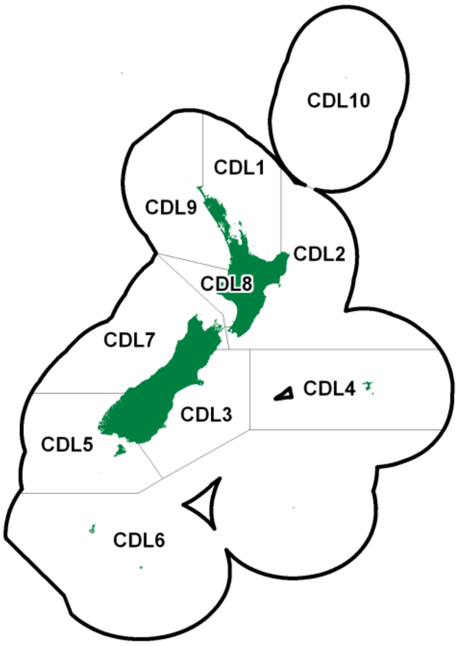
BLACK CARDINALFISH (CDL)

(*Epigonus telescopus*)
Akiwa



1. FISHERY SUMMARY

Black cardinal fish was introduced into the Quota Management System on 1 October 1998 with the following TACs, TACCs and allowances (Table 1).

Table 1: TACs (t), TACCs (t) and allowances (t) for black cardinal fish.

Fishstock	Recreational Allowance	Customary non-commercial Allowance	Other sources of mortality	TACC	TAC
CDL 1	0	0	120	1200	1320
CDL 2	0	0	20	440	460
CDL 3	0	0	-	196	196
CDL 4	0	0	-	22	22
CDL 5	0	-	79	3955	4036
CDL 6	0	0	-	1000	1000
CDL 7	0	0	-	39	39
CDL 8	0	0	-	0	0
CDL 9	0	0	-	4	4
CDL 10	0	0	-	0	0
Total	0	0	219	6856	7077

1.1 Commercial fisheries

Several species of *Epigonus* are widely distributed in New Zealand waters, but only black cardinalfish (*E. telescopus*) reaches a marketable size and is found in commercial concentrations. It occurs throughout the New Zealand EEZ at depths of 300–1100 m, mostly in very mobile schools up to 150 m off the bottom over hills and rough ground. Black cardinalfish have been caught since 1981 by research and commercial vessels, initially as a bycatch of target trawling for other high value species. The preferred depth range of schools (600–900 m) overlaps the upper end of the depth range of orange roughy and the lower end of alfonsino and bluenose. The exploitation of these species from 1986 resulted in the development of the major cardinalfish fishery in QMA 2.

It is primarily sold domestically due to the short freezer life of fillets. The species has a section of dark flesh under the lateral line that has caused problems with overseas marketing. The fillets can be tainted if this flesh is not removed quickly.
Landings for 1998–99 to 2008–09 are from QMR totals following introduction of the species into the QMS for 1998–99. For the 1982–83 to 1985–86 fishing years, the best estimate of landings was the sum of the FSU Inshore and FSU Deepwater (i.e., FSU Total) catch returns. For 1986–87 to 1988–89 the best estimate was taken as the greater value of either the FSU Total or the LFRR. From the 1989–90 fishing year, the best estimate was taken as the higher of either the LFRR or the sum of the CLR and CELR Landed data.

The best estimate of total landings was split between the nine QMAs and ET (outside the EEZ) based on FSU and QMS data (Table 2). For FSU data (1982–83 to 1987–88 fishing years), catch where area was unknown was pro-rated to QMAs according to the catch level where area was reported. For QMS data (1988–89 to 1994–95 fishing years), catch by area in CELR Landed and CLR reports were scaled to equal the best estimate of the total catch. Commercial landings of black cardinalfish have been made in QMAs 1–9 and outside the EEZ (ET).

In most years since 1982 more than 65% of black cardinalfish landings were from the east coast of the North Island (QMA 2). The large increase in landings from this area in 1986–87 was associated with the development of the orange roughy fishery around the Ritchie Banks and Tuaheni High, and an increase in targeted fishing to establish a catch history when it was anticipated to become a quota species. Landings from the Bay of Plenty (QMA 1) have fluctuated since 1988. The relatively large landings in 1990–91 were a combination of bycatch of the orange roughy fishery and target fishing for black cardinalfish. Between 1991–92 and 2005–06 occasional large catches were taken from outside the EEZ on the northern Challenger Plateau and the Lord Howe Rise.

Table 2: Reported landings (t) of black cardinalfish by QMA and fishing year (1 October to 30 September) from 1982–83 to 2013–14. The data in this table has been updated from that published in previous Plenary Reports by using the data through 1996–97 in table 32 on p. 262 of the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998. Data for 1997–98 based on catch and effort returns, since 1998–99 on QMR records.

	QMA 1		QMA 2		QMA 3		QMA 4		QMA 5		QMA 6	
Year	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC	Catch	TACC
1982–83	-	-	76	-	< 1	-	< 1	-	-	-	-	-
1983–84	-	-	212	-	7	-	< 1	-	-	-	-	-
1984–85	< 1	-	189	-	341	-	< 1	-	-	-	-	-
1985–86	< 1	-	238	-	50	-	3	-	2	-	-	-
1986–87	1	-	1 738	-	72	-	2	-	< 1	-	< 1	-
1987–88	3	-	1 556	-	28	-	1	-	3	-	-	-
1988–89	305	-	1 434	-	57	-	4	-	-	-	-	-
1989–90	613	-	1 718	-	20	-	18	-	-	-	-	-
1990–91	233	-	3 473	-	598	-	1	-	4	-	-	-
1991–92	7	-	1 652	-	146	-	3	-	< 1	-	2	-
1992–93	23	-	1 550	-	519	-	2	-	< 1	-	-	-
1993–94	364	-	2 310	-	277	-	10	-	5	-	-	-
1994–95	1 162	-	2 207	-	51	-	7	-	1	-	< 1	-
1995–96	1 418	-	2 621	-	57	-	4	-	10	-	-	-
1996–97	2 001	-	1 910	-	100	-	7	-	-	-	-	-
1997–98	995	-	1 176	-	40	-	351	-	-	-	-	-
1998–99	24	1 200	1 268	2 223	181	196	41	5	-	2	< 1	1
1999–00	980	1 200	2 158	2 223	215	196	36	5	< 1	2	< 1	1
2000–01	294	1 200	1 135	2 223	99	196	35	5	74	2	< 1	1
2001–02	455	1 200	1 693	2 223	146	196	29	5	18	2	< 1	1
2002–03	583	1 200	1 845	2 223	172	196	80	5	9	2	< 1	1
2003–04	481	1 200	966	2 223	96	196	148	5	27	2	< 1	1
2004–05	267	1 200	1 102	2 223	43	196	49	5	15	2	< 1	1
2005–06	643	1 200	2 153	2 223	50	196	53	5	< 1	2	< 1	1
2006–07	415	1 200	1 692	2 223	66	196	31	66	10	22	< 1	1
2007–08	202	1 200	861	2 223	7	196	23	66	20	22	<1	1
2008–09	197	1 200	1 135	2 223	52	196	58	66	11	22	< 1	1
2009–10	49	1 200	1 046	1 620	45	196	15	66	3	22	< 1	1
2010–11	84	1 200	736	1 020	17	196	19	66	5	22	< 1	1
2011–12	148	1 200	376	440	79	196	44	66	93	22	< 1	1
2012-13	35	1 200	470	440	40	196	10	66	14	22	1	1
2013-14	160	1 200	282	440	68	196	11	66	19	22	<1	1

Table 2 [Continued]

Year	QMA 7 Catch	QMA 7 TACC	QMA 8 Catch	QMA 8 TACC	QMA 9 Catch	QMA 9 TACC	Total (EEZ) Catch	Total (EEZ) TACC	ET Catch	Total Catch
1982–83	< 1	-	-	-	-	-	78	-	-	78
1983–84	< 1	-	-	-	-	-	220	-	-	220
1984–85	1	-	-	-	-	-	532	-	-	532
1985–86	< 1	-	-	-	45	-	292	-	-	292
1986–87	< 1	-	-	-	-	-	1 814	-	-	1 814
1987–88	2	-	< 1	-	< 1	-	1 638	-	-	1 638
1988–89	2	-	-	-	-	-	1 798	-	2	1 800
1989–90	15	-	-	-	-	-	2 385	-	< 1	2 385
1990–91	1	-	< 1	-	-	-	4 311	-	-	4 311
1991–92	11	-	-	-	-	-	1 821	-	17	1 838
1992–93	2	-	-	-	-	-	2 096	-	270	2 366
1993–94	6	-	-	-	-	-	2 972	-	829	3 801
1994–95	51	-	-	-	< 1	-	3 479	-	231	3 710
1995–96	26	-	-	-	-	-	4 150	-	340	4 490
1996–97	27	-	-	-	-	-	4 045	-	522	4 567
1997–98	76	-	-	-	108	-	2 338	-	405	2 743
1998–99	16	39	< 1	0	< 1	4	1 531	3 670	390	1 921
1999–00	27	39	0	0	< 1	4	3 415	3 670	962	4 377
2000–01	2	39	0	0	3	4	1 642	3 670	571	2 213
2001–02	3	39	0	0	5	4	2 349	3 670	490	2 839
2002–03	27	39	0	0	5	4	2 721	3 670	275	2 996
2003–04	2	39	0	0	6	4	1 727	3 670	58	1 785
2004–05	2	39	0	0	1	4	1 479	3 670	204	1 683
2005–06	1	39	0	0	2	4	2 901	3 670	44	2 945
2006–07	1	39	0	0	1	4	2 216	3 751	2	2 218
2007–08	2	39	< 1	0	19	4	1 134	3 751	1	1 135
2008–09	1	39	0	0	2	4	1 456	3 751	17	1 474
2009–10	< 1	39	0	0	5	4	1 163	3 148	-	-
2010–11	< 1	39	0	0	1	4	863	2 548	-	-
2011–12	< 1	39	0	0	< 1	4	742	1 968	-	-
2012–13	2	39	0	0	4	4	576	1 968	-	-
2013-14	1	39	0	0	<1	4	542	1 968		

Black cardinalfish was introduced into the QMS on 1 October 1998 and quotas were set for QMAs 2–8. Quotas for QMAs 1 and 9 were subsequently set for 1999–00. TACCs were increased from 1 October 2006 in CDL 4 to 66 t and in CDL 5 to 22 t. In these stocks landings were above the TACC for a number of years and the TACCs have been increased to the average of the previous eight years plus an additional 10%. From 1 October 2009 the TACC was reduced in CDL 2 to 1620 t, then reduced to 1020 t in 2010–11, and further reduced to 440 t in 2011–12. CDL 1 and CDL 2 have other mortality allocations of 120 t and 100 t respectively. Figure 1 shows the historical landings and TACC values for the main CDL stocks.

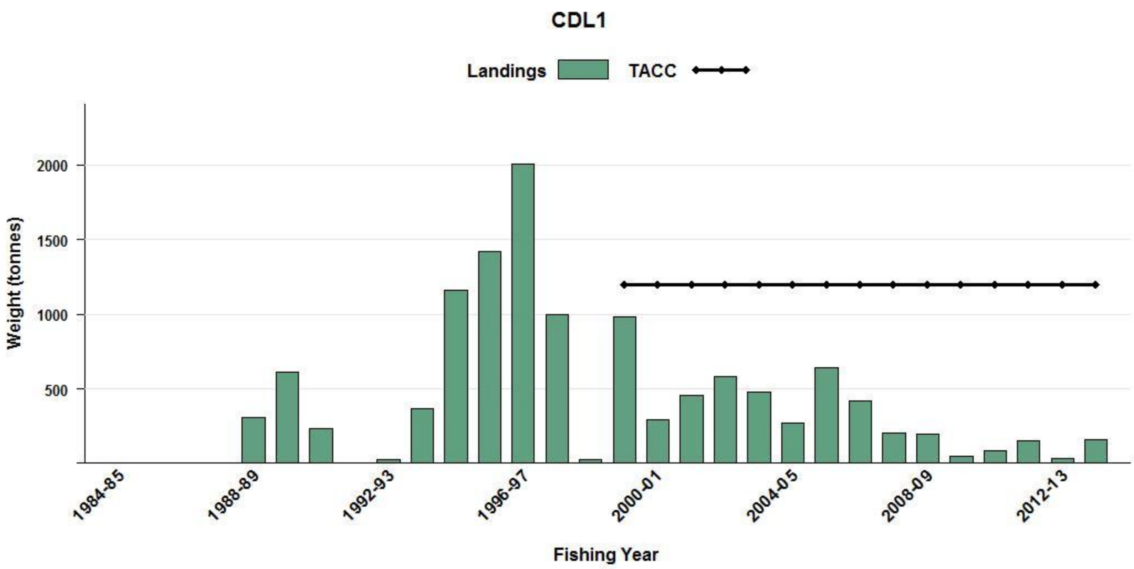


Figure 1: Reported commercial landings and TACC for the two main CDL stocks. CDL 1 (Auckland East).

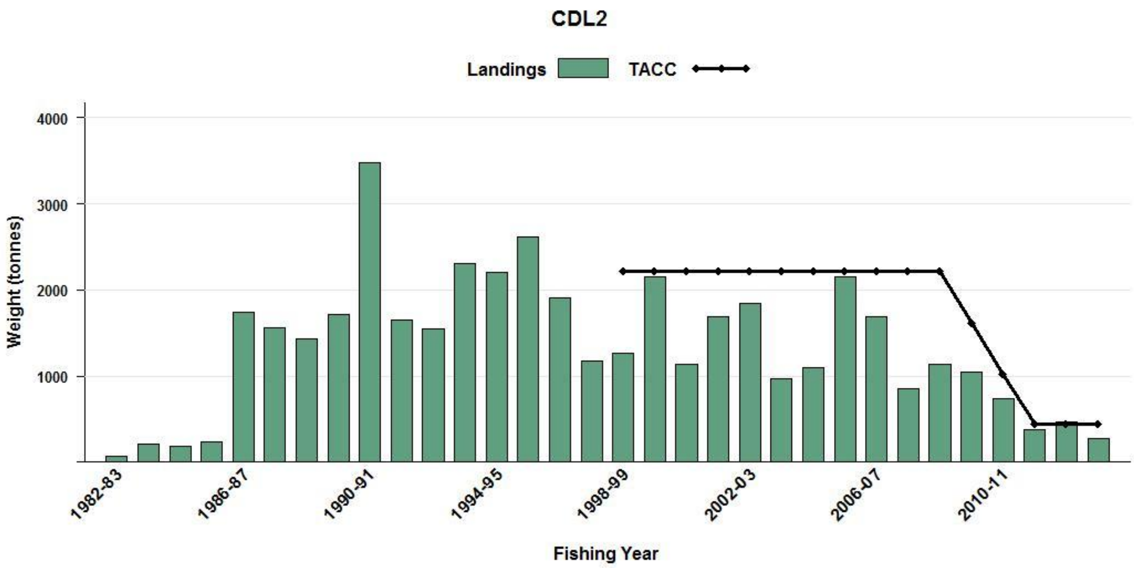


Figure 1:[Continued]: Reported commercial landings and TACC for the two main CDL stocks. CDL 2 (Central East).

1.2 Recreational fisheries
Recreational fishing for black cardinalfish is negligible.

1.3 Customary non-commercial fisheries
The level of this fishery is believed to be negligible.

1.4 Illegal catch
No information is available about illegal catch.

1.5 Other sources of mortality
There has been a history of catch overruns (unreported catch) from loss of fish through burst nets, and the discarding at sea of this species while target fishing for higher value species. In the assessment presented here, the total removals were assumed to exceed reported catches by the overrun percentages in Table 3 (Dunn 2009). All yield estimates make an allowance for the current estimated level of overrun of 10%.

Table 3: Catch overruns (%) for CDL 2 by year.

Year	Over-run	Year	Over-run
1982–83	100	1991–92	30
1983–84	100	1992–93	30
1984–85	100	1993–94	30
1985–86	100	1994–95	20
1986–87	50	1995–96	20
1987–88	50	1996–97	20
1988–89	50	1997–98	20
1989–90	50	1998–99 and	10
1990–01	50	subsequently	-

2. BIOLOGY

The average size of black cardinalfish landed by the commercial fishery is about 50–60 cm fork length (FL). Length frequency distributions from research surveys are unimodal with a peak at 55–65 cm FL. They reach a maximum length of about 75 cm FL. Otolith readings from 722 fish from QMA 2 have been validated using radiometric and bomb radiocarbon methods, and indicated that this species is relatively slow-growing and long lived (Andrews & Tracey 2007, Neil et al 2008). Maximum ages of over 100 years were reported, with the bulk of the commercial catch being between

35 and 55 years of age. The validation indicated that fish aged over 60 years tended to be under-aged, by up to 30%. This bias would be likely to have little impact on the estimated growth parameters, but would influence the estimate of natural mortality (*M*). Life history parameters are given below in Table 4.

Table 4: Life history parameters for black cardinalfish. All estimates are for CDL 2, except the length-weight parameters which are for CDL 2–4.

Fishstock	Estimate	Source
1. Natural mortality (*M*)	0.034*	(Tracey et al 2000)
Age at recruitment (A_r)	unknown	
Gradual recruitment (A_m)	unknown	
Age at full recruitment	45	(Tracey et al 2000)
Age at maturity (A_s)	35	(Field & Clark 2001)
Gradual maturity (S_m)	13	(Field & Clark 2001)

2. Weight = a(length)^b (weight in g, fork length in cm).

	Both sexes		
	a	b	
	0.113	2.528	Dunn (2009)

3. Von Bertalanffy growth parameters (Tracey et al 2000)

Both sexes			Female			Male		
L_∞	k	t_0	L_∞	k	t_0	L_∞	K	t_0
70.8	0.034	-6.32	70.9	0.038	-4.62	67.8	0.034	-8.39

* Because of uncertainties in ageing and *M*, the Deepwater Fisheries Assessment Working Group used a range of *M*'s in the assessments.

The reproductive biology of black cardinalfish is not well known (Dunn 2009). Indications from research survey and Observer Programme data are that spawning may occur between November and July. Spawning locations have been identified in CDL 1, CDL 2, CDL 7, CDL 9, and outside the EEZ on the northern Challenger Plateau, Lord Howe Rise, and West Norfolk Ridge. A probit analysis of maturity at length indicated that fish became sexually mature at around 50 cm length, at an age of approximately 35 years (Field & Clark 2001). Maturity was also inferred to be between ages 26 and 44 years (mean 33 years) from changes in $\delta^{13}C$ in otoliths (Neil et al 2008).

Juveniles are thought to be mesopelagic until they reach a length of about 12 cm (5 years of age), after which they become primarily demersal (Neil et al 2008). Larger juveniles have been caught in bottom trawls at depths of 400–700 m, extending into deeper water as they grow, with adult fish caught primarily at 800–1000 m (Dunn 2009). Prey items from research trawl samples include mesopelagic fish, natant decapod prawns and octopus.

Elevated levels of mercury (Hg) have been recorded in a sample of black cardinalfish from the Bay of Plenty (Tracey 1993).

3. STOCKS AND AREAS

The stock boundaries and number of black cardinalfish stocks in New Zealand are unknown. There are no data on genetics, or known movements of black cardinalfish which indicate possible stock boundaries.

There is evidence that spawning occurs in CDL 1, CDL 2, CDL 7 and CDL 9 and outside the EEZ (e.g., North Challenger, Lord Howe and West Norfolk Ridge). In CDL 2, three geographically close spawning locations have been identified: Tuaheni High, Ritchie Bank, and Rockgarden (Dunn 2009). Juveniles of less than 30 cm have been infrequently identified in CDL 2, and more frequently found on the northern flanks of the Chatham Rise, which is south of the spawning grounds in CDL 2. No spawning grounds have been identified on the Chatham Rise, where adult fish are relatively rare.

4. ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was updated for the 2013 Fishery Assessment Plenary after review by the Aquatic Environment Working Group. A more detailed summary from an issue-by-issue perspective is available in the 2012 Aquatic Environment and Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

4.1 Role in the ecosystem

Black cardinalfish is a part of the mid slope demersal fish assemblage identified by Francis et al, (2002). It is widely distributed with a range centred on a depth of about 750 m and latitude about 39.4° S (i.e., central and northern New Zealand). It occupies depths intermediate between the shallower southern community dominated by hoki (about 620 m, 49.5° S) and the deeper southern black oreo (about 930 m, 45.5° S) and smooth oreo (about 1090 m, 44.6° S), and the deeper centrally-located orange roughy (about 1090 m, 41.2° S) (Francis et al 2002). The role in the ecosystem is not well understood; and nor are the effects on the ecosystem of removing about an average of 2300 t of black cardinalfish per year between 1986–87 and 2010–11 from the New Zealand EEZ, mostly from the east coast of the North Island.

4.1.1 Trophic interactions

No detailed feeding studies for black cardinalfish have been documented for New Zealand waters. Prey items observed during research surveys in New Zealand waters include mesopelagic fish, particularly lighthouse fish (*Phosichthys argenteus*), natant decapod prawns, and cephalopods (Tracey 1993). Predators of black cardinalfish are not documented but predation is expected to vary with fish development.

4.1.2 Ecosystem Indicators

Tuck et al (2009) used data from the Sub-Antarctic and Chatham Rise middle-depth trawl surveys to derive indicators of fish diversity, size, and trophic level. However, fishing for cardinalfish occurs mostly deeper than the depth range of these surveys and is only a small component of fishing in the areas considered by Tuck et al (2009).

4.2 Incidental catch (fish and invertebrates)

Incidental catch and discards have not been estimated for the black cardinalfish target fishery. Anderson (2009, 2011) summarised the bycatch and discards from the target orange roughy and oreo trawl fisheries from 1999–2000 to 2004–05 and 2005–06 to 2008–09 respectively. The bycatch of these fisheries may be similar to that of the cardinalfish fishery, although both occur somewhat deeper than cardinalfish and oreo fisheries are found further to the south.

4.3 Incidental Catch (seabirds, mammals, and protected fish)

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp but not brought onboard the vessel, Middleton & Abraham 2007).

4.3.1 Marine mammal interactions

Trawlers targeting orange roughy or oreos occasionally catch New Zealand fur seal (which were classified as “Not Threatened” under the NZ Threat Classification System in 2010, Baker et al 2010). Between 2002–03 and 2011–12, there were 14 observed captures of NZ fur seal in orange roughy, oreo, and black cardinalfish trawl fisheries. In the 2010–11 fishing year there were no observed captures (Table 5) but there were 2 (95% c.i.: 0–13) estimated captures, with the estimates made using a statistical model (Thompson et al 2013). All observed fur seal captures occurred in the Sub-Antarctic region, and suggest a reduced probability of fur seal capture in the black cardinalfish fishery which is carried out in central and northern New Zealand. The average rate of capture for these years was 0.08 per 100 tows (range 0 to 0.25). This is a low rate compared with that in the hoki fishery (1.29 to 5.63 per 100 tows).

Table 5: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002–03 to 2011–12. No. Obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Thompson et al (2013), available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130304.

		Observed				Estimated		
	Tows	No.obs	%obs	Captures	Rate	Captures	95%c.i.	%inc.
2002–03	8 872	1 378	15.5	0	0.00	4	0–16	99.9
2003–04	8 007	1 261	15.7	2	0.16	7	2–21	99.9
2004–05	8 418	1 617	19.2	4	0.25	17	4–79	99.8
2005–06	8 304	1 293	15.6	2	0.15	9	3–32	99.8
2006–07	7 368	2 321	31.5	2	0.09	3	2–7	99.9
2007–08	6 731	2 812	41.8	4	0.14	7	4–17	100.0
2008–09	6 134	2 373	38.7	0	0.00	3	0–14	100.0
2009–10	6 011	2 132	35.5	0	0.00	2	0 –10	100.0
2010–11	4 179	1 205	28.8	0	0.00	2	0–13	99.9
2011–12†	3 630	897	24.7	0	0.00	-	-	-

† Provisional data, no model estimates available.

4.3.2 Seabird interactions

Annual observed seabird capture rates ranged from 0.1 to 3.5 per 100 tows in orange roughy, oreo, and cardinalfish trawl fisheries between 1998–99 and 2007–08 (Baird 2001, 2004 a, b, 2005, Baird and Smith 2004, Abraham & Thompson 2009, Abraham et al 2009, Abraham & Thompson 2011). However, capture rates have not been above 1 bird per 100 tows since 2004–05 and have fluctuated without obvious trend at this low level (Table 6). In the 2011–12 fishing year there were 2 observed captures of birds in orange roughy, oreo, and cardinalfish trawl fisheries at a rate of 0.22 birds per 100 observed tows (Abraham et al 2012). No estimates of total captures were made. The average capture rate in orange roughy, oreo, and cardinalfish trawl fisheries over the last eight years is only 0.42 birds per 100 tows, a low rate relative to trawl fisheries for squid (12.56 birds per 100 tows), scampi (5.1 birds per 100 tows) and hoki (2.35 birds per 100 tows) over the same period.

Table 6: Number of tows by fishing year and observed seabird captures in orange roughy, oreo, and cardinalfish trawl fisheries, 2002–03 to 2011–12. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130304.

	Fishing effort			Observed captures		Estimated captures		
	Tows	**No. obs**	**% obs**	**Captures**	**Rate**	**Mean**	**95% c.i.**	**% included**
2002–03	8 871	1 378	15.5	0	0.00	56	21–138	100.0
2003–04	8 005	1 261	15.8	3	0.24	47	21–104	100.0
2004–05	8 417	1 617	19.2	20	1.24	76	45–135	100.0
2005–06	8 305	1 294	15.6	7	0.54	54	29–99	100.0
2006–07	7 367	2 323	31.5	1	0.04	22	10–42	100.0
2007–08	6 730	2 811	41.8	5	0.18	28	14–50	100.0
2008–09	6 131	2 373	38.7	8	0.34	27	16–43	100.0
2009–10	6 011	2 133	35.5	19	0.89	44	28–79	100.0
2010–11	4 179	1 205	28.8	6	0.50	26	13–46	100.0
2011–12†	3 630	897	24.7	2	0.22	-	-	-

† Provisional data, no model estimates available.

Table 7: Number of observed seabird captures in orange roughy, oreo, and cardinalfish fisheries, 2002–03 to 2011–12, by species and area. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR (from Richard & Abraham 2013 where full details of the risk assessment approach can be found). It is not an estimate of the risk posed by fishing for jack mackerel. Other data, version 20130304.

Species	Risk Ratio	Chatham Rise	East Coast South Island	Sub-Antarctic	Stewart Snares Shelf	West Coast South Island	Total
Salvin's albatross	Very high	11	2	4	0	0	17
Southern Buller's albatross	Very high	3	0	0	0	0	3
Chatham Island albatross	Very high	7	0	1	0	0	8
NZ White capped albatross	Very high	5	0	0	0	1	6
Gibson's albatross	High	1	0	0	0	0	1
Northern royal albatross	Medium	1	0	0	0	0	1
Total albatrosses	**N/A**	**28**	**2**	**5**	**0**	**1**	**36**
Cape petrel	High	10	10	0	0	0	20
Northern giant petrel	Medium	1	0	0	0	0	1
White chinned petrel	Medium	0	1	0	0	0	1
Grey petrel	Medium	2	0	1	0	0	3
Sooty shearwater	Very low	1	3	0	1	0	5
Common diving petrel	-	2	0	0	0	0	2
Storm petrels	-	0	0	1	0	0	1
White-faced storm petrel	-	2	0	0	0	0	2
Total other birds	N/A	**18**	**14**	**2**	**1**	**0**	**35**

Salvin’s albatross was the most frequently captured albatross (47% of observed albatross captures) but six different species have been observed captured since 2002–03. Cape petrels were the most frequently captured other taxon (57%, Table 7). Seabird captures in the orange roughy, oreo, and cardinalfish fisheries have been observed mostly around the Chatham Rise and off the east coast South Island. These numbers should be regarded as only a general guide on the distribution of captures because the observer coverage is not uniform across areas and may not be representative.

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the orange roughy, oreo, and cardinalfish trawl fisheries. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Department of Internal Affairs 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being “paired streamer lines”, “bird baffler” or “warp deflector” as defined in the notice).

4.4 Benthic interactions

Cardinalfish, orange roughy, and oreos are taken using bottom trawls and collectively accounted for about 14% of all tows reported on TCEPR forms to have been fished on close to the bottom between 1989–90 and 2004–05 (Baird et al 2011). These tows were located in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2009) classes J, K (mid-slope), M (mid-lower slope), N, and O (lower slope and deeper waters) (Baird & Wood 2012), and 94% were between 700 and 1200 m depth (Baird et al 2011). Deepsea corals in the New Zealand region are abundant and diverse and, because of their fragility, are at risk from anthropogenic activities such as bottom trawling (Clark & O’Driscoll 2003, Clark & Rowden 2009, Williams et al 2010). All deepwater hard corals are protected under Schedule 7A of the Wildlife Act 1953. Rowden et al (2012) mapped the likely coral distributions using predictive models, and concluded that fisheries that pose the most risk to protected corals are these deepwater trawl fisheries.

Trawling for orange roughy, oreo, and cardinalfish, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., Rice 2006) and there may be consequences for benthic productivity (e.g., Jennings et al 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These consequences are not considered in detail here but are discussed in the 2012 Aquatic Environment and Biodiversity Annual Review 2012.

The NZ EEZ contains 17 Benthic Protection Areas (BPAs) that are closed to bottom trawl fishing and include about 52% of all seamounts greater than 1500 m elevation and 88% of identified hydrothermal vents.

4.5 Other considerations

4.5.1. Spawning disruption

Fishing during spawning may disrupt spawning activity or success. Morgan et al. (1999) concluded that Atlantic cod (*Gadus morhua*) "exposed to a chronic stressor are able to spawn successfully, but there appears to be a negative impact of this stress on their reproductive output, particularly through the production of abnormal larvae". Morgan et al. (1997) also reported that "Following passage of the trawl, a 300-m-wide "hole" in the [cod spawning] aggregation spanned the trawl track. Disturbance was detected for 77 min after passage of the trawl." There is no research on the disruption of spawning black cardinalfish by fishing in New Zealand. Spawning of this species appears to occur between February and July, peaking in April, and catches of black cardinalfish occur throughout the year (Dunn 2005).

4.5.2 Genetic effects

Fishing, environmental changes, including those caused by climate change or pollution, could alter the genetic composition or diversity of a species. There are no known studies of the genetic diversity of cardinalfish from New Zealand. Genetic studies for stock discrimination are reported under "stocks and areas".

4.5.3 Habitat of particular significance to fisheries management

Habitat of particular significance for fisheries management (HPSFM) does not have a policy definition (Ministry for Primary Industries 2012) although work is currently underway to generate one. O'Driscoll et al. (2003) reported spawning black cardinalfish mostly from around the North Island, but higher catch rates of juveniles on the northwest Chatham Rise and Puysegur area (O'Driscoll et al 2003). In both cases, sample sizes were small so these distributions should be treated with caution. It is not known if there are any direct linkages between the congregation of cardinalfish around features and the corals found on those features. Bottom trawling for cardinalfish has the potential to affect features of the habitat that could qualify as habitat of particular significance to fisheries management.

5. STOCK ASSESSMENT

A stock assessment for CDL 2–4 was completed in 2009. No assessments have been made for stocks in other areas. For the purposes of stock assessment, it has been assumed that black cardinalfish on the east coast North Island (CDL 2) are from the same stock as fish on the north Chatham Rise (CDL 3 and CDL 4).

5.1 Assessment inputs

The assessment inputs for CDL 2–4 were catches adjusted by overruns (Table 9), two CPUE indices (Table 8), and length frequency and maturity at length samples (Dunn 2009). The CPUE indices were derived from catch and effort data for fisheries focused on and around specific hill features in CDL 2 (Dunn & Bian 2009) with no overrun included. Whilst the CPUE indices accounted for a substantial proportion of the total catch (65–77%), the spatial extent of the fisheries was small compared with the overall area believed to be occupied by the stock. As a result, the indices may reflect local abundance, but it is less certain that they reflect overall stock biomass. The CPUE was split into two indices, before and after 1 October 1998, because of a change in reported fishing patterns in the late 1990s. This may have been caused, at least in part, by the introduction of the black cardinalfish TACC. The growth parameters used in the assessment are presented in Table 3. Length frequency samples were available for eight years between 1989–90 and 2007–08 from at-sea and market sampling. Maturity was input as the proportions mature at length from samples collected during research trawl surveys of the east coast North Island in 2001 and 2003.

Table 8: Standardised CPUE indices, and their calculated CVs, as used in the stock assessment.

Fishing year	Index a	CV (%)	Index b	CV (%)
1990–91	1.00	46	-	-
1991–92	0.73	43	-	-
1992–93	0.87	42	-	-
1993–94	0.58	46	-	-
1994–95	0.41	45	-	-
1995–96	0.26	39	-	-
1996–97	0.51	42	-	-
1997–98	0.29	47	-	-
1998–99	-	-	1.00	37
1999–00	-	-	0.57	32
2000–01	-	-	0.39	36
2001–02	-	-	0.50	35
2002–03	-	-	0.30	33
2003–04	-	-	0.26	38
2004–05	-	-	0.23	35
2005–06	-	-	0.34	34
2006–07	-	-	0.27	35
2007–08	-	-	0.17	37

Table 9: Estimated catches calculated by summing the CDL 2–4 catches from Table 2 (column 2), and increasing them by the overrun values in Table 3 (column 3), with the combined TACC for CDL 2–4 (column 4).

Year	Reported catch	Catch including overruns	TACC
1982–83	76	152	-
1983–84	219	438	-
1984–85	530	1 060	-
1985–86	291	582	-
1986–87	1 812	2 718	-
1987–88	1 585	2 378	-
1988–89	1 495	2 243	-
1989–90	1 756	2 634	-
1990–91	4 072	6 108	-
1991–92	1 801	2 341	-
1992–93	2 071	2 692	-
1993–94	2 597	3 376	-
1994–95	2 265	2 718	-
1995–96	2 682	3 218	-
1996–97	2 017	2 420	-
1997–98	1 567	1 880	-
1998–99	1 490	1 639	2 424
1999–00	2 409	2 650	2 424
2000–01	1 269	1 396	2 424
2001–02	1 868	2 055	2 424
2002–03	2 097	2 307	2 424
2003–04	1 210	1 331	2 424
2004–05	1 194	1 313	2 424
2005–06	2 256	2 482	2 424
2006–07	1 789	1 968	2 485
2007–08	891	980	2 485

5.2 Model structure and runs

Stock assessments were performed using the stock assessment program, CASAL (Bull et al 2002) to estimate virgin and current biomass (Dunn 2009). Preliminary model runs were completed using all of the observational data. The key assumptions of the final model runs were:

- The biomass information in the data is primarily contained in the CPUE indices. Therefore, a two-step approach was used to produce the final model runs. In the final runs, selectivity and maturity were fixed at estimates from the preliminary runs and the length frequency and maturity data were not fitted. This ensured that any biomass signal from the length frequency data, potentially caused by errors in estimated growth and selectivity, did not dominate the signal from the CPUE trends.

- Runs where maturity and selectivity were estimated separately resulted in selectivity curves displaced to the right of the maturity ogive for *M* = 0.04 and *M* = 0.06, resulting in a proportion of the spawning stock not being available to the fishery (called “cryptic biomass”). The Deepwater Fisheries Assessment Working Group considered that it was unlikely that there existed mature biomass that was not vulnerable to the fishery, and agreed that the age of vulnerability should be fixed to the age at maturity for the base case and for the case with *M* = 0.06. The WG agreed to present a sensitivity model run using *M* = 0.04 and with separately estimated maturity and selectivity to explore the implications of this scenario.

- For runs assuming an *M* of 0.027, the selectivity and maturity estimates were similar; therefore the two were estimated separately in final runs.

- The base case with *M* set at 0.04 and vulnerability set equal to the MCMC median of maturity was considered to be the most credible.

Four model runs are therefore presented, two with selectivity assumed to be the same as maturity and *M* assumed to be either 0.06 or 0.04, and two with selectivity and maturity fitted as separate ogives and *M* assumed to be 0.04 or 0.027 (Table 10).

Table 10: Four alternative assumptions to the stock assessment.

Model	*M*	Selectivity
Base	0.04	Equal to MCMC median maturity
Mat&sel	0.04	Estimated separately
M0.027	0.027	Estimated separately
M0.06	0.06	Equal to MCMC median maturity

The model was fitted using Bayesian estimation, and partitioned the population by age (age-groups used were 1–90, with a plus group). The model assumed a single sex, with growth modelled using the von Bertalanffy Growth formula. The stock was considered to reside in a single area, and have a single maturation episode, with maturation modelled by a logistic ogive which was estimated in preliminary model runs. Selectivity of the fishery was assumed to be equal to maturity, or modelled by a logistic ogive estimated in preliminary model runs. The catch equation used was the instantaneous mortality equation from Bull et al (2002), whereby half the natural mortality was applied, followed by the fishing mortality, then the remaining natural mortality. Deterministic recruitment was assumed. A Bayesian estimation procedure was used with a penalty function included to discourage the model from allowing the stock biomass to drop below a level at which the historical catch could not have been taken. Lognormal errors, with known (sampling error) CVs were assumed for the CPUE. In preliminary model runs, an additional process error was estimated and added to the length frequency distributions. Binomial errors were assumed for the proportions mature at length. The final model runs estimated virgin biomass, B_0, and two catchabilities. Confidence intervals were calculated from a posterior distribution of the model parameters, which was estimated using a Markov Chain Monte Carlo technique.

5.3 Biomass estimates

Biomass estimates depended on the assumed *M*, with the *M*0.027 run resulting in a larger and less productive stock, and the *M*0.06 run in a smaller and more productive stock (Table 11, Figure 2). Estimates of current biomass were lowest in the base case.

The mat&sel run estimated cryptic spawning stock biomass, where vulnerability to the fishery took place after maturity, such that a median of 86% and 62% of the mature biomass was vulnerable to the fishery at virgin and 2009 biomass levels, respectively. It is unclear whether cryptic biomass could occur for black cardinalfish, and it is possible that this result is an artefact generated from the model assumptions. Cryptic biomass was not estimated when maturity and selectivity were estimated separately and *M* was assumed to be 0.027, and in sensitivity runs the level of cryptic biomass was found to increase as *M* increased. The wide confidence intervals reflect the uncertainty in the model, which was fitted to only relative biomass indices having relatively high CVs (Table 10).

Table 11: Biomass estimates (medians rounded to the nearest 100 t, with 95% confidence intervals in parentheses) for the four model runs. $B_{current}$ is the mid-year biomass in 2009. $p(B_{2009} < 0.1\ B_0)$ is the probability of the mature biomass in 2009 being less than 10% of the virgin mature biomass (B_0). $p(B_{2009} < 0.2\ B_0)$ is the probability of the mature biomass in 2009 being less than 20% of the virgin mature biomass (B_0).

Run	B_0 (t)	B_{current} (t)	$\%B_0$	$p(B_{2009} < 0.1\ B_0)$	$p(B_{2009} < 0.2\ B_0)$
Base	36 800 (32 800–95 400)	4 400 (1 900–60 400)	11.9 (5.9–63.3)	0.41	0.70
Mat&sel	40 800 (35 600–96 700)	7 300 (3 500–61 300)	17.8 (9.9–63.5)	0.13	0.56
*M*0.027	45 100 (39 500–93 500)	6 100 (2 000–53 000)	13.6 (5.0–56.6)	0.32	0.69
*M*0.06	33 800 (25 500–10 700)	8 200 (2 400–82 800)	24.2 (9.6–74.9)	0.16	0.43

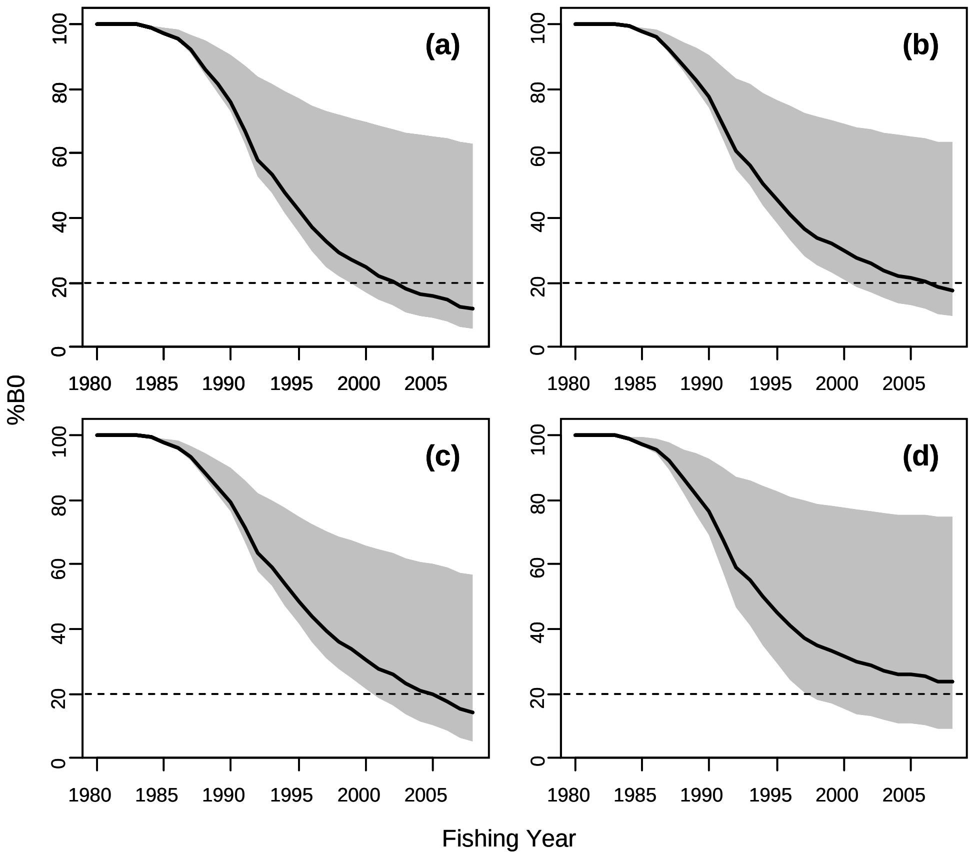


Figure 2: Estimated biomass trajectories (solid line) and 95% confidence intervals (shaded area) for the model runs (a) Base, (b) mat&sel, (c) *M*0.027, (d) *M*0.06. The horizontal broken line indicates 20% B_0.

5.4 Sensitivity analyses

Several sensitivity analyses were conducted (reported in more detail in Dunn 2009). The assessment was found to be relatively insensitive to the assumed catch over-runs. When over-runs were either assumed to be zero, or were doubled for the period before 1998–99 (before the TACC was introduced), the mature stock in 2009 was estimated to be slightly less depleted compared to the Base case, at 13.5% (5.9–67.0%) B_0, and 12.2% (5.5–58.3%) B_0, respectively.

5.5 5-year projection results

Forward projections were carried out over a 5 year period using a range of constant catch options. A catch level of 180 t is approximately the level associated with $F = M$, a catch of 890 t is approximately the current (2007–08) catch and a catch of 2490 t is approximately the current (2007–08) TACC. In all projections overrun of 10% was assumed for future catches. For each catch option, three measures of fishery performance were calculated. The first one, $\%B_0$, is the median biomass in 2009 as a percentage of B_0. The second one, $P_{0.1}$, is the probability that the biomass at the end of the 5-year period is less than 10% B_0. The third, $P_{0.2}$, is the probability that the biomass at the end of the 5-year period is less than 20% B_0. At high future catches the biomass may be reduced to such a low level that the catch is unlikely to be able to be taken (assumed to occur when the exploitation rate exceeds 0.9). This is indicated as P(no catch).

All projections indicate that the biomass would increase for all catch levels near or below the 2008–09 catch (890 t), and would continue to decline at catch levels of 1200 t in all runs except $M = 0.06$, where it would remain about the same (Table 12). In all runs the biomass would decline at catch levels equal to the current TACC (2490 t), and there was a 38–71% probability the biomass would decline to a level where the catch could not be taken.

Table 12: Results from forward projections to 2013 for the model runs. $P_{0.1}$ is the probability of the mature biomass in 2013 being less than 10% of the virgin mature biomass (B_0). $P_{0.2}$ is the probability of the mature biomass in 2013 being less than 20% of the virgin mature biomass (B_0). *P*(no catch) is the probability that the catch could not be taken, which is assumed to occur if the exploitation rate exceeds 90%). Current (2007–08) values of %B_0 are shown for each run in parenthesis next to the measure. 95% confidence intervals are shown for the %B_0 estimates in 2013. A catch of 180 t is approximately *M* times the current biomass, 890 t is the current catch and 2490 t is the current TACC.

		Future catch (t)					
Run	Measure	0	180	530	890	1200	2490
Base	%B_0 (11.9)	17.6	16.5	14.3	12.6	10.2	5.2
		(8.5–67.4)	(7.01–66.0)	(5.3–63.9)	(3.6–62.7)	(2.9–62.6)	(2.7–56.2)
	$P_{0.1}$	0.11	0.19	0.30	0.40	0.49	0.70
	$P_{0.2}$	0.57	0.60	0.65	0.71	0.74	0.83
	P(no catch)	0	0	0	0	0	0.38
mat&sel	%B_0 (17.8)	24.5	23.6	20.4	18.6	16.2	9.5
		(14.0–68.8)	(12.9–67.8)	(10.2–65.5)	(8.0–63.4)	(6.5–61.7)	(5.5–57.8)
	$P_{0.1}$	0.00	0.00	0.06	0.14	0.22	0.53
	$P_{0.2}$	0.35	0.38	0.49	0.55	0.61	0.75
	P(no catch)	0	0	0	0	0	0.42
*M*0.027	%B_0 (13.6)	17.9	16.7	14.3	12.0	10.0	4.3
		(7.1–59.4)	(6.2–59.1)	(4.5–56.7)	(2.9–56.5)	(2.2–55.0)	(2.0–50.1)
	$P_{0.1}$	0.14	0.19	0.28	0.40	0.49	0.71
	$P_{0.2}$	0.57	0.60	0.67	0.71	0.75	0.84
	P(no catch)	0	0	0	0	0	0.41
*M*0.06	%B_0 (24.2)	33.6	31.4	29.8	26.3	24.6	17.4
		(13.0–80.2)	(12.5–79.2)	(10.6 –77.5)	(8.3–77.2)	(6.7–75.7)	(4.8–71.2)
	$P_{0.1}$	0.02	0.33	0.07	0.15	0.17	0.35
	$P_{0.2}$	0.27	0.29	0.35	0.40	0.42	0.54
	P(no catch)	0	0	0	0	0	0.71

5.6 Updated characterisation and CPUE analyses

A characterisation and CPUE analyses were conducted using catch and effort data to the end of the 2013–14 fishing year (Bentley & MacGibbon, draft). Catch and effort data were examined in each of nine “zones” which encompassed groups of underwater features where the majority of the cardinalfish catch has been taken: North Colville (NC), Mercury-Colville (MC), White Island (WI), East Cape (EC), Tuaheni High (TH), Richie-Rockgarden (RR), Madden (MD), Wairarapa (WA), and Kaikoura (KK). Within these zones, only tows in the depth range 470-980m (the 2.5th and 97.5th percentiles of the distribution of cardinalfish catch by depth) were considered when characterising effort and performing CPUE analyses.

Catches in each zone have generally declined or remained stable. In CDL 1, most of the catch has come from the Mercury-Colville zone since the early 2000s. In CDL 2, concurrent with a reduction in the TACC, catches have declined in the East Cape, Tuaheni High and Richie-Rockgarden zones since 2010. In these zones, as in CDL 1, most of the cardinalfish is taken in target tows. In contrast, catches in the Wairarapa and Kaikoura zones have remained relatively constant during this period. In these southern two zones a greater proportion of the cardinalfish catch is taken as bycatch from tows that are targeting species other than cardinalfish and orange roughy. There was no evidence of substantial movement of fishing effort between features within zones.

A CPUE analysis was done using data from all nine zones and year effects estimated for each zone. This suggested that the CPUE trends in all zones were generally similar but that the Wairarapa and Kaikoura zones exhibited a flatter trend since 2000. On this basis, a final CPUE standardisation was done with separate year effects estimated for three regions North (zones North Colville, Mercury-Colville and White Island; i.e. CDL 1), Central (zones East Cape, Tuaheni High, Richie-Rockgarden and Madden: i.e. CDL 2 except for Wairarapa) and South (zones Wairarapa and Kaikoura). This standardisation model has the advantage over separate models for each region of using all the available data to estimate vessel coefficients.

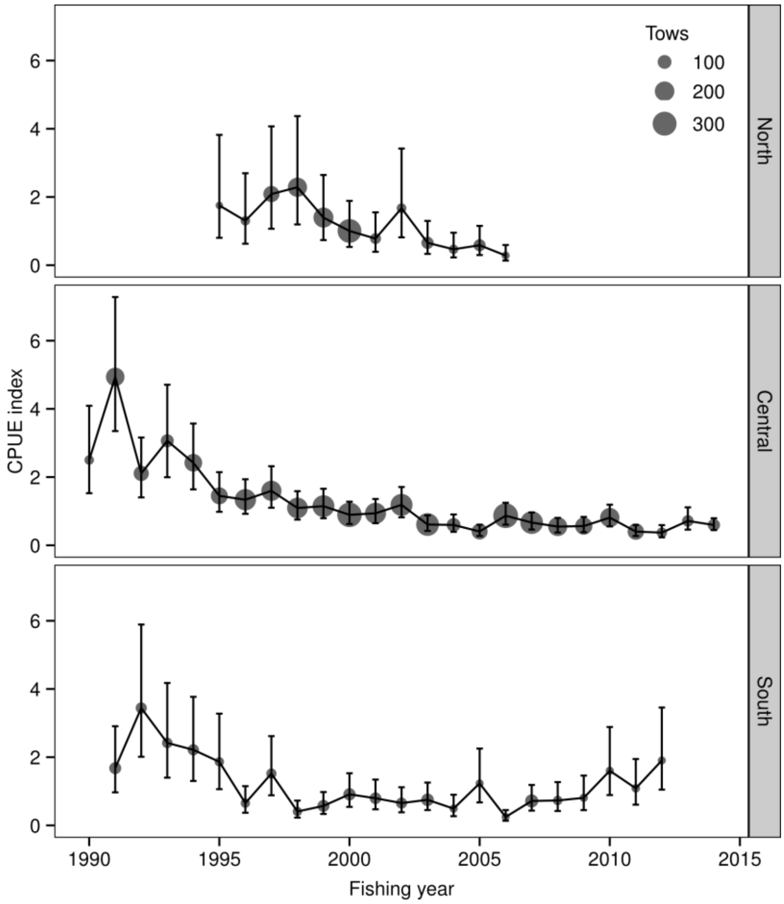


Figure 3: CPUE indices by region (see text for definitions of regions). Region/year combinations with less than 30 tows are not shown. Error bars indicate +/- one standard error. Fishing years are indicated by the later calendar year.

6. STATUS OF THE STOCKS

Stock Structure Assumptions

The stock boundaries and number of black cardinalfish stocks in New Zealand is unknown. There are no data on genetics, or known movements of black cardinalfish which indicate possible stock boundaries.

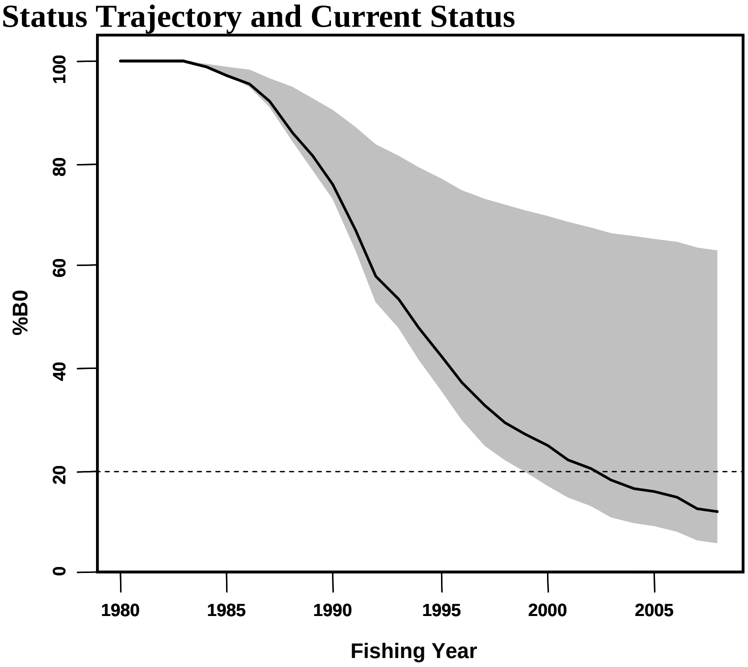
There is evidence that a spawning stock exists in CDL 2, with three geographically close spawning locations identified, on Tuaheni High, Ritchie Bank, and Rockgarden (Dunn 2009). Juveniles of less than 30 cm have been infrequently identified in CDL 2, and more frequently found on the northern flanks of the Chatham Rise, which is south of the spawning grounds in CDL 2. No spawning grounds have been identified on the Chatham Rise, where adult fish are relatively rare.

For the purposes of stock assessment, it has been assumed that black cardinalfish on the east coast North Island (CDL 2) are from the same stock as fish on the north Chatham Rise (CDL 3 and CDL 4).

CDL 2, 3 & 4

Stock Status	
Year of Most Recent Assessment	2009 full assessment 2014 CPUE updated
Assessment Runs Presented	One base case and three sensitivity runs Base case: M = 0.04; selectivity equal to maturity Sensitivity runs: various combinations of M and assumptions about the relationship between maturity and selectivity, considered to be less reliable than the base case
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: $U_{40\%}$
Status in relation to Target	Very Unlikely (< 10%) to be at or above the target
Status in relation to Limits	Base case: B_{2009} was estimated to be 12% B_0; Likely (> 60%) to be below the Soft Limit and About as Likely as Not (40–60%) to be below the Hard Limit. Other model runs: The range of B_{2009} was estimated to be 14–24% B_0; About as Likely as Not (40-60%) or Likely (> 60%) to be below the Soft Limit and Unlikely (< 40%) to be below the Hard Limit.
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Estimated biomass trajectories (solid line) and 95% confidence intervals (shaded area) for the base case. The horizontal broken line indicates 20% B_0

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	CPUE has been flat since 2008
Recent Trend in Fishing Intensity or Proxy	Unknown
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Model projections indicate that the biomass will increase at catch levels near or below the 2007–08 level but will decline sharply at catch levels equal to the TACC.
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Likely (> 60%) Hard Limit: About as Likely as Not (40–60%)
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Soft Limit: Likely (> 60%) Hard Limit: Likely (> 60%)

Assessment Methodology and Evaluation		
Assessment Type	2009 Level 1 - Full Quantitative Stock Assessment 2014 Level 2 - Partial Quantitative Stock Assessment	
Assessment Method	Age-structured CASAL model with Bayesian estimation of posterior distributions	
Assessment Dates	Latest assessment: 2009	Next assessment: Unknown
Overall assessment quality rank	1 – High Quality	
Main data inputs (rank)	- Two commercial catch-per-unit-effort (CPUE) series from the trawl fishery up to 2008 - Estimates of biological parameters	1 – High Quality 1 – High Quality
Data not used (rank)	N/A	
Changes to Model Structure and Assumptions	First accepted assessment for these stocks	
Major sources of Uncertainty	Major sources of uncertainty include the representativeness of the CPUE data, the relationship between CPUE and abundance, the assumption that recruitment has been constant throughout the history of the fishery, estimates of growth and natural mortality and the catch history.	

Qualifying Comments
The TACC was reduced from 2223 t in 3 stages to the level of 440 t in 2010-11. This level was the maximum annual catch required to rebuild the CDL 2 stock to 30%B_0 within the 24 year period specified in the Harvest Strategy Standard (twice Tmin). CPUE since 2008 has been flat.

Fishery Interactions
Main associated species are orange roughy, alfonsino and, to a lesser extent, hoki.

Other QMAs

There is no information on the status of cardinalfish stocks in other QMAs.

TACCs and reported landings for the 2013–14 fishing year are summarised in Table 13.

Table 13: Summary of TACCs (t) and reported landings (t) for black cardinalfish for the most recent (2013–14) fishing year.

			2013–14	2013–14
Fishstock	QMA	FMA	Actual TACC	Reported landings
CDL 1	Auckland (East)	1	1 200	160
CDL 2	Central (East)	2	440	440
CDL 3	South-east (Coast)	3	196	196
CDL 4	South-east (Chatham)	4	66	66
CDL 5	Southland	5	22	22
CDL 6	Sub-Antarctic	6	1	1
CDL 7	Challenger	7	39	39
CDL 8	Central (West)	8	0	0
CDL 9	Auckland (West)	9	4	4
CDL 10	Kermadec	10	0	0
Total			1 968	542

7. FOR FURTHER INFORMATION

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