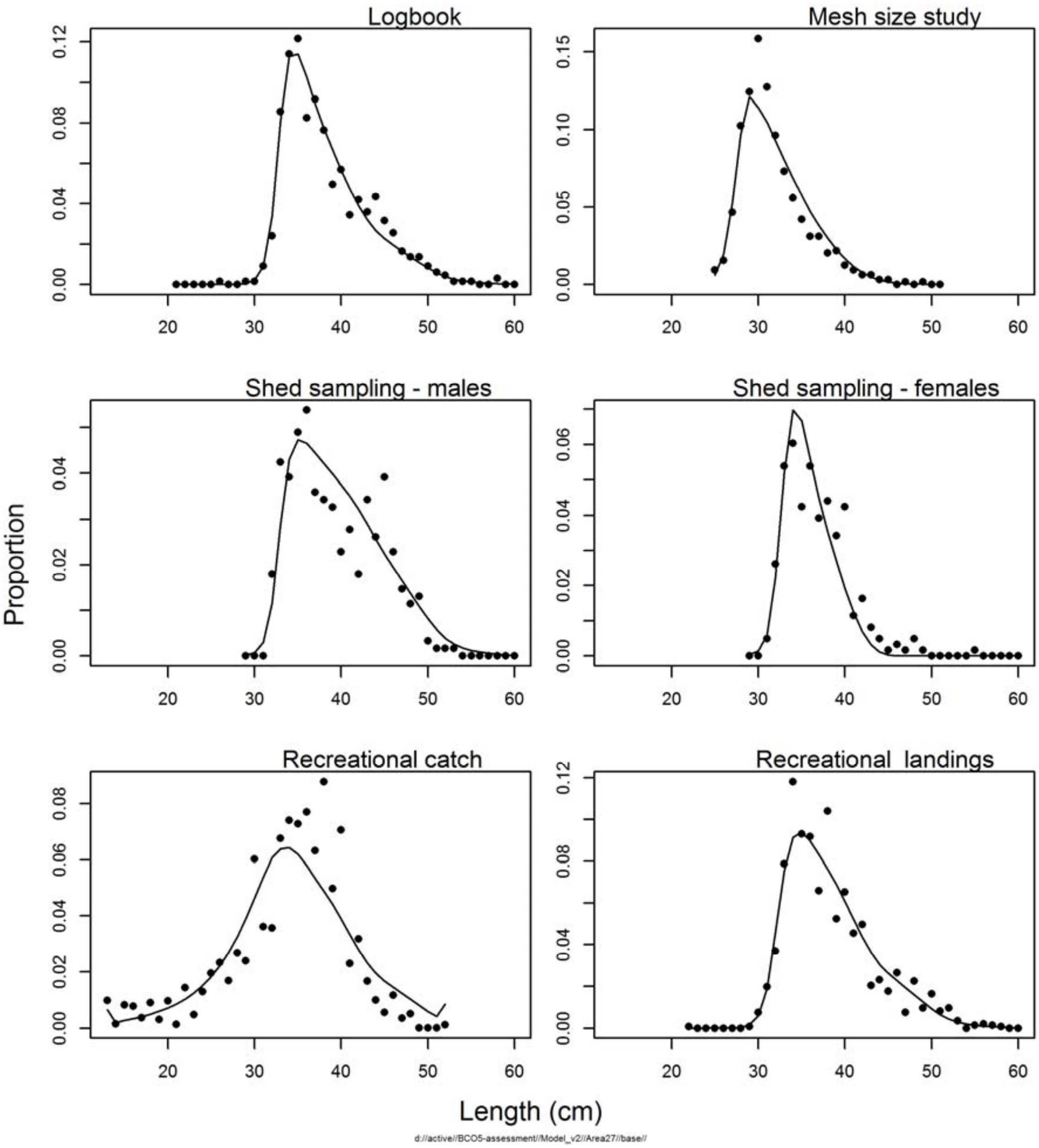


Figure 16: Area 027 *base case* model fits to the length-frequency data sets.

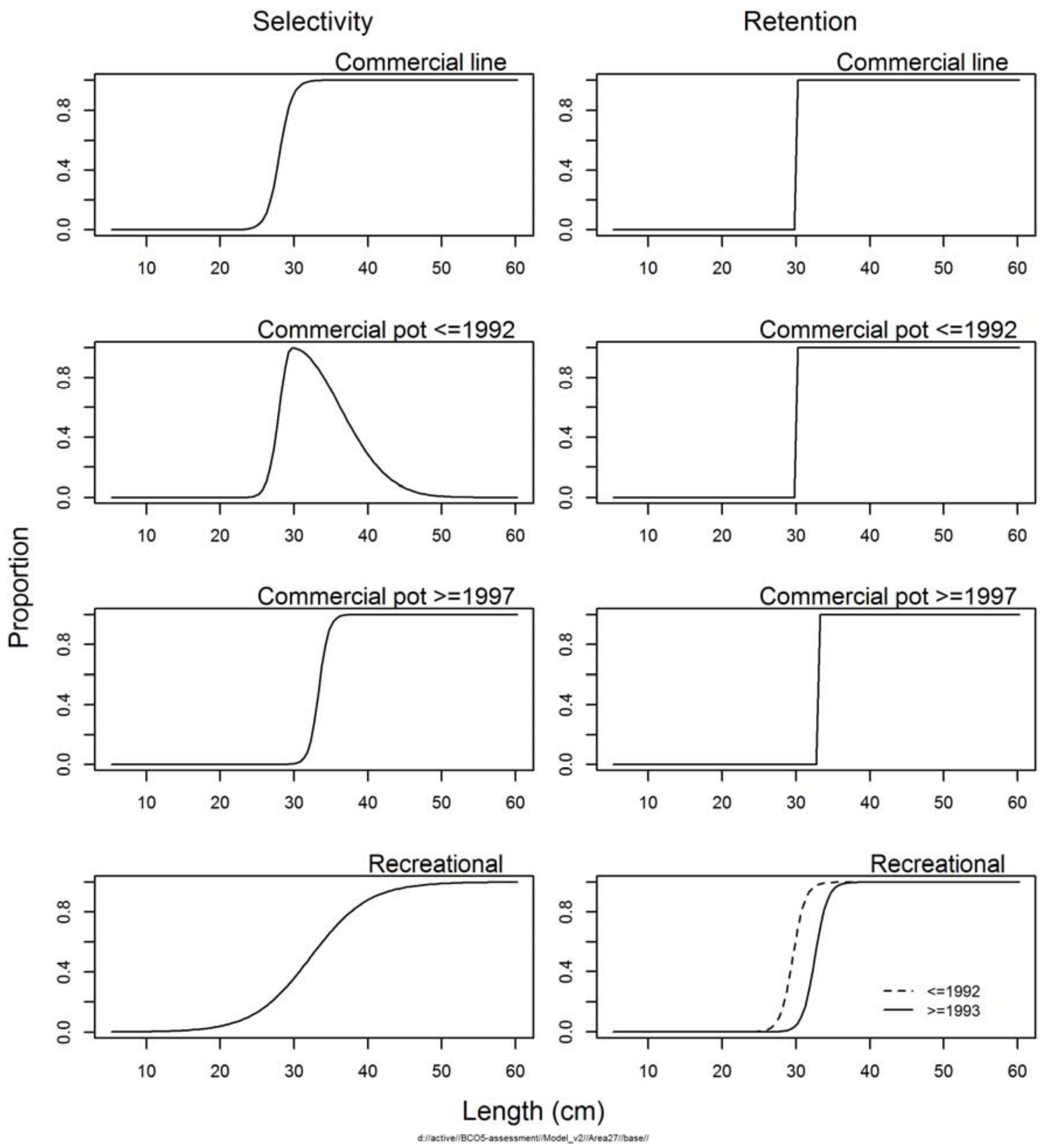


Figure 17: Estimated selectivity and retention ogives for the fisheries from the *base case* fit to the Area 027 data. Note that the commercial line selectivity ogive and the commercial line and commercial pot retention ogives are fixed rather than estimated in the analysis.

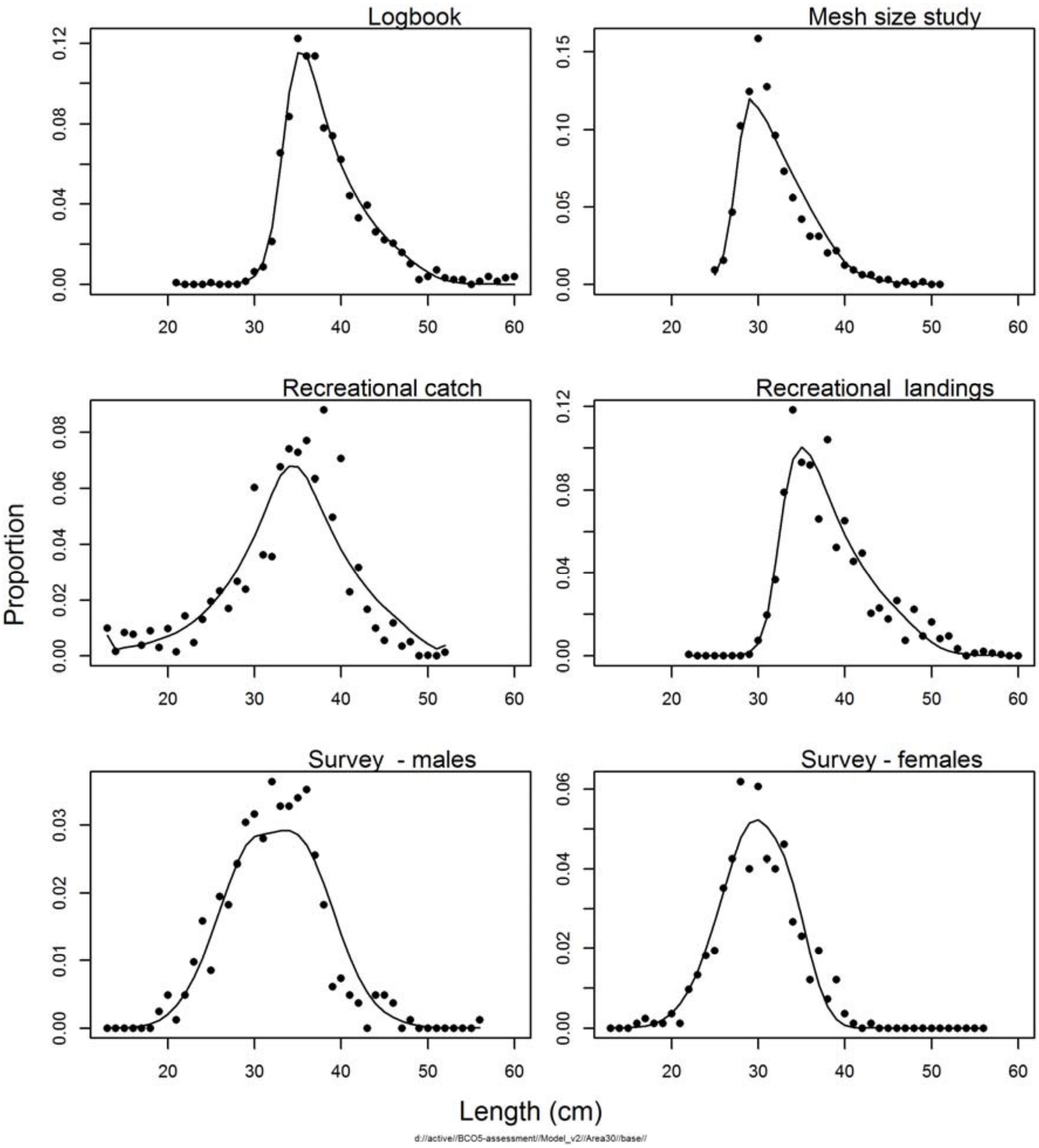


Figure 18: Area 030 *base case* model fits to the length-frequency data sets.

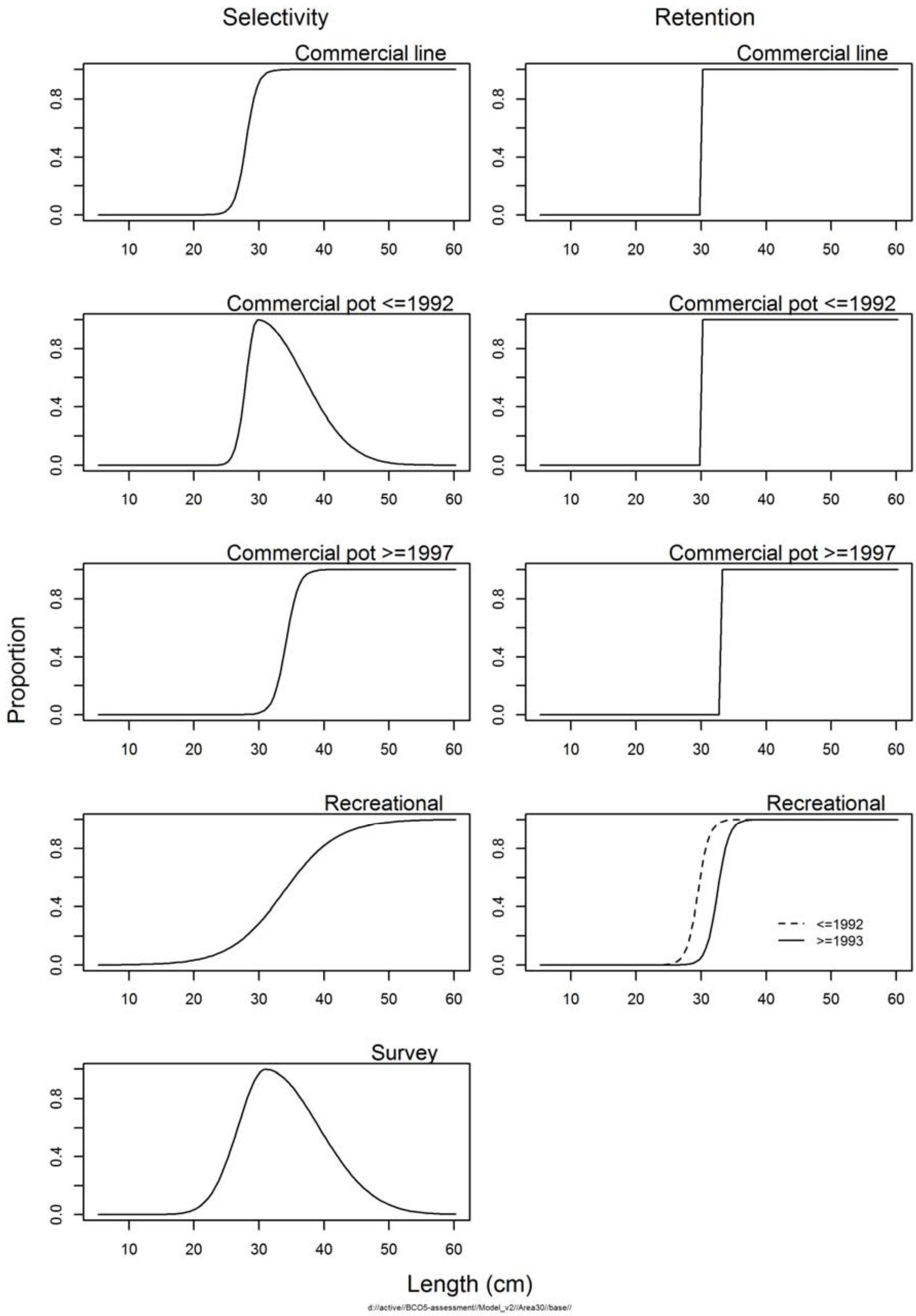


Figure 19: Estimated selectivity and retention ogives for the fisheries and potting survey from the *base case* fit to the Area 030 data. Note that the commercial line selectivity ogive and the commercial line and commercial pot retention ogives are fixed rather than estimated in the analysis.

Table 15: Model predicted mean weight (kg) of blue cod harvested in the recreational fishery from the *base case* model runs, and mean weights (kg) assumed in the recreational fishery surveys.

	Model predicted			Survey assumed	
Year	Area 025	Area 027	Area 030	Year(s)	Range
1990	1.33	1.09	1.08	1991/1992	0.94–1.25
1991	1.36	1.11	1.09	1996	1.10–1.43
1992	1.40	1.12	1.10	1999/2000	1.11–1.98
1993	1.51	1.24	1.22		
1994	1.51	1.23	1.22		
1995	1.48	1.21	1.19		
1996	1.40	1.18	1.12		
1997	1.27	1.12	1.00		
1998	1.13	1.03	0.90		
1999	1.03	0.95	0.84		
2000	0.97	0.91	0.83		

3.4 MCMC RESULTS

Bayesian posterior distributions were estimated for the *base case* and sensitivity trials using the ADMB Markov-chain Monte Carlo (MCMC) algorithm: chains of length 1 million were run and thinned to samples of 1000. Results are presented as medians of the marginal posterior distributions.

Trace plots along with the running median, 5th quantile and 95th quantile of the marginal posterior distribution are shown for key model and derived parameters in Figure 20 to Figure 22. MCMC convergence is good, with chains well mixed and no trends in model or derived parameters. These results are consistent across the three Statistical Areas.

Time series of the marginal posterior distributions of male and female spawning stock biomass and recruitment are shown in Figure 23 for the three areas. Stock trends are similar among the three areas: abundance decreases from 1900 through the mid-1930s when catches declined; over the next decade abundance increases somewhat and then declines again in response to fluctuations in catches; abundance is then relatively stable through to 1980 when increased catches again result in stock declines; a series of strong recruitment in the early 1990s results in a short-term increase in abundance with a subsequent declining trend to present. Male and female spawning biomass trends are similar, with slightly higher male abundance.

The recruitment time series, estimated for 1980–2010, are also similar among the Statistical Areas (Figure 23). This similarity may result from similar trends in the CPUE time-series as there are no LF time-series to help inform relative year-class strengths.

Model fits to the CPUE data are generally good (Figure 23). The model predicts a slight decrease in CPUE as a result of the MLS increase from 30 cm to 33 cm in 1993, and an increase in CPUE as a result of the change to the pot mesh size (and escape gap) regulation at the same time. The predicted CPUE increase happens because the estimated pot selectivity prior to the change is highly domed - a change to asymptotic selectivity increases the proportion of the populations vulnerable to the potting gear. The MLS increase came into effect in 1992, and is modelled as occurring in 1993 (the 1992/93 fishing season). The change in pot regulations was more complex: a regulation introduced in 1992 required either 50 mm mesh or escape gaps in the pots but this was changed to a requirement for 48 mm mesh in 1994 (Warren et al. 1997). The change in potting selectivity is modelled as occurring gradually between 1993 and 1997. This allows the model to fit the CPUE reasonably well.

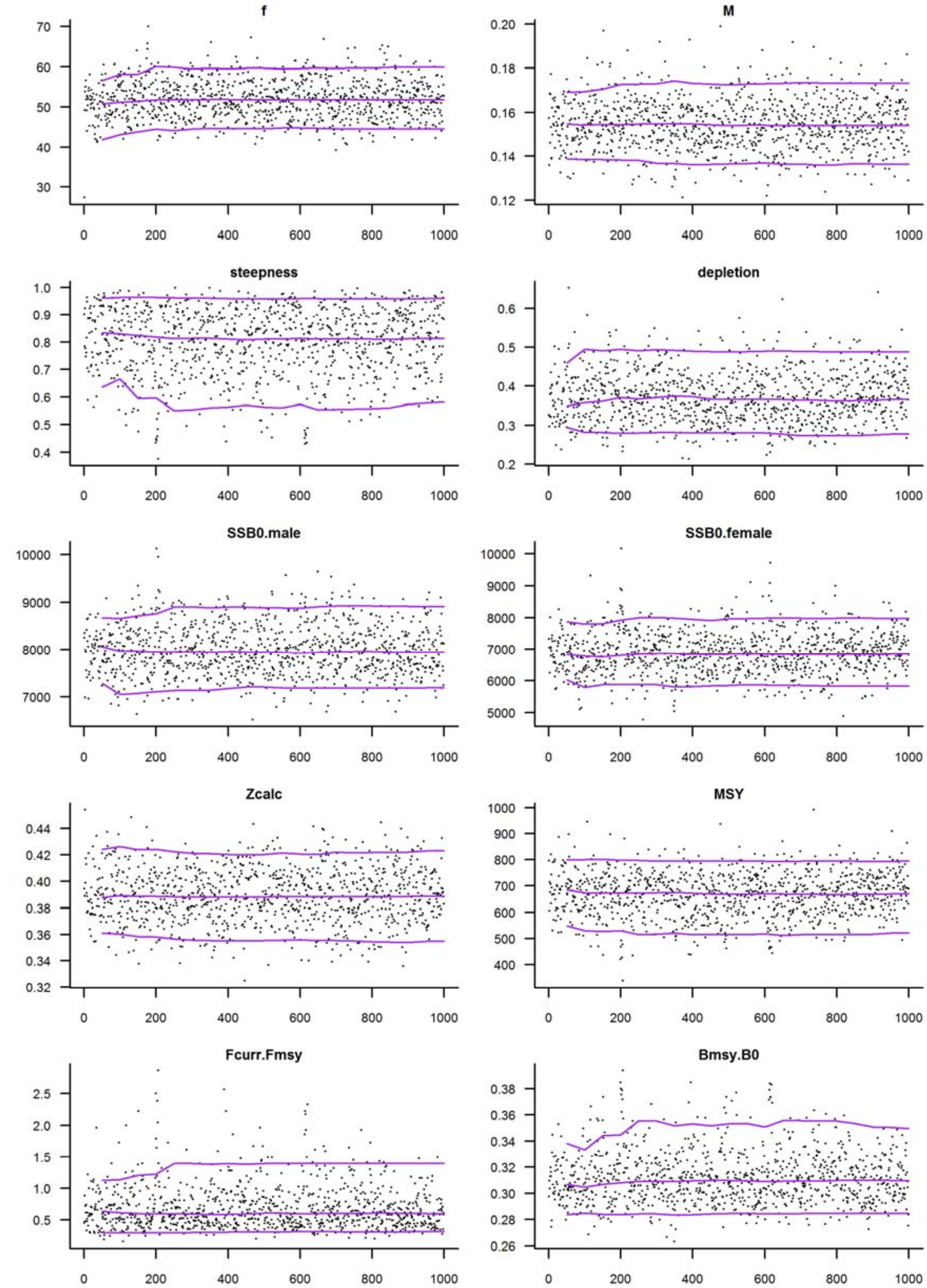


Figure 20: MCMC traces of key model and derived parameters for the Area 025 *base case* run. Running 5th, median, and 95th quantiles of the distribution, calculated for a set of 40 values, are shown with solid lines.

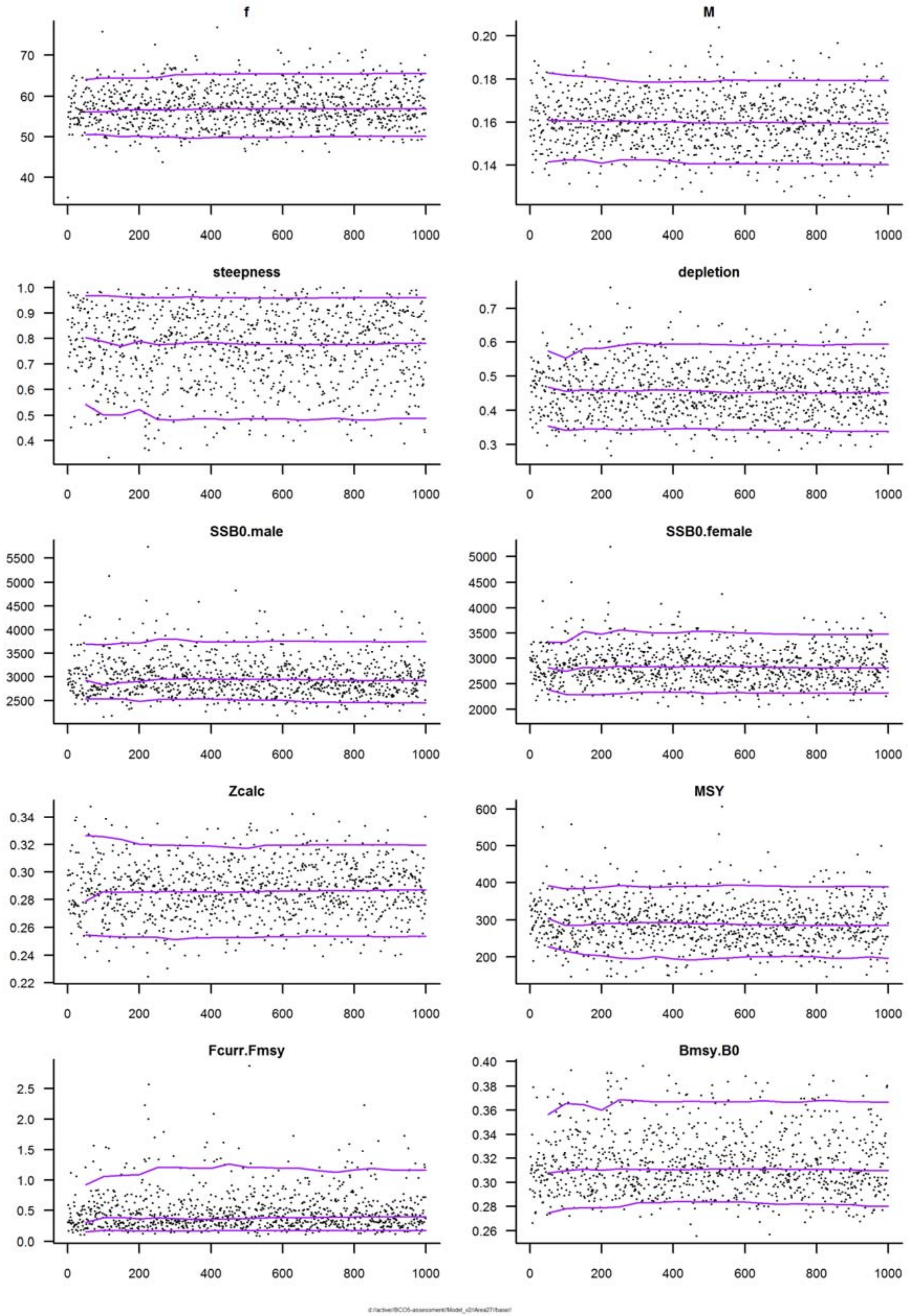


Figure 21: MCMC traces of key model and derived parameters for the Area 027 *base case* run. Running 5th, median, and 95th quantiles of the distribution, calculated for a set of 40 values, are shown with solid lines.

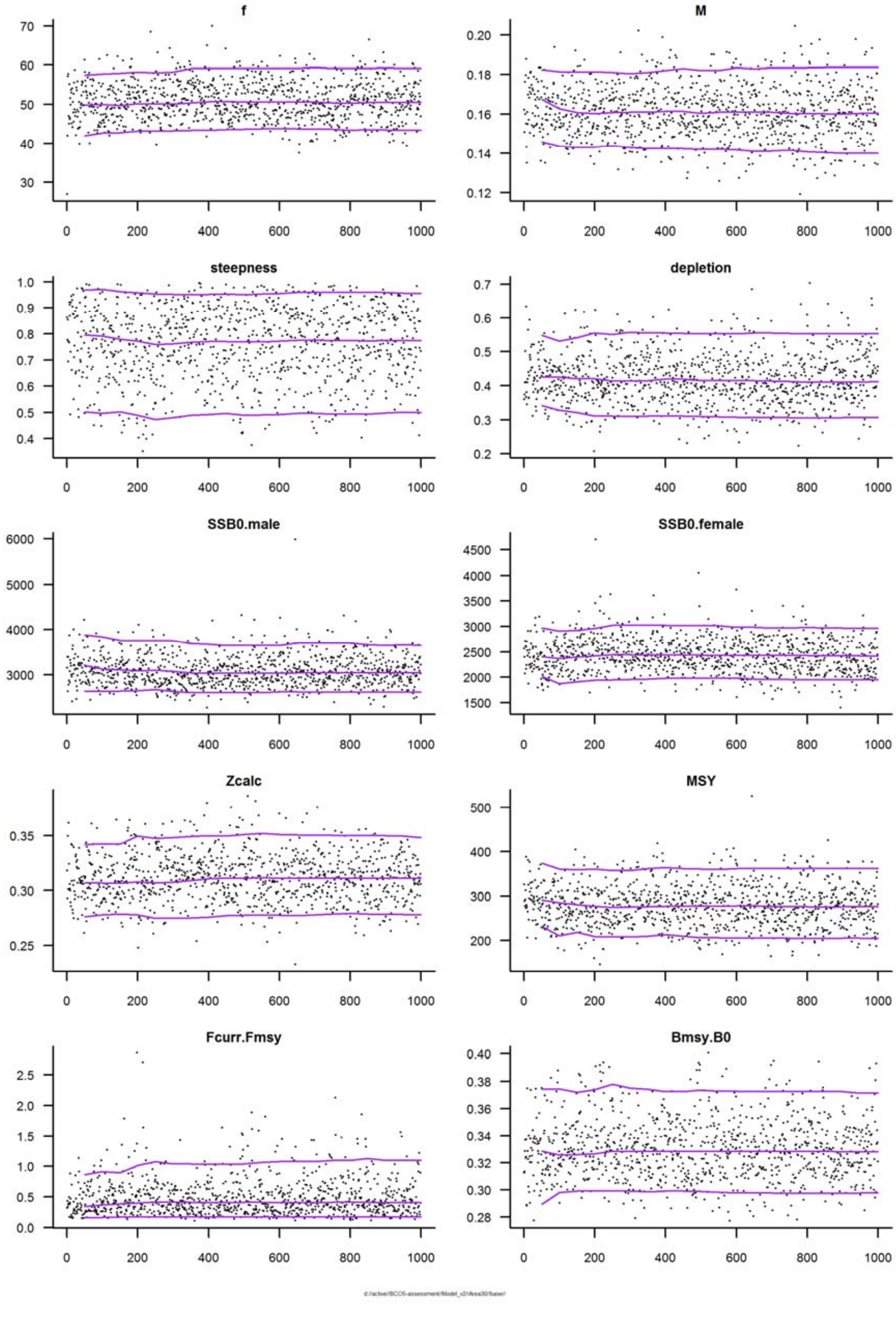


Figure 22: MCMC traces of key model and derived parameters for the Area 030 *base case* run. Running 5th, median, and 95th quantiles of the distribution, calculated for a set of 40 values, are shown with solid lines.

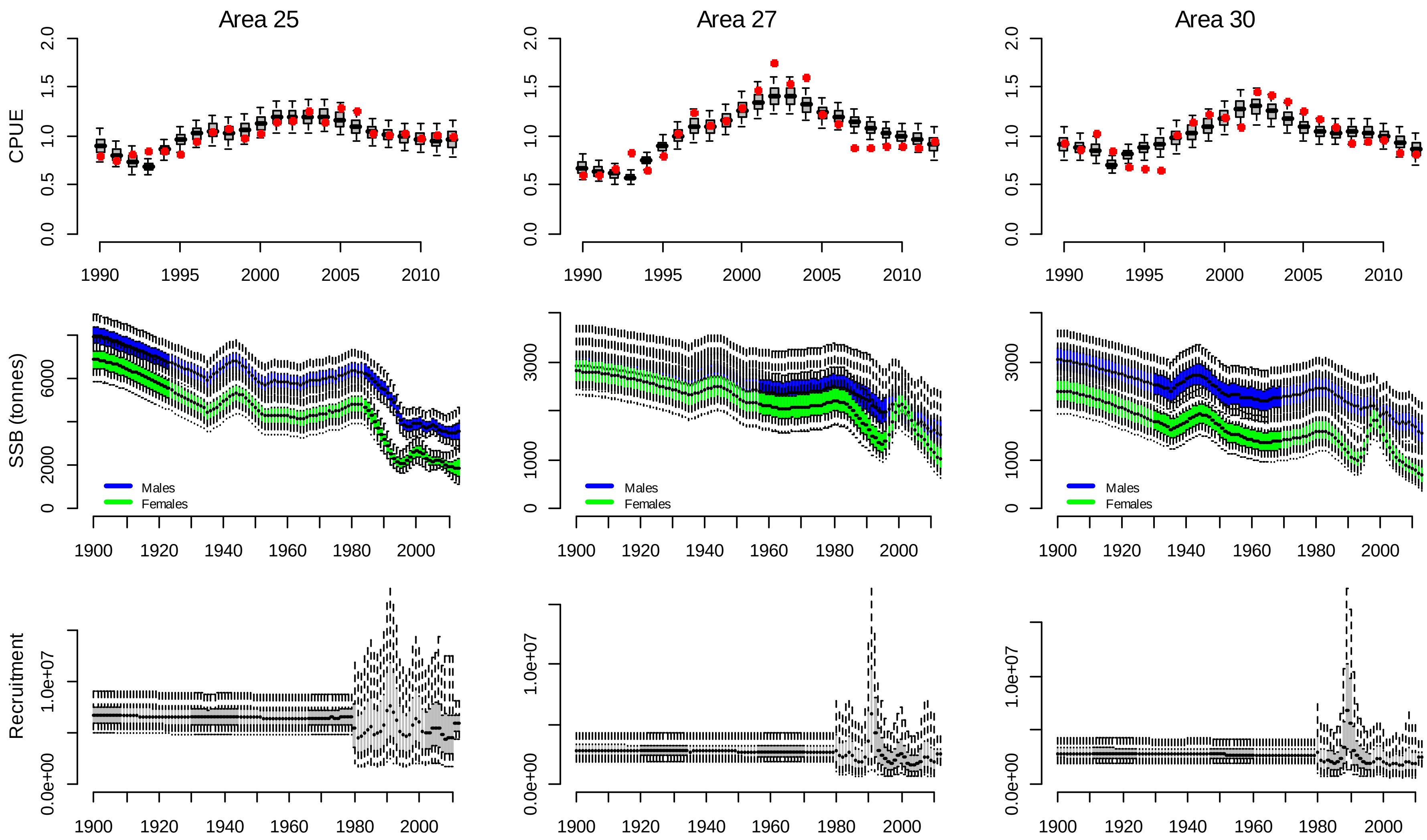


Figure 23: Quantile plots (solid line is median; boxes show the inter-quartile range; and whiskers show the 5th and 95th quantiles) of the marginal posterior distributions of: the predicted CPUE (top panel, red dots show the observed CPUE); the male and female spawning stock biomass (SSB, mid panel); and recruitment time series (bottom panel) for the Area 025, Area 027, and Area 030 base case models.

In Figures 24 to 26 marginal posterior distributions for key model parameters (*M* and steepness) are compared with their prior distributions and for derived parameters (Survey *Z* estimates and DUV abundance) are compared with their probability density functions. Results are generally similar among areas. The posterior distributions of *M* are shifted to higher *M* values relative to their prior distributions with the modes of the distributions between 0.16 and 0.17. Model estimates of mean *Z* (2002–2010, for fish over the MLS) are shifted to lower values and are more tightly distributed than their prior distributions (Statistical Areas 025 and 030). This implies that the stock reconstruction estimates of fishing mortality rates are lower than those that are obtained from potting survey analyses. The marginal posterior distributions of steepness are very similar to their prior distributions, which is not surprising given that there is little information in the data to inform this parameter.

A DUV-derived estimate of the absolute abundance of legal-sized blue cod is only available for Area 025. The marginal posterior distribution of the model-predicted DUV abundance is fairly similar to its prior, though the median is shifted to a slightly higher value (Figure 24).

The posterior density for stock depletion $\left(B_{curr}/B_0\right)$ is mostly in the range of 0.25 to 0.5 for Statistical Area 025 and in the range of 0.3 to 0.6 for Statistical Areas 027 and 030. The current fishing mortality rate $\left(F_{curr}\right)$ has a high probability of being less than $\left(F_{msy}\right)$, in particular for Statistical Areas 027 and 030. For all areas, the posterior density for the ratio of B_{msy} to B_0 is largely in the range of 0.28 to 0.38 (Figures 24 to 26). Note that MSY is calculated assuming a deterministic stock-recruitment relationship with recreational and customary catches fixed at their 2011/12 levels.

Trajectories of fishing intensity ($F_{\%SPR}$) and spawning biomass ($\%B_0$) over the assessment period (1990–2012) are shown as medians of their posterior distributions in Figures 27 and 28 for the three assessment areas and for the BCO 5 QMA. Fishing intensity is measured in terms of the spawning potential ratio – the spawning biomass per recruit that would result from long-term fishing at each year's level relative to the spawning biomass per recruit in an unexploited population. This metric was chosen to represent fishing intensity because it is straightforward to combine across the three statistical areas to generate a BCO 5 summary.

The general pattern seen in all the fishing intensity versus spawning biomass figures is a steady decline in spawning abundance and increase in fishing intensity. For Area 025, fishing intensity was above the $F_{40\%}$ level during the 1990s and spawning biomass has been less than the $40\%B_0$ target in recent years. For the other Statistical Areas and for BCO 5 as a whole, the stocks have remained in the healthy zone.

3.5 SENSITIVITY TRIALS

In general, results from the sensitivity trials do not suggest very different stock productivity characteristics than the *base case* (Tables 16 to 18).

Results from model runs with alternative values for the sex-change power parameter show the influence of this parameter on the population's sex ratio. With a higher sex-change power value (0.6), the unexploited population sex ratios are close to 1:1 and the current mature biomasses are more depleted for females than for males. The lower sex-change power value (0.2) results in a higher proportion of males in the unexploited population and approximately equal levels of current depletion for males and females. Estimates of natural mortality (*M*), *MSY*, and B_{msy} relative to B_0 are not affected by the alternative sex-change power parameter values.

The *low recreational catch* sensitivity runs result in slightly lower initial abundance, in particular for Area 025 where much of the recreational catch is taken. This results in slightly greater levels of current depletion. Natural mortality and *MSY* estimates are not affected in the *low recreational catch* scenario.

Stock trends and fits to the CPUE time series are generally quite similar among the sensitivity trials and *base cases*, and are not presented graphically.

Spawning stock biomass and *MSY* estimates for the entire BCO 5 blue cod stock are calculated as the sum of the Areas 025, 027 and 030 estimates (Table 19). The B_0 and *MSY* estimates assume that the three Statistical Areas represent 92% of the blue cod stock.

4. STOCK PROJECTIONS

Ten-year stock projections were conducted for the three Statistical Areas at constant catch levels, and summary statistics calculated at the end of 5 and 10 years.

Commercial catch levels were based on the current TACC and the average BCO 5 Statistical Area catch split over the past 10 years (Table 20). Although only 90% of the BCO 5 TACC was caught on average over the past 10 years, with the reduction of the TACC to 1239 t in 2011/12 over 98% of the allowable catch was caught that year (Table 20). Therefore stock projections based on the full TACC being caught appears reasonable. Alternative catch scenarios were simulated with commercial catch increased and reduced by 20%. Recreational and customary catch was assumed to remain constant at the 2011/12 levels.

Recruitment was simulated by randomly re-sampling (with replacement) from the time series of recruitment deviations, applied to the stock-recruitment relationship. Two alternative recruitment scenarios were simulated: recent recruitments were re-sampled from the 2001–2010 recruitment deviations and long-term recruitments were re-sampled from the 1980–2010 recruitments.

Summary statistics were calculated for the BCO 5 FMA by summing B_0, B_{msy} and projection biomass estimates across the three Statistical Areas.

The projections indicate that under the assumptions of commercial catch at the current TACC and recruitment at recent levels, the BCO 5 biomass is unlikely to change much over the next 10 years (Table 21, Figure 29). Recruitments closer to the long-term average or a reduction in catch from the current TACC results in slight increases in biomass, and an increase in catch above the TACC results in a slight decrease in biomass.

The projections indicate that the population sex ratio, as measured by proportion male, will not change much over the projection period under the alternative assumptions of recruitment or catch levels (Table 22).

The probabilities of the projected spawning stock biomass (2018 and 2023) being below the hard limit of 10%B_0, the soft limit of 20%B_0, the target of 40%B_0, and 25%, 50% and 100% of B_{msy} are presented in Table 23 for the base case model with recent or long-term recruitment and three different catch levels, and for the sensitivity runs with recent recruitment and commercial catch at the current TACC. With catches at the current TACC, the probability of the stock being less than either the soft or hard limit over the next five years is negligible.

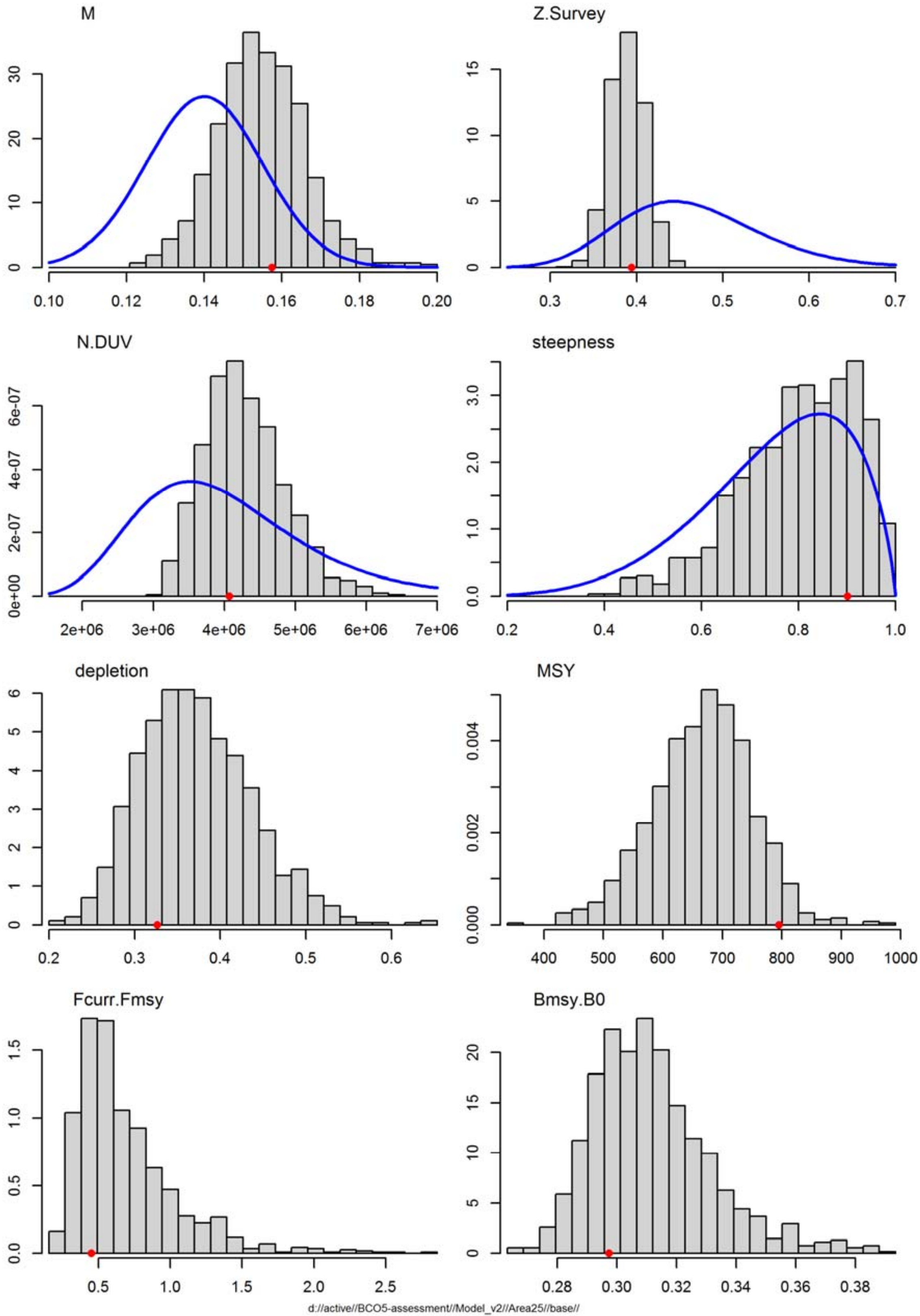


Figure 24: Marginal posterior distributions of key model parameters for the Statistical Area 025 *base case* model run. Prior distributions (*M*, steepness) and pdfs (N.DUV, *Z*.Survey) are shown with the solid blue lines, and the MPD values with red dots. Results are shown for: natural mortality (*M*); survey-derived *Z* (*Z*.Survey); DUV-derived abundance (N.DUV); stock-recruit steepness, stock depletion, MSY, current F relative to F_{msy} ($F_{curr}.F_{msy}$); and B_{msy} relative to B_0 ($B_{msy}.B_0$).

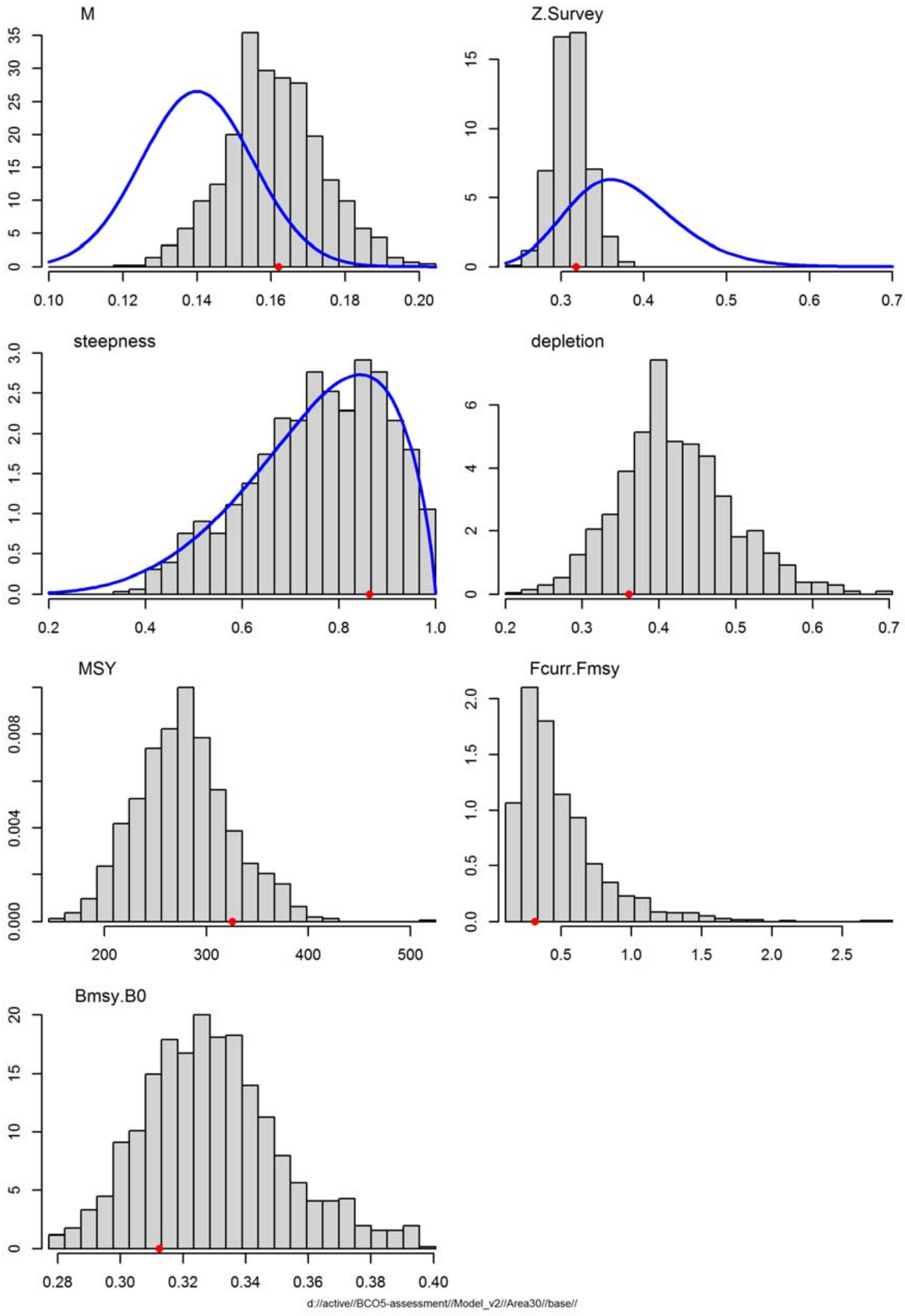


Figure 25: Marginal posterior distributions of key model parameters for the Statistical Area 027 *base case* model run. Prior distributions (*M,* steepness) are shown with the solid blue lines, and the MPD values with red dots. Results are shown for: natural mortality (*M*); stock-recruit steepness, stock depletion, MSY, current F relative to F_{msy} ($F_{curr}.F_{msy}$); and B_{msy} relative to B_0 ($B_{msy}.B_0$).

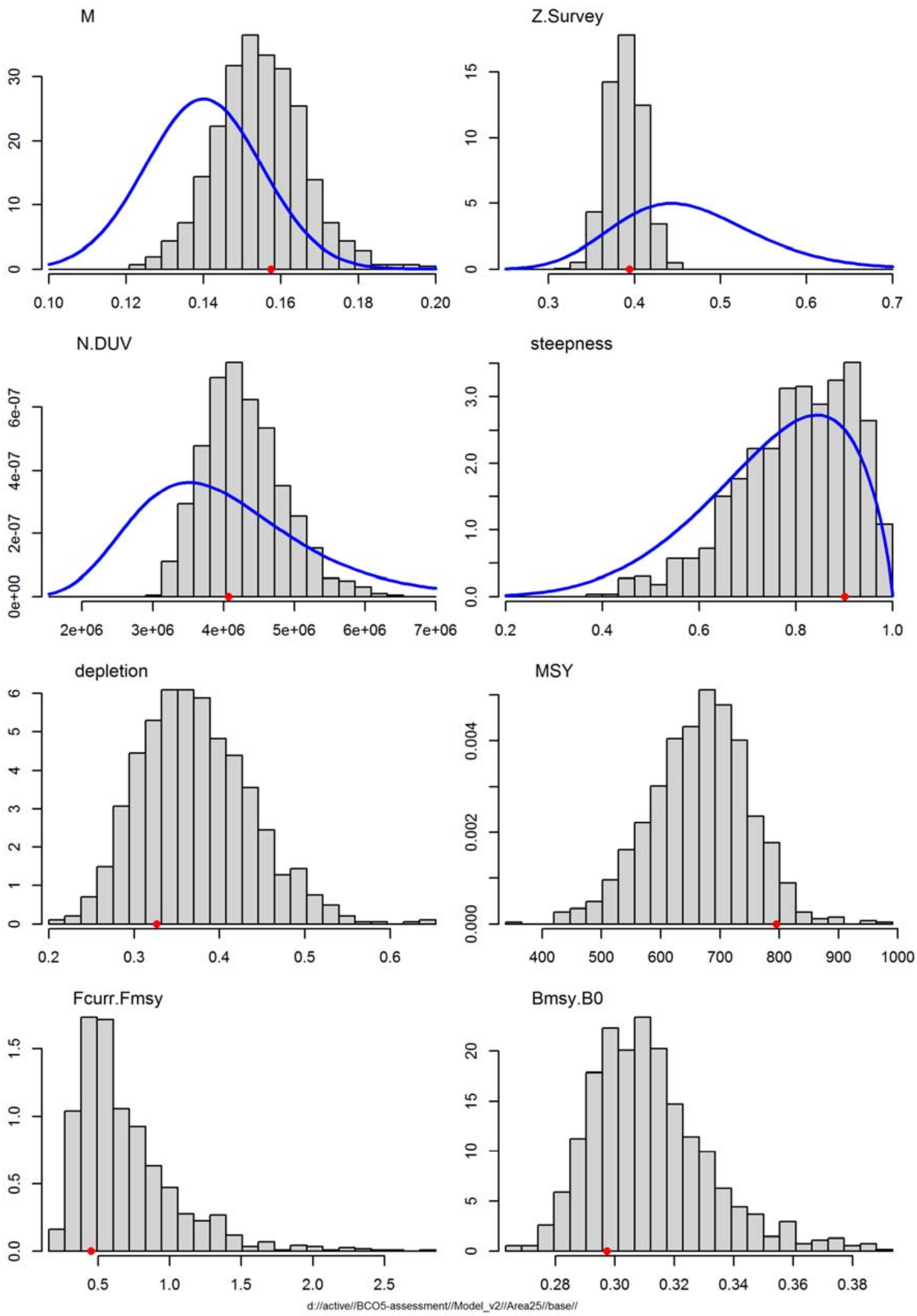
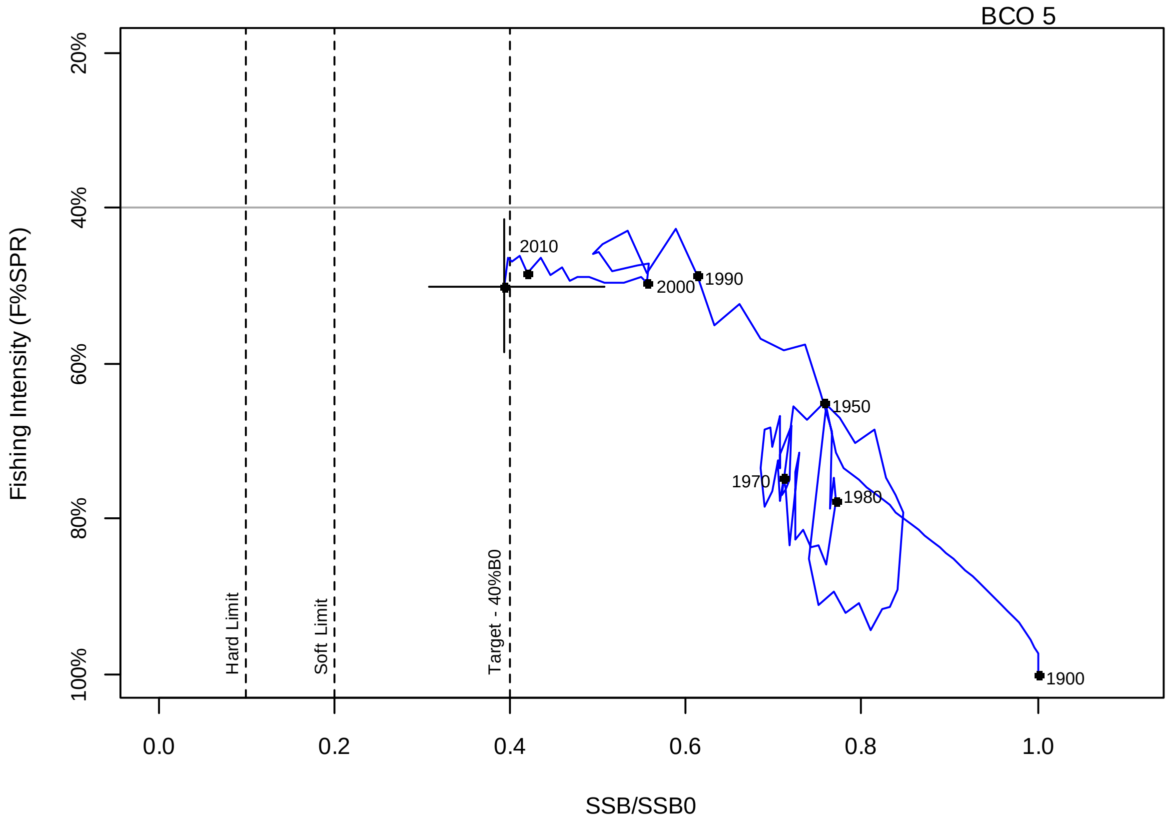


Figure 26: Marginal posterior distributions of key model parameters for the Statistical Area 030 *base case* model run. Prior distributions (*M*, steepness) and pdfs (*Z*.Survey) are shown with the solid blue lines, and the MPD values with red dots. Results are shown for: natural mortality (*M*); survey-derived *Z* (*Z*.Survey); stock-recruit steepness, stock depletion, MSY, current F relative to F_{msy} ($F_{curr}.F_{msy}$); and B_{msy} relative to B_0 ($B_{msy}.B_0$).



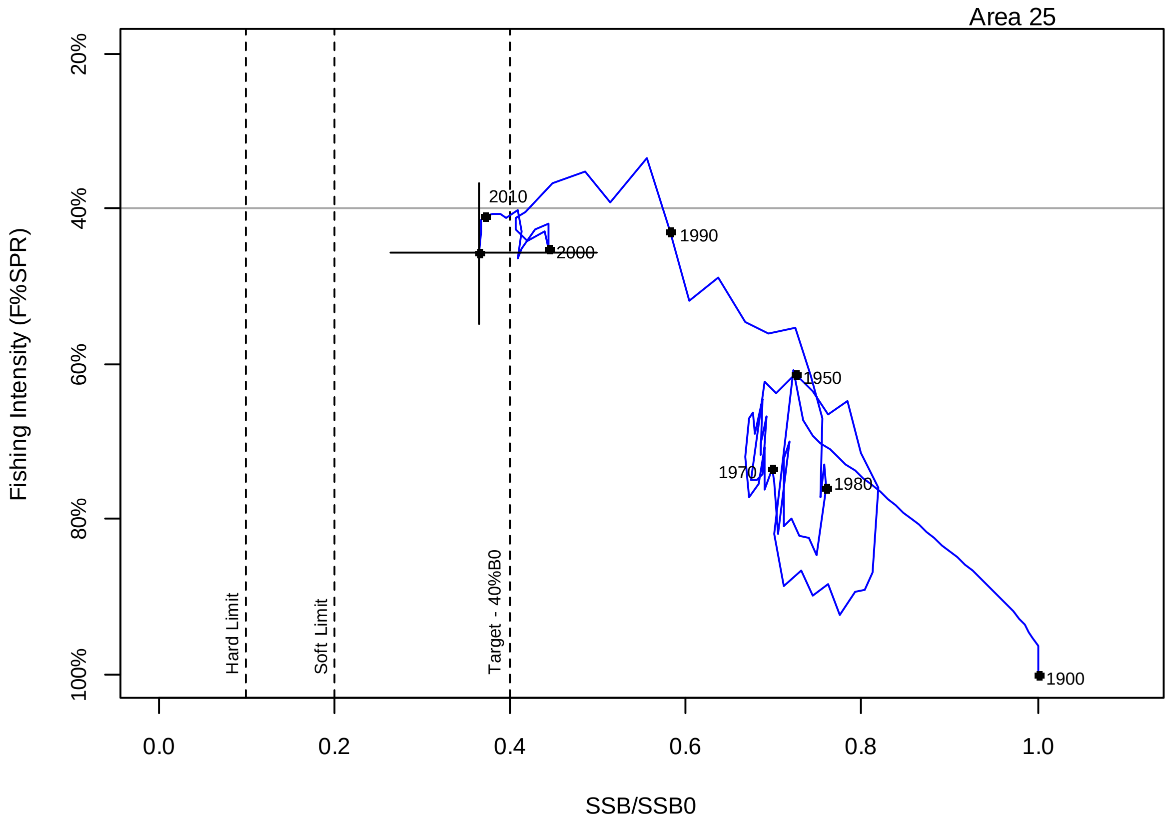


Figure 27: Trajectory of fishing intensity ($F_{\%SPR}$) and spawning biomass ($\%B_0$) for Area 025 and BCO 5 from the start of the assessment period in 1900 to 2013. The vertical lines at 10%B_0, 20%B_0 and 40%B_0 represent the soft limit, the hard limit and the target, respectively. Estimates are based on MCMC medians and the 2013 90% CI is shown by the crossed lines.

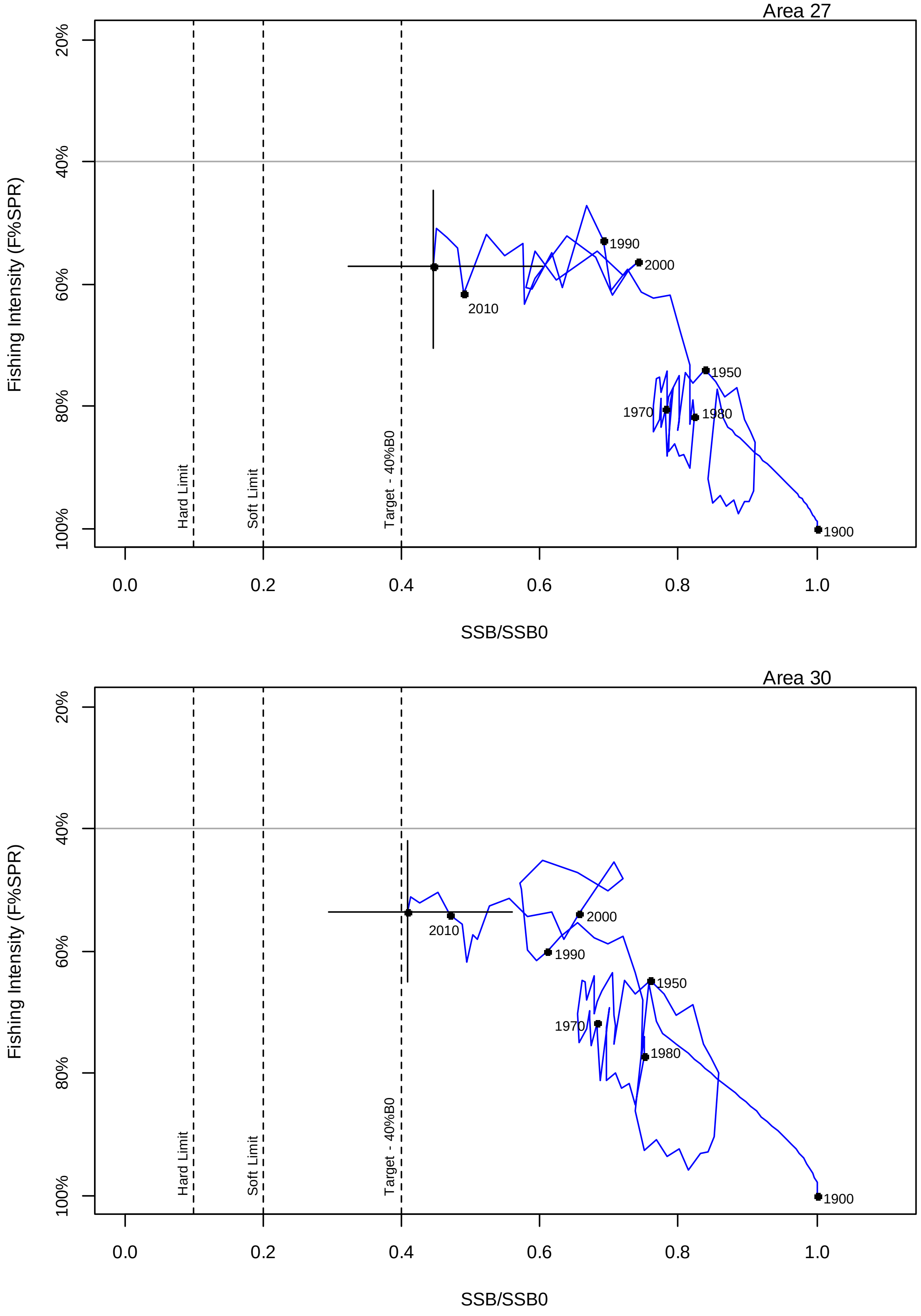


Figure 28: Trajectory of fishing intensity ($F_{\%SPR}$) and spawning biomass ($\%B_0$) for Area 027 and Area 030 from the start of the assessment period in 1900 to 2013. The vertical lines at $10\%B_0$, $20\%B_0$ and $40\%B_0$ represent the soft limit, the hard limit and the target. Estimates are based on MCMC medians and the 2013 90% CI is shown by the crossed lines.

Table 16: Median of marginal posterior distributions for Statistical Area 025 *base case* and sensitivity runs.

	Base case	Sex-change pow=0.2	Sex-change pow=0.6	Low Rec. catch
B_0	14 794	15 142	14 368	13 597
B_0-male	7 942	9 689	7 014	7 269
B_0-female	6 852	5 453	7 354	6 328
B_{curr}/B_0	0.37	0.36	0.35	0.36
B_{curr}/B_0 - male	0.45	0.37	0.47	0.45
B_{curr}/B_0 - female	0.27	0.36	0.23	0.27
MSY	671	658	668	675
F_{curr}/F_{msy}	0.60	0.63	0.61	0.57
B_{msy}/B_0	0.31	0.31	0.30	0.31
M	0.15	0.16	0.15	0.16
*Z*est	0.39	0.39	0.40	0.40
Steepness	0.81	0.83	0.80	0.82
Objective function value	52	52	52	51

Table 17: Median of marginal posterior distributions for Statistical Area 027 *base case* and sensitivity runs.

	Base case	Sex-change pow=0.2	Sex-change pow=0.6	Low Rec. catch
B_0	5 736	5 829	5 701	5 614
B_0-male	2 924	3 268	2 760	2 862
B_0-female	2 812	2 561	2 941	2 752
B_{curr}/B_0	0.45	0.43	0.46	0.44
B_{curr}/B_0 - male	0.52	0.44	0.57	0.52
B_{curr}/B_0 - female	0.36	0.41	0.35	0.36
MSY	285	276	292	283
F_{curr}/F_{msy}	0.39	0.44	0.36	0.40
B_{msy}/B_0	0.31	0.31	0.31	0.31
M	0.16	0.16	0.16	0.16
*Z*est	0.29	0.29	0.29	0.29
Steepness	0.78	0.78	0.77	0.77
Objective function value	57	56	57	57

Table 18: Median of marginal posterior distributions for Statistical Area 030 *base case* and sensitivity runs.

	Base case	Sex-change pow=0.2	Sex-change pow=0.6	Low Rec. catch
B_0	5 455	5 565	5 411	5 253
B_0-male	3 044	3 471	2 807	2 961
B_0-female	2 411	2 094	2 604	2 292
B_{curr}/B_0	0.41	0.39	0.42	0.41
B_{curr}/B_0 - male	0.51	0.41	0.57	0.51
B_{curr}/B_0 - female	0.28	0.36	0.24	0.28
MSY	276	267	283	275
F_{curr}/F_{msy}	0.40	0.44	0.39	0.40
B_{msy}/B_0	0.33	0.33	0.33	0.33
M	0.16	0.16	0.16	0.16
*Z*est	0.31	0.32	0.31	0.31
Steepness	0.77	0.78	0.78	0.77
Objective function value	51	51	51	51

Table 19: Estimates of BCO 5 spawning stock biomass, *MSY* and B_{MSY} for final runs (medians of marginal posterior distributions, with 90% confidence intervals in parentheses). B_0 and MSY are calculated assuming that Areas 025, 027 and 030 represent 92% of the BCO 5 blue cod stock.

Run	B_0 (,000 t)	$B_{current}$ (% B_0)	*MSY*	B_{MSY} (% B_0)
Base case	28(25,31)	39(31,51)	1 336(1 092,1 589)	31(29,35)
Sex-change pow=0.2	28(26,31)	39(30,50)	1 316(1 088,1 569)	32(29,35)
Sex-change pow=0.6	27(24,31)	39(30,50)	1 345(1 114,1 607)	31(28,34)
Low. Rec. catch	26(24,29)	40(31,51)	1 335(1 115,1 615)	31(29,35)

Table 20: Landed catch and TACC by Statistical Area for BCO 5, 2002/03 to 2011/12 and assumed commercial catch for stock projections.

		Landed catch (t)					Fraction of BCO 5 catch				Fraction of
	TACC	25	27	30	Other BCO 5	Total	25	27	30	Other BCO 5	TACC caught
02/03	1 548	644.4	320.9	356.0	175.7	1 496.9	0.430	0.214	0.238	0.117	0.967
03/04	1 548	603.5	351.5	401.1	201.4	1 557.4	0.387	0.226	0.258	0.129	1.006
04/05	1 548	734.3	299.8	262.7	176.1	1 472.9	0.499	0.204	0.178	0.120	0.951
05/06	1 548	829.1	212.7	202.8	101.7	1 346.2	0.616	0.158	0.151	0.076	0.870
06/07	1 548	726.2	219.5	320.6	115.3	1 381.6	0.526	0.159	0.232	0.083	0.892
07/08	1 548	727.0	173.3	271.3	108.2	1 279.8	0.568	0.135	0.212	0.085	0.827
08/09	1 548	710.7	244.2	310.4	126.4	1 391.8	0.511	0.175	0.223	0.091	0.899
09/10	1 548	692.0	253.5	183.7	79.9	1 209.0	0.572	0.210	0.152	0.066	0.781
10/11	1 548	647.4	290.3	258.9	99.8	1 296.5	0.499	0.224	0.200	0.077	0.838
11/12	1 239	597.0	245.0	268.1	105.0	1 215.1	0.491	0.202	0.221	0.086	0.981
2002/03 – 2011/12 Average		691.1	261.1	283.6	129.0	1 364.7	0.510	0.191	0.206	0.093	0.901
Projection		631.8	236.2	255.7	115.2	1 239.0	0.510	0.191	0.206	0.093	1.000

Table 21: Median estimates of spawning biomass (% B_0) in 2018 and 2023 at alternative recruitment and catch levels for the *base case* and sensitivity stock projections.

	Base Case						Sex-Change		Low Rec. Catch
							pow=0.2	pow=0.6	
Recruitment	Recent	Recent	Recent	Long-term	Long-term	Long-term	Recent	Recent	Recent
Catch Level	TACC	1.2·TACC	0.8·TACC	TACC	1.2·TACC	0.8·TACC	TACC	TACC	TACC
B_{2013}	39.4	39.4	39.4	39.4	39.4	39.4	38.8	39.2	39.6
B_{2018}	38.8	34.5	43.0	40.6	36.5	44.7	38.1	38.4	37.9
B_{2023}	40.0	32.5	47.4	47.0	38.8	54.2	40.2	39.8	38.1

Table 22: Median estimates of the proportion male in 1900, 2013, 2018 and 2023 BCO 5 spawning stock at alternative recruitment and catch levels for the *base case* and sensitivity stock projections.

Run	Base Case						Sex-Change		Low Rec. Catch
							pow=0.2	pow=0.6	
Recruitment	Recent	Recent	Recent	Long-term	Long-term	Long-term	Recent	Recent	Recent
Catch Level	TACC	1.2·TACC	0.8·TACC	TACC	1.2·TACC	0.8·TACC	TACC	TACC	TACC
1900	0.41	0.41	0.41	0.41	0.41	0.41	0.47	0.39	0.41
2013	0.51	0.51	0.51	0.51	0.51	0.51	0.49	0.51	0.51
2018	0.48	0.51	0.51	0.47	0.51	0.51	0.50	0.48	0.49
2023	0.51	0.52	0.49	0.49	0.51	0.48	0.49	0.52	0.51

Table 23: Probabilities of spawning biomass being below B_0 and B_{msy} reference levels in 2018 and 2023 at alternative recruitment and catch levels for the *base case* and sensitivity stock projections.

	Base Case						Sex Change		Low Rec. Catch
							Pow=0.2	Pow=0.6	
Recruitment	Recent	Recent	Recent	Long-term	Long-term	Long-term	Recent	Recent	Recent
Catch Level	TACC	1.2·TACC	0.8·TACC	TACC	1.2·TACC	0.8·TACC	TACC	TACC	TACC
$P(B_{2013} < 0.1\ B_0)$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.2\ B_0)$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.4\ B_0)$	0.538	0.538	0.538	0.538	0.538	0.538	0.576	0.549	0.532
$P(B_{2013} < 0.25\ B_{msy})$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.5\ B_{msy})$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < B_{msy})$	0.095	0.095	0.095	0.095	0.095	0.095	0.116	0.091	0.078
$P(B_{2018} < 0.1\ B_0)$	0.001	0.002	0	0	0.001	0	0	0	0
$P(B_{2018} < 0.2\ B_0)$	0.010	0.048	0.002	0.003	0.024	0	0.012	0.007	0.015
$P(B_{2018} < 0.4\ B_0)$	0.543	0.694	0.379	0.470	0.622	0.288	0.578	0.578	0.605
$P(B_{2018} < 0.25\ B_{msy})$	0	0.002	0	0	0	0	0	0	0
$P(B_{2018} < 0.5\ B_{msy})$	0.002	0.014	0	0	0.006	0	0.004	0.002	0.005
$P(B_{2018} < B_{msy})$	0.230	0.377	0.114	0.153	0.294	0.069	0.249	0.215	0.262
$P(B_{2023} < 0.1\ B_0)$	0.003	0.024	0.002	0	0.005	0	0.007	0.004	0.006
$P(B_{2023} < 0.2\ B_0)$	0.053	0.173	0.008	0.019	0.077	0	0.052	0.051	0.074
$P(B_{2023} < 0.4\ B_0)$	0.498	0.681	0.271	0.289	0.533	0.110	0.491	0.505	0.553
$P(B_{2023} < 0.25\ B_{msy})$	0.001	0.014	0	0	0.002	0	0.004	0.003	0.002
$P(B_{2023} < 0.5\ B_{msy})$	0.021	0.107	0.004	0.009	0.037	0	0.025	0.018	0.040
$P(B_{2023} < B_{msy})$	0.256	0.473	0.105	0.113	0.306	0.030	0.272	0.257	0.305

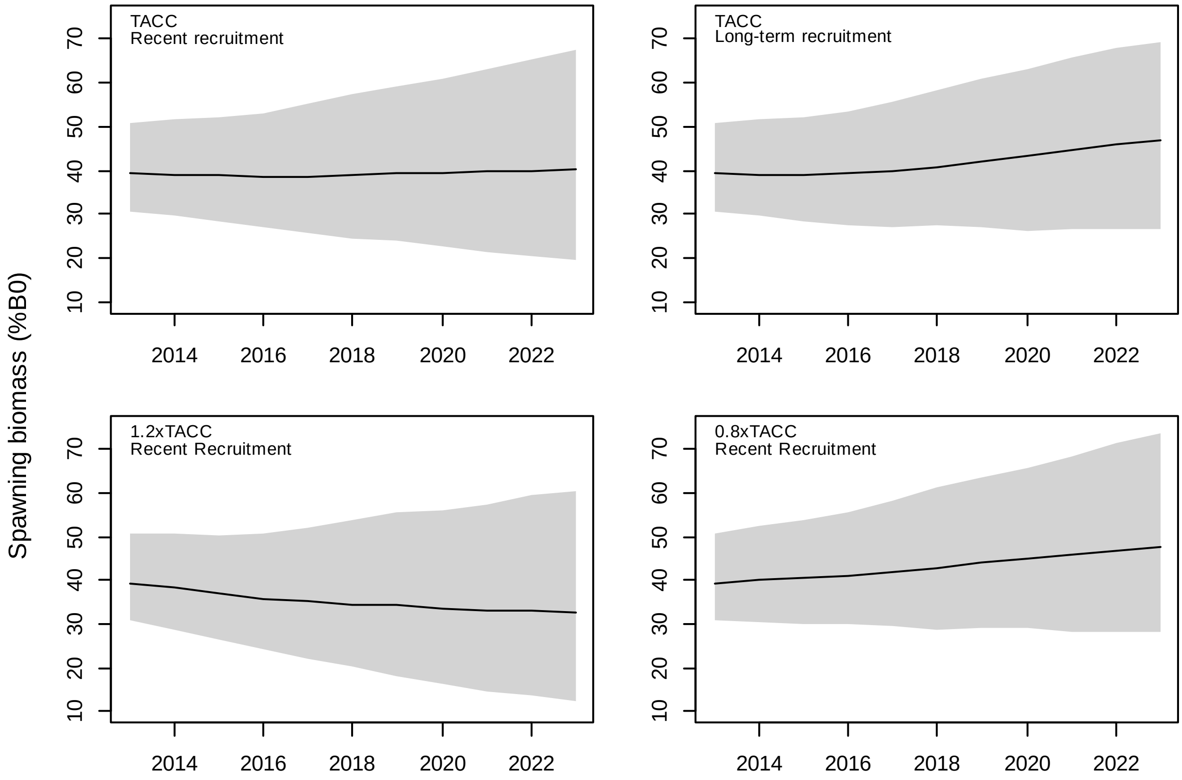


Figure 29: Projected spawning biomass (%B_0) assuming recent or long-term recruitment and catch at current TACC or increased/decreased by 20% for the base case run. Median estimates are shown as solid lines and 90% confidence intervals as shaded polygons.

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APPENDIX A. DATA TO SUPPORT RECREATIONAL CATCH ESTIMATES

Appendix Table A1: Population estimates for the Southland District, recreational harvest estimates for BCO 5, and extrapolated average catch per person residing in Southland. Census figures for 1901 to 1976 were obtained from New Zealand official year books (www.stats.govt.nz/browse_for_stats/snapshots-of-nz/nz-official-yearbooks.aspx) and for 1981 to 2011 from the New Zealand Infoshare web site (www.stats.govt.nz/infoshare).

Year	Population Estimate
1901	48 016
1911	59 349
1921	62 439
1926	65 529
1931	67 420
1936	72 856
1941	72 500
1946	70 178
1951	77 613
1956	81 600
1961	93 721
1966	102 686
1971	106 348
1976	108 860
1981	108 706
1986	105 512
1987	104 900
1988	104 700
1989	104 000
1990	103 700
1991	103 442
1992	102 500
1993	102 600
1994	102 600
1995	102 400
1996	99 000
1997	97 400
1998	95 500
1999	93 700
2000	92 700
2001	93 300
2002	93 500
2003	94 100
2004	94 100
2005	93 700
2006	93 200
2007	93 000
2008	93 000
2009	93 500
2010	94 200
2011	94 900

Appendix Table A2: Harvest estimates for blue cod in Statistical Area 025, for the three scenarios used in the stock assessment model. Modelled fisheries include: commercial line (Com. line), commercial pot (Com. pot) and recreational (Recr.)

	Base Catch			High Catch			Low Catch		
	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.
1900	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1901	13.2	0	54.3	13.2	0.0	80.4	13.2	0.0	26.1
1902	26.4	0	55.5	26.4	0.0	82.2	26.4	0.0	26.7
1903	39.6	0	56.7	39.6	0.0	84.1	39.6	0.0	27.4
1904	52.7	0	58.0	52.7	0.0	85.9	52.7	0.0	28.0
1905	65.8	0	59.2	65.8	0.0	87.8	65.8	0.0	28.6
1906	78.8	0	60.4	78.8	0.0	89.6	78.8	0.0	29.2
1907	91.9	0	61.7	91.9	0.0	91.5	91.9	0.0	29.8
1908	104.8	0	62.9	104.8	0.0	93.3	104.8	0.0	30.4
1909	117.8	0	64.1	117.8	0.0	95.2	117.8	0.0	31.1
1910	130.7	0	65.4	130.7	0.0	97.0	130.7	0.0	31.7
1911	143.6	0	66.6	143.6	0.0	98.9	143.6	0.0	32.3
1912	156.5	0	66.9	156.5	0.0	99.4	156.5	0.0	32.5
1913	169.3	0	67.3	169.3	0.0	99.9	169.3	0.0	32.6
1914	182.1	0	67.6	182.1	0.0	100.4	182.1	0.0	32.8
1915	194.8	0	67.9	194.8	0.0	100.9	194.8	0.0	33.0
1916	207.6	0	68.3	207.6	0.0	101.4	207.6	0.0	33.1
1917	220.3	0	68.6	220.3	0.0	101.9	220.3	0.0	33.3
1918	232.9	0	68.9	232.9	0.0	102.4	232.9	0.0	33.5
1919	245.5	0	69.3	245.5	0.0	102.9	245.5	0.0	33.6
1920	258.1	0	69.6	258.1	0.0	103.4	258.1	0.0	33.8
1921	270.7	0	70.0	270.7	0.0	103.9	270.7	0.0	34.0
1922	283.2	0	70.6	283.2	0.0	104.9	283.2	0.0	34.3
1923	295.7	0	71.3	295.7	0.0	106.0	295.7	0.0	34.7
1924	308.2	0	72.0	308.2	0.0	107.0	308.2	0.0	35.0
1925	320.6	0	72.6	320.6	0.0	108.0	320.6	0.0	35.3
1926	333.0	0	73.3	333.0	0.0	109.0	333.0	0.0	35.7
1927	345.3	0	73.7	345.3	0.0	109.6	345.3	0.0	35.9
1928	357.7	0	74.1	357.7	0.0	110.2	357.7	0.0	36.1
1929	370.0	0	74.6	370.0	0.0	110.8	370.0	0.0	36.3
1930	382.2	0	75.0	382.2	0.0	111.4	382.2	0.0	36.5
1931	394.4	0	75.4	394.4	0.0	112.1	394.4	0.0	36.7
1932	405.3	0	76.6	405.3	0.0	113.8	405.3	0.0	37.3
1933	444.7	0	77.7	444.7	0.0	115.6	444.7	0.0	37.9
1934	586.5	0	78.9	586.5	0.0	117.4	586.5	0.0	38.5
1935	153.5	0	80.1	153.5	0.0	119.2	153.5	0.0	39.1
1936	62.5	0	81.3	62.5	0.0	120.9	62.5	0.0	39.6
1937	90.7	0	81.2	90.7	0.0	120.8	90.7	0.0	39.6
1938	51.0	0	81.1	51.0	0.0	120.7	51.0	0.0	39.6
1939	73.5	0	81.1	73.5	0.0	120.6	73.5	0.0	39.5
1940	22.6	0	81.0	22.6	0.0	120.5	22.6	0.0	39.5
1941	67.7	0	80.9	67.7	0.0	120.4	67.7	0.0	39.5
1942	73.2	0	80.4	73.2	0.0	119.6	73.2	0.0	39.2
1943	112.5	0	79.9	112.5	0.0	118.8	112.5	0.0	38.9
1944	309.1	0	79.4	309.1	0.0	118.1	309.1	0.0	38.7
1945	350.3	0	78.9	354.7	0.0	117.3	350.3	0.0	38.4
1946	394.4	0	78.4	398.2	0.0	116.6	394.4	0.0	38.2
1947	539.3	0	80.0	543.1	0.0	119.0	539.3	0.0	39.0
1948	477.4	0	81.6	481.6	0.0	121.4	477.4	0.0	39.8
1949	536.0	0	83.2	546.7	0.0	123.9	536.0	0.0	40.6
1950	571.0	0	84.9	586.0	0.0	126.3	571.0	0.0	41.4
1951	488.8	0	86.5	507.7	0.0	128.7	488.8	0.0	42.2
1952	513.9	0	87.3	539.4	0.0	130.0	513.9	0.0	42.7
1953	245.9	0	88.2	290.8	0.0	131.3	245.9	0.0	43.1
1954	249.7	0	89.1	323.1	0.0	132.6	249.7	0.0	43.5
1955	266.1	0	89.9	350.0	0.0	133.9	266.1	0.0	44.0
1956	409.0	0	90.8	502.3	0.0	135.2	409.0	0.0	44.4
1957	354.2	0	93.4	428.2	0.0	139.2	354.2	0.0	45.7
1958	331.6	0	96.1	395.2	0.0	143.1	331.6	0.0	47.0
1959	299.0	0	98.7	353.8	0.0	147.1	299.0	0.0	48.4

	Base Catch			High Catch			Low Catch		
	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.
1960	444.5	0	101.4	494.3	0.0	151.0	444.5	0.0	49.7
1961	345.2	0	104.0	395.2	0.0	155.0	345.2	0.0	51.0
1962	397.0	0	106.0	452.5	0.0	157.9	397.0	0.0	52.0
1963	375.3	0	107.9	442.5	0.0	160.9	375.3	0.0	53.0
1964	276.1	0	109.9	332.6	0.0	163.8	276.1	0.0	53.9
1965	184.9	0	111.8	245.0	0.0	166.7	184.9	0.0	54.9
1966	219.4	0	113.8	283.2	0.0	169.6	219.4	0.0	55.9
1967	309.7	0	114.6	359.2	0.0	170.8	309.7	0.0	56.3
1968	286.1	0	115.4	333.1	0.0	172.0	286.1	0.0	56.7
1969	208.7	0	116.1	253.9	0.0	173.2	208.7	0.0	57.1
1970	262.6	0	116.9	317.7	0.0	174.4	262.6	0.0	57.5
1971	231.5	0	117.7	289.9	0.0	175.6	231.5	0.0	57.9
1972	120.3	0	118.3	163.5	0.0	176.4	120.3	0.0	58.1
1973	339.2	0	118.8	387.8	0.0	177.3	339.2	0.0	58.4
1974	289.6	0	119.4	326.9	0.0	178.1	289.6	0.0	58.7
1975	137.3	0	119.9	172.7	0.0	178.9	137.3	0.0	59.0
1976	156.2	0	120.5	197.0	0.0	179.7	156.2	0.0	59.2
1977	126.4	0	120.4	162.0	0.0	179.7	126.4	0.0	59.2
1978	125.8	0	120.4	170.8	0.0	179.6	125.8	0.0	59.2
1979	93.8	0	120.4	139.3	0.0	179.6	93.8	0.0	59.2
1980	205.4	29.2	120.3	239.2	34.0	179.5	205.4	29.2	59.2
1981	211.2	69.9	120.3	238.5	78.9	179.5	211.2	69.9	59.2
1982	125.0	74.3	119.6	146.2	86.9	178.4	125.0	74.3	58.8
1983	183.0	180.9	118.9	199.6	197.3	177.4	183.0	180.9	58.5
1984	167.6	275.1	118.2	179.8	295.1	176.3	167.6	275.1	58.1
1985	135.1	396.3	117.5	145.3	426.2	175.3	135.1	396.3	57.8
1986	61.2	409.9	116.8	66.2	442.7	174.3	61.2	409.9	57.4
1987	2.6	455.5	116.2	2.9	499.7	173.3	2.6	455.5	57.1
1988	0	519.3	116.0	0.0	550.5	172.9	0.0	519.3	57.0
1989	0	425.7	115.2	0.0	451.2	171.8	0.0	425.7	56.6
1990	0	560.0	114.9	0.0	574.8	171.3	0.0	560.0	56.4
1991	0	719.9	114.6	0.0	734.9	170.9	0.0	719.9	56.3
1992	0	532.9	113.6	0.0	546.0	169.3	0.0	532.9	55.8
1993	0	637.6	113.7	0.0	653.3	169.5	0.0	637.6	55.8
1994	0	728.9	113.7	0.0	741.6	169.5	0.0	728.9	55.8
1995	0	680.8	113.4	0.0	691.7	169.2	0.0	680.8	55.7
1996	0	695.8	109.7	0.0	695.8	163.6	0.0	695.8	53.9
1997	0	682.0	108.0	0.0	682.0	161.0	0.0	682.0	53.0
1998	0	600.0	105.9	0.0	600.0	157.9	0.0	600.0	52.0
1999	0	664.7	104.0	0.0	664.7	155.0	0.0	664.7	51.0
2000	0	616.0	102.9	0.0	616.0	153.3	0.0	616.0	50.4
2001	0	793.4	103.5	0.0	793.4	154.3	0.0	793.4	50.8
2002	0	758.0	103.8	0.0	758.0	154.6	0.0	758.0	50.9
2003	0	644.4	104.4	0.0	644.4	155.6	0.0	644.4	51.2
2004	0	603.5	104.4	0.0	603.5	155.6	0.0	603.5	51.2
2005	0	734.3	104.0	0.0	734.3	155.0	0.0	734.3	51.0
2006	0	829.1	103.4	0.0	829.1	154.2	0.0	829.1	50.7
2007	0	726.2	103.2	0.0	726.2	153.8	0.0	726.2	50.6
2008	0	727.0	103.2	0.0	727.0	153.8	0.0	727.0	50.6
2009	0	710.7	103.8	0.0	710.7	154.6	0.0	710.7	50.9
2010	0	692.0	104.5	0.0	692.0	155.8	0.0	692.0	51.3
2011	0	647.4	105.3	0.0	647.4	156.9	0.0	647.4	51.6
2012	0	597.0	105.3	0.0	597.0	156.9	0.0	597.0	51.6

Appendix Table A3: Harvest estimates for blue cod in Statistical Area 027, for the three scenarios used in the stock assessment model. Modelled fisheries include: commercial line (Com. line), commercial pot (Com. pot) and recreational (Recr.)

	Base Catch			High Catch			Low Catch		
	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.
1900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1901	2.2	0.0	4.7	2.2	0.0	7.0	2.2	0.0	2.3
1902	4.5	0.0	4.8	4.5	0.0	7.2	4.5	0.0	2.4
1903	6.8	0.0	4.9	6.8	0.0	7.4	6.8	0.0	2.5
1904	9.2	0.0	5.0	9.2	0.0	7.5	9.2	0.0	2.5
1905	11.6	0.0	5.1	11.6	0.0	7.7	11.6	0.0	2.6
1906	14.1	0.0	5.2	14.1	0.0	7.8	14.1	0.0	2.6
1907	16.6	0.0	5.3	16.6	0.0	8.0	16.6	0.0	2.7
1908	19.2	0.0	5.5	19.2	0.0	8.2	19.2	0.0	2.7
1909	21.8	0.0	5.6	21.8	0.0	8.3	21.8	0.0	2.8
1910	24.5	0.0	5.7	24.5	0.0	8.5	24.5	0.0	2.8
1911	27.2	0.0	5.8	27.2	0.0	8.7	27.2	0.0	2.9
1912	30.0	0.0	5.8	30.0	0.0	8.7	30.0	0.0	2.9
1913	32.9	0.0	5.8	32.9	0.0	8.8	32.9	0.0	2.9
1914	35.7	0.0	5.9	35.7	0.0	8.8	35.7	0.0	2.9
1915	38.7	0.0	5.9	38.7	0.0	8.9	38.7	0.0	3.0
1916	41.6	0.0	5.9	41.6	0.0	8.9	41.6	0.0	3.0
1917	44.7	0.0	6.0	44.7	0.0	8.9	44.7	0.0	3.0
1918	47.8	0.0	6.0	47.8	0.0	9.0	47.8	0.0	3.0
1919	50.9	0.0	6.0	50.9	0.0	9.0	50.9	0.0	3.0
1920	54.1	0.0	6.1	54.1	0.0	9.1	54.1	0.0	3.0
1921	57.3	0.0	6.1	57.3	0.0	9.1	57.3	0.0	3.0
1922	60.6	0.0	6.1	60.6	0.0	9.2	60.6	0.0	3.1
1923	63.9	0.0	6.2	63.9	0.0	9.3	63.9	0.0	3.1
1924	67.3	0.0	6.3	67.3	0.0	9.4	67.3	0.0	3.1
1925	70.7	0.0	6.3	70.7	0.0	9.5	70.7	0.0	3.2
1926	74.2	0.0	6.4	74.2	0.0	9.6	74.2	0.0	3.2
1927	77.7	0.0	6.4	77.7	0.0	9.6	77.7	0.0	3.2
1928	81.3	0.0	6.5	81.3	0.0	9.7	81.3	0.0	3.2
1929	85.0	0.0	6.5	85.0	0.0	9.7	85.0	0.0	3.2
1930	88.6	0.0	6.5	88.6	0.0	9.8	88.6	0.0	3.3
1931	92.4	0.0	6.6	92.4	0.0	9.9	92.4	0.0	3.3
1932	95.9	0.0	6.7	95.9	0.0	10.0	95.9	0.0	3.3
1933	106.2	0.0	6.8	106.2	0.0	10.2	106.2	0.0	3.4
1934	141.4	0.0	6.9	141.4	0.0	10.3	141.4	0.0	3.4
1935	37.4	0.0	7.0	37.4	0.0	10.5	37.4	0.0	3.5
1936	15.3	0.0	7.1	15.3	0.0	10.6	15.3	0.0	3.5
1937	22.5	0.0	7.1	22.5	0.0	10.6	22.5	0.0	3.5
1938	12.8	0.0	7.1	12.8	0.0	10.6	12.8	0.0	3.5
1939	18.6	0.0	7.1	18.6	0.0	10.6	18.6	0.0	3.5
1940	5.8	0.0	7.1	5.8	0.0	10.6	5.8	0.0	3.5
1941	17.4	0.0	7.1	17.4	0.0	10.6	17.4	0.0	3.5
1942	19.0	0.0	7.0	19.0	0.0	10.5	19.0	0.0	3.5
1943	29.5	0.0	7.0	29.5	0.0	10.5	29.5	0.0	3.5
1944	81.7	0.0	6.9	81.7	0.0	10.4	81.7	0.0	3.5
1945	94.8	0.0	6.9	98.5	0.0	10.3	94.8	0.0	3.4
1946	107.3	0.0	6.8	110.5	0.0	10.3	107.3	0.0	3.4
1947	147.6	0.0	7.0	150.7	0.0	10.5	147.6	0.0	3.5
1948	132.0	0.0	7.1	135.6	0.0	10.7	132.0	0.0	3.6
1949	151.3	0.0	7.3	160.3	0.0	10.9	151.3	0.0	3.6
1950	163.6	0.0	7.4	176.1	0.0	11.1	163.6	0.0	3.7
1951	143.0	0.0	7.6	158.9	0.0	11.3	143.0	0.0	3.8
1952	153.2	0.0	7.6	174.7	0.0	11.5	153.2	0.0	3.8
1953	83.5	0.0	7.7	121.3	0.0	11.6	83.5	0.0	3.9
1954	93.6	0.0	7.8	155.3	0.0	11.7	93.6	0.0	3.9
1955	101.9	0.0	7.9	172.5	0.0	11.8	101.9	0.0	3.9
1956	147.1	0.0	8.0	225.6	0.0	11.9	147.1	0.0	4.0
1957	126.2	0.0	8.2	188.5	0.0	12.3	126.2	0.0	4.1
1958	117.2	0.0	8.4	170.6	0.0	12.6	117.2	0.0	4.2
1959	105.6	0.0	8.7	151.7	0.0	13.0	105.6	0.0	4.3

	Base Catch			High Catch			Low Catch		
	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.
1960	148.9	0.0	8.9	190.8	0.0	13.3	148.9	0.0	4.4
1961	119.7	0.0	9.1	161.7	0.0	13.7	119.7	0.0	4.6
1962	137.9	0.0	9.3	184.6	0.0	14.0	137.9	0.0	4.7
1963	135.4	0.0	9.5	191.9	0.0	14.2	135.4	0.0	4.7
1964	102.2	0.0	9.7	149.7	0.0	14.5	102.2	0.0	4.8
1965	75.1	0.0	9.8	125.6	0.0	14.7	75.1	0.0	4.9
1966	87.5	0.0	10.0	141.1	0.0	15.0	87.5	0.0	5.0
1967	112.9	0.0	10.1	154.6	0.0	15.1	112.9	0.0	5.0
1968	105.3	0.0	10.1	144.9	0.0	15.2	105.3	0.0	5.1
1969	80.3	0.0	10.2	118.3	0.0	15.3	80.3	0.0	5.1
1970	101.1	0.0	10.3	147.5	0.0	15.4	101.1	0.0	5.1
1971	92.3	0.0	10.4	141.4	0.0	15.5	92.3	0.0	5.2
1972	51.7	0.0	10.4	88.0	0.0	15.6	51.7	0.0	5.2
1973	126.9	0.0	10.5	167.7	0.0	15.7	126.9	0.0	5.2
1974	107.9	0.0	10.5	139.2	0.0	15.8	107.9	0.0	5.3
1975	56.2	0.0	10.6	85.9	0.0	15.8	56.2	0.0	5.3
1976	64.4	0.0	10.6	98.7	0.0	15.9	64.4	0.0	5.3
1977	53.1	0.0	10.6	83.0	0.0	15.9	53.1	0.0	5.3
1978	55.6	0.0	10.6	93.4	0.0	15.9	55.6	0.0	5.3
1979	43.3	0.0	10.6	78.8	0.0	15.9	43.3	0.0	5.3
1980	83.0	11.8	10.6	114.3	16.2	15.9	83.0	11.8	5.3
1981	82.4	27.3	10.6	105.6	34.9	15.9	82.4	27.3	5.3
1982	50.8	30.2	10.5	69.7	41.4	15.8	50.8	30.2	5.3
1983	70.2	69.4	10.5	84.0	83.0	15.7	70.2	69.4	5.2
1984	64.2	105.4	10.4	74.6	122.4	15.6	64.2	105.4	5.2
1985	51.9	152.1	10.3	60.0	175.9	15.5	51.9	152.1	5.2
1986	24.1	161.4	10.3	28.8	192.5	15.4	24.1	161.4	5.1
1987	1.0	180.3	10.2	1.2	217.3	15.3	1.0	180.3	5.1
1988	0.0	199.0	10.2	0.0	219.1	15.3	0.0	199.0	5.1
1989	0.0	167.8	10.1	0.0	190.9	15.2	0.0	167.8	5.1
1990	0.0	222.3	10.1	0.0	237.7	15.2	0.0	222.3	5.1
1991	0.0	256.0	10.1	0.0	271.2	15.1	0.0	256.0	5.0
1992	0.0	150.5	10.0	0.0	164.3	15.0	0.0	150.5	5.0
1993	0.0	184.7	10.0	0.0	201.2	15.0	0.0	184.7	5.0
1994	0.0	171.1	10.0	0.0	187.8	15.0	0.0	171.1	5.0
1995	0.0	191.8	10.0	0.0	203.1	15.0	0.0	191.8	5.0
1996	0.0	270.3	9.6	0.0	270.3	14.5	0.0	270.3	4.8
1997	0.0	227.6	9.5	0.0	227.6	14.2	0.0	227.6	4.7
1998	0.0	288.1	9.3	0.0	288.1	14.0	0.0	288.1	4.7
1999	0.0	251.4	9.1	0.0	251.4	13.7	0.0	251.4	4.6
2000	0.0	306.6	9.0	0.0	306.6	13.6	0.0	306.6	4.5
2001	0.0	308.8	9.1	0.0	308.8	13.6	0.0	308.8	4.5
2002	0.0	261.0	9.1	0.0	261.0	13.7	0.0	261.0	4.6
2003	0.0	356.0	9.2	0.0	356.0	13.8	0.0	356.0	4.6
2004	0.0	401.1	9.2	0.0	401.1	13.8	0.0	401.1	4.6
2005	0.0	262.7	9.1	0.0	262.7	13.7	0.0	262.7	4.6
2006	0.0	202.8	9.1	0.0	202.8	13.6	0.0	202.8	4.5
2007	0.0	320.6	9.1	0.0	320.6	13.6	0.0	320.6	4.5
2008	0.0	271.3	9.1	0.0	271.3	13.6	0.0	271.3	4.5
2009	0.0	310.4	9.1	0.0	310.4	13.7	0.0	310.4	4.6
2010	0.0	183.7	9.2	0.0	183.7	13.8	0.0	183.7	4.6
2011	0.0	258.9	9.2	0.0	258.9	13.9	0.0	258.9	4.6
2012	0.0	268.1	9.2	0.0	268.1	13.9	0.0	268.1	4.6

Appendix Table A4: Harvest estimates for blue cod in Statistical Area 030, for the three scenarios used in the population assessment model. Modelled fisheries include: commercial line (Com. line), commercial pot (Com. pot) and recreational (Recr.)

	Base Catch			High Catch			Low Catch		
	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.
1900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1901	4.9	0.0	8.7	4.9	0.0	13.1	4.9	0.0	4.4
1902	9.8	0.0	8.9	9.8	0.0	13.4	9.8	0.0	4.5
1903	14.7	0.0	9.1	14.7	0.0	13.7	14.7	0.0	4.6
1904	19.5	0.0	9.4	19.5	0.0	14.0	19.5	0.0	4.7
1905	24.4	0.0	9.6	24.4	0.0	14.3	24.4	0.0	4.8
1906	29.2	0.0	9.8	29.2	0.0	14.6	29.2	0.0	4.9
1907	34.0	0.0	10.0	34.0	0.0	15.0	34.0	0.0	5.0
1908	38.8	0.0	10.2	38.8	0.0	15.3	38.8	0.0	5.1
1909	43.6	0.0	10.4	43.6	0.0	15.6	43.6	0.0	5.2
1910	48.4	0.0	10.6	48.4	0.0	15.9	48.4	0.0	5.3
1911	53.2	0.0	10.8	53.2	0.0	16.2	53.2	0.0	5.4
1912	58.0	0.0	10.9	58.0	0.0	16.3	58.0	0.0	5.4
1913	62.7	0.0	10.9	62.7	0.0	16.4	62.7	0.0	5.5
1914	67.5	0.0	11.0	67.5	0.0	16.4	67.5	0.0	5.5
1915	72.2	0.0	11.0	72.2	0.0	16.5	72.2	0.0	5.5
1916	76.9	0.0	11.1	76.9	0.0	16.6	76.9	0.0	5.5
1917	81.6	0.0	11.1	81.6	0.0	16.7	81.6	0.0	5.6
1918	86.3	0.0	11.2	86.3	0.0	16.8	86.3	0.0	5.6
1919	91.0	0.0	11.2	91.0	0.0	16.9	91.0	0.0	5.6
1920	95.6	0.0	11.3	95.6	0.0	17.0	95.6	0.0	5.7
1921	100.3	0.0	11.4	100.3	0.0	17.0	100.3	0.0	5.7
1922	104.9	0.0	11.5	104.9	0.0	17.2	104.9	0.0	5.7
1923	109.5	0.0	11.6	109.5	0.0	17.4	109.5	0.0	5.8
1924	114.2	0.0	11.7	114.2	0.0	17.5	114.2	0.0	5.8
1925	118.8	0.0	11.8	118.8	0.0	17.7	118.8	0.0	5.9
1926	123.3	0.0	11.9	123.3	0.0	17.9	123.3	0.0	6.0
1927	127.9	0.0	12.0	127.9	0.0	18.0	127.9	0.0	6.0
1928	132.5	0.0	12.1	132.5	0.0	18.1	132.5	0.0	6.0
1929	137.0	0.0	12.1	137.0	0.0	18.2	137.0	0.0	6.1
1930	141.6	0.0	12.2	141.6	0.0	18.3	141.6	0.0	6.1
1931	146.1	0.0	12.3	146.1	0.0	18.4	146.1	0.0	6.1
1932	150.2	0.0	12.5	150.2	0.0	18.7	150.2	0.0	6.2
1933	164.7	0.0	12.7	164.7	0.0	19.0	164.7	0.0	6.3
1934	217.3	0.0	12.9	217.3	0.0	19.3	217.3	0.0	6.4
1935	56.9	0.0	13.1	56.9	0.0	19.6	56.9	0.0	6.5
1936	23.1	0.0	13.3	23.1	0.0	19.9	23.1	0.0	6.6
1937	33.6	0.0	13.2	33.6	0.0	19.9	33.6	0.0	6.6
1938	18.9	0.0	13.2	18.9	0.0	19.8	18.9	0.0	6.6
1939	27.2	0.0	13.2	27.2	0.0	19.8	27.2	0.0	6.6
1940	8.4	0.0	13.2	8.4	0.0	19.8	8.4	0.0	6.6
1941	25.1	0.0	13.2	25.1	0.0	19.8	25.1	0.0	6.6
1942	27.1	0.0	13.1	27.1	0.0	19.7	27.1	0.0	6.6
1943	41.7	0.0	13.0	41.7	0.0	19.5	41.7	0.0	6.5
1944	114.5	0.0	12.9	114.5	0.0	19.4	114.5	0.0	6.5
1945	132.7	0.0	12.8	139.9	0.0	19.3	132.7	0.0	6.4
1946	148.6	0.0	12.8	154.9	0.0	19.1	148.6	0.0	6.4
1947	202.3	0.0	13.0	208.5	0.0	19.6	202.3	0.0	6.5
1948	179.7	0.0	13.3	186.6	0.0	20.0	179.7	0.0	6.7
1949	205.7	0.0	13.6	223.2	0.0	20.4	205.7	0.0	6.8
1950	221.5	0.0	13.8	245.9	0.0	20.8	221.5	0.0	6.9
1951	193.7	0.0	14.1	224.6	0.0	21.2	193.7	0.0	7.1
1952	207.4	0.0	14.3	249.0	0.0	21.4	207.4	0.0	7.1
1953	121.1	0.0	14.4	194.3	0.0	21.6	121.1	0.0	7.2
1954	141.7	0.0	14.6	261.4	0.0	21.8	141.7	0.0	7.3
1955	154.8	0.0	14.7	291.6	0.0	22.0	154.8	0.0	7.3
1956	214.0	0.0	14.8	366.1	0.0	22.3	214.0	0.0	7.4
1957	180.8	0.0	15.3	301.6	0.0	22.9	180.8	0.0	7.6
1958	165.4	0.0	15.7	269.1	0.0	23.6	165.4	0.0	7.9

	Base Catch			High Catch			Low Catch		
	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.	Com. line	Com. pot	Recr.
1959	147.4	0.0	16.2	236.8	0.0	24.2	147.4	0.0	8.1
1960	198.0	0.0	16.6	279.3	0.0	24.9	198.0	0.0	8.3
1961	161.4	0.0	17.0	242.9	0.0	25.6	161.4	0.0	8.5
1962	184.2	0.0	17.4	274.6	0.0	26.1	184.2	0.0	8.7
1963	184.0	0.0	17.7	293.5	0.0	26.5	184.0	0.0	8.8
1964	140.1	0.0	18.0	232.0	0.0	27.0	140.1	0.0	9.0
1965	108.7	0.0	18.4	206.7	0.0	27.5	108.7	0.0	9.2
1966	124.0	0.0	18.7	228.0	0.0	28.0	124.0	0.0	9.3
1967	147.9	0.0	18.8	228.8	0.0	28.2	147.9	0.0	9.4
1968	137.5	0.0	18.9	214.1	0.0	28.4	137.5	0.0	9.5
1969	107.6	0.0	19.1	181.2	0.0	28.6	107.6	0.0	9.5
1970	134.2	0.0	19.2	224.1	0.0	28.8	134.2	0.0	9.6
1971	124.8	0.0	19.3	220.0	0.0	29.0	124.8	0.0	9.7
1972	73.5	0.0	19.4	143.8	0.0	29.2	73.5	0.0	9.7
1973	158.2	0.0	19.5	237.4	0.0	29.3	158.2	0.0	9.8
1974	132.2	0.0	19.6	193.0	0.0	29.4	132.2	0.0	9.8
1975	74.5	0.0	19.7	132.2	0.0	29.6	74.5	0.0	9.9
1976	85.2	0.0	19.8	151.7	0.0	29.7	85.2	0.0	9.9
1977	70.7	0.0	19.8	128.7	0.0	29.7	70.7	0.0	9.9
1978	76.7	0.0	19.8	150.0	0.0	29.7	76.7	0.0	9.9
1979	56.4	0.0	19.8	113.9	0.0	29.7	56.4	0.0	9.9
1980	94.1	13.4	19.8	140.4	19.9	29.7	94.1	13.4	9.9
1981	96.2	31.8	19.8	140.1	46.3	29.7	96.2	31.8	9.9
1982	62.5	37.2	19.7	100.8	59.9	29.5	62.5	37.2	9.8
1983	81.6	80.6	19.5	113.6	112.4	29.3	81.6	80.6	9.8
1984	71.3	117.0	19.4	93.0	152.7	29.1	71.3	117.0	9.7
1985	57.2	167.9	19.3	74.5	218.6	29.0	57.2	167.9	9.7
1986	26.1	174.5	19.2	34.3	229.4	28.8	26.1	174.5	9.6
1987	1.1	196.9	19.1	1.5	266.2	28.6	1.1	196.9	9.5
1988	0.0	209.8	19.0	0.0	254.3	28.6	0.0	209.8	9.5
1989	0.0	180.7	18.9	0.0	233.4	28.4	0.0	180.7	9.5
1990	0.0	156.9	18.9	0.0	192.3	28.3	0.0	156.9	9.4
1991	0.0	144.2	18.8	0.0	179.1	28.2	0.0	144.2	9.4
1992	0.0	149.1	18.6	0.0	181.2	28.0	0.0	149.1	9.3
1993	0.0	207.3	18.7	0.0	239.6	28.0	0.0	207.3	9.3
1994	0.0	244.6	18.7	0.0	273.4	28.0	0.0	244.6	9.3
1995	0.0	316.1	18.6	0.0	343.6	27.9	0.0	316.1	9.3
1996	0.0	319.3	18.0	0.0	319.3	27.0	0.0	319.3	9.0
1997	0.0	317.6	17.7	0.0	317.6	26.6	0.0	317.6	8.9
1998	0.0	371.1	17.4	0.0	371.1	26.1	0.0	371.1	8.7
1999	0.0	467.9	17.0	0.0	467.9	25.6	0.0	467.9	8.5
2000	0.0	305.8	16.9	0.0	305.8	25.3	0.0	305.8	8.4
2001	0.0	263.2	17.0	0.0	263.2	25.5	0.0	263.2	8.5
2002	0.0	342.7	17.0	0.0	342.7	25.5	0.0	342.7	8.5
2003	0.0	320.9	17.1	0.0	320.9	25.7	0.0	320.9	8.6
2004	0.0	351.5	17.1	0.0	351.5	25.7	0.0	351.5	8.6
2005	0.0	299.8	17.0	0.0	299.8	25.6	0.0	299.8	8.5
2006	0.0	212.7	17.0	0.0	212.7	25.4	0.0	212.7	8.5
2007	0.0	219.5	16.9	0.0	219.5	25.4	0.0	219.5	8.5
2008	0.0	173.3	16.9	0.0	173.3	25.4	0.0	173.3	8.5
2009	0.0	244.2	17.0	0.0	244.2	25.5	0.0	244.2	8.5
2010	0.0	253.5	17.1	0.0	253.5	25.7	0.0	253.5	8.6
2011	0.0	290.3	17.3	0.0	290.3	25.9	0.0	290.3	8.6
2012	0.0	245.0	17.3	0.0	245.0	25.9	0.0	245.0	8.6

APPENDIX B. LETTER FROM GRL BROWN TO AP BAUCKHAM SUMMARIZING BLUE COD ESCAPE GAP STUDY.

18 November 1991

A P Bauckham
Manager Fisheries Administration
Greta Point
PO Box 297
WELLINGTON

SUBJECT: ESCAPE GAPS/MESH IN SOUTHLAND BLUE COD POTS

1.0 Introduction

The recent setting aside of the Southland Fisheries Management Plan (SFMP) has meant that a number of important fishery management measures have not been implemented. It is intended to proceed with many of these measures under other provisions of the Fisheries Act during 1992. However the provision of escape gaps/mesh in Southland blue cod pots is considered of such merit by the local industry that they want it implemented urgently.

Southland has New Zealand's largest blue cod fishery with over 75% of the national catch.

2.0 Reasons for a Regulation

To exploit a fish stock for the maximum benefit it is necessary to control both the total amount of fish which is caught and the size of these fish. The amount of fish caught is controlled largely by total allowable commercial catches (TACC) and individual daily bag limits. However, it is also important to manage the size of fish. If too many fish are caught too early in their lives then a fishery is inefficient as the maximum yield may not be attained.

2.1 To promote optimal yield

The best way to manage a fishery to give maximum yield is to regulate the size of first capture. Nowhere is this more possible than in the blue cod pot fishery. Unfortunately it is difficult to set a desired size of first capture to optimise yield. This requires data on growth rate, natural mortality, and fishing mortality.

2.2 To protect juvenile fish

Given the difficulty in estimating optimal yield this is probably the best reason to implement escape gaps. Unmodified cod pots can catch large quantities of juvenile fish and as these have low market value are usually returned to the sea. Although many survive, there is significant mortality from:

i) -embolism from being dragged quickly from the sea floor.
ii) -stress from handling and lying on deck.
iii) -predation by mollymawks and other sea life while the small fish are recovering on the surface.

2.3 To reduce the effect of fishing on reproductive dynamics

Blue cod are hermaphroditic, that is they change sex from female to male during their lifespan. This change from female to male occurs at about 33cm for Southland blue cod. It is unknown what the effect of having a fishery largely targeted on males might have on blue cod, however any possible effect of fishing on reproductive dynamics may be reduced by increasing the size at first capture.

2.4 For economic and marketing purposes

Processors often impose minimum sizes on fishers based on the size of fish the market demands. These sizes are based on consumer preference and sometimes the economics of processing.

3.0 Selectivity of blue cod pots

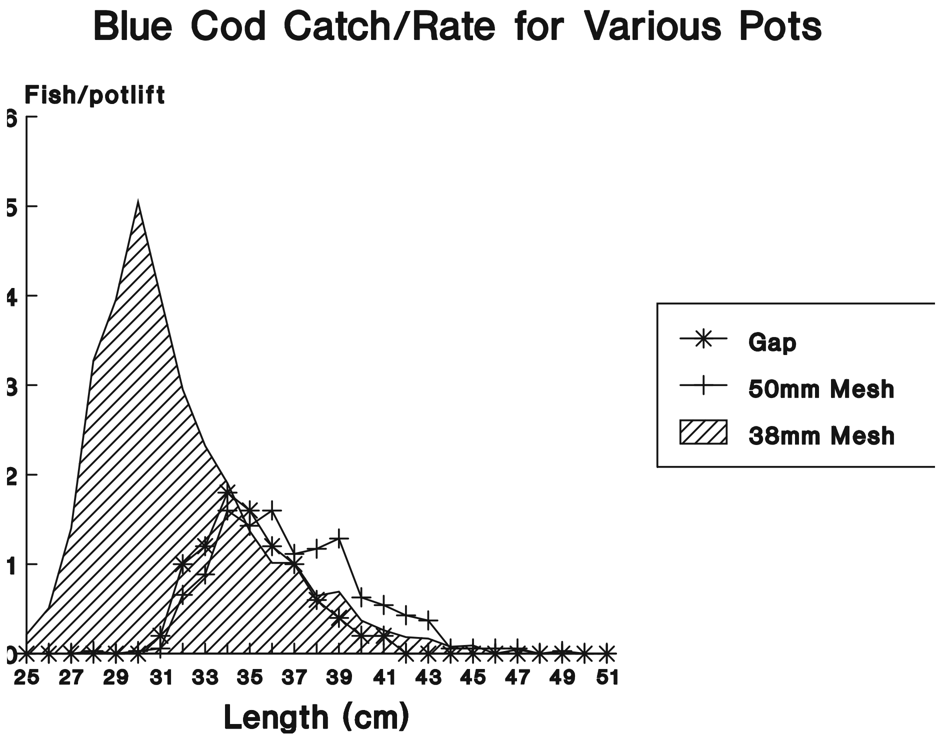
In 1986 MAF Fisheries initiated cod pot trials at Bluff and a year later at Stewart Island.

The objectives of the research were as follows:

1) To determine the selectivity of blue cod to various size gaps and mesh size.

2) To determine the effects of size gaps and mesh size on catch rates of blue cod.

The trials were successful, and found that blue cod were highly selected by both escape gaps and mesh size. In addition the effect of size gaps and larger mesh size did not impair catch rates of the desired size range, and surprisingly, in the case of increased mesh size could increase catch rates. Results for catch results selecting for blue cod greater than 33cm are given in figure 1.



4.0 Consultation

There has been extensive consultation on this issue. Escape gaps have been discussed at the Southland FMAC and Fisheries Liaison Committee meetings held at Bluff, Riverton, Stewart Island, and Te Anau. The history of consultation is given below:

4.1 Early Consultation 1986-87

The early consultation was concerned with determining a suitable minimum fish size that cod pots should select for. After research information became available there was a general consensus that a target size of 33cm (as compared with the minimum legal size of 30cm) was adequate to optimise yield, protect juvenile fish, allow male fish to develop, and provide a good minimum size for market demand.

4.2 Consultation on the FMP

From 1987 to 1990 cod pot mesh size restrictions were discussed in terms of their inclusion in the proposed Southland FMP. There was consensus for the need for cod pot escape gaps/minimum mesh and this was included in the draft FMP (appendix 1). Until the FMP was to become operational many Southland fishers agreed to a voluntary code of practise. Advice on the conditions of the code of practise was posted on notice boards at cod pot manufacturers.

4.3 Recent Consultation

The most recent meeting of the Southland FMAC (24 October 1991) agreed that blue cod escape gaps/mesh be regulated as soon as possible. In addition a delegation from Stewart Island has recently met with MAF Fisheries South staff to express their concern for the blue cod fishery, and in particular the breakdown of the voluntary code of practise. Mr Bill English, MP for Wallace, has also been approached by a concerned delegation, with the result of ministerial correspondence (appendix 2).

5.0 Recommendation

It is recommended that provision for escape gaps and/or minimum mesh be enacted under the Southern and Sub Antarctic Commercial Fishing Regulations at the earliest possible opportunity.

Agreed / Not Agreed / As Amended

GRL Brown
Regional Manager
MAF Fisheries South

Appendix 1

Proposed Amendment to Southland and Sub Antarctic Commercial Fishing Regulations.

Interpretation

"Blue cod" means the fish of which the scientific name is *Parapercis colias*:

"Blue cod pot"means any pot, whether baited or not, which is capable of catching or holding blue cod, and includes any device capable of catching, holding or storing blue cod, but does not including a rock lobster pot.

Cod Pots

Apertures to be incorporated

No blue cod pot shall be possessed, or used, unless it has incorporated on the edge of two opposite sides of the pot (excluding the top and bottom) at least one unencumbered aperture with a height of no less than 45mm and extending the length of the side of the pot.

Nothing in the above shall apply to a blue cod pot constructed entirely of unencumbered square meshes which have all sides of the meshes no less than 48mm.

APPENDIX C. BCO 5 CPUE ANALYSIS

C.1 GENERAL OVERVIEW

This report updates the standardisation of catch and effort data for the three main constituent statistical areas of the BCO 5 pot fishery, which were last described by Starr & Kendrick (2011). The fishery operates mainly in Statistical Area 025 which is the area most accessible to the home ports of Bluff, Riverton and Half Moon Bay (Stewart Island). There is also a considerable amount of catch taken from the adjacent Areas 027 and 030, and relatively little from the more remote Areas 029 and 031. The previously accepted series was based on data from Areas 025, 027 and 030 combined, although separate analyses for each constituent area were also presented to demonstrate their relative importance in the overall indices and to test for evidence of possible serial depletion. These separate statistical area series were subsequently used in a spatially discrete stock assessment and management strategy evaluation. These statistical area specific analyses are updated here with two additional years of data, improved core fleet definitions, more appropriate error distributions, and additional detailed diagnostics so that they can be used as inputs to the 2013 BCO 5 stock assessment. The CPUE series which combines all three statistical areas has not been repeated.

The previous study attempted, within the limits of the spatial data available in CELR format data, to explore the behaviour of vessels in the core fleet for evidence of serial depletion, and concluded that the indices were driven largely by the catch and effort in Area 025, considered to be the primary area of interest, and also concluded that a classical pattern of serial depletion (expansion of effort into more distant areas) was not evident in the data. Serial depletion within a statistical area may be occurring, but it was not possible to test for this effect given the lack of spatial detail in the CELR catch/effort data.

Poor reporting of effort by fishers is a concern for this fishing method because the CELR forms ask for two effort fields on the form, and these are commonly transposed. The approach taken by this analysis was to exclude from the dataset those vessels that were responsible for most of the suspect entries (as was done by Starr & Kendrick 2011), rather than attempting to correct them as had been done previously. The decision to drop the data, rather than to correct them, was made because it appeared that the vessels responsible for the transposition behaviour exhibited different mean CPUE and it was not known if this difference was an interaction with the transposing behaviour (see Appendix E for an update of the analysis evaluating the transposition behaviour).

Regulatory changes to the mesh size used for the pot covering (from 38 mm to 48 mm) implemented on 1 October 1994 means that CPUE is not comparable before and after the mesh size change.

C.2 DATA PREPARATION

Candidate trips were identified by selecting all trips that fished at least once with either cod or rock lobster potting gear in statistical areas (using the finfish or the rock lobster definitions) that are valid for BCO 5 and targeted or caught either BCO or CRA. Once a list of trips that satisfied these criteria was identified, all effort and landing records associated with these trips were extracted.

Extreme values in the effort data were identified as outliers by examining the distribution for each field by vessel and for the whole fleet. All records for a trip with missing or bad effort data were removed. Missing values for vessel ID, statistical area, method, or target species within any trip were substituted with the predominant (most frequent) value for that field over all records for the trip. Effort and estimated catch data were summarised by fishing trip, for every unique combination of fishing method, statistical area, and target species, referred to as a “trip strata”. This reduced the CELR format records to a lower resolution “amalgamated” dataset, giving fewer records per trip but retaining the original method, area, and target species recorded by the skipper for the trip.

The landed catches of BCO 5 for each trip were allocated to the "trip strata" (defined as statistical area, target species and method) in proportion to the appropriate estimated catches by species. In the case where there were no estimated catches, the allocation was made proportionate to the number of potlifts. The main assumption made in this allocation procedure is that the reporting of blue cod is consistent across statistical areas and target species within a trip. In contrast, if estimated catches were used directly, the assumption must be made that reporting rates are constant across the entire fleet and all statistical areas for all years, as well as making the assumption that the ratio of estimated catch to landed greenweight catch is also consistent across the entire fleet for all years.

The data available for each trip included estimated and landed catch of blue cod, the number of potlifts, the number of days fished, fishing year, statistical area, month of landing, and a unique vessel identifier. Data might not represent an entire fishing trip; just those portions of it that qualified, but the amount of landed catch assigned to the part of the trip that was kept would be proportional to the total landed catch for the trip using the estimated catches to apportion the landings to each trip stratum. Trips were not dropped because they targeted more than one species or fished in more than one statistical area. Trips landing more than one Fishstock of any species from one of the straddling statistical areas were entirely dropped.

C.3 ADDITIONAL GROOMING OF EFFORT FIELDS

An issue that is problematic for potting data entered on the CELR form is that the two effort fields can be transposed:

Column A: total number of traps/pots lifted in the day (`potlifts`)

Column B: number of traps/pots in the water at midnight (`effnum`)

For cod potting (Method: CP), a relatively small number of pots (usually <10) are lifted several times per day and then usually left in the water overnight. Consequently the expectation is that Column B should either be less than or equal to the value in Column A. However, in 27% of the records with valid paired observations in the BCO 5 cod potting dataset, the opposite is true. Some previous researchers have chosen to transpose the values in the two columns when this happens (Langley 2005). However, when the vessels exhibiting this behaviour were investigated, they showed differences in both means and trends from the remaining values, and it was concluded that it would be inappropriate to use them in a CPUE analysis (although they were retained for characterisation) (see Appendix E).

Exploration of the BCO 5 dataset showed that while there were over 330 vessels in the data set doing cod potting, 71 of those vessels were responsible for over 90% of the reporting where Column B>Column A. For this analysis, the data for those 71 vessels were excluded from the CPUE dataset, before the core fleet was selected. This approach was consistent with that adopted by Starr & Kendrick (2011).

C.4 DATA SELECTION AND METHODS

Those groups of events that satisfied the criteria of target species, method and statistical areas defining the defined fishery were selected from available fishing trips. Any effort strata that were matched to a landing of BCO 5 were termed "successful", and included relevant but unsuccessful effort, so that the analysis of catch rates in successful strata also incorporates much of the relevant zero catch information.

Strata which did not include any landed BCO 5 were assigned a value of zero. Target fisheries contain very few zero catch records, and those are largely a product of the merge process that assigns landed catch on the basis of estimated catch. Zero catches in this dataset were excluded, and a linear model was fit to those trip-strata with positive catches.

Regression models using five different distributional assumptions (lognormal, log-logistic, inverse gaussian, gamma and Weibull) that predicted catch based on a fixed set of explanatory variables (year, month, vessel and log[number of potlifts]) were evaluated by examining the residual diagnostics, selecting the error distribution with the best negative log likelihood for the final stepwise regression.

A linear regression model that assumed this error distribution was then fitted to log(catch) based only on records with successful catches of BCO 5. The regression was performed in a stepwise manner against the available explanatory variables; selecting each explanator until the improvement in model R^2 (deviance) was less than 0.01. The year effects are expressed in canonical form, allowing the calculation of confidence bounds for each year (Francis 1999). Fishing year was always forced as the first explanatory variable, and the explanatory variables offered to the model included month (of landing), and a unique vessel identifier. Continuous variables offered to the model included log(potlifts) and log(days fished).

C.4.1 Fishery definition for CPUE analysis

The fisheries used in 2011 to monitor BCO 5 were defined by the trip-strata that used the cod pot method (CP) in statistical areas 025, 027, or 030, and targeted and landed blue cod. The small proportion of zero catch records were excluded. In 2011, the analyses for each of the three main statistical areas were based on the same set of core vessels for each statistical area. These updated analyses have selected core vessels separately for each area (although this required relaxing the definition of qualifying participation for Areas 027 and 030) and include additional diagnostics.

Each fishery is defined by the trip-strata that used the cod pot method (CP) in either Statistical Area 025, 027, or 030, and targeted and landed blue cod. The small proportion of zero catch records were excluded. Data from the three statistical areas have been standardised separately and the fisheries, the models, and the indices obtained from them are specified by method and statistical area.

C.5 CP(AREA025), CP(AREA027), AND CP(AREA030)

C.5.1 Unstandardised CPUE

C.5.1.1 CP(Area 025): BCO 5 cod potting in Statistical area 025

The number of trips in this fishery peaked in the very early 1990s but by the late 1990s had dropped by about a third and has continued to decline slowly since then (Figure C.1). In every year a small percentage of trips report zero catches of blue cod (6–10%) (Figure C.2). Catch rates show an almost reciprocal pattern with effort, with the lowest values reported in the early 1990s when effort was greatest, and then steeply increasing over four years in the late 1990s when effort was declining. Catch rates then continued to increase in almost every year until 2004–05. There followed two consecutive years of decline and some subsequent recovery (Figure C.1).

The amalgamation caused by the preparation/allocation procedure has changed this data set very little, combining on average 1.2 original records into trip-strata for the first half of the series, increasing steadily to more than 1.4 during the 2000s. The number of potlifts per stratum also falls into two parts; declining to a low of less than 25 pots per stratum by 2000 and increasing since then to almost 40 potlifts per record in the most recent three years (Figure C.2). This level of amalgamation is inherent in the CELR data format (as single day trips already represent a level of amalgamation) and explains why the occurrence of zero catches is rare. The recent increase in average number of records per trip-stratum may indicate that vessels are moving between statistical areas less commonly than previously.

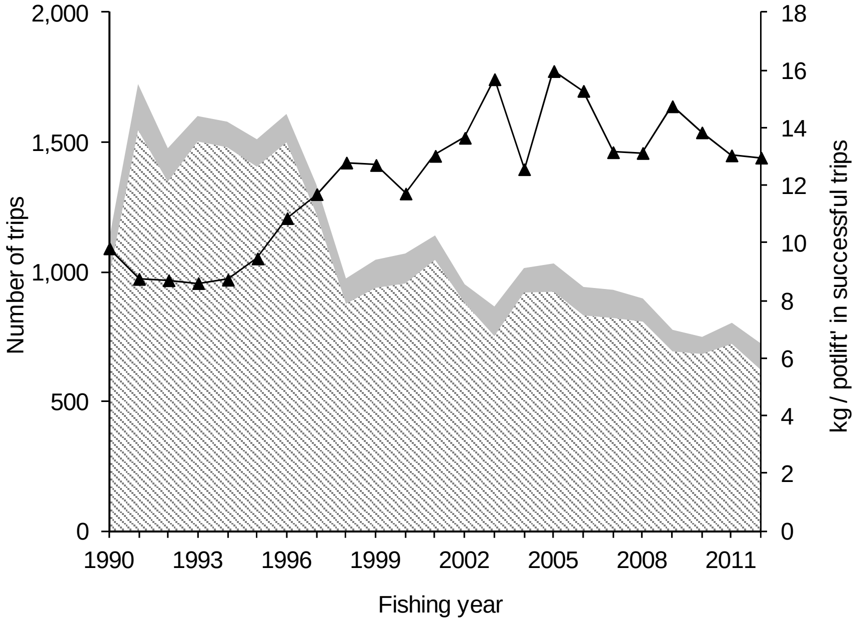


Figure C.1: Number of trips targeting blue cod by potting in Area 025, (dark area), the number of those trips that landed BCO 5 (light area) and the simple catch rate (kg/potlift) of BCO 5 in successful trips, by fishing year.

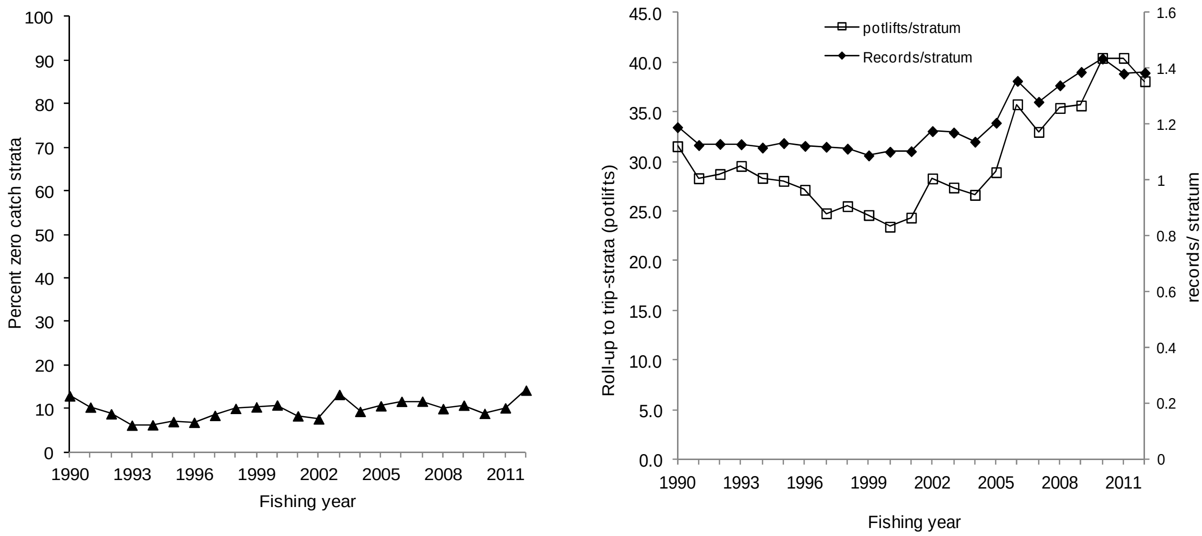


Figure C.2: The proportion of qualifying effort-strata targeted on blue cod by potting in Area 025, that landed zero BCO 5 (left), and the effect of data rollup indicated by the ratio of original records per trip-stratum, and number of potlifts per trip-stratum by fishing year [right].

C.5.1.2 CP(Area 027): BCO 5 cod potting in Statistical area 027

The number of trips in this fishery also peaked in the very early 1990s but then dropped to a constant low level of about a third of its peak, except for an anomolous peak in 1997–98 (Figure C.3). Catch rates have varied around a mean of about 17 kg per pot, peaking in the mid-2000s at 28 kg per pot, but with no overall trend up or down (Figure C.3). Very few trips have reported zero catches of blue cod in the last half of the time series (Figure C.4).

The amalgamation caused by the preparation/allocation procedure combined on average 2.5 original records into trip-strata for the first half of the series, increasing slightly during the 2000s. This indicates longer trips during the second half of the data, or possibly longer stays in the area than is seen in the Area 025 fishery. The number of potlifts per stratum is also proportionately greater at 60 to 80 potlifts per trip-stratum and has increased over time similarly (Figure C.4). This trend in the level of amalgamation may partly account for the decline in the occurrence of zero catches per stratum in this fishery.

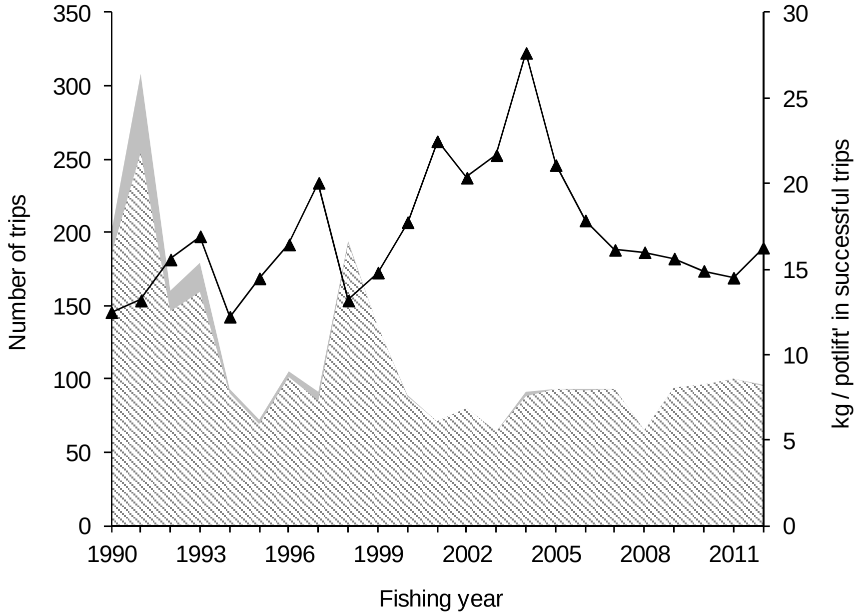


Figure C.3: Number of trips targeting blue cod by potting in Area 027, (dark area), the number of those trips that landed BCO 5 (light area) and the simple catch rate (kg/potlift) of BCO 5 in successful trips, by fishing year.

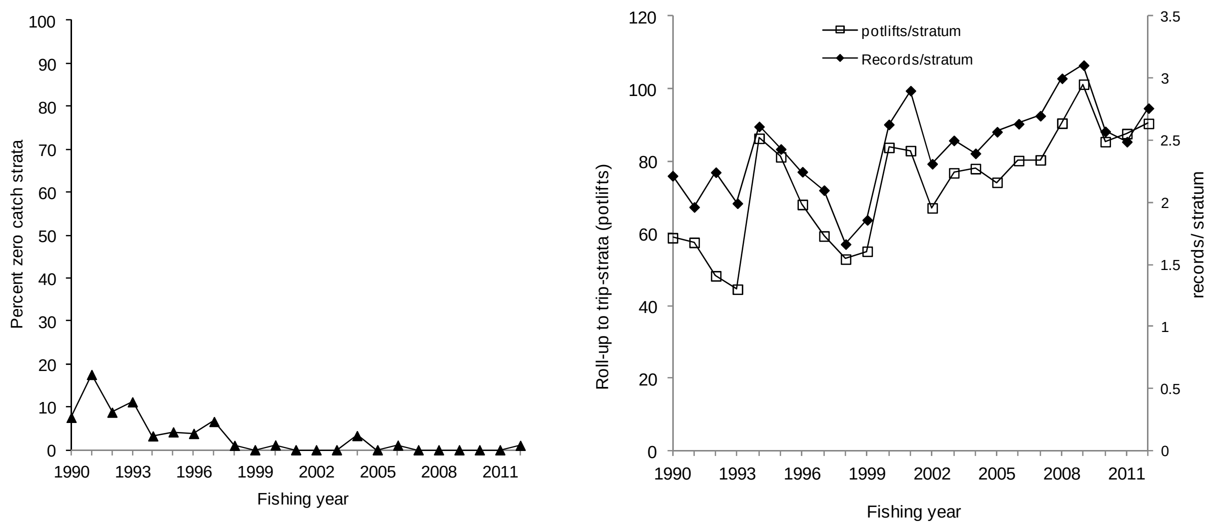


Figure C.4: The proportion of qualifying effort-strata targeted on blue cod by potting in Area 027, that landed zero BCO 5 (left), and the effect of data rollup indicated by the ratio of original records per trip-stratum, and number of potlifts per trip-stratum by fishing year [right].

C.5.1.3 CP(Area 030): BCO 5 cod potting in Statistical area 030

The number of trips in this fishery also peaked in the very early 1990s, declined steadily to about a third of its peak by 2007–08, and has peaked again in recent years. Catch rates were lowest (around 10 kg per potlift) during the early period of high effort, increased markedly during the late 1990s peaking at nearer 25 kg per potlift, and have varied around a mean of about 18 kg since then (Figure C.5). Very few trips have reported zero catches of blue cod in the last half of the time series (Figure C.6).

The amalgamation caused by the preparation/allocation procedure combined on average about 2 original records into trip-strata with very little trend. This probably indicates that longer trips, or possibly longer stays in the area than is seen for the Area 025 fishery. The number of potlifts per stratum is also proportionately greater at 50 to 60 potlifts per stratum and has increased over time. This trend in the level of amalgamation may partly account for the decline in the occurrence of zero catches per stratum in this fishery (Figure C.6).

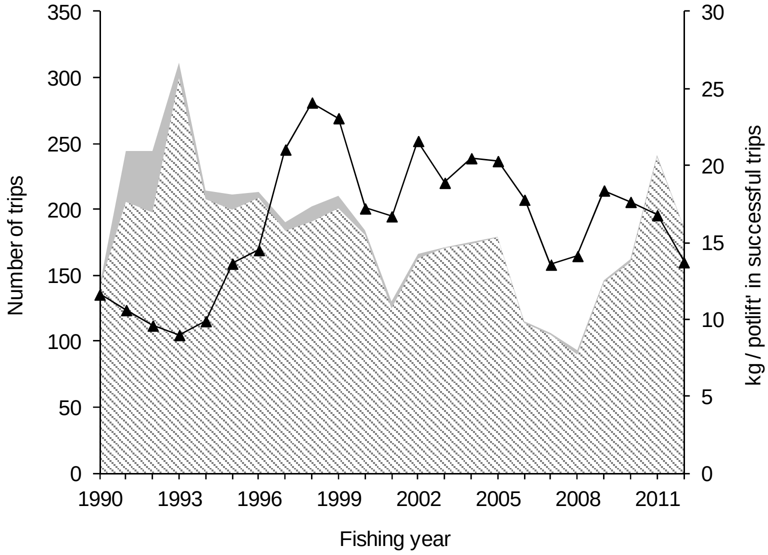


Figure C.5: Number of trips targeting blue cod by potting in Area 030, (dark area), the number of those trips that landed BCO 5 (light area) and the simple catch rate (kg/potlift) of BCO 5 in successful trips, by fishing year.

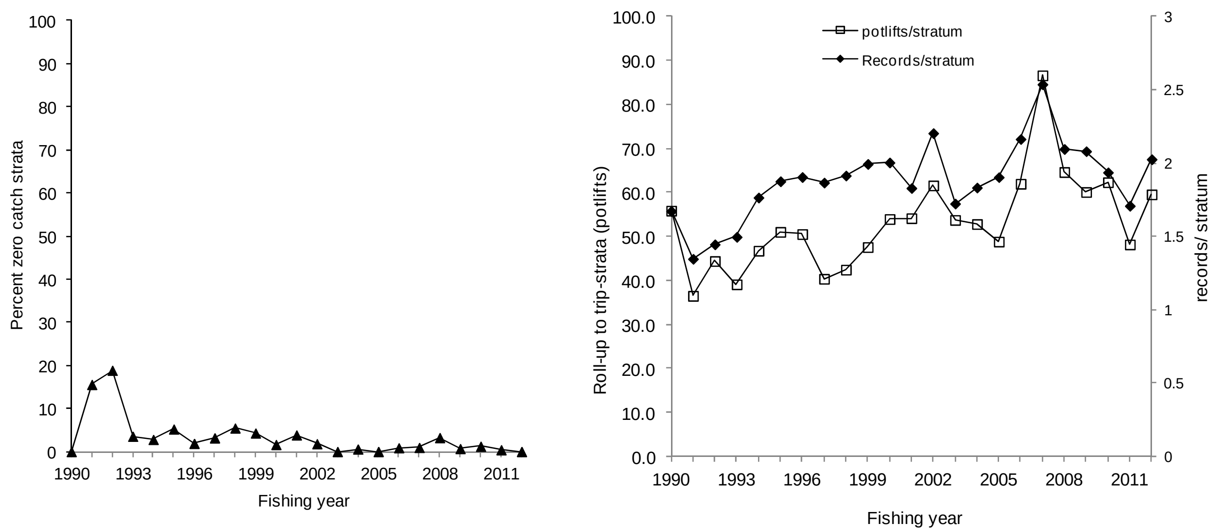


Figure C.6: The proportion of qualifying effort-strata targeted on blue cod by potting in Area 030, that landed zero BCO 5 (left), and the effect of data rollup indicated by the ratio of original records per trip-stratum, and number of potlifts per trip-stratum by fishing year [right].

C.5.2 Standardised CPUE analysis

C.5.2.1 Core fleet definitions

The data sets used for the standardised CPUE analysis were restricted to those vessels that participated with some consistency in the defined fisheries. Core vessels were selected by specifying two variables; the number of trips that determined a qualifying year, and the number of qualifying years that each vessel participated in the fishery. The effect of these two variables on the amount of landed blue cod retained in the dataset, the number of core vessels, and on the length of participation of the core vessels in each fishery are depicted for each of the defined fisheries in Appendix D.1. The core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of blue cod.

The definition used to determine core vessels in the CP (Area 025) fishery was that a selected vessel needed to have completed at least 10 trips per year over a minimum of 5 years. These criteria resulted in a core fleet size of 39 vessels which took 80% of the catch. For the CP (Area 027) fishery the definition was eased to 5 trips per year in at least 3 years, resulting in a core fleet size of 25 vessels which took 79% of the catch. For the CP (Area 030) fishery the definition of 5 trips per year in at least 3 years resulted in a core fleet size of 33 vessels which took 82% of the catch.

Data sets for the final core vessels in each statistical area are summarised in Appendix D.2.

C.5.2.2 Model selection, diagnostics and trends in model year effects

The family of model was selected by fitting saturated models (for simplicity), that assumed alternative error distributions to positive estimated catches, and comparing the resultant log likelihoods and residual patterns (Appendix C.3). The most appropriate family of model was then used in the selection of significant explanatory variables.

The final models selected for standardising positive catches in each fishery are described in Table C.1 CP (Area 025), Table C.2 CP (Area 027), and Table C.3 CP (Area 030). These tables include those explanatory variables that improved the AIC and do not necessarily include a complete list of the variables that were offered because some variables had no effect on the AIC. Variables that were accepted into the model needed to improve the R^2 by at least 1%; these variables are indicated with asterisks in the table, along with the amount of deviance they explained.

Following each table are step-influence plots that demonstrate the progressive effect on the annual indices by each explanatory variable as it enters the model, and compares the influence of each variable on observed catch (which the model adjusts for) in adjacent panels. These plots highlight the observation made in Bentley et al. (2011) that the variables that explain the most deviance are not necessarily the ones responsible for most of the difference between standardised and observed series of CPUE. The influence of an explanatory variable is a combination of its GLM coefficients and its distributional changes over years, and these are contrasted and combined in Coefficient-Distribution-Influence (CDI) plots (Bentley et al. 2011), presented in Appendix D for each accepted explanatory variable.

The time series of year effects from the models are then plotted, along with the unstandardised CPUE (annual geometric mean CPUE based on kg per potlift) for the core fleets. Also overlaid are series of standardised CPUE from the previous project (Starr & Kendrik 2011), which were based on a common core fleet in all three statistical areas and assuming a lognormal error distribution. The series are rescaled relative to the years they have in common. There is good agreement in the trends for each fishery with previous series over the years in common.

Diagnostic residual plots are presented for each model in Appendix C3 and all show a similar departure from the underlying distributional assumption at the extremes of the residual distribution. There are some particularly large negative residuals that are associated with low observed values. Considering that each record is on average the cumulative catch of over 30 potlifts, it is not surprising that the model might have trouble predicting very low values. In 2008, the 17 observations of lowest catch were removed from the dataset as a sensitivity exercise with a consequent improvement in the fit to the lognormal assumption but made no discernible difference to the year effects (not shown). Consequently, the leverage by the extreme outliers is not considered to be of concern.

The diagnostic plots of models fit to data from individual areas are based on datasets that have not been trimmed of these extremely low observed catches, and they can be seen to occur and to be associated with very low negative residuals in each area.

C.5.2.3 CP(Area 025): BCO 5 cod potting in Statistical area 025

The log-logistic error distribution provided the best model fit to the Area 025 data (Figure D.4). Fishing year was forced as the first variable and explained about 7% of the variance in catch. The log of potlifts is the most important variable, entering second and explaining an additional 41% of the variance. Vessel entered the model third and explained a further 20% of variance. The final model explained 68% of the variance in log(catch) (Table C.1). The annual indices are plotted at each step of this selection procedure in Figure C.7.

The influence (CDI) plot for log(potlifts) shows an early decline in the number of potlifts followed by a marked increase after 2000, with a positive overall influence on observed catches (Figure D.10). The model adjusts for these shifts by lifting the annual indices in the mid-1990s when effort was dropping steeply, and dropping the annual indices in the mid-2000s when effort was increasing again. The effect is to change an increasing trajectory to one that declines from a peak in 2004–05 and shows no trend in the most recent six years. The increase in observed CPUE coincides with a disappearance, in the distribution, of the mode at between 5 and 7 potlifts per day, and therefore may indicate improved reporting. It is possible that fishers have, in the past, misunderstood the requirement to report the number of potlifts per day and instead have reported the number of pots they fished. However, it is not correct to assume that small numbers of potlifts in a day are errors, because it is also possible that fishers lift pots only once in a day under a range of circumstances.

The coefficients for vessel show consistent differences in performance among vessels with respect to blue cod catch. Two vessels in particular did better than the rest of the fleet, one that participated over the middle part of the time series, leaving the fishery in 2006–07, and the other vessel replacing it in 2007–08 (Figure D.12). The influence of changes in the core fleet has been to increase catches over much of the period but was only weakly positive overall. Month entered with very little explanatory power and an imperceptible effect on the annual indices.

The year effects from the CP (Area 025) model show a stable period in the first six years (1989–90 to 1994–95) at levels that that are the lowest for the series (Figure C.8). These levels may be lower than those observed after October 1994 because of a change in regulations affecting the pot mesh size. That period is followed by ten years of consistent increase to reach levels about 50% higher than those seen in the early 1990s. There has been a reversal of this trend since then, and the indices have been relatively stable over the most recent six years at a level that is near the mean for the series. The trends are well-determined in that they hold over consecutive years with little interannual variation, and the confidence bounds on each index point are small. There is good agreement with the previous series presented in 2011 for the years in common (Figure C.8).

The effect of standardisation is to lift some early points and to reduce the magnitude of the peak so that the series is smoothed without changing the overall trend. The standardisation does not change the decline seen in the unstandardised CPUE in the most recent seven years.

Table C.1: Order of acceptance of variables into the lognormal model of successful catches of BCO 5 for core vessels in the CP (Area 025) fishery, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year (fyear) was forced as the first variable.

Log logistic term	DF	Log likelihood	AIC	R^2 (%)	Final
fyear	24	-127 575	255 197	7.33	*
poly(log(num) 3)	27	-121 986	244 026	48.44	*
vessel	189	-117 392	235 162	68.16	*
month	200	-117 253	234 907	68.62	*
poly(log(days) 3)	203	-117 231	234 868	68.70	

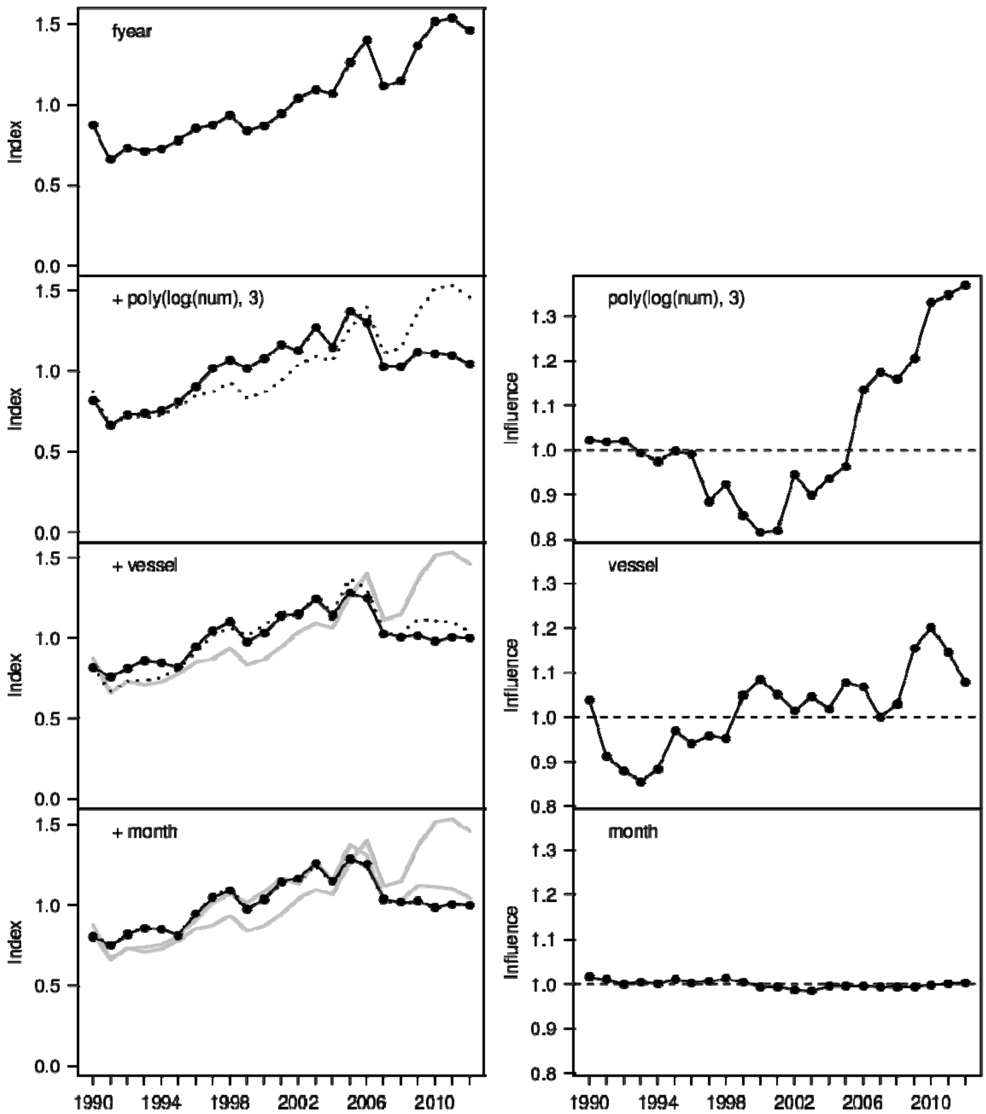


Figure C.7: [left column]: annual indices from the lognormal model of CP (Area 025) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

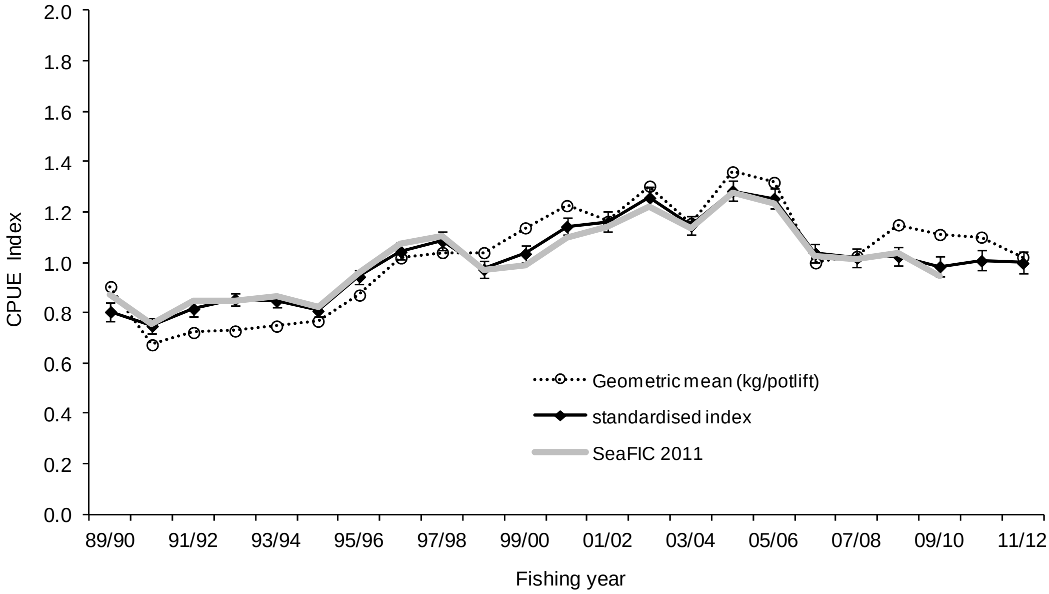


Figure C.8: The effect of standardisation on the raw CPUE of blue cod in successful trips by core vessels in the CP (Area 025) fishery. Broken line is the annual geometric mean of kg /potlift, bold line is standardised canonical indices with ± 2 * SE error bars. Grey line is the previous series (Starr & Kendrick 2011) for this fishery. All series are relative to the geometric mean over the years in common.

C.5.3 CP (Area 027): BCO 5 cod potting in Statistical area 027

The log-logistic error distribution provided the best model fit to the Area 027 data (Figure D.6). Fishing year was forced as the first variable and explained more than 20% of the variance in catch. The log of potlifts is the most important explanatory variable, explaining an additional 56% of the variance. Vessel entered the model third and explained a further 7% of the variance. The final model explained 85% of the variance in log(catch) (Table C.2). The annual indices are plotted at each step of this selection in Figure C.9 and show the influence of each variable on observed catches over time.

The influence (CDI) plot for log(potlifts) shows a steady increase in the average number of potlifts per record with an overall influence of about +50% on observed catches (Figure D.13). The model adjusts for these shifts by lifting the annual indices in the first half of the series, and dropping those in the last half. The effect is to change an increasing trajectory to one that is almost flat. The decline, in the distribution, of a mode at 10 potlifts per day, is gradual but may nevertheless indicate improved reporting of the number of potlifts per day instead of the number of pots fished.

The coefficients for vessel show large and consistent differences in performance among vessels with respect to blue cod catch, and the departure in 2006–07 of many of the poorer performing vessels (Figure D.14). The influence of these changes in the core fleet has been to increase catch rates in the last ten years by 40–50% which the model adjusts for by lifting the peak in the middle of the series and further lowering the indices in recent years. A trend towards more days per record also explains some increase in catches and is adjusted for by the model with some small shifts in the annual indices.

The year effects from the CP (Area 027) model show that the first six years (1989–90 to 1994–95) were the lowest for the series (Figure C.10). These levels may be lower than those observed after October 1994 because of a change in regulations affecting the pot mesh size. That period is followed by ten years of consistent increase to reach levels about 150% higher than those seen in the early 1990s. There has been a reversal of this trend since then, and the indices have been relatively stable over the most recent six years at a level that is just below the mean for the series. The trends are well-determined in that they hold over consecutive years with little interannual variation, and the confidence bounds on each point are small. Differences from the previous series presented in 2011 will be due to a different core fleet selection but the two series are not dissimilar for the years in common (Figure C.10).

The effect of standardisation is to lift the peak in the middle of the series and to reduce recent points so that the decline from peak levels is emphasised.

Table C.2: Order of acceptance of variables into the lognormal model of successful catches of BCO 5 for core vessels in the CP (Area 027) fishery, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Log logistic term	DF	Log likelihood	AIC	R^2 (%)	Final
fyear	24	-15 618	31 284	20.45	*
poly(log(num), 3)	27	-14 423	28 900	76.63	*
vessel	126	-14 067	28 385	83.78	*
poly(log(days), 3)	129	-13 985	28 228	85.08	*

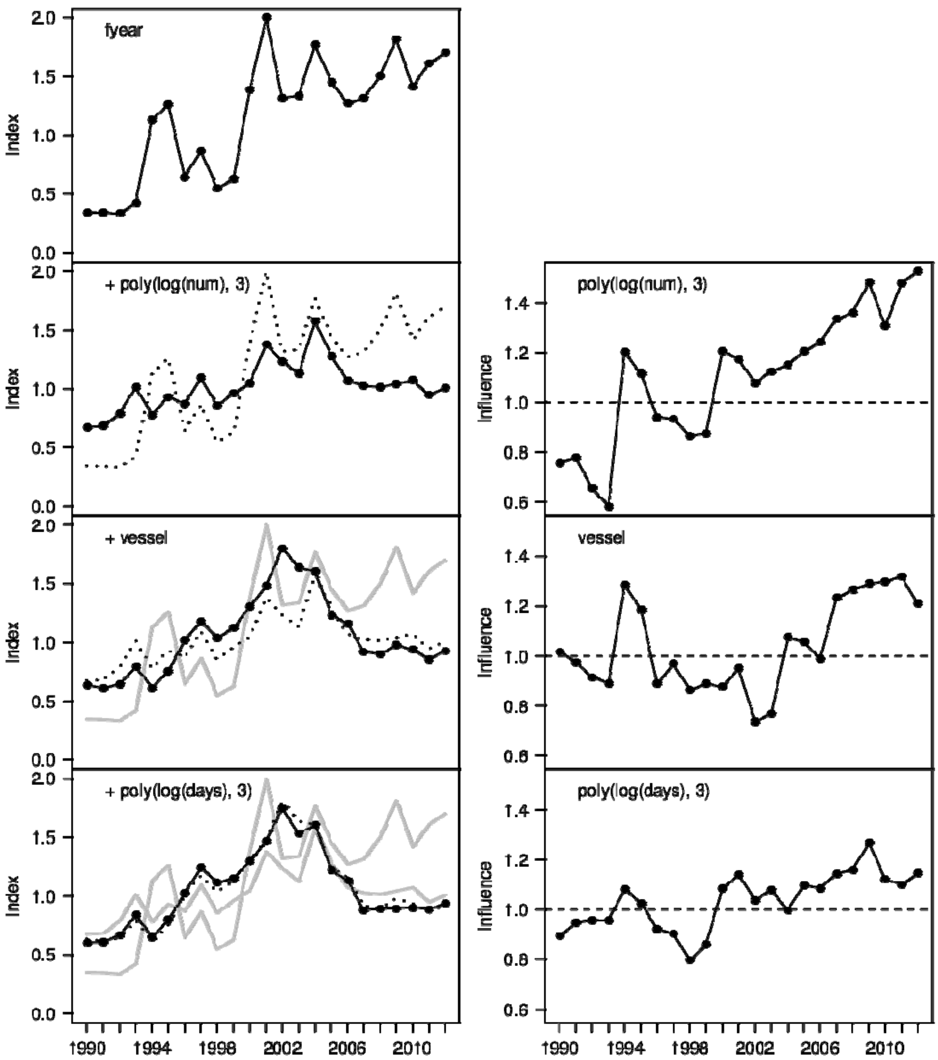


Figure C.9: [left column]: annual indices from the lognormal model of CP (Area 027) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

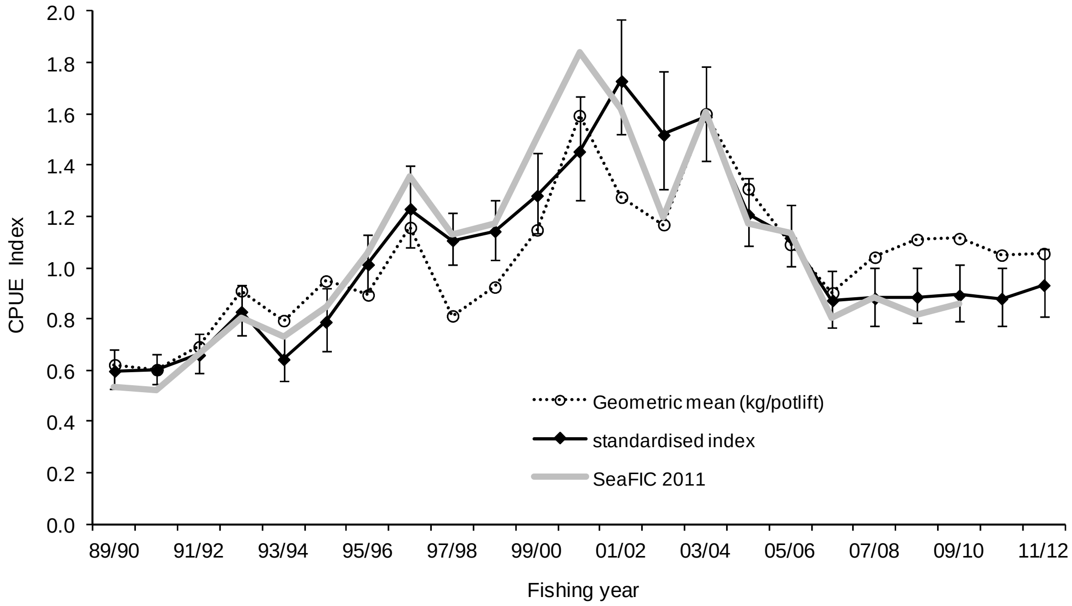


Figure C.10: The effect of standardisation on the raw CPUE of blue cod in successful trips by core vessels in the CP (Area 027) fishery. Broken line is the annual geometric mean of kg /potlift, bold line is standardised canonical indices with ± 2 * SE error bars. Grey line is the previous series (Starr & Kendrick 2011) for this fishery. All series are relative to the geometric mean over the years in common.

C.5.4 CP (Area 030): BCO 5 cod potting in Statistical area 030

The log-logistic error distribution produced the best model fit to the Area 030 data (Figure D.8). Fishing year was forced as the first variable and explained more than 15% of the variance in catch (Table C.3). The log of days fished was the most important variable in terms of explanatory power, explaining an additional 34% of the variance. Vessel entered the model next and explained a further 18% of the variance, but had more influence on the trend in the annual indices than days fished. Number of potlifts explained an additional 6% and month also entered the model but with very little explanatory power. The final model explained 74% of the variance in log(catch). The annual indices, plotted at each step of the selection procedure, show the influence of each variable on observed catches over years (Figure C.11).

The influence (CDI) plot for log(days) shows a slow but steady increase in the number of days per record over the period which had a small but positive overall influence on log(catch) (Figure D.16). The model adjusted for these shifts by lifting some initial points, removing some spikiness in the second half of the series, but without changing the overall trajectory very much. The influence of changes in the core fleet by contrast was strongly positive (Figure D.17), largely caused by the loss of poorer performing vessels from the fishery and the recent entrance of two particularly high performing vessels. Adjusting for these shifts in vessel participation changes the trajectory from one that increases to one that declines. The influence of the additional effort variable (number of potlifts) is slightly positive (Figure D.18), but results in a smoothing of the series without further changing the overall trend.

The year effects from the CP (Area 030) model show a slow decline in the first seven years (1989–90 to 1996–97) that is reversed following the change in regulations affecting the size of the pot mesh size (Figure C.12). That period is followed by six years of fairly consistent increase to reach levels about double those seen in the mid-1990s. There has been a reversal of this trend since then, and a steady decline over ten consecutive years to sit currently at a level that is just below the mean for the series. These trends are well-determined in that they hold over consecutive years with little interannual variation, and the confidence bounds on each point are small. Some of the differences from the 2011 series are likely to be due to a different core fleet selection procedure, but the two series seem reasonably similar for the years in common (Figure C.12).

The effect of standardisation is to lift initial points and drop recent ones changing a trajectory that increases to one that declines overall. It also smoothes the series considerably, giving some credibility to the assumption that it monitors the underlying abundance of blue cod.

Table C.3: Order of acceptance of variables into the lognormal model of successful catches of BCO 5 for core vessels in the CP (Area 030) fishery, with the amount of explained deviance and R^2 for each variable. Variables accepted into the model are marked with an *, and the final R^2 of the selected model is in bold. Fishing year was forced as the first variable.

Term	DF	Log likelihood	AIC	R^2 (%)	Final
fyear	24	-24 892	49 833	15.31	*
poly(log(days) 3)	27	-24 060	48 173	49.40	*
vessel	144	-23 358	47 004	67.21	*
poly(log(num) 3)	147	-23 017	46 327	73.45	*
month	158	-22 986	46 289	73.94	*

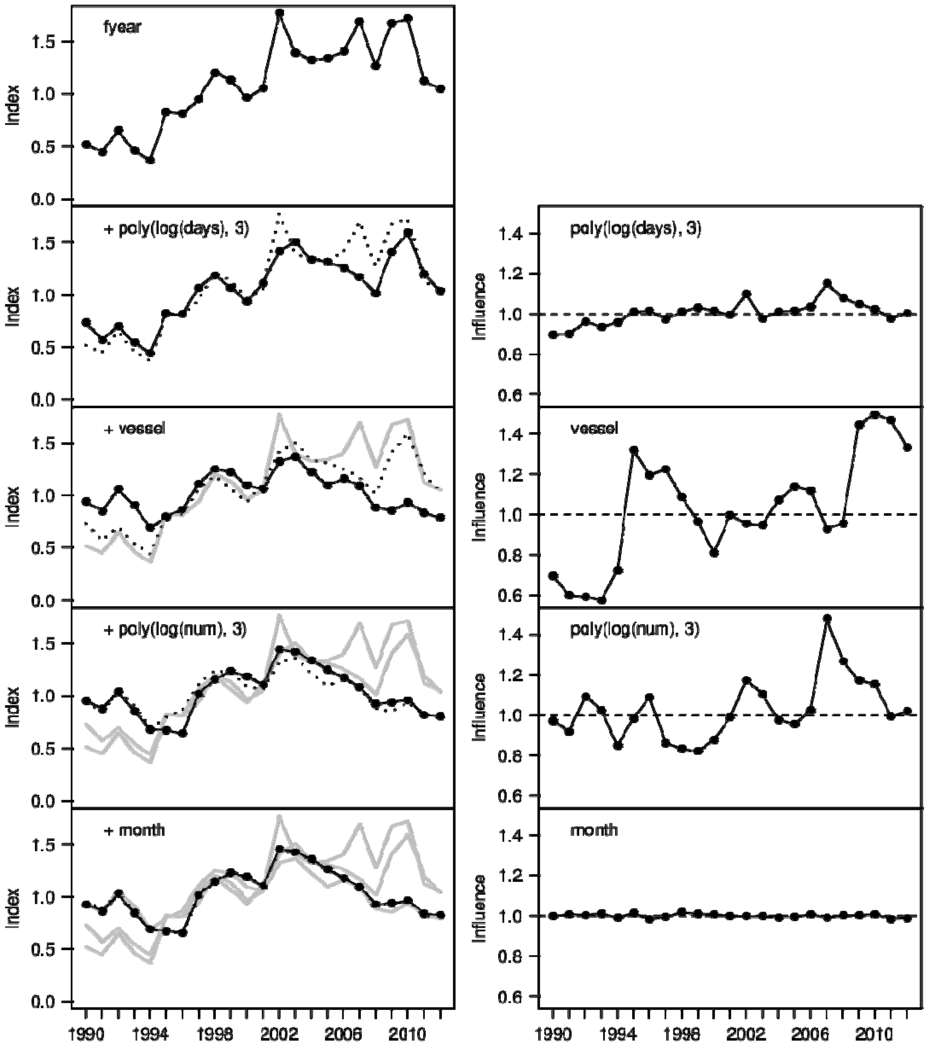


Figure C.11: [left column]: annual indices from the lognormal model of CP (Area030) at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

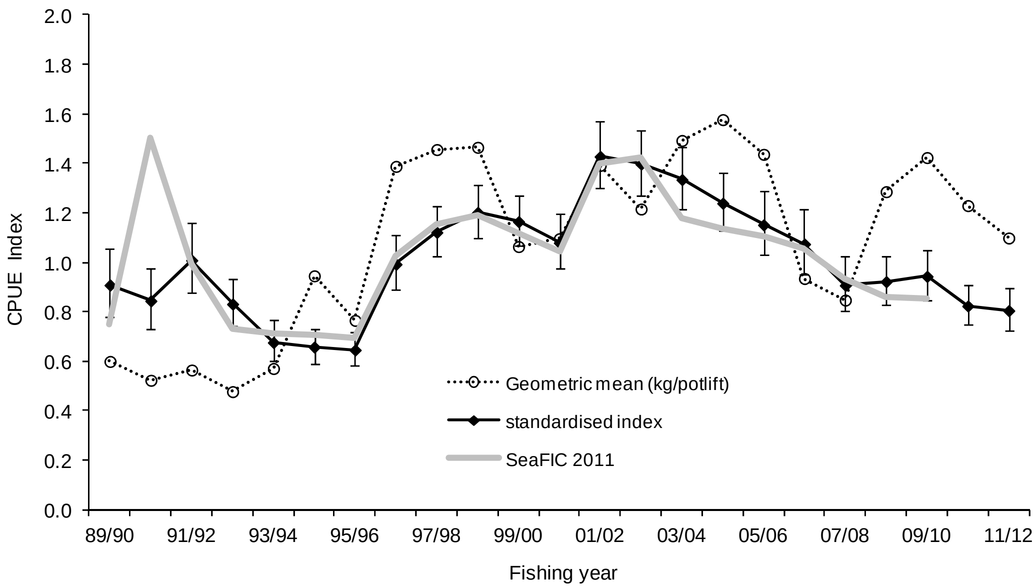


Figure C.12: The effect of standardisation on the raw CPUE of blue cod in successful trips by core vessels in the CP (Area 030) fishery. Broken line is the annual geometric mean of kg /potlift, bold line is standardised canonical indices with ± 2 * SE error bars. Grey line is the previous series (Starr & Kendrick 2011) for this fishery. All series are relative to the geometric mean over the years in common.

C.5.5 Comparison of models

The majority of the data for cod potting in BCO 5 comes from Statistical Area 025 and any overall analysis (not presented but an earlier version is available in Starr & Kendrick 2011) is dominated by and closely resembles the series obtained from Area 025. Independent series for the more remote areas 027 and 030 include many of the same vessels as the Area 025 analysis, but are based on less restrictive core vessel definitions (five trips and at least three years) to provide an adequate amount of data. The analyses for these two statistical areas are more variable and probably less reliable than the Area 025 series, but do not show markedly different overall trends. The three series agree on a sustained increase following the mesh size changes in 1994 to reach peaks in the early to mid-2000s, followed by subsequent and initially steep declines to new lower levels at which each series has been relatively stable in the most recent six to seven years (Figure C.13).

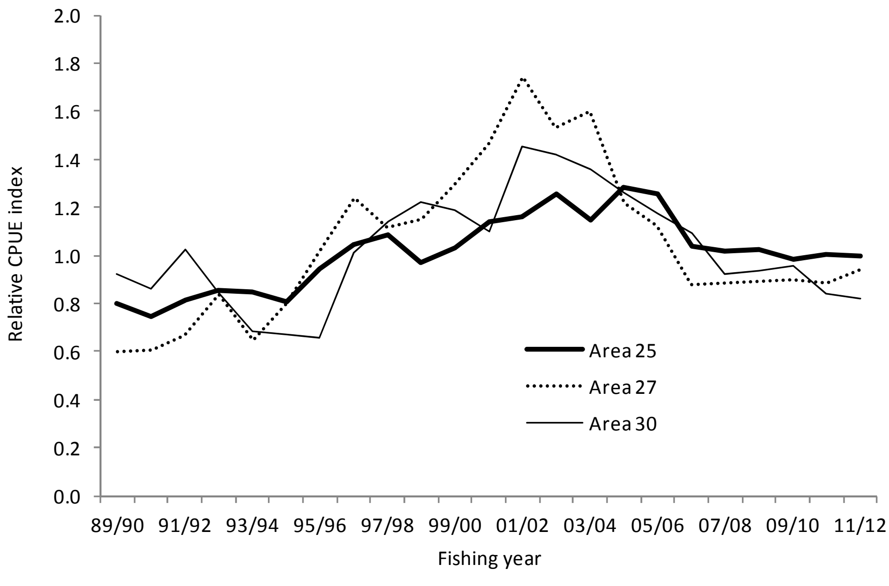


Figure C.13: Comparison of the standardised year effects based on cod potting fisheries for each of the three Statistical Areas comprising BCO 5.

C.5.6 Comparison with other models

The effect of selecting the error distribution that gave the most consistent residual pattern relative to the distributional assumption was not substantial: there is little difference in the estimated year indices when the "best" series is compared to an alternative series based on a lognormal distribution for all three statistical areas (Figure C.14).

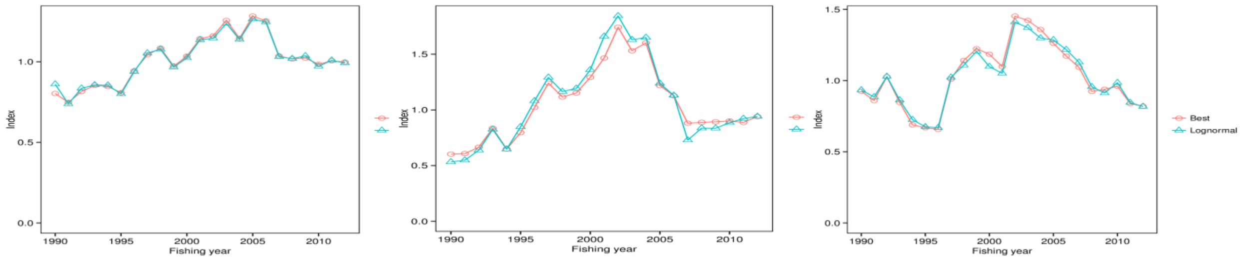


Figure C.14: Comparison between the log-logistic indices and indices obtained from similar models that assumed lognormal error distributions for CP (Area 025), CP (Area 027), and CP (Area 030).

An alternative approach that updated the combined area analysis using a common core fleet was also explored. The area by fishing year interactions were examined by plotting residual implied coefficients for each statistical area. This analysis was not well determined due to a scarcity of data because of the strong core fleet definition that was used (10 trips/5 years). However, the resultant series generally resembled the equivalent separate series for each statistical area (compare the black lines in Figure C.15 with either of the lines in Figure C.14).

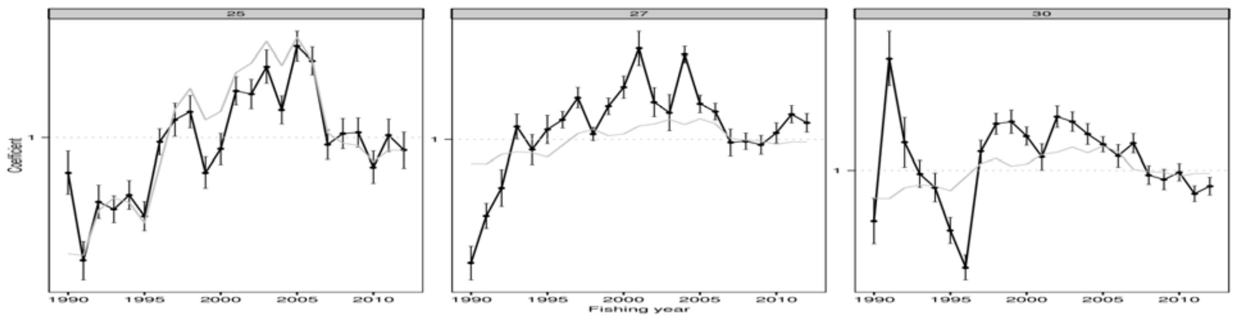


Figure C.15: Residual implied coefficients for area × fishing year interactions from an alternative analysis (not shown) that combined data from the three statistical areas and used a common core fleet. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and area. These values approximate the coefficients obtained when an area × year interaction term is fitted, particularly for those area × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals.

APPENDIX D. DETAILED DIAGNOSTICS FOR BCO 5 CPUE STANDARDISATIONS

D.1 CORE VESSEL SELECTION

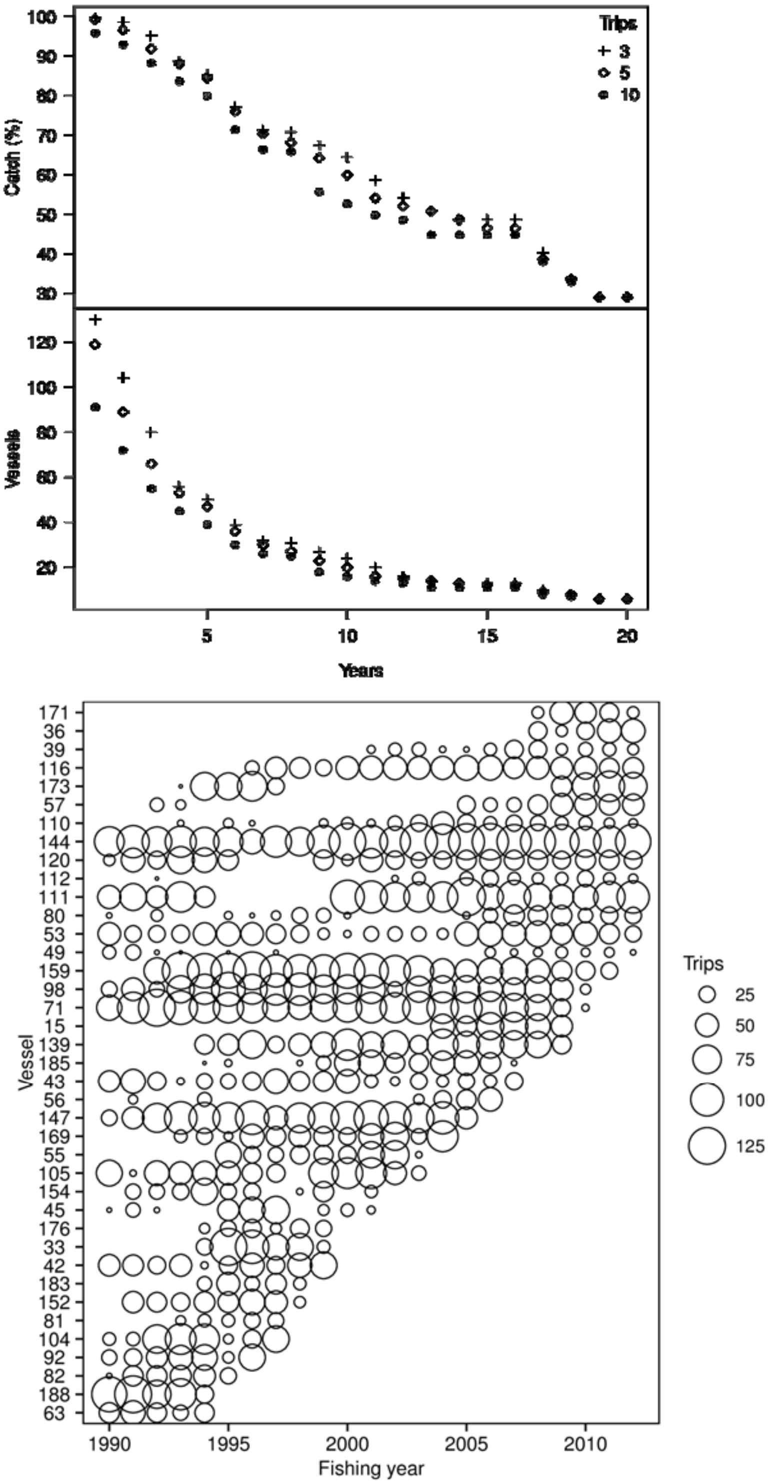


Figure D.1: The total landed BCO 5 [top left] and the number of vessels [middle] retained in the CP (Area 025) dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 10 trips in 5 or more fishing years); number of records for each vessel in each fishing year [bottom].

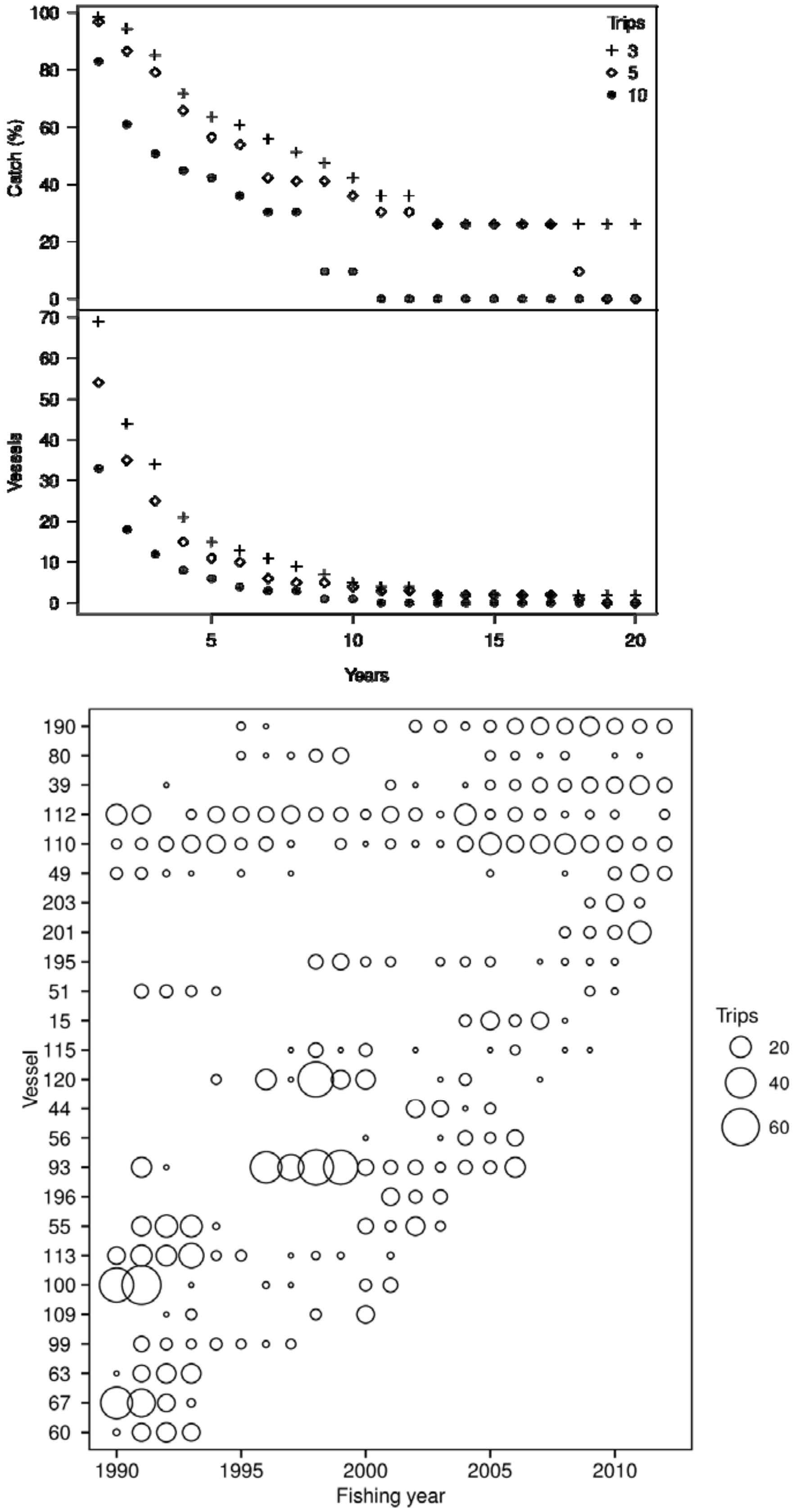
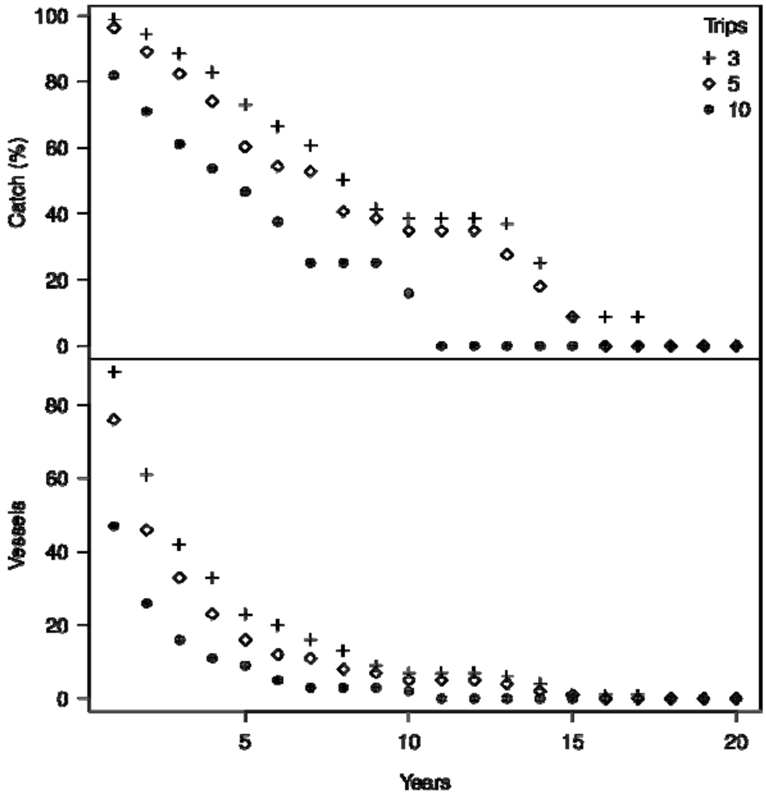


Figure D.2: The total landed BCO 5 [top left] and the number of vessels [middle] retained in the CP (Area 027) dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 5 trips in 3 or more fishing years); number of records for each vessel in each fishing year [bottom].



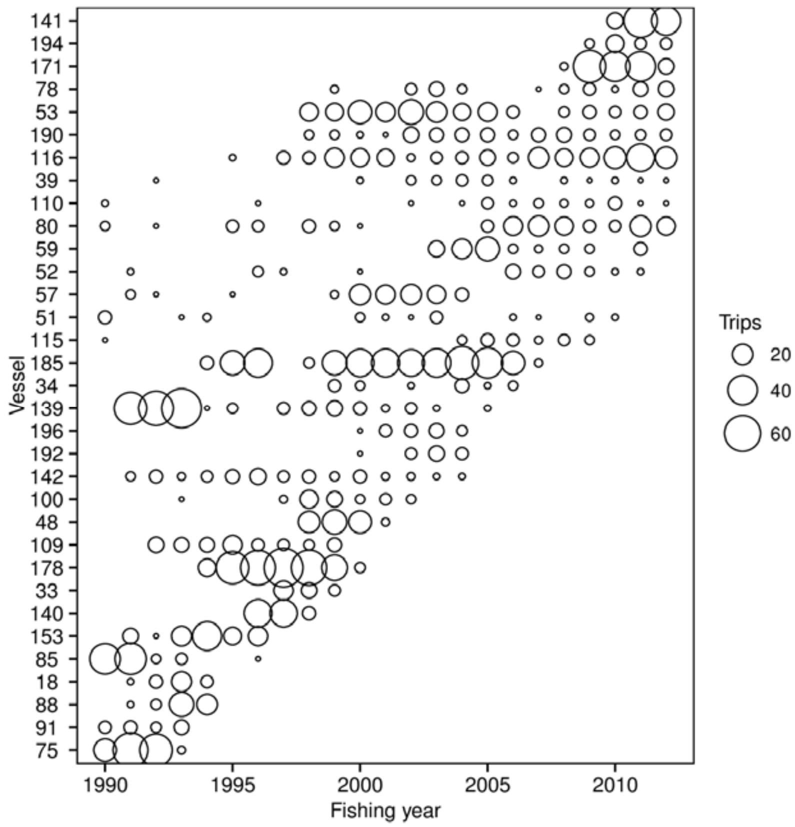


Figure D.3: The total landed BCO 5 [top left] and the number of vessels [middle] retained in the CP (Area 030) dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. The participation of selected core vessels (based on at least 5 trips in 3 or more fishing years); number of records for each vessel in each fishing year [bottom].

D.2 DATA SUMMARIES

Table D.1: Number of vessels, and trips, landed BCO 5 (t), number of potlifts, and percentage of zero catch records for core vessels (based on a minimum of 10 trips per year in at least 5 years) in the CP (Area 025) fishery, by fishing year.

Fishing year	Vessels	Trips	Catch (t)	Effort potlifts	% positive (records)
1990	19	672	177.2	19 422	84.1
1991	21	916	184.2	25 612	85.5
1992	24	958	211.3	27 935	89.6
1993	24	1173	255.8	32 342	92.5
1994	28	1262	269.8	33 320	92.4
1995	30	1250	286.9	33 568	92.0
1996	26	1318	335.5	35 049	92.9
1997	25	1048	274.4	25 134	90.8
1998	20	849	235.5	21 422	88.9
1999	21	955	240.7	22 582	88.8
2000	19	1048	252.5	24 215	89.1
2001	19	1080	289.8	24 332	91.6
2002	18	909	313.6	25 203	92.1
2003	19	838	310.2	22 308	86.4
2004	17	979	292	25 574	90.5
2005	20	960	384.5	26 695	88.9
2006	19	903	433.3	31 431	87.9
2007	18	848	327.6	29 201	87.3
2008	18	824	324	28 786	89.2
2009	19	723	322.1	24 979	88.7
2010	17	611	281.8	22 924	89.4
2011	15	615	275.3	23 063	88.8
2012	14	548	214.0	20 608	82.1

Table D.2: Number of vessels, and trips, landed BCO 5 (t), number of potlifts, and percentage of zero catch records for core vessels (based on a minimum of 5 trips per year in at least 3 years) in the CP (Area 027) fishery, by fishing year.

Fishing year	Vessels	Trips	Catch (t)	Effort potlifts	% positive (records)
1990	8	145	80.47	6 775	89.7
1991	12	232	133.79	12 481	76.7
1992	13	124	92.92	6 002	89.5
1993	12	123	90.95	5 437	84.6
1994	9	53	61.76	5 146	94.3
1995	7	40	59.42	3 696	97.5
1996	9	93	99.32	6 120	96.8
1997	10	65	79.49	3 892	96.9
1998	10	158	107.09	7 946	99.4
1999	9	111	91.54	5 907	100.0
2000	12	85	123.12	7 094	98.8
2001	10	70	129.93	5 679	100.0
2002	9	71	104.83	4 939	100.0
2003	11	53	89.45	4 193	100.0
2004	11	78	145.45	5 715	96.2
2005	13	89	142.87	6 648	100.0
2006	12	88	115.53	6 680	98.9
2007	9	65	78.59	5 419	100.0
2008	10	59	83.98	5 485	100.0
2009	12	69	114.35	7 596	100.0
2010	10	76	96.12	6 482	100.0
2011	8	76	104.88	7 270	100.0
2012	6	44	63.22	4 218	100.0

Table D.3: Number of vessels, and trips, landed BCO 5 (t), number of potlifts, and percentage of zero catch records for core vessels (based on a minimum of 5 trips per year in at least 3 years) in the CP (Area 030) fishery, by fishing year.

Fishing year	Vessels	Trips	Catch (t)	Effort potlifts	% positive (records)
1990	9	96	56.13	4 754	100.0
1991	11	191	54.62	6 801	80.1
1992	12	160	55.13	7 171	71.3
1993	11	179	61.52	7 543	93.9
1994	10	116	46.2	4 386	100.0
1995	13	142	94.44	7 128	96.5
1996	12	188	124.16	8 451	98.9
1997	10	161	136.79	6 023	96.3
1998	15	188	178.66	7 610	94.2
1999	15	192	206.69	8 593	95.3
2000	18	177	156.72	9 343	98.3
2001	15	123	108.82	6 529	95.9
2002	15	150	191.83	9 127	98.0
2003	13	157	155.8	8 106	100.0
2004	15	157	165.29	7 919	99.4
2005	11	145	156.13	6 900	100.0
2006	13	101	101.48	5 297	99.0
2007	12	80	87.05	5 939	98.8
2008	11	86	71.26	5 439	96.5
2009	13	127	140.73	7 364	99.2
2010	14	135	152.73	7 749	98.5
2011	13	199	168.2	9 599	100.0
2012	10	132	107.52	7 314	100.0

D.3 RESIDUAL AND DIAGNOSTIC PLOTS

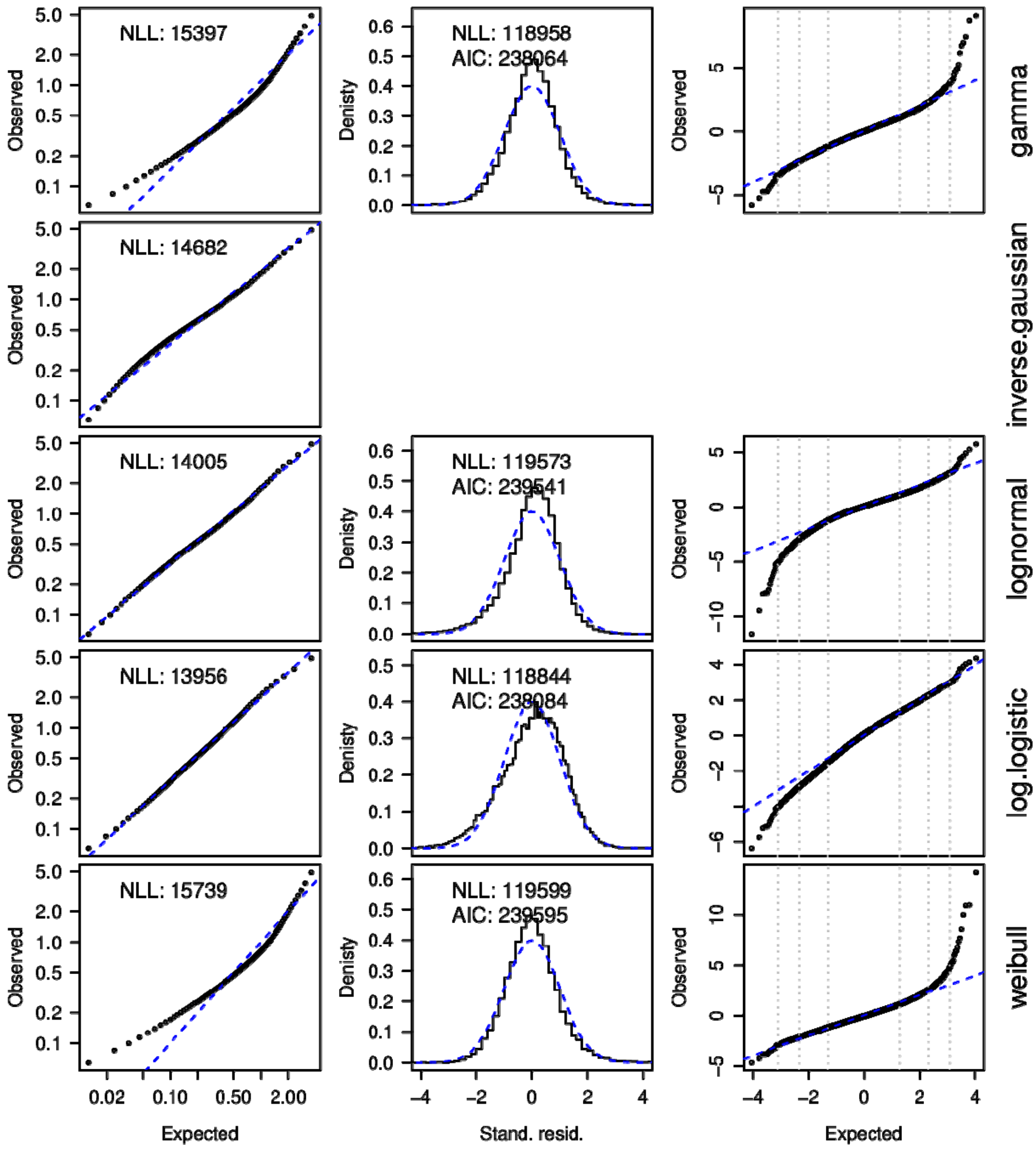


Figure D.4: Diagnostics for alternative distributional assumptions for catch in the CP (Area 025) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + vessel + log(potlifts) and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

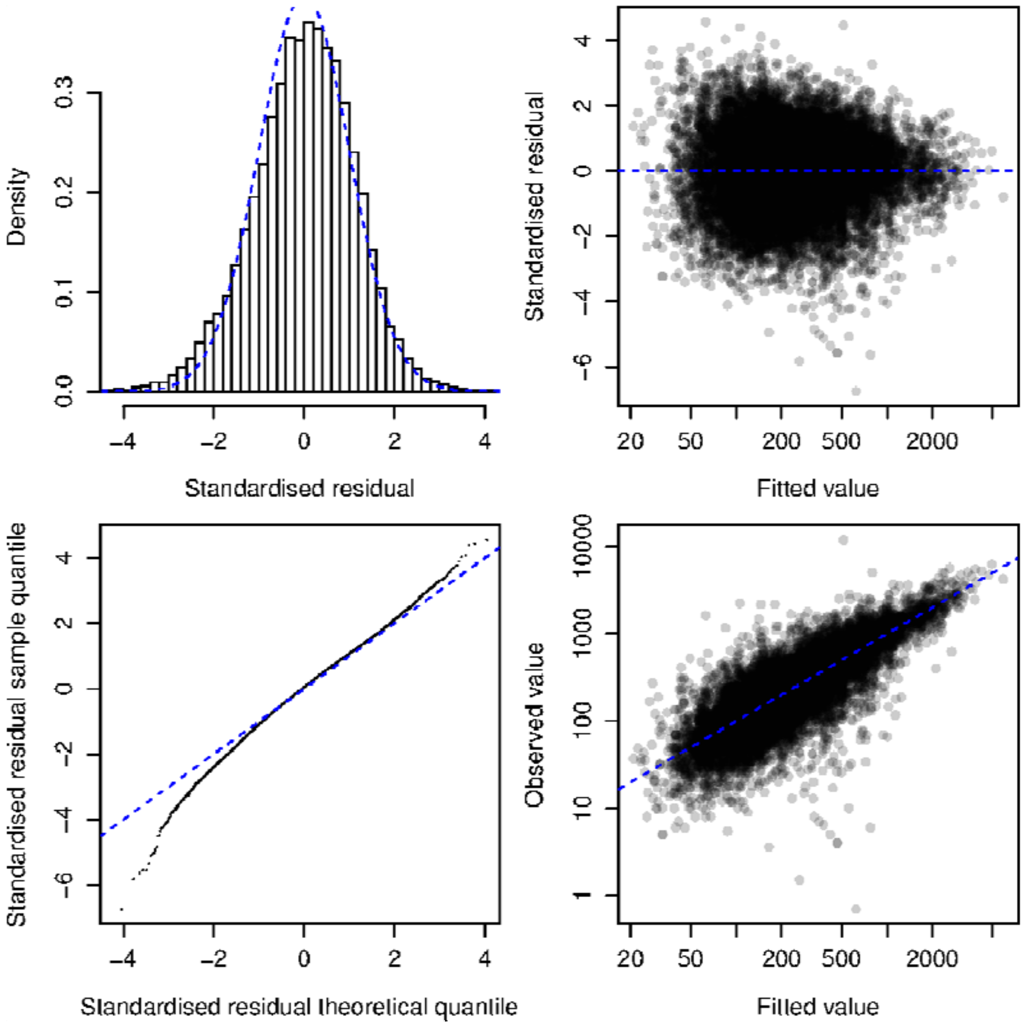


Figure D.5: Plots of the fit of the standardised CPUE model to successful catches of BCO 5 in the CP (Area 025) fishery[Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

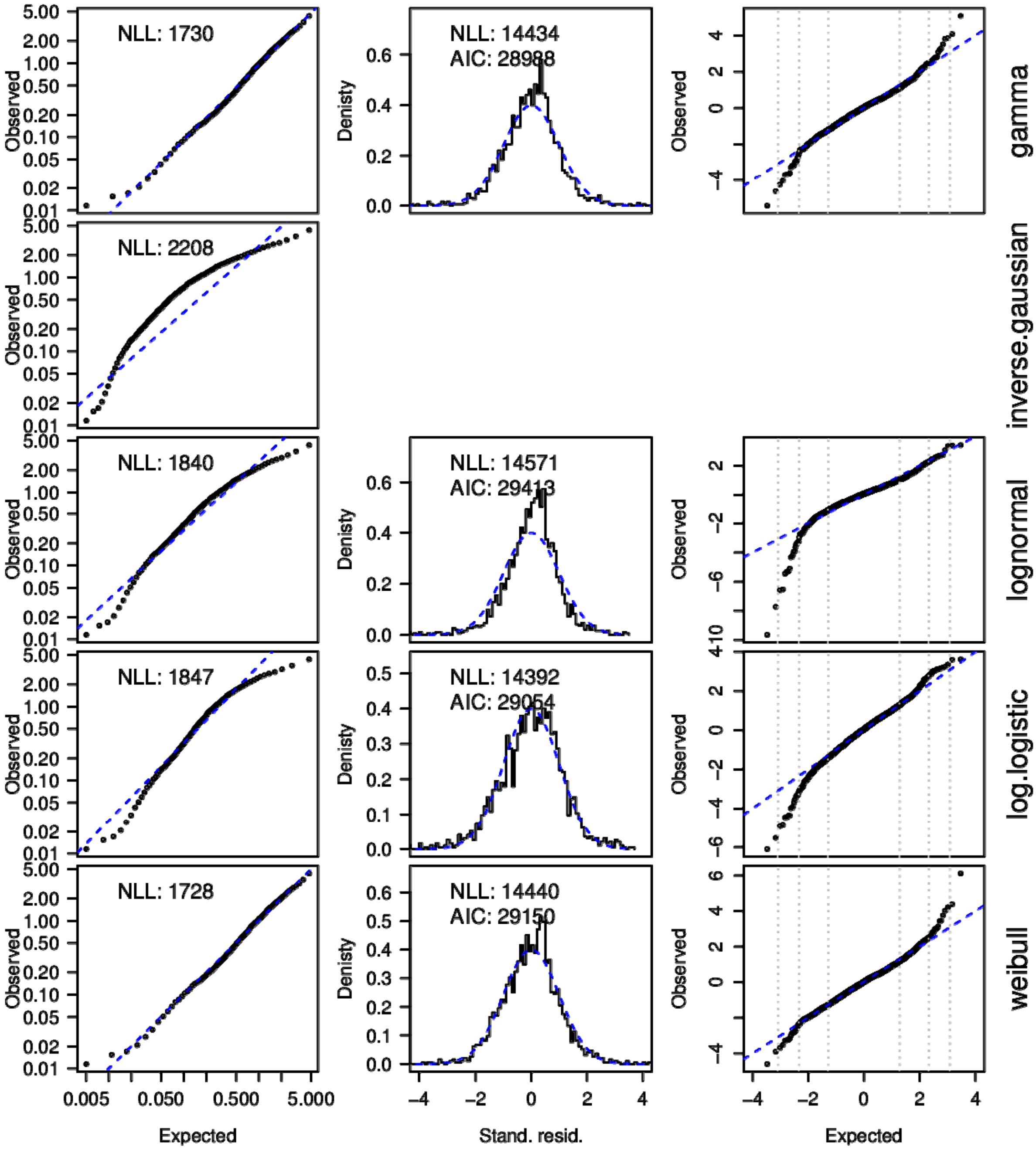


Figure D.6: Diagnostics for alternative distributional assumptions for catch in the CP (Area 027) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + vessel + log(potlifts) and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

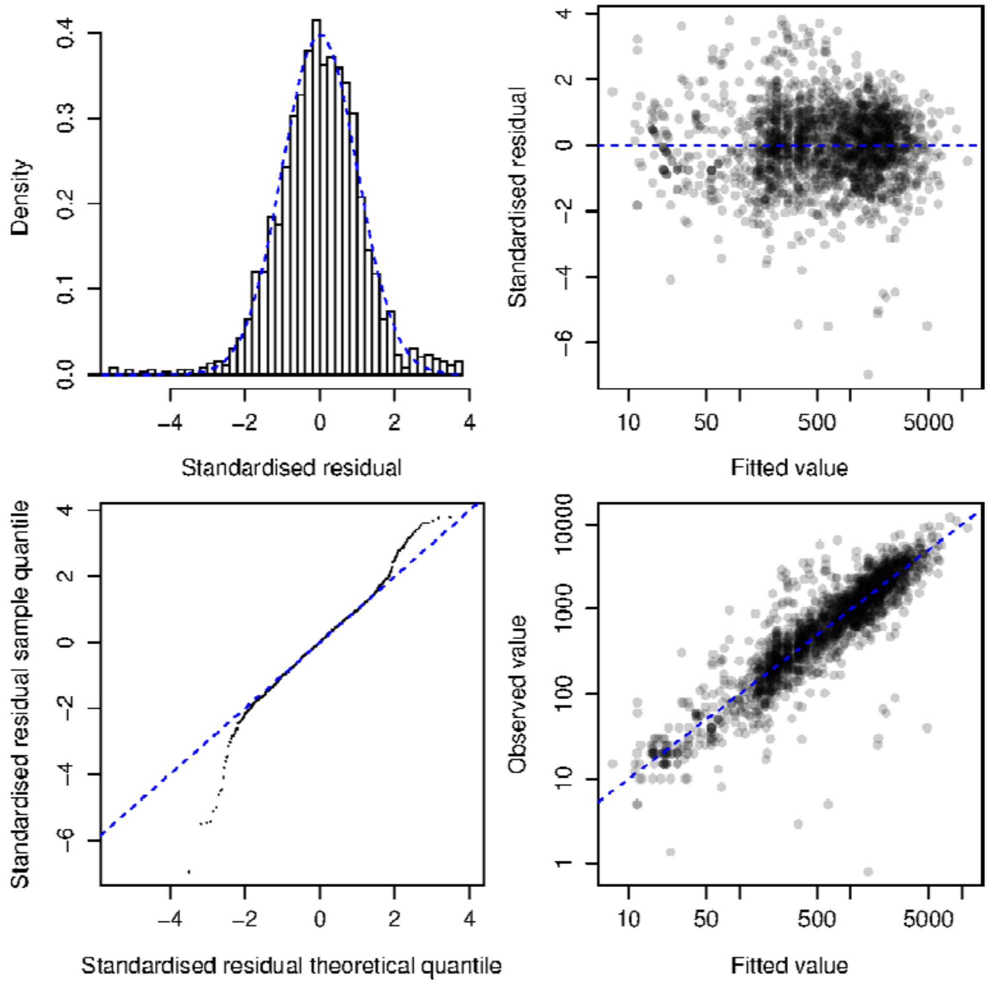


Figure D.7: Plots of the fit of the standardised CPUE model to successful catches of BCO 5 in the CP (Area 027) fishery[Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

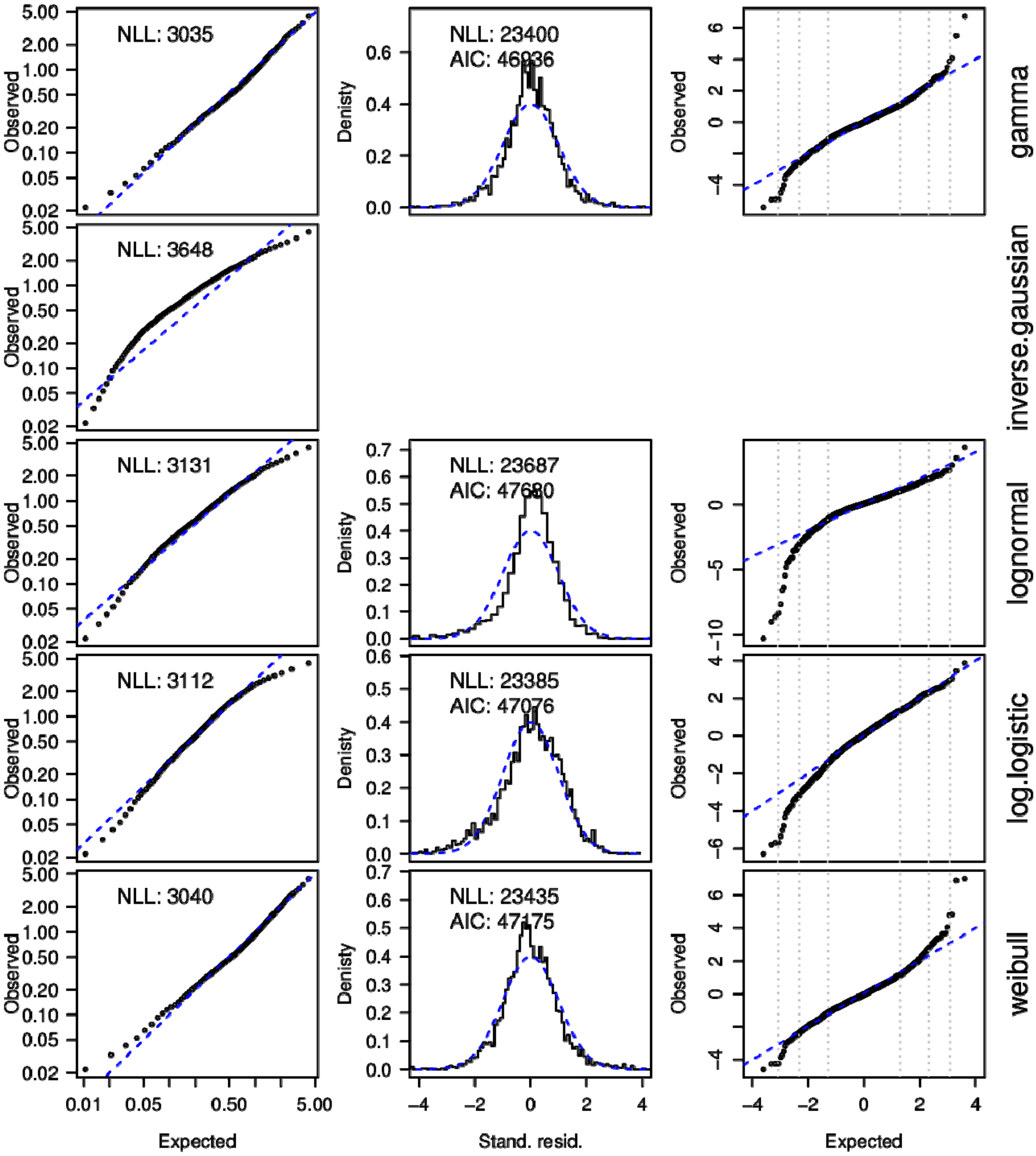


Figure D.8: Diagnostics for alternative distributional assumptions for catch in the CP (Area 030) fishery. Left: quantile-quantile plot of observed catches (centred (by mean) and scaled (by standard deviation) in log space) versus maximum likelihood fit of distribution (missing panel indicates that the fit failed to converge); Middle: standardised residuals from a generalised linear model fitted using the formula catch ~ fyear + month + vessel + log(potlifts) and the distribution (missing panel indicates that the model failed to converge); Right: quantile-quantile plot of model standardised residuals against standard normal (vertical lines represent 0.1%, 1% and 10% percentiles). NLL = negative log-likelihood; AIC = Akaike information criterion.

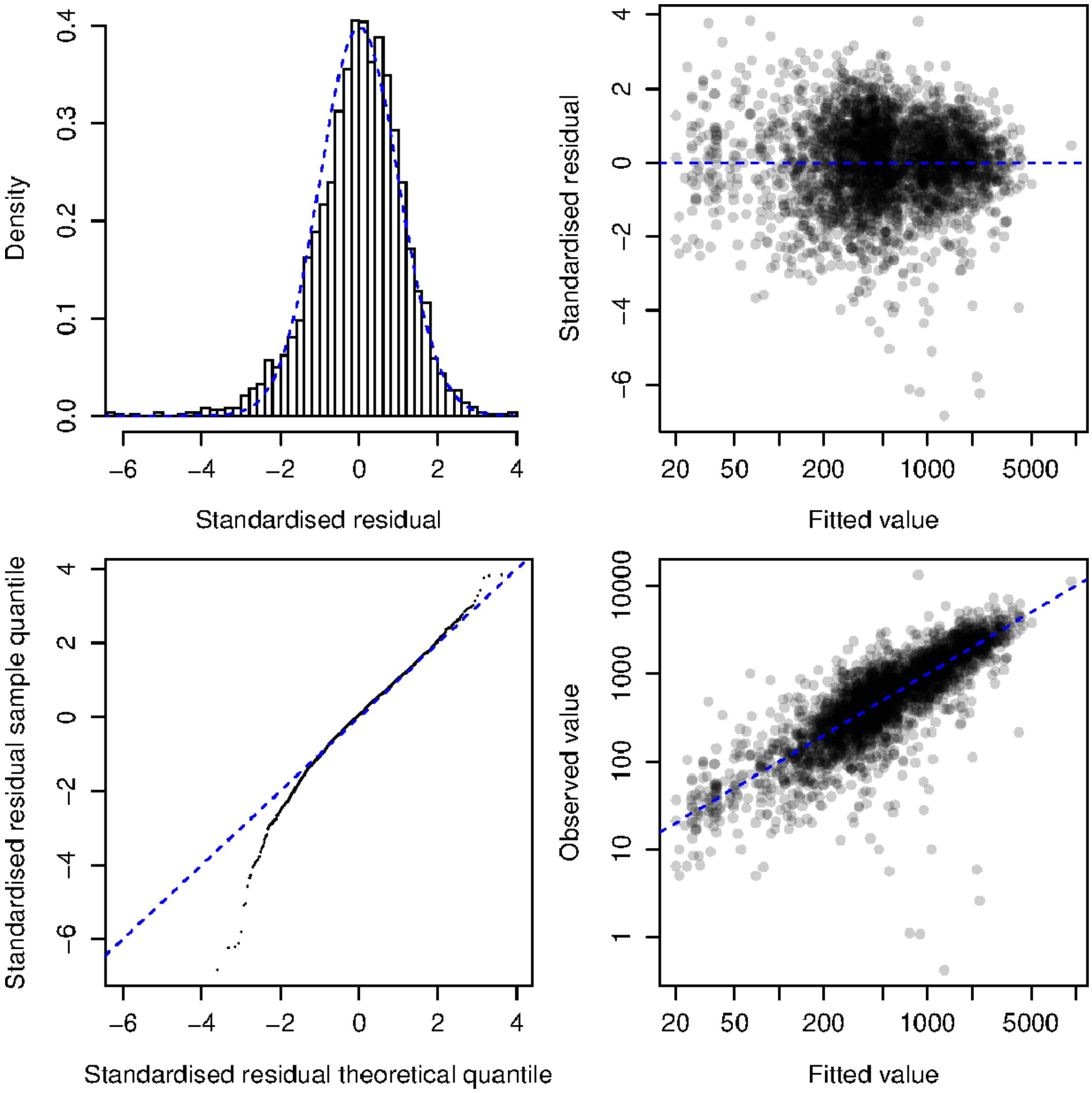


Figure D.9: Plots of the fit of the standardised CPUE model to successful catches of BCO 5 in the CP(Area 030) fishery[[Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [Upper right] Standardised residuals plotted against the predicted model catch per trip; [Lower left] Q-Q plot of the standardised residuals; [Lower right] Observed catch per record plotted against the predicted catch per record.

D.4 MODEL COEFFICIENTS

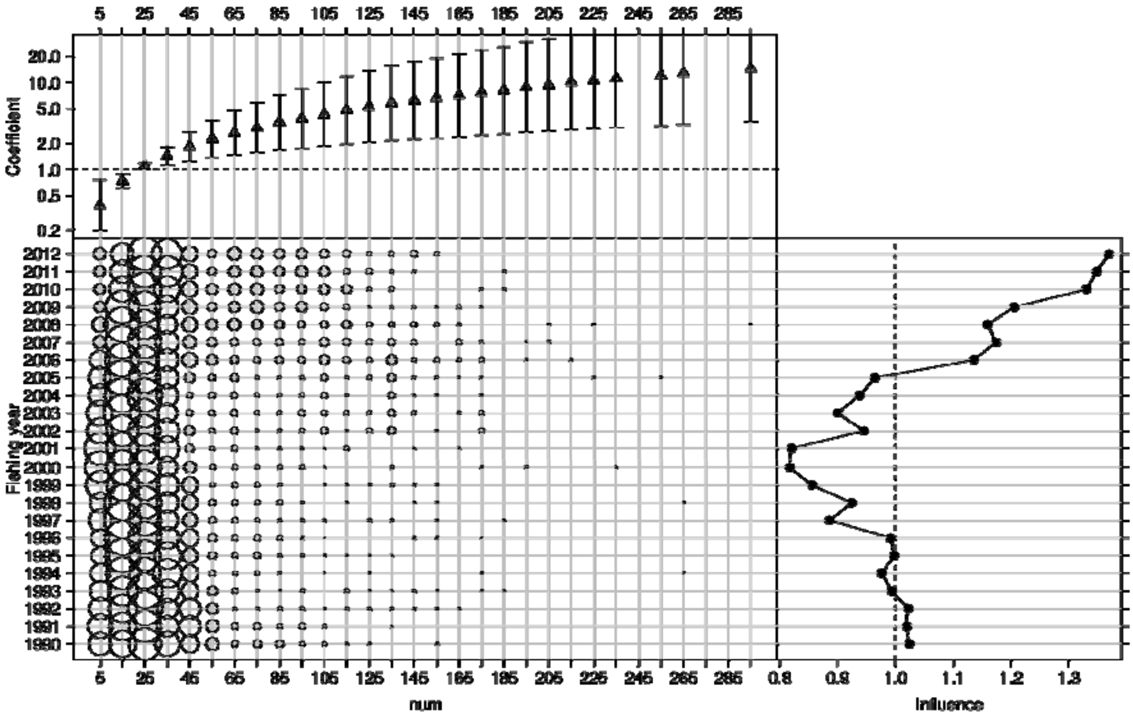


Figure D.10: Effect of log(potlifts) in the model for the BCO 5 CP (Area 025) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

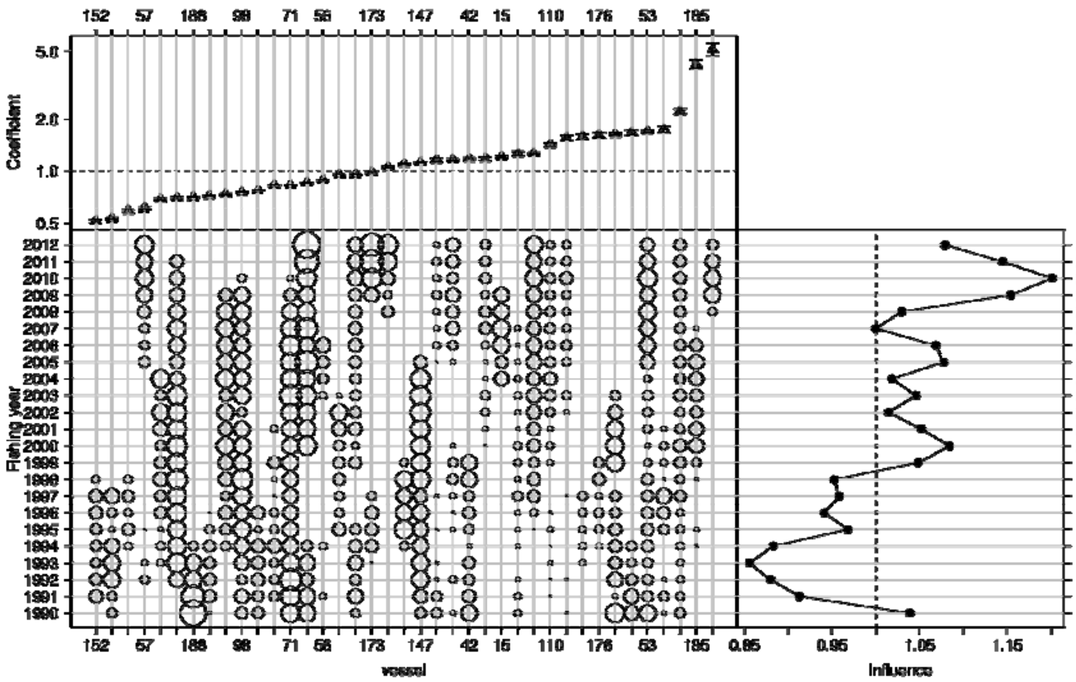


Figure D.11: Effect of vessel in the model for the BCO 5 CP (Area 025) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

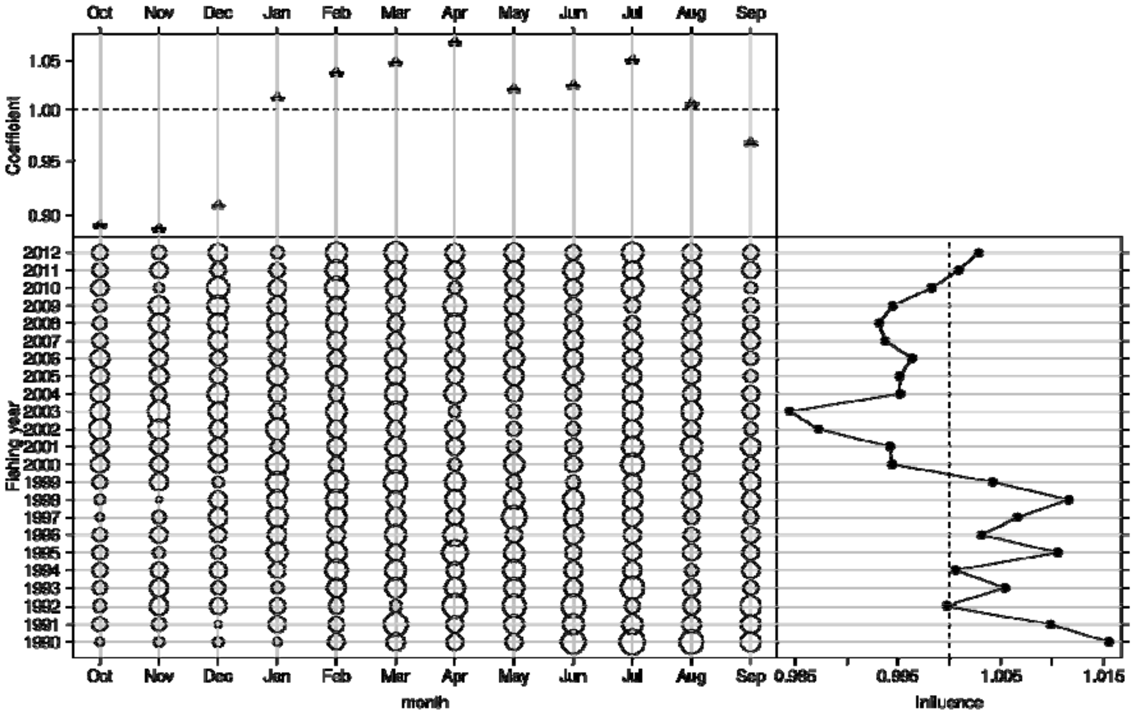


Figure D.12: Effect of month in the model for the BCO 5 CP (Area 025) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

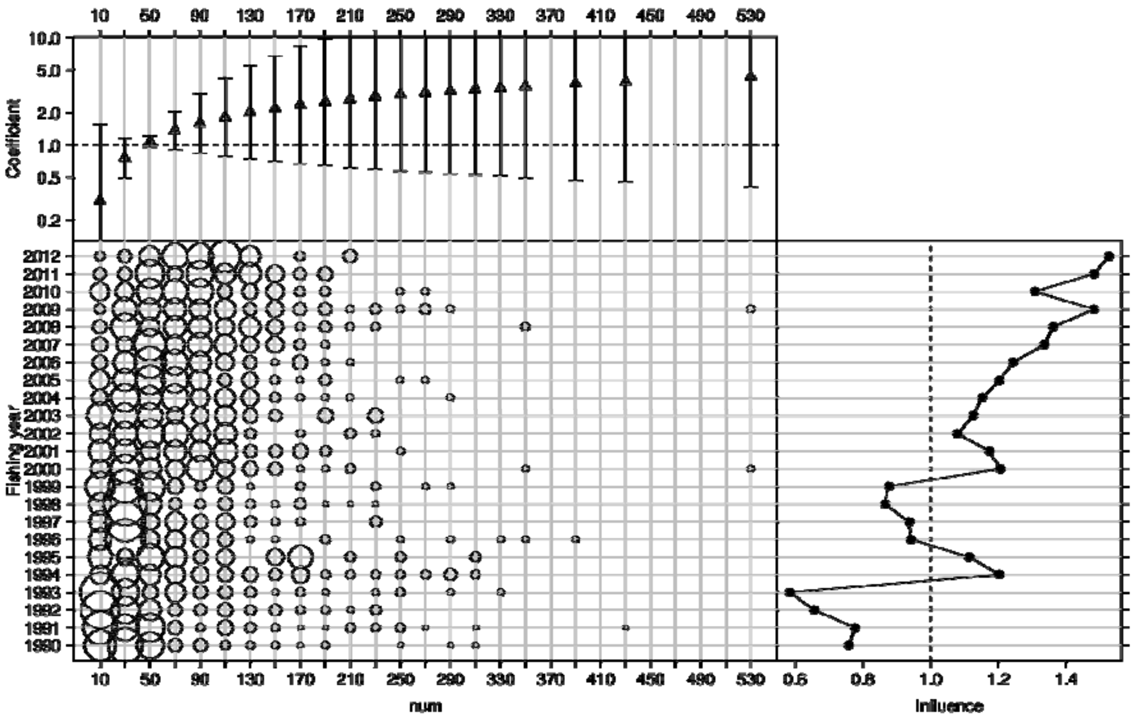


Figure D.13: Effect of log(potlifts) in the model for the BCO 5 CP (Area 027) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

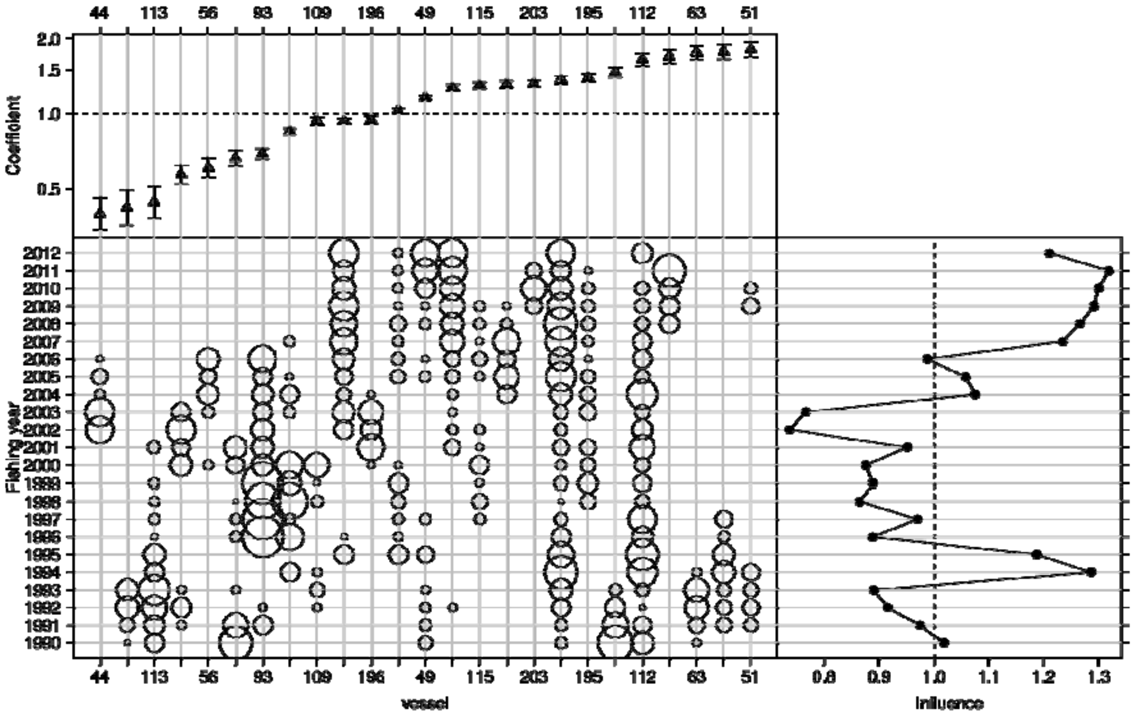


Figure D.14: Effect of vessel in the model for the BCO 5 CP (Area 027) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

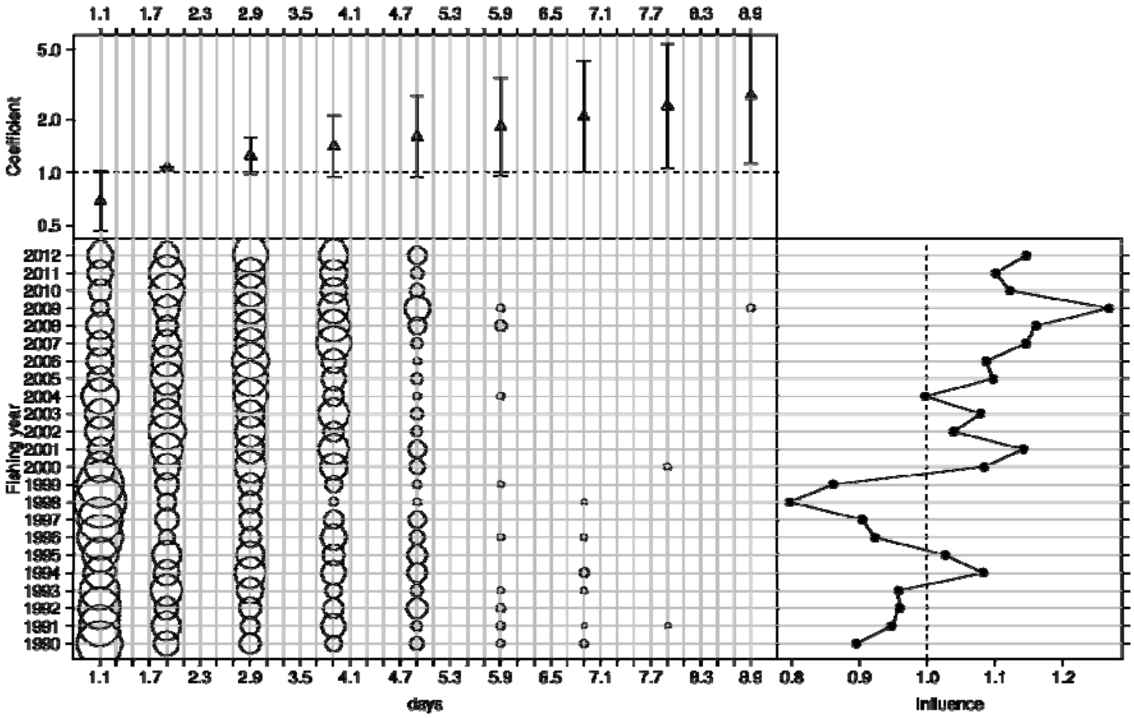


Figure D.15: Effect of log(days) in the model for the BCO 5 CP (Area 027) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

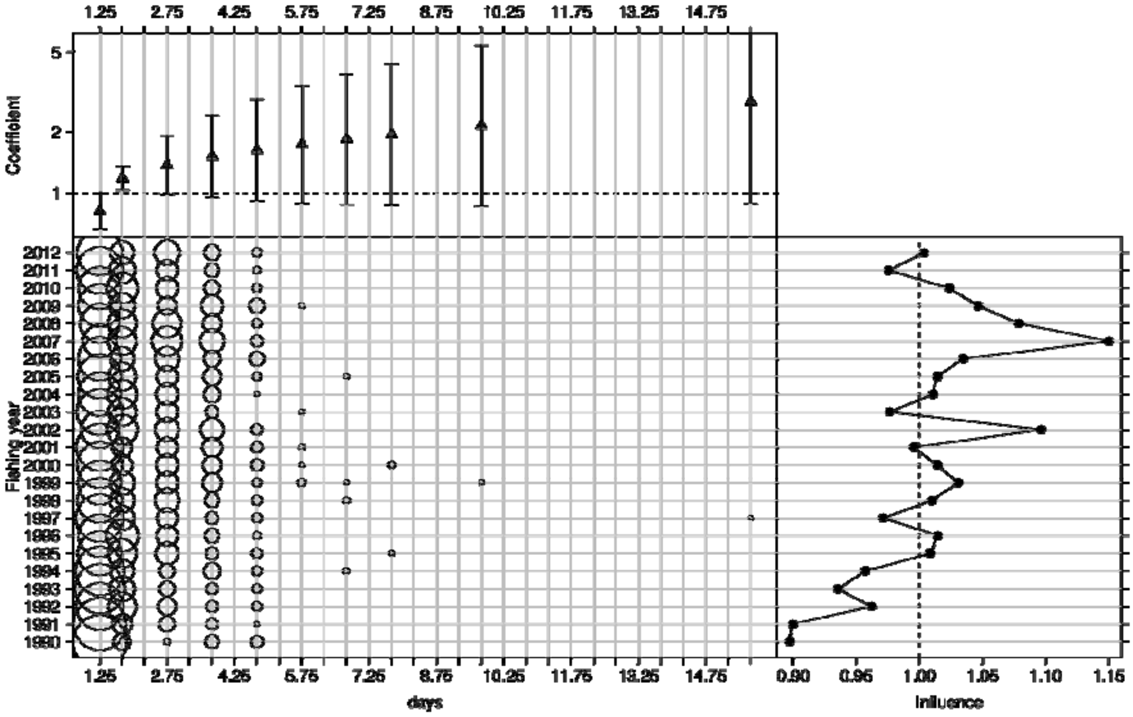


Figure D.16: Effect of log(days) in the model for the BCO 5 CP (Area 030) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

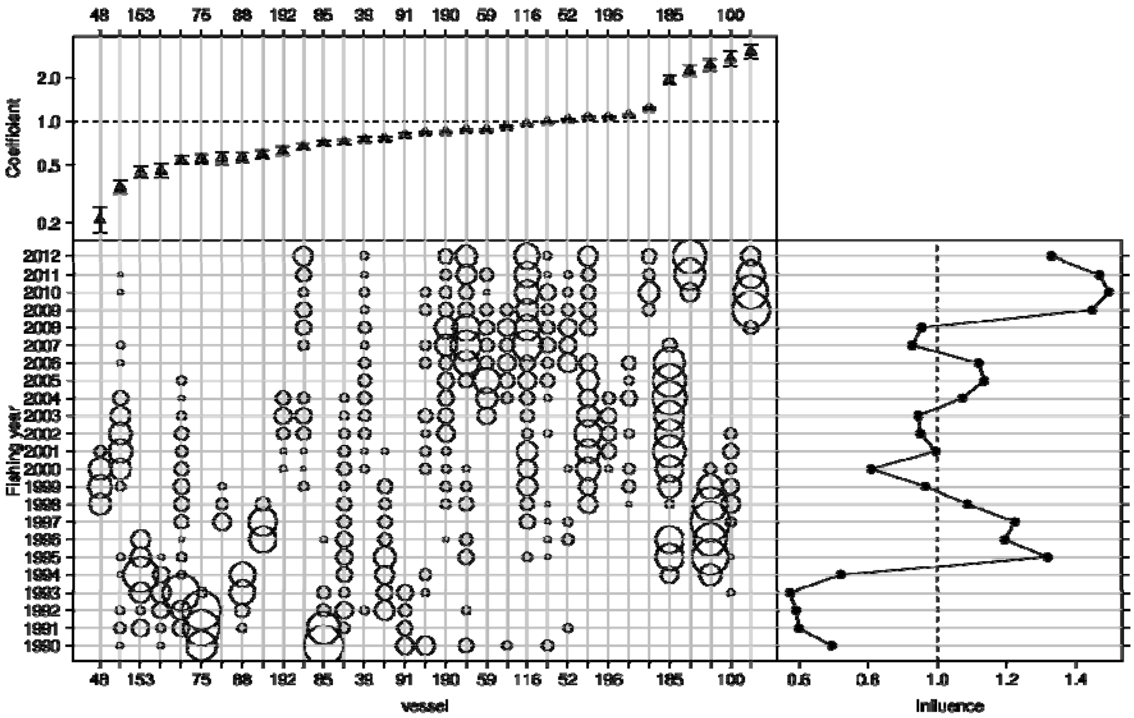


Figure D.17: Effect of vessel in the model for the BCO 5 CP (Area 030) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

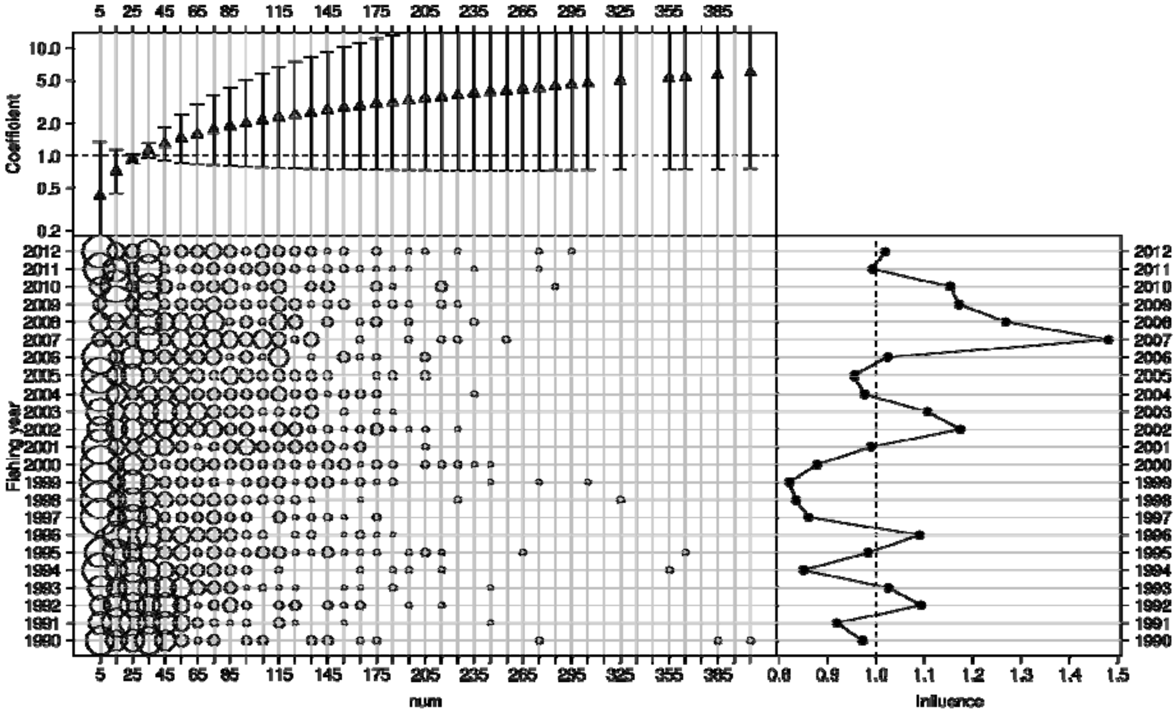


Figure D.18: Effect of log(potlifts) in the model for the BCO 5 CP (Area 030) fishery. Top: effect by level of variable (left-axis: log space, additive; right-axis: natural space, multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

D.5 CPUE INDICES

Table D.4: Arithmetic indices for the total and core data sets, geometric and lognormal standardised indices and associated standard error for the core data set by fishing year for each of the three CPUE models.

	CP (Area 025)					CP (Area 027)					CP (Area 030)				
					08/09										
Fishing	All				Core	All				Core	All				Core
Year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardised	SE	Arithmetic	Arithmetic	Geometric	Standardised	SE
1990	0.420	0.518	0.694	1.014	0.064	0.576	0.637	1.502	1.965	0.082	0.358	0.304	0.753	1.039	0.105
1991	0.672	0.757	0.828	0.918	0.051	0.518	0.619	1.305	1.191	0.075	0.325	0.290	0.592	1.038	0.114
1992	0.687	0.730	0.899	0.889	0.046	0.786	1.136	1.227	1.451	0.064	0.554	0.488	0.439	1.218	0.086
1993	0.763	0.807	0.999	0.921	0.046	0.675	0.705	0.756	1.057	0.063	0.363	0.366	0.529	0.924	0.062
1994	0.854	0.804	0.900	1.044	0.044	0.930	0.801	0.897	1.004	0.062	0.416	0.416	0.538	0.986	0.065
1995	0.915	0.871	0.848	0.984	0.046	0.995	0.945	0.964	0.872	0.068	0.528	0.512	0.517	1.252	0.067
1996	1.165	1.072	0.935	1.007	0.047	1.155	1.194	0.895	0.966	0.056	0.843	0.839	0.854	1.045	0.064
1997	0.900	0.932	0.815	1.058	0.046	1.576	1.163	1.122	1.320	0.057	1.231	1.192	0.906	0.902	0.053
1998	0.917	0.999	0.994	1.010	0.047	1.271	1.088	1.028	1.277	0.054	0.861	0.836	0.468	0.815	0.049
1999	0.911	0.916	1.133	1.011	0.041	1.069	1.013	1.225	1.274	0.049	1.135	1.092	0.491	1.019	0.053
2000	0.740	0.775	0.843	0.902	0.047	1.143	1.151	1.528	1.371	0.048	1.704	1.667	1.376	1.188	0.053
2001	1.243	1.219	1.022	1.355	0.042	1.262	0.981	1.339	1.304	0.052	0.975	0.965	0.981	0.804	0.055
2002	1.663	1.677	1.378	1.546	0.038	1.266	0.998	0.922	1.214	0.055	1.283	1.294	0.715	0.807	0.057
2003	1.454	1.371	1.347	1.443	0.037	0.847	0.890	1.029	1.144	0.056	1.813	1.918	2.262	1.016	0.061
2004	1.491	1.457	1.336	1.389	0.036	1.020	0.926	0.848	1.097	0.057	1.290	1.304	1.631	0.951	0.059
2005	1.186	1.145	1.083	1.084	0.037	1.475	1.128	0.615	0.928	0.059	1.671	1.655	2.102	1.128	0.061
2006	1.061	0.923	0.978	0.891	0.040	1.636	1.561	0.965	0.730	0.059	2.099	2.123	1.915	0.934	0.075
2007	1.072	1.068	1.038	0.822	0.044	1.141	1.197	0.682	0.554	0.056	1.942	1.712	1.181	0.893	0.075
2008	1.114	1.096	0.939	0.784	0.042	0.934	1.173	0.881	0.572	0.055	1.647	1.614	1.940	1.108	0.068
2009	1.180	1.131	1.122	0.798	0.040	1.021	1.196	1.043	0.680	0.058	1.440	1.565	1.649	0.947	0.070
2010	1.390	1.337	1.376	0.858	0.039	0.811	1.008	0.959	0.674	0.056	1.455	1.897	1.781	1.012	0.098
2011	1.211	1.141	0.869	0.728	0.044	0.823	0.988	0.856	0.574	0.059	1.639	2.183	2.034	1.148	0.095

APPENDIX E. TRANSPOSITION OF EFFORT DATA FIELDS IN THE CELR DATA

E.1 OVERVIEW

Previous investigators of the BCO 5 CPUE data have noted that data in the effort field "total number of pots in the water at midnight" ("Column B") have exceeded the "total number of pots lifted in the day" ("Column A") (Langley 2005) (see Figure E.1). Cod potting typically involves setting a relatively small number of pots (usually less than 10) and then lifting them several times in a day. Logically, the data in "Column A" should equal but rarely (if ever) exceed the data in "Column B". "Column B" could only exceed "Column A" if pots were put in the water before midnight but not lifted or if the number of pots were increased. This should happen only rarely. However, examination of the BCO 5 cod potting dataset showed that Column B exceeded Column A for 27% of the records where both columns held valid data that were not zero and for 17% of all CP records (Table E.1). Langley (2005) adopted the principle of transposing these two data fields, on the assumption that they arose from errors in data entry. While Starr & Kendrick (2009) ignored this problem, using the data as presented, Starr & Kendrick (2011) examined the data and concluded that the columns which were deemed to have been transposed showed different trends in effort compared to the non-transposed data. The solution they adopted was to exclude these data from the analysis rather than to transpose them as done by Langley (2005). The purpose of this Appendix is to update Starr & Kendrick (2011) with the new data and to re-evaluate if it is justified to drop these data, as was done in 2011.

E.2 RESULTS OF INVESTIGATIONS

This issue was investigated on a vessel basis, on the assumption that, if this problem were simply caused by transposition, then individual operators should show consistent patterns of being over or under in their reporting of these two effort fields. This analysis used an effort dataset based on an extract which identified every trip that landed to BCO 5, containing complete data from every trip that landed BCO 5 at least once and this dataset should be reasonably complete with respect to the effort used to take BCO 5 from 1989–90 to 2011–12.

Table E.1 summarises the effort data for the BCO 5 cod potting data set, showing that, while there were well over 300 vessels in the dataset doing cod potting, only 288 of these vessels used both columns of effort data. The remaining 43 vessels never filled in one or the other column (primarily missing Column B: the number of pots in the water at midnight). These vessels only accounted for about 1300 records, with another 30 000 records missing either Column A or Column B (and thus could not be used in this comparative analyis). Of the remaining 52 000 or more records with valid entries in both columns, just over 14 000 had Column B greater than Column A, contrary to expectations. However, further drilling into the data showed that 71 of the 288 vessels in the remaining dataset were responsible for over 90% of the reporting where Column B was greater than Column A (Table E.1). These vessels were identified by noting that the mean ratio of Column B/Column A was greater than 1.0. The 71 vessels were identified after dropping all vessels which in this dataset that had 10 or fewer observations. This filtering process identified a core of 98 vessels, all of which had a high incidence of apparently transposing Column A with Column B. The core group of 71 vessels were responsible for 93% of the records where Column B was greater than Column A (Table E.2). A plot showing the relative number of cod potting records in the dataset indicates that there has been a gradual decline in the total number of records in the 20 years in the dataset (Figure E.2). However, the number of records which apparently transpose the two effort fields is not as stable, showing a large increase in the early 1990s, after which the number has remained high and relatively constant, although quite variable.

The mean number of potlifts (Column A) showed little change over the 20 years of data, lying between 25 and 30 potlifts/day for those records where Column A was less than Column B (Figure E.3). The mean number of pots in the water at midnight for these same records was more variable, stepping up from between 6–7 in the early part of the series to near 10 in the middle section of the series and then dropping back towards the end of the series (Figure E.3). The same mean values (number of potlifts and number of pots in water at midnight, after transposition) have been plotted in Figure E.3 for three sets of vessels:

a) all records where Column A was greater than Column B;

b) the 98 vessels remaining after removing vessels from the dataset as described in Table E.1;

c) the 71 vessels where the mean ratio of Column B/Column A was greater than 1.

The mean number of potlifts/day in these three series is nearly identical because the data are dominated by the vessels identified in category "c" in the list above, a category accounting for 93% of the observations where Column B is greater than Column A (Table E.2). The mean annual number of potlifts and the mean number of pots in the water at midnight for these three categories ("a" to "c" above) show trends that differ considerably from the equivalent statistics calculated from the data which conform to our expectations that Column B is less than Column A (Figure E.3). Box plots of the nominal CPUE (kg/potlift) for the final 10 years of data show that the CPUE for the identified 71 vessels is notably lower than for the remaining vessels, beginning from about 2006–07 (Figure E.4). Consequently it was decided to conduct the main CPUE analysis for BCO 5 after excluding all trips from the 71 key vessels identified in Table E.1. A sensitivity analysis was also run using all the data, after transposing the two effort fields as was done by Langley (2005).

The two CPUE datasets (all trips and with 71 filtered vessels removed), described in the previous paragraph, were examined for the amount of data lost and for patterns which may affect the CPUE analysis. About 40% of the records were lost but this resulted in 46 and 45% of the catch and effort being lost respectively (Table E.3). A relative index of these three quantities by fishing year shows similar patterns for the two datasets, with the possible exception of potlifts, which are slightly higher than the "all trips" dataset in the early part of the series and lower in middle section (Figure E.5). It is likely that the dataset after elimination of the 71 vessels, although resulting in a considerable loss of data, appears to behave similarly to the full data set and should be more reliable for CPUE analysis because of the removal of the ambiguous effort data.

Table E.1. Number of vessels and records in a range of categories with respect to Column A (number potlifts) and Column B (number pots in water at midnight) on the CELR form for the BCO 5 cod potting dataset.

Category	Number vessels	Number records	Number records with Column B>Column A
Vessels reporting CP	331	83 694	
Vessels that don't ever fill in one of 2 columns (mostly Column B)	43	1 360	
Records missing either Column A or Column B	–	30 197	
Vessels with valid Column A & Column B pairs	288	52 137	14 073
Vessels where always Column A=Column B	21	235	
Vessels where mean(Column B/A)<=1 & p95(Column B/A)<=1	122	25 775	
Vessels with fewer than 10 records in remaining data set	47	191	
Remaining vessels	98	25 936	13 611
Remaining vessels with mean(Column B/Column A)>1	71	22 230	13 090

Table E.2. Number of records by fishing year in the BCO 5 cod potting dataset in different categories with respect to Column A and Column B (defined in Table E.1). The columns labelled "98 vessels" and "71 vessels" are the vessel categories defined in Table E.1.

Fishing year	Total "B"	Total valid records "C"	Total Records "D"	Total Records "E"	98 vessels "F"	71 vessels "G"
89/90	3 041	1 399	1 254	145	137	131
90/91	4 286	2 191	2 019	172	144	82
91/92	3 601	2 022	1 771	251	185	123
92/93	4 262	2 680	2 288	392	372	321
93/94	4 461	2 849	2 470	379	358	327
94/95	4 375	3 192	2 841	351	319	288
95/96	4 667	2 962	2 050	912	875	809
96/97	3 937	2 712	1 900	812	765	720
97/98	3 735	2 342	1 595	747	729	718
98/99	3 805	2 561	1 621	940	922	915
99/00	3 623	2 386	1 596	790	770	735
00/01	3 442	2 501	1 650	851	815	792
01/02	3 266	2 333	1 614	719	717	707
02/03	3 162	2 016	1 484	532	531	531
03/04	3 291	2 263	1 654	609	591	587
04/05	3 315	2 228	1 617	611	591	589
05/06	3 267	2 140	1 571	569	565	561
06/07	3 392	2 160	1 484	676	660	657
07/08	3 298	1 970	1 153	817	801	790
08/09	3 472	2 080	1 250	830	820	773
09/10	3 177	1 843	1 167	676	674	671
10/11	3 305	1 687	1 111	576	563	562
11/12	3 165	1 613	898	715	707	701
Total	83 345	52 130	38 058	14 072	13 611	13 090
Comparison				17%[1]	97%[2]	93%[2]

[1] % of all records (column 2)
[2] % of all records where Column B>Column A (column 5)

Table E.3. Summary statistics for number of records, total BCO 5 catch, and total potlifts for the two CPUE datasets presented in this report. These values were calculated after the selection of core vessels.

	Number Records	$\sum$ Catch (t)	$\sum$ Potlifts
BCO 5: all CP trips	52 587	25 260	2 041 179
BCO 5: remove 71 vessels	30 669	13 117	1 064 832
% difference in datasets	-42%	-48%	-48%

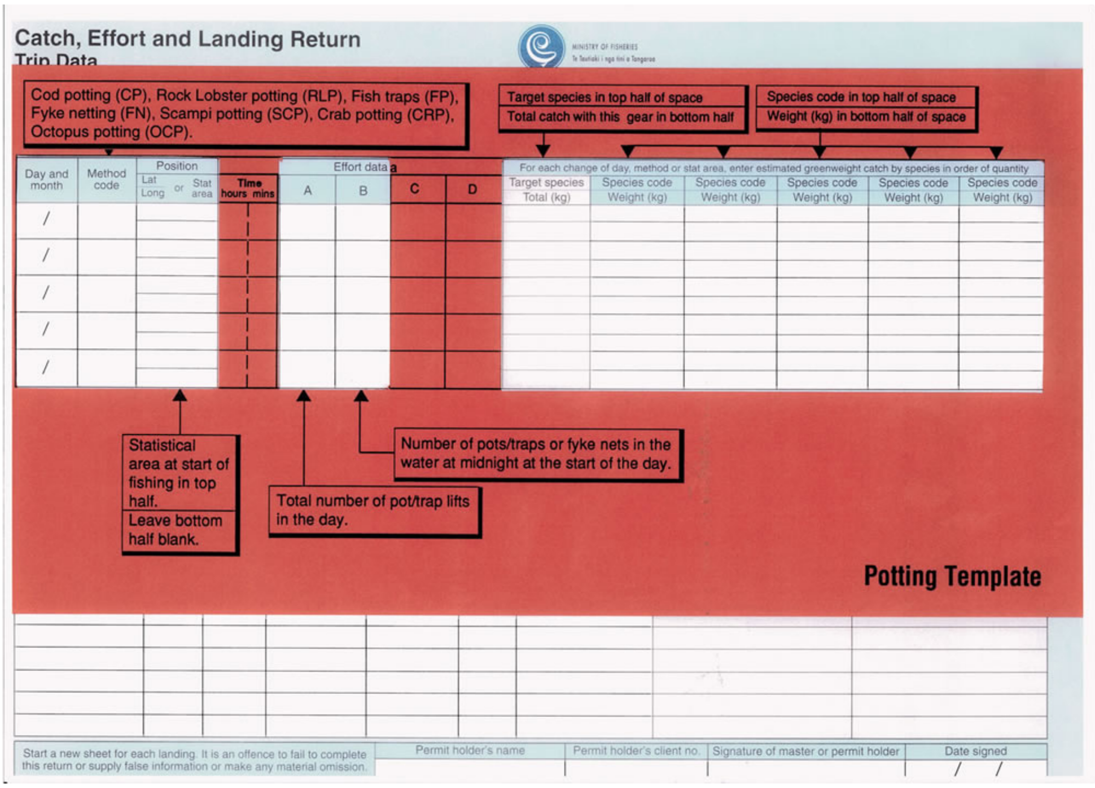


Figure E.1: The template used by potting fishers to fill out the effort section of the MPI CELR reporting form. The two columns holding effort data are labelled "A" and "B".

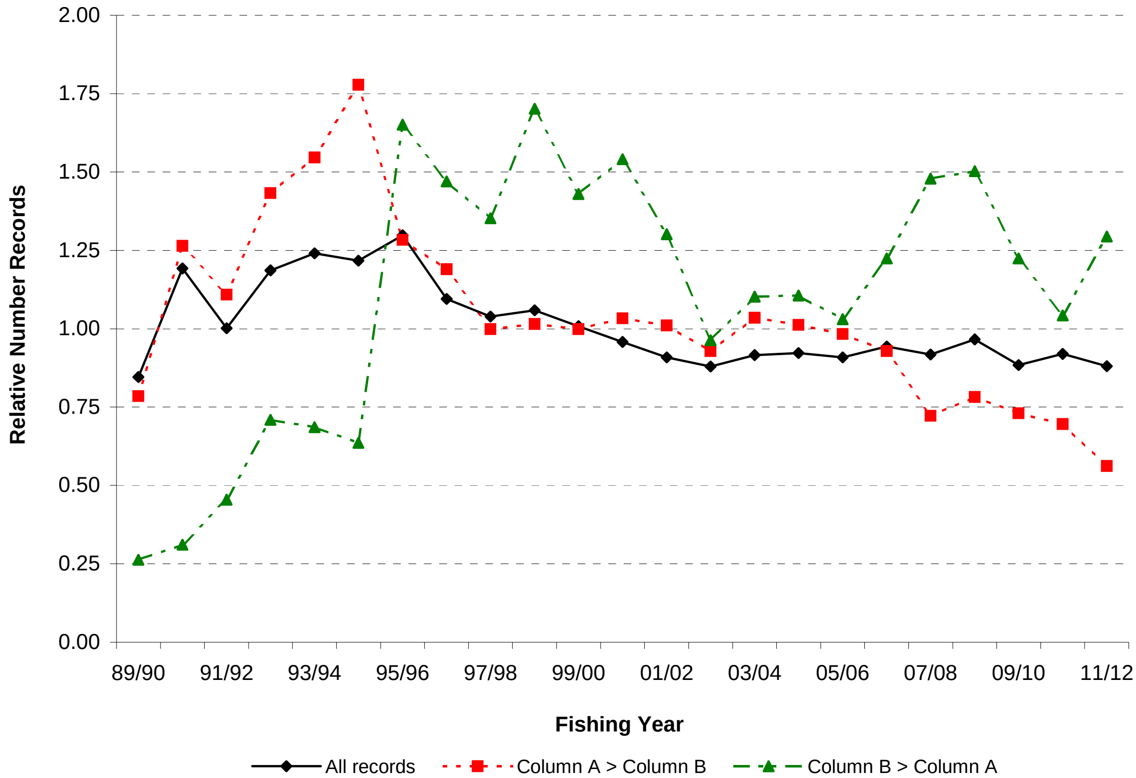


Figure E.2: Plot showing the relative number of records reporting method CP (cod potting) by fishing year for three categories: a) all data ("B" in Table E.2); b) only records where Column A > Column B ("E" inTable E.2); c) records where Column A < Column B ("F" in Table E.2). Note that the geometric mean for each series equals 1.0.

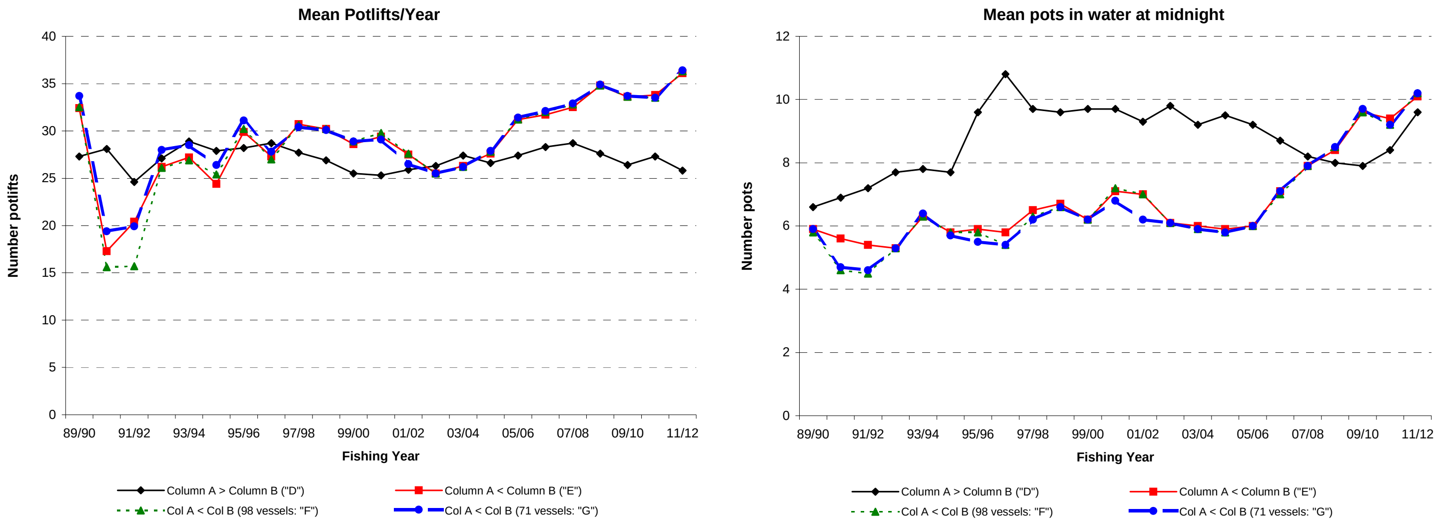


Figure E.3: Mean statistics by fishing year for four categories of reporting with respect to Column A and Column B. See Figure E.2 for the definitions of these categories: [left panel] mean number of potlifts (Column A); [right panel] mean number of pots in water at midnight (Column B). Note that the values used for "potlifts" and "pots in water" in the final three series have been transposed.

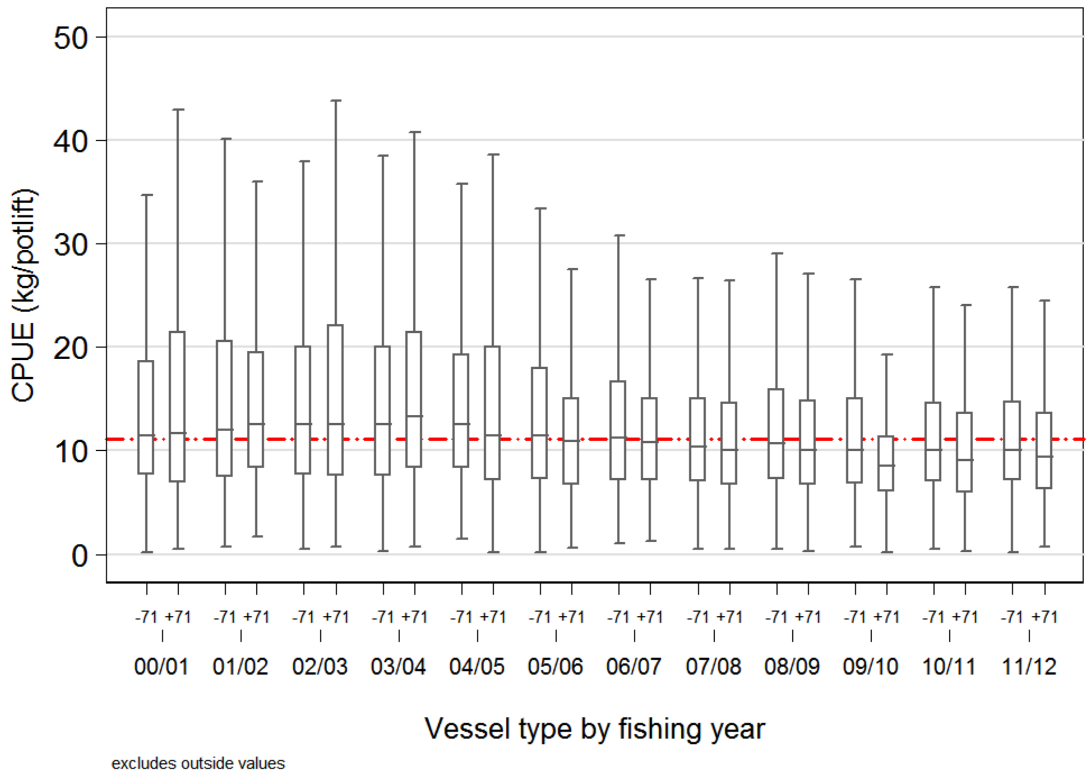


Figure E.4: Box plots of unstandardised CPUE (kg/potlift) for two parts of the BCO 5 cod-potting dataset from 2000–01 to 2011–12: one with the 71 vessels identified in Table E.1 removed ("-71") and the other is made up of these 71 vessels ("+71"). CPUE was calculated for each record in the effort data set using estimated catch and the effort field which had the largest value of the Column A/B pair. The horizontal line shows the median CPUE for the "-71" vessels from 2000–01 to 2011–12.

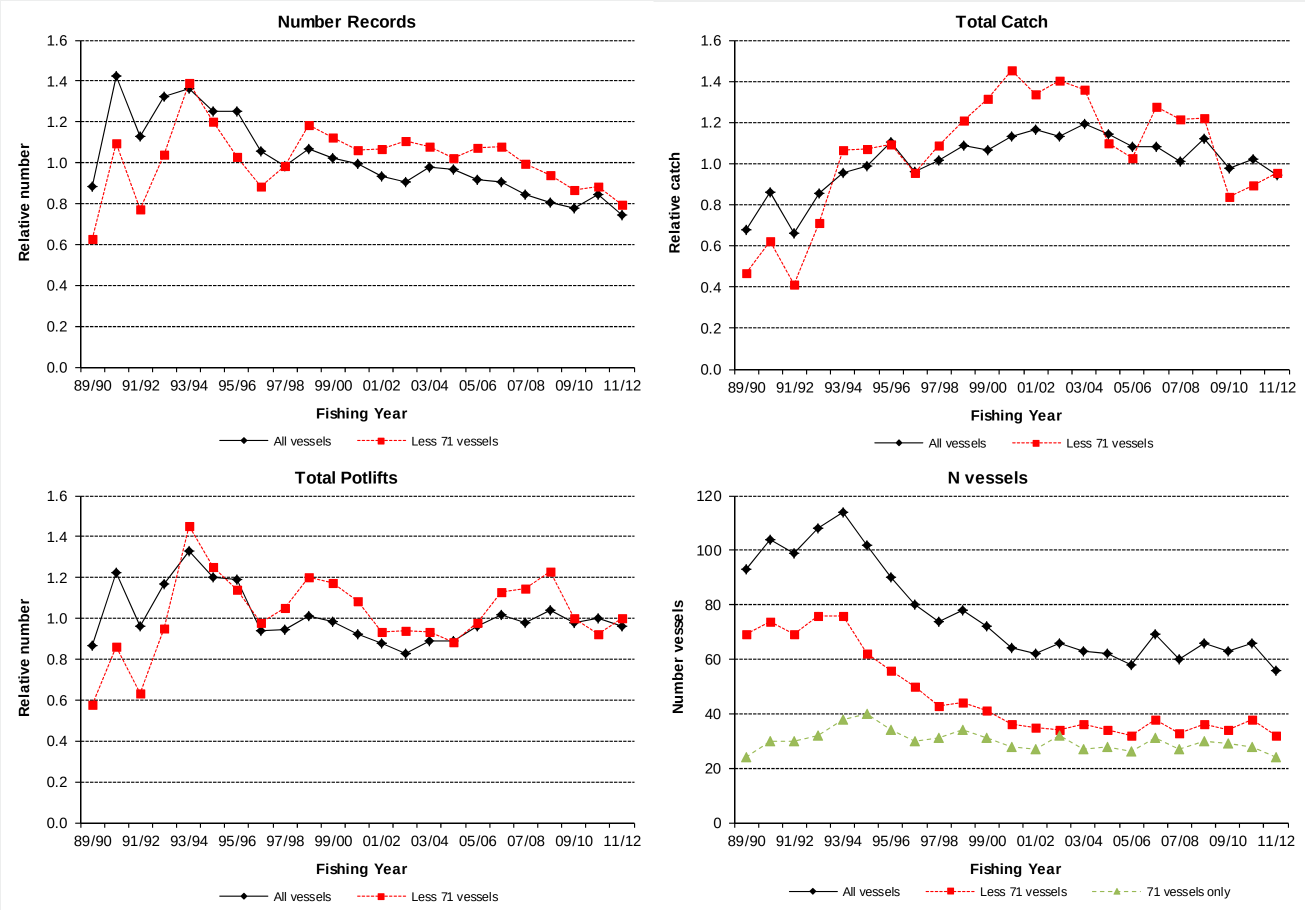


Figure E.5: Relative number of records, relative total catch and relative total potlifts by fishing year for two BCO 5 cod-potting CPUE datasets. One dataset is based on all vessels which reported cod potting in BCO 5 at least once, with Column B and Column A transposed if Column B>Column A. The other dataset drops the 71 vessels and transposes the few remaining records where Column B>Column A. The final panel gives the absolute number of vessels in each dataset, as well as the number of excluded vessels by fishing year.

APPENDIX F. GRID SEARCH METHOD IMPLEMENTED FOR BCO 5 DATA FOR 2013 ANALYSES

F.1 INTRODUCTION

The method previously used to identify “implausibly large” landings used arithmetic CPUE, with the presumption that trips with extremely large arithmetic CPUE values existed because the contributing landings were implausibly large. This method had two major problems: one was that the arithmetic CPUE for mixed-method trips could not be easily calculated and the other was that there was a lot of subjectivity in the process (how does one identify an “implausibly large” arithmetic CPUE?). Dropping “implausibly large” landings is necessary because there are large landings which are due to data errors (possibly at the data entry step), with landings from single trips occasionally exceeding 100–300 t for some species (greater than 2000 t for BCO). These errors can result in substantial deviations from the accepted QMR/MHR catches and affect the credibility of the characterisation and CPUE analyses. The previous method transferred the problem of identifying “implausibly large” landings to identifying unreasonably large CPUE values. A further problem with the procedure was that the CPUE method was difficult to automate, requiring intermediate evaluations.

F.2 METHODS

The method used for this procedure is less subjective and can be automated, evaluating trips with very large landings based on internal evidence within the trip that potentially corroborate the landings. The method proceeds in two steps:

Step 1 Trips with large landings above a specified threshold were selected using the empirical distribution of trip landing totals from all trips in the data set (for instance, all trips in the largest 1% quantile in terms of total trip landings);

Step 2 Internal evidence substantiating the landings within each trip was derived from summing the estimated catch for the species in question, as well as summing the “calculated greenweight” (=*number_bins*avg_weight_bin*conversion_factor*) (Eq. F.1). The ratio of each these totals was taken with the declared greenweight for the trip, with the minimum of the two ratios taken as the “best” validation (Eq. F.2). High values for this ratio (for instance, a value of 9 for this ratio implies that the declared green weight is 9 times larger than the “best” secondary total) are taken as evidence that the declared greenweight landing for the trip was not corroborated using the other available data, making the trip a candidate for dropping.

A two-way grid search was implemented for this procedure across a range of empirical quantiles (Step 1) and test ratio values (Step 2). The reason for stepping down through the quantiles was to minimise the number of trips removed by starting with trips that returned the largest catches. Similarly, the search started with the most extreme $rat_{t,s}$ values and stepped down from there. For each pair of values, the “fit” (SSq^z; Eq. F.3) of the annual sum of the landings was evaluated against the QMR/MHR totals, using a least-squares criterion. The pair of quantile and $rat_{t,s}$ values which gave the lowest SSq^z was used to select the set of candidate trips to drop because the resulting landings totals would be the closest overall to the QMR/MHR total catch. The search covered a plausible range for the ratio ($rat_{t,s}$: Eq. F.2), looking for the ratio and trip landing thresholds which resulted in the closest totals to the observed QMR/MHR landings.

F.3 EQUATIONS

For every trip, there exist three estimates of total greenweight catch for species *s*:

Eq. F.1
$$G_{t,s}^{d} = \sum_{i=1}^{n_t} gwt_{t,s,i}$$
$$G_{t,s}^{c} = \sum_{i=1}^{n_t} CF_s * W_{t,i} * B_{t,i}$$
$$G_{t,s}^{e} = \sum_{j=1}^{m_t} est_{t,s,j}$$

where $G_{t,s}^{d}$ = sum of declared greenweight (*gwt*) for trip *t* over all n_t landing records;

$G_{t,s}^{c}$ = sum of calculated greenweight for trip *t* over all n_t landing records, using conversion factor CF_s, weight of bin $W_{t,i}$ and number of bins $B_{t,i}$;

$G_{t,s}^{e}$ = sum of estimated catch (*est*) for trip *t* over all m_t effort records.

Assuming that $G_{t,s}^{d}$ is the best available estimate of the total landings of species *s* for trip *t*, calculate the following ratios:

Eq. F.2
$$r1_{t,s} = G_{t,s}^{d} / G_{t,s}^{c}$$
$$r2_{t,s} = G_{t,s}^{d} / G_{t,s}^{e}$$
$$rat_{t,s} = \min(r1_{t,s}, r2_{t,s})$$

where $G_{t,s}^{d}$, $G_{t,s}^{c}$ and $G_{t,s}^{e}$ are defined in Eq. F.1, and ignoring $r1_{t,s}$ or $r2_{t,s}$ if missing when calculating $rat_{t,s}$.

The ratio $rat_{t,s}$ can be considered the "best available information" to corroborate the landings declared in the total $G_{t,s}^{d}$, with ratios exceeding a threshold value (e.g. $rat_{t,s} > 9.0$) considered to be uncorroborated. This criterion can be applied to a set of trips selected using a quantile of the empirical distribution of total trip greenweight. The set of trips to drop was selected on the basis of the pair of criteria (quantile and ratio threshold) which gave the lowest SSq^z (Eq. F.3) relative to the annual QMR/MHR totals:

Eq. F.3
$$gg_y^z = \sum_{1}^{p_y^z} L_y^z$$
$$Ssq^z = \sum_{y=89/90}^{y=11/12} \left(gg_y^z - MHR_y\right)^2$$

where p_y^z is the number landing records in year *y* for iteration *z* (i.e. a combination of a ratio threshold criterion with an empirical quantile cutoff criterion);

L_y^z is a landing record included in year *y* for iteration *z*.

MHR_y is the corresponding MHR/QMR landing total for BCO 5 in year *y*.

F.4 RESULTS

This approach resulted in a clearly defined "minimum" when the search was extended to include quantiles below 90% and investigated threshold ratios down to 1.4. The selected minimum excluded 182 trips (from over 63 000 trips in the data set) (Table F.1), with the best Ssq^z obtained when trips which landed at least 1.4 tonne (92% quantile) were excluded if the "best ratio" (Eq. F.2) was greater than 1.6 (Table F.2). There is one very large landing in this data set which exceeds 2 300 t, occurring in 1995–96. The total excluded catch was 3 300 t, just over 900 t greater than the single very large landing, resulting in total landings that are 61 t less than the sum of the QMR/MHR landings over the same period (Table F.3). All quantile/threshold pairings identify the single large trip, but differ in the number and tonnage of additional trips to exclude.

By comparison, 131 trips representing 3 076 t were dropped in the previous BCO 5 analysis performed in 2011 (Starr & Kendrick 2011). For this data set, the procedure resulted in quite good agreement between the raw landings and the QMR/MHR totals (Figure F.1; Table F.4).

Table F.1: Number of trips dropped (from a total of 63 007 trips) after a search over the two parameters defined above: A) a quantile cut-off which selected the set of large landings over which to search and B) the ratio $\left(rat_{t,s}\right)$ (Eq. F.2) which sets the maximum criterion for accepting a landing. The quantile/ratio pair with the lowest Ssq^2 (Eq. F.3) is highlighted in colour.

Quantile	Minimum ratio $\left(rat_{t,s}\right)$ cut-off														
cut-off:	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	4	5	6	7	8	9
82	501	339	265	223	193	178	169	154	146	112	104	92	81	77	69
84	447	305	237	199	176	164	156	141	135	108	100	88	77	73	65
86	400	273	214	180	160	150	145	131	127	103	97	85	75	71	64
88	353	237	188	161	144	135	132	119	115	94	89	79	70	66	61
90	299	205	166	143	126	120	117	107	104	86	81	72	64	60	55
92	258	182	150	129	114	111	108	101	98	82	77	69	62	60	55
94	214	157	134	118	105	103	100	94	91	79	75	67	60	58	54
96	153	117	102	92	85	83	81	77	74	64	61	56	51	49	46
98	103	90	82	77	72	71	70	67	65	57	56	52	47	45	43
99	73	67	63	59	55	54	54	52	50	47	46	43	38	37	35
99.9	29	29	29	29	28	28	28	28	27	26	26	23	21	20	18
99.99	7	7	7	7	7	7	7	7	7	6	6	5	5	5	5

Table F.2: The Ssq^z (Eq. F.3) associated with each quantile/ratio pair over which the search was made to get the best "fit" to the QMR/MHR annual landings. The quantile/ratio pair with the lowest Ssq^z is highlighted in colour.

Quantile	Minimum ratio $\left(rat_{t,s}\right)$ cut-off														
cut-off:	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	4	5	6	7	8	9
82	15 667	9 190	9 315	10 099	11 398	10 934	11 550	12 862	13 575	16 294	17 411	17 254	21 651	21 918	23 776
84	13 859	8 672	9 333	10 317	11 576	11 205	11 742	13 079	13 750	16 390	17 510	17 355	21 765	22 032	23 945
86	12 283	8 056	9 147	10 409	11 624	11 323	11 850	13 215	13 804	16 404	17 429	17 334	21 749	22 016	23 943
88	10 847	7 726	9 066	10 255	11 543	11 361	11 811	13 220	13 816	16 580	17 549	17 581	22 060	22 327	24 167
90	9 029	6 968	8 706	10 165	11 547	11 426	11 898	13 402	13 883	16 884	17 883	18 006	22 571	22 838	24 685
92	7 643	6 741	8 678	10 293	11 615	11 536	12 008	13 490	13 971	16 954	17 952	18 028	22 617	22 838	24 685
94	6 974	6 964	9 057	10 762	12 121	11 863	12 350	13 852	14 403	17 120	18 092	18 243	22 832	23 054	24 723
96	7 464	8 384	11 069	12 880	14 258	14 015	14 500	15 745	16 357	18 838	19 821	20 054	24 434	24 656	26 397
98	11 130	11 502	13 534	14 850	16 090	15 775	16 277	17 323	17 492	20 084	20 427	20 647	25 136	25 401	27 063
99	13 053	13 354	15 281	16 742	18 094	17 876	17 876	19 081	19 383	21 334	21 719	21 935	26 631	26 924	28 586
99.9	25 201	25 201	25 201	25 201	25 436	25 436	25 436	25 436	25 282	26 646	26 646	27 082	32 388	32 772	34 571
99.99	55 623	55 623	55 623	55 623	55 623	55 623	55 623	55 623	55 623	57 505	57 505	56 383	56 383	56 383	56 383

Table F.3: The "trip tonnage threshold" associated with each quantile used in the search for the lowest Ssq^2 (Eq. F.3) among the 180 investigated quantile/ratio pairs. The remaining columns show the amount by which the total landings in the "landings" file either exceeded or were lower than the QMR/MHR catch, summed over the period 1989–90 to 2011–12. For instance, a quantile cut-off of 90% and a $rat_{t,s} = 2.0$ resulted in a catch sum that exceeded the total QMR/MHR landings by 62 t (grey cell). The quantile/ratio pair with the lowest Ssq^2 is highlighted in colour.

Quantile	Trip tonnage	Minimum ratio $\left(rat_{t,s}\right)$ cut-off														
cut-off:	threshold	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	4	5	6	7	8	9
82	0.7	-470	-209	-85	-11	47	71	83	117	143	224	238	311	374	390	416
84	0.8	-429	-183	-63	7	60	81	93	127	151	227	242	314	377	393	419

86	0.9	-389	-156	-44	23	74	93	102	135	158	231	244	317	379	395	420
88	1	-343	-121	-19	41	89	108	115	147	170	240	252	323	384	400	423
90	1.2	-283	-85	6	62	109	125	132	160	182	249	261	330	390	406	430
92	1.4	-230	-55	27	80	125	136	143	168	190	254	266	334	393	406	430
94	1.7	-162	-16	52	97	139	149	156	179	201	259	269	337	396	409	432
96	2.1	-47	60	113	147	177	187	192	211	233	287	296	359	413	427	447
98	2.8	74	126	161	184	208	216	219	236	255	304	308	368	423	436	454
99	3.5	167	198	220	239	260	268	268	282	301	335	339	396	451	461	479
99.9	8.3	394	394	394	394	403	403	403	403	417	441	441	498	535	545	563
99.99	23.5	655	655	655	655	655	655	655	655	655	679	679	715	715	715	715

Table F.4: Summary of QMR/MHR catches, "raw" (unedited) landings and landings after removal of 182 trips identified in Table F.1. Also shown are the "fits" for each set of landings data by fishing year, as defined by Eq. F.3.

Fishing year	QMR/MHR (t)	"raw" (unedited) landings	"best fit[1]" landings	SSq_y^z for "raw" landings	SSq_y^z for "best fit" landings
89/90	928	930	891	6	1 365
90/91	1 097	1 107	1 069	120	738
91/92	873	897	872	596	1
92/93	1 030	1 025	1 017	25	177
93/94	1 133	1 120	1 117	176	254
94/95	1 218	1 250	1 212	1 000	41
95/96	1 503	4 031	1 539	6 388 483	1 260
96/97	1 326	1 444	1 303	14 026	537
97/98	1 364	1 426	1 389	3 789	627
98/99	1 470	1 677	1 481	42 765	117
99/00	1 357	1 383	1 378	693	458
00/01	1 467	1 494	1 450	744	286
01/02	1 473	1 485	1 468	157	20
02/03	1 497	1 509	1 480	152	302
03/04	1 557	1 562	1 542	24	233
04/05	1 473	1 529	1 486	3 092	164
05/06	1 346	1 361	1 348	213	2
06/07	1 382	1 376	1 374	35	57
07/08	1 280	1 332	1 282	2 680	7
08/09	1 392	1 433	1 397	1 734	26
09/10	1 209	1 225	1 217	240	55
10/11	1 297	1 301	1 300	24	11
11/12	1 215	1 233	1 218	305	6
Total	29 885	33 130	29 828	6 461 077	6 741

[1] quantile=92% and $rat_{t,s} \geq 1.6$

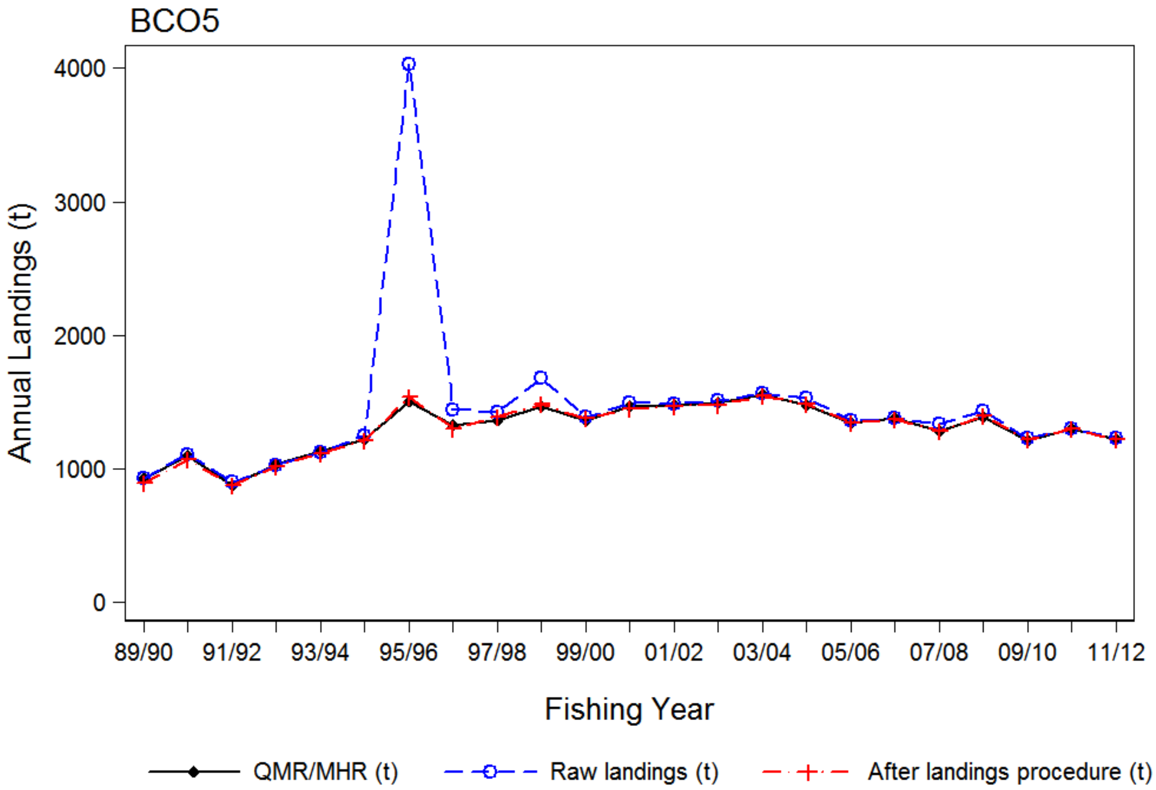


Figure F.1: Comparison of QMR/MHR annual total landings for BCO 5 with two extracts: A: unedited or "raw" landings; and B: total landings after dropping the 182 landings identified using the two-way search algorithm described in Table F.1 which resulted in the lowest *Ssq*^{z} criterion as defined by Eq. F.3.

APPENDIX G. CHARACTERISATION INFORMATION FOR BCO 5

G.1 INTRODUCTION

This Appendix has been prepared as background to Objectives 1 & 2 of MPI Project BCO2012-01 (Stock Assessment of BCO 5) fishery by updating, to the end of the 2011–12 fishing year, a reduced characterisation of the BCO 5 fishery. An update of the standardised CPUE analysis of the BCO 5 blue cod-potting fishery can be found in Appendix B. This Appendix and Appendix B use the statutory catch, effort and landings data reported to the Ministry for Primary Industries (MPI) for this task and build on previous reports prepared in 2005 (SeaFIC 2005), in 2008 (Starr & Kendrick 2009) and 2011 (Starr & Kendrick 2011).

G.2 TRENDS IN COMMERCIAL CATCH

The Southland blue cod fishery has a recorded catch history extending back to 1930, but the fishery only exceeded 1000 t/year in the early 1930s and in the late 1940s (following the 2nd World War; Warren et al 1997). The accuracy of these catch statistics is questionable, with landings mainly identified by port of landing and catches recorded to an unknown accuracy, particularly in the very early years. However, given the catch history plots in Warren et al. (1997), it seems unlikely that early catches in this fishery greatly exceeded current catch levels.

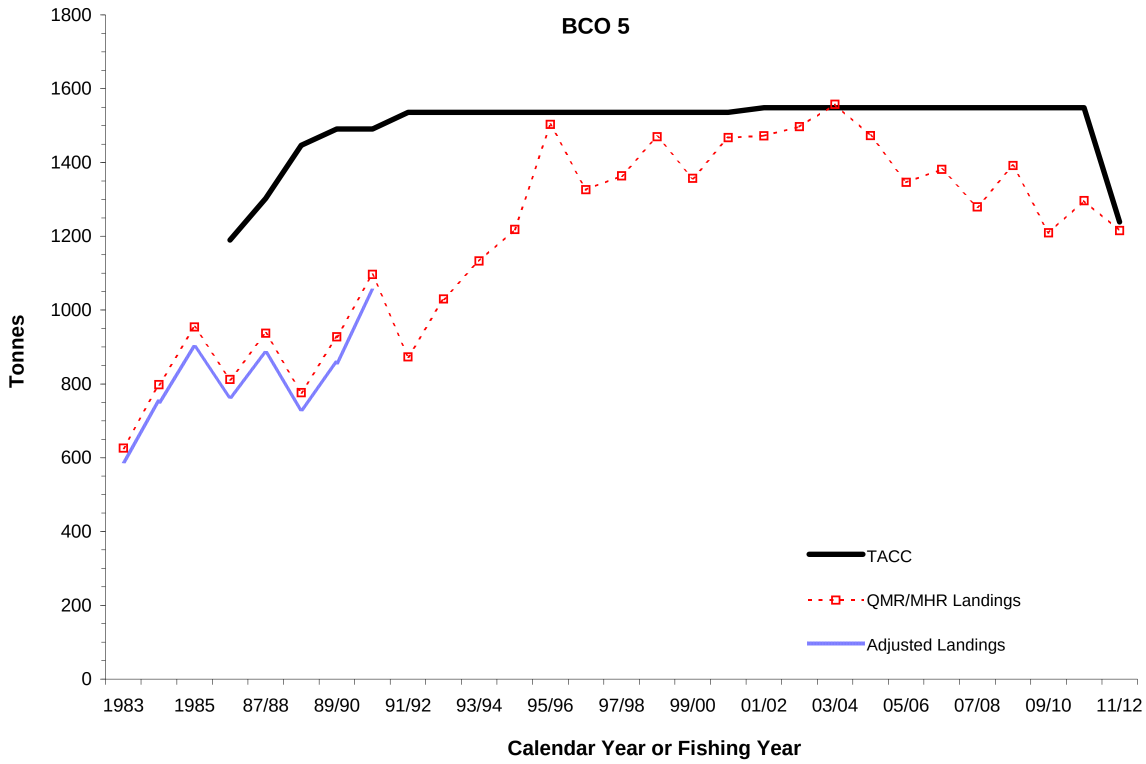


Figure G.1: Catch history and TACC (t) for BCO 5 from 1986–87 to the 2011–12 fishing years. (Data sources: QMR [1986–87 to 2000–01]; MHR [2001–02 to 2011–12]). "Adjusted" landings have been calculated using the ratio of adjusted to unadjusted landings $\left(R_y\right)$ as indicated in columns 4 and 5 in Table G.1.

Table G.1: Reported landings (t) and TACC (t) of blue cod in BCO 5 from 1986–87 to 2011–12 (Data sources: QMR [1986–87 to 2000–01]; MHR [2001–02 to 2011–12). $\tilde{S}L_y$ is the sum of landings in a year adjusted for changes in conversion factor (see caption for Table G.2) and SL_y is the sum of the same landings without adjustment.

Year	QMR_y	TACC_y	$R_y = \tilde{S}L_y / SL_y$	$\tilde{\text{Q}}\text{MR}_y = \text{QMR}_y * R_y$
1983	626		0.942	590
1984	798		0.942	752
1985	954		0.942	899
1986–87	812	1 190	0.942	765
1987–88	938	1 303	0.942	883
1988–89	776	1 447	0.942	731
1989–90	928	1 491	0.924	857
1990–91	1 096	1 491	0.960	1 053
1991–92	873	1 536	1.000	873
1992–93	1 030	1 536	1.000	1 030
1993–94	1 133	1 536	1.000	1 133
1994–95	1 218	1 536	1.000	1 218
1995–96	1 503	1 536	1.000	1 503
1996–97	1 326	1 536	1.000	1 326
1997–98	1 364	1 536	1.000	1 364
1998–99	1 470	1 536	1.000	1 470
1999–00	1 357	1 536	1.000	1 357
2000–01	1 467	1 536	1.000	1 467
2001–02	1 472	1 548	1.000	1 472
2002–03	1 497	1 548	1.000	1 497
2003–04	1 557	1 548	1.000	1 557
2004–05	1 473	1 548	1.000	1 473
2005–06	1 346	1 548	1.000	1 346
2006–07	1 382	1 548	1.000	1 382
2007–08	1 280	1 548	1.000	1 280
2008–09	1 392	1 548	1.000	1 392
2009–10	1 209	1 548	1.000	1 209
2010–11	1 296	1 548	1.000	1 296
2011–12	1 215	1 239	1.000	1 215

[1] average: 1989–90 and 1990–91

The TACC for BCO 5 was initially set at 1190 t on introduction into the QMS in 1986, but increased to above 1500 t in the early 1990s due to the quota appeal process (Warren et al 1997), and remained at that level until the TACC was reduced to 1239 t for the 2011–12 fishing year. Catches in this Fishstock gradually rose towards the TACC after its introduction into the QMS and slightly exceeded the TACC in 2003–04 for the first time (Figure G.1; Table G.1). Landings in BCO 5 subsequently dropped below the TACC, even in 2011–12, when landings were about 2% below the TACC.

Warren et al (1997) note that, prior to enactment of the Fisheries Act 1996, it was not necessary to record blue cod used as bait in rock lobster pots against quota holdings, although catches for bait were intended to be recorded on the Catch Effort and Landing Returns. This would cause catches prior to 1996 to be underestimated.

G.3 REGULATIONS AFFECTING THE FISHERY

Conversion factors used in the reporting of BCO greenweight have remained constant since 1990–91. The changes in conversion factors relative to those that existed prior to 1990–91 were generally small, but have been taken into account in the preparation of the catch/effort data used in this report (Figure G.1). Section G.5 presents the conversion factors by year and describes how the data were adjusted to a constant conversion factor.

A minimum mesh size of 48 mm was introduced for cod pots in 1994 (Warren et al 1997). Previous practice was to cover pots with 38 mm mesh. A requirement for escapement gaps was introduced in 1992, but this was superseded by the 1994 regulation of the 48 mm mesh. These changes in mesh size will affect how the CPUE indices presented in this paper are interpreted. Specifically, CPUE indices calculated prior to the change in mesh size will not be comparable to the CPUE indices which follow the change. This is because the distribution of fish sizes taken by the pots will differ in an unpredictable manner before and after the regulation change. Note that this regulation was designed to allow fish under the 33 cm minimum legal size to passively escape, thus reducing handling mortality associated with discarding sub-legal blue cod. For instance, undersized fish returned to the sea were reported to suffer seabird predation (Warren et al. 1997). Previously, the minimum legal size limit had been 30 cm, but the effective size limit even then was closer to 33 cm as processors preferred larger blue cod (Warren et al. 1997).

G.4 METHODS USED FOR 2013 ANALYSIS OF MPI CATCH AND EFFORT DATA

The methods used to prepare MPI catch and effort for analysis consist of matching the declared landed greenweight at the end of each trip with the effort and estimated catch data attributable to the corresponding trip (documented in Starr 2007). The most detailed level of information available for analysis after this merging procedure is the *trip stratum*, defined as the sum of the fishing events within a trip which have a of capture within unique method code, statistical area and declared target species code. The merging procedure collapses all the date information associated with a trip into a single date, usually the landing date, thus losing the information on date a trip. However, the remainder of the trip information stored in the CELR is retained by this method and has little impact for the BCO 5 potting fishery since most trips are short, lasting primarily one to two days.

This procedure:

- attributes effort, method of capture, target species and estimated catches to specific Fishstocks. Previously, the Fishstock taken had to be inferred from the statistical area of the fishing event. Therefore all records in the final dataset are uniquely attributable to fishing effort directed at the target Fishstock.
- removes some of the reliance on the estimated catch of the species and the bias which may result from using these data. There is always uncertainty in the accuracy of the estimate, particularly since the skipper is only required to estimate the catch of the top five species. Thus, catch estimates for the Fishstock of interest may be missing from the record or estimated inaccurately. However, the total landings for the Fishstock of interest should be reasonably well specified at the level of a complete trip.

However, there are still problems with analysing the catch and effort data in this manner and the procedure has to deal with the following issues:

- Trips which land to more than one Fishstock are discarded if they fish in "straddle" statistical areas which are valid for each of the Fishstocks landed. All trips which land multiple Fishstocks and fish in these ambiguous statistical areas have been dropped from the analysis.
- The most detailed level of area attributable for any trip is the statistical area because of a limitation in the design of the CELR system and the requirement to merge the CELR and TCEPR data for this species. Trips with missing statistical areas have used the predominant (most frequent) statistical area to fill in the missing datum. The few trips which had no statistical area information were dropped.
- Landed greenweight catch is attributed to specific statistical areas, method and target species by assuming that the estimated catches in these categories are distributed correctly. This will lead to some error because small catches from some strata are often not included in the original data. If no estimated catch is available for a trip, the procedure uses the distribution of effort to

partition the landed catch for that trip, a procedure which could lead to some bias because it assumes equal catchability in all strata.

- Trips with missing method codes are filled in with the method from the remaining events if only one method is reported for that trip. If a trip with a missing method code reports more than one method, the entire trip is dropped.
- Trips which report no target species codes are dropped but events within a trip which have missing target species codes are filled in with the predominant (most frequent) target species for the trip. Similarly, trips with missing statistical areas are filled in with the predominant (most frequent) statistical area for the trip and trips which report no statistical areas are dropped.

Table G.2. Comparison of the sum of the landed catch totals (t) with the total catch (t) reported by QMR/MHR for BCO 5 by fishing year. Also shown are the total landings from the analysis dataset and the sum of the estimated catches from the trips included in the analysis dataset. N_y =number trips/year in total dataset; A_y =number trips/year in analysis dataset; S_y =number of state codes in year *y*; $\tilde{L}_{i,s,y}=\left(cf_{s,2007}/cf_{s,y}\right)L_{i,s,y}$ =adjusted landed catch from trip stratum *i* in year *y* using state code *s* where $cf_{s,y}$ is the conversion factor used in year *y* for state code *s* and $cf_{s,2007}$ is the conversion factor for state *s* in 2011–12; $C_{i,y}$ =estimated catch from trip stratum *i* in year *y*; and $\tilde{C}_{i,y}=R_y\,C_{i,y}$ where R_y is defined in Table G.1.

Fishing Year	$\mathbf{QMR}_y$ [Column 5 Table G.1] (t)	$\tilde{SL}_y=\sum_{i=1}^{N_y}\sum_{s=1}^{S_y}\tilde{L}_{i,s}$ (t)	$\frac{\tilde{SL}_y}{\tilde{\text{QMR}}_y}$ (%)	$\tilde{AL}_y=\sum_{i=1}^{A_y}\sum_{s=1}^{S_y}\tilde{L}_{i,s}$ (t)	$\frac{\tilde{AL}_y}{\tilde{SL}_y}$ (%)	$\tilde{AC}_y=\sum_{i=1}^{A_y}\tilde{C}_{i,y}$ (t)	$\frac{\tilde{AC}_y}{\tilde{AL}_y}$ (%)
89/90	928	833	90	814	98	751	92
90/91	1 096	1 029	94	990	96	870	88
91/92	873	876	100	820	94	684	83
92/93	1 030	1 038	101	989	95	843	85
93/94	1 133	1 124	99	1 075	96	929	86
94/95	1 218	1 193	98	1 140	96	996	87
95/96	1 503	1 567	104	1 471	94	1 127	77
96/97	1 326	1 298	98	1 190	92	956	80
97/98	1 364	1 377	101	1 275	93	1 054	83
98/99	1 470	1 471	100	1 397	95	1 112	80
99/00	1 357	1 358	100	1 317	97	1 089	83
00/01	1 467	1 436	98	1 373	96	1 173	85
01/02	1 472	1 452	99	1 403	97	1 217	87
02/03	1 497	1 468	98	1 442	98	1 263	88
03/04	1 557	1 523	98	1 514	99	1 347	89
04/05	1 473	1 471	100	1 441	98	1 242	86
05/06	1 346	1 316	98	1 299	99	1 128	87
06/07	1 382	1 339	97	1 314	98	1 163	88
07/08	1 280	1 248	97	1 230	99	1 085	88
08/09	1 392	1 382	99	1 376	100	1 207	88
09/10	1 209	1 190	98	1 167	98	1 020	87
10/11	1 296	1 284	99	1 261	98	1 096	87
11/12	1 215	1 192	98	1 171	98	1 010	86
Total	29 885	29 465	99	28 472	97	24 363	86

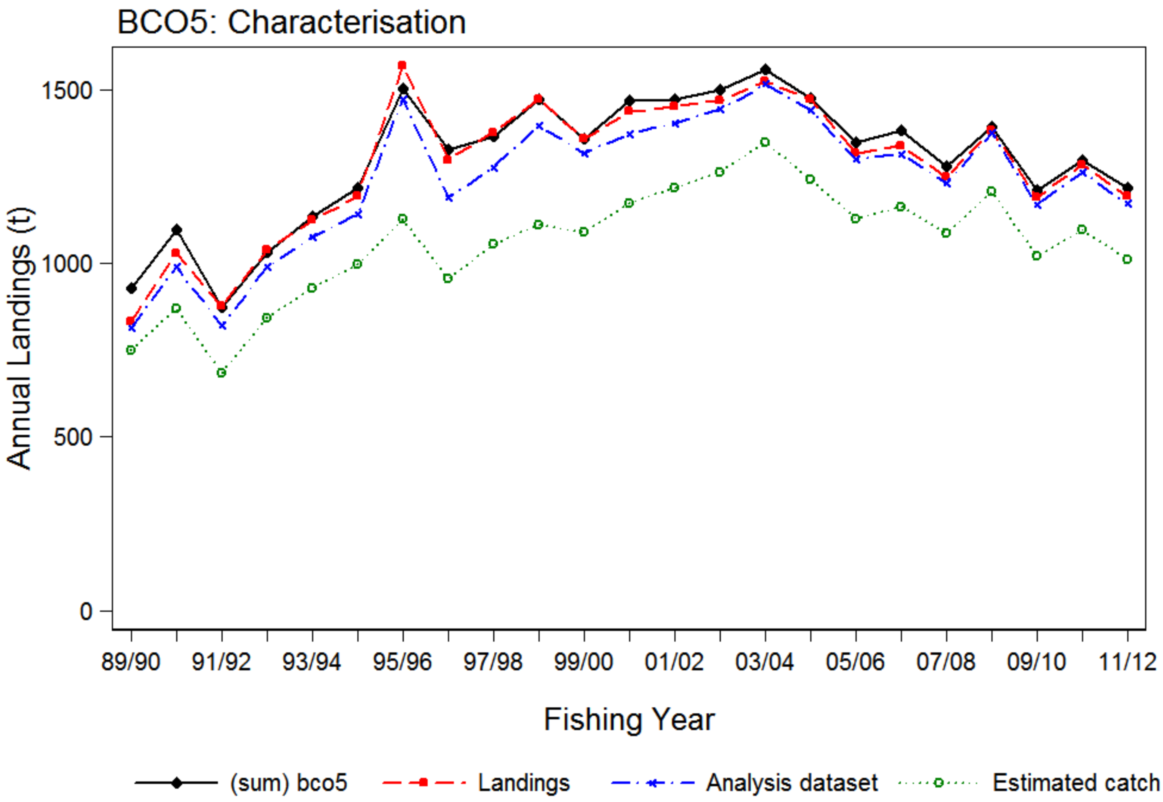


Figure G.2: Plot of catch datasets presented in Table G.2. The estimated catch total is the sum of the estimated catch in the analysis dataset, adjusted in 1989–90 and 1990–91 for changes in conversion factors as described in Table G.2.

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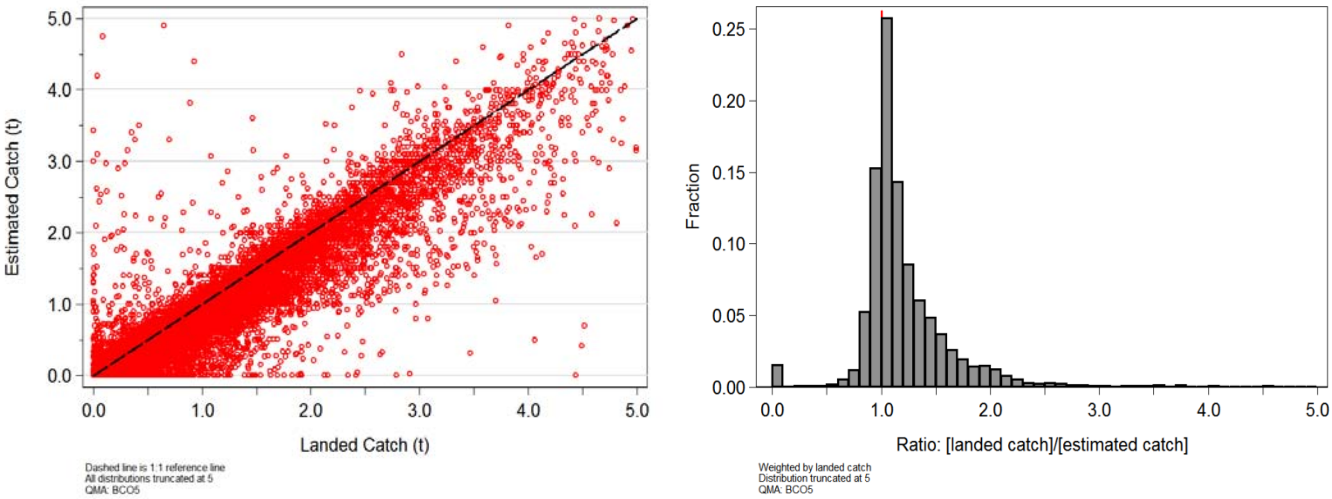

Figure G.3: [Left panel]: Scatter plot of the sum of landed and estimated blue cod catch for each trip in the analysis dataset. [Right panel]: Distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

Table G.3. Summary statistics pertaining to the reporting of estimated catch from the BCO 5 analysis dataset. A_y, $\tilde{L}_{i,y}$, $\tilde{A}L_y$, and $\tilde{A}C_y$ are defined in Table G.2; $\tilde{L}'_{i,y}$ is defined in Eq. G.1 $L'_{i,y} = L_{i,y}\dfrac{\mathbf{QMR}_y}{AL_y}$; Z_y: number of trips in year y with no estimated catch; 5%: fifth percentile; 50%: median; 95%: ninety-fifth percentile.

	Trips with landed catch but which report no estimated catch			Dataset statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
Fishing year	$\frac{Z_y}{A_y}$ (%)	$\frac{\sum_{i=1}^{Z_y}\tilde{L}_{i,y}}{\tilde{A}L_y}$ (%)	$\sum_{i=1}^{Z_y}\tilde{L}'_{i,y}$ (t)	$\left(\frac{\tilde{A}L_y}{\tilde{A}C_y}\right)_{5\%}$	$\left(\frac{\tilde{A}L_y}{\tilde{A}C_y}\right)_{50\%}$	$\left(\frac{\tilde{A}L_y}{\tilde{A}C_y}\right)_{\text{Mean}}$	$\left(\frac{\tilde{A}L_y}{\tilde{A}C_y}\right)_{95\%}$
89/90	2	1	5	0.84	0.94	1.23	2.00
90/91	2	1	8	0.85	1.00	1.26	1.97
91/92	3	1	8	0.82	1.02	1.35	2.46
92/93	3	1	7	0.84	1.02	1.68	2.24
93/94	3	1	6	0.85	1.04	1.31	2.25
94/95	2	0	2	0.83	1.07	1.31	2.30
95/96	7	3	46	0.81	1.13	1.42	2.30
96/97	8	4	54	0.79	1.10	1.45	2.37
97/98	12	6	77	0.80	1.08	1.31	2.20
98/99	12	7	104	0.80	1.08	1.28	2.07
99/00	7	2	32	0.84	1.13	1.33	2.18
00/01	4	1	11	0.83	1.10	1.27	2.09
01/02	7	1	9	0.84	1.07	1.25	2.09
02/03	8	1	12	0.85	1.09	1.26	2.03
03/04	7	1	8	0.86	1.08	1.25	2.03
04/05	10	1	9	0.85	1.10	1.33	2.03
05/06	10	1	8	0.82	1.10	1.26	2.06
06/07	8	1	8	0.77	1.09	1.27	2.11
07/08	9	0	6	0.62	1.09	1.37	2.15
08/09	10	0	6	0.61	1.08	1.20	2.09
09/10	12	0	6	0.70	1.10	1.35	2.00
10/11	13	1	9	0.77	1.10	1.23	1.99
11/12	15	1	11	0.67	1.10	1.35	2.01
Total	7	2	454	0.81	1.07	1.32	2.10

The catch totals (Table G.2; Figure G.2) resulting from the dataset used for this analysis may not be the same as those reported to the QMS system because the QMS is a separate reporting system from the MPI catch/effort reporting system. The data are further modified during the editing procedure described above because some trips are dropped with a corresponding loss of data, including dropping trips which have large landings of the target Fishstock without sufficient evidence to corroborate the large landing (see Appendix F). An important source of data loss in this procedure results from dropping trips which fished in straddling statistical areas and which report more than one valid Fishstock for that statistical area (Table G.2). Fortunately this is a relatively small component of the BCO 5 Fishstock, with the large majority of fishing for this species confined to FMA 5.

Catch totals in the fishery characterisation tables have been scaled to the QMR/MHR totals reported in Table G.1 by calculating the ratio of these catches with the total annual landed catch in the analysis dataset and scaling all the landed catch observations (i) within a trip using this ratio:

Eq. G.1 $$L'_{i,y} = L_{i,y}\frac{\mathbf{QMR}_y}{AL_y}$$

where $\mathbf{QMR}_y$, $L_{i,y}$ and AL_y are defined in the caption for Table G.2.

Annual totals from this dataset compared with the annual QMR/MHR totals in Table G.1 are presented in Table G.2 and Figure G.2. Total landings from the bottom part of the form (after some edits) exceeded the declared QMR/MHR landings in 1992–93, 1995–96 and 1997–98 (Table G.2). After that year, the totals are reasonably similar.

The shortfall between landed and estimated catch by trip for BCO 5 is variable, ranging from –8% to -23% of the landed catch used in the analysis data set (Table G.2). A comparison scatter plot of the estimated and landed catch by trip shows that relatively few trips overestimate the landing total for the trip (Figure G.3 [left panel]). A histogram of the distribution of the ratios of the landed relative to estimated catch shows a skewed distribution with a long right-hand tail and a mode at 1.0 (Figure G.3 [right panel]).

The 5% to 95% percentiles (excluding trips where there is no estimated catch) for the ratio of landed to estimated catch range from 0.81 to 2.10 for the dataset, with the median and mean ratios showing the landed catch 7% and 32% higher respectively than the estimated catch (Table G.3). Across all years, only 7 percent of trips estimated no catch of BCO 5 but reported BCO 5 in the landings (Table G.3). These landings represent 2% of the total BCO 5 landings for a total of 454 tonnes over all years (Table G.3).

G.5 DESCRIPTION OF BCO 5 LANDING INFORMATION

Landing data for blue cod were provided for all trips which landed BCO 5 at least once, with one record for every reported BCO landing from the trip (including other BCO QMAs). Each of these records contained a reported green weight (in kg), a code indicating the processed state of the landing, along with other auxiliary information such as the conversion factor used, the number of containers involved and the average weight of the containers. Every landing record also contained a "destination code" (Table G.4), which indicated the category under which the landing occurred. The majority of the landings were made using destination code "L" (landed to a Licensed Fish Receiver; Table G.4). However, other codes (e.g., F, U, and W; Table G.4) also potentially describe valid landings and were included in this analysis. A number of other codes (notably R, Q, B and T; Table G.4) were not included because it was felt that these landing were likely to be reported at a later date under the "L" destination category (or in the case of the "B" code as "U"). Two other codes (D and NULL) represented errors which could not be reconciled without making unwarranted assumptions. Unlike rock lobster in the same region (southern South Island), blue cod do not appear to be retained for later sale as the destination codes for this practice (R, Q, P and T) only account for less than 3% of the total landings (Table G.4).

Table G.4. Destination codes in the unedited landing data received for the BCO 5 analysis. The "how used" column indicates which destination codes were included in the characterisation and CPUE analyses.

Destination code	Number events	Total green weight (t)	Description	How used
L	79 202	33 376.3	Landed in NZ (to LFR)	Keep
F	10 011	178.7	Section 111 Recreational Catch	Keep
U	1 936	110.5	Bait used on board	Keep
W	267	11.7	Sold at wharf	Keep
E	506	11.2	Eaten	Keep
H	8	3.9	Loss from holding pot	Keep
A	63	2.8	Accidental loss	Keep
S	1	0.6	Seized by Crown	Keep
O	1	0.4	Conveyed outside NZ	Keep
Q	1 886	512.7	Holding receptacle on land	Drop
R	3 330	380.7	Retained on board	Drop
B	449	190.2	Bait stored for later use	Drop
T	119	50.1	Transferred to another vessel	Drop
NULL	92	13.5	Missing destination code	Drop
P	8	1.0	Holding receptacle in water	Drop

D	15	0.3 Discarded (non-ITQ)	Drop

Table G.5. Total greenweight reported and number of events by state code in the unedited landing file used to process the BCO 5 characterisation data.

State code	Number events	Total reported green weight (t)	Description
HGU	28 106	13 789.5	Headed and gutted
FIL	24 776	7 489.5	Fillets: skin-on
DRE	4 494	5 022.5	Dressed
GUT	13 481	4 678.6	Gutted
GGO	2 819	940.8	Gilled and gutted tail-on
GRE	7 359	723.3	Green (or whole)
SKF	5 521	396.9	Fillets: skin-off
NULL	192	32.8	Missing
GGT	10	24.6	Gilled and gutted tail-off
TSK	354	9.8	Fillets: skin-off trimmed
MEA	92	6.3	Fish meal
HGT	10	5.9	Headed, gutted, and tailed
UTF	9	5.4	Fillets: skin-on untrimmed
FIN	19	2.2	Fins
HDS	886	1.0	Heads
TEN	4	0.2	Tentacles
RLT	3	0.1	Tailed (rock lobster)
BEA	1	0.1	Beak and mouth
SHU	1	0.0	Shucked and shelled
USK	1	0.0	Fillets: skin-off untrimmed
TRF	1	0.0	Fillets: skin-on trimmed
LIB	1	0.0	Livers by-product
SHF	1	0.0	Shark fins
HET	1	0.0	Heads and tentacles
CHK	1	0.0	Cheeks

Landing data are primarily distributed between four state codes: HGU, FIL, DRE and GUT, which account for over 93% of the total landings (Table G.5). A further two state codes (GGO and GRE) account for another 5% of the landings, leaving less than 2% for the remaining state codes.

The conversion factors in use in the first two years of the data set (1989–90 and 1990–91) for the important state codes HGU, FIL, DRE, GUT and GGO differ slightly from the later conversion factors (Table G.6). Greenweight landings $\left(G'_{i,y}\right)$ were adjusted in the CPUE analysis and for some parts of the characterisation analysis for state codes HGU, FIL, DRE, GUT and GGO to a consistent conversion factor using the following equation:

Eq. G.2 $$G'_{i,s,y} = G_{i,s,y} \, {cf_{i,s,2006-07}} / {cf_{i,s,y}}$$

where

$G_{i,s,y}$ is the reported greenweight for record *i* using landed state code *s* in year *y*;

$cf_{i,s,y}$ is the conversion factor for record *i* using landed state code *s* in year *y*;

$cf_{i,s,2006-07}$ is the conversion factor for record *i* using landed state code *s* in year 2009–10 (=1.55 for DRE and HGU)

The net effect of these adjustments is relatively small, as is shown by the plot in Figure G.1 and the data in Table G.1.

Table G.6. Median conversion factor for the major state codes reported in Table G.5 and the total reported greenweight by fishing year in the landings attributed to BCO 5. '–': no landings recorded in corresponding fishing year/state code combination or unneeded.

Fishing year	HGU	FIL	GUT	DRE	GGO	GRE	SKF	OTH
								Landed State
* Mean conversion factor								
89/90	1.5	1.9	1.1	–	1.2	1	–	1.8
90/91	1.4	1.9	1.1	1.8	1.2	1	–	5.6
91/92	1.4	1.7	1.15	1.7	–	1	2.6	5.6
92/93	1.4	1.7	1.15	1.7	–	1	2.6	5.6
93/94	1.4	1.7	1.15	1.7	–	1	2.6	5.6
94/95	1.4	1.7	1.15	1.7	–	1	2.6	–
95/96	1.4	1.7	1.15	1.7	1	1	2.6	1
96/97	1.4	1.7	1.15	1.7	1	1	2.6	2.8
97/98	1.4	1.7	1.15	1.7	1	1	2.6	0
98/99	1.4	1.7	1.15	1.7	1	1	2.6	1
99/00	1.4	1.7	1.15	1.7	–	1	2.6	5.6
00/01	1.4	1.7	1.15	1.7	–	1	2.6	0
01/02	1.4	1.7	1.15	1.7	–	1	2.6	0
02/03	1.4	1.7	1.15	1.7	–	1	2.6	5.6
03/04	1.4	1.7	1.15	1.7	–	1	2.6	5.6
04/05	1.4	1.7	1.15	1.7	–	1	2.6	5.6
05/06	1.4	1.7	1.15	1.7	–	1	2.6	5.6
06/07	1.4	1.7	1.15	1.7	–	1	2.6	5.6
07/08	1.4	1.7	1.15	1.7	–	1	2.6	5.6
08/09	1.4	1.7	1.15	1.7	–	1	2.6	5.6
09/10	1.4	1.7	1.15	1.7	–	1	2.6	5.6
10/11	1.4	1.7	1.15	1.7	–	1	2.6	5.6
11/12	1.4	1.7	1.15	1.7	–	1	2.6	5.6
Total landings (t)								
89/90	507.5	272.5	23.2	–	15.0	25.2	–	0.6
90/91	581.8	322.8	13.3	80.4	0.8	41.6	–	0.6
91/92	463.7	247.1	23.1	74.6	–	40.2	38.8	0.6
92/93	504.4	307.0	49.5	96.9	–	46.8	40.0	0.4
93/94	421.4	303.2	166.1	147.6	–	58.0	33.9	0.0
94/95	460.6	224.7	342.3	126.0	0.0	46.0	14.2	–
95/96	607.8	309.0	195.6	173.4	104.1	152.2	25.2	4.8
96/97	488.4	214.4	238.7	162.9	46.4	102.5	34.8	16.5
97/98	535.5	266.8	160.6	164.8	126.4	98.5	29.0	8.1
98/99	670.6	393.5	78.3	132.1	146.7	30.0	20.7	9.1
99/00	555.7	396.1	97.9	181.0	126.5	7.3	11.8	2.2
00/01	552.2	405.8	119.2	206.0	123.7	14.1	24.6	5.2
01/02	597.7	396.2	84.5	187.5	173.4	8.2	20.4	1.7
02/03	622.0	417.1	195.5	208.9	0.3	22.0	10.8	3.1
03/04	652.2	495.4	134.4	216.9	11.7	17.2	4.1	10.4
04/05	574.3	504.6	207.5	138.7	16.8	22.7	4.3	16.9
05/06	549.6	464.6	211.6	95.2	4.9	11.0	6.8	3.8
06/07	689.8	317.1	277.8	68.3	–	11.0	9.7	0.4
07/08	615.0	259.0	333.0	42.2	–	18.4	12.9	1.7
08/09	704.6	225.7	394.0	35.7	–	24.7	10.6	1.5
09/10	628.7	171.6	373.4	25.9	–	10.3	6.6	0.0
10/11	690.6	120.0	446.5	23.0	–	9.9	9.5	0.3
11/12	678.8	118.8	374.0	22.0	0.0	11.1	12.3	0.9
Total	13 353.0	7 153.0	4 539.9	2 610.0	896.7	828.8	381.1	88.7

Total landings available in the complete data set are almost entirely for BCO 5, with almost no landings from other BCO Fishstocks, indicating that trips which land to BCO 5 generally only fish within the QMA (Table G.7). Over 99% of the BCO 5 landings have been reported on CELR forms, with no change over the 23 years of data (Table G.8). Reporting of BCO 5 landings on other form types is relatively rare, as this species is not commonly taken as bycatch in other fisheries (see Section G.6 below), with potting being the most effective way to take this species commercially and which is a method exclusively reported on the daily CELR forms.

Table G.7. Distribution of total landings (t) by blue cod Fishstock and by fishing year for the set of trips that recorded at least one landing in BCO 5.

Fishing year	BCO 1	BCO 2	BCO 3	BCO 4	BCO 5	BCO 7	BCO 8	Total
89/90	0		7		844	0	0	851
90/91			16	0	1 041	1		1 059
91/92			9	2	888	0	0	900
92/93			14		1 045	0	1	1 060
93/94			16	1	1 130	1	1	1 148
94/95			25		1 214	1		1 239
95/96	0	0	28	2	1 572	0	2	1 604
96/97	0		20	2	1 305	1	5	1 333
97/98	0		4	0	1 390	0	4	1 398
98/99	0	1	11	1	1 481	1	6	1 501
99/00		0	14	0	1 379	2	3	1 398
00/01	0	1	23	2	1 451	0	0	1 478
01/02			29	0	1 469	1	0	1 499
02/03	4		26	5	1 479	0	2	1 517
03/04	1		17	0	1 542	1	1	1 562
04/05			17	1	1 486	0	2	1 507
05/06			21	2	1 347	0	1	1 372
06/07		1	22	7	1 374	2	4	1 410
07/08			13	5	1 282	0	1	1 302
08/09	0	0	20	1	1 397	2	3	1 423
09/10	0	0	25	0	1 216	2	1	1 244
10/11	0		44	2	1 300	0	0	1 347
11/12	0		37	0	1 218	0	0	1 255
Total	6	3	458	34	29 850	17	37	30 406

Table G.8. Distribution by form type for landed catch by weight for each fishing year in BCO 5. Also provided is the number of days fishing and the associated distribution of days fishing by form type for the effort data using statistical areas consistent with BCO 5. CELR: Catch, effort, landing return; CLR: catch landing return; NCELR: netting catch effort landing return; TCEPR: trawl catch effort processing return; TCER: trawl catch effort return. Forms other than CELR and NCELR report their landings on CLR forms.

Fishing	Landings[1]			Days Fishing (%)[2]					Days Fishing					
Year	* C	* C	* NC	* C	TCEPR	TCER	NCELR	Lining[3]	CELR	TCEPR	TCER	NCELR	Lining[3]	Total
89/90	99.8	0.2	0.0	95.4	4.6	–	–	–	4 476	216	–	–	–	4 692
90/91	99.9	0.1	0.0	95.0	5.0	–	–	–	5 255	278	–	–	–	5 533
91/92	99.7	0.3	0.0	97.1	2.9	–	–	–	4 846	144	–	–	–	4 990
92/93	99.8	0.2	0.0	97.5	2.5	–	–	–	5 250	135	–	–	–	5 385
93/94	99.9	0.1	0.0	99.2	0.8	–	–	–	5 052	42	–	–	–	5 094
94/95	100.0	0.0	0.0	97.1	2.9	–	–	–	4 755	142	–	–	–	4 897
95/96	100.0	0.0	0.0	98.9	1.1	–	–	–	5 158	59	–	–	–	5 217
96/97	99.8	0.2	0.0	93.1	6.9	–	–	–	4 582	340	–	–	–	4 922
97/98	99.9	0.1	0.0	96.8	3.2	–	–	–	4 310	141	–	–	–	4 451
98/99	100.0	0.0	0.0	96.3	3.7	–	–	–	4 792	182	–	–	–	4 974
99/00	100.0	0.1	0.0	94.1	5.9	–	–	–	4 305	271	–	–	–	4 576
00/01	99.2	0.8	0.0	92.5	7.5	–	–	–	4 139	335	–	–	–	4 474
01/02	99.5	0.5	0.0	88.7	11.3	–	–	–	4 365	558	–	–	–	4 923
02/03	99.9	0.1	0.0	89.3	10.7	–	–	–	4 408	529	–	–	–	4 937
03/04	99.8	0.2	0.0	90.8	9.2	–	–	–	4 454	452	–	–	–	4 906
04/05	99.9	0.1	0.0	82.0	18.0	–	–	–	4 644	1 019	–	–	–	5 663
05/06	99.7	0.3	0.0	83.4	16.6	–	–	–	4 628	923	–	–	–	5 551
06/07	98.4	1.6	0.1	81.0	16.9	–	2.1	–	4 463	930	–	116	–	5 509
07/08	97.1	2.9	0.1	72.3	15.2	9.9	1.8	0.7	4 173	880	574	104	43	5 774
08/09	96.6	3.3	0.1	73.8	12.7	10.5	2.0	1.1	4 341	744	615	117	64	5 881
09/10	98.6	1.4	0.1	71.9	18.6	6.7	1.7	1.1	4 256	1 100	397	102	68	5 923
10/11	98.0	2.0	0.1	73.4	16.6	6.3	2.6	1.2	4 509	1 023	385	157	72	6 146
11/12	98.3	1.6	0.1	70.7	17.6	8.8	2.6	0.3	4 412	1 098	548	163	21	6 242
Total	99.3	0.7	0.0	87.5	9.6	2.1	0.6	0.2	105573	11 541	2 519	759	268	120 660

[1] Percentages of landed greenweight

[2] Percentages of number of days fishing

[3] combines 13 days for LCER (lining trip >28 m), and 255 days for LTCER (lining trip <28 m)

G.6 DESCRIPTION OF THE BCO 5 FISHERY

A large number of the statistical areas recorded for BCO 5 fishing events (nearly 21 000 records from a total of 144 000 records or about 14%) use the rock lobster statistical areas rather than the "general" or finfish statistical areas. This is understandable because most of these records (18 800 or 90%) record the RLP method and blue cod is a bycatch species in this fishery. Langley (2005) noted the same problem and we have adopted his solution in this paper (Table G.9) so that the catches can be properly compared for spatial distribution. The proposed mapping of the rock lobster statistical areas into the general statistical areas is not precise (see Figure G.8 for a comparison of the boundaries for the two types of statistical areas), but it is not possible to adopt a more robust approach given the lack of more detailed positional information in the data. The actual amount of blue cod catch taken by the RLP method is small, as demonstrated below in Table G.10.

Table G.9. Mapping algorithm used to convert rock lobster statistical areas into "general" or finfish statistical areas. See Figure G.8 for rock lobster and finfish statistical areas.

Rock lobster statistical area	General statistical area
921	026
922	026
923	025
924	027
925	029
926	030
927	031
928	032
929	033
930	034
931	035

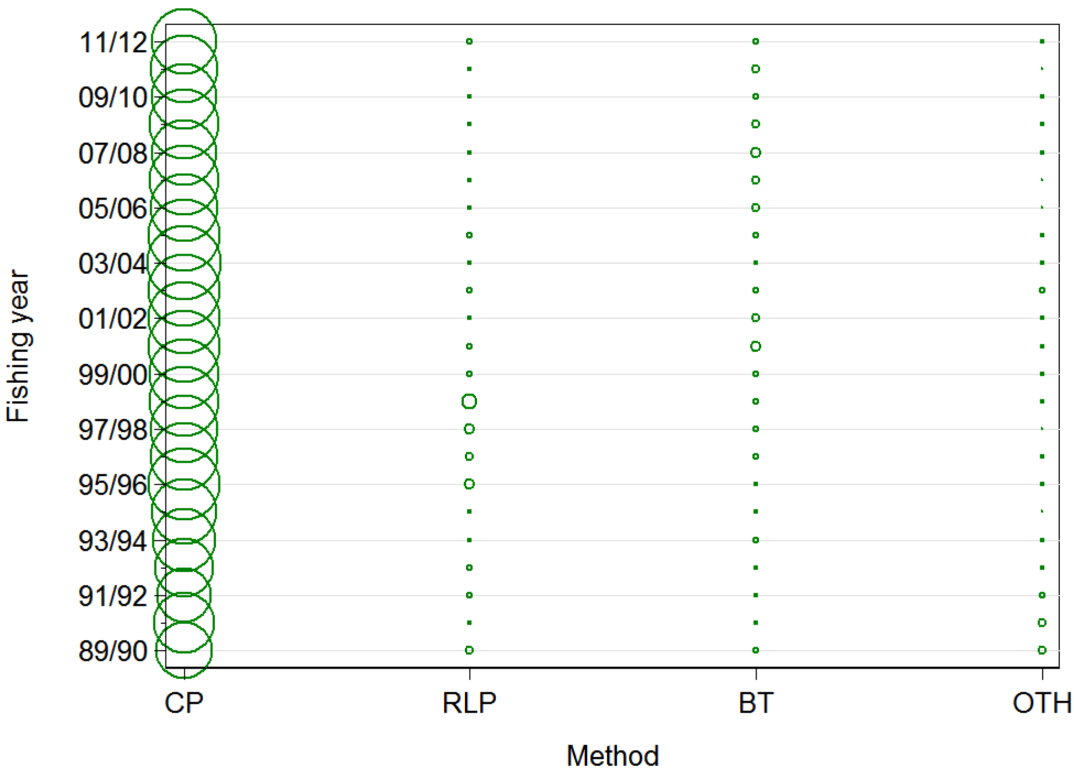

Figure G.4: Distribution of catches for the major fishing methods by fishing year from trips which landed BCO 5. Circles are proportional to the catch totals by method and fishing year, with the largest circle representing: 1535 t (03/04 for CP). CP=cod potting, RLP: rock lobster potting; BT: bottom trawl; OTH: other.

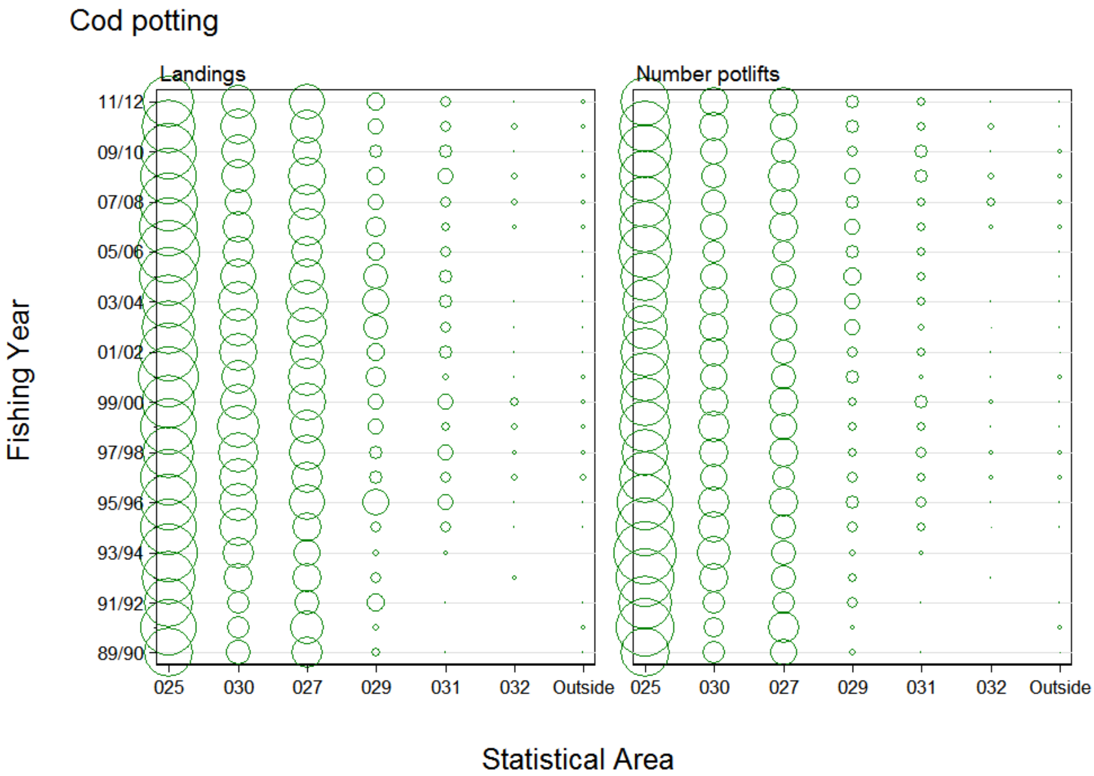

Figure G.5: Distribution of landings and number of tows for the cod potting method by statistical area and fishing year from trips which landed BCO 5. Circles are proportional within each panel: [landings] largest circle= 820 t in 05/06 for Area 025; [number potlifts] largest circle= 78 211 pots in 93/94 for Area 025.

Table G.10. Total landings (t) and distribution of landings (%) of blue cod from trips which landed BCO 5 grouped by important fishing methods (see Figure G.4 for explanation of method codes), and by statistical area [see Figure G.8] (the latter are ordered in descending importance of total landings), summed from 1989–90 to 2011–12. Landings (t) have been scaled to the QMR totals using Eq. F.1

Stat_					Method of capture					Method of capture
Area	CP	RLP	BT	OTH	Total	CP	RLP	BT	OTH	Total
	Distribution (%)					Total landings (t)				
025	53	12	39	33	52	15 327	39	125	47	15 538
030	20	53	43	42	20	5 745	174	137	59	6 115
027	20	18	7.5	3.6	20	5 789	60	24	5	5 878
029	5.1	3.8	1.1	2.0	5.0	1 483	12	4	3	1 502
031	2.1	11	0.3	9.5	2.2	608	37	1	13	659
032	0.3	1.2	0.6	6.6	0.3	88	4	2	9	103
Outside	0.2	0.3	8.8	3.5	0.3	56	1	28	5	90
Total	97	1.1	1.1	0.5	100	29 096	328	319	142	29 885

BCO 5 shares statistical areas with two other blue cod Fishstocks: Area 027 with BCO 3 and Area 032 with BCO 7 (Figure G.8). Almost all BCO 5 landings have been taken using the cod potting method, with almost negligible landings using other methods (Table G.10; Figure G.4). Slightly less than 800 t of blue cod landings (less than 3%) have been made using methods other than cod potting since 1989–90. Of these, about 300 t have been made using rock lobster pots as the catching method (Table G.10). There is an equivalent amount (319 t) of blue cod taken as a bycatch of the bottom trawl fishery in FMA 5 (Table G.10).

About one-half of the BCO 5 landings come from eastern Foveaux Strait (Area 025; Figure G.8) and there appears to be no trend towards or away from this statistical area over the 23 years of available data. Most of the remaining landings are almost evenly distributed between western Foveaux Strait (Area 030) and the Southeast coast of Stewart Island (Area 027; Figure G.8). Minor amounts of landings are taken from the southwest corner of Stewart Island (Area 029) and Fiordland (Areas 031 and 032). There appears to have been no trend in the distribution of cod potting landings or effort by statistical area over the past 20 years (Figure G.5).

Cod potting seems to occur throughout the year, with greater intensity in autumn and winter months, although the importance of spring and summer fisheries has varied over the years (Figure G.6; Table G.12).

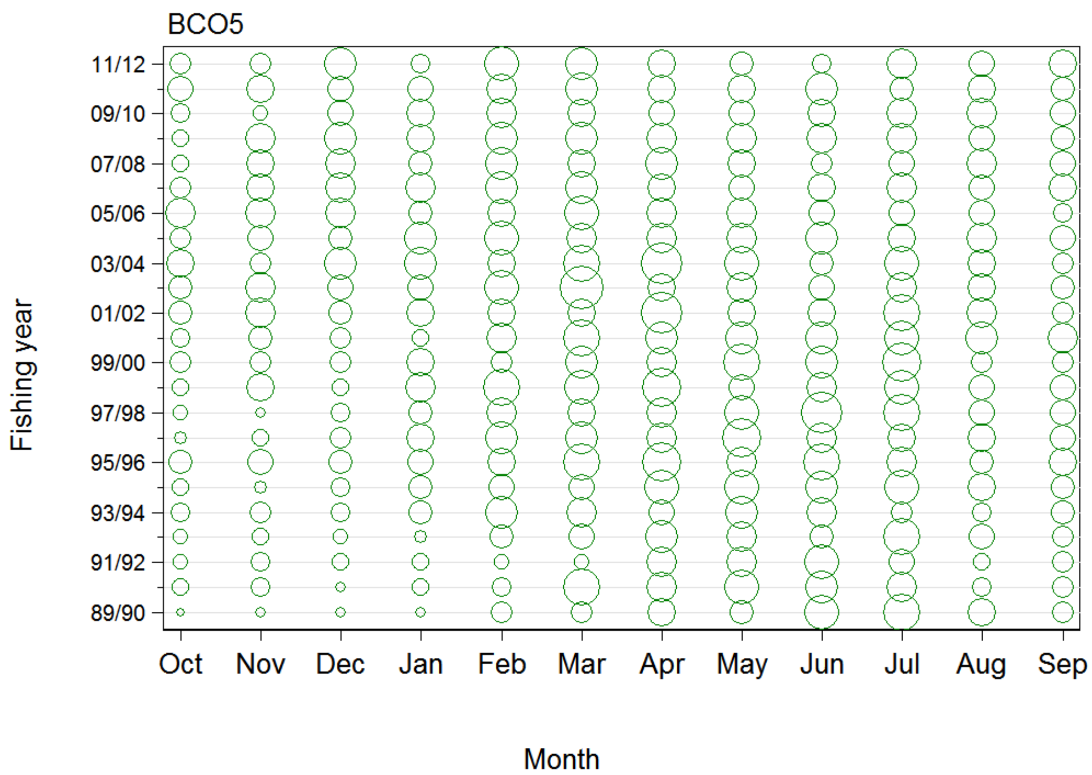

Figure G.6: Total landings by month and fishing year for all of BCO 5 (primarily cod potting) based on trips which landed BCO 5. Circle sizes are proportional to landings: largest circle=272 t in 02/03 for Mar.

Table G.11. Percent distribution of landings by statistical area (Figure G.8) and total annual landings (t) of BCO 5 from 1989–90 to 2011–12 for trips which landed BCO 5 for all methods (primarily cod potting) taking blue cod. Annual landings (t) have been scaled to the QMR totals using Eq. F.1.

Fishing	Statistical Area							Statistical Area							
Year	* 0 *		* 0 *	0	031	031	Other	025	030	027	029	031	031	Other	Total
	* % Distribution							* Distribution (t)							
89/90	59.5	14.9	23.1	2.2	0.3	0.0	0.1	552.1	138.1	214.1	20.2	2.5	0.0	0.7	927.8
90/91	64.9	11.5	22.6	0.7	0.0	0.0	0.3	711.9	125.7	247.9	7.1	0.5	0.1	3.2	1 096.5
91/92	60.2	15.1	16.4	7.7	0.3	0.1	0.1	526.0	132.0	143.2	67.6	2.9	0.5	0.8	873.0
92/93	61.1	18.5	17.1	2.6	0.3	0.4	0.0	629.3	190.2	175.9	26.8	3.3	4.5	0.2	1 030.1
93/94	63.8	20.2	14.3	1.0	0.6	0.1	0.0	722.1	229.3	162.3	11.8	6.3	1.0	0.0	1 132.8
94/95	55.4	24.7	15.3	2.6	1.9	0.1	0.1	675.0	301.5	185.8	31.8	22.8	0.8	0.8	1 218.4
95/96	46.3	21.2	18.0	11.0	3.4	0.1	0.1	695.8	319.3	270.3	164.9	50.4	1.0	1.4	1 503.0
96/97	51.4	24.0	17.2	3.4	2.3	0.7	1.0	682.0	317.6	227.6	44.7	30.9	9.4	13.7	1 326.0
97/98	44.0	27.2	21.1	3.1	3.8	0.5	0.4	600.0	371.1	288.1	41.7	51.3	6.7	5.1	1 364.0
98/99	45.2	31.8	17.1	3.4	1.5	0.7	0.2	664.7	467.9	251.4	50.7	21.6	10.7	3.1	1 470.0
99/00	45.4	22.5	22.6	3.6	4.2	1.3	0.4	616.0	305.8	306.6	49.4	56.8	17.0	5.4	1 357.0
00/01	54.1	17.9	21.0	5.4	0.6	0.2	0.8	793.4	263.2	308.8	78.9	8.5	2.9	11.5	1 467.1
01/02	51.5	23.3	17.7	4.6	2.7	0.1	0.1	758.0	342.7	261.0	68.4	39.2	1.6	1.6	1 472.5
02/03	43.0	21.4	23.8	9.4	2.1	0.1	0.2	644.4	320.9	356.0	140.5	31.9	1.1	2.3	1 496.9
03/04	38.7	22.6	25.8	9.5	3.0	0.2	0.2	603.5	351.5	401.1	147.8	46.9	3.8	2.9	1 557.4
04/05	49.9	20.4	17.8	8.7	3.0	0.1	0.1	734.3	299.8	262.7	127.9	44.7	1.5	2.0	1 472.9
05/06	61.6	15.8	15.1	5.5	1.8	0.1	0.1	829.1	212.7	202.8	74.1	24.5	1.1	2.0	1 346.2
06/07	52.6	15.9	23.2	5.8	1.8	0.4	0.3	726.2	219.5	320.6	80.3	24.9	5.9	4.2	1 381.6
07/08	56.8	13.5	21.2	4.1	2.7	0.8	0.9	727.0	173.3	271.3	52.0	34.5	10.6	11.1	1 279.8
08/09	51.1	17.5	22.3	4.6	3.6	0.6	0.3	710.7	244.2	310.4	63.4	50.1	8.3	4.6	1 391.8
09/10	57.2	21.0	15.2	2.7	3.3	0.1	0.4	692.0	253.5	183.7	32.9	40.4	1.8	4.9	1 209.0
10/11	49.9	22.4	20.0	4.3	2.2	0.9	0.3	647.4	290.3	258.9	56.4	28.0	11.9	3.5	1 296.5
11/12	49.1	20.2	22.1	5.2	2.9	0.1	0.4	597.0	245.0	268.1	62.8	35.7	1.2	5.4	1 215.1
Overall	52.0	20.5	19.7	5.0	2.2	0.3	0.3	15 537.7	6 114.9	5 878.5	1 501.9	658.6	103.5	90.3	29 885.3

Table G.12. Percent distribution of landings by month from 1989–90 to 2011–12 for all methods combined (but almost entirely cod-potting) for trips which landed BCO 5.

Fishing	Month											
year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
89/90	1	2	2	2	7	7	12	8	19	21	12	7
90/91	3	5	2	4	5	18	11	15	14	12	5	6
91/92	3	6	5	5	4	3	15	15	20	11	5	8
92/93	4	4	3	2	8	9	14	13	8	19	9	7
93/94	5	5	5	8	14	12	8	14	12	6	5	7
94/95	4	2	4	6	7	8	14	13	12	14	8	7
95/96	5	6	5	6	7	13	14	8	12	9	5	8
96/97	2	3	5	9	11	11	10	16	10	9	8	7
97/98	3	1	4	6	9	9	10	13	17	15	7	7
98/99	3	7	3	9	13	12	14	7	9	11	6	7
99/00	5	5	4	9	5	11	9	14	12	16	5	5
00/01	4	5	4	3	9	13	11	11	10	11	10	9
01/02	6	9	5	7	7	8	16	8	7	13	9	5
02/03	5	8	7	7	11	18	8	9	6	9	7	5
03/04	7	4	9	9	7	12	15	11	5	10	7	4
04/05	5	7	6	10	12	9	9	9	10	8	9	7
05/06	9	10	9	6	8	12	10	9	8	7	7	4
06/07	4	8	9	10	10	11	8	7	8	10	7	8
07/08	4	9	10	7	11	8	12	9	5	7	10	8
08/09	3	9	10	8	11	11	9	9	9	9	6	6
09/10	5	2	8	9	11	9	7	8	10	11	11	8
10/11	7	9	7	7	10	12	8	9	11	6	8	6
11/12	5	5	12	4	13	13	10	7	4	10	7	8
Mean	5	6	6	7	9	11	11	10	10	11	8	7

Cod potting for blue cod in BCO 5 is characterised as a target blue cod fishery with less than 0.1% of all landings targeted at species other than blue cod (Figure G.7, Table G.13). Surprisingly, some of the rock lobster potting catch (85 t from a total of 310 t; Figure G.7 and Table G.13) was targeted at blue cod in spite of using the rock lobster potting method. It is possible that these are data errors. BCO 5 bottom trawl catch taking blue cod is generally taken while targeting for flatfish or stargazer, although catches of blue cod are very small (Table G.13). There has been little change in these distributions since 1989–90 (Table G.14 and Figure G.7).

Table G.13. Total landings (t) and distribution of landings (%) of blue cod from trips which landed BCO 5 grouped by important fishing methods (CP: cod potting; RLP: rock lobster potting; BT: bottom trawl) and by target species (BCO: blue code; CRA: rock lobster; FLA: generic flatfish; OTH: other), summed from 1989–90 to 2011–12. Landings (t) have been scaled to the QMR totals using Eq. F.1. Columns sum to 100 for each target species.

	Method of capture					Method of capture				
Region	CP	RLP	BT	OTH	Total	CP	RLP	BT	OTH	Total
	Distribution (%)					Total landings (t)				
BCO	100	27	4	50	98	26 620	85	10	70	26 785
CRA	0	73	–	0	1	9	225	–	0	234
FLA	0	–	36	0	0	0	–	101	0	101
OTH	0	0	61	50	1	13	0	172	70	254
Total	100	100	100	100	100	26 641	310	283	140	27 375

Table G.14. Percent distribution of landings by target species and two potting methods (see caption for Table G.13 for explanation of abbreviations) from 1989–90 to 2011–12 for trips which landed BCO 5. '–': no landings recorded for cell.

	Cod potting						Rock lobster potting					
Fishing	* Distribution			* Total landings			* Distribution			Total landings (t)		
Year *	BCO *	CR *	OT *	BCO *	CR	OTH	CRA	BCO	OTH	CRA	BCO	OTH
89/90	99.9	0.10	0.00	883	0.9	0.0	99.2	0.7	0.05	16.9	0.1	0.0
90/91	100.0	0.03	0.00	1 062	0.4	0.0	99.3	0.7	–	7.7	0.1	–
91/92	100.0	0.00	0.00	839	0.0	0.0	87.5	12.5	–	14.3	2.0	–
92/93	99.8	0.17	0.03	1 003	1.7	0.3	86.8	13.2	0.00	9.6	1.5	0.0
93/94	99.9	0.02	0.04	1 106	0.2	0.5	81.6	18.4	–	6.7	1.5	–
94/95	100.0	–	0.01	1 208	–	0.1	96.2	3.8	–	4.2	0.2	–
95/96	99.8	0.11	0.05	1 452	1.7	0.7	29.9	70.1	0.01	10.0	23.4	0.0
96/97	99.8	0.05	0.13	1 284	0.6	1.7	62.4	37.6	–	16.3	9.8	–
97/98	100.0	0.00	0.02	1 315	0.0	0.3	71.9	28.1	–	23.0	9.0	–
98/99	99.6	0.24	0.16	1 392	3.4	2.2	82.3	17.7	0.00	49.3	10.6	0.0
99/00	99.9	0.02	0.12	1 328	0.3	1.6	86.4	13.6	–	10.0	1.6	–
00/01	99.9	0.00	0.05	1 421	0.0	0.8	46.8	53.2	–	4.0	4.6	–
01/02	99.9	0.00	0.06	1 437	0.0	0.8	67.5	32.5	–	5.2	2.5	–
02/03	100.0	0.00	0.00	1 460	0.0	0.0	65.5	34.5	–	10.3	5.4	–
03/04	100.0	0.00	–	1 535	0.0	–	84.9	15.1	–	6.2	1.1	–
04/05	99.9	–	0.12	1 442	–	1.8	47.8	52.2	–	4.3	4.7	–
05/06	99.9	0.00	0.06	1 319	0.0	0.8	80.8	19.2	–	5.8	1.4	–
06/07	100.0	–	0.00	1 352	–	0.0	85.6	14.4	–	6.6	1.1	–
07/08	100.0	0.00	–	1 240	0.0	–	81.6	18.4	–	6.0	1.4	–
08/09	99.9	0.00	0.07	1 358	0.0	0.9	88.0	12.0	0.00	4.9	0.7	0.0
09/10	100.0	0.00	0.00	1 182	0.0	0.0	83.2	16.8	–	6.7	1.4	–
10/11	100.0	0.00	0.04	1 267	0.0	0.5	91.2	8.8	–	6.8	0.7	–
11/12	100.0	0.00	0.02	1 186	0.0	0.2	92.9	7.1	–	8.0	0.6	–
Overall	99.9	0.03	0.05	29 074	9.2	13.1	74.0	26.0	0.00	242.6	85.2	0.0

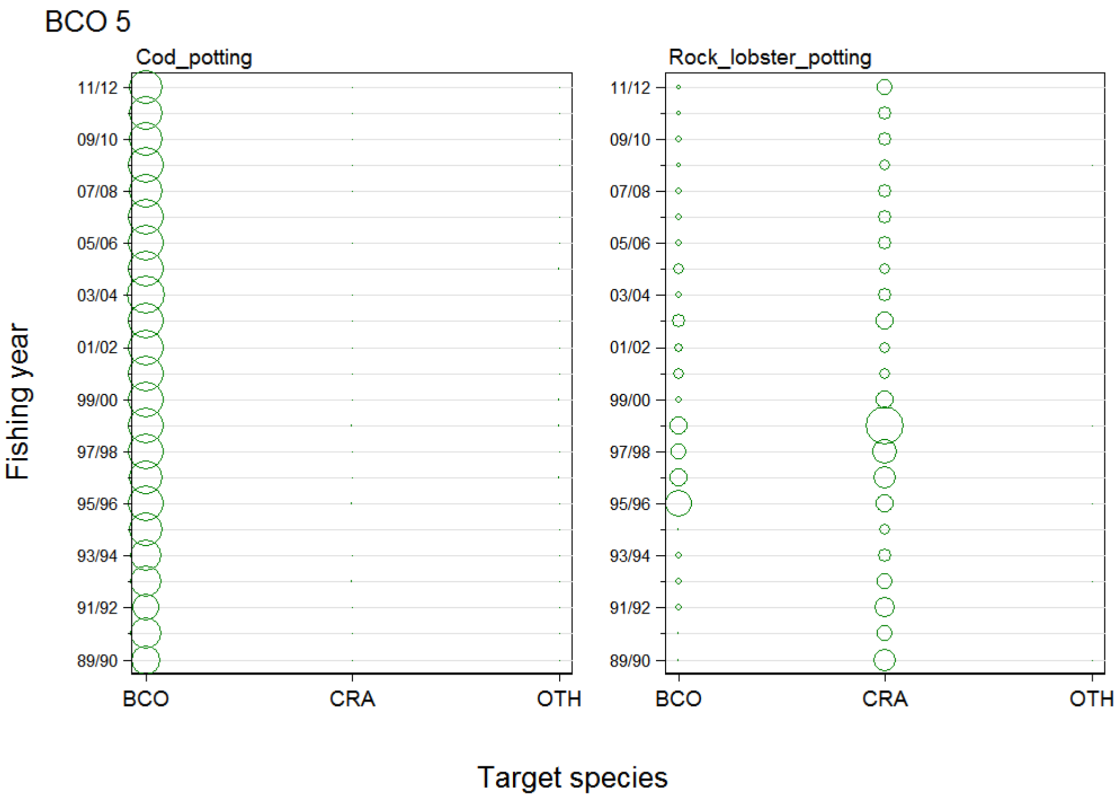

Figure G.7: Total landings by major target species (see caption for Table G.13 for explanation of abbreviations) and fishing year for cod potting and rock lobster potting for trips which landed BCO 5. Circle sizes are proportional within each panel: [cod potting] largest circle=1535 t in 03/04 for BCO; [rock lobster potting] largest circle= 49 t in 98/99 for CRA.

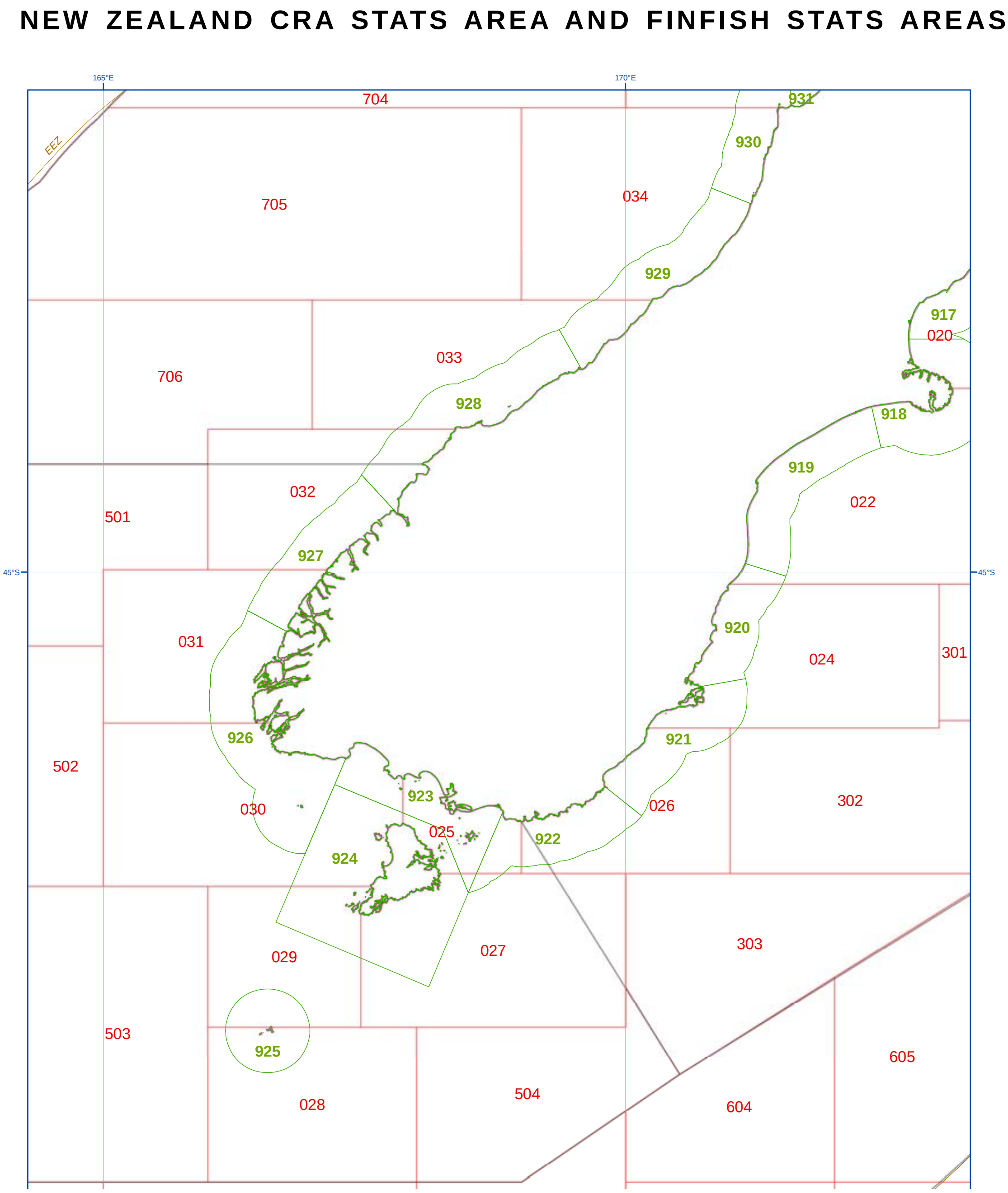

Figure G.8: Map showing the relationship of the MPI rock lobster and “general” (finfish) statistical areas in the southern part of New Zealand corresponding to BCO 5, CRA 7 and CRA 8. Also shown are the boundaries between FMAs 3, 5 and 7.