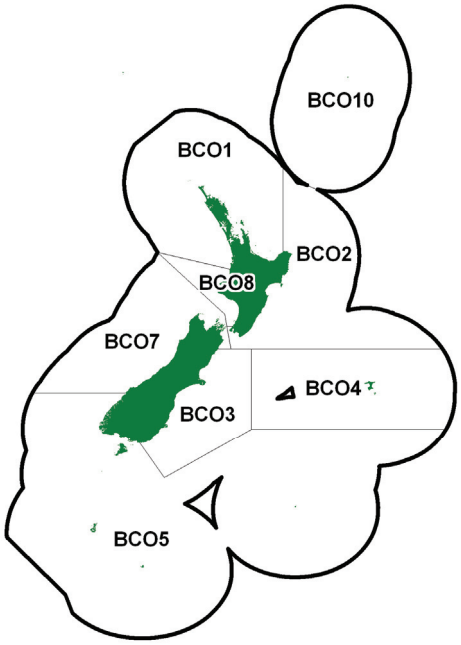
BLUE COD (BCO)

(Parapercis colias)
Raawaru



1. FISHERY SUMMARY

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 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 1 and historical landings in Table 2, 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 1: Reported landings (t) of blue cod by Fishstock from 1983 to 2008–09 and actual TACCs (t) from 1986–87 to 2008–09. QMS data from 1986-present. FSU data 1983-1986.

Fishstock	BCO 1		BCO 2		BCO 3		BCO 4		BCO 5	
FMA (s)	1 & 9		2		3		4		5 & 6	
	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

Fishstock	BCO 7		BCO 8		BCO 10			
FMA (s)	7		8		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	1527	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

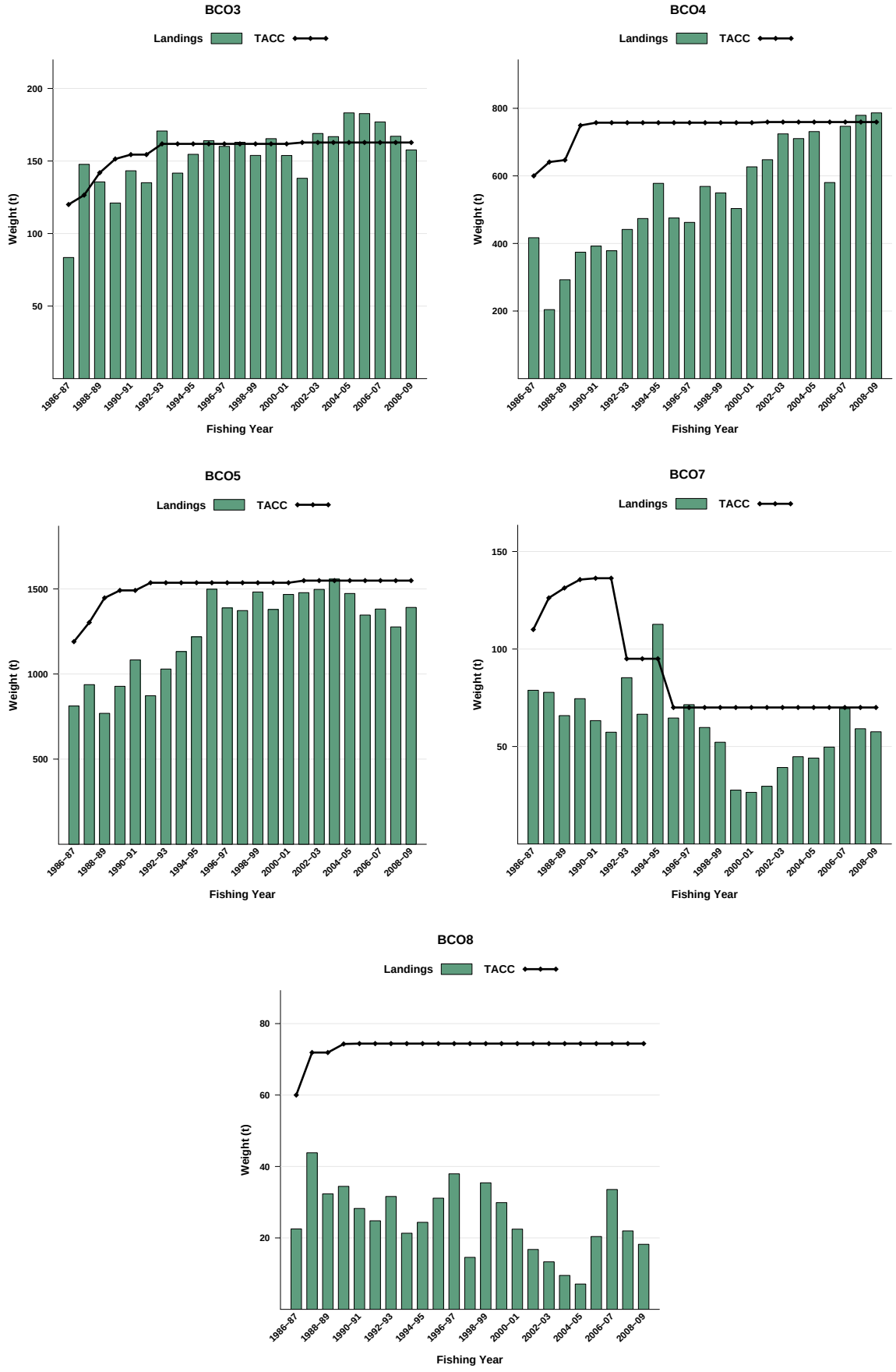


Figure 1: Historical landings and TACC for the five main BCO stocks. From top left: BCO3 (South East Coast), BCO4 (South East Chatham Rise), BCO5 (Southland), BCO7 (Challenger), and BCO8 (Central Egmont). Note that these figures do not show data prior to entry into the QMS.

Table 2: Reported total New Zealand landings (t) of blue cod for the calendar years 1970 to 1983. Sources MAF 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

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 3, 4 &5). Charter vessel catches have also been obtained separately in 1997–98 (Table 6).

Table 3: 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

* 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 4: 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 5: 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 6: 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	–	–	0.0

*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.

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 6) follow the same pattern as overall recreational catch (Tables 3 and 4). 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 7.

Table 7: Changes to minimum legal size (MLS in cm) and amateur maximum daily limits (MDL) of blue cod by Fishstock from 1986 to present.*

Fishstock	BCO 1		BCO 2		BCO 3		BCO 4		BCO 5		Sub area provisions: Paterson Inlet	
QMA(s)	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	BCO 7		BCO 7		BCO 8		BCO 10	
QMA(s)	7		Marlborough Sounds		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				

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).

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).

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 aggregations have 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, 60.2% travelled less than 1 km. A similar pattern was found in Dusky sound where four fish moved over 20km 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 8.

Table 8: Estimates of biological parameters for blue cod.

Fishstock	Estimate	Source
1. Natural mortality (*M*)		
All	0.14	Estimated from the maximum age in Carbines *et al*. 2007, using Hoenig's (1983) method.

2. Von Bertalanffy growth parameters

	Females			Males			
	L_∞	k	t_0	L_∞	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	0.1	-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.

3. Weight = $a(\text{length})^b$ (Weight in g, length in cm fork length).

Area	Year	Sex	a	b	R^2	Reference
North Canterbury	2004	Male	0.00985	3.1394	0.97	Carbines G., Beentjes MP. (2006a)
(Kaikoura)	2004	Female	0.00891	3.161	0.95	
Banks Peninsula	2005	Male	0.006941	3.232	0.95	Beentjes MP., Carbines GD. (2006)
	2005	Female	0.00895	3.1532	0.98	
North Otago	2005	Male	0.00641	3.2743	0.95	Carbines G., Beentjes MP. (2006b)
	2005	Female	0.00421	3.4013	0.97	
Fiordland	2002	Male	0.007825	3.1727	0.97	Carbines GD., Beentjes MP. (2003)
(Dusky Sound)	2002	Female	0.00506	3.2988	0.98	
Stewart Island	2006	Male	0.00703	3.2208	0.99	Carbines GD. (2007)
(Paterson Inlet)	2006	Female	0.00814	3.1824	0.98	

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. It is not known if there is more than one stock of blue cod in New Zealand.

There are no new data which would alter the stock boundaries given in previous assessment documents. However, tagging experiments suggest that blue cod populations may be isolated from each other and there may be several distinct populations within management areas.

4. STOCK ASSESSMENT

4.1 Estimates of fishery parameters and abundance

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. 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 (EOPE, OQCH, DURW), but little change occurred in the inner and middle Sounds areas (IQCH, OQCH, IPEL, MPEL, OPEL) 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 DURE stratum continued from 2001 to 2007, while relative abundance remained low for Separation Point (SEPR).

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 EQCH and EOPE between 1996 and 2004, then declining to 2007, while a declining trend occurred in OQCH, IPEL, and MPEL. No discernible trend was apparent for the other strata, although relative abundance was low in all strata for 2007, Blackwell (2009) (Figure 2).

Results from a fishery independent survey off Banks Peninsula (part of BCO 3) in 2002 using cod standardised pots 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 and 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.

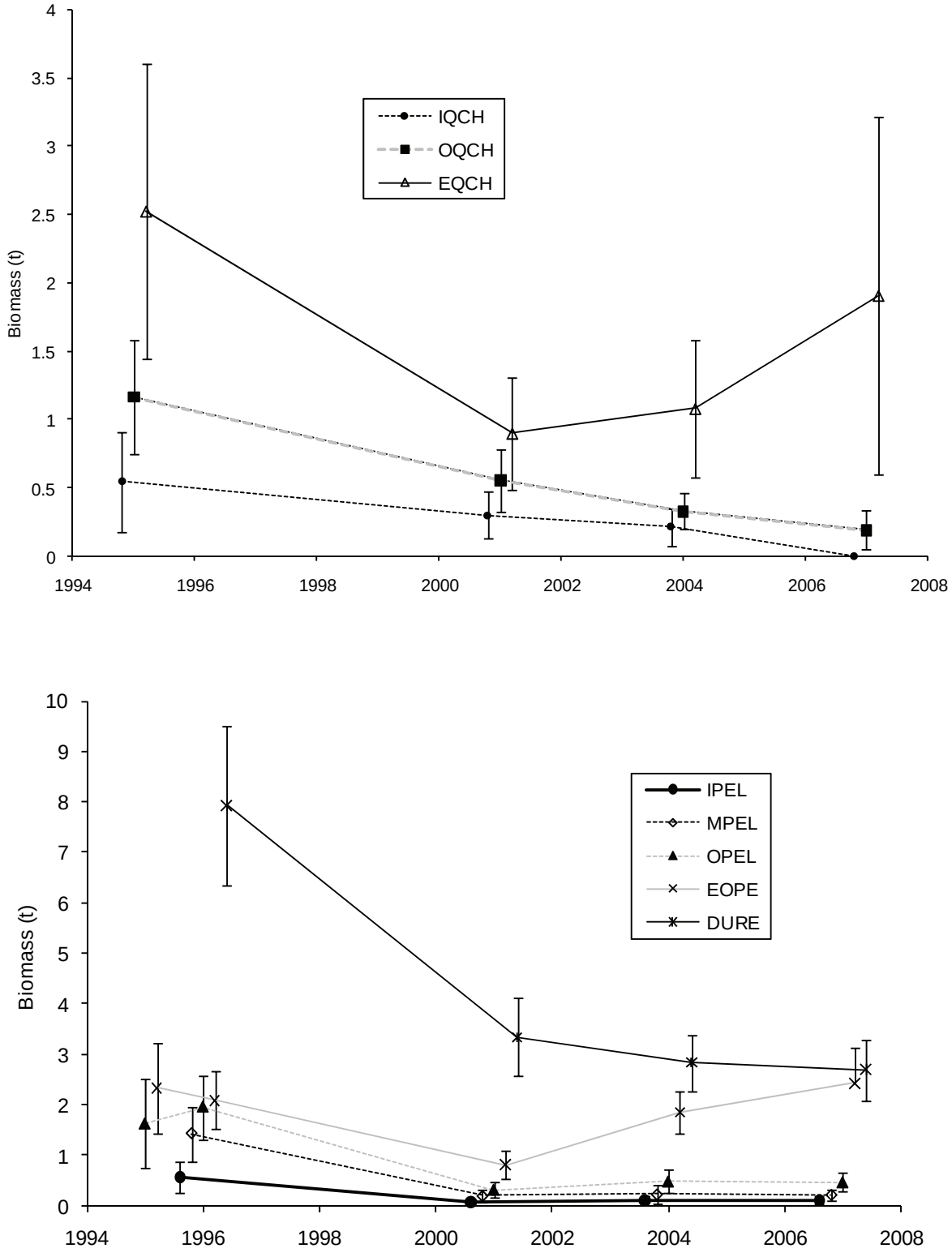


Figure 2: Mean catch rate in ten areas surveyed during the blue cod potting surveys conducted between 1995 and 2007 in the Marlborough sounds (data from Blackwell 2009).

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 survey of blue cod in North Canterbury (part of BCO 3) in 2004/05 using standardised cod pots 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 ≥ 30cm was 1.91 kg/pot hour (CV = 7.9%) for Kaikoura and 5.97 kg/pot (CV = 9.8%) for Motunau (Carbines and Beentjes 2006a). Another fishery independent survey of blue cod in North Otago (also part of BCO 3) in 2005 using standardised cod pots produced an overall mean catch rate for all blue cod of 10.14 kg/pot (CV = 5.4%). The catch rate of blue cod ≥ 30cm was 8.22 kg/pot hour (CV = 5.3%).

In 2008 (Carbines and Beentjes 2009) mean catch rates of blue cod (all sizes) in the Kaikoura ranged from 1.94 kg per pot per hour in stratum 2 (inshore, South Bay to south of Haumuri Bluffs), to 20.45 kg per pot per hour for offshore stratum 4 (100 to 200 m depth range off the Kaikoura Peninsula). Overall mean catch rate and CV were 5.00 kg per pot per hour and 8.2%. For blue cod 30 cm and over (minimum legal size), highest catch rates were also in stratum 4 (18.79 kg per pot per hour) and lowest catch rates in stratum 2 (1.16 kg per pot per hour). 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 strata estimates were between 0.31 and 0.37 and these mortality estimates are consistent with those from 2005 survey.

In 2008 (Carbines and Beentjes 2009) mean catch rates of blue cod (all sizes) in Motunau ranged from 4.11 kg per pot per hour in stratum 2 (north of Motunau to south of Sail Rock) to 8.86 kg per pot per hour for stratum 1 (south of Motunau to Double Corner). 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), highest catch rates were also in stratum 1 (4.93 kg per pot per hour) and lowest catch rates in stratum 2 (2.10 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 in all strata.

The substantial decrease in catch rates in all Motunau strata in 2008 compared to 2005 could not be explained by a relatively weak cohort in 2005, and as environmental conditions at Motunau were similar for both surveys it seems unlikely that catchability would have altered dramatically between the two surveys. The relatively high estimates of mortality and the overall 44% decline in catch rates of legal sized blue cod in Motunau since the 2005 potting survey is of concern.

A fishery independent survey of blue cod in Dusky Sound (part of BCO 5) in 2002 using standardised cod pots produced an overall mean catch rate for all blue cod of 2.69 kg/pot (CV = 6.7%). The catch rate of blue cod ≥ 30cm was 2.23 kg/pot hour (CV = 7.2%). Both the overall and catch rates for all blue cod and for fish ≥ 30cm were highest on the open coast (ie at the entrance to the Sound), being 8.42 and 5.46 kg/pot hour respectively (Carbines and Beentjes 2003).

Carbines *et al*. (2007) 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) were calculated and compared in conjunction with relative abundance estimates (CPUE [$kg.hour^{-1}$]) from potting surveys conducted in the Marlborough Sounds, Kaikoura, Motunau, Banks Peninsula, North Otago and Dusky Sound (Table 9). This also provided a new estimate of maximum age for blue cod.

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 9: Summary statistics from standardized blue cod potting surveys done throughout the South Island*.

Area/Year	Mean length Female	Mean length Male	Mean age Female	Mean age Male	Reported Indices kg/hr (CV)	Indices strata Range kg/hr	Mean mortality Z (CV)	Z range (5─8 years)
D'Urville Island 2001	27.3	30.5	7.2	7.2	5.9 (10.0%)	5.90	0.47(33%)	0.34 - 0.59
D'Urville Island 2004	27.9	30.8	6.8	6.9	Not reported [1]	4.03 - 4.68	0.55 (22%)	0.39 - 0.68
Dusky Sound 2002	30.1	34.7	6.9	7.6	2.7 (6.7%)	1.28 - 8.42	0.22 (18%)	0.27 - 0.31
Inshore Banks Peninsular 2002	25.3	28.3	4.9	5.5	Not reported [2]	0.04 - 2.61	0.70 (35%)	0.53 -0.94
Inshore Banks Peninsular 2005	27.1	32.7	5.4	6.7	Not reported [3]	1.02 - 4.16	0.51 (25%)	0.44 - 0.60
Kaikoura 2004	31.2	33.4	8.9	8.1	2.6 (8.7%)	0.03 - 7.54	0.28 (25%)	0.27 - 0.29
Motunau 2005	25.6	29.1	5.3	4.3	10.2 (7.3%)	9.53 - 15.37	0.62 (27%)	0.46 - 0.76
North Otago 2005	27.9	32.9	6.1	7.2	10.1 (5.4%)	7.45 - 14.5	0.41 (22%)	0.33 - 0.47
Offshore Banks Peninsular 2002	36.6	37.7	10.9	10.5	Not reported [3]	2.04 - 4.74	0.15 (47%)	0.14 - 0.15
Offshore Banks Peninsular 2005	37.3	41.2	9.0	11.4	Not reported [3]	5.68 - 7.27	0.17 (45%)	0.14 - 0.19
Pelorus Sound 2001	22.3	27.8	3.9	4.9	Not reported [4]	0.19 - 1.46	0.84 (23%)	0.88 - 1.01
Pelorus Sound 2004	23.6	28.2	4.5	4.8	Not reported [2]	0.32 - 3.03	0.81 (23%)	0.67 - 1.03
Queen Charlotte Sound 2001	24.2	28.7	4.4	5.4	Not reported [1]	0.57 - 1.68	0.50 (23%)	0.38 - 0.71
Queen Charlotte Sound 2004	24.4	28.6	5.8	5.8	Not reported [2]	0.37 - 2.04	0.94 (23%)	0.63 - 1.17

*Presented for each survey (including sub-areas of the Marlborough Sounds and Banks Peninsular) are the mean size and age of female and male blue cod caught, the average overall survey abundance indices for all sizes of blue cod (CV), the strata range of abundance indices in the survey area, the average total mortality (from 5─8 year olds) (CV), and the range of total mortality estimates (from 5-8 year olds). (Modified from Carbines *et al*. (in prep.)

BCO 3

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 and 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 and Kendrick 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 and 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

[1] Average abundance indices were not reported specifically for these sub-areas. The overall abundance indices for the Marlborough Sounds in 2004 was 1.1 kg/hr (CV=7.0%) (Blackwell 2006), average mortality (5─8 years) was 0.71 (CV=15%).

[2] Average abundance indices were not reported specifically for these sub-areas. The overall abundance indices for Banks Peninsular in 2001 was 2.1 kg/hr (CV=10.8%) (Beentjes & Carbines 2003), average mortality (5─8 years) was 0.26 (CV=33%).

[3] Average abundance indices were not reported specifically for these sub-areas. The overall abundance indices for Banks Peninsular in 2005 was 4.4 kg/hr (CV=5.71%) (Beentjes & Carbines 2006), average mortality (5─8 years) was 0.27 (CV=26%).

[4] Average abundance indices were not reported specifically for these sub-areas. The overall abundance indices for the Marlborough Sounds in 2001 was 1.6 kg/hr (CV=7.0%) (Blackwell 2002), average mortality (5─8 years) was 0.54 (CV=16%).

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.

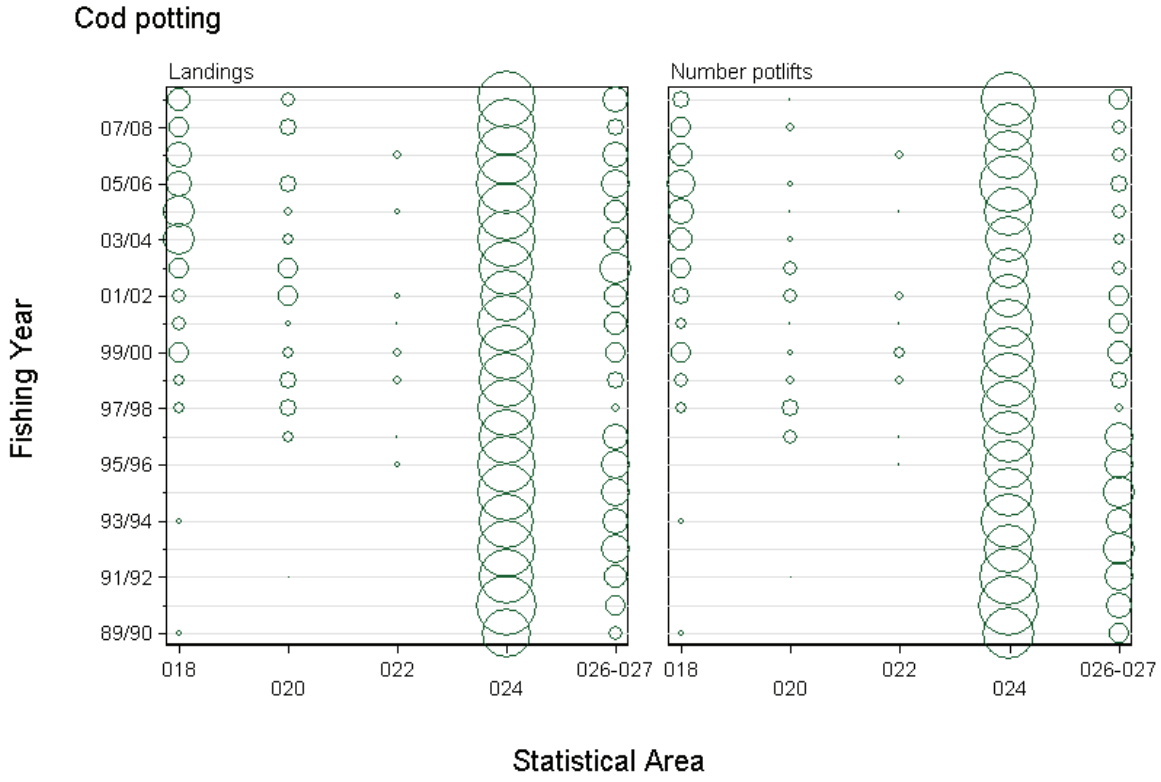


Figure 3: Distribution of landings and number of potlifts for the cod potting method by grouped statistical area (Table 9) and fishing year from trips which landed BCO 3. Circles are proportional within each panel: [catches] largest circle= 92 t in 05/06 for 024; [number potlifts] largest circle= 7 831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

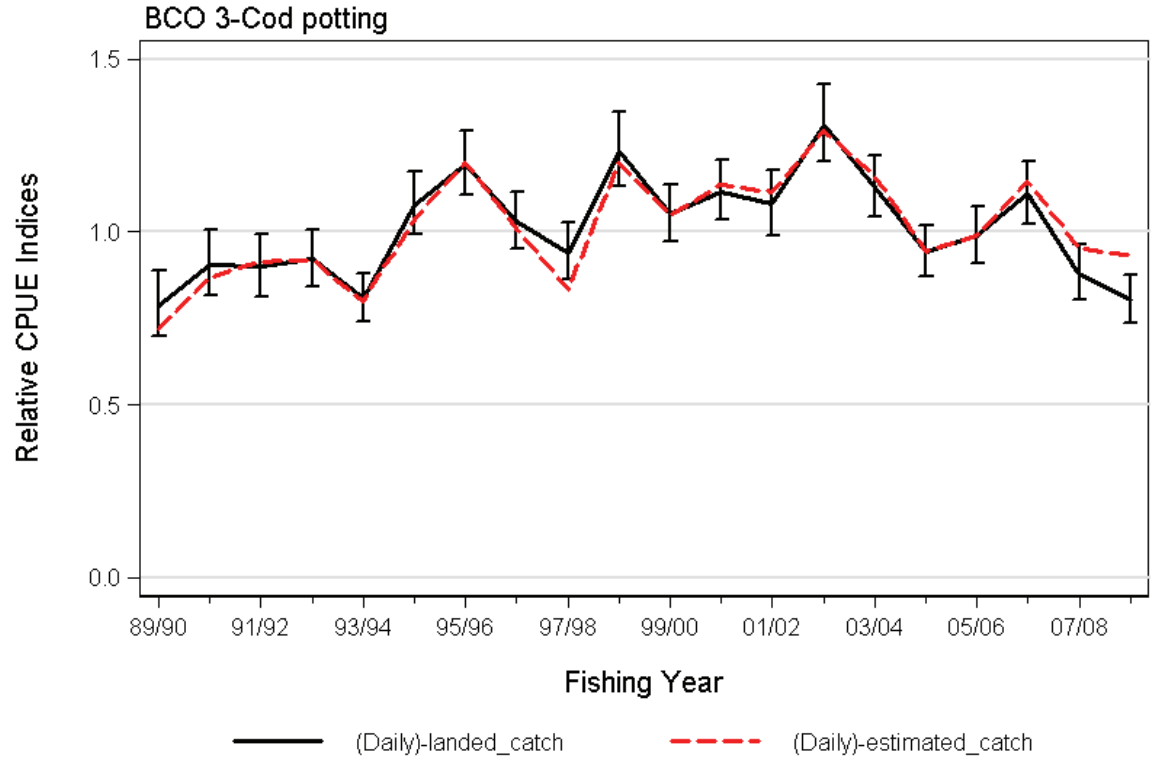


Figure 4: Comparison of BCO 3 standardised series based on landed greenweight catch data and daily estimated catch (Starr and Kendrick 2010).

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.

BCO 5

A standardised CPUE analysis was conducted on the target blue cod fishery operating in the three main statistical areas of BCO 5 (025, 027 and 030) for the 1989–90 to 1999–00 period (Langley 2002) and updated in 2005 (SeaFIC 2005) and again in 2009 (Starr and Kendrick 2009). The annual indices derived from the most recent analysis indicated catch rates were constant from 1989–90 to 1994–95, the increase in catch rates from 1994–95 to about 1999/2000 may be a result of mesh size regulation change. Catch rates have declined slightly since 2004/2005 in all areas (Figure 5).

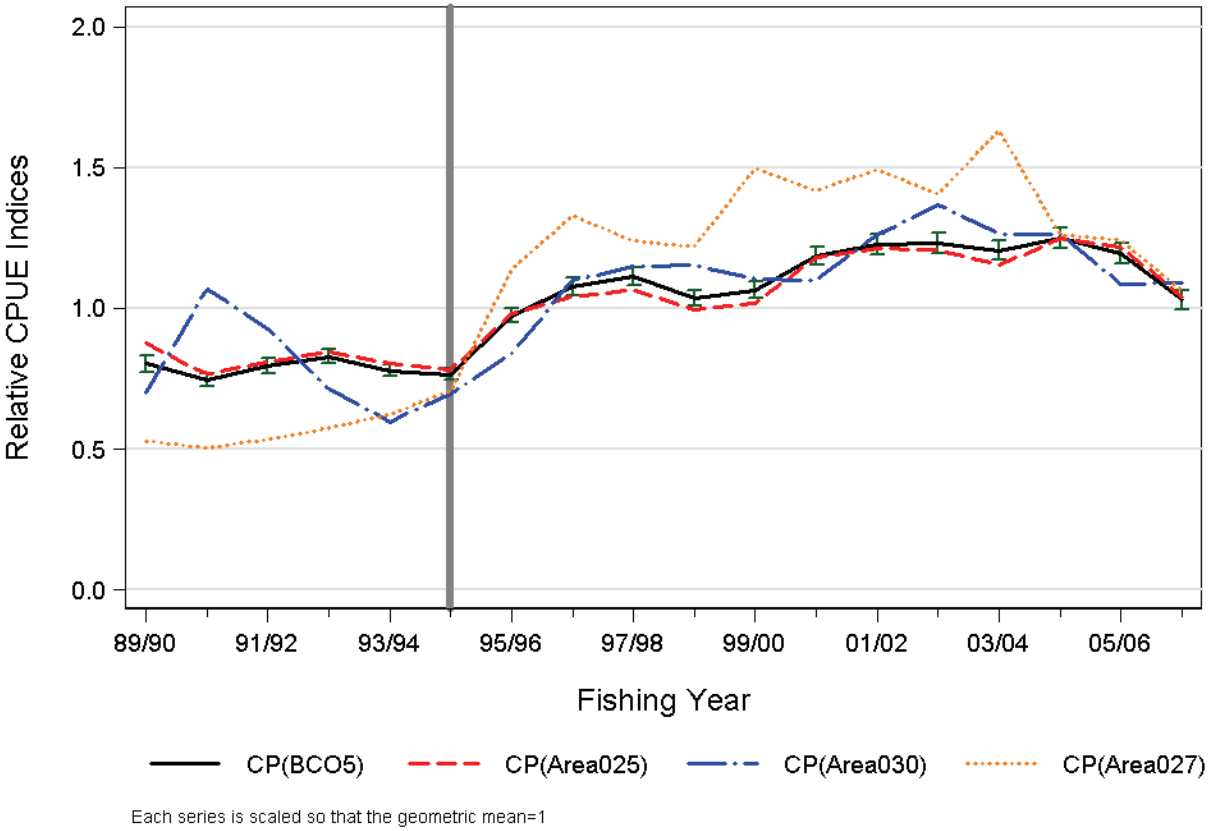


Figure 5: Standardised CPUE analysis of BCO 5 based on records of positive BCO catch by core vessels. Comparison of three statistical area series without error bars. Each series has been standardised to the 1989–90 to 2006–07 geometric mean. Vertical lines mark the introduction of the larger mesh size regulation in 1994–95. (Starr and Kendrick 2009)

4.2 Biomass estimates

No estimates of current or reference biomass are available.

4.3 Estimation of Maximum Constant Yield (MCY)

MCY was estimated from the equation MCY = cY_{AV} (method 4) and is based on commercial catches of blue cod only. Historical blue cod catch levels were closely correlated with fishing effort, and variations in recorded catch were probably due to changed fishing patterns. These have not changed since the 1992 Plenary Report, except for BCO 3 and BCO 5 which were updated in 1995.

In 2007 *M* for blue cod was estimated at 0.14, based on the age estimate of 32 years. The value of c was set equal to 0.9 based on the estimates of *M*. In all areas where blue cod catches were not reported (i.e., due to bait use, non-reporting and discarding), MCY is likely to be conservative.

Yield estimates were derived on a regional basis, as follows:

(i) Auckland (BCO 1)
Y_{AV} = average landings from 1983–1986.
MCY = 0.9 * 25 t = 23 t (rounded to 25 t)

(ii) Central (East) (BCO 2)
Y_{AV} = average landings from 1983–986.
MCY = 0.9 * 4 t = 4 t (rounded to 5 t)

(iii) South East (Coast) (BCO 3)
Y_{AV} = average landings from 1987–88 to 1993–94. These years were chosen because of stable effort and catches.
MCY = 0.7 * 143 t = 129 t (rounded to 130 t)

(iv) South–East (Chatham Rise) (BCO 4)
Y_{AV} = average landings from 1953–1965. These years were chosen because of stable catches after World War II and before the development of the rock lobster fishery.
MCY = 0.9 * 750 t = 675 t

(v) Southland and Sub–Antarctic (BCO 5)
Y_{AV} = average landings from 1987–88 to 1993–94. These years were chosen because of stable effort unrestricted by the TACC.
MCY = 0.9 * 967 t = 870 t

(vi) Challenger (BCO 7)
Y_{AV} = average landings from 1983 to 1986. These years were chosen because of stable catches.
MCY = 0.7 * 118 t = 106 t (rounded to 110 t)

(vii) Central (Egmont) (BCO 8)
Y_{AV} = average landings from 1983 to 1986.
MCY = 0.7 * 55 t = 50 t

The level of risk to the stock by harvesting the population at the estimated MCY value cannot be determined.

4.4 Estimation of Current Annual Yield (CAY)

No estimate of CAY is available for blue cod stocks.

Yield estimates are summarised in Table 10.

Table 10: Yield estimates (t).

Parameter	Fishstock	Estimate
MCY	BCO 1	25
	BCO 2	5
	BCO 3	130
	BCO 4	675
	BCO 5	870
	BCO 7	110
	BCO 8	50
	Total	1 865
CAY	All	Cannot be determined

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

Estimates of current and reference biomass are not available.

The estimates of MCY are probably conservative because of under-reporting of catch and large fluctuations in effort caused by movement of blue cod fishers to the rock lobster fishery.

For BCO 1, 2, 4, and 8, recent commercial catch levels and current TACCs are considered sustainable, the remaining Fishstocks are described below.

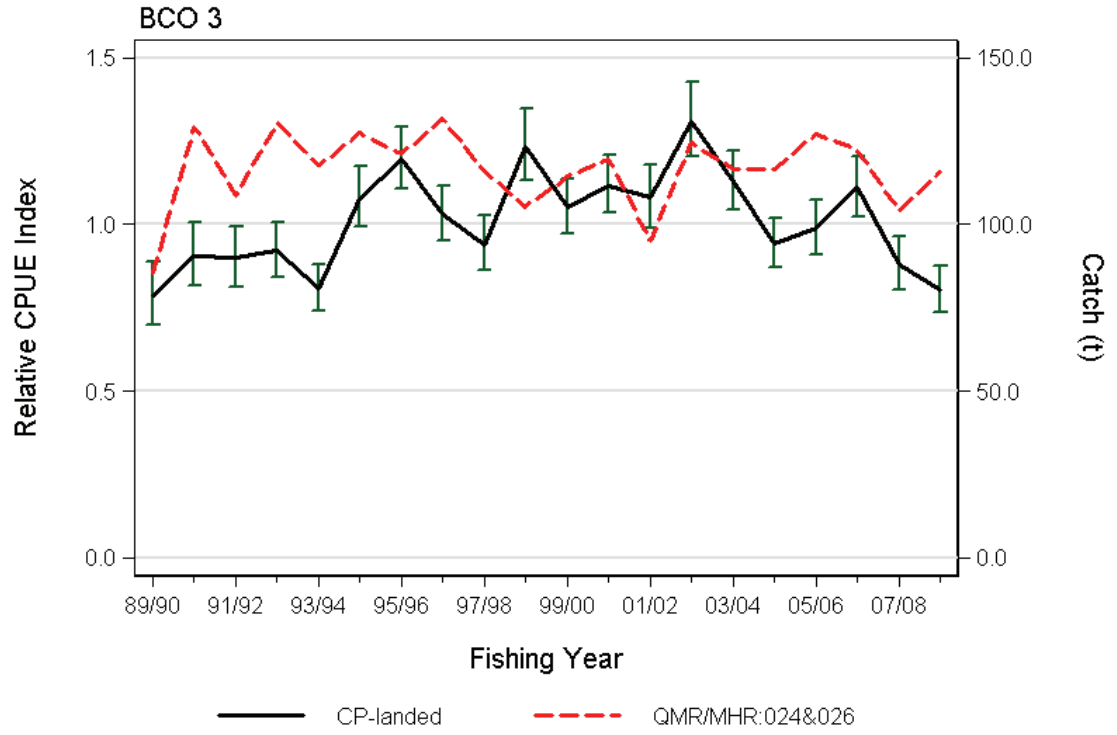
Fishstock name: BCO 3 (Stat areas 24 and 26)

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.

Stock Status	
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(s): 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 026, both CPUE and catch trends for BCO 3 are strongly influenced by catches in these areas. The estimate of *F* from the North Otago survey reflects both the commercial and recreational fisheries operating within the survey area. The estimate of *F* (0.15) from 2009 was larger than M (0.14). 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.
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%)

Assessment Methodology		
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	The relationship between CPUE and abundance of BCO 3 is unknown. The selective survey design may lead to a bias in the estimate of *Z*.	

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.

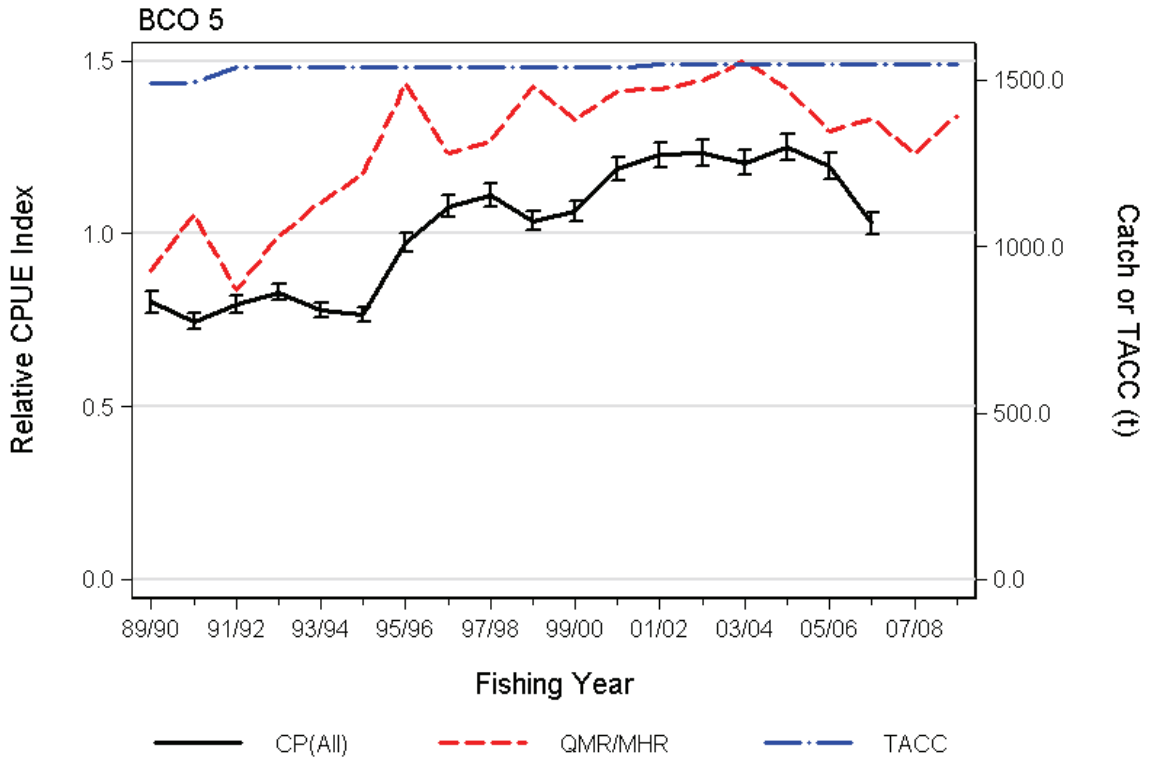
Fishstock name: BCO 5

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.

Stock Status	
Year of Most Recent Assessment	2008
Assessment Runs Presented	CPUE index based on landed catch
Reference Points	Target(s): Not yet determined 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 [all]), historical catches and TACC for BCO 5

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE remained consistently high through the 2000s but declined in the last year (2006/07) of the analysis to near the long-term mean.
Recent Trend in Fishing Mortality or Proxy	
Other Abundance Indices	
Trends in Other Relevant Indicators or Variables	Current levels of commercial catch, which are 10-20% below the TACC, have been maintained for about 15 years.

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing decline below Limits	Soft Limit: Unknown Hard Limit: Unlikely (< 40%)

Assessment Methodology		
Assessment Type	Level 2: Partial Quantitative Stock Assessment	
Assessment Method	Standardised CPUE analysis of a target cod-potting fishery	
Main data inputs	Catch and effort data derived from the Ministry of Fisheries catch reporting	
Period of Assessment	Latest assessment: 2008	Next assessment: 2011
Changes to Model Structure and Assumptions	The 2005 model was updated in 2008.	
Major Sources of Uncertainty	The relationship between CPUE and abundance of BCO 5 is unknown No historical biological information is available to corroborate/interpret the observed trends in CPUE	

Qualifying Comments
A random stratified potting survey is being developed in Foveaux Strait which should provide better information in the future. In addition, a fishery sampling programme was initiated at the beginning of 2010.

Fishery Interactions
Ninety seven percent of BCO 5 commercial catches are taken in a target cod-potting fishery which has very little interaction with other species.

Fishstock name: BCO 7

For Statistical Area 017 (in BCO 7) it is not known if the combined recreational and commercial catches are sustainable or if they are at levels that will allow the stock to move towards a size that will support the MSY. There are indications that stock abundance is low in the Marlborough Sounds. Recent (2007) survey results recorded no blue cod in the inner Queen Charlotte Sound and low abundance in the outer Sounds relative to previous years.

Table 11: Summary of yields (t), TACCs (t), and reported landings (t) for blue cod from the most recent fishing year.

Fishstocks	QMA		MCY	2008–09 Actual TACC	2008–09 Reported landings
BCO 1	Auckland	1 & 9	25	46	7
BCO 2	Central (East)	2	5	10	8
BCO 3	South–East (Coast)	3	130	163	158
BCO 4	South–East (Chatham Rise)	4	675	759	787
BCO 5	Southland and Sub–Antarctic	5 & 6	870	1 548	1 391
BCO 7	Challenger	7	110	70	58
BCO 8	Central (Egmont)	8	50	74	18
BCO 10	Kermadecs	10	–	10	0
Total			1 865	2 680	2 427

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