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RCO 2 and RCO 3 Fishery Characterisation, CPUE and Management Procedure Review

New Zealand Fisheries Assessment Report 2019/05

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EXECUTIVE SUMMARY

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The fisheries for red cod located off the east coast North Island/Cook Strait (RCO 2) and the east coast South Island/Foveaux Strait (RCO 3) are described for the period 1989–90 to 2016–17 using compulsory reported commercial catch and effort data held by Fisheries New Zealand. These fisheries are almost entirely bottom trawl, with 94% of the RCO 2 catch and 95% of the RCO 3 catch taken by this method over the 28 years of catch history. The remaining red cod catches in both QMAs are distributed between midwater trawl, Danish Seine, bottom longlining, set net and cod potting. The RCO 2 trawl fishery is almost entirely a by-catch fishery while the RCO 3 fishery is a mixed target and by-catch trawl fishery, depending on the abundance of red cod. The important RCO 2 target species which also capture red cod are red gurnard, tarakihi and flatfish. The important RCO 3 target species which also take red cod are squid, barracouta and flatfish. Red cod are taken all along the east coasts of both the North and South Islands, with a concentration of catches occurring in the outer sections of Pegasus Bay and Canterbury Bight. There are also concentrations of red cod catch in eastern Cook Strait near Clifford Bay. Target trawl fishing for red cod in RCO 3 tends to occur between 50 and 100 m, but the 5–95% distribution lies between 20 and 240 m, while in both QMAs the majority of successful red cod tows take place at depths of less than 100 m.

Four standardised CPUE analyses were conducted for RCO 2 and six for RCO 3. These analyses stepped from the standardised analyses used to drive the 2013 RCO 2 and RCO 3 management procedures (MPs) to the replacement analyses requested by the Southern Inshore Working Group (SINSWG). The main difference between the 2013 analyses and the replacement analyses was the addition of the binomial presence/absence series along with the development of combined positive and binomial models using the delta procedure. The SINSWG has determined that combined models are more likely to capture components of the CPUE trends, including trends in zero catch and trends in reporting small catches. The revised standardisation models adopted for RCO 2 and RCO 3 differ only slightly from the initial models developed to drive the MPs in 2013.

The RCO 2 "*no interaction*" series and the RCO 3 "*extended2*" series were accepted for driving the in-season management procedures (MPs) under a special provision of the 1996 Fisheries Act which allows for the setting of a "base" TACC plus allowing additional catch to be added during the fishing season if the abundance data warrant it. These RCO MPs, initially developed by Bentley (2013a), use early data from the current fishing year to predict the overall annual CPUE index for the year. This CPUE is then multiplied by the parameters of a regression which relates CPUE with the realised catches for the period 1989–90 to one year before the current year. This regression model effectively represents an average exploitation rate for the preceding period. The accuracy of the CPUE predictions was evaluated using a retrospective analysis which stepped through each fishing year, starting with 2002–03, and used five trial predictive months from December to April. These rules have moderate predictive capability as was demonstrated by a retrospective analysis which showed that the mean absolute relative error for CPUE in the predictions averaged from 0.32 (December) to 0.16 (April) (months indicate the final month in the predictive year) for RCO 2 and 0.24 (December) to 0.13 (April) for RCO 3. These error levels are high and are associated with high variability (CVs near 1.0). The nature of the regression which related the CPUE with the realised catch was also evaluated, with the recommendation that these models estimate the constant (intercept) parameter as well as the slope in order to avoid biased residual patterns. The SINSWG accepted these evaluations and recommended the continuation of these two MPs based on the revised methodology.

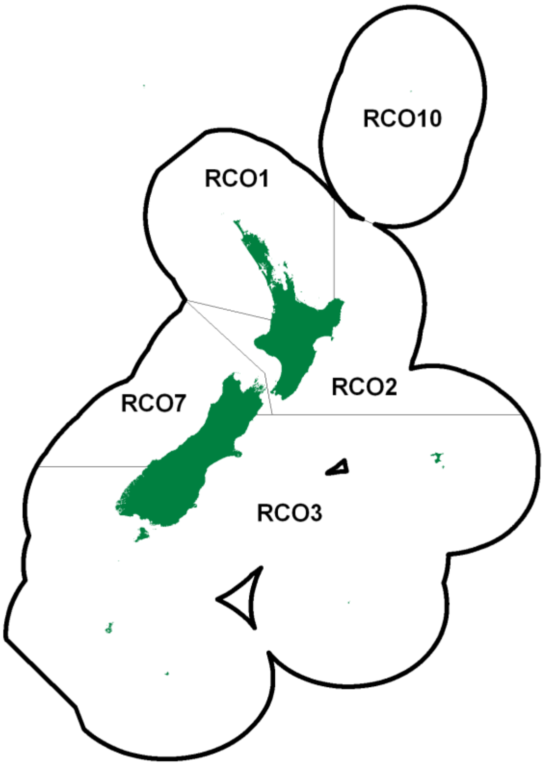

Figure 1: Map of RCO QMAs.

1. INTRODUCTION

This document describes work conducted under Objectives 1, 2, 3 and 4 of Ministry for Primary Industries project RCO2017-01.

Overall Objective:

1. To review the management procedures used in RCO 2 and RCO 3.

Specific Objectives:

1. To characterise the RCO 2 and RCO 3 fisheries.
2. To analyse existing commercial catch and effort data to the end of 2016–17 fishing year and undertake CPUE standardisations for each stock.
3. Use the above information to update the CPUE analysis and core vessel set used in the in-season increase model.
4. To evaluate the performance of the in-season management procedure for RCO 2 and RCO 3

1.1 Background

Red cod is a short-lived and “highly variable” species listed under Schedule 2 of the Fisheries Act (1996), which allows the Minister to increase the Total Annual Catch (TAC) within a fishing season. Increased commercial catch is provided through the creation of additional ‘in-season’ ACE and the base TACC is not changed by this process. A management procedure (MP) for RCO 2 and RCO 3 was developed by Bentley (2012, 2013a, 2013b, 2013c) to provide a basis from which the two RCO catch limits could be adjusted upward. This MP used the catch and effort data accumulated in the first three months of the active fishing year (October–December) to predict, through a positive catch standardised CPUE analysis, the CPUE for the entire fishing year. This predicted CPUE was then multiplied by a scalar which was the slope of a fitted line relating the CPUE with the total annual landings to obtain a predicted catch for the active fishing year. In effect, this catch/CPUE ratio is an estimate of the past average exploitation rate and the use of this ratio in the RCO 2 or RCO 3 MP ensured that the recommended catch was consistent with the historical exploitation rate. Only fishing years which did not reach 90% of the TACC were used in calculating this ratio, under the assumption that exploitation was not constrained in those years by a catch limit.

The existing RCO 2 and RCO 3 MPs expired in 2018, having been originally reviewed and accepted by the Southern Inshore Working Group (SINSWG) in 2013 (Bentley 2013a). The table below documents the years when RCO 2 and RCO 3 catch limit predictions were made, along with the applicable years:

Analysis year	RCO 2 Reference	RCO 3 Reference	Predictive fishing year in analysis
2013	Bentley 2013c	Bentley 2013b	2012–13
2014	Not available	Not available	2013–14
2015	Bentley 2015	Bentley 2015	2014–15
2016	Bentley 2016a	Bentley 2016b	2015–16
2017	Bentley 2017a	Bentley 2017b	2016–17
2018	Starr & Bentley 2018a	Starr & Bentley 2018b	2017–18

This paper will review and characterise the RCO 2 and RCO 3 fisheries, updating the analyses provided by Bentley (2013a) to the 2016–17 fishing year. It will update the standardised CPUE analyses that were used to operate the RCO 2 and RCO 3 MPs from 2013 to 2018. Finally, this paper will propose and evaluate a revised MP for each of RCO 2 and RCO 3.

2. INFORMATION ABOUT THE STOCK/FISHERY

2.1 Catches

There are five New Zealand red cod (RCO) QMAs (Figure 1), with RCO 3 having the largest TACC among the RCO QMAs, followed by RCO 7 and then RCO 2.

The TACC for red cod in RCO 2 was set at 353 t when this Fishstock was introduced into the QMS in 1986 and it then increased incrementally to 364 t in 1990–91 due to quota appeals. It was increased to 500 t in 1995–96, probably in response to strong abundance in the preceding three years (Figure 2; Table 1). Catch levels exceeded the higher TACC in 1995–96 but did not approach this level again until 2010–11 and 2011–12, with catches remaining below the TACC since then (Figure 2; Table 1). RCO 2 was placed under Schedule(2) of the 1996 Fisheries Act in 2007–08, along with all of the RCO Fishstocks. However, unlike in RCO 3, the RCO 2 TACC was not dropped to a lower level, thus allowing any increase to operate from a 500 t base TACC. ACE was added to the RCO 2 TACC under the provisions of Schedule(2) in 2012–13 and 2016–17. The 2016–17 RCO 2 increase was not authorised until late August, too late for the fishery to respond.

The RCO 3 TACC was set at 11 972 t when this Fishstock was introduced into the QMS in 1986 and it then increased gradually to its peak value of 12 396 t in 2001–02, again due to quota appeals (Figure 2; Table 1). RCO 3 catches approached or exceeded 10 000 t/year for five years from 1994–95 to 1998–99 and exceeded the TACC in 1994–95 and 1998–99 (Figure 2; Table 1). RCO 3 was placed under Schedule(2) of the 1996 Fisheries Act in 2007–08, along with all of the RCO QMAs. The RCO 3 “base” TACC was dropped to 4 600 t, a level close to the mean catch from 1999–2000 to 2004–05, a period which immediately followed the high catch levels of the mid-1990s. Within season ACE was added twice to the RCO 3 TAC under the provisions of Schedule(2): in 2012–13 to 4 944 t and in 2013–14 to 5 391 t. A recommendation was made in 2014–15 to add ACE to the TACC to 6 289 t, but this was never implemented. A recommendation was made in 2017–18 to add ACE to the TACC to 8 912 t, but catch rates dropped off in early 2018 and industry chose not to pursue the proposed increase (M Geytenbeek, Fisheries New Zealand Dunedin, *pers. comm.*).

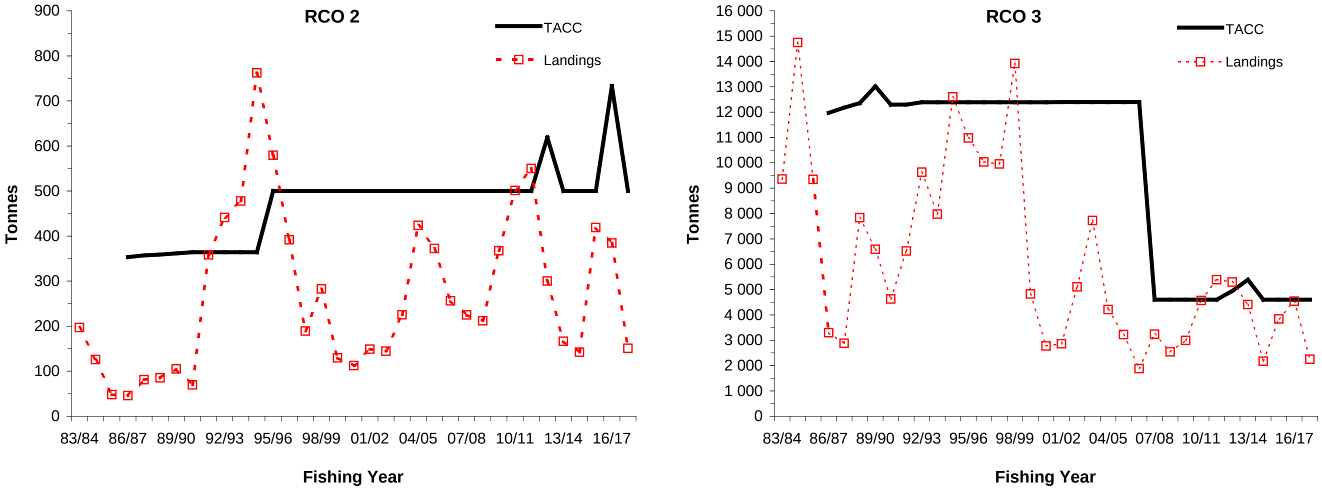

Figure 2: **Plots of RCO 2 and RCO 3 landings and TACCs from 1983–84 to 2017–18 (see Table 1 for list of landings and TACCs by RCO QMA; 2017–18 landings are provisional).**

Table 1. **Reported landings (t) and TACC (t) of red cod in RCO 2 and RCO 3 from 1983–84 to 2017–18 (Data sources: 1983–84 to 1985–86 (Fisheries New Zealand 2018, chapter 71, table 3); QMR [1986–87 to 2000–01]; MHR [2001–02 to 2017–18]. Coloured cells exceeded the 90% threshold specified by the 2013 RCO 2 and RCO 3 MPs.**

			RCO 2			RCO 3
Fishing Year	QMR_y	$TACC_y$	$QMR_y/TACC_y$	QMR_y	$TACC_y$	$QMR_y/TACC_y$
1983–84	197	–	–	9 357	–	–
1984–85	126	–	–	14 751	–	–
1985–86	48	–	–	9 346	–	–
1985–86	46	353	13%	3 300	11 972	28%
1987–88	81	357	23%	2 880	12 182	24%
1988–89	85	359	24%	7 840	12 362	63%
1989–90	105	362	29%	6 589	13 018	51%
1990–91	70	364	19%	4 630	12 299	38%
1991–92	358	364	98%	6 517	12 299	53%
1992–93	441	364	121%	9 635	12 389	78%
1993–94	478	364	131%	7 977	12 389	64%
1994–95	762	364	209%	12 603	12 389	102%
1995–96	579	500	116%	10 983	12 389	89%
1996–97	392	500	78%	10 037	12 389	81%
1997–98	189	500	38%	9 954	12 389	80%
1998–99	282	500	56%	13 919	12 389	112%
1999–00	130	500	26%	4 824	12 389	39%
2000–01	112	500	22%	2 776	12 389	22%
2001–02	149	500	30%	2 857	12 396	23%
2002–03	144	500	29%	5 107	12 396	41%
2003–04	225	500	45%	7 724	12 396	62%
2004–05	424	500	85%	4 212	12 396	34%
2005–06	372	500	74%	3 223	12 396	26%
2006–07	256	500	51%	1 877	12 396	15%
2007–08	225	500	45%	3 236	4 600	70%
2008–09	212	500	42%	2 542	4 600	55%
2009–10	367	500	73%	2 994	4 600	65%
2010–11	501	500	100%	4 568	4 600	99%
2011–12	550	500	110%	5 386	4 600	117%
2012–13	300	619[1]	60%	5 294	4 944[1]	115%
2013–14	167	500	33%	4 410	5 391[1]	96%
2014–15	142	500	28%	2 171	4 600[2]	47%
2015–16	419	500	84%	3 837	4 600	83%
2016–17	385	733[1]	77%	4 543	4 600	99%
2017–18	151[3]	500	30%	2 250[3]	4 600[4]	49%

[1] commercial catch allowance increased through application of in-season MP with additional ACE provided under S68 of FA1996
[2] recommended commercial catch allowance increase to 6 289 t consulted but not implemented
[3] November 2018 provisional totals
[4] recommended commercial catch allowance increase to 8 192 t not pursued by industry

2.2 Regulations affecting the fishery

There have been no specific regulations implemented that affect the RCO 2 or RCO 3 fishery. Headline height was decreased in 2008 for the FLA target fishery when fishing inside of two nautical miles. There has been a voluntary move on the part of Industry to use bigger mesh in the cod ends to reduce the catch of small fish, beginning around 2012–13 (M. Geytenbeek, Fisheries New Zealand Dunedin, *pers. comm.*).

2.3 Analysis of RCO 2 and RCO 3 catch and effort data

2.3.1 Methods used for 2018 analysis of Fisheries New Zealand catch and effort data

2.3.1.1 Obtaining data extracts

Two data extracts were obtained from the Fisheries New Zealand combined Warehou and EDW databases (Ministry of Fisheries 2010 and John Moriarity, Fisheries New Zealand Data Management, pers. comm.). One extract consisted of the complete data set (all fishing event information along with all red cod landing information) from every trip that recorded landing red cod in RCO 2 or RCO 3, starting from 1 October 1989 and extending to 30 September 2017. A second extract was obtained which consisted of all New Zealand trips using the methods BT (bottom trawl) and that did **not** target 'ORH', 'OEO', 'SOE', 'SOR', 'SSO', 'BOE', 'WOE', ‘CDL’, 'SBW', 'SCI' in the statistical areas valid for RCO 2 and RCO 3 (011–032, 036, 037, 039–041, 049–052, 201–206, 301–303, 401–412, 501–504, 601–625, 801). Once these trips were identified, all fishing event data and red cod landing data from the entire trip, regardless of method of capture, were obtained. These data extracts (Fisheries New Zealand replog 11581) were received 13 February 2018. The first data extract was used to characterise and understand the fisheries taking red cod. These characterisations are reported in Sections 2.3.2 and 2.3.3, plus detailed summary tables in Appendix C (RCO 2) and Appendix D (RCO 3). The second extract was used to calculate CPUE standardisations for BT (Section 3).

2.3.1.2 Preparation of data extracts

Data were prepared by linking the effort (‘fishing event’) section of each trip to the landing section, based on trip identification numbers supplied in the database. Effort and landing data were groomed to remove ‘out-of-range’ outliers (only one landing record was removed for being “out of range”; the remaining procedures used to prepare these data are documented in Starr [2007]).

The original level of time stratification for a trip is either by tow or day of fishing, depending on the type of form used to report the trip information. These data were amalgamated into a common level of stratification known as a ‘trip stratum’ (see table of definitions: Appendix A) for the characterisation part of this report. Depending on how frequently an operator changed areas, method of capture or target species, a trip could consist of one to several ‘trip strata’. This amalgamation was required so that these data could be analysed at a common level of stratification across all reporting form types. Landed catches of red cod by trip were allocated to the ‘trip strata’ in proportion to the estimated red cod catches in each ‘trip stratum’. In situations when trips recorded landings of red cod without any associated estimates of catch in any of the ‘trip strata’ (operators were only required to report the top five species in any fishing event), red cod landings were allocated proportionally to effort (usually number of tows for trawl data) in each ‘trip stratum’.

Table 2: Comparison of the RCO 2 and RCO 3 QMR/MHR catch (t) with the sum of the landed catch totals (bottom part of the Fisheries New Zealand CELR/CLR forms), the total catch after matching effort with landing data ('Analysis' data set) and the sum of the estimated catches from the Analysis data set. Data source: Fisheries New Zealand replog 11581: 1989–90 to 2016–17.

	RCO 2							RCO 3						
Fishing Year	QMR/MHR (t)	Total landed catch (t)	% landed/ QMR/MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis	QMR/MHR (t)	Total landed catch (t)	% landed/ QMR/MHR	Total Analysis catch (t)	% Analysis /Landed	Total Estimated Catch (t)	% Estimated /Analysis
89/90	105	77	74	76	99	61	80	6 589	5 560	84	5 277	95	3 887	74
90/91	70	64	92	61	96	49	80	4 630	3 983	86	3 911	98	3 483	89
91/92	358	116	32	109	94	75	69	6 517	5 766	88	5 676	98	5 112	90
92/93	441	361	82	345	96	236	68	9 635	7 826	81	7 747	99	6 974	90
93/94	478	460	96	415	90	276	67	7 977	7 270	91	7 075	97	6 396	90
94/95	762	723	95	650	90	461	71	12 603	11 289	90	11 097	98	10 347	93
95/96	579	553	95	428	77	297	69	10 983	9 494	86	9 384	99	9 147	97
96/97	392	381	97	261	69	198	76	10 037	9 434	94	9 235	98	8 647	94
97/98	189	194	103	136	70	95	70	9 954	9 696	97	9 488	98	8 626	91
98/99	282	335	119	206	61	140	68	13 919	13 911	100	13 739	99	12 397	90
99/00	130	150	116	98	65	77	78	4 824	4 740	98	4 723	100	4 371	93
00/01	112	121	107	88	73	56	64	2 776	2 779	100	2 702	97	2 419	90
01/02	149	155	104	125	80	74	60	2 857	2 818	99	2 672	95	2 267	85
02/03	144	143	99	116	81	79	68	5 107	5 110	100	5 068	99	4 413	87
03/04	225	224	99	173	77	120	69	7 724	7 640	99	7 587	99	6 922	91
04/05	424	411	97	253	62	177	70	4 212	4 142	98	4 097	99	3 554	87
05/06	372	368	99	287	78	193	67	3 223	3 274	102	3 255	99	2 762	85
06/07	256	262	102	202	77	125	62	1 877	1 843	98	1 827	99	1 472	81
07/08	225	228	101	151	66	107	71	3 236	3 176	98	3 152	99	2 870	91
08/09	212	214	101	175	82	125	72	2 542	2 547	100	2 532	99	2 232	88
09/10	367	364	99	335	92	250	75	2 994	2 948	98	2 924	99	2 551	87
10/11	501	486	97	455	94	373	82	4 568	4 492	98	4 461	99	4 044	91
11/12	550	564	103	531	94	453	85	5 386	5 279	98	5 176	98	4 443	86
12/13	300	286	95	267	94	223	83	5 294	5 247	99	5 179	99	4 445	86
13/14	167	167	100	139	83	108	77	4 410	4 366	99	4 335	99	3 755	87
14/15	142	141	99	106	76	84	79	2 171	2 149	99	2 128	99	1 730	81
15/16	419	404	96	386	96	298	77	3 837	3 756	98	3 716	99	3 087	83
16/17	385	381	99	353	93	277	78	4 543	4 567	101	4 518	99	3 973	88
Total	8 737	8 332	95	6 931	83	5 086	73	164 426	155 101	94	152 680	98	136 327	89

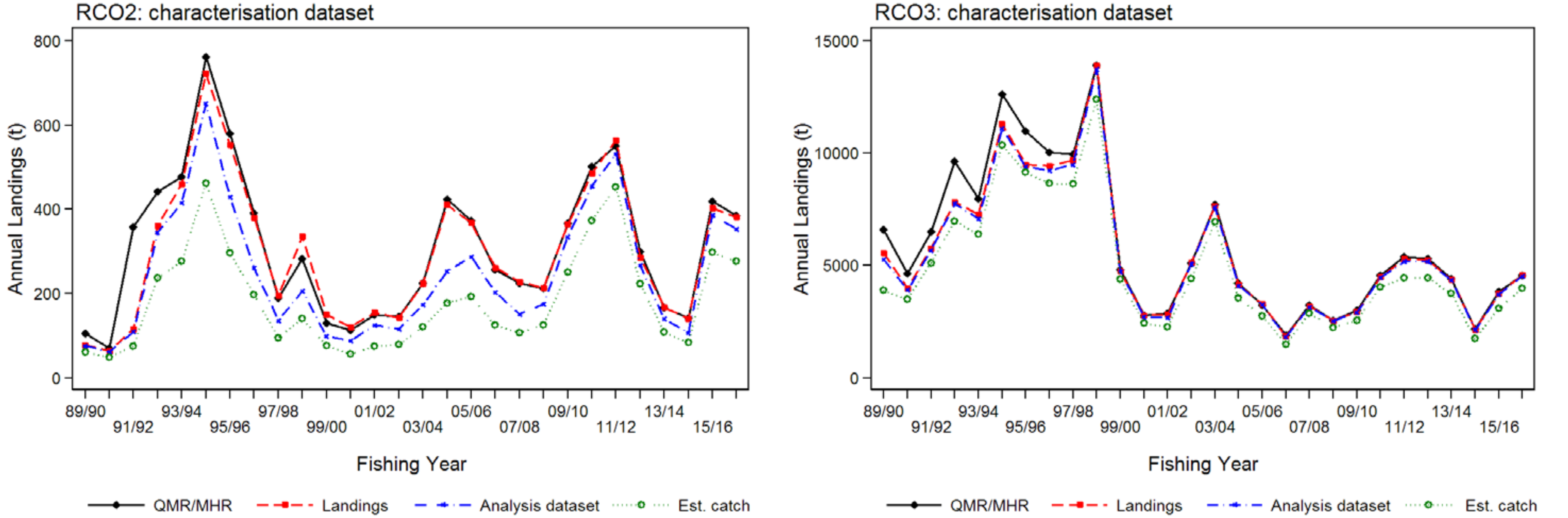

Figure 3: Plot of the RCO 2 and RCO 3 catch datasets for totals presented in Table 2.

Table 3: Summary statistics pertaining to the reporting of estimated catch from RCO 2 and RCO 3 analysis data sets.

	RCO 2							RCO 3						
	Trips with landed catch but that report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip				Trips with landed catch but that report no estimated catch			Statistics (excluding 0s) for the ratio of landed/estimated catch by trip			
Fishing year	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile	Trips: % relative to total trips	Landings: % relative to total landings	Landings (t)	5% quantile	Median	Mean	95% quantile
89/90	38	10	10	0.63	1.00	1.19	2.00	17	3	185	0.62	1.07	1.30	2.07
90/91	41	15	10	0.60	1.00	1.09	1.50	25	1	67	0.65	1.10	1.35	2.39
91/92	39	17	60	0.60	1.00	1.18	2.00	26	1	55	0.66	1.09	1.35	2.30
92/93	30	10	43	0.70	1.06	1.37	2.62	22	1	66	0.70	1.09	1.38	2.26
93/94	28	7	32	0.72	1.10	1.50	3.00	23	2	145	0.65	1.07	1.75	2.20
94/95	22	6	45	0.73	1.12	1.50	2.93	18	1	86	0.67	1.06	1.44	2.22
95/96	27	9	52	0.73	1.17	1.97	2.93	20	1	112	0.67	1.06	1.58	2.05
96/97	38	15	58	0.65	1.12	1.45	2.86	21	1	99	0.65	1.07	1.34	2.05
97/98	41	17	32	0.55	1.14	1.50	3.15	21	1	113	0.67	1.05	1.46	2.18
98/99	43	12	35	0.69	1.13	1.61	3.20	21	1	141	0.65	1.03	1.50	2.04
99/00	58	11	14	0.55	1.12	1.38	2.90	25	1	72	0.60	1.02	1.19	2.02
00/01	55	19	21	0.50	1.12	1.44	3.33	29	2	69	0.57	1.06	1.27	2.39
01/02	44	12	18	0.65	1.20	1.72	4.00	27	3	75	0.62	1.08	1.29	2.42
02/03	56	19	28	0.56	1.16	1.64	3.96	26	1	63	0.64	1.08	1.41	2.49
03/04	44	10	23	0.60	1.23	1.89	4.54	22	1	85	0.65	1.08	1.31	2.33
04/05	38	10	43	0.68	1.18	1.91	5.00	25	2	73	0.67	1.10	1.36	2.53
05/06	31	8	29	0.70	1.21	1.78	4.03	26	2	71	0.69	1.10	1.43	2.68
06/07	35	14	36	0.60	1.26	1.77	4.35	27	4	78	0.68	1.15	1.53	3.03
07/08	19	4	9	0.57	1.28	1.84	4.44	15	1	30	0.63	1.11	1.74	3.20
08/09	16	2	5	0.60	1.32	1.87	4.70	13	1	34	0.65	1.13	1.56	3.00
09/10	14	1	4	0.65	1.23	1.80	4.53	12	1	29	0.60	1.14	1.71	3.50
10/11	13	1	4	0.67	1.18	1.54	3.38	12	1	30	0.66	1.13	1.61	3.50
11/12	17	1	3	0.60	1.16	1.55	3.38	13	0	23	0.67	1.17	1.79	4.00
12/13	21	1	4	0.58	1.20	1.78	4.33	13	1	45	0.67	1.17	1.90	3.90
13/14	23	3	6	0.55	1.23	1.77	4.67	12	1	38	0.70	1.14	1.68	3.44
14/15	28	4	6	0.50	1.32	2.14	6.19	15	2	46	0.67	1.15	1.82	3.90
15/16	17	1	3	0.68	1.31	1.93	5.00	24	2	71	0.60	1.15	1.87	4.30
16/17	16	2	7	0.60	1.25	1.70	4.10	17	1	62	0.67	1.12	1.57	3.44
Total	30	7	642	0.62	1.17	1.66	3.72	21	1	2 064	0.65	1.09	1.50	2.67

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

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

where $\mathbf{QMR}_y$ is the annual QMR/MHR landings, AL_y is the corresponding total annual landings from the analysis data set and $L_{i,y}$ are the landings for record i in year y.

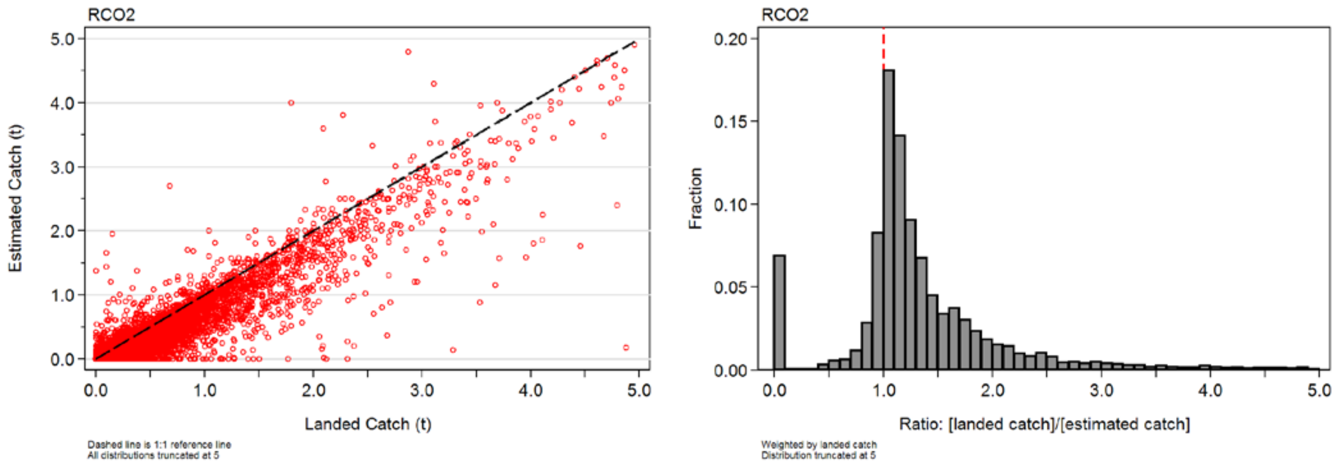

Figure 4A: [left panel]: Scatter plot of the sum of landed and estimated red cod catch for each trip RCO 2; [right panel]: Distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

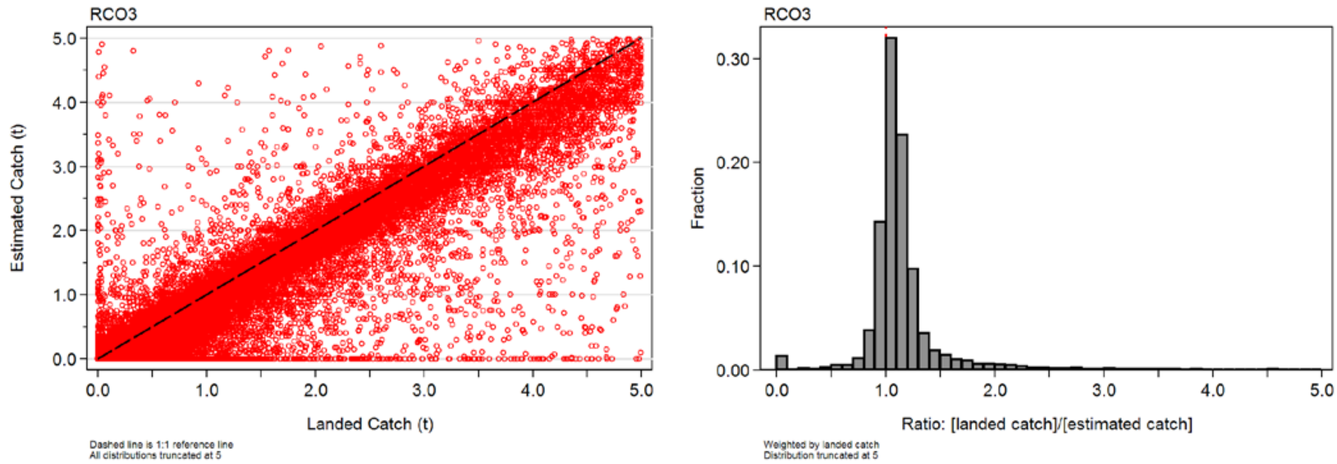

Figure 4B: [left panel]: Scatter plot of the sum of landed and estimated red cod catch for each trip RCO 3; [right panel]: Distribution (weighted by the landed catch) of the ratio of landed to estimated catch per trip. Trips where the estimated catch=0 have been assigned a ratio=0.

2.3.1.3 Characteristics and summary information from data extracts

The annual totals at different stages of the data preparation procedure are presented for both RCO 2 and RCO 3 in Table 2 and Figure 3. Landings in the Warehou database differ from the "official" QMR landings in both QMAs in the early 1990s. Shortfalls between the two totals extend from 1989–90 to 1992–93 for RCO 2, after which the totals from the two data systems match quite closely. Shortfalls in RCO 3 are proportionally less than for RCO 2 but extend over a longer period: from 1989–90 to 1995–96 (Table 2). RCO 3 landings by year in the subsequent fishing years vary from –3% to +2% relative to the QMR/MHR annual totals. A similar comparison for RCO 2 is more variable, with the difference between the landing totals compared to the QMR/MHR landings varying from +19% in 1998–99 and +16% in 1999–00 to a low of –5% in 2012–13 (Table 2). The shortfall between landed and estimated catch by trip and fishing year varies from –40% to +15% for RCO 2 (average=–27%) and from –26% to +3% for RCO 3 (average=–12%) (Table 2). The same average over the most recent 10 years is -22% for RCO 2 and –13% for RCO 3, indicating that there has not been any recent change in reporting practices for red cod estimated catch.

The incidence of trips which report landed catch but no estimated red cod is relatively high (30% for RCO 2 and 21% for RCO 3) but these trips account for only a small amount of the total RCO catch (overall 7% for RCO 2 and 1% for RCO 3) ([left panel] Figure 4A and Figure 4B). There is a downward shift in the percentage of trips with no estimated catch, but which report landed catch, after the introduction of the event-based forms in 2007–08. This occurred because operators using the CELR form were only required to estimate the catch of the top five species in any single day, but the requirement changed to 8 species by fishing event with the introduction of the TCER forms in 2007–08 and the NCELR forms in 2006–07.

A scatter plot of the estimated and landed catch by trip shows that relatively few trips overestimate the landing total for the trip ([left panel] Figure 4A and Figure 4B). Fishers tend to underestimate the landings of red cod, with the 5% to 95% quantiles for the ratio of landed to estimated catch (in the total RCO data set excluding trips where there was no estimated catch) ranging from 0.62 to 3.72 for RCO 2 and 0.50 to 2.67 for RCO 3. The median and mean ratios have the landed catch at 17% and 66% higher, respectively, than the estimated RCO 2 catch and at 9% and 50% higher than the estimated RCO 3 catch ([left panel] Figure 4A and Figure 4B), with no trend in these statistics over time. This large and consistent shortfall between estimated and landed catches (see Figure 3 and Figure 4A and Figure 4B) means that estimated catches must be adjusted to reflect actual landings in the characterisation and CPUE analyses.

2.3.1.4 Scaling estimated catches

The method of Starr (2007) apportions the landings of a trip to each trip-stratum in proportion to the sum of the estimated red cod catch in each trip-stratum. This method works well when trips land to a single red cod QMA, but it breaks down when a trip lands to multiple QMAs and fishes in a statistical area which is valid for more than one QMA (e.g., Area 018 – see Appendix B). Starr (2007) recommends dropping these trips, but this can lead to potential bias if many trips are discarded. Such a shortfall can be seen in RCO 2, where there is a considerable shortfall between QMR/MHR catches and the landings in the 'analysis' data set which is used for the characterisation study (see Figure 3 and Table 2). To get around this problem, the method of Starr (2007) was modified to scale the 'trip-stratum' estimated catches to the sum of the trip landings, without regard to the reported QMA. This requires using the statistical area to define the QMA in subsequent analyses, because catches in the shared statistical areas will consist of several QMAs. To test how well the 'stat_area' expansion works in this RCO data set, a comparison of the sum of landings to each of the important RCO 2 or RCO 3 statistical areas was made (Table 4). Table 4 demonstrates that the primary statistical areas (coloured light blue in Table 4) in both RCO 2 and RCO 3 have similar catch totals from either method. The shared statistical areas are not as well served, with important statistical areas (such as Area 018 or Area 037) having much larger total catches when using the 'stat_area' expansion method. Consequently, the 'total' landings for the statistical areas which contribute to RCO 2 nears 17 000 t when using the 'stat_area' expansion method while the equivalent total for the 'Fishstock' expansion is just under 7 000 t. The second total is more credible, given that the total RCO 2 landings over 29 years is only 8 700 t (second column, Table 2, with the higher total due to mixing RCO 2, RCO 3 and RCO 7 catches). Consequently, the 'Fishstock' expansion method will be used for the characterisation section of this paper because the catches will be reliably apportioned to either RCO 2 or RCO 3, while the 'stat_area' expansion procedure will be used for the CPUE standardisations and the fine-scale spatial plots in order to maximise the retention of data.

Table 4: Comparison of total (1989–90 to 2016–17) landings (t) by statistical area between two different expansion approaches: 'Fishstock' expansion, where red cod trips which landed to multiple RCO QMAs and fished in shared statistical areas are discarded and 'stat_area' expansion where all RCO landings in a trip are summed and then apportioned in proportion to the estimated catches in each 'trip-stratum'. Statistical areas used in the RCO 2 or RCO 3 standardised CPUE analyses are shaded light blue while statistical areas where there are high levels of catch shared between several QMAs are coloured yellow or light green.

	RCO 2					RCO 3			
Statistical area	'Stat_area' expansion	'Fishstock' expansion	Difference	% difference	Statistical area	'Stat_area' expansion	'Fishstock' expansion	Difference	% difference
011	369	360	10	2.7%	022	82 134	81 715	419	0.5%
012	274	266	8	2.9%	020	26 922	26 618	304	1.1%
013	2 354	2 352	2	0.1%	024	12 171	12 145	27	0.2%
014	1 638	1 623	15	0.9%	602	6 300	6 301	- 1	0.0%
015	333	299	34	10.3%	030	5 831	5 828	3	0.1%
016	1 704	871	832	48.9%	026	5 348	5 307	41	0.8%
017	2 799	271	2 529	90.3%	018	5 782	4 585	1 197	26.1%
018	5 782	40	5 742	99.3%	028	3 752	3 743	10	0.3%
019	7	1	7	87.7%	027	1 371	1 349	23	1.7%
036	57	1	56	97.5%	025	866	869	- 3	-0.3%
037	347	19	328	94.6%	021	753	749	4	0.5%
039	708	389	320	45.1%	504	577	560	17	3.1%
040	215	117	98	45.7%	050	494	492	3	0.5%
041	346	319	27	7.8%	401	392	405	- 12	-3.1%
201	0	0	0	-1.0%	049	402	400	2	0.5%
202	0	–	0	100.0%	023	281	277	4	1.3%
203	0	0	0	-0.8%	407	228	219	9	4.3%
204	3	2	0	10.0%	029	185	183	2	0.9%
205	2	0	1	84.1%	404	148	147	1	0.5%
206	0	0	0	-0.7%	052	136	135	1	0.6%
801	1	0	0	52.5%	410	135	134	1	0.4%
					610	121	121	0	0.2%
					Other	448	439	9	2.0%
Total	16 941	6 931	10 010	59.1%	Total	154 779	152 721	2 058	1.3%

2.3.1.5 'Daily effort stratum' data preparation procedure

Data used for CPUE analysis were prepared using the 'daily effort stratum' (Appendix A) procedure proposed by Langley (2014). As noted above, catch/effort data must be summarised to a common level of stratification in order to construct a time series of CPUE indices that spans the change in reporting forms instituted in the late 2000s. Although the 'trip-stratum' procedure proposed by Starr (2007) addresses the nominal instructions provided to fishers using the daily-effort CELR forms, Langley (2014) was able to show that the realised stratification in the earlier form types was daily, with the fisher tending to report the 'predominant' statistical area of capture and target species rather than explicitly following the instructions. He showed this by noting that the frequency of changes in statistical area of fishing or target species within a day of fishing was much higher for comparable tow-by-tow event-based forms than in the earlier daily forms. Consequently, we have adopted Langley's (2014) recommendation to use the 'daily stratum' method for preparing data for CPUE analysis. The following steps were used to 'rollup' the event-based data (tow-by-tow data) to a 'daily stratum':

1. discard trips that used more than one method in the trip (except for rock lobster potting, cod potting and fyke nets whereby these methods were simply dropped because they are unlikely to catch bottom trawl species) or used more than one form type;
2. sum effort for each day of fishing in the trip;
3. sum estimated catch for each day of fishing in the trip and only use the estimated catch from the top five species, sorted by weight in descending order; in the case of a tie for the fifth most prevalent species, a secondary sort is made on the species 3-letter code which results in taking the species that comes first in alphabetical order[1];
4. calculate the modal statistical area and target species for each day of fishing, each weighted by the number of fishing events: these are the values assigned to the effort and catch for that day of fishing;
5. create a list of "most relevant" target species in the total RCO 2/RCO 3 data set by summing the landings in the appropriate characterisation data set across all years to identify the main target fisheries which capture red cod (Table 5). This list was used to screen daily effort by discarding entire trips which reported target species that were not in this list. This was done because it was felt that the effort from the discarded species was not relevant nor necessary to include in the flatfish CPUE analysis. The decision to discard the entire trip rather than just discarding the effort with the non-relevant target species was made because analysis (not reported) showed that there was potential for bias when linking red cod landings by trip with the remaining partial trip – it is safer to drop the entire trip. A cutoff of 50 was used because an analysis (also not reported), which compared the retained catch using a cutoff of 25 with the retained catch from a cutoff of 50, showed that the 25 cutoff resulted in dropping 3% of the combined RCO 2/RCO 3 catch (3 960 t) compared to only 0.8% (1 050 t) dropped with a cutoff of 50;
6. distribute landings proportionately to each day of the trip based on the species estimated catch or to the daily effort when there is no species estimated catch.

Note that the above procedure was also applied to the daily effort (CELR) forms to ensure that each of these trips was also reduced to 'daily strata' if fishers reported more than one statistical area or target species in a day of fishing.

Table 5: Table of target species fisheries which take RCO 2 or RCO 3, summed over the period 1989–90 to 2016–17 based on the characterisation data set. The top 50 species were used in the BT CPUE analysis, with trips taking any of the remaining species dropped entirely.

Rank	Target species	Common Name	Total RCO landings (t)	% total landings
1	RCO	Red Cod	91 815.7	67.0
2	FLA	Flats	10 770.3	7.9
3	SQU	Arrow Squid	10 578.0	7.7
4	BAR	Barracouta	10 343.1	7.6
5	TAR	Tarakihi	4 626.3	3.4
6	HOK	Hoki	2 595.9	1.9
7	GUR	Gurnard	2 008.1	1.5
8	WAR	Common Warehou	866.4	0.63
9	SWA	Silver Warehou	683.5	0.50
10	SPE	Sea Perch	415.2	0.30
11	LIN	Ling	287.4	0.21
12	ELE	Elephant Fish	277.9	0.20
13	GSH	Ghost Shark	263.6	0.19
14	SPD	Spiny Dogfish	231.8	0.17
15	STA	Giant Stargazer	220.8	0.161

[1] This secondary sort needs to occur to ensure that repeat analyses of the same data will give the same results; otherwise the sort order will change randomly unless it is constrained by a rule.

Rank	Target species	Common Name	Total RCO landings (t)	% total landings
16	SKI	Gemfish	217.2	0.159
17	SCI	Scampi	207.5	0.152
18	BCO	Blue Cod	100.2	0.073
19	JMA	Jack Mackerel	89.9	0.066
20	SNA	Snapper	60.6	0.044
21	RSK	Rough Skate	45.6	0.033
22	SPO	Rig	36.8	0.027
23	TRE	Trevally	34.0	0.025
24	JDO	John Dory	25.7	0.019
25	ROC	Rock Cod	21.2	0.015
26	MOK	Moki	18.9	0.014
27	WWA	White Warehou	14.7	0.011
28	RAT	Rattails	13.4	0.010
29	SCH	School Shark	11.2	0.0082
30	THR	Thresher Shark	11.0	0.0080
31	HPB	Hapuku & Bass	6.5	0.0047
32	SUR	Kina	5.9	0.0043
33	SSK	Smooth Skate	3.7	0.0027
34	SKA	Skate	3.7	0.0027
35	ORH	Orange Roughy	3.5	0.0025
36	QSC	Queen Scallop	2.9	0.0021
37	KAH	Kahawai	2.4	0.0017
38	BOE	Black Oreo	2.3	0.0017
39	BYX	Alfonsino	2.1	0.0015
40	LEA	Leatherjacket	2.0	0.0015
41	HAK	Hake	2.0	0.0014
42	SSO	Smooth Oreo	1.4	0.0011
43	OEO	Oreos	1.3	0.0010
44	RBM	Rays Bream	0.9	0.0006
45	BNS	Bluenose	0.8	0.0006
46	SPF	Scarlet Wrasse	0.8	0.0006
47	LDO	Lookdown Dory	0.7	0.0005
48	PIP	Pipefish	0.7	0.0005
49	RBY	Ruby Fish	0.6	0.0004
50	CDL	Cardinal Fish	0.5	0.0004
51	ASQ		0.4	0.0003
52	CRA	Rock Lobster	0.2	0.0002
53	OYS	Oysters Dredge	0.2	0.0001
54	PAD	Paddle Crab	0.2	0.0001
55	SCO	Swollenhead Conger	0.2	0.0001
56	SPZ	Spotted Stargazer	0.1	0.0001
57	ALB	Albacore Tuna	0.1	0.0001
58	BAT	Large Headed Slickhead	0.1	0.0001
59	GAR	Garfish	0.1	0.0001
60	SFE	Short-finned Eel	0.1	0.0001
61	PAR	Parore	0.1	0.0001
62	BAI		0.1	0.0000
63	SQX	Squid	0.0	0.0000
64	SSH	Slender Smooth-hound	0.0	0.0000
65	RLA	Resania lanceolata	0.0	0.0000
66	STN	Southern Bluefin Tuna	0.0	0.0000
67	LEL	Longimactra elongata	0.0	0.0000
68	KIN	Kingfish	0.0	0.0000
69	SUN	Sunfish	0.0	0.0000
70	SDO	Silver Dory	0.0	0.0000
71	SBW	Southern Blue Whiting	0.0	0.0000
72	RSN	Red Snapper	0.0	0.0000

Rank	Target species	Common Name	Total RCO landings (t)	% total landings
73	BUT	Butterfish	0.0	0.0000
74	TOR	Pacific Bluefin Tuna	0.0	0.0000
75	MDO	Mirror Dory	0.0	0.0000
76	CAR	Carpet Shark	0.0	0.0000
77	FRO	Frostfish	0.0	0.0000
78	REC	Red Rock Crab	0.0	0.0000
79	CRB	Crab	0.0	0.0000
80	JAV	Javelin Fish	0.0	0.0000
81	CON	Conger Eel	0.0	0.0000
82	RUB	Rubbish Other Than Fish	0.0	0.0000
83	HOR	Horse Mussel	0.0	0.0000
84	SBO	Southern Boarfish	0.0	0.0000
85	BRA	Short-tailed Black Ray	0.0	0.0000
86	SEL	Seriolella labyrinthica	0.0	0.0000
87	OCT	Octopus	0.0	0.0000

Table 6: Destination codes in the unedited landing data received for the RCO 2 and RCO 3 CPUE analysis. The 'how used' column indicates which destination codes were included in the characterisation analysis. These data summaries have been combined over the period 1989–90 to 2016–17.

Destination code	Number events	Green weight (t)	Description	How used
RCO 2				
L	61 458	8 373.4	Landed in NZ (to LFR)	keep
O	12	35.0	Conveyed outside NZ	keep
W	554	17.0	Sold at wharf	keep
A	98	13.4	Accidental loss	keep
C	77	9.4	Disposed to Crown	keep
J	14	1.8	Returned to sea [Section 72(5)(2)]	keep
U	21	1.3	Bait used on board	keep
E	39	0.6	Eaten	keep
F	176	0.5	Section 111 Recreational Catch	keep
S	3	0.4	Seized by Crown	keep
T	91	178.1	Transferred to another vessel	drop
R	372	114.3	Retained on board	drop
D	18	6.6	Discarded (non-ITQ)	drop
Q	336	3.1	Holding receptacle on land	drop
B	49	0.5	Bait stored for later use	drop
RCO 3				
L	164 327	155 122.3	Landed in NZ (to LFR)	keep
J	312	371.0	Returned to sea [Section 72(5)(2)]	keep
O	65	367.5	Conveyed outside NZ	keep
A	1 064	327.7	Accidental loss	keep
E	1 963	102.7	Eaten	keep
U	2 889	68.1	Bait used on board	keep
W	605	9.7	Sold at wharf	keep
C	7	1.2	Disposed to Crown	keep
F	111	1.0	Section 111 Recreational Catch	keep
S	14	0.5	Seized by Crown	keep
H	2	0.0	Loss from holding pot	keep
T	596	7 036.3	Transferred to another vessel	drop
R	1 915	2 818.0	Retained on board	drop
Q	3 375	123.1	Holding receptacle on land	drop
D	153	42.1	Discarded (non-ITQ)	drop
B	645	19.5	Bait stored for later use	drop

2.3.2 Description landing information for RCO 2 and RCO 3

2.3.2.1 Destination codes in the RCO landing data

Landing data for red cod were provided for every trip that landed RCO 2 and RCO 3 at least once, with one record for every reported RCO landing from the trip. Each of these records contained a reported greenweight (in kilograms), 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 type code’ (Table 6), which indicated where the fish was landed to. The majority of the landings were made using destination type code ‘L’ (landed to a Licensed Fish Receiver; Table 6). However, other codes (e.g., ‘A’, ‘C’ or ‘W’; Table 6) also potentially described valid landings and were included in this analysis but these were minor compared to code ‘L’. A number of other codes (notably ‘Q’ and ‘R’; Table 6) were not included because it was assumed that these landings would be reported at a later date under the ‘L’ destination type code. Two other codes (‘D’ and ‘NULL’) represented errors that could not be resolved without making unwarranted assumptions and these were not included in the landing data set (note that D is meant for discards of non-QMS species only).

Some of the destination type codes (notably ‘P’, ‘Q’, ‘R’ and ‘T’) represent intermediate holding states that have the potential to invalidate the method of Starr (2007), which assumes that the reported landings for a trip have been taken using the effort reported for the trip. These intermediate landing destination codes are dropped (due to the potential for double counting). It is possible that ‘L’ landings reported for a trip may have been caught during another trip in which the landings were declared with an intermediate code. There is a relatively small amount of this type of behaviour in this RCO data set, with the incidence of intermediate landings accounting for only about 3.5% of the RCO 2 landings from all sources and 6% of RCO 3 landings. Consequently, this issue is ignored for this analysis.

Table 7: Total greenweight reported and number of events by state code in the landing file used to process the RCO 2 and RCO 3 characterisation and CPUE data, arranged in descending landed weight (only for destination codes indicated as ‘Keep’ in Table 6). These data summaries are summed over the period 1989–90 to 2016–17.

State code	Number events	Total reported green weight (t)	Description
RCO 2			
GRE	48 867	7 076.1	Green (or whole)
HGU	10 015	921.8	Headed and gutted
DRE	888	627.9	Dressed
GUT	3 295	84.9	Gutted
MEA	200	40.2	Fish meal
Other	67	8.6	Other [1]
RCO 3			
GRE	125 438	130 821.8	Green (or whole)
DRE	26 368	29 478.0	Dressed
HGU	21 954	2 922.2	Headed and gutted
MEA	2 349	966.6	Fish meal
MKF	14	891.1	Minced, skin-off fillets
FIL	127	402.1	Fillets: skin-on
HGT	102	380.5	Headed, gutted, and tailed
GUT	1 643	374.8	Gutted
Other	1 920	201.7	Other [2]

[1] Includes (in descending order): Headed, gutted, and tailed, Missing, Gilled and gutted tail-on, Roe, Fillets: skin-on, Fillets: skin-off.

[2] Includes (in descending order): Fillets: skin-off, Missing, Dressed-V cut (stargazer), Fillets: skin-on trimmed, Fillets: skin-off trimmed, Squid wings.

Table 8A: Median conversion factor for the five most important state codes reported in (in terms of total landed green weight). These data summaries are by RCO QMA over the period 1989–90 to 2016–17. '–': no observations.

	Landed state code											
Fishing	RCO 2						RCO 3					
year	GRE	HGU	DRE	GUT	MEA	Other	GRE	DRE	HGU	MEA	MKF	Other
89/90	1	1.30	–	1.1	–	1.3	1	–	1.30	5.556	–	1.1
90/91	1	1.65	1.8	1.1	–	–	1	1.8	1.65	5.6	–	1.1
91/92	1	1.65	1.8	1.1	–	–	1	1.8	1.65	5.6	–	1.1
92/93	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
93/94	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
94/95	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
95/96	1	1.65	1.8	1.1	5.6	0	1	1.8	1.65	5.6	–	1.1
96/97	1	1.65	1.8	1.1	5.6	2.5	1	1.8	1.65	5.6	–	1.1
97/98	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
98/99	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
99/00	1	1.65	1.8	1.1	5.6	2.5	1	1.8	1.65	5.6	–	1.1
00/01	1	1.65	1.8	1.1	5.6	2.5	1	1.8	1.65	5.6	–	1.1
01/02	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–[1]	1.1
02/03	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–[1]	1.1
03/04	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–[1]	1.1
04/05	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
05/06	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
06/07	1	1.65	1.8	1.1	5.6	2.5	1	1.8	1.65	5.6	–	1.1
07/08	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
08/09	1	1.65	1.8	1.1	5.6	2.5	1	1.8	1.65	5.6	–	1.1
09/10	1	1.65	1.8	1.1	5.6	2.5	1	1.8	1.65	5.6	–	1.1
10/11	1	1.65	1.8	1.1	5.6	3.1	1	1.8	1.65	5.6	–	1.1
11/12	1	1.65	1.8	1.1	5.6	3.1	1	1.8	1.65	5.6	–	1.1
12/13	1	1.65	1.8	1.1	5.6	3.1	1	1.8	1.65	5.6	–	1.1
13/14	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
14/15	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.1
15/16	1	1.65	1.8	1.1	5.6	2.5	1	1.8	1.65	5.6	–	1.1
16/17	1	1.65	1.8	1.1	5.6	–	1	1.8	1.65	5.6	–	1.8

[1] there are no associated conversion factors with the MKF landings summarised in Table 8B.

Table 8B: Total reported green weight for the five most important state codes by fishing year in the edited file used to process RCO 2 and RCO 3 landing data. These data summaries are by RCO QMA over the period 1989–90 to 2016–17. '–': no observations.

	Landed state code											
Fishing	RCO 2						RCO 3					
year	GRE	HGU	DRE	GUT	MEA	Other	GRE	DRE	HGU	MEA	MKF	Other
89/90	75.1	1.8	–	0.2	–	0.1	5 743.5	–	319.2	0.8	–	47.5
90/91	62.7	1.1	0.0	0.3	–	0.0	3 696.7	149.9	176.4	32.6	–	7.6
91/92	92.5	10.1	12.9	0.6	–	–	5 276.3	365.5	96.2	15.1	–	35.8
92/93	247.8	89.6	19.7	6.9	0.9	–	6 894.6	707.1	157.5	11.5	–	89.9
93/94	321.4	78.7	52.3	8.3	4.5	–	6 512.7	454.3	213.3	65.1	–	113.4
94/95	469.9	207.2	29.5	11.3	6.3	0.0	10 391.7	715.5	183.7	17.7	–	23.6
95/96	326.1	158.0	49.0	12.0	11.3	0.1	8 888.1	484.2	118.9	5.0	–	57.5
96/97	257.2	61.5	55.5	11.3	7.0	0.3	8 415.3	961.6	77.1	7.1	–	16.0
97/98	131.9	35.5	15.7	8.2	3.6	0.1	7 536.6	2 031.2	79.4	41.0	–	24.9
98/99	245.1	62.2	24.7	2.0	0.0	1.3	12 221.6	1 384.4	74.2	18.7	–	264.7
99/00	129.3	15.7	3.6	1.2	0.0	0.4	3 398.6	1 240.4	107.5	19.7	–	5.4
00/01	101.8	7.0	10.8	0.7	0.1	0.4	1 759.4	949.5	53.3	10.1	–	7.5
01/02	117.4	8.1	29.4	0.3	0.0	0.3	2 018.8	722.5	44.9	22.2	0.2	10.3
02/03	118.1	13.1	10.5	0.8	0.5	–	3 847.4	1 101.4	137.3	20.5	0.6	6.6
03/04	201.1	15.8	5.2	1.7	0.2	0.1	5 631.0	1 067.4	170.2	42.8	628.4[1]	116.3
04/05	387.4	20.0	3.1	0.3	0.2	–	2 881.2	1 115.6	111.7	24.8	–	21.6
05/06	337.9	24.0	5.1	1.1	0.7	–	2 191.6	992.7	80.6	15.0	–	3.0
06/07	243.0	12.2	6.1	0.5	0.5	0.0	1 096.2	645.9	76.2	24.9	–	1.5
07/08	207.2	16.6	4.6	1.3	0.2	–	2 090.0	1 033.2	46.2	26.7	–	6.0
08/09	196.6	12.0	2.6	2.3	0.3	0.0	1 884.7	608.4	42.7	20.7	–	1.4
09/10	322.8	33.4	9.4	2.0	0.4	0.0	2 198.8	706.1	44.7	24.3	–	5.5
10/11	472.2	9.0	7.1	3.3	0.2	0.0	2 265.9	2 156.6	58.5	54.8	–	6.4
11/12	544.3	7.8	12.9	2.3	0.3	0.1	3 695.3	1 495.7	58.9	44.5	–	1.0
12/13	282.0	5.4	3.5	1.1	0.4	0.0	3 908.5	1 265.6	49.7	34.2	–	1.2
13/14	157.5	1.2	8.0	1.2	0.5	–	3 060.2	1 234.7	41.7	39.3	–	5.5
14/15	136.8	1.5	1.8	0.6	0.2	–	1 457.5	642.8	30.9	26.3	–	7.8
15/16	398.3	5.4	1.8	1.6	0.1	0.0	2 831.0	840.5	30.0	88.7	–	15.4
16/17	375.7	4.1	1.4	1.4	0.2	–	3 198.2	1 164.6	76.1	53.6	–	99.6
Total	6 959.1	917.7	386.0	84.7	38.5	3.3	124 991.4	26 237.4	2 757.1	807.9	629.1	1 002.9

[1] this value is likely to be in error

2.3.2.2 State codes in the RCO landing data

About 80% of the valid landing data for RCO 2 and RCO 3 were reported using state code GRE, indicating that most RCO are landed green. This removes the need to convert the processed weight into the original unprocessed weight (Table 7). Most of the remaining landings (18–20%) were divided between two primary state codes (DRE and HGU). There is no evidence in the data of changes over time in the conversion factors used for RCO (Table 8).

Total landings are available in the data set for RCO 2 and RCO 3 while landings for RCO 1 and RCO 7 will be incomplete because they are only present if these QMAs were taken in conjunction when fishing for either RCO 2 or RCO 3 (Table 9).

Table 9: Distribution of total landings (t) by red cod Fishstock and by fishing year for all trips that recorded RCO landings, regardless of QMA, in the replog 11581 data set. One trip with an improbable green weight has been dropped.

Fishing year	RCO 1	RCO 2	RCO 3	RCO 7	Total
89/90	0.3	77.3	6 111.0	204.3	6 392.9
90/91	7.4	64.1	4 063.2	202.1	4 336.9
91/92	1.7	116.0	5 788.9	281.0	6 187.6
92/93	1.9	364.8	7 860.6	486.5	8 713.8
93/94	6.8	465.1	7 358.8	548.1	8 378.8
94/95	10.6	724.1	11 332.1	1 037.8	13 104.7
95/96	37.2	556.6	9 553.8	1 094.3	11 241.9
96/97	6.8	392.9	9 477.1	1 553.1	11 429.8
97/98	5.9	194.9	9 713.2	1 147.7	11 061.7
98/99	30.7	335.4	13 963.7	856.0	15 185.8
99/00	1.3	150.2	4 771.6	379.0	5 302.1
00/01	4.6	120.8	2 779.5	737.4	3 642.3
01/02	4.1	155.5	2 818.8	569.1	3 547.4
02/03	15.5	143.0	5 113.8	569.3	5 841.6
03/04	8.0	224.0	7 656.0	859.1	8 747.1
04/05	5.0	411.0	4 155.0	671.1	5 242.0
05/06	9.7	368.8	3 282.9	807.2	4 468.6
06/07	7.0	262.4	1 844.7	784.7	2 898.8
07/08	4.6	229.8	3 202.1	490.2	3 926.7
08/09	25.6	213.8	2 557.8	376.3	3 173.6
09/10	8.6	368.0	2 979.4	437.3	3 793.4
10/11	13.5	491.8	4 542.1	737.4	5 784.8
11/12	23.1	567.7	5 295.4	955.3	6 841.5
12/13	2.6	292.4	5 259.2	760.1	6 314.4
13/14	6.7	168.4	4 381.4	499.5	5 055.9
14/15	5.3	140.8	2 165.3	637.2	2 948.5
15/16	9.5	407.1	3 805.7	632.0	4 854.3
16/17	6.4	382.8	4 592.0	349.7	5 330.9
Total	270.3	8 389.5	156 425.4	18 662.9	183 748.0

Table 10A: Distribution by form type for landed catch by weight for each fishing year in the RCO 2 landings data set. Also provided are the number of days fishing and the associated distribution of days fishing by form type for the effort data in the RCO 2 data set. See Appendix A for definitions of abbreviations used in this table. '–': cell not available or applicable.

Fishing	Landings (%)[1]			Days fishing (%)[2]					Days fishing						
year	CELR	CLR	NCELR	CELR	TCEPR	TCER	NCELR	LTCER	CELR	TCEPR	TCER	NCELR	LTCER	LCER	Total
89/90	99	1	0	78	22	–	–	–	2 158	615	–	–	–	–	2 773
90/91	94	6	0	82	18	–	–	–	2 651	584	–	–	–	–	3 235
91/92	83	17	0	75	25	–	–	–	3 801	1 270	–	–	–	–	5 071
92/93	91	9	0	78	22	–	–	–	6 135	1 687	–	–	–	–	7 822
93/94	76	24	0	77	23	–	–	–	6 222	1 807	–	–	–	–	8 029
94/95	77	23	0	80	20	–	–	–	6 499	1 604	–	–	–	–	8 103
95/96	64	36	0	73	27	–	–	–	5 977	2 216	–	–	–	–	8 193
96/97	55	45	0	72	28	–	–	–	5 281	2 086	–	–	–	–	7 367
97/98	61	39	0	71	29	–	–	–	4 303	1 767	–	–	–	–	6 070
98/99	43	57	0	71	29	–	–	–	4 207	1 747	–	–	–	–	5 954
99/00	23	77	0	67	33	–	–	–	3 015	1 487	–	–	–	–	4 502
00/01	52	48	0	69	31	–	–	–	3 587	1 631	–	–	–	–	5 218
01/02	50	50	0	66	34	–	–	–	3 869	2 035	–	–	–	–	5 904
02/03	45	55	0	68	32	–	–	–	3 983	1 910	–	–	–	–	5 893
03/04	45	55	0	71	28	–	–	–	4 032	1 564	–	–	–	53	5 649
04/05	47	53	0	72	27	–	–	–	4 820	1 770	–	–	–	72	6 662
05/06	55	45	0	74	25	–	–	–	4 969	1 665	–	–	–	104	6 738
06/07	61	38	1.51	55	25	–	18	–	3 704	1 716	–	1 205	–	162	6 787
07/08	2.7	95	2.08	4.7	21	49	18	3.2	318	1 396	3 299	1 225	214	276	6 728
08/09	4.8	94	1.47	7.1	21	48	17	3.4	493	1 443	3 313	1 206	238	238	6 931
09/10	1.4	97	1.21	5.5	21	51	16	4.4	417	1 573	3 929	1 214	338	180	7 651
10/11	1.7	98	0.44	6.3	15	54	16	6.1	468	1 148	4 048	1 187	451	139	7 441
11/12	1.8	98	0.38	7.6	16	54	15	6.5	526	1 116	3 736	1 061	450	19	6 908
12/13	1.5	98	0.54	6.4	14	58	16	6.4	402	865	3 639	995	404	10	6 315
13/14	1.3	98	0.82	5.4	21	56	12	5.2	346	1 326	3 570	781	329	–	6 352
14/15	1.2	98	0.74	5.4	21	56	13	4.0	293	1 116	3 039	726	214	–	5 388
15/16	1.3	98	0.38	4.4	16	58	17	4.9	251	884	3 332	942	278	13	5 700
16/17	1.3	98	0.34	3.9	21	56	14	5.1	215	1 169	3 096	794	284	5	5 563
Total[3]	62	38	–	72	27	–	–	–	4 401	1 620	–	–	–	–	6 109
Total[4]	1.9	97	0.84	5.7	19	54	16	4.9	3 729	12 036	35 001	10 131	3 200	880	64 977

[1] Percentages of landed green weight
[2] Percentages of number of days fishing
[3] total or average: 1989–90 to 2006–07 only
[4] total or average: 2007–08 to 2016–17 only

Table 10B: Distribution by form type for landed catch by weight for each fishing year in the RCO 3 landings data set. Also provided are the number of days fishing and the associated distribution of days fishing by form type for the effort data in the RCO 3 data set. See Appendix A for definitions of abbreviations used in this table. '–': cell not available or applicable.

Fishing	Landings (%)[1]			Days fishing (%)[2]					Days fishing						
year	CELR	CLR	NCELR	CELR	TCEPR	TCER	NCELR	LCER	CELR	TCEPR	TCER	NCELR	LTCER	LCER	Total
89/90	51	49	0	65	35	–	–	–	7 333	4 003	–	–	–	–	11 336
90/91	70	30	0	62	38	–	–	–	7 087	4 356	–	–	–	–	11 444
91/92	45	55	0	57	43	–	–	–	7 557	5 757	–	–	–	–	13 314
92/93	50	50	0	60	40	–	–	–	8 580	5 751	–	–	–	–	14 331
93/94	62	38	0	65	35	–	–	–	9 768	5 311	–	–	–	–	15 079
94/95	63	37	0	60	40	–	–	–	9 691	6 384	–	–	–	–	16 075
95/96	52	48	0	56	44	–	–	–	9 057	7 015	–	–	–	–	16 072
96/97	60	40	0	60	40	–	–	–	10 029	6 571	–	–	–	–	16 600
97/98	48	52	0	56	44	–	–	–	9 519	7 468	–	–	–	–	16 987
98/99	59	41	0	54	46	–	–	–	9 182	7 823	–	–	–	–	17 005
99/00	51	49	0	53	47	–	–	–	8 820	7 934	–	–	–	–	16 754
00/01	52	48	0	50	50	–	–	–	8 288	8 376	–	–	–	–	16 664
01/02	62	38	0	48	52	–	–	–	7 464	8 048	–	–	–	–	15 512
02/03	54	46	0	50	50	–	–	–	8 378	8 411	–	–	–	–	16 789
03/04	57	43	0	49	49	–	–	2.9	7 846	7 836	–	–	–	470	16 152
04/05	59	41	0	47	49	–	–	3.8	8 282	8 764	–	–	–	679	17 725
05/06	61	39	0	49	48	–	–	3.1	7 830	7 687	–	–	–	489	16 006
06/07	63	35	1.90	43	46	–	6.8	3.9	6 195	6 642	–	977	–	559	14 373
07/08	6.0	93	0.75	6.5	48	33	6.7	4.6	836	6 105	4 191	851	188	593	12 764
08/09	9.2	90	0.67	7.7	44	37	6.5	3.9	1 013	5 800	4 838	855	194	516	13 216
09/10	6.1	93	0.40	6.1	40	42	5.7	3.8	818	5 367	5 633	765	221	502	13 306
10/11	2.9	97	0.38	5.8	44	37	6.4	4.3	809	6 122	5 090	889	358	594	13 862
11/12	3.6	96	0.38	6.4	41	40	6.5	3.9	836	5 321	5 159	847	288	511	12 962
12/13	5.2	95	0.30	6.6	38	43	6.2	1.9	915	5 297	5 895	853	555	257	13 772
13/14	5.1	95	0.17	7.2	36	44	5.0	2.8	1 014	5 141	6 272	709	569	399	14 104
14/15	5.5	94	0.26	6.3	40	41	6.0	2.8	778	4 940	5 019	736	538	350	12 361
15/16	5.2	94	0.57	7.3	39	37	7.7	5.1	882	4 753	4 505	937	410	621	12 108
16/17	4.1	96	0.20	7.1	39	39	7.4	5.0	957	5 239	5 219	998	415	682	13 510
Total[3]	57	43	–	55	44	–	–	–	8 384	6 897	–	–	–	–	15 457
Total[4]	5.3	94	0.41	6.7	41	39	6.4	3.8	8 858	54 085	51 821	8 440	3 736	5 025	131 965

[1] Percentages of landed green weight
[2] Percentages of number of days fishing
[3] total or average: 1989–90 to 2006–07 only
[4] total or average: 2007–08 to 2016–17 only

Table 11: Distribution (in %) of formtype in RCO 2 and RCO 3, weighted by landings, in the analysis data set. See Appendix A for definitions of abbreviations used in this table. '–': cell not available or applicable.

Fishing						RCO 2						RCO 3
year	CELR	TCEPR	TCER	NCELR	LTCER	LCER	CELR	TCEPR	TCER	NCELR	LTCER	LCER
89/90	99.6	0.4	–	–	–	–	55.4	44.6	–	–	–	–
90/91	96.0	4.0	–	–	–	–	71.6	28.4	–	–	–	–
91/92	85.5	14.5	–	–	–	–	45.4	54.6	–	–	–	–
92/93	93.0	7.0	–	–	–	–	49.4	50.6	–	–	–	–
93/94	80.2	19.8	–	–	–	–	62.7	37.3	–	–	–	–
94/95	80.2	19.8	–	–	–	–	63.5	36.5	–	–	–	–
95/96	78.3	21.7	–	–	–	–	51.9	48.1	–	–	–	–
96/97	72.2	27.8	–	–	–	–	59.0	41.0	–	–	–	–
97/98	70.1	29.9	–	–	–	–	48.1	51.9	–	–	–	–
98/99	55.5	44.5	–	–	–	–	59.2	40.8	–	–	–	–
99/00	33.0	67.0	–	–	–	–	51.1	48.9	–	–	–	–
00/01	53.1	46.9	–	–	–	–	52.8	47.2	–	–	–	–
01/02	50.7	49.3	–	–	–	–	62.1	37.9	–	–	–	–
02/03	46.3	53.7	–	–	–	–	53.8	46.2	–	–	–	–
03/04	50.9	49.0	–	–	–	0.0	56.4	43.4	–	–	–	0.2
04/05	61.6	38.4	–	–	–	0.0	58.9	40.5	–	–	–	0.6
05/06	62.8	36.9	–	–	–	0.3	60.9	38.3	–	–	–	0.8
06/07	66.5	31.6	–	1.1	–	0.7	62.8	33.4	–	1.9	–	1.9
07/08	3.6	18.0	75.1	1.8	0.6	0.9	5.8	30.0	62.1	0.7	0.1	1.2
08/09	2.2	20.6	74.4	1.3	0.9	0.7	8.6	26.3	62.8	1.0	0.4	1.0
09/10	1.3	15.9	81.4	0.7	0.6	0.1	5.9	28.6	64.3	0.6	0.4	0.3
10/11	1.7	17.5	80.0	0.3	0.5	0.0	2.7	55.1	41.2	0.5	0.1	0.4
11/12	1.7	4.7	92.8	0.3	0.5	0.0	3.4	34.2	61.2	0.6	0.1	0.5
12/13	1.3	2.8	94.8	0.4	0.7	0.0	5.1	27.7	66.0	0.4	0.2	0.6
13/14	1.1	7.1	89.9	0.4	1.5	–	4.9	28.5	65.3	0.2	0.4	0.7
14/15	0.9	8.8	88.3	0.3	1.7	–	5.3	28.4	64.2	0.4	0.9	0.9
15/16	1.3	4.4	93.6	0.3	0.4	–	5.1	35.6	57.2	0.7	0.5	0.8
16/17	1.2	11.0	86.9	0.3	0.5	–	4.1	34.1	60.0	0.2	0.9	0.7
Average [1]	71.8	28.2	–	–	–	–	56.5	43.5	–	–	–	–
Average [2]	1.6	10.5	86.7	0.5	0.6	0.1	4.8	33.6	60.0	0.5	0.4	0.7

[1] 1989–90 to 2006–07 only
[2] 2007–08 to 2016–17 only

Table 12: Landings (t) scaled to QMR totals (Eq. 1) for the top ten statistical areas in terms of total 1989–90 to 2016–17 landings for the combined RCO 2 and RCO 3 fisheries.

Fishing	Statistical Area											
year	022	020	024	602	030	026	018	028	013	014	027	OTH	Total
89/90	3 854	1 908	301	69	127	78	108	16	15	1	2	215	6 695
90/91	2 582	942	404	82	133	45	144	39	4	2	7	317	4 700
91/92	3 911	868	733	140	276	108	203	35	81	69	71	379	6 875
92/93	5 919	1 687	519	113	197	92	908	52	200	105	51	233	10 076
93/94	4 218	2 232	639	86	179	125	332	27	217	107	15	278	8 455
94/95	6 545	1 938	2 825	72	228	289	385	42	376	145	58	463	13 366
95/96	6 228	1 929	1 392	35	143	296	616	44	247	78	41	513	11 562
96/97	5 544	1 561	1 206	42	243	519	396	86	80	50	207	495	10 429
97/98	5 843	2 507	403	18	243	254	331	94	41	40	28	340	10 143
98/99	10 107	1 336	1 058	100	517	329	119	156	60	73	43	304	14 202
99/00	2 633	914	296	82	275	127	80	142	8	14	31	350	4 954
00/01	884	743	83	48	357	67	196	85	10	22	15	377	2 889
01/02	997	701	142	97	194	83	250	152	19	42	25	305	3 006
02/03	2 646	942	390	219	177	197	131	88	16	20	49	374	5 251
03/04	4 689	1 493	227	662	159	247	60	55	37	23	11	286	7 949
04/05	1 564	1 298	139	211	171	177	56	213	100	47	217	442	4 635
05/06	1 215	786	175	195	262	148	53	205	77	75	52	353	3 596
06/07	468	498	104	71	164	116	54	134	60	41	55	368	2 133
07/08	842	634	138	316	110	318	281	249	57	57	22	438	3 461
08/09	1 014	596	137	128	131	94	37	223	64	70	20	240	2 754
09/10	1 201	462	440	257	91	132	28	231	138	107	47	228	3 362
10/11	2 327	385	153	786	279	154	43	251	203	102	57	327	5 069
11/12	3 283	281	224	455	297	211	50	299	245	190	84	318	5 936
12/13	3 132	578	148	383	350	186	29	267	131	91	49	251	5 594
13/14	1 860	411	418	303	311	630	41	188	36	42	84	251	4 576
14/15	504	312	347	238	179	225	44	95	17	58	31	263	2 313
15/16	1 829	549	125	579	135	118	100	204	198	147	11	262	4 256
16/17	2 429	372	119	730	210	213	35	195	129	160	42	293	4 927
Total	88 269	28 865	13 283	6 516	6 138	5 581	5 111	3 867	2 868	1 980	1 422	9 263	173 164

2.3.2.3 Form types used in the RCO landing and effort data

There are a range of form types used by Fisheries New Zealand to collect catch and effort data (see Appendix A and Ministry of Fisheries 2010). The daily CELR form is an all-purpose form which reports effort, estimated catch and landings and has been in use by the entire inshore fleet since mid-1989. Deepwater vessels have used the event-based TCEPR form to report effort/estimated catch and the corresponding CLR form to report landings, again beginning in July 1989. The event-based TCER form replaced the CELR form in October 2007 for trawl vessels between 6 and 28 m. As with the TCEPR form, this form only reports effort/estimated catch. Landings are reported on the CLR form. Other event based form types tailored to specific capture methods were introduced in the mid-2000s, replacing the all-purpose daily CELR reporting (e.g., NCELR, LTCER). However, the fishing methods using these forms do not catch significant amounts of red cod.

These temporal changes in the form types used to report red cod catch and effort described in the previous paragraph are reflected in the RCO landings data. The percentage of RCO landings which used the all-purpose CELR form dropped from a pre-2007–08 average of 62% for RCO 2 (Table 10A) and 57% for RCO 3 (Table 10B) to a post-2007–08 average of 2% for RCO 2 and 5% for RCO 3. Similarly, a pre-2007–08 average of 72% of the days fishing in RCO 2 and 57% for RCO 3 were reported dropped to a post-2007–08 average of 6% for RCO 2 (Table 10A) and 7% for RCO 3 (Table 10B). The deepwater TCEPR forms represent a significant component of the days fishing that report RCO landings, contributing a pre-2007–08 average of 27% in RCO 2 (Table 10A) and 44% in RCO 3 (Table 10B). The percentages of effort collected on the TCEPR form dropped somewhat after the introduction of the TCER forms in 2007–08, reducing to 19% in RCO 2 (Table 10A) and 41% in RCO 3 (Table 10B). However, not all the effort collected on the TCEPR forms will be directed towards RCO, as the deepwater fleet fishes a range of targets and the days fishing summations in Table 10 reflect the entire trip, not just days fishing that resulted in RCO catch.

It is not possible to use the form type to distinguish between TCEPR and TCER landings because fishing from both of these form types use the same CLR form. We can use the matched effort and landing file represented by the 'analysis' data set (see Table 2 and Figure 3) to estimate the percentage of landings by form type, with a post-2007–08 average of 11% of the landings reported on the TCEPR form and 87% reported on the TCER form in RCO 2 (Table 11). The equivalent percentages for the post-2007–08 average form use in RCO 3 are 37% and 60% for the TCEPR and TCER forms respectively. It appears that the deepwater fleet captures proportionately more red cod in RCO 3 than in RCO 2.

2.3.3 Description of the RCO 2 and RCO 3 fisheries

2.3.3.1 Introduction

As discussed in Section 2.3.1, landings were matched with effort for every trip while maintaining the integrity of the QMA-specific information. This procedure worked well for RCO 3 where only 2% of the landing data were lost from the matching procedure (see column headed '`% analysis/landed`' in Table 2). The matching procedure worked less well for RCO 2, whereby about 17% of the landing data were discarded (see column headed '`% analysis/landed`' in Table 2). Table 4 demonstrates that the loss of RCO 2 landings occurs almost entirely in the shared east and west Cook Strait statistical areas, where the RCO 2 catches are mixed with landings from RCO 3 and RCO 7. This amount of lost landings was considered acceptable for the purposes of characterising the fishery (especially since the alternative of keeping all the data would exaggerate the importance of the RCO 2 fisheries in Cook Strait), but was not accepted for CPUE analyses, where trips were assigned to statistical areas without maintaining the integrity of the QMA information. The CPUE analysis data were then selected on the basis of the statistical area fished rather than by the QMA.

Table 12 shows the distribution of red cod landings by fishing year for the top 11 statistical areas in terms of total accumulated RCO landings. The top statistical area in terms of total landings is Area 022 (Canterbury Bight), which exceeds all other statistical areas by a wide margin and accounts for just over 50% of the total combined RCO landings over the 29 years of available data. The two statistical areas to the north (Area 020, Pegasus Bay) and to the south (Area 024, Otago) account for another 25% of the total accumulated landings (Table 12). Only two of the RCO 2 statistical areas appear in the top 11 landings (Areas 013 and 014, central North Island east coast) which account for only 3% of the total landings.

The characterisation analysis divides RCO 2 into three regions or sub-areas using statistical areas combined into logical units (Table 13): A) the five statistical areas on the east coast of the North Island (including the six outer deepwater statistical areas); B) four eastern Cook Strait statistical areas; and C) four statistical areas comprising the western part of Cook Strait plus two additional statistical areas (041 and 801) on the north side of Cape Egmont.

The characterisation analysis also divides RCO 3 into three regions or sub-areas using statistical areas combined into logical units (Table 13): A) the five statistical areas on the east coast of the South Island (this is the core fishing region for NZ red cod); B) a suite of 20 statistical areas to the east of the five inshore statistical areas, including all the Chatham Rise statistical areas; and C) the inshore Foveaux Strait statistical areas combined with 28 sub-Antarctic statistical areas.

Table 13: Divisions of the RCO 2 and RCO 3 spatial data into statistical area aggregations, showing the selection of statistical areas included in each sub-area designation.

Sub-area long name	Coded name	Statistical areas included
East coast North Island (RCO 2)	ECNI(RCO2)	011–015, 201–206
Eastern Cook Strait (RCO 2)	E Cook St(RCO2)	016–019
Western Cook Strait (RCO 2)	W Cook St(RCO2)	036, 037, 039–041, 801
East coast South Island (inside) (RCO 3)	Inside(RCO3)	018, 202, 022, 024, 026
East coast South Island (outside) (RCO 3)	Outside(RCO3)	019, 021, 023, 049–052, 301-303, 401–412
Foveaux Strait and outside waters (RCO 3)	Foveaux St(RCO3)	025, 027–032, 501–504, 601-625

2.3.3.2 Distribution of landings and effort by method of capture and QMA

Red cod are taken almost entirely by bottom trawl (BT) in all six sub-areas (Figure 5; Table 14; Table C.1; Table D.1), with BT accounting for 94% of the RCO 2 landings (97% in the most recent five years) and 95% of the RCO 3 landings (90% in the most recent five years). Other capture methods are relatively insignificant, accounting for 1% to 4% of accumulated landings (Table 14). Figure 5 shows that there are some bottom longline landings of red cod in the three ‘outside’ areas [W Cook St (RCO 2), Outside (RCO 3), Foveaux St (RCO 3)], while there is an emerging Danish seine fishery on RCO in Inside (RCO 3) (Figure 5; Table D.1). Midwater trawl (MW) only shows up in E Cook St (RCO 2) for about 10 years in the late 1990s/early 2000s (Table C.1) and in the Foveaux St (RCO 3) sub-area (Table D.1), where red cod appear to be taken in conjunction with the active squid fishery around the Auckland Islands (which accounts for the relatively large catches in Area 602 documented in Table 12).

2.3.3.3 Fine scale distribution of landings for bottom trawl

Fine scale location data with associated landings are available for the deepwater BT fleet from 1 Oct 1989 onwards and for the inshore BT fleet from 1 October 2007. Spatial distribution maps have been prepared which show mean landings per tow gridded into 0.1° × 0.1° cells, averaged over the most recent four years (North Island inshore: Figure 6; South Island inshore: Figure 7; South Island offshore: Figure 8). These plots show the extent of the red cod fishery as it applies to RCO 2 and RCO 3, including landings from RCO 1 and RCO 7 which were taken by vessels which also landed RCO 2 or RCO 3. The most recent four years were selected to characterise the spatial extent of the RCO 2 and RCO 3 fisheries because there is little evidence of much year to year variation in the spatial location of these fisheries. Averaging over the most recent four fishing years presents a complete picture of the current fishery while conforming to the Fisheries New Zealand data confidentiality restriction of at least three vessels in every displayed cell.

The North Island map (Figure 6) shows the east coast North Island fishery concentrated in Hawke’s Bay and the more northern part of the Wairarapa coast. It then extends into Cook Strait, with the highest mean catches occurring in Areas 016 and 017. There are also high catch rates off the Kapiti Coast (Area 039) and spilling into the top part of Area 018. Note that, although red cod is taken in the western part of Cook Strait (see Table C.1), the locations of these catches are not visible in Figure 6 because they are excluded due to the Fisheries New Zealand data confidentiality three vessel rule. Most of the catches in Area 016 and Area 017 are likely to be RCO 7. Table 4 indicates that only about 50% of the Area 016 landings and 10% of the Area 017 landings can be assigned to RCO 2. Because neither of these statistical areas are valid for RCO 3, the unassigned catches must be from RCO 7. Table 4 indicates that about 75% of the Area 018 landings can be assigned to RCO 3, with the remainder going to RCO 7 because less than 1% of the Area 018 landings are attributable to RCO 2.

The east coast South Island inshore fishery for red cod begins at the upper end of Pegasus Bay (still in Area 018) and extends nearly to the Otago Peninsula (Area 024) (Figure 7). It also extends out to about 400 m, conforming closely to that contour. There are "hot spots" for RCO in Foveaux Strait (Areas 025 and 030), but the greatest intensity for that fishery is in Canterbury Bight (Area 022) between the 100 to the 400 m depth contours. The wider South Island spatial map (Figure 8) shows red cod landings along both sides of the Chatham Rise, with small hot spots around the Chatham Islands. There are also landings along the Snares shelf, sitting on the 400 m contour, continuing uninterrupted to the Auckland Islands (Area 602) where the spatial extent of the landings broaden.

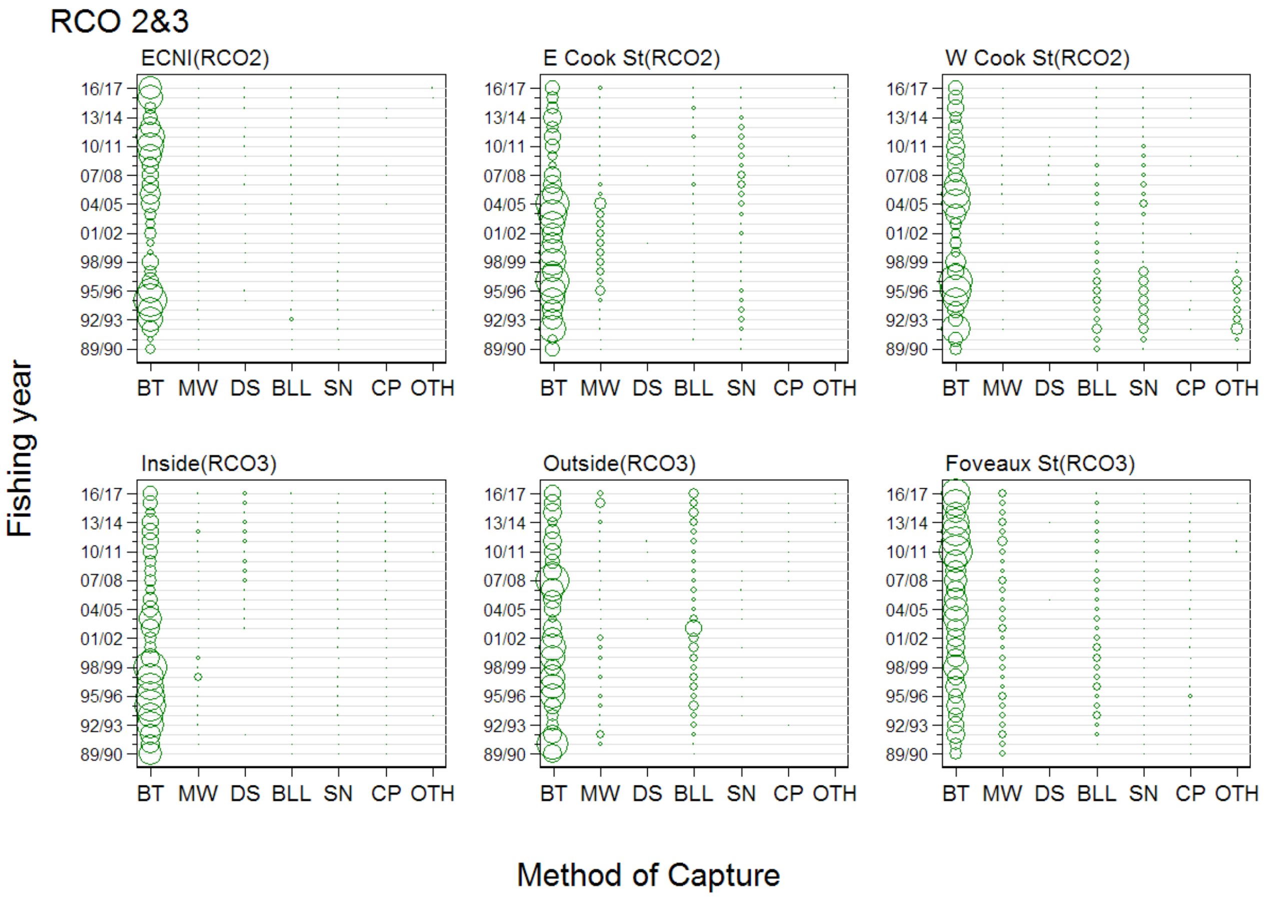

Figure 5: Distribution of red cod landings for the major fishing methods by fishing year in each RCO sub-area (Table 13) from 1989–90 to 2016–17. Circles are proportional to catch totals by method and fishing year within each sub-graph: [ECNI(RCO2)]: largest circle=606 t in 94/95 for BT; [E Cook St(RCO2)]: largest circle=121 t in 04/05 for BT; [W Cook St(RCO2)]: largest circle=94 t in 96/97 for BT; [Inside(RCO3)]: largest circle=12 902 t in 98/99 for BT; [Outside(RCO3)]: largest circle=269 t in 07/08 for BT; [Foveaux St(RCO3)]: largest circle=1 356 t in 10/11 for BT. Data for these plots are presented in Table C.1A and Table D.1A.

Table 14: Total landings (t) and distribution of landings (%) for red cod by fishing year for important fishing methods over the RCO QMAs from trips that landed red cod, summed from 1989–90 to 2016–17. See Appendix A for definitions of abbreviations used in this table.

Fishing	Capture method (t)							Capture method distribution (%)						
year	BT	MW	DS	BLL	SN	CP	Other	BT	MW	DS	BLL	SN	CP	Other
	RCO 2													
89/90	100	0.03	–	4.0	1.2	–	0.05	94.9	0.0	–	3.8	1.2	–	0.0
90/91	60	0.1	–	3.6	3.8	–	2.1	86.3	0.1	–	5.1	5.4	–	3.0
91/92	321	0.3	–	9.3	13	–	14	89.6	0.1	–	2.6	3.6	–	4.0
92/93	407	1.2	–	13	15	–	5.1	92.3	0.3	–	3.0	3.3	–	1.2
93/94	447	1.3	–	5.0	18	0.3	6.4	93.6	0.3	–	1.1	3.7	0.1	1.3
94/95	736	3.5	0.5	5.1	13	0.01	3.7	96.6	0.5	0.1	0.7	1.7	0.0	0.5
95/96	540	12	1.1	5.9	14	–	6.6	93.2	2.0	0.2	1.0	2.4	–	1.1
96/97	358	4.1	–	6.4	13	0.03	11	91.3	1.0	–	1.6	3.3	0.0	2.7
97/98	163	6.4	–	4.5	12	–	2.3	86.4	3.4	–	2.4	6.6	–	1.2
98/99	271	7.8	0.2	1.6	1.5	–	0.2	96.0	2.8	0.1	0.6	0.5	–	0.1
99/00	120	7.7	0.1	0.9	0.8	–	0.003	92.7	5.9	0.1	0.7	0.6	–	0.0
00/01	101	8.0	0.2	1.7	1.4	–	–	90.0	7.1	0.2	1.5	1.2	–	–
01/02	138	7.2	0.6	1.0	2.1	0.01	–	92.6	4.8	0.4	0.7	1.4	0.0	–
02/03	131	10	–	1.7	1.7	–	–	90.6	7.1	–	1.1	1.2	–	–
03/04	211	10	0.04	1.5	2.9	–	–	93.6	4.4	0.0	0.7	1.3	–	–
04/05	386	21	0.2	3.6	13	0.1	–	91.1	5.0	0.1	0.9	3.0	0.0	–
05/06	359	2.3	–	2.9	8.4	–	–	96.3	0.6	–	0.8	2.3	–	–
06/07	237	3.1	1.8	4.3	10	–	–	92.7	1.2	0.7	1.7	3.8	–	–
07/08	209	1.1	0.7	3.6	10	–	–	93.1	0.5	0.3	1.6	4.5	–	–
08/09	200	1.0	0.8	3.8	5.6	0.1	–	94.6	0.5	0.4	1.8	2.7	0.1	–
09/10	357	0.7	0.6	2.8	6.3	0.01	0.01	97.1	0.2	0.2	0.8	1.7	0.0	0.0
10/11	488	0.7	5.3	2.7	4.8	–	–	97.3	0.1	1.1	0.5	1.0	–	–
11/12	536	0.5	3.9	2.8	6.8	–	–	97.5	0.1	0.7	0.5	1.2	–	–
12/13	292	0.6	0.1	2.0	5.1	–	–	97.4	0.2	0.0	0.7	1.7	–	–
13/14	161	0.5	–	2.5	2.4	0.01	–	96.8	0.3	–	1.5	1.4	0.0	–
14/15	137	1.1	0.7	2.4	1.1	0.01	–	96.3	0.7	0.5	1.7	0.8	0.0	–
15/16	410	0.4	5.1	1.8	1.3	–	0.1	97.9	0.1	1.2	0.4	0.3	–	0.0
16/17	374	1.3	4.2	2.0	1.6	–	1.7	97.2	0.3	1.1	0.5	0.4	–	0.4
Total	8 251	114	26	103	189	0.6	54	94.4	1.3	0.3	1.2	2.2	0.0	0.6
last 5 years	1 374	3.8	10	11	12	0.03	1.8	97.3	0.3	0.7	0.8	0.8	0.0	0.1
	RCO 3													
89/90	6 535	49	–	0.01	4.3	0.3	–	99.2	0.7	–	0.0	0.1	0.0	–
90/91	4 551	72	–	3.3	2.9	0.3	–	98.3	1.6	–	0.1	0.1	0.0	–
91/92	6 376	113	0.3	20	6	0.7	–	97.8	1.7	0.0	0.3	0.1	0.0	–
92/93	9 457	134	–	30	12	1.2	–	98.2	1.4	–	0.3	0.1	0.0	–
93/94	7 769	91	–	82	21	2.8	12	97.4	1.1	–	1.0	0.3	0.0	0.1
94/95	12 390	102	–	74	29	7.7	–	98.3	0.8	–	0.6	0.2	0.1	–
95/96	10 795	117	–	27	16	28	–	98.3	1.1	–	0.2	0.1	0.3	–
96/97	9 864	25	–	126	18	4.1	–	98.3	0.3	–	1.3	0.2	0.0	–
97/98	8 908	937	–	78	22	7.7	–	89.5	9.4	–	0.8	0.2	0.1	–
98/99	13 753	82	–	70	4.1	11	–	98.8	0.6	–	0.5	0.0	0.1	–
99/00	4 508	184	–	111	11	10	–	93.5	3.8	–	2.3	0.2	0.2	–
00/01	2 619	30	–	97	26	4.3	–	94.3	1.1	–	3.5	0.9	0.2	–
01/02	2 707	39	–	100	9.3	2.3	–	94.7	1.3	–	3.5	0.3	0.1	–
02/03	4 849	119	15	105	15	2.9	–	95.0	2.3	0.3	2.1	0.3	0.1	–
03/04	7 497	70	58	80	13	5.0	–	97.1	0.9	0.7	1.0	0.2	0.1	–
04/05	4 012	56	68	41	21	13	–	95.3	1.3	1.6	1.0	0.5	0.3	–
05/06	3 066	19	67	27	17	27	–	95.1	0.6	2.1	0.8	0.5	0.8	–
06/07	1 670	47	70	39	37	15	–	89.0	2.5	3.7	2.1	2.0	0.8	–
07/08	2 914	81	158	44	26	13	–	90.1	2.5	4.9	1.4	0.8	0.4	–
08/09	2 238	36	173	34	29	32	–	88.0	1.4	6.8	1.4	1.1	1.3	–
09/10	2 739	40	143	22	21	29	–	91.5	1.4	4.8	0.7	0.7	1.0	–
10/11	4 316	77	97	23	27	23	5.6	94.5	1.7	2.1	0.5	0.6	0.5	0.1
11/12	4 990	149	149	32	41	24	1.6	92.6	2.8	2.8	0.6	0.8	0.5	0.0
12/13	4 675	288	234	44	27	27	–	88.3	5.4	4.4	0.8	0.5	0.5	–
13/14	3 952	186	161	48	15	48	0.01	89.6	4.2	3.7	1.1	0.3	1.1	0.0
14/15	1 946	64	88	38	11	25	–	89.6	3.0	4.0	1.7	0.5	1.1	–
15/16	3 484	79	169	51	30	24	0.7	90.8	2.0	4.4	1.3	0.8	0.6	0.0
16/17	4 137	138	155	72	12	28	0.4	91.1	3.0	3.4	1.6	0.3	0.6	0.0
Total	156 717	3 424	1 805	1 519	523	417	20	95.3	2.1	1.1	0.9	0.3	0.3	0.0
last 5 years	18 194	755	806	253	95	151	1.1	89.8	3.7	4.0	1.2	0.5	0.7	0.0

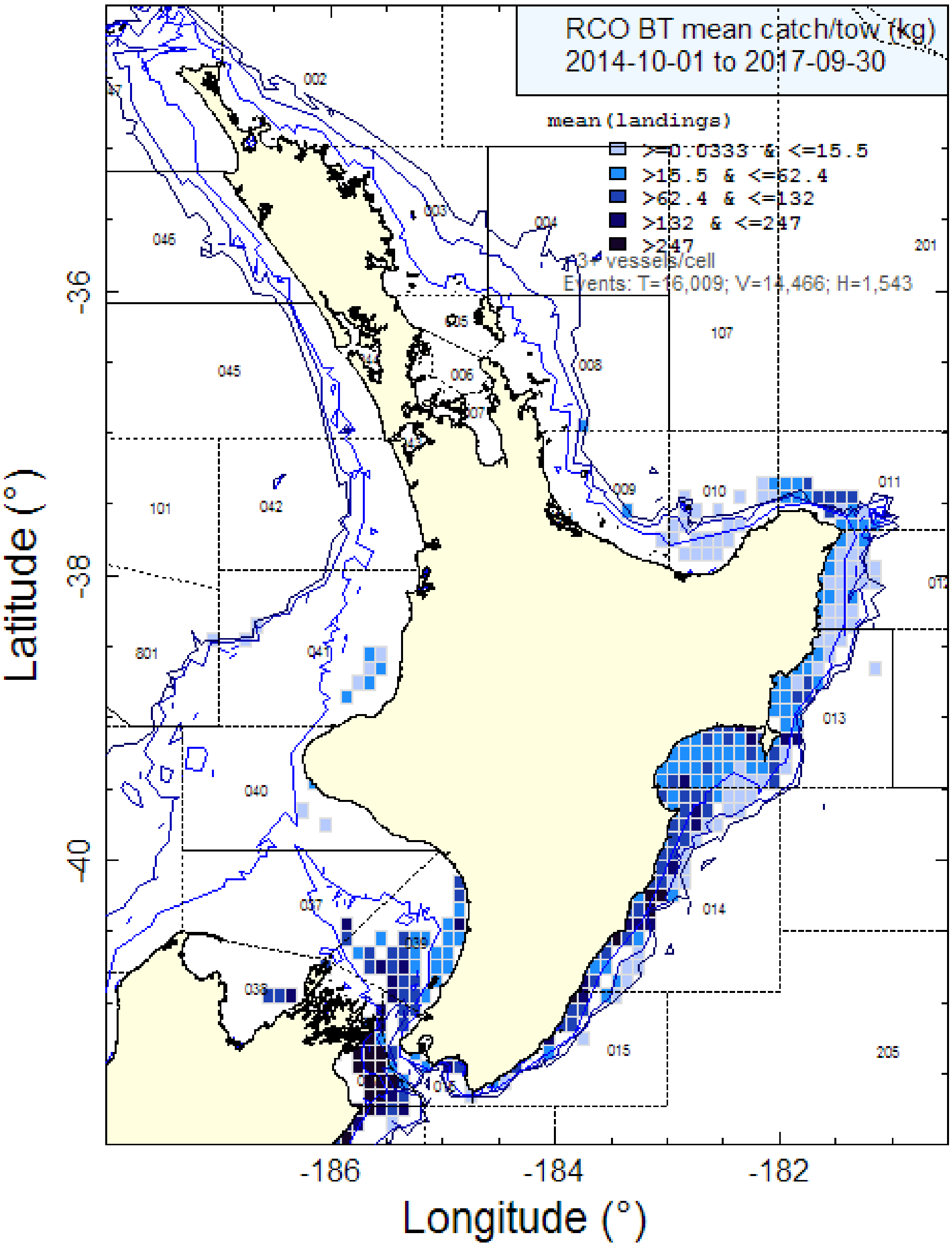

Figure 6: Spatial distribution of red cod bottom trawl landings (t) on the North Island, arranged in 0.1° × 0.1° grids, averaged over 2014–15 to 2016–17. Legend colours divide the distribution of total landings into 0–50, 50–75, 75–90, 90–95 and 95+ percentiles. Only grids that have at least three reporting vessels are plotted (1 543 tows omitted). Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

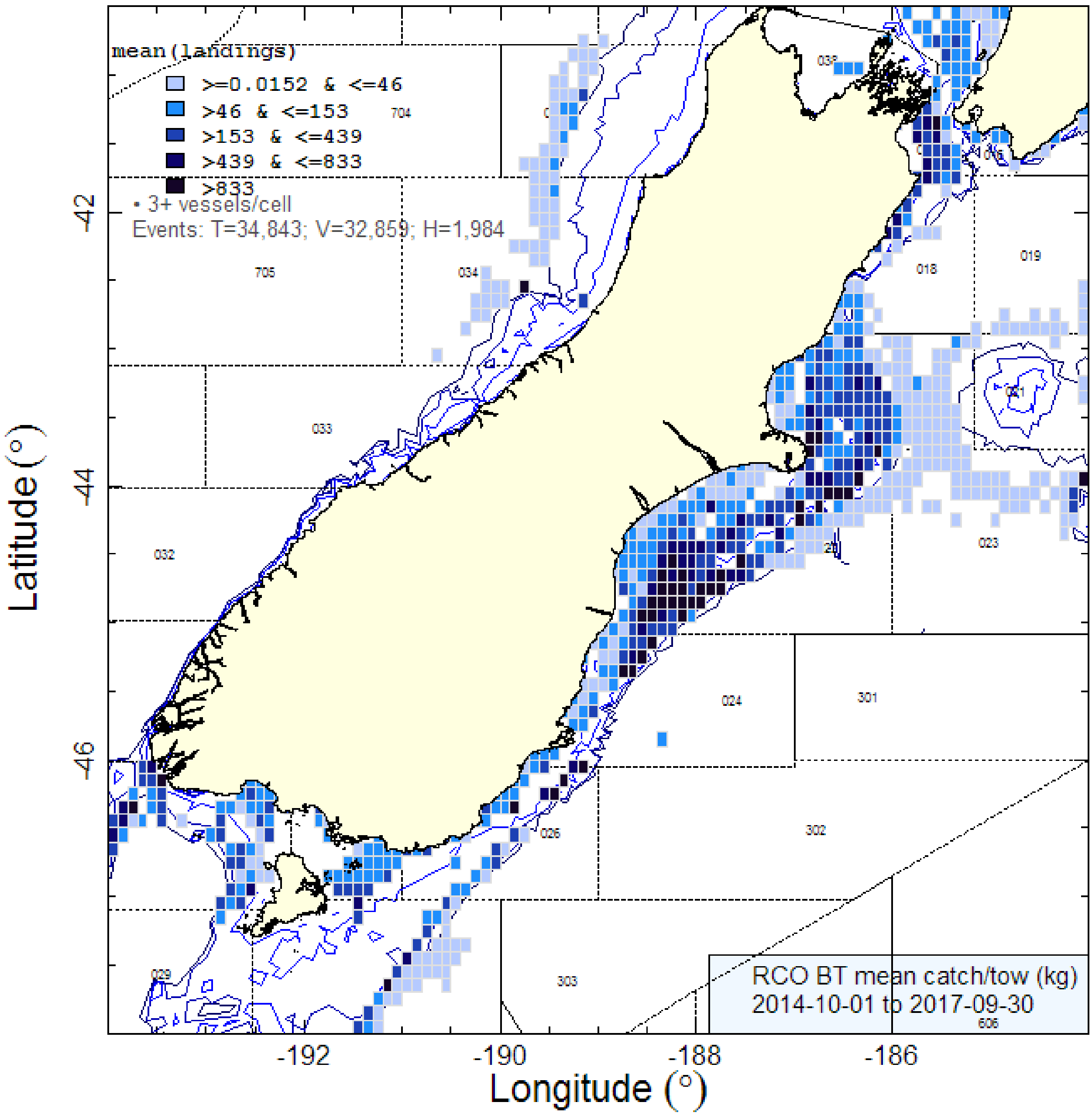

Figure 7: Spatial distribution of red cod bottom trawl landings (t) on the South Island, arranged in 0.1° × 0.1° grids, averaged over 2014–15 to 2016–17. Legend colours divide the distribution of total landings into 0–50, 50–75, 75–90, 90–95 and 95+ percentiles. Only grids that have at least three reporting vessels are plotted (1 984 tows omitted). Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.

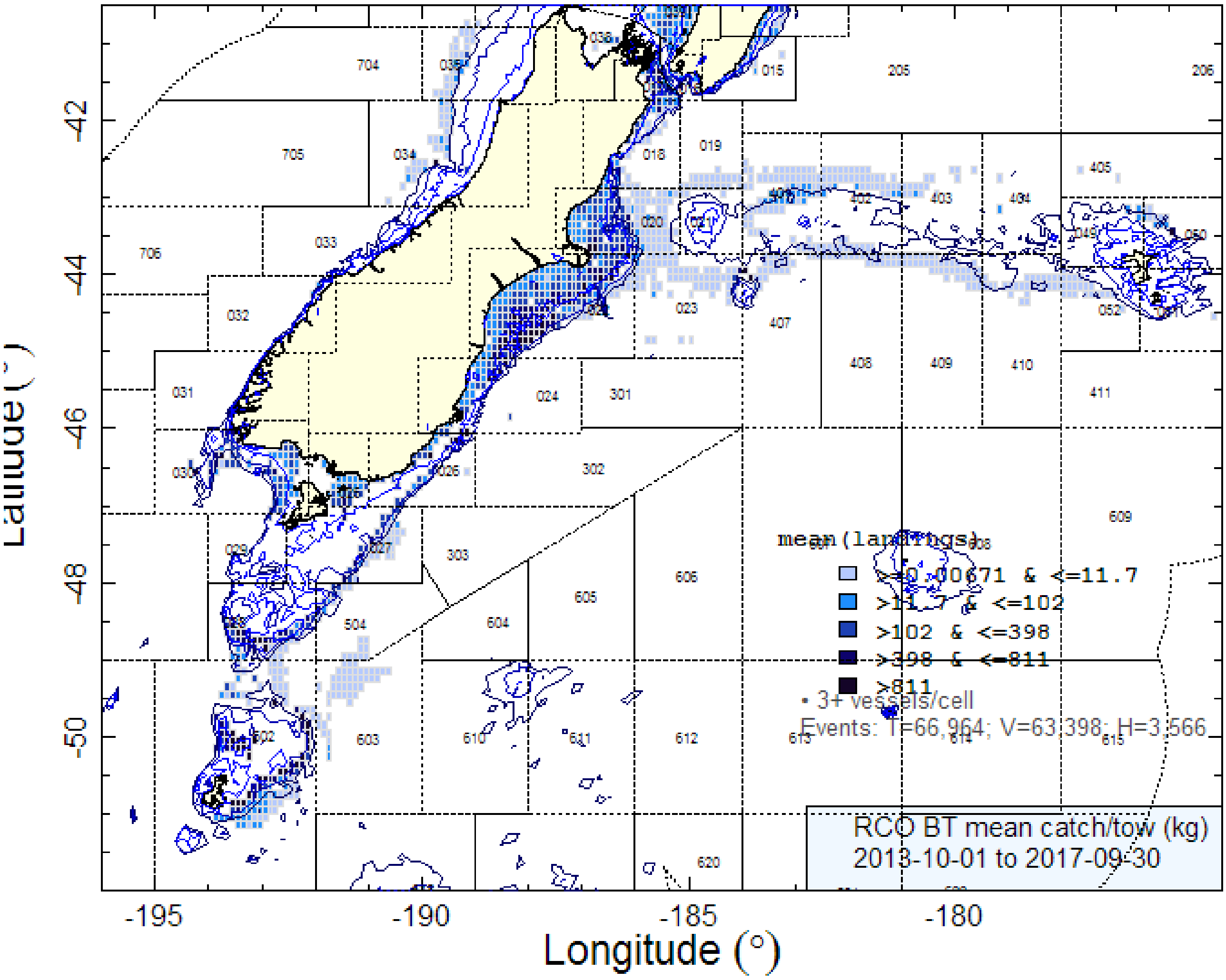

Figure 8: **Spatial distribution of red cod bottom trawl landings (t) on the South Island, arranged in 0.1° × 0.1° grids and showing a wider spatial distribution than in Figure 7, averaged over 2013–14 to 2016–17. Legend colours divide the distribution of total landings into 0–50, 50–75, 75–90, 90–95 and 95+ percentiles. Only grids that have at least three reporting vessels are plotted (3 566 tows omitted). Boundaries are shown for the general statistical areas plotted in Appendix B and the bathymetry indicates the 100 m, 200 m and 400 m depth contours.**

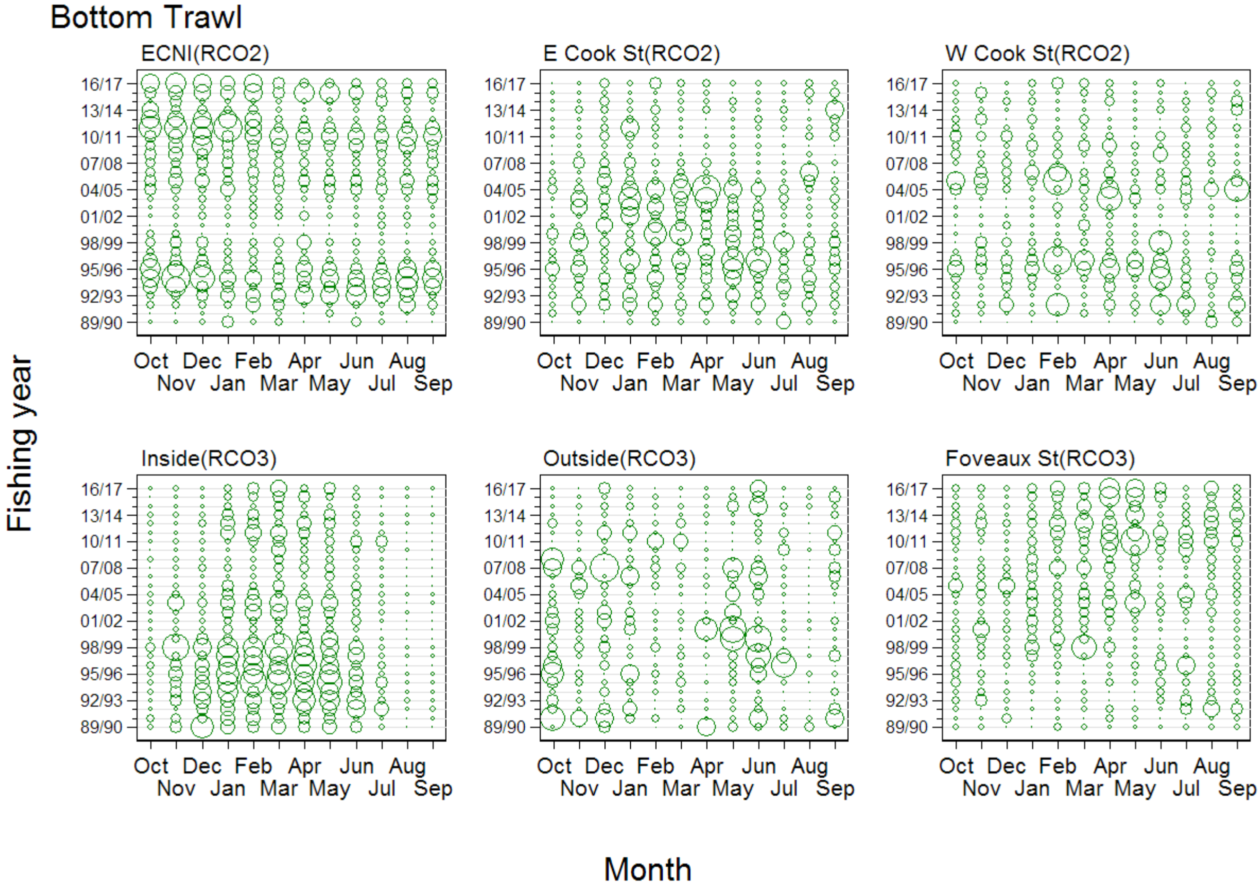

Figure 9: Distribution of landings by month and fishing year for bottom trawl in each RCO sub-area (Table 13) based on trips that landed red cod. Circle sizes are proportional within each panel: [ECNI(RCO2)]: largest circle= 106 t in 94/95 for Nov; [E Cook St(RCO2)]: largest circle= 34 t in 04/05 for Apr; [W Cook St(RCO2)]: largest circle= 28 t in 05/06 for Feb; [Inside(RCO3)]: largest circle=2779 t in 98/99 for Mar; [Outside(RCO3)]: largest circle= 86 t in 07/08 for Dec; [Foveaux St(RCO3)]: largest circle= 484 t in 10/11 for May. Values for the plotted data are provided in Table C.2 and Table D.2.

2.3.3.4 Seasonal distribution of landings

The seasonal distribution of the RCO 2 BT fishery is relatively uniform across the majority of the year in all three of the RCO 2 sub-areas (Figure 9; Table C.2). This uniformity in the seasonality of trawl landings of red cod probably reflects the timing of the target species of interest to the fishery, rather than having much to do with the availability of red cod. This is because the RCO 2 BT fisheries rarely target red cod (see Section 2.3.3.5 below), but target a number of species throughout the year, and therefore tend to capture red cod as an associated catch while targeting the more abundant or desirable species. What is also notable about the seasonal distributions in Figure 9 is the consistency within years (particularly in the main ECNI fishery): poor years remain poor throughout the year while the strong years continue strong. This reflects the biology of red cod, being a short-lived, fast growing species with only a few year classes present in the fishery at any one time. Abundance can vary greatly between years, depending on the recruitment success of specific year classes.

The seasonal distribution of the RCO 3 BT fishery is not uniform, with a tendency to be concentrated in the months of December to May, with occasional spill over into November and June (Figure 9; Table D.2). This reflects the nature of the RCO 3 red cod fishery, with vessels targeting this species when it is abundant. The strong red cod fisheries in the Inside (RCO 3) sub-area during the 1990s are clearly visible in Figure 9, with most years having a strong November catch and a nearly complete attenuation of the fishery by the end of

June. In recent years the fishery has narrowed, with catches not building until January and the season appearing to be nearly complete by the end of May. This change in catching pattern has important implications in the capacity of the partial year RCO 3 MP to predict the final annual CPUE. The seasonal pattern of the Outside (RCO 3) fishery is erratic, reflecting the diverse nature of this fishery (Figure 9; Table D.2). The patterns of the Foveaux St (RCO 3) fishery are more stable and encompass more months because this fishery, like the RCO 2 BT fishery, is directed at a range of target species (see Section 2.3.3.5 below).

2.3.3.5 Distribution of landings by declared target species

The distribution of BT target species in the six RCO 2 and RCO 3 sub-areas varies, with only Inside (RCO 3) having a significant component of RCO target fishing (about 70% of the Inside (RCO 3) landings that are targeted at RCO (Table 15). The primary target species in the other RCO 2 and 3 sub-areas in terms of the RCO by-catch are GUR, FLA and TAR for ECNI (RCO 2), HOK and TAR for E Cook St (RCO 2), GUR and TAR for W Cook St (RCO 2), LIN, BAR and SQU for Outside (RCO 3) and SQU and FLA for Foveaux St (RCO 3) (see Table C.3, Table D.3, Figure 10).

The relative importance of the three main target species which are responsible for RCO by-catch in the ECNI (RCO 2) BT fishery varies between years with the abundance of RCO, but not among the three species within any year (Table C.3). The by-catch of RCO in the E Cook St (RCO 2) BT HOK target fishery ended in the mid-2000s and has not resumed. The by-catch of RCO in the Foveaux St (RCO 3) SQU target fishery using BT and MW gear (see Table 15) developed in the early 2000s (Figure 10) and occurs primarily on the Snares Shelf and around the Auckland Islands. Another by-catch of RCO in Foveaux St (RCO 3) has developed in the inshore FLA BT fishery from the mid-2000s (Table D.3). The degree of RCO target fishing by the BT fleet varies with RCO abundance, with a lower percentage RCO target catch during years of lower abundance (Table D.3).

Table 15 provides information by RCO 2 and RCO 3 sub-area as to the composition of the target species which capture red cod using capture methods other than BT. These vary among the six areas, without a strong pattern. For instance, Danish seine fishing in ECNI (RCO 2) is primarily targeted GUR, while MW in E Cook St (RCO 2) targets HOK, BLL in W Cook St (RCO 2) targets GUR and SNA, and SN in W Cook St (RCO 2) is a WAR target fishery. For the three RCO 3 sub-areas, MW in Inside (RCO 3) targets RCO, SQU, BAR and JMA, while the Danish seine fleet in the same area targets RCO (Table 15). The BLL fisheries in Outside (RCO 3) and Foveaux Strait (RCO 3) target LIN, while MW in Outside (RCO 3) targets BAR and targets SQU in Foveaux Strait (RCO 3) (Table 15).

A potentially interesting issue is the reporting of RCO 3 by-catch landings using the cod potting (CP) capture method, which seems to be an unlikely method to capture red cod. Table 16 indicates that the three primary target species for this method in Inside (RCO 3) are RCO, BCO and LIN while BCO predominates as the target species in Foveaux St (RCO 3). Both of these areas have active BCO CP fisheries, so it is possible that these reports that RCO is taken using this method are reliable. This could also be a data entry error, with BCO 3 interpreted by the data entry clerks as RCO 3.

Table 15: Scaled QMR landings (Eq. 1 in tonnes) and distribution of landings (%) for red cod by target species and method of capture for each RCO sub-area (Table 13) from trips that landed red cod, summed from 1989–90 to 2016–17. '–': no data for indicated sub-area/method/target species cell. See Appendix A for definitions of abbreviations used in this table.

	Method of capture (t)							Total	Method of capture (%)							Total
	BT	MW	DS	BLL	SN	CP	Other	(t)	BT	MW	DS	BLL	SN	CP	Other	(%)
ECNI (RCO2)																
GUR	1 888	–	22	0.6	0.6	–	0.3	1 912	32.0	–	91.4	1.9	2.6	–	25.9	31.9
TAR	1 780	0.4	0.5	0.03	0.5	–	0.8	1 783	30.2	6.4	2.0	0.1	2.4	–	63.6	29.8
FLA	1 422	–	0.1	–	8.6	–	–	1 431	24.1	–	0.6	–	40.1	–	–	23.9
SCI	276	–	–	–	–	–	–	276	4.7	–	–	–	–	–	–	4.6
RCO	176	–	–	0.4	1.1	–	–	178	3.0	–	–	1.3	5.3	–	–	3.0
SNA	68	–	1.4	11	0.002	–	0.001	80	1.1	–	5.8	34.9	0.0	–	0.1	1.3
SKI	71	0.4	–	0.02	0.004	–	–	72	1.2	6.4	–	0.1	0.0	–	–	1.2
HOK	68	1.6	–	–	0.007	–	0.1	69	1.1	28.5	–	–	0.0	–	6.7	1.2
BAR	42	0.04	–	–	–	–	0.008	42	0.7	0.7	–	–	–	–	0.6	0.7
Other	111	3.2	0.04	19	11	0.2	0.04	144	1.9	58.0	0.2	61.8	49.4	100.0	3.0	2.4
Total	5 904	5.5	24	30	21	0.2	1.2	5 987	98.6	0.1	0.4	0.5	0.4	0.0	0.0	100.0
E Cook St (RCO2)																
HOK	471	107.0	–	–	–	–	0.9	579	33.6	99.9	–	–	–	–	99.8	36.4
TAR	520	–	–	–	0.1	–	–	520	37.1	–	–	–	0.1	–	–	32.7
WAR	145	–	–	–	0.5	–	–	146	10.4	–	–	–	0.7	–	–	9.2
RCO	63	–	–	0.1	34	–	–	98	4.5	–	–	1.3	48.8	–	–	6.1
FLA	30	–	0.009	–	25	–	–	54	2.1	–	77.0	–	35.3	–	–	3.4
BAR	51	0.002	–	–	–	–	–	51	3.7	0.0	–	–	–	–	–	3.2
GUR	46	–	0.003	–	0.005	–	–	46	3.3	–	23.0	–	0.0	–	–	2.9
SWA	18	–	–	–	–	–	–	18	1.3	–	–	–	–	–	–	1.1
JDO	15	–	–	–	–	–	–	15	1.1	–	–	–	–	–	–	1.0
OTH	43	0.1	–	11	11	0.1	0.001	65	3.1	0.1	–	98.7	15.1	100.0	0.2	4.1
Total	1 403	107	0.011	11	70	0.1	0.9	1 592	88.1	6.7	0.0	0.7	4.4	0.0	0.1	100.0
W Cook St (RCO2)																
GUR	244	–	1.9	27	10	–	27	309	25.8	–	95.8	43.3	9.8	–	52.1	26.6
TAR	225	–	0.0	3.5	0.4	0.0	–	229	23.9	–	0.6	5.7	0.4	2.9	–	19.8
TRE	117	–	–	0.006	4.6	–	4.4	126	12.4	–	–	0.0	4.7	–	8.6	10.9
FLA	101	–	0.1	–	0.8	–	0.1	102	10.7	–	2.8	–	0.8	–	0.1	8.8
SNA	48	–	0.0	22	1.3	0.0	20	92	5.1	–	0.8	35.3	1.4	2.8	39.2	7.9
BAR	60	0.0	–	–	0.2	–	–	60	6.3	3.4	–	–	0.2	–	–	5.2
WAR	7	–	–	0.02	43	–	–	50	0.7	–	–	0.0	44.5	–	–	4.3
JMA	46	0.9	–	0.01	0.2	–	–	47	4.8	87.0	–	0.0	0.2	–	–	4.0
RCO	29	–	–	4.2	7.9	–	–	41	3.0	–	–	6.8	8.1	–	–	3.5
OTH	68	0.1	0.0	5.5	29	0.4	–	104	7.3	9.6	0.0	8.9	29.9	94.3	–	8.9
Total	944	1.1	2.0	62	98	0.4	51.4	1 159	81.5	0.1	0.2	5.3	8.4	0.0	4.4	100.0

	Method of capture (t)							Total	Method of capture (%)							Total
	BT	MW	DS	BLL	SN	CP	Other	(t)	BT	MW	DS	BLL	SN	CP	Other	(%)
Inside (RCO3)																
RCO	98 170	448	1 220	2.9	4.5	157	5.4	100 007	72.0	25.2	67.6	2.0	0.9	43.9	42.1	70.9
SQU	11 018	318	0.6	–	–	–	6.4	11 343	8.1	17.8	0.0	–	–	–	50.5	8.0
BAR	10 576	515	0.1	–	0.03	–	–	11 092	7.8	29.0	0.0	–	0.0	–	–	7.9
FLA	10 184	–	243	0.1	0.2	0.2	–	10 427	7.5	–	13.5	0.1	0.0	0.0	–	7.4
TAR	2 304	–	240	–	379	1.7	–	2 924	1.7	–	13.3	–	73.0	0.5	–	2.1
SWA	683	0.2	0.2	–	–	–	0.024	683	0.5	0.0	0.0	–	–	–	0.2	0.5
WAR	638	0.9	–	–	7.1	–	–	646	0.5	0.0	–	–	1.4	–	–	0.5
LIN	285	0.1	–	136	26	125	–	572	0.2	0.0	–	94.9	5.0	34.8	–	0.4
JMA	64	462	–	–	–	–	–	525	0.0	26.0	–	–	–	–	–	0.4
OTH	2 517	35.7	101	4.4	103	74	0.9	2 835	1.8	2.0	5.6	3.0	19.8	20.8	7.2	2.0
Total	136 439	1 779	1 804	144	519	357	12.8	141 055	96.7	1.3	1.3	0.1	0.4	0.3	0.0	100.0
Outside (RCO3)																
LIN	305	–	–	382	0.1	–	0.006	687	10.8	–	–	95.8	22.8	–	6.9	20.6
BAR	505	67	–	–	–	–	–	572	17.8	69.8	–	–	–	–	–	17.2
SQU	562	0.7	–	–	–	–	–	563	19.8	0.7	–	–	–	–	–	16.9
HOK	366	16	–	–	–	–	0.016	382	12.9	16.9	–	–	–	–	20.4	11.5
RCO	284	–	0.1	0.3	–	0.1	–	285	10.0	–	5.7	0.1	–	59.4	–	8.5
SCI	275	–	–	–	–	–	–	275	9.7	–	–	–	–	–	–	8.3
SWA	153	0.0	–	–	–	–	–	153	5.4	0.0	–	–	–	–	–	4.6
TAR	126	–	–	–	0.3	–	–	126	4.5	–	–	–	47.5	–	–	3.8
SPE	82	–	–	–	–	–	–	82	2.9	–	–	–	–	–	–	2.5
OTH	176	12	1.5	17	0.2	0.1	0.1	206	6.2	12.6	94.3	4.1	29.7	40.6	72.8	6.2
Total	2 836	96	1.6	399	0.6	0.2	0.1	3 333	85.1	2.9	0.0	12.0	0.0	0.0	0.0	100.0
Foveaux St (RCO3)																
SQU	9 329	1 337	–	–	–	–	0.1	10 666	53.5	86.3	–	–	–	–	0.9	53.2
FLA	2 471	–	0.1	–	0.7	–	–	2 472	14.2	–	90.0	–	18.0	–	–	12.3
LIN	1 161	0.2	–	969	0.1	0.5	5.1	2 136	6.7	0.0	–	99.2	2.8	0.9	69.7	10.7
HOK	1 084	30	–	–	–	–	–	1 113	6.2	1.9	–	–	–	–	–	5.6
STA	858	–	–	–	–	–	–	858	4.9	–	–	–	–	–	–	4.3
RCO	754	1.2	–	–	–	0.5	–	756	4.3	0.1	–	–	–	0.8	–	3.8
SCI	506	–	–	–	–	–	–	506	2.9	–	–	–	–	–	–	2.5
SWA	360	0.0	–	–	–	–	–	360	2.1	0.0	–	–	–	–	–	1.8
BAR	266	63	–	–	–	–	–	330	1.5	4.1	–	–	–	–	–	1.6
OTH	653	118	0.0	7.9	3.1	58	2.1	842	3.7	7.6	10.0	0.8	79.3	98.3	29.4	4.2
Total	17 443	1 549	0.1	977	3.9	59	7.3	20 038	87.0	7.7	0.0	4.9	0.0	0.3	0.0	100.0

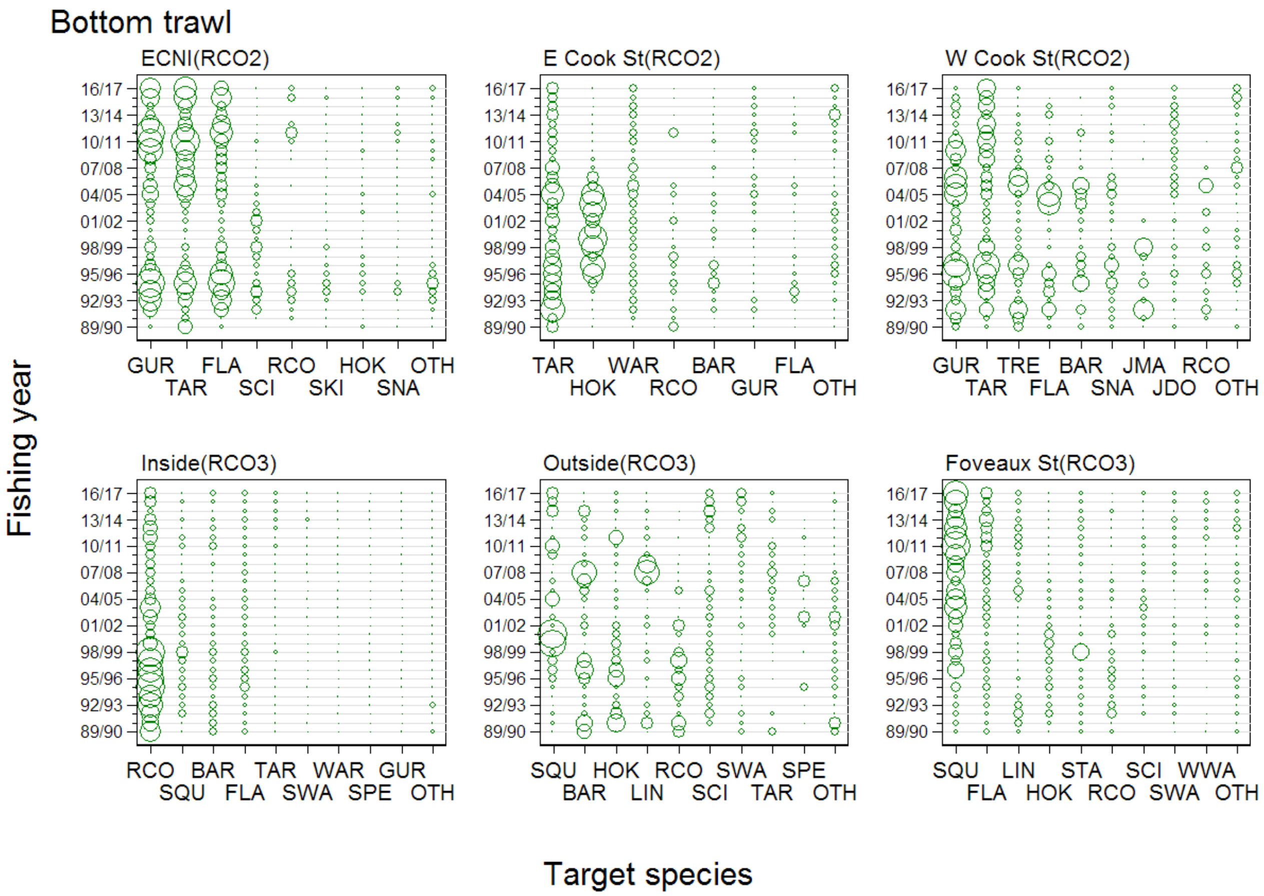

Figure 10: **Distribution of landings by target species (ranked in terms of descending order of total landings) and fishing year for bottom trawl in each RCO sub-area (Table 13) based on trips that landed red cod. Circle sizes are proportional within each panel: [ECNI(RCO2)]: largest circle= 206 t in 94/95 for GUR; [E Cook St(RCO2)]: largest circle= 74 t in 99/00 for HOK; [W Cook St(RCO2)]: largest circle= 33 t in 95/96 for GUR; [Inside(RCO3)]: largest circle=9219 t in 94/95 for RCO; [Outside(RCO3)]: largest circle= 152 t in 00/01 for SQU; [Foveaux St(RCO3)]: largest circle=1 003 t in 10/11 for SQU. Values for the plotted data are provided in Table C.2 and Table D.2.**

Table 16: **Total landings (t) by fishing year and target species for the two RCO 3 sub-areas that reported cod potting by-catch of RCO at a level that exceeded 50 t over the 29 years of record.**

	Inside (RCO 3)					Foveaux St (RCO 3)				
	RCO	BCO	LIN	OTH	Total	RCO	BCO	LIN	OTH	Total
89/90	–	0.11	–	0.01	0.12	–	0.19	–	–	0.19
90/91	–	0.17	–	–	0.17	–	0.11	–	–	0.11
91/92	–	0.13	0.48	–	0.60	–	0.05	–	–	0.05
92/93	–	1.01	0.10	–	1.11	–	0.00	–	–	0.00
93/94	0.04	2.46	0.05	0.02	2.56	–	0.24	–	–	0.24
94/95	–	2.77	0.09	–	2.87	–	4.86	–	–	4.86
95/96	0.04	1.15	0.03	0.06	1.27	–	26.35	–	–	26.35
96/97	0.05	1.02	1.42	0.10	2.59	–	1.51	–	–	1.51
97/98	0.25	1.65	4.97	0.07	6.94	–	0.72	–	–	0.72
98/99	0.07	0.45	9.80	0.00	10.32	–	0.74	–	–	0.74
99/00	0.95	4.87	3.71	0.20	9.73	–	0.38	–	–	0.38
00/01	1.21	0.46	–	–	1.67	–	2.64	–	–	2.64
01/02	0.87	1.40	0.04	–	2.31	–	0.04	–	–	0.04
02/03	1.51	1.12	–	0.00	2.63	–	0.26	–	–	0.26
03/04	2.55	2.00	0.44	–	4.98	–	0.04	–	–	0.04
04/05	2.79	6.32	2.06	0.01	11.18	0.02	2.18	0.01	–	2.21

	Inside (RCO 3)					Foveaux St (RCO 3)				
	RCO	BCO	LIN	OTH	Total	RCO	BCO	LIN	OTH	Total
05/06	18.09	5.19	3.05	0.03	26.35	0.44	0.27	–	–	0.71
06/07	9.28	1.70	2.64	0.03	13.65	–	1.28	0.03	–	1.32
07/08	5.86	2.70	1.86	0.27	10.70	–	1.51	0.11	0.76	2.39
08/09	26.26	4.18	0.55	0.08	31.07	–	1.14	–	–	1.14
09/10	16.90	4.49	7.98	0.05	29.41	–	0.05	0.00	–	0.05
10/11	10.60	3.54	4.04	0.10	18.28	–	4.22	–	0.04	4.26
11/12	15.56	4.51	2.61	0.07	22.74	–	1.52	–	–	1.52
12/13	19.22	2.10	2.82	0.39	24.53	–	1.95	0.08	–	2.04
13/14	17.95	3.86	21.09	2.74	45.64	–	1.79	0.31	–	2.09
14/15	5.36	4.79	12.57	1.07	23.80	–	0.74	–	–	0.74
15/16	0.24	2.27	20.48	0.20	23.20	–	1.15	–	–	1.15
16/17	1.11	2.28	21.64	1.91	26.94	–	1.24	–	–	1.24
Total	156.75	68.69	124.53	7.41	357.38	0.46	57.15	0.54	0.81	58.96

2.3.3.6 Preferred bottom trawl fishing depths for red cod

Depth information is available from TCEPR and TCER forms reporting bottom trawl catches pertaining to red cod (either recorded as an estimated catch of red cod or declaring red cod as the target species) (Figure 11; Figure E.1; Figure E.2; Table 17; Table 18; Table E.1; Table E.2). These data come either from the recently introduced (from 1 October 2007) TCER forms or the longstanding TCEPR forms, which are primarily used by larger offshore vessels but have been in use since the first year of data in this report (1989–90). The large majority of the depth observations reported in Table 17 originate from the TCER forms, ranging from 37% to 99%, depending on the sub-area being fished (Table 18). The Outside (RCO 3) sub-area has the lowest percentage of TCER records (37%), but it only represents 2% of the combined RCO 2/RCO 3 landings since 1989–90 (Table 15). TCER records predominate in the three RCO 2 sub-areas (91–99% of the depth observations; Table 18) while 96% of the depth observations originate from the TCER form type in the area with the largest RCO catch (Inside [RCO 3]; Table 18) This predominance of TCER reports reflects the inshore nature of the red cod bottom trawl fisheries. Only data from 2007–08 onwards are reported here, so that a complete picture will be obtained for the combined inshore and deepwater bottom trawl red cod fishery.

Depth observations for target red cod appear primarily in the two east coast inside waters fisheries (ECNI (RCO 2) and Inside (RCO 3)) (Table E.1; Table E.2). The east coast North Island fishery is more shallow than the RCO 3 fishery, with 5–95% quantiles ranging from 14–80 m (median=25 m), while the east coast South Island fishery ranges from 20 to 240 m (median=58 m). Note how few target RCO observations there are in the ECNI fishery, indicating that this is mainly a by-catch fishery for red cod. The depth statistics for the non-RCO target fisheries will reflect the preferred depths for these target species, rather than for red cod. The overall 0.05 quantile (12 and 14 m) and the median (54 and 49 m) for red cod capture are very similar for both RCO 2 and RCO 3 (Table 18). The 0.95 quantile for red cod capture is much deeper for RCO 3 than for RCO 2, given the wide ranging topography of RCO 3 compared to RCO 2. The 0.95 quantile for RCO 2 is 155 m compared to 325 m for RCO 3; this difference affects the mean depth for RCO capture, which is 67 m in RCO 2 compared to 86 m in RCO 3 (Table 18).

Table 17: Summary statistics for bottom depth by target species for RCO 2 and RCO 3 from all records (combined TCER and TCEPR form types) using the bottom trawl method for effort that targeted or caught red cod (estimated catches). Data are summarised for RCO 2 or RCO 3 from 2007–08 to 2016–17.

					Depth (m)
Target species category	Number observations	Lower 5% of distribution	Mean of distribution	Median (50%) of distribution	Upper 95% of distribution
RCO 2					
TAR	17 793	40	97	92	170
GUR	13 843	20	43	40	75
FLA	6 589	10	18	15	32
WAR	642	50	92	90	145
SNA	531	25	48	45	87
JDO	350	40	79	70	149
MOK	302	38	99	100	142
RCO	282	14	37	27	103
TRE	232	25	46	41	80
HOK	198	90	262	210	537
BAR	128	47	98	90	182
Other	397	34	210	186	393
Total	41 287	12	67	54	155
RCO 3					
FLA	42 754	11	31	25	64
RCO	14 954	20	83	58	241
TAR	8 223	48	91	89	135
SQU	7 436	140	210	194	325
BAR	4 994	33	87	80	164
SCI	2 335	316	409	407	500
ELE	2 159	12	32	27	71
STA	2 136	32	109	100	223
WAR	1 896	38	57	53	97
GUR	1 845	18	37	36	58
LIN	1 719	125	392	395	606
Other	3 824	13	169	103	506
Total	94 275	14	86	49	325

Table 18: Overall summary statistics for bottom depth for the six RCO 2 and 3 sub-areas as well as all of RCO 2 and RCO 3 from combined TCER and TCEPR form types using the bottom trawl method for effort that targeted or caught red cod (estimated catch). Data are summarised for RCO 2 or RCO 3 from 2007–08 to 2016–17. Also shown is the percentage of the two form types for each QMA or RCO sub-area.

					Depth (m)		Form type
RCO 2 and 3 sub-area (Table 13) or QMA	Number observations	Lower 5% of distribution	Mean of distribution	Median (50%) of distribution	Upper 95% of distribution	TCEPR (%)	TCER (%)
ECNI (RCO 2)	36 525	12	62	50	143	8.5	91
E Cook St (RCO 2)	2 513	34	114	109	219	3.0	97
W Cook St (RCO 2)	2 249	30	94	87	184	1.3	99
Inside (RCO 3)	69 305	14	62	45	190	4.5	96
Outside (RCO 3)	2 010	121	271	310	376	63	37
Foveaux St (RCO 3)	22 960	13	142	64	475	39	61
RCO 2	41 287	12	67	54	155	7.8	92
RCO 3	94 275	14	86	49	325	14	86

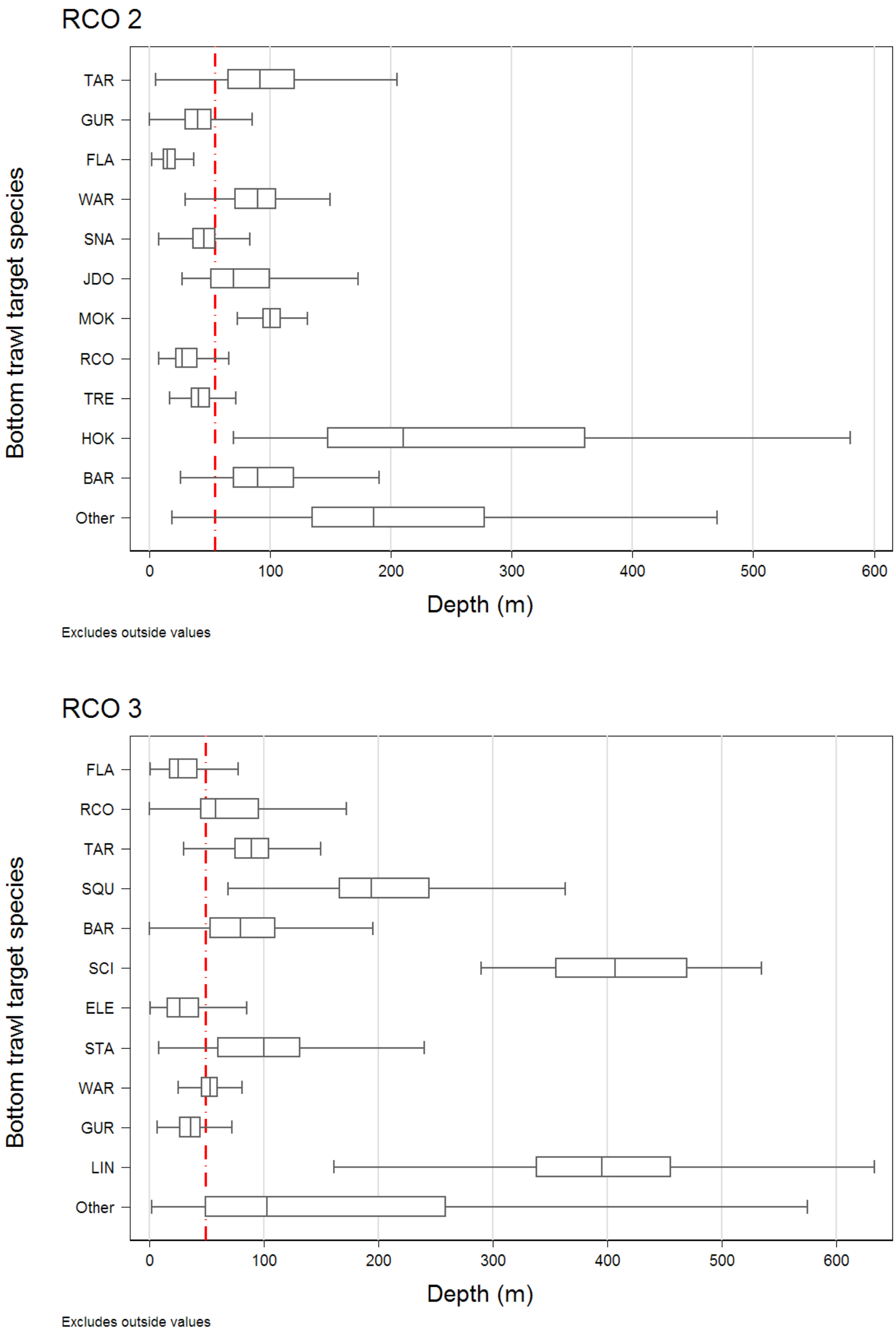

Figure 11: Box plot bottom depth distributions by target species for RCO 2 and RCO 3 from combined TCER and TCEPR form types using the bottom trawl method for effort that targeted or caught red cod (estimated catch) over the period 2007–08 to 2016–17. Vertical line in each sub graph indicates the median depth from all tows that caught or targeted red cod (estimated catch) in RCO 2 or RCO 3.

3. RCO 2/RCO 3 STANDARDISED CPUE ANALYSES

3.1 Description and specification of analyses

The standardised CPUE analyses developed by Bentley (2013a, 2013b, 2013c) for RCO 2 (Table 19) and RCO 3 (Table 20) for driving the respective MPs were repeated, along with a range of new analyses intended to update the procedures to match SINSWG standards. Chief among these additional expectations is the addition of the binomial analysis of species occurrence in bottom trawl using the same data set (see Appendix F.2.2) and then combining the positive catch and binomial standardised analyses using the delta procedure (Eq. F.4). Other modifications were made to the analyses which had minor impacts on the overall trends.

Table 19: Specifications for the RCO 2 standardised analyses undertaken for this project. The standardised CPUE series used in the RCO 2 MP is shaded grey.

RCO 2 Analysis Name	First Year	Final Year	Distribution Positive	Distribution Occurrence	Statistical Areas	Target Species	Core Fleet	Interaction Term	Diagnostics Location
2013-NB[1]	1990	2012[1]	lognormal	–	011–015	RCO, FLA, GUR, TAR	5/5+	month×area	not available
2018-repeat	1990	2017	lognormal	–	011–015	RCO, FLA, GUR, TAR	5/5+	month×area	not presented
2018-no interaction	1990	2017	lognormal	binomial	011–015	RCO, FLA, GUR, TAR	5/5+	none	Appendix G
2018-tow-by-tow	2008	2017	lognormal	binomial	011–015	RCO, FLA, GUR, TAR	5/5+	none	Appendix H

[1] Bentley (2013c): 2013 index reported but not used because it was an incomplete year.

Table 20: Specifications for the RCO 3 standardised analyses undertaken for this project. The standardised CPUE series used in the RCO 3 MP is shaded grey.

RCO 3 Analysis Name	First Year	Final Year	Distribution Positive	Distribution Occurrence	Statistical Areas	Target Species	Core Fleet	Interaction Term	Diagnostics Location
2013-NB[2]	1990	2012[2]	log-logistic	–	020, 022, 024	RCO, FLA, BAR, TAR, SQU	5/5+	month×area	not available
2018-repeat	1990	2017	log-logistic	–	020, 022, 024	RCO, FLA, BAR, TAR, SQU	5/5+	month×area	not presented
2018-no interaction	1990	2017	log-logistic	binomial	020, 022, 024	RCO, FLA, BAR, TAR, SQU	5/5+	none	not presented
2018-extended	1990	2017	lognormal	binomial	018, 020, 022, 024, 026	RCO, FLA, BAR, TAR, SQU, GUR, STA, SWA, WAR, SPE	5/5+	none	not presented
2018-extended2	1990	2017	lognormal	binomial	020, 022, 024, 026	RCO, FLA, BAR, TAR, SQU, GUR, STA	5/5+	none	Appendix I
2018-tow-by-tow	2008	2017	lognormal	binomial	020, 022, 024, 026	RCO, FLA, BAR, TAR, SQU, GUR, STA	5/5+	none	Appendix J

[2] Bentley (2013b): 2013 index reported but not used because it was an incomplete year.

3.2 Comparison with previous RCO 2/RCO 3 analyses

Comparison of equivalent current data set analyses with the indices published by Bentley (2013b, 2013c) shows reasonable correspondence for both RCO 2 (left panel, Figure 12) and RCO 3 (right panel, Figure 12), with some deviations in the late 2000s (RCO 2) or early 2010s (RCO 3). Bentley (2013b, 2013c) reports using a variant of the "daily effort stratum" preparation procedure (see Section 2.3.1.5) whereby, rather than selecting the modal statistical area and target species, they stratified within a fishing day by statistical area and target species. Such an approach would lead to many more strata after the introduction of the tow-by-tow TCER forms (Langley 2014) and could lead to some deviation in the calculated indices after the 2008 introduction of these forms. The SINSWG accepted the Figure 12 differences as being the consequence of the gradual improvement of data preparation and analytical procedures.

Bentley (2013b, 2013c) used an interaction term for month × area instead of offering these terms as independent variables. Comparing these interaction models with corresponding models fitted with month and area as independent variables showed no difference in the estimated index series for either RCO 2 (left panel, Figure 13) or RCO 3 (right panel, Figure 13). Consequently all subsequent models used month and area as independent variables, reasoning that the month × area interaction term was an unnecessary complication.

For RCO 3, two additional categories were added to the area categorical variable and five additional categories to the target species categorical variable (model "*extended*" in Table 20). Several of these categories had very little data in them and the residuals for Statistical Area 018 indicated a different annual trend. These categories were removed in a subsequent model (model "*extended2*" in Table 20), but the overall impact on the annual CPUE trend was minimal (Figure 14, both panels). Figure 14 also shows very little impact from moving away from the log-logistic distribution to the lognormal distribution for the positive catch model (compare the "*2018-no interaction*" series with either of the two "*extended*" series").

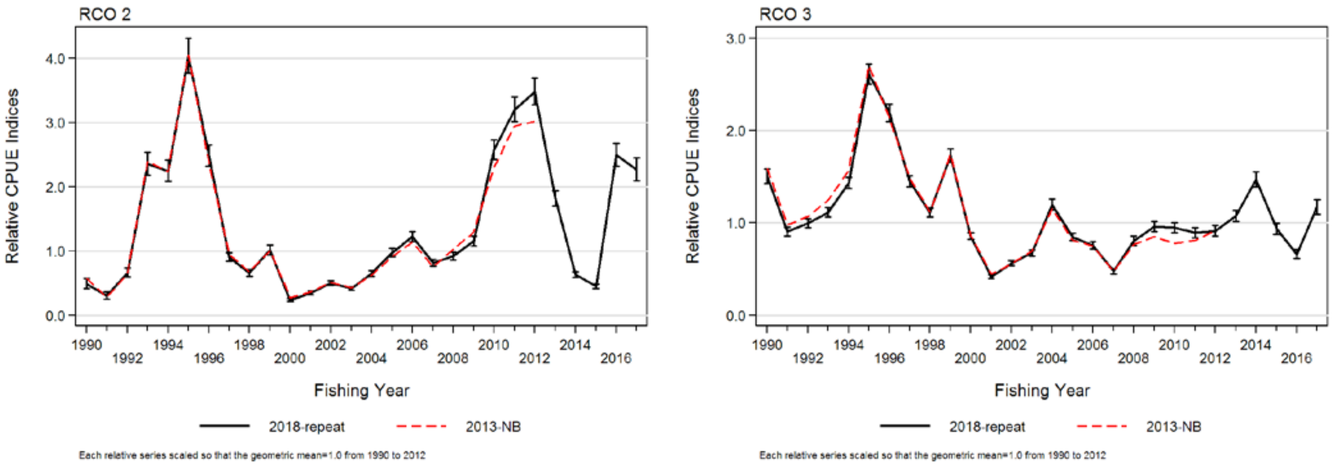

Figure 12: Comparison of 2013 standardised positive models with 2018 repeat models; [left panel]: RCO 2; [right panel]: RCO 3. See Table 19 and Table 20 for model identification codes and specifications. Confidence bounds are ± 2SE.

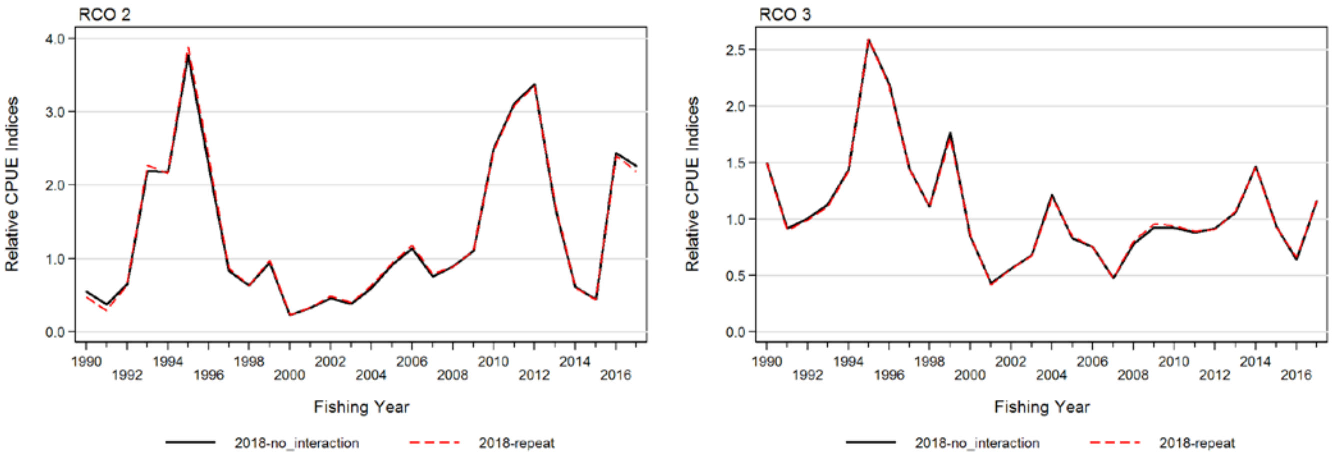

Figure 13: Comparison of standardised positive models with and without month×area interaction term; [left panel]: RCO 2; [right panel]: RCO 3. See Table 19 and Table 20 for model identification codes and specifications.

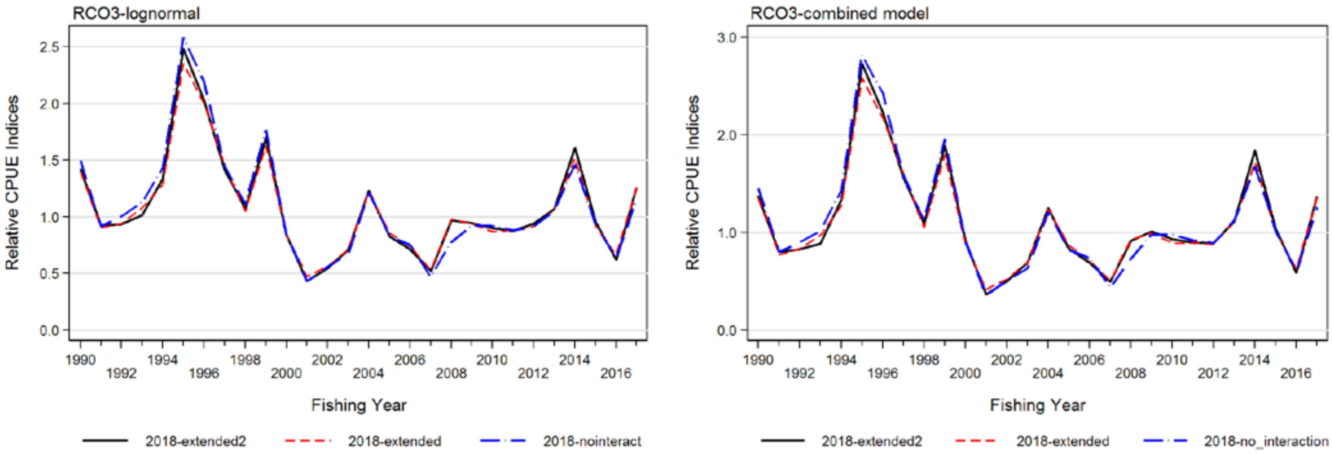

Figure 14: Comparison of RCO 3 standardised models; [left panel]: lognormal positive catch models, "extended" and "extended2"; [right panel]: combined (Eq. F.4) models "no interaction", "extended" and "extended2". See Table 20 for model identification codes and specifications.

The SINSWG selected the combined (Eq. F.4) version of the "*2018-no interact*" model (Table 19, Figure G.10) for use in the RCO 2 MP and the combined (Eq. F.4) version of the "*2018-extended2*" model (Table 20, Figure I.11) for the RCO 3 MP. These models had good diagnostic characteristics (as presented in Appendix G for RCO 2 and in Appendix I for RCO 3) and represented relatively little change from the models used in 2013 (Figure 12). A comparison of these accepted series with equivalent standardisations using TCER/TCEPR tow-by-tow data available from 2008 shows good correspondence with the "daily effort stratum" series in both RCO QMAs (Figure 15).

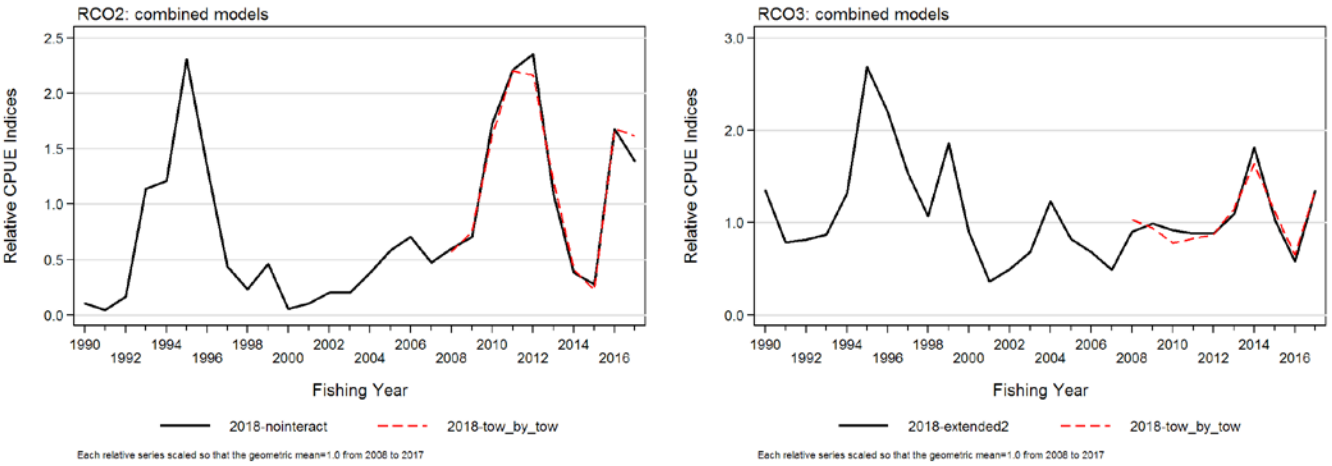

Figure 15: Comparison of 2018 combined (Eq. F.4) "daily effort stratum" models with corresponding tow-by-tow model; [left panel]: RCO 2; [right panel]: RCO 3. See Table 19 and Table 20 for model identification codes and specifications.

3.3 Comparison of RCO 3 standardised CPUE analysis with ECSI *Kaharoa* winter trawl survey

The time series of east coast South Island winter (May-June) trawl surveys (Beentjes & Stevenson 2000) conducted by the RV *Kaharoa* showed variable red cod abundance over the period 1991 to 1996 with high survey CVs (near to or much greater than 30%) (Table 21). The winter series was abandoned in favour of a summer survey due to the "*...high coefficients of variation for the target species red cod and other key species, the codend mesh size (60 mm) was considered too large to adequately sample pre-recruit juvenile fish, and the minimum depth range of the winter surveys (30 m) was too deep to adequately sample red gurnard and elephantfish*" (Beentjes & Stevenson 2008). This survey was resumed in May 2007 due to the highly correlated variability among species observed in the summer trawl survey (Francis et al. 2001). Results for these resumed surveys appeared to be consistent with the previous surveys, both in terms of estimated biomass levels and CVs (Beentjes et al. 2016) (Table 21). This survey does not contradict the selected RCO 3 "*extended2*" standardised series (Figure 16), but the correlation between the 'recruited' biomass index and the combined standardised index is low (ρ=0.27) for the overlapping years. Weighting the series index values by the inverse of the survey squared CV does not improve the correlation (ρ drops to 0.18). If 2012, the year with very high CV, is dropped, the correlation with the recruited biomass is still low at ρ=0.22. There are some clear misses between the survey and series indices, notably in 2009 and 2014, where the survey error bars do not even overlap with the "*extended2*" standardised series (Figure 16).

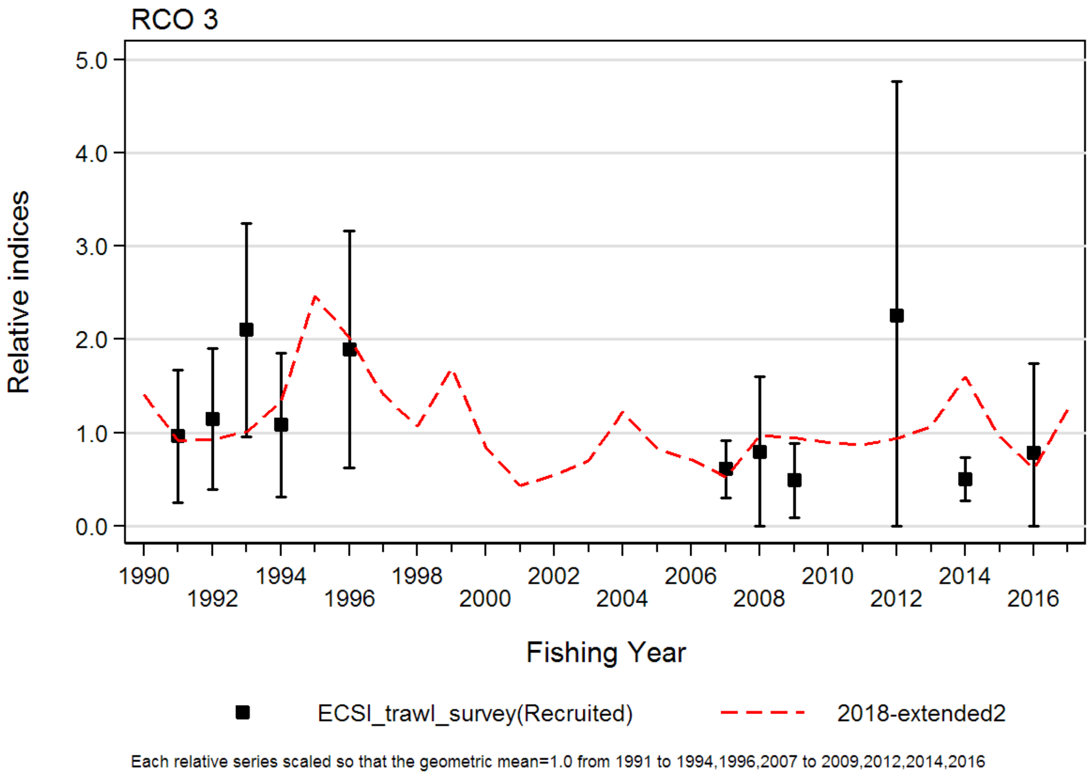

Figure 16: Recruited (at least 40 cm) red cod biomass indices from the east coast South Island winter (May–June) trawl surveys. Bootstrapped 95% confidence bounds shown. Data are from NIWA (Dan MacGibbon, *pers. comm.*)

Table 21: Total and recruited biomass indices with survey coefficients of variation (CV) for red cod from the east coast South Island winter (May–June) trawl surveys. Data are from NIWA (Dan MacGibbon, *pers. comm.*). Recruited biomass estimates include red cod greater than 40 cm fork length.

Year	Trip code	Number stations	Total Biomass (t)	CV (%)	Recruited Biomass (t)	CV (%)
1991	KAH9105	55	3 920.8	32.9	2 049.4	36.8
1992	KAH9205	80	4 527.2	39.5	2 438.5	33.1
1993	KAH9306	74	5 601.0	29.5	4 469.0	27.2
1994	KAH9406	100	5 637.3	34.9	2 299.0	35.6
1996	KAH9606	118	4 619.3	29.9	4 028.9	33.5
2007	KAH0705	94	1 485.8	24.8	1 295.3	25.2
2008	KAH0806	96	1 824.4	48.9	1 695.4	50.1
2009	KAH0905	87	1 870.8	39.9	1 038.2	40.8
2012	KAH1207	84	11 820.7	79.2	4 805.7	55.4
2014	KAH1402	97	2 095.9	38.9	1 057.4	23.2
2016	KAH1605	92	2 267.8	54.3	1 670.5	61.1

4. RCO 2/RCO 3 MANAGEMENT PROCEDURE EVALUATION

4.1 Operation of the existing RCO 2 and RCO 3 MPs

Management Procedures (MP) to inform in-season adjustments to the RCO 2 and RCO 3 TACC were developed in 2013 by Bentley (2013a) (see also Bentley 2012). These MPs were based on a predictive relationship between annual standardised CPUE for RCO 2/RCO 3 with the total annual RCO 2/RCO 3 landings. A standardisation model was used to predict the annual CPUE for the active fishing year based on the accumulated data to the month preceding the evaluation month. The slope parameter from the predictive regression was applied to the index based on incomplete data from the final year in the standardised model, resulting in a catch prediction. The partial year in-season estimate of standardised CPUE was used as a proxy for the final annual index, with the recommended catch defined by the slope of the regression line (Eq. 2).

The 2013 MP rule stipulated that:

a) only the positive catch data would be used in developing the standardised index.

b) the regression would be forced to go through the origin (i.e., estimated without a constant);

c) only years which were less than 90% of the TACC were used in the regressions.

The 2013 MP for RCO 2 was operated six times from 2013 up to and including 2018 (Table 22). Two of the six evaluations resulted in recommendations for an ACE increase in RCO 2, with the other years near to or less than the current TACC of 500 t. The 2013 MP for RCO 3 was operated six times from 2013 up to and including 2018 (Table 22). Four of the six evaluations resulted in a recommendation for an ACE increase with the other two years at less than the current TACC of 4600 t.

Table 22: Results of the operation of the 2013 MP for RCO 2 and RCO 3 by prediction year, including the resulting base TACC + added ACE (Eq. 2).

Prediction Year	Fishing Year	CPUE Prediction	CPUE Total year[1]	Calculated catch	Base TACC + added ACE	Final catch (t)	Reference
RCO 2							
2013*	2012–13	2.4606	–[2]	738	619	300	Bentley 2013c
2014	2013–14	–	–	–	500	167	–[2]
2015	2014–15	0.2015	0.5181	53	500	142	Bentley 2015
2016	2015–16	1.9008	2.5544	527	500	419	Bentley 2016a
2017*	2016–17	3.3860	2.3219	966	733	385	Bentley 2017a
2018	2017–18	1.5642	–	448	500	151[3]	Starr & Bentley 2018a
RCO 3							
2013*	2012–13	0.9392	–[2]	4 944	4 944	5 294	Bentley 2013b
2014*	2013–14	–	–	–	5 391	4 410	–[2]
2015*	2014–15	1.1948	0.8112	6 289	4 600	2 171	Bentley 2015
2016	2015–16	0.4838	0.7112	2 405	4 600	3 837	Bentley 2016b
2017	2016–17	0.8480	1.1489	4 291	4 600	4 543	Bentley 2017b
2018*	2017–18[3]	1.7055	–	8 912	4 600[4]	2 250[3]	Starr & Bentley 2018b

[1] calculated in the year following
[2] supporting documents are contradictory and inconsistent: require further research
[3] provisional total
[4] industry chose not to pursue the proposed increase (M Geytenbeek, Fisheries New Zealand Dunedin, *pers. comm.*).
* MP operation that resulted in an ACE increase recommendation

The following series of equations define the RCO 2/RCO 3 MP developed by Bentley (2013a), which estimates the amount of available ACE in incomplete (predicted) year y (note: fishing year 2006–07 coded as 2007):

Eq. 2

$$TACC_{\text{base}} = 500 \text{ t (RCO2) or } 4600 \text{ t (RCO3)}$$
$$I_y: \text{ CPUE index in year } y \text{ based on partial year data}$$
$$b = \text{slope}\left\{C_{1990} \text{ to } C_{y-1}, I_{1990} \text{ to } I_{y-1}\right\} \text{ (no constant)}$$
$$\text{where } C_i < 0.9TACC_i$$
$$ACE_y = b * I_y - TACC_{\text{base}}$$
$$\text{if } b * I_y < TACC_{\text{base}} \text{ then } ACE_y = 0$$

where

$$C_i = \text{QMR/MHR catch in year 1990 to } y-1$$
$$I_i = \text{ positive catch standardised RCO2/RCO3 CPUE index in year 1990 to year } y-1$$

4.2 Catch, TACC and CPUE summary for RCO 2/RCO 3

Catches tended to be high in years with high CPUE in RCO 2 (left panel, Figure 17) and in the years before the TACC was reduced in RCO 3 (right panel, Figure 17). High CPUE in 2013–14 did not translate into high catches, probably because the MP operation was not sensitive enough to detect the high catch rate in that year.

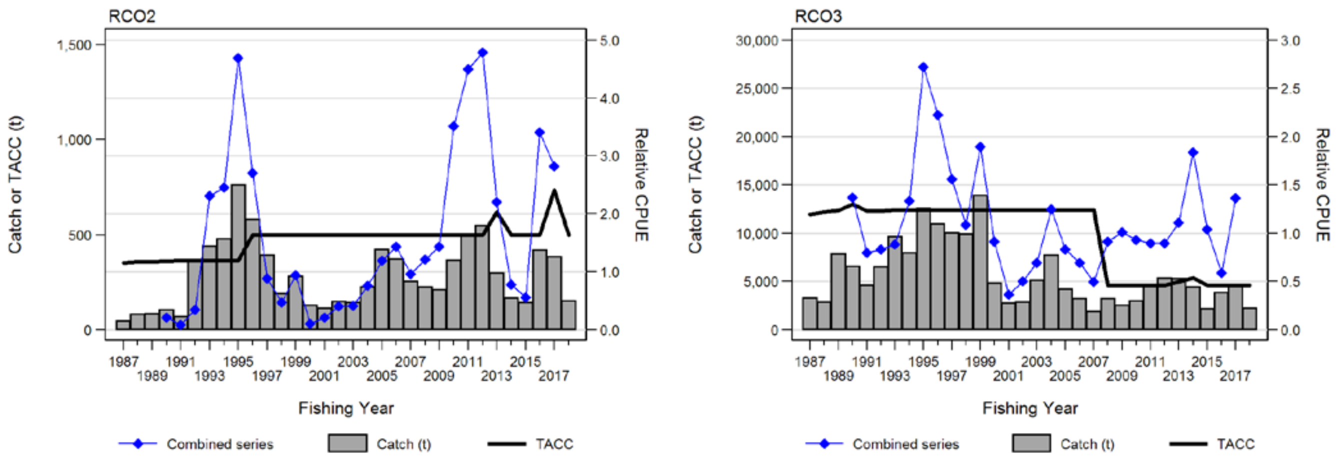

Figure 17: Plots of annual total catch (t) and TACC(t) from 1986–87 to 2017–18 (2017–18 data are provisional) and the accepted combined index series from 1986–87 to 2016–17; [left panel]: RCO 2; [right panel]: RCO 3. Note that plotted TACCs include additional in-season ACE. Fishing years are coded with the final year of the pair.

4.3 Data preparation

The SINSWG reviewed the existing RCO 2/RCO 3 MPs in March 2018, and agreed to use the combined series in preference to the positive catch series used in the 2013 RCO 2/RCO 3 MP because the SINSWG has determined that such models are more likely to capture all components of the CPUE trends, including trends in zero catch and trends in reporting small catches. The combined series from the standardised RCO 2 model "*no interaction*" and the RCO 3 model "*extended2*" (see Table 19 and Table F.1 for definitions of these analyses) were accepted to drive the respective RCO 2 and RCO 3 MPs. The data sets were the same as the CPUE analyses that are reported in Appendix G (RCO 2) and Appendix I (RCO 3) with one important difference: data for the final (partial year) are accumulated up to the end of a specified month, which in turn are used to predict the CPUE in the final (incomplete) year.

4.4 Retrospective performance of the RCO 2 and RCO 3 predictive procedure

A retrospective analysis was conducted to test the predictive capacity of this procedure. This analysis, starting with the 2002–03 fishing year, only used the accumulated data available up to and including the predicted fishing year. Within the predicted fishing year, only data up to the end of the trial predictive month were used to estimate the annual standardised CPUE for the year in question. While this analysis approximates the situation that would exist during the actual operation of the MP, the simulation is not completely correct. Because this analysis is working from a complete set of data, the predictive month data used in this retrospective analysis will be complete, unlike the situation that exists when the MP is operated in real time. During the actual MP operation, there will always be a component of the data that is not available, either because fishers have yet to submit their data or there is a lag in the data entry process. This component (missing data up to the end of the predictive month) was not simulated in this retrospective analysis.

The retrospective analysis took the following form:

1. Beginning with the 2002–02 fishing year, the relevant RCO 2 or RCO 3 combined (Eq. F.4) model was estimated, using complete year data up to fishing year y–1 and using partial year data for final year y across five trial prediction months from December to April. That is, the December analysis would use three months of data in the partial year, the January analysis would use four months, up to April which would be based on seven months of data, to predict the annual CPUE for the final year. The full estimation procedure was followed at each estimation step, including selecting the core vessel data set and the stepwise variable selection for both the positive and binomial models.

2. A performance index (P_y: Eq. 3) was generated for each pair of observations: the partial year prediction of the full year CPUE in year y and the CPUE for year y generated in the <u>next</u> estimation year y+1 after the full twelve months of data have been accumulated for year y. The absolute value of P_y is taken because it is the proportional error that is of importance, not the direction of the error.

Eq. 3 $$\text{ABS}(P_y) = \frac{\left(I_y^p - I_y^t\right)}{I_y^t}$$

where:

I_y^p : partial year predictive CPUE in year y

I_y^t : complete year CPUE for year y in following year

This analysis tested the capacity of the partial year data to predict the total CPUE for the year, not the performance of the MP. These rules have moderate predictive capability with wide variation in the performance of the predictor, varying from very good (with values of P_y below 0.1) to very poor (with values of P_y >0.9) (Table 23). Mean P_y ranged from 0.32 (December) to 0.16 (April) for RCO 2 and 0.24 (December) to 0.13 (April) for RCO 3. The CVs associated with P_y were near to 1.0 for RCO 2 for all months, even for March and April when half or more than half of the data had been accumulated (Table 23). While the CVs for the RCO 3 predictor were lower than for RCO 2 (Table 23), they were still very high, ranging from 0.53 (April) to 0.87 (December). Because the error associated with P_y was relatively high in both QMAs, the SINSWG recommended that data be accumulated at least up to the end of January because the drop in mean P_y between those two months was sufficient to justify the delay (from 0.32 to 0.28 for RCO 2 and from 0.24 to 0.20 for RCO 3).

Table 23: Performance index (Eq. 3) for RCO 2 and RCO 3 by fishing year and estimation month, with the estimation month being the final month in the partial data prediction year. The row "Average" is the unweighted average of the 14 fishing years in the analysis, with an associated standard deviation (StDev) and CV.

Estimation	RCO 2					RCO 3				
year	December	January	February	March	April	December	January	February	March	April
02/03	0.008	0.093	0.084	0.041	0.004	0.186	0.208	0.041	0.037	0.060
03/04	0.244	0.245	0.124	0.123	0.112	0.143	0.161	0.145	0.153	0.109
04/05	0.016	0.013	0.027	0.014	0.003	0.191	0.199	0.228	0.226	0.219
05/06	0.130	0.011	0.120	0.198	0.265	0.163	0.118	0.142	0.125	0.174
06/07	0.103	0.216	0.390	0.438	0.362	0.027	0.220	0.233	0.165	0.088
07/08	0.197	0.080	0.080	0.064	0.044	0.586	0.497	0.348	0.148	0.092
08/09	0.207	0.169	0.056	0.013	0.017	0.148	0.022	0.144	0.191	0.163
09/10	0.102	0.033	0.006	0.005	0.013	0.011	0.129	0.240	0.204	0.214
10/11	0.152	0.150	0.159	0.098	0.067	0.166	0.131	0.084	0.043	0.071
11/12	0.711	0.726	0.567	0.384	0.289	0.244	0.071	0.000	0.040	0.123
12/13	0.721	0.798	0.767	0.537	0.330	0.266	0.243	0.042	0.218	0.223
13/14	1.272	0.943	0.680	0.518	0.353	0.310	0.166	0.002	0.021	0.069
14/15	0.402	0.347	0.345	0.296	0.300	0.794	0.344	0.156	0.000	0.017
15/16	0.208	0.157	0.174	0.160	0.110	0.145	0.297	0.333	0.238	0.221
Average	0.320	0.284	0.256	0.206	0.162	0.241	0.200	0.153	0.129	0.132
Minimum	0.008	0.011	0.006	0.005	0.003	0.011	0.022	0.000	0.000	0.017
Maximum	1.272	0.943	0.767	0.537	0.362	0.794	0.497	0.348	0.238	0.223
StDev	0.353	0.309	0.253	0.193	0.145	0.210	0.120	0.113	0.085	0.070
CV	1.104	1.088	0.988	0.936	0.893	0.872	0.602	0.739	0.656	0.529

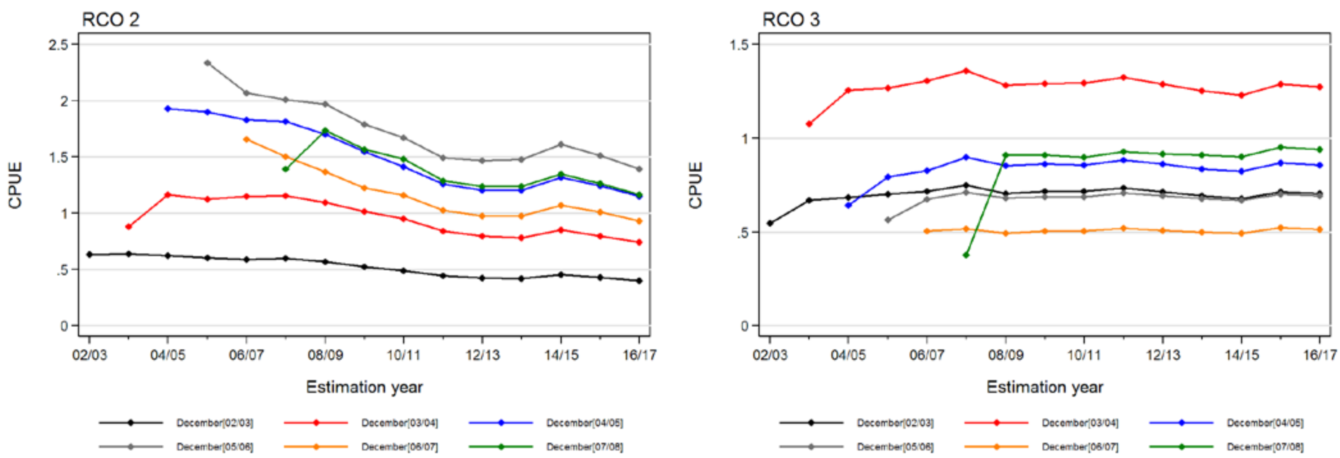

Figure 18: Plots of successive estimation year indices for RCO 2 (left panel) and RCO 3 (right panel) showing the first six fishing years (2002–03 to 2007–08) for the December predictive year trial. All year CPUE index values across the 14 estimation years and for each monthly predictive trial can be found in Appendix K for both QMAs.

Of concern is the gradual downward drift of the RCO 2 CPUE index estimates for the same fishing year over successive estimation years (Figure 18; see also Appendix K). The reason for this gradual drift is unknown, but may be related to the adopted retrospective procedure, which re-selected the core vessel data set and repeated the variable selection procedure with every estimation step. This procedure could result in data sets that are not comparable over time when the data set is relatively small. In contrast, the RCO 3 CPUE index estimates are stable, with little change over time (Figure 18; Appendix K) which probably can be attributed to the much larger data set for this QMA (compare Table G.1 with Table I.1).

4.5 Evaluation of the RCO 2/RCO 3 MP

The preceding retrospective analysis (Section 4.4) evaluated the capacity of the predictive component of the MP; that is, the capability of the partial year data to predict the eventual complete year CPUE index. Table 23 indicates that this component of the MP is problematic for RCO 2, with a strong likelihood that the predicted annual CPUE will not accurately reflect the final CPUE when it is calculated in the following year. There is a similar problem for RCO 3, but it is less acute. However, it is more difficult to evaluate how the procedure will predict catch, particularly since the catch that eventuates will depend on many factors other than abundance, including implementation error (see Table 22 for a summary of the implementation of this MP since 2013).

A residual analysis was conducted to evaluate how well the catch estimation component of the MP functioned, using all available data up to the end of the 2016–17 fishing year in both QMAs. Four contrasting regression models were evaluated for each QMA:

a) no estimated constant and only regress years where catch was less than 90% of TACC;

b) no estimated constant and regress all years, regardless of catch/TACC ratio;

c) estimated with a constant and only regress years where catch was less than 90% of TACC;

d) estimated with a constant and regress all years, regardless of catch/TACC ratio.

Parameter estimates and residual statistics for each of these models by QMA are presented in Table 24. Plots of each regression model and the associated residuals are presented for RCO 2 (models: Figure 19; residuals: Figure 20). Equivalent plots are presented for RCO 3 (models: Figure 21; residuals: Figure 22).

Forcing the RCO 2 regression through the origin resulted in a much steeper slope and in biased residuals (Figure 20). Table 24 indicates that the constant (intercept) parameter was highly significant and should be included in the regression model. There was very little difference between the models which constrained the regression to years where the catch was less than 90% TACC and the models which included all catch years.

Table 24: Parameter estimates and absolute residual statistics for four contrasting models applied to the RCO 2/RCO 3 data sets from 1989–90 to 2016–17. Each model regresses the appropriate RCO 2 or RCO 3 combined (Eq. F.4) standardised model against two annual catch assumptions: all data or only those years where catch<90% TACC. SE: standard error; SD: standard deviation; CV: coefficient of variation.

		Regression model				Absolute residual statistics				
Model	Parameter	Coefficient	SE	t-value	P>t-value	Mean	SD	CV	Min	Max
RCO 2										
no constant+90% rule	slope	156.6	17.5	9.0	0	101.6	62.8	0.62	12.8	253.2
no constant	slope	150.5	11.9	12.7	0	100.8	64.8	0.64	4.1	258.6
constant										
estimated+90% rule	slope	85.4	16.4	5.2	0	54.0	47.8	0.89	0.0	178.1
	constant	143.7	24.9	5.8	0					
constant estimated	slope	98.1	12.3	8.0	0	64.1	41.7	0.65	1.4	155.1
	constant	151.7	26.6	5.7	0					
RCO 3										
no constant+90% rule	slope	5 120.2	444.5	11.5	0	1 657.3	1 537.4	0.93	58.5	5 102.7
no constant	slope	5 151.0	346.0	14.9	0	1 658.1	1 536.9	0.93	84.2	5 075.5
constant										
estimated+90% rule	slope	3 998.5	1 106.6	3.6	0.002	1 636.8	1 460.3	0.89	29.1	4 751.9
	constant	1 343.7	1 215.2	1.1	0.282					
constant estimated	slope	4 498.6	805.5	5.6	0	1 609.7	1 509.1	0.94	80.4	4 765.1
	constant	887.8	989.2	0.9	0.378					

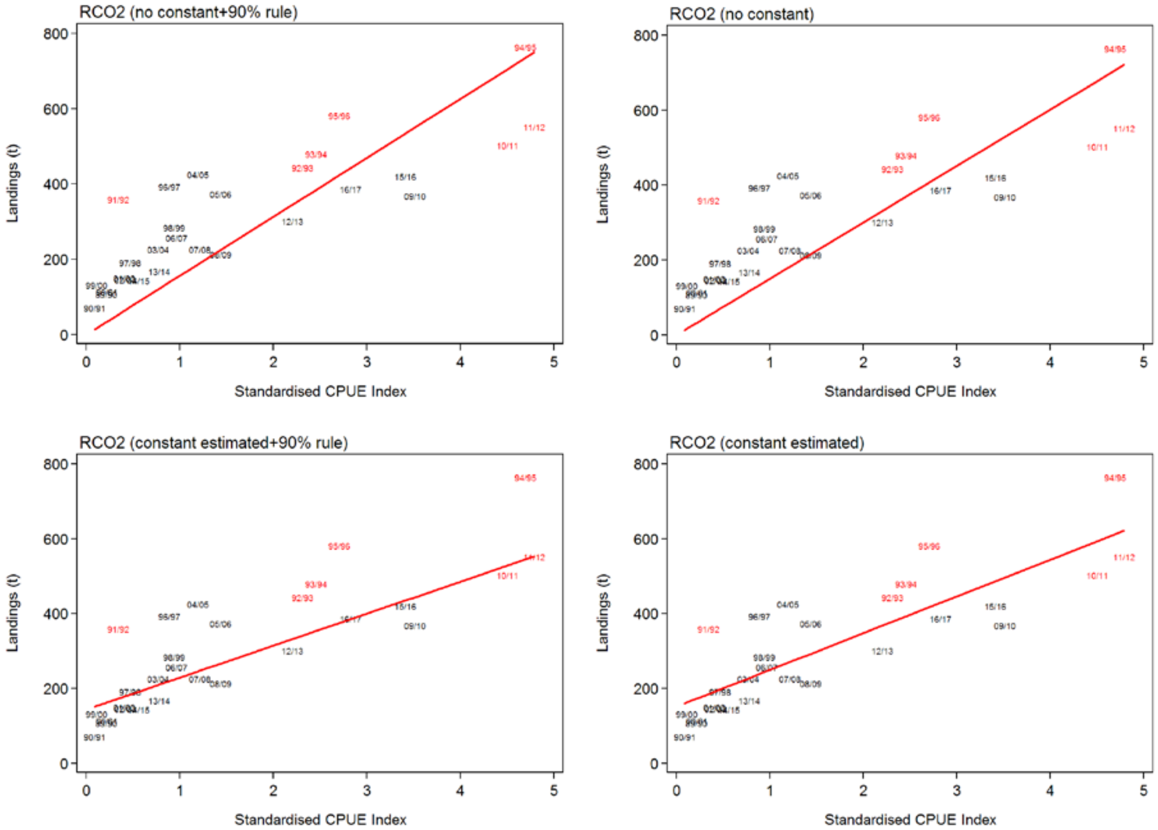

Figure 19: Four RCO 2 regression models with model parameters and statistics presented in Table 24. Model years in red are those where catch was more than 90% of the TACC.

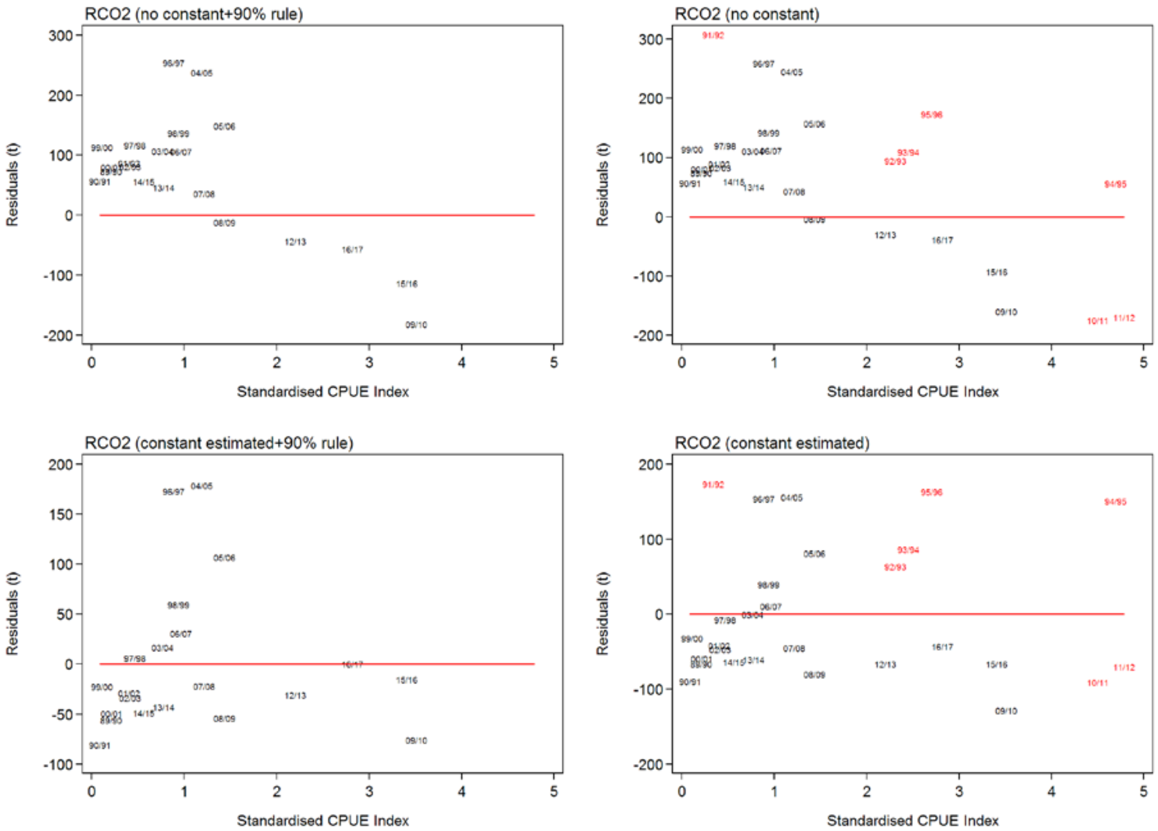

Figure 20: Absolute residuals for four RCO 2 regression models with residual statistics presented in Table 24. Model years in red are those where catch was more than 90% of the TACC.

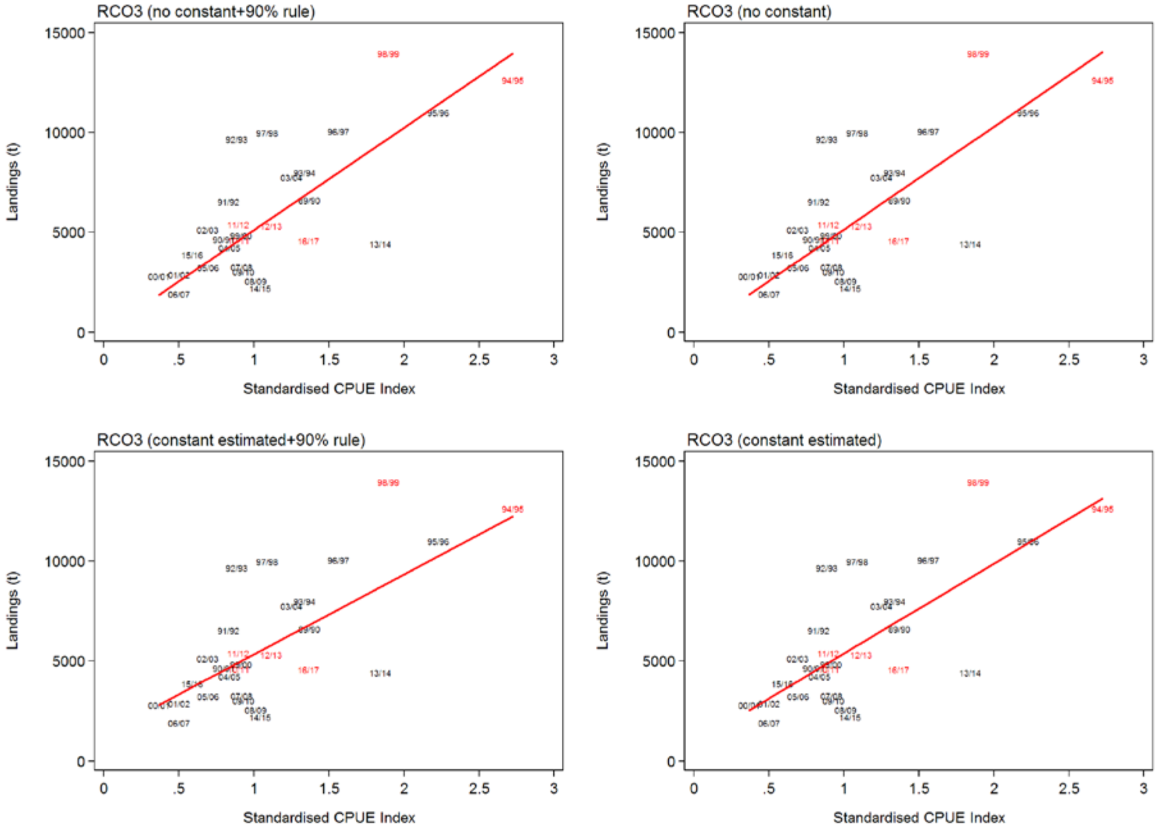

Figure 21: Four RCO 3 regression models with model parameters and statistics presented in Table 24. Model years in red are those where catch was more than 90% of the TACC.

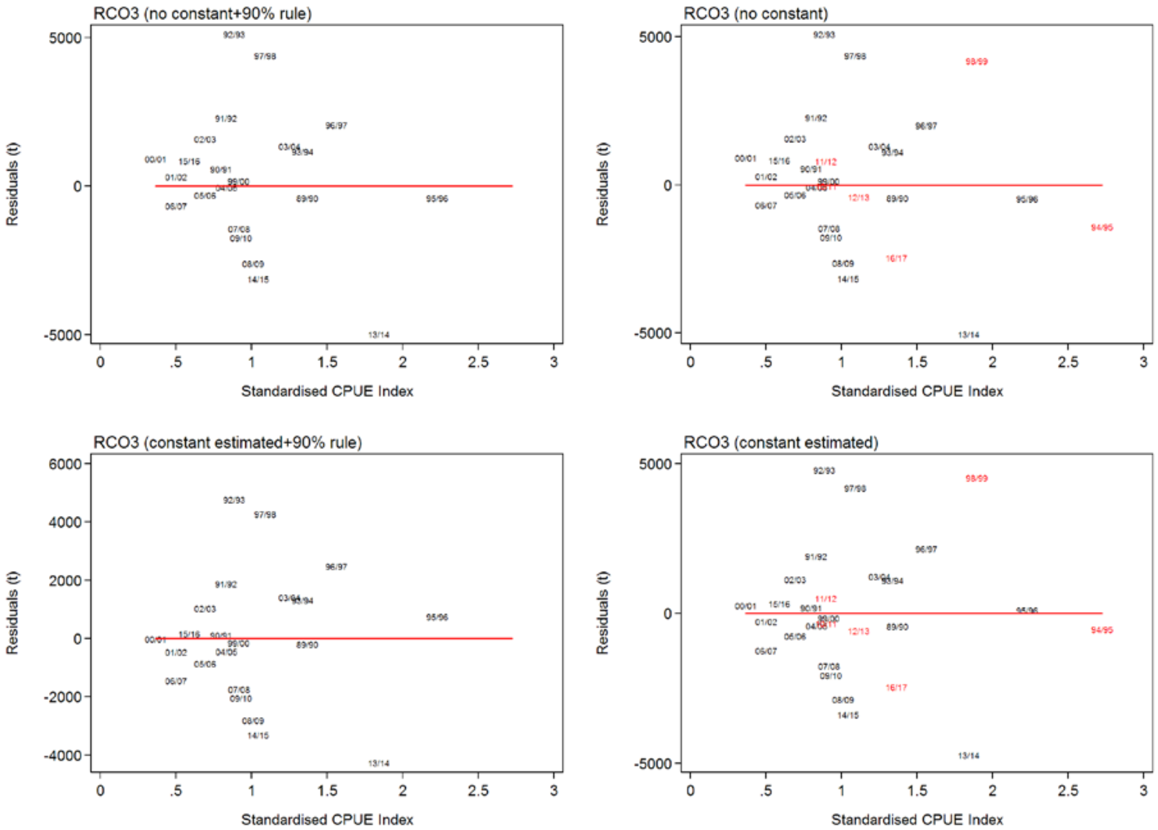

Figure 22: Absolute residuals for four RCO 3 regression models with residual statistics presented in Table 24. Model years in red are those where catch was more than 90% of the TACC.

The RCO 3 regression models which estimated a constant (intercept) parameter resulted in slightly less steep slopes and non-significant constant parameter estimates (Figure 21). The two "*no constant*" models had the same slope, regardless of the catch constraint assumption, while the two models which estimated a constant (intercept) parameter differed with respect to the catch assumption. The "*with constant*" model which used all the catch years had a steeper slope than the model which excluded the years where catch was greater than 90% TACC. However, neither slope was as steep as the "*no constant*" models (Figure 21). None of the RCO 3 models appeared to have strongly biased residual patterns, indicating that all four regression models would likely to be acceptable in the MP (Figure 22).

4.6 Selection of the RCO 2/RCO 3 MP

The information in this report was presented to the SINSWG in March 2018, which made the following decisions with respect to the continuation of the RCO 2/RCO 3 MPs:

a) the combined (Eq. F.4) series from the standardised RCO 2 model "*no interaction*" and the RCO 3 model "*extended2*" would drive the respective RCO 2 and RCO 3 MPs;

b) catch data up to at least the end of January would be used to predict the complete year CPUE;

c) a full standardised analysis would be conducted, including selecting the core vessel data set and the stepwise selection of model parameters in both the lognormal and binomial models;

d) all years would be used to calculate the predictive regression model;

e) slope and intercept parameters would be included in the predictive equation.

These MPs are both defined in Eq. 4.

Eq. 4

$$
\begin{aligned}
& TACC_{\text{base}} = \text{ 500 t (RCO2) or 4600 t (RCO3)} \\
& I_y : \text{ CPUE index in year } y \text{ based on partial year data} \\
& a = \text{intercept}\left\{C_{1990} \text{ to } C_{y-1}, I_{1990} \text{ to } I_{y-1}\right\} \\
& b = \text{slope}\left\{C_{1990} \text{ to } C_{y-1}, I_{1990} \text{ to } I_{y-1}\right\} \\
& ACE_y = \left(a + b * I_y\right) - TACC_{\text{base}} \\
& \text{if } \left(a + b * I_y\right) < TACC_{\text{base}} \text{ then } ACE_y = 0
\end{aligned}
$$

where

$$
\begin{aligned}
& C_i = \text{QMR/MHR catch in year 1990 to } y-1 \\
& I_i = \text{ combined standardised RCO2/RCO3 CPUE index in year 1990 to year } y-1
\end{aligned}
$$

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Beentjes, M.P. MacGibbon, D.J.; Parkinson, D. (2016). Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61*. 135 p.

Beentjes, M.P. Stevenson, M.L. (2000). Review of the east coast South Island winter trawl survey time series, 1991–1996. *NIWA Technical Report 86.* 64 p.

Beentjes, M.P. Stevenson, M.L. (2008). Inshore trawl survey of Canterbury Bight and Pegasus Bay, May-June 2007 (KAH0705). *New Zealand Fisheries Assessment Report 2008/38*. 95 p.

Bentley, N. (2012). Approaches for determining in-season TAC Increases for 2nd Schedule Stocks (RCO3 and RCO7). Document 2012-34. (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N. (2013a). Development and evaluation of management procedures for red cod fisheries in RCO 2, RCO 3, and RCO 7. SINSWG Document 2013-08. (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N. (2013b). Development and evaluation of management procedures for red cod fisheries in RCO 2, RCO 3, and RCO 7 – Appendices for RCO 3. SINSWG Document 2013-08a. (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N. (2013c). Development and evaluation of management procedures for red cod fisheries in RCO 2, RCO 3, and RCO 7 – Appendices for RCO 2. SINSWG Document 2013-08c. (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N. (2015). Start-of-season CPUE and in-season adjustment of TACC for RCO 3 and RCO 2 in 2014/2015. SINSWG Document 2015-6C. 23 p. . (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N. (2016a). Start-of-season CPUE and in-season adjustment of TACC for RCO 2 in 2015/2016. SINSWG Document 2016-10. 19 p. (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N. (2016b). Start-of-season CPUE and in-season adjustment of TACC for RCO 3 in 2015/2016. SINSWG Document 2016-11. 20 p. (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N. (2017a). Start of season CPUE and in season adjustment of TACC for RCO 2: February 2017 update. SINSWG Document 2017-09. 23 p. (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N. (2017b). Start of season CPUE and in season adjustment of TACC for RCO 3: February 2017 update. SINSWG Document 2017-10. 23 p. (Unpublished document held by Fisheries New Zealand, Wellington).

Bentley, N.; Kendrick, T.H.; Starr, P.J.; Breen, P.A. (2011). Influence plots and metrics: tools for better understanding fisheries catch-per-unit-effort standardisations. *ICES Journal of Marine Science*. doi:10.1093/icesjms/fsr174.

Fisheries New Zealand (2018). Fisheries Assessment Plenary, May 2018: stock assessments and stock status. Compiled by the Fisheries Science and Information Group, Fisheries New Zealand, Wellington, New Zealand. 1674 p. (Red Cod found in Chapter 71 of Volume 3)

Fletcher, D.; Mackenzie, D.; Villouta, E. (2005). Modelling skewed data with many zeros: A simple approach combining ordinary and logistic regression. *Environmental and Ecological Statistics 12*: 45–54.

Francis, R.I.C.C. (1999). The impact of correlations in standardised CPUE indices. New Zealand Fisheries Assessment Research Document 99/42. 30 p. (Unpublished report held in NIWA library, Wellington).

Francis, R.I.C.C. (2001). Orange roughy CPUE on the South and East Chatham Rise. *New Zealand Fisheries Assessment Report 2001/26*. 30 p.

Francis, R.LC.C.; Hurst, R.J.; Renwick, J.A. (2001). An evaluation of catchability assumptions in New Zealand stock assessments. *New Zealand Fisheries Assessment Report 2001/01*. 37 p.

Langley, A.D. (2014). Updated CPUE analyses for selected South Island inshore finfish stocks. *New Zealand Fisheries Assessment Report 2014/40*. 116 p.

Ministry of Fisheries. (2010). WAREHOU Database Documentation Catch Effort Base Views and Fields. Version 9. 80 p. (Unpublished report held by Fisheries New Zealand, Wellington. Obtainable from mailto:RDM.Shared@mpi.govt.nz).

Quinn, T.R.; Deriso, R.B. (1999). Quantitative Fish Dynamics. Oxford University Press. 542 p.

Starr, P.J. (2007). Procedure for merging MFish landing and effort data, version 2.0. Report to the Adaptive Management Programme Fishery Assessment Working Group: AMP WG/07/04. 17 p. (Unpublished document held by Fisheries New Zealand, Wellington).

Starr, P.J.; Bentley, N. (2018a). Prediction of 2017–18 RCO 2 CPUE and Operation Of RCO 2 Management Procedure. Report to the Southern Inshore WG SINSWG 2018-07. 20 p. (Unpublished document held by Fisheries New Zealand, Wellington).

Starr, P.J.; Bentley, N. (2018b). Prediction of 2017–18 RCO 3 CPUE and Operation Of RCO 3 Management Procedure. Report to the Southern Inshore WG SINSWG 2018-08. 20 p. (Unpublished document held by Fisheries New Zealand, Wellington).

Appendix A. GLOSSARY OF ABBREVIATIONS, CODES, AND DEFINITIONS OF TERMS

Table A.1: Table of abbreviations and definitions of terms

Term/Abbreviation	Definition
AIC	Akaike Information Criterion: used to select between different models (lower is better)
AMP	Adaptive Management Programme
analysis data set	data set available after completion of grooming procedure (Starr 2007)
arithmetic CPUE	sum of catch/sum of effort, usually summed over a year within the stratum of interest
CDI plot	Coefficient-distribution-influence plot (Bentley et al. 2011)
CELR	Catch/Effort Landing Return (Ministry of Fisheries 2010): active since July 1989 for vessels less than 28 m. Fishing events are reported on a daily basis on this form. This form has been replaced for vessels between 6 m and 28 m by the TCER, LTCER, and NCELR forms.
CLR	Catch Landing Return (Ministry of Fisheries 2010): active since July 1989 for all vessels not using the CELR or NCELR forms to report landings
CPUE	Catch Per Unit Effort
daily stratum or daily effort stratum	summarisation within a trip by day of fishing with the modal statistical area of occupancy and modal declared target species assigned to the day of fishing; only trips that used a single capture method are used
destination code	code indicating how each landing was directed after leaving vessel (see Table 6)
EEZ	Exclusive Economic Zone: marine waters under control of New Zealand
estimated catch	an estimate made by the operator of the vessel of the weight of red cod captured, which is then recorded as part of the 'fishing event'. Only the top five species are required for any fishing event in the CELR and TCEPR data (expanded to eight for the TCER form type)
fishing event	a record of activity in a trip. It is a day of fishing within a single statistical area, using one method of capture and one declared target species (CELR data) or a unit of fishing effort (usually a tow or a line set) for fishing methods using other reporting forms
fishing year	1 October – 30 September for red cod
FMA	Fisheries New Zealand Fishery Management Areas: 10 legal areas used by Fisheries New Zealand to define large scale stock management units; inshore QMAs usually consist of one or more of these regions
landing event	weight of red cod off-loaded from a vessel at the end of a trip. Every landing has an associated destination code and there can be multiple landing events with the same or different destination codes for a trip
LCER	Lining Catch Effort Return (Ministry of Fisheries 2010): active since October 2003 for lining vessels larger than 28 m and reports set-by-set fishing events
LFR	Licensed Fish Receiver: processors legally allowed to receive commercially caught species
LTCER	Lining Trip Catch Effort Return (Ministry of Fisheries 2010): active since October 2007 for lining vessels between 6 and 28 m and reports individual set-by-set fishing events
MHR	Monthly Harvest Return: monthly returns used after 1 October 2001. Replaced QMRs but have same definition and utility
NCELR	Netting Catch Effort Landing Return (Ministry of Fisheries 2010): active since October 2006 for inshore vessels between 6 and 28 m using setnet gear and reports individual fishing events
QMA	Quota Management Area: legally defined unit area used for red cod management (Figure 1)
QMR	Quota Management Report: monthly harvest reports submitted by commercial fishers. In use from 1986 to 2001 until replaced by MHR
QMS	Quota Management System: name of the management system used in New Zealand to control commercial and non-commercial catches
replog	data extract identifier issued by Fisheries New Zealand data unit
residual implied coefficient plots	plots that mimic interaction effects between the year coefficients and a categorical variable by adding the mean of the categorical variable residuals in each fishing year to the year coefficient, creating a plot of the 'year effect' for each value of the categorical variable
rollup	a term describing the average number of records per 'trip-stratum' or 'daily stratum'
SINSWG	Southern Inshore Fisheries Assessment Working Group: Fisheries New Zealand Working Group overseeing the work presented in this report
standardised CPUE	procedure used to remove the effects of explanatory variables such as vessel, statistical area and month of capture from a data set of catch/effort data for a species; annual abundance is usually modelled as an explanatory variable representing the year of capture and, after

Term/Abbreviation	Definition
	removing the effects of the other explanatory variables, the resulting year coefficients represent the relative change in species abundance
statistical area	sub-areas (Appendix B) within an FMA that are identified in catch/effort returns. The boundaries for these statistical areas do not always coincide with the QMA/FMA boundaries, leading to ambiguity in the assignment of effort to a QMA
TACC	Total Allowable Commercial Catch: catch limit set by the Minister of Fisheries for a QMA that applies to commercial fishing
TCEPR	Trawl Catch Effort Processing Return (Ministry of Fisheries 2010): active since July 1989 for deepwater vessels larger than 28 m and reports tow-by-tow fishing events
TCER	Trawl Catch Effort Return (Ministry of Fisheries 2010): active since October 2007 for inshore vessels between 6 and 28 m and reports tow-by-tow fishing events
trip	a unit of fishing activity by a vessel consisting of 'fishing events' and 'landing events', which are activities assigned to the trip. Fisheries New Zealand generates a unique database code to identify each trip, using the trip start and end dates and the vessel code (Ministry of Fisheries 2010)
trip-stratum	summarisation within a trip by fishing method used, the statistical area of occupancy and the declared target species
unstandardised CPUE	geometric mean of all individual CPUE observations, usually summarised over a year within the stratum of interest

Table A.2: Code definitions used in the body of the main report and in Appendix C, Appendix D and Appendix E.

Code	Definition	Code	Description
BLL	Bottom longlining	BAR	Barracouta
BPT	Bottom trawl – pair	BNS	Bluenose
BS	Beach seine/drag nets	BUT	Butterfish
BT	Bottom trawl – single	ELE	Elephant fish
CP	Cod potting	FLA	Flatfish (mixed species)
DL	Drop/dahn lines	GMU	Grey mullet
DS	Danish seining – single	GSH	Ghost shark
HL	Handlining	GUR	Red gurnard
MW	Midwater trawl – single	HOK	Hoki
RLP	Rock lobster potting	HPB	Hapuku & Bass
SLL	Surface longlining	JDO	John Dory
SN	Setnetting (includes gill nets)	JMA	Jack mackerel
T	Trolling	KAH	Kahawai
TL	Trot lines	KIN	Kingfish
		LEA	Leatherjacket
		LIN	Ling
		MOK	Moki
		POR	Porae
		RCO	Red cod
		SCH	School shark
		SCI	Scampi
		SKI	Gemfish
		SNA	Snapper
		SPD	Spiny dogfish
		SPE	Sea perch
		RCO	Red cod
		SQU	Arrow squid
		STA	Giant stargazer
		SWA	Silver warehou
		TAR	Tarakihi
		TRE	Trevally
		WAR	Blue warehou

Appendix B. MAP OF FISHERIES NEW ZEALAND STATISTICAL AND MANAGEMENT AREAS

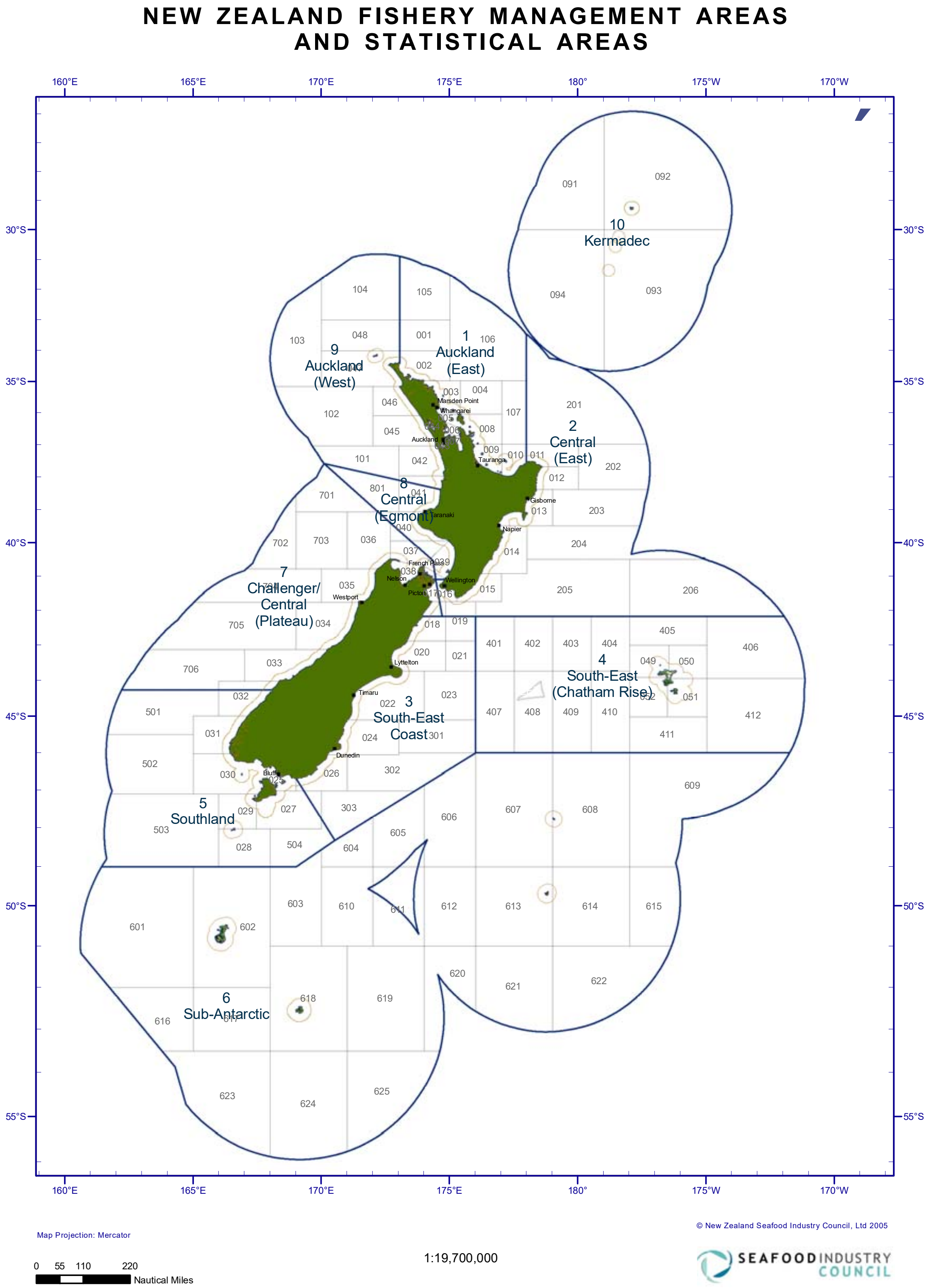

Figure B.1: Map of Fisheries New Zealand statistical areas and Fishery Management Area (FMA) boundaries, showing locations where FMA boundaries are not contiguous with the statistical area boundaries

Appendix C. DATA SUMMARIES BY RCO 2 STATISTICAL AREA GROUP FOR BOTTOM TRAWL

Table C.1A: RCO 2 scaled QMR landings (Eq. 1 in tonnes) by fishing year and capture method for the three RCO 2 sub-areas (Table 13) based on trips which landed red cod. These values are plotted in Figure 5.

Fishing	Method of capture								Method of capture								Method of capture							
year	BT	MW	DS	BLL	SN	CP	Other	Total	BT	MW	DS	BLL	SN	CP	Other	Total	BT	MW	DS	BLL	SN	CP	Other	Total
	ECNI (RCO2) (t)								E Cook St (RCO2) (t)								W Cook St (RCO2) (t)							
89/90	65	0.0	–	0.1	0.0	–	–	65	22	0.0	–	–	0.5	–	–	23	13	–	–	3.9	0.7	–	0.0	18
90/91	27	0.0	–	0.0	0.1	–	–	27	15	0.1	–	0.2	0.4	–	–	15	19	–	–	3.4	3.3	–	2.1	27
91/92	164	0.0	–	0.5	2.2	–	–	167	79	0.3	–	0.0	2.6	–	–	82	78	0.0	–	8.9	8.3	0.0	14.5	109
92/93	344	0.2	–	9.8	0.6	–	–	355	47	1.0	–	0.1	4.6	–	–	52	16	0.0	–	3.5	9.4	–	5.1	34
93/94	374	0.7	–	1.6	1.4	–	0.3	378	46	0.6	–	0.1	5.0	–	–	51	28	–	–	3.4	11.1	0.3	6.1	48
94/95	606	0.5	0.5	0.3	1.4	–	–	609	74	3.0	–	0.1	2.5	–	–	79	56	0.0	–	4.8	9.3	0.0	3.7	74
95/96	368	0.4	1.1	0.1	2.5	–	–	372	88	11.2	–	0.2	1.3	–	–	101	84	0.0	–	5.6	10.3	–	6.6	107
96/97	144	0.1	–	0.0	0.8	–	–	145	121	3.9	–	0.2	0.6	–	–	125	94	–	–	6.2	11.5	0.0	10.7	122
97/98	92	0.1	–	0.0	0.9	–	–	93	46	6.3	–	0.0	0.2	–	–	53	25	0.0	–	4.4	11.4	–	2.3	43
98/99	150	0.5	0.2	0.1	0.5	–	–	151	81	7.3	–	0.2	0.3	–	–	89	40	–	–	1.4	0.7	–	0.2	42
99/00	25	0.2	0.1	0.0	0.2	–	–	26	87	7.5	–	0.0	0.2	–	–	95	8	–	–	0.9	0.4	–	0.0	9
00/01	38	0.2	0.2	0.1	0.1	–	–	39	50	7.8	0.0	0.1	0.8	–	–	58	13	–	–	1.6	0.5	–	–	15
01/02	75	0.2	0.6	0.1	0.2	–	–	77	53	7.0	–	0.1	1.6	–	–	62	9	0.0	–	0.8	0.4	0.0	–	10
02/03	51	0.4	–	0.3	0.1	–	–	52	67	9.8	–	0.2	0.8	–	–	78	12	0.0	–	1.1	0.9	–	–	14
03/04	83	0.3	0.0	0.8	0.3	–	–	84	93	9.6	–	0.1	1.2	–	–	103	36	–	–	0.6	1.3	–	–	38
04/05	193	0.5	0.2	1.2	0.4	0.1	–	195	121	20.5	–	0.3	5.5	–	–	147	73	0.0	–	2.2	6.7	–	–	81
05/06	234	0.1	–	0.6	0.6	–	–	236	50	2.0	–	1.0	5.7	–	–	58	75	0.2	–	1.3	2.1	–	–	78
06/07	152	0.2	0.9	1.7	0.9	–	–	156	37	2.8	–	1.4	6.1	–	–	47	49	0.1	0.9	1.1	2.6	–	–	53
07/08	160	0.1	0.5	2.0	1.6	–	–	164	32	1.0	–	0.9	6.7	–	–	40	18	0.0	0.2	0.7	1.9	–	–	21
08/09	165	0.0	–	2.1	1.7	0.0	–	169	8	0.7	0.0	0.1	3.1	0.1	–	12	27	0.2	0.8	1.7	0.9	0.0	–	31
09/10	313	0.4	0.6	2.2	1.3	–	–	318	12	0.1	–	0.0	4.0	0.0	–	16	31	0.2	0.0	0.6	1.1	0.0	0.0	33
10/11	435	0.1	5.3	1.8	0.6	–	–	443	22	0.6	–	0.1	3.3	–	–	26	30	0.0	0.0	0.8	0.9	–	–	32
11/12	485	0.0	3.8	1.0	0.7	–	–	490	33	0.4	–	1.2	5.7	–	–	41	18	0.0	0.1	0.6	0.4	–	–	19
12/13	255	0.0	0.1	0.9	0.5	–	–	256	18	0.5	–	1.0	4.0	–	–	23	20	0.0	–	0.1	0.6	–	–	21
13/14	110	0.0	–	0.8	0.2	0.0	–	111	36	0.3	–	0.9	1.8	–	–	39	15	0.1	–	0.8	0.4	0.0	–	16
14/15	94	0.1	0.7	0.6	0.1	0.0	–	96	20	1.0	–	1.3	0.7	–	–	23	22	0.0	–	0.5	0.2	0.0	–	23
15/16	373	0.0	5.1	1.0	1.0	–	0.0	380	19	0.3	–	0.4	0.3	–	0.1	20	18	0.0	–	0.5	0.1	0.0	–	18
16/17	327	0.0	4.2	0.9	0.6	–	0.9	334	27	1.3	–	0.8	0.8	–	0.8	31	19	0.0	–	0.3	0.3	–	–	20
Total	5 904	5.5	24.2	30.4	21.4	0.2	1.2	5 987	1 403	107.1	0.0	10.8	70.2	0.1	0.9	1 592	944	1.1	2.0	61.8	97.6	0.4	51.4	1 159
last 5 years	1 159	0.2	10.1	4.3	2.4	0.0	0.9	1 177	121	3.5	0.0	4.4	7.6	0.0	0.9	137	94	0.1	0.0	2.1	1.6	0.0	0.0	98

Table C.1B: Distribution of RCO 2 landings (%) by fishing year and capture method for the three RCO 2 sub-areas (Table 13) based on trips which landed red cod.

Fishing	Method of capture							Method of capture							Method of capture						
year	BT	MW	DS	BLL	SN	CP	Other	BT	MW	DS	BLL	SN	CP	Other	BT	MW	DS	BLL	SN	CP	Other
	ECNI (RCO2) (%)							E Cook St (RCO2) (%)							W Cook St (RCO2) (%)						
89/90	99.8	0.01	–	0.12	0.07	–	–	97.8	0.13	–	–	2.06	–	–	73.7	–	–	22.02	4.04	–	0.26
90/91	99.6	0.02	–	0.03	0.39	–	–	95.9	0.46	–	1.01	2.59	–	–	68.0	–	–	12.48	11.91	–	7.61
91/92	98.4	0.01	–	0.28	1.30	–	–	96.5	0.39	–	0.01	3.13	–	–	71.0	0.00	–	8.13	7.61	0.00	13.28
92/93	97.0	0.05	–	2.75	0.17	–	–	89.1	1.92	–	0.10	8.90	–	–	47.6	0.00	–	10.08	27.35	–	15.02
93/94	98.9	0.19	–	0.42	0.36	–	0.08	88.9	1.13	–	0.17	9.77	–	–	56.8	–	–	6.92	22.97	0.64	12.65
94/95	99.6	0.07	0.08	0.04	0.23	–	–	92.9	3.80	–	0.11	3.14	–	–	75.8	0.06	–	6.47	12.65	0.01	5.00
95/96	98.9	0.11	0.30	0.03	0.66	–	–	87.4	11.14	–	0.17	1.29	–	–	78.8	0.04	–	5.28	9.69	–	6.22
96/97	99.3	0.09	–	0.01	0.57	–	–	96.3	3.15	–	0.13	0.45	–	–	76.7	–	–	5.09	9.41	0.02	8.77
97/98	98.9	0.09	–	0.04	0.99	–	–	87.6	12.00	–	0.07	0.32	–	–	57.5	0.01	–	10.40	26.65	–	5.46
98/99	99.2	0.34	0.11	0.04	0.31	–	–	91.3	8.20	–	0.19	0.29	–	–	94.5	–	–	3.33	1.75	–	0.39
99/00	97.8	0.87	0.30	0.08	0.91	–	–	91.9	7.87	–	0.02	0.26	–	–	86.4	–	–	9.59	3.95	–	0.03
00/01	98.5	0.58	0.52	0.17	0.19	–	–	85.2	13.33	0.00	0.13	1.29	–	–	86.3	–	–	10.24	3.42	–	–
01/02	98.6	0.21	0.85	0.08	0.22	–	–	86.0	11.32	–	0.20	2.50	–	–	88.3	0.02	–	7.92	3.64	0.10	–
02/03	98.5	0.83	–	0.59	0.12	–	–	86.1	12.57	–	0.31	1.01	–	–	86.0	0.13	–	7.78	6.07	–	–
03/04	98.2	0.35	0.04	0.97	0.41	–	–	89.5	9.24	–	0.09	1.20	–	–	94.7	–	–	1.72	3.54	–	–
04/05	98.7	0.28	0.12	0.60	0.23	0.05	–	82.1	13.92	–	0.19	3.76	–	–	89.1	0.04	–	2.71	8.17	–	–
05/06	99.4	0.06	–	0.27	0.25	–	–	85.1	3.40	–	1.69	9.84	–	–	95.4	0.27	–	1.63	2.69	–	–
06/07	97.6	0.12	0.58	1.07	0.60	–	–	78.0	5.94	–	3.07	13.04	–	–	91.2	0.22	1.60	2.13	4.81	–	–
07/08	97.5	0.05	0.29	1.24	0.95	–	–	78.7	2.39	–	2.24	16.68	–	–	86.2	0.08	1.05	3.43	9.24	–	–
08/09	97.7	0.03	–	1.22	1.00	0.03	–	67.1	5.95	0.07	0.57	25.66	0.62	–	88.3	0.70	2.70	5.47	2.80	0.02	–
09/10	98.6	0.12	0.19	0.68	0.42	–	–	74.4	0.91	–	0.08	24.58	0.05	–	94.3	0.58	0.05	1.91	3.16	0.00	0.04
10/11	98.2	0.01	1.20	0.41	0.13	–	–	84.5	2.50	–	0.32	12.67	–	–	94.4	0.05	0.00	2.60	2.93	–	–
11/12	98.9	0.01	0.78	0.20	0.13	–	–	82.0	1.06	–	2.98	13.93	–	–	93.9	0.08	0.42	3.36	2.21	–	–
12/13	99.4	0.01	0.02	0.34	0.19	–	–	75.9	2.37	–	4.31	17.44	–	–	96.3	0.03	–	0.67	3.06	–	–
13/14	99.1	0.03	–	0.74	0.17	0.00	–	92.1	0.88	–	2.39	4.58	–	–	92.3	0.60	–	4.63	2.36	0.07	–
14/15	98.4	0.09	0.70	0.68	0.13	0.00	–	87.2	4.16	–	5.41	3.19	–	–	97.0	0.01	–	2.12	0.85	0.04	–
15/16	98.1	0.01	1.35	0.26	0.26	–	0.00	94.8	1.61	–	1.85	1.27	–	0.49	96.9	0.02	–	2.45	0.59	0.00	–
16/17	98.0	0.00	1.27	0.28	0.18	–	0.26	88.2	4.23	–	2.54	2.42	–	2.65	97.1	0.07	–	1.54	1.31	–	–
Total	98.6	0.09	0.40	0.51	0.36	0.00	0.02	88.1	6.73	0.00	0.68	4.41	0.01	0.06	81.5	0.09	0.17	5.34	8.43	0.03	4.44
last 5 years	98.5	0.02	0.86	0.36	0.20	0.00	0.07	88.1	2.56	0.00	3.18	5.53	0.00	0.67	96.1	0.13	0.00	2.18	1.61	0.02	0.00

Table C.2A: Distribution of RCO 2 landings (%) by fishing year and by month for bottom trawl in RCO sub-area ECNI (RCO 2) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for ECNI (RCO 2) are available in Table C.1A. These values are plotted in Figure 9.

												Month
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	ECNI (RCO2) (%)											
89/90	2.5	3.1	6.9	31.2	9.8	11.7	0.9	1.0	23.0	7.4	1.1	1.4
90/91	3.5	3.3	6.7	0.3	0.7	23.6	1.0	42.2	1.2	5.1	6.6	5.9
91/92	4.8	6.3	5.3	6.1	18.8	11.4	3.2	4.1	4.7	3.4	22.3	9.5
92/93	2.7	4.0	5.2	8.8	9.2	7.1	12.2	12.1	16.1	11.6	7.7	3.3
93/94	7.7	15.6	5.3	5.9	2.6	2.8	5.9	6.0	11.1	12.1	15.4	9.7
94/95	7.3	17.4	12.8	6.4	6.5	3.8	4.6	6.7	5.6	7.0	12.2	9.8
95/96	15.2	10.8	10.5	4.6	2.8	5.5	9.3	7.0	5.4	5.2	12.6	10.9
96/97	18.3	14.0	12.1	5.8	7.5	5.1	11.6	7.2	2.9	5.3	7.0	3.2
97/98	11.1	17.2	10.8	7.5	13.4	3.9	3.9	3.7	4.9	5.6	6.6	11.4
98/99	10.7	15.7	14.6	4.6	7.2	8.0	16.8	7.0	6.7	2.6	2.2	3.9
99/00	41.7	32.0	4.7	2.7	2.6	0.5	0.6	1.6	1.3	5.7	3.3	3.3
00/01	1.6	7.3	8.8	7.5	16.5	2.8	2.0	2.1	6.3	18.1	16.1	10.8
01/02	4.2	8.0	10.1	7.1	9.6	11.4	17.2	5.5	5.2	10.4	9.5	1.9
02/03	5.8	9.2	11.3	12.4	15.9	17.3	1.6	5.8	3.7	6.3	4.6	6.0
03/04	8.1	7.3	8.8	5.5	13.4	6.0	4.5	9.9	6.0	8.3	7.5	14.7
04/05	9.2	7.9	5.0	12.5	4.5	6.4	3.7	10.1	10.0	9.2	11.1	10.2
05/06	8.1	11.0	12.7	5.2	6.2	7.5	7.4	8.7	8.3	5.5	11.5	7.9
06/07	9.7	14.3	5.6	9.2	13.8	9.4	7.2	6.8	6.3	7.5	5.8	4.4
07/08	7.2	7.6	13.3	11.6	7.1	8.7	8.6	6.5	5.5	7.0	5.7	11.1
08/09	13.0	17.2	12.0	7.2	7.0	5.7	3.3	2.3	6.9	9.2	6.6	9.6
09/10	4.5	9.7	18.9	6.5	5.5	8.9	6.4	7.5	9.1	6.0	10.6	6.4
10/11	5.3	6.4	11.0	4.4	9.3	9.4	7.3	8.5	7.6	7.1	13.0	10.7
11/12	14.9	13.9	14.8	21.7	6.7	2.7	4.1	4.5	3.0	3.5	4.2	6.0
12/13	16.1	15.1	16.8	17.5	12.6	4.3	3.3	2.1	1.8	3.6	4.3	2.6
13/14	29.5	11.3	13.2	9.0	12.8	6.0	2.8	3.2	3.8	2.4	3.7	2.3
14/15	2.6	20.3	4.0	6.5	5.4	5.4	5.6	7.8	10.6	18.4	9.2	4.1
15/16	4.7	8.3	9.5	7.7	11.7	5.9	14.8	13.7	8.4	3.4	5.7	6.2
16/17	13.9	18.8	14.8	7.7	12.6	5.9	4.4	4.3	4.2	4.5	4.0	4.9
Average	9.4	12.0	11.1	8.8	8.3	6.3	6.9	7.1	7.0	6.7	9.0	7.4

Table C.2B: Distribution of RCO 2 landings (%) by fishing year and by month for bottom trawl in RCO sub-area East Cook Strait (RCO 2) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for E Cook St (RCO 2) are available in Table C.1A. These values are plotted in Figure 9.

												Month
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	E Cook St (RCO2) (%)											
89/90	0.3	2.4	1.0	8.6	11.7	7.8	6.2	3.0	5.8	41.7	9.7	1.9
90/91	20.0	3.5	1.8	13.9	9.8	11.6	2.9	10.9	6.0	4.6	8.8	6.2
91/92	2.1	11.4	8.5	12.4	10.8	9.5	12.1	5.3	9.8	0.9	11.9	5.2
92/93	6.5	3.7	9.7	18.1	5.0	3.6	8.5	16.3	5.9	10.8	6.8	5.1
93/94	4.3	10.2	7.8	3.5	9.8	3.4	4.2	3.5	10.9	21.0	12.1	9.1
94/95	4.7	7.0	10.0	7.6	15.1	5.8	8.3	13.9	5.9	7.3	12.0	2.5
95/96	8.6	11.7	1.6	5.8	2.9	8.0	8.3	22.1	14.9	5.3	2.4	8.5
96/97	1.8	4.9	2.8	15.3	4.8	12.0	6.1	17.9	20.0	4.2	4.5	5.6
97/98	7.2	3.1	5.5	6.1	4.8	7.3	25.3	12.1	5.8	5.9	7.8	9.1
98/99	2.0	16.7	4.7	5.9	6.2	3.3	3.3	12.4	8.4	20.1	8.0	9.0
99/00	8.3	6.7	2.1	3.4	26.3	23.3	7.4	11.7	4.2	1.7	0.7	4.1
00/01	1.9	2.5	23.1	4.3	17.5	11.5	10.6	12.3	9.9	2.1	1.5	2.8
01/02	1.1	3.4	5.8	28.8	7.9	6.8	10.4	14.1	13.4	2.7	3.2	2.3
02/03	0.3	17.2	3.5	20.7	16.7	8.7	9.4	9.2	7.4	2.5	2.2	2.2
03/04	0.8	12.8	8.0	22.7	5.6	8.6	23.4	5.1	2.0	5.1	0.7	5.2
04/05	3.1	3.3	2.0	10.5	12.9	14.3	27.9	11.1	7.7	3.1	2.8	1.3
05/06	7.0	2.6	19.1	9.2	5.7	18.3	6.7	8.7	3.6	0.8	13.8	4.5
06/07	5.5	2.1	18.9	9.1	2.9	7.5	5.2	6.6	2.2	3.3	36.0	0.7
07/08	2.9	17.5	14.6	18.7	7.0	9.2	12.5	6.6	1.4	1.9	1.3	6.3
08/09	3.9	15.3	16.0	11.3	4.4	5.2	4.2	7.4	8.0	2.9	21.2	0.3
09/10	1.9	6.5	12.8	11.3	14.4	2.7	18.1	12.3	11.1	7.2	1.3	0.5
10/11	4.6	6.5	18.5	17.5	6.2	3.7	2.5	4.3	3.9	0.8	10.8	20.7
11/12	1.5	3.0	7.4	46.3	10.8	2.8	0.8	2.9	5.2	5.7	6.0	7.7
12/13	6.3	3.8	6.6	14.4	7.1	2.6	0.8	2.4	18.3	6.6	2.3	28.8
13/14	2.8	6.1	6.2	4.7	10.4	4.6	8.3	3.4	2.8	6.3	1.1	43.4
14/15	4.5	2.7	18.9	9.9	5.0	8.3	9.4	11.1	6.5	5.2	9.8	8.7
15/16	5.0	3.3	6.2	5.7	3.8	9.5	6.4	1.8	4.3	4.9	26.4	22.7
16/17	1.1	2.3	16.1	5.1	24.8	11.8	8.9	4.6	5.9	6.4	8.1	4.8
Average	3.9	7.5	7.5	12.3	10.0	9.5	10.9	10.6	8.3	6.1	6.7	6.7

Table C.2C: Distribution of RCO 2 landings (%) by fishing year and by month for bottom trawl in RCO sub-area West Cook Strait (RCO 2) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for W Cook St (RCO 2) are available in Table C.1A. These values are plotted in Figure 9.

												Month
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	W Cook St (RCO2) (%)											
89/90	3.5	0.5	0.3	0.3	0.6	–	0.3	0.3	10.3	10.7	44.8	28.4
90/91	14.5	8.2	2.7	9.2	2.5	11.6	6.6	6.5	8.0	11.7	10.0	8.6
91/92	1.4	3.0	9.0	0.9	23.7	0.7	6.2	5.3	20.4	14.7	1.8	12.9
92/93	11.6	3.3	7.1	2.5	1.2	9.9	6.8	8.2	3.3	16.0	10.7	19.4
93/94	4.4	4.1	13.8	8.3	5.5	2.1	17.1	3.0	16.3	14.6	5.9	4.8
94/95	8.0	1.4	8.1	7.6	2.4	4.1	6.3	4.6	32.3	6.8	8.5	9.9
95/96	11.8	6.8	4.0	7.6	2.8	9.4	17.8	12.6	14.3	3.7	0.1	9.1
96/97	6.2	5.8	5.4	5.0	29.7	14.6	6.8	9.1	8.4	2.2	0.7	6.0
97/98	6.7	16.1	3.0	8.6	13.9	5.4	8.8	6.4	10.3	7.2	10.3	3.4
98/99	0.3	12.0	9.4	6.6	6.4	6.0	5.2	4.4	45.0	2.4	1.4	1.0
99/00	5.6	2.5	3.4	6.6	7.8	6.3	14.8	22.1	8.3	13.1	5.4	4.1
00/01	1.3	5.2	19.6	3.2	6.9	40.3	12.5	5.1	2.1	1.7	1.8	0.4
01/02	6.5	4.5	7.0	4.4	11.9	7.9	31.0	3.7	5.5	4.4	8.1	5.0
02/03	2.9	2.1	1.5	3.4	26.2	16.5	8.6	3.6	14.5	10.4	7.8	2.6
03/04	0.8	1.2	0.6	3.0	0.2	2.6	57.5	15.8	0.3	15.6	0.6	1.6
04/05	6.6	7.3	2.7	1.2	3.9	5.1	17.4	6.1	4.4	7.1	10.6	27.6
05/06	15.8	9.4	2.6	5.3	37.4	6.0	2.7	1.1	5.0	5.8	1.3	7.7
06/07	0.4	9.5	7.3	17.2	27.5	4.1	12.1	4.3	5.6	8.2	1.6	2.1
07/08	6.3	7.9	23.6	6.8	2.5	1.6	8.5	8.6	1.8	9.7	14.2	8.6
08/09	12.7	6.6	6.5	4.5	12.1	6.1	4.3	2.2	27.6	10.9	3.6	2.7
09/10	6.2	0.7	3.4	19.7	5.5	15.3	25.3	9.3	4.3	5.8	2.8	1.6
10/11	19.6	10.4	15.4	4.7	12.6	3.4	9.9	0.9	13.6	2.5	4.7	2.3
11/12	16.4	1.5	6.3	3.8	2.7	6.1	2.1	2.4	1.4	22.6	21.1	13.5
12/13	9.4	23.3	0.5	20.4	2.2	22.4	2.6	1.8	0.6	7.7	8.3	0.9
13/14	8.3	7.2	3.2	3.2	4.1	5.9	1.6	4.2	16.8	7.8	4.3	33.4
14/15	4.2	3.6	8.8	9.5	2.2	3.9	16.0	2.6	4.8	9.4	7.5	27.5
15/16	7.0	26.5	3.4	5.8	2.4	10.3	12.2	1.9	2.8	2.5	18.8	6.4
16/17	6.9	0.3	3.7	10.4	25.1	16.7	10.9	3.2	9.6	0.6	7.6	5.1
Average	7.4	6.7	6.2	6.5	13.2	7.7	11.8	6.0	12.1	7.6	5.5	9.3

Table C.3A: Distribution of RCO 2 landings (%) by fishing year and target species for bottom trawl in RCO sub-area ECNI (RCO 2) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for ECNI (RCO 2) are available in Table C.1A. The values are plotted in Figure 10.

Fishing year	GUR	TAR	FLA	SCI	RCO	SKI	HOK	SNA	Other
	ECNI (RCO2)								
89/90	6.6	73.3	9.4	–	–	0.7	4.6	1.8	3.5
90/91	7.7	56.3	6.8	4.3	21.3	1.2	0.0	0.0	2.3
91/92	29.8	11.7	35.7	16.2	3.1	1.1	0.0	0.0	2.3
92/93	40.4	13.7	29.1	5.0	6.2	0.8	0.3	0.5	3.9
93/94	33.5	17.7	17.1	10.4	6.5	3.8	2.0	3.6	5.5
94/95	33.9	20.7	29.1	3.1	2.3	2.2	1.8	1.1	5.7
95/96	29.5	16.9	36.4	1.6	5.0	2.7	2.6	0.6	4.6
96/97	30.4	18.7	32.1	6.7	0.7	1.8	3.7	0.3	5.6
97/98	23.3	10.0	35.0	21.6	–	2.4	6.6	0.2	1.0
98/99	29.4	9.1	25.3	25.9	1.5	5.3	1.6	0.3	1.6
99/00	36.8	7.4	28.1	15.3	6.1	0.7	3.2	0.2	2.1
00/01	14.7	14.8	19.2	44.6	0.3	1.5	0.5	0.3	3.9
01/02	20.5	17.6	9.8	48.6	–	0.1	0.2	0.1	3.1
02/03	32.1	21.3	8.0	26.1	–	2.6	5.2	1.1	3.5
03/04	28.5	30.7	20.4	12.4	–	1.2	2.9	2.0	2.0
04/05	32.3	40.0	18.0	2.8	–	0.7	1.3	1.2	3.6
05/06	23.2	57.0	16.3	1.2	0.2	0.0	0.5	0.6	0.9
06/07	13.7	60.2	20.4	1.4	–	1.0	0.9	1.0	1.3
07/08	24.9	51.4	20.8	0.8	–	0.0	0.0	1.1	0.9
08/09	21.3	50.8	23.9	0.0	0.5	0.3	0.3	1.4	1.5
09/10	49.1	34.7	12.8	0.5	0.5	0.1	1.0	0.5	0.8
10/11	36.8	46.1	11.3	0.9	1.9	0.3	0.4	1.0	1.2
11/12	42.4	20.2	27.0	0.1	7.9	0.0	0.1	2.0	0.2
12/13	37.1	22.8	35.3	0.0	2.8	0.1	0.2	1.2	0.4
13/14	20.6	39.1	36.5	0.0	–	0.3	1.3	1.1	1.0
14/15	15.2	58.8	23.9	0.1	–	0.2	0.1	0.3	1.2
15/16	24.2	35.7	31.9	0.0	4.3	1.3	0.4	0.8	1.4
16/17	36.8	38.3	16.4	0.2	3.2	0.3	0.2	1.7	3.0
Average	32.0	30.2	24.1	4.7	3.0	1.2	1.1	1.1	2.6

Table C.3B: Distribution of RCO 2 landings (%) by fishing year and target species for bottom trawl in RCO sub-area East Cook Strait (RCO 2) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for E Cook St (RCO 2) are available in Table C.1A. The values are plotted in Figure 10.

Fishing year	TAR	HOK	WAR	RCO	BAR	GUR	FLA	Other
	E Cook St (RCO2)							
89/90	55.2	1.3	1.4	38.9	0.1	0.5	0.1	2.4
90/91	74.7	0.1	8.0	7.5	0.5	5.0	0.0	4.3
91/92	75.7	0.2	9.4	4.4	6.0	3.3	0.0	1.0
92/93	62.1	0.6	12.3	1.5	4.1	7.5	10.0	1.9
93/94	51.6	2.5	10.4	6.8	3.2	1.6	22.0	1.9
94/95	46.3	13.9	9.2	7.7	17.2	0.8	3.4	1.4
95/96	32.9	43.5	7.7	2.3	2.8	0.5	2.4	7.9
96/97	27.6	50.6	3.7	3.3	7.7	0.6	0.1	6.3
97/98	38.3	25.2	5.8	19.3	0.0	0.1	4.6	6.7
98/99	25.2	61.0	6.0	1.8	0.8	0.7	0.1	4.5
99/00	7.5	85.1	2.8	1.0	1.8	0.4	0.2	1.2
00/01	21.1	47.0	13.3	1.1	5.9	2.3	0.0	9.3
01/02	39.7	33.1	10.5	11.3	0.5	0.1	0.1	4.8
02/03	22.1	58.8	4.5	0.0	1.9	2.0	0.3	10.4
03/04	14.8	69.5	6.7	0.5	5.1	1.2	0.0	2.2
04/05	37.8	42.4	7.8	3.0	1.8	4.4	0.7	2.1
05/06	37.6	20.4	24.6	7.2	–	3.5	5.6	1.2
06/07	37.6	37.4	12.3	–	0.6	9.8	0.5	1.8
07/08	59.7	3.7	28.6	–	5.0	1.1	–	1.8
08/09	47.8	16.0	22.9	–	–	5.7	0.4	7.1
09/10	59.1	1.1	17.7	–	0.0	11.2	–	10.9
10/11	37.6	0.8	33.5	–	6.1	14.0	–	8.0
11/12	33.7	0.5	16.7	26.6	2.6	14.4	2.8	2.8
12/13	37.9	3.6	20.4	–	3.5	9.1	9.0	16.5
13/14	37.2	1.3	17.5	0.3	1.2	3.9	1.3	37.4
14/15	49.9	0.5	24.0	–	0.0	19.2	0.4	6.0
15/16	61.4	0.1	16.4	0.4	0.5	12.4	1.3	7.4
16/17	49.8	0.8	23.1	0.0	0.0	8.0	–	18.3
Average	37.1	33.6	10.4	4.5	3.7	3.3	2.1	5.4

Table C.3C: Distribution of RCO 2 landings (%) by fishing year and target species for bottom trawl in RCO sub-area West Cook Strait (RCO 2) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for W Cook St (RCO 2) are available in Table C.1A. The values are plotted in Figure 10.

Fishing year	GUR	TAR	TRE	FLA	BAR	SNA	JMA	JDO	RCO	Other
	W Cook St (RCO2)									
89/90	18.8	6.4	39.2	5.8	11.9	7.3	2.1	5.5	–	3.2
90/91	30.0	6.4	39.8	3.8	0.3	6.9	8.2	0.1	4.5	–
91/92	21.3	12.9	20.1	9.9	5.2	2.0	22.9	0.1	5.2	0.3
92/93	32.9	5.8	19.8	5.8	0.2	12.3	11.5	5.7	5.7	0.3
93/94	20.9	38.0	2.6	26.3	1.2	5.6	–	0.6	4.2	0.5
94/95	17.3	22.2	5.9	9.6	22.1	10.9	6.5	1.3	0.2	4.0
95/96	39.7	20.1	8.4	11.3	4.1	2.3	0.8	2.6	5.2	5.5
96/97	29.5	31.6	18.4	1.3	3.9	10.4	0.2	0.1	1.7	3.0
97/98	19.8	17.9	19.9	–	16.0	8.7	13.7	2.8	–	1.2
98/99	10.0	27.2	3.0	1.1	1.9	6.1	39.3	3.1	5.8	2.5
99/00	22.8	38.1	14.1	0.0	3.5	2.6	–	2.0	–	17.0
00/01	42.2	14.5	11.1	5.4	4.7	0.9	–	1.1	15.0	5.2
01/02	26.4	32.5	4.4	2.2	13.3	4.8	5.6	10.8	–	0.0
02/03	37.0	18.9	9.0	0.9	7.9	3.6	–	0.3	22.4	0.1
03/04	6.9	4.2	4.2	64.2	16.5	2.5	–	1.1	–	0.4
04/05	31.6	9.8	3.7	36.2	8.5	5.9	–	4.2	–	0.1
05/06	27.8	7.8	23.1	5.3	13.8	6.0	–	3.6	10.5	2.1
06/07	41.7	12.2	28.7	4.1	0.0	6.3	–	6.3	–	0.9
07/08	18.6	18.5	7.8	2.7	3.7	0.0	–	11.4	3.9	33.2
08/09	25.0	38.8	12.4	10.5	0.3	0.7	0.6	6.0	–	5.6
09/10	53.2	29.1	3.5	1.0	0.9	0.1	–	8.1	–	4.0
10/11	28.4	46.8	7.3	7.5	0.2	1.8	0.0	4.5	0.0	3.4
11/12	9.5	45.5	9.1	0.2	16.1	6.1	–	11.2	–	2.4
12/13	6.2	65.9	2.5	0.0	0.1	1.4	0.0	23.6	–	0.3
13/14	15.9	34.5	4.9	20.5	0.1	1.4	–	16.8	–	6.1
14/15	16.6	48.2	1.5	6.9	–	6.1	–	11.4	–	9.4
15/16	13.0	55.2	1.7	0.2	0.3	2.8	–	4.9	–	21.8
16/17	4.7	67.6	2.9	–	–	2.3	–	7.3	–	15.1
Average	25.8	23.9	12.4	10.7	6.3	5.1	4.8	4.1	3.0	3.8

Appendix D. DATA SUMMARIES BY RCO 3 STATISTICAL AREA GROUP FOR BOTTOM TRAWL

Table D.1A: RCO 3 scaled QMR landings (Eq. 1 in tonnes) by fishing year and capture method for the three RCO 3 sub-areas (Table 13) based on trips which landed red cod. These values are plotted in Figure 5.

Fishing	Method of capture								Method of capture								Method of capture							
year	BT	MW	DS	BLL	SN	CP	Other	Total	BT	MW	DS	BLL	SN	CP	Other	Total	BT	MW	DS	BLL	SN	CP	Other	Total
	Inside (RCO3) (t)								Outside (RCO3) (t)								Foveaux St (RCO3) (t)							
89/90	6 245	–	–	0.0	4.3	0.1	–	6 249	97	–	–	0.0	–	–	–	97	194	49	–	–	0.0	0.2	–	243
90/91	4 103	8	–	2.1	2.9	0.2	–	4 116	241	2.7	–	1.0	–	–	–	245	207	62	–	0.2	0.0	0.1	–	269
91/92	5 812	0	0.3	0.8	6.1	0.6	–	5 820	86	20.1	–	5.7	–	–	–	112	478	93	–	13.8	0.2	0.1	–	585
92/93	9 021	90	–	0.7	12.2	1.1	–	9 125	38	1.1	–	7.9	–	0.1	–	47	398	43	–	21.8	0.0	0.0	–	463
93/94	7 463	46	–	1.5	20.9	2.6	11.8	7 546	45	1.3	–	7.2	0.0	–	–	54	261	44	–	73.1	0.0	0.2	–	378
94/95	11 911	37	–	0.7	29.3	2.9	–	11 981	65	2.9	–	24.3	–	–	–	93	413	62	–	49.0	0.1	4.9	–	530
95/96	10 403	40	–	0.9	15.7	1.3	–	10 460	156	3.8	–	10.9	0.0	–	–	171	236	74	–	15.1	0.4	26.3	–	352
96/97	9 193	9	–	0.9	17.8	2.6	–	9 223	148	0.2	–	16.2	–	–	–	164	523	17	–	108.5	0.0	1.5	–	650
97/98	8 384	915	–	0.5	22.2	6.9	–	9 329	155	6.3	–	13.5	0.0	–	–	175	369	16	–	64.0	0.2	0.7	–	450
98/99	12 902	30	–	2.9	4.1	10.3	–	12 949	65	1.1	–	8.0	–	–	–	74	786	51	–	58.7	0.0	0.7	–	896
99/00	3 893	136	–	0.3	10.7	9.7	–	4 050	167	2.5	–	20.8	–	–	–	190	448	45	–	90.3	0.1	0.4	–	584
00/01	1 942	2	–	0.3	25.9	1.7	–	1 972	199	3.1	–	26.2	0.0	–	–	228	478	25	–	70.3	0.0	2.6	–	576
01/02	2 142	8	–	1.5	9.3	2.3	–	2 164	105	8.1	–	31.5	–	–	–	144	460	22	–	67.5	0.0	0.0	–	549
02/03	4 262	9	15.1	1.6	15.3	2.6	–	4 306	95	0.3	–	69.1	–	–	–	165	491	110	–	34.6	0.0	0.3	–	636
03/04	6 630	4	57.6	4.9	13.3	5.0	–	6 715	21	0.0	0.0	14.9	0.0	–	–	36	846	66	–	60.6	0.0	0.0	–	973
04/05	3 112	7	67.9	13.2	20.5	11.2	–	3 232	73	0.0	–	3.9	0.0	–	–	77	827	49	–	24.4	0.1	2.2	–	903
05/06	2 257	4	67.2	2.4	16.8	26.4	–	2 374	81	1.0	–	4.4	0.0	–	–	86	728	14	0.1	20.6	0.1	0.7	–	763
06/07	1 112	1	69.9	7.6	36.6	13.7	–	1 241	131	0.3	–	6.9	0.4	–	–	139	427	46	–	24.2	0.1	1.3	–	498
07/08	2 005	3	158.4	5.1	25.7	10.7	–	2 207	269	0.0	0.0	3.1	0.0	0.0	–	272	640	78	–	35.5	0.0	2.4	–	756
08/09	1 637	2	173.2	5.8	28.7	31.1	–	1 878	87	0.7	–	6.1	0.0	0.0	–	94	513	32	–	22.5	0.1	1.1	–	570
09/10	2 051	7	143.0	10.9	20.8	29.4	–	2 262	49	0.5	–	4.0	–	0.0	–	54	639	32	–	6.9	0.0	0.0	–	678
10/11	2 896	18	96.9	5.3	27.0	18.3	0.0	3 061	64	0.5	0.3	3.6	–	0.0	–	68	1 356	58	–	14.1	0.2	4.3	5.6	1 438
11/12	3 812	20	147.8	3.0	39.3	22.7	–	4 045	88	0.8	1.2	11.6	0.0	0.0	–	102	1 090	128	–	17.5	1.3	1.5	1.6	1 239
12/13	3 538	243	234.1	6.9	26.7	24.5	–	4 073	55	0.8	–	13.3	0.0	0.0	–	70	1 082	44	–	23.6	0.1	2.0	–	1 151
13/14	3 027	100	161.3	9.3	14.6	45.6	–	3 357	28	3.7	–	14.8	–	–	0.0	47	897	83	0.0	23.8	0.3	2.1	–	1 006
14/15	1 294	6	87.6	9.5	11.0	23.8	–	1 431	97	1.8	–	24.3	0.0	0.0	–	123	555	57	–	4.0	0.1	0.7	–	617
15/16	2 477	8	168.6	13.3	30.1	23.2	0.6	2 720	67	23.9	–	16.2	0.2	0.0	0.0	107	940	47	–	21.4	0.0	1.1	0.1	1 010
16/17	2 915	27	154.8	31.9	11.2	26.9	0.3	3 167	63	7.9	–	29.8	0.0	–	0.1	101	1 159	104	–	10.6	0.4	1.2	–	1 275
Total	136 439	1 779	1803.7	143.8	518.9	357.4	12.8	141 055	2 836	95.7	1.6	399.1	0.6	0.2	0.1	3 333	17 443	1 549	0.1	976.6	3.9	59.0	7.3	20 038
last 5 years	13 250	382	806.4	70.9	93.5	144.1	0.9	14 748	310	38.1	0.0	98.4	0.2	0.0	0.1	447	4 634	334	0.0	83.4	0.9	7.3	0.1	5 059

Table D.1B: Distribution of RCO 3 landings (%) by fishing year and capture method for the three RCO 3 sub-areas (Table 13) based on trips which landed red cod.

Fishing	Method of capture							Method of capture							Method of capture						
year	BT	MW	DS	BLL	SN	CP	Other	BT	MW	DS	BLL	SN	CP	Other	BT	MW	DS	BLL	SN	CP	Other
	ECNI (RCO2) (%)							E Cook St (RCO2) (%)							W Cook St (RCO2) (%)						
89/90	99.9	–	–	0.00	0.07	0.00	–	100.0	–	–	0.01	–	–	–	79.6	20.30	–	–	0.00	0.08	–
90/91	99.7	0.20	–	0.05	0.07	0.00	–	98.5	1.11	–	0.40	–	–	–	77.0	22.92	–	0.07	0.01	0.04	–
91/92	99.9	0.00	0.01	0.01	0.10	0.01	–	76.9	17.95	–	5.11	–	–	–	81.7	15.88	–	2.36	0.04	0.01	–
92/93	98.9	0.99	–	0.01	0.13	0.01	–	80.5	2.39	–	16.87	–	0.24	–	86.1	9.21	–	4.71	0.00	0.00	–
93/94	98.9	0.61	–	0.02	0.28	0.03	0.16	84.0	2.51	–	13.51	0.00	–	–	69.1	11.52	–	19.32	0.01	0.06	–
94/95	99.4	0.31	–	0.01	0.24	0.02	–	70.7	3.11	–	26.23	–	–	–	78.0	11.78	–	9.25	0.02	0.92	–
95/96	99.5	0.38	–	0.01	0.15	0.01	–	91.4	2.25	–	6.37	0.01	–	–	67.1	20.98	–	4.28	0.12	7.49	–
96/97	99.7	0.09	–	0.01	0.19	0.03	–	90.0	0.15	–	9.87	–	–	–	80.5	2.55	–	16.69	0.00	0.23	–
97/98	89.9	9.81	–	0.01	0.24	0.07	–	88.7	3.62	–	7.70	0.00	–	–	82.1	3.51	–	14.23	0.04	0.16	–
98/99	99.6	0.23	–	0.02	0.03	0.08	–	87.7	1.49	–	10.81	–	–	–	87.7	5.70	–	6.55	0.00	0.08	–
99/00	96.1	3.35	–	0.01	0.26	0.24	–	87.7	1.33	–	10.98	–	–	–	76.7	7.78	–	15.46	0.01	0.07	–
00/01	98.5	0.11	–	0.02	1.31	0.08	–	87.2	1.34	–	11.48	0.00	–	–	83.0	4.31	–	12.21	0.00	0.46	–
01/02	99.0	0.39	–	0.07	0.43	0.11	–	72.6	5.61	–	21.84	–	–	–	83.7	4.02	–	12.29	0.00	0.01	–
02/03	99.0	0.21	0.35	0.04	0.36	0.06	–	57.9	0.18	–	41.90	–	–	–	77.3	17.27	–	5.44	0.00	0.04	–
03/04	98.7	0.06	0.86	0.07	0.20	0.07	–	58.6	0.05	0.13	41.25	0.00	–	–	87.0	6.79	–	6.24	0.00	0.00	–
04/05	96.3	0.22	2.10	0.41	0.63	0.35	–	94.9	0.04	–	5.06	0.00	–	–	91.6	5.42	–	2.71	0.02	0.24	–
05/06	95.1	0.19	2.83	0.10	0.71	1.11	–	93.7	1.19	–	5.05	0.04	–	–	95.4	1.78	0.02	2.70	0.01	0.09	–
06/07	89.6	0.06	5.64	0.62	2.95	1.10	–	94.5	0.21	–	5.00	0.27	–	–	85.7	9.15	–	4.87	0.01	0.26	–
07/08	90.8	0.13	7.17	0.23	1.16	0.48	–	98.8	0.01	0.02	1.15	0.00	0.00	–	84.7	10.32	–	4.70	0.00	0.32	–
08/09	87.2	0.13	9.22	0.31	1.53	1.65	–	92.8	0.71	–	6.45	0.00	0.01	–	90.1	5.68	–	3.95	0.02	0.20	–
09/10	90.6	0.33	6.32	0.48	0.92	1.30	–	91.5	0.98	–	7.47	–	0.00	–	94.2	4.78	–	1.02	0.00	0.01	–
10/11	94.6	0.59	3.16	0.17	0.88	0.60	0.00	93.6	0.76	0.41	5.25	–	0.03	–	94.3	4.03	–	0.98	0.01	0.30	0.39
11/12	94.2	0.49	3.65	0.07	0.97	0.56	–	86.6	0.81	1.20	11.36	0.02	0.00	–	87.9	10.31	–	1.41	0.10	0.12	0.13
12/13	86.9	5.96	5.75	0.17	0.66	0.60	–	79.6	1.21	–	19.15	0.00	0.00	–	94.0	3.81	–	2.05	0.01	0.18	–
13/14	90.2	2.97	4.80	0.28	0.44	1.36	–	60.4	8.02	–	31.61	–	–	0.01	89.2	8.23	0.00	2.36	0.03	0.21	–
14/15	90.4	0.40	6.12	0.66	0.77	1.66	–	78.8	1.42	–	19.76	0.00	0.03	–	90.0	9.21	–	0.65	0.01	0.12	–
15/16	91.0	0.28	6.20	0.49	1.11	0.85	0.02	62.3	22.37	–	15.14	0.15	0.01	0.01	93.1	4.65	–	2.12	0.00	0.11	0.01
16/17	92.1	0.84	4.89	1.01	0.35	0.85	0.01	62.5	7.82	–	29.60	0.00	–	0.07	90.9	8.13	–	0.83	0.03	0.10	–
Total	96.7	1.26	1.28	0.10	0.37	0.25	0.01	85.1	2.87	0.05	11.97	0.02	0.01	0.00	87.0	7.73	0.00	4.87	0.02	0.29	0.04
last 5 years	89.8	2.59	5.47	0.48	0.63	0.98	0.01	69.4	8.53	0.00	22.02	0.04	0.01	0.02	91.6	6.61	0.00	1.65	0.02	0.14	0.00

Table D.2A: Distribution of RCO 3 landings (%) by fishing year and by month for bottom trawl in RCO sub-area Inside (RCO 3) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for Inside (RCO 3) are available in Table D.1A. These values are plotted in Figure 9. '–': no data.

												Month
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Inside (RCO3) (%)											
89/90	1.6	8.1	26.6	10.8	7.5	10.5	9.4	12.3	9.8	2.5	0.5	0.5
90/91	5.6	10.7	8.1	15.4	18.4	8.6	14.9	11.2	3.8	1.8	0.3	1.3
91/92	0.8	1.5	7.8	10.9	10.0	9.4	13.7	11.2	20.1	11.8	1.2	1.7
92/93	0.8	6.0	11.7	6.9	11.1	9.6	20.9	16.2	12.1	2.6	1.3	0.7
93/94	2.3	8.1	15.1	18.0	7.3	10.5	14.0	14.5	6.2	2.0	1.1	0.9
94/95	1.0	4.1	6.9	11.7	20.4	16.6	11.5	16.7	6.1	3.9	0.7	0.5
95/96	1.6	7.9	7.8	16.9	14.4	16.2	12.8	14.1	6.1	1.4	0.5	0.4
96/97	2.1	5.0	8.5	12.7	16.2	14.5	21.8	11.8	4.5	2.2	0.3	0.3
97/98	1.4	2.4	4.5	23.1	13.6	15.5	17.2	8.9	10.5	1.4	0.8	0.9
98/99	2.6	20.5	8.4	10.9	12.1	21.5	8.9	8.3	4.9	1.1	0.3	0.5
99/00	1.6	4.9	14.1	9.2	8.7	13.1	18.1	22.8	4.3	2.2	0.7	0.3
00/01	2.5	6.8	5.7	15.7	10.5	13.2	21.0	15.0	6.0	1.6	1.0	1.0
01/02	2.1	7.1	5.6	8.8	12.5	13.0	17.2	11.1	18.1	3.0	0.6	1.0
02/03	1.3	2.2	3.1	11.4	20.3	24.1	14.3	12.6	5.2	3.7	1.1	0.7
03/04	1.7	14.5	4.8	12.3	13.4	16.6	15.2	14.6	4.2	1.5	0.4	0.7
04/05	3.3	6.3	3.0	16.1	16.2	9.0	12.6	13.1	13.4	3.5	2.1	1.4
05/06	2.9	5.6	6.5	23.9	8.4	21.1	6.2	7.0	14.4	3.0	0.8	0.4
06/07	3.3	5.1	3.0	5.9	13.5	11.0	11.4	28.4	11.8	3.4	1.9	1.2
07/08	0.7	4.7	11.7	9.0	8.2	18.3	18.0	16.0	8.5	3.0	0.4	1.5
08/09	6.5	6.6	7.5	8.4	6.3	20.2	15.6	15.4	7.0	2.8	1.7	2.0
09/10	1.5	2.6	3.1	4.0	8.1	31.8	13.9	13.2	13.5	4.6	2.4	1.5
10/11	2.7	3.5	5.3	4.4	12.3	16.8	8.9	12.0	15.9	16.2	1.1	0.9
11/12	1.4	0.9	2.1	18.1	23.5	25.8	12.1	6.7	3.9	4.1	0.5	0.7
12/13	3.1	1.7	5.3	23.6	14.2	7.0	23.2	14.3	4.7	1.5	1.0	0.5
13/14	5.5	4.5	3.8	15.5	19.0	14.4	6.8	16.4	9.2	1.6	1.9	1.4
14/15	3.2	5.1	3.7	17.6	9.2	25.9	13.2	11.5	6.0	1.4	2.0	1.2
15/16	0.7	3.2	1.4	11.4	17.7	20.4	20.1	10.4	9.9	1.6	2.0	1.3
16/17	1.9	4.0	3.1	7.3	16.2	31.8	10.2	15.5	5.3	1.3	1.9	1.4
Average	2.0	7.0	8.2	13.2	13.7	15.8	14.4	13.1	8.0	3.0	0.9	0.8

Table D.2B: Distribution of RCO 3 landings (%) by fishing year and by month for bottom trawl in RCO sub-area Outside (RCO 3) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for Outside (RCO 3) are available in Table D.1A. These values are plotted in Figure 9. '–': no data.

												Month	
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total (t)
	Outside (RCO 3) (%)												
89/90	1.3	0.1	18.2	–	0.0	1.3	38.9	11.0	8.4	6.9	11.8	2.0	97
90/91	26.2	12.4	15.9	5.0	3.4	0.0	0.8	1.4	14.4	2.9	2.2	15.3	241
91/92	11.8	2.5	18.0	22.5	0.8	7.3	2.2	3.9	7.4	2.2	0.0	21.2	86
92/93	46.9	8.3	2.4	3.7	0.7	4.8	4.4	10.0	17.8	0.1	0.0	1.0	38
93/94	11.8	5.7	30.1	14.7	7.5	4.1	0.1	6.3	4.8	0.9	0.2	13.8	45
94/95	21.5	13.1	6.9	12.1	1.9	19.3	2.0	12.4	2.2	5.7	1.3	1.6	65
95/96	36.1	5.1	0.4	24.6	4.1	2.7	0.0	3.9	17.3	0.0	2.8	3.0	156
96/97	26.0	0.1	7.9	0.0	1.2	1.5	0.2	5.7	15.8	41.6	–	0.0	148
97/98	7.7	3.6	3.2	2.6	0.5	3.9	3.1	6.2	42.8	15.1	1.5	9.5	155
98/99	15.5	14.4	22.9	4.8	20.0	7.5	1.1	0.7	10.2	1.0	0.3	1.7	65
99/00	1.7	2.9	3.9	0.3	1.3	0.3	2.8	39.3	44.6	1.2	0.0	1.7	167
00/01	8.7	3.2	1.2	7.5	0.8	1.4	26.8	41.8	3.9	2.6	0.7	1.4	199
01/02	20.0	6.7	24.6	10.0	1.5	5.2	6.4	8.9	6.1	2.2	1.3	7.3	105
02/03	15.9	8.0	24.5	11.3	3.1	3.4	2.5	28.2	0.5	2.2	0.2	0.1	95
03/04	32.0	4.3	24.0	8.8	0.0	0.2	1.5	0.2	21.5	2.0	1.0	4.7	21
04/05	9.9	14.7	5.3	4.3	0.7	2.0	0.2	32.9	22.0	3.3	0.9	3.7	73
05/06	3.5	34.7	10.5	3.9	9.1	2.7	4.8	3.7	9.6	5.6	1.0	11.0	81
06/07	2.4	4.6	2.2	29.4	3.0	2.4	3.3	11.0	26.0	1.4	0.4	13.9	131
07/08	13.8	8.8	32.0	1.7	4.8	4.3	0.1	18.5	9.4	1.2	0.1	5.4	269
08/09	66.1	2.4	0.5	7.4	9.3	0.1	2.7	1.7	8.6	0.2	0.1	0.8	87
09/10	0.7	2.4	11.0	3.3	8.0	2.1	3.6	1.6	0.1	33.3	5.7	28.2	49
10/11	0.6	0.8	4.8	2.2	41.4	34.9	1.0	0.7	7.8	3.4	0.2	2.3	64
11/12	2.0	5.7	25.6	22.0	1.7	0.6	0.2	0.2	6.3	11.2	0.1	24.3	88
12/13	23.3	5.7	3.5	16.5	7.3	21.7	4.2	3.8	10.8	1.5	1.6	0.1	55
13/14	10.0	0.8	11.3	3.3	2.0	9.4	14.5	3.9	5.7	8.2	2.9	28.0	28
14/15	2.2	3.5	8.4	6.4	4.8	4.0	1.9	18.3	35.9	6.2	3.1	5.3	97
15/16	2.3	3.6	5.2	6.9	4.7	1.4	6.0	12.6	26.1	0.2	4.5	26.4	67
16/17	3.5	1.1	24.6	5.7	1.1	3.8	4.1	3.9	41.8	3.6	2.9	4.0	63
Average	15.0	6.5	12.4	8.3	4.3	4.1	5.2	13.0	16.3	6.0	1.5	7.6	2 836

Table D.2C: Distribution of RCO 3 landings (%) by fishing year and by month for bottom trawl in RCO sub-area Foveaux Strait (RCO 3) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for Foveaux St (RCO 3) are available in Table D.1A. These values are plotted in Figure 9. '–': no data.

	Month												
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total (t)
	Foveaux St (RCO 3) (%)												
89/90	12.3	10.3	1.1	1.4	16.6	9.1	3.7	6.0	4.7	13.5	12.9	8.5	194
90/91	3.5	4.5	34.7	2.0	3.4	1.7	15.3	11.4	2.8	2.4	5.5	12.9	207
91/92	3.7	0.4	2.5	1.3	1.4	4.1	8.0	4.8	3.3	18.1	35.1	17.2	478
92/93	9.5	20.9	4.5	0.4	4.2	7.8	1.0	1.3	10.4	19.6	18.4	2.0	398
93/94	9.6	14.7	7.9	4.9	1.8	8.8	1.0	1.3	16.6	6.7	17.4	9.3	261
94/95	17.8	4.6	3.4	4.3	2.8	3.2	8.0	6.7	18.1	11.3	10.6	9.1	413
95/96	21.0	15.2	1.5	10.8	3.8	2.0	3.5	5.0	2.8	9.0	12.0	13.4	236
96/97	12.3	1.0	5.4	2.1	7.4	0.7	5.4	7.5	14.9	37.5	3.2	2.5	523
97/98	10.4	10.5	9.3	21.2	6.8	4.7	3.7	7.1	9.6	4.6	6.1	6.1	369
98/99	2.5	4.6	3.7	17.7	4.4	45.0	12.7	1.0	2.9	1.7	1.8	2.1	786
99/00	10.1	16.2	6.0	13.3	25.6	13.3	2.8	1.6	0.7	1.8	3.1	5.4	448
00/01	8.6	32.2	8.0	12.7	9.1	7.9	2.3	5.3	2.9	1.2	4.6	5.2	478
01/02	5.8	9.2	6.3	20.6	12.8	15.1	11.6	4.3	1.7	4.0	2.5	6.2	460
02/03	5.4	4.4	6.0	10.4	8.1	14.0	11.9	10.8	8.1	6.3	11.2	3.5	491
03/04	1.7	3.1	2.7	9.3	4.4	9.3	15.5	32.7	6.5	9.3	3.0	2.5	846
04/05	4.1	6.5	5.2	10.8	7.9	9.6	8.2	6.4	3.7	21.5	11.3	4.7	827
05/06	15.6	8.0	20.9	4.5	5.2	6.6	7.3	14.2	4.1	2.5	4.1	6.9	728
06/07	11.5	9.5	9.0	19.2	7.1	6.4	4.5	7.1	0.6	2.4	12.3	10.4	427
07/08	1.7	6.0	5.0	10.0	24.9	18.3	14.1	6.8	1.1	2.3	6.3	3.4	640
08/09	2.2	5.3	4.1	20.9	4.8	5.6	9.8	11.6	5.6	8.5	13.2	8.5	513
09/10	3.3	0.8	1.2	7.9	7.0	10.5	18.1	9.1	11.0	22.1	5.6	3.4	639
10/11	2.7	1.3	1.2	5.0	4.4	5.6	14.3	35.7	4.7	9.1	8.3	7.7	1 356
11/12	5.4	3.9	1.5	1.6	12.0	8.9	17.0	14.1	10.2	12.2	9.9	3.2	1 090
12/13	4.9	8.3	4.6	5.2	14.6	20.5	12.9	3.9	2.7	3.7	12.6	6.1	1 082
13/14	3.7	8.5	1.8	6.6	7.1	6.9	6.8	22.5	3.0	4.2	14.9	13.9	897
14/15	6.4	4.4	3.3	3.1	7.7	24.9	4.8	14.3	1.4	7.1	12.9	9.7	555
15/16	2.6	2.7	1.3	5.7	9.5	3.5	29.1	21.0	9.5	2.1	7.7	5.4	940
16/17	4.3	4.2	2.2	4.8	11.6	8.3	22.5	17.4	8.6	1.7	10.5	4.0	1 159
Average	6.0	6.6	4.7	8.0	8.7	10.9	11.9	13.0	6.0	8.4	9.5	6.3	17 443

Table D.3A: Distribution of RCO 3 landings (%) by fishing year and target species for bottom trawl in RCO sub-area Inside (RCO 3) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for Inside (RCO 3) are available in Table D.1A. The values are plotted in Figure 10.

Fishing year	RCO Inside (RCO 3)	SQU	BAR	FLA	TAR	SWA	WAR	SPE	GUR	Other
89/90	76.1	1.0	13.4	5.7	1.0	0.1	0.1	0.2	0.3	2.2
90/91	73.3	0.8	17.4	4.7	0.7	0.5	0.1	0.0	0.3	2.2
91/92	70.2	12.5	11.7	3.0	0.6	0.1	0.3	0.2	0.1	1.4
92/93	78.5	6.0	7.4	3.3	0.5	0.1	0.1	0.4	0.1	3.7
93/94	83.2	4.9	2.8	6.9	0.6	0.1	0.2	0.5	0.0	0.7
94/95	77.4	6.5	4.9	9.3	0.5	0.2	0.0	0.2	0.3	0.6
95/96	77.8	4.9	7.4	7.9	0.6	0.1	0.1	0.1	0.3	0.9
96/97	81.5	5.2	4.1	7.1	0.5	0.1	0.0	0.3	0.3	0.9
97/98	80.8	9.2	3.7	4.8	0.1	0.0	0.0	0.2	0.0	1.1
98/99	71.1	13.4	6.9	6.3	1.1	0.0	0.2	0.3	0.1	0.6
99/00	61.4	13.6	13.6	8.7	0.7	0.1	0.3	0.5	0.1	1.0
00/01	54.9	26.7	7.6	7.2	0.5	0.0	0.2	0.7	0.3	1.8
01/02	68.1	14.3	5.6	9.0	0.7	0.2	0.4	0.3	0.3	1.1
02/03	60.8	21.5	6.6	8.3	0.4	0.4	0.7	0.3	0.2	0.9
03/04	80.0	5.2	4.7	7.9	0.5	0.0	0.4	0.1	0.2	1.1
04/05	61.7	13.3	6.1	11.5	3.2	0.5	2.5	0.1	0.1	0.9
05/06	61.7	15.6	3.4	10.5	3.5	0.2	1.9	0.0	0.7	2.4
06/07	54.3	11.5	3.9	21.9	4.2	0.6	0.9	0.1	0.8	1.8
07/08	65.3	3.6	3.7	19.0	2.8	1.0	1.4	0.2	0.6	2.4
08/09	64.1	4.1	7.9	10.9	4.9	1.6	1.6	0.1	1.0	3.8
09/10	70.2	4.5	4.6	9.2	4.7	1.0	1.3	0.2	0.7	3.6
10/11	41.7	13.1	29.1	4.8	5.3	2.2	1.0	0.7	0.4	1.7
11/12	65.3	8.2	13.6	5.4	2.3	2.5	1.1	0.3	0.1	1.2
12/13	73.2	2.1	9.1	7.4	4.1	1.9	0.3	0.2	0.8	1.0
13/14	53.6	8.5	7.1	14.3	7.1	4.3	0.4	0.5	1.3	2.7
14/15	41.7	7.2	7.1	18.1	9.8	2.5	2.4	5.7	1.2	4.4
15/16	62.5	5.9	8.7	5.8	8.1	1.4	3.9	0.7	0.6	2.4
16/17	60.6	1.0	11.4	10.5	9.8	1.7	0.9	0.4	0.5	3.1
Average	72.0	8.1	7.8	7.5	1.7	0.5	0.5	0.3	0.3	1.5

Table D.3B: Distribution of RCO 3 landings (%) by fishing year and target species for bottom trawl in RCO sub-area Outside (RCO 3) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for Outside (RCO 3) are available in Table D.1A. The values are plotted in Figure 10.

Fishing year	SQU	BAR	HOK	LIN	RCO	SCI	SWA	TAR	SPE	Other
	Outside (RCO 3)									
89/90	0.6	42.0	1.6	0.0	28.2	–	5.6	10.3	–	11.6
90/91	2.0	23.7	26.1	13.1	16.6	3.8	0.8	–	0.0	13.7
91/92	4.3	8.0	34.7	7.7	5.1	23.9	10.7	4.0	–	1.8
92/93	0.0	7.1	43.1	13.4	11.1	22.5	0.2	–	0.0	2.5
93/94	0.9	5.5	13.1	0.0	44.7	30.1	1.5	–	–	4.2
94/95	3.9	3.0	6.7	0.6	22.3	27.9	7.9	–	19.3	8.5
95/96	7.8	16.4	30.6	3.0	23.9	6.9	5.1	0.0	–	6.2
96/97	12.2	45.3	27.3	–	7.0	3.9	0.0	–	–	4.3
97/98	12.5	22.7	14.3	5.7	34.0	4.4	0.3	0.0	–	6.0
98/99	7.9	1.5	25.3	2.9	35.8	22.0	0.5	0.0	0.7	3.4
99/00	82.9	0.0	10.8	0.7	0.1	3.9	0.0	0.1	–	1.6
00/01	76.3	2.3	7.6	0.4	4.5	3.7	0.1	3.7	–	1.4
01/02	4.6	15.3	12.2	5.5	24.3	3.7	6.0	5.1	4.3	18.9
02/03	9.8	8.2	1.2	3.0	0.7	11.6	1.0	6.3	32.5	25.8
03/04	1.9	1.1	18.9	0.0	0.0	34.4	1.2	27.9	0.1	14.5
04/05	58.1	7.8	3.0	0.1	–	10.6	5.3	5.7	0.8	8.4
05/06	4.5	20.5	3.5	5.0	15.4	21.4	3.2	14.4	0.9	11.3
06/07	6.4	30.2	1.2	17.7	0.3	3.5	3.4	6.6	20.2	10.5
07/08	0.3	41.4	0.7	45.2	0.2	1.2	0.7	9.1	0.2	1.2
08/09	0.1	9.2	3.6	68.1	1.3	2.0	9.1	6.1	0.0	0.4
09/10	36.5	9.9	4.1	10.3	0.2	3.2	18.7	15.0	0.4	1.7
10/11	68.0	0.0	4.0	1.1	–	2.2	6.3	16.3	0.0	2.1
11/12	5.2	7.7	41.6	10.6	0.3	1.6	25.6	0.1	5.4	1.9
12/13	0.6	16.6	2.7	8.7	–	44.0	25.7	–	0.1	1.5
13/14	0.0	23.8	4.4	2.9	0.0	37.7	2.4	27.5	0.0	1.3
14/15	26.0	25.9	5.1	3.7	0.0	26.8	6.0	6.1	–	0.5
15/16	25.1	1.6	6.6	1.5	–	32.8	27.2	0.3	–	4.7
16/17	43.0	0.8	4.2	2.2	–	16.1	30.2	3.2	–	0.4
Average	19.8	17.8	12.9	10.8	10.0	9.7	5.4	4.5	2.9	6.2

Table D.3C: Distribution of RCO 3 landings (%) by fishing year and target species for bottom trawl in RCO sub-area Foveaux Strait (RCO 3) (Table 13) based on trips which landed red cod. Annual total bottom trawl landings (t) for Foveaux St (RCO 3) are available in Table D.1C. The values are plotted in Figure 10.

Fishing year	SQU	FLA	LIN	HOK	STA	RCO	SCI	SWA	WWA	Other
	Foveaux St (RCO 3)									
89/90	16.1	30.3	11.2	0.8	15.1	12.8	–	0.4	3.4	10.0
90/91	26.8	15.1	37.4	6.4	6.5	1.7	–	1.9	0.2	4.1
91/92	7.8	6.3	25.1	21.7	3.5	24.9	4.4	3.3	0.3	2.7
92/93	11.7	12.0	23.4	15.4	7.4	19.1	2.3	7.6	–	1.3
93/94	11.3	20.8	19.4	10.1	13.5	4.7	11.0	2.9	–	6.3
94/95	29.8	19.6	2.8	17.8	3.2	13.2	4.6	5.4	0.1	3.5
95/96	2.5	21.0	8.7	15.2	6.1	28.0	3.5	0.6	–	14.3
96/97	58.1	9.7	1.0	10.8	2.3	13.5	0.8	1.4	–	2.3
97/98	30.6	17.8	1.4	25.5	1.3	15.8	1.4	1.3	0.0	4.9
98/99	34.6	4.9	1.3	7.8	43.4	4.6	2.1	0.6	0.1	0.7
99/00	47.2	6.8	1.1	34.6	1.6	0.7	1.3	3.7	1.8	1.2
00/01	21.9	6.8	2.4	33.1	3.4	18.5	6.9	1.6	4.5	0.9
01/02	52.5	10.0	1.8	12.2	1.8	5.0	6.3	4.5	2.9	3.0
02/03	50.1	22.1	1.2	5.9	2.1	2.3	9.2	0.8	0.2	6.1
03/04	74.7	8.0	1.2	2.1	2.6	0.2	9.3	0.0	1.2	0.9
04/05	67.7	9.2	4.8	2.3	1.7	1.9	6.1	0.1	0.7	5.3
05/06	58.7	6.6	16.0	4.3	2.7	1.7	2.9	1.5	3.5	2.0
06/07	34.5	17.0	13.5	6.1	3.0	5.6	1.5	1.7	3.3	13.9
07/08	69.5	10.2	5.1	1.0	1.1	0.7	2.4	3.1	4.4	2.5
08/09	60.7	20.1	3.2	1.4	4.4	0.2	2.9	2.4	1.3	3.4
09/10	79.4	8.5	3.9	0.4	2.4	–	0.6	1.9	1.4	1.4
10/11	73.9	14.8	4.9	0.5	1.2	0.4	1.3	1.6	0.7	0.6
11/12	63.7	15.2	7.7	0.2	3.8	0.9	1.2	1.4	3.5	2.4
12/13	54.5	20.5	8.1	0.5	4.3	0.6	0.8	2.0	2.7	6.0
13/14	47.6	28.4	5.0	0.9	3.9	1.0	0.9	4.4	2.2	5.7
14/15	51.2	28.1	5.4	1.1	3.0	2.7	0.5	1.5	2.4	4.1
15/16	75.1	9.0	5.5	0.9	1.7	0.0	0.9	2.0	3.7	1.4
16/17	66.7	15.2	4.5	0.8	1.9	0.1	2.6	2.1	2.0	4.1
Average	53.5	14.2	6.7	6.2	4.9	4.3	2.9	2.1	1.8	3.4

Appendix E. DEPTH SUMMARIES BY RCO 2 AND 3 STATISTICAL AREA GROUP FOR BOTTOM TRAWL

Table E.1: Summary statistics by declared target species for the three RCO 2 sub-areas (see Table 13) from distributions from all records (combined TCER and TCEPR form types) using the bottom trawl method for effort that targeted or caught red cod by target species category. Data are summarised by RCO 2 sub-area from 2007–08 to 2016–17.

		Depth (m)			
Target species category	Number observations	Lower 5% of distribution	Mean of distribution	Median (50%) of distribution	Upper 95% of distribution
ECNI (RCO 2)					
TAR	15 567	40	92	83	160
GUR	13 123	20	43	40	76
FLA	6 432	10	17	15	30
SNA	459	25	47	44	80
RCO	256	14	32	25	80
HOK	144	89	204	191	380
BAR	80	35	100	88	195
MOK	77	51	93	97	115
TRE	76	22	50	42	116
SKI	70	82	178	180	276
WAR	61	60	76	73	100
Other	180	25	263	322	434
Total	36 525	12	62	50	143
E Cook St (RCO 2)					
TAR	1 356	65	124	120	214
WAR	547	48	90	90	125
GUR	202	25	39	38	60
MOK	127	34	95	100	117
SWA	58	122	137	135	185
HOK	50	177	437	484	570
FLA	43	13	36	34	80
LIN	34	161	220	220	260
BAR	32	60	92	90	143
RCO	18	18	83	83	225
Other	46	28	86	68	202
Total	2 513	34	114	109	219
W Cook St (RCO 2)					
TAR	870	80	140	147	207
GUR	518	24	48	45	77
JDO	320	40	78	70	150
TRE	143	26	45	42	70
FLA	114	25	35	34	50
MOK	98	73	110	103	168
SNA	64	31	57	48	104
SCH	37	123	157	153	193
WAR	34	89	151	166	213
BAR	16	39	102	111	187
SPO	15	19	56	60	100
Other	20	41	125	124	213
Total	2 249	30	94	87	184

Table E.2: Summary statistics by declared target species for the three RCO 3 sub-areas (see Table 13) from distributions from all records (combined TCER and TCEPR form types) using the bottom trawl method for effort that targeted or caught red cod by target species category. Data are summarised by RCO 3 sub-area from 2007–08 to 2016–17.

		Depth (m)			
Target species category	Number observations	Lower 5% of distribution	Mean of distribution	Median (50%) of distribution	Upper 95% of distribution
Inside(RCO3)					
FLA	31 458	11	29	22	60
RCO	14 812	20	83	58	241
TAR	7 676	49	88	88	126
BAR	4 664	32	83	78	151
ELE	2 000	12	32	25	70
GUR	1 711	18	35	35	55
WAR	1 581	38	54	50	93
SQU	1 458	120	217	208	322
STA	712	54	94	96	120
SPE	666	78	99	95	129
SWA	577	112	210	190	360
Other	1 990	13	140	67	400
Total	69 305	14	62	45	190
Outside(RCO3)					
SCI	870	310	343	342	381
TAR	430	93	152	140	242
LIN	208	253	326	336	380
SQU	152	148	209	217	270
BAR	135	130	234	250	285
SWA	84	220	292	283	384
STA	59	155	221	217	308
HOK	26	251	343	352	507
FLA	17	10	22	21	36
RCO	13	25	124	121	220
Other	16	14	137	83	441
Total	2 010	121	271	310	376
Foveaux St(RCO3)					
FLA	11 279	10	37	34	72
SQU	5 826	142	208	190	327
SCI	1 465	398	448	444	504
STA	1 365	28	112	108	355
LIN	1 059	300	441	422	620
WWA	319	340	477	490	610
WAR	313	52	73	73	102
SWA	227	140	313	325	418
BAR	195	44	84	81	142
SPO	169	8	15	13	26
ELE	158	14	36	32	80
Other	585	26	140	56	568
Total	22 960	13	142	64	475

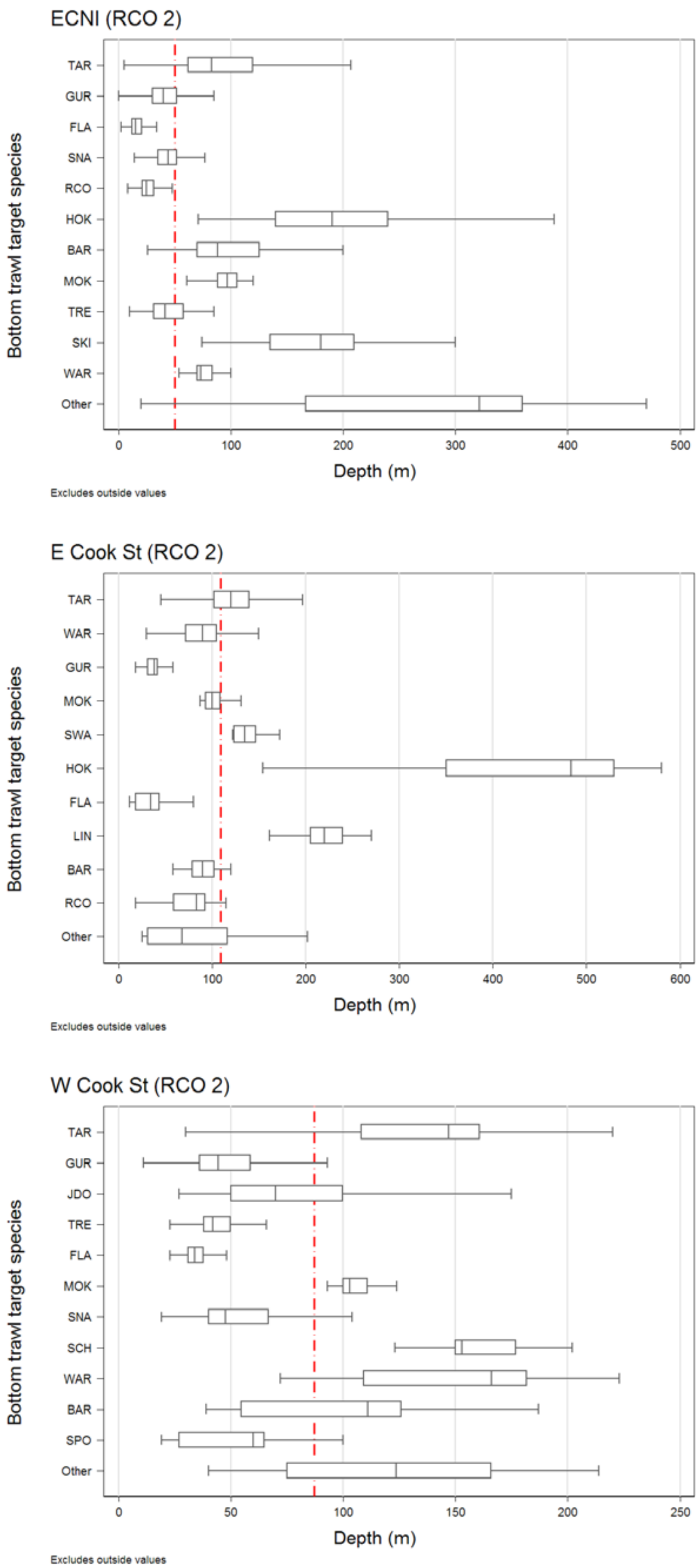

Figure E.1: Box plot bottom depth distributions by target species for the three RCO 2 sub-areas (see Table 13) from combined TCER and TCEPR form types using the bottom trawl method for effort that targeted or caught estimated red over the period 2007–08 to 2016–17. Vertical line in each sub graph indicates the median depth from all tows that caught or targeted red cod in the indicated RCO 2 sub-area.

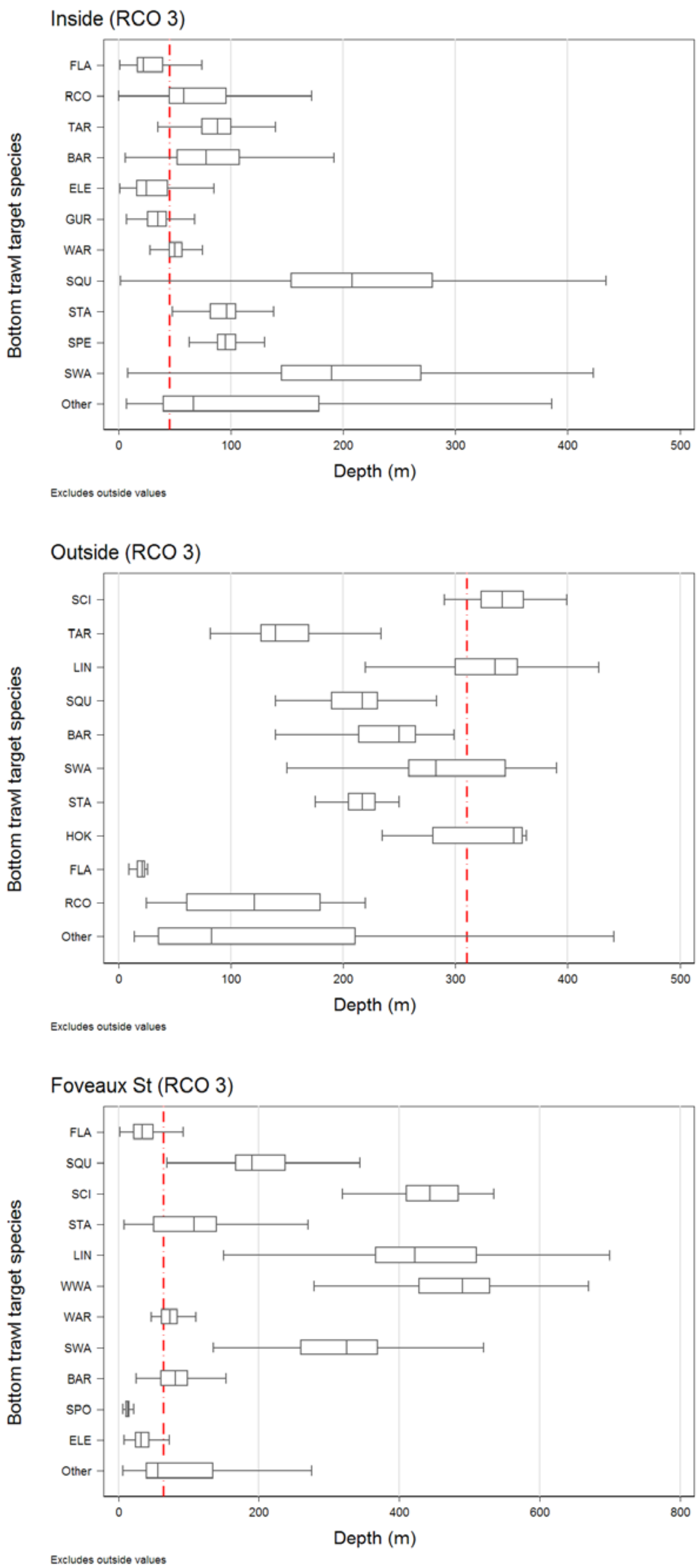

Figure E.2: Box plot bottom depth distributions by target species for the three RCO 3 sub-areas (see Table 13) from combined TCER and TCEPR form types using the bottom trawl method for effort that targeted or caught estimated red cod over the period 2007–08 to 2016–17. Vertical line in each sub graph indicates the median depth from all tows that caught or targeted red cod in the indicated RCO sub-area.

Appendix F. RED COD CPUE ANALYSES: INTRODUCTION

F.1 General overview

Results and diagnostics for RCO CPUE standardisations are presented for RCO 2 (Appendix G; Appendix H) and RCO 3 (Appendix I, Appendix J). These analyses support the descriptions and conclusions presented in Section 3 of the main report. This appendix contains the procedures followed in data preparation, the equations used, and definitions of each standardisation analysis. Appendix G, Appendix H, Appendix I and Appendix J provide tables and figures with statistics and diagnostics, and final tables giving the estimated indices with the standard error for each of the analyses defined in Table F.1.

F.2 Methods

F.2.1 Data Preparation

The identification of candidate trips for these analyses and the methods used to prepare them are described in Section 2.3.1 in the main report. Landings were allocated to effort at the "daily effort stratum" resolution procedure described in Section 2.3.1.5. The CPUE data set was prepared using the "Statistical Area" expansion procedure, whereby all expansions are made relative to the statistical area of capture without regard to the QMA of origin. Consequently the analyses may include catch from mixed RCO QMAs (RCO 2, RCO 3 and RCO 7) for shared statistical areas (see Appendix B).

Those groups of events that satisfied the criteria of target species, method of capture and statistical areas that defined each fishery were selected from available fishing trips. Any effort strata that were matched to a landing of red cod were termed "successful" and may include relevant but unsuccessful effort given that a "daily-effort stratum" represents amalgamated catch and effort. Consequently, the analysis of catch rates in successful strata also incorporate zero catch information.

The potential explanatory variables available from each trip in these data sets include fishing year, the number of tows, the duration of fishing, statistical area, target species, month of landing, and a unique vessel identifier. The dependent variable will be either log(catch), where catch will be the scaled daily landings, or presence/absence of red cod. Data might not represent an entire fishing trip; just those portions of it that qualified. Trips were not dropped because they targeted more than one species or fished in more than one statistical area.

Datasets were further restricted to core fleets of vessels, defined by their activity in the fishery, thus selecting only the most active vessels without dropping too much of the available catch and effort data.

F.2.2 Analytical methods for standardisation

Arithmetic CPUE $\left(\hat{A}_y\right)$ in year y was calculated as the mean of catch divided by effort for each observation in the year:

Eq. F.1
$$\hat{A}_y = \frac{\sum_{i=1}^{N_y} C_{i,y} / E_{i,y}}{N_y}$$

where $C_{i,y}$ is the [*catch*] and $E_{i,y} = L_{i,y}$ ([*tows*]–for bottom trawl) in record *i* in year *y*, and N_y is the number of records in year *y*.

Unstandardised CPUE $\left(\hat{U}_y\right)$ in year y is the geometric mean of the ratio of catch to effort for each record i in year y:

Eq. F.2 $$\hat{U}_y = \exp\left[\frac{\sum_{i=1}^{N_y} \ln\left(C_{i,y} \big/ E_{i,y}\right)}{N_y}\right]$$

where C_i, $E_{i,y}$ and N_y are as defined for Eq. F.1. Unstandardised CPUE assumes a log-normal distribution, but does not take into account changes in the fishery. This index is the same as the "year index" calculated by the standardisation procedure, when not using additional explanatory variables and using the same definition for $E_{i,y}$. Presenting the arithmetic and unstandardised CPUE indices in this report provides measures of how much the standardisation procedure has modified the series from these two sets of indices.

A standardised abundance index (Eq. F.3) was calculated from a generalised linear model (GLM) (Quinn & Deriso 1999) using a range of explanatory variables including [*year*], [*month*], [*vessel*] and other available factors:

Eq. F.3 $$\ln(I_i) = B + Y_{y_i} + \alpha_{a_i} + \beta_{b_i} + \ldots\ldots + f\left(\chi_i\right) + f\left(\delta_i\right)\ldots\ldots + \varepsilon_i$$

where $I_i = C_i$ for the i^{th} record, Y_{y_i} is the year coefficient for the year corresponding to the i^{th} record, α_{a_i} and β_{b_i} are the coefficients for factorial variables a and b corresponding to the i^{th} record, and $f\left(\chi_i\right)$ and $f\left(\delta_i\right)$ are polynomial functions (to the 3rd order) of the continuous variables χ_i and δ_i corresponding to the i^{th} record, B is the intercept and ε_i is an error term. The actual number of factorial and continuous explanatory variables in each model depends on the model selection criteria. Fishing year was always forced as the first variable, and month (of landing), statistical area, target species, and a unique vessel identifier were also offered as categorical variables. Number of tows $\left(\ln\left(T\right)_i\right)$ and fishing duration $\left(\ln\left(H_i\right)\right)$ were offered to the bottom trawl models as continuous third order polynomial variables.

It was decided to force the lognormal distribution for analysing the positive catch part of this CPUE analysis. Previous work by Bentley (2013a) used a log-logistic model but experience has shown that there is very little difference among models using either distribution (see Figure 14, which compares the "*no interaction*" series which used the log-logistic distribution with two other series based on the lognormal distribution) and the lognormal distribution was selected because this distribution has been shown to work well with New Zealand bottom trawl data.

For the positive catch records, log(*catch*) was regressed against the full set of explanatory variables in a stepwise procedure, selecting variables one at a time until the improvement in the model R^2 was less than 0.01. The order of the variables in the selection process was based on the variable with the lowest AIC, so that the degrees of freedom were minimised.

Canonical coefficients and standard errors were calculated for each categorical variable (Francis 1999). Standardised analyses typically set one of the coefficients to 1.0 without an error term and estimate the remaining coefficients and the associated error relative to the fixed coefficient. This is required because of parameter confounding. The Francis (1999) procedure rescales all coefficients so that the geometric mean of the coefficients is equal to 1.0 and calculates a standard error for each coefficient, including the fixed coefficient.

The procedure described by Eq. F.3 is necessarily confined to the positive catch observations in the data set because the logarithm of zero is undefined. Observations with zero catch were modelled by fitting a logit regression model based on a binomial distribution and using the presence/absence of red cod as the dependent variable (where 1 is substituted for $\ln(I_i)$ in Eq. F.3 if it is a successful catch record and 0 if it is not successful), using the same data set. Explanatory factors were estimated in the model in the same manner as described for Eq. F.3. Such a model provides an alternative series of standardised coefficients of relative annual changes that are analogous to the equivalent series estimated from the positive catch regression.

A combined model, integrating the two sets of relative annual changes estimated by the lognormal and binomial models, can be estimated using the delta distribution, which allows zero and positive observations (Fletcher et al. 2005). Such a model provides a single index of abundance which integrates the signals from the positive (lognormal) and binomial series. This approach uses the following equation to calculate an index based on the two contributing indices, after standardising each series to a geometric mean=1.0:

Eq. F.4 $$^{C}Y_y = {}^{L}Y_y \, {}^{B}Y_y$$

where $^{C}Y_y$ = combined index for year ,

$^{L}Y_y$ = lognormal index for year ,

$^{B}Y_y$ = binomial index for year

Confidence bounds, while straightforward to calculate for the binomial and lognormal models, were not calculated for the combined model because a bootstrap procedure (recommended by Francis 2001) has not yet been implemented in the available software. The index series plots below present normalised values, i.e., each series is divided by its geometric mean so that the series is centred on 1.0. This facilitates comparison among series.

F.3 Fishery definitions

The following selection criteria were used for defining the bottom trawl fishery models described in this report. Estimated catches were scaled to the trip landings using either the daily effort-stratum method of Langley (2014) (described in Section 2.3.1.5) or proportionately to each tow with recorded RCO catch within the trip.

Table F.1: List of specifications for modelled RCO bottom trawl (BT) fisheries.

Model	Data type	Statistical area definition	Target species definition	Core fleet definition	Number vessels and % retained landings	Positive distribution	Document reference
RCO 2	Daily effort	011, 012, 013, 014, 015	RCO, FLA, GUR, TAR	5 trips/5 years	61 vessels/89%	lognormal	Appendix G
RCO 2	Tow-by-tow				27 vessels/85%		Appendix H
RCO 3	Daily effort	020, 022, 024, 026	RCO, FLA, BAR, TAR, SQU, GUR, STA	5 trips/5 years	140 vessels/86%	lognormal	Appendix I
RCO 3	Tow-by-tow				53 vessels/84%		Appendix J

The lognormal distribution was selected for these analyses for consistency with other New Zealand bottom trawl analyses. A binomial model based on the presence/absence of species in each data set was calculated for the models as there were relatively high proportions of records with no species catch in each analysis (see final columns in Table G.1, Table H.1, Table I.1 and Table J.1). The two series for each model were combined using the delta-lognormal method (Eq. F.4).

Appendix G. DIAGNOSTICS AND SUPPORTING ANALYSES FOR RCO 2 “*NO INTERACTION*” BOTTOM TRAWL CPUE

G.1 Model definition and preliminary analyses

The RCO 2 “*no interaction*” bottom trawl CPUE analysis was accepted for driving the RCO 2 MP by the Southern Inshore Fishery Assessment Working Group in 2018 (Fisheries New Zealand 2018).

G.1.1 Fishery definition

RCO 2: The fishery is defined from bottom trawl daily fishing events which occurred in Statistical Areas 011, 012, 013, 014, or 015, declaring target species RCO, FLA, GUR, TAR (Table F.1). Positive catch were those records which recorded an estimated catch of RCO while zero catch records were events which did not catch RCO. Daily events with more than 6 tows or 20 hours of accumulated effort were excluded from the analysis.

G.1.2 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of RCO catch. These criteria resulted in a core fleet size of 61 vessels which took 89% of the catch (Figure G.1).

G.1.3 Data summary

Table G.1: Summaries by fishing year for core vessels, trips, daily effort strata, events (number records in the original data), events per daily-effort stratum, tows, hours fished, landed RCO 2 (t), and percentage of trips with catch for the RCO 2 “*no interaction*” BT core vessel data set. Final two columns apply to trips that declared no estimated catch of red cod but reported RCO landings, giving the proportion of those trips relative to trips that reported RCO and the proportion of reported catch relative to the total annual RCO reported catch.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Sum (tows)	Sum (hours)	Catch (t)	% trips with catch	% trips: 0 estimated catch	% catch: 0 estimated catch trips
1990	22	783	1 279	1 290	1.01	3 140	10 606	19.2	21.1	44.9	12.3
1991	28	946	1 834	1 927	1.05	4 835	16 678	19.2	12.5	56.8	6.6
1992	31	1 364	2 332	2 511	1.08	5 989	21 438	28.6	33.5	39.0	31.2
1993	36	1 599	2 807	2 869	1.02	7 325	26 377	191.9	64.7	19.4	8.2
1994	36	1 768	2 955	3 250	1.10	7 270	27 440	189.8	65.6	17.5	5.5
1995	34	1 920	3 166	3 614	1.14	7 862	29 165	386.1	73.2	13.0	5.2
1996	38	1 820	3 125	3 727	1.19	7 653	27 592	219.6	70.9	19.2	5.8
1997	35	1 576	2 806	3 221	1.15	6 868	24 091	68.2	62.4	41.8	27.2
1998	34	1 628	2 962	3 366	1.14	7 247	25 804	42.9	44.2	43.3	24.1
1999	33	1 635	2 876	3 413	1.19	7 195	26 504	66.7	54.2	45.3	19.1
2000	30	1 551	2 872	3 035	1.06	6 947	26 867	12.8	23.7	68.7	19.6
2001	35	1 573	2 925	3 415	1.17	7 269	26 902	14.9	32.6	63.0	34.6
2002	35	1 638	3 167	3 737	1.18	7 737	27 883	26.8	45.4	54.7	23.0
2003	34	1 527	3 068	3 587	1.17	7 530	27 822	24.4	52.1	66.4	37.3
2004	34	1 303	2 682	3 160	1.18	6 707	24 506	49.4	66.9	49.0	19.1
2005	32	1 472	3 054	3 629	1.19	7 871	29 333	86.5	72.6	39.2	19.5
2006	34	1 620	3 304	4 073	1.23	8 702	30 933	129.5	73.3	31.2	13.1
2007	32	1 589	3 345	4 392	1.31	8 759	30 477	99.7	69.7	36.0	13.5
2008	33	1 343	3 053	7 993	2.62	8 033	27 588	90.9	76.3	38.3	14.8
2009	32	1 397	3 166	8 541	2.70	8 541	29 867	122.1	69.9	35.3	11.9
2010	31	1 447	3 445	9 387	2.72	9 387	32 769	264.1	86.3	21.1	5.8
2011	32	1 424	3 438	9 507	2.77	9 507	32 821	374.3	85.5	17.1	2.9
2012	31	1 418	3 174	8 616	2.71	8 616	29 999	456.2	86.5	15.2	1.7
2013	27	1 157	2 800	7 819	2.79	7 819	27 350	220.0	84.0	25.9	6.2
2014	27	1 140	2 871	7 985	2.78	7 985	27 963	81.3	71.7	51.7	18.9
2015	26	1 051	2 477	6 857	2.77	6 857	24 412	55.9	60.2	60.7	21.1
2016	23	1 111	2 264	6 097	2.69	6 097	21 741	238.1	81.6	25.2	6.0
2017	21	976	2 026	5 402	2.67	5 402	19 274	225.8	79.8	28.2	4.4

G.1.4 Core vessel plots

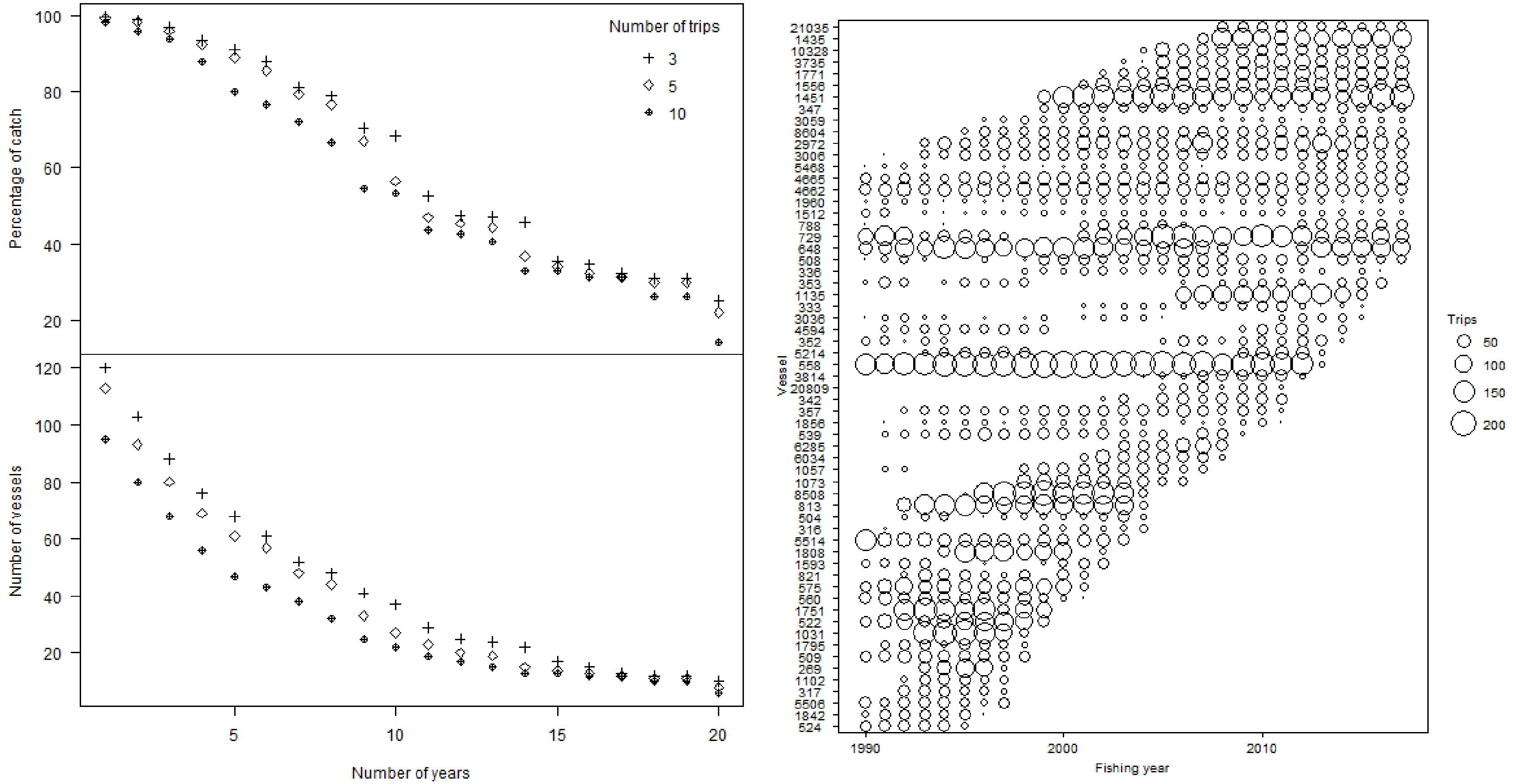

Figure G.1: [left panel] total landed RCO and number of vessels plotted against the number of years used to define core vessels participating in the RCO 2 "*no interaction*" BT dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

G.1.5 Exploratory data plots for core vessel data set

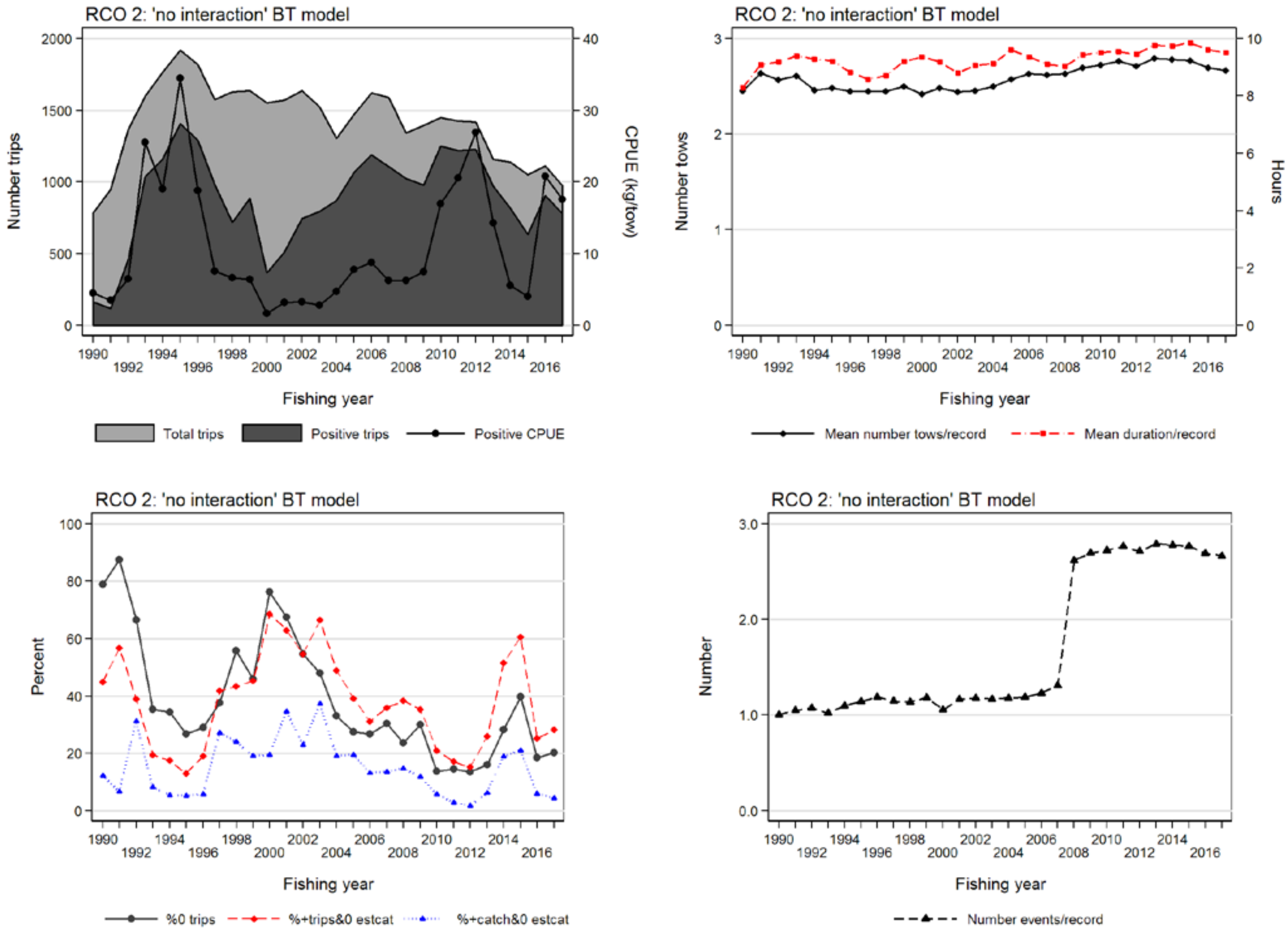

Figure G.2: Summary plots by fishing year for the RCO 2 "*no interaction*" BT core vessel data set: [upper left panel]: total trips (light grey) and trips with red cod catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of tows and mean duration per daily-effort stratum record; [lower left panel]: a) percentage of trips with no catch of red cod, b) percentage of trips with no estimated catch but with landed catch, c) percentage of catch with no estimated catch relative to total landed catch; [lower right panel]: mean number of events per daily-effort stratum record.

G.2 Positive catch model

Three explanatory variables entered the model after fishing year (vessel, number tows, target species; Table G.2). The variables area, month and hours fishing were not accepted. A plot of the model is provided in Figure G.3 and the CPUE indices are listed in Table G.4.

Table G.2: Order of acceptance of variables into the lognormal RCO 2 "*no interaction*" BT model, 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.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	29	-211 503	423 065	23.1	*
vessel	89	-209 292	418 762	30.6	*
poly(log(tows), 3)	92	-208 321	416 826	33.7	*
target species	95	-207 943	416 076	**34.9**	*
area	99	-207 651	415 500	35.7	
month	110	-207 382	414 984	36.5	
poly(log(duration), 3)	113	-207 360	414 946	36.6	

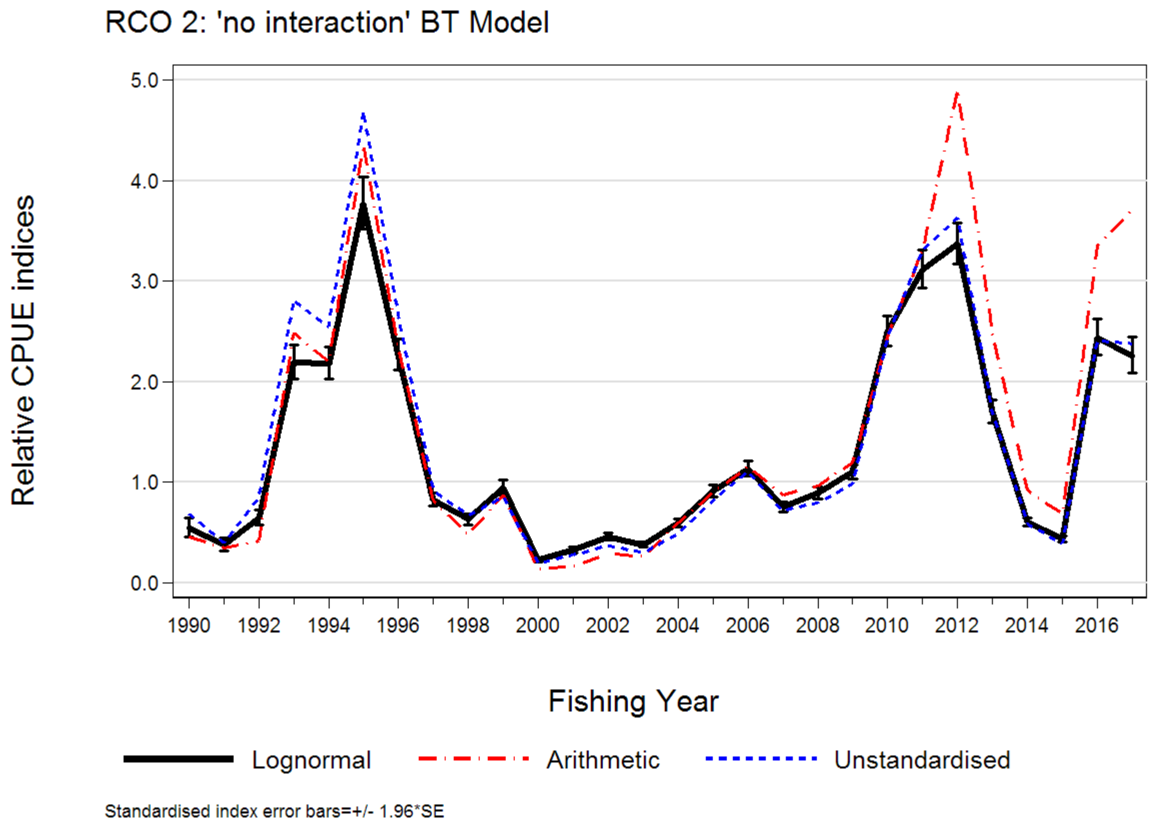

Figure G.3: Relative CPUE indices for RCO using the lognormal non-zero model based on the RCO 2 "*no interaction*" BT fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

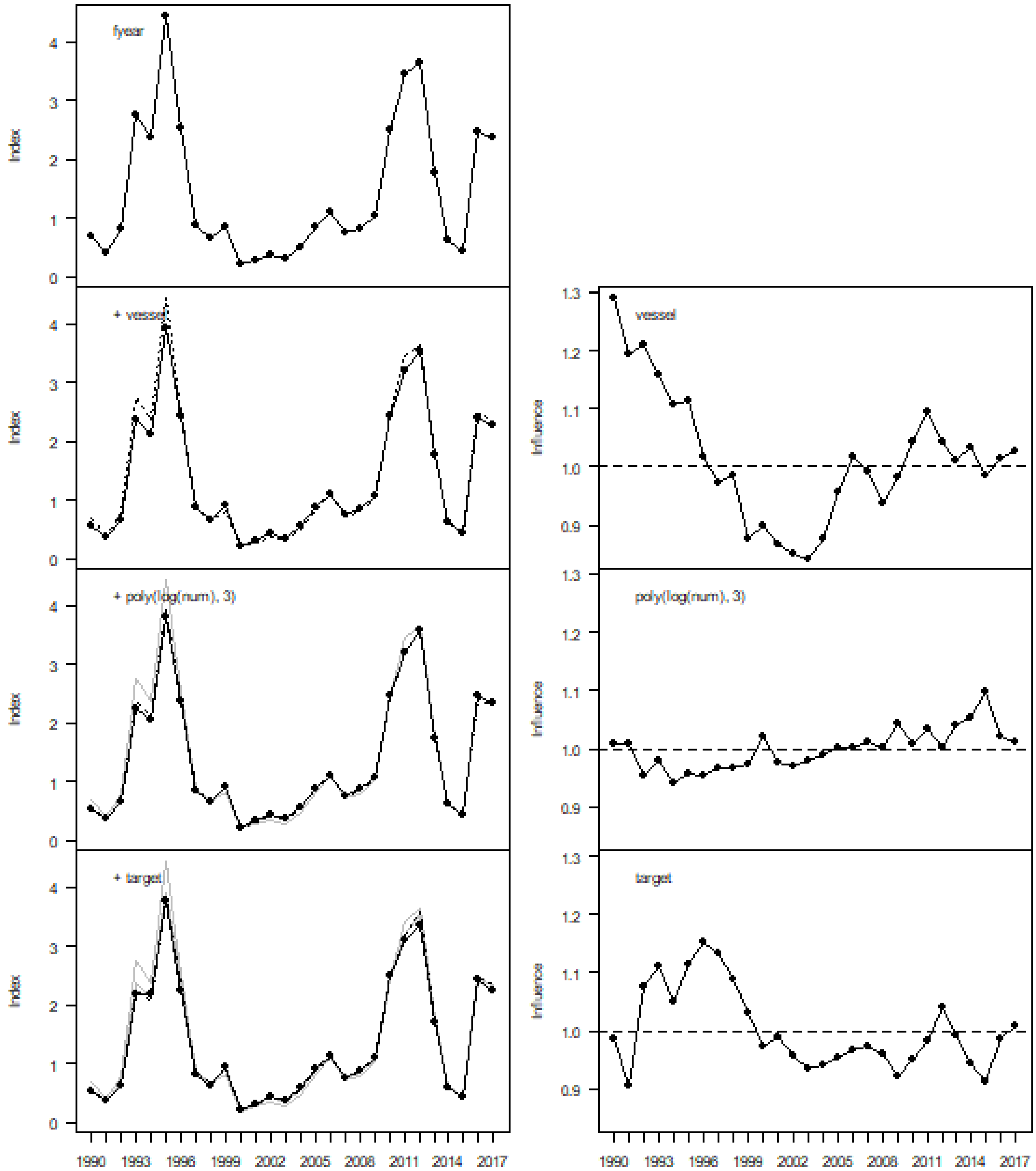

Figure G.4: [left column]: annual indices from the lognormal RCO 2 "*no interaction*" BT model at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

G.2.1 Residual and diagnostic plots

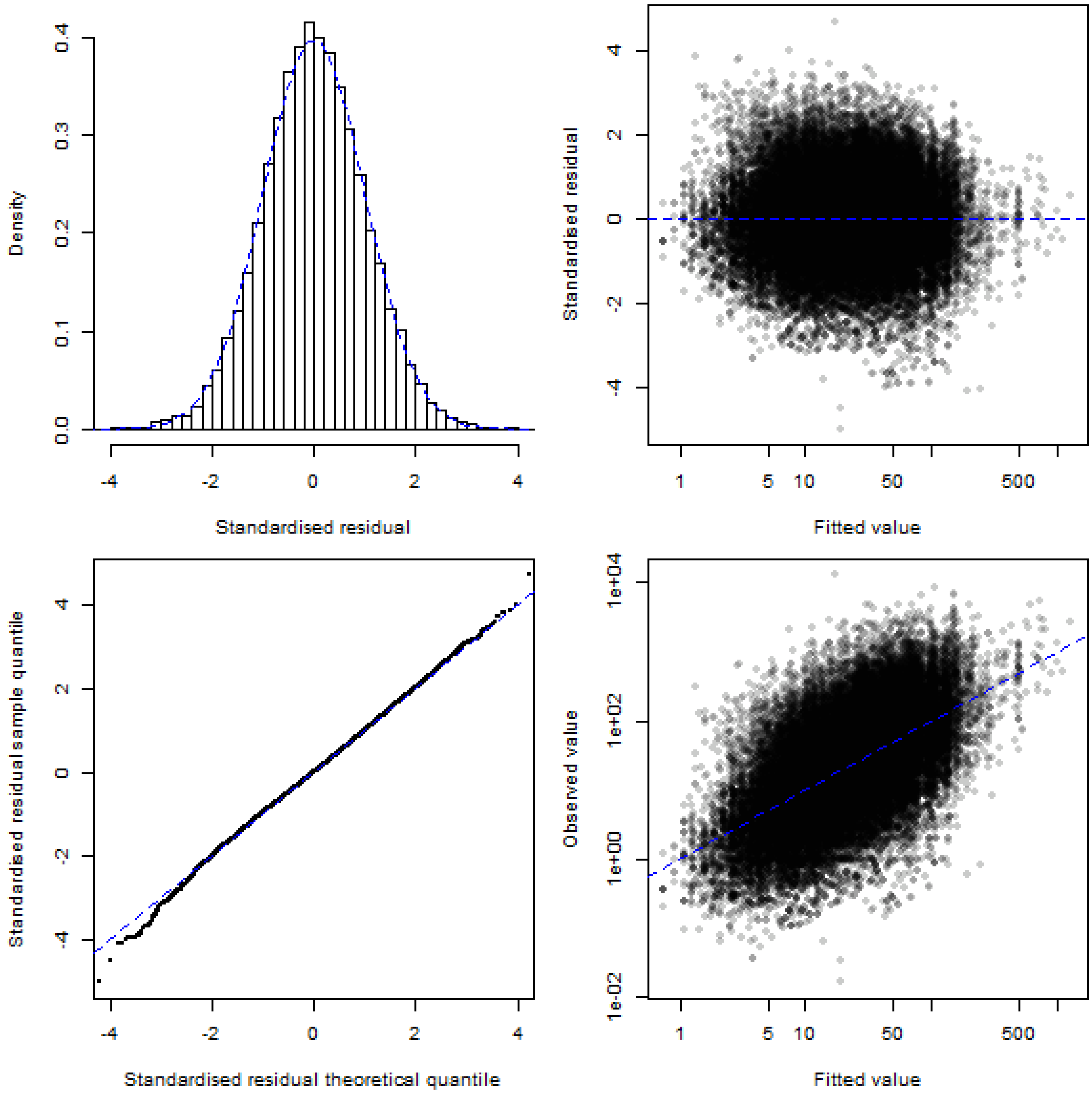

Figure G.5: Plots of the fit of the standardised lognormal CPUE model of successful RCO 2 *"no interaction"* BT catches. [Upper left] histogram of the standardised residuals compared to a lognormal distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

G.2.2 Model coefficient plots

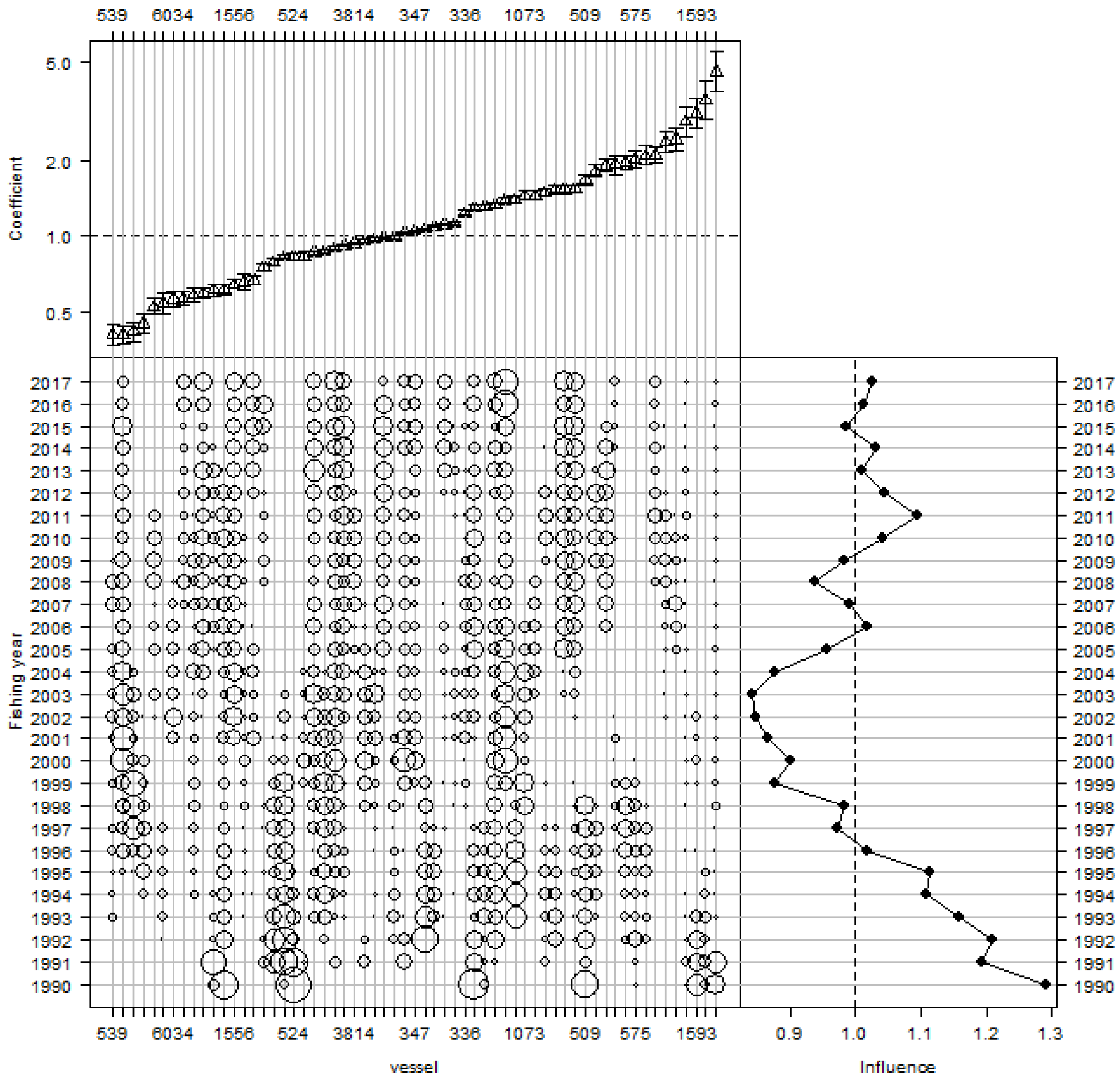

Figure G.6: Effect of vessel in the lognormal RCO 2 "*no interaction*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

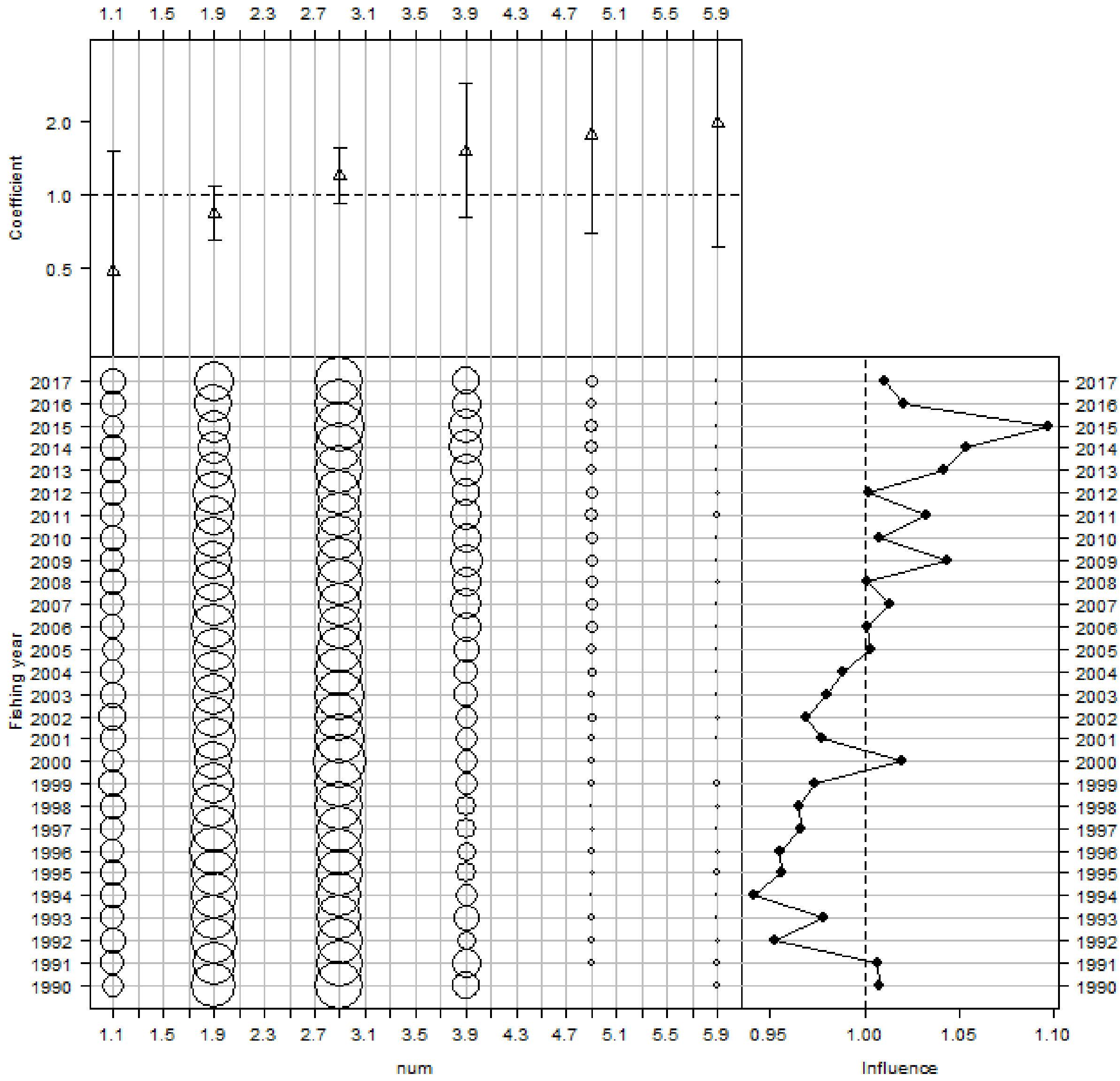

Figure G.7: Effect of log(number tows) in the lognormal RCO 2 "*no interaction*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

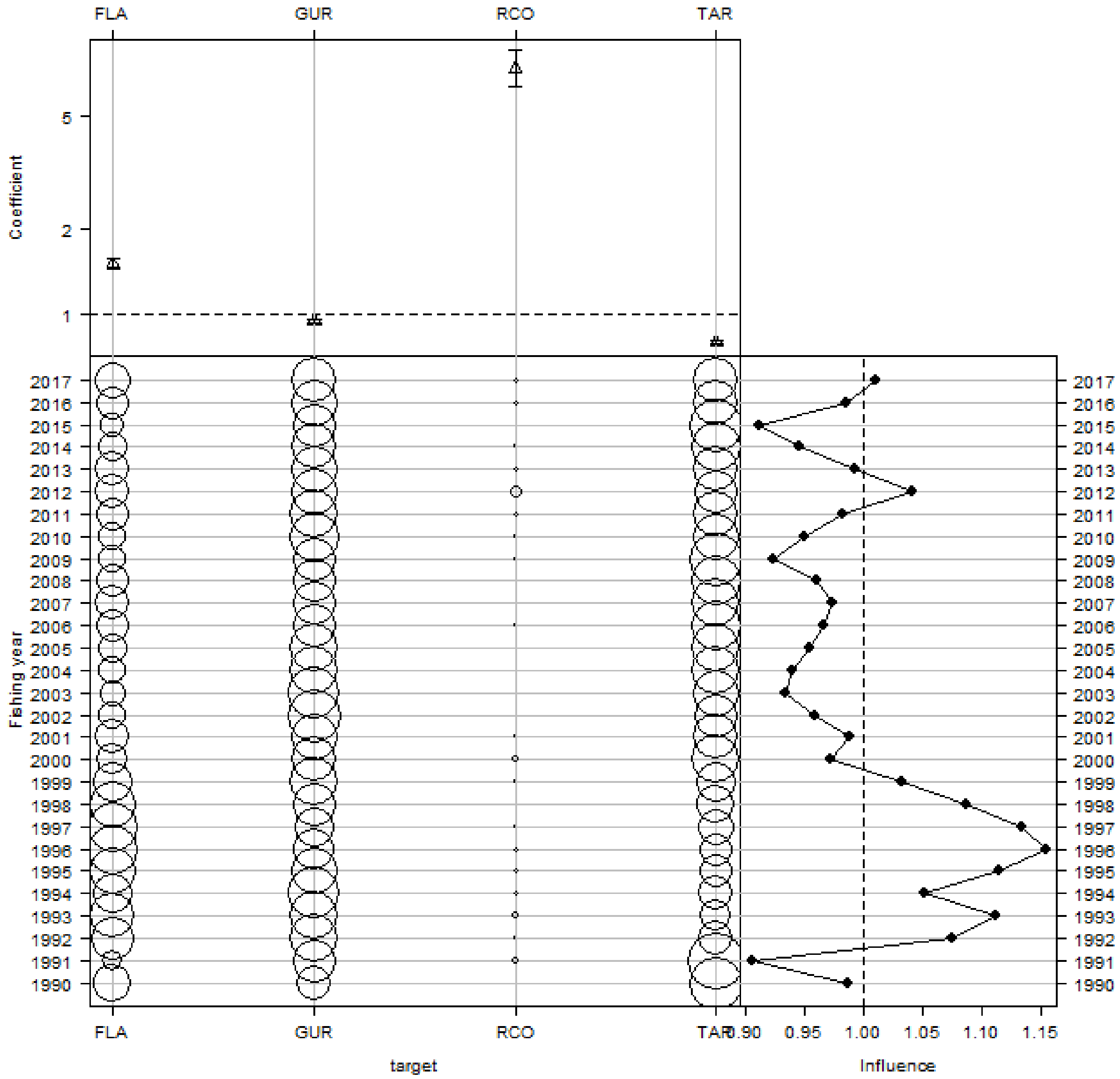

Figure G.8: Effect of target species in the lognormal RCO 2 "*no interaction*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

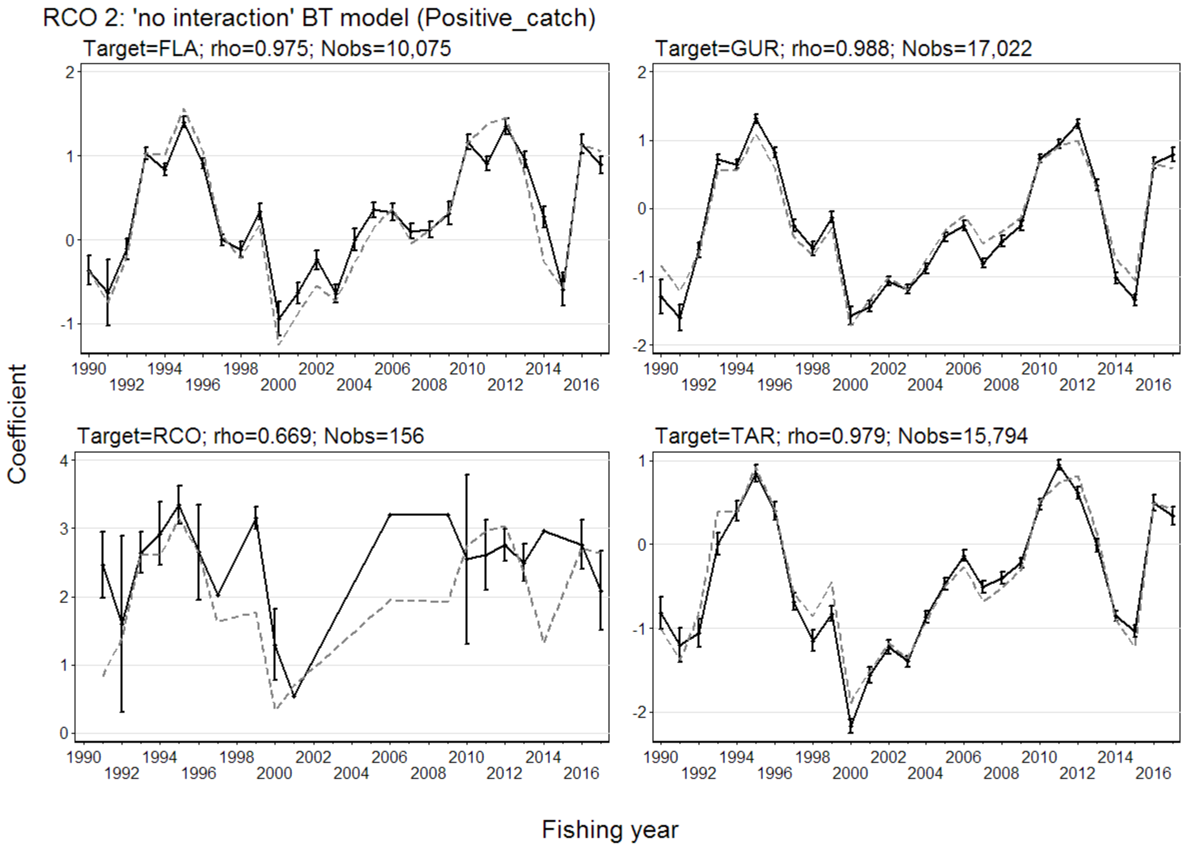

Figure G.9: Residual implied coefficients for target species × fishing year interaction (interaction term not offered to the model) in the RCO 2 lognormal *"no interaction"* BT model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when a target species × year interaction term is fitted, particularly for those target species × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

G.3 Binomial presence/absence model

Two explanatory variables entered the model after fishing year (vessel and target species). Variables hours fished, month, area and number tows were not accepted (Table G.3). A plot of the binomial model and the combined delta-lognormal model is provided in Figure G.10 and the CPUE indices are listed in Table G.4.

Table G.3: Order of acceptance of variables into the RCO 2 "*no interaction*" BT presence/absence binomial model, 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.

Variable	DF	Neg. Log likelihood	AIC	Deviance R^2	Nagelkerke R^2	Model use
fishing year	28	-50 956	101 967	6.0	10.5	*
vessel	88	-48 776	97 729	10.0	17.2	*
target species	91	-48 362	96 907	10.7	**18.4**	*
poly(log(duration), 3)	94	-48 132	96 452	11.2	19.1	
month	105	-47 928	96 067	11.5	19.6	
area	109	-47 835	95 888	11.7	19.9	
poly(log(tows), 3)	112	-47 808	95 840	11.8	20.0	

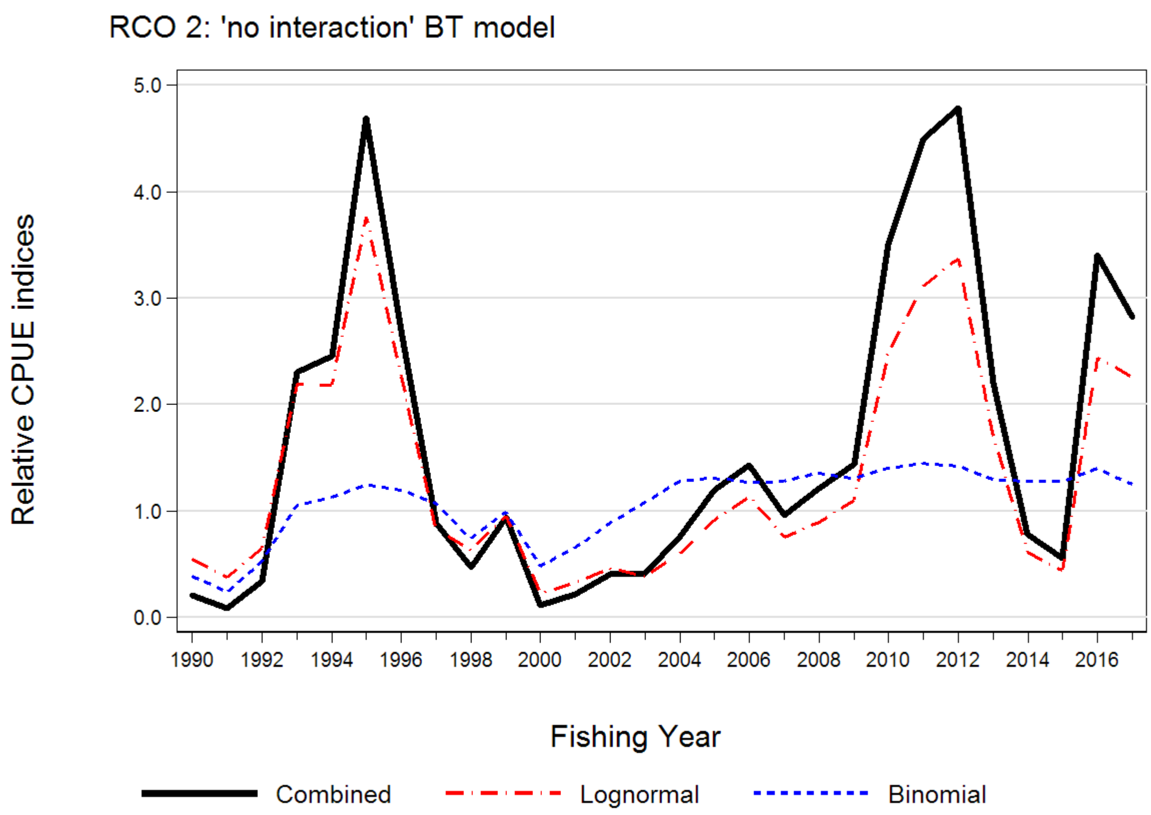

Figure G.10: Three relative CPUE indices for red cod based on the RCO 2 "*no interaction*" BT fishery definition: a) the lognormal non-zero model, b) the binomial standardised model using the logistic distribution and a regression based on presence/absence of red cod, and c) the combined model using the delta-lognormal procedure (Eq. F.4).

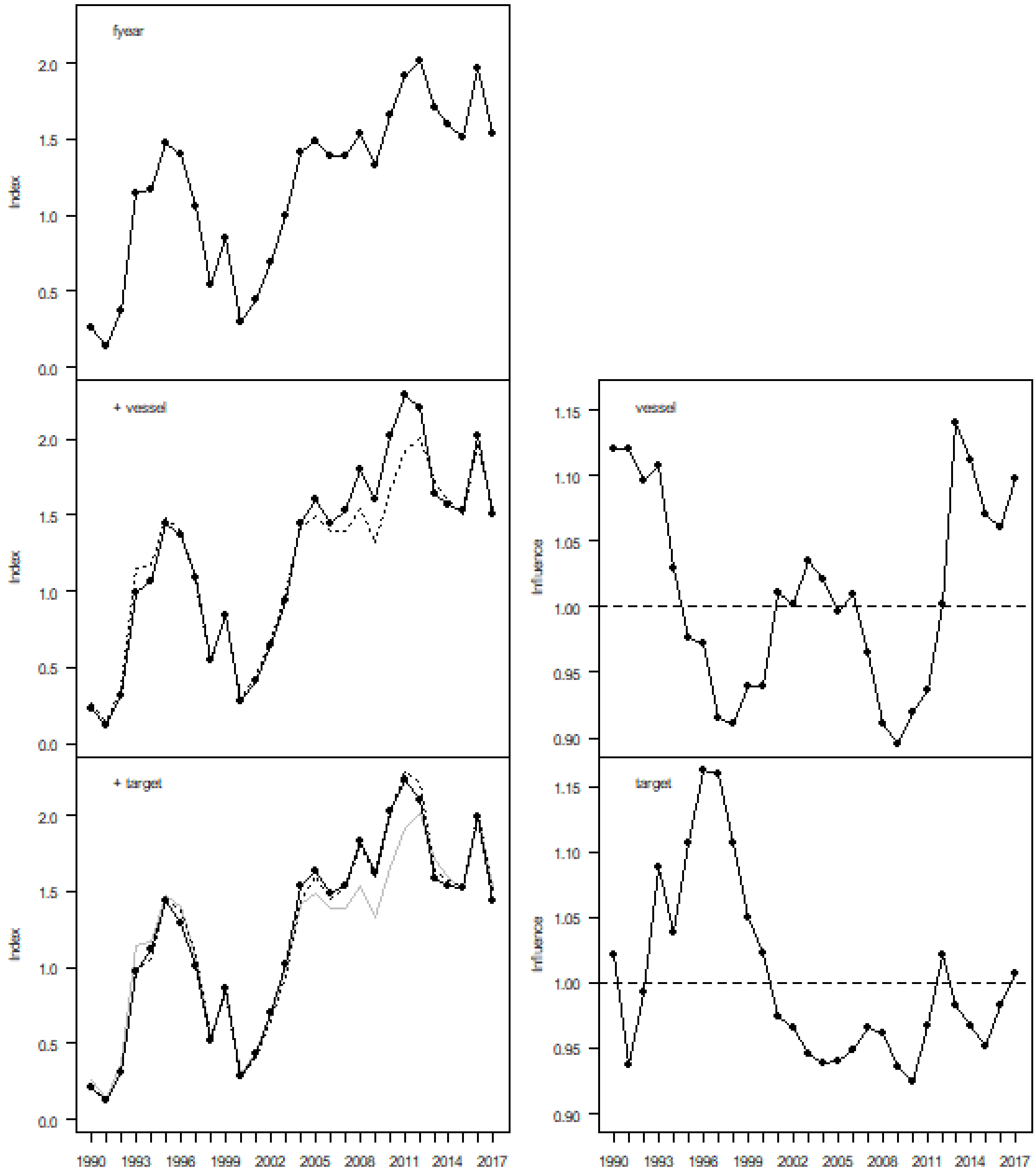

Figure G.11: [left column]: annual indices for the binomial RCO 2 “*no interaction*” BT model at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

G.4 Model coefficients

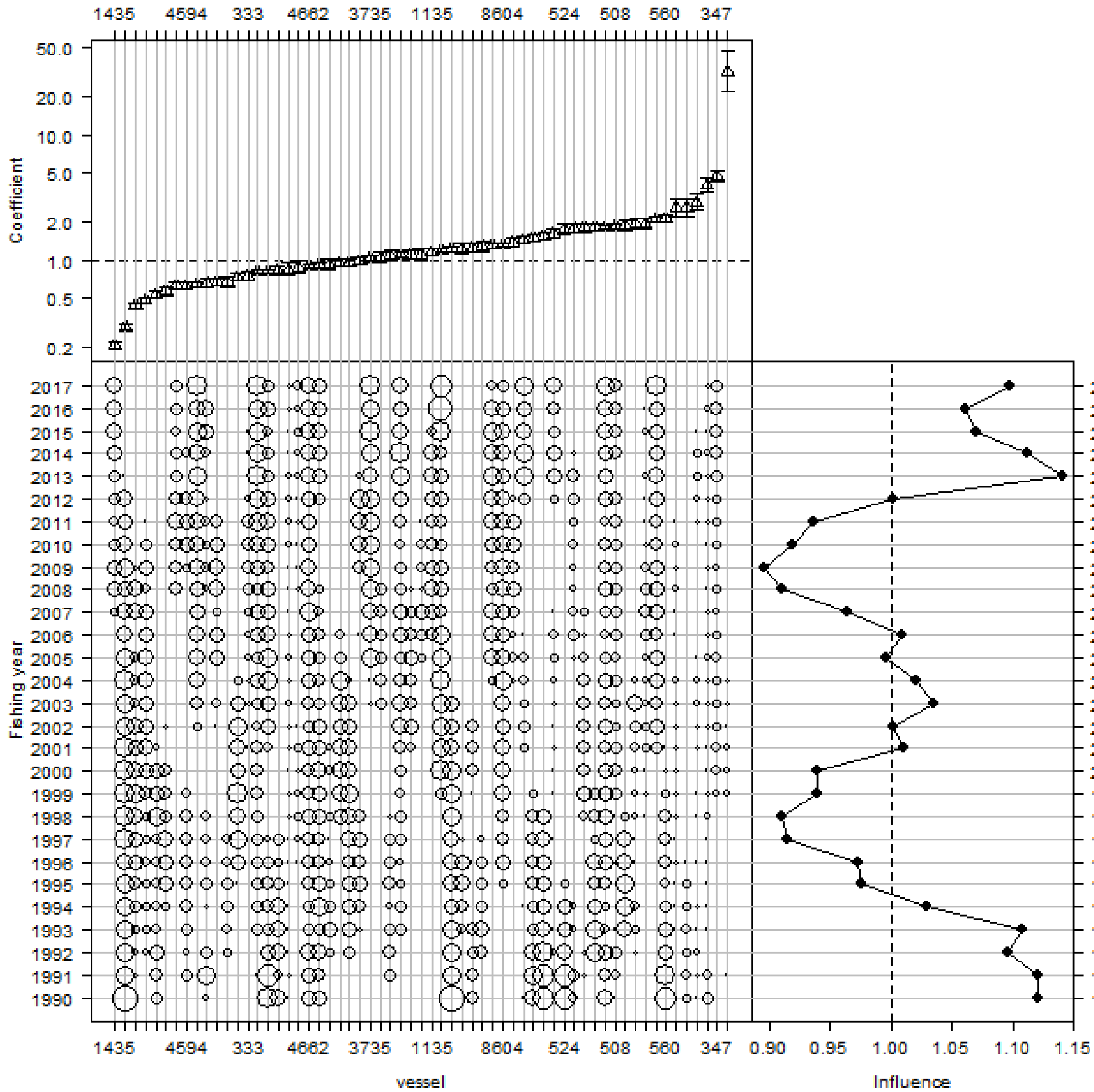

Figure G.12: Effect of vessel in the binomial RCO 2 “*no interaction*” BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

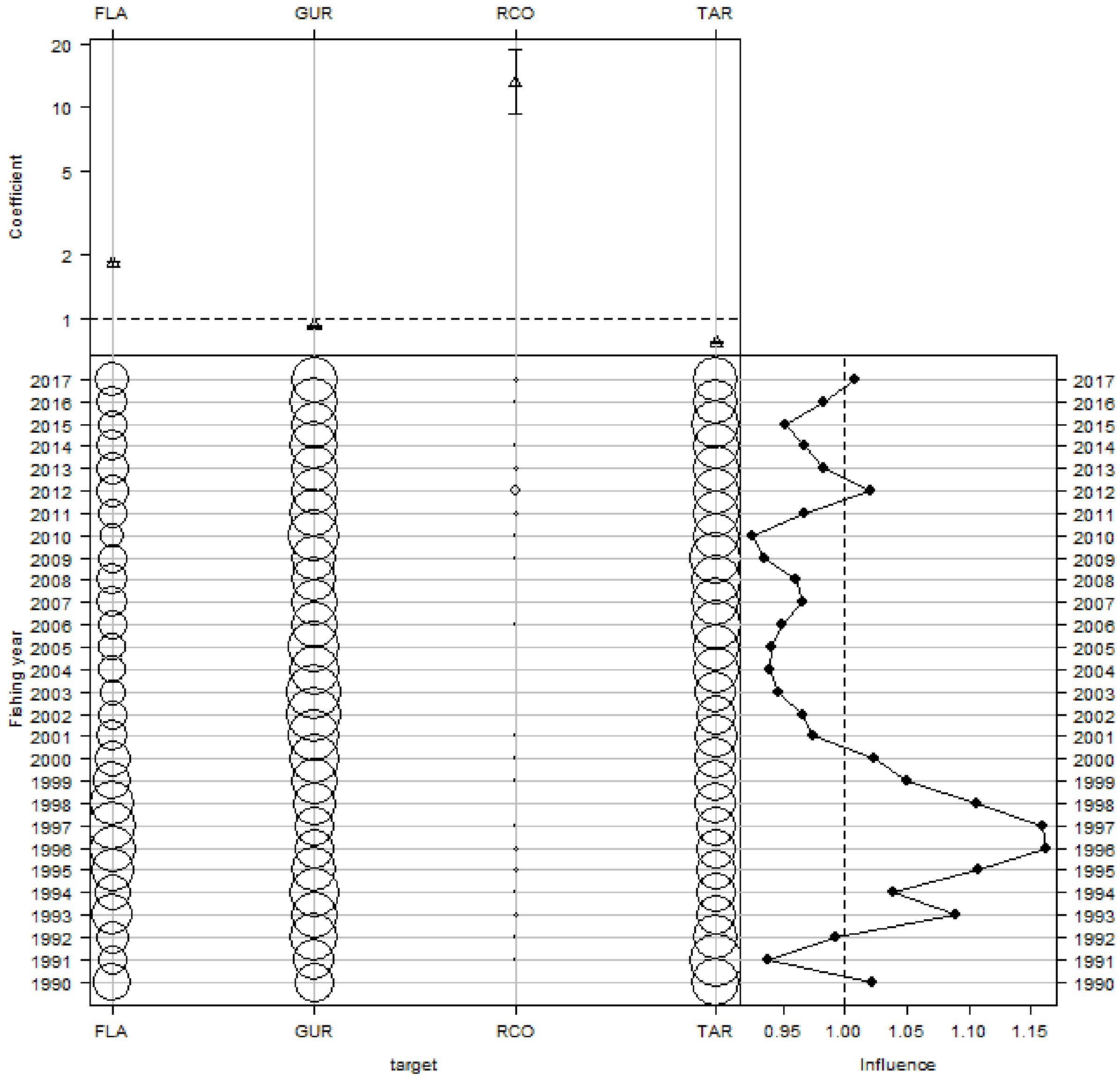

Figure G.13: Effect of target species in the binomial RCO 2 "*no interaction*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

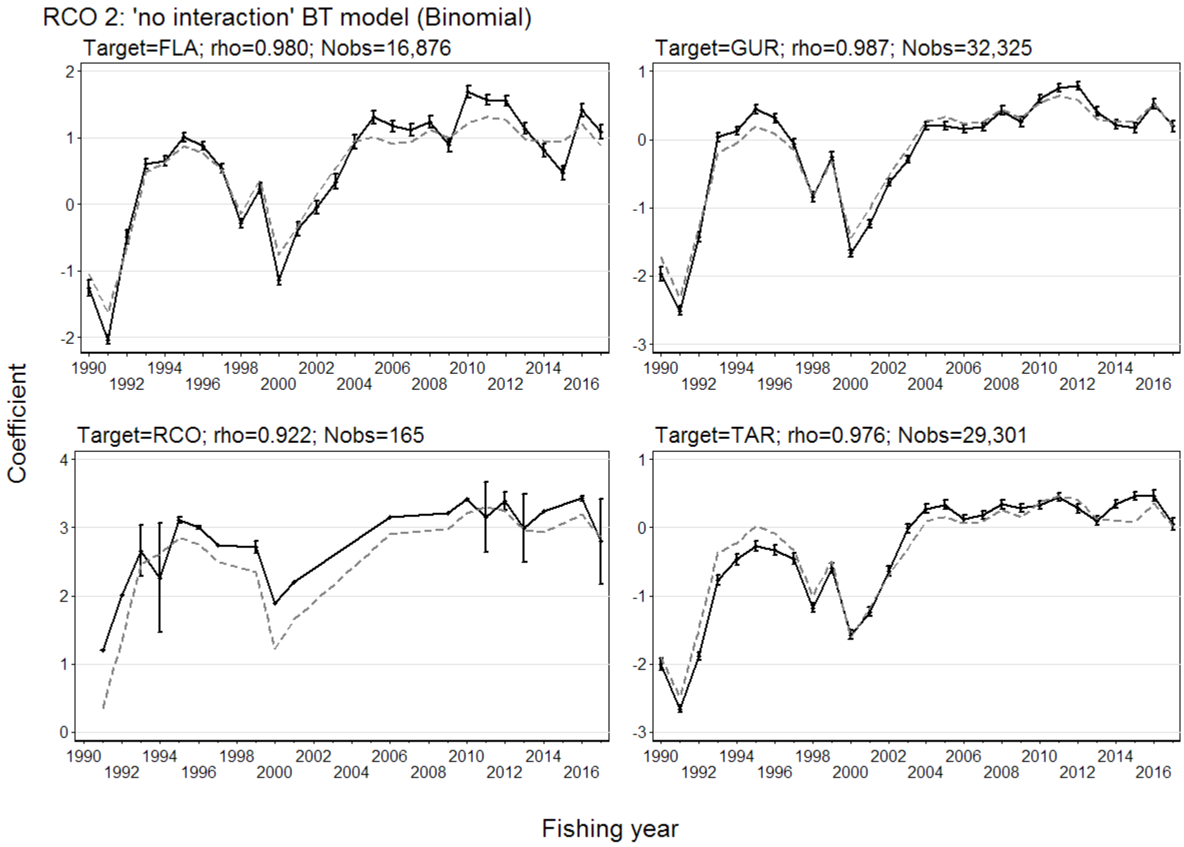

Figure G.14: Residual implied coefficients for target species × fishing year interaction (interaction term not offered to the model) in the RCO 2 binomial "*no interaction*" BT model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when a target species × year interaction term is fitted, particularly for those target species × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

G.5 CPUE indices

Table G.4: Arithmetic indices for the total and core data sets, geometric, lognormal (including standard error [SE]), binomial and combined indices for the core data set by fishing year for the RCO 2 "*no interaction*" BT model. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1990	0.516	0.456	0.686	0.544	0.0850	0.386	0.210
1991	0.263	0.349	0.399	0.373	0.0902	0.235	0.088
1992	0.386	0.412	0.839	0.647	0.0558	0.525	0.340
1993	2.469	2.490	2.813	2.195	0.0392	1.052	2.308
1994	2.269	2.195	2.543	2.181	0.0372	1.125	2.453
1995	4.135	4.355	4.693	3.766	0.0350	1.246	4.692
1996	2.233	2.323	2.647	2.263	0.0349	1.194	2.702
1997	0.806	0.816	0.908	0.827	0.0382	1.071	0.886
1998	0.451	0.481	0.674	0.631	0.0434	0.738	0.466
1999	0.796	0.870	0.853	0.946	0.0390	0.991	0.938
2000	0.157	0.139	0.190	0.225	0.0528	0.481	0.108
2001	0.150	0.158	0.277	0.326	0.0452	0.655	0.214
2002	0.308	0.290	0.370	0.456	0.0384	0.885	0.403
2003	0.263	0.263	0.298	0.381	0.0362	1.080	0.411
2004	0.586	0.591	0.489	0.596	0.0356	1.279	0.762
2005	0.916	0.897	0.819	0.910	0.0332	1.309	1.191
2006	1.317	1.154	1.109	1.134	0.0326	1.264	1.433
2007	0.917	0.877	0.719	0.754	0.0327	1.278	0.963
2008	0.929	0.967	0.795	0.893	0.0334	1.358	1.212
2009	1.191	1.196	0.983	1.100	0.0337	1.304	1.435
2010	2.419	2.446	2.447	2.501	0.0313	1.404	3.511
2011	3.297	3.311	3.309	3.116	0.0308	1.444	4.499
2012	4.889	4.907	3.633	3.370	0.0314	1.420	4.785
2013	2.402	2.484	1.689	1.701	0.0342	1.293	2.200
2014	0.887	0.921	0.590	0.606	0.0343	1.280	0.775
2015	0.746	0.686	0.386	0.437	0.0370	1.276	0.558
2016	4.043	3.350	2.406	2.439	0.0371	1.397	3.407
2017	3.743	3.710	2.379	2.261	0.0404	1.247	2.820

Appendix H. DIAGNOSTICS AND SUPPORTING ANALYSES FOR RCO 2 "*TOW-BY-TOW*" BOTTOM TRAWL CPUE

H.1 Model definition and preliminary analyses

H.1.1 Fishery definition

RCO 2: The fishery is defined from bottom trawl tow events in Statistical Areas 011, 012, 013, 014, or 015 and declared target species RCO, FLA, GUR, TAR (Table F.1). Positive catch were those records which recorded an estimated catch of RCO while zero catch records were events which did not catch RCO. Single tow events with more than 20 hours of accumulated effort were excluded from the analysis. Tows were required to have trawl headline height between 1–10 m, trawl wingspread between 5–100 m and vessel speed more than 0 km/h.

H.1.2 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of RCO catch. These criteria resulted in a core fleet size of 27 vessels which took 85% of the catch (Figure H.1).

H.1.3 Data summary

Table H.1: Summaries by fishing year for core vessels, trips, events (number of records in the original data), tows, hours fished, landed RCO 2 (t), percentage of trips with catch and percentage of tows with RCO catch for the "*tow-by-tow*" BT core vessel data set. Final two columns apply to trips that declared no estimated catch of red cod but reported RCO landings, giving the proportion of these trips relative to trips that reported RCO and the proportion of the reported catch from these trips relative to the total annual RCO reported catch.

Fishing year	Vessels	Trips	Events	Sum (tows)	Sum (hours)	Catch (t)	% trips with catch	% tows with catch	% trips: 0 estimated catch	% catch: 0 estimated catch trips
2008	26	1 172	6 638	6 638	22 240	79.9	75.5	44.7	12.3	2.5
2009	24	1 277	7 066	7 066	24 262	105.1	68.2	45.7	8.8	1.4
2010	25	1 315	7 891	7 891	27 008	219.8	85.7	53.3	4.2	0.6
2011	24	1 342	8 556	8 556	29 358	349.4	86.1	62.2	3.8	0.3
2012	27	1 379	8 178	8 178	28 271	433.3	86.4	60.1	4.0	0.2
2013	24	1 139	7 600	7 600	26 601	218.0	84.5	51.5	6.9	0.6
2014	24	1 116	7 713	7 713	26 928	79.1	72.8	40.3	16.6	3.0
2015	23	1 056	6 704	6 704	23 858	58.7	60.9	39.3	20.7	3.1
2016	21	1 121	6 062	6 062	21 702	244.0	81.8	53.7	5.8	0.5
2017	21	985	5 283	5 283	18 841	225.9	78.7	50.4	7.0	0.6

H.1.4 Core vessel plots

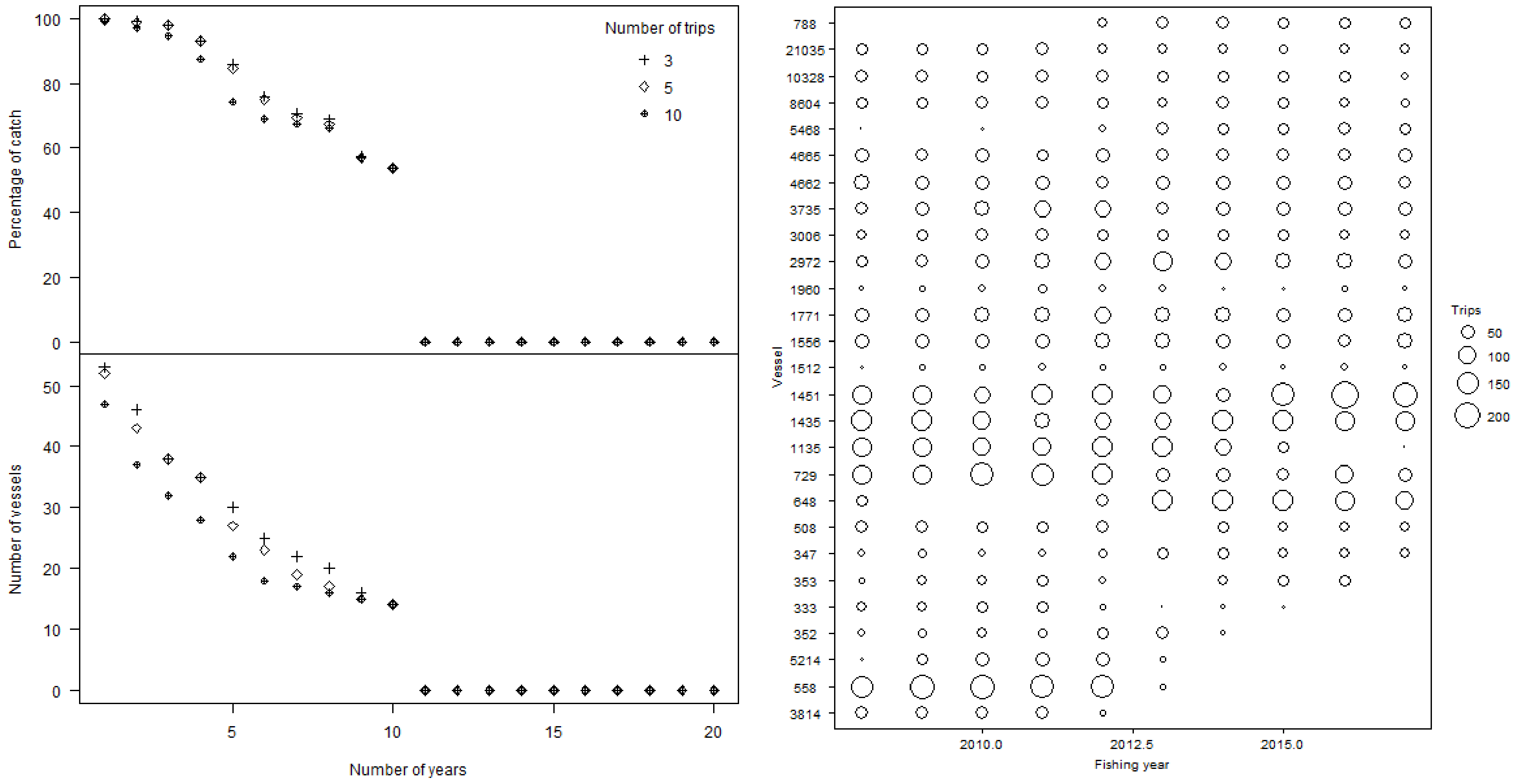

Figure H.1: [left panel] total landed RCO and number of vessels plotted against the number of years used to define core vessels participating in the RCO 2 "*tow-by-tow*" positive catch dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

H.1.5 Exploratory data plots for core vessel data set

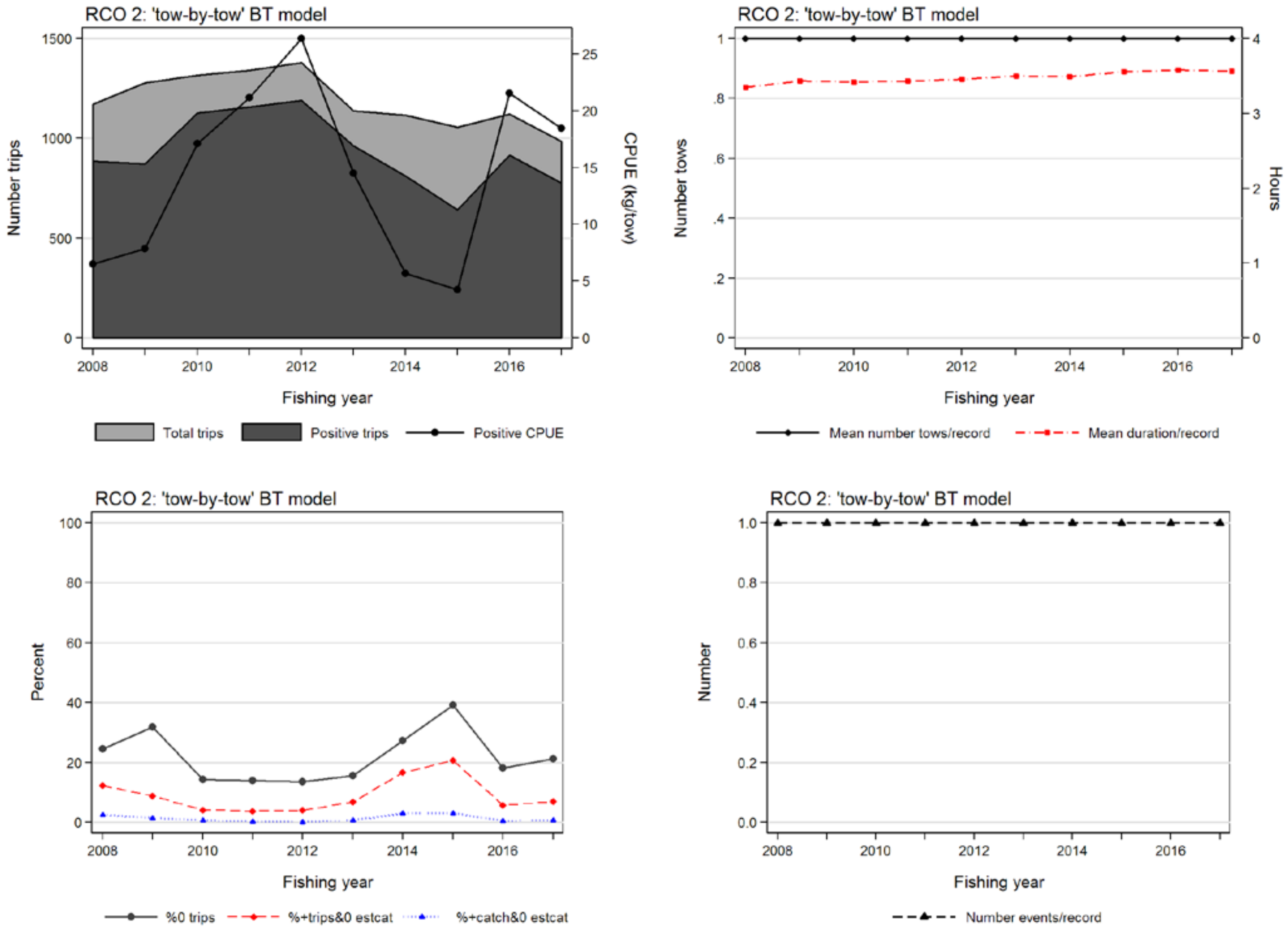

Figure H.2: Core vessel summary plots by fishing year for the RCO 2 "*tow-by-tow*" BT data set: [upper left panel]: total trips (light grey) and trips with red cod catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of tows and mean duration per daily-effort stratum record; [lower left panel]: a) percentage of trips with no catch of red cod, b) percentage of trips with no estimated catch but with landed catch, c) percentage of catch with no estimated catch relative to total landed catch; [lower right panel]: mean number of events per daily-effort stratum record.

H.2 Positive catch model

Only one explanatory variable entered the model after fishing year (area; Table H.2). The variables target species. vessel speed, month, headline height, hours fished and wingspread were not accepted. The variable bottom depth was discarded. A plot of the model is provided in Figure H.3 and the CPUE indices are listed in Table H.4.

Table H.2: Order of acceptance of variables into the lognormal RCO 2 "*tow-by-tow*" BT model, 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.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	11	-162 590	325 202	11.7	*
area	15	-161 738	323 506	**15.8**	*
target species	18	-161 539	323 113	16.8	
vessel speed	19	-161 308	322 654	17.9	
month	30	-161 136	322 333	18.7	
headline height	31	-161 075	322 212	19.0	
poly(log(duration), 3)	34	-161 048	322 163	19.1	
wingspread	35	-161 046	322 162	19.1	
bottom depth	–				

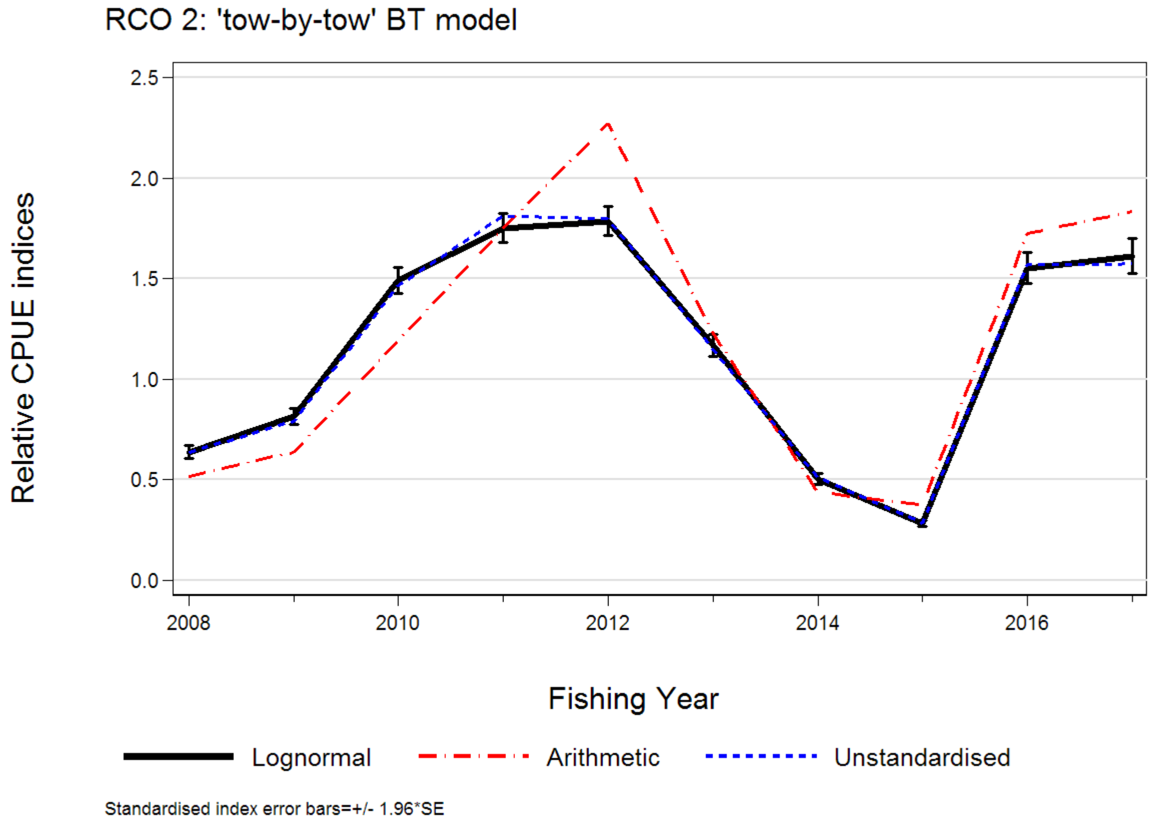

Figure H.3: Relative CPUE indices for RCO using the lognormal non-zero model based on the RCO 2 "*tow-by-tow*" BT fishery definition. Also shown are two unstandardised series from the same data set: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

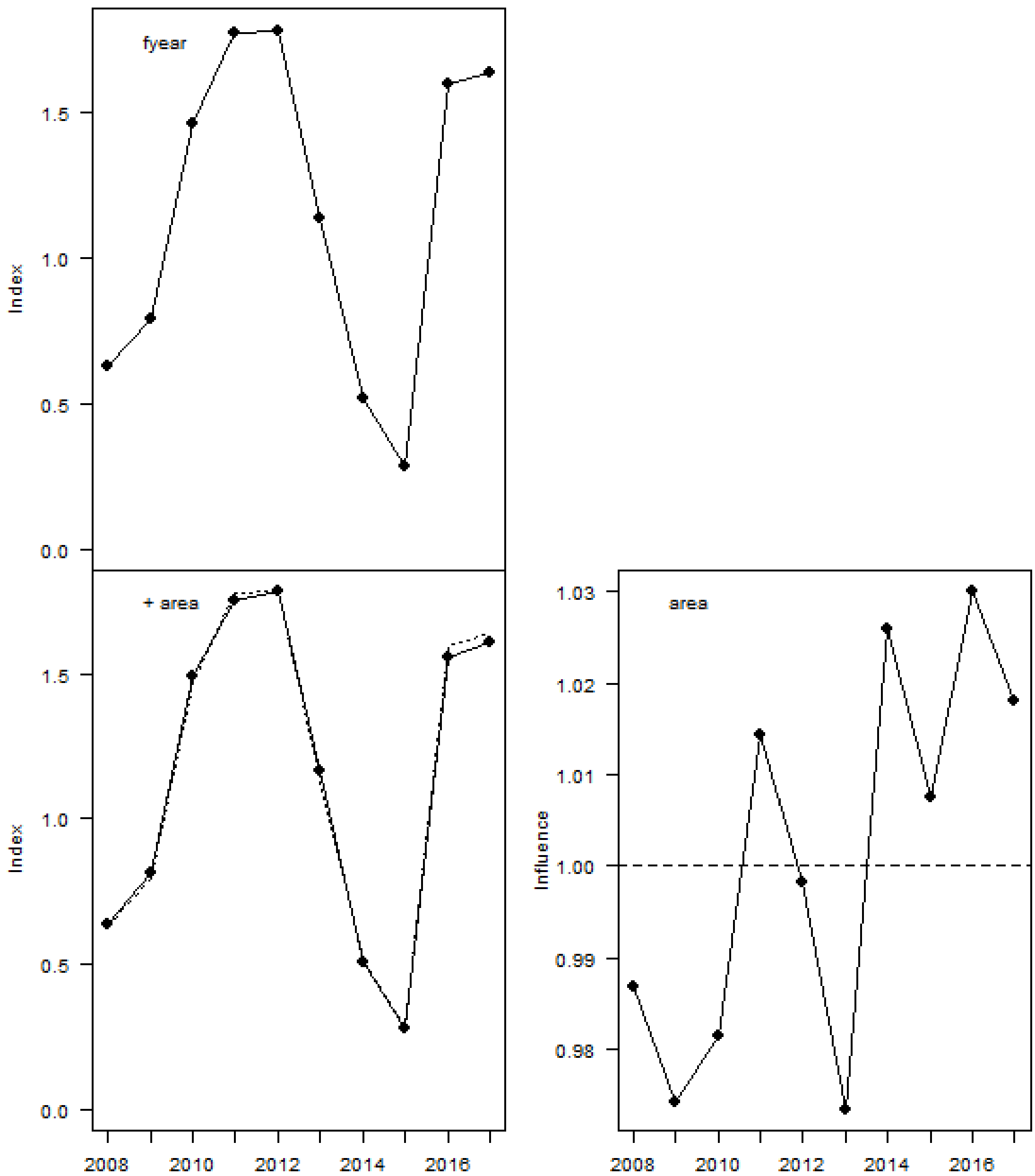

Figure H.4: [left column]: annual indices from the lognormal RCO 2 "*tow-by-tow*" BT model at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

H.2.1 Residual and diagnostic plots

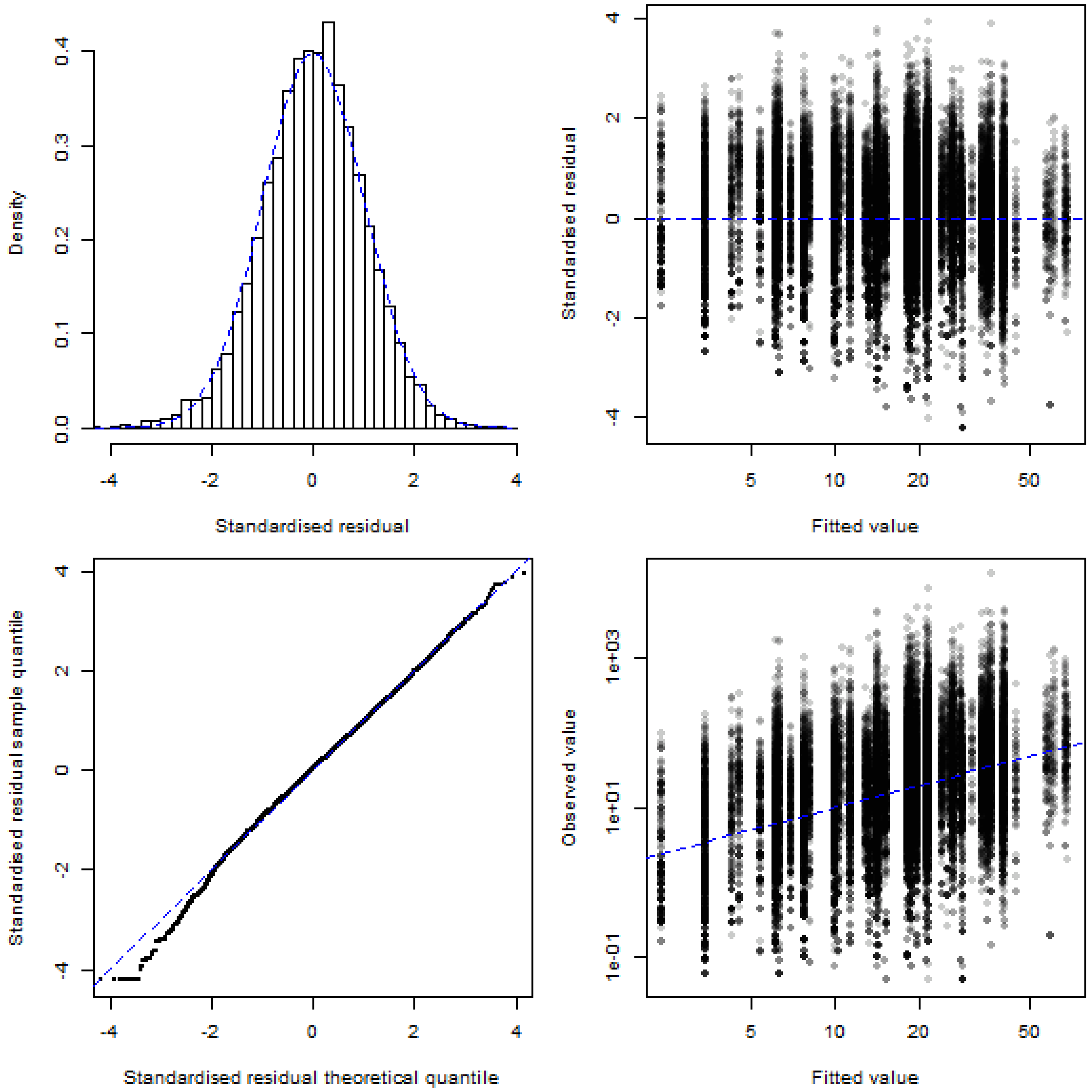

Figure H.5: Plots of the fit of the lognormal standardised CPUE model of successful catches of red cod to the RCO 2 "*tow-by-tow*" BT data set. [Upper left] histogram of the standardised residuals compared to a lognormal distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

H.2.2 Model coefficient plots

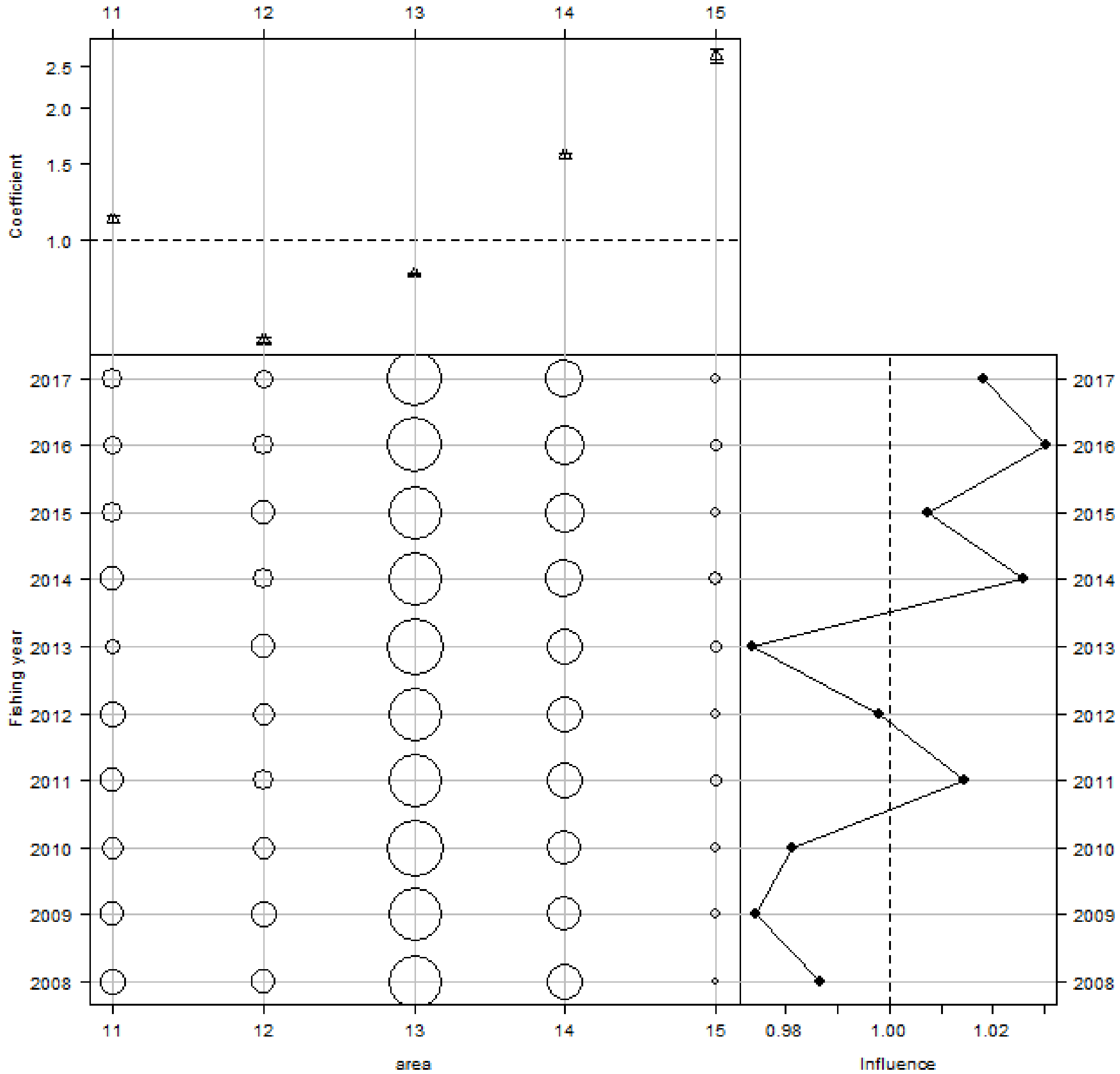

Figure H.6: Effect of area in the lognormal RCO 2 "*tow-by-tow*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

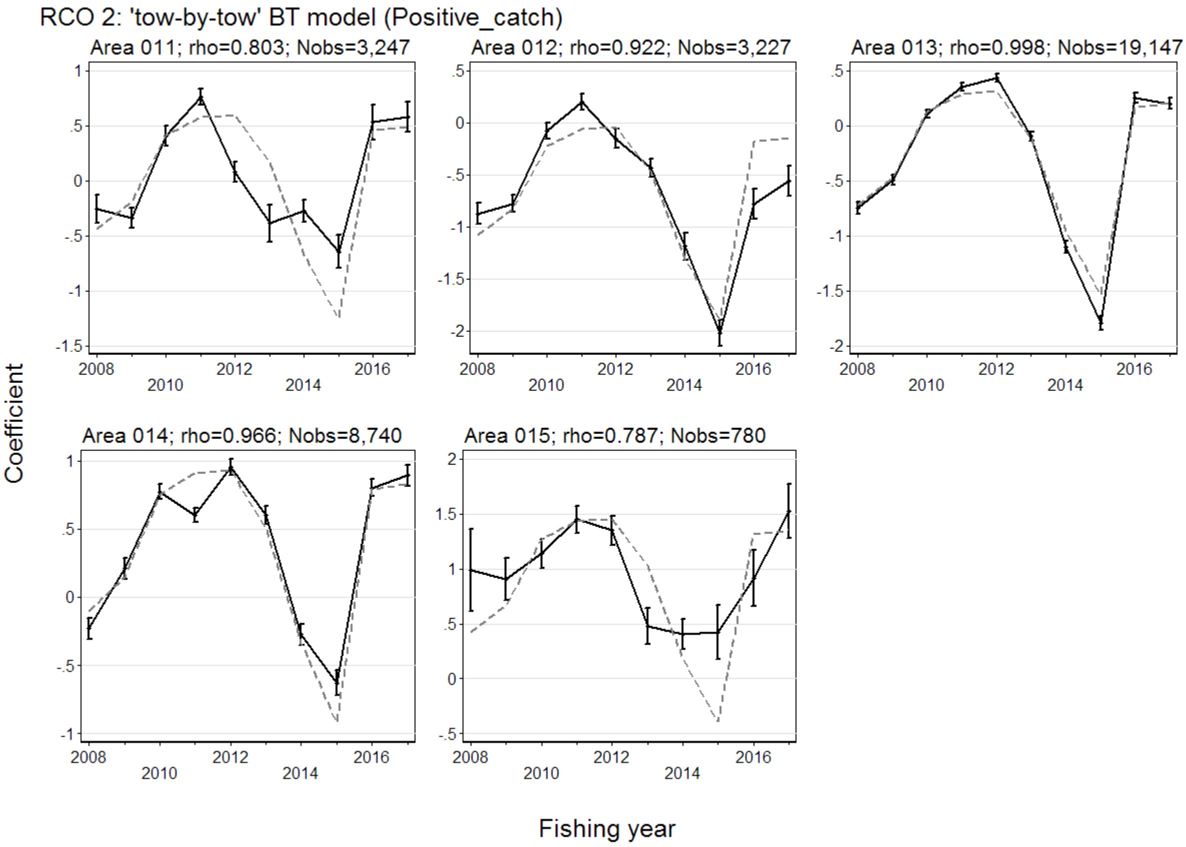

Figure H.7: Residual implied coefficients for area × fishing year interaction (interaction term not offered to the model) in the RCO 2 "*tow-by-tow*" BT lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised 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. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

H.3 Binomial presence/absence model

One explanatory variable entered the model after fishing year (target species). Variables area, headline height, month, bottom depth, hours fished, vessel speed and wingspread were not accepted (Table H.3). A plot of the binomial model and the combined delta-lognormal model is provided in Figure H.8 and the CPUE indices are listed in Table H.4.

Table H.3: Order of acceptance of variables into the RCO 2 "*tow-by-tow*" BT binomial presence/absence model, 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.

Variable	DF	Neg. Log likelihood	AIC	Deviance R^2	Nagelkerke R^2	Model use
fishing year	10	-47 201	94 422	1.69	3.09	*
target species	13	-46 848	93 723	2.42	**4.41**	*
area	17	-46 727	93 488	2.68	4.86	
headline height	18	-46 601	93 238	2.94	5.32	
month	29	-46 472	93 002	3.21	5.80	
bottom depth	30	-46 408	92 876	3.34	6.04	
poly(log(duration), 3)	33	-46 370	92 807	3.42	6.17	
vessel speed	34	-46 347	92 763	3.47	6.26	
wingspread	35	-46 344	92 759	3.47	6.27	

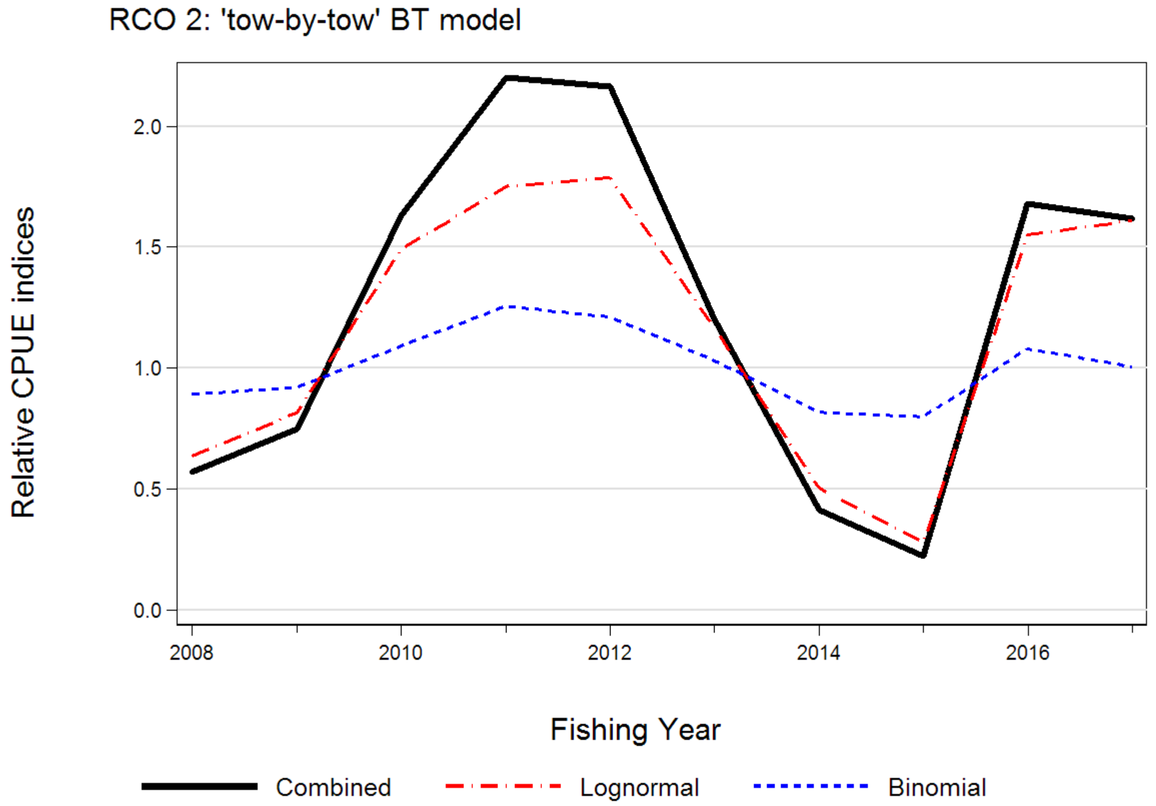

Figure H.8: Three relative CPUE indices for red cod based on the RCO 2 "tow-by-tow" BT fishery definition: a) the lognormal non-zero model, b) the binomial standardised model using the logistic distribution and a regression based on presence/absence of red cod, and c) the combined model using the delta-lognormal procedure (Eq. F.4).

H.4 CPUE indices

Table H.4: Arithmetic indices for the total and core data sets, geometric, lognormal (including standard error [SE]), binomial and combined indices for the core data set by fishing year for the RCO 2 "*tow-by-tow*" BT standardised model. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
2008	0.491	0.516	0.636	0.637	0.0267	0.443	0.569
2009	0.620	0.637	0.792	0.816	0.0255	0.457	0.750
2010	1.211	1.194	1.468	1.491	0.0226	0.543	1.629
2011	1.713	1.750	1.813	1.751	0.0205	0.624	2.200
2012	2.263	2.271	1.798	1.787	0.0211	0.602	2.164
2013	1.162	1.229	1.151	1.167	0.0236	0.513	1.204
2014	0.421	0.440	0.511	0.503	0.0262	0.406	0.412
2015	0.385	0.375	0.285	0.281	0.0281	0.397	0.224
2016	2.026	1.725	1.570	1.552	0.0255	0.537	1.678
2017	1.832	1.833	1.575	1.610	0.0279	0.500	1.619

Appendix I. DIAGNOSTICS AND SUPPORTING ANALYSES FOR RCO 3 “*EXTENDED2*” BOTTOM TRAWL CPUE

I.1 Model definition and preliminary analyses

The RCO 3 “*extended2*” bottom trawl CPUE analysis was accepted for driving the RCO 3 MP by the Southern Inshore Fishery Assessment Working Group in 2018 (Fisheries New Zealand 2018).

I.1.1 Fishery definition

RCO 3: The fishery is defined from bottom trawl daily fishing events which fished in Statistical Areas 020, 022, 024, or 026, declaring target species RCO, FLA, GUR, TAR, BAR, SQU, STA (Table F.1). Positive catch were those records which recorded an estimated catch of RCO while zero catch records were events which did not catch RCO. Daily events with more that 6 tows or 20 hours of accumulated effort were excluded from the analysis.

I.1.2 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of RCO catch. These criteria resulted in a core fleet size of 140 vessels which took 86% of the catch (Figure I.1).

I.1.3 Data summary

Table I.1: Summaries by fishing year for core vessels, trips, daily effort strata, events (number records in the original data), events per daily-effort stratum, tows, hours fished, landed RCO 3 (t), and percentage of trips with catch for the RCO 3 “*extended2*” BT core vessel data set. Final two columns apply to trips that declared no estimated catch but reported RCO landings, giving the proportion of these trips relative to trips that reported RCO and the proportion of the reported catch from these trips relative to the total annual RCO reported catch.

Fishing year	Vessels	Trips	Daily effort strata	Events	Events per stratum	Sum (tows)	Sum (hours)	Catch (t)	% trips with catch	% trips: 0 estimated catch	% catch: 0 estimated catch trips
1990	73	4 473	5 726	6 515	1.14	15 798	44 260	2 770	66.9	10.2	3.8
1991	73	4 333	5 766	6 594	1.14	15 594	48 655	2 236	62.9	18.5	0.9
1992	83	4 833	6 624	7 886	1.19	18 510	58 855	3 389	66.1	17.4	0.6
1993	87	5 956	8 089	9 619	1.19	22 647	69 350	4 376	66.1	15.9	0.6
1994	94	6 511	8 447	9 842	1.17	23 280	67 461	5 715	71.7	17.2	1.0
1995	88	6 664	8 397	9 570	1.14	22 286	64 974	9 515	76.6	10.9	0.4
1996	89	5 992	7 559	9 438	1.25	21 690	62 809	7 610	77.4	11.4	0.4
1997	92	6 397	8 227	9 904	1.20	24 797	68 622	7 363	80.1	13.9	0.8
1998	85	6 410	8 371	10 280	1.23	25 467	69 993	6 568	75.2	15.3	0.7
1999	79	5 951	7 895	9 257	1.17	23 364	64 879	10 658	79.6	12.7	0.8
2000	76	5 115	7 029	8 274	1.18	20 588	58 196	3 149	79.1	17.3	1.0
2001	80	4 424	6 713	7 622	1.14	20 695	60 804	1 332	69.1	23.8	2.9
2002	73	3 916	5 913	7 067	1.20	18 332	49 940	1 535	69.3	21.7	1.8
2003	70	4 329	6 795	7 886	1.16	21 607	60 566	3 062	72.8	21.9	1.0
2004	75	4 391	6 544	7 395	1.13	19 333	54 495	5 249	75.2	16.6	0.4
2005	72	4 623	6 904	7 620	1.10	19 916	58 779	2 563	74.8	20.0	1.0
2006	67	3 769	5 743	6 398	1.11	16 742	51 002	1 841	75.2	19.0	1.3
2007	63	3 005	4 697	5 254	1.12	14 266	44 202	963	74.2	27.6	2.8
2008	61	2 577	4 031	10 624	2.64	10 987	33 806	1 583	69.5	25.2	1.0
2009	57	2 862	4 418	11 254	2.55	11 650	38 439	1 484	79.6	25.1	1.6
2010	57	2 871	4 596	12 068	2.63	12 229	40 272	1 765	80.7	22.6	1.4
2011	56	2 645	4 217	11 105	2.63	11 161	37 457	1 638	79.8	22.6	1.2
2012	56	2 827	4 457	11 663	2.62	11 791	37 653	3 222	73.1	25.1	0.4
2013	57	3 140	4 877	12 691	2.60	12 800	41 847	3 191	80.7	27.1	0.7
2014	54	3 055	4 847	12 626	2.60	12 679	44 653	2 367	87.7	17.9	0.7
2015	48	2 249	3 634	9 386	2.58	9 451	33 953	955	83.2	27.3	2.5
2016	47	2 543	3 953	9 929	2.51	10 117	34 656	2 038	69.4	42.0	1.2
2017	43	2 372	3 659	9 123	2.49	9 236	31 601	2 398	82.8	26.6	0.7

I.1.4 Core vessel plots

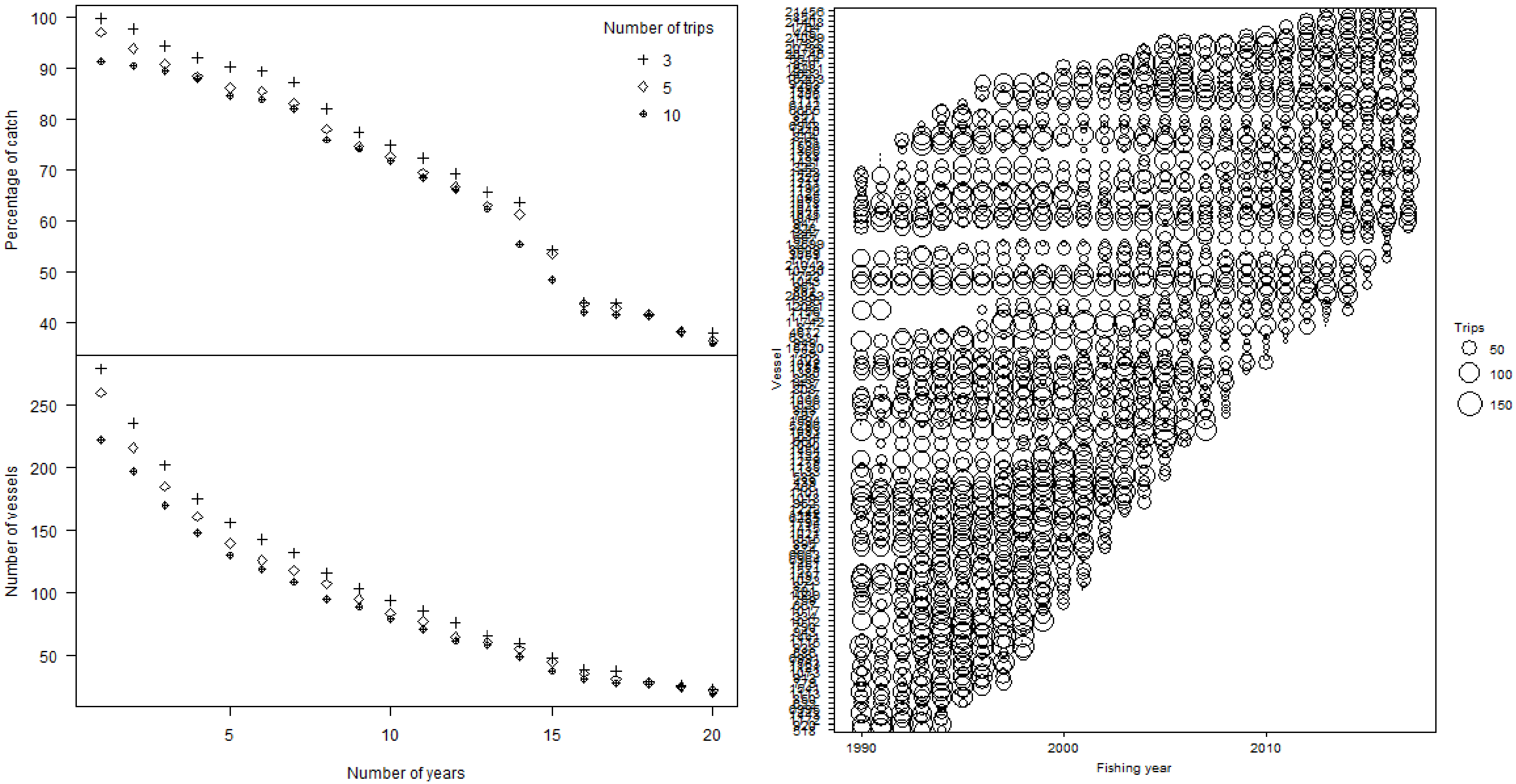

Figure I.1: [left panel] total landed RCO and number of vessels plotted against the number of years used to define core vessels participating in the RCO 3 "*extended2*" BT dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

I.1.5 Exploratory data plots for core vessel data set

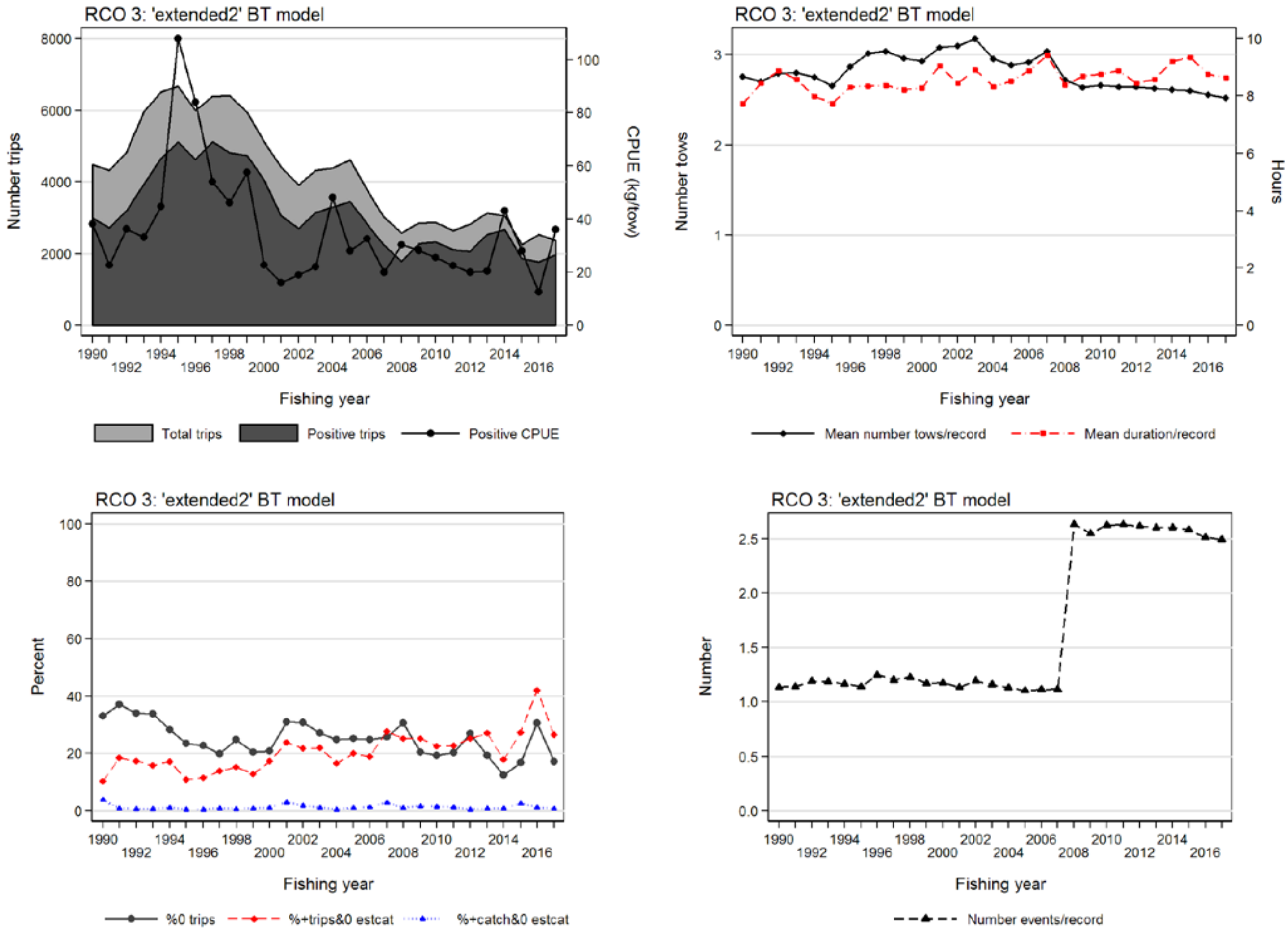

Figure I.2: Core vessel summary plots by fishing year for the RCO 3"*extended2*" BT data set: [upper left panel]: total trips (light grey) and trips with red cod catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of tows and mean duration per daily-effort stratum record; [lower left panel]: a) percentage of trips with no catch of red cod, b) percentage of trips with no estimated catch but with landed catch, c) percentage of catch with no estimated catch relative to total landed catch; [lower right panel]: mean number of events per daily-effort stratum record.

I.2 Positive catch model

Four explanatory variables entered the model after fishing year (vessel, month, target species and number tows; Table I.2). The variables area and hours fishing were not accepted. A plot of the model is provided in Figure I.3 and the CPUE indices are listed in Table I.4.

Table I.2: Order of acceptance of variables into the lognormal model of the RCO 3 "*extended2*" BT data set, 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.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	29	-796 174	1 592 406	4.0	*
vessel	168	-774 767	1 549 870	33.7	*
month	179	-767 652	1 535 661	41.3	*
target species	185	-762 088	1 524 547	46.7	*
poly(log(tows), 3)	188	-760 546	1 521 468	**48.1**	*
area	191	-760 415	1 521 211	48.2	
poly(log(duration), 3)	194	-760 367	1 521 122	48.2	

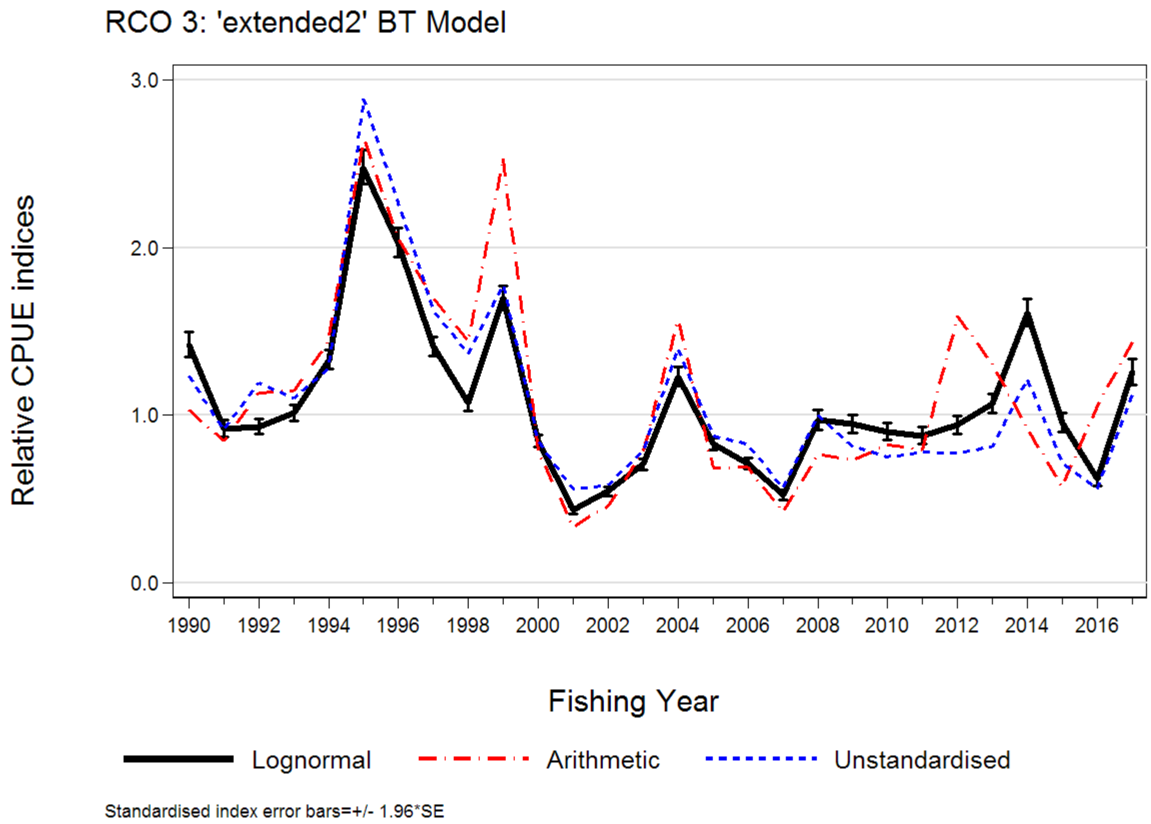

Figure I.3: Relative CPUE indices for RCO using the lognormal non-zero model based on the RCO 3 "*extended2*" BT fishery definition. Also shown are two unstandardised series from the same data: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

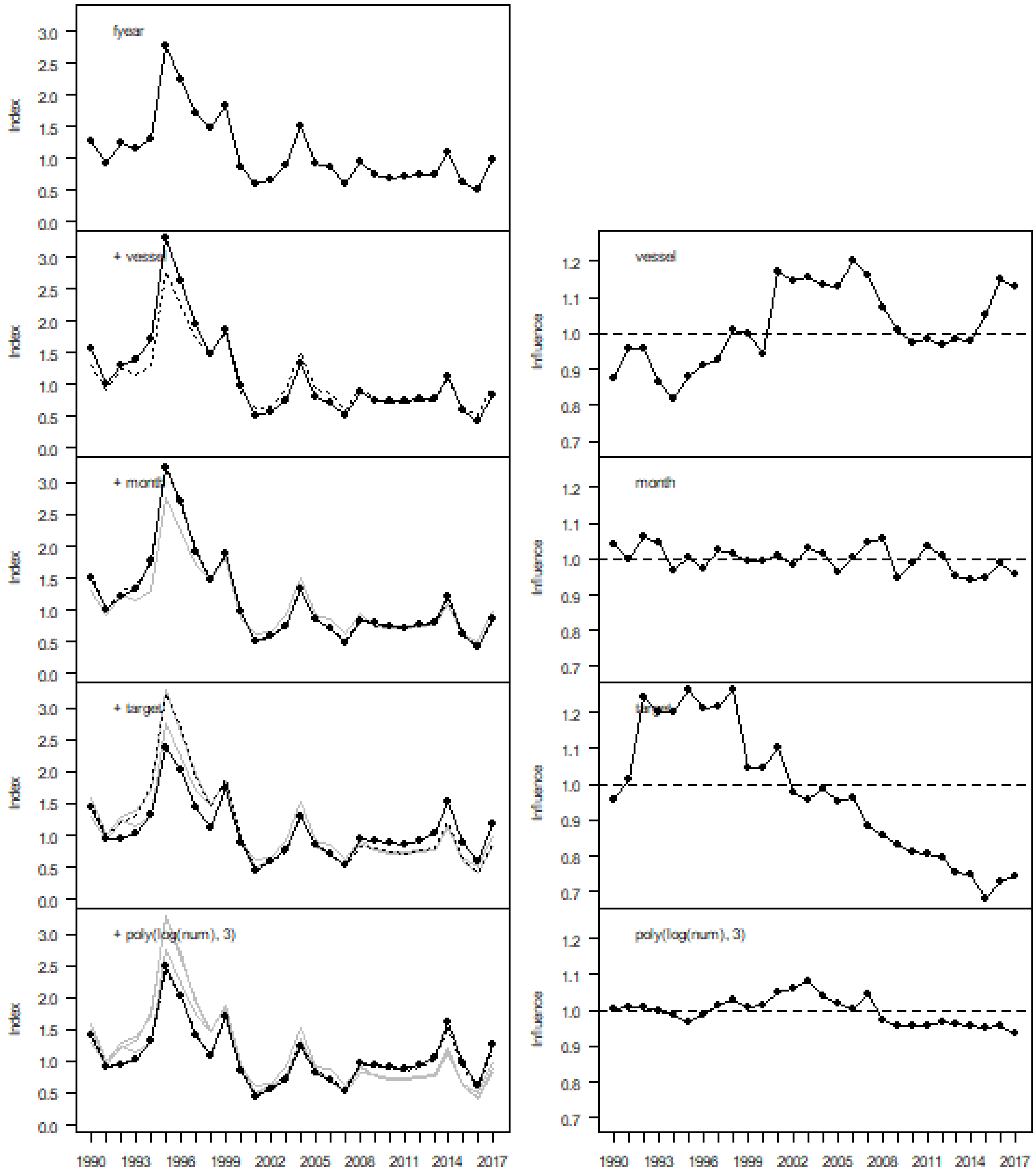

Figure I.4: [left column]: annual indices from the lognormal RCO 3 "*extended2*" BT model at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

I.2.1 Residual and diagnostic plots

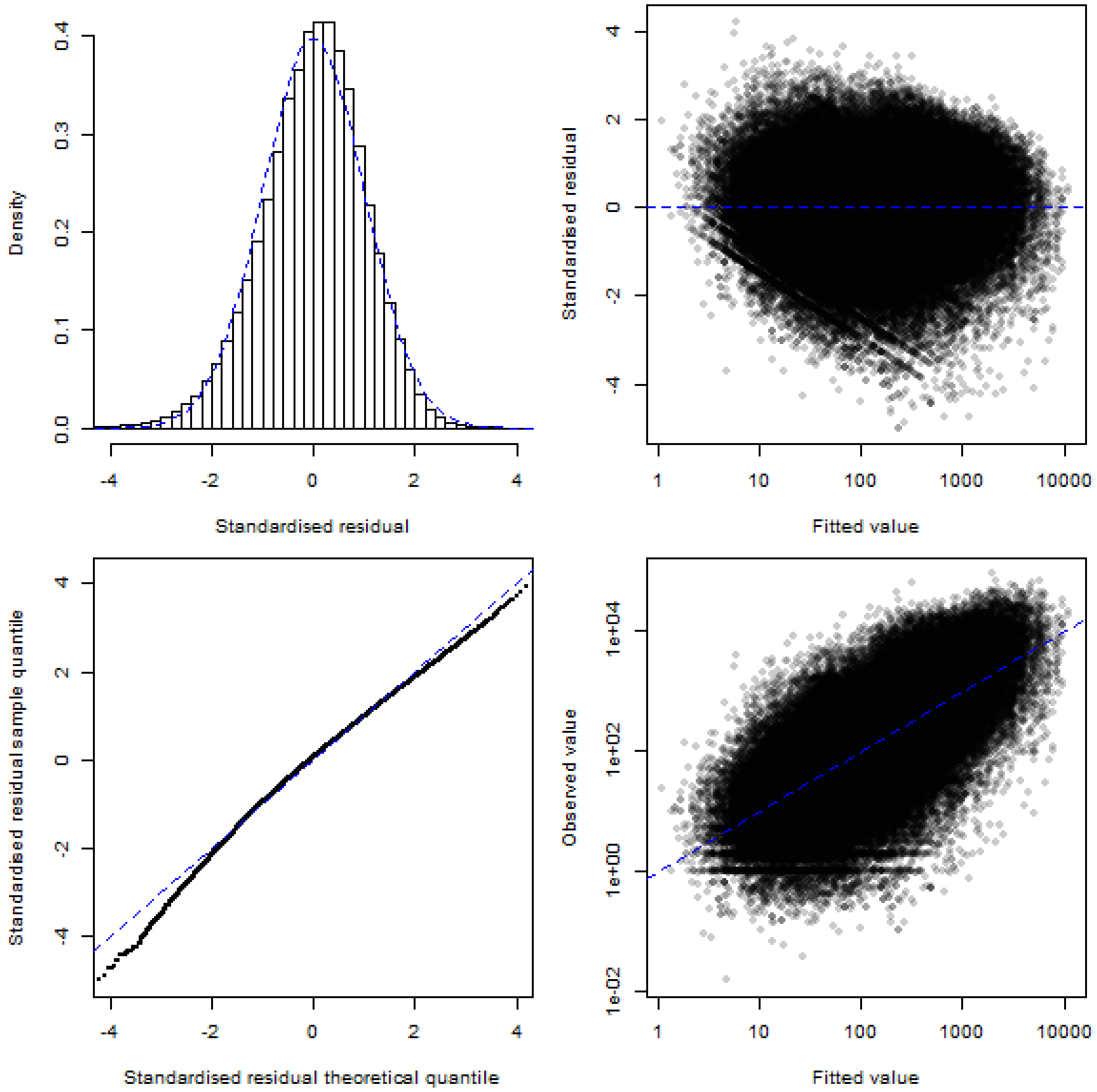

Figure I.5: Plots of the fit of the lognormal standardised CPUE model of successful catches in the RCO 3 "*extended2*" BT fishery model. [Upper left] histogram of the standardised residuals compared to a lognormal distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

I.2.2 Model coefficient plots

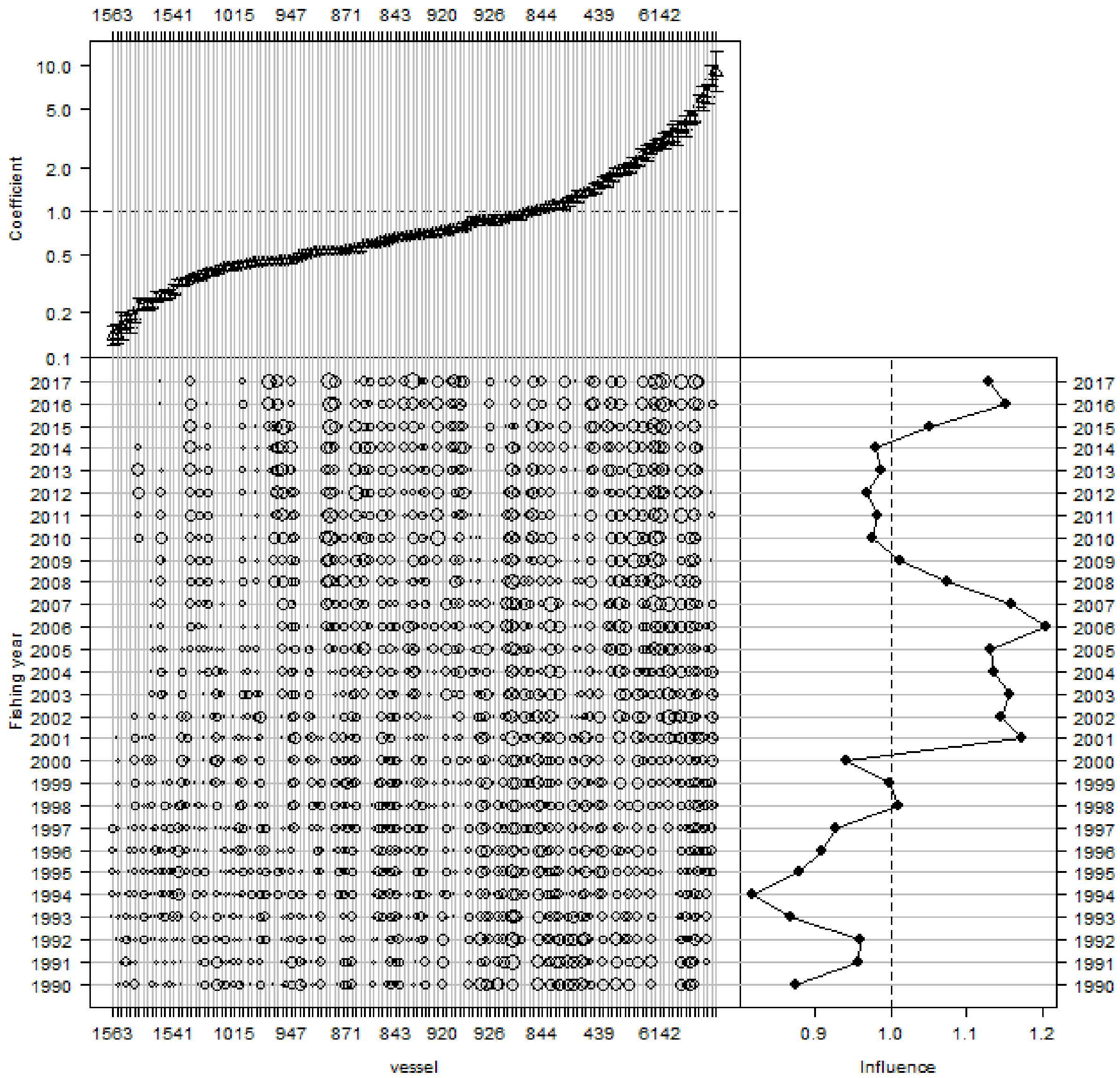

Figure I.6: Effect of vessel in the lognormal RCO 3 "*extended2*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

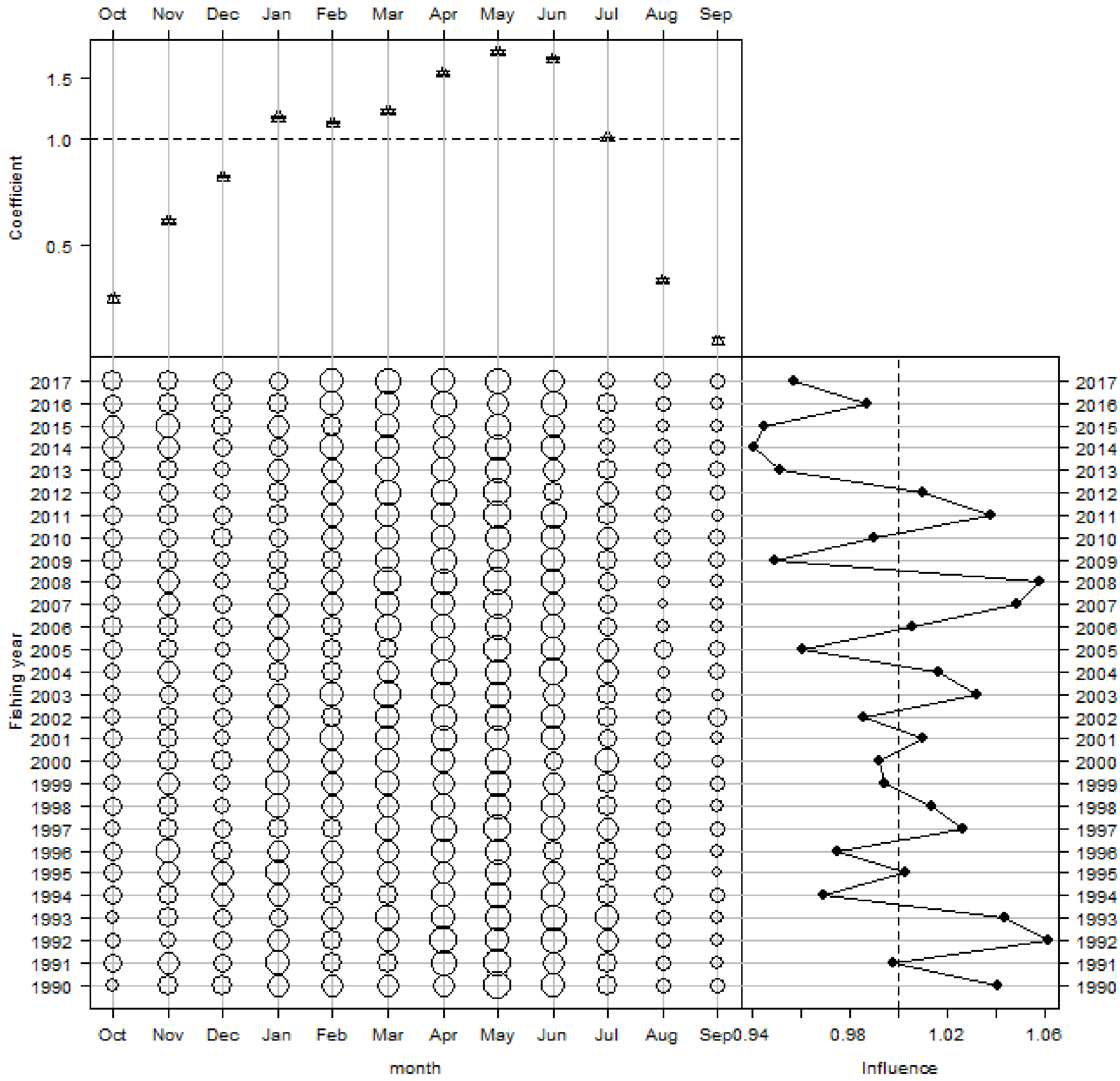

Figure I.7: Effect of month in the lognormal RCO 3 "*extended2*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

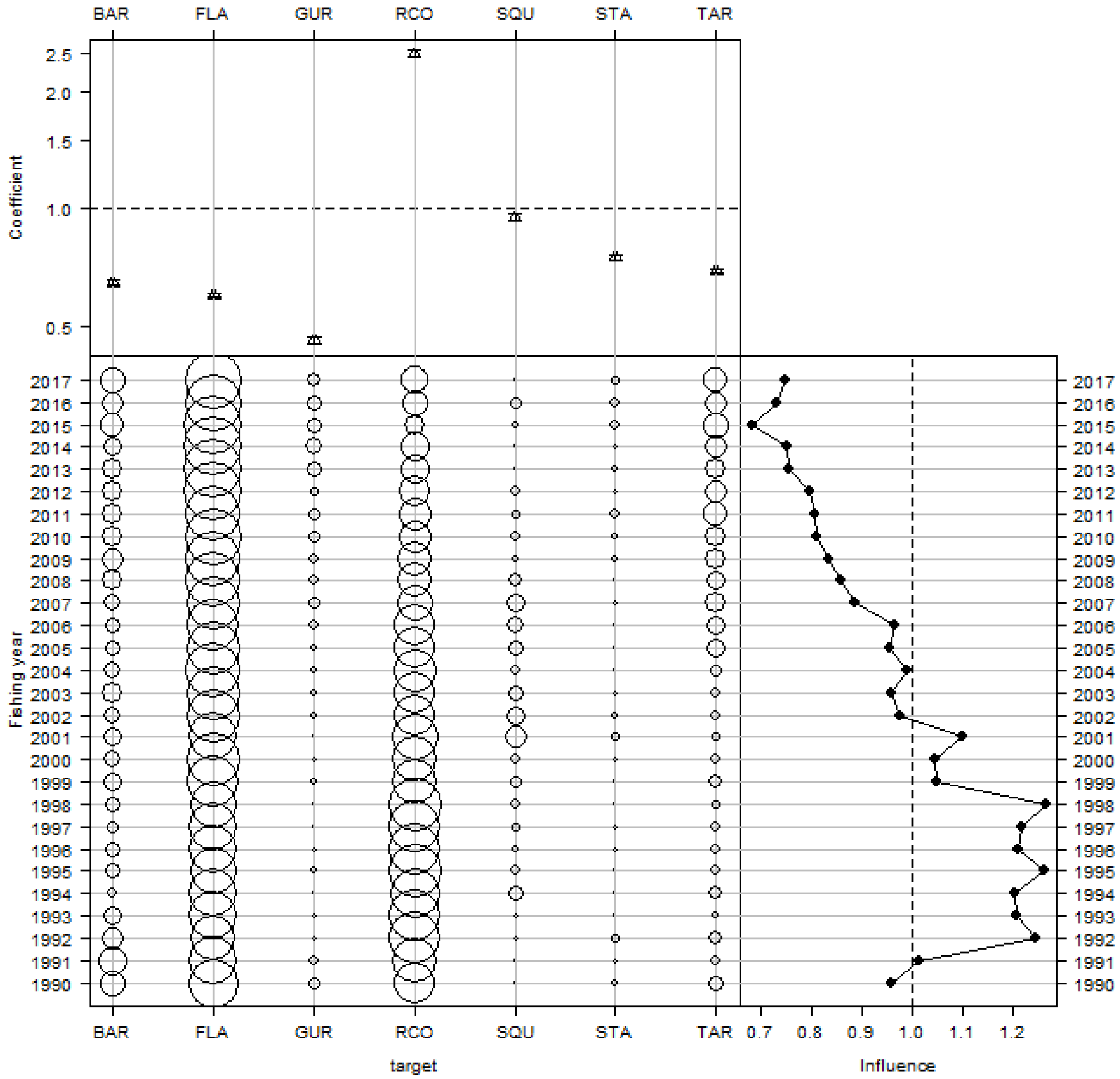

Figure I.8: Effect of target species in the lognormal RCO 3 "*extended2*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

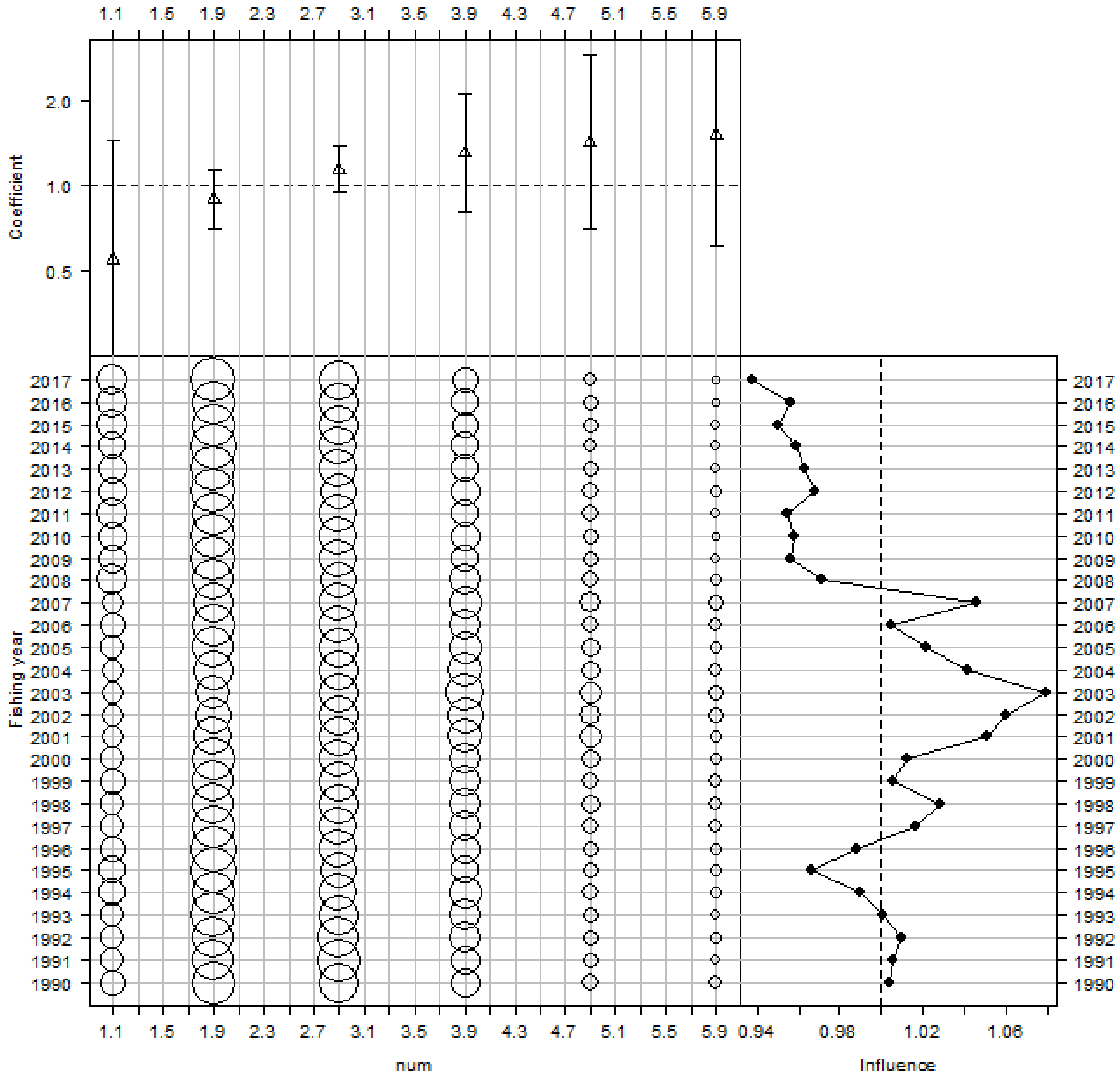

Figure I.9: Effect of log(number tows) in the lognormal RCO 3 "*extended2*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

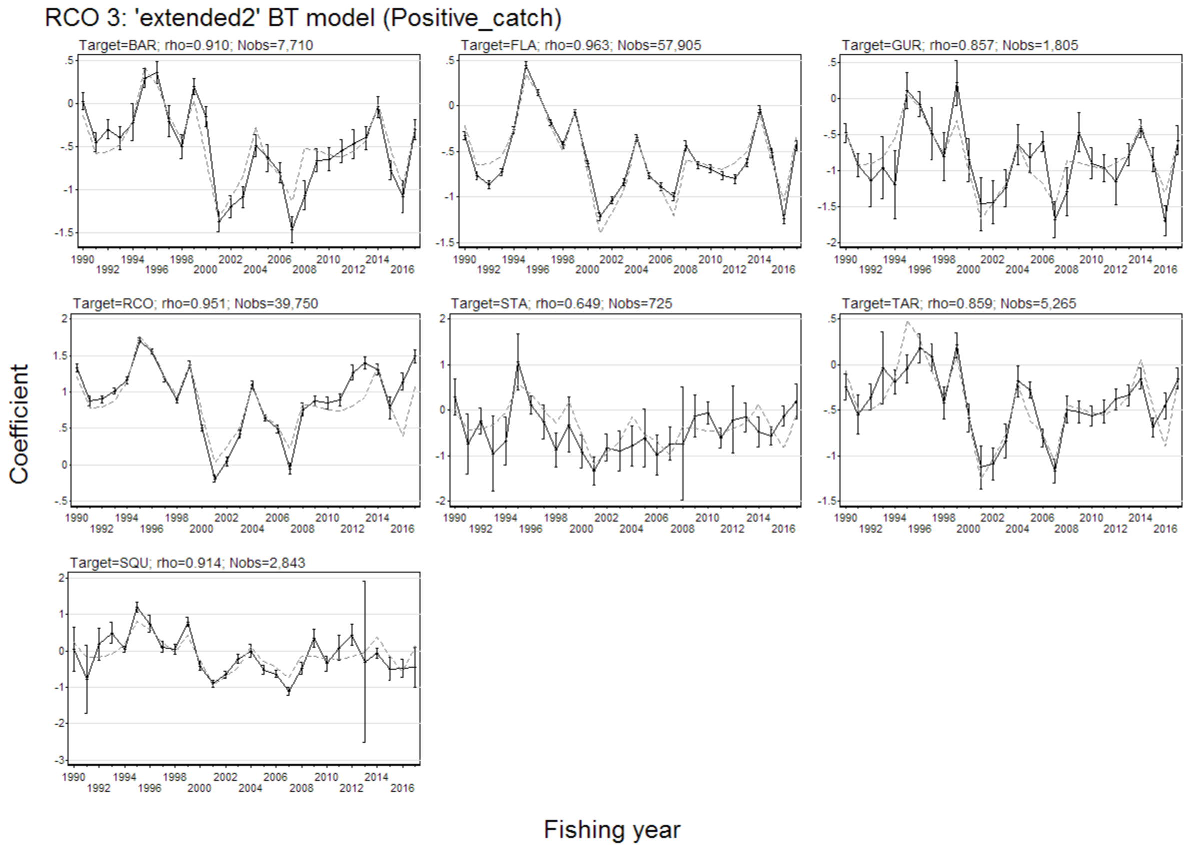

Figure I.10: Residual implied coefficients for target species × fishing year interaction (interaction term not offered to the model) in the lognormal RCO 3 "*extended2*" BT model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when a target × year interaction term is fitted, particularly for those target × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

I.3 Binomial presence/absence model

Four explanatory variables entered the model after fishing year (vessel, month, target species and hours fished). Variables area and number tows were not accepted (Table I.3). A plot of the binomial model and the combined delta-lognormal model is provided in Figure I.11 and the CPUE indices are listed in Table I.4.

Table I.3: Order of acceptance of variables into the binomial presence/absence model for the RCO 3 *"extended2"* BT data set, 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.

Variable	DF	Neg. Log likelihood	AIC	Deviance R^2	Nagelkerke R^2	Model use
fishing year	28	-97 798	195 653	1.0	1.7	*
vessel	167	-90 453	181 240	8.5	13.8	*
month	178	-86 382	173 120	12.6	20.1	*
target species	184	-84 564	169 496	14.4	22.8	*
poly(log(duration), 3)	187	-83 578	167 531	15.4	**24.2**	*
poly(log(tows), 3)	190	-83 380	167 140	15.6	24.5	
area	193	-83 242	166 870	15.8	24.7	

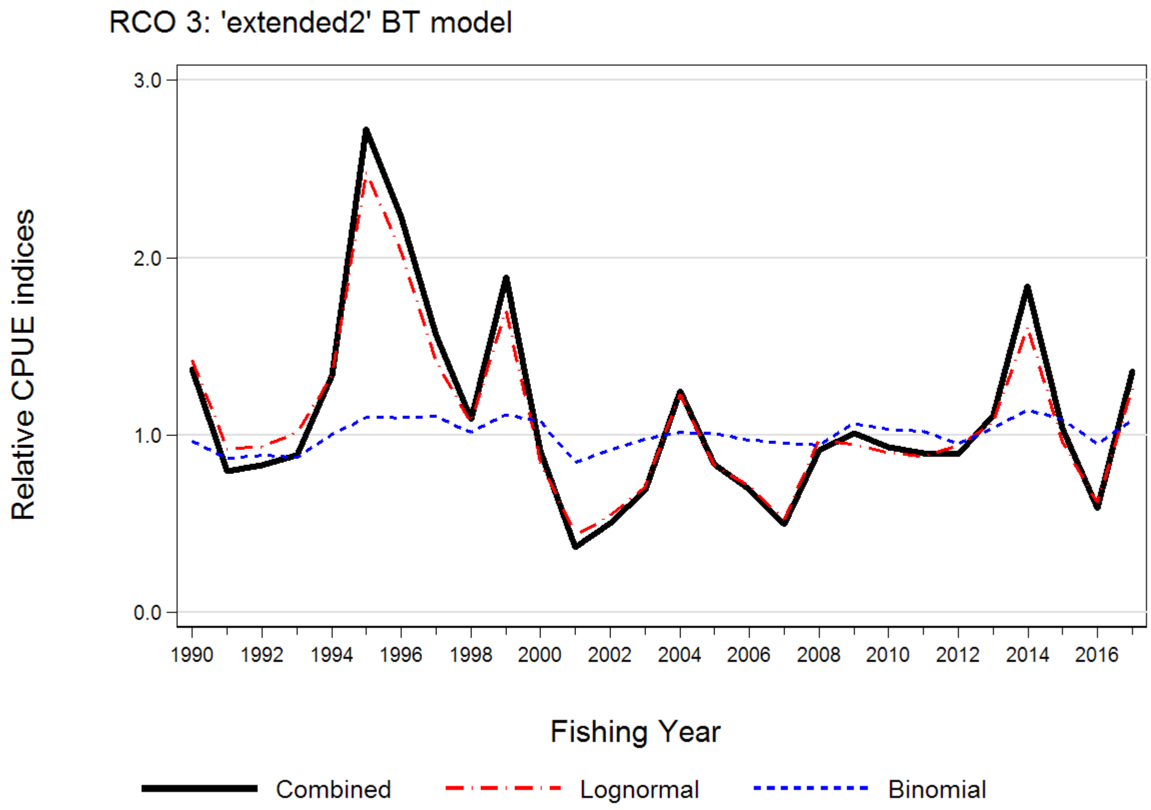

Figure I.11: Three relative CPUE indices for red cod based on the RCO 3 *"extended2"* BT fishery definition: a) the lognormal non-zero model, b) the binomial standardised model using the logistic distribution and a regression based on presence/absence of red cod, and c) the combined model using the delta-lognormal procedure (Eq. F.4).

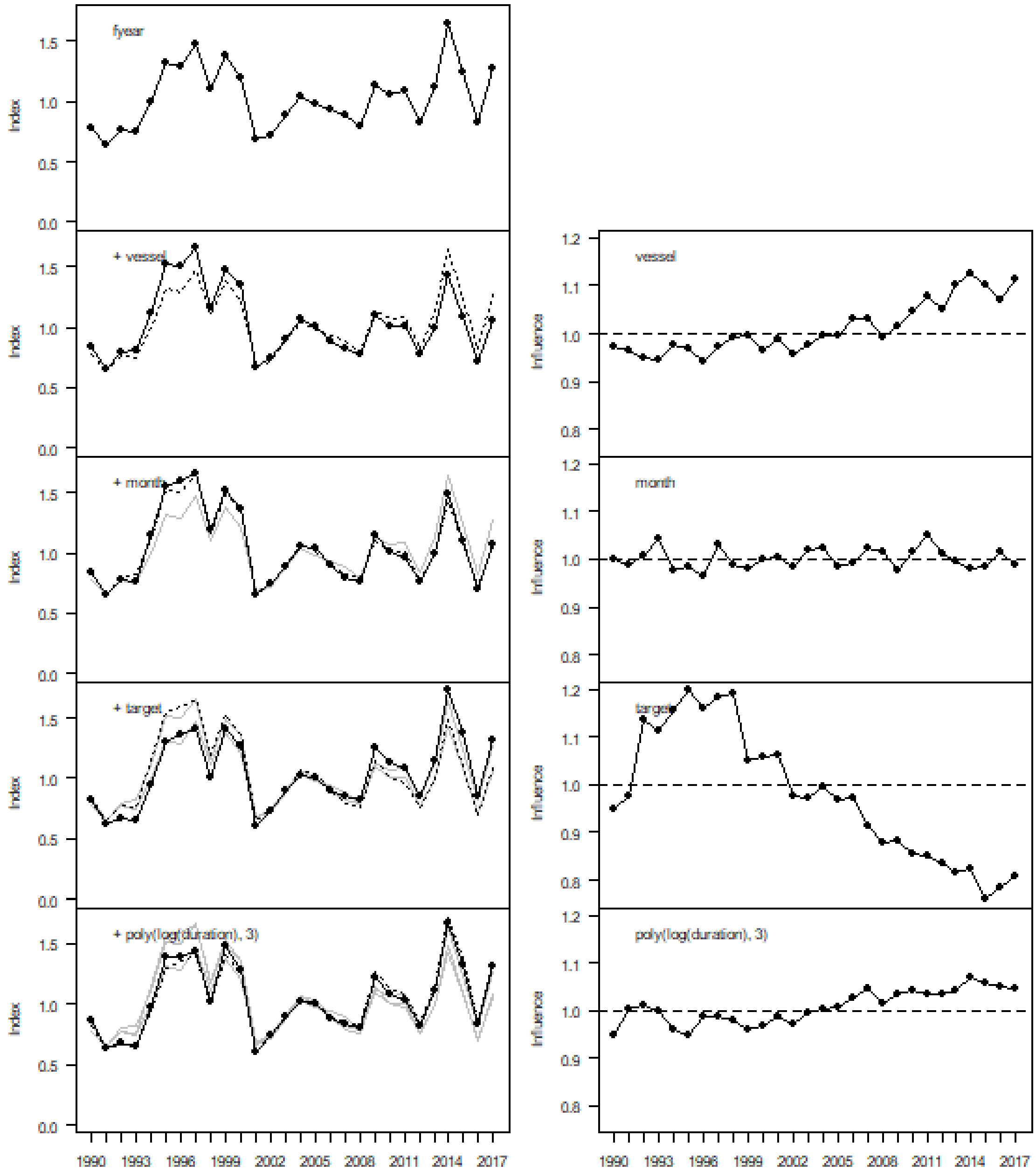

Figure I.12: [left column]: annual indices from the binomial RCO 3 "*extended2*" BT model at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

I.4 Model coefficients

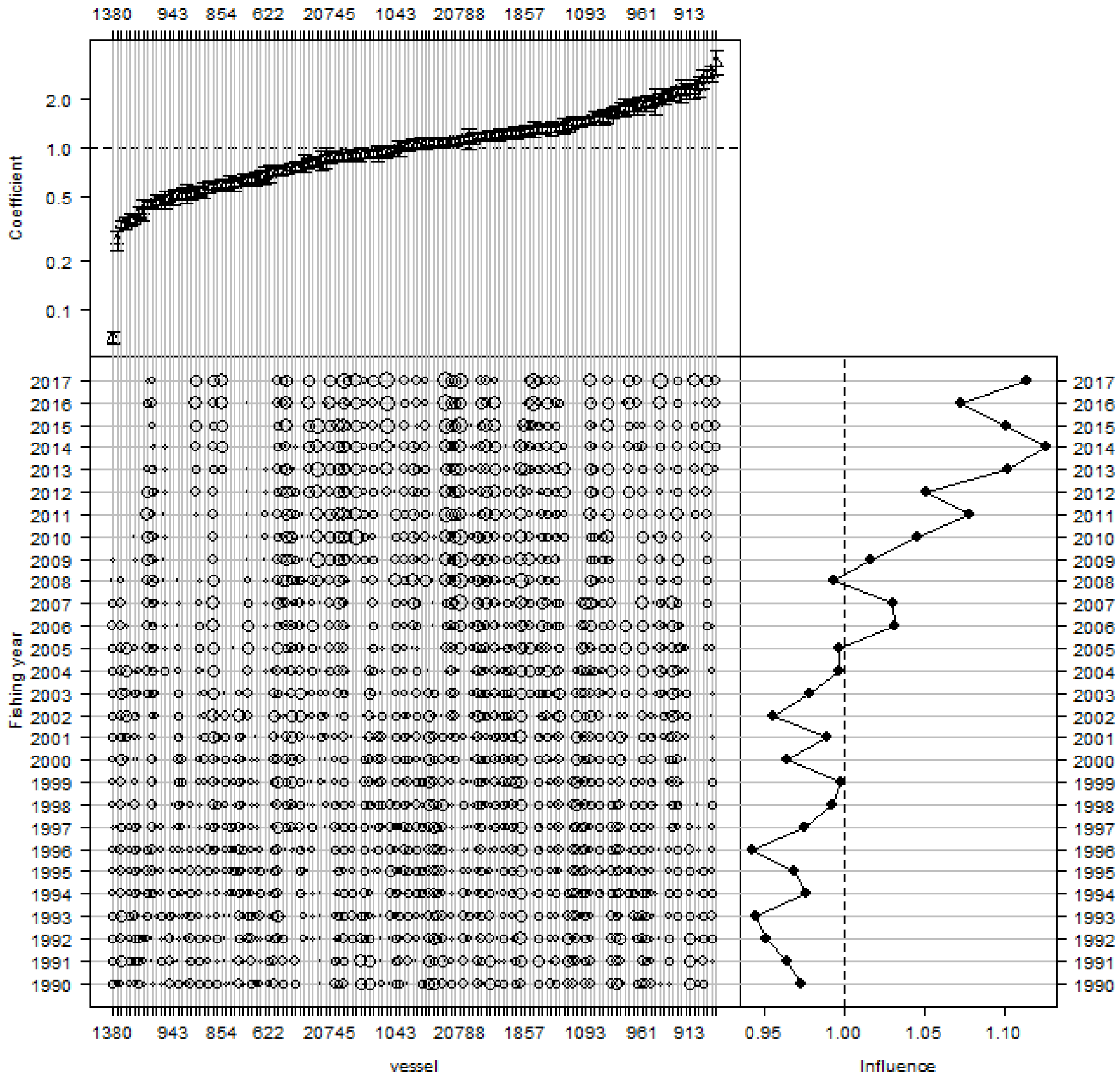

Figure I.13: Effect of vessel in the binomial RCO 3 "*extended2*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

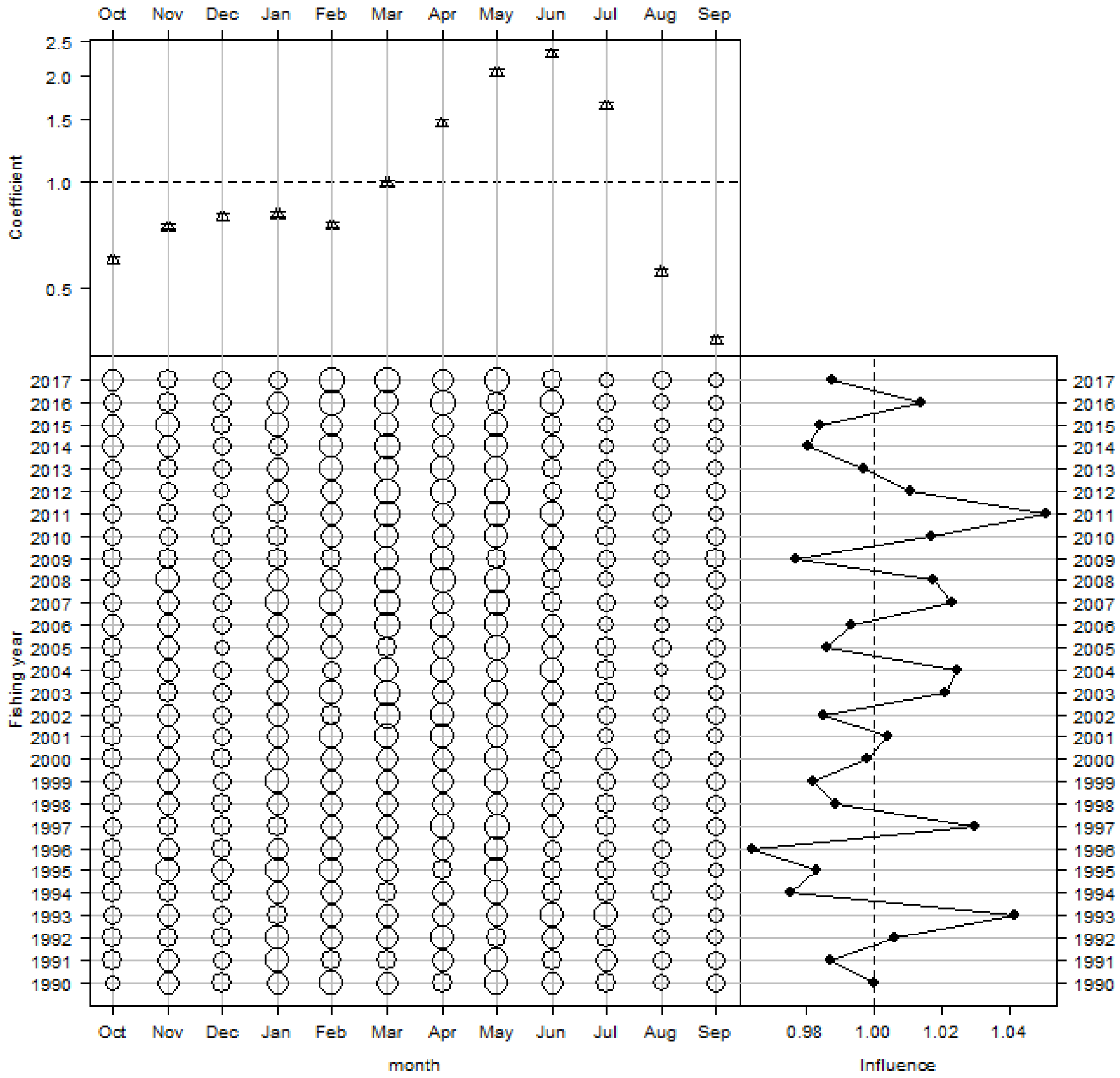

Figure I.14: Effect of month in the binomial RCO 3 "*extended2*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

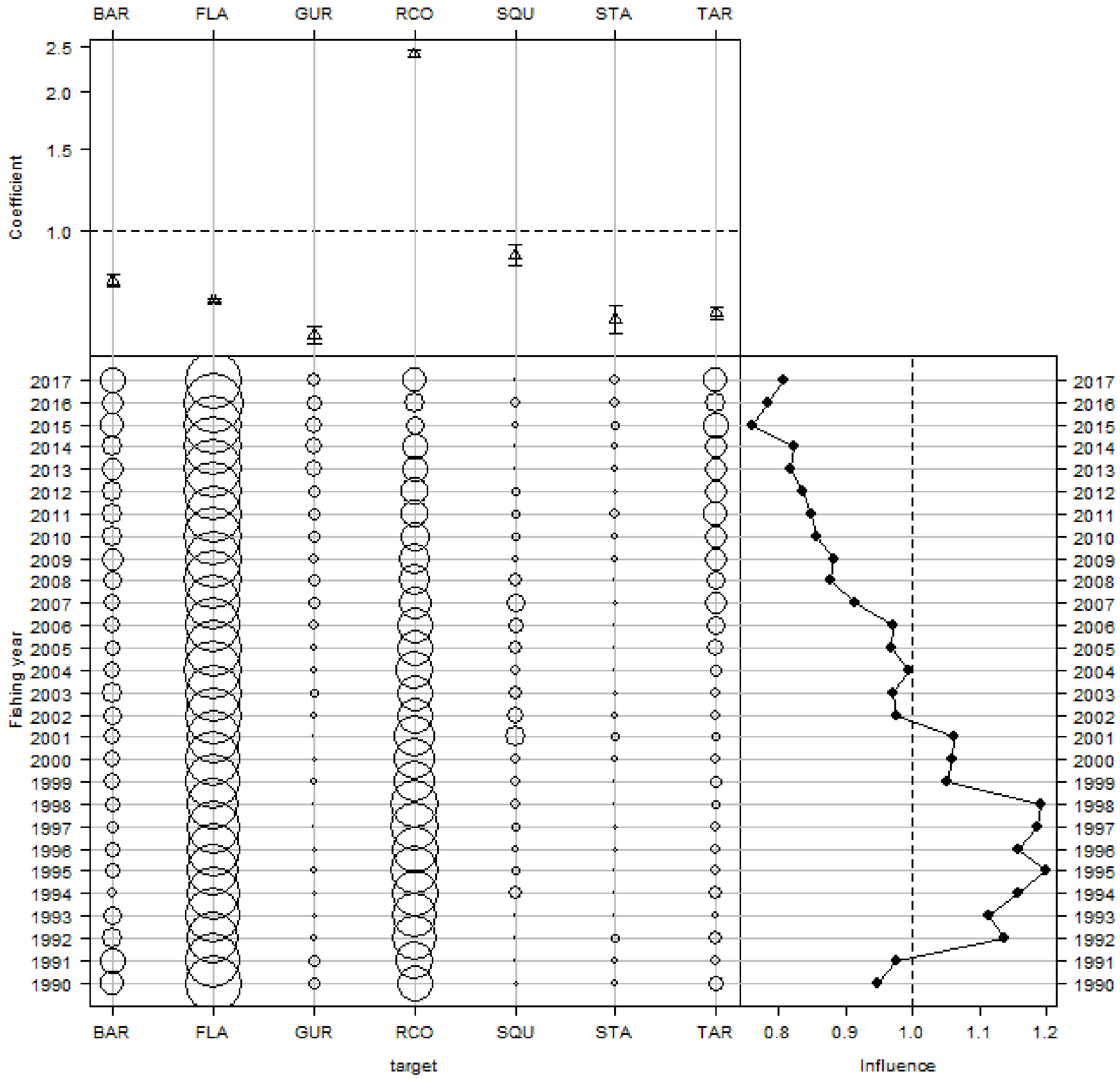

Figure I.15: Effect of target species in the binomial RCO 3 "*extended2*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

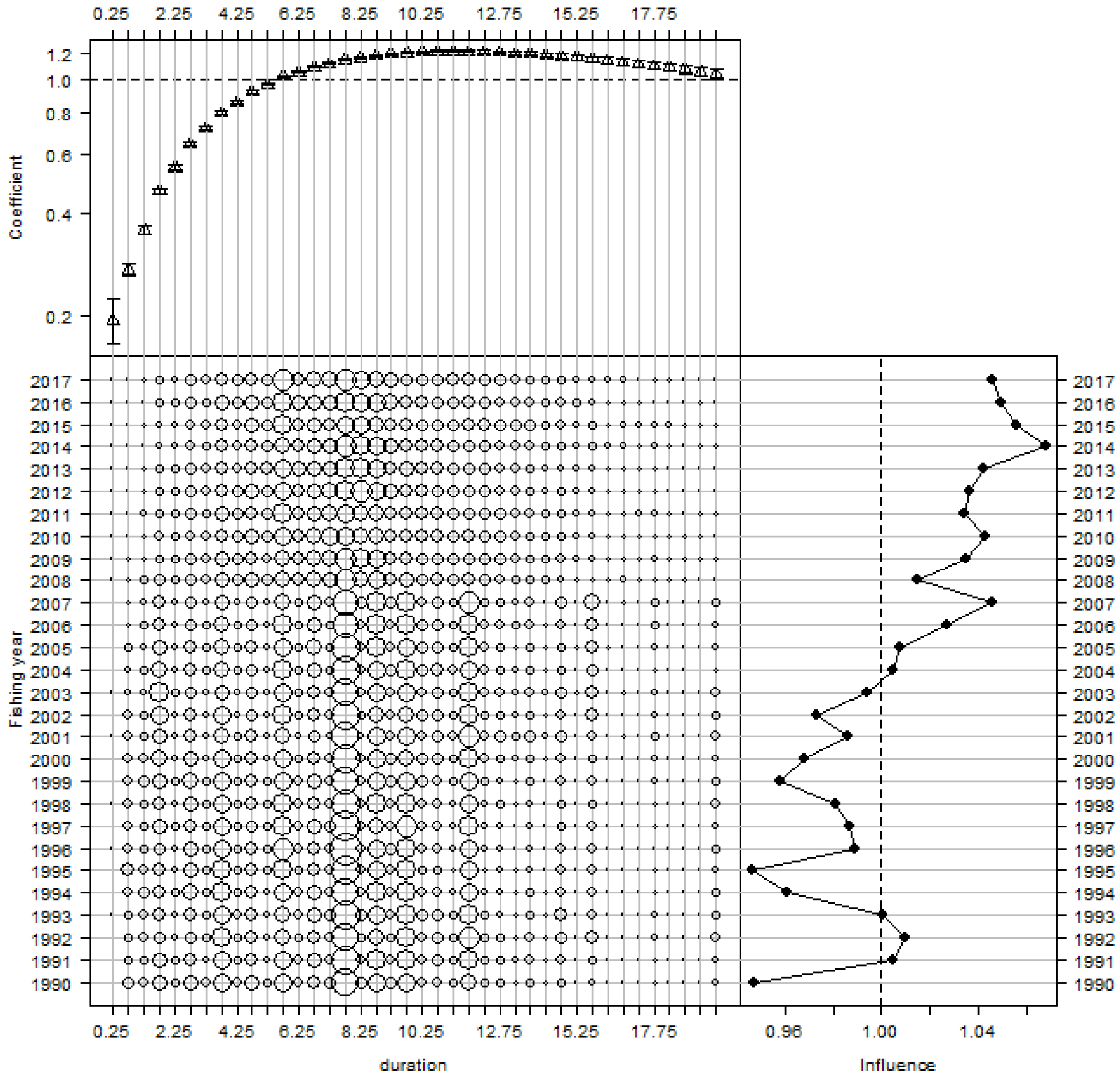

Figure I.16: Effect of log(duration) in the binomial RCO 3 "*extended2*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

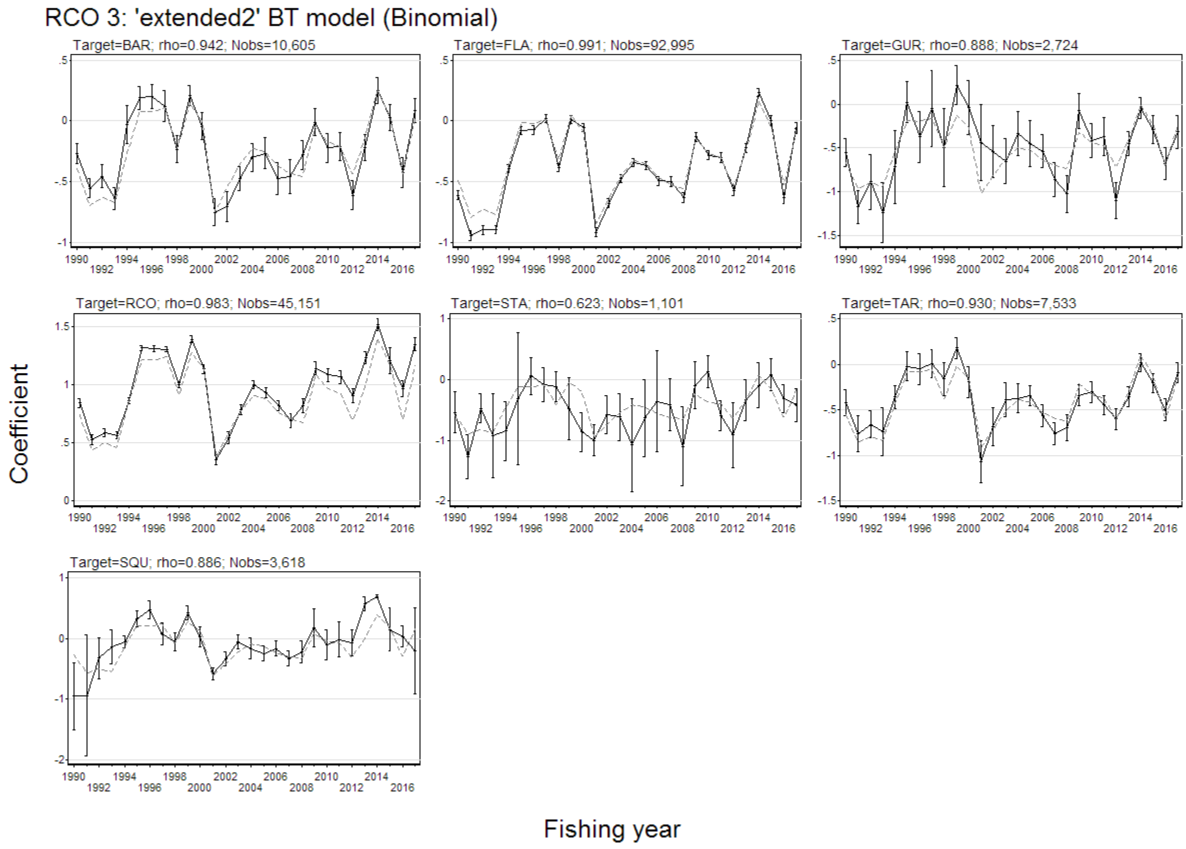

Figure I.17: Residual implied coefficients for target species × fishing year interaction (interaction term not offered to the model) in the binomial RCO 3 "*extended2*" BT model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when a target × year interaction term is fitted, particularly for those target × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

I.5 CPUE indices

Table I.4: Arithmetic indices for the total and core data sets, geometric, lognormal (including standard error [SE]), binomial and combined indices for the core data set by fishing year for the RCO 3 "*extended2*" BT model. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
1990	1.067	1.031	1.234	1.419	0.0267	0.964	1.368
1991	0.802	0.845	0.913	0.920	0.0274	0.865	0.796
1992	1.088	1.133	1.195	0.933	0.0250	0.887	0.828
1993	1.249	1.148	1.102	1.013	0.0230	0.873	0.885
1994	1.264	1.442	1.279	1.332	0.0215	1.002	1.335
1995	2.293	2.662	2.887	2.480	0.0208	1.099	2.724
1996	1.743	2.047	2.268	2.029	0.0219	1.097	2.226
1997	1.525	1.700	1.625	1.412	0.0206	1.105	1.560
1998	1.427	1.441	1.367	1.072	0.0210	1.015	1.088
1999	2.527	2.534	1.779	1.700	0.0209	1.113	1.893
2000	0.778	0.784	0.843	0.848	0.0224	1.078	0.914
2001	0.359	0.335	0.558	0.432	0.0247	0.846	0.366
2002	0.445	0.458	0.583	0.546	0.0259	0.916	0.500
2003	0.836	0.786	0.784	0.707	0.0233	0.976	0.690
2004	1.569	1.566	1.400	1.230	0.0231	1.015	1.249
2005	0.703	0.688	0.877	0.828	0.0228	1.007	0.834
2006	0.695	0.689	0.827	0.712	0.0250	0.972	0.692
2007	0.392	0.422	0.566	0.523	0.0276	0.952	0.498
2008	0.720	0.766	1.000	0.970	0.0302	0.943	0.915
2009	0.700	0.732	0.814	0.947	0.0277	1.064	1.008
2010	0.781	0.826	0.751	0.901	0.0276	1.031	0.929
2011	1.228	0.794	0.782	0.878	0.0286	1.020	0.896
2012	1.585	1.590	0.773	0.941	0.0289	0.948	0.892
2013	1.338	1.304	0.814	1.069	0.0270	1.040	1.111
2014	1.085	0.919	1.215	1.611	0.0261	1.141	1.838
2015	0.601	0.575	0.714	0.957	0.0310	1.087	1.040
2016	1.026	1.058	0.563	0.618	0.0313	0.950	0.587
2017	1.443	1.437	1.124	1.256	0.0307	1.084	1.362

Appendix J. DIAGNOSTICS AND SUPPORTING ANALYSES FOR RCO 3 "*TOW-BY-TOW*" BOTTOM TRAWL CPUE

J.1 Model definition and preliminary analyses

J.1.1 Fishery definition

RCO 3: The fishery is defined from bottom trawl tow events which fished in Statistical Areas 020, 022, 024, or 026 and declared target species RCO, FLA, GUR, TAR, BAR, SQU, STA (Table F.1). Positive catch were those records which recorded an estimated catch of RCO while zero catch records were events which did not catch RCO. Single tow events with more than 20 hours of accumulated effort were excluded from the analysis. Tows were required to have trawl headline height between 1–10 m, trawl wingspread between 5–100 m and vessel speed more than 0 km/h.

J.1.2 Core vessel selection

The criteria used to define the core fleet were those vessels that had fished for at least 5 trips in each of at least 5 years using trips with at least 1 kg of RCO catch. These criteria resulted in a core fleet size of 53 vessels which took 84% of the catch (Figure J.1).

J.1.3 Data summary

Table J.1: Summaries by fishing year for core vessels, trips, events (number of records in the original data), tows, hours fished, landed RCO 3 (t), percentage of trips with catch and percentage of tows with RCO catch for the "*tow-by-tow*" BT core vessel data set. Final two columns apply to trips that declared no estimated catch of red cod but reported RCO landings, giving the proportion of these trips relative to trips that reported RCO and the proportion of the reported catch from these trips relative to the total annual RCO reported catch.

Fishing year	Vessels	Trips	Events	Sum (tows)	Sum (hours)	Catch (t)	% trips with catch	% tows with catch	% trips: 0 estimated catch	% catch: 0 estimated catch trips
2008	41	2 141	9 099	9 099	28 598	1 376.9	72.7	55.3	9.4	0.22
2009	43	2 610	10 139	10 139	33 986	1 339.0	81.3	59.8	8.0	0.22
2010	45	2 724	11 216	11 216	37 125	1 628.9	81.8	57.3	6.4	0.17
2011	47	2 625	10 747	10 747	36 123	1 523.8	80.9	59.2	6.9	0.26
2012	50	2 804	11 398	11 398	36 609	3 222.5	73.6	53.0	8.4	0.07
2013	52	3 124	12 454	12 454	40 934	3 180.0	81.0	58.5	8.8	0.25
2014	50	3 031	12 266	12 266	43 452	2 341.0	88.1	69.9	4.9	0.12
2015	46	2 242	9 152	9 152	33 167	946.5	84.1	60.4	8.3	0.41
2016	41	2 463	9 174	9 174	31 945	1 803.0	68.9	52.5	18.7	0.33
2017	39	2 358	8 703	8 703	29 971	2 364.9	82.5	62.5	9.7	0.18

J.1.4 Core vessel plots

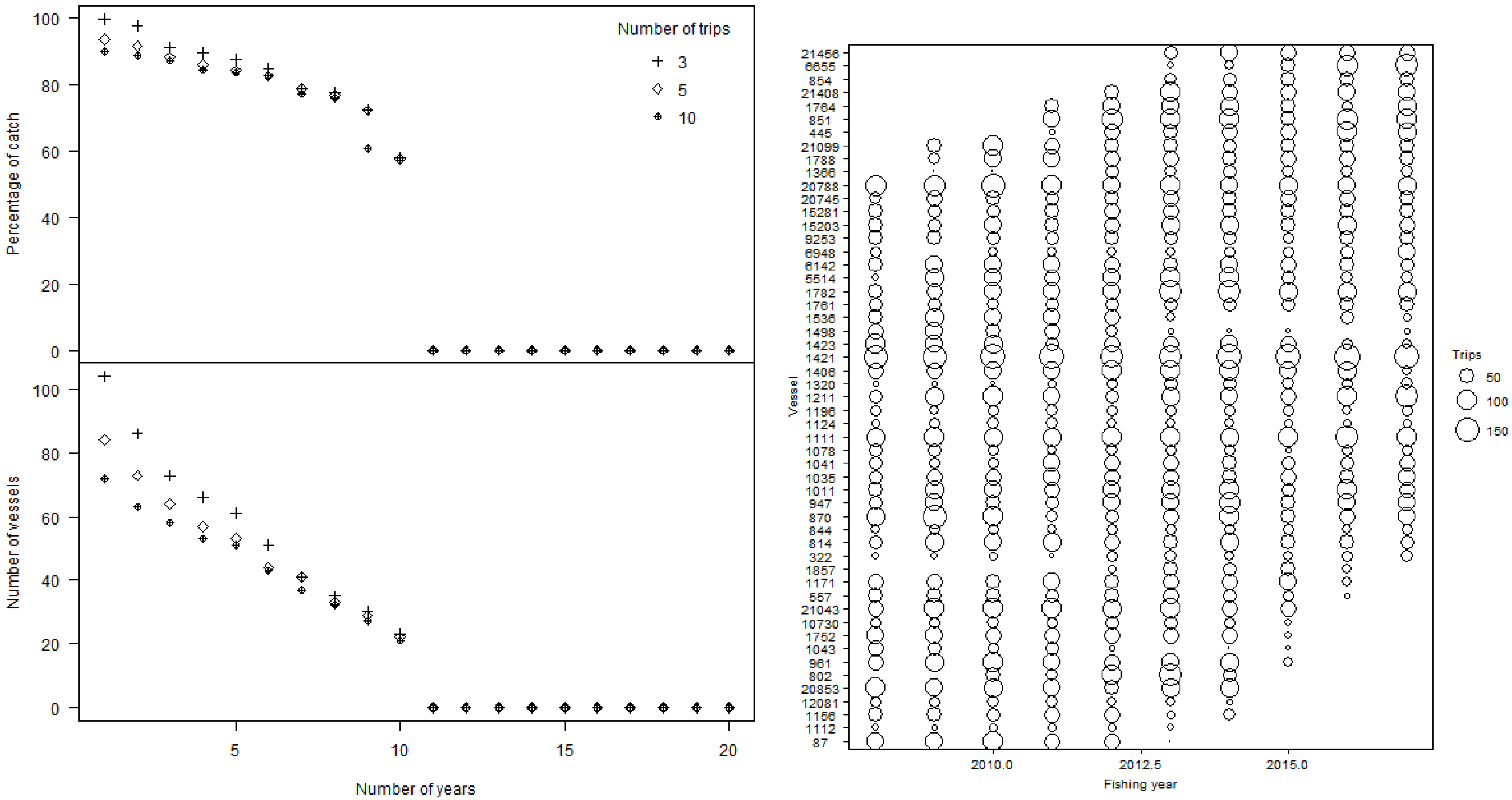

Figure J.1: [left panel] total landed RCO and number of vessels plotted against the number of years used to define core vessels participating in the RCO 3 "*tow-by-tow*" positive catch dataset. The number of qualifying years (minimum number of trips per year) for each series is indicated in the legend. [right panel]: bubble plot showing the number of daily-effort strata for selected core vessels (based on at least 5 trips in 5 or more fishing years) by fishing year.

J.1.5 Exploratory data plots for core vessel data set

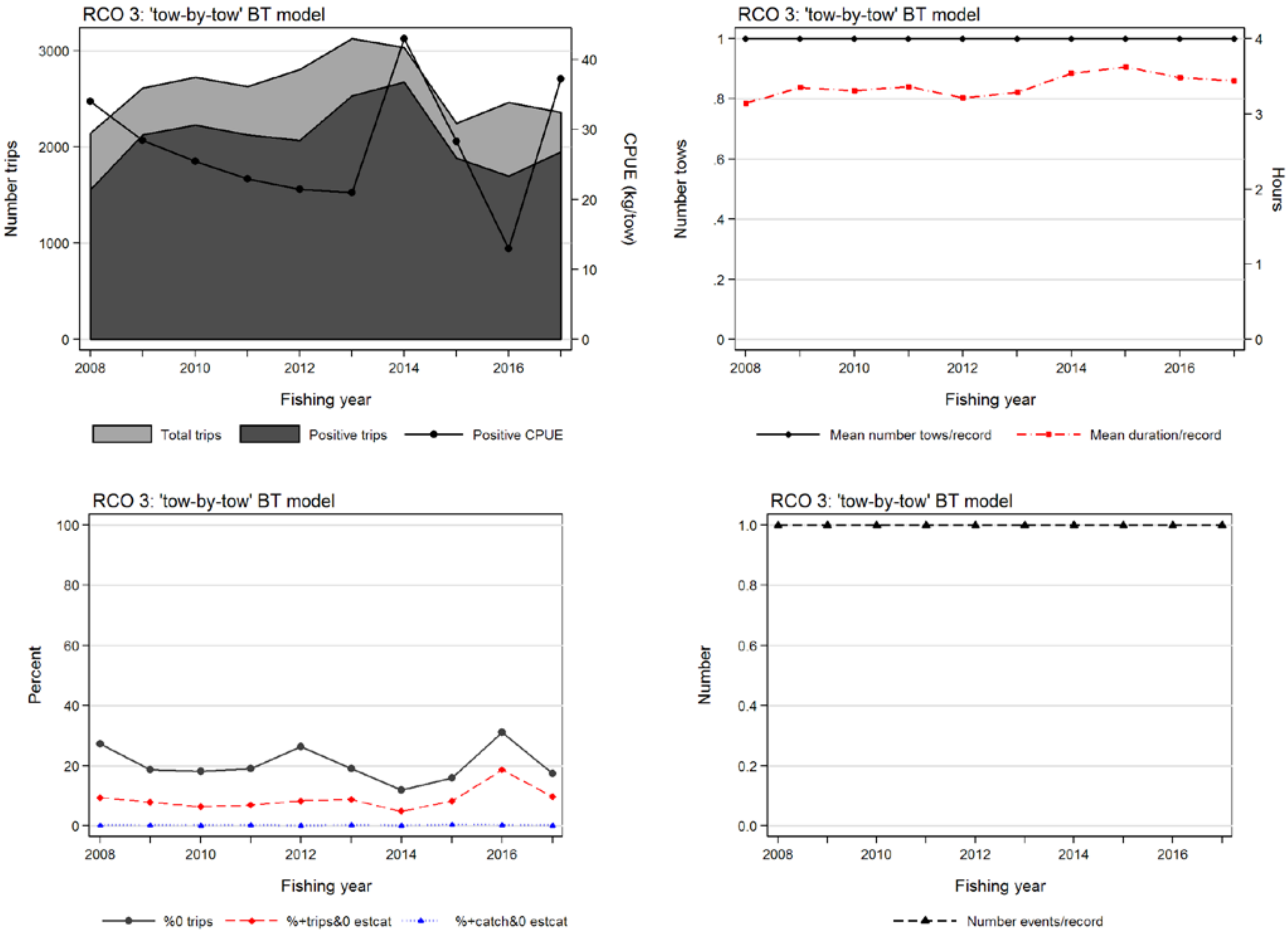

Figure J.2: Core vessel summary plots by fishing year for the RCO 3 "*tow-by-tow*" BT data set: [upper left panel]: total trips (light grey) and trips with red cod catch (dark grey) overlaid with median annual arithmetic CPUE (kg/tow) for all trips *i* with positive catch: $A_y = \text{median}\left(C_{y,i}/E_{y,i}\right)$; [upper right panel]: mean number of tows and mean duration per daily-effort stratum record; [lower left panel]: a) percentage of trips with no catch of red cod, b) percentage of trips with no estimated catch but with landed catch, c) percentage of catch with no estimated catch relative to total landed catch; [lower right panel]: mean number of events per daily-effort stratum record.

J.2 Positive catch model

Four explanatory variables entered the model after fishing year (target species, month, bottom depth and vessel speed; Table J.2). The variables area, headline height and wingspread were not accepted. The variable hours fished was discarded. A plot of the model is provided in Figure J.3 and the CPUE indices are listed in Table J.4.

Table J.2: Order of acceptance of variables into the lognormal RCO 3 "*tow-by-tow*" BT model, 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.

Variable	DF	Neg. Log likelihood	AIC	R^2	Model use
fishing year	11	-333 673	667 368	0.98	*
target species	17	-323 024	646 082	32.29	*
month	28	-321 406	642 867	36.09	*
bottom depth	29	-320 023	640 104	39.16	*
vessel speed	30	-319 356	638 772	**40.59**	*
area	33	-319 072	638 209	41.19	
headline height	34	-319 010	638 089	41.32	
wingspread	35	-318 972	638 015	41.40	
poly(log(duration), 3)	–				

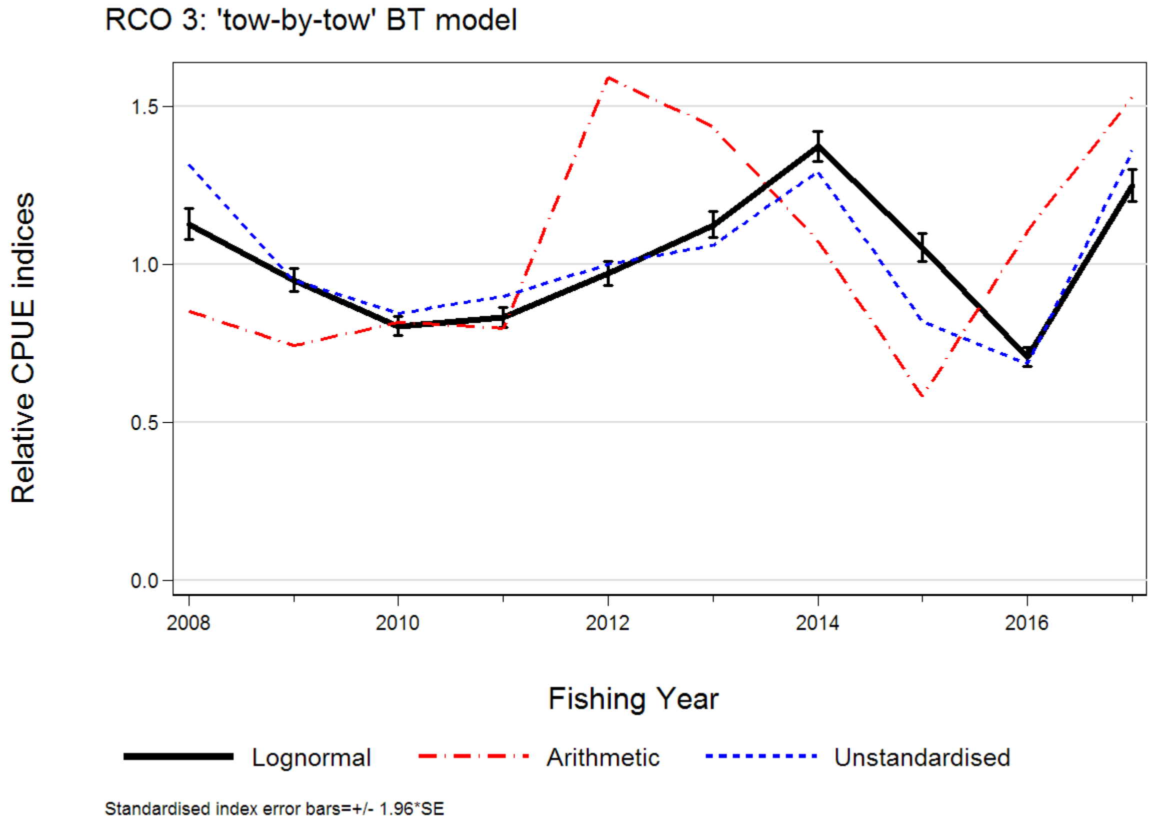

Figure J.3: Relative CPUE indices for RCO using the lognormal non-zero model based on the RCO 3 "*tow-by-tow*" BT fishery definition. Also shown are two unstandardised series from the same data set: a) Arithmetic (Eq. F.1) and b) Unstandardised (Eq. F.2).

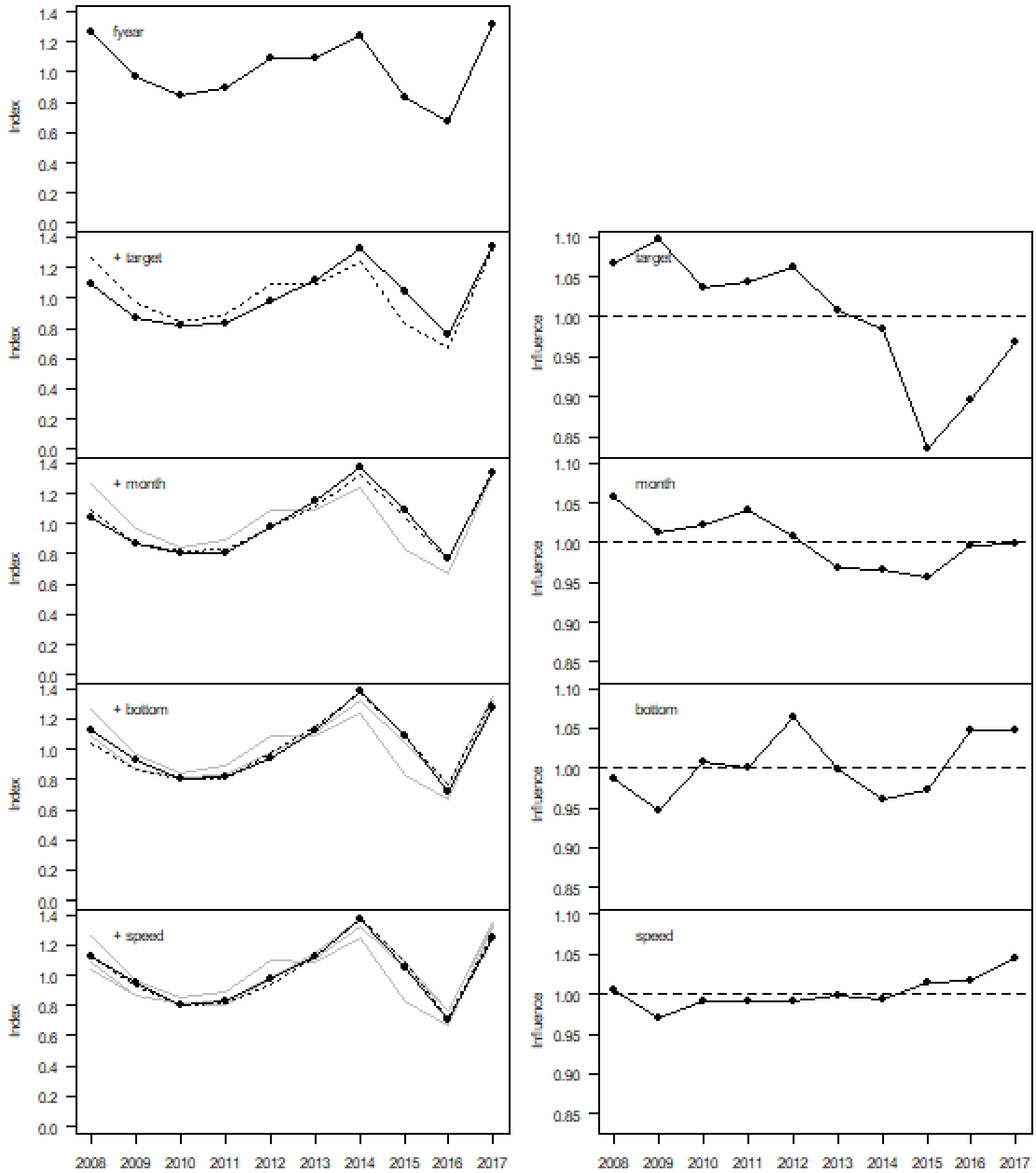

Figure J.4: [left column]: annual indices from the lognormal RCO 3 "*tow-by-tow*" BT model at each step in the variable selection process; [right column]: aggregate influence associated with each step in the variable selection procedure.

J.2.1 Residual and diagnostic plots

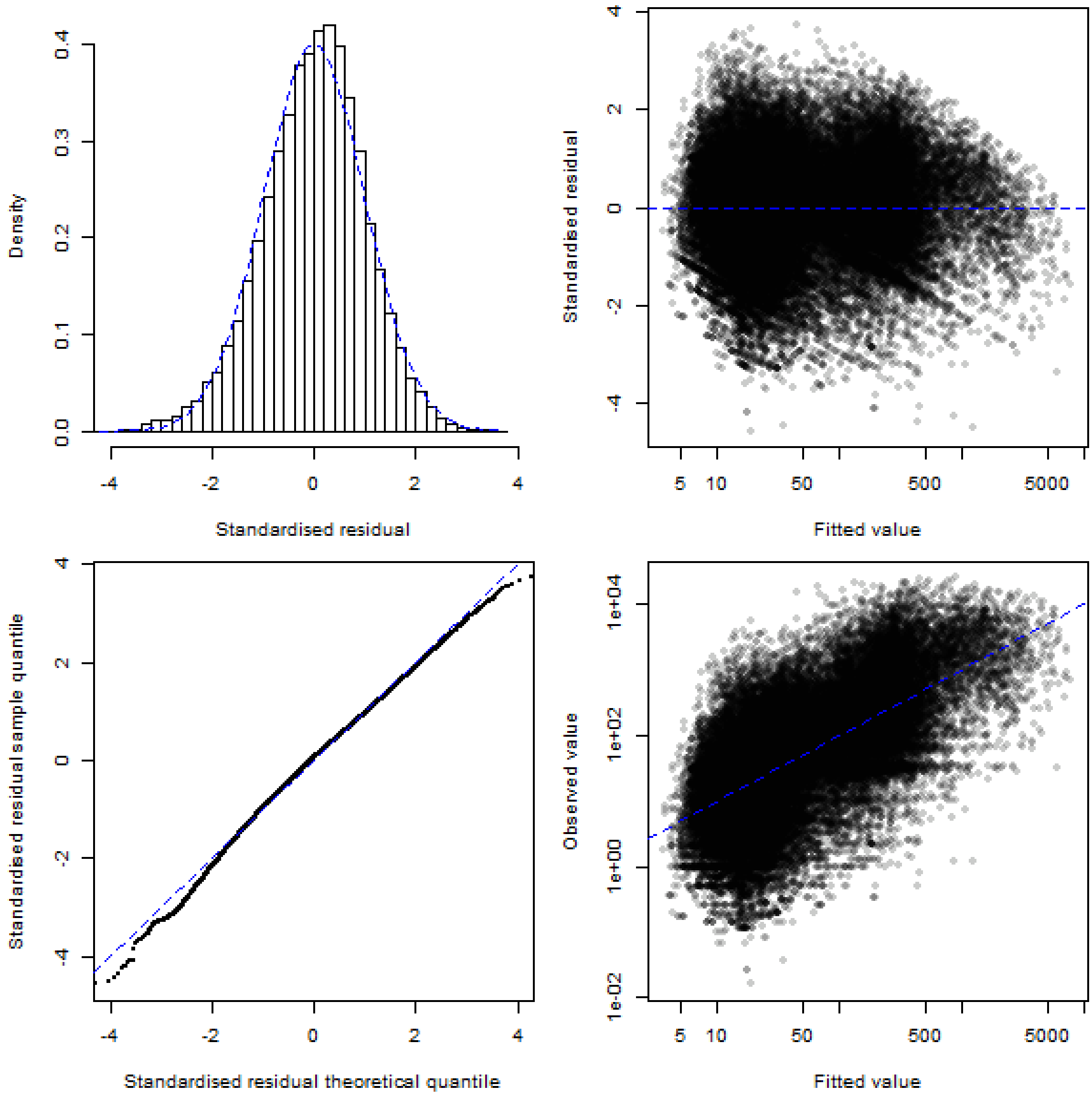

Figure J.5: Plots of the fit of the lognormal standardised CPUE model of successful catches of red cod to the RCO 3 "*tow-by-tow*" BT data set. [Upper left] histogram of the standardised residuals compared to a lognormal distribution; [Upper right] Q-Q plot of the standardised residuals; [Lower left] Standardised residuals plotted against the predicted model catch per trip; [Lower right] Observed catch per record plotted against the predicted catch per record.

J.2.2 Model coefficient plots

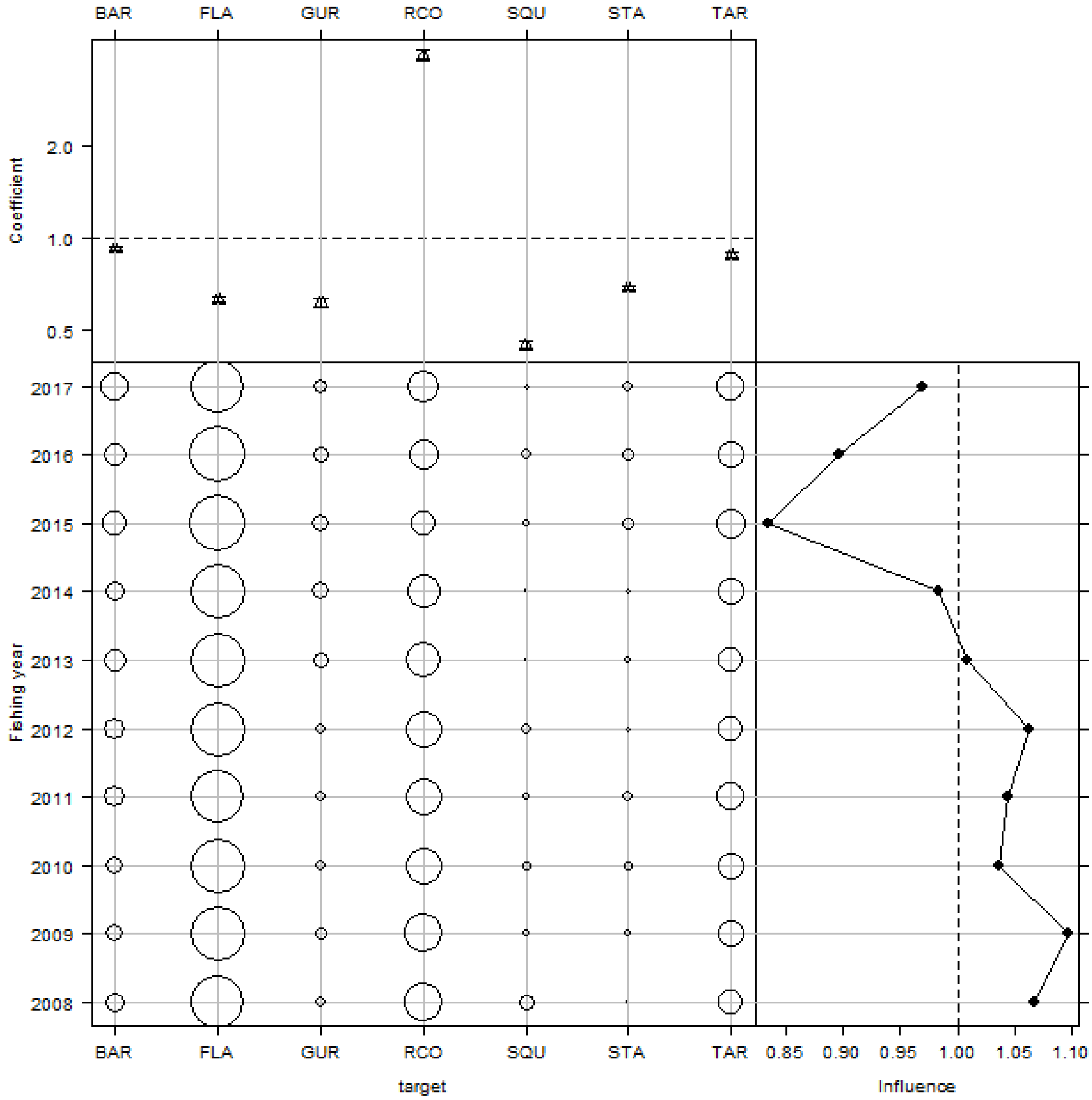

Figure J.6: Effect of target species in the lognormal RCO 3 "*tow-by-tow*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

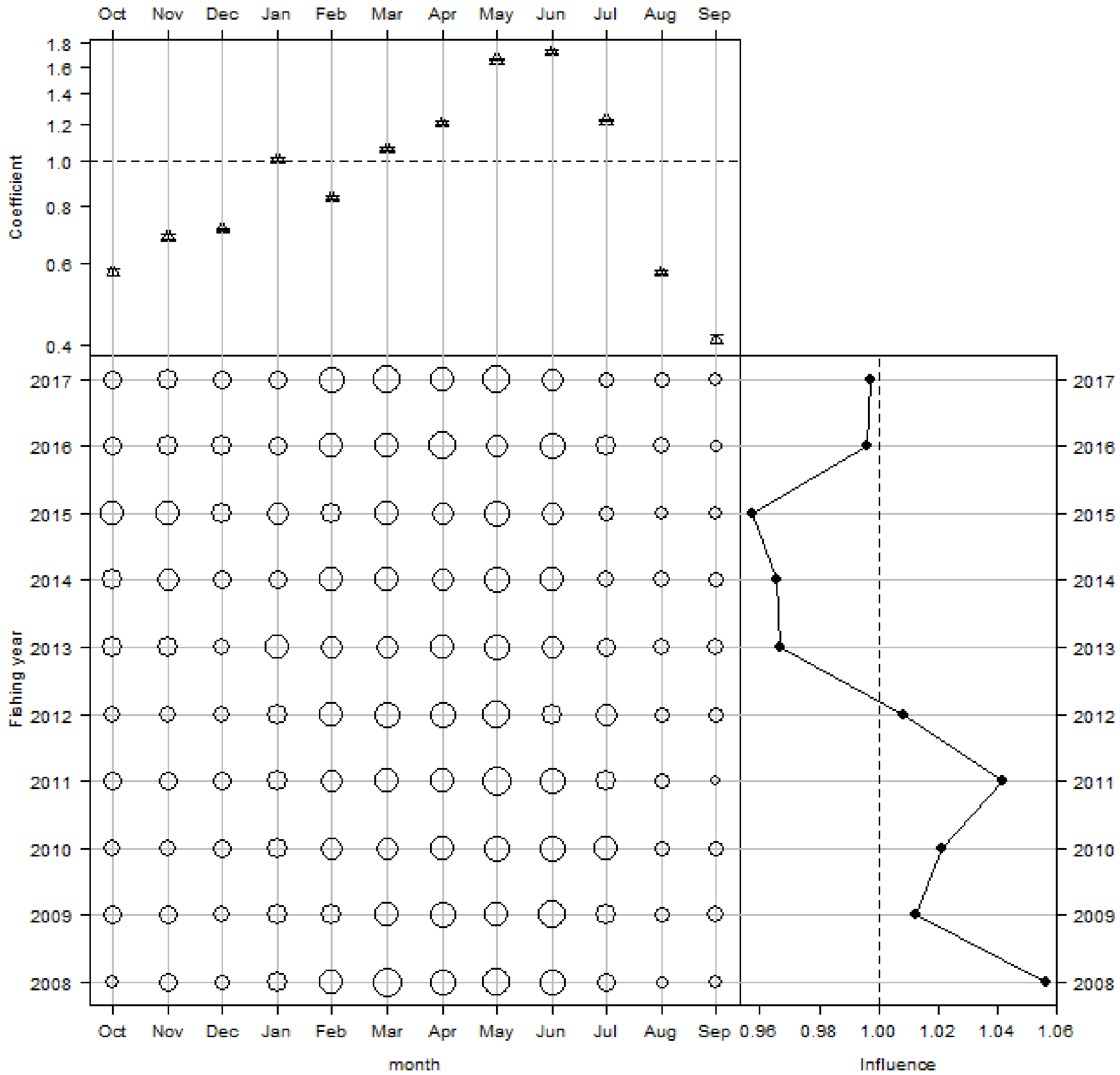

Figure J.7: Effect of month in the lognormal RCO 3 “*tow-by-tow*” BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

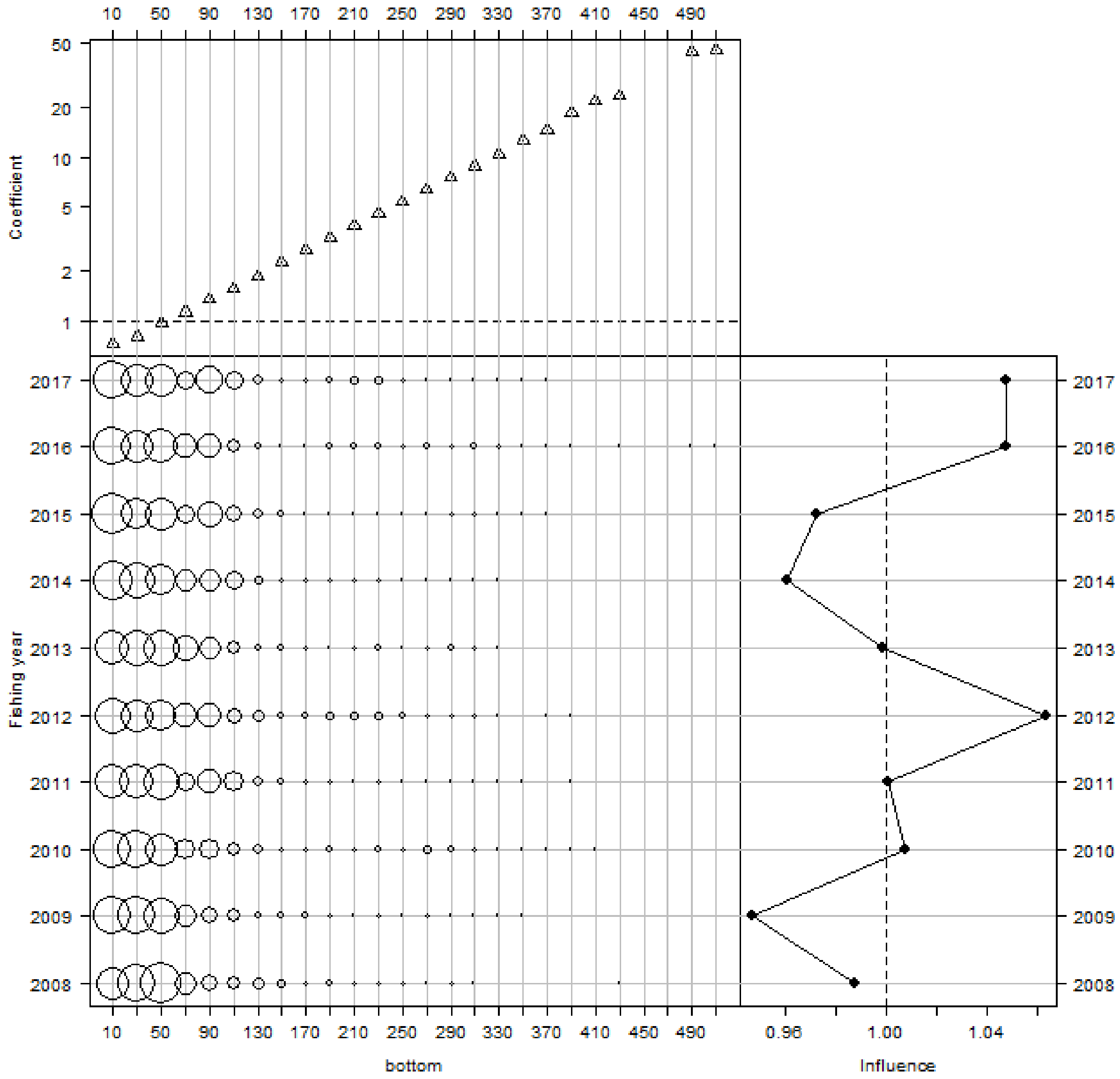

Figure J.8: Effect of bottom depth in the lognormal RCO 3 "*tow-by-tow*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

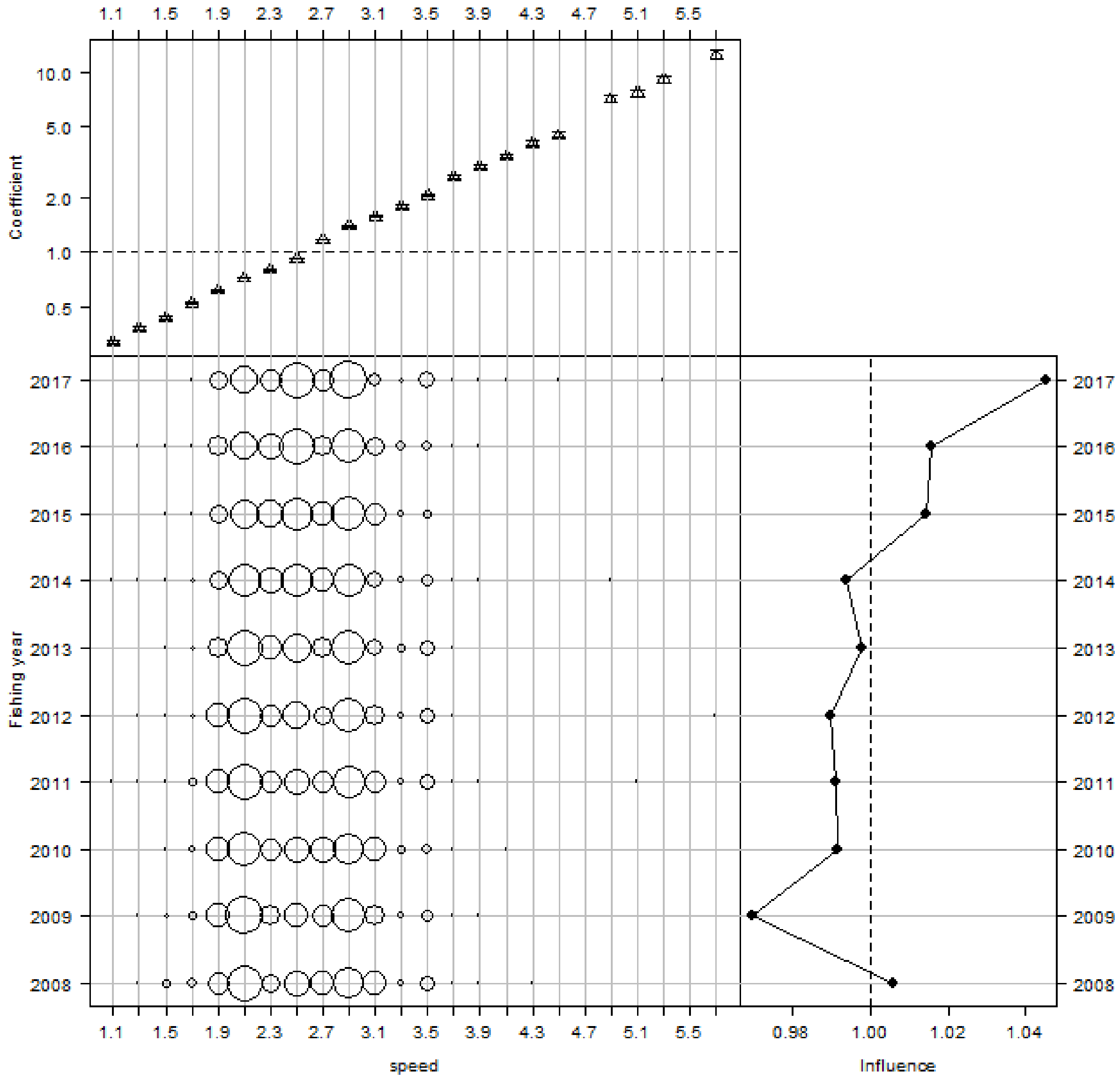

Figure J.9: Effect of vessel speed in the lognormal RCO 3 "*tow-by-tow*" BT model. Top: effect by level of variable (left-axis: log space additive; right-axis: natural space multiplicative). Bottom-left: distribution of variable by fishing year. Bottom-right: cumulative effect of variable by fishing year (bottom-axis: log space additive; top-axis: natural space multiplicative).

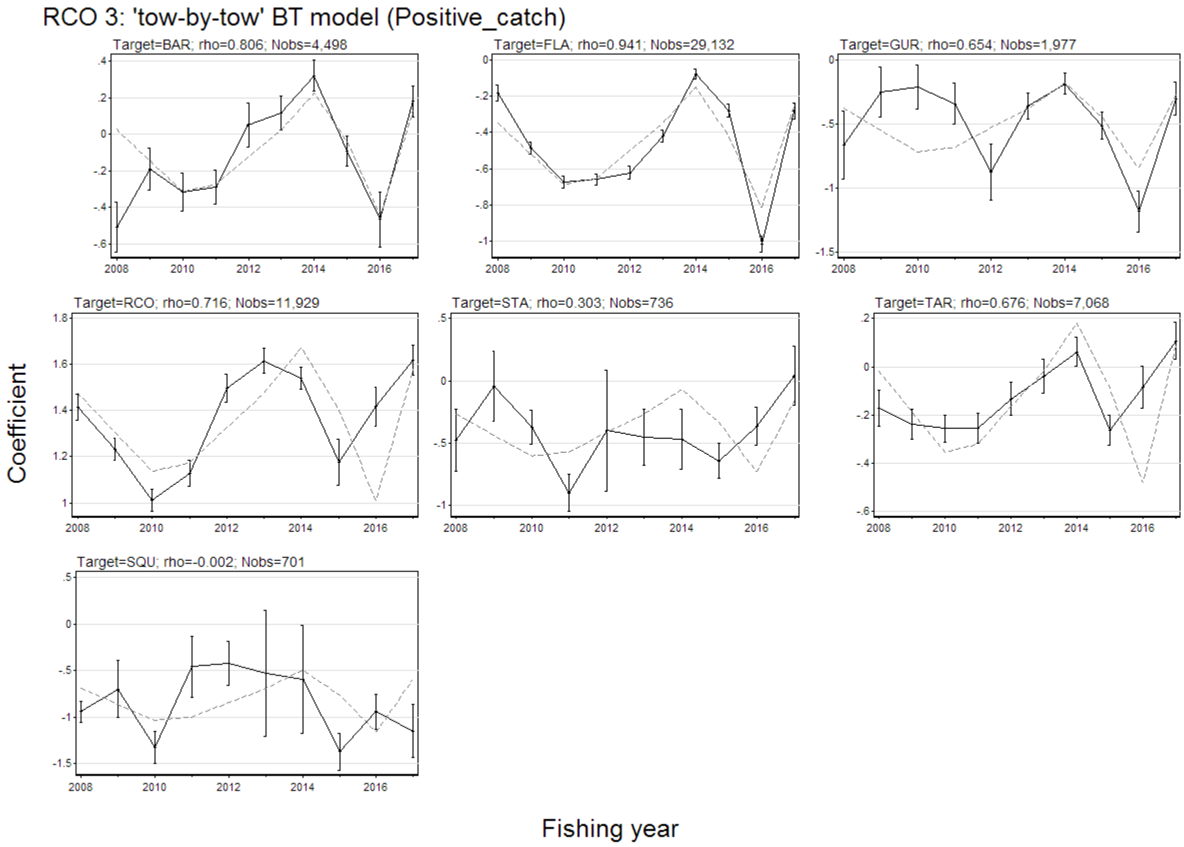

Figure J.10: Residual implied coefficients for target species × fishing year interaction (interaction term not offered to the model) in the RCO 3 "*tow-by-tow*" BT lognormal model. Implied coefficients (black points) are calculated as the normalised fishing year coefficient (grey line) plus the mean of the standardised residuals in each fishing year and target species. These values approximate the coefficients obtained when a target species × year interaction term is fitted, particularly for those target species × year combinations which have a substantial proportion of the records. The error bars indicate one standard error of the standardised residuals. The information at the top of each panel identifies the plotted category, provides the correlation coefficient (*rho*) between the category year index and the overall model index, and the number of records supporting the category.

J.3 Binomial presence/absence model

Two explanatory variables entered the model after fishing year (target species and month; Table J.3). Variables hours fished, area, wingspread, bottom depth and headline height were not accepted. The variable vessel speed was discarded. A plot of the binomial model and the combined delta-lognormal model is provided in Figure J.11 and the CPUE indices are listed in Table J.4.

Table J.3: Order of acceptance of variables into the RCO 3 "*tow-by-tow*" BT binomial presence/absence model, 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.

Variable	DF	Neg. Log likelihood	AIC	Deviance R^2	Nagelkerke R^2	Model use
fishing year	10	-61 487	122 994	0.7	1.3	*
target species	16	-58 434	116 901	5.7	9.9	*
month	27	-56 727	113 507	8.4	**14.5**	*
poly(log(duration), 3)	30	-56 304	112 668	9.1	15.6	
area	33	-56 220	112 506	9.2	15.8	
wingspread	34	-56 159	112 386	9.3	15.9	
bottom depth	35	-56 131	112 333	9.4	16.0	
headline height	36	-56 114	112 300	9.4	16.0	
vessel speed	–	–	–	–	–	

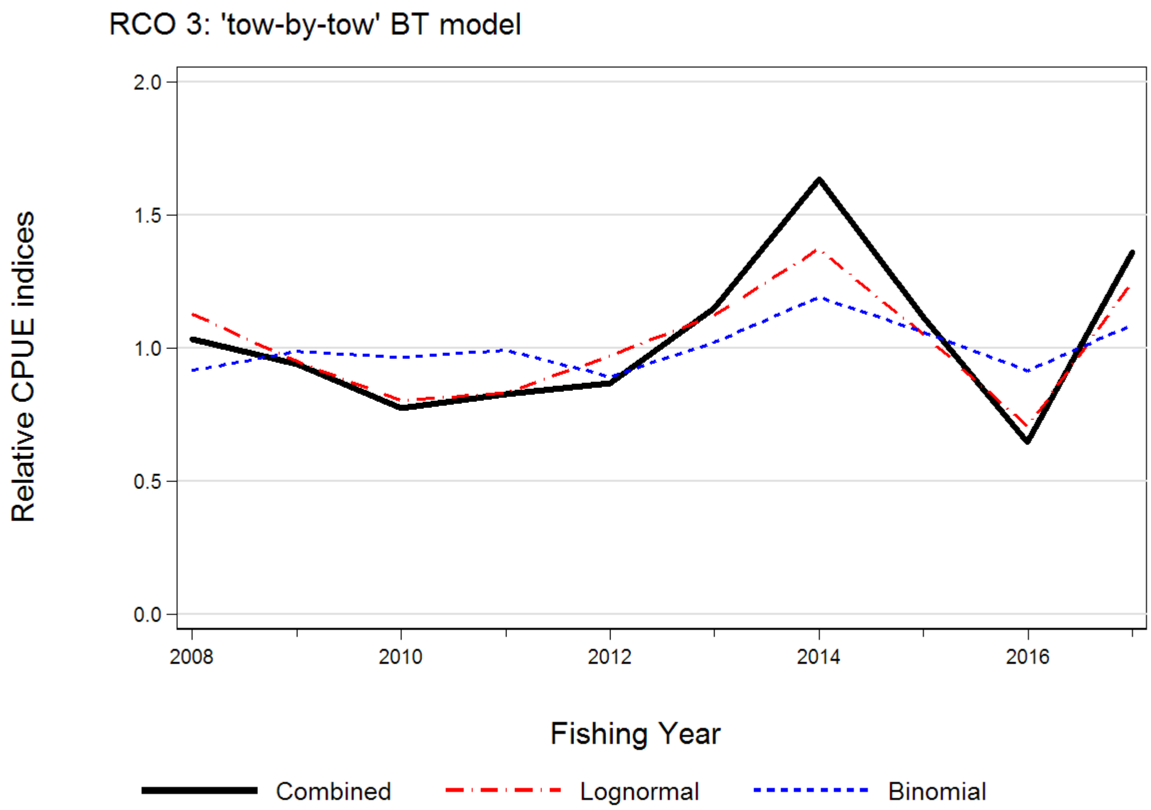

Figure J.11: Three relative CPUE indices for red cod based on the RCO 3 "tow-by-tow" BT fishery definition: a) the lognormal non-zero model, b) the binomial standardised model using the logistic distribution and a regression based on presence/absence of red cod, and c) the combined model using the delta-lognormal procedure (Eq. F.4).

J.4 CPUE indices

Table J.4: Arithmetic indices for the total and core data sets, geometric, lognormal (including standard error [SE]), binomial and combined indices for the core data set by fishing year for the RCO 3 "*tow-by-tow*" BT standardised model. All series (except SE) standardised to geometric mean=1.0.

Fishing	All vessels						Core vessels
year	Arithmetic	Arithmetic	Geometric	Standardised	SE	Binomial	Combined
2008	0.778	0.852	1.316	1.128	0.0216	0.916	1.033
2009	0.714	0.743	0.951	0.951	0.0197	0.988	0.940
2010	0.758	0.817	0.846	0.804	0.0191	0.966	0.776
2011	1.136	0.798	0.899	0.832	0.0194	0.993	0.826
2012	1.535	1.591	1.001	0.971	0.0203	0.893	0.867
2013	1.382	1.437	1.061	1.125	0.0184	1.022	1.150
2014	1.106	1.074	1.295	1.373	0.0174	1.193	1.638
2015	0.574	0.582	0.819	1.053	0.0211	1.061	1.116
2016	1.100	1.106	0.686	0.706	0.0219	0.916	0.647
2017	1.410	1.530	1.360	1.250	0.0208	1.088	1.361

Appendix K. RETROSPECTIVE ANALYSIS: SEQUENCE OF STANDARDISED CPUE INDICES BY ESTIMATION MONTH AND FISHING YEAR

The following tables show the annual combined (Eq. F.4) index for a fishing year (rows) that was calculated in successive estimation years (columns). Each panel of the table gives the final month for the partial data year. Only the first (left-hand) estimate is made with incomplete data, with all succeeding years on the same row using all months for the indicated year.

Table K.1: RCO 2: "*no interaction*" combined index. Each panel shows, by the final month of the incomplete predictive year, the annual combined index resulting in each successive estimation year. Only the first estimate in each row is based on data from an incomplete year. All successive estimates on the same row are based on complete year data.

Sequence of CPUE estimates by estimation year. Month: December

Fishing	Estimation year														
year	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
02/03	0.634	0.639	0.624	0.600	0.589	0.596	0.567	0.523	0.491	0.442	0.423	0.419	0.456	0.428	0.399
03/04		0.880	1.163	1.123	1.147	1.153	1.093	1.014	0.948	0.841	0.797	0.784	0.850	0.798	0.740
04/05			1.928	1.897	1.830	1.813	1.702	1.547	1.413	1.256	1.204	1.203	1.320	1.242	1.148
05/06				2.337	2.068	2.010	1.966	1.792	1.668	1.493	1.467	1.475	1.612	1.512	1.393
06/07					1.655	1.500	1.367	1.223	1.161	1.026	0.975	0.976	1.070	1.010	0.931
07/08						1.394	1.736	1.568	1.481	1.286	1.239	1.237	1.346	1.262	1.163
08/09							2.322	1.924	1.767	1.554	1.470	1.468	1.605	1.507	1.384
09/10								4.619	4.191	3.692	3.555	3.565	3.901	3.654	3.365
10/11									4.184	4.935	4.639	4.608	5.032	4.723	4.328
11/12										8.487	4.960	4.884	5.292	5.002	4.605
12/13											3.946	2.293	2.459	2.314	2.137
13/14												1.981	0.872	0.821	0.758
14/15													0.352	0.589	0.543
15/16														2.630	3.321
16/17															5.517

Sequence of CPUE estimates by estimation year. Month: January

Fishing	Estimation year														
year	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
02/03	0.698	0.639	0.629	0.606	0.588	0.592	0.567	0.525	0.491	0.443	0.422	0.422	0.454	0.427	0.402
03/04		0.884	1.171	1.135	1.145	1.144	1.095	1.016	0.948	0.842	0.794	0.789	0.846	0.795	0.745
04/05			1.889	1.914	1.825	1.800	1.699	1.554	1.414	1.255	1.203	1.213	1.315	1.238	1.156
05/06				2.038	2.060	1.996	1.965	1.797	1.670	1.490	1.467	1.486	1.606	1.507	1.403
06/07					1.808	1.486	1.367	1.227	1.162	1.023	0.975	0.985	1.067	1.006	0.938
07/08						1.593	1.731	1.576	1.481	1.282	1.238	1.246	1.342	1.258	1.170
08/09							2.264	1.936	1.768	1.550	1.470	1.481	1.601	1.502	1.393
09/10								4.335	4.195	3.679	3.554	3.600	3.891	3.642	3.383
10/11									4.180	4.918	4.635	4.654	5.018	4.704	4.349
11/12										8.545	4.951	4.921	5.277	4.983	4.631
12/13											4.149	2.308	2.450	2.306	2.151
13/14												1.688	0.869	0.818	0.762
14/15													0.384	0.588	0.546
15/16														2.817	3.340
16/17															4.582

Sequence of CPUE estimates by estimation year. Month: February

Fishing	Estimation year														
year	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
02/03	0.688	0.635	0.633	0.604	0.580	0.593	0.570	0.525	0.493	0.445	0.422	0.425	0.454	0.427	0.404
03/04		1.031	1.178	1.133	1.132	1.144	1.103	1.018	0.951	0.843	0.793	0.794	0.846	0.796	0.748
04/05			1.856	1.907	1.798	1.799	1.708	1.561	1.419	1.257	1.205	1.221	1.315	1.239	1.161
05/06				2.230	1.991	1.995	1.973	1.804	1.675	1.495	1.471	1.495	1.606	1.507	1.408
06/07					2.060	1.482	1.376	1.235	1.162	1.025	0.977	0.992	1.067	1.007	0.941
07/08						1.602	1.741	1.584	1.478	1.284	1.241	1.253	1.340	1.259	1.174
08/09							2.058	1.949	1.764	1.552	1.474	1.490	1.598	1.503	1.398
09/10								4.214	4.190	3.687	3.568	3.627	3.885	3.645	3.393
10/11									4.135	4.919	4.648	4.690	5.010	4.705	4.361
11/12										7.765	4.954	4.951	5.277	4.989	4.645
12/13											4.091	2.315	2.450	2.309	2.158
13/14												1.459	0.869	0.819	0.764
14/15													0.385	0.589	0.548
15/16														2.767	3.351
16/17															4.057

Sequence of CPUE estimates by estimation year. Month: March

Fishing	Estimation year														
year	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
02/03	0.678	0.651	0.632	0.601	0.581	0.594	0.570	0.525	0.491	0.447	0.425	0.426	0.453	0.427	0.407
03/04		1.036	1.181	1.128	1.135	1.144	1.102	1.017	0.947	0.847	0.798	0.797	0.844	0.796	0.754
04/05			1.871	1.897	1.800	1.798	1.704	1.559	1.416	1.265	1.215	1.227	1.313	1.238	1.169
05/06				2.381	1.988	1.997	1.968	1.803	1.671	1.504	1.481	1.503	1.604	1.505	1.419
06/07					2.129	1.480	1.374	1.234	1.158	1.031	0.984	0.997	1.066	1.006	0.949
07/08						1.622	1.733	1.584	1.473	1.291	1.249	1.258	1.336	1.258	1.183
08/09							1.927	1.952	1.757	1.562	1.484	1.496	1.591	1.502	1.409
09/10								4.195	4.174	3.711	3.593	3.644	3.871	3.641	3.419
10/11									4.458	4.942	4.679	4.711	4.993	4.699	4.393
11/12										6.899	4.985	4.969	5.267	4.984	4.678
12/13											3.571	2.324	2.452	2.306	2.172
13/14												1.316	0.867	0.817	0.769
14/15													0.414	0.588	0.552
15/16														2.830	3.371
16/17															3.353

Sequence of CPUE estimates by estimation year. Month: April

Fishing year	Estimation year														
	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
02/03	0.652	0.655	0.633	0.602	0.584	0.595	0.570	0.525	0.491	0.446	0.427	0.429	0.454	0.427	0.408
03/04		1.049	1.182	1.129	1.140	1.145	1.102	1.016	0.946	0.855	0.803	0.801	0.845	0.794	0.756
04/05			1.890	1.897	1.808	1.799	1.701	1.523	1.415	1.284	1.223	1.234	1.315	1.233	1.174
05/06				2.524	1.995	1.998	1.966	1.790	1.670	1.519	1.493	1.510	1.606	1.499	1.424
06/07					2.011	1.477	1.371	1.235	1.155	1.034	0.990	1.002	1.068	1.001	0.952
07/08						1.655	1.730	1.564	1.470	1.295	1.257	1.264	1.336	1.251	1.187
08/09							1.904	1.936	1.750	1.566	1.493	1.504	1.589	1.494	1.413
09/10								4.215	4.160	3.720	3.618	3.662	3.870	3.623	3.428
10/11									4.613	4.945	4.705	4.734	4.991	4.675	4.405
11/12										6.454	5.007	4.990	5.271	4.962	4.694
12/13											3.101	2.331	2.455	2.297	2.179
13/14												1.173	0.867	0.815	0.771
14/15													0.409	0.585	0.553
15/16														3.012	3.383
16/17															3.086

Table K.2: RCO 3: "*extended2*" combined index. Each panel shows, by the final month of the incomplete predictive year, the annual combined index resulting in each successive estimation year. Only the first estimate in each row is based on data from an incomplete year. All successive estimates on the same row are based on complete year data.

Sequence of CPUE estimates by estimation year. Month: December

Fishing year	Estimation year														
	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
02/03	0.545	0.669	0.684	0.700	0.718	0.748	0.704	0.717	0.716	0.734	0.714	0.693	0.679	0.713	0.705
03/04		1.077	1.256	1.267	1.305	1.359	1.283	1.292	1.294	1.323	1.289	1.253	1.227	1.288	1.274
04/05			0.641	0.793	0.827	0.896	0.853	0.862	0.857	0.883	0.861	0.836	0.825	0.868	0.857
05/06				0.564	0.674	0.709	0.680	0.687	0.685	0.707	0.692	0.676	0.667	0.702	0.693
06/07					0.503	0.517	0.491	0.504	0.504	0.519	0.508	0.499	0.494	0.521	0.514
07/08						0.377	0.910	0.909	0.899	0.927	0.916	0.909	0.900	0.951	0.938
08/09							1.133	0.987	0.974	1.020	0.987	0.983	0.975	1.027	1.016
09/10								0.819	0.828	0.857	0.869	0.894	0.897	0.947	0.940
10/11									1.023	0.878	0.879	0.880	0.869	0.918	0.913
11/12										0.662	0.876	0.853	0.847	0.901	0.899
12/13											1.377	1.088	1.075	1.125	1.123
13/14												2.276	1.737	1.826	1.851
14/15													1.809	1.008	1.044
15/16														0.509	0.595
16/17															1.048

Sequence of CPUE estimates by estimation year. Month: January

Fishing year	Estimation year														
	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
02/03	0.533	0.673	0.684	0.697	0.727	0.739	0.710	0.721	0.717	0.728	0.714	0.695	0.686	0.718	0.706
03/04		1.051	1.254	1.261	1.322	1.342	1.294	1.299	1.296	1.311	1.290	1.257	1.239	1.296	1.277
04/05			0.631	0.788	0.838	0.886	0.861	0.867	0.859	0.875	0.862	0.839	0.833	0.874	0.858
05/06				0.603	0.683	0.702	0.686	0.691	0.686	0.700	0.693	0.679	0.674	0.707	0.695
06/07					0.399	0.512	0.496	0.507	0.504	0.515	0.509	0.501	0.499	0.524	0.515
07/08						0.461	0.917	0.913	0.900	0.920	0.919	0.913	0.909	0.957	0.941
08/09							0.969	0.991	0.975	1.012	0.990	0.988	0.984	1.033	1.019
09/10								0.722	0.829	0.851	0.872	0.901	0.906	0.954	0.943
10/11									0.984	0.870	0.882	0.885	0.878	0.924	0.916
11/12										0.815	0.877	0.857	0.857	0.909	0.902
12/13											1.360	1.094	1.087	1.135	1.127
13/14												2.047	1.756	1.843	1.857
14/15													1.371	1.021	1.049
15/16														0.421	0.598
16/17															0.971

Sequence of CPUE estimates by estimation year. Month: February

Fishing year	Estimation year														
	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
02/03	0.645	0.673	0.686	0.698	0.728	0.727	0.714	0.727	0.719	0.724	0.722	0.699	0.690	0.719	0.707
03/04		1.073	1.256	1.261	1.323	1.312	1.297	1.310	1.299	1.306	1.305	1.264	1.246	1.297	1.276
04/05			0.609	0.789	0.839	0.878	0.865	0.874	0.861	0.872	0.871	0.845	0.838	0.875	0.858
05/06				0.588	0.685	0.694	0.690	0.696	0.687	0.698	0.700	0.683	0.678	0.707	0.695
06/07					0.387	0.504	0.502	0.510	0.506	0.514	0.515	0.504	0.502	0.525	0.516
07/08						0.603	0.925	0.919	0.903	0.920	0.930	0.921	0.914	0.959	0.942
08/09							0.854	0.998	0.977	1.011	1.003	0.997	0.989	1.035	1.020
09/10								0.632	0.831	0.851	0.884	0.910	0.911	0.957	0.944
10/11									0.945	0.872	0.894	0.894	0.883	0.927	0.917
11/12										0.890	0.890	0.864	0.862	0.914	0.903
12/13											1.057	1.103	1.092	1.142	1.130
13/14												1.768	1.765	1.855	1.862
14/15													1.189	1.029	1.053
15/16														0.401	0.601
16/17															0.947

Sequence of CPUE estimates by estimation year. Month: March

Fishing year	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
							Estimation year								
02/03	0.695	0.670	0.685	0.695	0.725	0.715	0.717	0.724	0.721	0.725	0.729	0.698	0.694	0.713	0.702
03/04		1.061	1.252	1.260	1.317	1.293	1.302	1.306	1.300	1.308	1.317	1.264	1.252	1.290	1.269
04/05			0.620	0.801	0.836	0.867	0.869	0.872	0.868	0.874	0.878	0.845	0.842	0.871	0.854
05/06				0.598	0.683	0.685	0.692	0.695	0.693	0.699	0.707	0.684	0.682	0.703	0.692
06/07					0.415	0.497	0.503	0.510	0.509	0.515	0.520	0.505	0.505	0.523	0.513
07/08						0.791	0.929	0.917	0.907	0.923	0.939	0.923	0.921	0.954	0.937
08/09							0.806	0.997	0.997	1.015	1.012	1.000	0.996	1.031	1.016
09/10								0.670	0.841	0.854	0.893	0.915	0.918	0.954	0.941
10/11									0.838	0.876	0.903	0.897	0.890	0.925	0.914
11/12										0.865	0.901	0.866	0.870	0.912	0.901
12/13											0.866	1.107	1.102	1.141	1.128
13/14												1.743	1.781	1.854	1.861
14/15													1.028	1.029	1.055
15/16														0.459	0.603
16/17															1.067

Sequence of CPUE estimates by estimation year. Month: April

Fishing year	02/03	03/04	04/05	05/06	06/07	07/08	08/09	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17
							Estimation year								
02/03	0.706	0.666	0.683	0.697	0.715	0.712	0.715	0.724	0.723	0.728	0.729	0.699	0.694	0.712	0.701
03/04		1.114	1.251	1.264	1.300	1.288	1.297	1.305	1.302	1.314	1.317	1.265	1.252	1.287	1.267
04/05			0.627	0.803	0.847	0.863	0.866	0.872	0.868	0.878	0.879	0.848	0.843	0.869	0.854
05/06				0.567	0.687	0.683	0.690	0.695	0.694	0.703	0.707	0.686	0.682	0.702	0.691
06/07					0.452	0.496	0.502	0.510	0.510	0.518	0.520	0.507	0.506	0.522	0.513
07/08						0.840	0.925	0.917	0.908	0.928	0.941	0.926	0.923	0.952	0.936
08/09							0.834	0.997	0.998	1.022	1.015	1.004	0.997	1.030	1.015
09/10								0.662	0.842	0.861	0.896	0.921	0.919	0.954	0.941
10/11									0.821	0.883	0.906	0.901	0.890	0.925	0.914
11/12										0.792	0.904	0.870	0.870	0.913	0.900
12/13											0.863	1.112	1.101	1.142	1.129
13/14												1.656	1.780	1.858	1.864
14/15													1.017	1.034	1.058
15/16														0.471	0.605
16/17															1.085