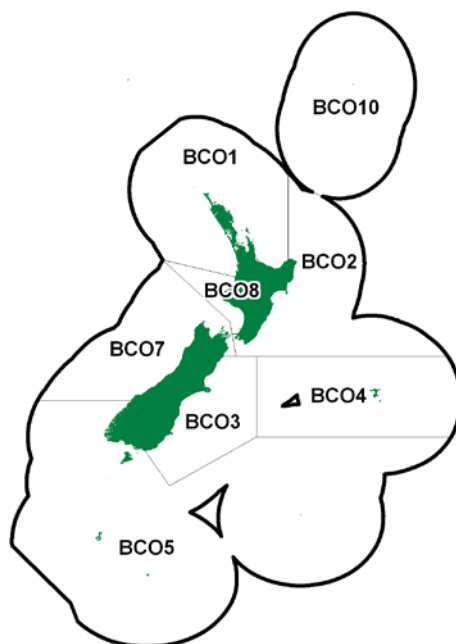


**BLUE COD (BCO)***(Parapercis colias)*

Rawaru

**1. FISHERY SUMMARY**

Allowances, TACCs and TACs in Table 1.

**Table 1: Recreational and Customary non-commercial allowances, other mortality, TACCs and TACs for blue cod by Fishstock.**

Fishstock	Recreational Allowance	Customary non-commercial allowance	Other mortality	TACC	TAC
BCO 1	2	2	-	46	46
BCO 2	-	-	-	10	10
BCO 3	-	-	-	163	163
BCO 4	-	-	-	759	759
BCO 5	191	2	20	1 239	1 452
BCO 7	-	-	-	70	20
BCO 8	188	2	2	34	226
BCO 10	-	-	-	10	10

**1.1 Commercial fisheries**

Blue cod is predominantly an inshore domestic fishery with very little deepwater catch. The major blue cod fisheries in New Zealand are off Southland and the Chatham Islands, with smaller but regionally significant fisheries off Otago, Canterbury, the Marlborough Sounds and Wanganui.

The fishery has had a long history. National landings of up to 3000 t were reported in the 1930s and catches of 2500 t were sustained for many years in the 1950s and 1960s. Fluctuations in annual landings since the 1930s can be attributed to World War II, the subsequent market for frozen blue cod for a short period of time and then the development of the rock lobster fishery. Annual landings of blue cod also vary with the success of the rock lobster season. Traditionally many blue cod fishers were primarily rock lobster fishers. Therefore, the amount of effort in the blue cod fishery may depend on the success of the rock lobster season, with weather conditions in Southland affecting the number of 'fishable' days.

The commercial catch from the BCO 5 fishery is almost exclusively taken by the target cod pot fishery operating within Foveaux Strait and around Stewart Island (statistical areas 025, 027, 029 and 030). Similarly, the BCO 3 commercial catch is dominated by the target pot fishery, although blue cod is also taken as a small bycatch of the inshore trawl fisheries operating within BCO 3. Most of

## BLUE COD (BCO)

the catch from BCO 3 is taken in the southern area of the fishstock (statistical area 024). Catches from BCO 3 and 5 fishstocks peak during autumn and winter and the seasonal nature of the fishery is influenced by the operation of the associated rock lobster fishery.

Total landings built up to a peak in 1985, the year before the QMS was implemented. Landings then declined up to 1989, but have since increased, coinciding with a change in the main fishing method from hand-lines to cod pots. Recent reported landings are shown in Table 2 and historical landings in Table 3, while Figure 1 shows the historical landings and TACC values for the five main BCO fish stocks.

Since 1994-95, total landings have exceeded 2000 t annually, peaking at 2501 t in 2003-04. Historically, the largest catches of blue cod have been taken in BCO 5 (1556 t in fishing year 2003-04). The total catch from this fishery remained relatively stable from 1982 to 1993 and subsequently increased to approach the level of the TACC in 1995-96. Catches have remained stable at this higher level in recent years.

Since 1989-90, a large proportion of the total catch from the BCO 5 fishery has been taken from Foveaux Strait (statistical area 025) and catches from this area have remained relatively stable. The recent increase in total catch has been attributed to an increase in catch from the western approaches to Foveaux Strait (stat area 030) and, to a lesser extent, from off eastern Stewart Island (statistical area 027). In BCO 3, catches have consistently fluctuated around the TACC of 163 t exceeding it in most years since 1997-98. In other Fishstocks, landings have generally been lower than the TACC. In BCO 7, commercial landings declined in response to a reduction in TACC (to 70 t) implemented in 1995-96, but from 2000-01 annual landings in this QMA have increased steadily.

**Table 2: Reported landings (t) of blue cod by Fishstock from 1983 to 2011-12 and actual TACCs (t) from 1986-87 to 2011-12. QMS data from 1986-present. FSU data 1983-1986. [Continued on next page].**

Fishstock FMA (s)	BCO 1		BCO 2		BCO 3		BCO 4		BCO 5	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	23	-	4	-	81	-	192	-	626	-
1984*	39	-	6	-	74	-	273	-	798	-
1985*	21	-	3	-	55	-	274	-	954	-
1986*	19	-	2	-	82	-	337	-	844	-
1986-87	8	30	1	10	84	120	417	600	812	1 190
1987-88	9	40	1	10	148	140	204	647	938	1 355
1988-89	8	42	1	10	136	142	279	647	776	1 447
1989-90	10	45	1	10	121	151	358	749	928	1 491
1990-91	12	45	< 1	10	144	154	409	757	1 096	1 491
1991-92	10	45	1	10	135	154	378	757	873	1 536
1992-93	12	45	4	10	171	156	445	757	1 029	1 536
1993-94	14	45	2	10	142	162	474	757	1 132	1 536
1994-95	13	45	1	10	155	162	565	757	1 218	1 536
1995-96	11	45	2	10	158	162	464	757	1 503	1 536
1996-97	13	45	2	10	156	162	423	757	1 326	1 536
1997-98	16	45	4	10	163	162	575	757	1 364	1 536
1998-99	12	45	2	10	150	162	499	757	1 470	1 536
1999-00	14	45	2	10	168	162	490	757	1 357	1 536
2000-01	15	45	2	10	154	162	627	757	1 470	1 536
2001-02	12	46	2	10	138	163	648	759	1 477	1 548
2002-03	11	46	4	10	169	163	724	759	1 497	1 548
2003-04	9	46	4	10	167	163	710	759	1 556	1 548
2004-05	9	46	5	10	183	163	731	759	1 473	1 548
2005-06	7	46	1	10	183	163	580	759	1 346	1 548
2006-07	6	46	4	10	177	163	747	759	1 382	1 548
2007-08	6	46	3	10	167	163	779	759	1 277	1 548
2008-09	7	46	8	10	158	163	787	759	1 391	1 548
2009-10	8	46	7	10	171	163	691	759	1 210	1 548
2010-11	7	46	8	10	183	163	781	759	1 296	1 548
2011-12	6	46	8	10	166	163	753	759	1 215	1 239

**Table 2 [Continued]: Reported landings (t) of blue cod by Fishstock from 1983 to 2011-12 and actual TACCs (t) from 1986-87 to 2011-12. QMS data from 1986-present. FSU data 1983-1986.**

Fishstock FMA (s)	BCO 7		BCO 8		BCO 10		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1983*	91	-	53	-	0	-	1 070	-
1984*	129	-	56	-	0	-	1 375	-
1985*	169	-	70	-	0	-	1 546	-
1986*	83	-	42	-	0	-	1 409	-
1986-87	79	110	22	60	0	10	1 422	2 130
1987-88	78	126	44	72	0	10	1 420	2 400
1988-89	66	131	32	72	0	10	1 298	2 501
1989-90	75	136	34	74	0	10	1 527	2 666
1990-91	63	136	28	74	0	10	1 752	2 677
1991-92	57	136	25	74	0	10	1 480	2 722
1992-93	85	136	32	74	0	10	1 777	2 724
1993-94	67	95	21	74	0	10	1 852	2 689
1994-95	113	95	24	74	0	10	2 089	2 689
1995-96	65	70	31	74	0	10	2 234	2 664
1996-97	71	70	38	74	0	10	2 029	2 664
1997-98	60	70	15	74	0	10	2 197	2 664
1998-99	52	70	35	74	0	10	2 220	2 664
1999-00	28	70	30	74	0	10	2 089	2 664
2000-01	26	70	22	74	0	10	2 316	2 664
2001-02	30	70	17	74	0	10	2 319	2 680
2002-03	39	70	13	74	0	10	2 457	2 680
2003-04	45	70	10	74	0	10	2 501	2 680
2004-05	44	50	7	74	0	10	2 452	2 680
2005-06	50	70	20	74	0	10	2 184	2 680
2006-07	69	70	34	74	0	10	2 413	2 680
2007-08	59	70	22	74	0	10	2 313	2 680
2008-09	58	70	18	74	0	10	2 427	2 680
2009-10	59	70	16	74	0	10	2 162	2 680
2010-11	51	70	16	74	0	10	2 342	2 681
2011-12	54	70	10	34	0	10	2 214	2 332

**Table 3: Reported total New Zealand landings (t) of blue cod for the calendar years 1970 to 1983. Sources MPI and FSU data.**

Year	Landings
1970	1 022
1971	644
1972	459
1973	846
1974	696
1975	356
1976	524
1977	383
1978	378
1979	437
1980	536
1981	696
1982	539
1983	1 135

# BLUE COD (BCO)

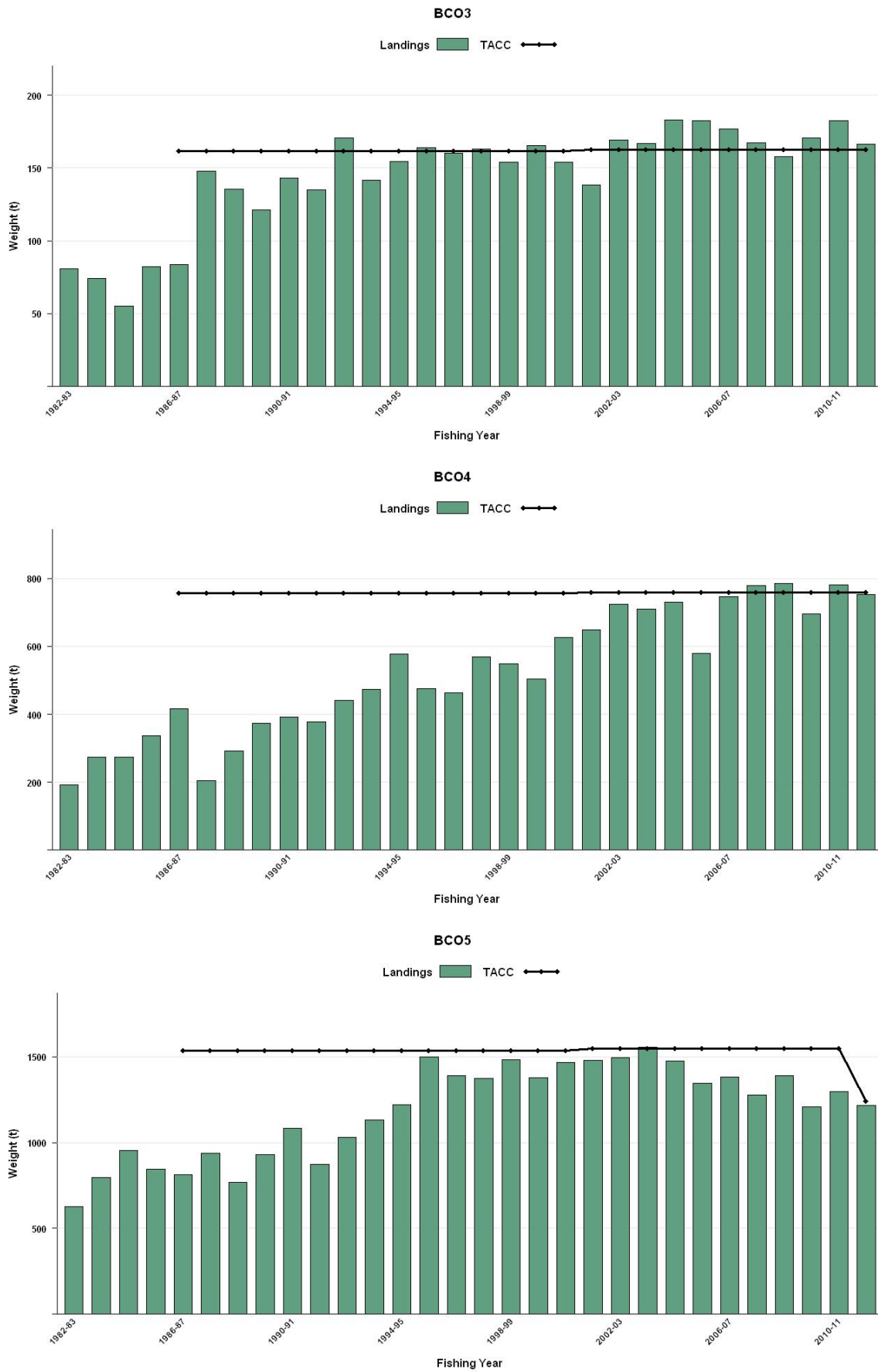


Figure 1: Historical landings and TACC for the five main BCO stocks. From top: BCO3 (South East Coast), BCO4 (South East Chatham Rise), and BCO5 (Southland). [Continued on next page].

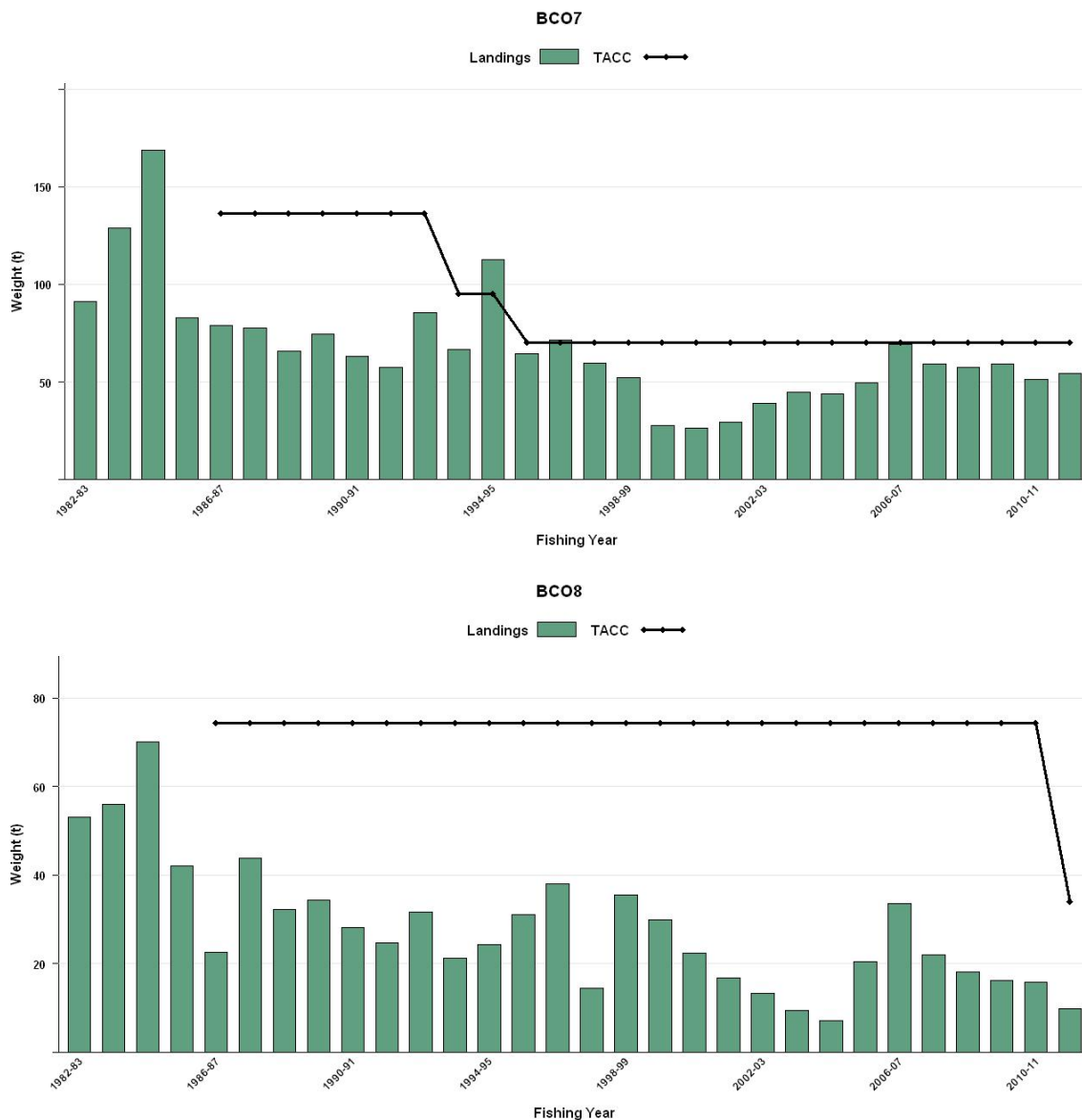


Figure 1 [Continued]: Historical landings and TACC for the five main BCO stocks. From top: BCO7 (Challenger) and BCO8 (Central Egmont).

### 1.2 Recreational fisheries

Blue cod are generally the most important recreational finfish in Marlborough, Otago, Canterbury, Southland and the Chatham Islands. Recreational catches have been obtained from diary surveys in 1991-94, 1996 and December 1999 to November 2000 (Tables 4, 5 & 6). Charter vessel catches have also been obtained separately in 1997-98 (Table 7).

Table 4: Estimated number of blue cod harvested by recreational fishers by Fishstock and survey.\*

Fishstock	Survey	Number caught	CV (%)	Estimate Harvest range (t)
BCO 1	North	33 000	14	15-30
BCO 1	Central	4 000	-	0-5
BCO 2	North	1 000	-	0-5
BCO 2	Central	117 000	21	55-85
BCO 3	South	206 000	16	205-285
BCO 5	North	1 000	-	0-5
BCO 5	South	188 000	22	150-230
BCO 7	North	2 000	-	0-5
BCO 7	Central	311 000	16	145-205
BCO 7	South	62 000	21	20-40
BCO 8	North	2 000	-	0-5
BCO 8	Central	124 000	35	50-110

## BLUE COD (BCO)

\* Surveys were carried out in different years in the Ministry of Fisheries regions: South in 1991-92, Central in 1992-93 and North in 1993-94 (Teirney *et al.* 1997).

**Table 5: Results of a national diary survey of recreational fishers in 1996.\***

Fishstock	Number caught	CV(%)	Estimated harvest range (t)	Point Estimate (t)
BCO 1	34 000	11	10-20	17
BCO 2	145 000	13	70-90	81
BCO 3	217 000	11	135-165	151
BCO 5	171 000	12	120-155	139
BCO 7	356 000	9	220-260	239
BCO 8	159 000	12	70-90	79

\*Estimated number of blue cod harvested by recreational fishers by Fishstock and the corresponding harvest tonnage. The mean weights used to convert numbers to catch weight are considered the best available estimates. Harvest estimates (t) are also presented as a range to reflect the uncertainty in the estimates (from Bradford 1998).

**Table 6: Results of the 1999-2000 national diary survey of recreational fishers (Dec 1999 - Nov 2000).\***

Fishstock	Number caught	CV(%)	Estimated harvest range (t)	Point Estimate (t)
BCO 1	37 000	31	15-30	23
BCO 2	187 000	25	121-201	161
BCO 3	1 026 000	29	530-973	752
BCO 5	326 000	28	165-293	229
BCO 7	542 000	20	230-347	288
BCO 8	232 000	32	127-249	188

\*The mean weights used to convert numbers to catch weight are considered the best available estimates. Harvest estimates (t) of blue cod are also presented as a range to reflect the uncertainty in the estimates (from Boyd & Reilly 2002).

**Table 7: Results of a national marine diary survey of recreational fishers from charter vessels, 1997-98 (November 1997 to October 1998).\***

Fishstock	Number caught	CV(%)	Estimated landings (number of fish killed)	Point Estimate (t)
BCO 1	430	18	2 500	2.4
BCO 2	34	50	300	0.2
BCO 3	17 272	29	72 000	58
BCO 5	16 750	36	63 000	51
BCO 7	32 026	13	110 000	76
BCO 8	2	-	-	0

\*Estimated number of blue cod harvested by recreational fishers on charter vessels by Fishstock and the corresponding harvest tonnage. The mean weights used to convert numbers to catch weight are considered the best available estimates (James & Unwin 2000).

A key component of estimating recreational harvest from diary surveys is determining the proportion of the population that fish. The Recreational Technical Working Group concluded that the harvest estimates from the diary surveys should be used only with the following qualifications: a) they may be very inaccurate; b) the 1996 and earlier surveys contain a methodological error; and, c) the 2000 and 2001 estimates are implausibly high for many important fisheries. The 1999-2000 Harvest estimates for each Fishstock should be evaluated with reference to the coefficient of variation.

The recreational catches estimated for BCO 2, 3, 7 and 8 in the 1999-2000 fishing year far exceeded the current TACCs and commercial landings in those areas. The last nationwide recreational survey was undertaken in 2001, but the results are still under review and are not currently available.

**Table 8: Changes to minimum legal size (MLS in cm) and amateur maximum daily limits (MDL) of blue cod by Fishstock from 1986 to present.\***

Fishstock QMA(s)	BCO 1		BCO 2		BCO 3		BCO 4		BCO 5		Sub area provisions: Paterson Inlet	
	1&9		2		3		4		5 &6			
	MLS	MDL	MLS	MDL	MLS	MDL	MLS	MDL	MLS	MDL	MLS	MDL
1986	30	30	30	30	30	30	30	30	30	30	30	30
1993	33	20	33	20	30	30	33	30	33	30	33	30
1994	33	20	33	20	30	30	33	30	33	30	33	15
	-	-	-	-	-	*30	*10	-	-	-	-	-

Fishstock QMA(s)	BCO 7		BCO 7 Marlborough Sounds		BCO 8		BCO 10	
	7		8		8		10	
	MSL	MDL	MSL	MDL	MSL	MDL	MSL	MDL
1986	30	30	30	12	30	30	30	30
1993	33	20	33	10	33	20	33	20
1994	33	20	28	6	33	20	33	20
2001	33	10	-	-	-	-	-	-
2003			30	3				
2010			SLOT	2				
			30-35					

\*All maximum daily limits are restricted within mixed species maximum daily bag limits which may vary between areas - (\* for the in north Canterbury area only).

The national marine diary survey of recreational fishing from charter vessels in 1997-98 found blue cod to be the second most frequently landed species nationally and the most frequently landed species in the South Island. Results indicate that recreational catches from charter vessels (Table 7) follow the same pattern as overall recreational catch (Tables 4 and 5). The estimated recreational catches from charter vessels in BCO 7 exceeded the 1997-98 TACC and the commercial landings in QMA 7.

During 1992-93, the amateur bag limit for blue cod was reduced and the minimum size increased from 30 cm to 33 cm for both amateur and commercial fishers (except for BCO 3). However, this was amended in 1993-94 for the Marlborough Sounds where the size limit was reduced to 28 cm. Bag limits were also reduced for the Marlborough Sounds and Paterson Inlet (Stewart Island), in 2003 the minimum legal size and daily bag limit in the Marlborough Sounds was changed to 30 cm and 3 per person per day respectively. Recent changes to amateur size and bag limits are shown in Table 8.

### 1.3 Customary non-commercial fisheries

No quantitative data on historical or current blue cod customary non-commercial catch are available. However, bones found in middens show that blue cod was a significant species in the traditional Maori take of pre-European times.

### 1.4 Illegal catch

No quantitative data on the levels of illegal blue cod catch are available.

### 1.5 Other sources of mortality

Blue cod have traditionally been used for bait within the rock lobster fishery. Pots are either set specifically to target blue cod or have a bycatch of blue cod that is used for bait. However, these fish are frequently not recorded and the quantity of blue cod used as bait cannot be accurately determined.

Cod pots covered in 38 mm mesh frequently catch undersized blue cod. It has been estimated that in Southland, 65% of blue cod caught in these pots are less than 33 cm. When returned, the mortality of these fish can be high due to predation by mollymawks following commercial boats. It is estimated by the fishing industry that up to 50% of returned fish can be taken. To reduce the problem of predation of returned undersized fish, a minimum 48 mm mesh size was introduced to BCO 5 in 1994. However, no mesh size restrictions exist in any other area.

Recreational line fishing often results in the harvest of undersized blue cod. The survival of these has been shown to be a factor of hook size. A small scale experiment showed that returned undersized fish caught with small hooks (size 1/0) experience 25% mortality, whereas those caught with large hooks (size 6/0) appear to have little or no mortality (Carbines 1999).

## BLUE COD (BCO)

### 2. BIOLOGY

Blue cod is a bottom-dwelling species endemic to New Zealand. Although distributed throughout New Zealand near foul ground to a depth of 150 m, they are more abundant south of Cook Strait and around the Chatham Islands. Growth may be influenced by a range of factors, including sex, habitat quality and fishing pressure relative to location (Carbines 2004a). Size-at-sexual maturity also varies according to location. In Northland, maturity is reached at 10-19 cm total length (TL) at an age of 2 years, whilst in the Marlborough Sounds it is reached at 21-26 cm (TL) at 3-6 years. In Southland, the fish become mature between 26-28 cm (TL), at an age of 4-5 years. Blue cod have also been shown to be protogynous hermaphrodites, with individuals over a large length range changing sex from female to male (Carbines 1998). Validated age estimates using otoliths have shown that blue cod males grow faster and are larger than females (Carbines 2004b). The maximum recorded age for this species is 32 years.

$M$  was estimated using the equation  $M = \log_e 100/\text{maximum age}$ , where maximum age is the age to which 1% of the population survives in an unfished stock. Using the maximum age of 32 years, (Carbines *et al.* 2007)  $M$  was calculated to be 0.14. This estimate seems feasible as in lightly fished areas such as the offshore Banks Peninsula  $Z$  is thought to approximate  $M$  and was calculated at 0.14 to 0.19 (Carbines *et al.* 2007).

Blue cod have an annual reproductive cycle with an extended spawning season during late winter and spring. Spawning has been reported within inshore and mid shelf waters. It is also likely that spawning occurs in outer shelf waters. Ripe blue cod are also found in all areas fished commercially by blue cod fishers during the spawning season. Eggs are pelagic for about five days after spawning, and the larvae are pelagic for about five more days before settling onto the seabed. Juveniles are not caught by commercial potting or lining, and therefore blue cod are not vulnerable to the main commercial fishing methods until they are mature. Recreational methods do catch juveniles but the survival of these fish is good if they are caught using large hooks (6/0) and returned to the sea quickly.

Tagging experiments carried out in the Marlborough Sounds in the 1940s and 1970s suggested that most blue cod remained in the same area for extended periods. A more recent tagging experiment carried out in Foveaux Strait (Carbines 2001) showed that although some blue cod moved as far as 156 km, 60% travelled less than 1 km. A similar pattern was found in Dusky sound where four fish moved over 20 km but 65% had moved < 1 km (Carbines & McKenzie 2004). The larger movements observed during this study were generally eastwards into the fiord. The inner half of the fiord was found to drain the outer strata and had 100% residency.

Biological parameters relevant to stock assessment are shown in Table 9.

**Table 9: Estimates of biological parameters for blue cod.**

Fishstock	Estimate						Source
<u>1. Natural mortality (M)</u>							
All	0.14						Estimated from the maximum age in Carbines <i>et al.</i> 2007, using Hoenig's (1983) method.
<u>2. Von Bertalanffy growth parameters</u>							
	Females			Males			
	$L_{\infty}$	k	$t_0$	$L_{\infty}$	k	$t_0$	
Southland (Sub area 025)	34.5	0.4	1.2	41.6	0.3	1.2	Carbines (1998)
Queen Charlotte Sound (Over all)	32.2	0.3	-0.70	*	*	*	Carbines (1998)
Inner Queen Charlotte Sound	†	†	†	41.4	0.1	-5.2	Carbines (2000)
Outer Queen Charlotte Sound	†	†	†	33.7	0.4	1.07	Carbines (2000)
Extreme Outer Queen Charlotte Sound	†	†	†	50.2		-1.9	Carbines (2000)
Pelorus Sound (Over all)	33.2	0.2	-2.0	*	*	*	Carbines (2000)
Outer Pelorus Sound	†	†	†	36.8	0.27	-0.3	Carbines (2000)
Extreme Outer Pelorus Sound	†	†	†	40.8	0.22	-0.3	Carbines (2000)
† Sub areas showed no significant difference from pooled area growth estimates.							
* Pooled area growth estimates showed significant differences from sub areas.							
<u>3. Weight = a(length)<sup>b</sup> (Weight in g, length in cm fork length).</u>							
Area	Year	Sex	a	b	R <sup>2</sup>		
North Canterbury (Kaikoura)	2004	Male	0.00985	3.1394	0.97		Carbines & Beentjes (2006a)
	2004	Female	0.00891	3.161	0.95		
Banks Peninsula	2005	Male	0.006941	3.232	0.95		Beentjes & Carbines (2006)
	2005	Female	0.00895	3.1532	0.98		
North Otago	2005	Male	0.00641	3.2743	0.95		Carbines & Beentjes (2006b)
	2005	Female	0.00421	3.4013	0.97		
Fiordland (Dusky Sound)	2002	Male	0.007825	3.1727	0.97		Carbines & Beentjes (2003)
	2002	Female	0.00506	3.2988	0.98		
Stewart Island (Paterson Inlet)	2006	Male	0.00703	3.2208	0.99		Carbines (2007)
	2006	Female	0.00814	3.1824	0.98		

The preliminary results of a mitochondrial DNA analysis (Smith & Ritchie In prep.) suggest that the Chatham Island blue cod are likely to be genetically distinct from mainland New Zealand. Over larger distances the mainland New Zealand blue cod appear to show a pattern of Isolation-by-Distance or continuous genetic change among populations.

### 3. STOCKS AND AREAS

The FMAs are used as a basis for Fishstocks, except FMAs 5 and 6 and FMAs 1 and 9, which have been combined. The choice of these boundaries was based on a general review of the distribution and relative abundance of blue cod within the fishery.

There are no data that would alter the current stock boundaries. However, tagging experiments suggest that blue cod populations may be isolated from each other and there may be several distinct populations within each management area.

## 4. STOCK ASSESSMENT

### 4.1 Estimates of fishery parameters and abundance

#### 4.1.1 South Island blue cod potting surveys

In 1995-96, a fishery independent survey using standardised cod pots at fixed stations provided catch rate estimates for recruited blue cod in Queen Charlotte Sound, Pelorus Sound and the east coast of D'Urville Island, and Marlborough Sounds (part of BCO 7) (Blackwell 1997 & 1998). In September 2001, the survey was repeated (Blackwell 2002), and the weighted mean catch rate for recruited blue cod (total length greater than 28 cm) was estimated to be 1.07 kg/pot hour (CV = 7%). The stratum mean catch rates ranging from 0.09 kg/pot hour in the inner Pelorus Sounds to 4.54 kg/pot hour at D'Urville Island. The estimated catch rates from the 2001 survey were lower (in all strata) than those estimated in 1995-96 (by 36 to 87%). Catch rates were highest in the outer Marlborough Sounds areas in both surveys. A third potting survey was completed in 2004 (Blackwell 2005), in which the survey area was extended to include west D'Urville and Separation Point. In 2004 the potting catch rates by stratum for fish > 30 cm (MLS) had both further declined in Queen Charlotte Sound and D'Urville Island, and increased in the most outer Pelorus Sound Stratum. However, catch rates were generally similar to those obtained in 2001 and remained much lower than those obtained during the 1995 and 1996 surveys. The relative biomass of pre-recruit (< 30 cm) blue cod generally followed similar trends to recruited blue cod between 1995-96 and 2004. The relative biomass of juveniles (17-27 cm) followed a similar, but more variable pattern.

Blackwell (2009) reported that during the 1995 to 2001 period, the relative abundance of blue cod followed a generally declining trend, but between 2001 and 2004, relative abundance became more variable among strata. Relative abundance increased in the outer Sounds strata, but little change occurred in the inner and middle Sounds areas between 2001 and 2004. These trends have continued between 2004 and 2007, with a continued increase in relative abundance in the outer sounds strata, but little change in the inner and mid Sounds strata. The declining trend for the D'Urville Island stratum continued from 2001 to 2007, while relative abundance remained low for Separation Point.

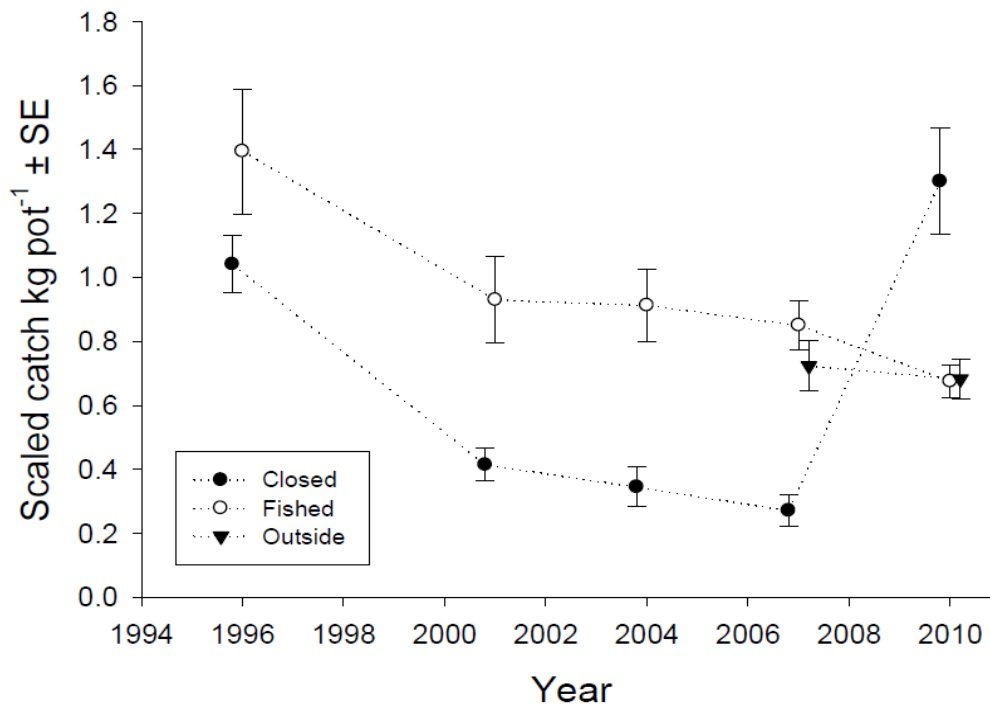
The relative abundance for all blue cod and pre-recruits (< 30 cm) generally followed similar trends to the recruited blue cod between 1995 and 2007. Trends for small blue cod were variable among strata, with relative abundance increasing in the extreme outer Queen Charlotte Sound and extreme outer Pelorus Sound between 1996 and 2004, then declining to 2007, while a declining trend occurred in all other areas surveyed. From October 2008 to April 2011 the inner Sounds were closed to blue cod fishing. The 2010 potting survey showed that the areas that were open to fishing continued to decline while the area that was closed increased markedly (Figure 2).

Results from a fishery independent potting survey off Banks Peninsula (part of BCO 3) in 2002 estimated total mean catch rates for all blue cod of 2.13 kg/pot hour (CV = 10.8%). This ranged from 0.04 kg/pot hour near Akaroa Harbour entrance to 4.74 kg/pot hour for the offshore stratum located over Pompeys Rock (Beentjes & Carbines 2003). The Banks Peninsula survey was repeated in 2005 and the estimated total mean catch rate for all blue cod was 4.43 kg/pot hour (CV = 5.7%), strata ranging from 1.02 to 7.27 kg/pot hour (Beentjes & Carbines 2004). The survey was repeated in 2008 (Beentjes & Carbines 2009) and the mean catch rates of blue cod (all sizes) ranged from 0.07 kg per pot per hour in stratum 2 (Akaroa Harbour entrance), to 5.80 kg per pot per hour for offshore stratum 6 located over Le Bons Rock. Overall mean catch rate and CV were 2.59 kg per pot per hour and 7.7%. For blue cod 30 cm and over (minimum legal size), highest catch rates were also in stratum 6 (5.74 kg per pot per hour) and lowest catch rates in stratum 2 (0.04 kg per pot per hour). Overall mean catch rate and CV for blue cod 30 cm and over were 2.30 kg per pot per hour and 8.3% respectively.

In 2008 the sex ratio for inshore strata (1-5) was 2.4:1 (male:female), for offshore strata (6 and 7) 0.98:1, and overall 1.5:1. Mortality is markedly greater for blue cod inshore compared to those offshore. Estimates are consistent with those from 2002 and 2005 surveys. Strong recruitment in 2002 occurred in both inshore and offshore strata, but was particularly strong inshore. Growth of these recruited fish resulted in much higher catch rates in 2005, an increase in the mean size and a change in

the age distribution consistent with the growth characteristics of blue cod. By 2008 catch rates, size and age structure were similar to 2002, but there was no strong juvenile length mode.

A fishery independent potting survey of blue cod in North Canterbury (part of BCO 3) in 2004/05 produced an overall mean catch rate for all blue cod of 2.45 kg/pot (CV = 8.7%) for Kaikoura and 10.19 kg/pot (CV = 7.3%) for Motunau. The catch rate of blue cod  $\geq 30$ cm was 1.91 kg/pot hour (CV = 7.9%) for Kaikoura and 5.97 kg/pot (CV = 9.8%) for Motunau (Carbines & Beentjes 2006a). Another potting survey of blue cod in North Otago (also part of BCO 3) in 2005 produced an overall mean catch rate for all blue cod of 10.14 kg/pot (CV = 5.4%). The catch rate of blue cod  $\geq 30$ cm was 8.22 kg/pot hour (CV = 5.3%).



**Figure 2:** Scaled catch rate from the fixed site potting survey in the Marlborough Sounds Management Area (MSA) divided into the area that was subject to a fishery closure (Closed) and the area that remained open to fishing (Fished). The areas outside of the MSA (Outside) are the Cook Strait and D'Urville Island and have only been surveyed since 2007 (Beentjes and Francis 2011).

In 2008 (Carbines & Beentjes 2009) mean catch rates of blue cod (all sizes) in the Kaikoura ranged from 1.94 to 20.45 kg per pot per hour. Overall mean catch rate and CV were 5.00 kg per pot per hour and 8.2%. Overall mean catch rate and CV for blue cod 30 cm and over were 4.01 kg per pot per hour and 9.2%. The overall sex ratio was 0.7:1 (male:female), although the two strata with the lowest catches of blue cod were biased in favour of males (1.4:1). Total mortality ( $Z$ ) for Kaikoura blue cod populations in 2007 was estimated from catch-curve analysis using the Chapman Robson estimator (CR). The combined estimates were between 0.31 and 0.37, consistent with those from 2005 survey.

In 2008 (Carbines & Beentjes 2009) mean catch rates of blue cod (all sizes) in Motunau ranged from 4.11 to 8.86 kg per pot per hour. Overall mean catch rate and CV were 5.50 kg per pot per hour and 8.8%. For blue cod 30 cm and over (minimum legal size), catch rates ranged from 2.10 to 4.93 kg per pot per hour. Overall mean catch rate and CV for blue cod 30 cm and over were 3.33 kg per pot per hour and 15.7%. The overall sex ratio was 3.2:1 (male:female) and the bias toward males was consistent for all strata.

The substantial decrease in catch rates in all Motunau strata in 2008 compared to 2005 could not be explained by the relatively weak cohort in 2005; or catchability, as environmental conditions at Motunau were similar for both surveys. The relatively high estimates of mortality and the overall

## BLUE COD (BCO)

44% decline in catch rates of legal sized blue cod in Motunau since the 2005 potting survey is of concern.

**Table 10: Summary statistics from standardised blue cod potting surveys done in the Marlborough Sounds. CPUE – catch per unit effort (kg/pot); CV – coefficient of variation; Z – Total mortality;  $F_{\%SPR}$  estimated for for age-at-full recruitment = 6 years and  $M = 0.14$ . Mean length, mean age and Z are from population scaled length and age (Beentjes and Francis 2011). CPUE taken from Beentjes and Francis (2011).**

Area/Year	Mean length		Mean age		Survey CPUE	CPUE range (CV) CV is pot based or set based*	Mean Z (CV)	$F_{\%SPR}$
	Female	Male	Female	Male				
Marlborough Sounds								
Marlborough Sounds Management area								
1995								
1996								
2001	25.5	29.2	5.8	6.0	1.67	0.19–5.9 (*10.8%)	0.51 (18%)	21.9%
2004	25.5	28.9	5.8	5.7	1.57	0.2–4.67 (*10.4%)	0.65 (18%)	17.8%
2007	26.1	30.0	4.3	5.1	1.34	0–2.92 (*8.3%)	0.86 (11%)	14.6%
2010 (fixed sites)	28.4	32.7	7.1	8.5	2.46	0.59–3.86 (*9.2%)	0.35 (23%)	32.0%
Outside the Marlborough Sounds Management area								
1995	–	–	–	–	–	–	–	–
1996	–	–	–	–	–	–	–	–
2001	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	–	–
2007	29.6	32.4	4.9	5.9	3.6	0.3–4.2 (*10.5%)	0.57 (17%)	19.8%
2010 (fixed sites)	29	31.5	7	7.7	3.49	0.11–5.64 (*9%)	0.46 (32%)	24.1%

A potting survey of blue cod in Dusky Sound (part of BCO 5) in 2002 produced an overall mean catch rate for all blue cod of 2.69 kg/pot (CV = 6.7%). The catch rate of blue cod  $\geq 30$  cm was 2.23 kg/pot hour (CV = 7.2%). Both the overall and catch rates for all blue cod and for fish  $\geq 30$  cm were highest on the open coast (i.e., at the entrance to the Sound), being 8.42 and 5.46 kg.pot.hour<sup>-1</sup> respectively (Carbines & Beentjes 2003).

Carbines *et al.* (2007) and Beentjes (in press a) have generated age frequency distributions using age length keys derived from otolith collected during potting surveys. Using catch-at-age, estimates of total mortality (Z) and Spawner Biomass per Recruit (at a range of age-at-full recruitment) were calculated and compared in conjunction with relative abundance estimates (CPUE [kg.hour<sup>-1</sup>]) from potting surveys conducted in the Marlborough Sounds, Kaikoura, Motunau, Banks Peninsula, North Otago, Foveaux Strait, Paterson Inlet and Dusky Sound (Tables 10-14).

Relative abundance indices from trawl surveys are available for BCO 3, BCO 5 and BCO 7, but these have not been used because of the high variance and concerns that this method may not appropriately sample blue cod populations.

**Table 11: Summary statistics from standardised blue cod potting surveys done in the northeast coast of the South Island (BCO 3). CPUE – catch per unit effort (kg/pot); CV – coefficient of variation; Z – Total mortality;  $F_{\%SPR}$  estimated for age at full recruitment = 6 years and  $M = 0.14$ . Mean length, mean age and Z are from population scaled length and age. Mean length, mean age, Z and  $F_{\%SPR}$  from Beentjes (In press a). CPUE taken from Carbines & Beentjes (2006; 2009).**

Area/Year	Mean length		Mean age		Survey CPUE	CPUE range (CV) CV is pot based or set based*	Mean Z (CV)	$F_{\%SPR}$
	Female	Male	Female	Male				
North Canterbury								
Kaikoura								
2004	30.3	32.5	8.4	7.8	2.45	0.60 – 7.97 (8.7%)	0.30 (26%)	36.9%
2007	29.8	32.5	7.0	6.9	5.0	1.91–20.45 (8.2%)	0.35 (24%)	16.1%
Motunau								
2005	25.7	29.6	5.7	6.3	10.2	9.53 – 15.37 (7.3%)	0.80 (42%)	13.6%
2008	25.2	29.3	5.1	6.2	5.5	4.1–8.9 (8.8%)	0.60 (18%)	30.3%
Banks Peninsula								
All strata								
2002	32.3	31.6	9.1	7.4	2.1	0.04 – 4.74	–	–
2005	32.4	35.5	8.9	8.6	4.4	1.02 – 7.27 (5.7%)	–	–
2008	32.5	35.5	9.2	8.0	2.6	0.07 – 5.80 (7.7%)	–	–
Inshore								
2002	25.4	28.3	5.0	5.6	*	0.04 – 2.61	0.69 (23%)	13.8%
2005	27.2	32.7	5.8	6.9	*	1.02 – 4.16	0.48 (24%)	19.7%
2008	25.5	29.8	4.5	5.1	*	0.07 – 2.3	0.54 (23%)	18.0%
Offshore								
2002	36.6	37.6	11.6	10.9	*	2.04 - 4.74	0.14 (45%)	100%
2005	37.4	41.2	11.7	12.1	*	5.68 - 7.27	0.17 (45%)	90.6%
2008	35.6	41.8	11.7	11.9	*	3.13 – 5.80	0.15 (47%)	90.8%

\* The overall CPUE value for Banks Peninsula were not reported specifically for these inshore and offshore strata but, for all strata combined (Beentjes & Carbines 2003; 2006; 2009).

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**Table 12: Summary statistics from standardised blue cod potting surveys done in the southeast coast of the South Island (BCO 3). CPUE – catch per unit effort (kg/pot); CV – coefficient of variation; Z – Total mortality;  $F_{\%SPR}$  estimated for age at full recruitment = 6 years and  $M = 0.14$ . Mean length, mean age and Z are from population scaled length and age. North Otago survey - mean length, mean age, Z and  $F_{\%SPR}$  from Beentjes (In press a), CPUE from Carbines & Beentjes (2006; 2011). South Otago survey - all results from Beentjes & Carbines (2011).**

Area/Year	Mean length		Mean age		Survey CPUE	CPUE range (CV) CV is pot-based or set-based*	Mean Z (CV)	$F_{\%SPR}$
	Female	Male	Female	Male				
North Otago								
2005 (no stratum 6)	27.8	32.8	6.2	7.5	10.1	7.45 - 14.5 (5.4%)	0.44 (19%)	18.7%
2009 (incl. stratum 6)	27.4	32.3	7.0	8.3	11.5	6.21 – 19.88 (*6.8%)	0.30 (23%)	31.7%
South Otago								
2009** (fixed sites)	29.4	33.6	8.7	9.7	9.7	3.3–16.9 (*17.1%)	0.23 (23%)	50.3%
2009 (random sites)	23.7	29.0	6.0	7.8	4.4	1.2 – 6.0 (*17.8%)	0.28 (26%)	39.4%

\*\* 2009 south Otago survey only covered half the survey strata. Results are shown for fixed and random sites from all pot placements.

**Table 13: Summary statistics from standardised blue cod potting surveys done in the south and southwest coast of the South Island (BCO 5). CPUE – catch per unit effort (kg/pot); CV – coefficient of variation; Z – Total mortality;  $F_{\%SPR}$  estimated for age at full recruitment = 6 years and  $M = 0.14$ . Mean length, mean age and Z are from population scaled length and age. North Otago survey - mean length, mean age, Z and  $F_{\%SPR}$  from Beentjes (in press a), CPUE from Carbines & Beentjes 2006, 2011. Foveaux Strait survey- all results from Carbines & Beentjes in press; Paterson Inlet survey -all results from Carbines 2007, Carbines & Haist in press; Dusky Sound survey - mean length, mean age, Z, and  $F_{\%SPR}$  from Beentjes (in press) and CPUE from Carbines & Beentjes (2003; 2011).**

Area/Year	Mean length		Mean age		CPUE	CPUE range (CV) CV is pot-based or set-based*	Mean Z (CV)	$F_{\%SPR}$
	Female	Male	Female	Male				
Foveaux Strait								
2010 (random sites)	27.8	30.5	6.9	7.1	4.8	1.17 – 14.14 (*11.3%)	0.41 (23%)	35.3%
Paterson Inlet								
2006 (fixed sites) (excl. marine reserve)	26.9	32.8	6.4	7.9	4.8	1.47 – 8.42 (11.9%)	Pending	Pending
2010 (fixed sites) (excl. marine reserve)	27.5	32.2	6.9	8.5	3.2	1.43 – 3.29 (11.3%)	0.29	48.5%
2010 (random sites) (excl. marine reserve)	25.9	29.0	6.2	7.1	0.4	0.22 – 0.53 (24.2%)	0.32	44.9%
Dusky Sound								
2002 (fixed sites)	29.9	34.7	7.0	7.7	2.69	1.28–8.42 (6.7%)	0.32 (17%)	34.3%
2008 (fixed sites) (excl. marine reserve)	32.2	37.9	7.9	10.1	4.20	2.49 – 8.13 (5.5%)	0.27 (24%)	42.4%

**Table 14: Total mortality estimates ( $Z$ ) and 95% confidence intervals (CI) of blue cod for each blue cod potting survey, and corresponding spawner per recruit estimates ( $F_{SPR\%}$ ). Fishing mortality ( $F$ ) is calculated from  $F = Z - M$  where natural mortality ( $M$ ) is set at 0.14. MR, marine reserve; ageR, age-at-full recruitment to the fishery; –, no estimate made. The original estimates of  $Z$  in earlier Plenary reports are incorrect and should not be used in future. Beentjes and Francis (2011). [Continued on next page].**

Survey area	Year	ageR	$Z$	lowCI	upCI	$F$	$F_{SPR}$
Dusky Sound	2002	5	0.30	0.23	0.40	0.16	$F_{37.1\%}$
		6	0.32	0.24	0.41	0.18	$F_{34.3\%}$
		7	0.31	0.23	0.4	0.17	$F_{35.7\%}$
		8	0.28	0.21	0.37	0.14	$F_{40.4\%}$
		9	0.23	0.17	0.29	0.09	$F_{51.9\%}$
		10	0.23	0.17	0.30	0.09	$F_{51.0\%}$
Dusky Sound (excl. MR)	2008	5	0.22	0.17	0.29	0.08	$F_{55.5\%}$
		6	0.27	0.2	0.35	0.13	$F_{42.4\%}$
		7	0.29	0.21	0.38	0.15	$F_{38.8\%}$
		8	0.32	0.23	0.41	0.18	$F_{34.4\%}$
		9	0.36	0.27	0.46	0.22	$F_{30.0\%}$
		10	0.35	0.26	0.46	0.21	$F_{31.0\%}$
Dusky (MR)		5	0.19	0.14	0.24	0.05	$F_{66.7\%}$
		6	0.22	0.16	0.28	0.08	$F_{55.1\%}$
		7	0.24	0.17	0.31	0.1	$F_{49.2\%}$
		8	0.28	0.2	0.36	0.14	$F_{40.5\%}$
		9	0.33	0.24	0.44	0.19	$F_{33.2\%}$
		10	0.36	0.26	0.47	0.22	$F_{30.0\%}$
North Otago	2005	5	0.35	0.25	0.47	0.21	$F_{25.1\%}$
		6	0.44	0.31	0.58	0.3	$F_{18.7\%}$
		7	0.47	0.33	0.63	0.33	$F_{17.3\%}$
		8	0.54	0.38	0.75	0.4	$F_{14.8\%}$
		9	0.62	41%	0.89	0.48	$F_{12.8\%}$
		10	0.52	0.33	0.76	0.38	$F_{15.4\%}$
North Otago	2009	5	0.25	0.18	0.34	0.11	$F_{41.2\%}$
		6	0.30	0.22	0.4	0.16	$F_{31.7\%}$
		7	0.35	0.25	0.45	0.21	$F_{25.6\%}$
		8	0.41	0.29	0.54	0.27	$F_{20.9\%}$
		9	0.50	0.36	0.67	0.36	$F_{16.6\%}$
		10	0.56	0.39	0.77	0.42	$F_{14.7\%}$

**BLUE COD (BCO)**

**Table 14 [Continued].**

Survey area	Year	ageR	Z	lowCI	upCI	F	F%SPR		
Banks Peninsula (all strata)	2002	5	0.22	0.16	0.28	0.08	F <sub>52.6%</sub>		
		6	0.19	0.14	0.25	0.05	F <sub>64.6%</sub>		
		7	0.18	0.13	0.23	0.04	F <sub>69.8%</sub>		
		8	0.17	0.13	0.23	0.03	F <sub>75.7%</sub>		
		9	0.18	0.14	0.24	0.04	F <sub>69.8%</sub>		
		10	0.19	0.14	0.26	0.05	F <sub>64.6%</sub>		
		inshore		5	0.65	0.43	0.93	0.51	F <sub>14.6%</sub>
				6	0.69	0.45	0.96	0.55	F <sub>13.8%</sub>
				7	0.47	0.3	0.69	0.33	F <sub>20.1%</sub>
				8	0.59	0.34	0.89	0.45	F <sub>16.0%</sub>
9	0.60			0.33	1	0.46	F <sub>15.8%</sub>		
10	0.78			0.38	1.4	0.64	F <sub>12.5%</sub>		
offshore		5	0.14	0.11	0.18	0	F <sub>100%</sub>		
		6	0.14	0.1	0.18	0	F <sub>100%</sub>		
		7	0.15	0.11	0.2	0.01	F <sub>90.6%</sub>		
		8	0.15	0.11	0.2	0.01	F <sub>90.6%</sub>		
		9	0.17	0.13	0.22	0.03	F <sub>75.7%</sub>		
		10	0.18	0.14	0.24	0.04	F <sub>69.8%</sub>		
Banks Peninsula (all strata)	2005	5	0.23	0.16	0.29	0.09	F <sub>49.4%</sub>		
		6	0.23	0.17	0.3	0.09	F <sub>49.4%</sub>		
		7	0.23	0.17	0.31	0.09	F <sub>49.4%</sub>		
		8	0.23	0.17	0.31	0.09	F <sub>49.4%</sub>		
		9	0.23	0.16	0.3	0.09	F <sub>49.4%</sub>		
		10	0.21	0.15	0.28	0.07	F <sub>56.1%</sub>		
		inshore		5	0.43	0.31	0.58	0.29	F <sub>22.2%</sub>
				6	0.48	0.33	0.67	0.34	F <sub>19.7%</sub>
				7	0.53	0.36	0.75	0.39	F <sub>17.7%</sub>
				8	0.62	0.41	0.89	0.48	F <sub>15.2%</sub>
9	0.63			0.39	0.91	0.49	F <sub>15.0%</sub>		
10	0.64			0.36	0.99	0.5	F <sub>14.8%</sub>		
offshore		5	0.13	0.1	0.17	0.01	F <sub>100%</sub>		
		6	0.15	0.11	0.19	0.01	F <sub>90.6%</sub>		
		7	0.16	0.12	0.21	0.02	F <sub>82.6%</sub>		
		8	0.18	0.13	0.23	0.04	F <sub>69.8%</sub>		
		9	0.18	0.13	0.24	0.04	F <sub>69.8%</sub>		
		10	0.19	0.13	0.24	0.05	F <sub>64.6%</sub>		

Table 14 [Continued].

Survey area	Year	ageR	Z	lowCI	upCI	F	F%SPR
Banks Peninsula (all strata)	2008	5	0.17	0.13	0.22	0.03	<i>F</i> <sub>76.1%</sub>
		6	0.16	0.12	0.20	0.02	<i>F</i> <sub>82.9%</sub>
		7	0.17	0.12	0.22	0.03	<i>F</i> <sub>76.1%</sub>
		8	0.17	0.12	0.22	0.03	<i>F</i> <sub>76.1%</sub>
		9	0.16	0.12	0.21	0.02	<i>F</i> <sub>82.9%</sub>
		10	0.17	0.13	0.23	0.03	<i>F</i> <sub>76.1%</sub>
inshore		5	0.54	0.36	0.76	0.40	<i>F</i> <sub>18.0%</sub>
		6	0.54	0.35	0.80	0.40	<i>F</i> <sub>18.0%</sub>
		7	0.69	0.43	1	0.55	<i>F</i> <sub>14.4%</sub>
		8	0.74	0.4	1.20	0.60	<i>F</i> <sub>13.6%</sub>
		9	0.58	0.29	1.07	0.44	<i>F</i> <sub>16.8%</sub>
		10	0.86	0.35	1.9	0.72	<i>F</i> <sub>12.1%</sub>
offshore		5	0.14	0.1	0.17	0	<i>F</i> <sub>100%</sub>
		6	0.15	0.11	0.19	0.01	<i>F</i> <sub>90.8%</sub>
		7	0.15	0.11	0.19	0.01	<i>F</i> <sub>90.8%</sub>
		8	0.16	0.12	0.21	0.02	<i>F</i> <sub>82.7%</sub>
		9	0.17	0.12	0.21	0.03	<i>F</i> <sub>76.1%</sub>
		10	0.17	0.13	0.22	0.03	<i>F</i> <sub>76.1%</sub>
Kaikoura	2004	5	0.27	0.20	0.36	0.13	<i>F</i> <sub>42.1%</sub>
		6	0.30	0.22	0.39	0.16	<i>F</i> <sub>36.9%</sub>
		7	0.30	0.22	0.40	0.16	<i>F</i> <sub>36.9%</sub>
		8	0.28	0.20	0.37	0.14	<i>F</i> <sub>40.2%</sub>
		9	0.26	0.19	0.35	0.12	<i>F</i> <sub>44.1%</sub>
		10	0.27	0.19	0.37	0.13	<i>F</i> <sub>42.1%</sub>
Kaikoura	2007	5	0.31	0.22	0.42	0.17	<i>F</i> <sub>35.1%</sub>
		6	0.35	0.25	0.47	0.21	<i>F</i> <sub>30.3%</sub>
		7	0.43	0.31	0.59	0.29	<i>F</i> <sub>23.9%</sub>
		8	0.47	0.32	0.63	0.33	<i>F</i> <sub>21.8%</sub>
		9	0.41	0.27	0.57	0.27	<i>F</i> <sub>25.2%</sub>
		10	0.33	0.22	0.46	0.19	<i>F</i> <sub>32.5%</sub>

## BLUE COD (BCO)

Table 14 [Continued].

Survey area	Year	ageR	Z	lowCI	upCI	F	F%SPR
Motunau	2005	5	0.53	0.33	0.77	0.39	$F_{19.5\%}$
		6	0.80	0.47	1.23	0.66	$F_{13.6\%}$
		7	0.74	0.41	1.17	0.6	$F_{14.5\%}$
		8	0.73	0.41	1.26	0.59	$F_{14.6\%}$
		9	1.34	0.63	2.26	1.2	$F_{9.0\%}$
		10	1.13	0.48	2.13	0.99	$F_{10.8\%}$
Motunau	2008	5	0.53	0.37	0.72	0.39	$F_{18.2\%}$
		6	0.60	0.42	0.83	0.46	$F_{16.1\%}$
		7	0.71	0.48	0.98	0.57	$F_{13.8\%}$
		8	0.79	0.49	1.16	0.65	$F_{12.6\%}$
		9	0.95	0.52	1.49	0.81	$F_{11.0\%}$
		10	1.12	0.50	2.29	0.98	$F_{9.8\%}$

## 4.2 BCO 3

### Cod potting

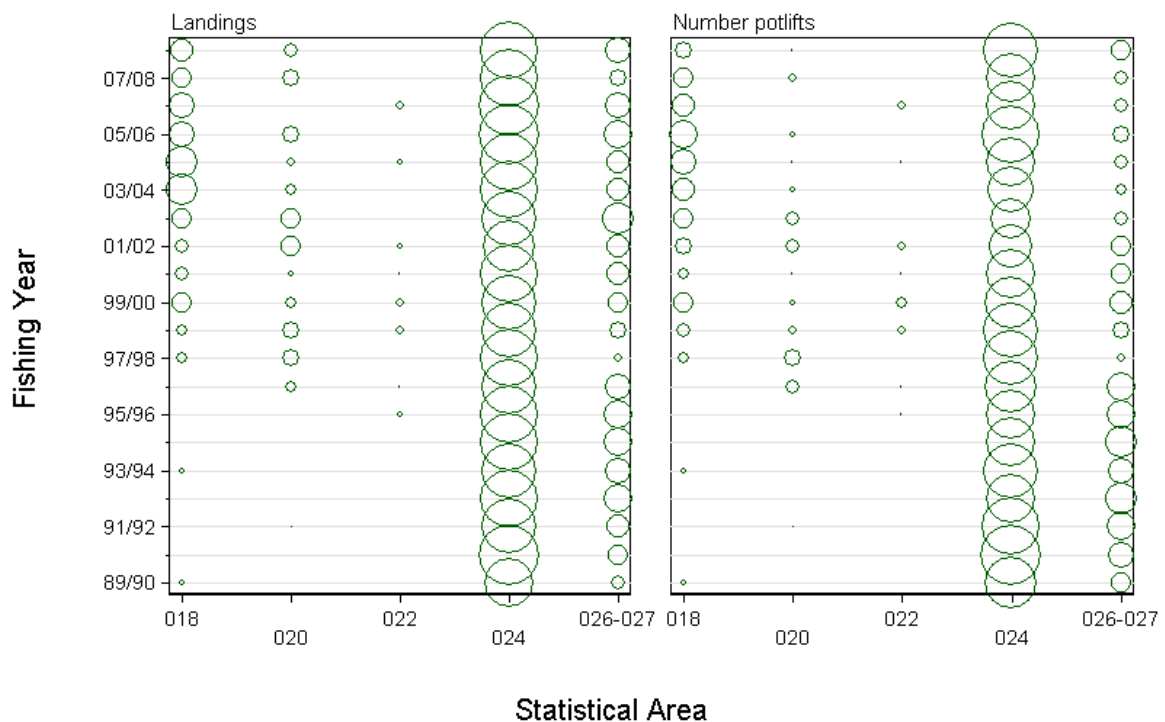


Figure 3: Distribution of landings and number of potlifts for the cod potting method by grouped statistical area (Table 9) and fishing year from trips which landed BCO 3. Circles are proportional within each panel: [catches] largest circle = 92 t in 05/06 for 024; [number potlifts] largest circle = 7 831 pots in 90/91 for 024 (Starr & Kendrick 2010).

A standardised CPUE analysis was conducted in 2010 on the target blue cod potting fishery operating in BCO 3. This fishery accounted for two-thirds of the total BCO 3 landings in the 20 years from 1989-90 to 2008-09 (see Table 10; Starr & Kendrick 2010), predominantly in the two southernmost BCO 3 Statistical Areas: 024 and 026. Together these two areas represented about 90% of the total target blue cod potting fishery over the same 20 years (Figure 3 and see Table 12; Starr & Kendrick 2010).

2010). There was a serious impediment to this analysis in that it was discovered that there was likely misreporting of RCO 3 landings as BCO 3, probably due to data entry errors. This problem was resolved prior to undertaking the CPUE analysis (Starr & Kendrick 2010).

The effort data were matched with the landing data at the trip level and the daily stratification inherent in the CELR data was maintained. Each analysis was confined to a set of core vessels which had participated consistently in the fishery for a reasonably long period. The explanatory variables offered to the model included fishing year (forced), month, vessel, statistical area, and number of pots lifted in a day. Because there was also an estimated catch of blue cod recorded with nearly every effort record, it was also possible to repeat the standardised analysis based on estimated catch as well as the landed catch. This was done to provide a check on the methods used to groom the landing data of the spurious RCO 3 landing data. Only a lognormal model based on successful catch records was presented as there were too few unsuccessful fishing events to justify pursuing a binomial model.

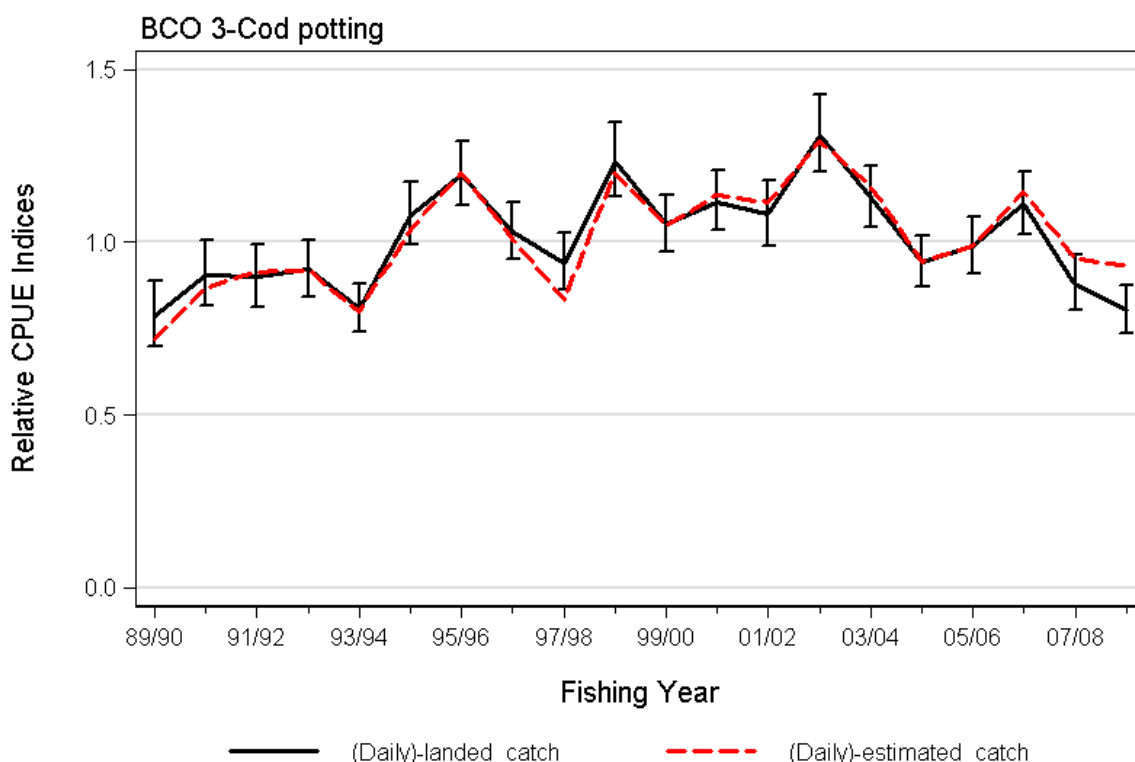


Figure 4: Comparison of BCO 3 standardised series based on landed greenweight catch data and daily estimated catch (Starr & Kendrick 2010).

The lognormal standardised model for BCO 3 (Figure 4) showed a declining trend in commercial CPUE since 2002-03 after a relatively long period of stability. While the Estimated Daily Catch model was thought to be more reliable, both models showed similar trends, with the exception of 2007-08 and 2008-09, where the estimated catch model showed a lesser decline. During the period 2002-03 to 2008-09, commercial catches in all of BCO 3 exceeded the TACC by 5%. As the bulk of the total BCO 3 commercial catch (74%) was taken from Statistical Areas 024 and 026 (along with about 90% of the CPUE data), both the CPUE and catch trends for BCO 3 are strongly influenced by the catches in these areas. Therefore, the Working Group agreed that the CPUE trend presented for the Daily Landed Catch analysis in Figure 4 is representative of the southerly portion of BCO 3 (Areas 024 and 026) and is not applicable to those parts of BCO 3 north of Area 024.

### 4.3 BCO 4

The cod potting fishery in BCO 4 is entirely targeted on blue cod and reported on the daily CELR form. The spatial resolution of the catch effort data is therefore defined by general statistical area, and by day (or part of a day). CPUE was standardised for the cod pot fishery operating in statistical areas 049 to 052 (Kendrick & Bentley 2011). The analysis was based on a lognormal model of positive allocated landed catches from a core fleet of vessels.

## BLUE COD (BCO)

The annual indices from the model increase steadily up to 2001-02 and has fluctuated without trend since then (Figure 5). The fishery shows considerable stability in the way that it has operated over time, although there have been some spatial shifts in catch. Catch rates aren't predicted to vary significantly among statistical areas and so the spatial shifts haven't influenced observed CPUE significantly.

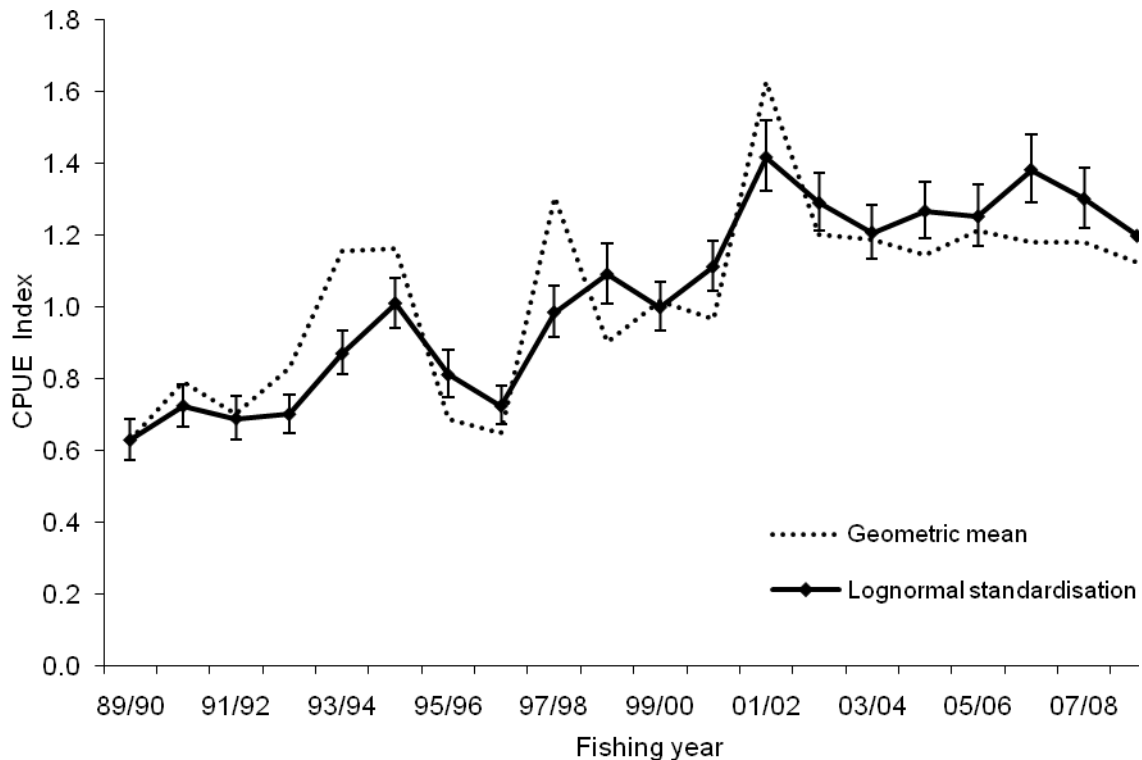


Figure 5: Standardised CPUE analysis of BCO 4 based on records of positive BCO catch by core vessels standardised to the 1994-95 to 2009-10 geometric mean (Kendrick 2011).

### 4.4 BCO 5 (Southland)

The first fully quantitative stock assessment for blue cod in BCO 5 was carried out in 2013. A custom-built length-based model, which used Bayesian estimation, was fitted separately to data from Statistical Areas 25, 27 and 30.

#### 4.4.1 Methods

##### 4.4.1.1 Model structure

The stock assessment model is length-based and sex-specific, using growth transition matrices calculated from the von Bertalanffy growth models to transition fish through size bins. This approach is similar to that used for New Zealand rock lobster (Haist et al. 2009).

The model is conditioned on the landings for the three modelled fisheries (commercial line, commercial pot, and recreational line), using a Newton-Raphson algorithm to calculate fishing mortality rates for each sex, length bin and fishery. Each fishery is modelled with a selectivity ogive and a retention ogive (Table 15). Catch and catch LFs are a function of the selectivity ogive and landings and landings LFs are a function of the product of selectivity and retention ogives. Separate pre-1993 and post-1992 commercial and recreational fishery retention functions account for the change in minimum legal size (MLS) in 1993. Separate pre-1993 and post-1993 commercial fishery selectivity functions account for change in mesh size regulation at that time, with the assumption that

the selectivity change was gradual over 5 years. Discard mortality is assumed for fish that are caught but not landed.

Sex change is modelled as a dynamic process, with the proportion of females (at length) transitioning to males a function of male depletion. Spawning stock biomass (SSB) is measured as the total mature biomass.

A Beverton-Holt stock recruitment relationship is assumed. The standard deviation of recruitment residuals (log-scale) is fixed at 0.6 and the steepness prior is beta distributed (mean= 0.75, std. dev.=0.10). Recruitment residuals are estimated for 1980 to 2010. Fish recruit to the model at age 0+ with 65% of fish recruiting as females.

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

The populations are initialised at unexploited equilibrium conditions in 1900.

The assumed prior distributions for model parameters are given in Table 16.

**Table 15: Model selectivity and retention ogives by fishery, their parametric form, and parameter values if fixed or data fitted in the model to inform their estimation. DHN = double half normal.**

Ogives	Type	Parameters if fixed or data to inform
<u>Selectivity</u>		
Commercial line fishery	Logistic	50% selected at 280 mm; 95% selected at 305 mm
Commercial pot fishery <=1992	DHN	Mesh size trial LF
Commercial pot fishery >=1997	Logistic	Logbook & Shed sampling LF
Recreational fishery	DHN	Recreational catch LF
Survey	DHN	Survey LF
<u>Retention</u>		
Commercial line fishery	Knife-edge	MLS (330 mm)
Commercial pot fishery <=1992	Knife-edge	MLS
Commercial pot fishery >=1993	Knife-edge	MLS
Recreational fishery <=1992	Logistic	Recreational landings LF
Recreational fishery >=1993	Logistic	Shifted +3 cm from <=1992 retention curve

**Table 16: Assumed prior distributions for model parameters.**

Model parameters	Distribution	Parameters
M	Normal	Mean: 0.14 Std. dev: 0.015
S-R steepness	Beta (defined on 0.2 – 1.0)	Mean: 0.75 Std. dev: 0.10
Recruitment variation	Normal-log	Std. dev: 0.60
1995 sex-change <i>dmax</i>	Normal-log	Mean: ln(410) Std. dev: 0.05

#### 4.4.1.2 Data

Separate data sets were compiled and analysed for Statistical Areas 25, 27, and 30. The data available for each of these areas differs, and little data are available for the remainder of the BCO 5 Statistical Areas. Combined, Statistical Areas 25, 27 and 30 represent 92% of the recent commercial fishery landings. The general categories of data used in the stock assessment models include: catch and landings; fishery and survey length frequency data (LFs); abundance indices; and biological information on growth, maturation, and sex change.

Historical time series of BCO 5 landings were constructed for 3 gear types: commercial hand line fishing, commercial pot fishing, and recreational fishing. Additionally, non-reported blue cod catch used as bait in the CRA 8 rock lobster fishery was estimated and included with the commercial landings, and customary catch estimates were included with the recreational harvest.

## BLUE COD (BCO)

Commercial landings data are available beginning in 1931 (Warren et al. 1997) and these were linearly decreased to 1900, when the fishery was assumed to begin. The 1989-90 to 2011-12 average proportion of the total BCO 5 catch in each Statistical Area was used to prorate the earlier landings estimates to Statistical Area. A time series of non-reported blue cod used as bait in the rock lobster fishery was developed based on a 1985 diary study (Warren et al. 1997) in conjunction with CRA 8 rock lobster landings.

A time series of recreational blue cod harvest was developed based on the 1991-92 and 1996 diary survey estimates of BCO 5 recreational catch. The average blue cod catch per Southland resident was estimated from the survey data, and assuming a constant per capita catch rate extrapolated to a time series using Southland District population census data.

Commercial fishery LF data were collected through a commercial fishers' logbook project and a shed sampling project from 2009 through 2011. The shed sampling was sex-specific while the logbook sampling was not. It is unclear whether samples collected for shed sampling were of the entire catch or of landings. Mean size of fish from the shed samples were smaller than those from the logbook program (for Areas 25 and 27, there were not shed samples from Area 30), which may have resulted because the shed samples were not representative of the entire fishing area. The shed and logbook LF data are each fitted to model predictions of the average commercial catch size distribution for 2009 through 2011.

Recreational fishery LFs were obtained from a 2009-10 study of the Southland recreational blue cod fishery (Davey & Hartill 2011). This study included a boat ramp survey (Bluff, Riverton/Colac, and Halfmoon Bay) and a logbook survey of charter and recreational vessels. Blue cod measured through the boat ramp program were assumed to represent the landings and fish measured through the logbook program were assumed to represent the catch.

Length frequency data from a blue cod mesh size selectivity study, conducted by MAF in 1986 at Bluff and Stewart Island, were available. The LFs from pots fitted with the then-standard 38 mm mesh were assumed to represent the size composition of the BCO 5 commercial pot fishery catch prior to the 1992 and 1994 pot regulation changes. In the model, this data is fitted to the predicted average size distribution of the 1985 through 1992 potting fishery.

LF data is also available from random stratified potting surveys conducted in Areas 25 and 30 in 2010. These surveys provide not only length frequency data, but also are one of the few information sources about the population sex structure. These data are fitted in the model assuming domed survey selectivity.

Three sets of data are available that can inform stock abundance estimates: fishery-based standardised CPUE estimates (Table 17), survey-based estimates of total mortality ( $Z$ ), and a drift underwater video survey (DUV) estimate of absolute stock abundance.

$Z$  estimates were derived from the 2010 Area 25 and Area 30 random-stratified potting survey data using standard methods described in Beentjes and Francis (2011). The distributions of  $Z$  estimates are approximately lognormal and are fitted with lognormal priors in the stock assessment model. The mean  $Z$  estimate for Area 30 (0.377) is slightly lower than that for Area 25 (0.465).

A DUV survey was conducted in Area 25 in 2010, surveying a number of the random-stratified sites that were sampled during the potting survey. The survey estimate of the mean density of legal-sized blue cod was extrapolated to the total Area 25 area to generate a total abundance estimate. This was fitted to model-predicted 2010 legal-sized blue cod abundance.

The data fitted in the models for each Statistical Area are shown in Table 18 and the assumed error structure of each data series is shown in Table 19.

**4.4.1.3 Further assumptions**

Sex-specific von Bertalanffy growth parameters are available from Area 25 and Area 30 random-stratified potting surveys (refs.). The Area 25 growth models were assumed for Area 27. Both male and female blue cod are assumed to mature at a length of 280 mm (Carbines 2004).

Sex-change data was available from a 1995 Foveaux Strait study that characterised blue cod by state: male, female, or transitional (Carbines 2004). The proportions of transitional females by length bin were fitted with a parametric relationship to describe the sex-change process. The maximum proportion transitional was observed at 410 mm.

Assuming that sex-change is a function of the relative abundance of mature males was found to result in fewest model convergence issues. The length at 50% sex change ( $dmax$ ) is modelled as a function of the ratio of mature male biomass in year  $y$  ( $B_y^M$ ) relative to mature male biomass in the virgin state

$$(B_0^M):$$

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

where the parameters  $\lambda$  and  $\delta$  are estimated through the model fitting. In practice, only  $\lambda$  was estimated and  $\delta$  was fixed. This model results in the form of the sex-change relationship remaining the same except that it is shifted along the length-axis. With this parameterisation it is not possible to fix the 1995 length at 50% sex change (to 410 mm, as observed in the sex transition data set collected in 1995), so a penalty function is used to encourage that value.

**Table 17: Standardised CPUE indices for Statistical Areas 25, 27 and 30.**

Fishing Year	Area 25	Area 27	Area 30
1990	0.803	0.603	0.925
1991	0.748	0.607	0.860
1992	0.815	0.665	1.026
1993	0.854	0.835	0.846
1994	0.847	0.648	0.689
1995	0.808	0.796	0.669
1996	0.943	1.022	0.657
1997	1.043	1.241	1.011
1998	1.084	1.116	1.141
1999	0.972	1.152	1.224
2000	1.034	1.292	1.185
2001	1.143	1.466	1.098
2002	1.160	1.743	1.453
2003	1.256	1.532	1.422
2004	1.145	1.602	1.359
2005	1.283	1.219	1.262
2006	1.253	1.127	1.172
2007	1.035	0.881	1.093
2008	1.017	0.888	0.924
2009	1.023	0.894	0.939
2010	0.984	0.901	0.961
2011	1.006	0.888	0.839
2012	0.998	0.940	0.819

## BLUE COD (BCO)

**Table 18: Data series fitted in the stock assessments for Areas 25, 27, and 30.**

Data type	Series	Area 25	Area 27	Area 30
LF data:	Shed	✓	✓	-
	Logbook	✓	✓	✓
	Survey	✓	-	✓
	Mesh sel. trials	data common to all areas		
	Rec. landings	data common to all areas		
	Rec. catch	data common to all areas		
Abundance Index:	CPUE	✓	✓	✓
	Survey Z	✓	-	✓
	DUV abundance	✓	-	-

**Table 19: Assumed distributions for data fitted in the models.**

Data type	Distribution	Parameters
Logbook LF	Multinomial	N: 100
Shed samples LF	Multinomial	N: 100
Mesh size trials LF	Multinomial	N: 100
Recreational catch LF	Multinomial	N: 100
Recreational landings LF	Multinomial	N: 100
Survey LF	Multinomial	N: 100
CPUE	Normal-log	Std. dev: 0.20
Survey Z –Area 25	Normal-log	Mean: -0.782 Std. dev: 0.178
Survey Z –Area 30	Normal-log	Mean: -0.991 Std. dev: 0.173
DUV LegalN	Normal-log	Mean: 15.163 Std. dev: 0.300

### 4.4.1.4 Calculation of fishing intensity and $B_{MSY}$

Fishing intensity is measured as the spawning biomass per recruit (SPR).  $F_{\%SPR}$  is the ratio of spawning biomass per recruit at a given level of fishing mortality relative to the spawning biomass per recruit in the absence of fishing. This metric was selected to represent fishing intensity because estimates for the entire BCO 5 stock can readily be calculated from the Statistical Area estimates.

MSY statistics are calculated assuming deterministic recruitment and the final years' selectivity and retention ogives. The recreational and customary fisheries are held fixed at the current levels, and only the commercial fishery varied to determine MSY.  $B_{MSY}$  is measured as total mature biomass and MSY is presented as the commercial catch at  $B_{MSY}$ .

#### *Caution about the interpretation of $B_{MSY}$ estimates*

There are several reasons why  $B_{MSY}$ , as calculated in this way, is not a suitable target for management of blue cod fisheries. First, it assumes a harvest strategy that is unrealistic in that it involves perfect knowledge (current biomass must be known exactly in order to calculate the target catch) and annual changes in TACC (which are unlikely to happen in New Zealand and not desirable for most stakeholders). Second, it assumes perfect knowledge of the stock-recruit relationship, which is actually very poorly known. Third, it makes no allowance for extended periods of low recruitment. Fourth, it would be very difficult with such a low biomass target to avoid the biomass occasionally falling below 20%  $B_0$ , the default soft limit according to the Harvest Strategy Standard.

### 4.4.1.5 Biomass Estimates

The assessment was conducted in two steps. First, a set of initial exploratory model runs was carried out generating point estimates (MPD runs, which estimate the mode of the posterior distribution). Their purpose was to decide which sets of assumptions should be carried forward to the final runs. The final runs were fully Bayesian, estimating posterior distributions for all quantities of interest.

The modelling assumptions and approaches investigated through the exploratory model runs included: the dynamics of sex-change; what assumptions to make about LF data from the logbook and shed sampling programs; the magnitude of recruitment variation; the magnitude of error in fits to the CPUE data; the form of the survey and recreational fishery selectivity; and sensitivity to alternative assumptions about recreational catch, bait usage, and discard mortality rates.

Four final runs were chosen by the Working Group: a *base case* and three sensitivities to the *base case*. The sensitivity runs each modify a single assumption of the *base case*. The sex-change power parameter (delta in equation above) is fixed at 0.4 for the *base case*. Two of the sensitivity runs modify this parameter to values of 0.2 and 0.6. The third sensitivity run reduces the recreational catch time series by 50%.

Label	Description
1.1	Base case
1.2	Sex-change power parameter=0.2
1.3	Sex-change power parameter=0.6
1.4	Recreational catch reduced by 50%

Bayesian posterior distributions were estimated for each of these runs using a Markov Chain Monte Carlo (MCMC) approach. For each run a chain of 1 million was completed and the chains thinned to produce a posterior sample of 1000. BCO 5 summary statistics are calculated summing across Areas 25, 27, and 30.  $B_{MSY}$  and  $MSY$  are calculated assuming these areas account for 92% of the BCO 5 stock.

The model estimates are summarised in Table 20 (estimates of spawning biomass and  $MSY$ ), Figure 6 (biomass trajectories), Figure 7 (current biomass distribution), Figure 8 (fishing intensity trajectories), and Figure 9 (recruitment trajectories).

The runs with the higher sex-change power parameter (run 1.3) have higher male and lower female spawning abundance in the unfished populations and runs with the lower sex-change power parameter (run 1.2) have lower male and higher female initial abundance. Current biomass and the combined male and female  $B_0$  do not differ much among the runs. Assuming lower recreational catch (run 1.4) results in a slightly lower  $B_0$  estimate and slightly higher current biomass. Area 25 is somewhat more depleted than Areas 27 and 30.

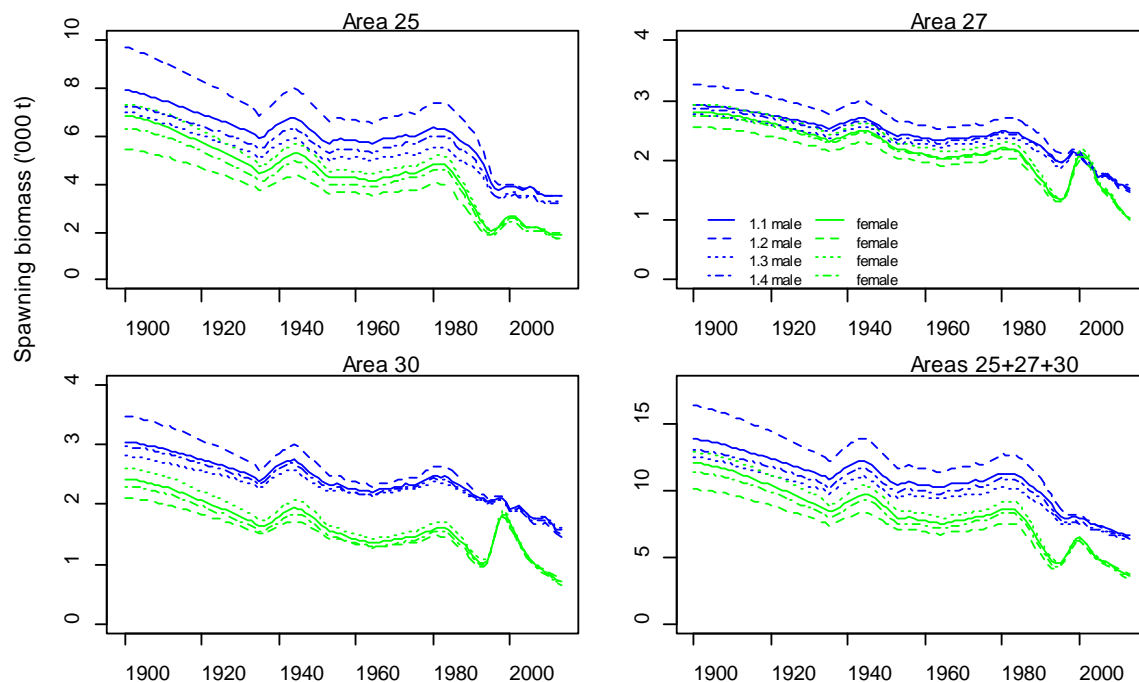
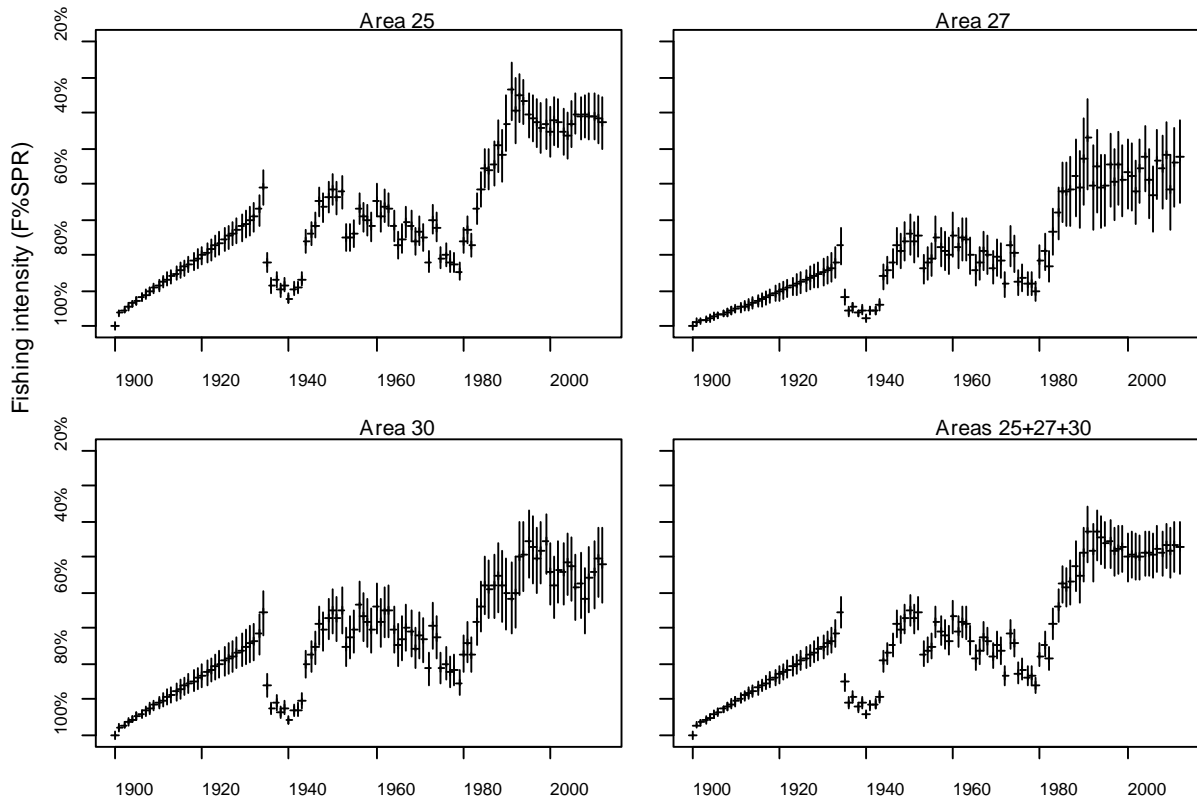
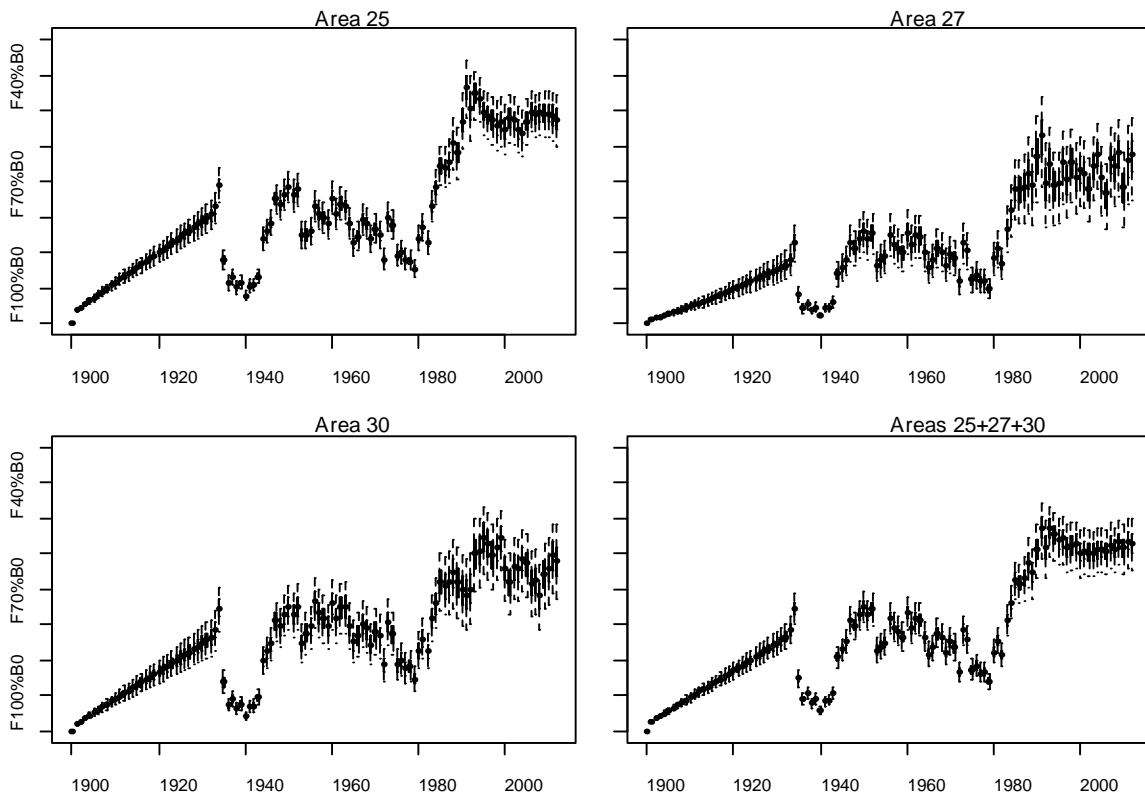


Figure 6: Median estimates of Area 25, Area 27, Area 30, and Areas combined male and female spawning biomass for the base case and sensitivity runs, 1900 – 2012.

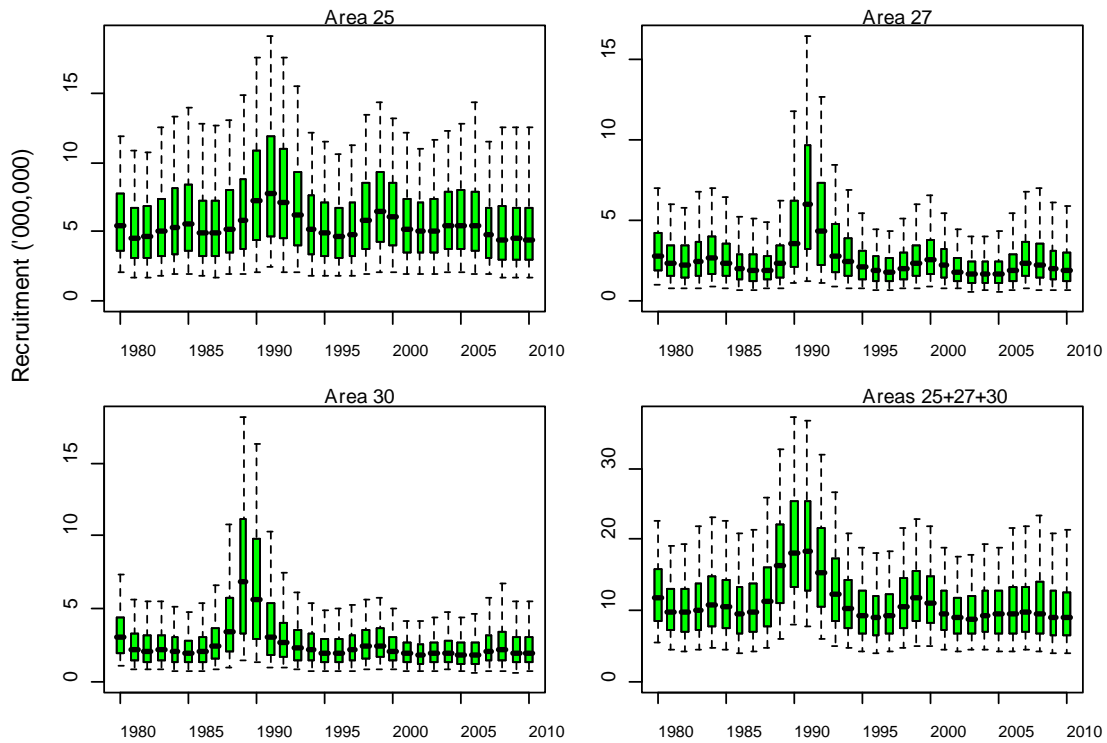
**BLUE COD (BCO)**



**Figure 7: Fishing intensity ( $F_{\%SPR}$ ) estimates from the base case runs for Areas 25, 27, 30, and the Areas combined, 1900-2012. The horizontal lines show the median and the vertical lines show the 90% confidence intervals.**



**Figure 8: Fishing intensity ( $F_{\%SPR}$ ) estimates from the base case runs for Areas 25, 27, 30, and the Areas combined, 1900-2012. The solid boxes show the interquartile range and the whiskers show the 90% confidence limits.**



**Figure 9: Recruitment estimates from the base case runs for Areas 25, 27, 30, and the Areas combined, 1980-2010. The boxes show the interquartile range, the whiskers show the 90% confidence limits, and the bars show the medians.**

Fishing intensity has remained below  $F_{40\%SPR}$ , except in Area 25 for a brief period in the 1990s. Recruitment has been slightly below average in all three Areas over the last decade.

**Table 20: Estimates of BCO 5 spawning stock biomass,  $MSY$  and  $B_{MSY}$  for final runs (medians of marginal posterior distributions, with 90% confidence intervals in parentheses).  $B_0$  and  $MSY$  are calculated assuming Areas 25, 27 and 30 represent 92% of the BCO 5 blue cod stock.**

Run	$B_0$ (,000 t)	$B_{current}$ (% $B_0$ )	$MSY$	$B_{MSY}$ (% $B_0$ )
1.1	28(25,31)	39(31,51)	1336(1092,1589)	31(29,35)
1.2	28(26,31)	39(30,50)	1316(1088,1569)	32(29,35)
1.3	27(24,31)	39(30,50)	1345(1114,1607)	31(28,34)
1.4	26(24,29)	40(31,51)	1335(1115,1615)	31(29,35)

#### 4.4.1.6 Yield estimates and projections

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

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

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

## BLUE COD (BCO)

recruitment deviations and long-term recruitments were re-sampled from the 1980 through 2010 recruitments.

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

The projections indicate that under the assumptions of commercial catch at the current TACC and recruitment at recent levels the BCO 5 biomass is unlikely to change much over the next 10 years (Figure 10). Recruitments closer to the long-term average or a reduction in catch from the current TACC results in slight increases in biomass and an increase in catch above the TACC results in a slight decrease in biomass. Although the spawning stock sex ratio is variable among the sensitivity trials, by 2013 and through the projection period the sex ratio remains relatively constant (Table 21).

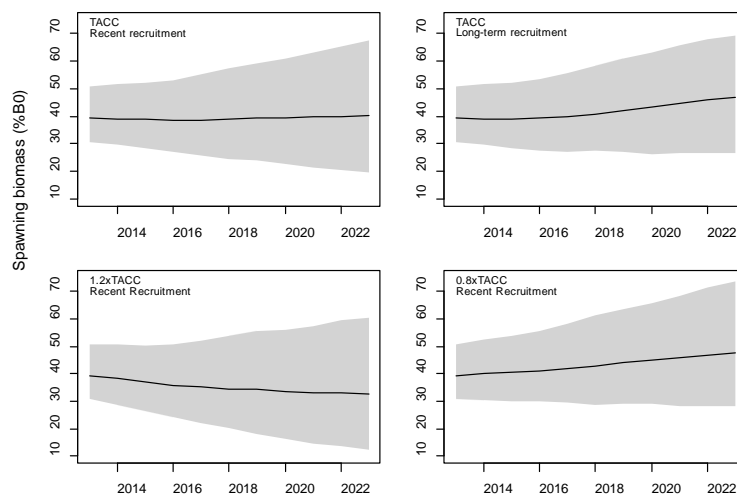
The probabilities of the projected spawning stock biomass (2018 and 2023) being below the hard limit of 10%  $B_0$ , the soft limit of 20%  $B_0$ , the target of 40%  $B_0$ , and 25%, 50% and 100% of  $B_{MSY}$  are presented in Table 22, for the base case model with recent or long-term recruitment and 3 catch levels and for the sensitivity runs with recent recruitment and commercial catch at the current TACC. With catches at the current TACC, the probability of the stock being less than either the soft or hard limit over the next five years is negligible.

There are no time series of length frequency observations for the BCO 5 stock assessment. So, while the assessment indicates a BCO 5 recruitment pulse in the early 1990s, the information to support this pulse comes solely from the CPUE data, and hence may be spurious.

The sex change predictions also need to be viewed with caution as there are few data to inform the parameters and the form of the equation.

**Table 21: Median estimates of the proportion male in the 1900, 2013, 2018 and 2023 BCO 5 spawning stock at alternative recruitment and catch levels for the *base case* and sensitivity stock projections.**

Run	1.1						1.2	1.3	1.4
Recruitment	Recent	Recent	Recent	Long-term	Long-term	Long-term	Recent	Recent	Recent
Catch Level	TACC	1.2·TACC	0.8·TACC	TACC	1.2·TACC	0.8·TACC	TACC	TACC	TACC
1900	0.41	0.41	0.41	0.41	0.41	0.41	0.47	0.39	0.41
2013	0.51	0.51	0.51	0.51	0.51	0.51	0.49	0.51	0.51
2018	0.48	0.51	0.51	0.47	0.51	0.51	0.50	0.48	0.49
2023	0.51	0.52	0.49	0.49	0.51	0.48	0.49	0.52	0.51



**Figure 10: Projected BCO 5 spawning biomass (% $B_0$ ) assuming recent or long-term recruitment and catch at current TACC or increased/decreased by 20% for the base case run. Median estimates are shown as solid lines and 90% confidence intervals as shaded polygons.**

**Table 22: Probabilities of SSB being below  $B_0$  and  $B_{msy}$  reference levels in 2013, 2018 and 2023 at alternative recruitment and catch levels for the *base case* and sensitivity stock projections.**

Run	1.1						1.2	1.3	1.4
	Recent	Recent	Recent	Long-term	Long-term	Long-term	Recent	Recent	Recent
Catch Level	TACC	1.2·TACC	0.8·TACC	TACC	1.2·TACC	0.8·TACC	TACC	TACC	TACC
$P(B_{2013} < 0.1 B_0)$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.2 B_0)$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.4 B_0)$	0.538	0.538	0.538	0.538	0.538	0.538	0.576	0.549	0.532
$P(B_{2013} < 0.25 B_{msy})$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < 0.5 B_{msy})$	0	0	0	0	0	0	0	0	0
$P(B_{2013} < B_{msy})$	0.095	0.095	0.095	0.095	0.095	0.095	0.116	0.091	0.078
$P(B_{2018} < 0.1 B_0)$	0.001	0.002	0	0	0.001	0	0	0	0
$P(B_{2018} < 0.2 B_0)$	0.010	0.048	0.002	0.003	0.024	0	0.012	0.007	0.015
$P(B_{2018} < 0.4 B_0)$	0.543	0.694	0.379	0.470	0.622	0.288	0.578	0.578	0.605
$P(B_{2018} < 0.25 B_{msy})$	0	0.002	0	0	0	0	0	0	0
$P(B_{2018} < 0.5 B_{msy})$	0.002	0.014	0	0	0.006	0	0.004	0.002	0.005
$P(B_{2018} < B_{msy})$	0.230	0.377	0.114	0.153	0.294	0.069	0.249	0.215	0.262
$P(B_{2023} < 0.1 B_0)$	0.003	0.024	0.002	0	0.005	0	0.007	0.004	0.006
$P(B_{2023} < 0.2 B_0)$	0.053	0.173	0.008	0.019	0.077	0	0.052	0.051	0.074
$P(B_{2023} < 0.4 B_0)$	0.498	0.681	0.271	0.289	0.533	0.110	0.491	0.505	0.553
$P(B_{2023} < 0.25 B_{msy})$	0.001	0.014	0	0	0.002	0	0.004	0.003	0.002
$P(B_{2023} < 0.5 B_{msy})$	0.021	0.107	0.004	0.009	0.037	0	0.025	0.018	0.040
$P(B_{2023} < B_{msy})$	0.256	0.473	0.105	0.113	0.306	0.030	0.272	0.257	0.305

#### 4.5 Other factors

The target blue cod fishery is chiefly a pot fishery and there are few significant bycatch problems. However, in recent years bycatch associated with the inshore fleet of trawlers has increased in BCO 3 and BCO 7. Blue cod is only a very minor bycatch of the offshore fleet.

Before the introduction of the QMS, blue cod landings were affected by factory limits imposed in some parts of Southland, and there were economic constraints to the development of the fishery at the Chatham Islands (BCO 4).

Blue cod fishing patterns have been strongly influenced by the development and subsequent fluctuations in the rock lobster fishery, especially in the Chatham Islands, Southland and Otago. Once a labour intensive handline fishery, blue cod are now taken mostly by cod pots. The fishery had decreased in the past; however, with the advent of cod pots it rapidly redeveloped. Large areas are currently not heavily fished and there are some areas such as the Mernoo Bank, the Puysegur Bank and South Traps which are potentially productive fisheries. Anecdotal information from recreational fishers suggests that there is local depletion in some parts of BCO 3, BCO 5 and BCO 7 where fishing has been concentrated. Both blue cod catch (Cranfield *et al.* 2001) and productivity (Jiang & Carbines 2002, Carbines *et al.* 2004) may also be affected by disturbance of benthic habitat.

## 5. STATUS OF THE STOCKS

For BCO 1 and 8 recent commercial catch levels are considered sustainable. The status of the remaining fishstocks is summarised below.

**BLUE COD (BCO)**

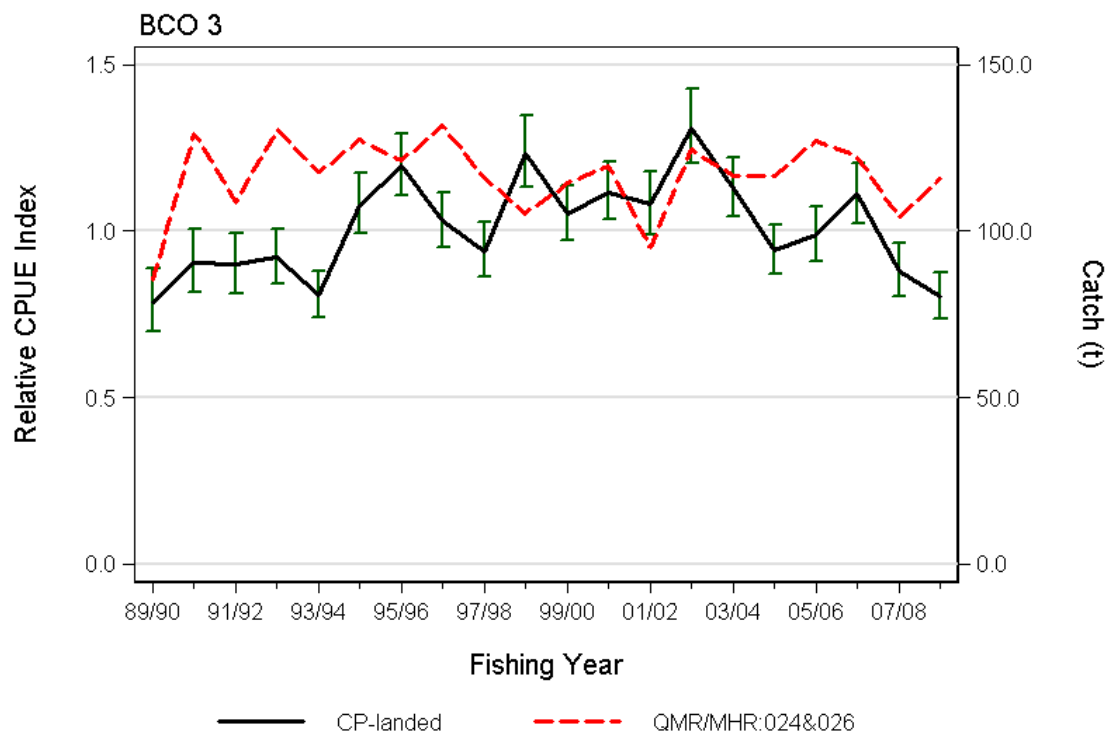
- BCO 3 (Stat areas 24 and 26)**

**Stock Structure Assumptions**

Tagging experiments suggest that blue cod populations may be isolated from each other and there may be several distinct populations within management areas. For the purposes of this summary, BCO 3 is split into two sub-areas along the Stat Area 022 and 024 boundary.

<b>Stock Status</b>	
Year of Most Recent Assessment	2009 (North Otago potting survey); 2010 (CPUE analysis)
Assessment Runs Presented	Potting survey CPUE index based on daily landed catch
Reference Points	Target: Not established but $B_{MSY}$ assumed Soft Limit: 20% $B_0$ Hard Limit: 10% $B_0$
Status in relation to Target	Unknown
Status in relation to Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%) to be below

**Historical Stock Status Trajectory and Current Status**



Cod-potting CPUE index (CP-landed), along with historical catches for Statistical areas 024 and 026 in BCO 3.

**Fishery and Stock Trends**

Recent Trend in Biomass or Proxy	Biomass has declined from a reasonably stable level in the early 2000s to the current level which is about 20% below the long-term mean and similar to the level at the beginning of the series.
Recent Trend in Fishing Mortality or Proxy	Total mortality (catch curve analysis) from the North Otago potting survey was lower in 2009 than 2005.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

**Projections and Prognosis**

Stock Projections or Prognosis	For all of BCO 3, the commercial CPUE has declined since 2002/03 and the catch has exceeded the TACC since 2002/03. As the bulk of the commercial catch (74%) is taken from Statistical Areas 024 and
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	<p>026, both CPUE and catch trends for BCO 3 are strongly influenced by catches in these areas.</p> <p>The estimate of <math>F</math> from the North Otago survey reflects both the commercial and recreational fisheries operating within the survey area. The estimate of <math>F</math> (0.15) from 2009 was larger than <math>M</math> (0.14).</p> <p>Commercial catches during the period of the CPUE decline have been on average 5% greater than the TACC. Recent commercial catches and commercial catch at the level of the TACC combined with current recreational catch are Likely to cause the biomass in Areas 024 and 026 to decline in the short- to medium-term.</p>	
Probability of Current Catch or TACC causing decline below Limits	<p>Soft Limit: Unknown Hard Limit: Unlikely (&lt; 40%)</p>	
<b>Assessment Methodology</b>		
Assessment Type	Level 2: Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE analysis of a target cod-potting fishery, estimation of $Z$ and survey abundance trends.	
Main data inputs	Catch and effort data derived from the Ministry of Fisheries catch reporting and survey catch, length and age data.	
Period of Assessment	Latest assessment: 2009 (survey) 2010 (CPUE)	Next assessment: 2013 (survey) 2014 (CPUE)
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	<p>The relationship between CPUE and abundance of BCO 3 is unknown.</p> <p>The selective survey design may lead to a bias in the estimate of <math>Z</math>.</p>	

**Qualifying Comments**

A recent (June 2009) change in regulations governing commercial pots (change from 38 mm mesh to 48 mm square grids) will affect future CPUE indices, losing the comparability with the earlier series.

**Fishery Interactions**

About 2/3 of BCO 3 commercial catches are taken in a target cod-potting fishery which has very little interaction with other species. Most of the remaining BCO 3 catch is taken in the inshore bottom trawl fishery operating on the east coast of the South Island, largely directed at flatfish, red cod and tarakihi.

• **BCO 4**

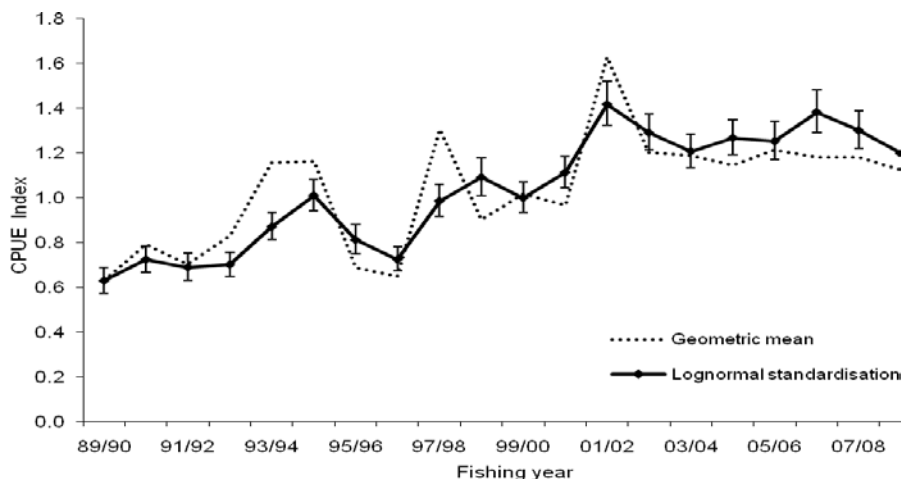
**Stock Structure Assumptions**

For the purposes of this summary BCO 4 is considered to be a single management unit.

<b>Stock Status</b>	
Year of Most Recent Assessment	2011
Assessment Runs Presented	CPUE index based on landed catch
Reference Points	<p>Target: Not established but <math>B_{MSY}</math> assumed</p> <p>Soft Limit: 20% <math>B_0</math></p> <p>Hard Limit: 10% <math>B_0</math></p>
Status in relation to Target	About as Likely as Not (40-60%) to be at or above the target
Status in relation to Limits	<p>Soft Limit: Unlikely (&lt; 40%) to be below</p> <p>Hard Limit: Very Unlikely (&lt; 10%) to be below</p>

**BLUE COD (BCO)**

**Historical Stock Status Trajectory and Current Status**



Standardised CPUE analysis of BCO 4 based on records of positive BCO catch by core vessels standardised to the 1994-95 to 2009-10 geometric mean (Kendrick 2011).

**Fishery and Stock Trends**

Recent Trend in Biomass or Proxy	CPUE has increased from 1989-90 to a high in 2001-02, thereafter the index has fluctuated without trend.
Recent Trend in Fishing Mortality or Proxy	Increasing catch since 1987-88 coincide with increasing abundance suggest that fishing mortality may have remained relatively constant.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

**Projections and Prognosis**

Stock Projections or Prognosis	The current catch and TACC are Unlikely (< 40%) to cause the stock to decline
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unlikely (< 40%) Hard Limit: Very Unlikely (< 10%)

**Assessment Methodology**

Assessment Type	Level 2: Partial Quantitative Stock Assessment	
Assessment Method	Fishery characterisation and CPUE analysis	
Main data inputs	Potting catch and effort	
Period of Assessment	Latest assessment: 2011	Next assessment: Unknown
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	A relationship between CPUE and stock abundance is assumed.	

**Qualifying Comments**

-

**Fishery Interactions**

The catch is almost entirely taken by target cod potting and there is little interaction with other species.

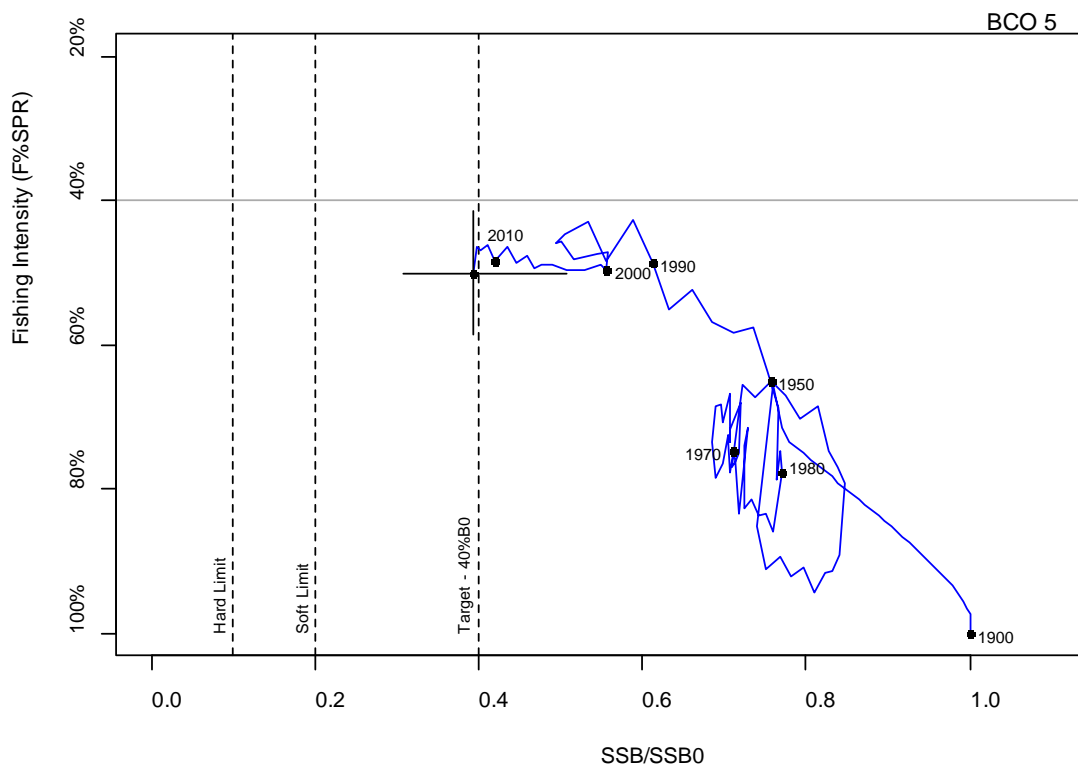
● **BCO 5**

**Stock Structure Assumptions**

Tagging experiments suggest that blue cod populations may be isolated from each other and there may be several distinct populations within management areas. For the purposes of this summary, BCO 5 is treated as a unit stock.

<b>Stock Status</b>	
Year of Most Recent Assessment	2013
Assessment Runs Presented	One base case model was used to evaluate BCO 5 stock status in this assessment. Three sensitivity runs are also presented.
Reference Points	Interim Management Target: 40% $B_0$ Soft Limit: 20% $B_0$ Hard Limit: 10% $B_0$ Overfishing threshold: $F_{MSY}$
Status in relation to Target	$B_{2013}$ was estimated to be 39.4% of $B_0$ ; About as Likely as Not (40-60%) to be at or above the Interim Management Target
Status in relation to Limits	$B_{2013}$ is Very Unlikely (< 10%) to be below the Soft Limit and Exceptionally Unlikely (< 1%) to be below the Hard Limit
Status in relation to Overfishing	Unlikely that overfishing is occurring

**Historical Stock Status Trajectory and Current Status**



Trajectory of fishing intensity ( $F_{\%SPR}$ ) and spawning biomass ( $\%B_0$ ) for BCO 5 from the start of the assessment period in 1990 to 2012. The vertical lines at 10% $B_0$ , 20% $B_0$  and 40% $B_0$  represent the soft limit, the hard limit and the target, respectively, and the shaded area shows the  $B_{MSY}$  90% CI. Estimates are based on MCMC medians and the 2012 90% CI is shown by the crossed lines

<b>Fishery and Stock Trends</b>	
Recent Trend in Biomass or Proxy	Biomass has been slowly decreasing since 2000.
Recent Trend in Fishing Intensity or Proxy	Fishing intensity is estimated to have been relatively constant since 2000.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	Recent recruitment (2002 – 2010) is estimated to be slightly below the long-term average.

<b>Projections and Prognosis</b>	
Stock Projections or Prognosis	BCO 5 biomass is expected to stay steady over the next 5 to 10 years at the 2012 TACC which approximates the 2012 catch.
Probability of Current Catch or	Soft Limit: Very Unlikely (<10%)

**BLUE COD (BCO)**

TACC causing Biomass to remain below or to decline below Limits	Hard Limit: Very Unlikely (<10%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Very Unlikely (< 10%)

<b>Assessment Methodology and Evaluation</b>		
Assessment Type	Level 1 - Full quantitative assessment	
Assessment Method	Length-based model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2013	Next assessment: 2018
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- CPUE time series - Proportion at length data from surveys and commercial catch - Estimates of biological parameters - DUV survey absolute biomass estimate - Potting survey Z estimates	1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality 1 – High Quality
Data not used (rank)	-	-
Changes to Model Structure and Assumptions	New model	
Major Sources of Uncertainty	Degree to which CPUE reflects abundance; the age, size and sex structure of the population; relationship between abundance and sex change dynamics	

<b>Qualifying Comments</b>
-

<b>Fishery Interactions</b>
Historically, significant quantities of blue cod, taken by potting, were used as bait in the commercial rock lobster fishery. Since 1996, reporting of blue cod used for bait is mandatory and included as part of the commercial catch reporting. Some blue cod are landed as bycatch in rock lobster pots and oyster dredges.

<b>Research needs</b>
Research into the sex change dynamics of blue cod would assist in improving the information that goes into the BCO 5 stock assessment. Histological analysis of gonads from the randomly stratified surveys would be a useful approach to assess sex change dynamics. Catch sampling should be undertaken in BCO 5 and needs to be scheduled as part of the medium term research plan.

- **BCO 7 - Marlborough Sounds only**

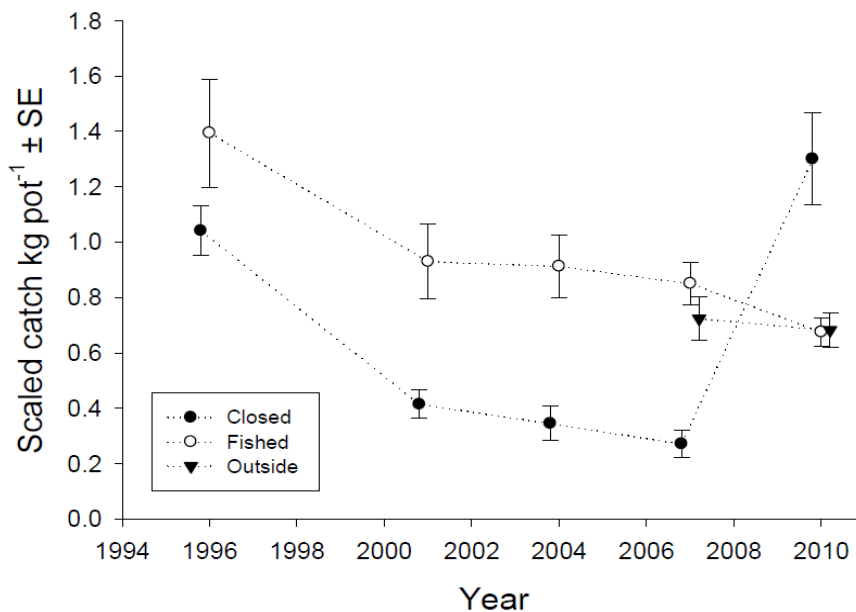
**Stock Structure Assumptions**

For the purposes of this summary BCO - Marlborough Sounds is considered to be a single management unit.

<b>Stock Status</b>	
Year of Most Recent Assessment	2010 potting survey
Assessment Runs Presented	Catch rates from the fixed site Marlborough Sounds Potting survey
Reference Points	Target: $B_{MSY}$ -compatible proxy based on the Marlborough Sounds potting survey (to be determined)

	Soft Limit: 20% $B_0$ Hard Limit: 20% $B_0$
Status in relation to Target	Unknown
Status in relation to Limits	Unknown

**Historical Stock Status Trajectory and Current Status**



Scaled catch rate from the fixed site potting survey in the Marlborough Sounds Management Area (MSA) divided into the area that was subject to a fishery closure (Closed) and the area that remained open to fishing (Fished). The areas outside of the MSA (Outside) are the Cook Strait and D'Urville Island and have only been surveyed since 2007.

**Fishery and Stock Trends**

Recent Trend in Biomass or Proxy	The Marlborough Sounds fixed site potting survey index of abundance for the Marlborough Sounds Management area (MSA) (fished) has declined from 1996 to 2010. The MSA (closed) index declined from 1996 to 2007 but increased substantially in 2010.
Recent Trend in Fishing Mortality or Proxy	Frequent regulatory changes to the recreational fishery (e.g. fishery closures, changes to MLS and daily bag limits) are likely to have resulted in a reduction in fishing mortality up to April 2011, after which mortality increased with the re-opening of the fishery.
Other Abundance Indices	Age and size composition of catches from the 2010 blue cod potting survey contained few fish greater than 37 cm or older than 10 years, which is considerable smaller and younger than observed in equivalent surveys elsewhere on the South Island.
Trends in Other Relevant Indicators or Variables	None but in future sex ratio-at-size should be assessed.

**Projections and Prognosis**

Stock Projections or Prognosis	It is likely that, with the re-opening of this fishery, biomass will decline from the 2010 level.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unknown

**Assessment Methodology and Evaluation**

Assessment Type	2 – Partial Quantitative Stock Assessment	
Assessment Method	Fixed site fishery-independent potting survey	
Assessment Dates	Latest assessment: 2010	Next assessment: 2014
Overall assessment quality rank	1 - High Quality	

## BLUE COD (BCO)

Main data inputs (rank)	Potting survey catch rates Age length	1- High Quality 1- High Quality 1- High Quality
Data not used (rank)	$F_{\%SPR}$	$F_{\%SPR}$ was not used due to the frequent regulatory changes for this fishery resulting in inconsistent fishing mortality over the lifetime of the fish.
Changes to Model Structure and Assumptions	-	
Major Sources of Uncertainty	The total removals from the recreational sector and the distribution of recreational effort are not well estimated.	

### Qualifying Comments

The survey is moving from a fixed site to a random stratified potting survey, in the interim both survey types will be undertaken simultaneously so that the random survey can be calibrated to the historic data.

### Fishery Interactions

Most of the catch is taken by recreational fishers, there is probably high catch of associated species such as spotted and other wrasses as well as other targeted species such as tarakihi. Most of the commercial catch is taken by potting and has little bycatch.

**Table 23: Summary of yields (t), TACCs (t), and reported landings (t) for blue cod from the most recent fishing year.**

Fishstocks	QMA		Actual TACC	2011-12 Reported landings
BCO 1	Auckland	1 & 9	46	6
BCO 2	Central (East)	2	10	8
BCO 3	South-East (Coast)	3	163	166
BCO 4	South-East (Chatham Rise)	4	759	753
BCO 5	Southland and Sub-Antarctic	5 & 6	1 239	1 215
BCO 7	Challenger	7	70	54
BCO 8	Central (Egmont)	8	34	10
BCO 10	Kermadecs	10	10	0
Total			2 332	2 214

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