Fishery characterisation and Catch-Per-Unit-Effort indices for blue cod in BCO 4; 1989–90 to 2008–09

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EXECUTIVE SUMMARY

Kendrick, T.H.; Bentley, N. (2011). Fishery characterisation and catch-per-unit-effort indices for blue cod in BCO 4; 1989–90 to 2008–09.

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This study was contracted as MFish project BCO2009/04 with the specific objectives: To characterise the BCO 4 fishery, and to analyse CPUE trends in the commercial BCO 4 fishery up to the end of 2008/2009

The South East Chatham Rise BCO 4 fishery may once have been a labour intensive handline fishery, but blue cod are now taken mostly by cod pots. Before the introduction of the QMS, there were economic constraints to the development of the fishery at the Chatham Islands, however, since then and with the advent of cod pots it rapidly redeveloped. The TACC for BCO 4 was set in 1986–87 at 600 t and by 2001–02 had increased to 759 t. Catches, however, have been considerably lower than the TACC for most of that time and had only approached the TACC by the early 2000s. In the 2006–07 fishing year, the commercial fishery landed 736 t making it the second most important BCO fishery nationally. In 2007–08, catches exceeded the TACC for the first time.

Blue cod in BCO 4 is almost entirely caught by potting in a target fishery that reports entirely on CELR forms. The same vessels also account for most of the rock lobster catch in CRA 6, but there is less interaction with the paua fishery. Fishing for blue cod starts each year in March, a month during which there is little lobster potting, but cod potting then operates concurrently with rock lobster fishing through the winter. A low point in catches in June coincides with a peak in rock lobster fishing, but also reflects a decline in availability of blue cod during that month. Catches and CPUE peak again in August/September, and there is very little blue cod landed after September in each year. Observed CPUE has increased steadily over the study period, and it was not markedly altered by standardisation. The fishery has operated with considerable consistency, operating across the four coastal statistical areas with some spatial shifts that are not predicted to have influenced CPUE, and changes to the core fleet as well as in the seasonality of fishing that are predicted to have had a neutral influence on observed catches overall.

Data were prepared by allocating landed catch to effort proportionate to estimated catch. There was no further amalgamation done as all records are in daily CELR format and the analysis was done on data in their original resolution. A lognormal model was fit to positive records in the cod potting fishery, a fishery that accounts for almost all of the landed BCO 4 and in which zero catches were rare. There have been no mesh size changes in this QMA that might have affected CPUE.

There is concern about how effort has been reported for this gear type because the template used to fill out CELRs for the potting methods was designed primarily for the rock lobster fishery and requires the number of pots in the water (at midnight) to be recorded, as well as the number of potlifts in the day. The two fields are commonly transposed, or otherwise misunderstood, and there are obvious errors that can either be corrected or selected out of the dataset, although some assumptions need to be made in either case. The annual indices proved robust to alternative grooming of effort however, and there were no trends in the reporting/misreporting of effort that might potentially bias the series.

The Southern Inshore Working Group accepted that the series based on positive catches in target cod potting around the coat of the Chatham Islands is an index of abundance and can be used to monitor the abundance of blue cod in BCO 4.

INTRODUCTION

1.1. The fishery

The South East Chatham Rise BCO 4 fishery was once a labour intensive handline fishery, but blue cod are now taken almost entirely by cod pots. Before the introduction of the QMS, there were economic constraints to the development of the fishery at the Chatham Islands (BCO 4), however, since then and with the advent of cod pots it rapidly developed. The TACC for BCO 4 was set in 1986–87 at 600 t and by 2001–02 had increased to 759 t. Catches, however, have been considerably lower than the TACC for most of that time and had only approached the TACC by the early 2000's. In BCO 4 the commercial fishery landed 736 t in the 2006–07 fishing year making it the second most important BCO fishery nationally. In 2007–08, catches exceeded the TACC for the first time (Figure 1, Table 1).

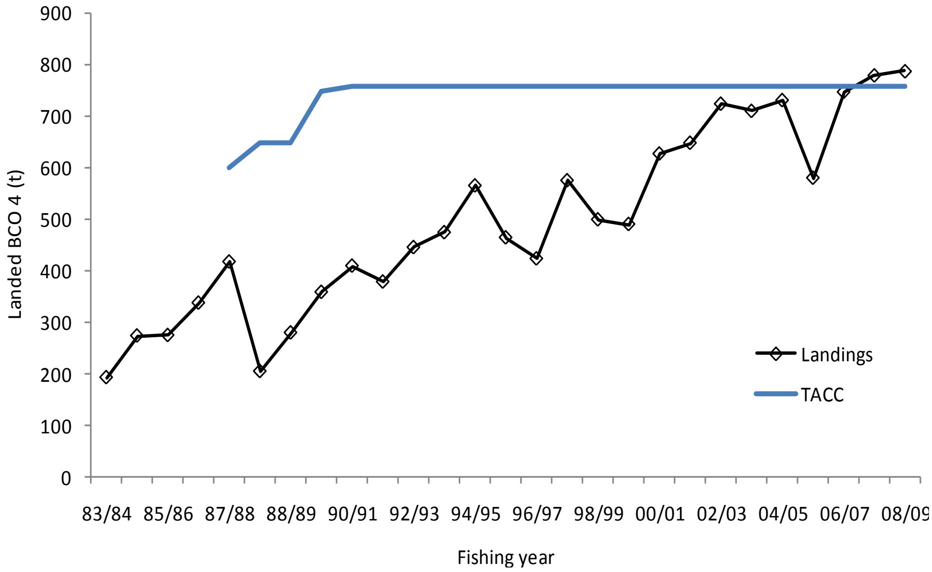

Figure 1: Reported landings of blue cod (t) in BCO 4 from 1983–84 to 2008–09 and gazetted and actual TACCs (t) for 1986–87 to 2008–09. QMS data from MFish 2009.

1.2. Previous work

Blue cod is generally monitored in targeted cod potting pots in the commercial fishery, as for BCO 5 (Langley 2005, Starr & Kendrick 2005, 2009, 2011) or by fishery independent potting surveys as in BCO 3 (Beentjes and Carbines 2009), BCO 5 (Carbines and Beentjes 2003), and BCO 7 (Blackwell 2009). There has been no accepted means of monitoring blue cod in BCO 4.

2 DATA SOURCES AND METHODS

Catch and effort for the cod potting method is entirely reported on the Catch Effort Landing Return (CELR) which reports daily totals of the number of potlifts and the estimated catch of the top species unless the fisher has changed statistical area or target species, in which case a single record may represent only part of a day. The verified landed greenweight that is obtained at the end of the trip is also reported on the bottom part of the form.

The fishery characterisation and the CPUE standardisation were both done using landed greenweight of blue cod as verified at the end of each fishing trip, linked to effort proportionate to estimated catch using a variation of the method of Starr (2007). The data were not amalgamated to trip-stratum, because that resolution mimics CELR resolution to allow data from various form types (daily and event-based) to be combined. Further amalgamation is therefore not required when all observations are reported in a common resolution as in the case of cod potting.

This methodology ensures that all unambiguous landed catch is included in the characterisation data set, not just the catch when estimated among the top five species. It also allows an elegant combining of catch effort data from multiple form types (when relevant) and rescales the catch to equal the annual totals reported to the Quota Management system so that all tables and graphs represent the total commercial catch.

2.1. Methods used for grooming and collation of MFish catch and effort data

Catch and effort data were obtained from the MFish data base "*warehou*" using a two-part extract. The first part identified candidate trips by searching for all trips that occurred between 01 Oct 1989 and 01 Oct 2009, and that:

* were undertaken by vessels that ever landed to BCO4

OR

* had fishing events that:

  - were in statistical area(s) 049, 050, 051, 052, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412

  AND

  - used method(s) CP.

Once trips that satisfied these criteria were identified, all effort and landing records for BCO, CRA, and PAU associated with these trips were extracted.

This request was slightly different from our usual requests because (a) we have changed the usual qualifying criteria for trips from "landed BCO 4" to "were undertaken by vessels that ever landed to BCO 4" and (b) we are requesting data for multiple species. This was done so that a characterisation of the activities of these vessels could be done and the interaction between fisheries for blue cod, lobster and paua described.

Landings, estimated catch and associated effort were all groomed separately before merging and the resultant annual total landed and estimated catches are compared in Figure 2 and Table 1.

2.1.1 Description of landings

Outlier values in the landing data were identified by finding the trips with very high landings for blue cod based on verified maximum values supplied by the Ministry of Fisheries data unit. The effort data for these trips were then used to calculate the trip CPUE and the associated estimated catch was also examined. Trips which had a ratio of landed to estimated catch which exceeded four and a CPUE which exceeded two times the 95^{th} percentile of the trip CPUE distribution for the entire dataset, were excluded from the analysis.

Almost all blue cod in BCO 4 are landed green (whole) with most of the balance being dressed or headed and gutted (Table 2). The conversion factors used to back-calculate greenweight from landed (processed) weights for the three main processed states were collated by fishing year and small changes made in 1990–91 are described. All greenweights in the database were corrected using the most recent conversion factor for the processed state.

Most blue cod (96%) , were landed to destination code "L" (landed to a Licensed Fish Receiver in New Zealand), and there were very few landings reported to destination code "R" meaning that they were retained on board, or “Q” meaning they were held in a receptacle on land for subsequent landing (Table 3). These fish are not identifiable when subsequently landed and are therefore at risk of being double counted. Where these destination codes were reported, the entire trip was dropped.

Fishers sometimes report having transferred catches to another vessel using destination code 'T'. Unlike for destination codes P, Q and R, these catches can be accounted for because the destination vessel is recorded in a column called *tranship_vessel_key*. This check retains landings with a destination code 'T' but, to avoid double counting, excludes all trips for the destination vessel for the next 3 months. The entire trip is excluded.

Landings were re-scaled in the dataset to equal the verified totals from Monthly Harvest Returns (MHR) or, before October 2001, from Quota Management Returns (QMR). For the CPUE standardisation part of this study, records for which any field had been corrected or replaced during grooming were dropped.

Table 1: TACC and landed catch totals (t) from MFish catch and effort forms by fishing year compared with the total landings (t) reported to the QMS (MFish 2009). Also shown are the catch totals (t) which remain after the dataset has been prepared for analysis by dropping trips which reported to more than one blue cod fishstock and fished in a straddling statistical area or that used multiple and incompatible gear types. The estimated catch total is the sum from all trips with matching landing data.

Fishing year	TACC (t)	Landed catch (t) from catch effort, landings forms	Landed catch (t) from QMR/HMR forms(t)	Landed catch for analysis (t)	Estimated catch in analysis dataset (t)	% analysis catch of landed catch	% analysis catch of QMR	% estimated catch of analysis
89/90	749	325	374	307	296	94	82	96
90/91	757	380	392	361	346	95	92	96
91/92	757	367	378	347	340	95	92	98
92/93	757	447	442	441	434	99	100	98
93/94	757	523	474	513	511	98	108	100
94/95	757	597	578	571	559	96	99	98
95/96	757	548	475	465	419	85	98	90
96/97	757	452	462	435	410	96	94	94
97/98	757	590	569	579	550	98	102	95
98/99	757	720	550	563	522	78	102	93
99/00	757	512	503	496	480	97	99	97
00/01	757	645	627	639	616	99	102	96
01/02	759	645	648	641	617	99	99	96
02/03	759	729	724	710	679	97	98	96
03/04	759	693	710	684	662	99	96	97
04/05	759	764	731	758	711	99	104	94
05/06	759	560	580	557	529	99	96	95
06/07	759	750	749	741	714	99	99	96
07/08	759	774	779	761	712	98	98	94
08/09	759	793	787	785	757	99	100	97

Table 2: The median conversion factor in each fishing year for the main processed states (at least 100 records in the analysis dataset); total landed greenweight (t) of blue cod in the unedited file (includes other fishstocks) by processed state. GRE, Green; DRE, dressed; GUT, gutted; HGU, head and gutted. 0, less than 0.5 t.

	Conversion factor							Landed BCO 4 (t)						
Fishing year	GRE	HGU	FIL	GUT	DRE	SKF	GGU	GRE	HGU	FIL	GUT	DRE	SKF	GGU
89/90	1	1.5	1.9	1.1			1.2	312	56	69	1			28
90/91	1	1.4	1.9	1.1	1.8		1.2	376	99	87	37	17		0
91/92	1	1.4	1.7	1.15	1.7	2.6		363	86	61	32	36	19	
92/93	1	1.4	1.7	1.15	1.7	2.6		447	90	102	57	38	20	
93/94	1	1.4	1.7	1.15	1.7	2.6		525	92	92	80	61	28	
94/95	1	1.4	1.7	1.15	1.7	2.6	1.2	584	101	74	149	49	4	
95/96	1	1.4	1.7	1.15	1.7	2.6	1.2	481	247	114	133	19	2	
96/97	1	1.4	1.7	1.15	1.7	2.6	1.2	469	157	115	154	43	3	
97/98	1	1.4	1.7	1.15	1.7	2.6	1.2	613	182	99	104	71	3	
98/99	1	1.4	1.7	1.15	1.7	2.6	1.2	753	285	155	81	21	3	
99/00	1	1.4	1.7	1.15	1.7	2.6	1.2	512	308	190	99	23	3	
00/01	1	1.4	1.7	1.15	1.7	2.6	1.2	650	308	215	106	34	19	
01/02	1	1.4	1.7	1.15	1.7	2.6	1.2	627	300	170	107	6	15	
02/03	1	1.4	1.7	1.15	1.7	2.6	1.2	705	308	163	185	8	7	
03/04	1	1.4	1.7	1.15	1.7	2.6	1.2	666	333	204	137	10	2	
04/05	1	1.4	1.7	1.15	1.7	2.6	1.2	681	328	213	200	27	3	
05/06	1	1.4	1.7	1.15	1.7	2.6	1.2	531	270	182	163	21	3	
06/07	1	1.4	1.7	1.15	1.7	2.6		693	341	118	222	27	8	
07/08	1	1.4	1.7	1.15	1.7	2.6		728	239	102	271	31	11	
08/09	1	1.4	1.7	1.15	1.7	2.6		791	264	76	200	27	9	

Table 3: Total landed greenweight (t) of blue cod in the unedited file (includes other Fishstocks) by the main destination codes and whether kept or excluded from the analysis dataset. 0, less than 0.5 t.

Destination	Kept	Records	Landings (t)	Landings (%)
L	Y	50031	21846	95.98
F	Y	3002	39	0.17
R	Y	2148	375	1.65
Q	N	1396	389	1.71
U	Y	1256	43	0.19
B	N	368	10	0.05
E	Y	223	4	0.02
A	Y	59	5	0.03
-	N	58	11	0.05
W	Y	51	9	0.04
D	N	21	0	0
T	Y	17	22	0.1
P	N	3	0	0
H	Y	2	0	0
S	Y	2	0	0

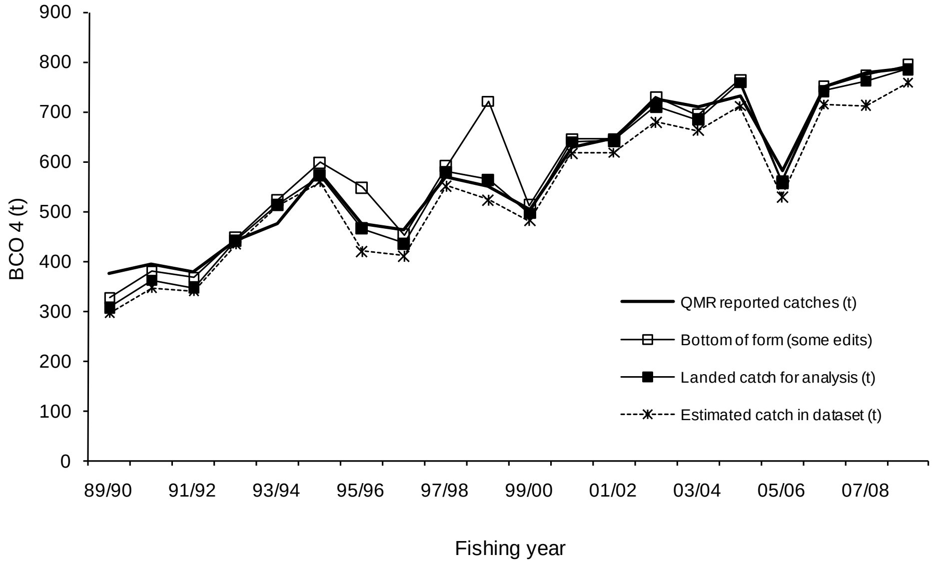

Figure 2: Comparison of BCO 4 landed catch totals (t) from the MFish catch and effort forms by fishing year with the total reported landings (t) to the QMS. Also shown are the catch totals (t) which remain after the dataset has been prepared for analysis by dropping trips which reported to more than one blue cod fishstock and fished in a straddling statistical area or that used multiple and incompatible gear types. The estimated catch total is the sum from all trips with matching landing data. Values are given in Table 1.

2.1.2 Description of Effort variables

Occasional outlier values (input errors) in the effort data were identified by comparison with empirical distributions derived from the effort variable (duration or number of sets) and where the values were in the extreme upper and lower tails of the distribution (a multiple of the 95^{th} percentile value), they were replaced with the median value for the effort field for the affected vessel. Missing values for 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. Trips with all fields missing for one of these descriptors were dropped entirely.

There are two measure of effort related to pot numbers required when the CELR form is completed in association with the potting template. This design is more relevant to the rock lobster potting fishery in which a large number of pots are left in the water and lifted a maximum of once per day. The cod potting fishery operates quite differently, with a small number of pots in the water that are checked several times a day, typically with soak times of only an hour or two. In this fishery, it is the number of pot-lifts that is of interest, and the two columns create confusion, with some fishers filling out one or other of the columns, and others transposing them or duplicating the relevant measure (Figure 3, Figure 4).

Column A: total number of traps/pots lifted in the day (effort_total_num)
Column B: number of traps/pots in the water at midnight (effort_num).

In the past, researchers have either ignored the problem (Starr & Kendrick 2005, 2009), or have assumed that the number of lifts should always be greater than the number of pots in the water at midnight and have switched values when they appear to have been recorded in the wrong column (Langley 2005). Starr & Kendrick (2011) reported some contradictory trends in data transposed in that way, and preferred not to use records for vessels that reported effort in the wrong columns. This study adopts a similar approach, but the sensitivity of the results to both treatments is presented in Appendix A (see sensitivities).

There remains some small values in the potlifts field that appear to be more consistent with the number of pots that have been fished (typically about 10), than the total number of potlifts in a day. It is not possible to assume that low numbers represent this misunderstanding however, so this error remains unavoidably embedded in the datasets used this study. Diagnostics from the lognormal model for the core fleet does not suggest any aberrant relationship between catch and those lower numbers of potlifts, nor is there any trend in the reporting of low numbers of potlifts per day that might potentially bias the results of the standardisation.

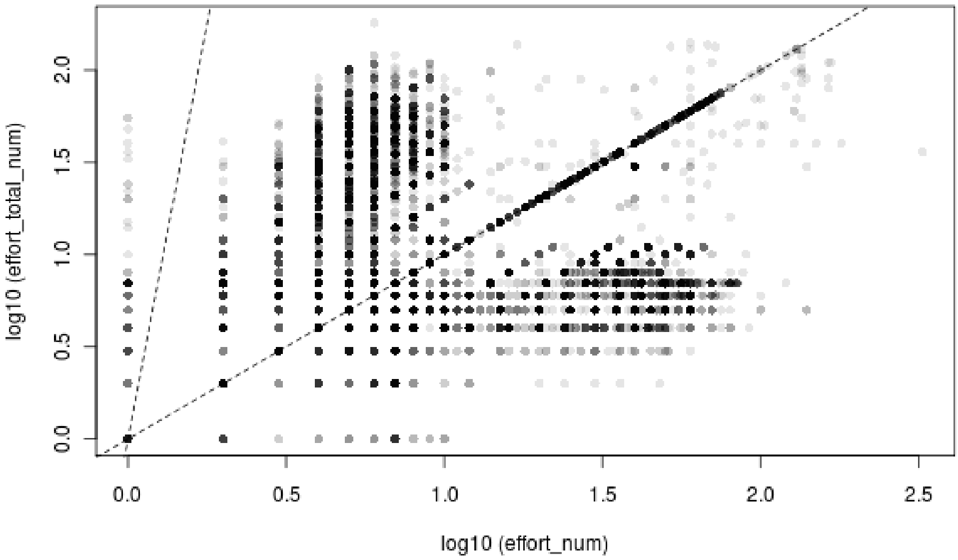

Figure 3: Relationship between total potlifts (effort_total_num) and pots in the water at midnight (effort_num) for method CP.

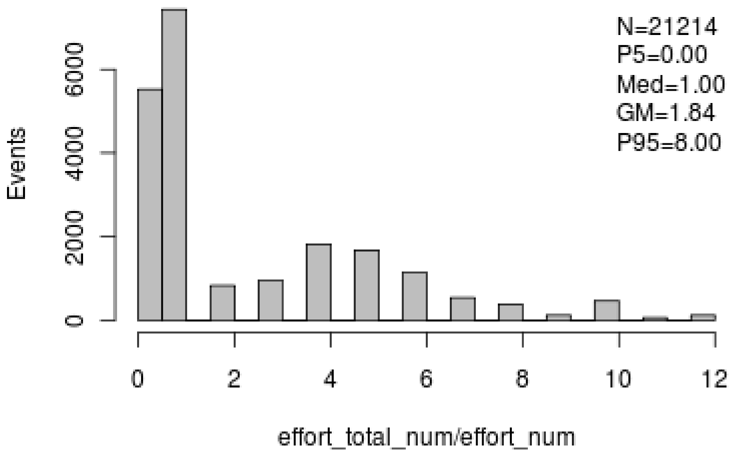

Figure 4: Histogram of the ratio of potlifts (effort_total_num) to pots in the water at midnight (effort_num) for method CP in the unedited file. N; number of fishing events, P5; 5th percentile, Med; median, GM; geometric mean, P95; 95th percentile.

2.1.3 Statistical areas

Events reported to paua and lobster statistical areas within the general statistical areas of 049 to 052 were also retained and included in the zone definitions. These records included small amounts of blue cod that were caught in rock lobster pots or were reported by the area code used for the main target species, but were included so that the catch of paua and rock lobster by the same vessels that fish for blue cod could be described.

2.2. Methods used for catch-per-unit-effort analysis

2.2.1 Defining fisheries

Fisheries are identified in a characterisation as likely candidates in which to monitor abundance based on a consideration of whether: 1) effort is effective with respect to the species of interest (accounts for a significant proportion of landed catch), 2) the gear type is suitable for sampling, 3) the selected target fisheries are equally effective with respect to the species of interest (similar depth, catch rates, encounter rates, and / or other evidence of association), and 4) there has been reasonable stability in the operation of the fishery (based on examination of the spatial and seasonal distribution of effort).

For blue cod in BCO 4 this process was simplified by the species being almost entirely targeted using a single gear type, and reported on a single form type. It is therefore a well-reported species caught in a well-defined fishery.

2.2.2 Inclusion of zero catch information

When an appropriate fishery in which abundance might be monitored has been defined, then all effort in that fishery is considered relevant, and current practice in New Zealand fisheries is to model the encounter rate (probability of capture) in that fishery if there is an adequate proportion of unsuccessful effort records (usually considered to be at least 5% in each year).

The fishery defined for monitoring blue cod is a target fishery with very few zero catch records. No separate analysis of the probability of capture was possible or warranted, but it should be remembered, that because CELR resolution data rolls-up totals of catch and effort for a day (or part of a day) it subsumes the zero catches at set and pot level (and any signal that there may be in that information) into the daily average catch rates.

2.2.3 Landed greenweight versus estimated catch

The decision of whether to base the CPUE analysis on 'estimated' or 'landed' catch depends firstly on whether CPUE is monitored in target fishing or in a bycatch/mixed target fishery, and secondly on whether the species is commonly processed at sea and the processed weight rather than the greenweight is often erroneously recorded. For BCO 4, the total estimated and allocated landed catches at trip stratum resolution are compared in Figures 5 and 6. There is evidence of some over, and under estimation but generally blue cod is a well reported (estimated) species.

Although there may be little advantage to using allocated landed catch in this instance it is nevertheless considered advisable as it represents the best attempt to address a potential bias in estimated catch towards the larger catches, because it is the larger catches of a species that are more likely to be reported among the top five species.

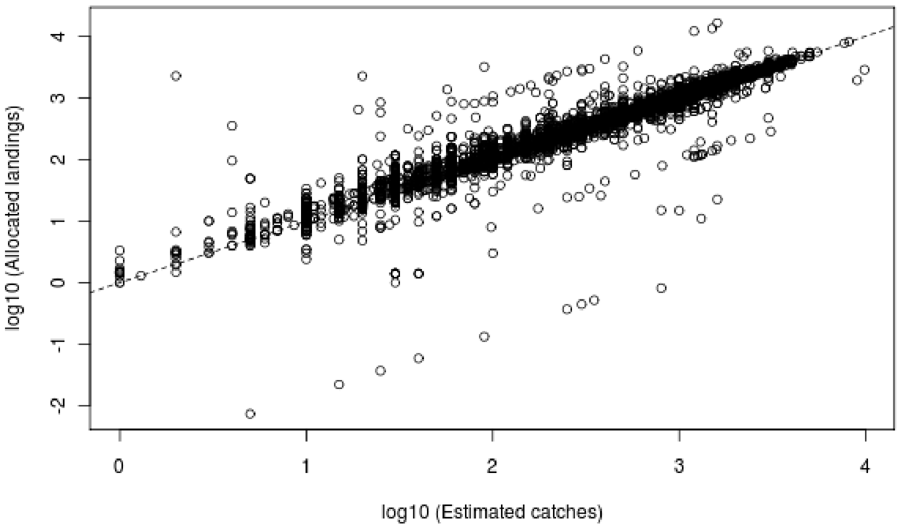

Figure 5: Scatter plots of the landed greenweight compared to the estimated catches in the analysis dataset (at trip resolution). Log-scale axes (log tonnes) have been used to reduce the visual effect of large catches.

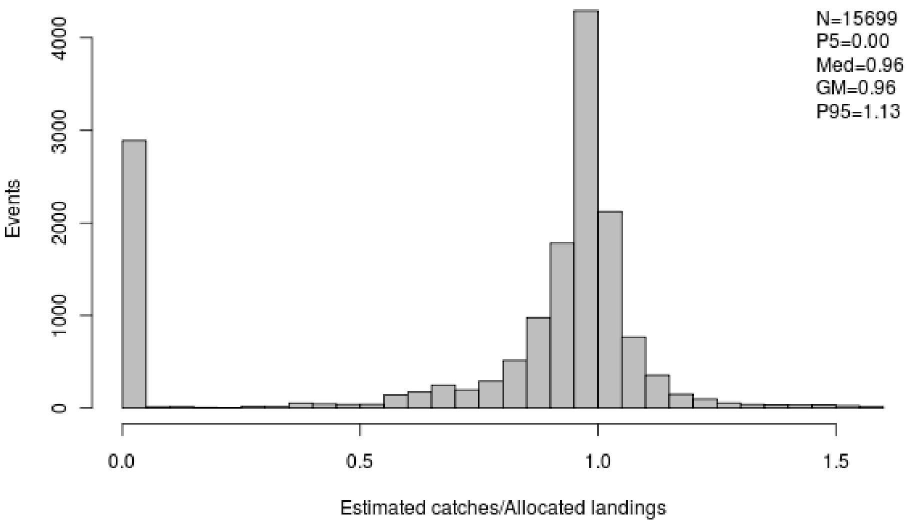

Figure 6: Frequency of the ratio of estimated catches/landed greenweight in the analysis dataset (at trip resolution). This should centre tightly on 1.0 if the catch is well estimated.

2.2.4 Core fleet definitions

The data sets used for the standardised CPUE analyses were further restricted to those vessels that participated with some consistency in the defined fishery. 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 core fleet was selected by choosing variable values that resulted in the fewest vessels while maintaining the largest catch of blue cod. This selection process generally reduces the number of vessels in the dataset by about 70% while reducing the amount of landed blue cod catch by about 20%. Note that the vessels thus selected are not necessarily the top vessels with respect to catching blue cod.

The definition used to define core vessels was that they must have completed at least 5 trips targeting blue cod using the CP method in at least five years. Once a core vessel was selected, all data for the vessel was included in the core dataset. The restriction to a core fleet reduced the number of vessels in the dataset from 119 to 37 but still accounted for 6 836 of the 8 439 t of BCO 4 landed from this fishery.

2.2.5 Models

A lognormal linear model was fitted to successful landed catches of BCO 4, excluding zero catches. Catches were standardised for variance in the explanatory variables using a stepwise multiple regression procedure, selecting explanatory variables until the improvement in model R^2 was less than 0.01. The year effects were extracted as canonical coefficients (Francis 1999) so that confidence bounds could be calculated for each year.

The dependent variable for the lognormal models based on allocated landings was the log of landed weight of BCO 4 per record (trip-stratum). The explanatory variables offered to the model were: *fishing year* (always forced as the first variable), and *month* (of catch), S*tatistical Area*, *target species* and a unique *vessel* identifier. The log of the *number of potlifts* was offered as an additional measure of effort to explain the variance in catch per day. Environmental variables offered included sea surface temperature as monthly anomalies and *moon phase* calculated from the datetime field (http://aa.usno.navy.mil/cgi-bin/aa_moonphases.pl?year=1988&ZZZ=END). Continuous effort variables were offered as third order polynomials.

The effect of the variables accepted into the lognormal model will be examined using Influence plots (Jiang & Bentley 2008). These plots consider the combined effect of the coefficients for each level of the factor and the distribution of the underlying data across time to calculate the influence of a variable on moving the standardised index away from the nominal CPUE.

3 RESULTS

Blue cod in BCO 4 is caught almost entirely by cod potting (90–99% annually), with most of the balance taken by bottom longline and very small amounts in each year (less than 10 t annually) taken as bycatch of the rock lobster potting fishery (Table 4).

Table 4: Distribution of landed blue cod in BCO 4, by method and fishing year, in tonnes and in percent of annual landings. Catches are raised to equal the annual catch reported to the QMS (Table 1) 0 = less than 0.5 t. Percentages sum to 100 by year. CP; cod pot, BLL; bottom longline, RLP; rock lobster pot.

								BCO 4
Fishing	Fishing method (t)				Fishing method (%)			
year	CP	BLL	RLP	Other	CP	BLL	RLP	Other
89/90	372	0	0	2	99	0	0	1
90/91	385	3	3	1	98	1	1	0
91/92	375	1	0	3	99	0	0	1
92/93	439	1	0	1	99	0	0	0
93/94	461	9	3	1	97	2	1	0
94/95	556	5	2	15	96	1	0	3
95/96	436	27	4	8	92	6	1	2
96/97	430	26	4	2	93	6	1	1
97/98	544	20	4	1	96	3	1	0
98/99	533	7	5	5	97	1	1	1
99/00	491	1	4	7	97	0	1	1
00/01	616	3	5	3	98	0	1	1
01/02	632	1	3	12	97	0	0	2
02/03	698	24	0	2	96	3	0	0
03/04	698	10	1	2	98	1	0	0
04/05	680	46	2	3	93	6	0	0
05/06	520	36	5	20	90	6	1	3
06/07	695	46	6	2	93	6	1	0
07/08	709	69	1	1	91	9	0	0
08/09	750	16	7	14	95	2	1	2

3.1. Characterisation of the cod potting fishery

The cod potting fishery in BCO 4 is entirely targeted on blue cod and is entirely reported on the daily CELR form. The spatial and temporal resolution of the catch effort data is therefore defined by general statistical area, and by day (or part of a day). There is no depth information available.

The fishery is distributed reasonably evenly among the four statistical areas of the Chatham Islands, with Area 052 accounting for the smallest proportion (2–20 % annually) of the landed catch in each year, and Area 049 generally accounting for the most (22–47 % annually) (Table 5). There have been some shifts in the relative importance of the four areas over the time series, noticeably a general increase in catch from Area 049 until the most recent year, and a slump in catches from Area 051 in the late 1990s that was made up for by small increases from Areas 050 and 052. More recently, catches from Areas 051 and 052 have increased (Figure 7).

Table 5: Distribution of CP caught blue cod in BCO 4, by statistical area and fishing year, in tonnes and in percent of annual landings. Catches are to equal the annual catch reported to the QMS (Table 1) (Table 1) 0 = less than 0.5 t. Percentages sum to 100 by year.

	BCO 4									
Fishing	Statistical area (t)					Statistical area (%)				
year	049	050	051	052	Other	049	050	051	052	Other
89/90	102	70	192	8	0	28	19	52	2	0
90/91	86	94	165	41	0	22	24	43	11	0
91/92	163	64	137	11	0	44	17	36	3	0
92/93	190	101	119	26	3	43	23	27	6	1
93/94	135	156	110	61	0	29	34	24	13	0
94/95	178	171	104	104	0	32	31	19	19	0
95/96	136	90	144	65	0	31	21	33	15	0
96/97	175	86	132	37	0	41	20	31	9	0
97/98	189	182	118	55	0	35	33	22	10	0
98/99	295	101	98	39	0	55	19	18	7	0
99/00	251	90	95	55	0	51	18	19	11	0
00/01	261	150	150	55	0	42	24	24	9	0
01/02	269	161	172	26	2	43	26	27	4	0
02/03	320	132	157	90	0	46	19	22	13	0
03/04	322	122	177	77	0	46	17	25	11	0
04/05	251	127	198	95	8	37	19	29	14	1
05/06	224	113	153	30	0	43	22	29	6	0
06/07	325	104	199	67	0	47	15	29	10	0
07/08	288	117	208	96	0	41	16	29	14	0
08/09	233	103	261	152	0	31	14	35	20	0

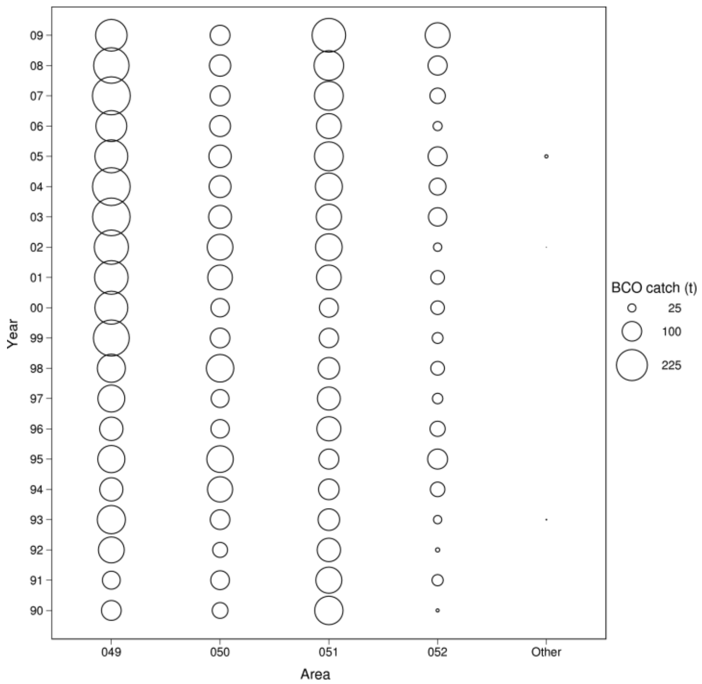

Figure 7: Comparison of the spatial distribution of blue cod catches across the four main statistical areas, by fishing year. Circle areas are proportional to the catch totals for month and area, summing to the annual totals given in Table 5.

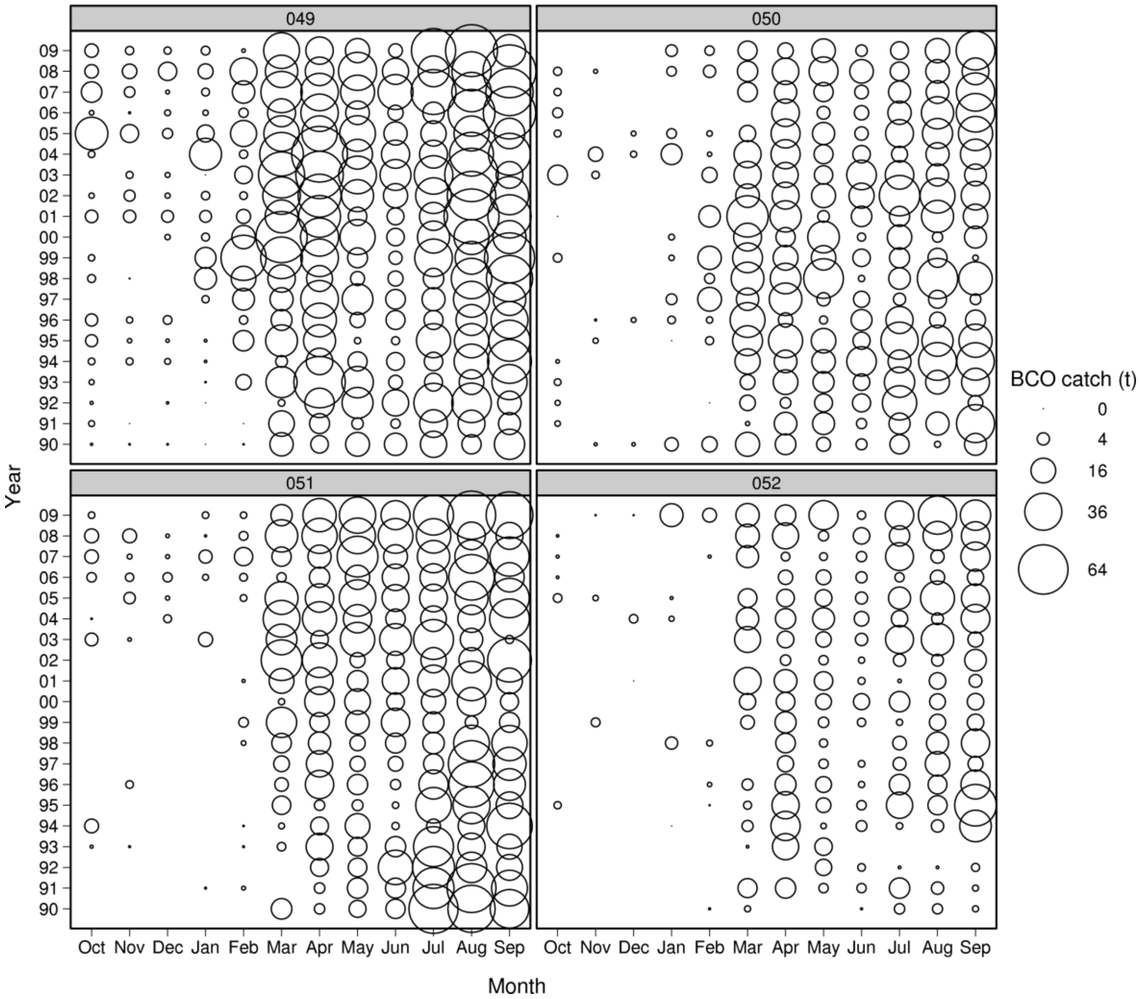

Figure 8: Comparison of the seasonal distribution of blue cod catches in the four main statistical areas, by fishing year. Circle areas are proportional to the catch totals for month and area, summing to the annual totals given in Table 5.

The seasonal distribution of catches is also similar and consistent across areas and years. Blue cod is landed mostly during the last half of the fishing year, starting in March but with a prominent dip during June (Figure 8).

3.2. Interaction with rock lobster and paua fisheries

To examine the interaction between the BCO 4 fishery and other fisheries we examined the landings and fishing activities of the 51 vessels, which between 1989–90 and 2008–09 had accounted for 90% of the BCO 4 landings. In this section we refer to those vessels as the 'main BCO 4 vessels'.

The main BCO 4 vessels also accounted for a large proportion of the landings of rock lobster in CRA 6 (40–70 % annually), but generally less than 25% of paua in PAU 4 (Figure 9). Most days were spent rock lobster potting Figure 10), although this percentage is declining as blue cod potting becomes an increasingly important activity for these vessels. The main BCO 4 vessels spent very few days engaged in paua diving. The other activities described for these vessels include dredging for scallops, bottom trawling for John dory, bottom longlining for ling and set netting for tarakihi (Figure 10) but the nature of the data extract means that these have not necessarily been done concurrently with cod potting and may even reflect changes in ownership or operator.

The interaction between the rock lobster and cod potting fisheries can be partly explained by the different fishing years for rock lobster and finfish. The rock lobster year runs from 1 April to 31 March, and the first and last months of the rock lobster fishing year are historically ones of low activity for rock lobster but peak activity for blue cod fishing.

In March and April, effort is dominated by blue cod fishing but the rock lobster fishery ramps up quickly in May, peaks in June, and then continues through the year except for a dip in activity during August and September. The blue cod fishery runs concurrently with the rock lobster fishery through the autumn and winter months (Figure 11), though not necessarily in the same trips (only a small proportion of trips report multiple methods; Figure 12), with a dip in activity during June, and a peak towards the end of the finfish fishing year in August and September. Effort directed at blue cod is almost non-existent in each year from October through until March.

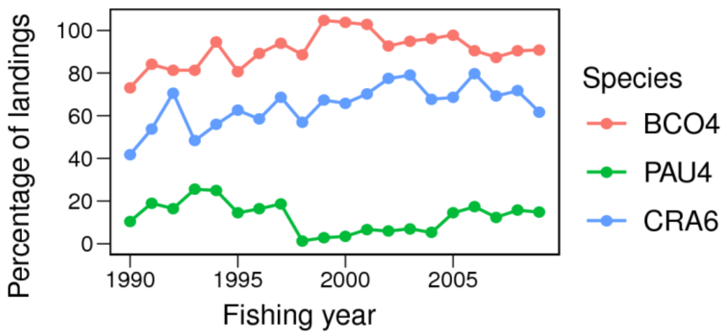

Figure 9: The percentage of landings of BCO 4, PAU 4 and CRA 6 taken by the main BCO 4 vessels. The percentage of landings is calculated from the landings recorded in the Plenary document (MFish 2009). Note that for CRA, the fishing year definitions do not coincide.

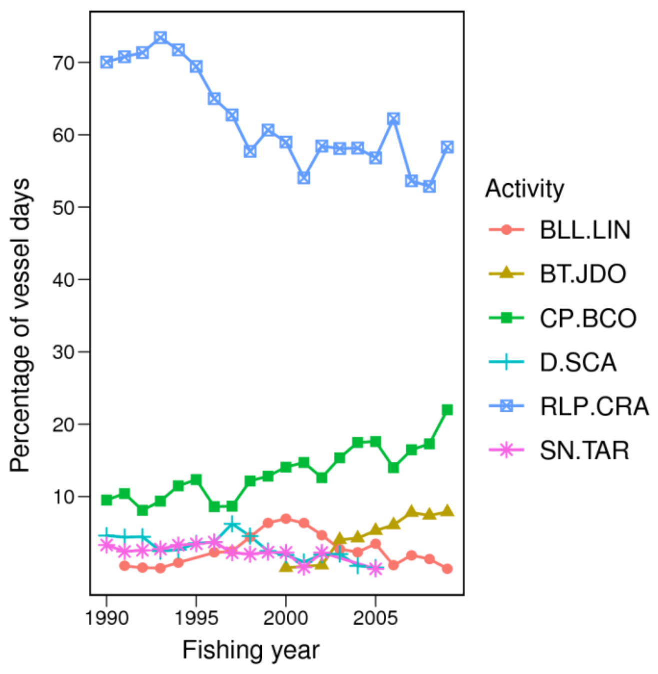

Figure 10: The percentage of vessel days that the main BCO 4 vessels spent on various fishing activities (defined as a combination of method and target species). Note that only the top six activities are shown.

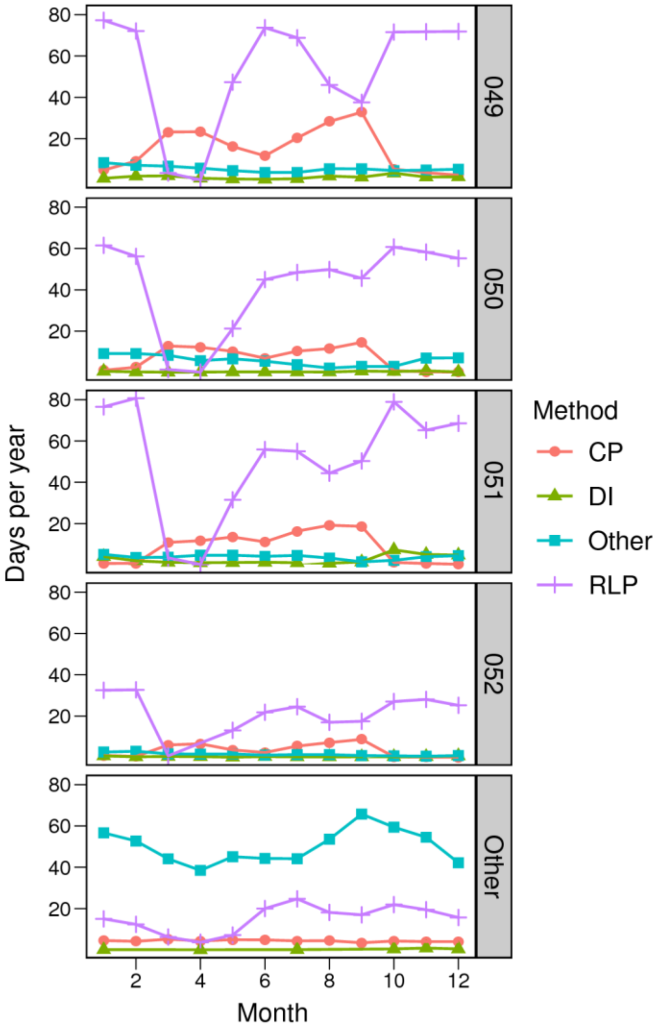

Figure 11: The number of days per year that the main BCO 4 vessels spend on combinations of method (CP, cod potting; DI, diving; RLP, rock lobster potting; Other includes lining and trawl methods) and statistical area.

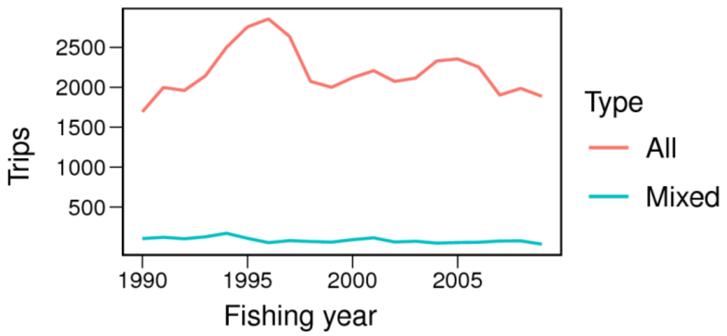

Figure 12: The number of fishing trips in the dataset (All) and the number of those trips that reported both CP and RLP potting methods (Mixed) by the main vessels (only for Chatham Island statistical areas 049-052).

3.3. Standardised CPUE

3.3.1 Fishery definition used for standardised CPUE analysis

BCO4 _CP

Trips that landed BCO 4

Events that;

- Used cod pot method (targeted at BCO)
- Fished in inshore statistical areas 049, 050, 052, 053
- Positive allocated landed catches standardised, lognormal only
- Core vessels completed at least 5 trips per year in at least 5 years

3.3.2 Description of the defined fishery BCO4_CP

Effort in this fishery has been relatively stable, fluctuating between 350 and 500 trips per year except for a poorer year in 1991–92. It is rare for an entire trip to have landed zero kilograms of blue cod (Figure 13), and at the record level, less than 5% of catches are zero. There is no information about success rate (the probability of capture) at pot or even at set level, and that statistic is incorporated into the catch rate per day (or part of a day).

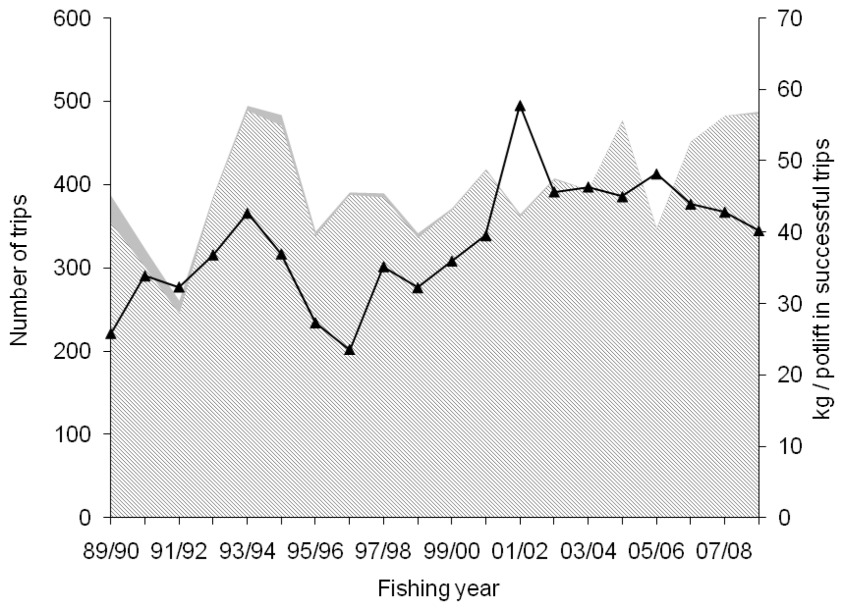

Figure 13: Total effort (qualifying trips [dark grey]) and the proportion of those trips that landed blue cod [light grey] by fishing year for the defined BCO4_CP fishery. Simple arithmetic catch rate (kg per potlift in successful trip-strata [line]).

3.3.3 Core vessel selection

Core vessels were selected visually using Figure 14 as a guide and were defined as vessels that had completed at least 5 trips per year in at least 5 years. This resulted in a fleet with good overlap across years (Figure 15). The data set based on the core fleet of vessels is summarised in Table A1.

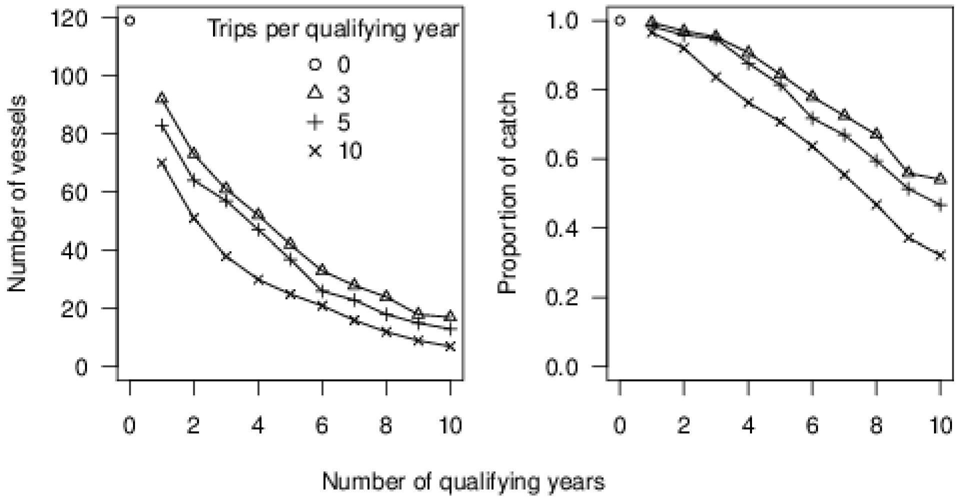

Figure 14: The number of vessels [left] and the proportion of total landed BCO 4 [right] retained in the BCO4_CP dataset depending on the minimum number of qualifying years used to define core vessels. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend.

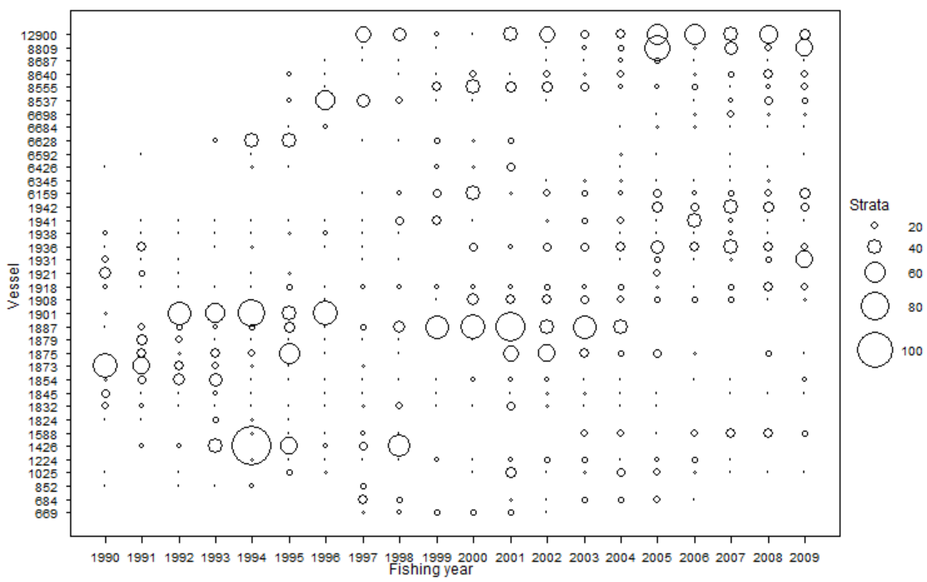

Figure 15: The participation of selected core vessels (based on at least five trips per year in at least five years) for the BCO4_CP fishery; number of records for each vessel in each fishing year.

3.3.4 Model selection

The lognormal model explained more than 45% of the variance in log(catch) (Table 6), largely by accounting for shifts from year to year in the number of potlifts per record. Fishing year was forced as the first variable to allow the extraction of canonical indices and explained less than 7% of the variance in log catch. Changes in the core fleet and in the months fished, also had significant explanatory power but did not move the standardised series far from the unstandardised (observed) CPUE.

The relationship between the log(potlifts) and log(catch) per record is positive though not linear (Figure C1). Changes from year to year were accounted for by the model, but with an overall neutral influence. There were a considerable number of records in each year that reported fewer than eight potlifts, and these may indicate where fishers reported the physical number of pots fished rather than the total number of potlifts in a day (or part of a day). However, it is also conceivable that pots are lifted only once per day in many situations (for example when they are also involved in other activities such as rock lobster potting or paua diving). The inclusion of log(potlifts) in the lognormal model smoothed the year effects somewhat by removing peaks in 2006–07 and 2008–09 and a low in 1993–94 (Figure 16).

Table 6: Summary of final lognormal model for the BCO4_CP fishery based on the vessel selection criterion of at least 5 trips per year in at least five or more fishing years. Independent variables are listed in the order of acceptance to the model. AIC: Akaike Information Criterion, R^2: Proportion of deviance explained, Final: Whether or not variable was included in final model. Fishing year was forced as the first variable.

Lognormal term	DF	Deviance	AIC	R^2	Final
None	0	6 142	18 196	0.0000	
fyear	20	5 731	17 779	0.0669	*
poly(log(total), 3)	23	4 862	16 706	0.2085	*
vessel	59	3 581	14 770	0.4171	*
month	70	3 355	14 365	**0.4538**	*
area	73	3 325	14 311	0.4587	
moon	74	3 322	14 307	0.4592	

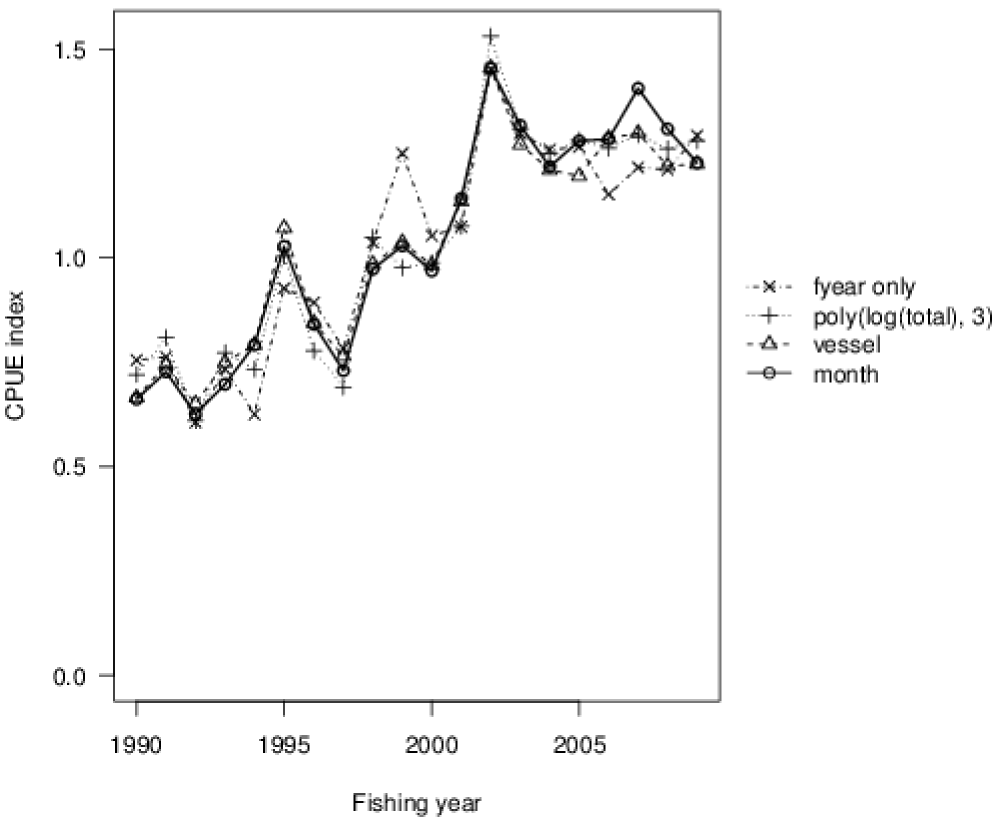

Figure 16: Annual indices from the BCO4_CP lognormal model at each step in the variable selection process.

Quite large differences in performance between vessels are evident and shifts in the participation of the vessels in the core fleet were accounted for by the model, but overall the influence of vessel on observed CPUE was slightly negative (Figure C2). The inclusion of vessel into the lognormal model lifted some points in the early 2000s when four or five of the better performing vessels left the fishery but did not markedly alter the overall trend (Figure 16).

The seasonal pattern in catches can also be seen to reflect changes in the availability of blue cod and not just the patterns of effort in the rock lobster fishery (Figure C3). The month effects are lowest for October to December, and only increase to about the average in March. They are above average until September except for a pronounced low in June. Shifts in the months fished have been accounted for by the model but with very low influence and no overall trend. The inclusion of month in the lognormal model lifts points in 2006–07 to 2007–08 when there was a little more fishing outside of the main season than usual, but does not change the overall trend (Figure 16).

Statistical area did not enter the model even though there have been noticeable shifts in emphasis among statistical areas over time, which may indicate that there is no significant difference in catch rates between areas.

3.3.5 Model fits

The fit of the model can be examined in residual plots (Figure 17) and shows a reasonable fit of the data to the lognormal assumption over the range in which most of the data occurs, but with some departure at the extremes and some un-modelled patterns in the residuals.

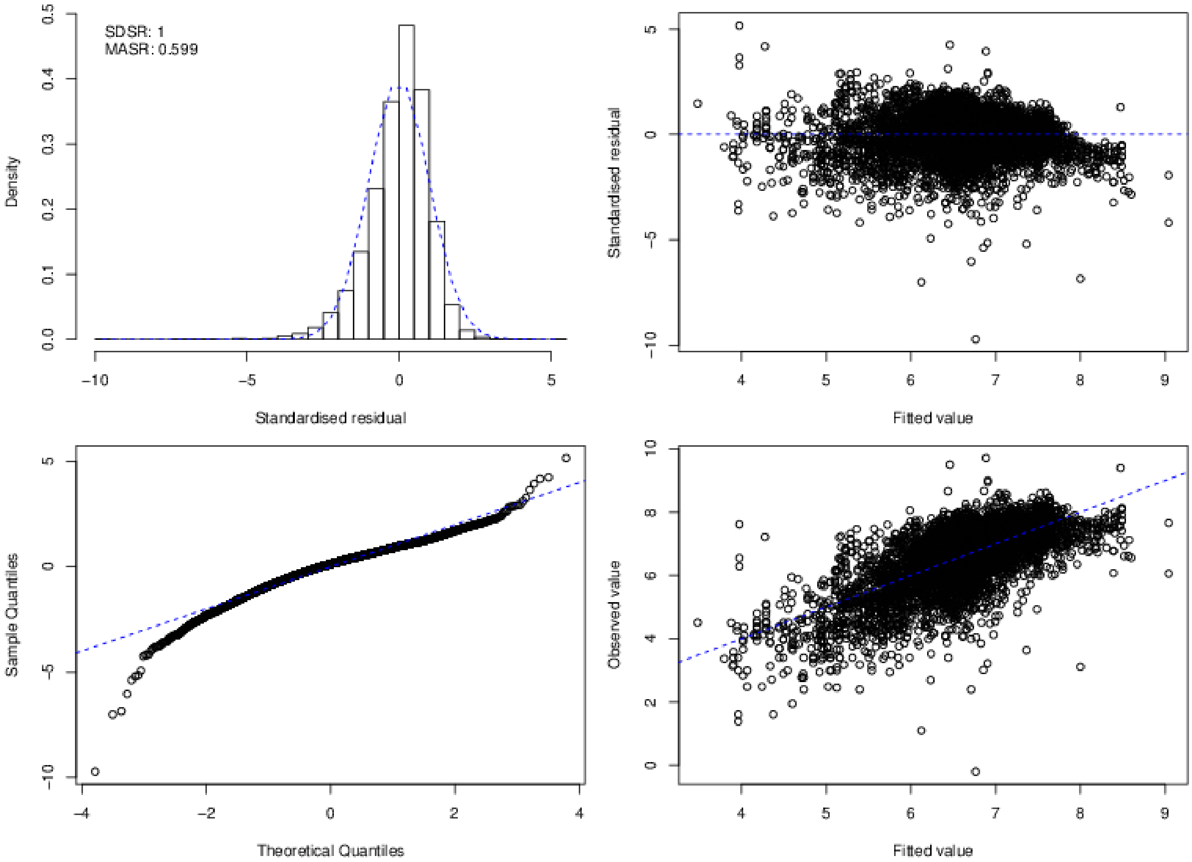

Figure 17: Plots of the fit of the standardised CPUE model to successful catches of blue cod in the BCO4_CP fishery. [Upper left] histogram of the standardised residuals compared to a lognormal distribution (SDSR: standard deviation of standardised residuals. MASR: median of absolute standardised residuals); [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.

3.3.6 Trends in model year effects

The annual indices from the final model increase steadily over most of the time series (except for a low two years in 1995–96 and 1996–97), and then decline from a peak in 2001–02 to a level slightly lower than that peak where they have been relatively stable for the six most recent years (Figure 18, Table B1). The effect of standardisation was to smooth the series by reducing or removing some peaks and lows, but it did not change the overall increasing trend evident in the unstandardised series. The trend is well-determined, in that changes in direction are maintained over subsequent years without much interannual variation and the error bars around each point are not large relative to the changes from year to year. The indices are also robust to the likely errors remaining in the effort fields (Figure 19).

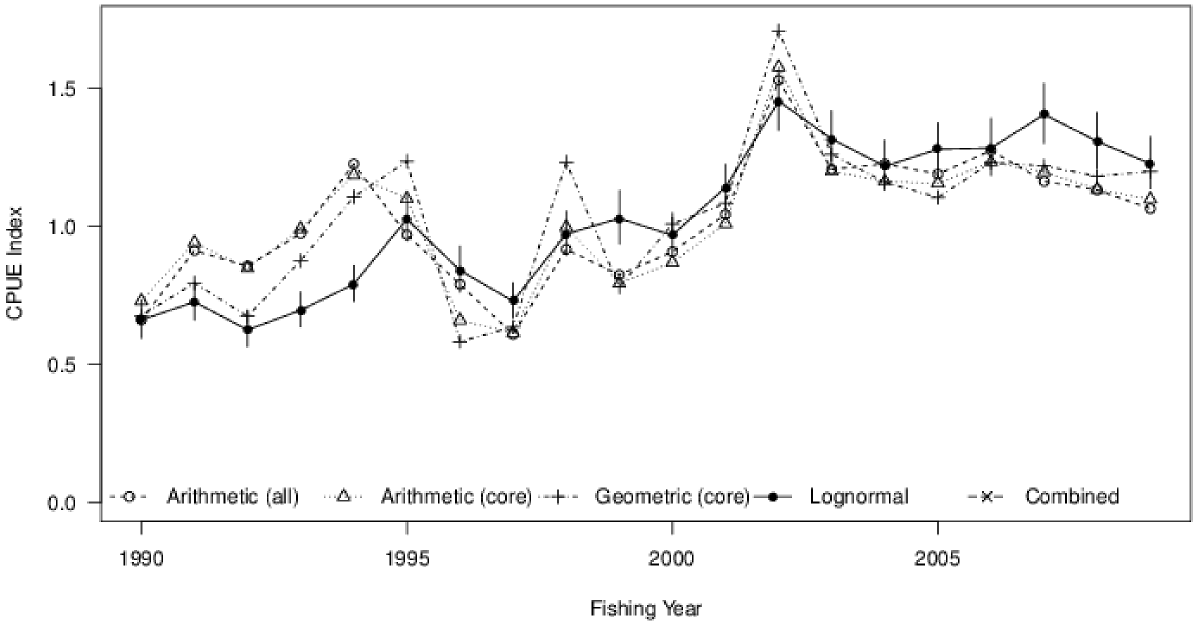

Figure 18: Effect of core vessel selection, and standardisation, on lognormal annual indices. Unstandardised CPUE is based on kg/potlift.

3.3.7 Sensitivities and comparisons with other models

Alternative datasets were prepared based on assumptions made about the effort field for potlifts (column A). Model "Edt1" used whichever of column A or column B was the greatest (assuming that the fisher had transposed them). This is the approach most commonly used by previous researchers (Langley 2005). Model "Edt2" used potlifts (column A) only when it was greater or equal to column B (assuming that incorrect reporting made the record unreliable). This was the treatment recommended by Starr & Kendrick (2011) and used in the final model presented this study. Model "Edt3" further dropped records where the number of potlifts was seven or less (assuming that these operators were reporting the number of pots that they fished rather than the total number of lifts done).

The amount of catch in the dataset for the defined fishery (before selection of a core fleet) was generally between 90 and 100% of the QMS totals for this Fishstock with more stability in the last half of the series. Edt1 retained the same amount of catch, Edt 2 retained between 65 and 90% of the landed catch annually with no trend, and Edt 3 retained between 40 and 60% with no trend (Figure A1).

The effect of alternative grooming procedures nevertheless had little effect on the annual indices (Figure 19) from lognormal models that used the same core fleet selection as BCO4 _CP.

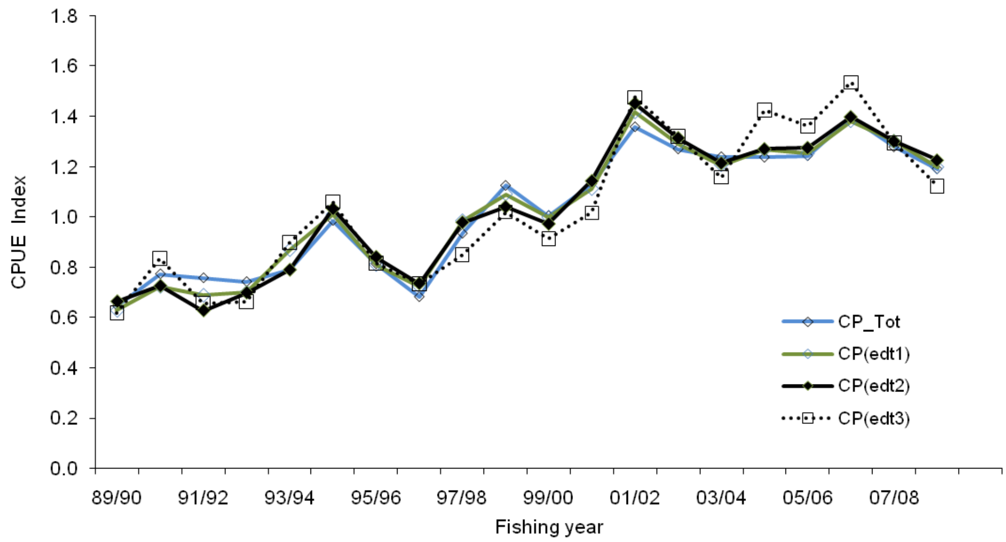

Figure 19: Sensitivity of the annual indices to alternative grooming of the potlifts field. CP_Tot, all positive values of potlifts unedited. Edt1, whichever of column A or column B was the greatest, Edt2, potlifts (column A) only when it was greater or equal to column B. This was the treatment used in the final model presented this study. Edt3 further excluded records where the number of potlifts was seven or less.

4 CONCLUSIONS

The fishery shows considerable stability in the way that it has operated over time and there is little effect of standardisation on observed CPUE. Although there have been some shifts in where catch has come from, catch rates are not predicted to vary significantly between statistical areas and so the shifts have not significantly influenced observed CPUE. The variables that entered the lognormal model with significant explanatory power enabled the model to account for changes from year to year in the core fleet, and in the seasonality of the fishing, but shifts in these factors are not predicted to have positively influenced observed CPUE, and are not the cause of the increasing trajectory seen in that series.

There is some concern about how well fishers complete the effort fields and alternative methods of editing the dataset were investigated but with almost indiscernible differences to the annual indices; except that the series referred to as edt 3 (excluding records with potlifts of seven or less) demonstrated a steeper decline in recent years than the other series. This series is based on an assumption that the actual number of pots instead of the number of potlifts in a day was being recorded by the fishers, but this assumption is difficult to verify. Nevertheless, there has been no trend up or down evident in the distribution of the number of potlifts per record and the sensitivity of the annual indices to removing ambiguous observations completely from the analysis did not markedly change the overall increasing trend.

The Southern Inshore Working Group accepted the series of standardised CPUE from the cod potting fishery of BCO 4 as an index of abundance.

5 ACKNOWLEDGEMENTS

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Starr, P.J.; Kendrick, T.H. (2011). Report to Southeast Finfish Management LTD: Review of the BCO 5 fishery. 51p. (Unpublished report held by NZ Seafood Industry Council, Wellington.)

APPENDIX A: DATA SUMMARIES

Table A1: Data summary for the (BCO4_CP) cod potting fishery defined for standardised CPUE analysis for core vessels; (core vessels based on a minimum of 5 trips per year for at least 5 years); Number of trips, percentage of strata that recorded a zero catch of blue cod, number of core vessels, total number of potlifts, landed weight of BCO 4 (tonnes), and the simple catch rate of BCO 4 across qualifying tows (kg/potlift).

Fishing year	Trips	% zero strata	Vessels	Number of potlifts	Catch (t)	CPUE kg / potlift
1989/90	241	12	15	6 723	186	28
1990/91	253	6	16	6 599	232	35
1991/92	214	7	16	5 685	183	32
1992/93	264	1	16	6 702	255	38
1993/94	338	1	21	7 559	302	40
1994/95	335	3	21	7 954	332	42
1995/96	230	2	21	8 136	210	26
1996/97	286	1	23	9 862	236	24
1997/98	304	1	20	8 505	328	39
1998/99	247	2	17	10 025	312	31
1999/00	330	1	18	9 626	325	34
2000/01	400	0	18	11 262	438	39
2001/02	348	1	21	8 213	493	60
2002/03	359	1	20	9 656	444	46
2003/04	368	0	25	10 341	462	45
2004/05	435	0	24	11 677	518	44
2005/06	329	1	23	7 648	361	47
2006/07	377	0	23	9 556	439	46
2007/08	366	0	22	9 132	398	44
2008/09	375	1	21	10 241	429	42

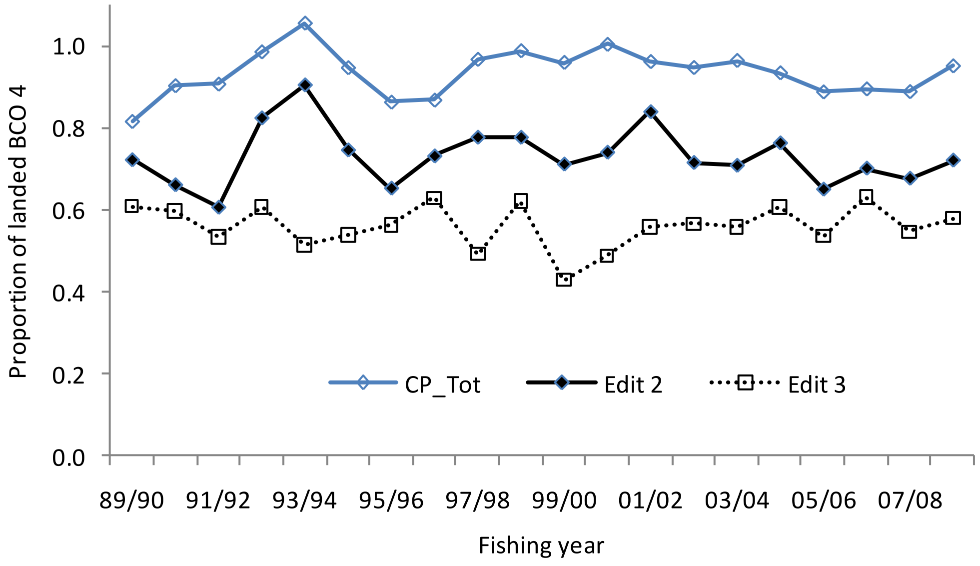

Figure A1: Proportion of BCO 4 landed catch (QMS t) retained in the analysis dataset for alternative grooming of the potlifts field. CP_Tot, all positive values of potlifts unedited (Edt1 retained the same catch as CP_Tot). Edt2, potlifts (column A) only when it was greater or equal to column B. This was the treatment used in the final model presented this study. Edt3 further excluded records where the number of potlifts was seven or less.

APPENDIX B: CPUE INDICES

Table B1: Relative year effects and 95% confidence intervals for the CPUE models fitted to the dataset for BCO4_CP.

Fishing year	Arithmetic mean(all vessels)	Arithmetic mean(core vessels)	Geometric mean(core vessels)	Lognormal standardisation
1989/90	0.661	0.730	0.677	0.661 (0.596-0.733)
1990/91	0.913	0.942	0.796	0.727 (0.662-0.798)
1991/92	0.857	0.848	0.674	0.625 (0.564-0.693)
1992/93	0.975	0.991	0.876	0.697 (0.637-0.762)
1993/94	1.226	1.187	1.107	0.791 (0.729-0.858)
1994/95	0.970	1.101	1.236	1.027 (0.947-1.113)
1995/96	0.790	0.660	0.583	0.841 (0.761-0.928)
1996/97	0.609	0.614	0.635	0.729 (0.669-0.796)
1997/98	0.917	0.997	1.233	0.973 (0.897-1.056)
1998/99	0.825	0.794	0.781	1.029 (0.936-1.130)
1999/00	0.909	0.869	1.009	0.969 (0.894-1.050)
2000/01	1.044	1.010	1.084	1.142 (1.064-1.226)
2001/02	1.530	1.577	1.709	1.454 (1.349-1.568)
2002/03	1.207	1.201	1.261	1.317 (1.222-1.419)
2003/04	1.226	1.163	1.160	1.218 (1.131-1.313)
2004/05	1.190	1.157	1.105	1.280 (1.191-1.376)
2005/06	1.275	1.233	1.232	1.284 (1.186-1.392)
2006/07	1.163	1.198	1.219	1.406 (1.302-1.519)
2007/08	1.132	1.135	1.182	1.308 (1.212-1.413)
2008/09	1.065	1.099	1.199	1.227 (1.137-1.325)

APPENDIX C: INFLUENCE OF MODEL TERMS

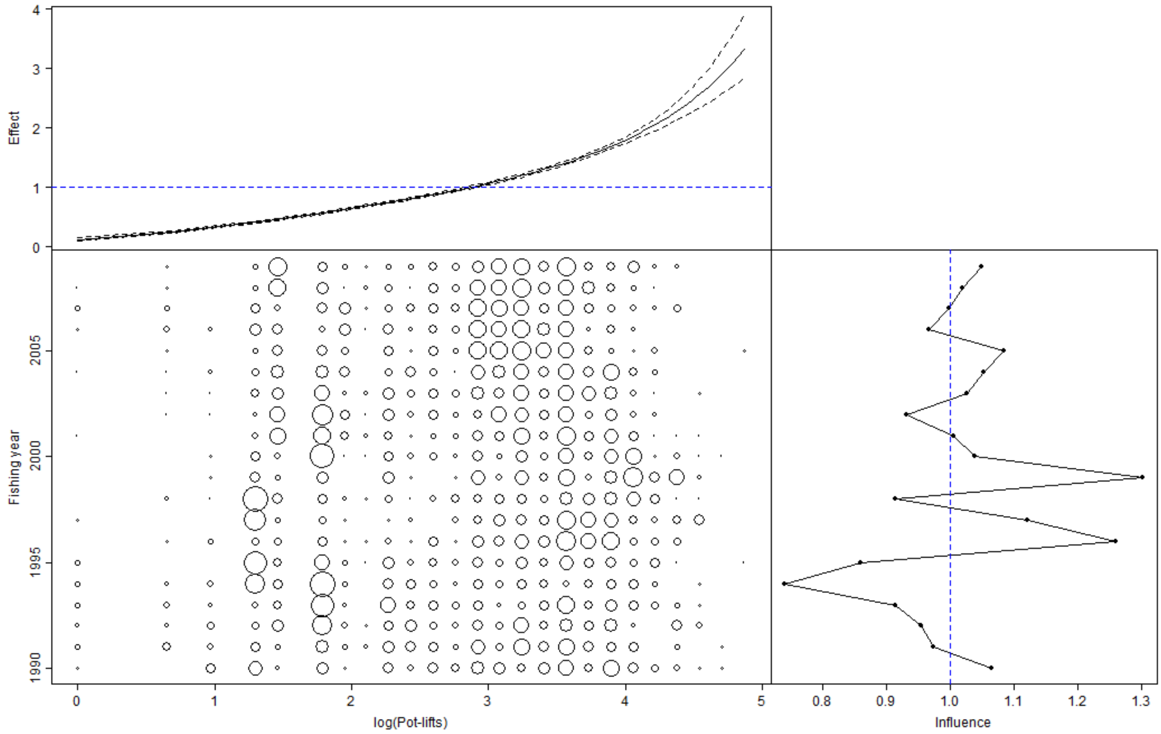

Figure C1: Effect and influence of log(potlifts) in the BCO4_CP lognormal model. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.

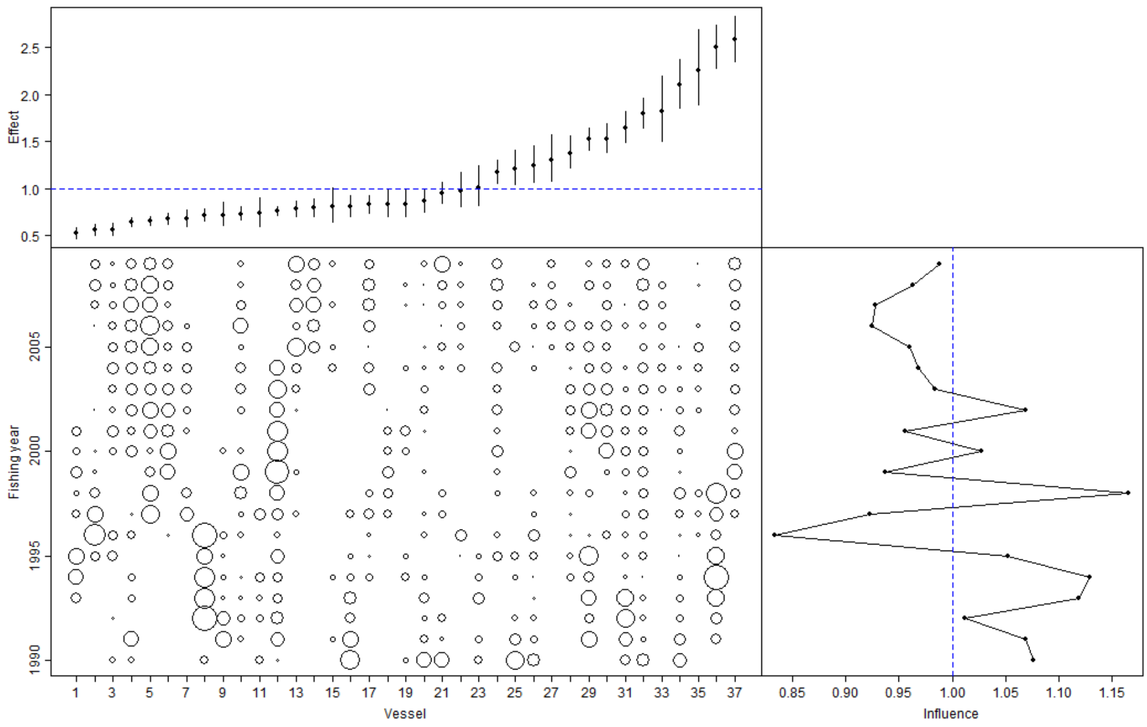

Figure C2: Effect and influence of vessel in the BCO4_CP lognormal model. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.

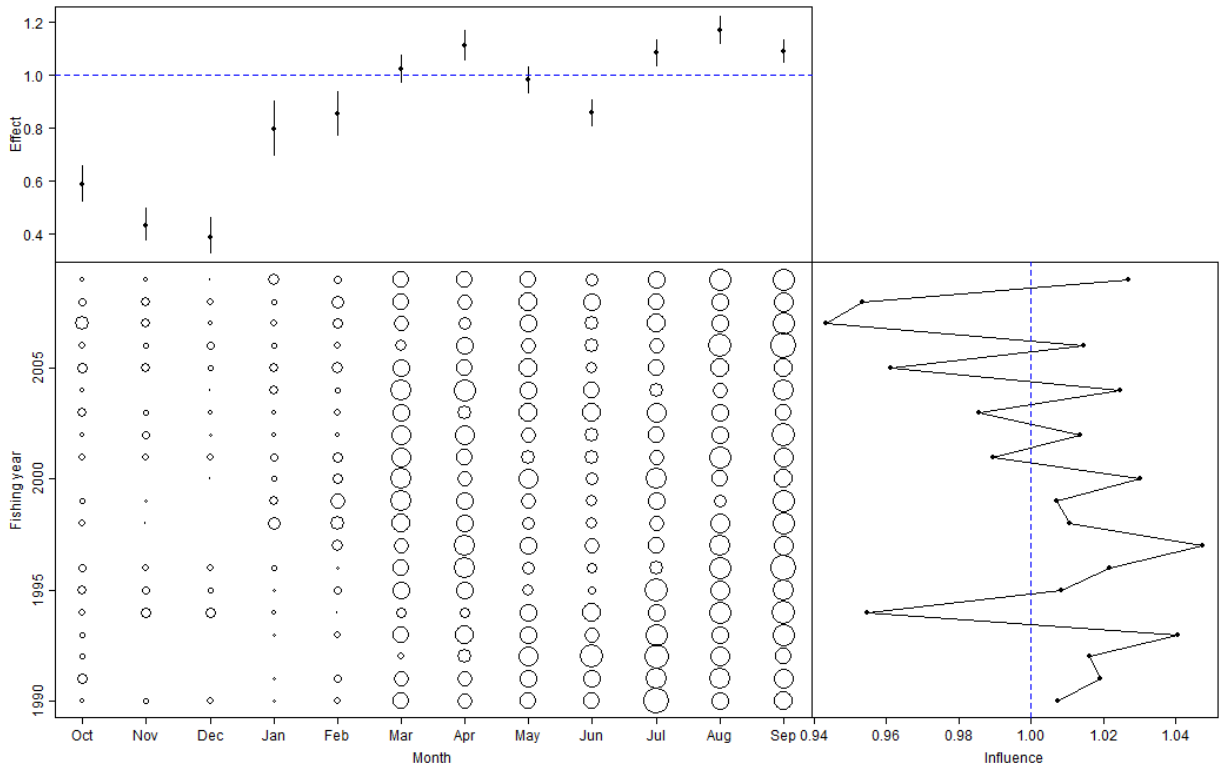

Figure C3: Effect and influence of month in the BCO4_CP lognormal model. Top: relative effect by level of variable. Bottom-left: relative distribution of variable by fishing year. Bottom-right: influence of variable on unstandardised CPUE by fishing year.